大连理工大学
Dalian University Of Technology

Sponge City Construction: Case Study in Dalian

Dalian University of Technology

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Outline

1. ***Background***
2. ***Planning for flood control and drainage***
3. ***Planning for rainwater resource utilization***
4. ***Planning for Sponge City construction***
5. ***Study on the reclaimed land on islands***

Ⅰ. Background

——Frequent occurrence of flood disaster

- *639 cities have flood control missions, only 236 of the country's flood control standards are met, and **63% of the cities does not meet to the design standard***
- *Flooding events occurred in **213 cities** frequently, accounting for **62%** of the city*
- *There are **137 cities** with flooding event more than three times a year*


2012.7.21 Beijing


2013.7.19 Xiamen


2013.10.7 Yuyao


2015.8.24 Shanghai


2016.7.6 Wuhan


2017.6.11 Nanjing

The urban flood disaster is ubiquitous in China

Ⅰ. Background

——Water resource shortage

More than 400 cities in China have the water resource shortage problem, and more than 110 cities are more severe.

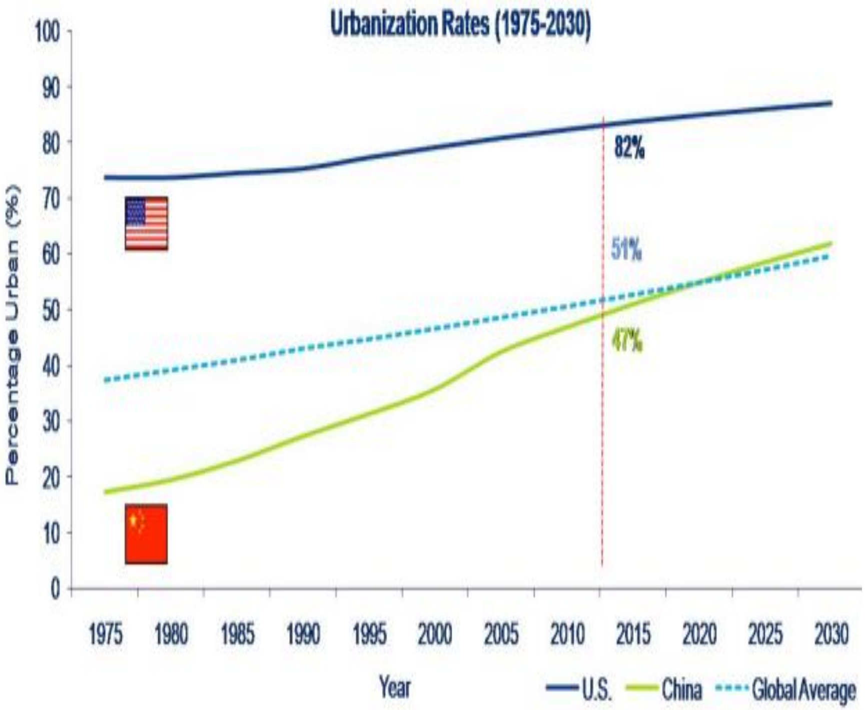
Droughts

Urban drainage causing non-point source pollution

The water shortage problem is becoming severe

Ⅰ. Background

—— Capacity of infiltration and water detention declined



- ✓ Urbanization has changed nature drainage systems

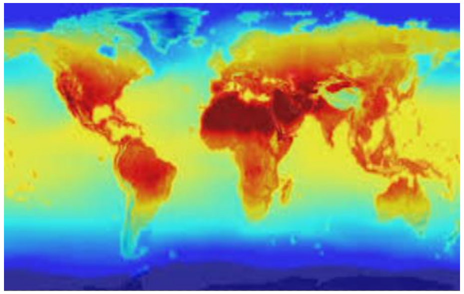
  99% of cities in china are in fast drainage pattern, which is that after the storm, the rainwater is drained immediately.

- ✓ Urbanization reduces the storage and drainage space of rivers and lakes

  Urban expansion led to the lose a large number of cultivated land, forest land, rivers ,lakes and wetlands, and the capacity of rainwater storage and control descend.

- ✓ The change of urban topography tend to flood disaster

- ✓ The urban construction destroyed the original drainage structure



The main reasons for both flood disaster and water shortage are that the capacity of infiltration, water storage, and purification declined in cities

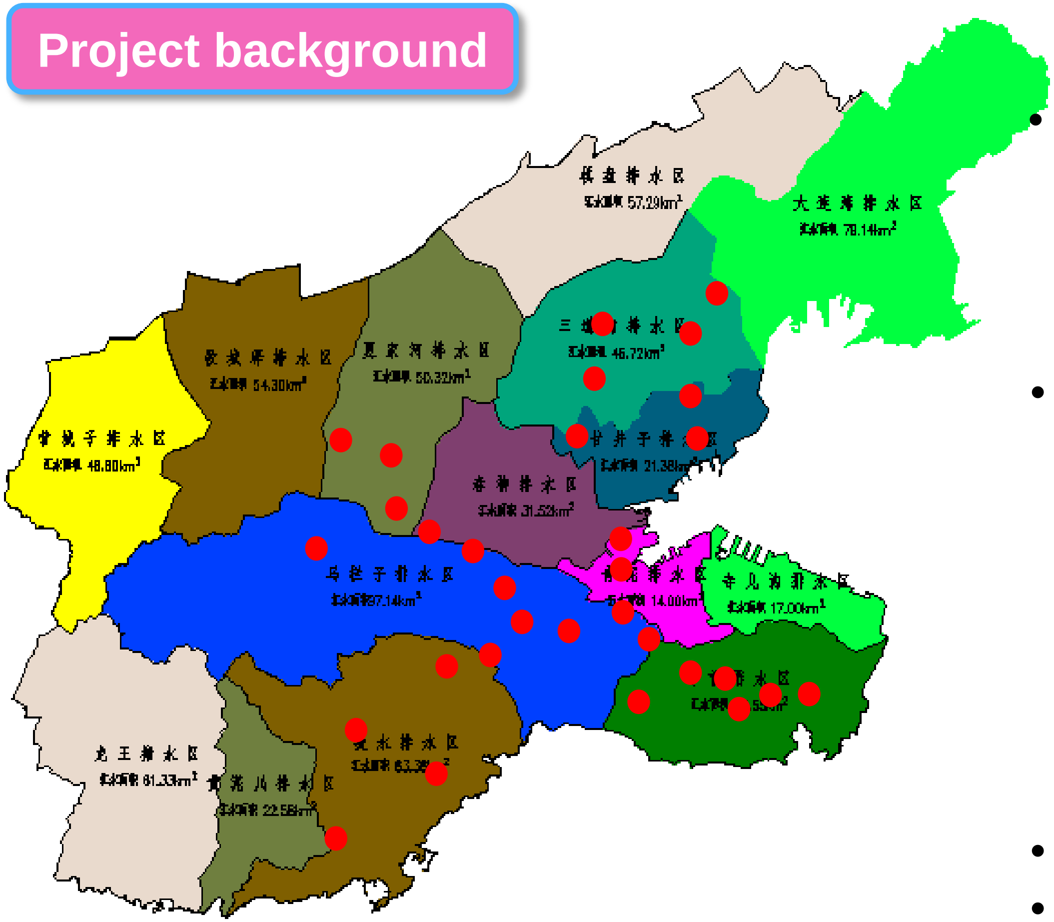
Where is Dalian?

- ***Planning for flood control and drainage in Dalian***
- ***Planning for rainwater resource utilization***
- ***Planning for Sponge City Construction***
- ***Focusing on reclamation land on islands***

Dalian is selected as one of sixteenth demonstration city at the first round!

