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IMPLEMENTING LOW IMPACT DEVELOPMENT IN SOUTH KOREA

2018 TIECA Conference
Toronto, Canada
March 21, 2018

Steven Trinkaus

- Invited presenter on LID & water quality issues in Taiwan, South Korea & China
- Consultant to Pusan National University, Land & Housing Institute, Korean Water & HECOREA, LLC in South Korea and Shenzhen University in China for LID
- Licensed Professional Engineer (CT)
- Over 37 years in the Land Development Field with 17 years applying LID

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What is really happening elsewhere in the world

- Annual rainfall amounts are fairly consistent,
- Rainfall intensities are increasing,
- Rainfall durations are becoming shorter, so more rainfall occurs in a shorter time period,
- Over a given impervious area, runoff occurs faster at a higher rate and significantly higher runoff volume

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Extreme Rainfall Event in South Korea

- August 2014 rainfall event in Busan Area,
- 14.2 cm of rain in **1 hour**
- **Highest Rainfall Intensity = 2.37 cm per 10 minutes**
- Occurred in Red River Watershed (channelized stream through center of Busan)
- 66% of annual rainfall occurs between mid June and Mid August
- Highly urbanized environment

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August 2014 Rainfall Event
14.2 cm in an hour

IMPACT SUSTAINABLE DEVELOPMENT
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August 2014 Rainfall Event
14.2 cm in an hour

Korean Smart GI & LID Research Group

- History of the Research Group:
- Founder/Principal Researcher:
  - Dr. Hyun-Suk Shin of Pusan National University
- Created in 2011:
  - Created Work Plan and received funding from South Korean Government,
  - Reached out to LID experts in the US and other countries,
  - Construct "State of the Art" demonstration project and Research Facility for GI/LID

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Goals of the Korean LID Project

- Analysis of Korean Environmental Conditions necessary for consideration of LID,
  - Rainfall Evaluation,
  - Soils Evaluation,
  - Topographic Considerations,
  - Water Quality of Non-Point Source Runoff in Urban & Agricultural Areas

Key Targets of Korean LID

- Urban Flood Control,
- Urban Water Conservation,
- NPS Pollution Control,
- River & Ocean Management,
- Climate Change,
- Green Space & Community Improvements,
- Green Jobs & Economy,
- Construction & Building Codes

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Rendering of Smart GI & LID Research Facility (PNU)

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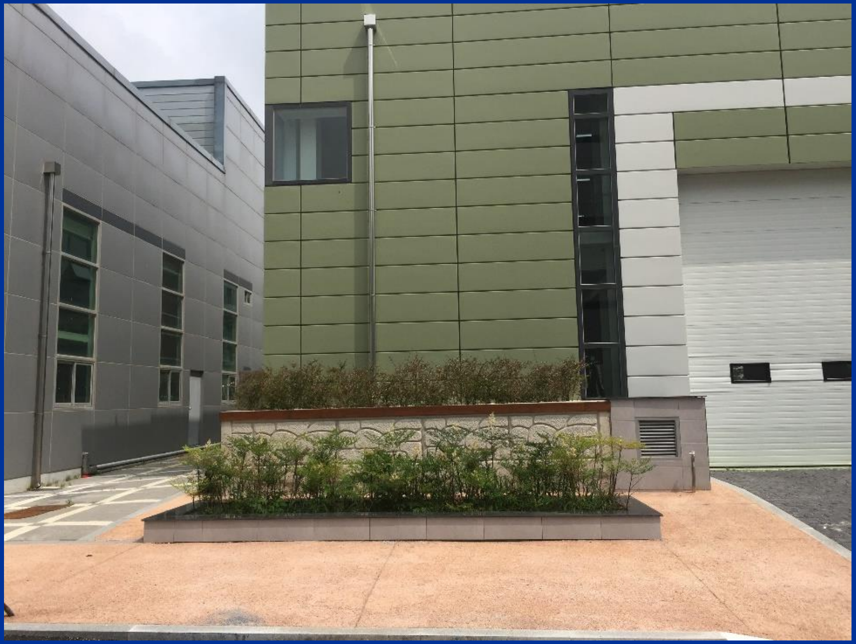
LID Building and Street Planters

Building Planter & Street Side Planter on left
Rain Barrels & Street Side Planter on right



Pavers and Porous Concrete

Interlocking Concrete Pavers on left
Porous Concrete on right

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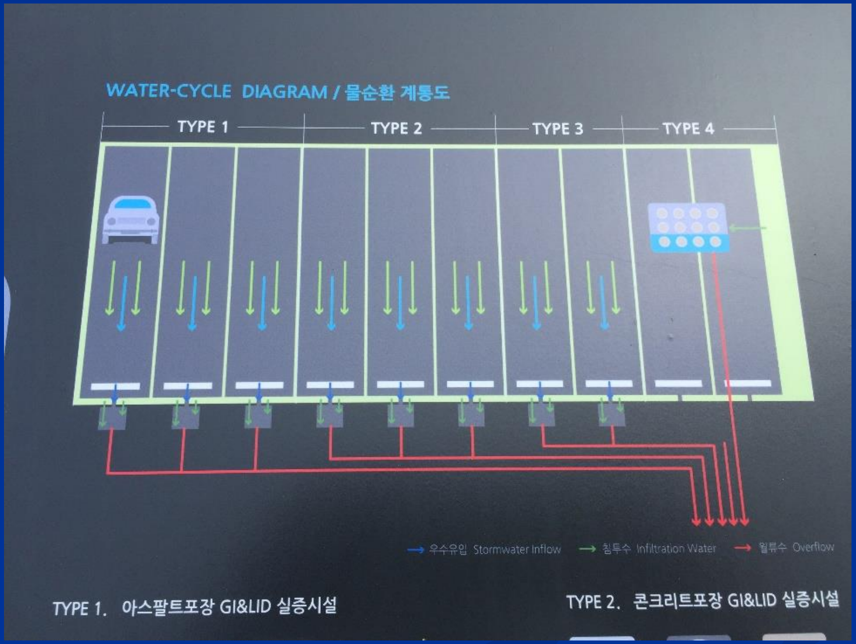
Porous Asphalt & Monitoring Diagram

Porous Asphalt Pavement on left
Diagram of Pavement Monitoring System on right



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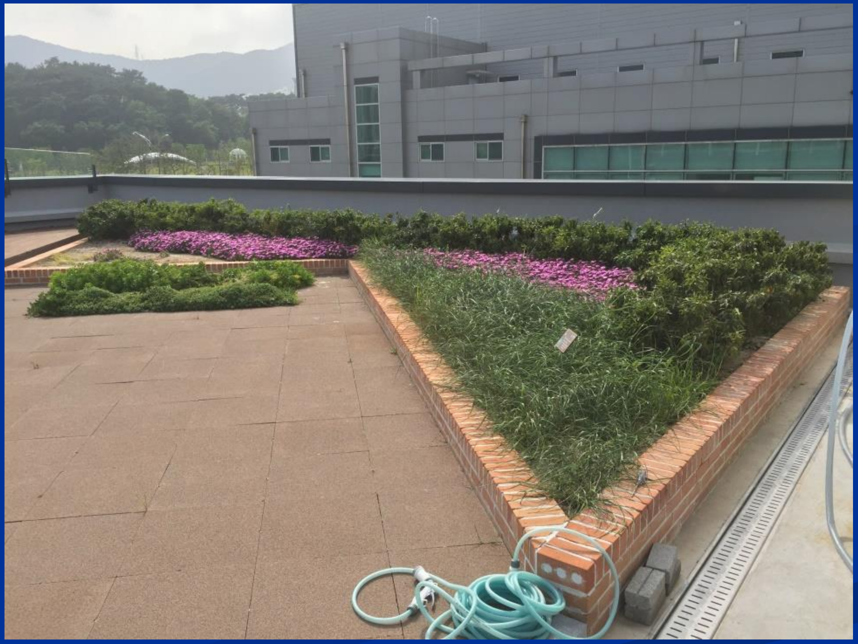
Bioretention Systems

Bioretention systems planted with perennials

Street side Planter & Green Roof Systems at LID Center

Street Side Planter on left
Portion of Green Roof on right



Monitoring Systems

- All of the LID & conventional systems are fully monitored to provide data,
- During real or artificial rainfall events, data is taken at 1 minute intervals in real time:
  - Rainfall Amount, Rainfall Intensity,
  - Infiltration Amount, Runoff Amount,
  - Depth & wetting front as rainfall infiltrates,
  - Summary data (rainfall, infiltration & runoff) for storm duration,
  - Water quality

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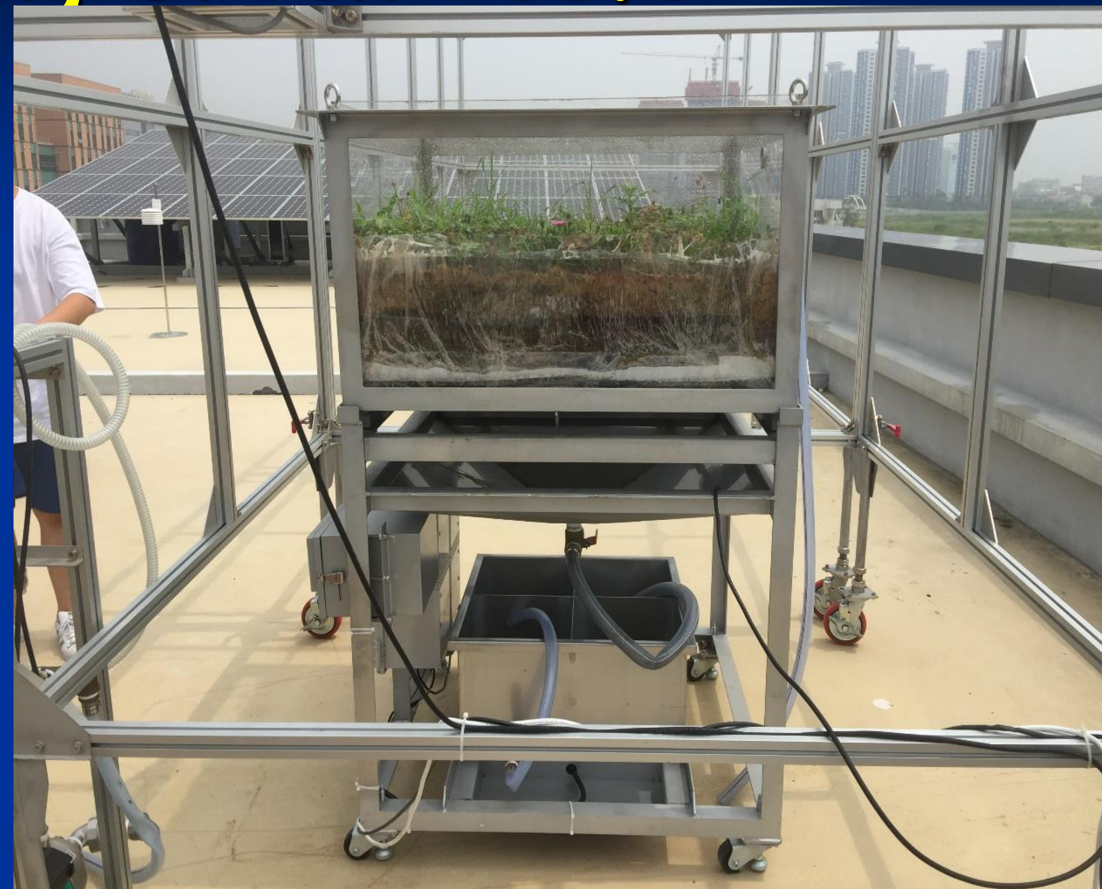
Field Monitoring Equipment

