Low impact stormwater management in urban landuses using small-decentralized system approach: Features of the first ‘green’ campus in Korea

Des aménagements à faible impact hydrologique utilisant des petits systèmes décentralisés : caractéristiques du premier Ecocampus en Corée

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RÉSUMÉ

Malgré les efforts considérables déployés par le gouvernement coréen au cours des 30 dernières années pour contrôler les sources ponctuelles de pollution, la qualité de l’eau dans les quatre fleuves les plus importants a continué de se détériorer en raison des charges accrues de polluants provenant de sources diffuses. En conséquence, le Ministère de l’Environnement a mis au point et encouragé l’application de nouvelles politiques en vue d’un système de gestion plus moderne et systématique, et ciblant la pollution diffuse. L’équipe de recherche de l’Université nationale de Kongju a mené des recherches sur les moyens de contrôler efficacement la pollution diffuse et sur la gestion à faible impact écologique des eaux pluviales dans les plans de développement urbain, en utilisant une approche décentralisée avec des systèmes plus petits. Depuis 2009 et jusqu’à récemment, neuf technologies nouvelles ont été mises au point et construites sur le campus de l’université afin d’étudier l’applicabilité des systèmes dans les conditions climatiques locales. Les résultats obtenus grâce à la surveillance continue des systèmes ont été utilisés pour établir les méthodologies d’échantillonnage efficaces, les caractéristiques de la qualité de l’eau, les mécanismes de traitement, l’efficacité des performances, les facteurs de conception, les considérations relatives aux coûts et à l’entretien, ainsi que la rénovation et l’affinage des technologies. En fin de compte, les résultats des recherches ont été utilisés pour servir de base à l’application de politiques et de réglementations pour le contrôle de la pollution diffuse en exigeant l’application des technologies sur les projets de développement coréens.

ABSTRACT

Despite the extensive efforts of the Korean government during the last 30 years to control point source pollution, the water quality in the four major rivers has continued to deteriorate due to the increased pollutant loadings from nonpoint sources. Consequently, the Ministry of Environment established and promoted new policies for a more advanced and systematic management system targeting nonpoint source pollution. The research team at the Kongju National University performed the research on the effective control of nonpoint source pollution and low impact stormwater management in urban landuses using small-decentralized system approach. Since 2009 up until recently, nine new technologies were developed and constructed at the university campus to investigate the applicability of the systems under local climate condition. The results obtained from the continuous monitoring on the systems were used to determine efficient sampling methodologies, water quality characteristics, treatment mechanisms, performance efficiency, design factors, cost and maintenance considerations, as well as renovations and refinement of the technologies. Ultimately, the research results were used as basis to implement policies and regulations for nonpoint source pollution control by requiring the application of the technologies to development projects in Korea.

KEYWORDS

Decentralized, green campus, low impact development, nonpoint source; stormwater management
1 INTRODUCTION

1.1 Background

Land development can have severe adverse stormwater impacts, particularly if the land is converted from a natural condition to a highly disturbed area with large percentages of impervious and non-native vegetated covers. Such impacts typically include an increase in stormwater runoff volume, rate, velocity, and pollutants and a corresponding decrease in the quality of runoff and stream flow (Paul and Meyer 2001; Shuster et al. 2005). Traditionally, storm drain systems have been designed to directly convey stormwater runoff from developed areas to curb and gutter systems, storm drain inlets and a network of underground storm drain pipes as quickly and efficiently as possible. More frequently, management of stormwater impacts has focused on collecting and conveying the runoff from the entire site through a structural conveyance system to a centralized facility where it is stored and treated prior to discharge downstream. In effect, such practices first allow the adverse runoff impacts to occur throughout the site and then provide remedial and/or restorative measures immediately prior to releasing the runoff downstream. In addition, these conventional engineering solutions do not address stormwater quality or improvement of groundwater recharge, increasingly costly and unaffordable and the ongoing maintenance of the facilities becomes a continuous financial burden (Coffman 2000). Thus, it is essential to always look upon ecologically-informed landscapes as being multi-functional and delivering multiple benefits, rather than becoming fixated on single issues (Dunnett and Clayden 2007).