Planning for flood control and drainage in Dalian

Project background



● **flooding areas**

Division of drainage area in central districts of Dalian

➢ River system

- *There are more than 200 rivers that are basicly seasonal rivers, and many wetlands and lakes in Dalian*

➢ Drainage basin

- *The central district area of Dalian (except Lushun and Jinzhou District), are divided into 15 drainage areas according to terrain characteristics and drainage layout. the total catchment area is 703km²*

➢ Historical flooding

- *The flooding area exists extensively.*
- *Upgrading drainage networks in critical regions, the urban flooding has been alleviated.*

Planning for flood control and drainage in Dalian

Problem analysis

- ✓ *Most of the drainage pipe network belongs to the combined system;*
- ✓ *Intercepting pipe networks are still not complete;*
- ✓ *In old districts the drainage pipes have been constructed within the low standards;*
- ✓ *With the urbanization, the proportion of impervious surface increases, which results in the increase in runoff and decrease in confluence time and thus increasing peak flows;*
- ✓ *Natural retention ponds gradually disappeared;*
- ✓ *Tend to be impacted by tidal backwater;*
- ✓ *Lack of scientific guidance when facing flush floods;*

Planning for flood control and drainage in Dalian

Project scheme

Urban drainage capacity and flooding risk assessment

- Precipitation analysis
- Underlying surface analysis
- Drainage capacity evaluation
- Flooding risk assessment

Planning for urban drainage system

- Drainage system
- Drainage partition
- Drainage network
- Ancillary facilities

Planning for urban flood control system

- Match with urban construction plan
- Integrated Water System Management
- Drainage facilities layout
- Connection with other flood control facilities

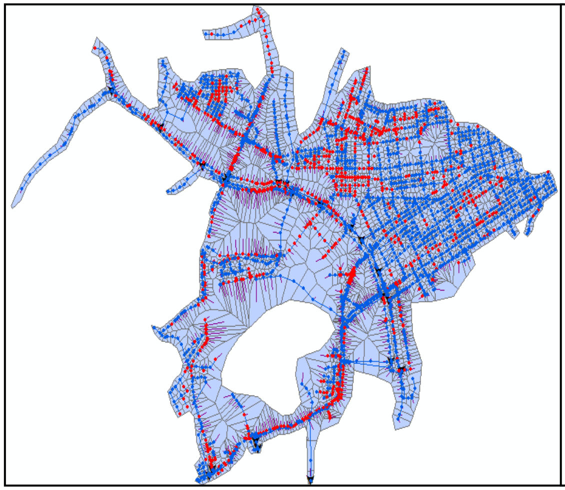
Planning for management

- System mechanism
- Communication system
- Emergency management
- save measures

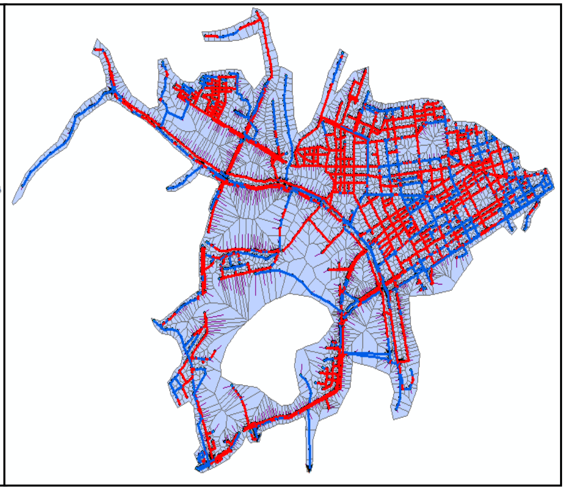
Planning for flood control and drainage in Dalian

Drainage Capacity Assessment

- *The length of pipelines which meet the rainfall recurrence period of 5 years is about 336.39 km (accounting for 42.69%);*
- *The length of pipelines which meet 3-5 years is about 31.49 km (accounting for 4%);*
- *The length of pipelines which meet 2-3 years is about 18.05 km (accounting for 2.29%);*
- *The length of pipelines which meet 1-2 years is about 37.46 km (accounting for 4.75%);*
- *The length of pipelines which meet less than 1 years is about 364.55 kilometers (accounting for 46.27%);*



node overflow



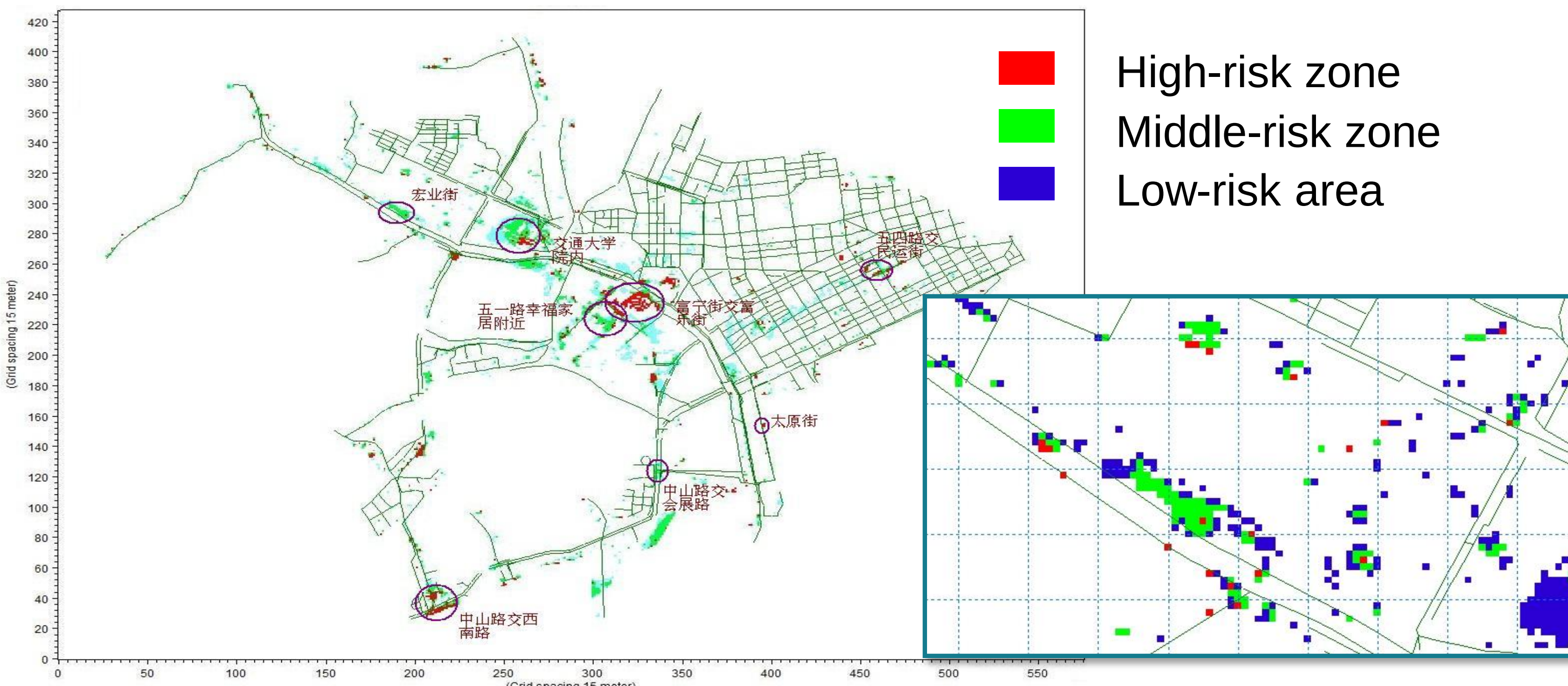
Full capacity pipes

Planning for flood control and drainage in Dalian

Flooding Risk Assessment

The risk of urban flooding occurrence is assessed in Dalian through rainfall simulation with the typical 24h rainfall pattern that occurred every 50 year.(6h)