Evaluating Green Roofs

Research to determine evapo-transpiration rate from a green roof:

- 1 sq. meter of soil & plants
- Tray under soil measures weight
- Lower Tray underneath collects in filtrated rainfall
- Apply synthetic rainfall to system
- Determine evapotranspiration rate by substrating infiltrated rainfall & water stored in soil from rainfall applied



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Interior Research Facility

- Hydraulic beds to conduct column studies of various LID systems,
- Artificial Rainfall Simulators developed by Dr. Shin of Pusan National University,
- Using radar to measure size and frequency of actual raindrops from Rainfall Simulator. Data is automatically downloaded to excel file, color coded for size and frequency of rain drops

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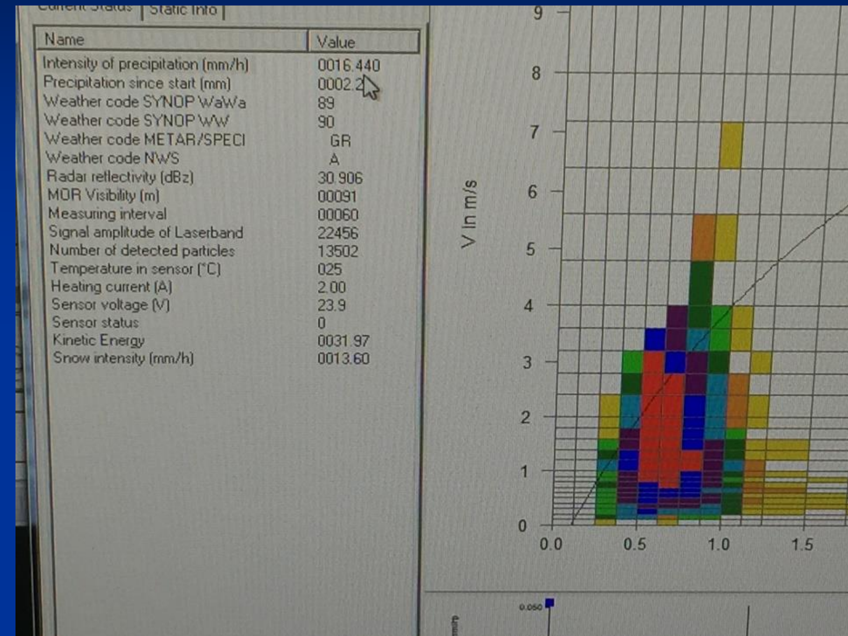
Interior Research Facility



- Using Radar to measure size, & frequency of rainfall event created by rainfall simulator
- Rainfall simulator can be set to deliver a pre-determined amount of rain in a specific time frame. It can also vary the intensity of the r ainfall event over time. Swivel heads allow for wind to be applied to rainfall event to more closely mimic a natural event

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Dr. Shin & Research Group at official opening of Center in June 2016

Classification of ecosystem services

Provisioning Services

Products obtained from ecosystem

- Food
- Fresh water
- Fuel wood
- Fiber
- Biochemicals
- Genetic resource

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation/Ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

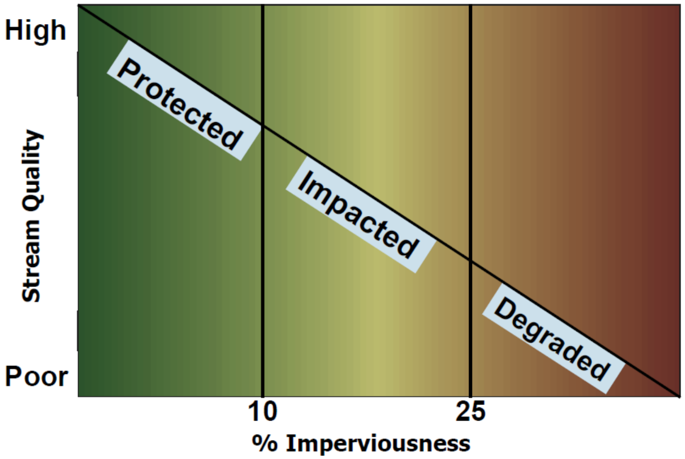
Supporting Services

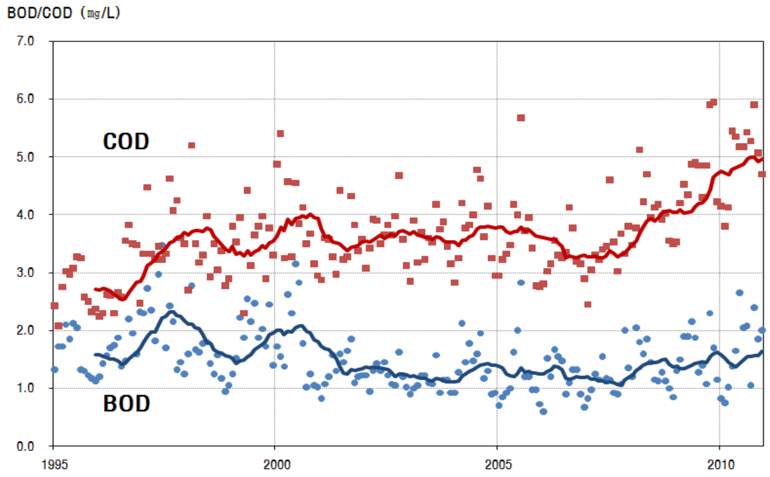
Services necessary for the production of all other ecosystem services

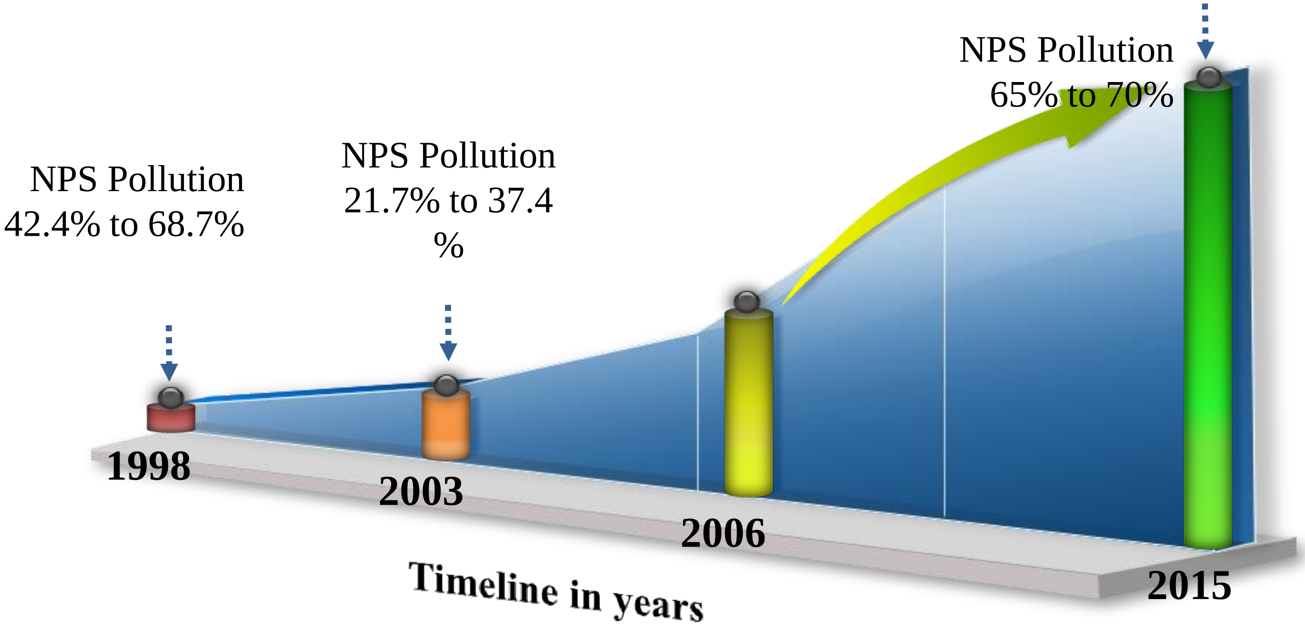
- Soil formation
- Nutrient cycling
- Primary production

MA. (2005). *Millennium Ecosystem Assessment: ecosystems and human well-being: synthesis*. Washington, D.C: Island Press.

