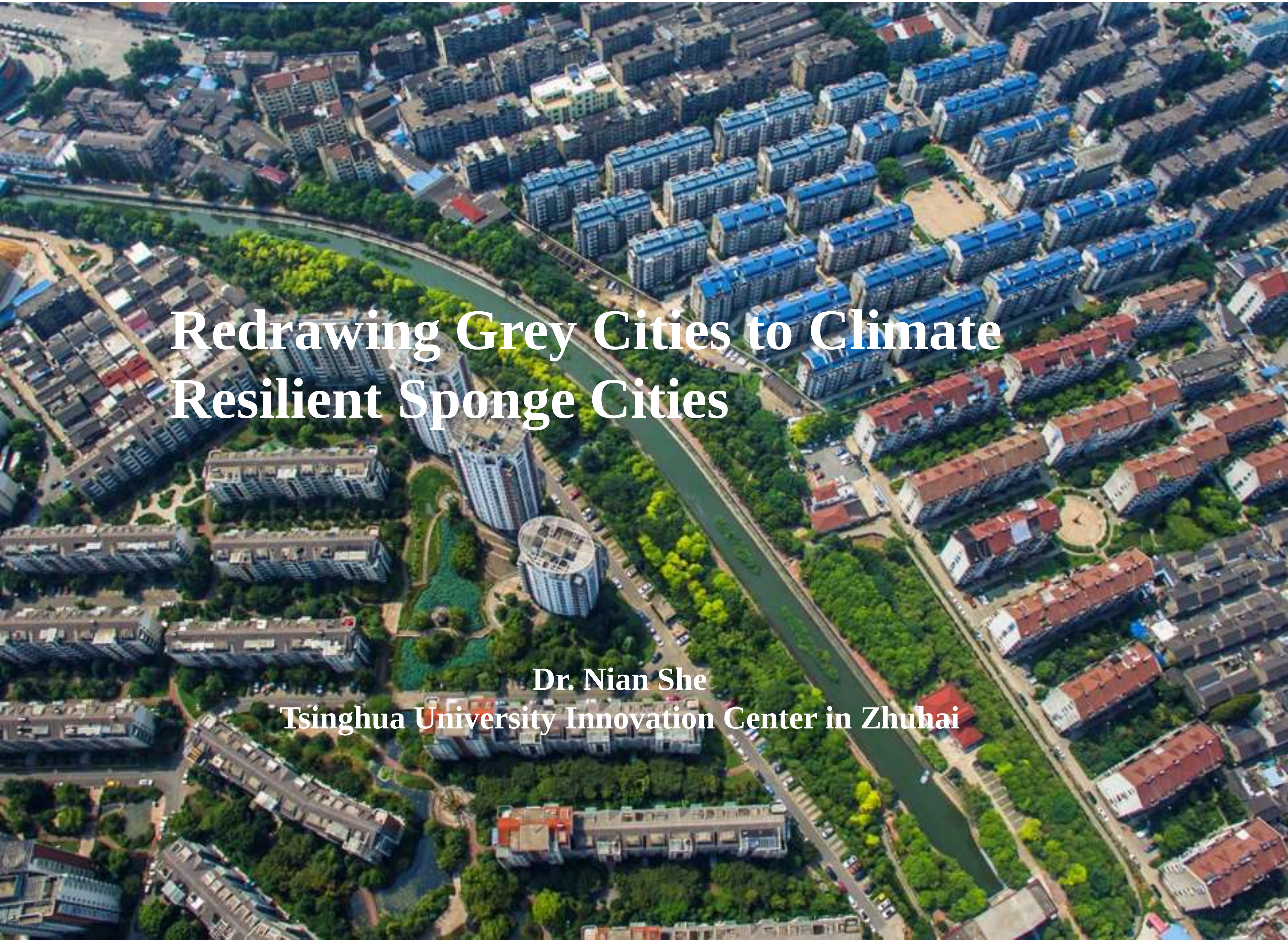


Redrawing Grey Cities to Climate Resilient Sponge Cities

Dr. Nian She
Tsinghua University Innovation Center in Zhuhai

Rapid Urbanization in China

Forest of Concrete

“BBQ” Square in Jieyang, Guangdong


landscape only for Aesthetics

Dalian City Square

Concrete River

Senseless aesthetics

Landscape in Northern China (Precipitation 450-550mm/yr)

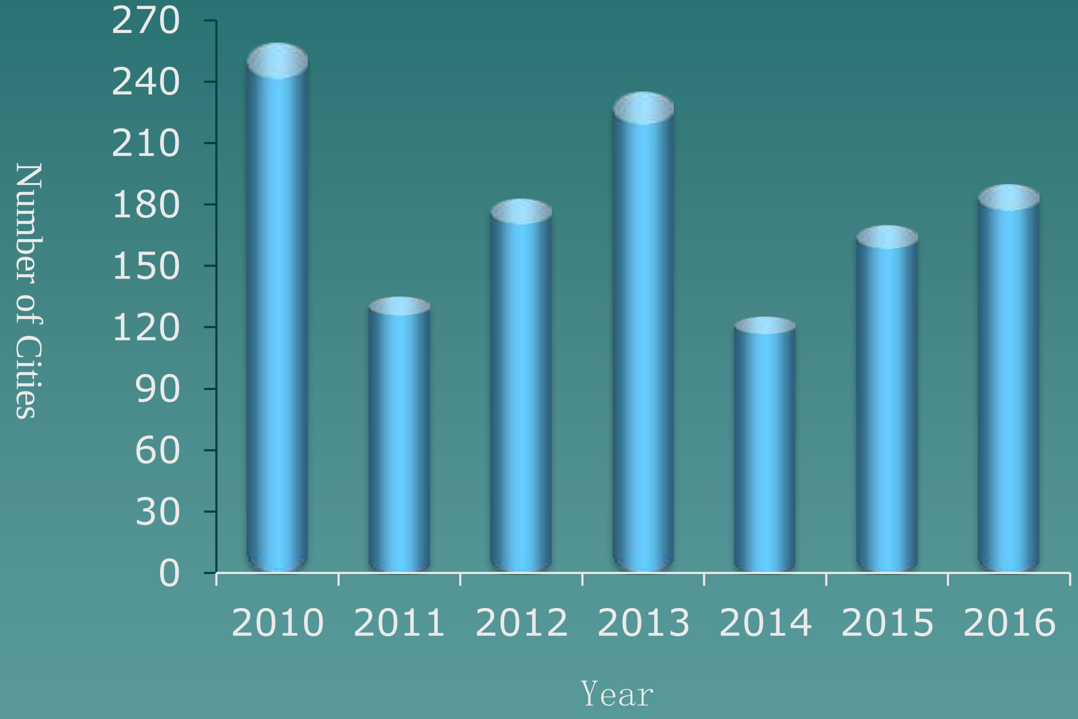

Where are These Native species?

In 1980s This Blvd Becomes a Model for Many Chinese Cities

Don’t Understand Why the Landscape Architects Designed the Road in such a Way

The Consequences 7/21/2012 Beijing

Number of cities suffering from flooding threats in China from 2010 - 2016



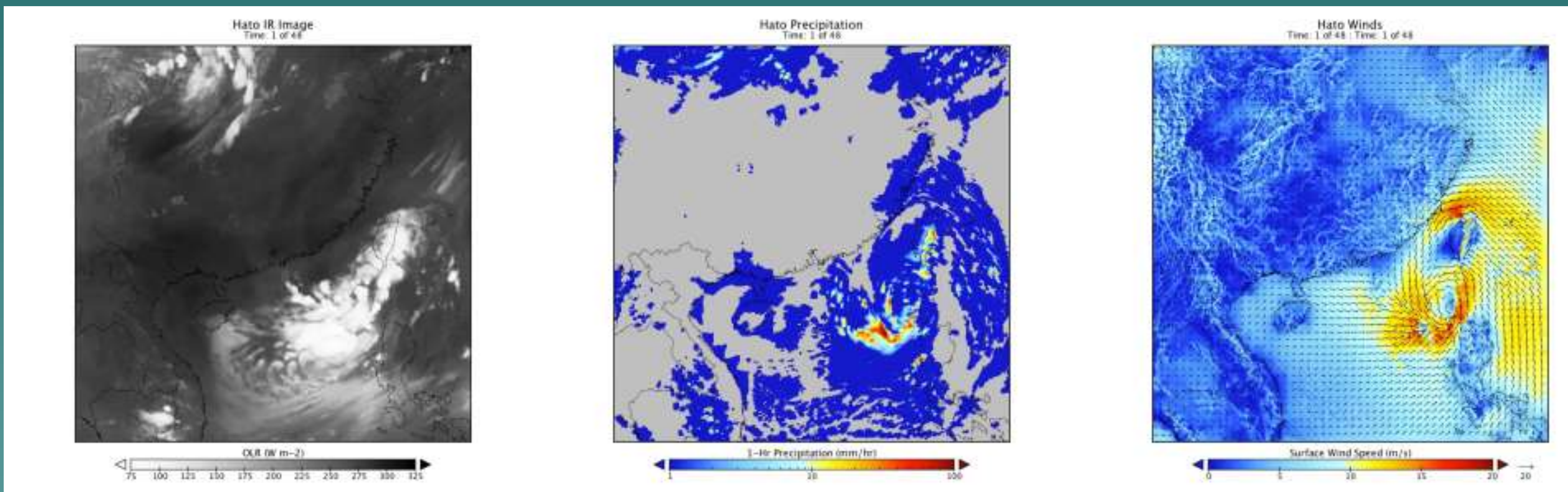
Eutrophication of Lakes

Clear Evidence of Climate Change in Macau

WRF Model Typhoon Hato

Simulation with WRF model at 4-km Grid Spacing and ERA-Interim boundary conditions

August 22-23 2017, one-hour time step



How to Solve These Problems

Flooding
Water Pollution
Extreme Weather Caused by Climate Change
Aesthetic Perception





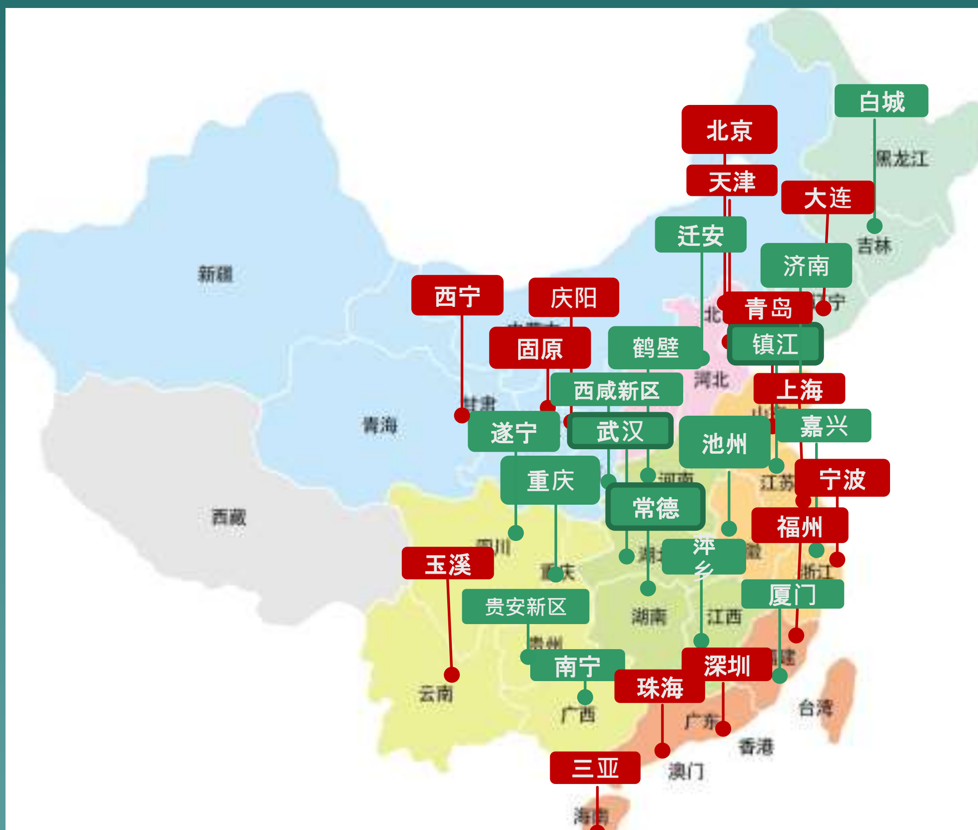

Sponge City

The Sponge City is referred to sustainable urban development including flood control, water conservation, water quality improvement, natural ecosystem protection, and water resources utilization. It also makes cities more resilient to climate change.

Today's Concrete Forest

Functioning like Forest

30 Pilot Sponge Cities Chosen by the Central Government (2015 – 2016)



- **First（16 Cities） （2015）**
  Qianan, Baicheng, Zhenjiang, Jiaxing, Chizhou, Xiamen, Pingxiang, Jinan, Hebi, Wuhan, Changde, Nanning, Chongqin, Suining, Guian New District and Xixian New District
- **Second（14 Cities） （2016）**
  Fuzhou, Zhuhai, Ningbo, Yuxi, Dalian, Shenzhen, Shanghai, Qinyang, Xining, Sanya, Qingdao, Guyuan, Tianjin, Beijing

Sponge City Construction

- By year 2020, 20% developed urban area must be retrofit to meet the sponge city target
- By year 2030, 80% developed urban area must be retrofit to meet the sponge city target
- The construction cost is about \$15-22.5 million USD/km^2
- The total investment is estimated about \$0.9 trillion USD

Source: Economic Information Daily

Investment of Pilot Sponge Cities

- Wuhan: \$2.44 billion
- Chongqing：\$1.05 billion
- Nanning：\$1.3 billion
- Zhenjiang: \$1.2 billion
- Jinan: \$1.17 billion
- Jiaxing: \$0.34 billion
- Among the first 16 pilot cities, the total area is 450 km^2
- The investment is about \$12.97 billion with 3 years, \$3.6 billion come from the central government.

Where does the money come from

- Central and provincial governments fund part of the construction cost as incentive to these
- Public-Private Partnership
  - Private sectors provide initial fund for the constructions
  - Governments will purchase the services to pay for part of the cost
  - Pay-for-performance
  - Pay for the operations and maintenances
- Sponge City Construction Industry Alliance
  - System design
  - Investment and finance
  - Implementation
  - Innovation
  - Products/Production

ZHENJIANG SPONGE CITY

Project Overview

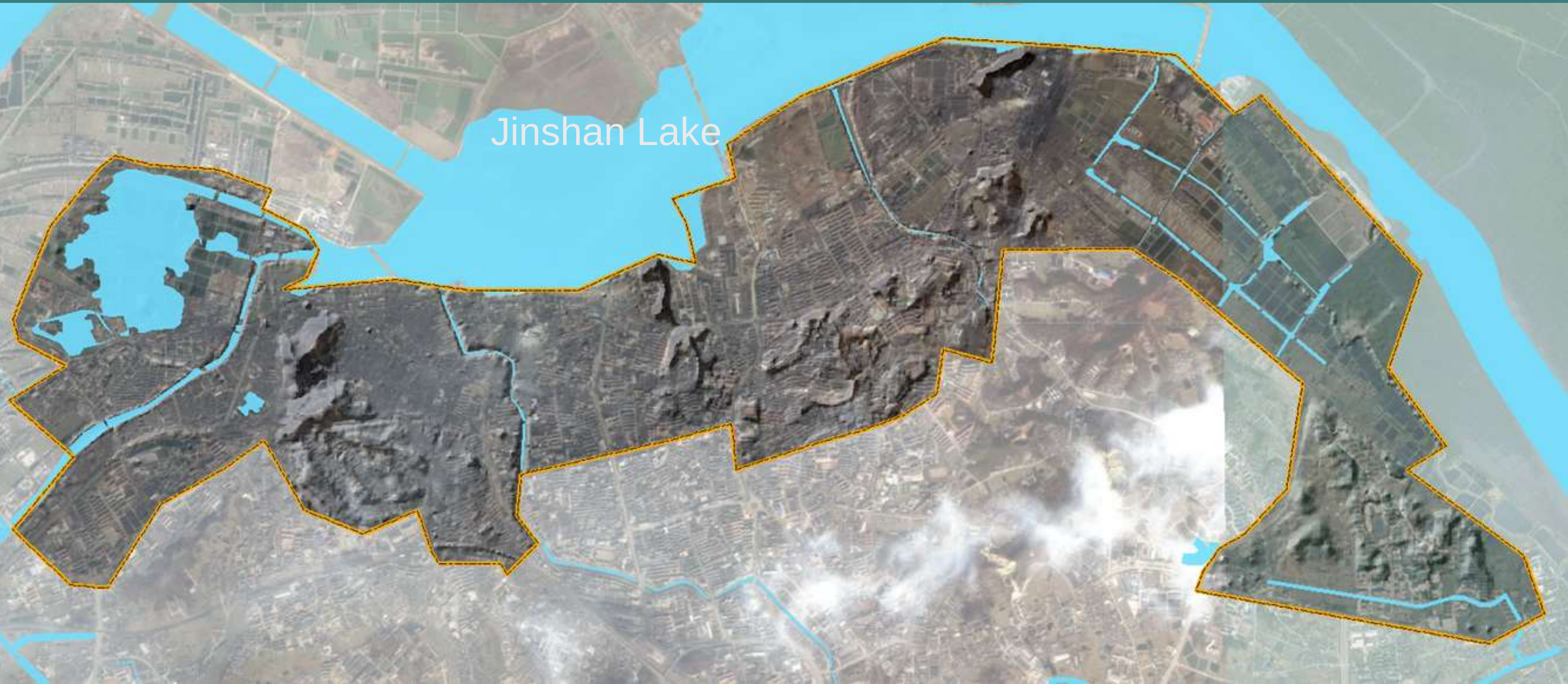
Project Scope: Assess and plan stormwater management retrofits for 22 km^2 of watersheds within the City of Zhenjiang

Project Goals:

- Convey 30-year storm event (with no city water-logging)
- Improve Water Quality of Receiving Water to Chinese Class III
- Treat 75% of annual runoff volume
- Reduce annual TSS load by 60%.