- *High-risk zone: water depth 0.25-0.50m flooding duration 30-60min*
- *Middle-risk zone: water depth 0.50-1.00m flooding duration >60min*
- *Low-risk area: water depth >1.00m flooding duration >60min*

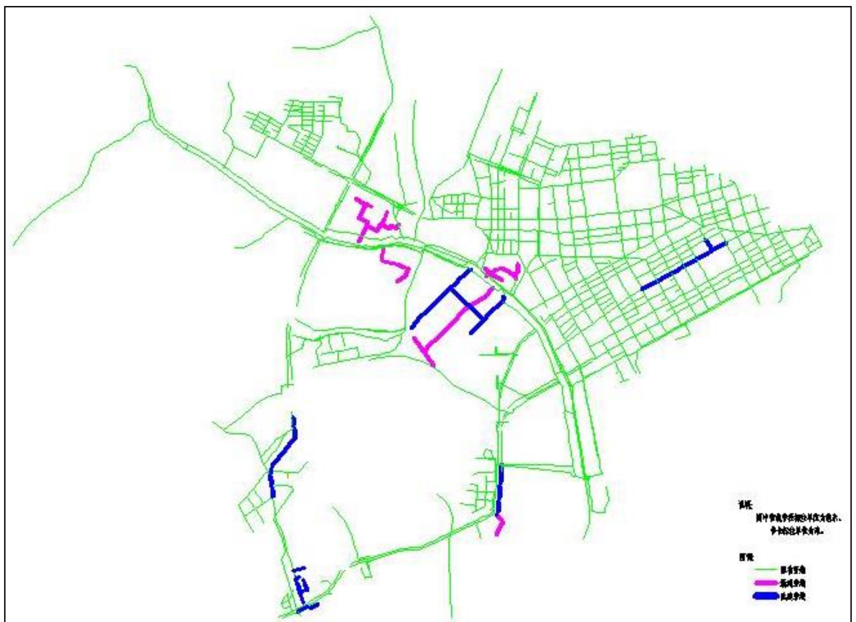


Simulation results of water risk in Malan reservoir

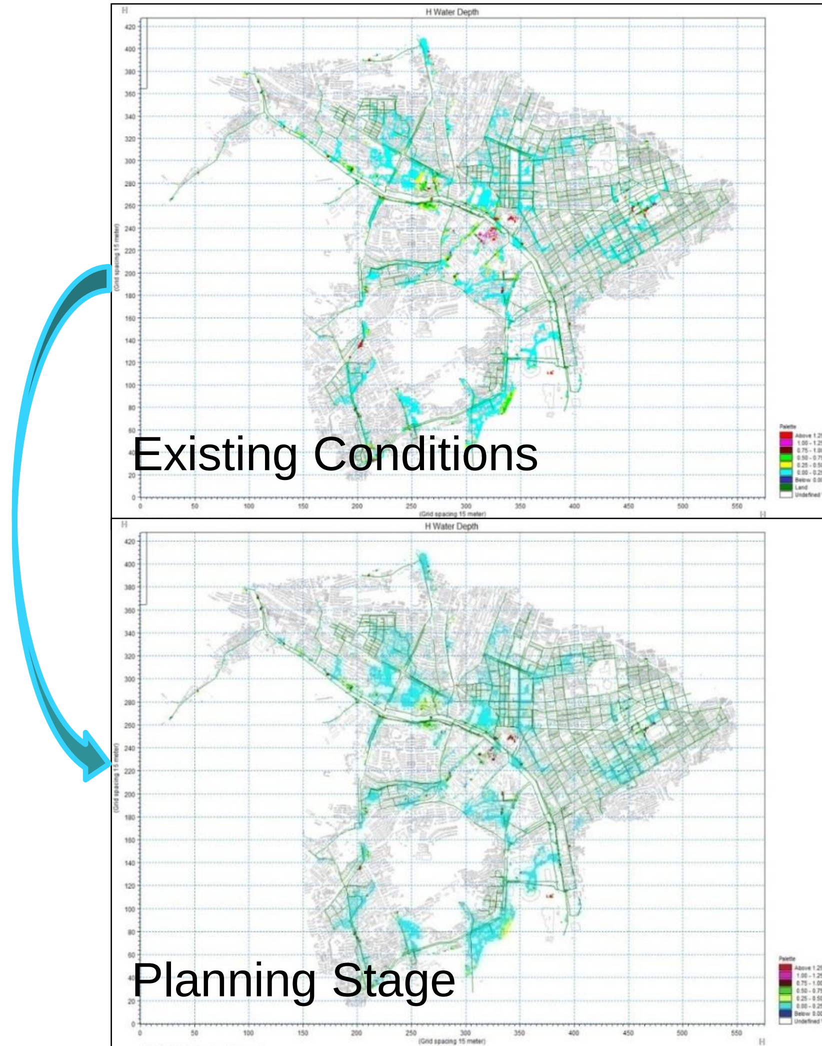
Planning for flood control and drainage in Dalian

Planning Solutions

Upgrade drainage conduit in total 15 drainage divisions and assess the risk of urban flooding.



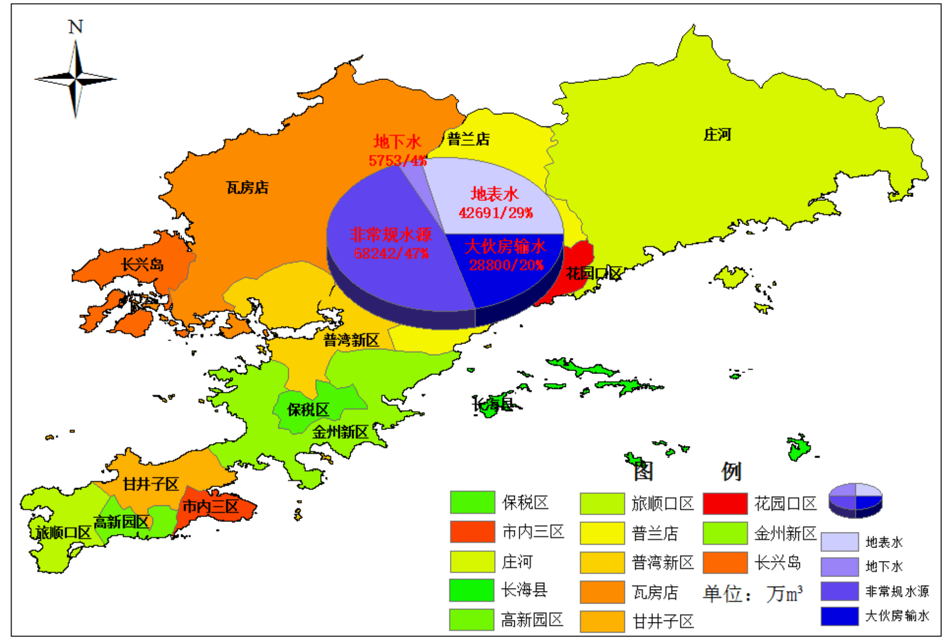
Planning for drainage network in Malan District



The water flooded area at a certain time in Malan dam drainage area

Planning for of rainwater resource utilization in Dalian

Project background



Water resource composition in Dalian

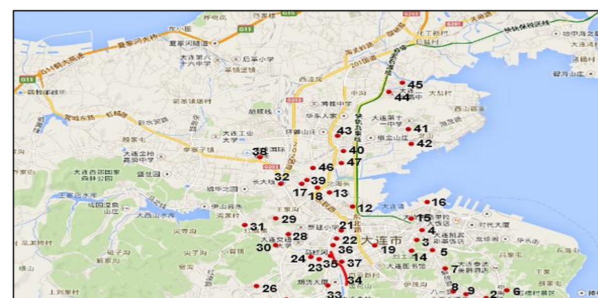
- ***Surface water*** *accounts for 29% of water supply and groundwater accounts for 3%*
- ***Non conventional water sources*** *account for 47% of the water supply*
- ***Dahuofang diversion*** *accounts for 20% of the water supply*