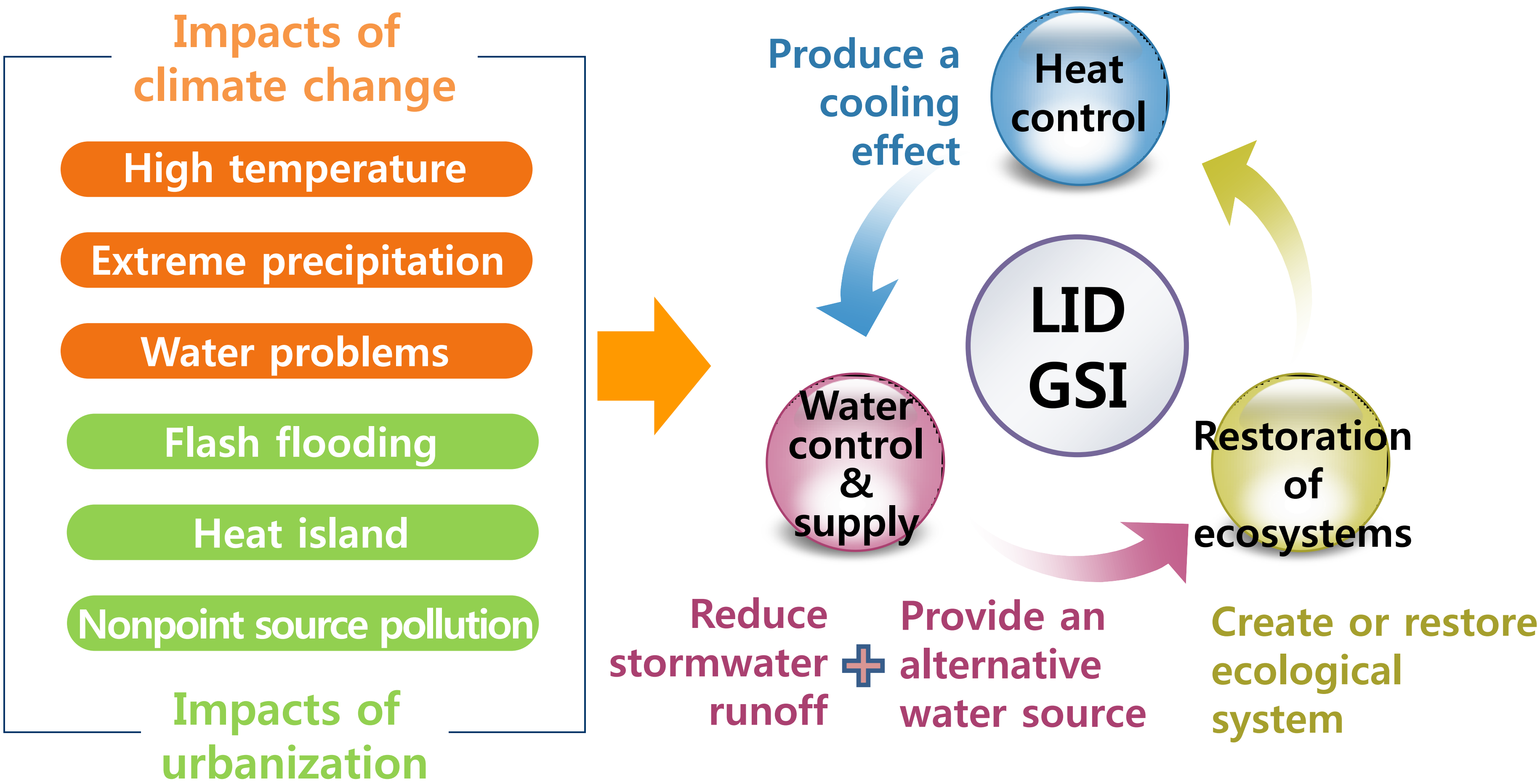
Impact of urbanization on water quality



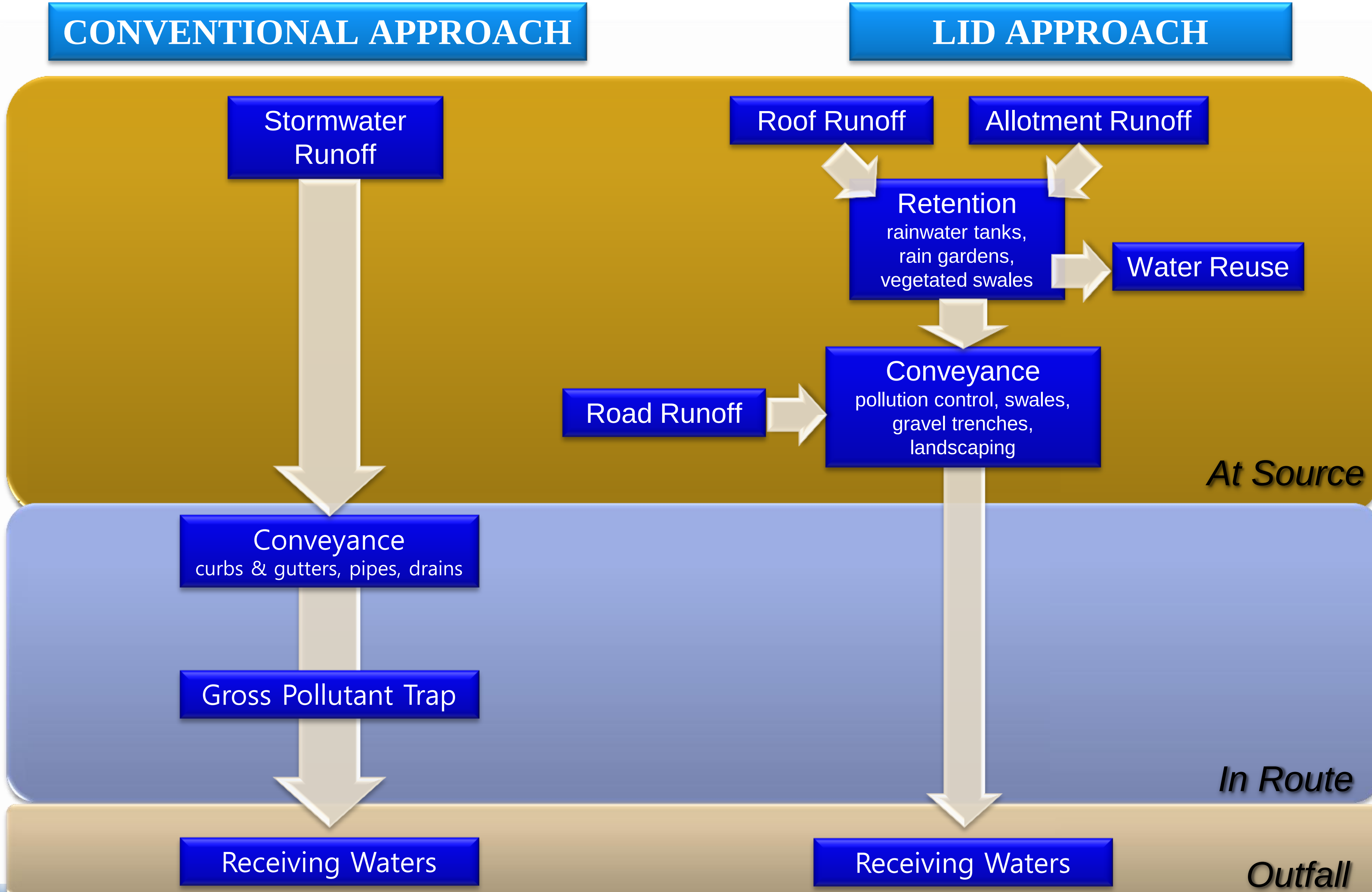




Impacts of climate changes and urbanization



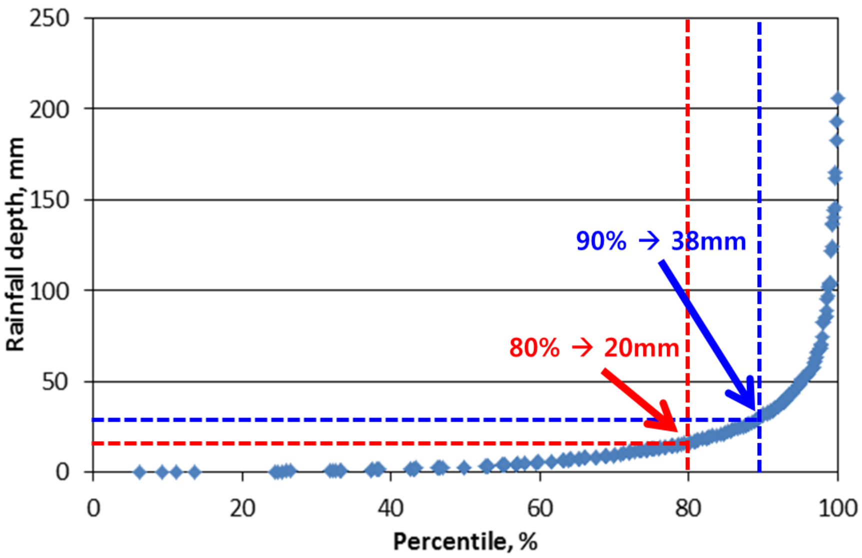
Stormwater management



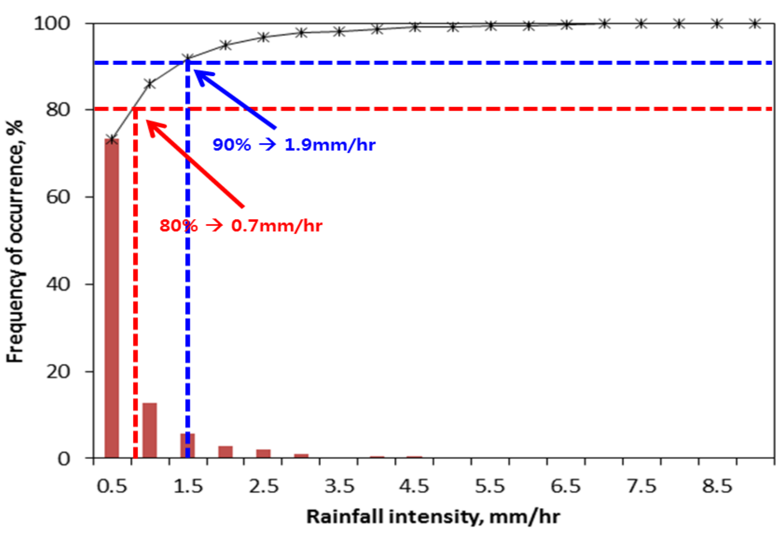
Sizing of LID/GI facility

BMPs		Sizing
Constructed wetland	Constructed wetland	WQv
Infiltration facility	Permeable pavement Infiltration basin Infiltration trench	
Vegetation facility	Vegetated strip Vegetated swale	WQF
	Bioretention Planters Tree box filter	WQv

WQv (Water Quality Volume): frequency of 80% or 90% rainfall event



WQF (Water Quality Flow): frequency of 80 or 90% rainfall intensity



Applicable LID/GI facility with soil type

Soil type	Applicable LID facility		
Type A	 Infiltration trench	 Infiltration basin	 Planters
Type B, C	 Bioretention	 Rain garden	 Vegetated swale
Type D	 Constructed wetland	 Ponds	 Underground storage tank