With the increasing emphasis on nonpoint source pollution and concerns over the environmental impacts of land development, it has become necessary to develop effective alternatives to the centralized conveyance and treatment strategy that has been the basis for much of the stormwater management regulations. Compared to urban point source pollution, stormwater runoff shows very different and specific characteristics, concerning quality and discharge mode in the environment. Stormwater runoff occurs depending on rainfall events and concentrations of pollutants change very much both within and between events (Kim et al. 2005). Additionally, a large variability between different sites is observed (Maniquiz et al. 2012). Although the type of pollutants should be the same as found elsewhere, concentrations, accumulation and removal processes may vary, and specific climate conditions are an important factor controlling these mechanisms (Kim et al. 2007). Therefore, new strategies must be developed to minimize and even prevent adverse stormwater runoff impacts from occurring on specific landuse sites and then to provide necessary treatment from the source or closer to the origin of those impacts.

1.2 Legal basis

Since the establishment of the Ministry of Environment (MOE) in 1998, the national water policy of the Korean government was shifted from ‘Water Quality Preservation Act’ to ‘Watershed Management Act’. The former introduced various measures related to wastewater discharge control, while the latter provided a legal framework for the special measures in the four major rivers. In 2004, the ‘Comprehensive Measures for Nonpoint Source Pollution Management’ was established after realizing that the policies focused on point source pollution have shown limitations in achieving water quality improvement, pointing out the need for an advanced and systematic management system for nonpoint source pollution. The major goals are addressed in three phases (Figure 1a). In the first phase (2007 to 2010), the development of new technologies through survey and research is the major concern. The
next phase (2010 to 2012) is focused on pilot scale testing to validate the new technology and the last phase (2012 to 2020) involves the nationwide implementation of the technologies for aqua-ecosystem restoration. However, after the first phase in 2006, a new water management plan the ‘Clean Water, Eco-Clean Eco-River 2015’ was promoted to provide policy directions in a ten-year period from 2006 to 2015 reducing the third phase by five years. Most recently, the ‘Water Environment Comprehensive Management Plan’ was issued focusing on rainwater management until 2050 (Figure 1b). The goal in this new plan is to circulate at least 40% of the total annual rainfall by reducing the surface runoff and maximizing water evapotranspiration and infiltration.

1.3 Research purpose and goals

In response to the growing cost of addressing nonpoint source pollution impacts in Korea, there has been much recent interest in exploring low impact mitigation strategies that concentrate and retain contaminants onsite while concurrently reducing stormwater volume through storage and infiltration. Such strategies, known as low impact development or LID has been adapted in Korea as an innovative stormwater management approach complementing other urban planning techniques such as ‘Smart Growth,’ ‘Green Building,’ ‘Sustainable Urban Drainage System (SUDS),’ ‘Water Sensitive Urban Design (WSUD),’ ‘Sustainable Development,’ and ‘Green Stormwater Infrastructure (GSI).’ Rather than responding to the rainfall-runoff process like centralized structural facilities, LID interact with the process, accomplished first with appropriate site planning and then by directing stormwater towards small-scale systems that are dispersed throughout the site with the purpose of managing water in an evenly distributed manner that can significantly reduce the overall impact of land development on stormwater runoff. As such, low impact development promotes the concept of designing with nature.

In our research, the importance of low impact stormwater management measures in urban landuses such as roads, parking lots and impervious rooftops using small-decentralized system approach was addressed. Particularly, placing an emphasis on the effectiveness, hydrologic and environmental effects after the application of LID. Important considerations and guidelines in designing LID technologies and practices were also presented.

