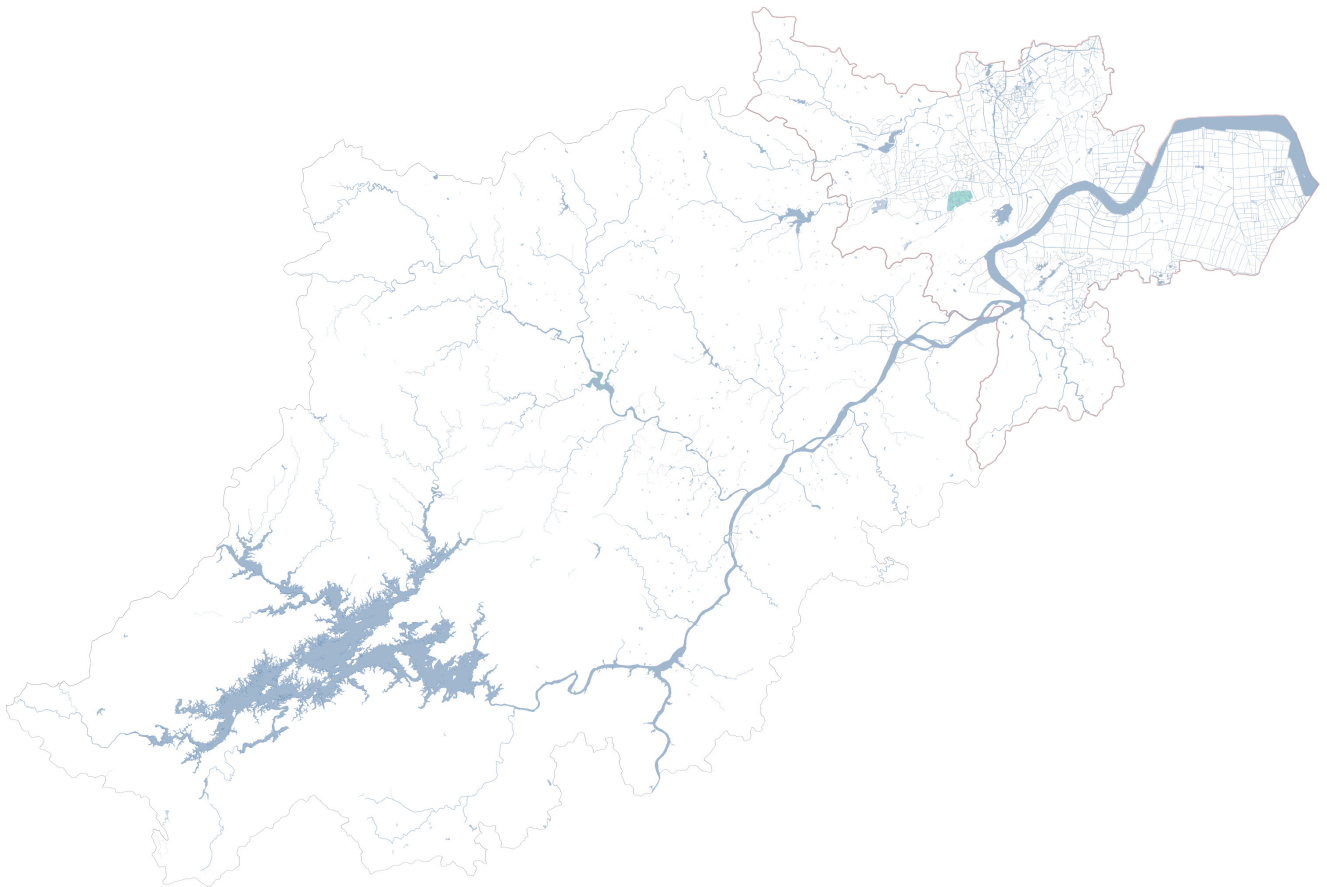


# LEARNING FROM VERNACULAR WATER- MANAGEMENT PRACTICES IN HANGZHOU 治水

**Towards a water sensitive urbanizing delta**

**Zhouyiqi Chen**

TU Delft, Faculty of Architecture, Department of Urbanism  
EMU – European Post-master in Urbanism





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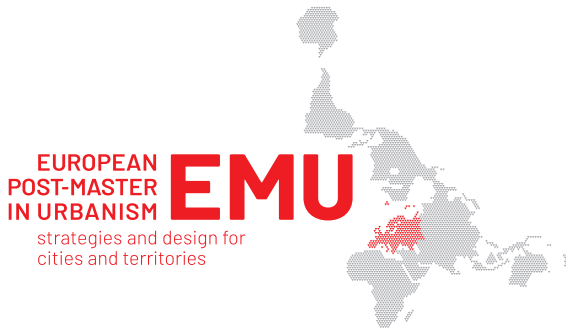
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Special thanks to Chenkun Long, for all his love and caring. Thank you for always being there for me.