Stormwater management in Korea

- 2004: Comprehensive measures in nonpoint source management
- 2006: National water environment management plan: BMPs for EIA projects
- 2006~2014: NPS Demo projects: assessment of 45 BMPs
- **2014: Modified comprehensive measures in nonpoint source management: LID/GI for water circulation and NPS management**
- 2014~present: GI project for public institution
- 2014~present: Civic participation project for NPS management
- **2014~present: Demo projects of stormwater runoff reduction from city areas: 2 cities Osong and Jeonju**
- 2014: Seoul Ordinance of LID in Seoul metropolitan areas
- 2016: National water environment management plan: LID and GI for urbanized areas
- **2016: Water Circulation City:**
  - Select 5 cities in 2015: Gwangju, Daejeon, Gimhae, Ulsan, Andong
  - All cities > population of 100,000
  - Provide central government finance of 50%
  - Enact LID Ordinance for all of water circulation cities

Cities applied or planned LID/GI

- Seoul: LID ordinance(2014)
- Suwon: Green infra(GI) application(2014)
- Pyeongtack: LID application for new city(designing)
- New city of Asan-Cheon: LID application(2015)
- Sejong city: LID for new development area(designing)

- **Demo project cities for green infra(2014~2015): Osong(26 ha), Jeonju(31ha)**

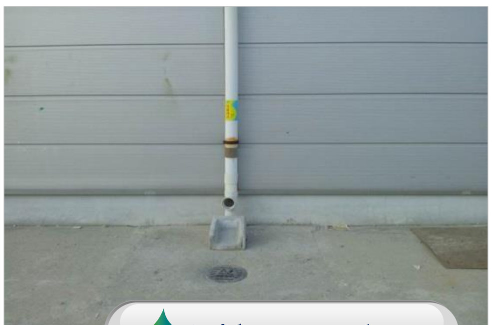
- **Water circulation city: Gwangju, Daejeon, Gimhae, Ulsan, Andong selected on 2016**

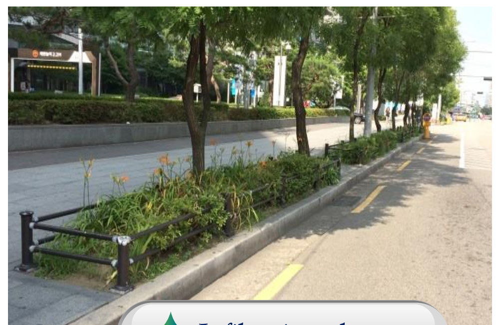
GI Techniques used in urban areas


Bioretention


Infiltration trench


Tree box filter


Infiltration device


Infiltration planter


Infiltration inlet/gutter


Constructed wetland


Floating islands

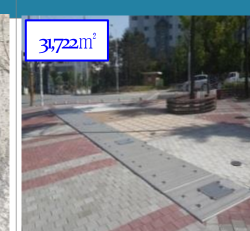

Permeable pavement/block

Case 1: Osong industrial areas

GI	Block A(No)
Infiltration planter	42
bioretention	1
Tree box filter	66
Infiltration device	
Infiltration trench	-
Infiltration inlet	-
Permeable block	19,917㎡

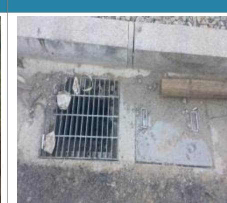
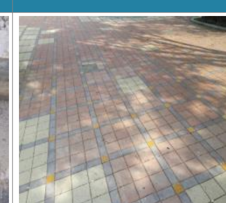
GI	Block B (No)
Infiltration planter	22
bioretention	3
Tree box filter	58
Infiltration device	12
Infiltration trench	338.0m
Infiltration inlet	5
Permeable block	11,805㎡

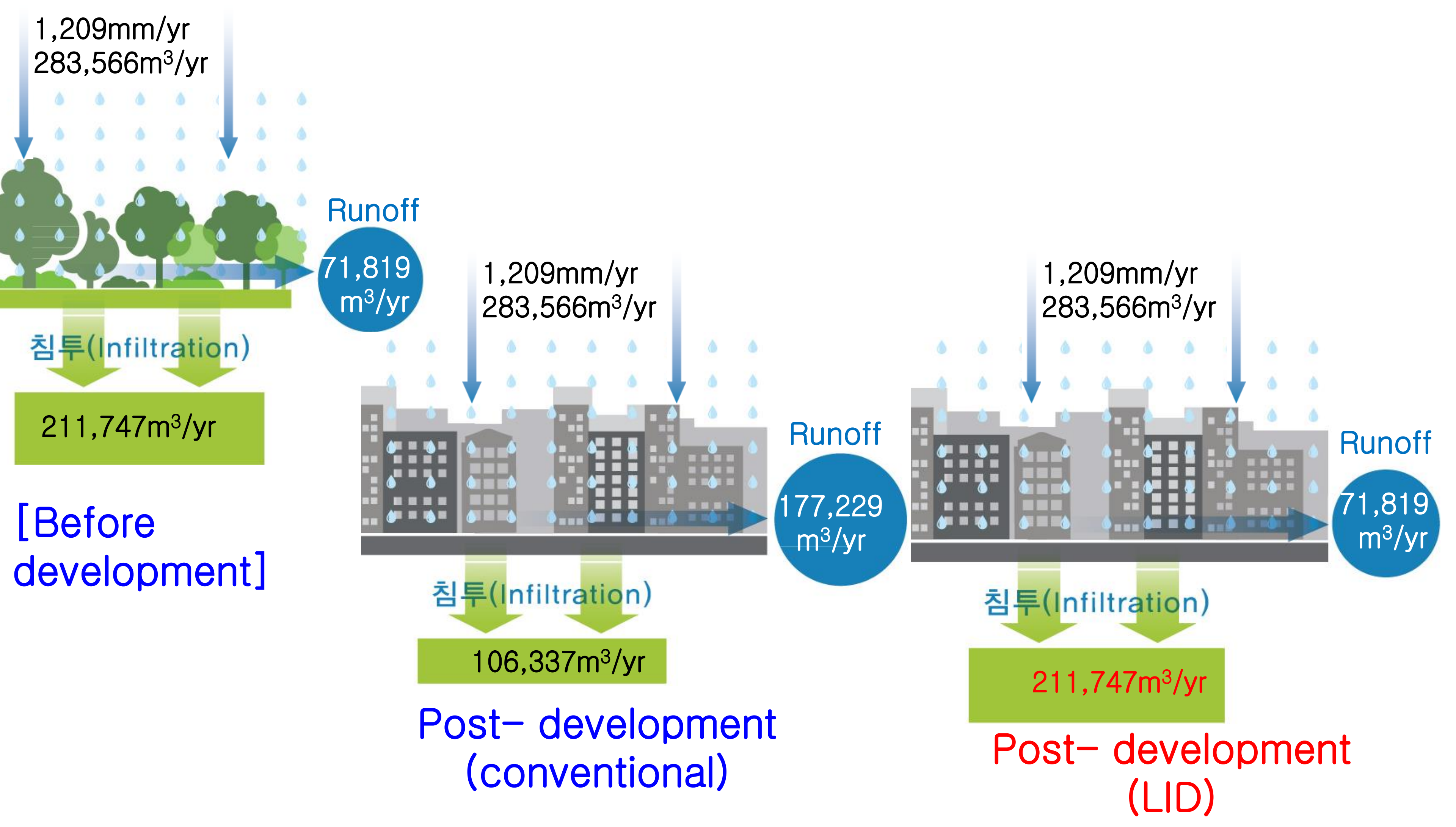
Infiltration planter	Bioretention	Tree box filter	Infiltration device	Infiltration trench	Infiltration inlet	Permeable block



Case 2:Cheonju city (urban area)

GI	No. (area)
Bioretention	4 (337.0㎡)
Tree box filter	15 (29.7㎡)
Infiltration planter	1,691.9㎡
Infiltration device	40 (33.2㎡)
Infiltration inlet	30 (44.7㎡)
Infiltration trench	131.4㎡
Permeable block	17,668.50㎡
Green roof	5 (695.0㎡)

Bioretention	Tree box filter	Infiltration planter	Infiltration device	Infiltration trench	Infiltration inlet	Permeable block	Green roof
							


1,209mm/yr
283,566m3/yr
Runoff
71,819 m3/yr
침투(Infiltration)
211,747m3/yr
[Before development]
1,209mm/yr
283,566m3/yr
Runoff
177,229 m3/yr
침투(Infiltration)
106,337m3/yr
Post- development (conventional)
1,209mm/yr
283,566m3/yr
Runoff
71,819 m3/yr
침투(Infiltration)
211,747m3/yr
Post- development (LID)

Case 5: LID/GI in Seoul: Goal for rainwater management until 2050

620mm Urban Runoff/1,550m Annual Rainfall

Source: Seoul Metropolitan (2015. 4. 8)

Water Environment Comprehensive Management Plan 2020 (mm/year)

