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Review

Performance and implementation of low impact development – A review☆

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HIGHLIGHTS

- Reviewed literature on the low impact development strategies for stormwater management.
- Compiled the performance of different LIDs under various conditions.
- Identified research needs and professional practice needs on LIDs.

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ABSTRACT

Climate change, urbanization, and ecological concerns are all driving the need for new stormwater management strategies. The effects of urbanization are exaggerated by climate change and thus the development of innovative stormwater management techniques are necessary to mitigate these impacts. One emerging stormwater management philosophy is low impact development (LID). LID utilizes distributed stormwater controls (often green infrastructure) as well as green spaces and natural hydrologic features in order to bring the hydrology of urban catchments closer to pre-development conditions. The review provides a summary of the knowledge of LID as a stormwater management technique and climate change mitigation measure as well as the current state of research and implementation of this topic. In order to provide a better understanding of the extensive scope that should be considered for design of low impact developments, methods of optimization, modelling, monitoring and the performance of LID alternatives is covered. LID has been widely adopted and proven successful in many cases; however, there remains uncertainty of its benefits. This review brings together knowledge from many sources in order to provide an overview of LID and examine its performance and implementation.

Contents

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1. Introduction

Urban stormwater management (SWM) is an essential part of any development. It has significant ecological, economical, and social importance. The vast increase in urbanization around the world and the increasingly more evident effects of climate change are two major contributors to excessive runoff that conventional stormwater management systems cannot adequately handle. Urbanization produces numerous changes in the natural environment putting more stresses on conventional stormwater management systems (Chen et al., 2016). The traditional approach to urban stormwater management has been to use curbs, gutters, other grey infrastructure and sewers to convey the stormwater through a centralized system as rapidly and safely as possible. The improved conveyance of stormwater in urban areas combined with the increase in impervious surfaces has resulted in increased peak flows, reduced times of concentration, reduced infiltration rates and consequent groundwater recharge rates, and redistribution of the water balance (Konrad and Booth, 2005; Wong and Eadie, 2000). This approach generally does not contribute to sustainable urban development (Chen et al., 2016; Mitchell, 2006; Paule-Mercado et al., 2017; van Roon, 2007; Wong and Eadie, 2000). Urban flooding with increased frequency and severity is intensified by increased urbanization, population growth, and climate change (Stovin et al., 2012; Visitacion et al., 2009).

Methods for urban stormwater management must evolve to meet the increased demands resulting from urbanization, climate change and budgetary constraints. One way in which urban stormwater management has evolved to accommodate this is the increasing use of low impact development (LID) controls. At its most ambitious, LID aims to return the developed watersheds to pre-development hydrological conditions (i.e. to mimic natural water cycles or achieve hydrologic neutrality) (Damodaram et al., 2010; Shuster et al., 2008; van Roon, 2005, 2007; van Roon and Knight-Lenihan, 2004). LID is often used as a retrofit designed to reduce the stress on urban stormwater infrastructure and/or create the resiliency to adapt to climate changes. Stormwater quality regulations are another major driver for the adoption of LID as some controls have also been implemented to improve water quality. In order to achieve stormwater objectives, LID relies heavily on infiltration and evapotranspiration and attempts to incorporate natural features into design. Compared with traditional urban stormwater management patterns, LID alternatives have the function of returning the runoff to the natural hydrologic cycle, including reduction in runoff volume (Ahiablame et al., 2013; Jia et al., 2012) infiltration improvement (Ahiablame et al., 2012), reduction in peak flow (Drake et al., 2013), extending lag time, reduction in pollutant loads (Liu et al., 2015), and increase in baseflow (Hamel et al., 2013).

Low impact development was first introduced in Maryland as a means to mitigate the effects of increased impervious surfaces (Prince George's County, 1999), though some individual techniques were already in place before the term "low impact development" was coined. Prince George's County, in an effort to increase adoption of LID, produced a municipal Low Impact Development Design Manual (Coffman, 1997). This was soon republished and distributed to a national audience (Coffman, 2000). Low impact development is the North American terminology for a design philosophy that has become popular in many parts of the world. Other names for LID, or at least similar design philosophies, are urban design and development (LIUDD) in New Zealand, water sensitive urban design (WSUD) in Australia, and sustainable urban drainage systems (SuDS) in Europe. These approaches might also include strategies such as integrated urban stormwater management (IUSM) and integrated urban water management (IUWM). Fletcher et al. (2014) discuss the development and application of these and other terminology used in the urban drainage field. LID aims to reduce stormwater management costs by considering a site's natural features in the design. Small scale stormwater treatment devices that encourage infiltration and evaporation and are located at or near the runoff source are considered as LID controls. WSUD is a methodology that attempts to manage water balance, improve water quality, encourage conservation of water and maintain environmental opportunities related to water. Similar to LID, it sets out to minimize the hydrological impacts of urban development. SuDs is a range of techniques and technologies that are applied to drain stormwater in a more sustainable manner than conventional systems. SuDs aim to replicate the pre-development conditions at a site. Best Management Practice (BMP) is a term used to describe a practice or technique implemented to prevent pollution. Green Infrastructure (GI) attempts to include as much green space as possible in urban planning and aims to maximize the benefit from these green spaces (Fletcher et al., 2014). Henceforth, in some cases, this paper may refer to any one of these approaches as low impact development (LID).

Specific examples of stormwater controls used as part of LID include green roofs, rain gardens, bioretention cells, soakaways, swales, permeable pavements, infiltration basins, infiltration trenches, ponds, rain barrels or cisterns, tree box filters, curbless roads with swales, downspout disconnection, as well as other green infrastructures and even community education (Debusk and Hunt, 2011; Shuster et al., 2008; Stovin et al., 2012). CVC (2010) and WEF (2012) are good sources on the design of these stormwater controls.

In heavily urbanized areas it might be most feasible simply to retrofit existing infrastructure, such as parking lots, roads, sidewalks and buildings (Damodaram et al., 2010). Existing pervious areas, such as parks, lawns, and gardens might provide additional capacity for infiltration in urban areas depending on site conditions (Shuster et al., 2008). LID measures can usually be built into these public spaces without compromising their primary function (CVC, 2010). Another infiltration strategy is to direct runoff from impervious surfaces to pervious surfaces or retention facilities (Brander et al., 2004) before diverting the stormwater runoff to catch basins/storm sewers. An effective non-