Last but not least, I would like to thank the great wisdom of ancient Chinese people. Thank you all for creating these fantastic achievements of water management. I sincerely wish my thesis could contribute to remind people of the forgotten beauty.



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FIG. 1.1 River vally plain: A view like Chinese landscape painting of a fish man and his wife fishing with a wooden boat in the upstream of Qiantang River.  
Source: Mswweekly [online] available at: <http://www.mswweekly.com/show.html?id=93939> [accessed on 26 March 2018].

# Abstract

This project explores the potential of integrating the wisdom and principles of ancient water management methods in the contemporary urban context. As one of the most highly developed and urbanized delta area, Yangtze River Delta (YRD), which also has a long history dealing and/or living with water, is selected and investigated in this work. Being one of the most important cities in the YRD, the city of Hangzhou is taken as an example which presents an alternative way for future urbanism. Vernacular water-management examples in Hangzhou will be explored according to two different natural watersheds. Based on the understanding of these examples, this project intends to develop a set tool-kits, methods, and possible interventions by testing principles and lessons learned in different scales, and dealing with different conditions between the natural environment and human activities. It is expected that the results of this project will make contributions to the field of landscape urbanism in terms of combining ancient methods with up-to-date theories.

1 The story of 治水 (*Zhi Shui* water management)

2 Problem field

3 Hypothesis

4 Objective and research questions

5 Relevance



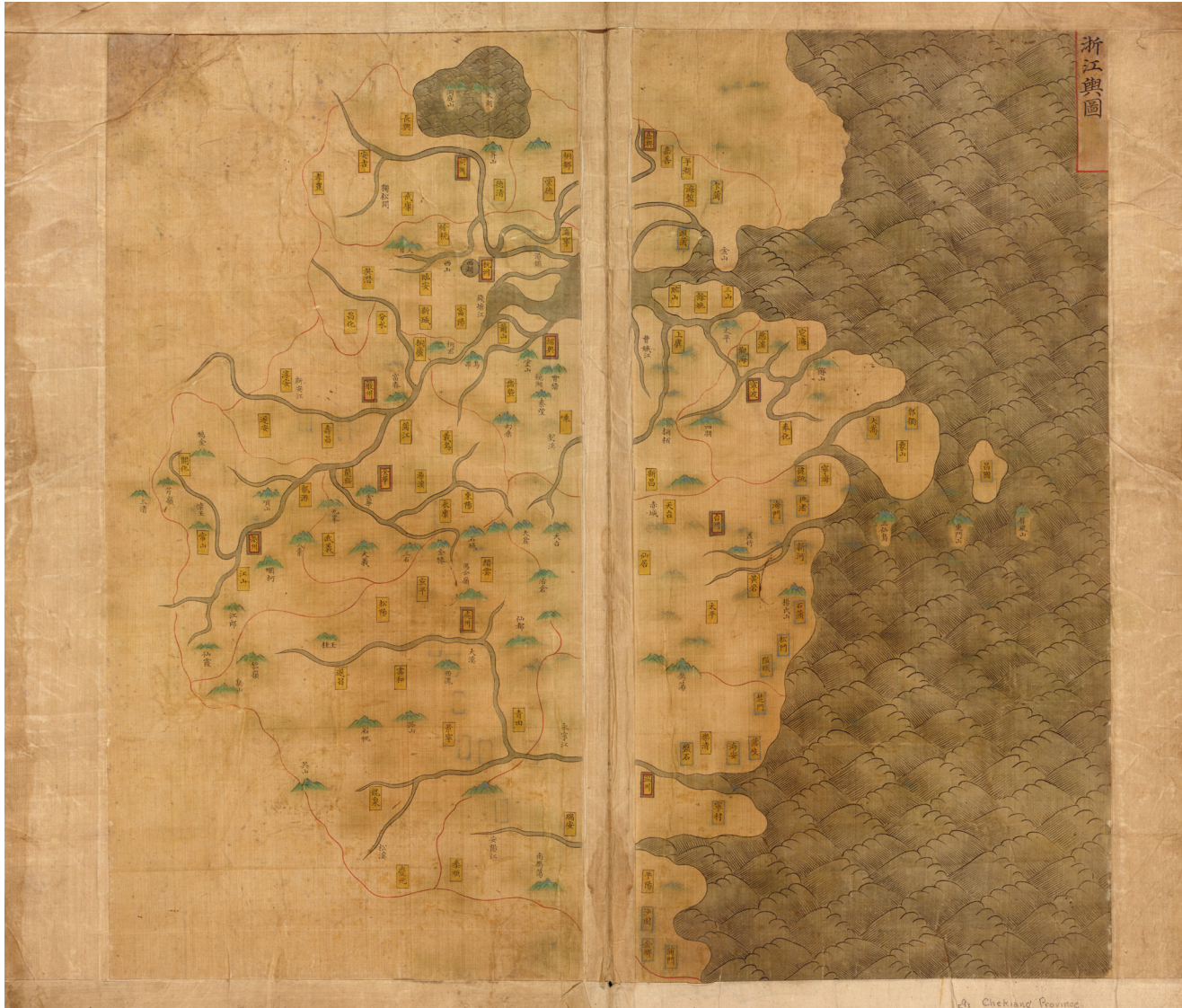


FIG. 1.1 Zhejiang Province in the Atlas of the Ming Empire (1547-1559)  