2020 Evapotranspiration

435.4mm/ yr

38.3mm ↑

Compared to 2014

9.7% increase

397.1mm/yr in 2014

2020 Surface Runoff

670.4mm/ yr

104.6mm ↓

Compared to 2014

11.4% decrease

757.0mm/yr in 2014

2020 Infiltration

633.6mm/ yr

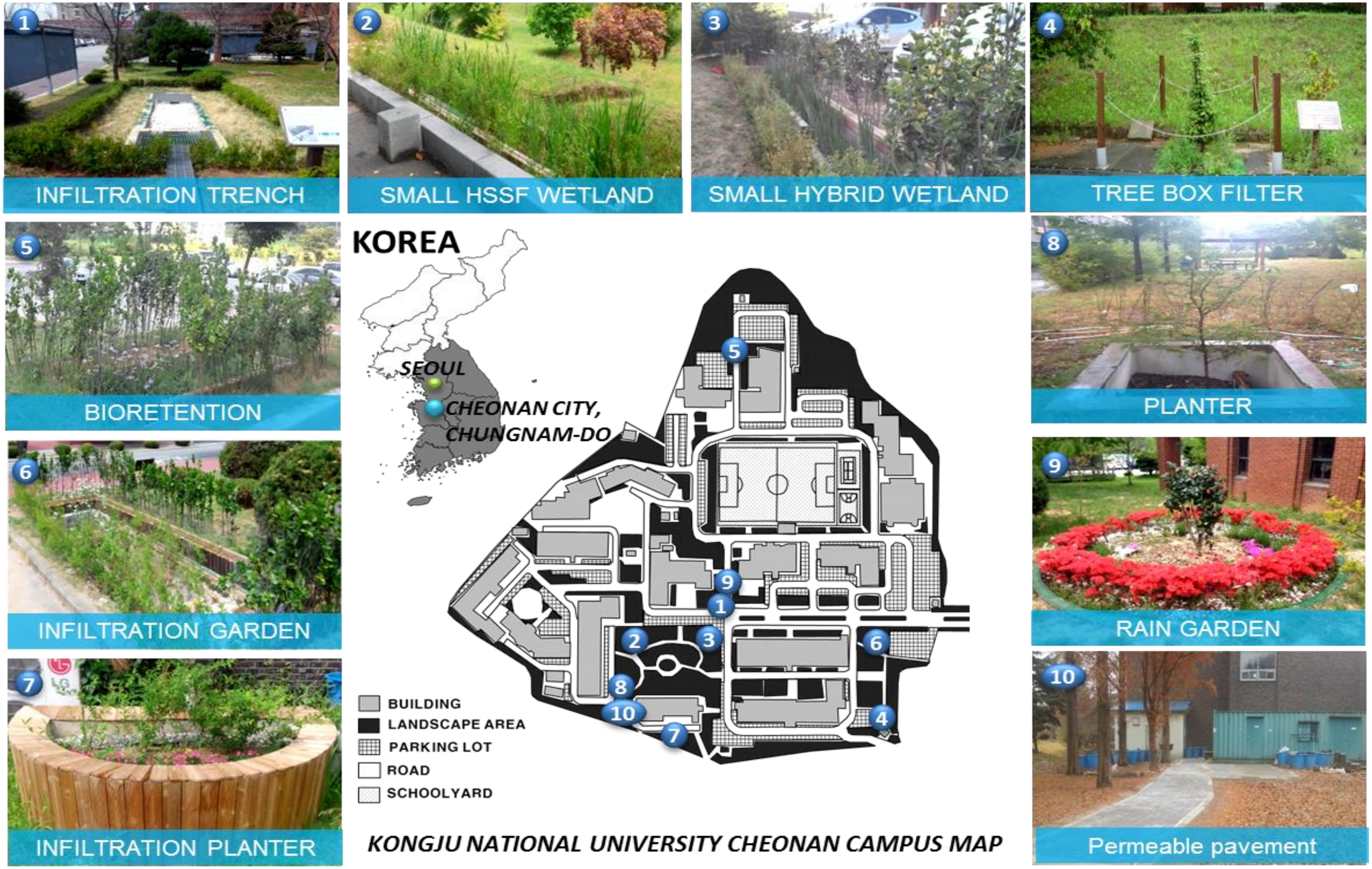
58.2mm ↑

Compared to 2014

8.2% increase

575.4mm/yr in 2014

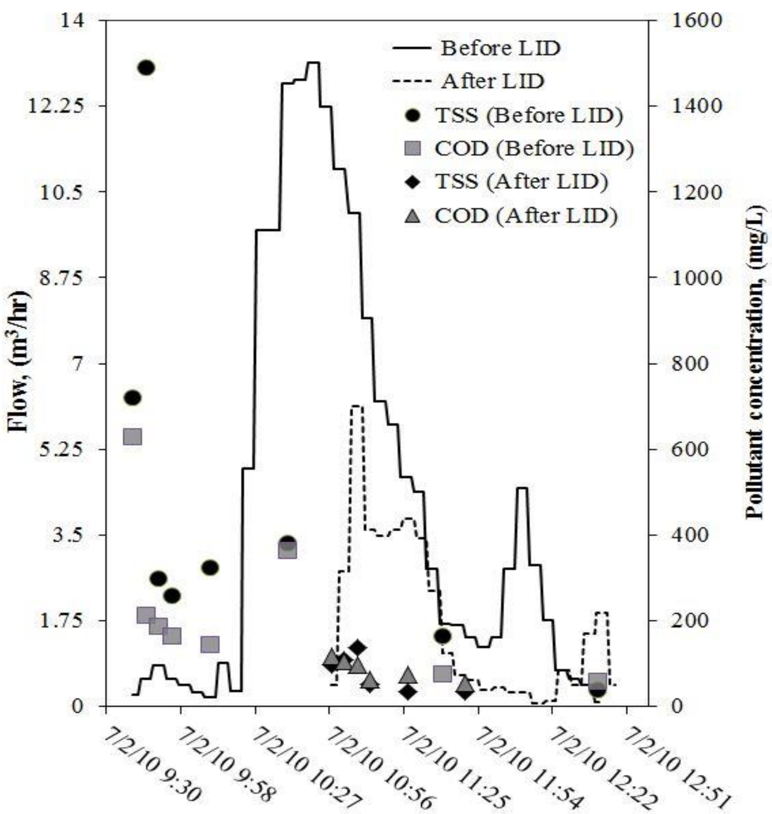
Case 6: Green LID campus (KNU)



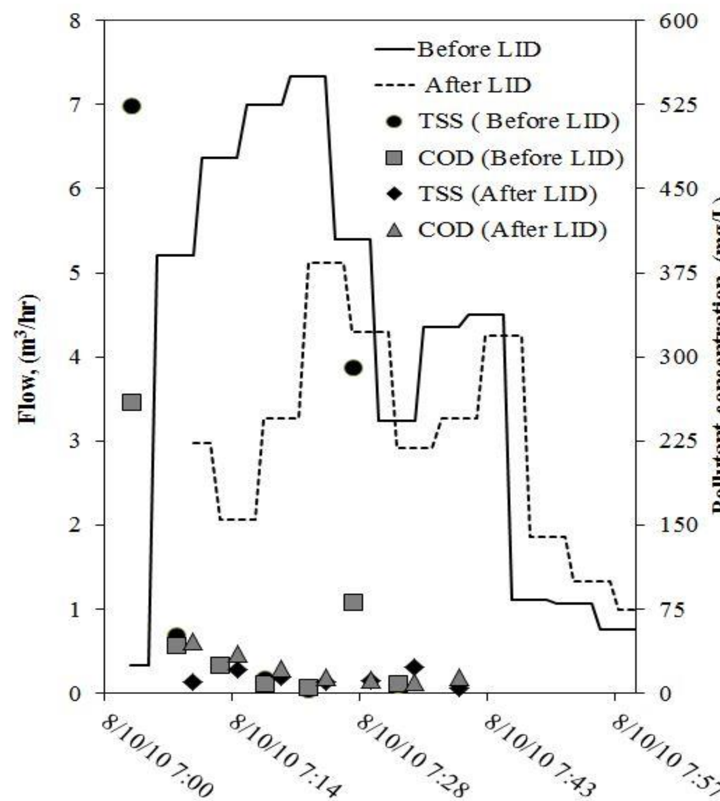
Changes of water quality and runoff flow before/after LID application

Before LID application

After LID application



Infiltration trench



Tree box filter

Thank you

Lee-Hyung Kim, Ph.D, Professor

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LID Retrofits – Land & Housing Institute (LHI)

- Dr. Hyun of LHI provided the following slides (& more) to me of LID retrofits recently installed at the Institute Research Center in Daejeon, South Korea and I thank him for this.
- In 11/14, Dr. Hyun and I walked the LHI campus in the rain and I pointed out the locations for possible LID retrofits.   It was great to see them actually implemented.

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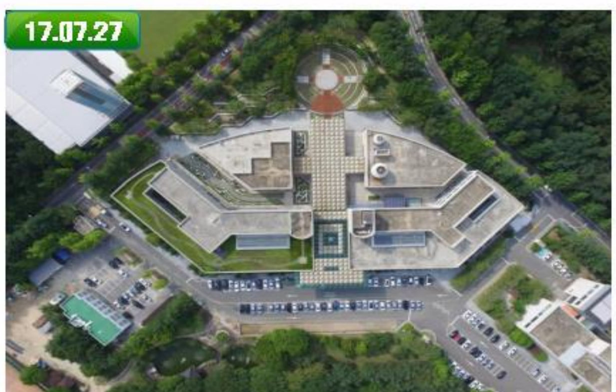
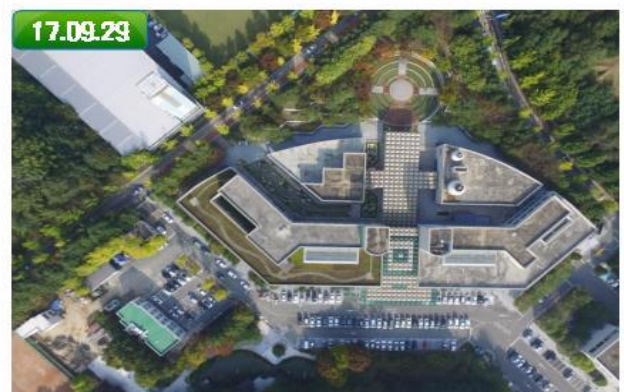
Overhead View of Campus

Ⅰ LID 단지재생 조성 과정

17 드론촬영





추가 영상

Plan showing Drainage Patterns

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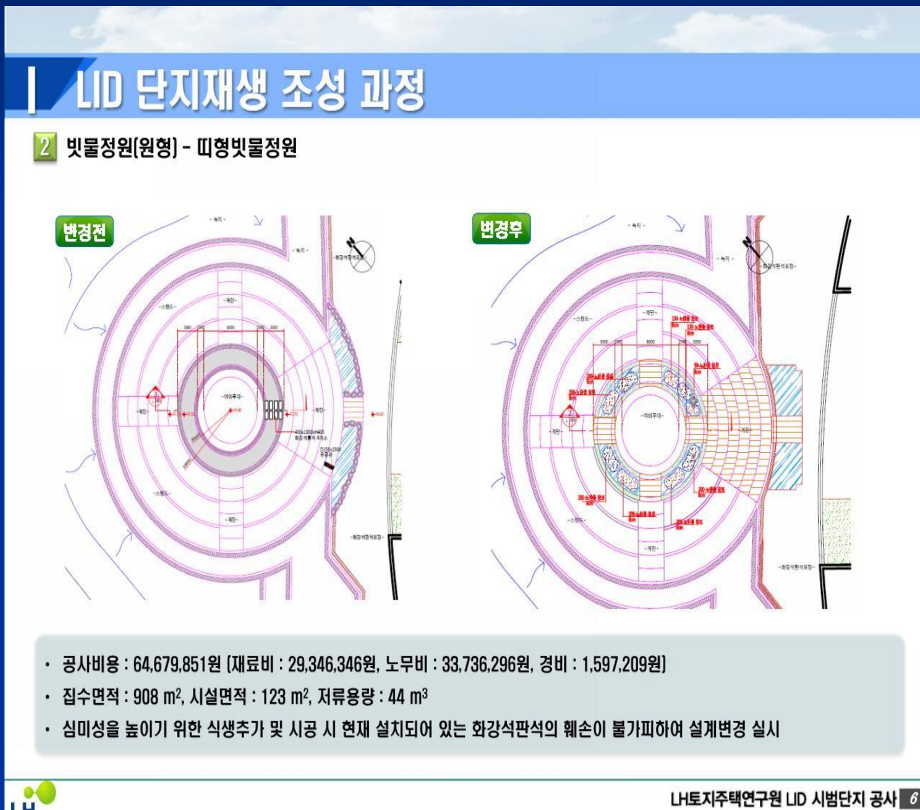
Bioretention Retrofit

