Redrawing Grey Cities to Climate Resilient Sponge Cities

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Rapid Urbanization in China

Shanghai

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, Chongqing, 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
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 km²

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
Project Overview

**Project Scope:** Assess and plan stormwater management retrofits for 22 km² 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
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
Landuse
Delineation of a Neighborhood
Drainage Sub-Basins
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

<table>
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<tr>
<th>No</th>
<th>Basin</th>
<th>boundary</th>
<th>area (km²)</th>
<th>Drainage</th>
<th>Receiving water</th>
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<tbody>
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<td>金山湖</td>
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</table>
Build a Resilience and Aesthetic Landscape in an Old Ultra Dense Residential Community

There are hundreds of communities within 22 km²
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
For decades there was no maintenance. The pavements in the neighborhood were damaged. Many green spaces were destroyed.
The garbage were dumped into landscape sites.
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

- **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.
**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
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Volume (hectare-m)</th>
<th>Depth (mm)</th>
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<td>Runoff Quantity Continuity</td>
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<tr>
<td>Initial LID Storage</td>
<td>0.022</td>
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<tr>
<td>Total Precipitation</td>
<td>0.413</td>
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<td>Evaporation Loss</td>
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<td>0.000</td>
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<td>Infiltration Loss</td>
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<td>Surface Runoff</td>
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<td>Final Surface Storage</td>
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<td>Continuity Error (%)</td>
<td>0.160</td>
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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)
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:

<table>
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<tr>
<th>Rainfall (mm)</th>
<th>Peak rainfall (min)</th>
<th>Peak runoff (min)</th>
<th>Runoff Volume (m³)</th>
<th>Peak runoff (m³ /s)</th>
<th>Runoff Coefficient</th>
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<td><strong>Before</strong></td>
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<td></td>
<td>598</td>
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<td>40</td>
<td>50</td>
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<tr>
<td><strong>After</strong></td>
<td></td>
<td></td>
<td>198</td>
<td>0.07</td>
<td>0.28</td>
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<tr>
<td>37.5</td>
<td>40</td>
<td>50</td>
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*72% runoff volume reduction*
### 10YRS-24HR径流控制效果对比图

#### 模型模拟

<table>
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<tr>
<th></th>
<th>Rainfall (mm)</th>
<th>Rainfall peak (min)</th>
<th>Runoff peak (min)</th>
<th>Runoff Volume (m³)</th>
<th>Runoff peak (m³ /s)</th>
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<tr>
<td>Before</td>
<td>175.0</td>
<td>1115</td>
<td>1120</td>
<td>2810</td>
<td>0.30</td>
<td>0.85</td>
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<tr>
<td>After</td>
<td>175.0</td>
<td>1115</td>
<td>1125</td>
<td>1290</td>
<td>0.17</td>
<td>0.40</td>
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**Volume Reduction 54%, Peak Reduction 43%, Peak shifting**
30yr-24h:

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<tr>
<th></th>
<th>Rainfall (mm)</th>
<th>Rainfall peak (min)</th>
<th>Runoff peak (min)</th>
<th>Runoff volume (m³)</th>
<th>Runoff peak (m³/s)</th>
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<td>1115</td>
<td>1120</td>
<td>3600</td>
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<td>1125</td>
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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
Post Construction
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)
WTS: 2400m², Capacity: 25,000m³/d, TSS removal: 119.9t/yr, 97% removal rate
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

CMIE International
EFFECT DISPLAY
EFFECT DISPLAY
EFFECT DISPLAY
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 m³ for 1” rainfall. The channel had no habitat due to worse water quality, and it smelled terrible during storm events.
Fix it (Design)
Construction
Water Quality Channel In Zhenjiang
Water Quality Channel In Zhenjiang

Water Quality Before

Water Quality After

<table>
<thead>
<tr>
<th>取样时间</th>
<th>pH</th>
<th>COD (mg/L)</th>
<th>BOD₅ (mg/L)</th>
<th>NH₃-N (mg/L)</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
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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 Reservoir

Project Description:
Yudai River is a small stream originates from Mengjiawang Reservoir, 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.
**Yudai River**

**Advanced Bioretention System (ABS)**

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.

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<thead>
<tr>
<th>CHINESE LITERATURE LOADING EMCs</th>
<th>国内研究中对污染物负荷EMCs的取值</th>
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<td>Mean of 20 studies</td>
<td>TSS</td>
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<td>Mean inflows平均入水浓度</td>
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<tr>
<td>Mean Outflows平均出水浓度</td>
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<td>Percent Removals 移除率</td>
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<td>Percent Removals 移除率</td>
<td>&gt;90%</td>
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Yudai River

After

Before

Images showing the comparison of Yudai River before and after a project.
Under Construction
Mengjiawan Reservoir
Mengjiawan Reservoir

Advanced Bioretention System (ABS)
Yudai River in Jiangsu University Campus
Advanced Bioretention System (ABS)