Strengthening urban water resilience in response to climate change: A case analysis of Busan Eco-Delta City

By

HWANG, Jintea

CAPSTONE PROJECT

Submitted to

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ABSTRACT

Strengthening urban water resilience in response to climate change: A case analysis of Busan Eco-Delta City

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To improve the resilience of cities to respond to climate change and environmental pollution, which are becoming more severe around the world, this paper proposes improvement measures for urban water cycle restoration facilities centered on the new city of Busan (Eco Delta City) to restore a healthy urban water cycle and introduces a review method for spreading to other regions.

Water circulation facilities, which are urban infrastructure, can act as an obstacle to the formation of social consensus for the entire city, such as the refusal of local governments to take over and excessive management costs, as has been confirmed in various cases recently. While the need and motivation for water cycle urban policies are clear and valid to solve urban water problems due to recent climate change, to lead to more realistic results experienced by local governments and citizens, we would like to explore practical ways for policy implementers to move beyond theoretical limitations and consider the needs of various stakeholders and cooperate with each other.

In the end, the success of urban water cycle recovery policies requires the development of new evaluation techniques, including technical hardware. To introduce collaborative software that can reasonably reflect the needs of various stakeholders, it is necessary to improve the understanding of the process of urban development that can be understood by various actors in urban development, and to enhance the implementation of water cycle policies by providing improvement effects and numerical analysis results based on specific regions to secure the need for introduction.

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1. Introduction

1.1 Background

1.1.1 Urban Growth and the Importance of Water Management

Cities have continuously evolved and developed in response to the changing times, adapting to the desires of their residents. Until now, cities have played a crucial role as vessels that support the rise in population and living standards, accommodating the diverse needs and trends of different members of society. With the increase in national income, cities are transforming into spaces that enhance the quality of citizens' lives, providing pleasant and leisurely environments (Kim, et al., 2017). The role of water in the city affects every aspect of human life. Particularly, waterfront cities, along with water, can provide a new momentum by offering key solutions to this paradigm shift.

Examining advanced foreign cities such as Germany and the United Kingdom, it is evident that they consider waterfront areas as a core growth factor in the process of new city development and urban regeneration. This includes addressing and improving distorted urban water circulation systems. In the domestic context, the importance of water circulation in waterfront cities can be interpreted similarly (Lee, 2018). The increase in the urban population has led to a simultaneous increase in the city's area and density. According to the Ministry of Land, Transport and Maritime Affairs (2008), the urbanization rate, which was only 50% since the 1970s, exceeded 90% after 2005. Due to the proliferation of automobiles, the construction of roads, parking lots, and large-scale residential complexes, more than 75% of the urban surface has become impermeable. This has resulted in a 45% increase in surface runoff and a 35% decrease in rainfall infiltration compared to natural green areas. Additionally, the recent intensification of extreme weather conditions has led to an increase in the frequency and intensity of concentrated heavy rainfall, causing an unprecedented number of urban flooding incidents in 2020.

These issues arise due to the inefficient water circulation in urban areas. The lack of efficient water circulation in cities can be compared to arterial sclerosis in humans. Currently, urban water is fragmented and disconnected due to various development projects. Connecting the broken links of water circulation to enhance its circularity can reduce flood damage caused by heavy rainfall and enable flexible adaptation to climate change.

1.1.2 Urban Transformation and the Current Status of Urban Water Circulation

In South Korea, the new city development policy has been centered around two main objectives: "National Land and Regional Development" and "Resolution of Major Urban Issues." Since the late 1980s, as part of the government's policy to construct two million homes for expanded housing supply, the development of five first-phase new cities in the metropolitan area has been actively pursued in a public development format (Kim, 2013). However, according to the National Assembly's Abolition of the Land Development Promotion Act (2016), South Korea achieved an absolute resolution of housing shortages as the housing supply rate reached 103.5% in 2014, and a population decline is anticipated from around 2030. According to a report by the Gyeonggi Research Institute in 2014, the urbanization of the Gyeonggi Province has expanded by approximately 17.9% since 2000 due to land development, and 184 development zones have been designated. Moreover, until 2025, the newly designated public housing supply area for downtown housing is planned to be equivalent in scale to the total area of the three-phase new cities (MOLIT, 2021).

Furthermore, since the 2010s, the economic growth rate has shown around 3%, entering a period of low growth. The per capita gross national income has maintained a high-income level of over $20,000 since 2010. The paradigm shifts in this new era, characterized by increasing housing supply, population decline due to low birth rates, low growth, and increased national income, is diminishing the utility of the existing large-scale residential-focused new city policies. It is argued that a modification of current new city policies is inevitable.

Additionally, modern urban planning theories promote three-dimensional city planning that utilizes both above ground and underground spaces. It is expected that the utilization of underground spaces will be a focal point in the future (Hyun et al., 2013). This three-dimensional city development is deemed inevitable to accommodate high urban density and is actively utilized, particularly with policy support in urban nations.

These trends, coupled with the rapid structuring of underground spaces along with imperviousness to surface permeability, necessitate a different approach to the urban water circulation system. Therefore, future domestic urban policies should incorporate techniques that are resilient and adaptable based on the density and ground structure of the city, allowing for the true cyclic circulation of water in the urban environment.

1.2 Evaluation Status of Water Circulation Recovery Cities

1.2.1 Current Status of Water Circulation Policies

Research on evaluation criteria for domestic urban water circulation systems is still in its early stages. However, there is a high level of interest from policymakers and academia, particularly in connection with the current government's water management integration policy. Various institutions in Korea are classifying techniques in urban water management, analyzing their application effects, and providing guidelines to achieve desirable water circulation cities (Cho, 2011; DSRI, 2017; JRI, 2017; KEI, 2010). Additionally, it is expected that water circulation waterfront city projects, which create and utilize riverfront areas in an eco-friendly manner, will become mainstream. The focus will shift from profitability to public interest and from efficiency to socio-environmental values (MOE, 2018).

However, to achieve the practical effects of a healthy water circulation city, there is a lack of comprehensive research on expanded evaluation criteria considering water budgets for the entire city, the acceptance of stakeholders, and other process-related aspects. The limitations of previous research on water circulation recovery cities can be summarized into three main points. Firstly, it does not provide process-specific evaluation criteria for the entire water circulation system, including urban watershed goals and principles, urban planning, strategies for facilities, and maintenance/monitoring systems. Secondly, most of the research is confined to structural green infrastructure facilities aimed at reducing stormwater runoff. It lacks a comprehensive water balance system that interconnects water demand, usage, and reuse, including establishing links with grey infrastructure such as healthy and safe water supply and wastewater reuse. Lastly, there is a need for research on the social aspects to consider the perspectives of all stakeholders, especially the acceptance of local governments, the ultimate maintenance managers of infrastructure. According to LHI (2017), the LID infiltration channel in Kimpo Han River New City was demolished due to a lack of design and construction experience and complaints, and the Asan Tangjeong District, which introduced the first decentralized rainwater management system in Korea, invested a significant cost (7.7% of the total construction cost, 68 billion won) in water circulation facilities. However, due to difficulties in maintenance, it was downsized, and even after installation, residents continued to raise concerns about safety. Local government refusal to take over infrastructure can lead to social conflicts, waste of investment costs through reconstruction, and hinder the formation of social consensus for the entire water circulation city. While the necessity and motivation for water circulation city policies to address urban water problems caused by climate change are clear and valid, policymakers need to go beyond theoretical limitations. They must explore more practical methods that balance the demands of diverse stakeholders, consider a variety of viewpoints, and foster collaboration for realistic outcomes that local governments and citizens can perceive.