Bioretention Retrofit



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Bioretention Retrofits

LOW IMPACT SUSTAINABLE DEVELOPMENT
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Bioretention Retrofits

Permeable Pavers & Bioretention Retrofit

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Ⅲ LID 시범단지의 도시재생 활용

1 교육 및 견학(17.10.26 LID 시범단지 준공식 및 심포지움)

Asan Tangjeong New Town Project

- Developed by Land and Housing Corporation
- LID research systems and stormwater management design by Land and Housing Institute,
- 1st widespread application of LID concepts in urban development is South Korea,
- Asan Tangjeong project encompasses 1.75 sq.km (435 acres)

Asan Tangjeong New Town Project

- Home Building District = 0.54 sq.km (30.7%)
- Commercial/Business District = 0.32 sq.km (18.4%)
- Public Facilities District = 0.86 sq.km (48.8%)
- Projected Population Density = 104 persons per ha (42 person per acre or 17,610 people for the entire project)
- Green Ratio = 25%

City of Asan, South Korea

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Picture of before construction

Existing Conditions of Site – Fall 2012

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Picture of construction in progress (April. 2014)

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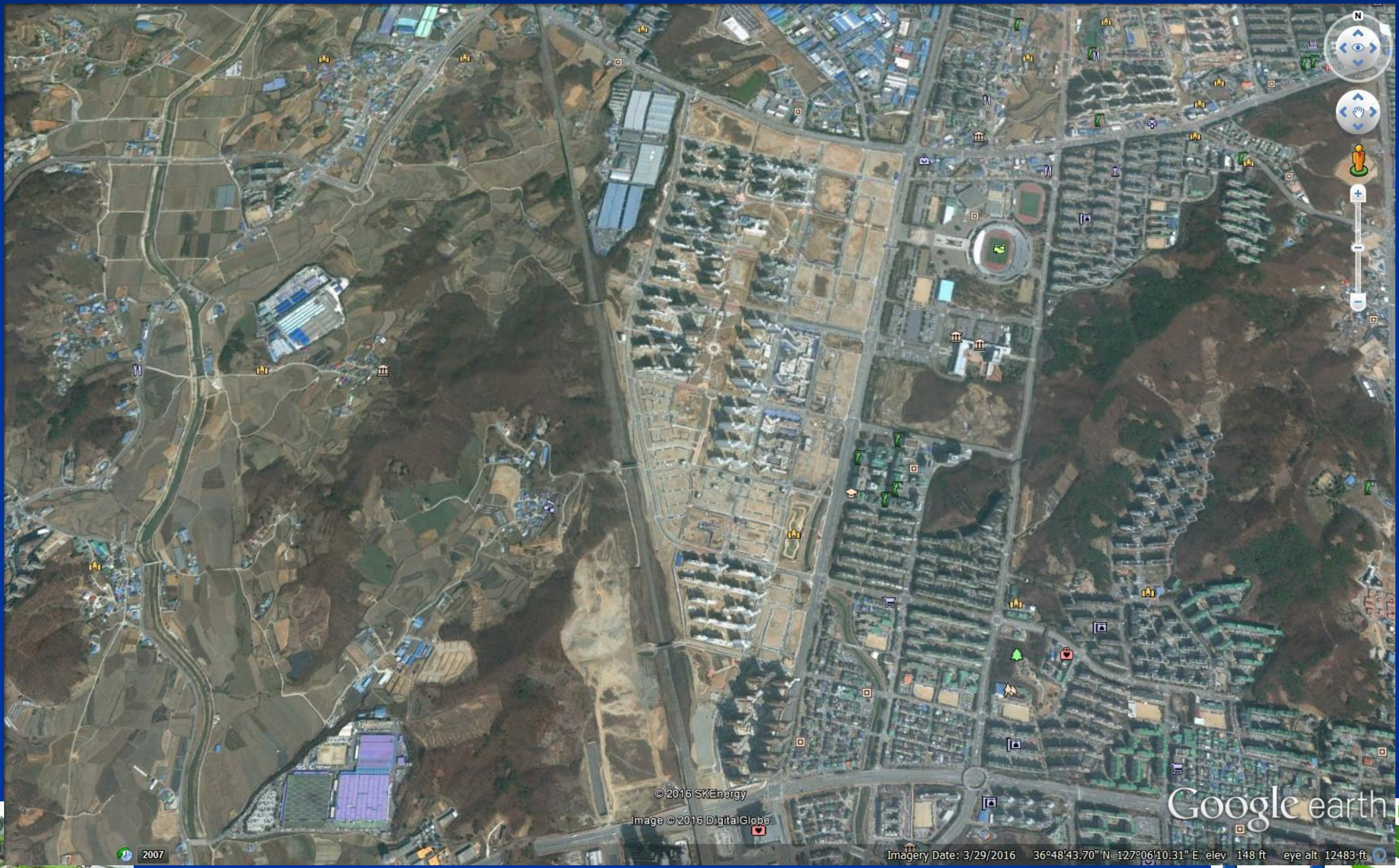
Conditions – Fall 2014

Site Conditions – July 2016



Site Conditions

- Soils:
  - Most soils on the site have high percentage of clay,
  - Other soil types is coarse stratified sands,
- Groundwater Depths:
  - Groundwater depths on the site vary between 3.8 m and 5.0 m below the ground surface,
  - Average groundwater depth is 4.4 m,
  - A vertical separation of approximately 2.5 to 3 m will be provided from the bottom of a LID system to the groundwater table

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Hydrologic Design Requirements

- Water Quality/Runoff Volumes:
  - Use LID systems to filter runoff to reduce pollutant loads to Maximum Extent Possible
  - The initial 5 mm (0.2") of rainfall must be infiltrated back into the ground
  - This standard was set forth by the Ministry of Environment in South Korea to control non-point source runoff,
  - Rainfall events of 5 mm or less constitute 60% of total annual rainfall events in South Korea according to Korean Meteorological Administration.

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LID Strategies to be used in the Asan Tangjeong Project

- Rainwater Harvesting:
  - Rainfall on building roofs will be directed to storage tanks located in the basements of the building,
  - The harvested rainfall will be used for watering of landscaped areas, public parks and for cleaning of streets within the Asan Tangjeong project,
  - A total of five rainwater harvesting systems will be installed for the project:
    - 3 each with a capacity of 600 tons (19,230 cubic feet) of storage
    - 2 each with a capacity of 1,200 tons (38,460 cubic feet) of storage
    - The total storage volume is 431,521 gallons

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LID Strategies to be used in the Asan Tangjeong Project

- Infiltration Swale,
  - To be used in highly urbanized area along roads
- Infiltration L Drain,
  - To be used in highly urbanized area along roads
- Vegetation Swale,
  - To be used in less dense areas of the development
- Urban Wetlands,
  - Used for polishing of stormwater prior to discharge

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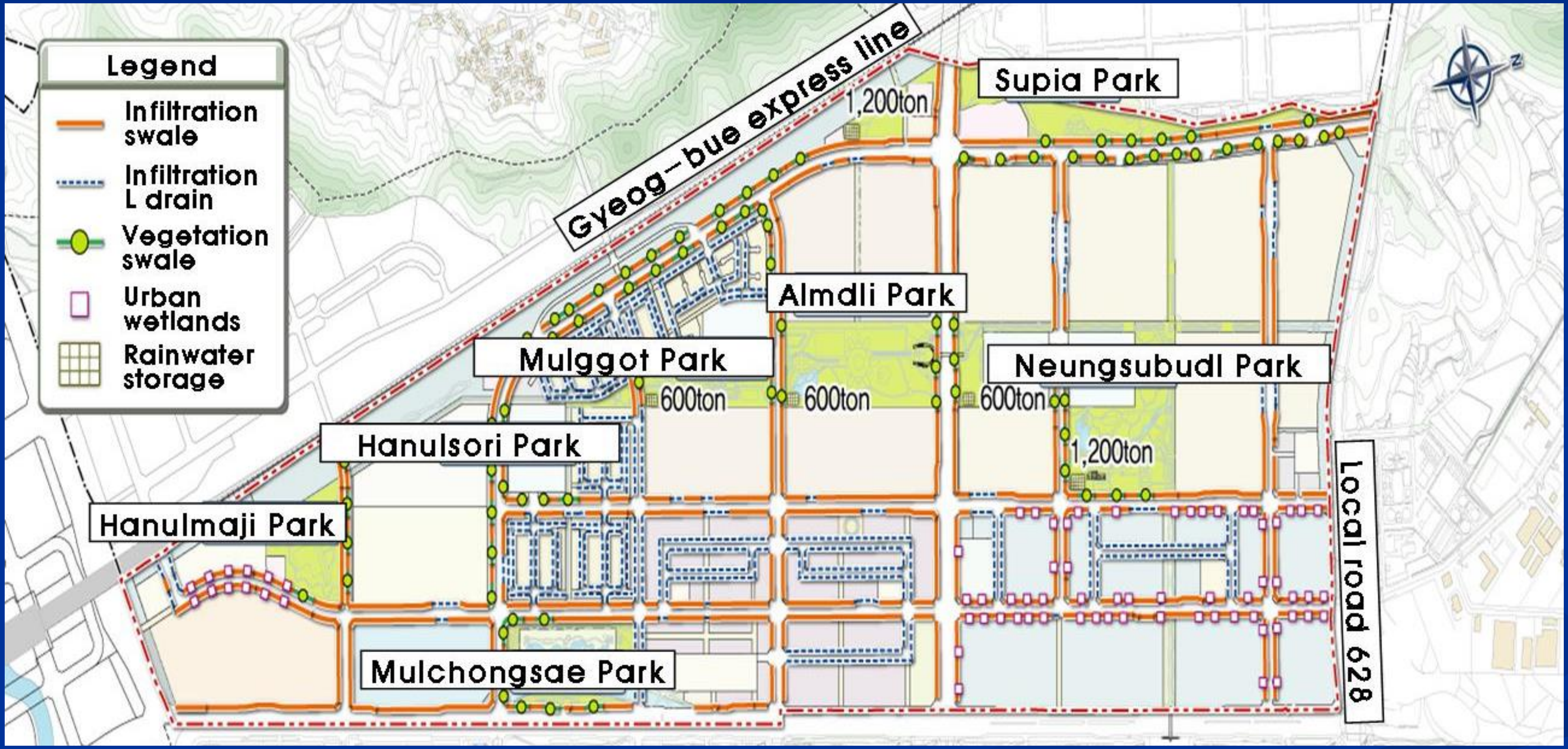
Location of LID systems