Background

- Zhenjiang City is located at Jiangsu Providence of China
- It is one of the 16 pilot “sponge cities” chosen by the federal government in 2015
- The pilot area is 22 square kilometers of old high density urban residential and business neighborhood



The Problems

1. Flooding (2015-06-29)

2. Water Quality Deterioration caused by CSO/Stormwater Runoff

A6 北固湾水体污染

污染源或为初期雨水和生活污水

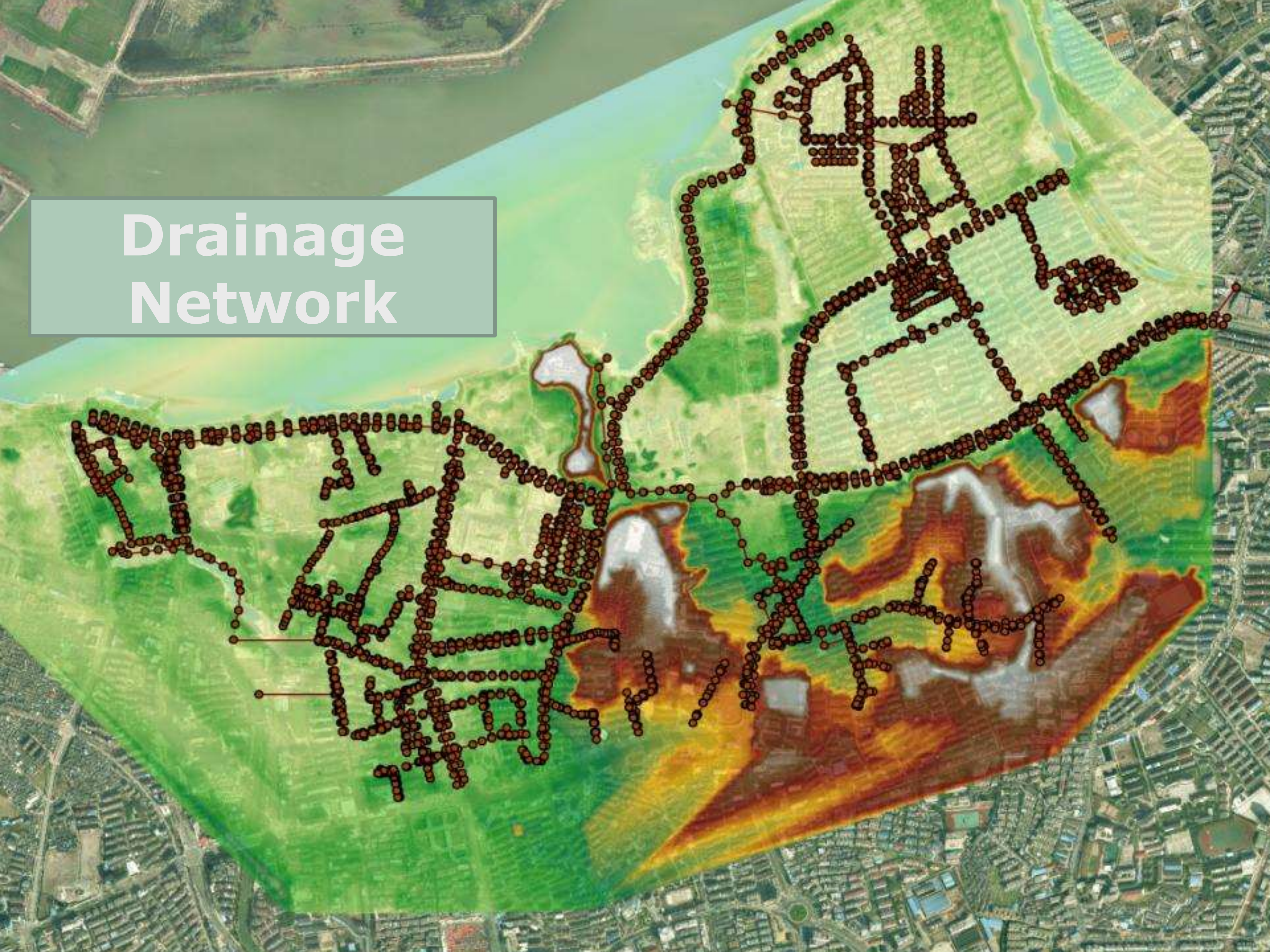
Data Collection and Initial Investigation

- Weather data
- Topo
- Land use
- Drainage network
- River and Lakes
- Site visit
- SWMM model
- Monitoring network
- SWMM Calibration
- Flood location identification