1.2.2 Urban Water Cycle Policy in Korea

It is a natural phenomenon that urban development paradigms change to reflect the circumstances of the times (Lee, 2006). In the 60s, Korea's urban policy promoted quantitative growth-oriented new urban development such as industrial parks and hinterland development for rapid economic growth, but negative perceptions spread, including traffic and environmental problems due to urban overcrowding and social problems such as poor community conditions (Kim, 2013). In the early 2000s, to realize the international sustainability agenda represented by the SDGs, the government established new city planning standards for sustainable development as a sub-regulation of the Land Development Promotion Act and attempted to incorporate various values for cities from the second phase of new cities (MOLIT, 2007). Kim, et al (2005) synthesized the conceptual discussion of urban sustainability and the results of previous studies and prepared 45 planning indicators categorized into four areas of sustainability, environmental sustainability, self-sufficiency, and living culture, adding value to the sustainable new town planning standards. However, according to Kim, et al. (2008), the interim evaluation of the second phase of new towns based on the sustainable new town planning standards showed an overall improvement in socio-cultural, economic, and environmental sustainability compared to the first phase of new towns, but the water circulation field, which lacks clear guidelines and evaluation criteria, is excluded from review, or passively promoted.

[Table 1-1] Compare the cost of LID to traditional stormwater management systems (stormwater exclusion facilities, detention basins, etc.)

Project Name	Conventional Stormwater Management	LID Construction Cost	Reduction Cost	Percentage Reduction
Aubum Hills	$2,360,385	$1,598,989	$761,396	32%
Laurel Spring	$1,654,021	$1,149,552	$504,469	30%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

※ USEPA, 2007. “Reducing Stormwater Costs through Low Impact Development(LID) Strategies and Practices”

On the other hand, since 2010, in conjunction with the project to revitalize the four major rivers promoted as part of the Korean Green New Deal, a new form of new urban development has been born: the Friendly Water Zone Development Project, which promotes sustainable development through the systematic and planned creation of areas around national rivers (Kim, et al., 2017). The project places water ecology and water cycle planning, which were marginalized in the existing sustainable new city planning standards, as the main goals of achievement. However, while the "Guidelines for Creating Friendly Zones" enacted in 2011 provides a basic planning and evaluation framework for the urban water cycle system, the indicators are qualitative and have ambiguous limitations. Kang, et al. (2014). pointed out that these planning standards need to be further refined as they have a significant impact on policy implementation. Therefore, it is important to focus on efforts to quantify the essential items as much as possible, excluding the individual characteristics of the location, rather than rhetoric, to achieve the actualization of the policy.

1.2.3 Research Directions for Improving Water Cycle Policies

The awareness of diverse values influencing economic and financial considerations in water-related decision-making processes has globally advanced and disseminated. Alongside the recognition of the various values of water, there is a growing need for more systematic measurement and evaluation methods to facilitate mutual trade-offs.

The current rapid urbanization has hindered the smooth circulation of groundwater and surface water, leading to distorted urban water circulation systems. The research aims to study methodologies for improving these systems and optimizing the use of scarce water resources. Through the restoration of urban aquatic ecosystems, the goal is to propose urban planning techniques that enhance accessibility and usability by creating more waterfront spaces. Additionally, the research aims to consider various intrinsic values of different groups in decision-making related to water resources and land resources management to ensure legitimacy and reliability.

2. Research questions and methods

2.1. Research questions

Distorting the natural water circulation system generated by rapid urban growth, surface water and groundwater are frequently scarce under normal conditions, and climate change is causing rainfall patterns to repeat in short periods of time with concentrated heavy rainfall, requiring the dual functions of urban infrastructure facilities managing rainwater and rivers to maintain water resources during dry seasons and to effectively eliminate water during seasons of concentrated rainfall. Therefore, we will examine how the dual requirements, which are difficult to satisfy under current facility standards, should be introduced and developed, how they can increase the acceptability of maintenance entities and reduce factors that hinder policy development, such as wasteful investment costs, by integrating various advanced cases and previous studies and projecting them onto actual urban development areas. The project will examine how the policy can be implemented in a real urban development area.

Therefore, this research attempts to develop an institutional framework for urban water circulation facilities with flexible functions to overcome the limitations of existing infrastructure and respond to various changes that will occur in the future. To propose institutional improvement measures in the process of applying and verifying quantified water circulation functions for the entire process of planning, installation, and management of urban water circulation infrastructure to new urban sites currently under construction.

2.2. Research methods

In this research, a watershed analysis model technique such as SWMM was introduced to analyze the effectiveness of distributed water management facilities compared to the existing centralized water management facilities as a methodology for the active introduction of LID low-impact development techniques that promote groundwater inflow by reducing surface imperviousness, which has increased due to urbanization, and reduce the burden on rivers by increasing the runoff time of rainfall.

First, the analysis target area was specifically selected, and next, the city's proper water management goal was set, and then the effect of the introduction of decentralized water management facilities was analyzed and compared with the pre-introduction method.

As a result, this study aims to provide a steppingstone for the introduction of urban water circulation policies by identifying various effects of water circulation facilities.

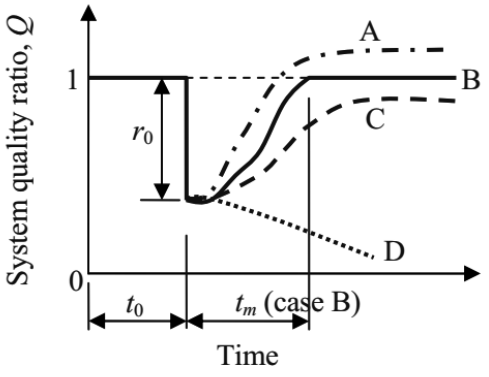
3. Analysis and findings

3.1 Deriving water supply resilience for city characteristics.

3.1.1 Concept of resilience

Resilience generally refers to the ability or energy of a system to return to its original state when it loses or is significantly damaged by a disaster or accident. This concept is applied in various academic fields, and in the United States, interest in urban resilience has increased after disasters such as 9/11 (2001) and Hurricane Sandy (2012) and was adopted by the UN General Assembly in 2015 as the Sustainable Development Goals (SDGs) as a successor to the Millenium Development Goals (MDGs) in 2000, and 9 and 11 of the 17 goals correspond to building sustainable cities, including resilience.

[Figure 3-1] Resilience in the context of the UN's SDGs and damage response and recovery.

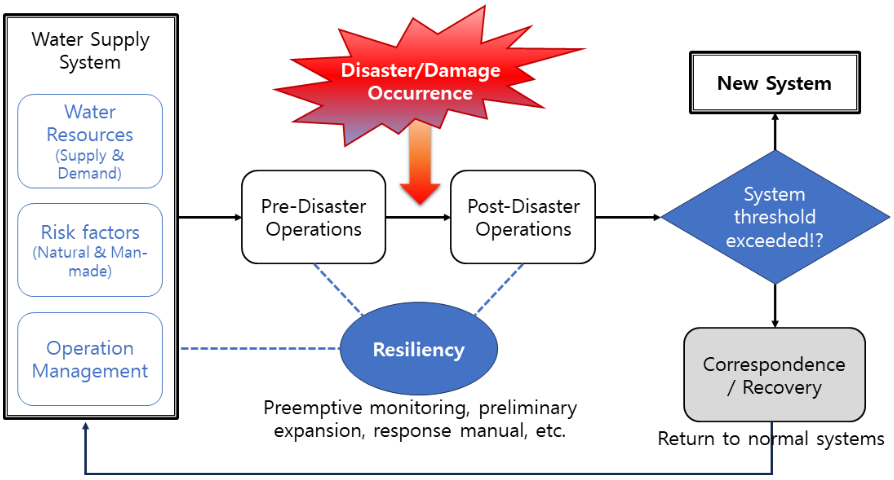
	
The UN's Sustainable Development Goals (SDGs). Numbers 9 and 11 of these include resilience.	Evaluate the resilience of a system based on the time and state of recovery after a damage. (Wang and Blackmore, 2009)

3.1.2 The concept of resilience in relation to water supply

According to the World Water Development Report 2021, the risks associated with water supply are significant due to high production costs, low revenues and resulting financial losses. These risks impact a wide range of sectors, including high operating costs, supply chain disruptions, water supply interruptions, growth constraints and image damage due to increased water scarcity, flooding and climate change. Risks specifically related to urban water supply include (1) reduced water withdrawals due to high temperatures and drought, (2) increased flood damage due to increased urban impervious area and increased rainfall events due to extreme rainfall, (3) water quality issues due to water intake complaints and the growth of algae and protozoa (cryptosporidium) in rivers, (4) water quality and water outages in the supply system due to aging water supply pipes; (5) urban non-point source runoff and deterioration of wastewater treatment facilities; and (6) unauthorized discharge of wastewater from industrial parks.