Water demand prediction of Dalian

- *Demand for water will be* ***1.49 billion m³*** *in* ***2020***
- *Demand for water will be* ***2.33 billion m³*** *in* ***2030***
- *In existing conditions, the volume of water shortage will be* ***400 million m³*** *in 2030*

Seawater intrusion

Non-point pollution



flooding risk

III. Project introduction

Planning for utilization of rainwater resource in Dalian

Research features

CITY

Main objective：
Water Pollution reduction
Main scope：
Waterscape
Main target：
Improve the utilization ratio of rainwater resources

COUNTRYSIDE

Main objective：
rainwater harvesting
Main scope：
Aquaculture and Irrigation
Main target：
Reduce the use of ground water

ISLAND

Main objective：
rainwater harvesting
Main scope：
Domestic water
Main target：
Improve the utilization ratio of rainwater resources

Planning for utilization of rainwater resource in Dalian

Project Scheme

Background and goals

CITY

COUNTRYSIDE

ISLAND

- Analysis of the **current utilization** of rainwater resources
- Analysis of the **exploitation potential** of rainwater resources
- Selection of typical research area
- Recommendation for appropriate measures of rainwater use
- Measures combination and optimization
- Evaluation for effect of rainwater use

Simulation

Critical measures analysis
Modeling
Parameter calibration

Evaluation

Benefits assessment
Integration assessment
Technical assessment

Planning for utilization of rainwater resource in Dalian

Modeling

- **Evaluation for exploitation potential of rainwater resources**

Total rainwater resources $R_1 = \mathrm{P} \times \mathrm{A} \times 10^3$

Theoretical exploitation potential of rainwater resources $R_2 = \varphi \times R_1$

Practical exploitation potential of rainwater resources $R_3 = \alpha \times \beta \times R_2$

R_2: Total volume of rainwater resources（m^3）, P：Precipitation yearly（mm）,

A: Coverage area by land type（km^2）

φ：Runoff coefficient α：Seasonal delay rate β：Initially reduced flow coefficient

- **Evaluation for rainwater harvesting scale**

methods

Daily regulation calculation

Water balance law

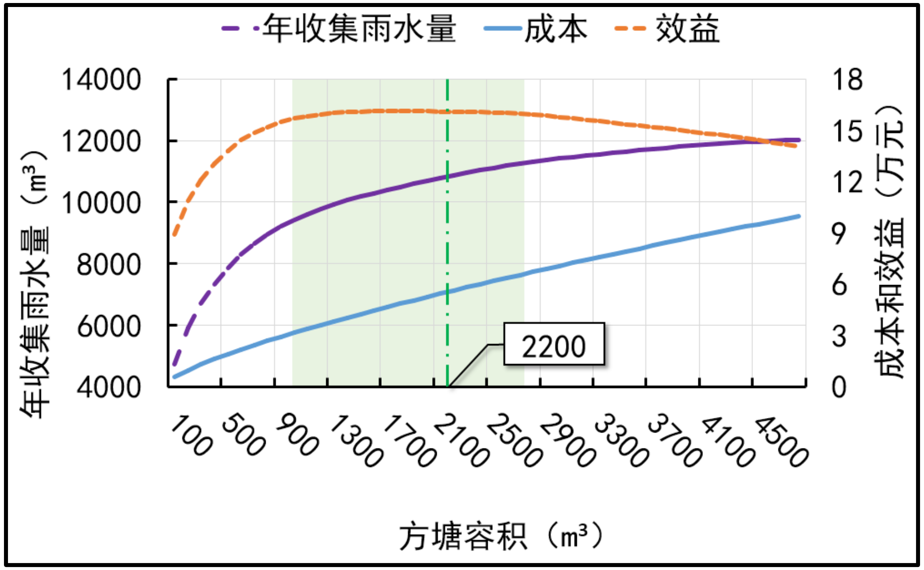
$$V_{initial}+V_{inflow}+V_{supplement}-V_{use}=V_{end}+V_{release}$$

Planning for utilization of rainwater resource in Dalian

Countryside Results

Aquaculture water

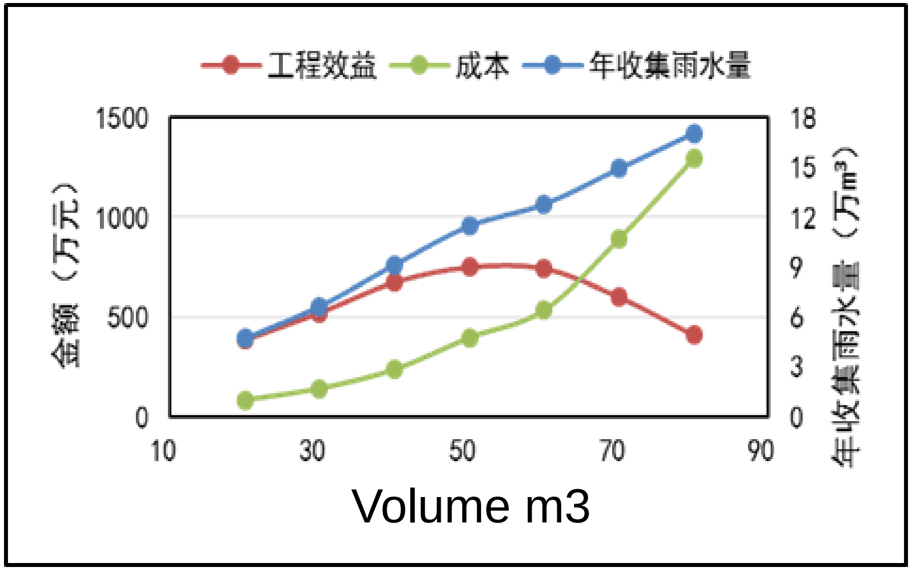
The rainwater that is used for aquaculture is collected by ponds



- *When volume of pond reaches to 2200 m^3, the pond can collect 543,000m^3 yearly, with meeting 39% of water demand.*