Source: Library of Congress [online] available at: <http://lccn.loc.gov/2002626776> [accessed on 13 March 2018].

# 1 – The story of 治水 (Zhishui, water management)

The Chinese language uses ideographs, from which it is possible to get a glance of shape and meaning from original objects or movement.

$$\text{治} = \text{氵} + \text{台}$$

FIG. 1.2 The composition of 治 (Zhi) in ancient font  
Source: Vividict [online] available at: <http://www.vividict.com/WordInfo.aspx?id=2241> [accessed on 20 May 2018].

The Chinese term, 治水 (Zhishui water management), means ‘preventing floods by water control’ or ‘regulation of rivers and watercourses’. It is a bit old-fashioned but was commonly used in ancient times. For instance, the first thing that is easily related to it is the famous Chinese myth about the great flood of Gun-Yu (鯀禹), which described the success of the Emperor Yu in controlling flooding by learning from failures. He first tried to use stones to block the waterway but didn’t work. After detailed field research, he finally decided to follow the natural flows of water, dredged rivers, and canals, and let water flow to big rivers and the sea. From this story, the history of Chinese people living and fighting with water also indicates the trend of learning from nature.

To look at 治水 (Zhi Shui water management) itself, it is combined two ideographs. The first one is 治 (Zhi). Its meaning in the book of 说文解字 (Shuowen Jiezi Explaining Graphs and Analysing Characters) is same as the meaning of the word 治水 (Zhi Shui water management). Moreover, the ideograph could be split into two parts, of which the left one means ‘water’ or ‘floods’ while the right means ‘elevated platform’ like dyke built from stones. The ideograph also has the meaning of ‘following the water’ which shows a respect for nature. So, in a word like 治水 (Zhi Shui water management), we can see one of the possible methods of flood defence, the main principles of learning from nature are shown.