Our research team at Kongju National University has been engaged in nonpoint source pollution research in Korea since a decade ago. With much effort, we have tried to be the first and only ‘green’ campus in Korea because of the developed and constructed LID technologies in our university. Our research findings and experiences have been a great contribution to the Ministry of Environment in Korea (whom have funded most of our major projects) serving as a basis to revise and make new policies relating to nonpoint source pollution management in the country. It is also our hope to offer guidance and contribute to the integral change on the stormwater management not only in a university setting but also for both new development and redevelopment sites; that is to produce smaller less obtrusive facilities that are more aesthetic and less burdensome on those responsible for long-term maintenance and performance while sustaining a healthy environment.

Figure 2. LID application at KNU campus (full names are listed in Table 1).
2 MATERIALS AND METHODS

2.1 Site characteristics

2.1.1 Site location and description

LID facilities as shown in Figure 2 were developed and constructed at the Kongju National University grounds in Cheonan City, northeast of South Chungnam Province, Korea (36°51’1.11”N, 127°9’0.23”E). The infiltration trench, our first facility was constructed in April 2009 and four facilities were developed and constructed the following year including a tree box filter, two constructed wetlands and a planter. The sites were initially selected because of suitability to the research purpose; to construct a pilot-scale facility for the management of stormwater runoff on a real-scale catchment in a highly-use paved and impervious areas. New facilities were added based on the preliminary studies. Up until recently, we have a total of nine facilities in our campus including a rain garden, bioretention, etc. The facilities were sited either on a small landscape area near a side road or close to the edge of a parking lot. The detailed characteristics of the sites and facilities are summarized in Table 1.

Table 1. Summary on the characteristics of the LID facilities.

<table>
<thead>
<tr>
<th>Characterization</th>
<th>LID Type</th>
<th>Location in the map (Fig. 1)</th>
<th>Year constructed</th>
<th>Infiltration capability</th>
<th>Vegetation</th>
<th>Filter media</th>
<th>Pretreatment volume (m$^3$)</th>
<th>Catchment area (m$^2$)</th>
<th>Aspect ratio (L:W:H)</th>
<th>Pretreatment</th>
<th>Pretreatment volume (m$^3$)</th>
<th>Surface area to catchment area ratio (%)</th>
<th>Storage volume to total volume ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bioretention</td>
<td>1</td>
<td>2013</td>
<td>Yes</td>
<td>Korean Fan, Columbine, Shrubby Cinquefoil, Aster</td>
<td>Sand, Soil, Bottom ash, Woodchip</td>
<td>0.16</td>
<td>139</td>
<td>1:0.3:0.4</td>
<td>Yes</td>
<td>-</td>
<td>2.20</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Planter</td>
<td>2</td>
<td>2010</td>
<td>No</td>
<td>Dawn Redwood, Bridal wreath, Rainbow pink</td>
<td>Sand, Gravel, Woodchip</td>
<td>-</td>
<td>48</td>
<td>1:1:1.4</td>
<td>No</td>
<td>-</td>
<td>0.04</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>Infiltration Planter</td>
<td>3</td>
<td>2013</td>
<td>Yes</td>
<td>Dawn Redwood, Bridal wreath, Rainbow pink</td>
<td>Sand, Soil, Gravel, Woodchip</td>
<td>-</td>
<td>81</td>
<td>1:1:0.9</td>
<td>No</td>
<td>-</td>
<td>0.02</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Tree Box Filter</td>
<td>4</td>
<td>2010</td>
<td>Yes</td>
<td>Iris, Iris</td>
<td>Sand, Gravel, Woodchip</td>
<td>2.7</td>
<td>450</td>
<td>1:0.3:0.3</td>
<td>Yes</td>
<td>Yes</td>
<td>0.33</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Infiltration Garden</td>
<td>5</td>
<td>2014</td>
<td>Yes</td>
<td>Iris</td>
<td>Sand, Gravel, Woodchip</td>
<td>0.41</td>
<td>481</td>
<td>1:0.2:0.1</td>
<td>Yes</td>
<td>Yes</td>
<td>0.41</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Small Hybrid Wetland</td>
<td>6</td>
<td>2010</td>
<td>Yes</td>
<td>Rainbow pink</td>
<td>Sand, Gravel, Woodchip</td>
<td>0.44</td>
<td>597</td>
<td>1:0.1:0.1</td>
<td>Yes</td>
<td>Yes</td>
<td>0.44</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>Small HSSF Wetland</td>
<td>7</td>
<td>2010</td>
<td>Yes</td>
<td>Rainbow pink</td>
<td>Sand, Gravel, Woodchip</td>
<td>1.0</td>
<td>457</td>
<td>1:0.2:0.26</td>
<td>Yes</td>
<td>Yes</td>
<td>1.0</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Infiltration Trench</td>
<td>8</td>
<td>2009</td>
<td>Yes</td>
<td>Iris, Iris</td>
<td>Sand, Gravel, Woodchip</td>
<td>2.47:1</td>
<td>520</td>
<td>1:0.2:0.26</td>
<td>Yes</td>
<td>Yes</td>
<td>2.47:1</td>
<td>5.40</td>
</tr>
<tr>
<td></td>
<td>Rain Garden</td>
<td>9</td>
<td>2011</td>
<td>Yes</td>
<td>Rainbow pink</td>
<td>Sand, Soil, Gravel</td>
<td>0.12</td>
<td>200</td>
<td>2.47:1</td>
<td>Yes</td>
<td>Yes</td>
<td>0.12</td>
<td>-</td>
</tr>
</tbody>
</table>

