Low Impact Development Stormwater Management Practices for Wupatki National Monument and Grand Canyon National Park

Robert London, Michael Carroll, Krizelle Mabuti and Charles Schlinger

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Department of Civil Engineering, Construction Management & Environmental Engineering
Northern Arizona University
P.O. Box 15600
Flagstaff, Arizona 86011-5600

Table of Contents

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As part of a larger project completed for Wupatki National Monument in 2010-2011, this summary for Wupatki National Monument and Grand Canyon National Park managers was developed as an introduction to Low Impact Development (LID) stormwater management practices. LID practices have gained wide acceptance in the past decade; witness their recent formal adoption by the City of Flagstaff (2009). We believe that LID practices have widespread applicability in various National Park settings and consider herein their application at both Wupatki National Monument and Grand Canyon National Park.

Traditional Stormwater Management

Traditional stormwater management practices focus on collecting stormwater and conveying it as efficiently as possible to existing onsite or offsite drainage channels (streams, washes, arroyos, etc.), catchments (reservoirs, lakes), or to onsite detention basins where it is released to drainage catchments at a slower rate. Infrequently, where site soils have favorable infiltration characteristics, onsite stormwater retention basins or areas have been used. Retention involves keeping the water onsite, usually allowing it to infiltrate into the subsurface. The goal of these practices is to mitigate stormwater damage by minimizing flooding and erosion, and promoting site drainage so that stormwater will not interfere with human activities (EPA, 2000).

Regulatory requirements on stormwater management have usually focused on controlling pollution in the runoff and maintaining peak storm flow runoff values at or below pre-development values. This has resulted in mainly “end of pipe” (EPA, 2007) stormwater management practices that do not address development-caused hydrologic changes in watershed characteristics. These development-related modifications tend to reduce groundwater recharge while increasing total stormwater runoff. Traditional stormwater management practices do not address controlling pollutants such as nutrients, pathogens, and metals (EPA, 2007). Further, reduction in stream base flow, changes in stream water temperatures, and flashy hydrographs (each having a negative connotation), have been documented after installation of traditional stormwater management technologies (EPA, 2000).

What is Low Impact Design?

Low Impact Design, or LID, is a stormwater management strategy with the goal of minimizing disruption of the pre-development (also known as: existing, or pre-project) hydrologic regime by using design and development techniques to create a hydrologic landscape functionally equivalent to the pre-development condition (EPA, 2000). The basic premise of LID is to minimize the volume of stormwater runoff leaving a site by means of reduction of impervious surface area and to manage the runoff that is generated. This is accomplished through applications of porous pavements, functional landscapes that act as stormwater facilities, gentler slopes than those that are existing, depression detention or retention, open drainage swales and the lengthening of flow paths and runoff times. LID also encompasses preserving and protecting environmentally active features such as riparian areas, wetlands, woodlands and stands of mature trees, and areas with highly permeable soils (EPA, 2000). Other microscale and distributed techniques to achieve desired post-development hydrologic conditions include: bioretention facilities, dry wells, filter/buffer strips, wet swales, rain barrels, cisterns, and infiltration trenches (EPA, 1999).

Illustrations & examples of, along with design guidance for LID stormwater management practices are abundant (e.g., City of Flagstaff, 2009; Prince George's County, 1999; EPA, 2000; EPA, 2007; EPA, 2009; etc.) and are not reproduced here.

LID reduces overall costs by promoting the use of natural systems to reduce the overall volume of runoff as well as slowing the runoff, reducing the peak volume through reduced grading, landscaping, paving, and infrastructure cost (curbing, pipes, and catch basins) (EPA, 2009). While LID practices can reduce the need for traditional stormwater management infrastructure, some aspects of traditional infrastructure may still be required to handle runoff from higher-intensity and longer-duration storms. The decision to install these backup systems must take into consideration the value of the property to be protected and the level of protection desired. In other words, can the facility endure some flooding from the 50- or 100-yr storm event?

The EPA (2007) completed a study comparing the costs of conventional and LID approaches for several developments. Several of the comparisons are presented in Table 1.