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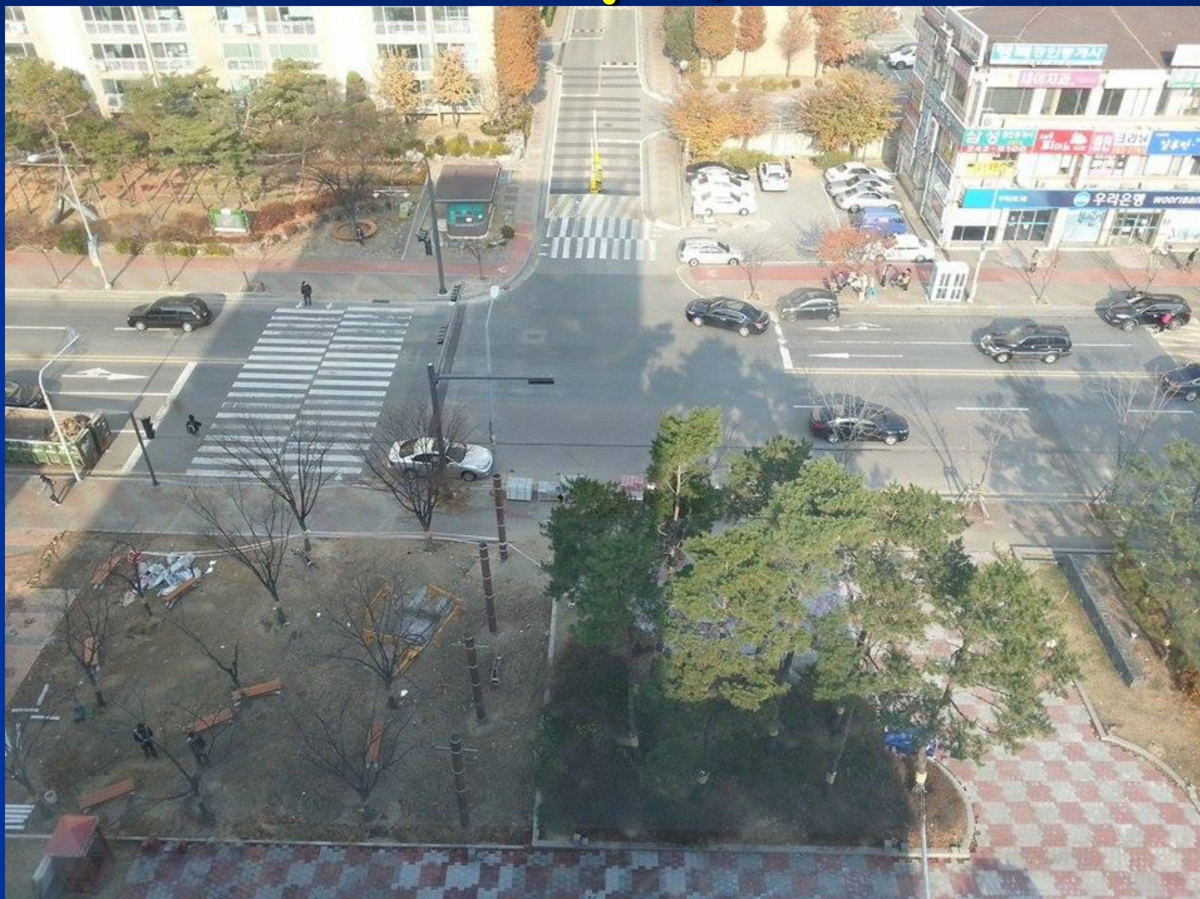
LID Demonstration Project
Asan Tangjeong

LID Demonstration Project
Suwon City (Seoul, South Korea)



LID Demonstration Project
Suwon City (Seoul, South Korea)

Infiltration trench bedded in sand

LID Demonstration Project Suwon City (Seoul, South Korea)

Rainwater harvesting tank for runoff from elevated highway

LID Demonstration Project
Suwon City (Seoul, South Korea)

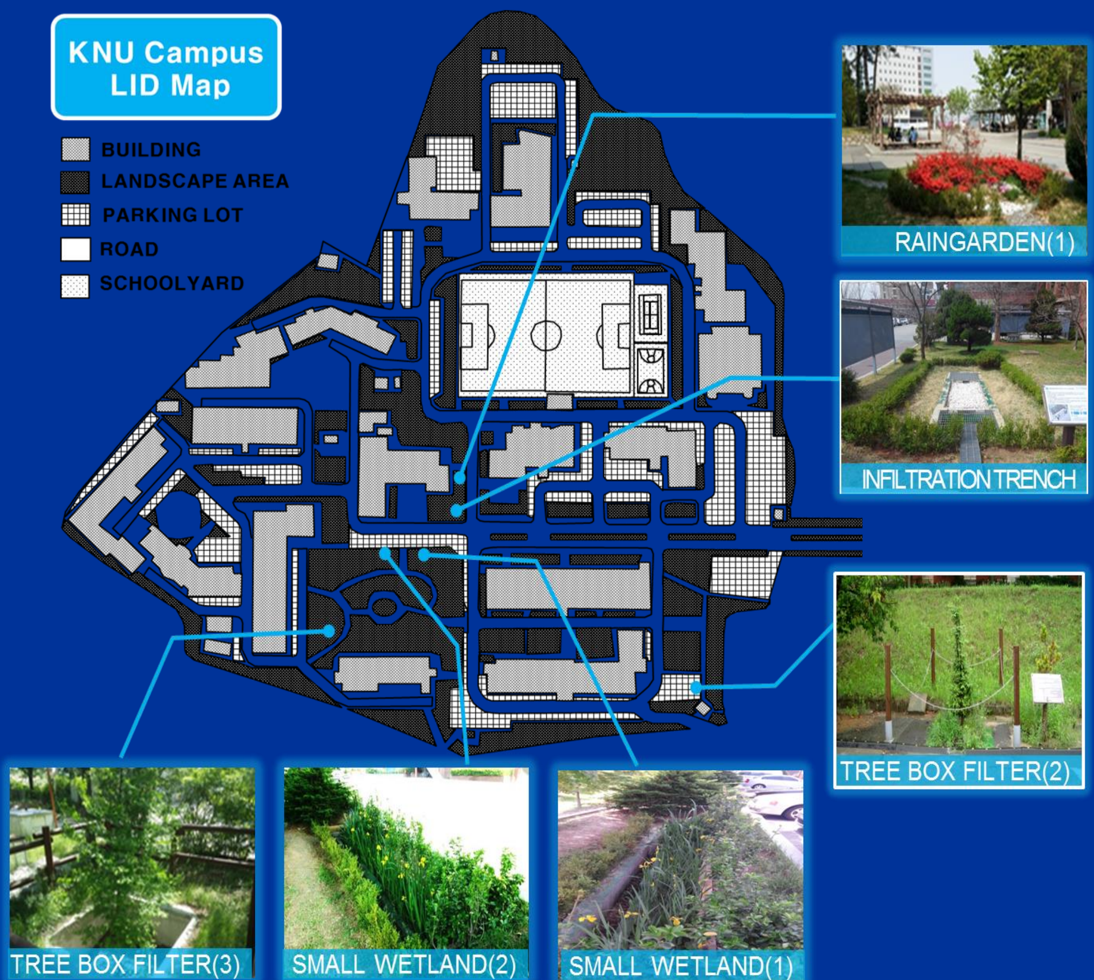
Standard pavers
Permeable pavers

LID Demonstration Project Suwon City (Seoul, South Korea)

Rain Garden Installation

LID facility at KNU campus

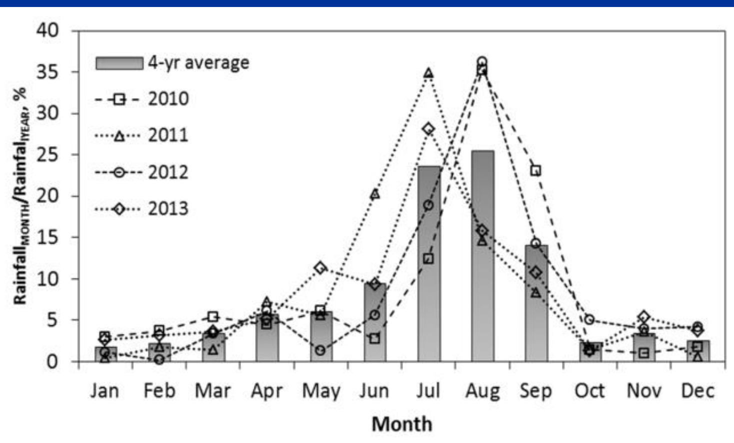
(1) Facility & Monitoring site

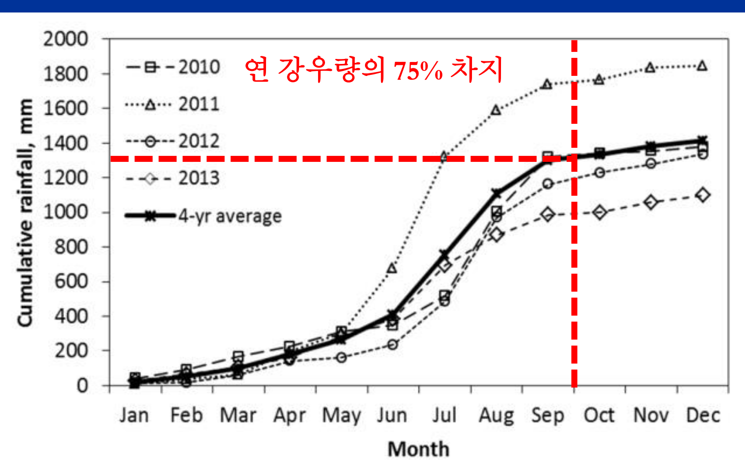


LID facility	Land Use	Basin Area (m^2)	Capacity (m^3)	Design Rainfall (mm)
Rain garden (RG)	Roof	200	2.8	8
Infiltration Trench (IT)	Road	520	3.9	25
Tree Box Filter-1 (TBF-1)	Parking lot	450	1.8	5
Tree Box Filter-2 (TBF-2)	Road	48	4.5	10
Small Wetland-1 (SW-1)	Parking lot	323	2.7	5
Small Wetland-2 (SW-2)	Parking lot	424	2.9	5