Irrigation

The rainwater used for indoor farming is collected by tanks

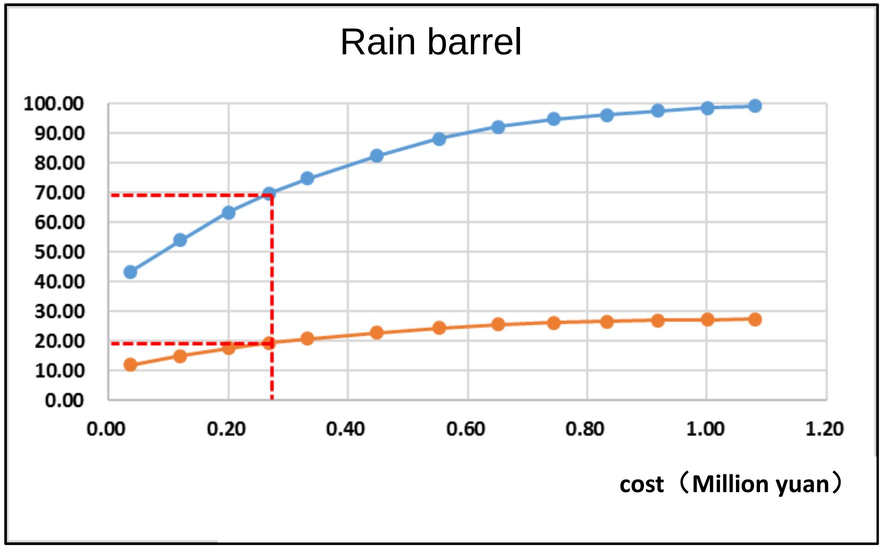


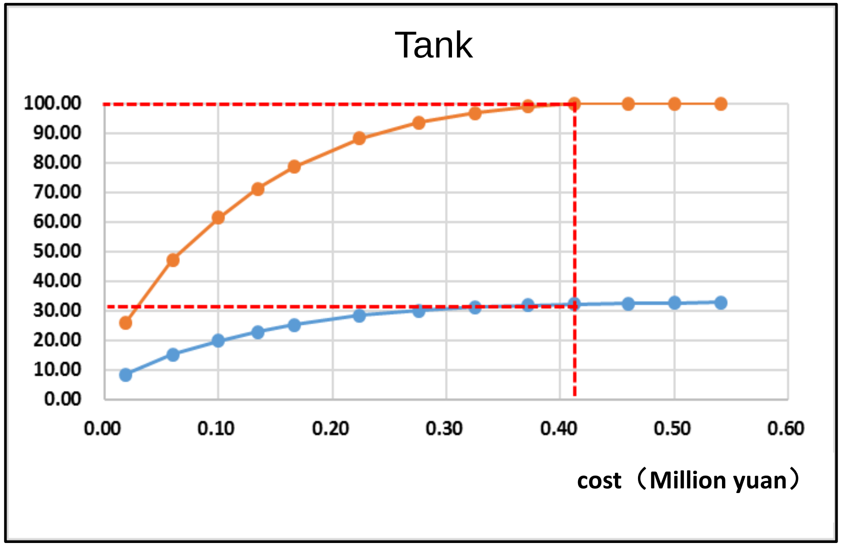
- *When volume of tank gets to 40 m^3, the reservoir can collect 114,800 m^3 yearly, with meeting 50% of water demand.*

Planning for utilization of rainwater resource in Dalian

Islands results

Percentage of demand met
Rainwater collection efficiency





- *When the volume of rainwater barrel is 1.5m³, the rainwater collection efficiency and percentage of meeting requirement increase as the cost increases, and the growth rate slows down.*
- *When the volume of the tank is 2.5m³, the rainwater collection efficiency and percentage of meeting requirement increase as the cost increases, and the growth rate slows down.*

Planning for Sponge City Construction in Dalian

Problems and background

Water resource

- *Low rate of rainwater utilization*
- *Lack of water reuse facilities*
- *Use of reclaimed water is low*
- *Lack of scientific guidance*

Water security

- *The drainage system is not sufficient for the changing conditions.*
- *Old city has lower elevation in Dalian.*
- *Many prone flooding location*

Water environment

Water supply is not sufficient for the local use
The water quality of surface water is not good
Shallow groundwater pollution exists
Urban non-point source pollution is serious
The initial rainwater runoff management is not good and has high pollution concentration

Water ecology

Underground table declined
Sea water intrusion
Ecological shoreline hardening
Ecological water demand

Planning for Sponge City Construction in Dalian

Research Strategy

Water Resources

Drinking Water Safety

1.Usage of non-traditional water

2.Protection of water source

Water Security

Flood Drainage

1.Reinforce the flood control engineering

2. Increase the standard of drainage networks

Water Ecology

Water Protection

1.Ecological rehabilitation

2. Increase the rate of water surface

Water Environment

Pollution Control

1. Reduce the surface pollution

2. Detailed pollution contrlol

Big Sponge
Flood Control

→

Medium Sponge
Flood Drainage

→

Small Sponge
Surface Pollution Control

Planning for Sponge City Construction in Dalian

Zone Decomposition

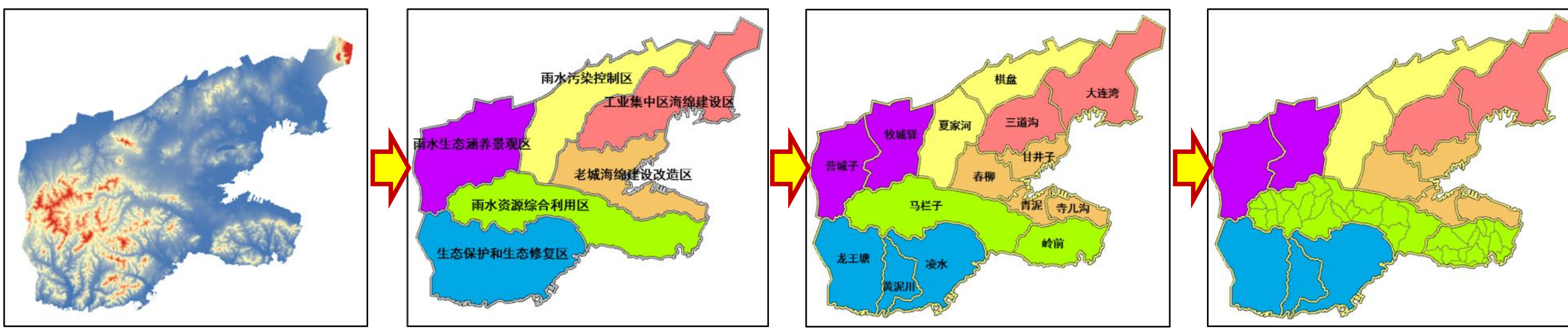
- Urban physical geography
- Quality of urban water environment
- Risk of flood disaster
- Construction standard
- Improvement condition

Hydrological characteristics

Drainage basin division

Regional water ecology sensitivity

Spatial pattern of natural ecology

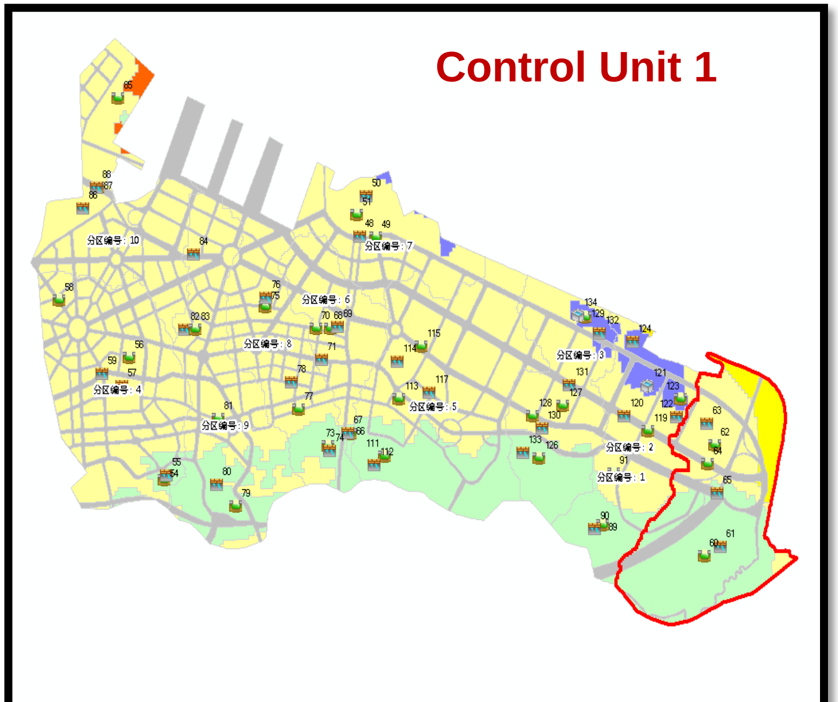


Planning **Function positioning** **Catchment area division**

Planning for Sponge City Construction in Dalian

Design

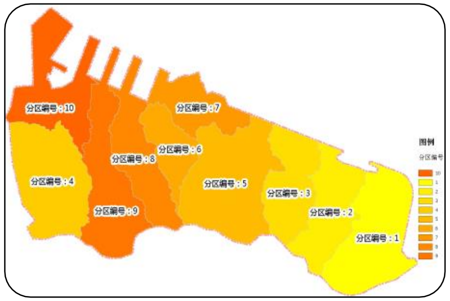
Select the control units in Siergou area as a representative
Implement the LID measures for various land-use types
Total annual runoff reach to 75% off



