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Enhancing LID Designs Using Manufactured Treatment Devices and Materials

Introduction

One of the leading topics today in stormwater management is a drive for sustainability and low impact development (LID) design strategies. As a result, the implementation of green infrastructure and LID concepts has dramatically expanded in recent years. Innovative approaches to stormwater management can be accomplished through various site design strategies that minimize the adverse impact of site development on receiving waters. The unique constraints of a given development project often require that both conventional and innovative stormwater strategies be deployed to fully meet stormwater goals. This paper explores how LID designs can be enhanced or complemented through the use of manufactured treatment devices (MTDs) or materials. Two case studies are provided that demonstrate the enhancement of LID designs through the use of MTDs.

LID Principles

At its core, LID is a design methodology that strives to maintain predevelopment hydrology by minimizing site disturbance and the amount of runoff leaving the site. Stormwater management is considered much earlier in the design process so that important natural areas and buffers may be preserved; the creation of new impervious area minimized and runoff managed near the source with decentralized small scale controls and integrated management practices (IMPs). Some common IMPs, also referred to as green infrastructure, include infiltration areas, vegetated swales, rain gardens, green roofs, biofilters, rainwater harvesting systems and permeable surfaces (pavement, pavers, concrete etc).

Some of the core objectives of LID design include minimizing land disturbance, minimizing creation of impervious surfaces, maintaining predevelopment hydrology characteristics and treating runoff at the source using a variety of IMPs that provide the following benefits:

- Capture/retain rainfall
- Reduce peak flows
- Reduce runoff volumes
- Enhance infiltration
- Filter out pollutants

Prior to site development, the vast majority of rainfall is either taken up by plants, evaporates back to the atmosphere (evapotranspiration), or infiltrates into the subsurface. Following typical site development when vegetation is cleared, soil stripped away and impervious surfaces are constructed, infiltration and evapotranspiration both decrease and surface runoff tends to increase dramatically. A conventional stormwater management strategy often calls for routing runoff through a single large end of pipe treatment system and ultimately discharging the excess runoff into nearby receiving waters. Generally, pre-existing hydrologic patterns are not preserved, leading to stressed and degraded stream channels and diminished groundwater recharge. In contrast, an LID site design reduces the impact of development and treats stormwater as a valuable resource that can be effectively utilized onsite. By preventing runoff from occurring, infiltrating what does occur through small scale IMPs and capturing rainwater for reuse onsite, the environmental impact of development can be reduced substantially.

While providing many benefits, the use of small scale IMPs within an LID design can prove highly challenging in some cases, especially when confronting the realities of the urban environment. In some areas land may be too expensive to devote extensive areas to above-ground management practices, soils may not be suitable for infiltration or existing infrastructure and utilities may limit stormwater management options. Land space constraints can often be overcome by relying on both natural IMPs and MTDs to achieve the objectives set forth within an LID design strategy. An expanded best management practice (BMP) toolbox that integrates MTDs into LID designs becomes essential and invaluable to overcome many obstacles presented by urban site development.

Complementing LID Designs with MTDs

Various types of MTDs are well suited to employment within an urban LID design:

- Media filtration
- Permeable pavers
- Underground infiltration
- Modular bioretention
- Rainwater harvesting
- Hydrodynamic separation

A matrix is presented in Table 1 that identifies how different types of MTD technologies can be utilized to compliment LID design goals and effectively manage stormwater when facing various design constraints. From this matrix it is apparent that all primary LID benefits can be achieved through the use of one or a combination of MTDs.

Table 1 Types of MTDs	LID Benefits				
	Capture Rainfall	**Reduce Peak Flows**	**Reduce Runoff Volumes**	**Enhance Infiltration**	**Filter Out Pollutants**
Media Filtration					X
Permeable Pavers	X	X	X	X	X
Underground Infiltration	X	X	X	X	X
Modular Biofiltration	X	X	X	X	X
Rainwater Harvesting	X	X	X		

A more detailed discussion of each MTD category and their compatibility with LID design goals is provided below.

Media Filtration

Media filtration technologies are typically standalone flow-through water quality treatment devices that provide a high level of treatment to efficiently remove fine-grained particulate and other pollutants of concern such as nutrients, heavy metals, hydrocarbons and bacteria. The filtration media can be customized in order to maximize removal of the target pollutants. When surface infiltration is neither practical nor an option because of site constraints, underground media filtration (or infiltration) provides a viable means of meeting water quality goals. Media filtration systems may be installed underneath surface improvements such as parking lots or landscaping which can also aid in preserving natural land areas that would otherwise be dedicated for above-ground treatment practices.