*100% Impervious

2.1.2 Design characteristics and strategy

Figure 3. Typical design strategy utilized for the management of stormwater runoff in (a) road, (b) parking lot, and (c) impervious rooftop; and (d) the key elements of the design approach.
The basic LID strategy employed for the management of stormwater runoff in our campus is to regulate the volume and decentralize flows. Developing a design that reduces the runoff will result in a water quality benefit since the pollutant load is a product of runoff volume and the concentration of pollutant. Thus, small detention/retention areas (typically less than 2% of catchment areas) were created with filtering, infiltration, biological uptake, or storage and reuse component that permanently removes some volume of runoff and pollutant loads. The constructed systems are used to treat stormwater as close to the point of discharge to the storm sewer system. The basic elements are shown in Figure 2a and implemented in combination depending on the landuse type, i.e., road, parking lot, and roof (Figure 2b-d). The stormwater management measures employed focus on minimizing both the quantitative and qualitative changes to a site’s pre-developed hydrology and then providing treatment as necessary through a network of facilities distributed throughout the site.

2.2 Monitoring and data collection

A total of 207 storm events were monitored since May 2009 and manual grab sampling technique was performed to collect runoff samples. Samples were collected at the inlet and outlet units of each facility with more extensive sampling at the first hour of runoff with a maximum of 12 samples for six hours. The sample collection frequency and time were adjusted depending on the hydrograph. Flow measurements were also manually conducted at the inflow and outflow units of each facility in five or ten minute interval from the start until the end of runoff/outflow. The flow rates were calculated as the volume of runoff collected in a graduated container or volumetric flask per unit time. The rainfall data for all the storm events on the LID sites were obtained from the Korean Meteorological Association (KMA). Water quality parameters analytically measured include total suspended solids (TSS), nutrients (TN, TP, etc.), organics (BOD, COD, etc.), and heavy metals (Cu, Pb, Fe, Ni, Zn, Cr, and Cd). The data from the monitoring of storm events were used for the concentration, runoff volume, and pollutant loading reduction calculations.

3 RESEARCH RESULTS AND MAJOR FINDINGS

3.1 Hydrologic and storm events characterization

Figure 4. Rainfall frequency distribution on the site, 2009 to 2014.

- The rainfall frequency distribution in the LID sites for the monitoring period of 2009 to 2014 indicates that the total annual rainfall was highly variable for each year, smallest being 768 mm in 2013 and highest in 2012 with 2,212 mm (Figure 4). In low rainfall year, the proportion of storms 15 mm or less accounts for 45% of the total annual rainfall; whereas in high rainfall years, it accounts for only 20%.