Securing resilience to flexibly respond to various risks faced by urban water supply systems consists of three elements: securing performance thresholds, crisis response capabilities, and securing adaptive capabilities such as proactive monitoring and reserve capacity (Wang & Blackmore, 2009).

[Figure 3-2] Resilience in water supply systems



[Table 3-1] Resilience components and characteristics of water supply systems

classification	System Performance Thresholds	Response and resilience	Adaptability (manageability)
Definition	The amount of damage that performance can sustain	Speed of recovery after damage	Prevention of major incidents
Purpose	Stabilize against damage	Returning systems to normal operation	Reduce the likelihood and magnitude of damage
Key words	Localization, change, unpredictability	Efficiency, continuity, predictability	Preemptive monitoring of system maintenance (self-inspection) and preparation for damages

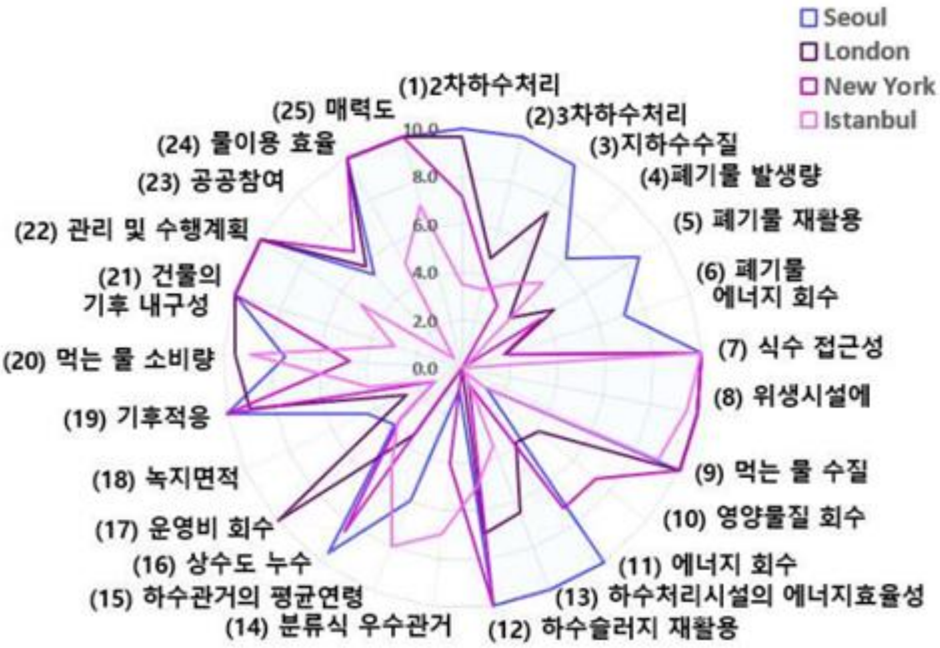
3.1.3 Previous research on urban water resilience assessment techniques

The City Blueprint Approach (CBA) was developed by the KWR Water Cycle Research Institute in the Netherlands to assess the sustainability of a city's integrated water management and is being disseminated and utilized by European cities through EIP Water (The European Innovation Partnership on Water). It primarily assesses urban water management, waste disposal, and climate adaptation, and has the advantage of quickly identifying how well a city is managing water compared to other cities. The main purpose is to share best practices through networking with cities around the world and to provide a basis for medium- and long-term planning for water management (Koop and van Leeuwen, 2015).

In the Netherlands, Van Leeuwen (2013) applied the CB method to the water cycle and resilience of three cities, including Rotterdam, and the Tanzanian capital, Dar es Salaam, and found that Tanzania's water self-sufficiency is high compared to the Netherlands, but that it is very low in terms of drinking water supply and sanitation and citizen participation.

Using publicly available data, estimates, and various expert surveys, we conduct a quantitative assessment of 24 relevant indicators, quantified on a 10-point scale, and present the results in tables.area of the Daesan Water Supply Zone and the P-A small area of the Chari Water Supply Zone, where the meter reading system through smart metering is stabilized. The DB-5 block is a block containing a representative island area, and a small flow rate and water pressure monitoring system was installed at the point of inflow from Daesan Reservoir to the DB-5 block to monitor the flow rate by separating the entire DB-5 and the island area (Ungdo rear). In addition, the P-A block was divided into four small areas, and a small flow rate and water pressure sensing system were installed at the inflow point of each small area.

[Figure 3-3] Water cycle assessment results of megacities (Seoul, London, New York, Istanbul) compared through CBA (Kim, 2018)



At the initiative of the Rockefeller Foundation, 100 major cities around the world have established a voluntary partnership to mutually share information on cases and projects related to resilience, including climate change, natural disasters, urban infrastructure, social issues, environmental issues, and economics and politics, and have selected urgent topics for each participating city for a total of 58 urban issues, including climate change, natural disasters, urban infrastructure, social issues, environmental issues, and economics and politics, and are implementing various projects to promote resilience to disasters (www.100resilientcities.org).

[Table 3-2] Water Cycle Business Case for Resilient Cities (100RC)

City (nation)	Project name (year)	Contents

Paris (france)	OASIS* Schoolyards (2017)	- More than 700 people died due to a heat wave in 2003 and large-scale flooding occurred along the Seine River. - Applied and implemented to 761 schools to reduce the heat island effect and reduce flood damage by expanding low-lying green spaces	
Wellington (New Zealand)	Community Infrastructure Resilience(CIR) Program (2017)	- Promote the expansion of reserve facilities to respond to pipeline collapse and water treatment facility damage due to earthquakes. - Securing groundwater and riverside treatment water facilities capable of supplying 20 liters of drinking water per day to residents within a 1km radius for approximately 100 days.	
Atlanta (USA)	Proctor Creek Greenway trail (2017-2022)	- Provide health, welfare, and environmental amenities to poor residents in the western area of Atlanta, and create green space and waterways around Ptoctor Creek to prevent floods.	

Based on the examples of other cities and previous studies, it can be said that what is needed to improve the resilience of cities is a strategy to analyze the vulnerability of the city's water supply and establish and implement adaptation measures, such as preparing relevant personnel and recovery equipment for various disasters and possible shocks to water resources.

3.2 Analysis of Available Water Sources for Ensuring Water Supply Stability

3.2.1 Types, Characteristics, and Case Analysis of Water Sources

Typically, water sources utilized for domestic and industrial water supply, ensuring substantial and stable quantities, include rivers and lakes. In this study, we aim to investigate alternative water sources beyond conventional large-scale surface water, such as rivers and lakes. This exploration is crucial for enhancing the stability and efficiency of water resources through the utilization of multiple water sources, especially in response to climate crises. The analysis will focus on various water sources, examining their characteristics to understand their suitability for securing stable water resources.