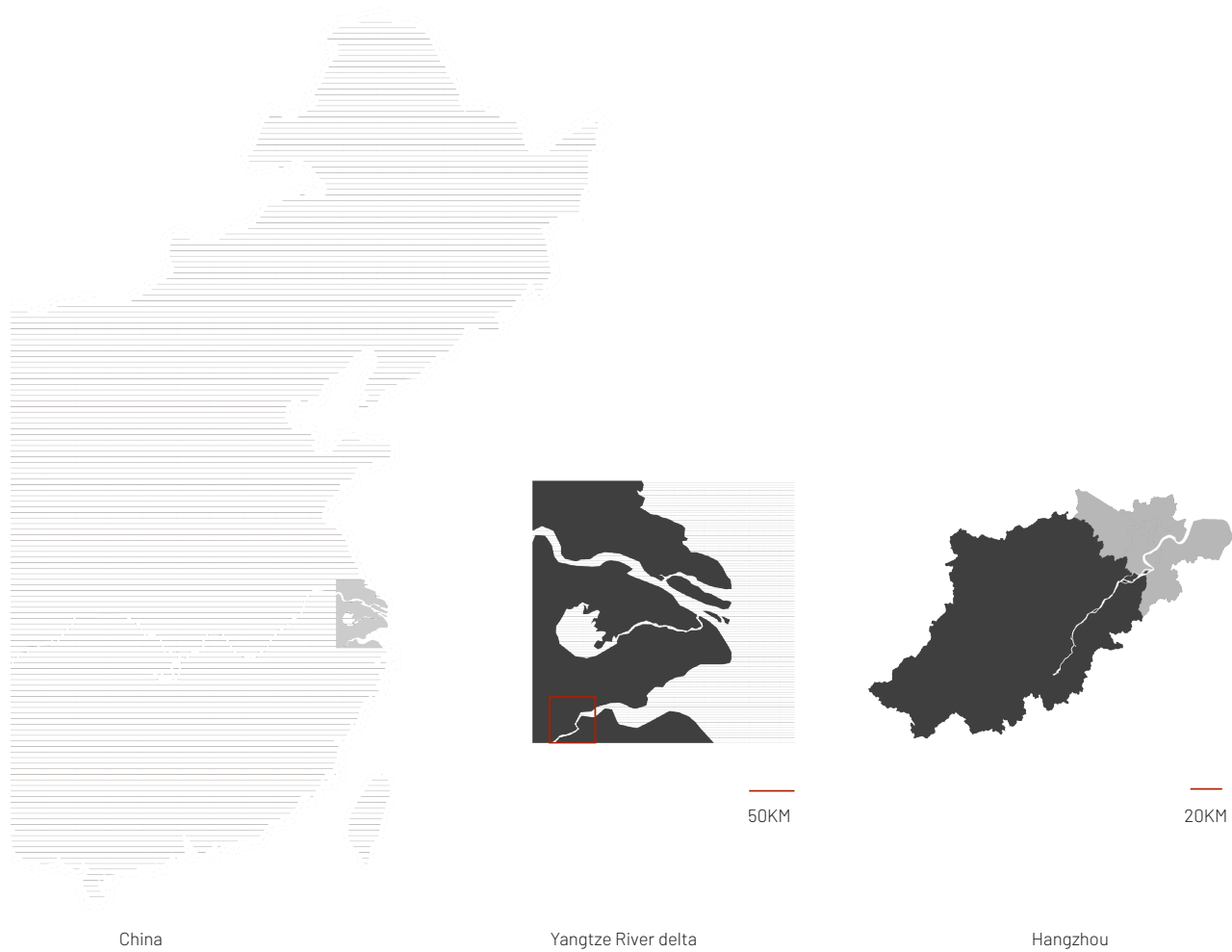


FIG. 1.3 Location of research site  
Source: author

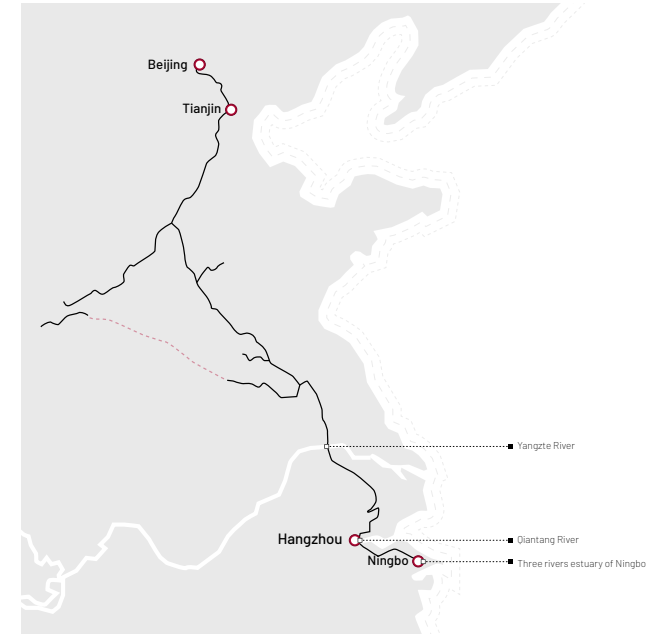


FIG. 1.4 Location of Hangzhou along the Grand Canal  
Source: author

This thesis begins with a rethinking of Chinese ancient water management methods in Hangzhou and the YRD region. In recent years, Hangzhou as a city with a long history of dealing with water is facing increasingly frequent flooding. Although the West Lake and the Grand Canal are UNESCO cultural heritage sites, their function as being main water infrastructure and water resources for thousands of years is often being forgotten and neglected. The rapid growth of economy and population shifted the way of living and relationship between human and water. This condition motivates me to further think as an urban planner or designer's role in exploring the method to improve city's water-sensitivity by looking back through ancient methods.