Table 1: Conventional Cost compared to LID Cost (EPA, 2007)

Project	**Conventional Development Cost (Estimate)**	**LID Cost**
2nd Ave SEA Street, Seattle, WA	$ 868,803	$ 651,548
Auburn Hills, WI	$ 2,360,385	$ 1,598,989
Gap Greek, AR	$ 4,620,360	$ 3,942,100
Kensington Estates, WA	$ 765,700	$ 1,502,900
Laurel Springs, WI	$ 1,654,021	$ 1,149,552
Mill Creek (per lot), IL	$ 12,510	$ 9,100
Somerset, MD	$ 2,456,843	$ 1,671,461
Tellabs Corporate Campus, IL	$ 3,162,160	$ 2,700,650

It is evident from this comparison that projects incorporating LID practices are cost competitive with and often less expensive than those relying on conventional stormwater management practices.

Maintenance of stormwater facilities has always been and continues to be a consideration, and maintenance of LID facilities is no exception. Maintenance actions include: sediment removal, erosion repair, and vegetation pruning. Unlike maintenance of traditional stormwater management, LID maintenance does not usually require specialized equipment (EPA 2009).

LID vs. Conventional Stormwater Management

Traditional stormwater conveyance systems are designed to collect, convey, and discharge runoff as efficiently as possible. The intent is to create a highly efficient drainage system, which will prevent flooding, promote good drainage and quickly convey runoff to detention basins, receiving waters, or treatment facilities. This practice typically involves the use of hard infrastructure such as curbs, gutters, and culverts. On the other hand, LID practices use natural drainage features, vegetated areas, swales, and contoured land surfaces to convey stormwater and remove pollutants (EPA, 2007). Utilization of LID practices can reduce the amount of engineered hard material (concrete, asphalt, PVC) needed to manage stormwater on a site.

Traditional stormwater management practices may be designed to keep peak discharge volumes at or below predevelopment peaks. While satisfying this constraint, the traditional approach allows for increased total runoff volumes, possibly increased erosion due to longer periods of sustained flow, increased frequency of runoff events, and increased pollutant conveyance in the increased stormwater volume. The latter provides for the further degradation of receiving waters (EPA, 2000). On the other hand, LID practices strive to mitigate these negative consequences with reduced total runoff volumes, frequency of runoff events, and pollution of receiving waters.