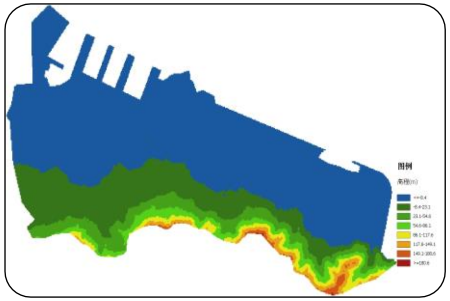
Land-use Type		Resident land	Industrial land	Greenbelt	Road	Sum
Area		467295	0	974402	383256	1824953
Rate(%)		26	0	53	21	100
Low elevation greenbelt	Installation area	46730	0	97440	38326	182495
	Rate(%)	10	0	10	10	10
Permeabale pavement	Installation area	28038	0	77952	30660	136650
	Rate(%)	6	0	8	8	7
Control rate of unit total tannual runoff		73				

Planning for Sponge City Construction in Dalian

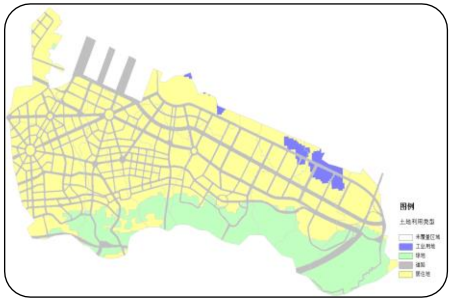
Comparison and Analysis



Control unit division

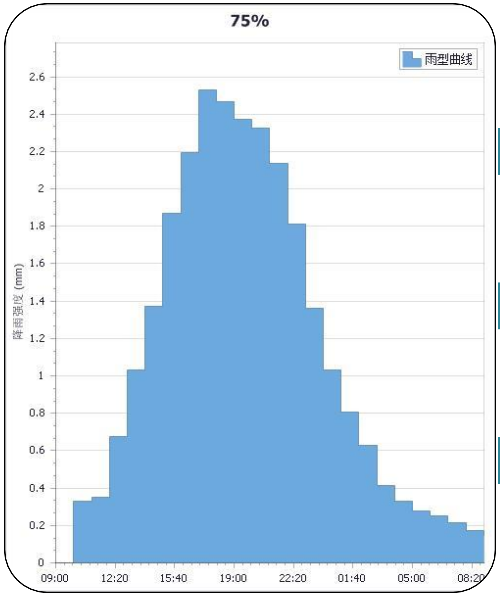


DEM elevation analysis



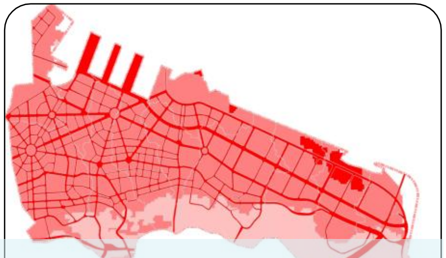
Land-use

Coupling pipe network and Drainage data



Designed rainfall

total annual runoff



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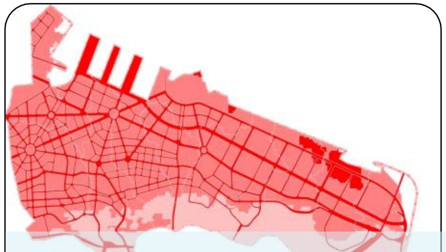

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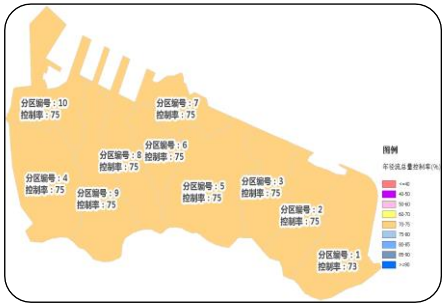
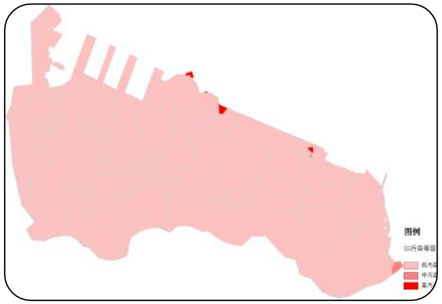




Utilization of Rainwater in artificial islands

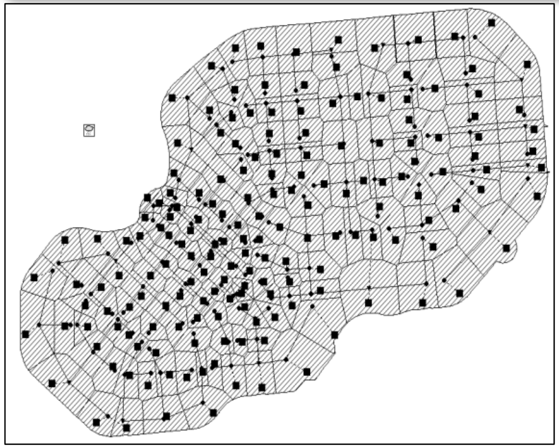
Research Background

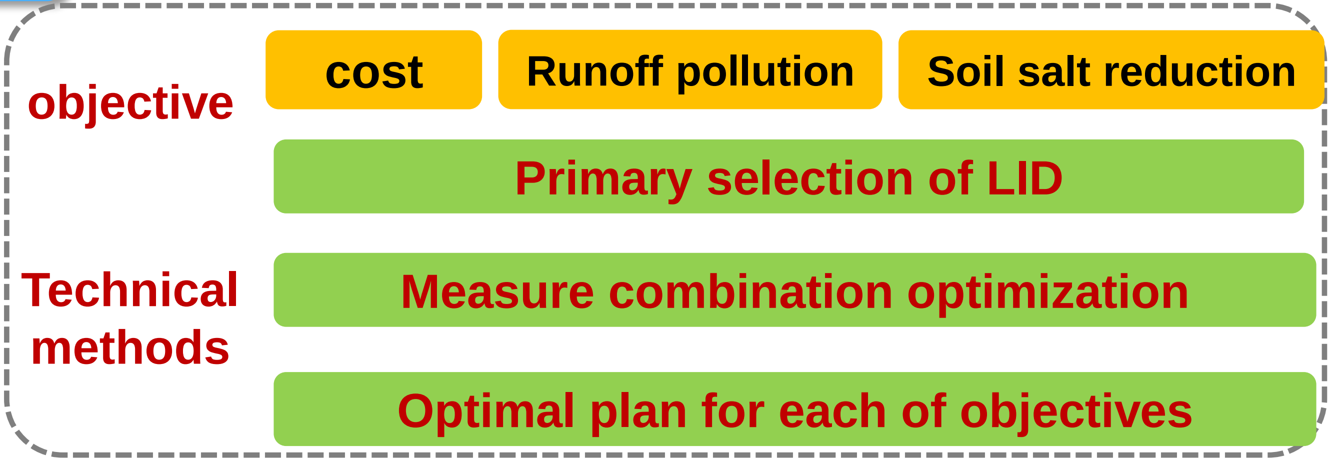
Runoff pollution + **Soil Salinization**

- **Runoff pollution**
  - The second biggest surface pollution for river quality.
  - Island runoff flows into the sea through the drainage pipes directly
  - A big threat to the ocean ecology
- **Soil Salinization**
  - The artificial island has no stable underground water table resulting in highly salinized soil
  - Trees may be risked due to high-salt soil after the artificial island is built