- Based on Korea’s climatic condition, a significant number of storms (70%) occurred mostly during the summer months (July, August and September) and the rest of the months corresponded only to 30% of the total annual rainfall; thus several stormwater management practices are designed to control these most frequent storms.

- Table 2 shows the summary characteristics of the sampled storm events. The average rainfall depth monitored for all the sites was 10.2 mm with coefficient of variation (CV) between 0.6 and
1.8. Almost 80% of sampled events have rainfall intensity of less than the average of 4.2 mm/hr. The average runoff duration was short (2.5 hr), corresponding to approximately 60% of the average rainfall duration. Average HRT varies from 10 minutes to about 4 hr.

Table 2. Summary of monitored storm events (refer to mean values and coefficient of variation inside the parentheses).

<table>
<thead>
<tr>
<th>Characterization</th>
<th>Unit</th>
<th>Bioretention</th>
<th>Planter</th>
<th>Infiltration Planter</th>
<th>Tree Box Filter</th>
<th>Infiltration Garden</th>
<th>Small Hybrid Wetland</th>
<th>Small HSSF Wetland</th>
<th>Infiltration Trench</th>
<th>Rain Garden</th>
</tr>
</thead>
<tbody>
<tr>
<td>N events</td>
<td></td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>26</td>
<td>14</td>
<td>28</td>
<td>22</td>
<td>42</td>
<td>30</td>
</tr>
<tr>
<td>ADD</td>
<td>day</td>
<td>5.5 (0.7)</td>
<td>5.5 (0.8)</td>
<td>4.7 (0.7)</td>
<td>6.4 (1.2)</td>
<td>6.9 (0.9)</td>
<td>5.7 (1.5)</td>
<td>6.1 (0.8)</td>
<td>5.8 (0.8)</td>
<td>5.2 (1.0)</td>
</tr>
<tr>
<td>Rainfall depth</td>
<td>mm</td>
<td>8.4 (1.8)</td>
<td>12.4 (0.8)</td>
<td>7.1 (0.9)</td>
<td>6.6 (0.9)</td>
<td>8.8 (1.0)</td>
<td>12.6 (1.3)</td>
<td>12.2 (0.7)</td>
<td>8.0 (0.8)</td>
<td>15.4 (0.6)</td>
</tr>
<tr>
<td>Rainfall duration</td>
<td>hr</td>
<td>3.6 (0.6)</td>
<td>4.1 (0.7)</td>
<td>3.5 (0.6)</td>
<td>2.9 (0.7)</td>
<td>2.8 (0.7)</td>
<td>4.0 (0.9)</td>
<td>5.3 (0.6)</td>
<td>5.0 (0.5)</td>
<td>5.8 (0.7)</td>
</tr>
<tr>
<td>Average rainfall</td>
<td>mm/hr</td>
<td>2.8 (1.3)</td>
<td>3.6 (0.8)</td>
<td>3.3 (1.4)</td>
<td>2.5 (1.0)</td>
<td>4.9 (1.4)</td>
<td>7.2 (2.6)</td>
<td>5.8 (1.7)</td>
<td>2.4 (1.5)</td>
<td>5.1 (1.2)</td>
</tr>
<tr>
<td>Runoff duration</td>
<td>hr</td>
<td>2.3 (0.7)</td>
<td>2.3 (1.0)</td>
<td>1.9 (0.9)</td>
<td>1.9 (0.6)</td>
<td>2.1 (0.9)</td>
<td>3.0 (0.8)</td>
<td>2.5 (0.7)</td>
<td>2.6 (0.5)</td>
<td>3.2 (0.8)</td>
</tr>
<tr>
<td>HRT</td>
<td>hr</td>
<td>1.2 (0.8)</td>
<td>3.4 (1.1)</td>
<td>1.0 (0.3)</td>
<td>0.4 (1.2)</td>
<td>0.2 (1.0)</td>
<td>3.9 (1.8)</td>
<td>0.6 (1.2)</td>
<td>2.9 (0.4)</td>
<td>1.9 (1.2)</td>
</tr>
</tbody>
</table>

