清華大学环境学院
SCHOOL OF ENVIRONMENT, TSINGHUA UNIVERSITY

Sustainable urban water system and several case studies

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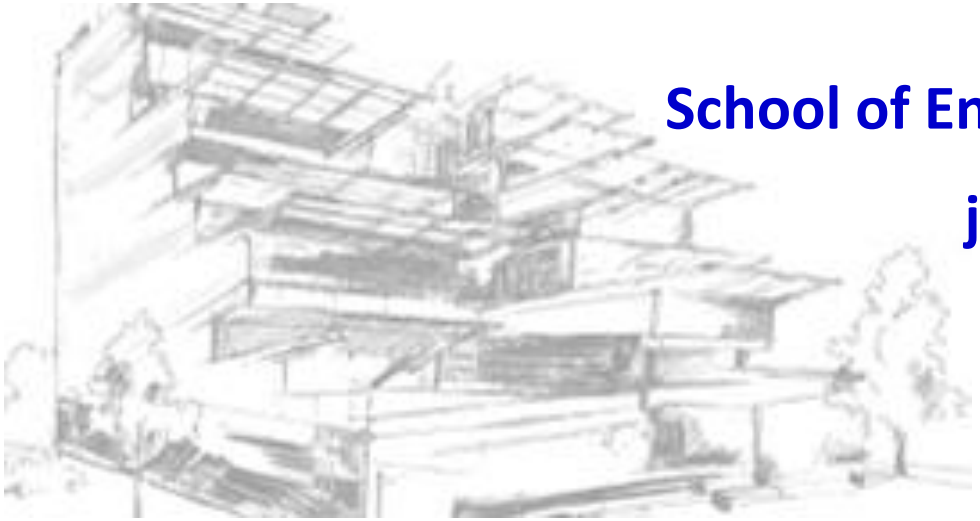


July, 2017

Outlines

1. Challenge of Urban Water Sustainability
2. Development of a New Urban Water System
3. Implementations : case studies

1.1 International Movement on Sustainable Development

1972 — UN Conference on the Human Environment
- Discussed state of global environment
- Resulted in Stockholm Declaration
- Presented UN's new Environmental agenda

1987 — Brundtland Commission: World Commission on Environment and Development
- Officially defines sustainable development

1992 — UN Conference on Environment and Development (Earth Summit)
- Created plan for sustainable development
- Brought world-wide attention to sustainable development movement

2002 — World Summit on Sustainable Development
- Resulted in Johannesburg Declaration
- agreed to focus on threats to sustainable development

2006 — Stern Review on the Economics of Climate Change
- Discuss effect of global warming
- Gives several strategies for reducing environmental harms

2011 — UNEP's Towards a Green Economy
- Contribution to Rio+20
- Addresses poverty and sustainable development

2012 — UN Conference on Sustainable Development (Rio+20)
- Addressed economic and environmental goals
- Shape global environmental policy

Key milestones

1.2 Introduction: Urban Water Sustainability

- The scarcity of freshwater resources directly threatens human water security and biodiversity in many rapidly urbanizing areas of the world.
- International Concerns: global climate change, population growth, water shortage, flooding, water pollution and unsustainable water use practices.
- To sustain the continuous development, a water management revolution is necessary to redesign the urban water from a aging centralized infrastructure to a new, self-sustaining urban community.

1.3 Challenge of Urban Water Sustainability

- Wastewater system focus on energy saving and resources recovery:
  - Energy intensive, sewage leakage into the environment due to long distance conveyance.
  - Mixing of grey water and black water adds unnecessary cost of pumping, treatment and difficulties on resources recovery
- Water recycling:
  - Reclaimed water, Sea water, Storm
- Sustainable urban storm-water management.

2. Development of a New Urban Water System

Some New Urban Water System Design and Concerns

2.1 Domestic Onsite source-separation system

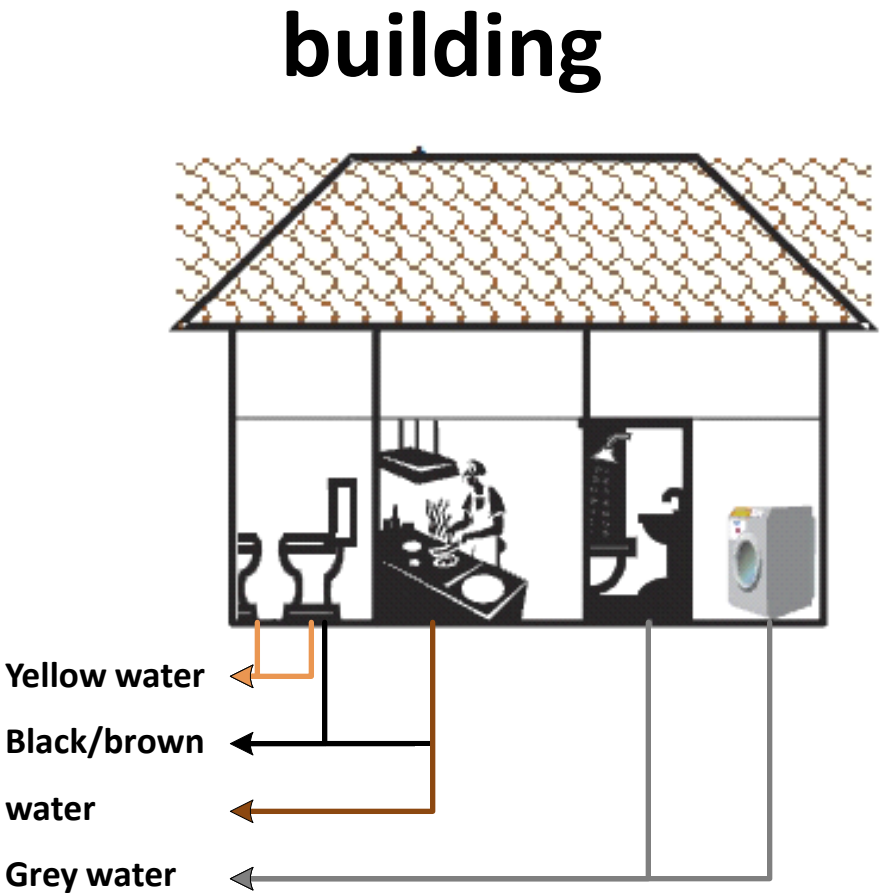
2.2 Sustainable Urban Stormwater Management

2.3 Wastewater recycling

2.4 Basic Water-energy-resource Nexus

2.1 Domestic Onsite source-separation system

- **Separating water at source**
  - Grey water: washing, flushing, bathing wastewater
  - Yellow water: urine wastewater
  - Brown/black water: fecal wastewater
- **Separated treatment units**
  - Grey water: Water reuse
  - Yellow water: Recovery of N, P and K
  - Brown/black water: New energy production

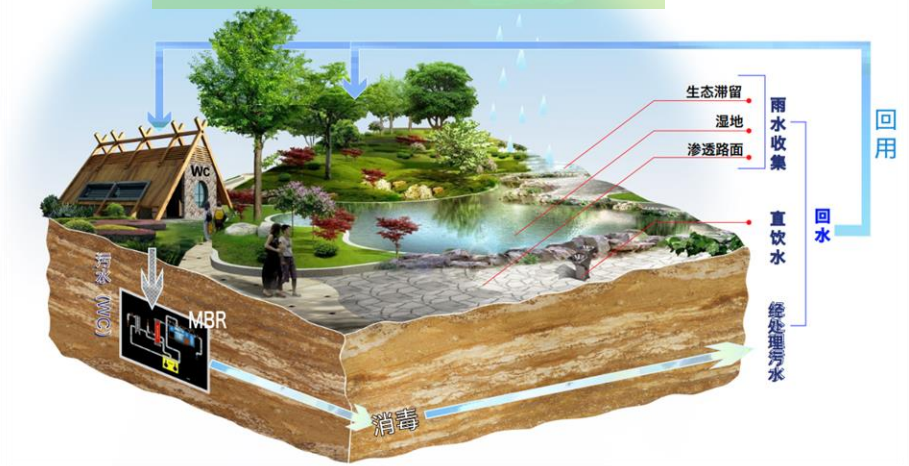


2.2 Sustainable Urban Stormwater Management

Outdoor： Surface runoff (Storm water)

Urban communities

Landscape & Park



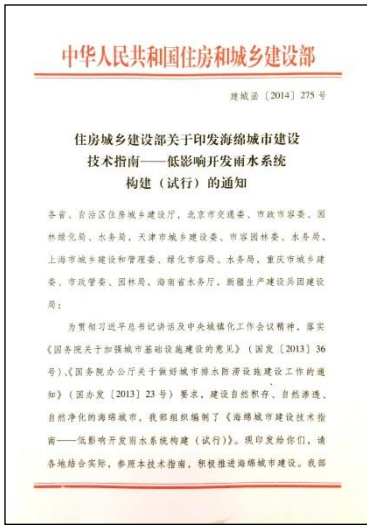
Road & Parking

Sponge city in China!