Like all stormwater BMPs, media filtration systems must be regularly maintained to ensure proper functionality. Maintenance cycles are often dictated by site-specific pollutant loads, but media filters should be designed to account for expected pollutant loads and a realistic maintenance frequency. By matching the expected pollutant load to a given media filter's capacity to capture said pollutant, an estimated maintenance interval may be established. Once installed, media filtration systems should be inspected periodically (e.g., quarterly) for several years in order to establish an appropriate maintenance schedule. When installing media filtration systems downstream of ponds or other detention systems, it is particularly important to make sure the system has been designed to account for the large volume of runoff draining from these systems. Utilizing a system that treats the low discharge rates from detention systems but does not account for the large volume of runoff (and pollutant mass) to be treated will often result in frequent media occlusion and an excessive maintenance burden.

Permeable Pavers

Permeable pavers provide an excellent opportunity to retain water onsite and increase infiltration. Many different paver options now exist that are well suited for walkways, fire lanes, driveways and overflow parking areas. Permeable pavers help to mimic the predevelopment hydrology by reducing the amount of runoff from a given site. Furthermore, permeable pavers provide a degree of pollutant filtration through the use of an aggregate base material that also serves as an underground reservoir. Construction materials can vary from plastic to concrete or even drivable grass. The viewscape can be enhanced as well through a wide variety of shapes, sizes and materials.

Underground Infiltration

When site constraints make aboveground infiltration impractical, underground infiltration systems often provide a viable means of keeping runoff onsite and achieving groundwater recharge objectives. Underground infiltration reduces runoff rates and volumes, recharges groundwater, keeps pollutants out of receiving waters and allows development to move forward on sites without space to accommodate aboveground infiltration facilities. There are a wide variety of systems available for underground infiltration. Perforated pipe, plastic arched chambers, modular plastic structures, modular concrete structures and concrete arches all serve as viable underground infiltration systems. When designing an underground infiltration system, care should be taken to ensure adequate access is provided to allow for maintenance. Many practitioners opt to provide pretreatment upstream of underground infiltration facilities with a hydrodynamic separator or other treatment practice designed to remove particulate and other pollutants that would otherwise begin to reduce infiltration capacity.

Modular Biofiltration

Modular biofiltration and bioretention systems are typically small scale decentralized treatment practices that include engineered soil media and vegetation chosen to optimize pollutant removal through a combination of filtration and biological processes. Modular biofiltration units provide a high level of treatment and effectively remove sediment, metals, nutrients, bacteria and hydrocarbons. In addition to providing a high level of environmental protection, modular biofiltration systems also serve to enhance the aesthetics of a site. When underlying soil conditions allow, modular biofiltration systems can be configured to serve as bioretention systems allowing water to infiltrate into the underlying soils, reducing runoff volumes and recharging the groundwater table.

The modular aspect of these systems allows them to be distributed throughout a site as needed, and the engineered soil media eliminates the variability inherent in trying to mix biofiltration media to specification onsite. A consistent media blend minimizes premature clogging and ensures consistent performance from one location to the next.

Rainwater Harvesting

Rainwater harvesting allows for the capture and subsequent reuse of rainwater which helps maintain predevelopment hydrology by reducing runoff volumes while simultaneously reducing the demand for freshwater. In short, rainwater harvesting helps manage runoff and preserve freshwater supplies. Harvesting can be accomplished using a variety of either underground or above-ground cisterns. Underground cisterns can be designed to accommodate virtually any amount of needed storage without taking up surface space. Aboveground cisterns tend to accommodate smaller storage requirements and can often be incorporated into the site's architectural design.

Rainwater harvesting treats runoff as a valuable resource instead of a liability by using water that would otherwise have been lost for beneficial purposes. Using harvested water for irrigation, toilet flushing or wash water will decrease the use of potable water (public utility) and the associated costs. Conservation is becoming vital, especially in dry regions where the availability of fresh water often dictates whether a development moves forward. Rainwater harvesting also provides an opportunity to earn a number of LEED points for stormwater management and water conservation.