N = Number of monitored storm events; ADD = antecedent dry day; HRT = hydraulic retention time

3.2 Runoff water quality characterization

- Particulates like TSS and total heavy metals including turbidity have the highest CVs ranging between 0.7 and 1.1. Soluble metal constituents tend to have slightly lower CVs than total metals (CV=0.5 and 0.95). Nutrients such as TN and TP have the least variations (less than 0.5). Fe, Pb and Zn were the dominant metals particularly due to leaded gasoline, tire wear, and atmospheric fallout. Constituent runoff EMCs vary to a large extent from event to event. During spring/summer, the CV of runoff EMC ranges between 0.6 and 1.1, while between 0.3 and 0.7 during the fall/winter season.

- Figure 5 shows the behaviour of the concentration for selected parameters during the initial four hours of sampling which clearly indicates that the runoff during the early period of storm exhibited the ‘first flush’ containing most of the pollutant load. It was also observed that the site mean concentration (SMC) corresponded to the concentration after at least 1 to 3 hours after the runoff commenced.

3.3 Environmental effects after LID application

3.3.1 Capture stormwater runoff and the contaminants present in it

- On average almost 35 to 50% of rainfall was collected as runoff. Between March and September, the greatest captured runoff was achieved at 60%. Lowest captured runoff occurred during the winter months of January, February and December that was between 30 and 45% of monthly precipitation.

3.3.2 Change the hydrologic balance

- Figure 6 demonstrates a simple diagram representing the flow balance in the LID facilities. Once the runoff entered the system, the runoff could be infiltrated into the surrounding soil, evaporated, retained or stored in the pre-treatment tank and/or within the pores of the facility media, and the excess volume will be discharged to the sewer. The overall reduced volume was calculated as the difference between the inflow and discharge volume.

- Figure 7 shows that rainfall depth highly influenced the runoff volume. The percentage of reduced volume decreases as the rainfall depth increases. Conversely, as the rainfall increases, the discharged volume increases. The discharge (treated) runoff could serve for possible reuse, e.g. irrigation to landscape areas nearby.
Comparing the LID types, infiltration type demonstrated better hydraulic performance than non-infiltration type. The difference in average reductions were 30 to 35%, favoring the infiltration type. The interquartile ranges (IQR) for the reductions in volume, average and peak flows were extremely higher in infiltration type than non-infiltration type, the differences were between 40 and 60%.

Figure 6 Conceptual diagram of flow balance

Figure 7 Relationship of reduced and discharged volume with rainfall depth.

3.3.3 Change the rate, frequency and duration of peak flows

The flow velocities and peak flows were significantly reduced and the occurrence time was delayed in most rainfall events after the application of LID, which indicates retention and infiltration in the filter media bed and soil. The infiltrated outflow was supplied as ecological water for the ecosystem of streams in the dry season by being sent to underground water, thereby used to improve water quality and ecosystems and also reducing flood risk in urban areas.

3.3.4 Treatment of pollutants and water quality improvement

The constructed LID facilities were designed to provide water quality treatment control for at least the first 10 to 25 mm of runoff from impervious areas depending on landuse type. The use of small-decentralized system approach resulted in much higher levels of water quality treatment control since much greater volume of annual runoff was reduced than the designed water quality volume. The flow control also resulted to the reduction in the pollutant transport capacity and overall pollutant loading as can be seen in Figure 8. Among the pollutants, TSS, Total Fe and COD showed the highest pollutant removal (50 to 60%) even with no volume reduction (runoff just passed the system). Other pollutants also showed satisfactory pollutant removal that is increasing as the volume reduction increases.