[Table 3-3] Comparison table of characteristics and application cases by water intake source

Water intake source	Characteristic	Advantages	Disadvantage	Application examples
Sewage treatment water	-Reuse sewage treatment effluent directly or reprocess it depending on the purpose and use it as water. -It is mainly used as river maintenance water, cleaning water, and landscaping water, and is partly supplied directly or indirectly as domestic water.	-Compared to seawater desalination, water intake and treatment methods are relatively simple. -Reduce pollutant load discharged into public waters -Able to secure stable supply of good water	-Reuse options are limited due to water quality issues. -During large-scale treatment, a large amount of concentrated water is generated, and reprocessing is required.	Singapore (NEWater Factory) Germany (MULTI-ReUse) Pohang (industrial water) Paju (industrial water)
Riverside filtered water	-A method of installing a pumping facility in a river and filtering surface water and groundwater as they pass through the stratum. -Divided into direct water intake method and indirect water intake method linked to artificial recharge. -Depending on the water collection well, it is divided into radial water collection well and vertical water collection well.	-It is possible to secure high-quality raw water in an economical and nature-friendly way. -In the case of large rivers, there are relatively many suitable areas and there are various application cases. -Effective in removing turbidity with low maintenance costs -Process flexibility can be secured	-Insufficient accumulation of domestic expertise -There is an impact due to a decrease in groundwater level. -Injection well blockage occurs frequently, reducing water intake. -Influenced by soil pollution and non-point pollution sources -Directly affected by river water quality accidents	Germany (Rhine, Danube, Elbe, etc., indirect water intake method) Austria (lower Danube) Netherlands (Reck River, indirect water intake method) United States (Missouri River, Ohio River) Haman-gun, Busan-si, Gimhae-si, etc.
Artificial recharge of groundwater	-This is a technology that stores rainwater, river water, etc. in an underground aquifer and uses it as water during dry periods. It is divided into soil permeation method and injection well method. -Operated with a rainy season injection and dry season recovery strategy	-Able to secure a stable source of quality water -Able to maintain groundwater and river levels -Low losses due to land use or evaporation -Initial investment cost is relatively low	-High maintenance costs -There are few domestic application cases and lack of professional technology. -Difficult to check storage amount -It is difficult to use a large amount of water at once	There are many cases of application of the indirect water intake method, especially in the United States. Middle East (Dubai), North Africa (Tunisia) Application cases of underground dams in Asia (Korea, Japan, China, etc.)
Use of	-Rainwater is	- It is possible to	-Utilization of	Germany (using

rainwater	collected and stored in facilities with a certain roof area and used in emergencies.	secure raw water of good quality and use it for various purposes. -Initial investment and maintenance costs are low -High utilization of water in urban areas	rainwater is limited due to the nature of rainfall in Korea, which is concentrated in the summer season.	rainwater for groundwater protection purposes) Japan (toilet water) Korea (garden, toilet water, car wash water)
Seawater desalination	Evaporation and membrane filtration are mainly used as technologies to create fresh water by removing dissolved substances from seawater, brackish water, etc.	-A vast supply can be secured -Can maintain stable water quality -Verified through full-scale commercialization	-High energy consumption requires high maintenance costs -Problem in processing high-concentration salt concentrated water	Middle East, Singapore Melbourne, Victoria, Australia California, Florida, USA Busan Gijang, Daesan Waterfront Industrial Complex

3.2.2 Application to the Busan Eco Delta City Project

Eco Delta City (EDC) was designated as a hydrophilic zone (Special Act on Utilization of Hydrophilic Zones) in December 2012, and Busan Metropolitan City, Korea Water Resources Corporation, and Busan Urban Corporation are planning to sequentially supply land with 30,000 housing units (population 75,000) on an area of 11.88㎢ in Myeongji-dong, Gangdong-dong, and Daejeo 2-dong, Gangseo-gu, Busan, as a joint project implementer.

Eco Delta City is an area that borders water bodies such as rivers and estuaries and is developed by giving value to residential and cultural spaces through water, and has a concept of next-generation urban development that improves the quality of life of citizens, and restores water circulation, decentralized water management, and reduces non-point pollution as a method of creating a waterfront complex city, In order to secure urban resilience by actively applying water circulation along with low-impact development such as urban regeneration, we are promoting the improvement of the water circulation system through decentralized rainfall-runoff management in cities that combine integrated management technology of Green Infrastructure (GI) and Low Impact Development (LID) technologies and advanced ICT.

Therefore, this study investigates and analyzes the low-impact development technologies planned and applied to the Busan Eco Delta City to examine the appropriateness of the target amount of water cycle management and derives the basic design direction and specific improvement measures to achieve it, thereby providing a basis for conducting comprehensive and systematic water cycle management of the Eco Delta City.

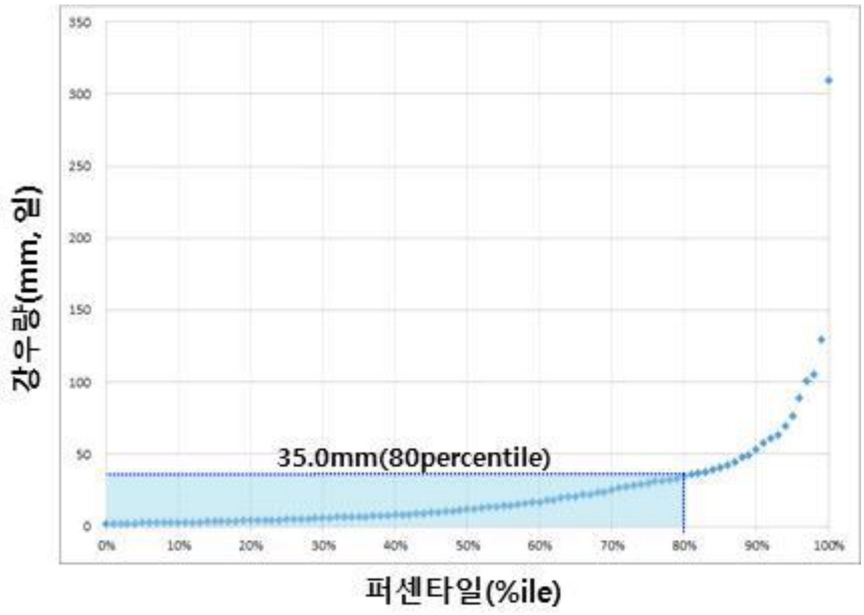
3.2.3 Setting Water Cycle Management Goals for EDC

The target area of this study is an eco-delta city located in Gangdong-dong, Gangseo-gu, Busan, and it is necessary to set rainwater management targets to secure urban water cycle resilience through the application of LID.

For integrated water cycle management, it is necessary to have a consistent rainfall management target standard and apply LID technology accordingly. For this purpose, rainfall data from the Busan Observatory closest to the location of the project area were used, and rainfall percentage analysis was performed using rainfall observation records from 2009 to 2018 (10 years).

Currently, the EDC's water cycle management goal is set at a cumulative 80% percentile of daily rainfall, and the corresponding rainfall was calculated to be 35.0 mm because of the analysis. Therefore, this study set the rainfall of 35.0 mm as the rainfall management goal and used it to analyze the application status and improvement effect of LID element technology.

[Figure 3-4] Analysis of rainfall percentiles at Busan Observatory (2009~2018)



In this study, the following items were established as a database for each LID element technology to calculate the actual rainfall management depth as described later.

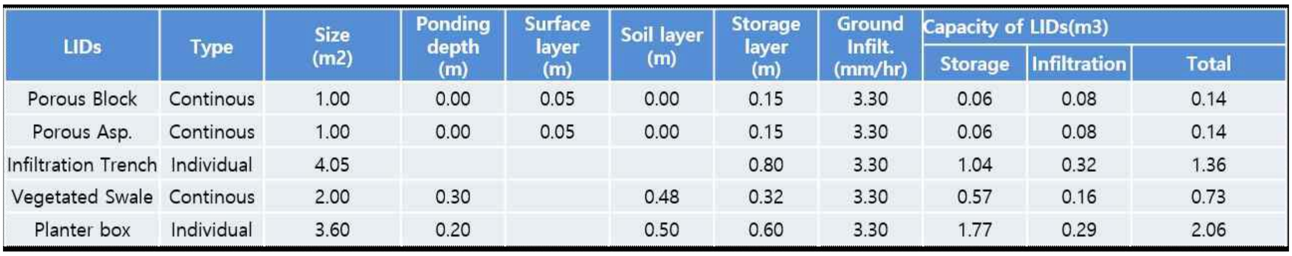
(1) Specifications for each LID element technology

(2) Storage capacity = sum of (depth of each layer × porosity)

(3) Infiltration capacity = floor area of LID element technology × ground permeability

(4) LID facility treatment capacity = storage capacity + infiltration capacity

[Table 3-4] Example of building a facility treatment capacity D/B by LID element.