(2) Monitoring Results

■ Rainfall characteristic of Chunan, Korea

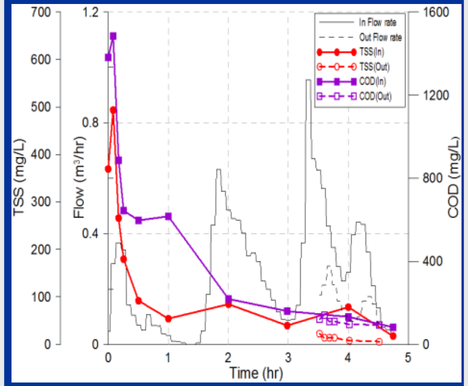


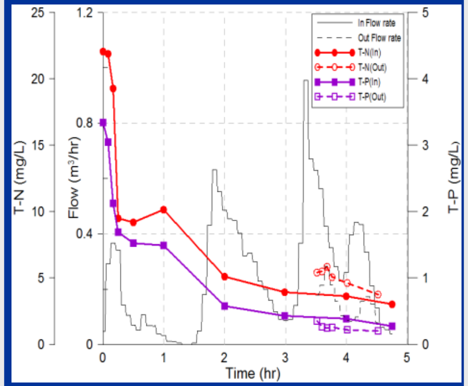


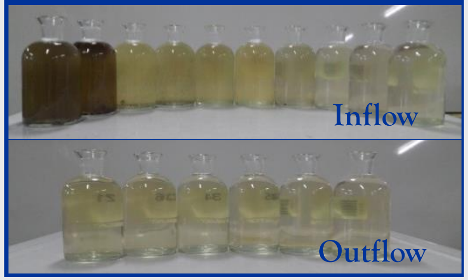
No.	Event Date	ADD (day)	Total Rainfall (mm)	Total Rainfall Duration (hr)	Total Runoff Duration (hr)	Time Before Runoff starts (hr)	Time Before outflow starts (hr)
Infiltration Trench (IT)							
E-1	04/27	9.3	6.5	5.63	4.73	0.90	3.50
E-2	05/11	3.5	8.5	2.58	2.16	0.41	1.57
Tree Box Filter-1 (TBF-1)							
E-1	04/17	3.9	3.0	2.00	0.50	1.38	0.00
E-2	04/27	9.3	6.5	5.23	2.67	2.57	0.00
E-3	05/11	3.5	18.0	6.12	4.17	1.95	1.02
Small Wetland-1 (SW-1)							
E-1	04/17	3.9	3.0	2.18	0.92	1.27	0.77
E-2	04/27	9.3	6.5	5.65	4.67	0.98	0.30
E-3	05/11	3.5	9.5	4.33	2.50	1.83	0.30
E-4	06/02	7.3	2.0	1.25	0.50	0.75	0.28
Small Wetland-2 (SW-2)							
E-1	04/17	3.9	4.0	3.92	2.75	1.17	0.83
E-2	05/11	3.5	7.5	2.15	1.73	0.41	0.58
E-3	06/02	7.3	2.0	1.25	0.92	0.50	0.67

Pollutant Load Evaluation

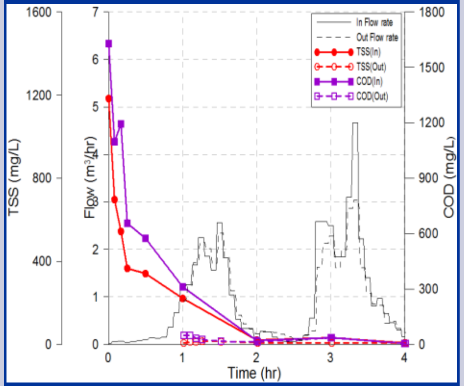
IT (04/27)

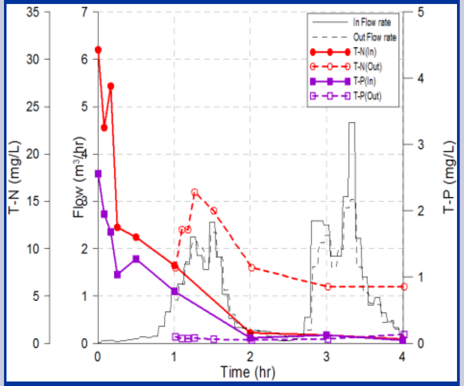


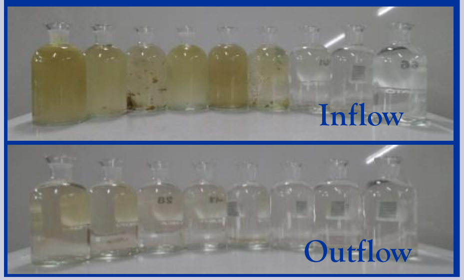




TBF-1 (05/11)







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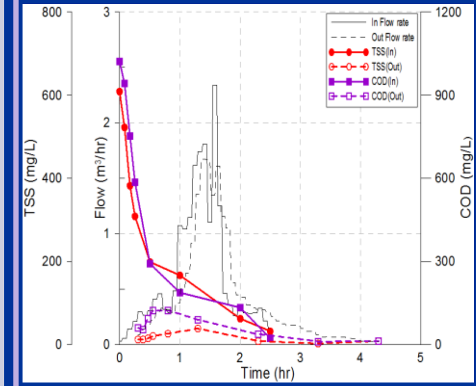
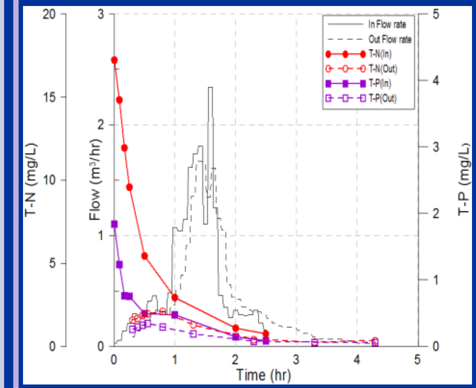
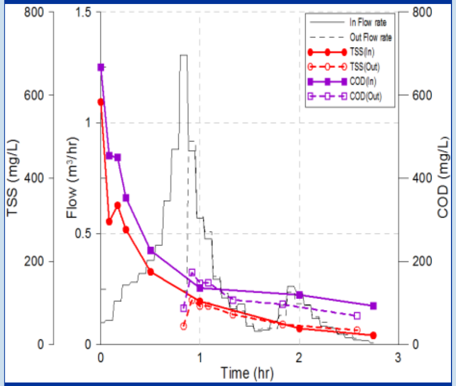
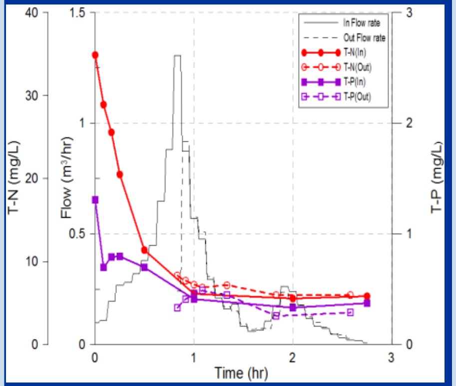




SW-2 (04/17)





■ Inflow and Outflow EMC

No.			TSS	BOD	COD	Oil & Grease	TN	TP	Total Cu	Total Zn	Total Pb
Infiltration Trench (IT)	E-1	In	85.6	38.4	249.4	0.7	5.39	0.65	0.033	0.267	0.036
		Out	11.1	23.8	106.9	0.2	4.80	0.20	0.024	0.283	0.024
	E-2	In	102.4	19.0	196.0	TBU	3.39	0.25	TBU	TBU	TBU
		Out	25.1	10.9	25.1	TBU	3.16	0.12	TBU	TBU	TBU
Tree Box Filter-1 (TBF-1)	E-1	In	85.7	8.8	99.4	0.9	5.26	0.54	0.055	0.523	0.065
		Out	0.0	0.0	0.0	0.0	0.00	0.00	0.000	0.000	0.000
	E-2	In	101.7	39.1	250.8	0.5	6.18	0.82	0.090	0.250	0.083
		Out	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
	E-3	In	84.9	20.2	115.4	1.0	3.06	0.31	0.142	0.194	0.179
		Out	9.2	5.4	27.7	0.6	0.8	0.1	0.147	0.214	0.146
Small Wetland-1 (SW-1)	E-1	In	200.3	19.7	228.6	1.1	8.86	0.54	0.082	0.618	0.066
		Out	97.3	41.7	242.2	0.3	5.23	0.43	0.059	0.352	0.035
	E-2	In	73.0	26.0	115.4	1.3	5.35	0.50	0.050	0.276	0.039
		Out	34.3	37.2	210.0	0.7	3.22	0.50	0.040	0.272	0.035
	E-3	In	136.8	22.1	189.3	1.6	2.76	0.37	0.057	0.597	0.137
		Out	25.7	73.5	15.7	0.2	0.54	1.10	0.032	0.173	0.043
	E-4	In	TBU	TBU	TBU	TBU	TBU	TBU	TBU	TBU	TBU
		Out	TBU	TBU	TBU	TBU	TBU	TBU	TBU	TBU	TBU
Small Wetland-2 (SW-2)	E-1	In	131.2	20.8	182.1	1.1	9.07	0.51	0.072	0.414	0.045
		Out	76.9	15.2	128.9	0.9	6.90	0.39	0.057	0.362	0.032
	E-2	In	108.0	17.8	158.1	TBU	4.71	0.27	TBU	TBU	TBU
		Out	31.2	7.0	95.3	TBU	3.99	0.13	TBU	TBU	TBU
	E-3	In	181.4	52.8	516.2	TBU	13.45	0.59	TBU	TBU	TBU
		Out	49.4	26.7	263.5	TBU	7.16	0.34	TBU	TBU	TBU

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