Natural stormwater retention, permeability and cleansing abilities

Sponge city in China

- Oct. 2014, Ministry of Housing and Urban-Rural Development issued
  - Guidelines for construction technology of Sponge city-The establishment of LID stormwater system



中华人民共和国住房和城乡建设部

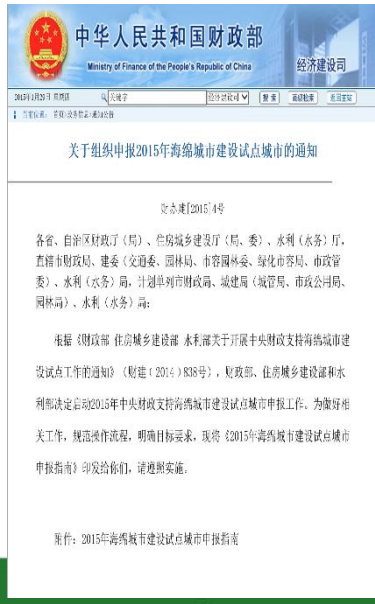
建城函［2014］275号

住房城乡建设部关于印发海绵城市建设技术指南——低影响开发雨水系统构建（试行）的通知

各省、自治区住房城乡建设厅，北京市交通委、市政市容委、园林绿化局、水务局，天津市城乡建设委、市容园林委、水务局，上海市城乡建设和管理委、绿化市容局、水务局，重庆市城乡建委、市政管委、园林局，海南省水务厅，新疆生产建设兵团建设局：

为贯彻习近平总书记讲话及中央城镇化工作会议精神，落实《国务院关于加强城市基础设施建设的意见》（国发［2013］36号）、《国务院办公厅关于做好城市排水防涝设施建设工作的通知》（国办发［2013］23号）要求，建设自然积存、自然渗透、自然净化的海绵城市，我部组织编制了《海绵城市建设技术指南——低影响开发雨水系统构建（试行）》。现印发给你们，请各地结合实际，参照本技术指南，积极推进海绵城市建设。我部

- Dec. 2014, Ministry of Finance and Ministry of Housing and Urban-Rural Development and Ministry of Water Resource jointly launched the pilot sponge city program, around 200 cities applied.
- 2015, 2016 , 30 cites were selected
- Next 3 years, central government would provide between US$48.42 million and 80.7 million annually to each cities



中华人民共和国财政部

Ministry of Finance of the People's Republic of China

经济建设司

关于组织申报2015年海绵城市建设试点城市的通知

财办建[2015]4号

各省、自治区财政厅（局）、住房城乡建设厅（局、委）、水利（水务）厅，直辖市财政局、建委（交通委、园林局、市容园林委、绿化市容局、市政管委）、水利（水务）局，计划单列市财政局、城建局（城管局、市政公用局、园林局）、水利（水务）局：

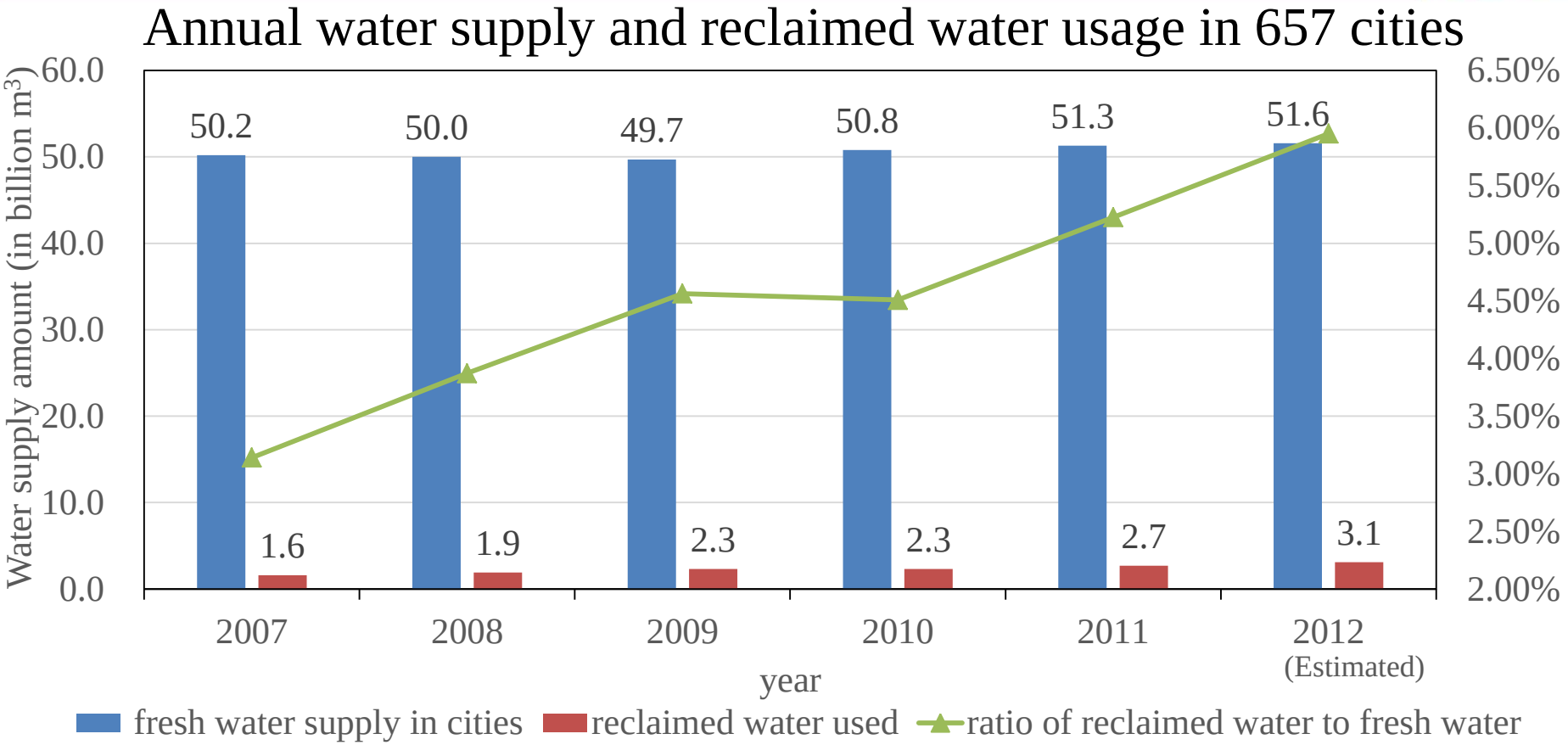
根据《财政部 住房城乡建设部 水利部关于开展中央财政支持海绵城市建设试点工作的通知》（财建［2014］838号），财政部、住房城乡建设部和水利部决定启动2015年中央财政支持海绵城市建设试点城市申报工作。为做好相关工作，规范操作流程，明确目标要求，现将《2015年海绵城市建设试点城市申报指南》印发给你们，请遵照实施。

附件：2015年海绵城市建设试点城市申报指南

Sponge city in China

- International Attractions
  - Sponge City – China's movement toward resilient infrastructure

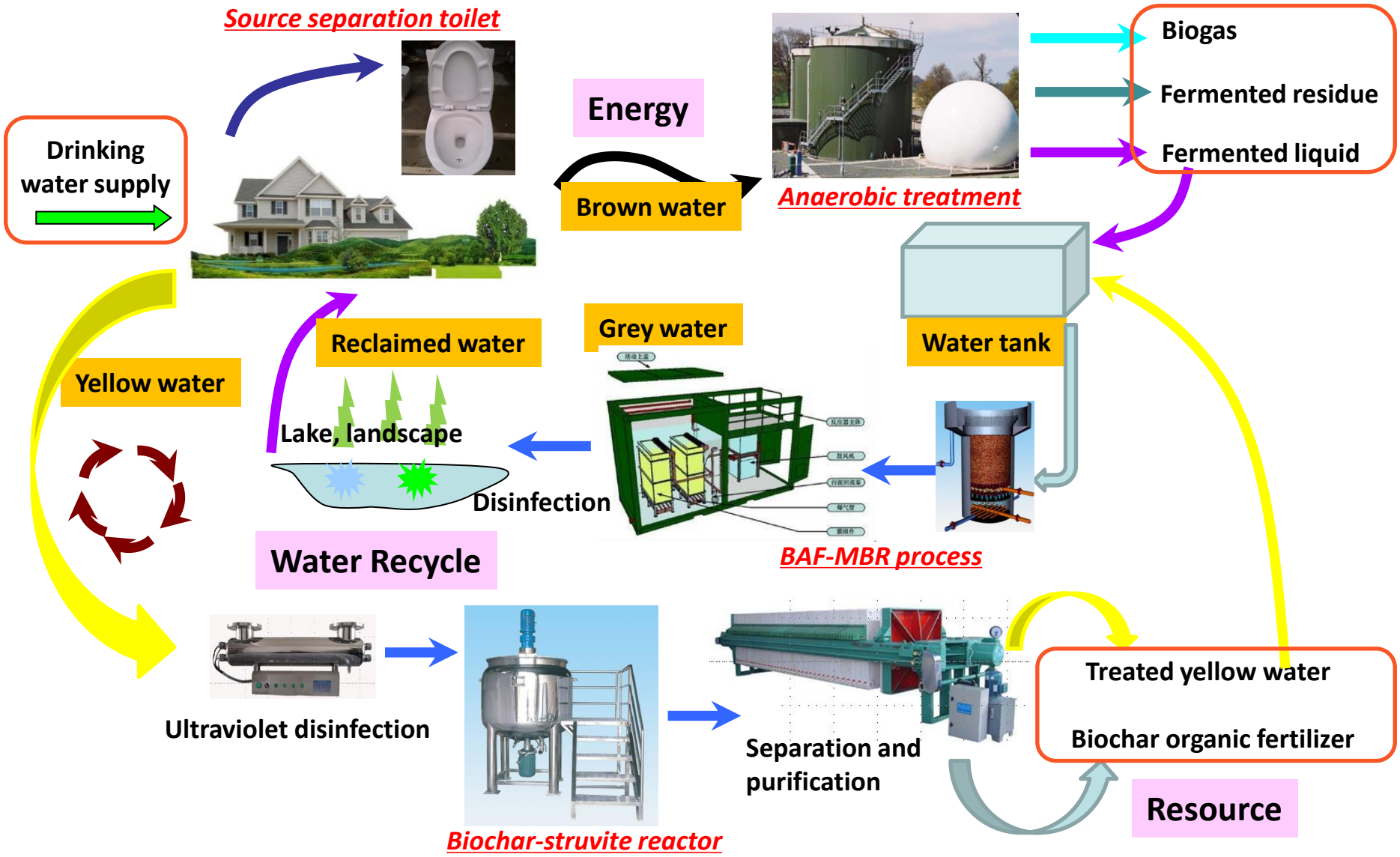
2.3 Wastewater Recycling



2.3 Wastewater Recycling

In addition, large amounts of high quality reclaimed water were used in agriculture, landscaping and for ecological purposes.