LIDs	Type	Size (m2)	Ponding depth (m)	Surface layer (m)	Soil layer (m)	Storage layer (m)	Ground Infilt. (mm/hr)	Capacity of LIDs(m3)		
								Storage	Infiltration	Total
Porous Block	Continous	1.00	0.00	0.05	0.00	0.15	3.30	0.06	0.08	0.14
Porous Asp.	Continous	1.00	0.00	0.05	0.00	0.15	3.30	0.06	0.08	0.14
Infiltration Trench	Individual	4.05				0.80	3.30	1.04	0.32	1.36
Vegetated Swale	Continous	2.00	0.30		0.48	0.32	3.30	0.57	0.16	0.73
Planter box	Individual	3.60	0.20		0.50	0.60	3.30	1.77	0.29	2.06

In calculating the actual rainfall management depth, a database of the actual rainfall management depth for each street area was established by considering the following points, and the actual rainfall management amount was calculated based on that.

In this study, the SWMM LID (Ver. 5.1) model was applied to perform quantitative analysis of runoff reduction, water circulation improvement, and water quality improvement effects of introducing LID facilities in the EDC project site, and the LID calculation module mounted in the above model applied an improved method to enable hydrological impact analysis of stormwater management facilities. The vertical layer consists of five layers: Surface layer, Pavement layer, Soil layer, Storage layer, and Underdrain layer. It can be applied to a property with different land cover characteristics, and the degree of storage and circulation within each layer is analyzed. The facilities include Bio-retention of Cells, Porous Pavement, Infiltration Trench, Rain Barrels, Vegetative Swale, Rain Garden, and Rooftop Disconnection, and various LID techniques not included in the above seven categories were simulated by varying the variables that determine the hydraulic and hydrologic characteristics of individual component technologies.

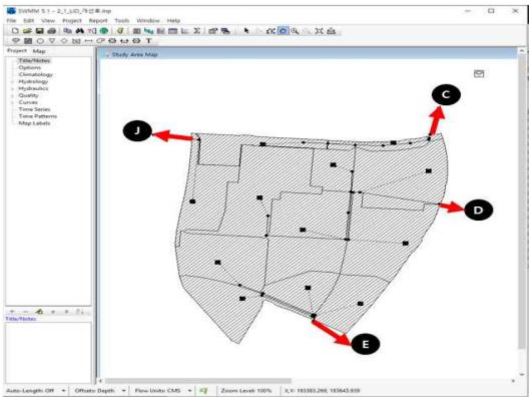
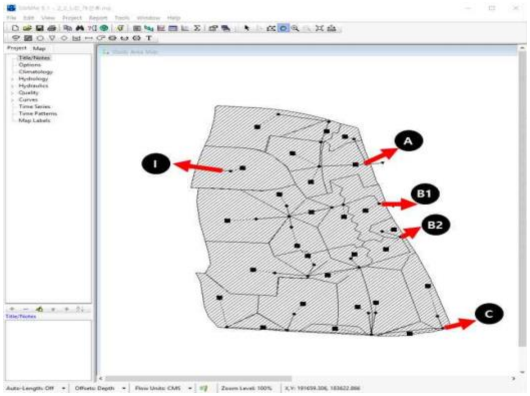
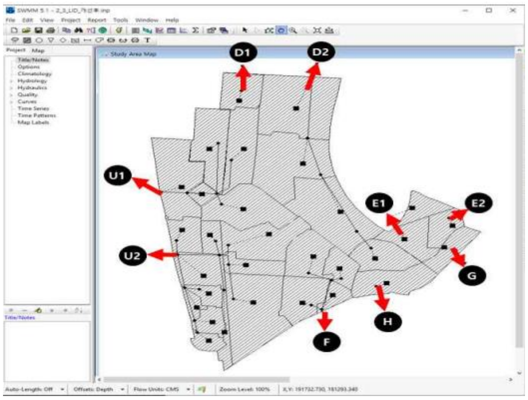
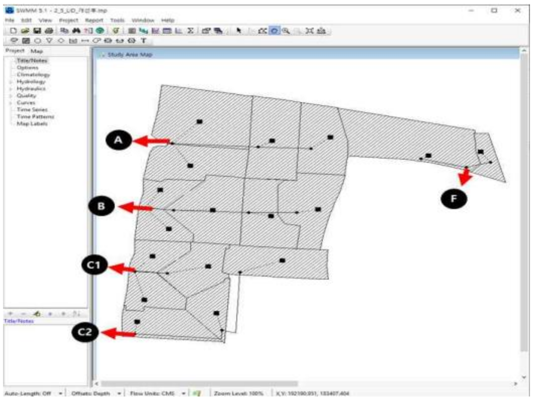
(1) The area of the street zone is calculated by dividing the area corresponding to each wide,

boulevard, middle, and small street into vehicle driving area, bicycle path, sidewalk, and drinking fountain, respectively, and the runoff volume of the street zone is calculated by multiplying the area of the section excluding the drinking fountain by the target rainfall depth (road zone runoff rate of 0.9 is applied).

(2) The LID facility capacity is calculated by multiplying the facility treatment capacity calculated in the previous section for LID elemental technologies installed to treat stormwater runoff generated in the corresponding road area by the number of elemental technologies planned to be applied to each unit road area, and the sum of the treatment capacity for each elemental technology is set as the total LID facility capacity.

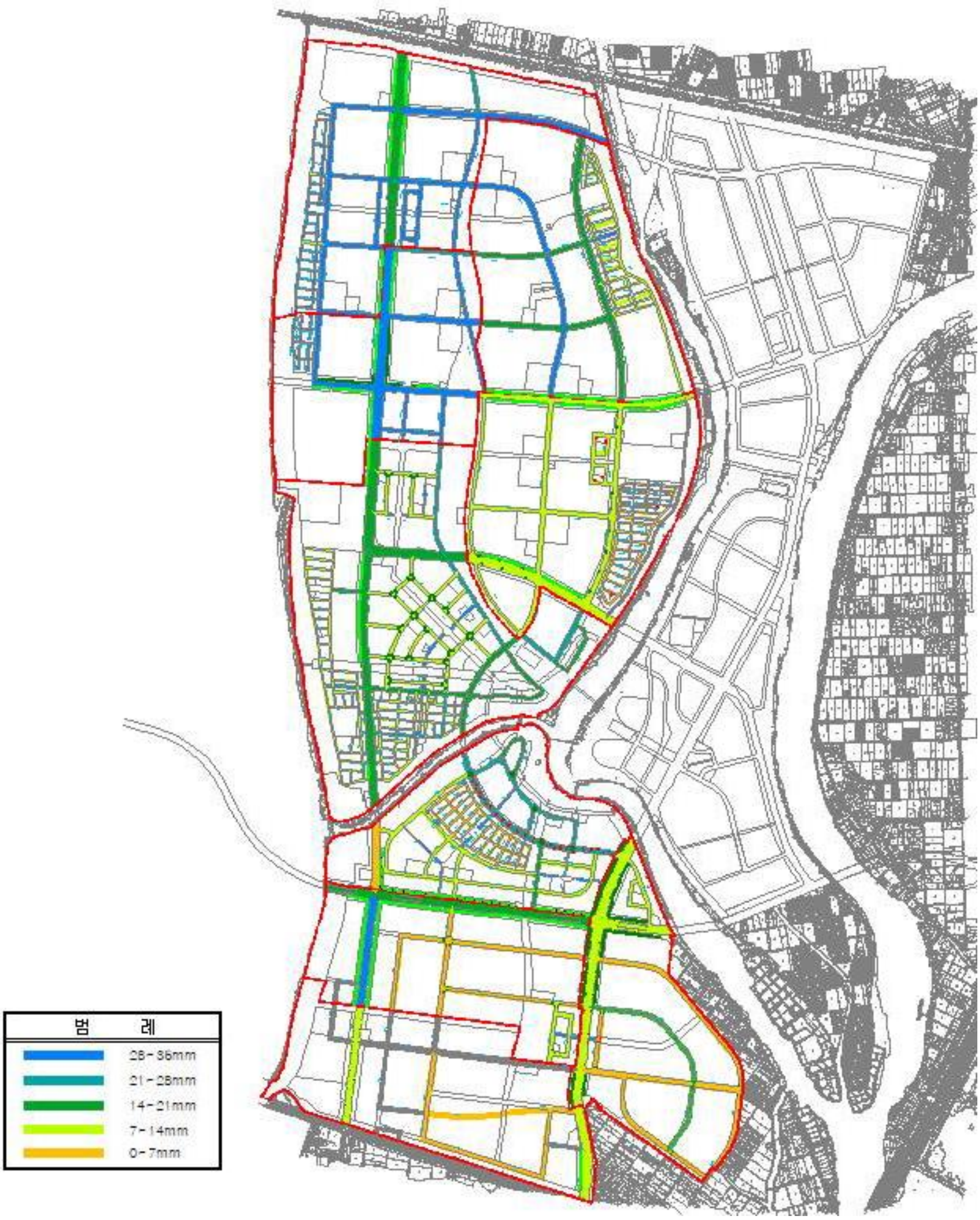
(3) The actual stormwater management volume is calculated by considering the area of the catchment area of the area where each LID element technology is installed to calculate the treatment volume of the target rainfall, and the rainfall management depth is calculated by dividing the actual stormwater management volume by the corresponding area.