The research area Hangzhou locates in the southeast part of China. It sits at the head of Hangzhou Bay, which is the mouth of Qiantang River (FIG 1.3). And it is also the most important connection point in southern part of the Grand Canal, connecting Jiangnan Canal and Eastern Zhejiang Canal which goes to one of the most important ports along the coast of China, Ningbo (FIG 1.4).

The landscape around Hangzhou various from mountains, hills, river, lakes and man-made reservoirs (FIG 1.5).





**Taihu Lake**  
Third largest freshwater lake in China. It locates between two rivers. One is Yangtze River and the other is Qiantang River.

**Tianmu Mountains**  
Natural protection area. It has the head-stream of one of the source of Taihu Lake. Most important ecological patch close to the city.

**West Lake**  
UNESCO world cultural heritage. It's a freshwater lake in Hangzhou. West Lake has influenced poets and painters throughout Chinese history for its natural beauty and historic relics. It's the most important green area in the city.

**Qiantao Lake**  
Qiantao lake means it's made of thousand island. It formed after the complementation of Xian River hydroelectric station in 1959.

**Yu area**  
Yu area has dense network of waterway, field and fish ponds. It's famous for its high quality of rice and silk production.

**The Grand Canal**  
UNESCO world heritage site. The total length is 1,776 km and connects Hangzhou to the northern part of China.

**Qiantang River**  
The river and the Hangzhou Bay are known for the world's largest tidal bore.

**Reclaimed area**  
The soil is mainly salt and saline.

FIG. 1.5 Environment and significant water landscape around Hangzhou  
Source: author



2 – Problem field

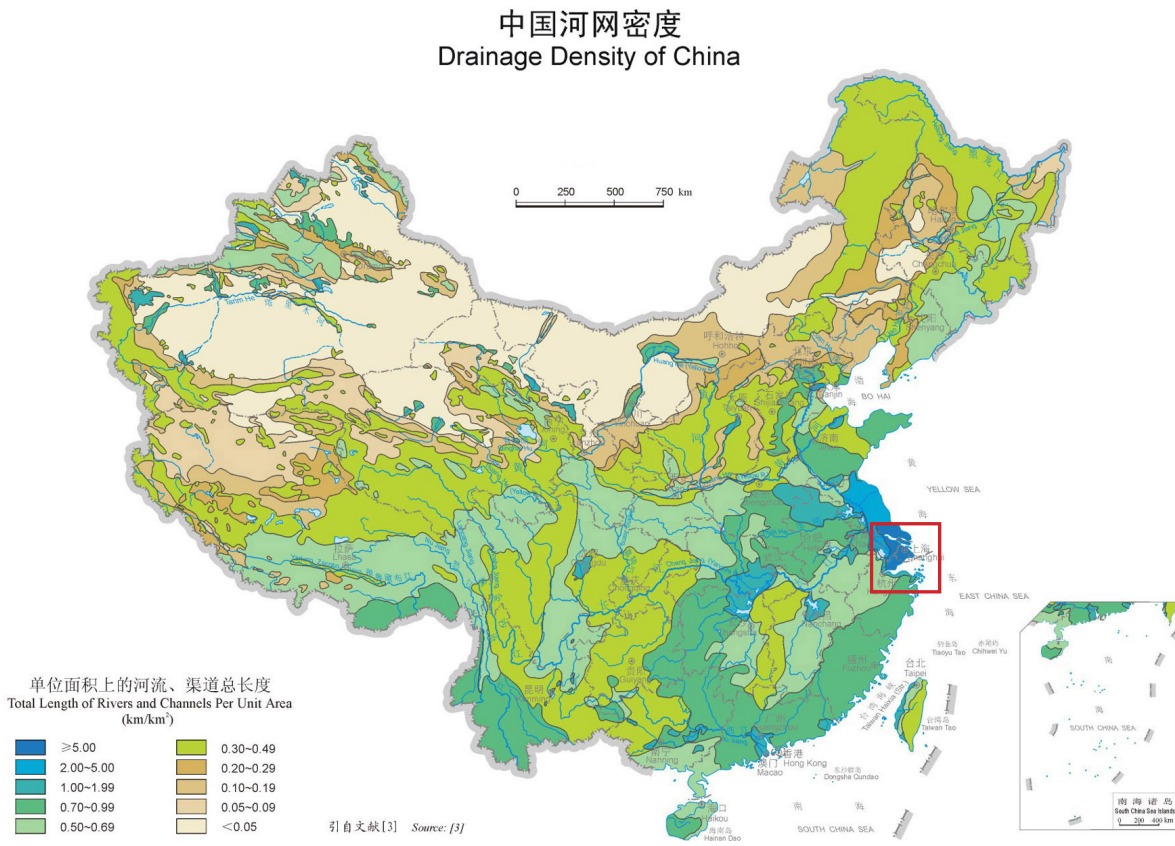


FIG. 1.6 Drainage density of China  
Source: Yearbook of Meteorological Disasters in China, 2000