2.4 Basic Water-energy-resource Nexus

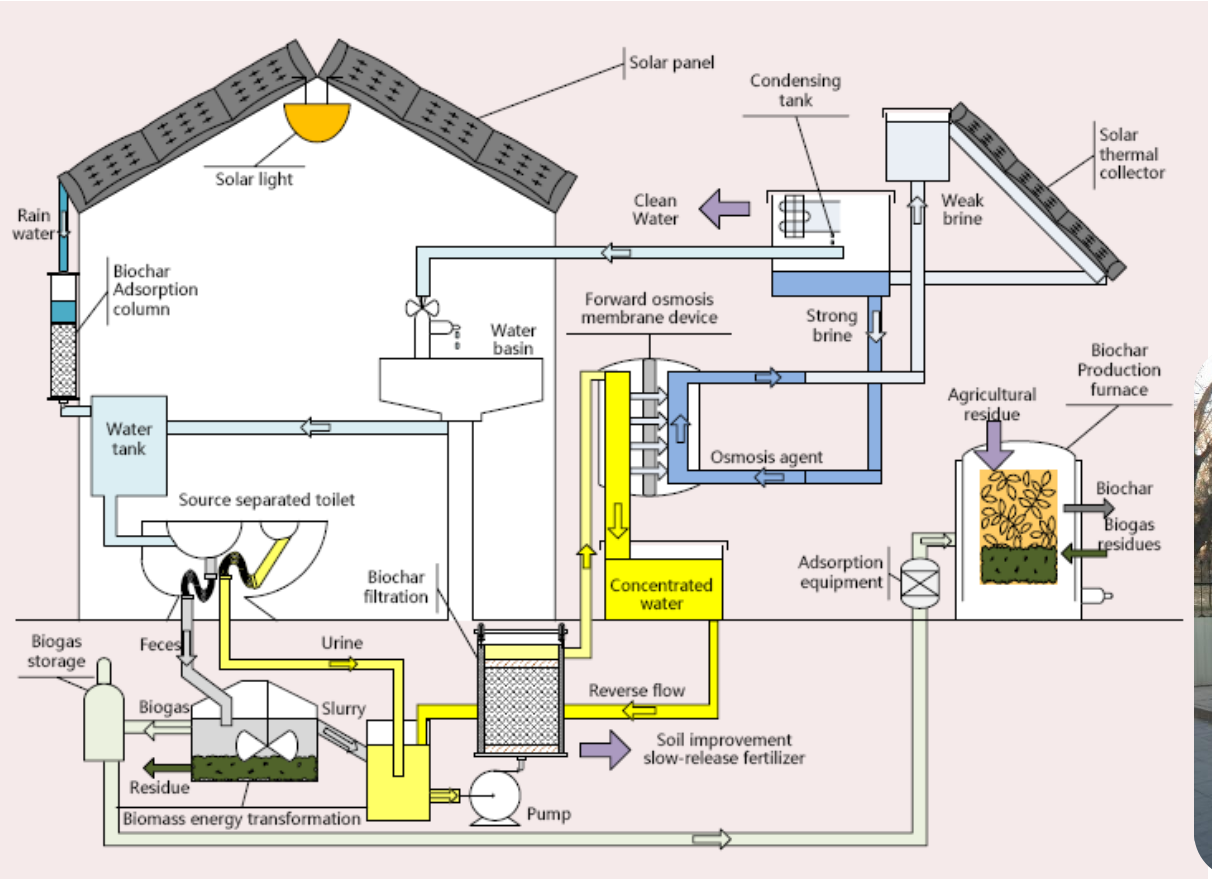


3. Implementation: Case studies

3. Implementation: Case studies

- **For a toilet**: Wastewater treatment and resource system (Tsinghua University, Beijing)
- **For a building**: Vacuum and source-separation system (Tsinghua University, Beijing)
- **For an Sponge campus:** Urban Stormwater Runoff BMPs Planning (Foshan)
- **For a modern urban community:** A closed scenic urban water system by treated stormwater using LID BMPs technology in a historical revitalization district (Suzhou)
- **For a City**: Reclaimed water utilization (Beijing)

3.1 A new toilet system



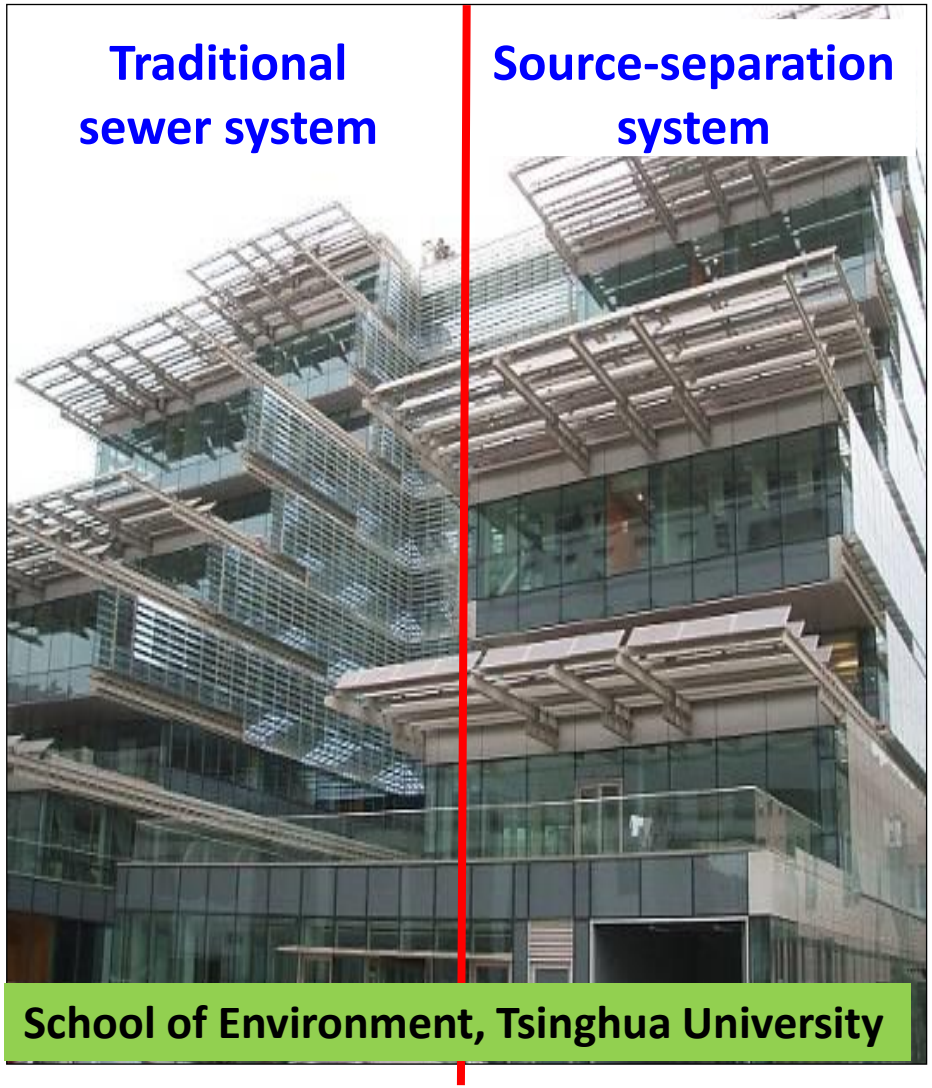
Based on a source-separation toilet system separating faeces and urine at source, this project aims to research and develop combination processes of biochar adsorption and forward osmosis concentration for treating toilet wastewater to produce eco-fertilizer and clean water.

3.1 A new toilet system

Source separated toilet

Inside: Waste separated toilet and men's urinals, washbasins

3.2 A source-separation Building



Separating toilets

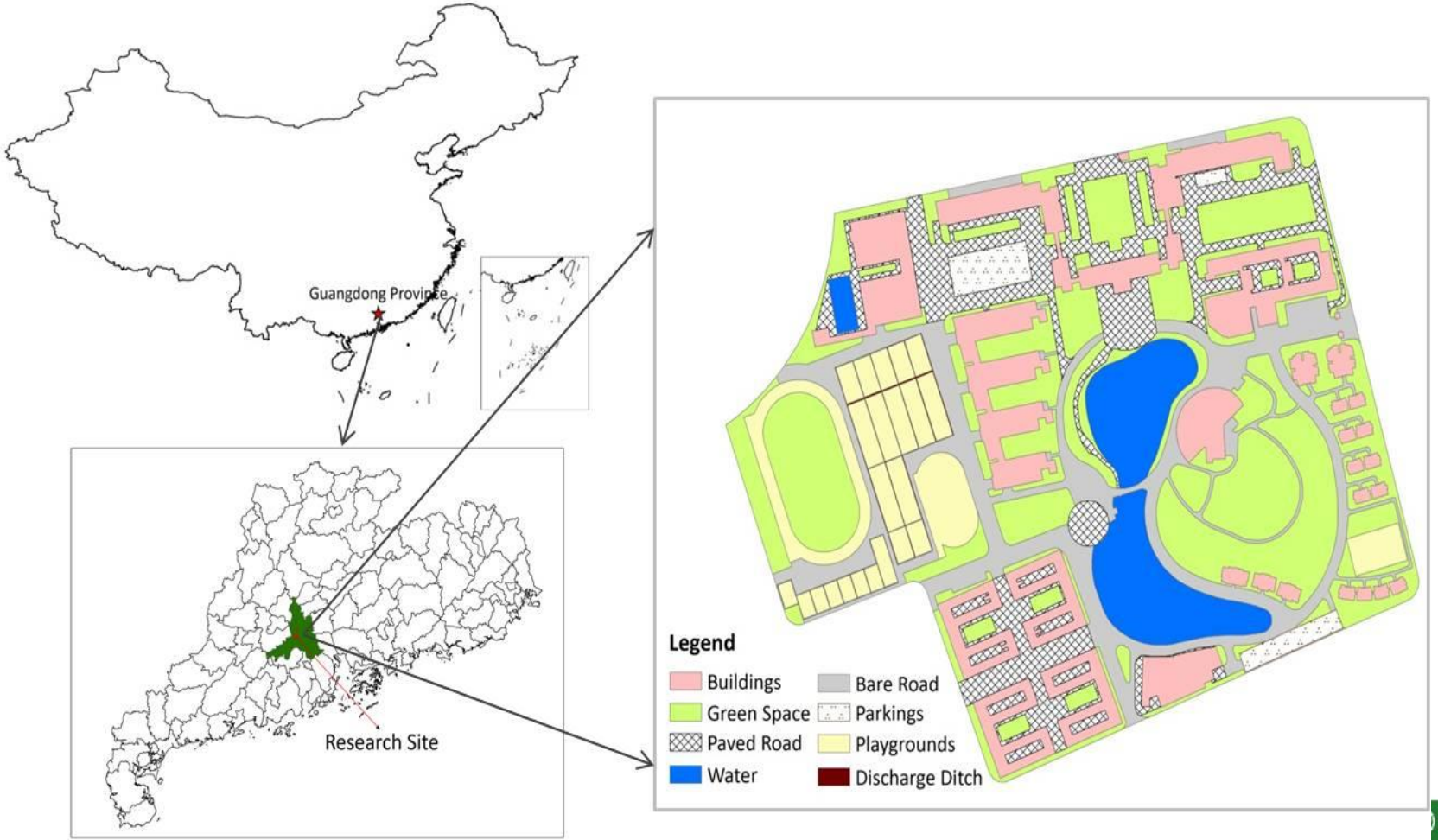
Storage tanks

Urine-diverting toilet

- Urine is collected separately through yellow water pipes, and then enters temporary storage tanks for 3~5 days.
- Both of the brown water and grey water are collected together into septic tank.