[Figure 3-5] Setting up analysis targets by watershed (draft)

	
2-1 Watershed	2-2 Watershed
	
2-3 Watershed	2-4 Watershed

The rainfall management depth was calculated by considering the area of each unit road in the tool that can be managed by the LID element technology applied in the design, and the actual rainfall management volume and the corresponding rainfall management depth considering the divided area, effective area, total runoff volume, LID facility capacity, and stormwater collection area of each road in the tool are shown in [Figure 3-6].

[Figure 3-6] Depth of rainfall management per EDC road - current status



3.3 EDC Improvement Measures

3.3.1 How to Select Improvements Applicable to EDC

To improve the effectiveness of LID application, this study sets the basic direction as follows and suggests improvement (plan) accordingly.

(1) Review of the optimal technology for the runoff characteristics of each basin in the target area

(2) Optimization of LID installation locations to maximize catchment area and efficiency.

(3) Improving management efficiency by increasing the maintainability of existing facilities

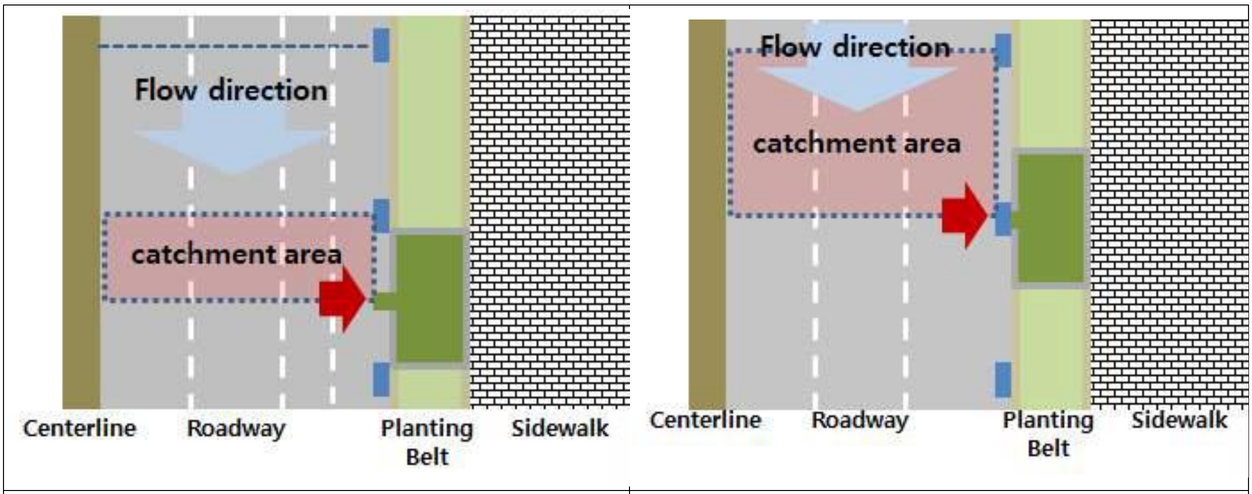
(4) Reviewing efficiency according to land use characteristics, topography, and rainfall patterns

- Although planted swales are planned along paths and boulevards, there is no inlet for stormwater runoff from the roadway area to flow into the planted swale, so the swale can only treat stormwater runoff from its own area, which is very small compared to the treatment capacity of the swale.

- In this study, we propose not to directly exclude stormwater runoff collected from storm drains, but to introduce it into a planted swale, flow it through a planted swale, and then exclude it into a stormwater pipe through a collection filter.

- At this time, the stormwater inlet of the stormwater catchment and the LID facility should be installed so that they can be connected by using a wall flow type stormwater catchment.

[Figure 3-7] Improving the placement of natural rainwater harvesting facilities.



Existing Facility Layouts

Improvement Layouts

- In addition, bus stop roof greening technology is the easiest LID element technology to introduce and apply to draw residents' attention to environmental issues such as stormwater runoff management and water circulation, and among the facilities installed in the street area, bus stops are the most optimized place to install roof greening due to their uniform design and high pedestrian traffic.

[Figure 3-8] Bus Stop Roof Greening Case Study

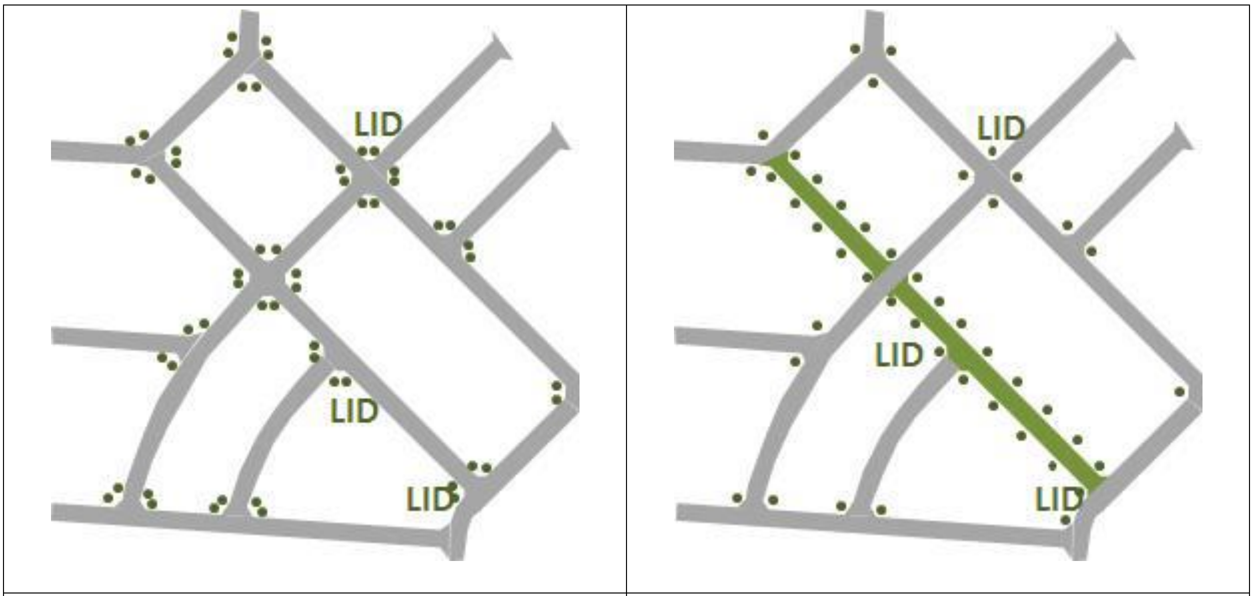
	
Green Roof on Bus Stop at the Corner of 15th and Market in Philadelphia, PA	Green Roof on a Bus Stop in Philadelphia

- LID element technologies such as planting beds are planned to be grouped around intersections, which is expected to reduce the efficiency of stormwater management for the entire roadway compared to the number of installed facilities.