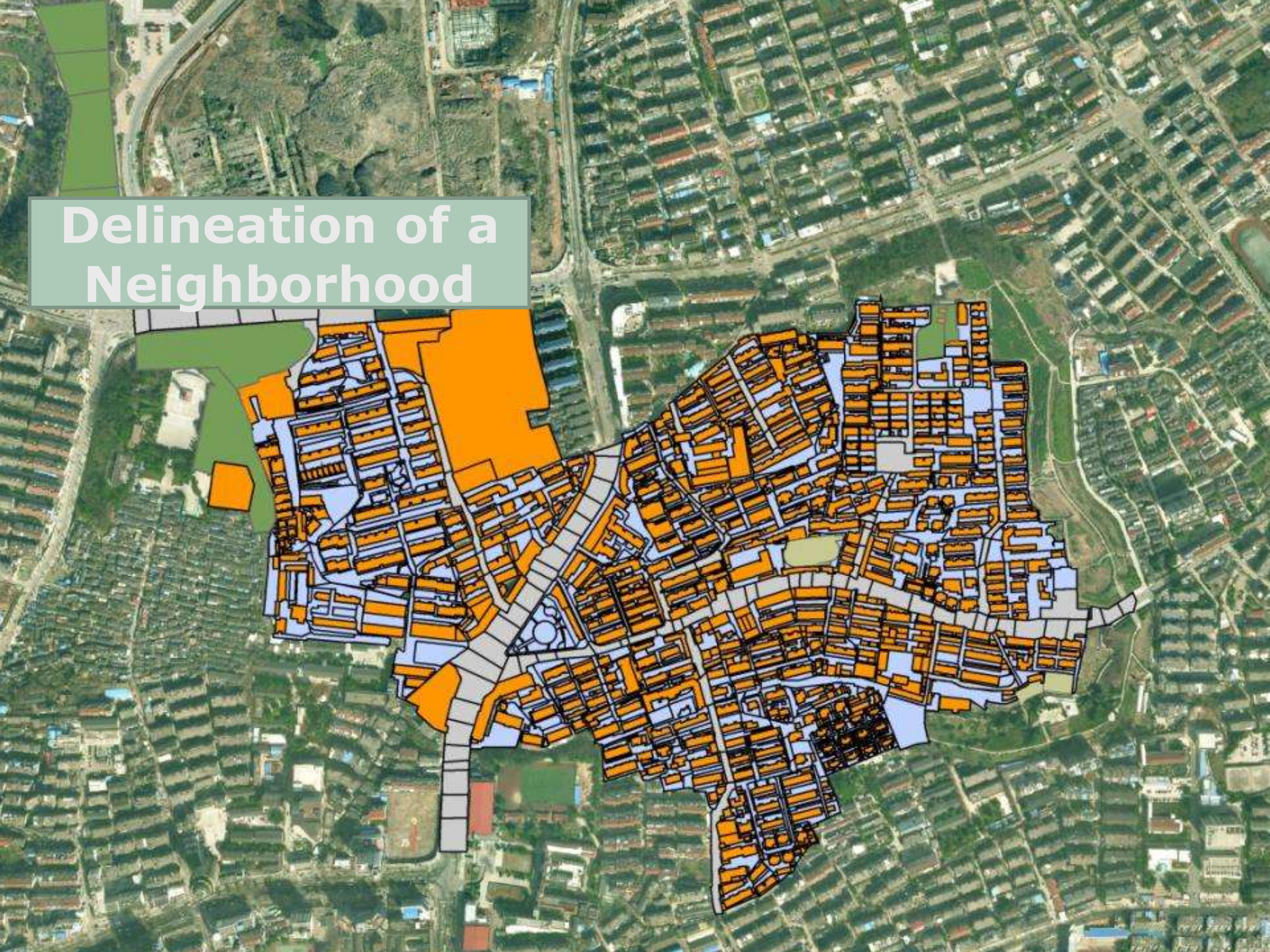

Arial Photo

Landuse

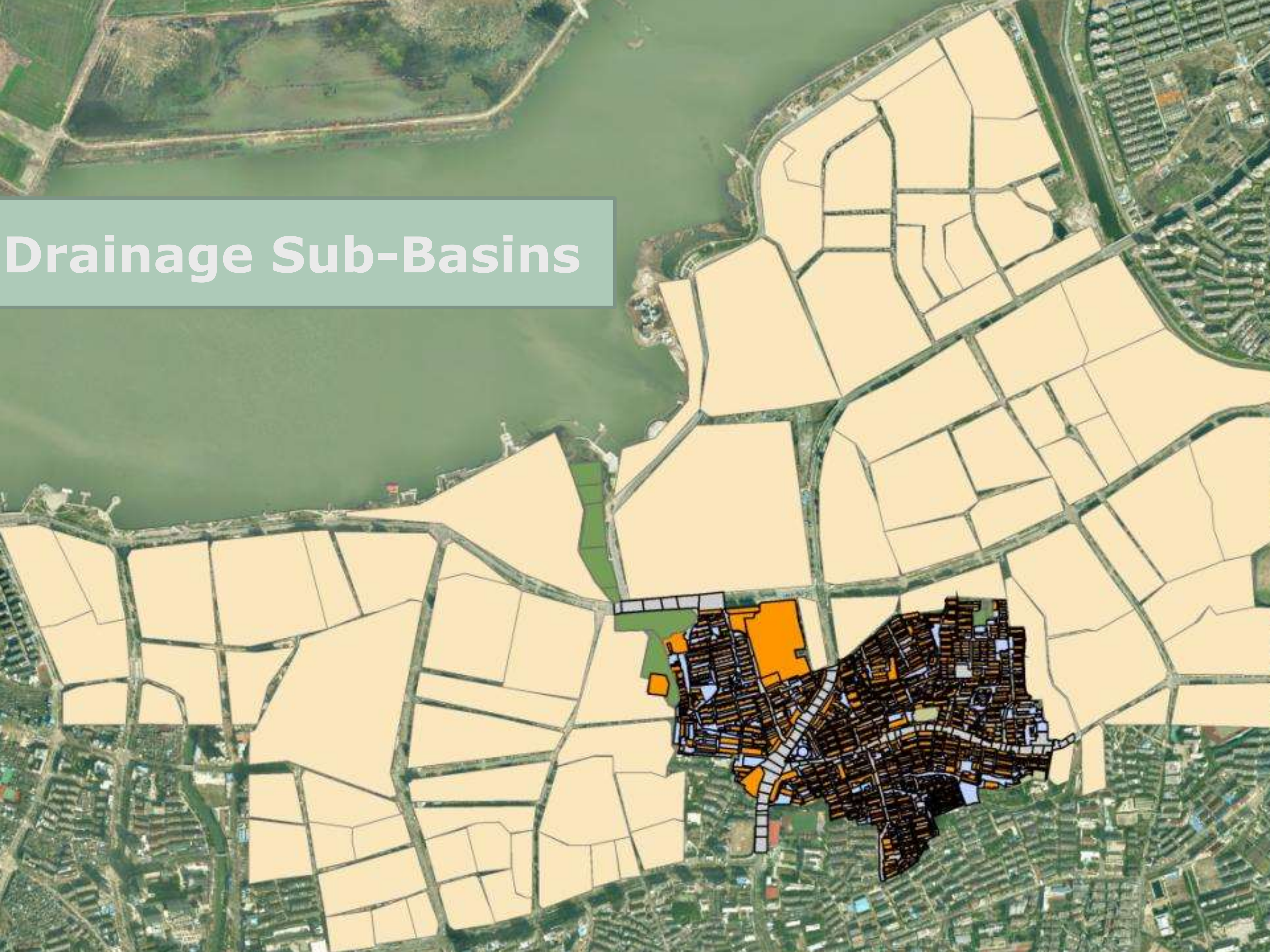
Topography


Drainage Network

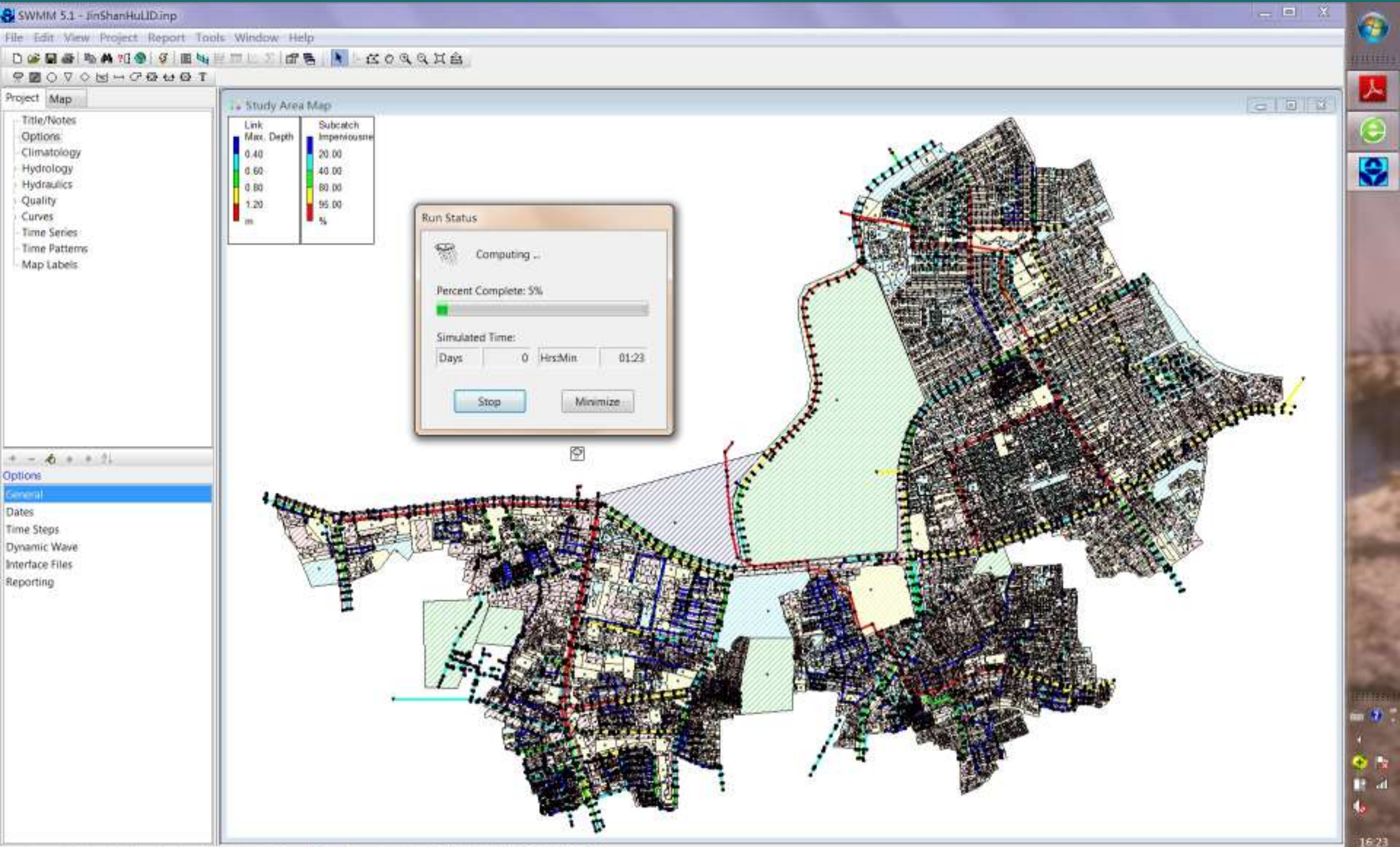
Delineation of a Neighborhood



Drainage Sub-Basins

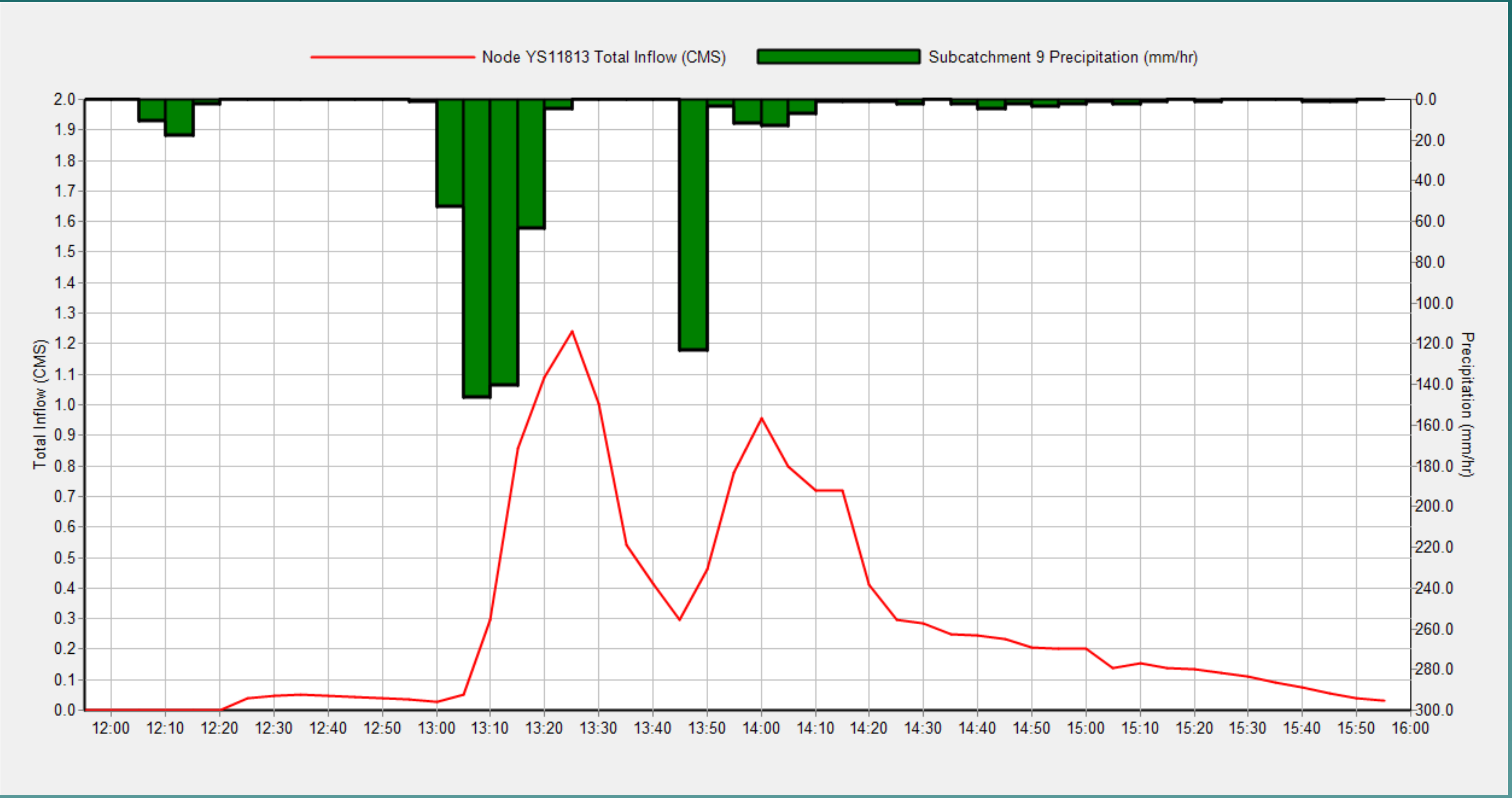


SWMM Model



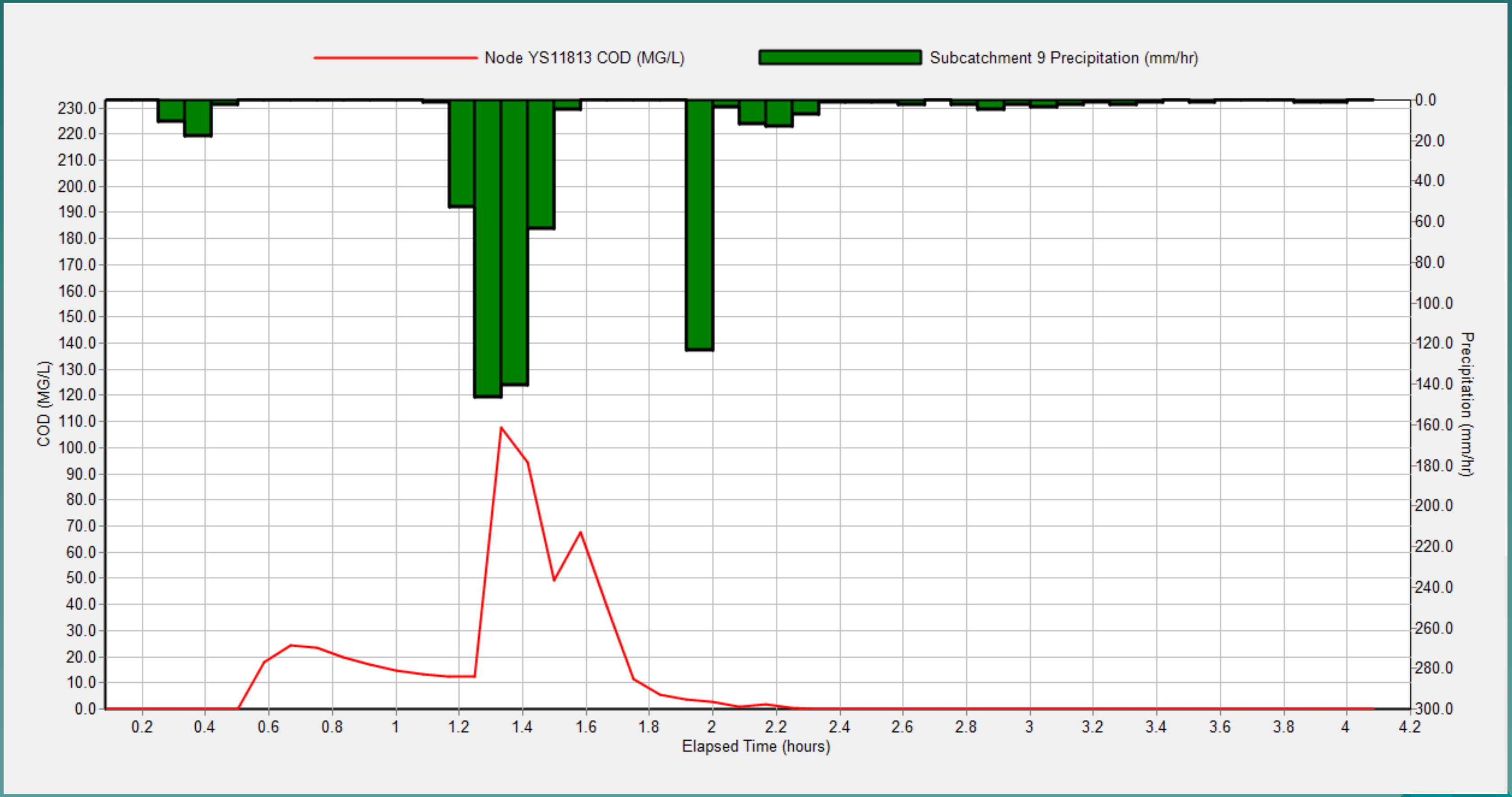
SWMM 5.1 - JinShanHuLID.inp
File Edit View Project Report Tools Window Help
Project Map
Title/Notes
Options
Climatology
Hydrology
Hydraulics
Quality
Curves
Time Series
Time Patterns
Map Labels
Options
General
Dates
Time Steps
Dynamic Wave
Interface Files
Reporting
Study Area Map
Link Max. Depth
0.40
0.60
0.80
1.20
m
Subcatch Imperviousne
20.00
40.00
80.00
95.00
%
Run Status
Computing ...
Percent Complete: 5%
Simulated Time:
Days 0 Hrs:Min 01:23
Stop
Minimize

Initial Validation

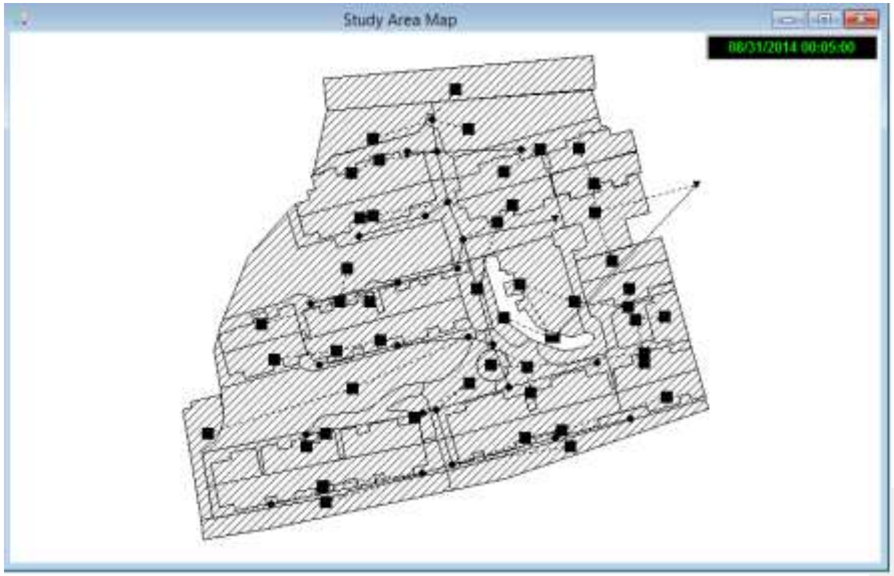


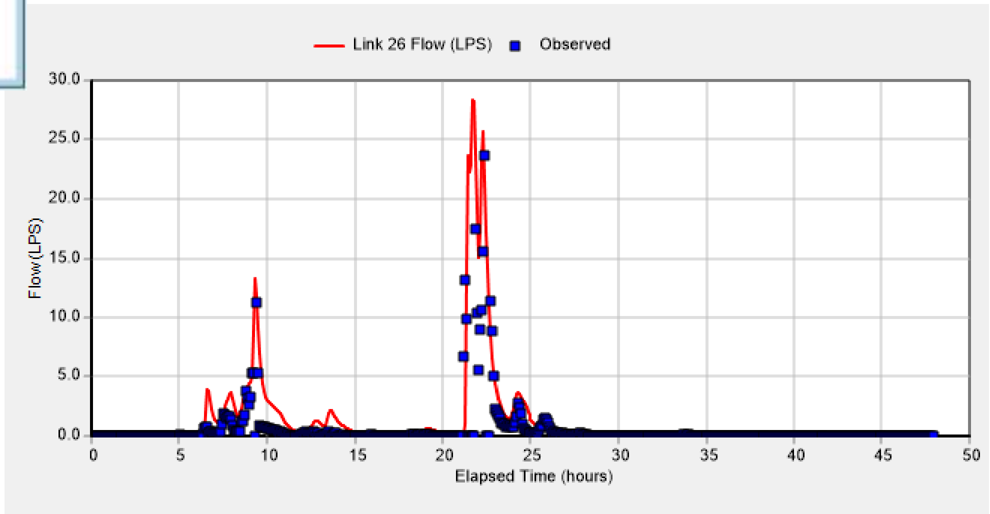
Hydrograph of a sub basin (Event simulation)

Initial Wash - off



SWMM Calibration to Determine model parameters

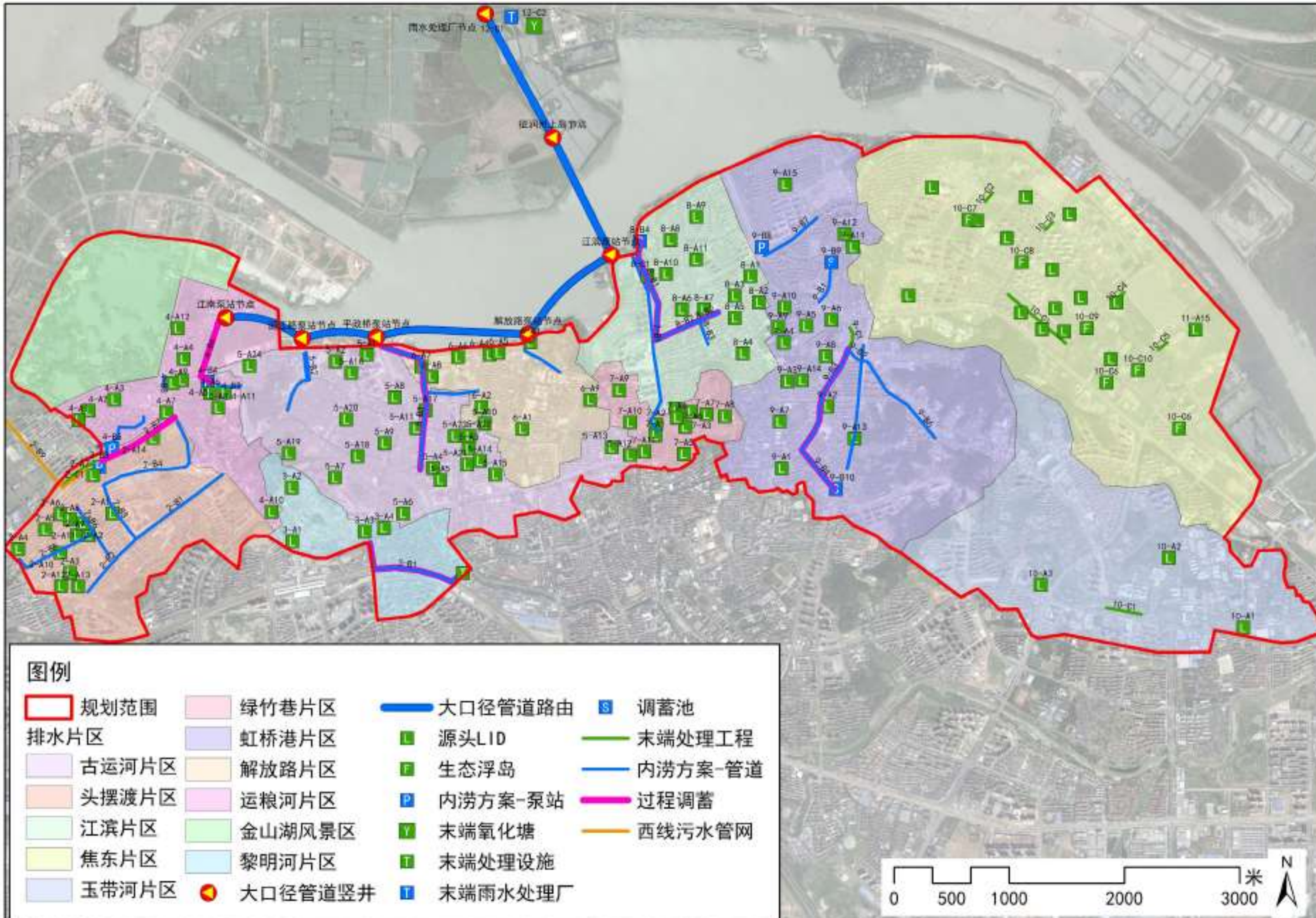




Flood Locations

These communities are well known for flooding every year. These photos were taken on 6/29/2015 before LID construction and retrofit.