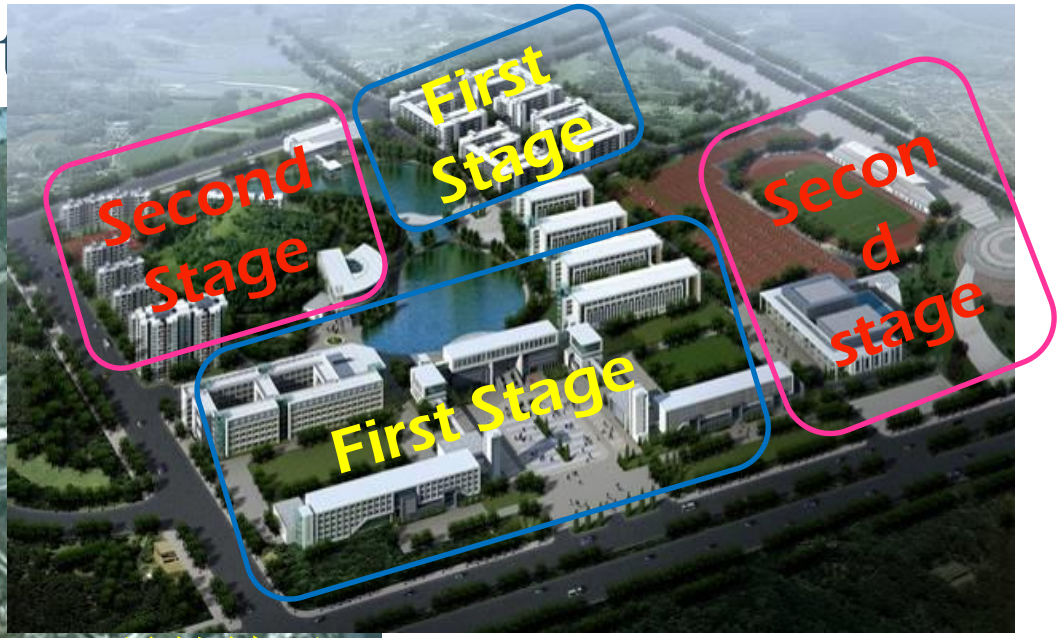
3.3 Urban Stormwater Runoff BMPs Planning

- Guangdong College of Environment Protection: New campus in Foshan city



Site Information

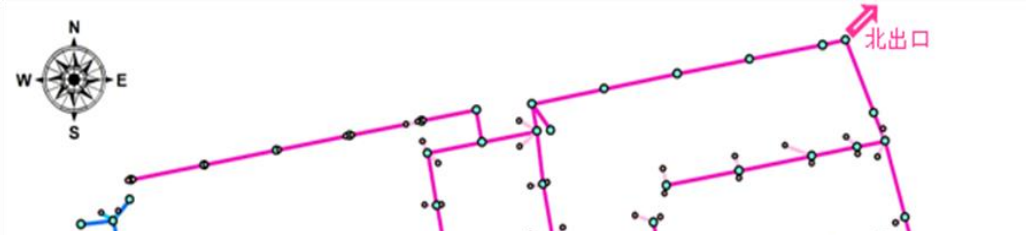
- New campus of Guangdong College of Environment Prot

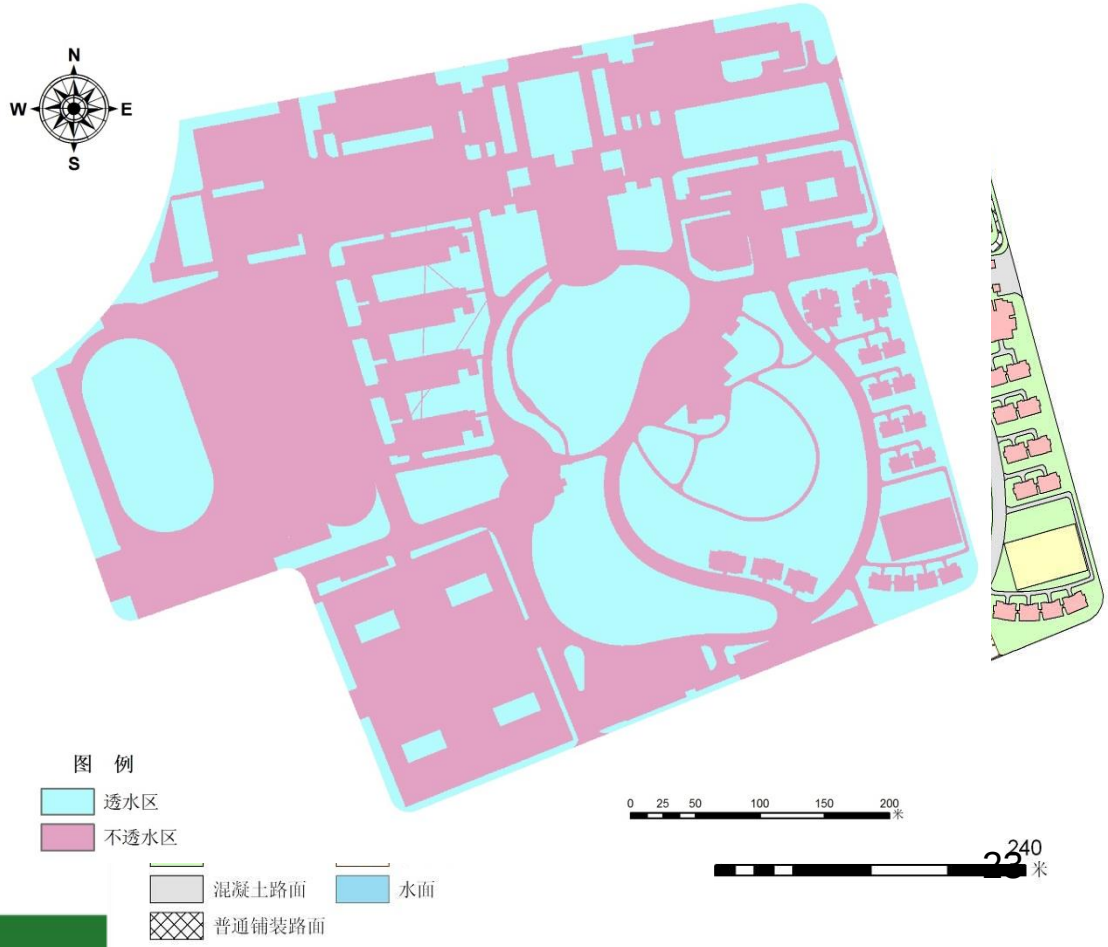


Yellow: constructed
Red: under construction

Data collection and analysis

- Climate
  - Subtropical monsoon climate, Plenty of sunshine
  - Annual average temperatur 22-23℃,
  - Annual rainfall: 1622mm
- Rainfall in Typica year
- Topography
- Land use
- Drainage system
- Soil characteristics





Watershed Delineation

Preliminary selection of suitable LID- BMPs

BMPs	Landuse and Location			Soil	Groundwater	Topography	Watershed characteristics		Space
	Landuse type	Pollution load intensity	Special requirement	type	Groundwater level to bottom of BMPs facility	Slope (%)	Service areas (hm)	Ratio of impervious areas (%)	occupied (hm)
Infiltration Trench	R,C,S,T,G	medium	Building buffer distance >3m Stream buffer distance >30m	A-B	>3	<15	<2	>0	medium
Infiltration Basin	R,C,S,G	medium	Stream buffer distance >30m	A-B	>3	<15	1-4	>0	Large
Dry Detention Pond	R,C,S,G	medium	Higher topography Stream buffer distance >30m	A-D	>1.22	<10	>4	>0	large
Wet Detention Pond	R,C,S,G	medium	Stream buffer distance >30m	A-D	>1.22	<10	>6	>0	large
Vegetated Filter Strip	R,C,S,M,T,G	high	Around Impervious surface Road buffer distance <30m	A-D	>0.61	<5	-	>0	medium
Grassed Swale	R,C,S,T,G	medium	Around Impervious surface Road buffer distance <30m	A-D	>0.61	0.5-5	<2	>0	medium
Constructed Wetland	R,C,G	medium	Stream buffer distance >30m	B-D	>1.22	4-15	>10	>0	large
Sand Filter	R,C,M,T	medium	Stream buffer distance >30m	A-D	>0.61	<10	<40	0-50	small
Green Roof	R,C,M	low	Flat roof	-	-	<4	-	-	-
Rain Barrel	R,C	low	Building buffer distance	-	-	-	-	-	small