In Figure 9, the influence of rainfall range depth in the reduction and discharge of pollutant load was emphasized. For rainfall range less than 20 mm, the pollutant reduction was all positive and high in between 55 and 75%. However, negative reduction was observed for rainfall range greater than 20 mm for some pollutant parameters, especially heavy metals. In the case of discharged load, pollutants exhibited high variation in discharged between 10 and 80%. However, the maximum discharge was only 55% for rainfall range less than 10 mm.

3.3.5 A multitude of benefits

LID has numerous benefits and advantages and is a more environmentally sound technology. LID can enhance the local environment and protect public health, environmental assets and water
quality; and builds community livability. Natural functions can be maintained with the use of LID practices, which includes reduced impervious surfaces, functional grading, open channel sections, disconnection of hydrologic flowpaths, and the use of bioretention/filtration landscape areas (Coffman 2002; CSD 2007). LID practices increase natural rainfall penetration and natural groundwater recharge, thus reducing potential impacts to biological habitat and reduced base flow into reservoirs from extended drought periods (CSD 2007; Gilroy and McCuen 2009). The natural processes employed by LID practices allow pollutants to be filtered or biologically or chemically degraded before stormwater reaches the water bodies (CSD 2007). LID facilities may also contribute to the reduction of heat island phenomenon in urban areas through infiltration and retention of stormwater runoff.

• The LID in our campus also promotes public awareness, education and participation in environmental protection. Educational boards were installed at each site to provide information about the functions of the technologies for the visitors and university students and staff to be aware of the benefit and importance of nonpoint source management. The unique character of a LID green development has created a greater sense of pride in our university having visitors from the government, policy makers, researchers, company personnel, engineers, etc. By constructing the LID facilities in our campus, the aesthetic appeal of the surrounding environment was also greatly enhanced.

3.4 Design considerations

• Findings revealed that the storage volume ratio (ratio of storage volume of presettling basin to the facility volume) was an important parameter in designing the presettling basin or pretreatment units of LID facilities. For practicality, optimizing the design of the presettling basin means that the storage volume ratio should be designed based on the desired captured amount of runoff and sediment from runoff to limit the frequency of maintenance caused by the accumulation of sediment. It is recommended that pretreatment of runoff should be employed when the site in which the LID facility is to be sited has high TSS loading, runoff rate, and subjected to high intensity rainfall (Maniquiz et al. 2014).

• In terms of LID application, it is important to consider the ratio of facility surface area to catchment area (SA/CA) as these ratios have shown to influenced the efficacy of the design of LID facilities (Figure 10). For instance, as the SA/CA ratio increases, higher volume and pollutant load reduction could be achieved; however, this would mean a more costly system. It is recommended that the selection of SA/CA ratio depends on the requirement of volume and load reduction that should be specified in the regulations.

![Figure 10 Volume and TN load reduction with respect to rainfall depth for various SA/CA ratios.](image)

4 CONCLUSIONS

Nine innovative stormwater technologies were developed and applied to for nonpoint source pollution management at Kongju National University campus, first among all universities in Korea. The technologies were designed following the low impact development design principles. Basic stormwater management techniques were employed to help reduce the volume of runoff and capture nonpoint source pollutants on site by mechanisms of infiltration, filtration, adsorption, biological and plant uptake. The technologies underwent extensive renovations and refinement in the design using the experiences acquired from the monitoring and data analyses. Fact sheets together with the design
and maintenance guidelines for each technology were prepared. Consequently, the research on the technologies developed provided basis on revising and making new policies concerning NPS for nationwide implementation, management directions to the companies, and provide new market in the field of aqua-ecosystem restoration. The technologies were patented and commercialized. Several similar systems were already constructed nationwide.

In our research, the opportunities, effectiveness, and benefits of controlling stormwater runoff through numerous small-scale decentralized system approach have been explored. The application of LID in our campus creatively prevent, retain, detain, use, and treat runoff within multifunctional unique landscape features resulting to a multitude of environmental benefits making us a ‘green’ campus in Korea.

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LIST OF REFERENCES