Redraw the City: Green + Grey + Blue Solutions



In my opinion the Sponge City is the redrawing of urban landscape to meet the challenge of climate change, flooding, water shortage, water pollution and water culture. The implementation of the sponge city should be an integrated system of grey and green infrastructures that reduce the runoff and pollution from the source, control the runoff and pollution inline and treat the runoff at the end of the pipe. Rivers and lakes can also be used as water quality channel for pollution removal and establish aquatic habitats






Retrofit Old Neighborhoods Using LID

No	Basin	boundary	**area (km^2)**	Drainage	Receiving water
1	绿竹巷片区	南起花山湾新村，西自烈士陵园墓，北至金山湖	**0.79**	CSO	金山湖（原北湖）
2	解放路片区	北自长江路，南到中山东路，西起古运河东侧，东至第一楼街	**1.22**	separate	金山湖（原北湖）
3	江滨片区	南自镇江市江南学校，东起虹桥河西侧，北至滨水路	**1.81**	separate	金山湖（原北湖）






Build a Resilience and Aesthetic Landscape in an Old Ultra Dense Residential Community

There are hundreds of communities within 22 km^2

Cause Study – Second Community of Riverfront Community

This is a high density neighborhood built in 1970s. Most residents are low income retirees. Due to the lack of maintenance, this neighborhood had endured annual flooding, deterioration of aging infrastructure, lack of appropriate sanitary conditions and no parking lot . Young people moved out

Problem 1 - Flooding

Flooding Event in 2015 before the retrofit

Problem 2 – Pavement Damage

For decades there was no maintenance. The pavements in the neighborhood were damaged. Many green spaces were destroyed

Problem 3 – Landscape Sites Became Garbage Dumping Ground

The garbage were dumped into landscape sites

Problem 4 – Lack of Parking Space

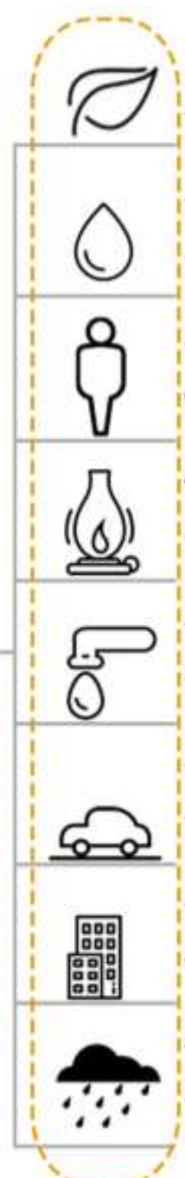
Due to lack of parking space some green space became “illegal parking lots”

Problem 5 – Building Surface Deterioration and Lack of Appropriate Infrastructures

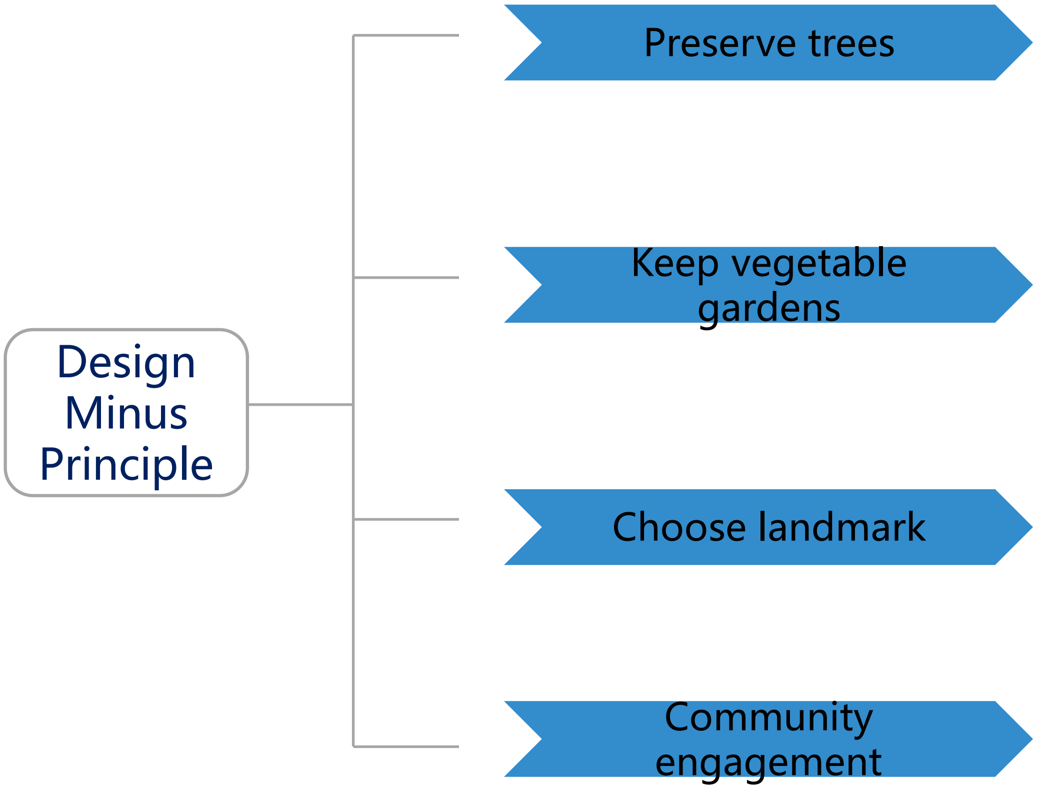


Our Approach

Landscape +N



Improve Livability	●Increase recreational spaces ●Preserve big trees ●Landscape reclamation
Flood Mitigation	●Route impervious surface into rain gardens and green spaces ●Change sidewalk into permeable pavement
Better Property Management	●Re-organize property management ●Setup maintenance guidance
Retrofit Gaslines	●Switch from coal gas to natural gas
Upgrade Water Supply Infrastructure	●Repair leaking pipes and meters ●Replace eroded pipes
Increase Parking Space	●Increase parking spaces ●Install porous parking lots
Energy Conservation	●Utilize thermal insulation materials ●Install window shading ●Upgrade electrical system and lighting
Sewer Separation	●Disconnect illegal connections ●Separate sewer from storm drains



Design minus principle is minimizing the landscape intervention because this neighborhood has about 40 years of history. Residents spent most of their life in the neighborhood. Keep their memory is so important in the design work. After the retrofit it is desirable to minimize the maintenance cost, and encourage the residents to maintain their vegetable gardens and fruit trees.

Design Process

Design

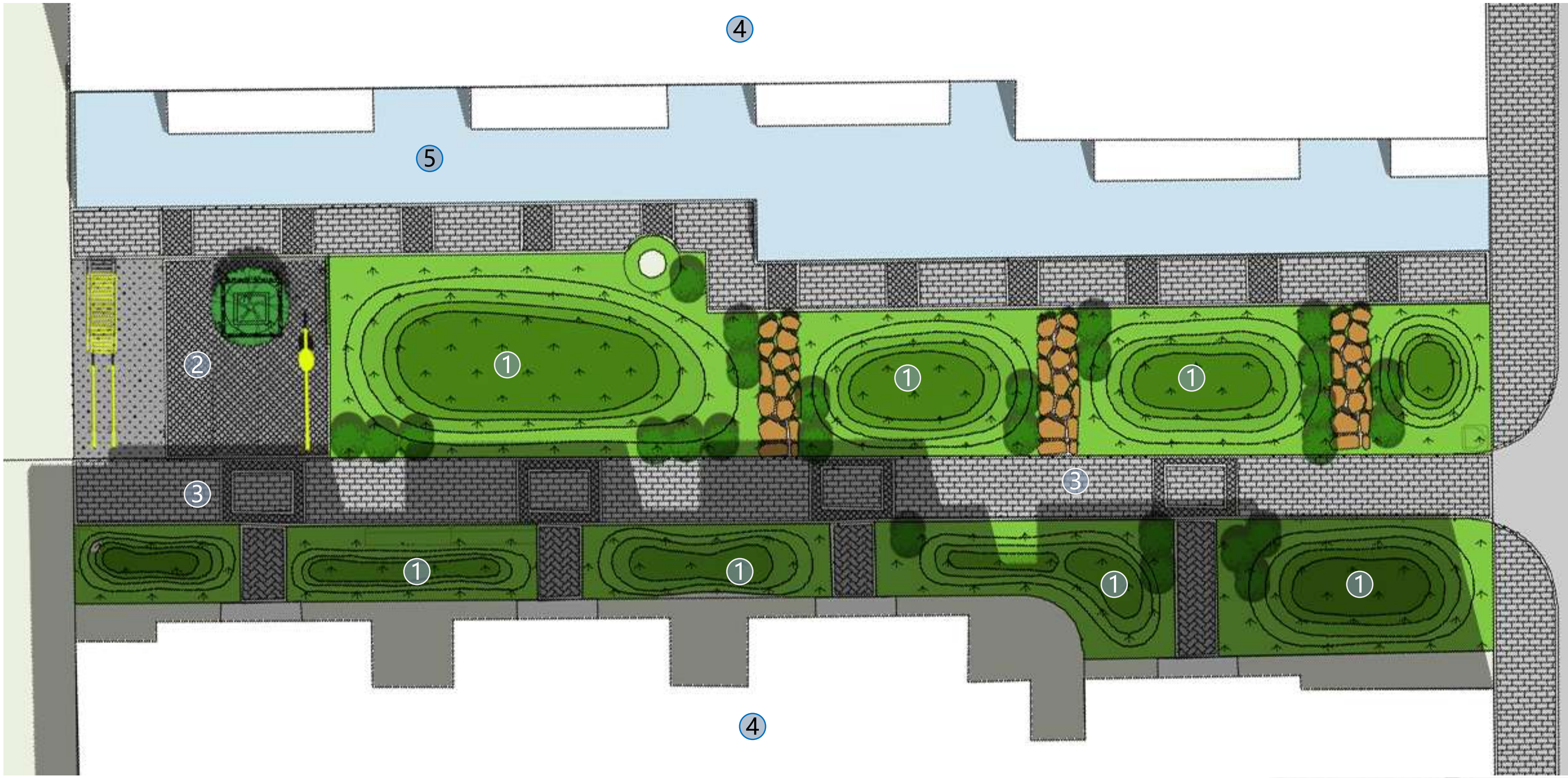
LID design process:

1. Site Investigation
2. Survey drainage network
3. Subcatchment delineation
4. Communication with residents
5. Soil infiltration testing
6. LID layout and modeling
7. Separation
8. Monitoring

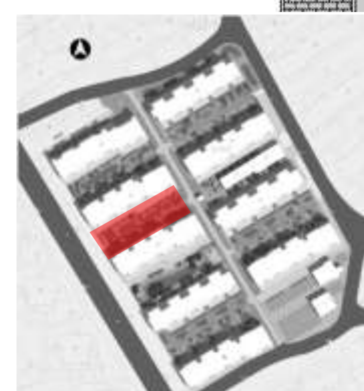
Layout

1
2
3
4
5
6
7
8
9
LEGEND
PRESERVE EXISTING FRUIT TREE
PRESERVE EXISTING VEGETABLE PATCH
RAIN GARDEN
VEHICEL ENTRANCE
PEDESTRIAN ENTRANCE
1 PERMEABLE PARKING LOT
2 RAIN GARDEN
3 PERMEABLE SIDEWALK
4 PERMEABLE SIDEWALK
5 OPEN SPACE
6 PLAYGROUND
7 ORCHARD
8 PUBLIC SQUARE/OPEN SPACE
9 VEHICLE ROAD
0 500 1000 2000m

Section Design



1. Bioretention
2. Recreation space
3. Porous pavement
4. Building
5. Yard



How Green Stormwater Infrastructure Works

Experiments before the construction

Growing Media Test

Plants Selections

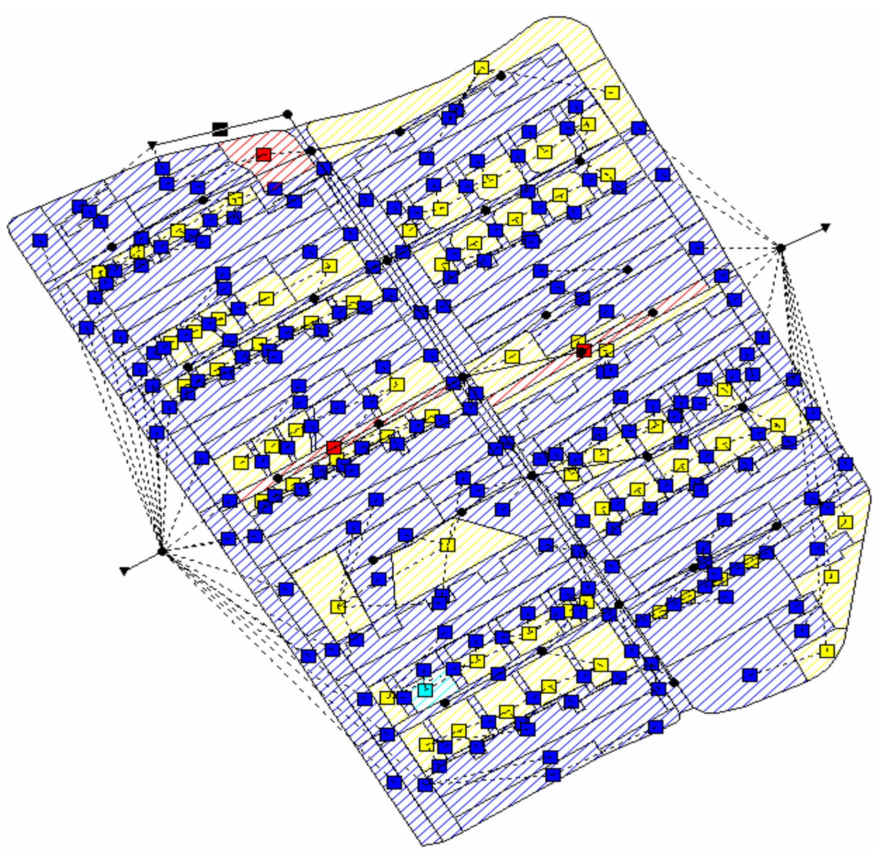
Infiltration Test

Observation of Plant Growth

Site Delineation and Modeling:

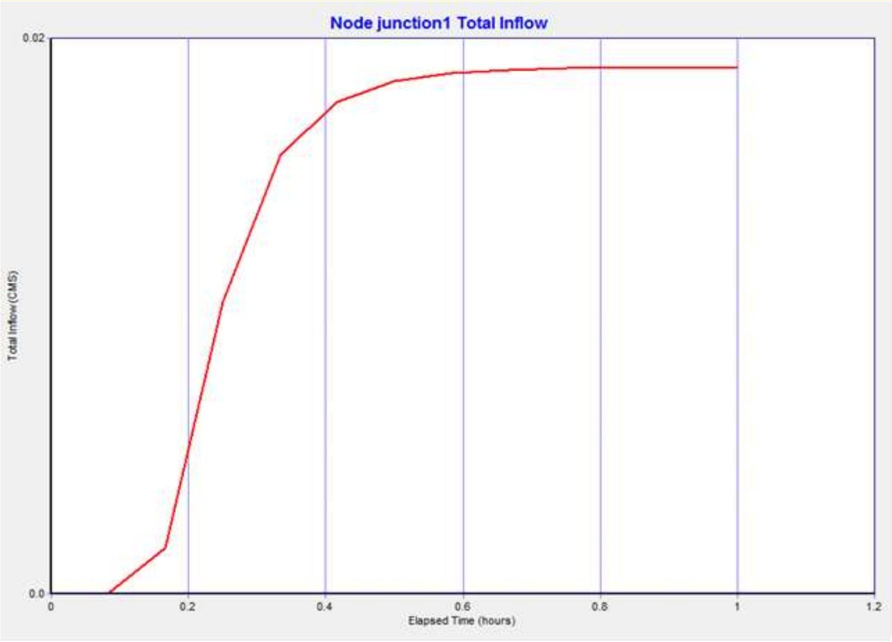
Delineation: Rooftop, Road, Green Space and “Yard”

Model: SWMM

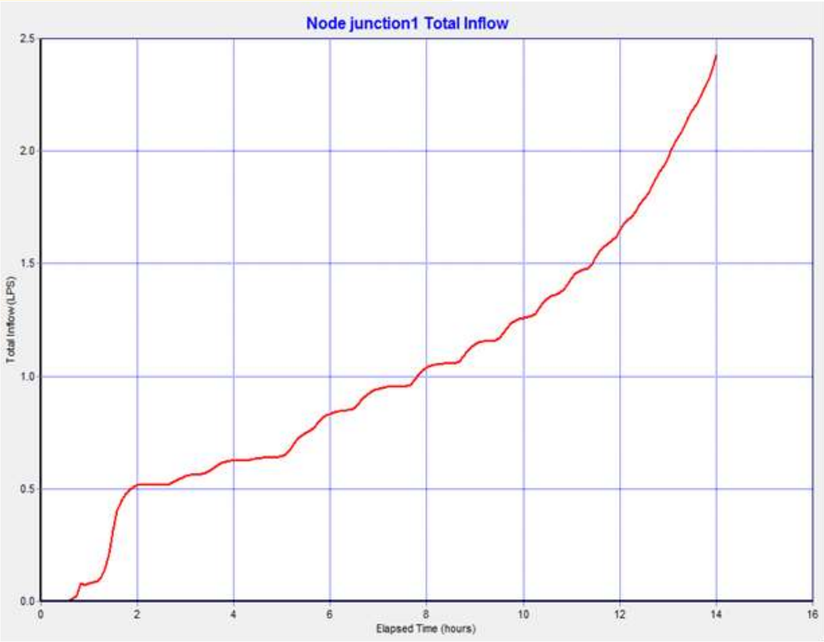


**************************	Volume	Depth
Runoff Quantity Continuity	hectare-m	mm
**************************	---------	-------
Initial LID Storage	0.022	11.521
Total Precipitation	0.413	219.979
Evaporation Loss	0.000	0.000
Infiltration Loss	0.052	27.927
Surface Runoff	0.189	100.574
Final Surface Storage	0.193	102.629
Continuity Error (%)	0.160	

30yr-24hr



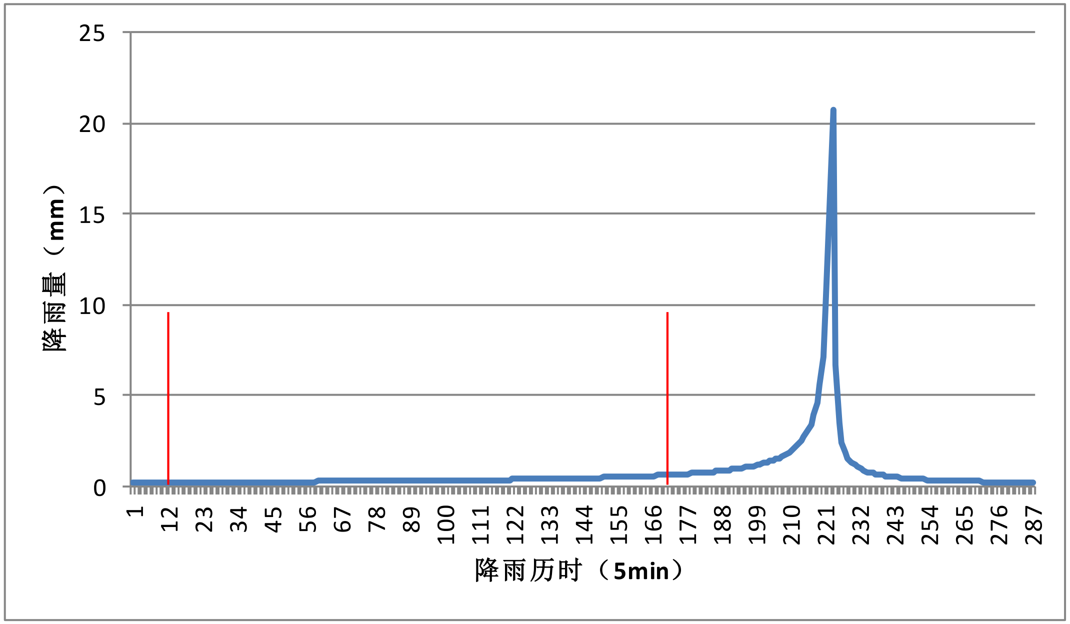
NO-LID (Before) 6.2mm rainfall detention

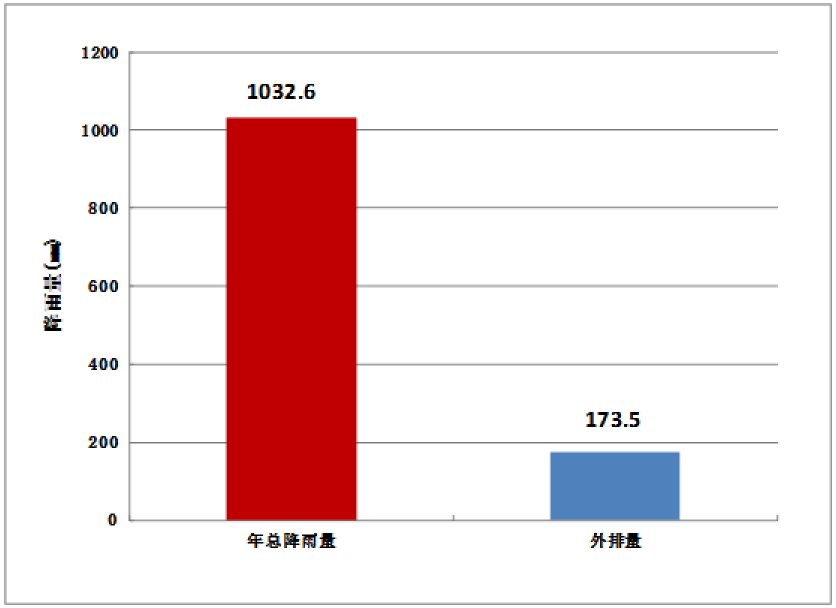


LID (After) 34.6mm rainfall detention

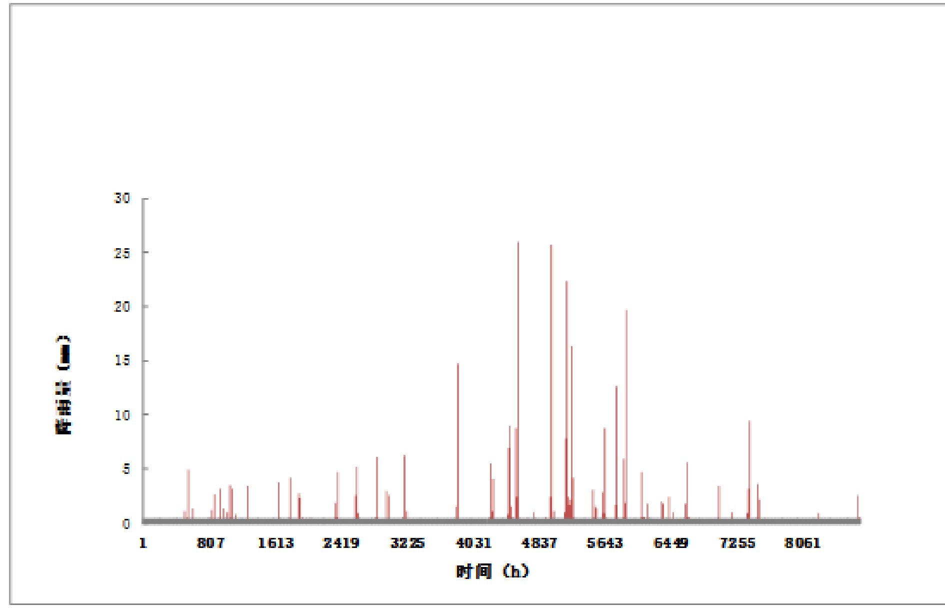
Concluding:

LID can delay 13 hours of discharge at the outfall. (Without LID it is just 1 hour)





Annual rainfall vs discharge



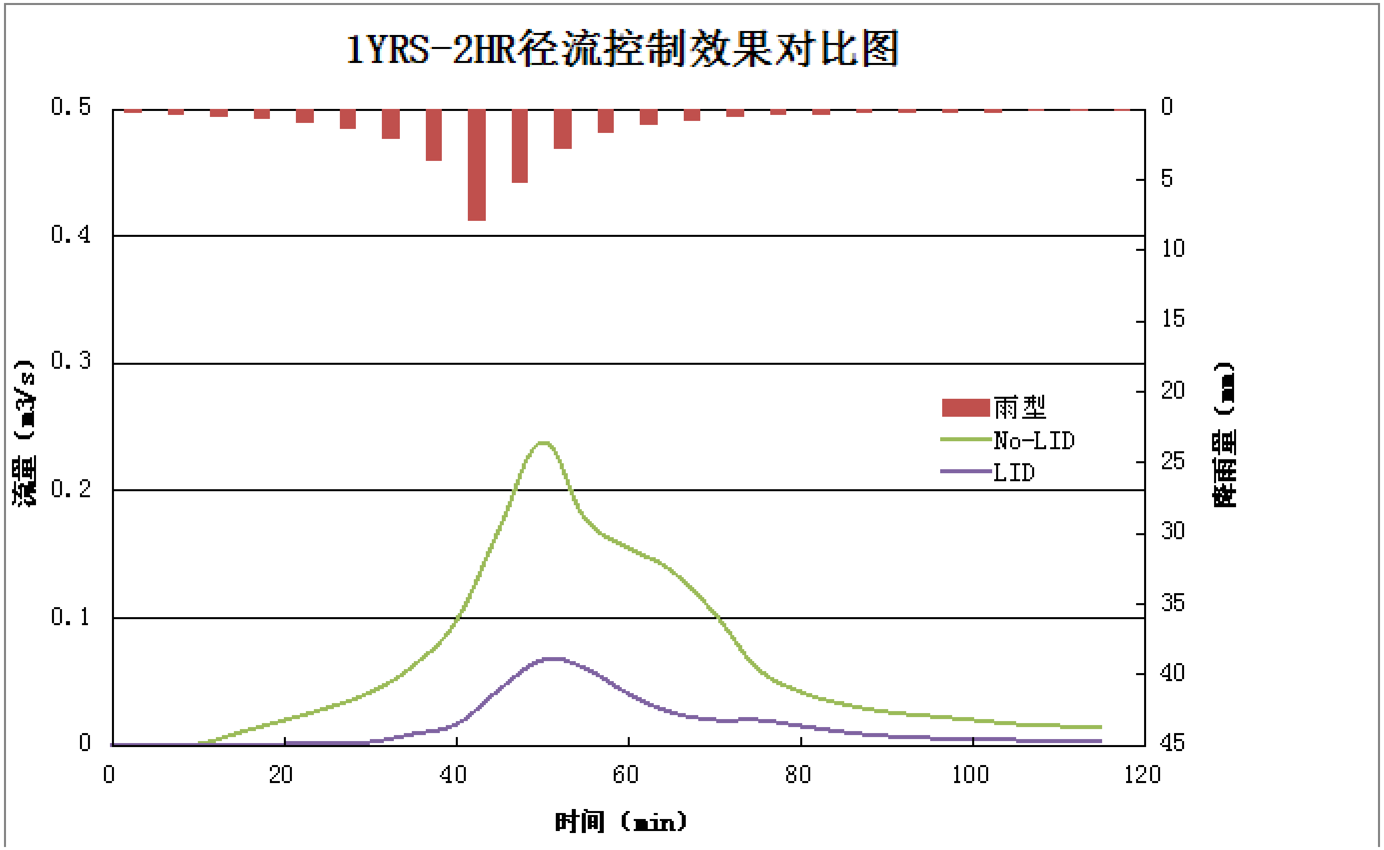
2005 rainfall data（5-min）

Data Analysis：113 events，7 events exceed 34.6mm，6.2%。

Annual rainfall 1032.6mm， Discharged runoff 173.5mm，16.8%。

注：以上年总降雨量及实测降雨量均参考2005年南京实测数据。

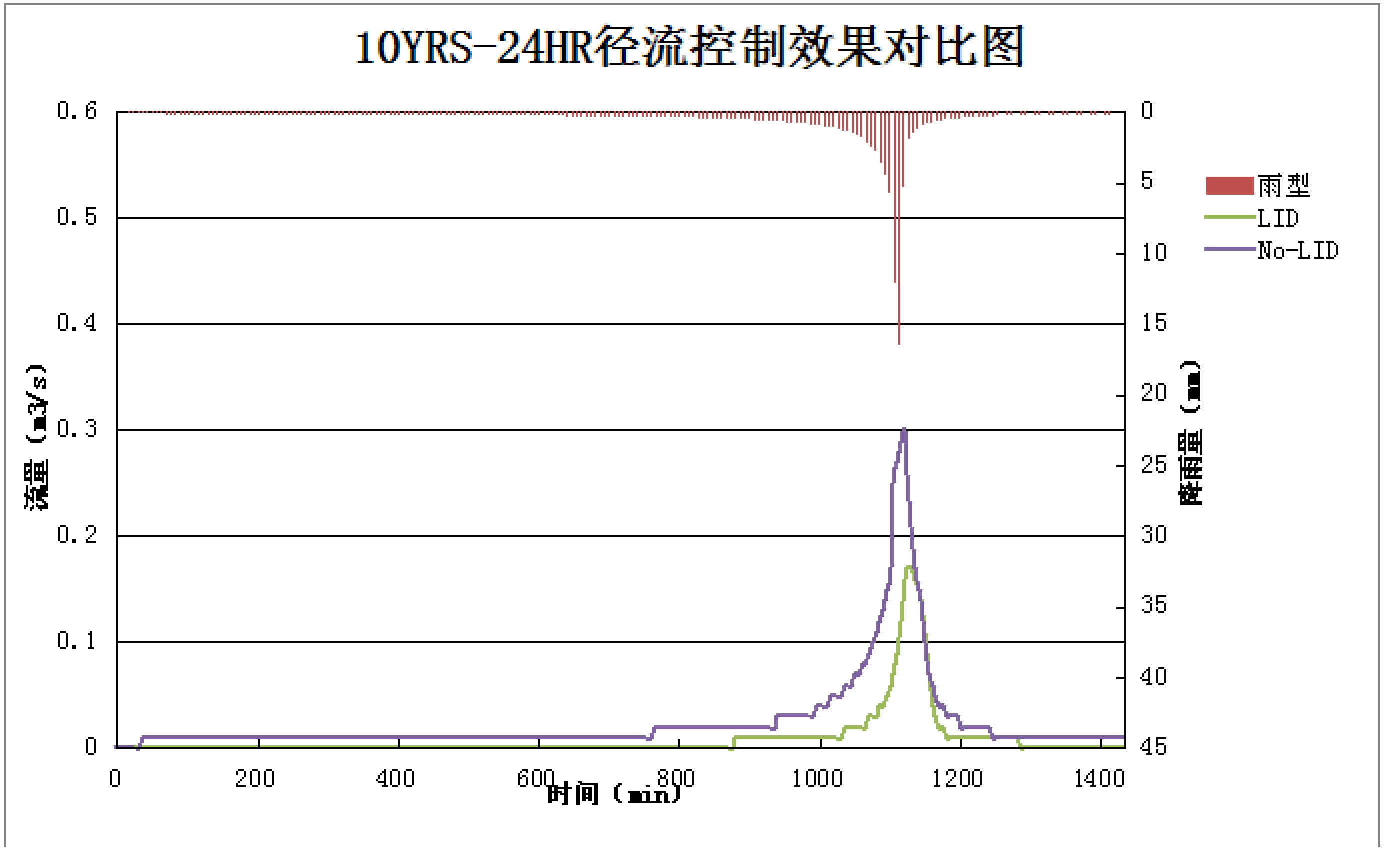
1yr-2h:



	Rainfall（mm）	Peak rainfall（min）	Peak runoff（min）	Runoff Volume（m^3）	Peak runoff（m^3 /s）	Runoff Coefficient
Before	37.5	40	50	598	0.24	0.85
After	37.5	40	50	198	0.07	0.28

72% runoff volume reduction

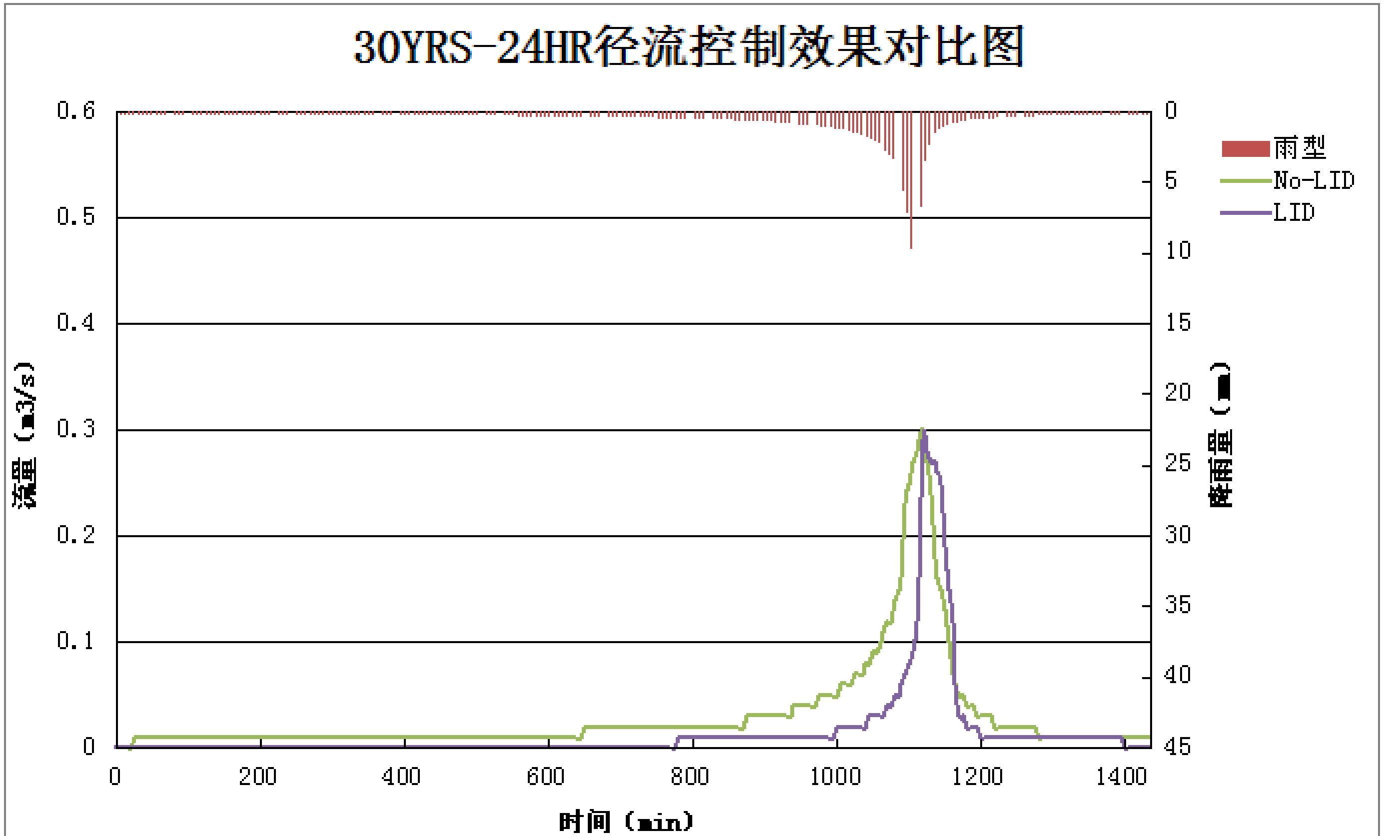
10yr-24h:



	Rainfall（mm）	Rainfall peak（min）	Runoff peak（min）	Runoff Volume（m³）	Runoff peak（m³ /s）	Runoff Coefficient
Before	175.0	1115	1120	2810	0.30	0.85
After	175.0	1115	1125	1290	0.17	0.40

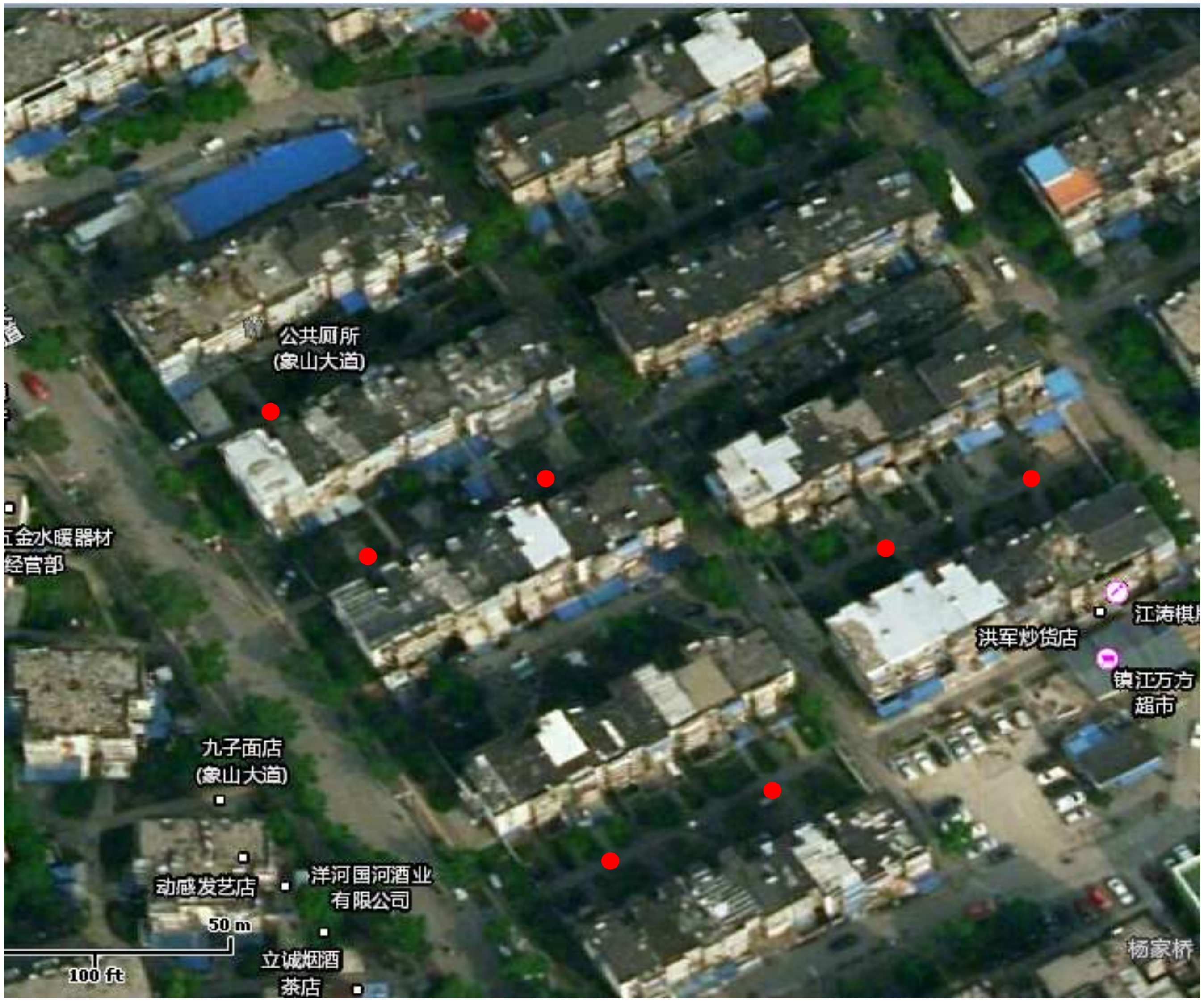
Volume Reduction 54%，Peak Reduction 43%，Peak shifting

30yr-24h:



	Rainfall（mm）	Rainfall peak（min）	Runoff peak（min）	Runoff volume（m^3）	Runoff peak（m^3 /s）	Runoff Coefficient
Before	220.0	1115	1120	3600	0.30	0.87
After	220.0	1115	1125	1890	0.29	0.46

Runoff volume reduction 47.5%，No significant reduction of peak



There are 24 hot spots before. Flood volume 512m3，14 spots exceed 15cm in depth。

Only 7 hot spots left after. Flood volume 62m3, Only 1 spot exceeds 15cm in depth. Flood time 30min。

Design Process

Design Discussion

Outreach

Public Comments

Construction


Preparation


Escavation


Pipe layout


Gravel


Maintenance


Planting


Growth media

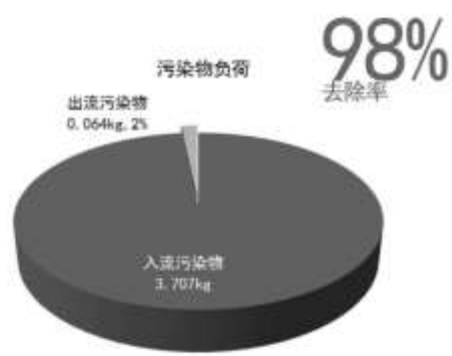
Completion

Post Construction

During Heavy Storm

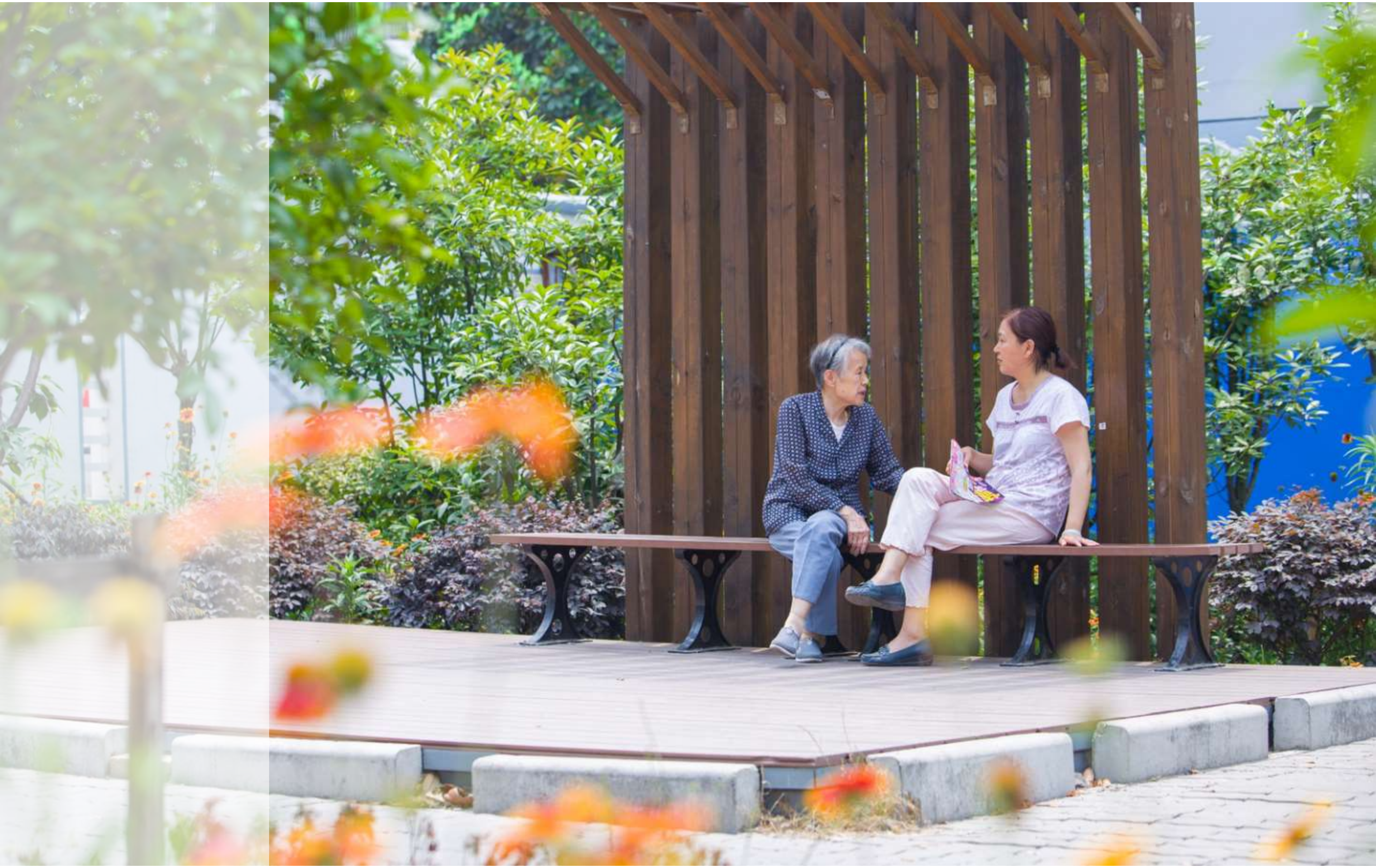
After completion of the project the neighborhood experience two heavy storm events. One is 138 mm rainfall in 2016 and another is 125mm rainfall in 2017.