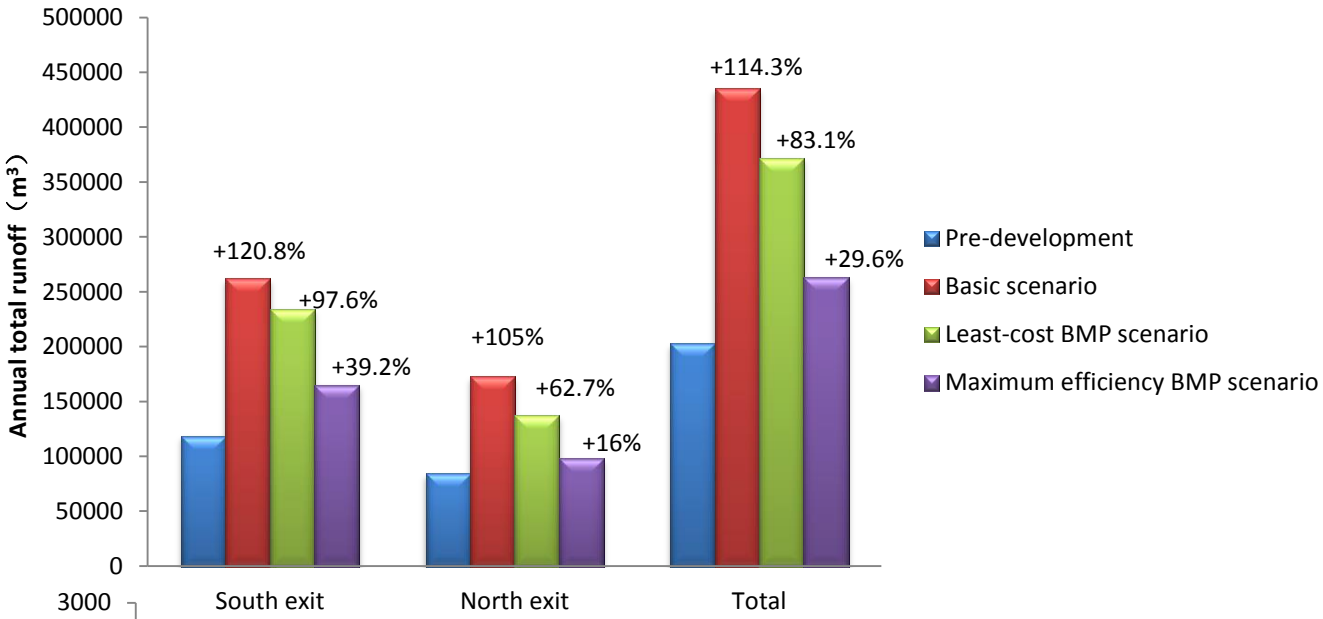
Basic scenario: the previous development scheme

- Drainage System simplification
  - Reclassification of Landcover : Roof; Road; Grass; water
- Basic scenario
  - Water Quantity simul
    - Total runoff
    - Peak flow
  - Water Quality simula
    - COD
    - SS
    - TN
    - TP

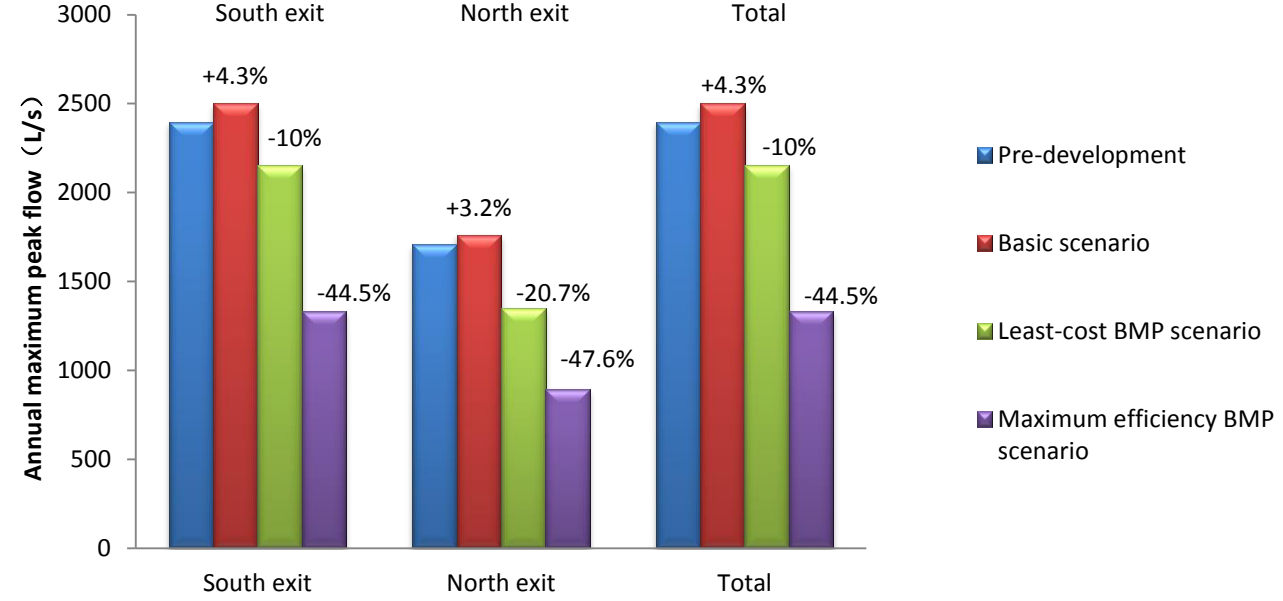
LID-BMPs Scenarios Design

Scenario: The least-cost scenario Maximum

LID-BMPs Scenarios Simulation

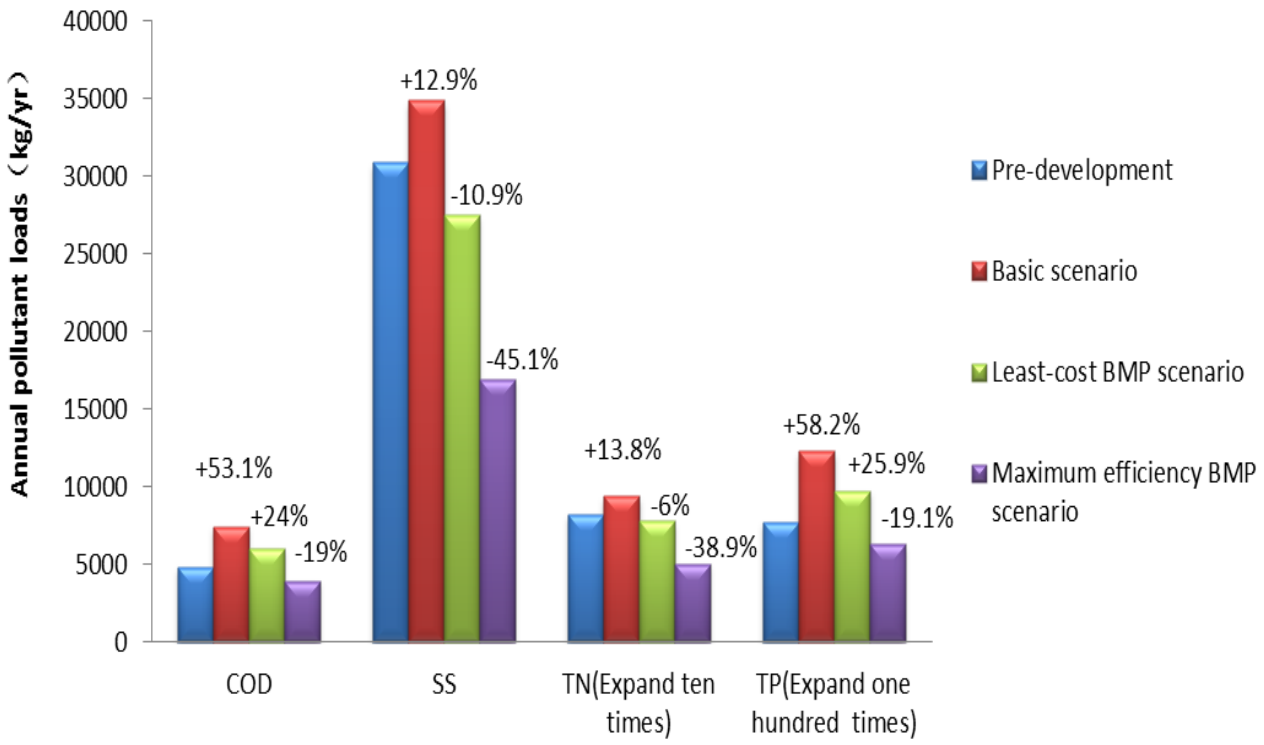


Total runoff



Peak flow

LID-BMPs Scenarios Simulation



Pollutants removal

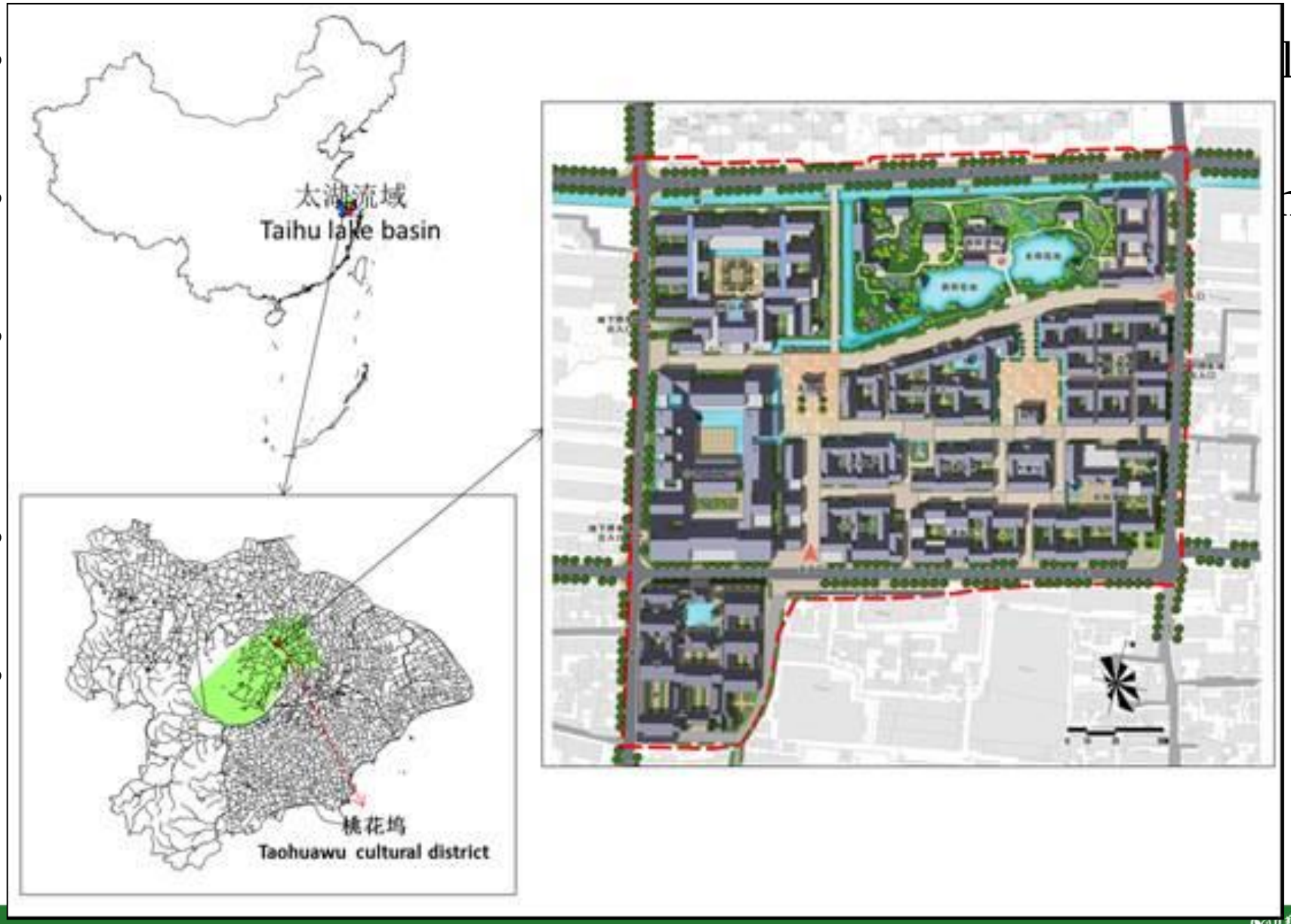
3.4 For a modern urban community

A closed scenic urban water system by treated stormwater using LID BMPs technology in a historical revitalization district