- In addition, stormwater management difficulties may occur in areas other than intersections (roadway traveled), and if additional LID element technologies are present in the roadway, LID facilities may be reduced to facilities with simple landscape functions.

- In this study, we propose to increase the usability of LID facility groups, improve the scenic quality, and create LID specialized streets through the distributed placement of LID facility groups.

[Figure 3-9] Improved placement of street-side LID facilities.



Existing Facility Layouts

Improvement Layouts

- The LID-based smart fine dust reduction system can recycle the stormwater runoff collected in the underground reservoir through a filtering process into sprinkling water in connection with the vegetated waterways, rain gardens, and underground reservoirs mentioned in the previous section, and has the advantage of removing household pollutants (fine dust, etc.) from the atmosphere by converging urban water circulation, IoT technology, and water spray systems, and can preemptively respond to abnormal weather phenomena such as heat waves.

- In Eco Delta City, the groundwater level is investigated to be around GL. -1.0m because of the groundwater level survey, so considerable attention should be paid to the application of infiltration LID facilities, and this study proposes the application of a groundwater level-linked LID storage system as follows.

- As a groundwater-linked storage system to overcome the limitations of water utilization efficiency of rainwater cisterns due to the characteristics of rainfall concentrated in summer, it has the advantage of improving the water utilization rate of rainwater cisterns by more than 30% compared to the installed capacity of rainwater cisterns through groundwater linkage.

- The stormwater runoff generated during rainfall flows into the reservoir through the inlet pipe and can be utilized as environmental maintenance water after filtering by inducing groundwater inflow according to changes in groundwater level and can prevent external leakage of stored water when the groundwater level drops by installing a groundwater backflow prevention device.

[Figure 3-10] Smart technology applications based on LID facilities.

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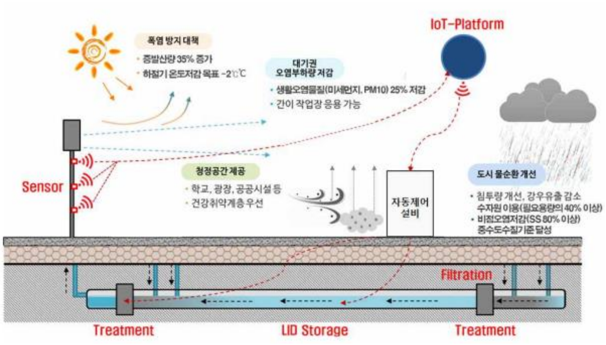
<td>
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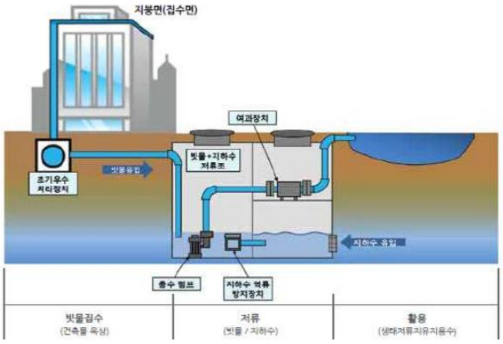
<td>
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<tr>
<td>LID-based Smart Fine Dust Reduction System</td>
<td>Groundwater-connected rainwater storage and utilization systems</td>
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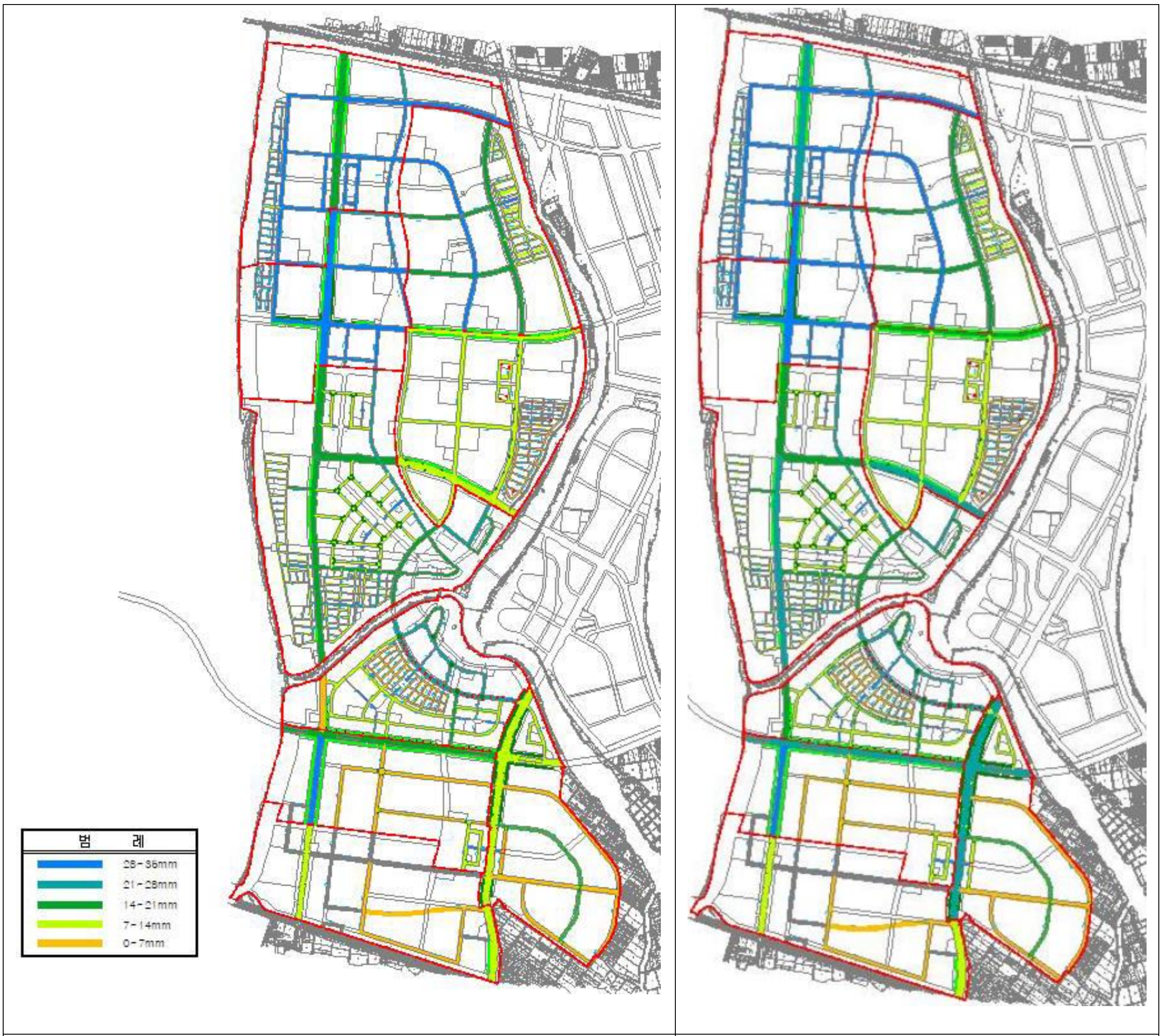
</table>

3.3.2 Results of Applying Improvements to EDC

The results of applying the improvements proposed in the previous section are shown in [Table 3-4] and [Figure 3-5]. When examined by stage, the average rainwater volume of the entire stage 1 tool increased by about 355.99 m^3 from 1,197.66 m^3 before improvement to 1,553.65 m^3 after improvement, and the average rainwater volume of the entire stage 2 tool increased by 245.33 m^3 from 2,858.20 m^3 before improvement to 3,103.53 m^3 after improvement. As the actual amount of stormwater management increased, the rainfall management depth also increased, and was evaluated to have increased from 4.48~32.21 mm before the improvement to 5.02~32.21 mm after the improvement; the average depth of the entire Phase 1 tool increased by about 1.49 mm from 12.14 mm before the improvement to 13.47 mm after the improvement; and the average depth of the entire Phase 2 tool increased by 0.30 mm from 21.00 mm before the improvement to 21.30 mm after the improvement.