Utilization of Rainwater Resources in artificial islands

Research Contents





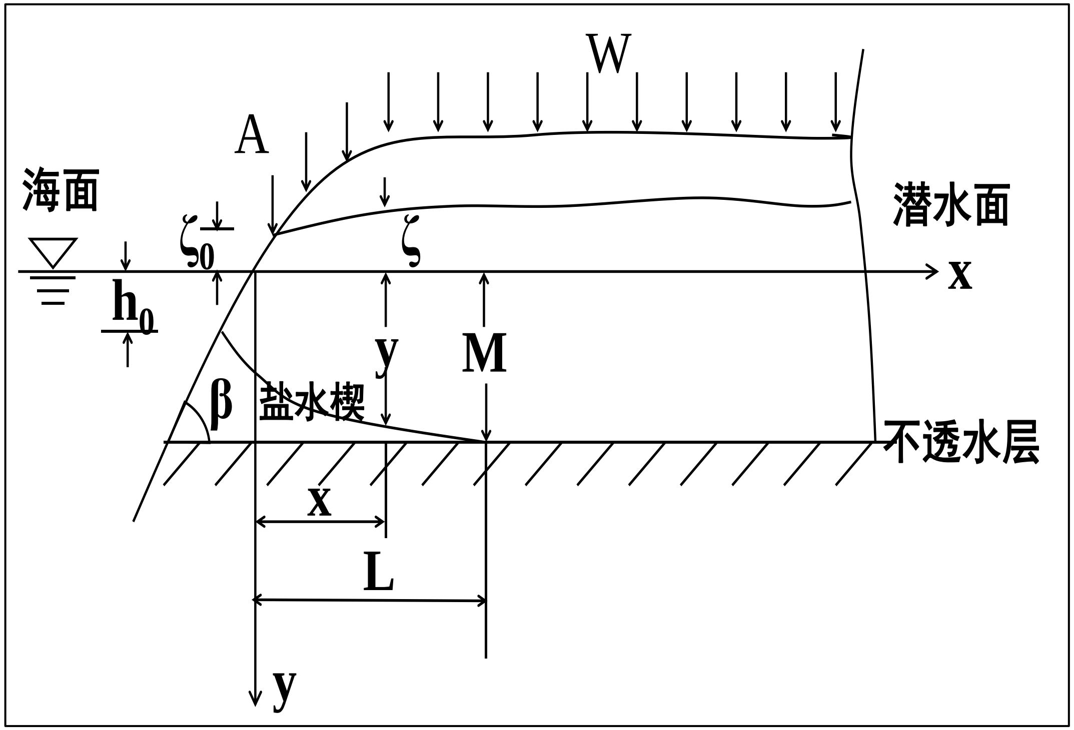
LID measures	Scope of application	Spatial demand	Maintance requirement	Gradient	Other requirements
Permeabale pavement	road	——	low	<0.01	Layout in non-mobile way
Green roof	Building community	small	low	<0.04	Small-gradient and flat roof
Low elevation greenbelt	Park and greenbelt	medium	low	<0.05	Depth of greenbelt:<0.20m
Biological detention facility	Park community	small	medium	<0.12	Distance from the building:>6m Distance from the road:<30m
Rain barrels	Building community	small	low	——	Distance from the building:<10m
Bio-swale	road	mediun	low	<0.03	Distance from the building:>3m
Infiltration ditch	road	medium	high	<0,15	Distance from the building:>6m Distance from the hardened face:>6m
infiltration pond	Park and greenbelt	medium	medium	<0.15	Distance from the water:>30m The highest water depth:<0.6m

Utilization of Rainwater Resources in artificial islands

Key content:Soil Salinization Evaluation Model

Establish the relationship between rainwater permeability and groundwater table

Analyze the relationship between rainwater infiltration and soil salinization reduction



$$y^2 = \frac{2q\rho_f^2}{K\rho_X\Delta\rho}X + 0.55\left(\frac{q\rho_f^2}{K\rho_X\Delta\rho}\right)^2$$

y: distance between the sea surface salt and fresh water interface

X: distance between the sea island and salt and coast

q:single width flow rate in any section

K:Permeability coefficient of aquifer

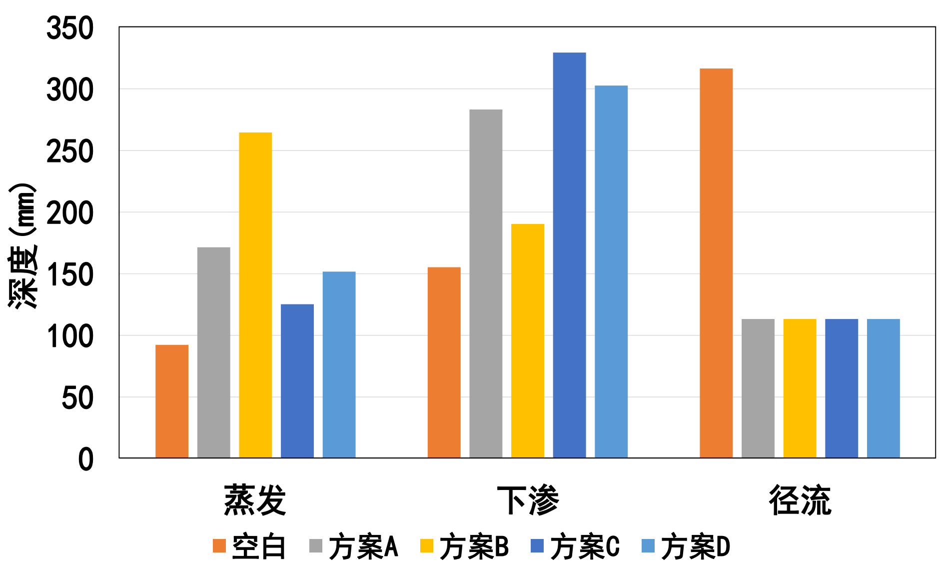
ρ_X、ρ_f **:** density of sea water and fresh water

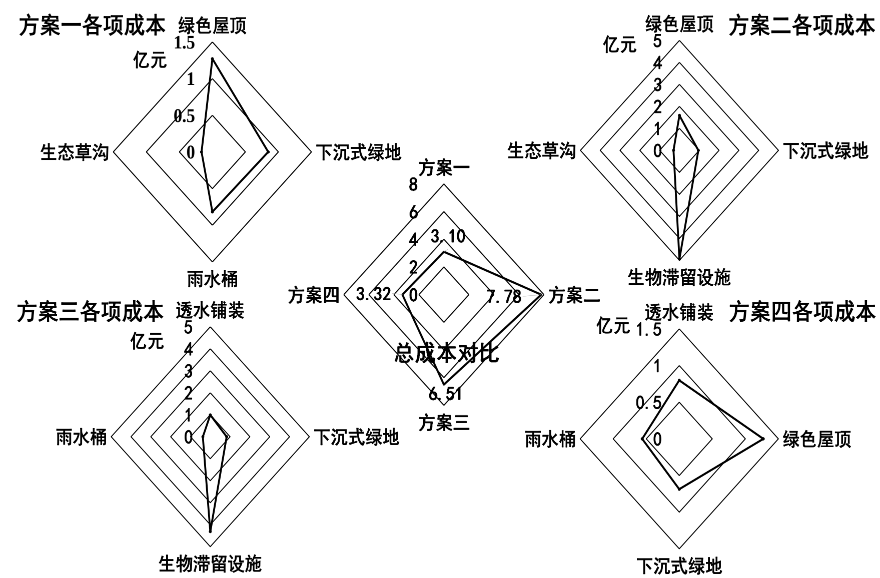
$\Delta\rho$**:** ρ_x-ρ_f , Density difference