Background

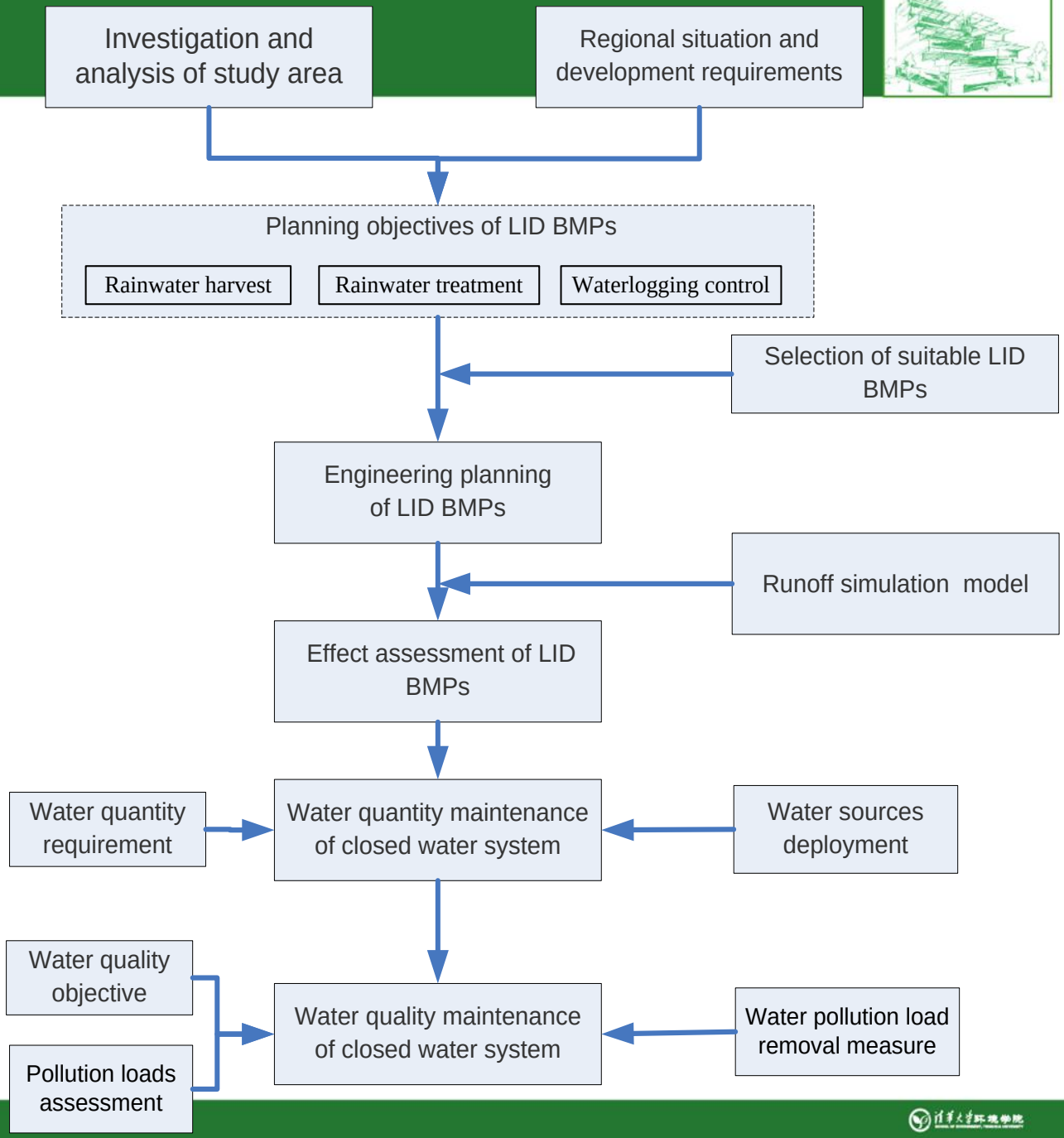
- Along with the rapid urbanization, many cities have faced serious urban water system problems:
  - water area was decreased
  - river was truncated
- Numbers of blocked off river and closed water system became more and more, which has weak self-purification ability and degraded ecosystem
- How to incorporate the LID strategy in the new urban development or old urban revitalization has been the focus.

Background



Background

The roadmap of research



Planning Objectives

- The primary objective of the LID BMPs planning is to
  - select the suitable LID BMPs according to the local condition, and then
  - draft the integrated LID BMPs scheme to harvest and treat the local runoff to serve as the water sources for Taohuawu closed water system.

- Meanwhile, considering the increasing of storm disasters in recent years, the secondary objective is to reduce waterlogging disasters in Taohuawu by LID BMPs facilities.

LID BMPs selection and planning scheme

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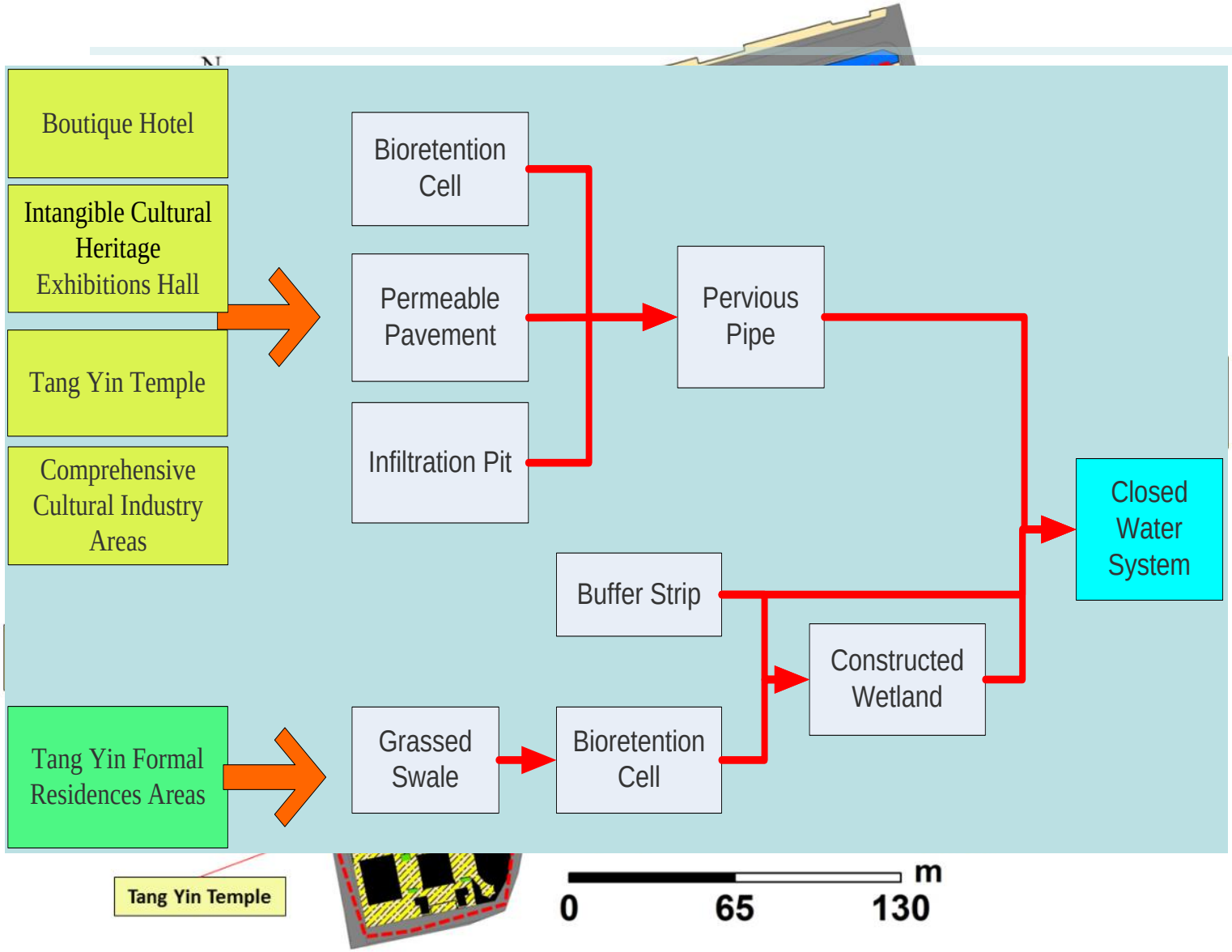
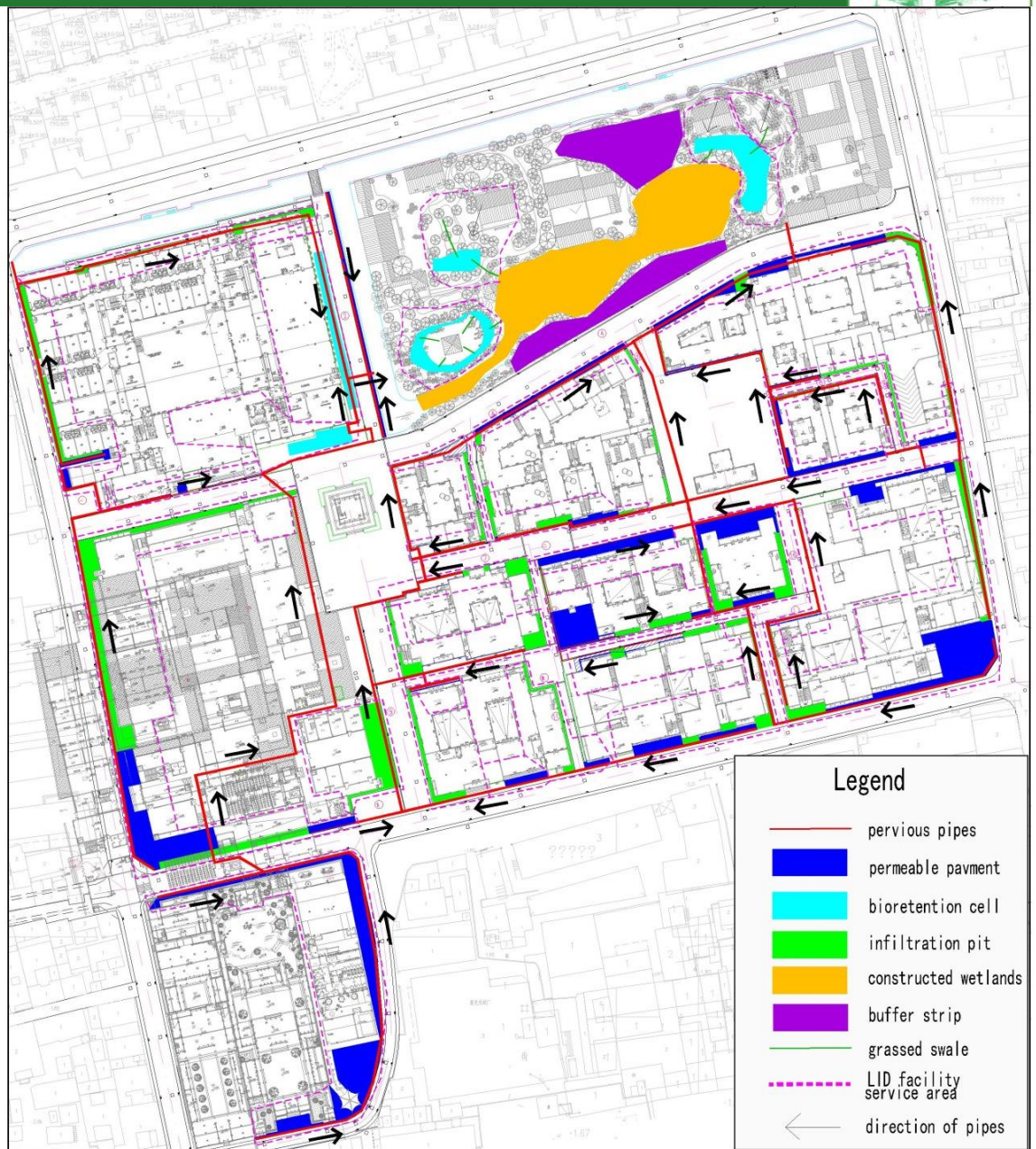