Hydrodynamic Separation

Hydrodynamic separators (HDS) are underground flow-through water quality treatment devices designed to remove coarse sediment, debris and in some instances free-floating oil via gravity separation. While HDS systems can provide effective standalone treatment, they are perhaps best suited as pretreatment structures to complement the operation of other BMPs. For example, an HDS system can be installed upstream of an infiltration system to provide pretreatment. Sequestering pollutants in an easily accessible HDS system preserves the hydraulic capacity of the downstream infiltration system and reduces the required maintenance frequency. HDS systems occupy a small footprint, can be installed underneath land improvement features, and can often be utilized when particularly challenging site constraints like existing utilities or limited drop rule out other treatment options.

Case Study #1: Media Filtration Addresses Overflow from Infiltration Swales

When the Maryland Department of Transportation pursued stormwater management options for a small parking lot at one of their facilities near Baltimore, Maryland they put LID near the top of the list. The parking lot was divided into three sections and the runoff from each section was directed to a vegetated swale designed to infiltrate the runoff. This design allowed for the elimination of curb and gutter onsite, helped replicate predevelopment hydrology and treated the runoff near the source. However, the site proved challenging in that the swales did not have sufficient infiltration capacity to address the entire water quality volume. The problem was solved by incorporating a small linear media filtration system into the design. When the infiltration swales exceed their capacity, the excess runoff overflows into a conveyance system and is then routed to the media filtration system for treatment.

Incorporating media filtration into the design ensured that the entire water quality flow was treated onsite. The ability to install the filtration system underground was crucial given the restrictive footprint of the project. The filtration media was chosen specifically to address the pollutants of concern for the project including sediments, metals and hydrocarbons. By first infiltrating as much runoff as possible through a natural IMP, site designers were able to minimize the impact on receiving waters, recharge the groundwater table and minimize the size of the media filtration system and conveyance infrastructure needed to address the overflow, all sound LID design decisions (CONTECH 2008).

Case Study #2: HDS, Media Filtration, Harvesting and Permeable Pavers Address Land and Water Use

A sustainable approach to stormwater management was used for a new LEED-inspired 12,500 square foot corporate headquarters building in Chattanooga, Tennessee. The integration of IMPs and MTDs serve to reduce pollution from stormwater runoff, limit the disruption to the natural site hydrology by reducing impervious cover, increase infiltration, decrease runoff and peak flows, conserve water, and reduce potable water use. The design approach allowed for the maximization of land use compared to a conventional end of pipe stormwater management plan. A conventional stormwater management plan included the use of a detention pond allowing 89% land use. The unconventional approach allowed for 100% land use while meeting the water management goals of the site.

Stormwater and roof runoff are pretreated through an underground hydrodynamic separator and filtration system. Treated water is then harvested within a 13,000 gallon underground modular polypropylene storage unit. Stored water is used for non-potable property applications including landscape irrigation, an outdoor fountain, and toilet flushing. Infiltration and runoff reduction is maintained within the parking areas through the combination of load-supporting drivable grass and gravel paving technologies. These unique surface features serve to reduce the urban heat island effect caused by traditional paving materials; and, enhance the visual aesthetics of the property.

The benefits of their implementation can also be realized in terms of practical land uses, cost recovery and equity enhancement. Through the integration of the stormwater management technologies, an increase in the equitable position for the owner was achieved leading to a quick return on investment. By allowing for 100% land use, an option became available to construct a larger commercial office building and additional parking spaces beyond that of the headquarters building alone. Thus, additional commercial office rental income could be realized for the larger building. This integrated approach to stormwater management in an urban setting not only allowed for environmental protection and water conservation, but also served to provide a beneficial financial return. (AquaShield™, Inc. 2009).

Conclusion

LID design approaches offer considerable environmental and aesthetic benefits not typically achieved by conventional stormwater management strategies alone. There is no question that our wholesale shift toward reliance on LID concepts is sound, but we will need a well rounded BMP toolbox to address the unique challenges some sites present. As demonstrated above, there are a variety of instances where the incorporation of MTDs into the framework and goals of LID design result in enhanced site utilization and stormwater management that otherwise would not be possible. While the management of stormwater runoff within the urban landscape can be a formidable challenge, the unconventional blend of IMPs and MTD technologies can serve to overcome those obstacles. Each development site is unique, and the ability to reach into and draw from an expanded BMP toolbox will help us concentrate development in existing urban areas, thus preserving open space, and ensure stormwater treatment goals are fully met in instances where green infrastructure alone is insufficient.

References

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