Monitoring Results

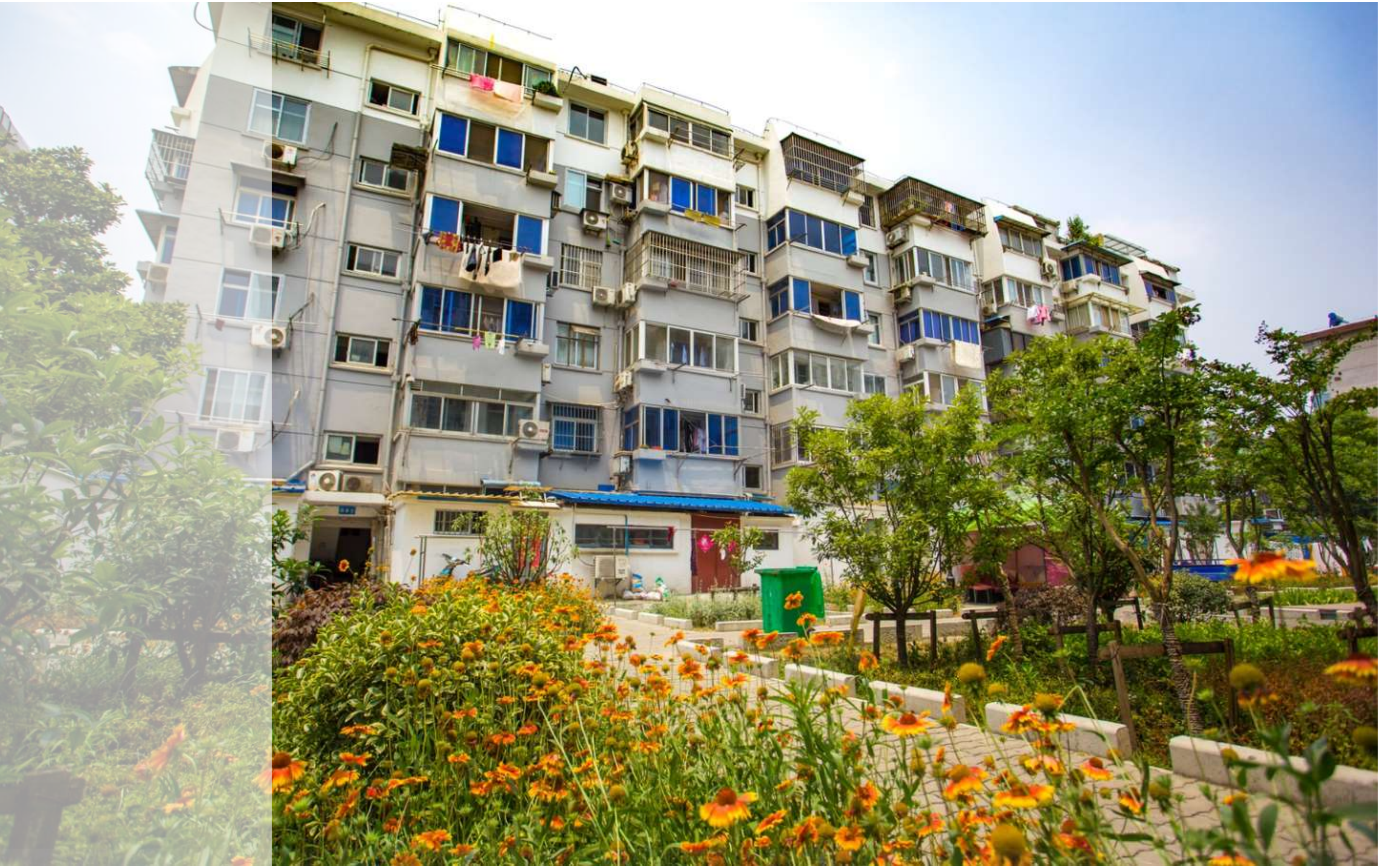


95% Flow Reduction, and 98% TSS Removal

An Ideal Place for Social Interactions of the Residents



Beautiful Landscape – Reduced Symptoms of Depression and Anxiety



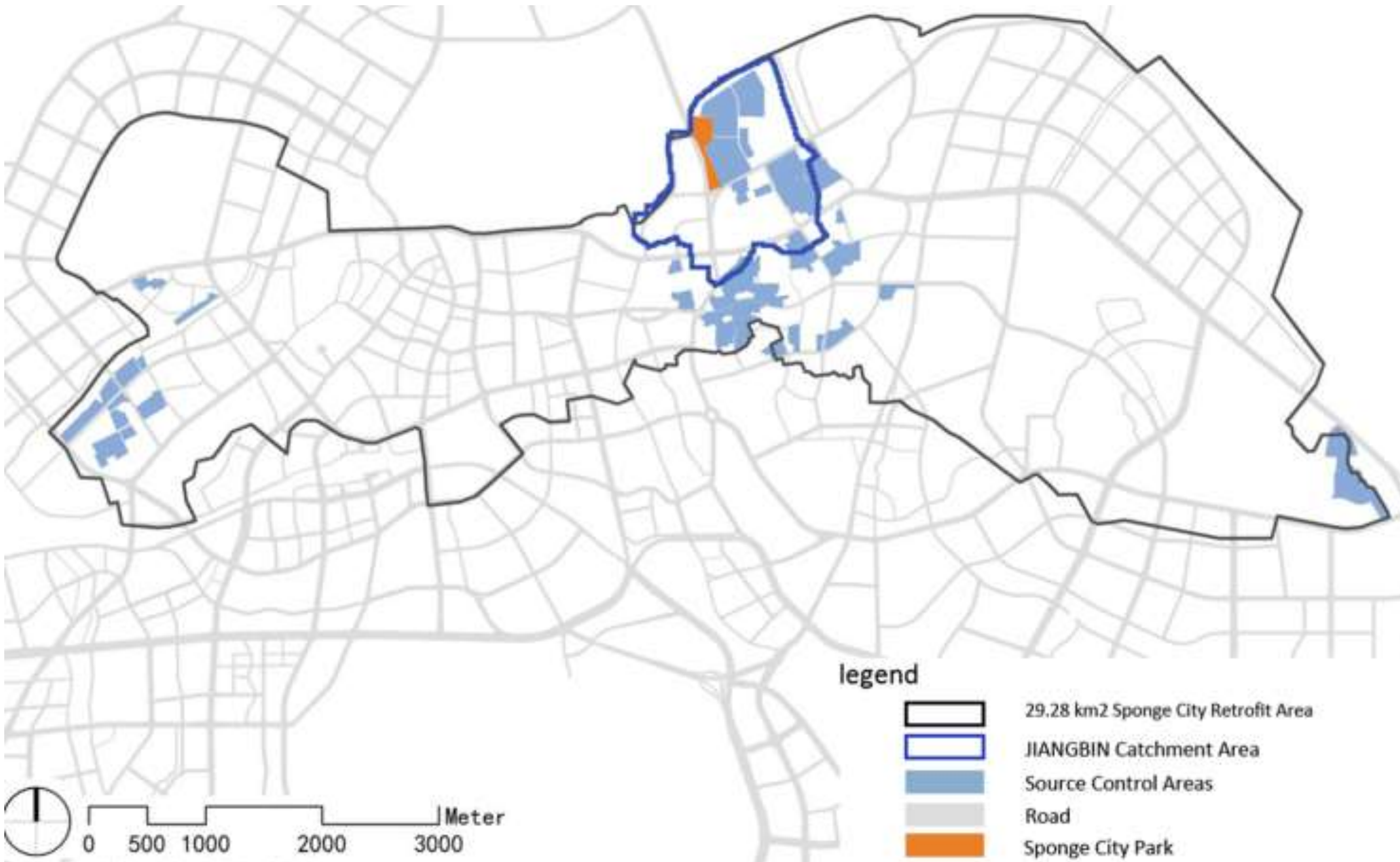
Rain Garden + Porous Access = Improved Personal Safety

Happiness – Yong People bring their Children back

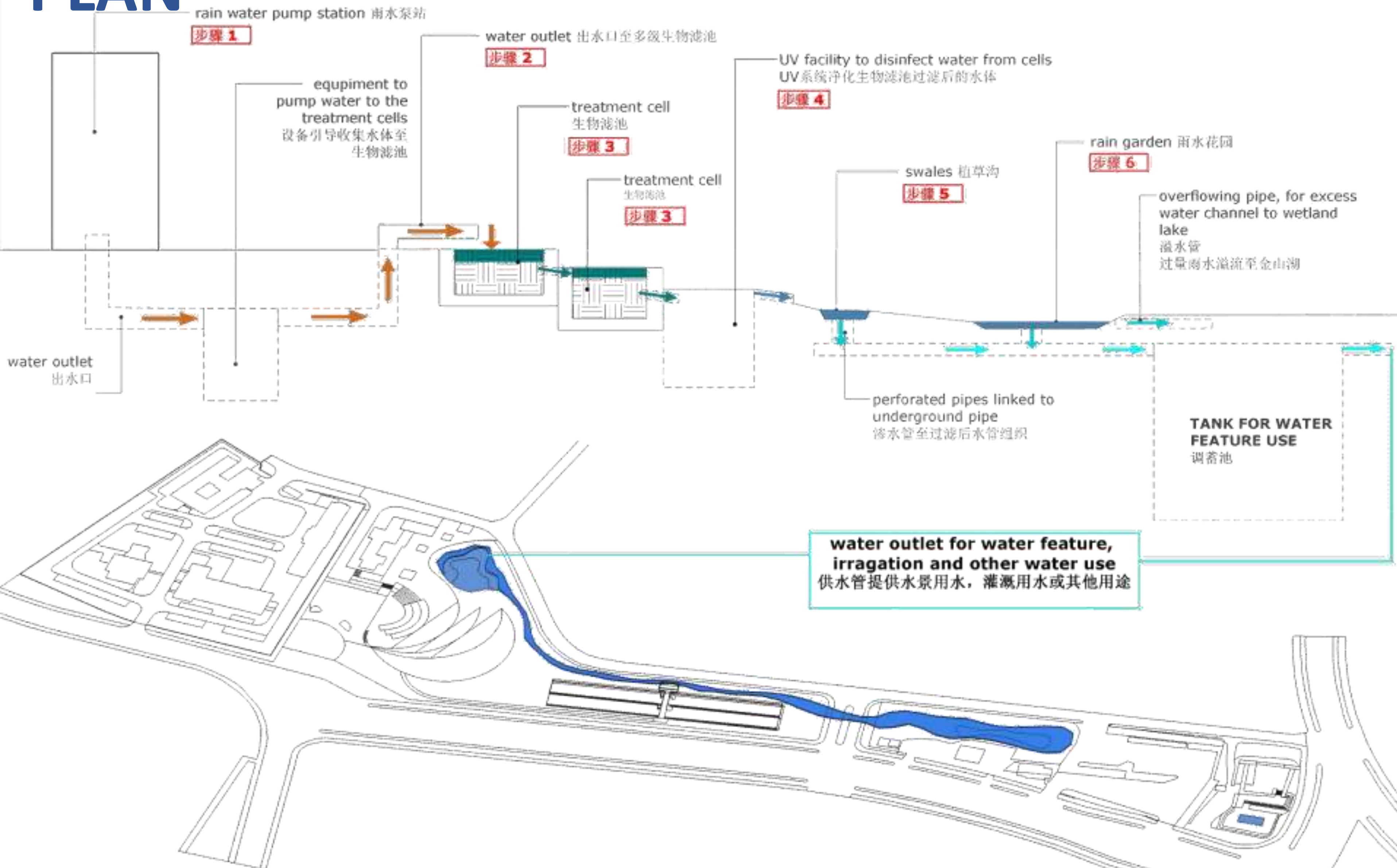
Increase Parking Lot

Too dense to retrofit

Regional Treatment (End of Pipe)



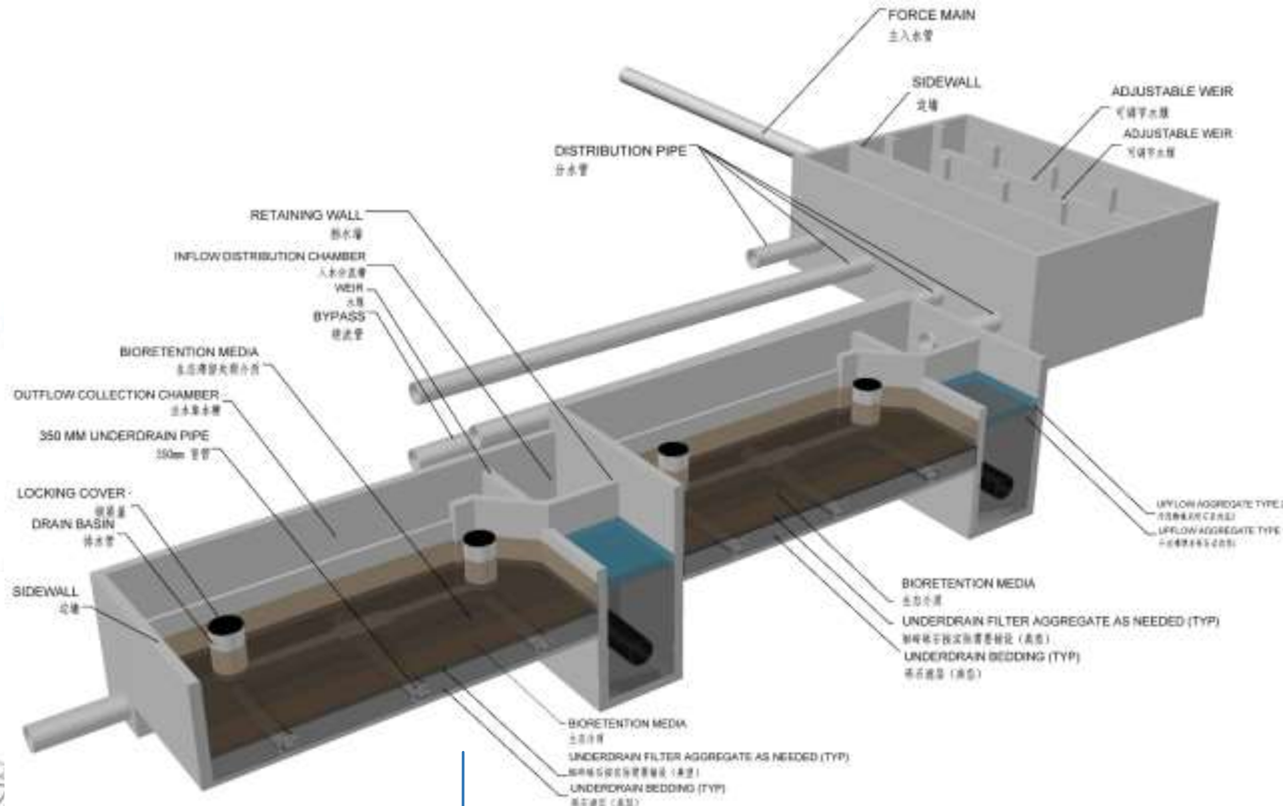
PLAN

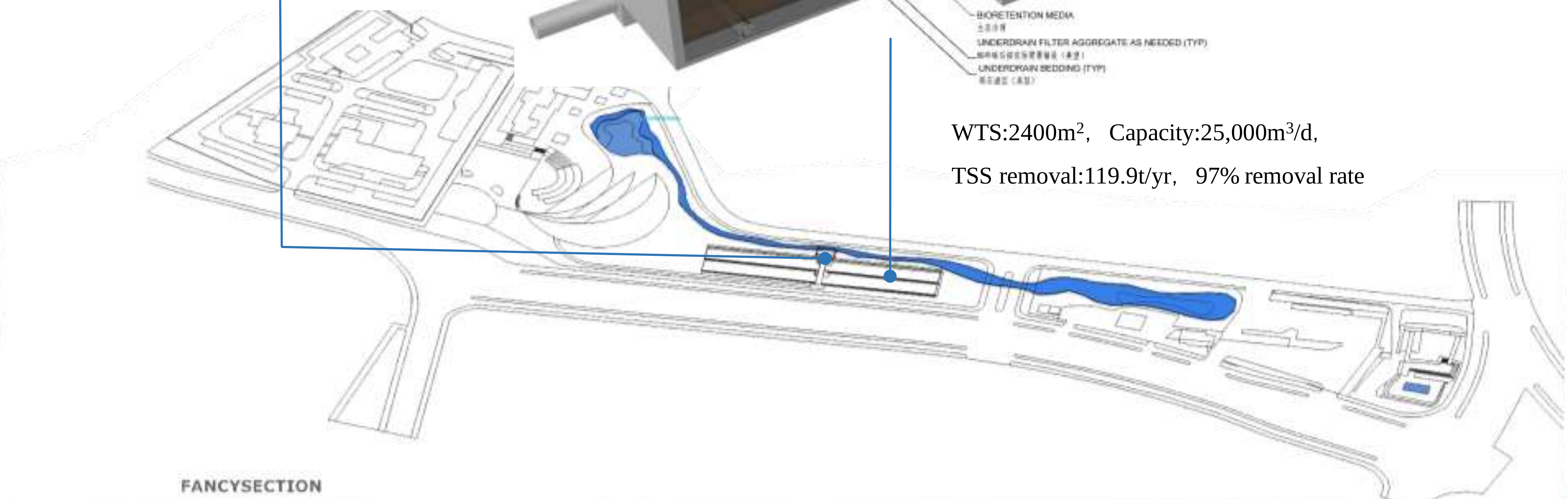


FANCYSECTION

CMIE 中机国际

PLAN





WTS:2400m^2, Capacity:25,000m^3/d,

TSS removal:119.9t/yr, 97% removal rate

FANCYSECTION

CMIE 中机国际

PLAN

Rain garden

Permeable pavement

Concave square

Vertical greening

Roof greening

Rainwater tank

Storage tank

Ecological planter

Basket filter

Regional green infrastructure

In-line treatment

Infiltration trench

Permeable pavement

swale

PLAN

图例

LEGEND :