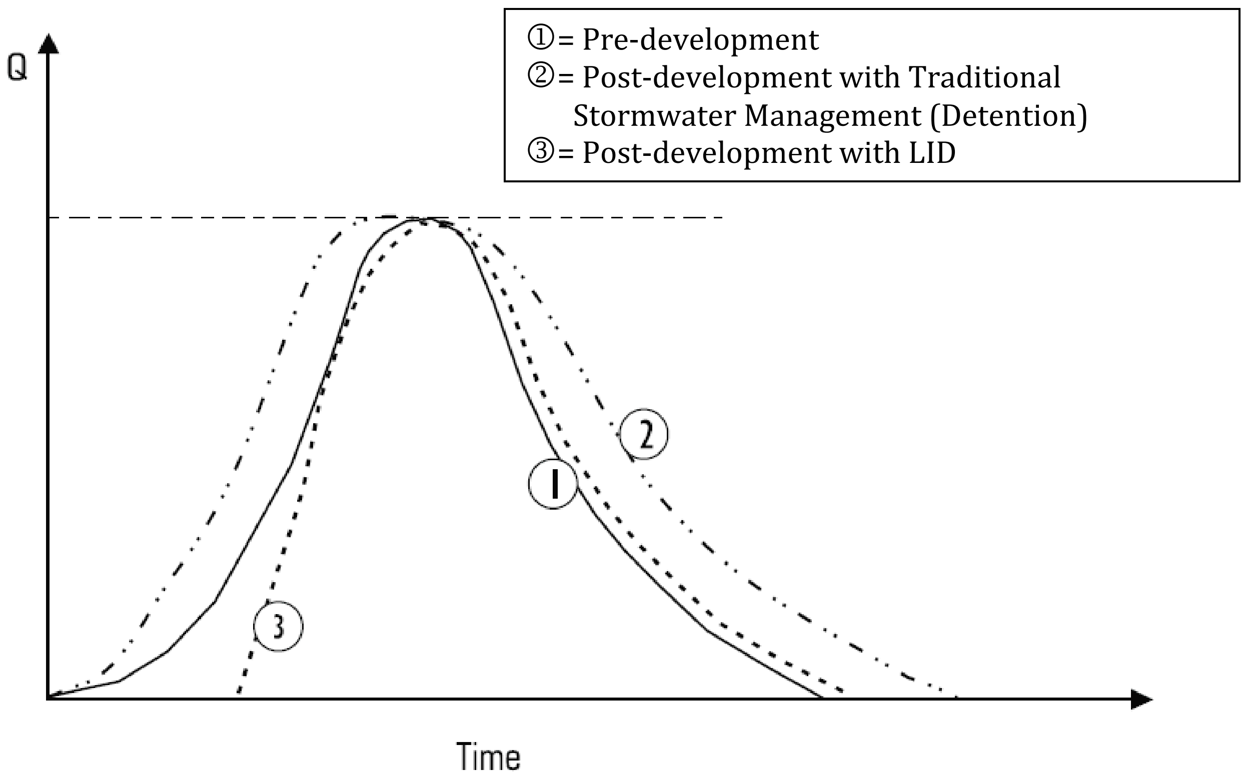
Benefits of LID

By installing green roofs on the tops of buildings, stormwater volume can be reduced. Further, excess stormwater from the green roofs may be captured and reused for toilet flushing or irrigation. An important advantage of LID is the reduction of volume and intensity of stormwater runoff, which reduces the likelihood of downstream flooding. Overall, LID has a beneficial impact on public and ecosystem safety and health. With proper design and maintenance, LID systems can effectively remove pathogens, metals, and nutrients from the water before they become concentrated in detention basins or natural lakes and streams (EPA, 2007). Considering disease vectors, LID filtration systems are typically designed to completely drain standing water within 48 to 72 hours, which will prevent mosquito breeding and reproduction (EPA, 2009).

LID practices are also capable of eliminating or reducing the size of stormwater structures (culverts, catch basins, etc.). This will provide more open space for a variety of uses, while reducing development costs (EPA, 2009).

The EPA did a study comparing the hydrologic response of sites with conventional stormwater management practices to sites with LID practices. Figure 1 presents a set of hydrographs (site runoff, or flow, referred to as Q, versus time) that show a comparison of the runoff responses for each of these two approaches to the pre-development site runoff. Development with implementation of LID practices has runoff time variation that is very similar to the runoff from the site in the undeveloped condition.

Figure 1: Comparison for Hydrologic Response of Conventional and LID IMPs (Integrated Management Practices) (EPA, 1999)



Climatic Issues

All LID practices function to some extent year round, but some practices are more effective in the cold seasons of temperate and colder climates. Thus, care needs to be exercised in the selection and implementation of LID practices in these types of climates.

In an effort to better understand and quantify the effectiveness of LID improvements, EPA (2009) assessed the performance of: bioretention systems, tree filters, porous asphalt parking lots, sand filters, and gravel wetlands. These approaches all performed as intended, demonstrating desired water quality maintenance and peak flow reduction year round (EPA, 2009). An LID practice that functions well during the winter is porous asphalt, which is formed with considerably larger pore space and permeability than traditional asphalt pavement. Other approaches, such as drainage swales, are diminished in their ability to improve water quality and manage water quantity when covered by snow or ice (EPA, 2009).

Application to Wupatki National Monument and Grand Canyon National Park

LID stormwater management practices at National Parks and Monuments can be implemented as part of new construction, reconstruction, or as part of a dedicated initiative. However, the various National Park Service (NPS) settings provide some unique constraints on LID implementation. For example, many of the structures at Wupatki National Monument and Grand Canyon National Park are registered historic structures and modifying their roofs according to LID principles will not be permissible. However, these NPS sites include parking areas, patios, sidewalks, trails, and other areas that could benefit from the application of LID practices.

Wupatki National Monument

The temperature at Wupatki National Monument ranges from 44.1 to 71.7 °F with an average annual precipitation of 8 inches and minimal snowfall. These conditions mean most LID practices are applicable, however the facility is small and stormwater runoff or receiving water issues are minimal to non-existent.

Porous pavement designs allow stormwater to flow though the pavement layer to a coarse gravel layer below. This allows the water to percolate into the ground or flow laterally to a nearby vegetated area or to be collected and used for irrigation. At Wupatki park headquarters, the parking lot, access road, and sidewalks around the visitor's center and housing area could be converted to a porous pavement system, thus reducing the amount of impervious area. The water in this system could be directed to an area, or areas, where it might be used for irrigation purposes. However, the reality is that there is simply too little paved surface area at the park headquarters to have any corresponding stormwater issues.