FIG. 2.1 1. Typical landscape in Taihu Lake plain  
Source: Chinese National Geography [online] available at: <http://blog.mjqq.com/archives/1841.html> [accessed on 25 March 2018].  
2. Stamps of Qiantang River  
Source: Chinese Stamps [online] available at: <http://chinesestamps.info/archives/19355> [accessed on 25 March 2018].



FIG. 2.2 Diagram of height change of the plain area  
Source: author

2.1 – Problem 1: Complex environmental condition

The city of Hangzhou belongs to two main natural watersheds. The first is the area of the city centre, which is located in the northeast part of the city and is the plain area of Taihu Lake basin as a part of the Yangtze River Delta. The other is the rest part of the city, which belongs to downstream and river mouth of Qiantang River. And Hangzhou has the highest density of waterways in China (FIG 1.6).

Natural challenges and threats

The city of Hangzhou locates between the third largest freshwater lake, Taihu Lake and the river mouth of QiantangRiver. Its special location gives the city different natural challenges and threats over the years.

First, Qiantang River and the Hangzhou Bay are known for the world’s largest tidal bore. Tidal bore brings strong waves which threaten the safety of people and property, and also bring a lot of salt water which causes salinity of water and soil. Moreover, with the sand brought by waves, it’s been difficult to fully use the function of transportation along the river especially the part downstream of the river.

Second, the plain area of Taihu Lake is surrounded by hills and sand dune which causes the problem of discharging water (FIG 2.2).

Then, the subtropical monsoon climate results in the uneven rainfall along the year. The average precipitation of Hangzhou is around 1462 mm. However, 69% - 77% of it takes place from April to October. This uneven distribution of water is easy to cause floods in the wet season and drought during the dry season. Also, typhoon in the summer will bring excessive rainfall and strong wind. Apparently, a well-organized water resource management is necessary for the area.

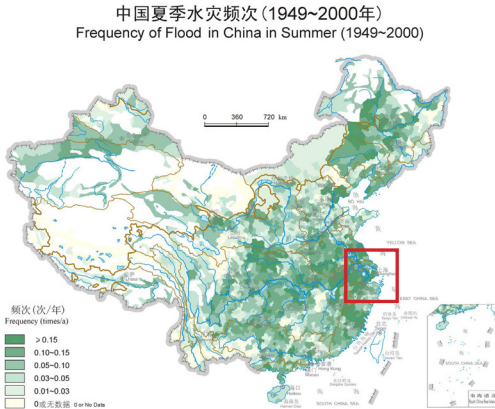
For the centre of the city, it has a high possibility of facing the water and landslide from the hilly area in the west.

As a result, Hangzhou is one of the areas with the highest frequency of natural disasters happened in the history most of which are related to water (FIG 2.3).

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FIG. 2.3 1. Frequency of flood in China in spring  
Source: Yearbook of Meteorological Disasters in China, 2000  
2. Frequency of flood in China in summer  
Source: Yearbook of Meteorological Disasters in China, 2000  
3. Frequency of flood in China in autumn  
Source: Yearbook of Meteorological Disasters in China, 2000  
4. Frequency of flood in China in winter  
Source: Yearbook of Meteorological Disasters in China, 2000

FIG. 2.4 Frequency of flood in China (500B.C. - 1980A. D. )  
Source: Yearbook of Meteorological Disasters in China, 2000