Utilization of Rainwater Resources in artificial islands

Research results

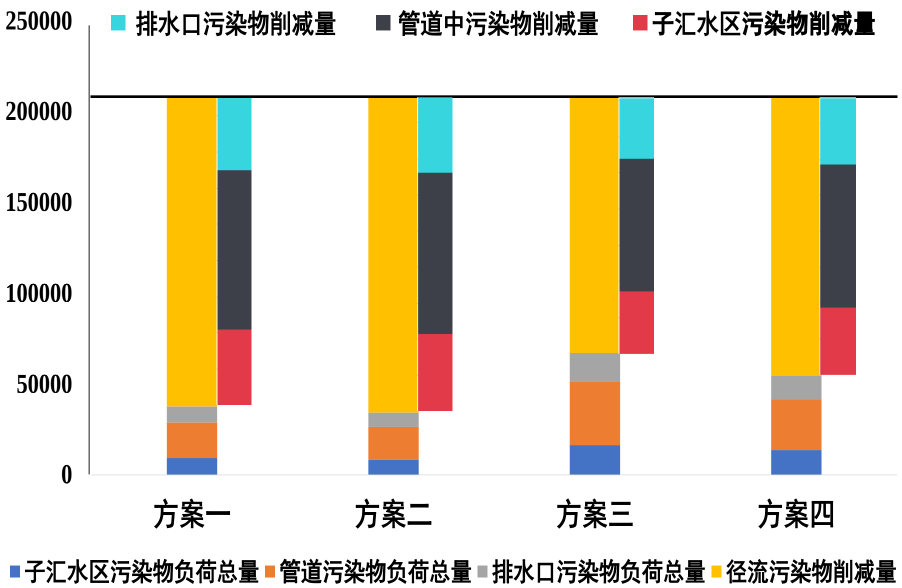
Economic Scenario 1	**Runoff reduction** Scenario 2	**Soil salt reduction** Scenario 3	**Tradeoff** Scenario 4
Green roof	Green roof	Permeabale pavement	Permeabale pavement
Low elevation greenbelt	Low elevation greenbelt	Low elevation greenbelt	Green roof
Rain barrels	Biological detention facility	Biological detention facility	Low elevation greenbelt
Bio-swale	Bio-swale	Rain barrels	Rain barrels

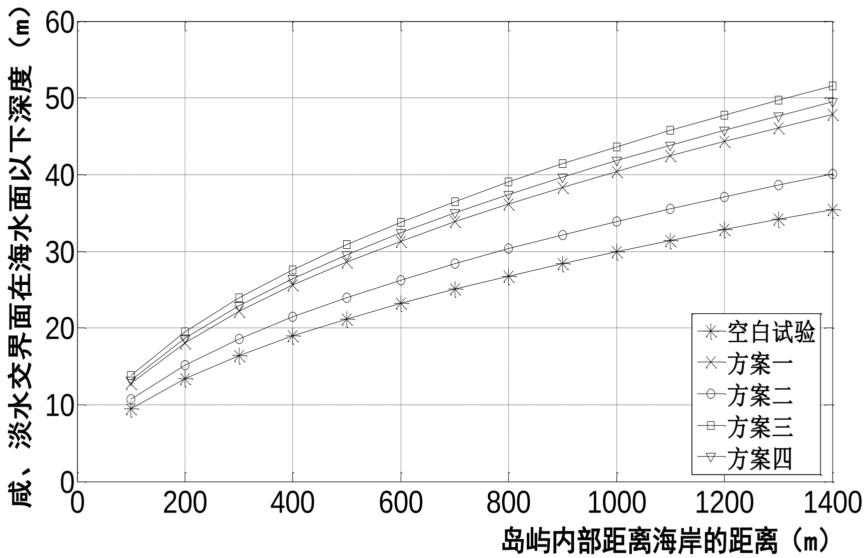




Utilization of Rainwater Resources in artificial islands

Research results





In terms of the effect of sewage control, the Scenario 2 is best and Scenario 1 is second;

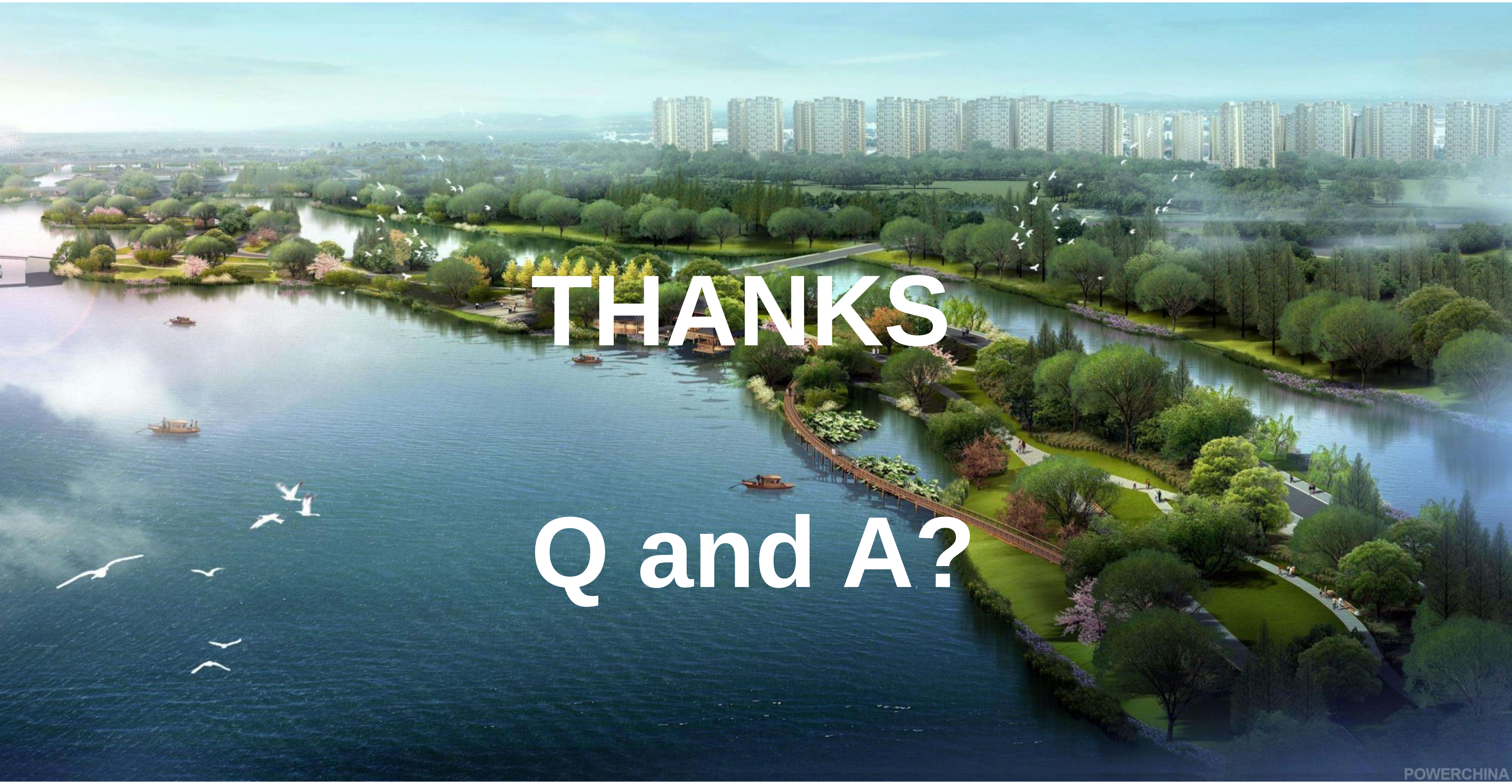
Analysis:

- *Green roof is better for reducing the pollution of roof runoff;*
- *Setting the bio-swale on both sides of road is a better measure.*

In terms of the effect of sewage control, the Scenario 3 is best and Scenario 4 is second;

Analysis:

- *Permeabale pavement is better for increasing the rain infiltration;*
- *Combine green roof with rain barrels*
- *Make full use of roof and underground space*



THANKS

Q and A?