Even though modifying the roofs of most of the structures at Wupatki as part of green roof implementation may not be feasible, because of these structures' historic nature, the existing roofs could be fitted with rain barrels or a system of pipes leading to cisterns. This would capture runoff providing water useful for irrigation or other non-potable uses.

Most feasible and readily implementable, would be one or more rain gardens. Because of uncertain runoff frequency and quantity, a viable rain garden would have to make use of drought-tolerant vegetation. Another option is that irrigation from infrequent runoff could be supplemented using gray water from the onsite housing units.

Grand Canyon National Park

Given its large size and the corresponding high level of development, Grand Canyon National Park is a serious candidate for LID practices. The Grand Canyon's weather varies greatly due to an elevation range of nearly 5,900 ft. At the South Rim, the low monthly mean temperature is 30 °F in January, and the high is in July, at 67 °F, with an average annual precipitation of 16.5 inches. At the North Rim the low monthly mean temperature is 27 °F in January, and the high is in July, at 62 °F, with an average annual precipitation of 25.4 inches. At the bottom of the Grand Canyon, in the vicinity of Phantom Ranch, the low monthly mean temperature is 47 °F in January, and the high is in July, at 91 °F, with average annual precipitation of 9.02 inches. These climatological statistics are from: http://www.americansouthwest.net/arizona/grand_canyon/weather.html#map

In conjunction with climate, the key consideration for implementation of LID stormwater management practices is the presence or absence of stormwater management issues – which exist primarily due to the intensity and expansiveness of development. Due to the size of Grand Canyon National Park, this report will focus only on the South Rim and the LID practices that may be applicable there. Clearly, if there are no issues, there is no need for LID practices.

Porous pavements have been known to work most efficiently in cold weather. Such pavements are designed with intentional connected void space, which allows water to percolate to the underlying or adjacent soil, or to flow to vegetated areas ultimately mitigating the volume of stormwater runoff. This approach will help maintain and enhance the pre-development hydrologic regime by compensating for losses of rainfall abstraction through maintenance of infiltration potential, evapotranspiration, and surface storage, as well as increased travel time to reduce rapid concentration of excess runoff (EPA, 1999).

The paved surfaces of the many parking lots, access roads, and sidewalks at the South Rim at Grand Canyon National Park could be gradually converted to porous pavements, as these surfaces are replaced as a part of normal maintenance, over a period of decades. Because of the high volume of traffic these access roads and parking lots receive, it may be feasible to incorporate sand filters or other LID practices in the runoff catchment structures to improve the quality of stormwater runoff. In those areas where oil and/or gasoline spills are somewhat frequent, more complex designs, such as oil/water separators, may be necessary, but their application will not be discussed in this document.

Grand Canyon has many historic buildings; therefore modifying the roofs will not be feasible. The runoff from the roofs may be taken care of using IMP techniques, such as rain barrels or cisterns. The captured runoff can then be used for irrigation or various non-potable uses.

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References

EPA, 2000, U.S. Environmental Protection Agency (EPA). "Low Impact Development (LID), A Literature Review, EPA-841-B-00-005" US Environmental Protection Agency, October 2000

EPA, 2007, U.S. Environmental Protection Agency (EPA). "Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices" US Environmental Protection Agency, Nonpoint Source Control Branch (4503T), December 2007

EPA, 2009, U.S. Environmental Protection Agency (EPA). "Managing Stormwater with Low Impact Development Practices: Addressing Barriers to LID, EPA-901-F-09-003" US Environmental Protection Agency New England, April 2009

Prince George's County, 1999, Low-Impact Development Design Strategies: An Integrated Design Approach. Department of Environmental Resources Programs and Planning Division Largo, Prince George's County, MD. Available at: http://www.lowimpactdevelopment.org/pubs/LID_National_Manual.pdf

South Carolina Sea Grant, 2009, Low Impact Development. U.S. Department of Commerce, Grant NO. NA06OAR4170015 awarded to University of South Carolina. http://www.scseagrant.org/pdf_files/lid_final_brochure.pdf

City of Flagstaff, 2009, Low Impact Development Guidance Manual for Site Design and Implementation. http://www.flagstaff.az.gov/DocumentView.aspx?DID=8401