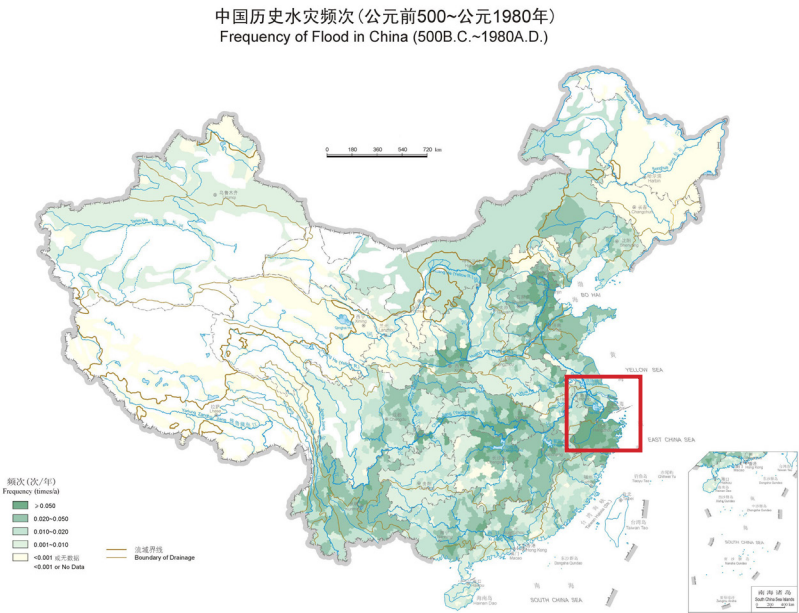
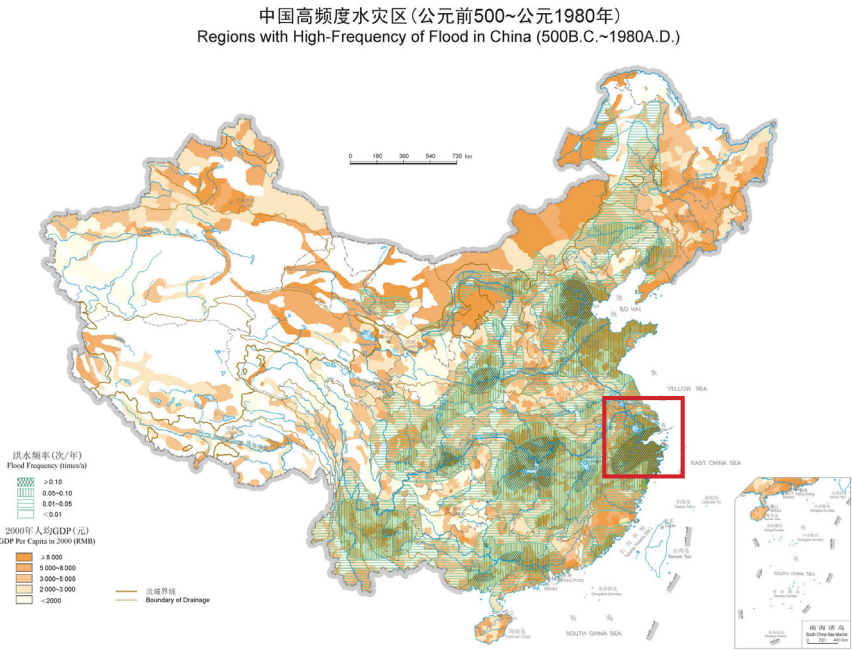


FIG. 2.5 Regions with high-frequency of flood in China (500B.C. - 1980A. D. )  
Source: Yearbook of Meteorological Disasters in China, 2000s in China, 2000