LID BMPs selection and planning scheme

Stormwater runoff from most areas would be collected and treated.

- The total area of LID facilities in Taohuawu are 3303 m^2, 4.8% of the whole:
  - constructed wetland 1718 m^2,
  - bioretention cell 337 m^2
  - permeable pavement 300 m^2
  - grassed swale 445 m^2
  - infilitration pit 288 m^2
  - buffer strip is 215 m^2



Water quantity maintenance

- The development of runoff simulation model
  - EPA-SWMM based Taohuawu urban runoff simulation model was developed
- Effect assessment on rainwater harvest
  - a typical Suzhou average year (2005) data
  - total annual rainfall is 45,346 m^3

	Scenario 1 (m^3)	Scenario 2 (m^3)	Change ratio （%）
Runoff could be used	0	7598	/
Runoff could not be used	29700	17877	-39.81
Infiltration	10021	14316	42.86
Evaporation of river and lake	5555	5555	0
Total	45346	45346	0

Water quantity maintenance

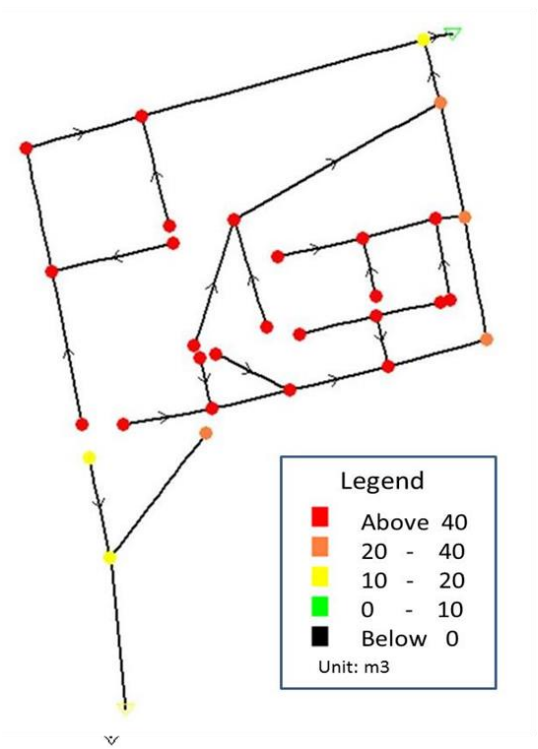
- **Water quantity requirement**
  - It includes the water replenishment for evaporation, leakage and the water consumption by on-site filtration equipment.
  - According to the local conditions, the water requirement are calculated. The annual total is about 21,802 m^3. The monthly demand is between 1,540 – 2,038 m^3.
- **Water sources deployment**
  - types of water: harvest rain water, groundwater.
  - Harvested rainwater priority.
  - Due to seasonal variation, local groundwater is used as the supplemented to guarantee the water quantity requirement

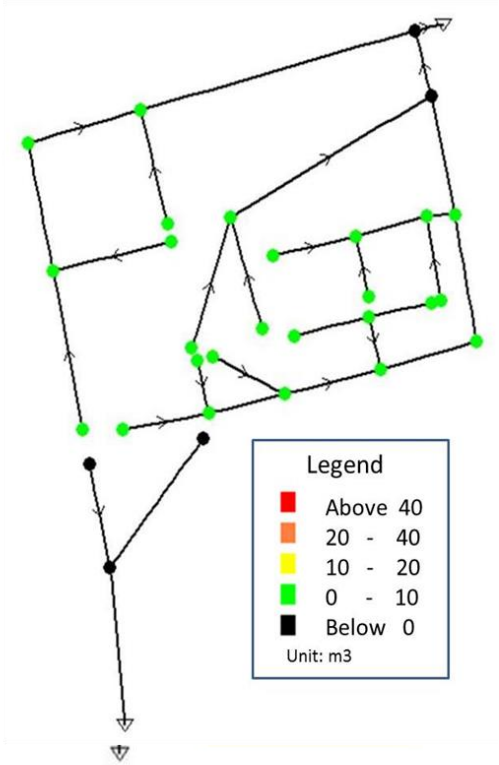
Water quantity maintenance

- it could be found that
  - In wet season, rainwater could be the main source, and the maximum monthly groundwater water requirement is 914 m^3.
  - In dry season, groundwater is the only water sources. The maximum monthly groundwater water requirement is 1855 m^3.
  - The total annual water requirement is 21,802 m^3, in which, 7,598 m^3 by harvested rainwater, 14,204 m^3 by groundwater.
  - the amount of infiltration by LID BMPs facilities is 14,316 m^3. It could be considered that the closed water system could maintain water quantity by itself.

Water quantity maintenance

- **Effect assessment on flood control**
- flooding would not occur in the stormwater with 5 years recurrence interval in scenario 2.
- Even in the stormwater with 20 years recurrence interval, the flooding situation is not serious in scenario 2





Scenario 1 with 20 years recurrence interval	Scenario 2 with 20 years recurrence interval

Water quality maintenance

- **Water quality objectives**
  - Based on the comprehensive analysis of beneficial use and the ecological function of the closed water system, Class V in GB3838-2002 is chosen as the water quality objectives.
  - NH_3-N, TN and TP are selected as the main concerned water quality indicator

Indicator	DO≥	CODMn ≤	CODCr ≤	BOD_5≤	NH_3-N≤	TP≤	TN≤
Values	3	10	30	6	1.5	0.3	1.5

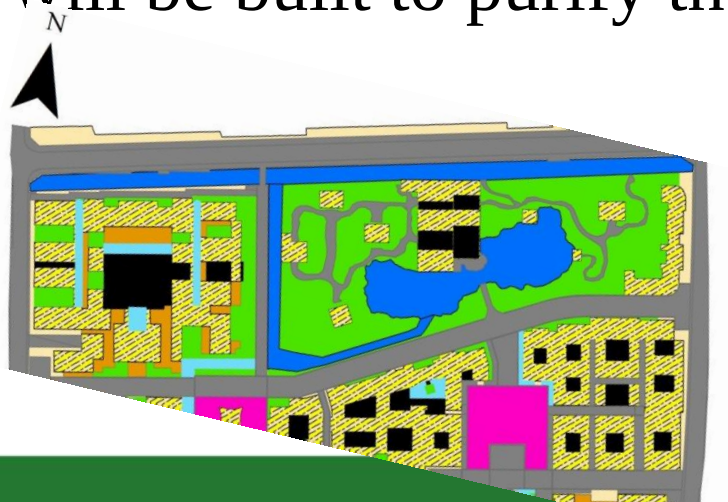
Water quality maintenance

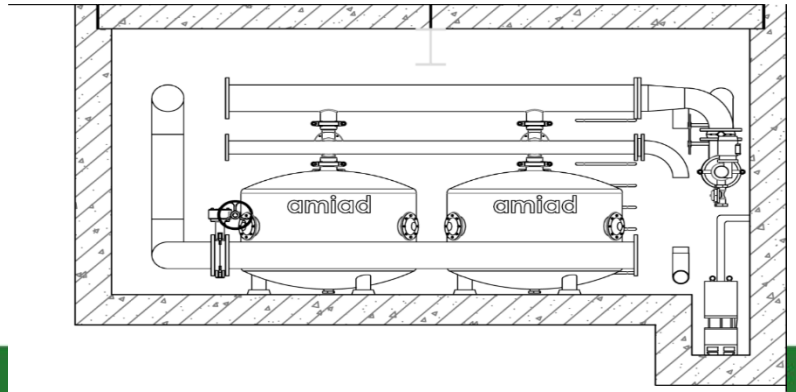
- **Pollution loads assessment and the required pollution loads removal rate**
  - All the loads are from diffuse pollutants.
  - Export Coefficient Model is used.
  - pollution removal rate is about 60%.