[Figure 3-11] Change in depth of rainfall management by EDC roadway.



Before Improvements

After improvement

4. Conclusion

4.1 Summary and policy recommendations

The current method of analyzing the water cycle consists of selecting a target area, setting a target amount, selecting a rainwater management site, and applying LID facilities. While there are many previous studies on the target volume setting method, there are insufficient studies on the selection of rainwater management sites and application of LID facilities.

In this study, we analyzed the application plan and improvement plan of low-impact development technology in the field of water management to secure urban resilience for Busan Eco

Delta City. We examined the appropriateness of the target amount of water circulation management, and derived basic design directions and specific improvement plans to achieve it.

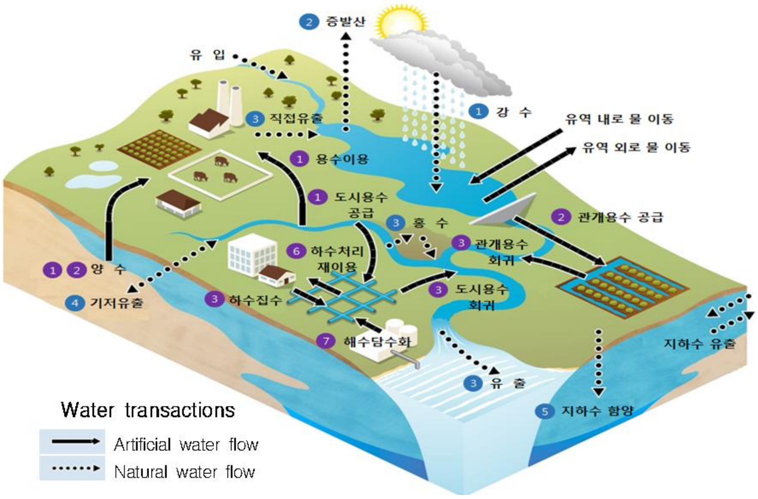
To derive improvement plans for the application of low-impact development, we presented a plan for linking LID element technology with stormwater runoff for each street area by EDC tool, analyzed the runoff reduction effect of the improvement, and provided opinions on technical roadmaps and management plans.

Through the improved application of LID element technology in EDC, it is expected to create a clean residential environment by efficiently managing stormwater runoff and reducing non-point source pollution, create a resident-friendly space by increasing green space, and improve the comfort of urban residents' residential environment by inducing rapid water infiltration through infiltration LID facilities.

To analyze the effect of applying LID element technology, the effect was analyzed quantitatively by analyzing the peak runoff reduction effect, water circulation improvement effect, and non-point source reduction effect based on the runoff analysis result using the SWMM LID model. In addition, considering the convenience of maintenance for LID element technology, it reflected the practicality of field application as much as possible.

[Figure 4-1] Classifying natural and man-made facilities in the water cycle

category	Components
Natural world	Precipitation, evapotranspiration Surface spillage Medium spill Groundwater runoff (sacral, deep)
Artificial systems	Raw water (rivers, dams, reservoirs, groundwater, etc.) Raw water (purified water, wide area) Agricultural water (rivers, dams, reservoirs, groundwater, etc.) Returning water (living, industry, agriculture) Water reuse, seawater desalination, etc.



4.2 Limitations and Further Research

This study focused on rainwater management in new cities, but to improve the overall water cycle at the basin level, it is necessary to establish and apply a quantitative evaluation system of the basin-level water cycle process based on actual data in the future. Therefore, it is necessary to set the appropriate space (basin setting) and target point and prepare a quantification plan in connection with a model based on actual data based on the results of the observation and measurement status survey (real-time and non-real-time data, etc.) for each water circulation element.

In addition, the method for analyzing the extent of the existing water cycle is to select a target, set a target amount, set a target value for rainwater management, and apply general LID facilities. While there are many previous studies on how to set the target amount, there is a lack of research on analyzing the characteristics of each rainwater management target site and applying optimal LID facilities. It is necessary to refine the method of presenting the share of water circulation by land cover and facility to the area and analyzing the type and scale of LID facilities through follow-up studies.

This study focused on rivers, stormwater, and water circulation as the most cost-effective targets, but in the future, it is necessary to apply it to various facilities such as flood prevention, natural wetlands and reservoirs, lakes, and waterfront spaces to promote its spread.

Therefore, to improve the water circulation analysis system, this study suggests that if additional analyses are conducted in the old city center and highly urbanized areas in the future, and the characteristics of the facilities that can be applied in practice are identified, the analysis results that reflect the exact area and watershed characteristics can be used in the design of LID implementation.

Bibliography

Cho, E. Y. (2011). The Analysis of LID Adaptation Efficiency on Urban Basin Based on SWMM-LID Model. University of Pusan National.

Congressional Bill Information System (2016). Bill No. 2002532, Repeal of the Land Development Promotion Act Reason for Proposal

DSRI (Daejeon Sejong Research Institute). (2017). Feasibility study and introduction of low-impact development techniques to promote water circulation. Policy Report 2017-02.

Hyeon, Y. J. et al (2013). Environmental Impacts of Deep Underground Space Development in Urban Areas and Policy Suggestions, U, Policy report, 2013-16. pp.5-8.

JRI (Jeju Reserarch Institute). (2017). Introduction of low-impact development (LID) method in Jeju area. Basic research 2017.

Kang, J. E., Hyun, K. H., & Park, J.B. (2014). Assessment of Low Impact Development (LID) Integrated in Local Comprehensive Plans for Improving Urban Water Cycle. Journal of the Korean Society of Civil Engineers, 34 (5), 1625-1638.

KEI (Korea Environment Institute). (2010). Application plan and effect of low-impact development technique (LID) in urban regeneration in waterfront areas. Basic research 2010.

Kim D. W., Jang Y. H., & Hwang H. Y. (2008). Evaluation of Second New-Town by the Sustainable New-Town Planning Criteria. Korean Society of Land and Urban Planning, 321-328

Kim, D. Y. (2013). Evaluation and Direction of the New Town Development in Korea. Journal of the Korean Digital Architecture Interior Association, 13 (2), 5-16.

Kim, H. W. (2018). Assessing Water Cycle Sustainability of Seoul by using City Blueprint Framework.

Kim, Y. G., Jung, J. Y., Kang, J. K. (2017). A Study on the Revitalization Plan of the Waterfront Area System According to the Change of Housing. Residential environment: Journal of the Residential environment Institute of Korea 15(2), 227-241

Koop, S. H. A., and Cornelis J. van Leeuwen. (2015), Application of the Improved City Blueprint Framework in 45 Municipalities and Regions, Water Resources Management. 29, pp.4629-4647.

LHI (Land and Housing Institute). (2017). Study on the Application of Rational Rainfall-runoff Reduction Facilities by Quantification of Runoff Effect of LID Facilities(I).

Lee, S.J. (2018). Water cycle waterfront cities. Journal of Water Policy & Economy, 30(0), 5-13.

Lee, S. S. (2006). Significance of Urban Paradigm Change. Architecture & Urban Information Center, 295, 2-12.

MOE (Ministry of Environment). (2018). A healthy and pleasant environment that everyone creates together. Annual Work Plan Report 2019.

MOLMA (Ministry of Land, Transport and Maritime Affairs). (2008). Research on underground space utilization and management improvement.

Van, Leeuwen, C.J., Sjerps, R.M.A. (2015), The City Blueprint of Amsterdam: an assessment of,integrated water resources management in the capital of the Netherlands, Water Sci Technol Water Supply. 15, pp.404-410.

Wang & Blackmore (2009). Resilience Concepts for Water Resource Systems. Journal of Water Resources Planning and Management, American Society of Civil Engineers.