1. 抵达处和开敞广场
   Arrival and Open Plaza
2. 展示中心
   Exhibition Center
3. 休闲区
   Recreation Area
4. 下沉草坪
   Sunken Lawn
5. 湿地与溪流
   Wet Land and Stream
6. 多级生物滤池
   Regional Storm Water Treatment Facilities Building
7. 栈道
   Boardwalk
8. 次入口
   Secondary Entrance
9. 车行通道
   Vehicular Access
10. 雨水庭院
    Rain Garden
11. 屋顶花园
    Roof Garden
12. 空中廊道
    Future Staff Parking
13. 公园
    Public Park
14. 泵站主入口
    Main Entrance Pump Station
15. 次入口
    Secondary Entrance
16. 泵站
    Pump Station
17. 垃圾站
    Rubbish Bin Collection Building
18. 巴士转换站
    Bus Interchange
19. 庭院
    Courtyard
20. 户外健身区
    Outdoor fitness
21. 太极广场
    TI-CHI Plaza

SCALE 1:1000

CMIE
中机国际

EFFECT DISPLAY

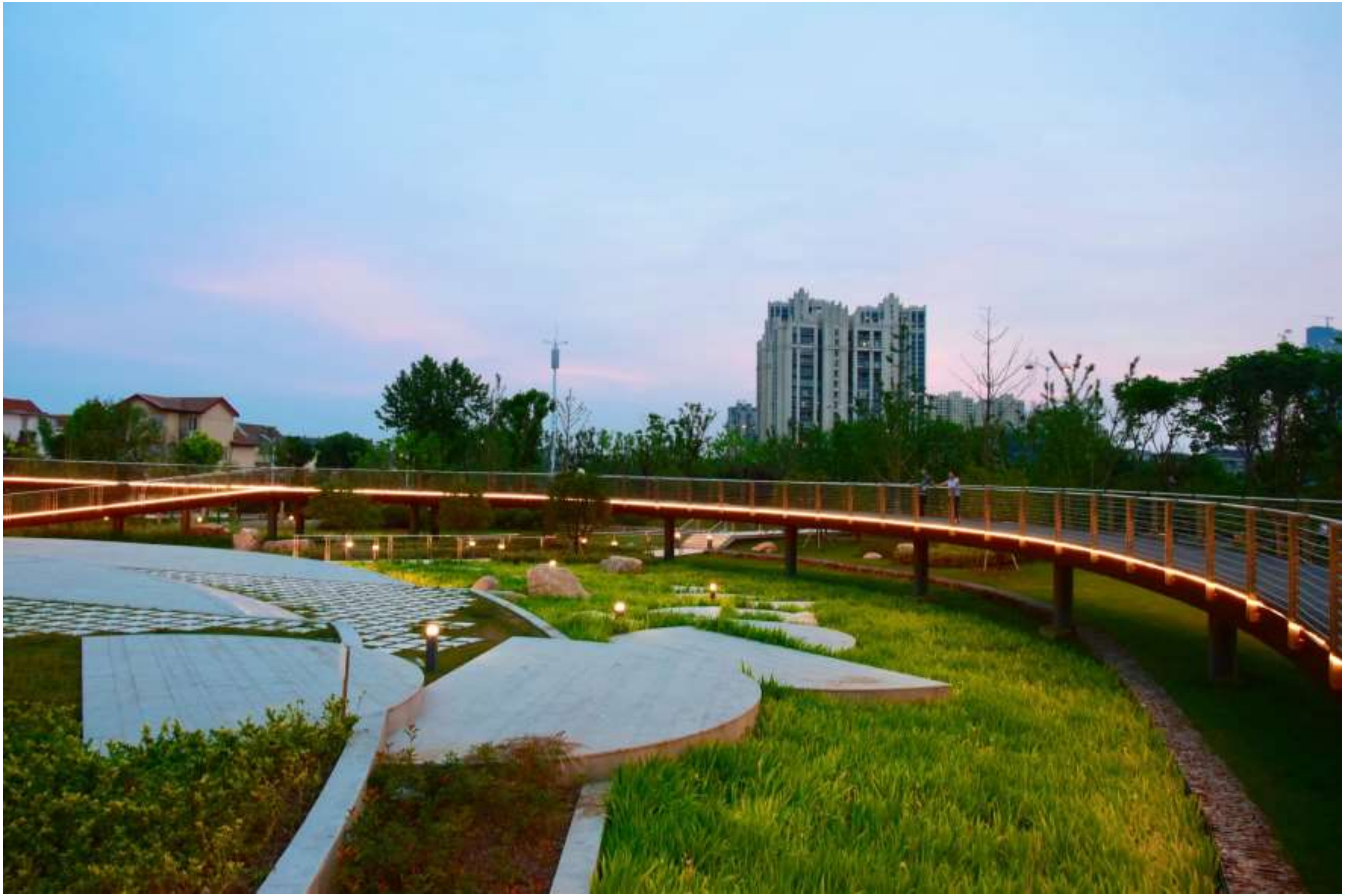
CMIE
中机国际

EFFECT DISPLAY

CMIE
中机国际

EFFECT DISPLAY

EFFECT DISPLAY



CMIE
中机国际

EFFECT DISPLAY

CMIE 中机国际

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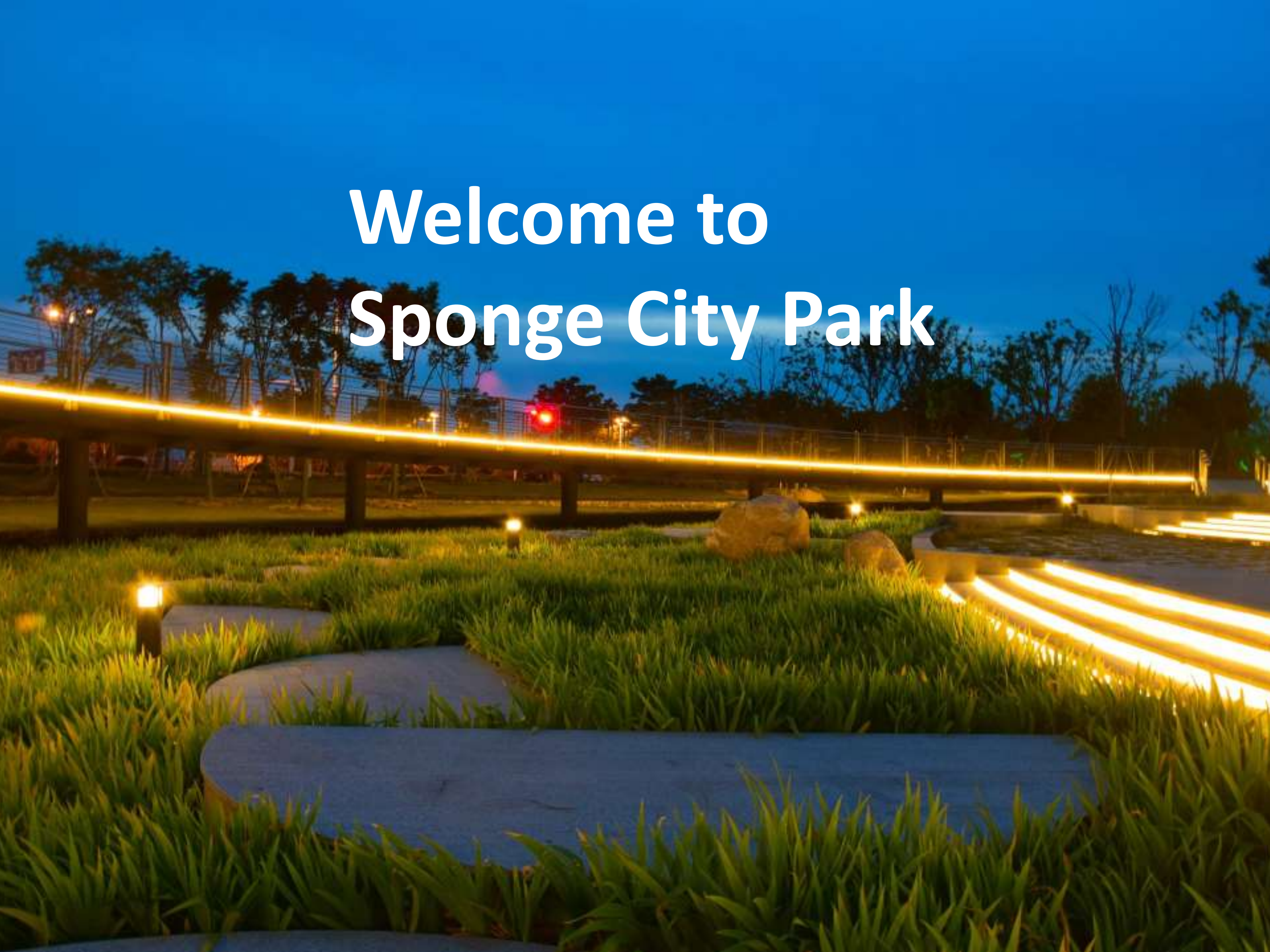
EFFECT DISPLAY

中机国际


Welcome to
Sponge City Park

Change Concrete Channel to Water Quality Channel

Hongqiao Channel is a spill way that receives CSO and SSO from large area of the city. The overflow is about 30,000 m^3 for 1” rainfall

The channel had no habitat due to worse water quality, and it smelled terrible during storm events

Fix it (Design)

Construction

Completion

Water Quality Channel In Zhenjiang

Water Quality Channel In Zhenjiang

Water Quality Before

Water Quality After

取样时间	测量参数						
	pH	COD（mg/L)	BOD_5 (mg/L)	NH_3-N (mg/L)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
2015.6.5	——	11.8	1.3	0.133	[illegible]	0.097	——
	——	17.2	0.9	0.073	[illegible]	0.092	——
2015.6.5	——	24.2	——	[illegible]	[illegible]	[illegible]	——
	——	19.5	——	[illegible]	[illegible]	[illegible]	——
2015.6.8	——	27.7	——	[illegible]	[illegible]	1	——
	——	22	——	0.503	[illegible]	[illegible]	——
2015.6.18	7.4	18.8	[illegible]	0.493	[illegible]	[illegible]	——
	7.5	26.9	[illegible]	0.362	[illegible]	[illegible]	——
2015.6.19	7.48	21.6	9	[illegible]	[illegible]	[illegible]	——
	7.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	——
20.15.6.30	7.36	39	8	[illegible]	——	[illegible]	34
	7.37	[illegible]	[illegible]	1.75	——	[illegible]	21
2015.7.1	7.61	[illegible]	——	[illegible]	——	[illegible]	26
	7.53	[illegible]	——	[illegible]	——	[illegible]	19
2015.7.2	7.61	[illegible]	——	[illegible]	——	[illegible]	30
	7.74	[illegible]	——	[illegible]	——	[illegible]	26
2015.8.10	7.42	[illegible]	——	[illegible]	——	[illegible]	140
	7.33	[illegible]	——	[illegible]	——	[illegible]	168
2015.8.12	8.09	21.4	——	0.094	——	[illegible]	22
	7.71	27	——	[illegible]	——	[illegible]	30

取样时间	测量参数						
	pH	COD（mg/L)	BOD_5 (mg/L)	NH_3-N (mg/L)	TN (mg/L)	TP (mg/L)	TSS (mg/L)
	8.1	16.3	——	1.11	——	0.155	16
	8.09	17.5	——	0.9	——	0.135	26
	8.06	23.7	——	0.681	——	0.174	11
2016.3.14	8.5	15.8	——	0.124	——	0.131	30
	8.41	13.3	——	0.068	——	0.127	12
	8.57	18.2	——	0.42	——	0.19	12
	8.31	14.1	——	0.491	——	0.16	18
2016.3.25	9.29	29.3	——	0.786	——	0.274	41
	9.17	26	——	0.283	——	0.176	38
	9.05	28.4	——	0.411	——	0.219	71
	9.12	29	——	0.335	——	0.274	56
2016.3.28	8.59	17.7	——	0.511	——	0.122	35
	8.87	12.8	——	0.153	——	0.114	30
	8.8	16.5	——	0.499	——	0.098	34
	8.82	19.8	——	0.479	——	0.21	41
2016.3.31	8.48	16.7	——	0.257	——	0.113	8
	8.60	18	——	0.205	——	0.108	12
	8.58	13.5	——	0.619	——	0.129	10
	8.68	15.5	——	0.28	——	0.157	19

I类	
II类	
III类	
IV类	
V类	
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So Proud of it

Case Study: Jiangsu University Campus

Applying Advanced Bioretention System to Clean Yudai River

The Source of Yudai River – Mengjiawan Reservior

Project Description：

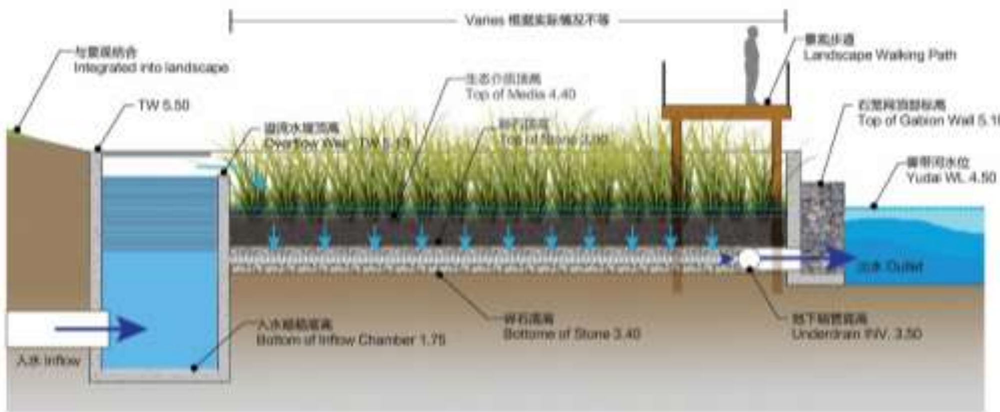
Yudai River is a small stream originates from Mengjiawang Reservior, passing through Jiangsu University Campus before entering to Yangtze River. Due to urbanization and nonpoint source pollution, the reservoir is polluted, very eutrophicated and a lot of algae. This project utilizes stormwater runoff as resource to increase reservoir's environmental capacity by treating the runoff using Advanced Bioretention System. The reservoir is also a storage for extreme storm event.

Section passing through Jiangsu University Campus

Upstream

Yudai River

Advanced Bioretention System (ABS)



Gravity Swale Section

Advantages：

1. Treating runoff as well as reservoir water as needed to remove 95% of TSS;
2. It was designed for gravity flow;
3. Landscape can be added to ABS；
4. Habitat was created.

CHINESE LITERATURE LOADING EMCs 国内研究中对污染物负荷EMCs的取值						
Mean of 20 studies	TSS	COD	TP	NH4-N	TN	Other N
Mean inflows平均入水浓度	**147**	**194**	**1.25**	**24.1**	**27.2**	**3.01**
Mean Outflows平均出水浓度	**72**	**108**	**0.83**	**13.7**	**15.1**	**1.48**
Percent Removals 移除率	51%	44%	33%	43%	44%	51%

SATURATED VERTICAL FLOW CONSTRUCTED WETLAND LITERATURE 重力流湿地对污染物去除率						
Mean of 16studies	TSS	COD	TP	NH4-N	TN	NO3-N
Percent Removals 移除率	>90%	83%	58%	73%	51%	68%

Yudai River

After

Before

Under
Construction

Mengjiawan
Reservior

Mengjiawan Reservior

Advanced Bioretention System (ABS)

Yudai River in Jiangsu University Campus

Advanced Bioretention System (ABS)