Underlying surface	Areas proportion	TP (mg/L）	TN (mg/L）	NH_3-N (mg/L）
Road	31.15%	0.28	5.10	3.00
Green space	12.70%	0.20	4.00	1.80
Yard	9.90%	0.28	4.90	2.70
Piazza	6.76%	0.28	4.90	2.70
Building	39.50%	0.22	4.50	2.10
The aggregated water quality of runoff		0.25	4.69	2.44
Water quality objectives		0.40	2.00	2.00
Pollution processing degree		0.00	57.4%	18.1%

Water quality maintenance

- **Water pollution load removal measure and water quality maintenances**
  - LID BMPs facilities are used as the first step to reduce the pollution loads, reduce about 35-50% of the pollutants by model assessment.
  - Then, integrated with the hydraulic optimization, a continuous on-site river water filtration equipment will be built to purify the urban water





Water quality maintenance

- Hydraulic optimization
  - 1.5KW flow-pushing device with 360 m^3/h.
- Ecological river
  - Floating islands
  - Ecological bank

3.5 For a City: Reclaimed water utilization in Beijing

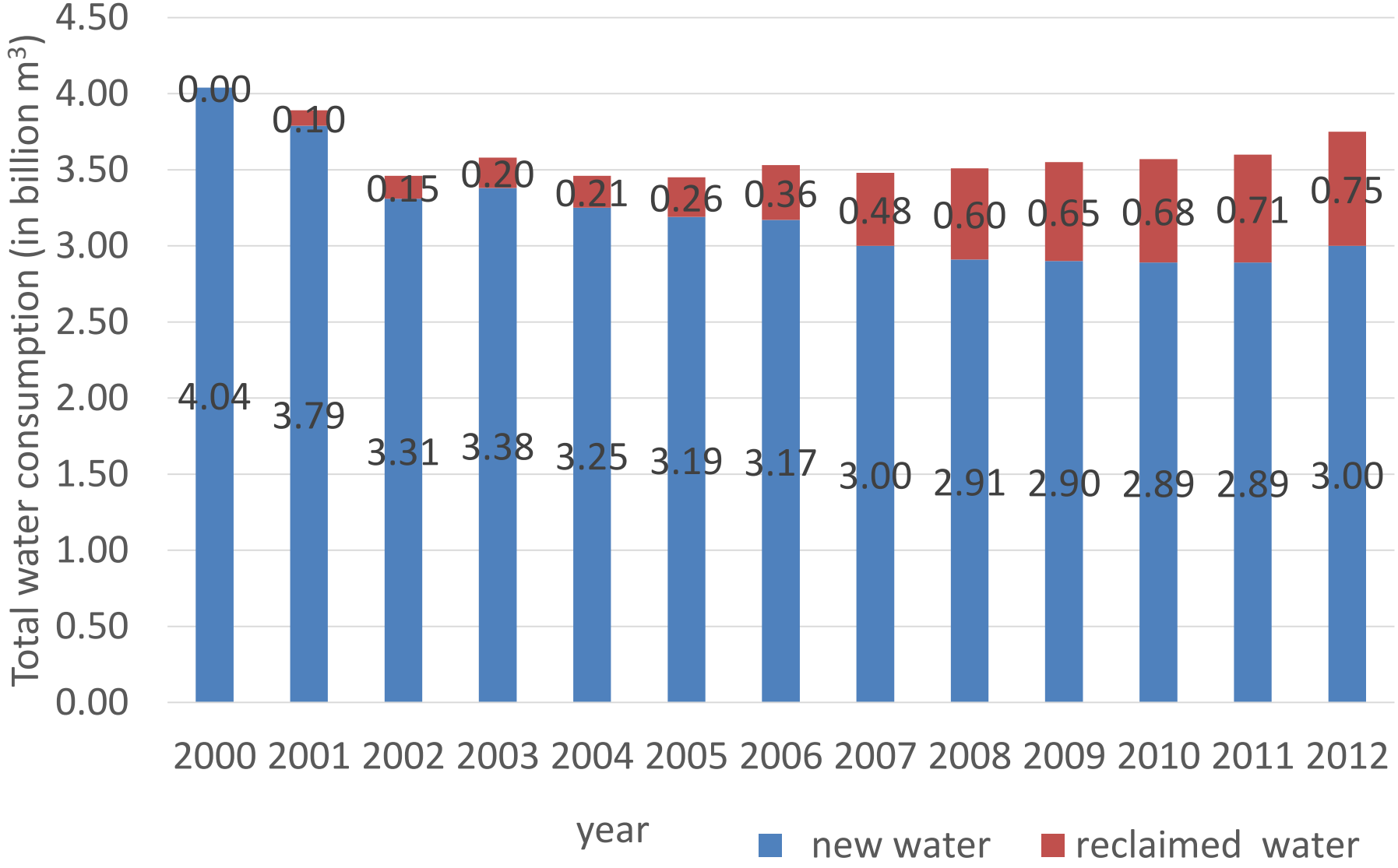
Beijing highly values the importance of reclaimed water.

Reclaimed water was taken into consideration when balancing the allocation of water resources, which simultaneously resulted in relief in the water resources crisis and in the reduction of pollutants discharge.

In 2012, reclaimed water usage in Beijing was 750 million m^3, which was nearly 60% of the total wastewater treated and accounted for 20% of all the water consumed (including agriculture).

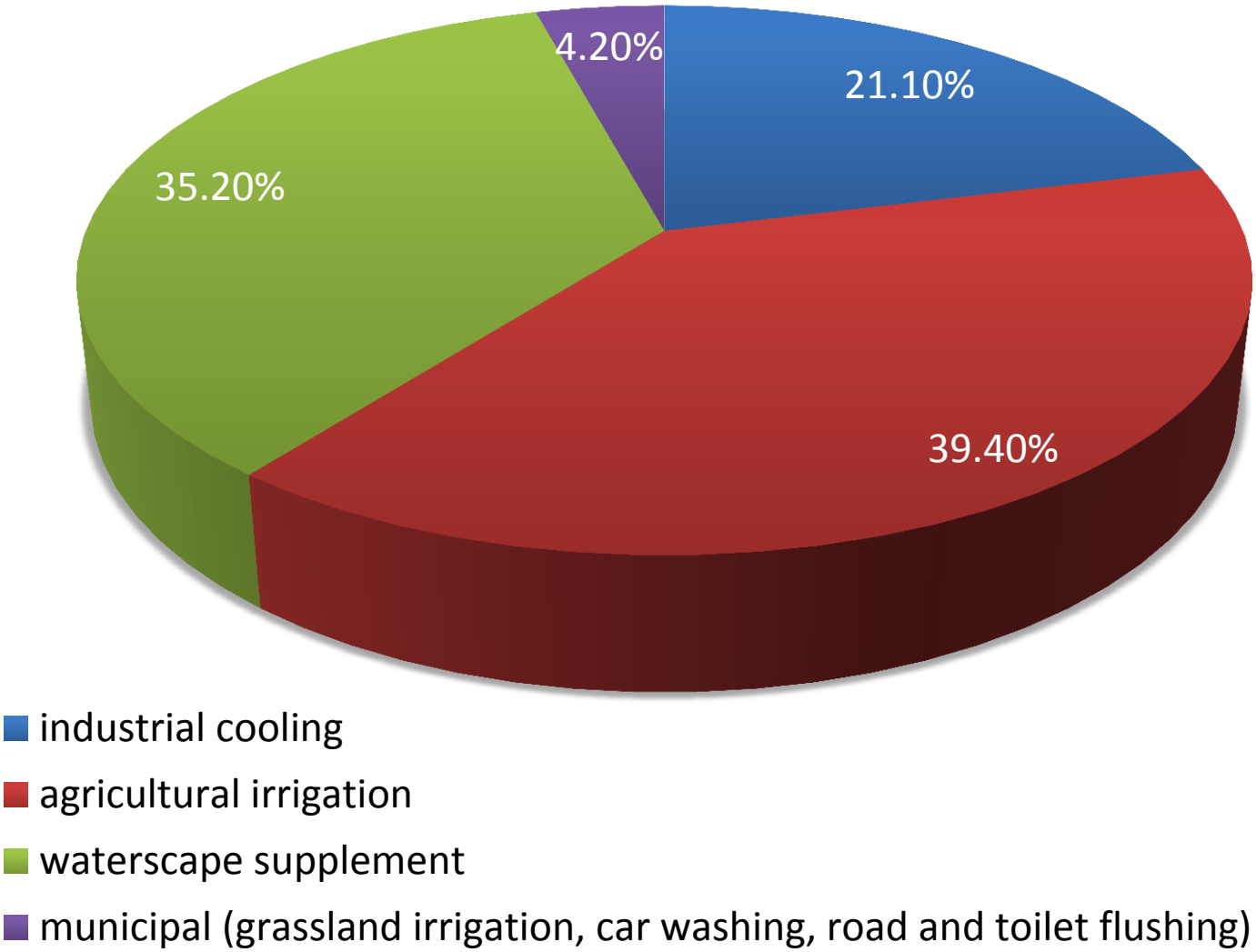
Reclaimed water in Beijing

Structure of total water consumption in Beijing in 2000-2012(including agriculture)



Reclaimed water in Beijing

Reclaimed water usage in different sectors in Beijing in 2011



Reclaimed Water Plants in Beijing

Qinghe Reclaimed Water Plant in Beijing, largest using Membrane (500,000m3/d)

Beixiaohe Reclaimed Water Plant in Beijing, using RO

Reclaimed Water Usage in Beijing

Grassland Irrigation

Agricultural Irrigation

Road Flushing

Reclaimed Water Filling Auto-service Station in Beijing

Reclaimed Water Usage in Beijing

Huaneng Power Plant using reclaimed water for cooling

The Birds Nest using reclaimed water for landscape

Yuanmingyuan Park using reclaimed water for landscaping

Beitucheng River using reclaimed water as a supplement

Thank you for your attention !!!

Questions and Comments ??

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