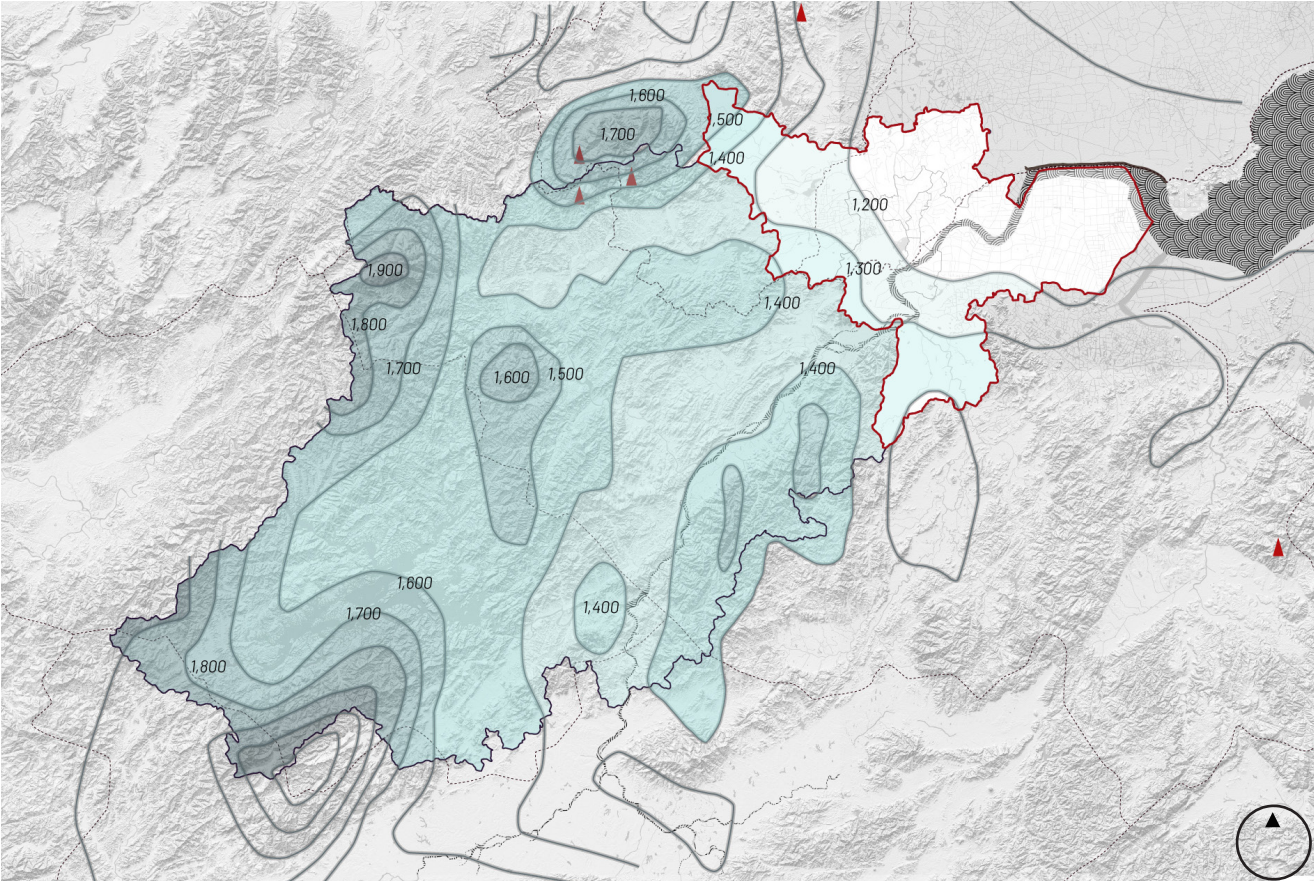


FIG. 2.6 Natural challenge and thread in Hangzhou  
Source: author based on data from Zhejiang Province about average yearly rainfall

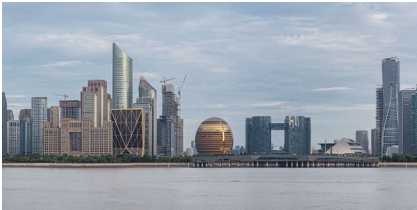
**Vernacular practices dealing with flood**

The city of Hangzhou has a long history of dealing with water issues since thousands of years ago. Around 3400-2250 B. C., The Liangzhu Cultural started to build the ancient city in the wetland environment on the plain of river networks between Daxiong Mountain and Dazhe Mountain of the Tianmu Mountain Range (FIG 2.7). There are numerous waterway entrances both inside and outside the city, linking it to the river networks. These waterways worked both for agricultural irrigation and flood defence.



FIG. 2.7 The Liangzhu Ancient City  
Source: hznews [online] available at: [http://hznews.hangzhou.com.cn/chengshi/content/2018-01/26/content\\_6783868.htm](http://hznews.hangzhou.com.cn/chengshi/content/2018-01/26/content_6783868.htm) [accessed on 25 May 2018].

Besides the initial forms of water infrastructures, such as former Eastern Zhejiang Canal, Jiangnan Canal, Xixian embankment, the West Lake and seawall started to appear after. All these water infrastructures made a huge contribution to the social and economic development of this region and turned this previous swamp area into one of the richest and most beautiful regions in China.



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- 1. Skyline of Hangzhou along the Qiantang  
Source: Studio Qi [online] available at: <http://www.qiarchitects.net/eventsinfo.php?id=78> [accessed on 25 May 2018].
- 2. High speed railway station  
Source: Urcities [online] available at: <http://www.urbcities.com/civicBuilding/20141210/13607.html> [accessed on 25 May 2018].
- 3. High risen buildings along the Grand Canal  
Source: Sina [online] available at: [http://slide.zj.sina.com.cn/slide\\_32\\_35533\\_371985.html#p=2](http://slide.zj.sina.com.cn/slide_32_35533_371985.html#p=2) [accessed on 25 May 2018].

**2.2 – Problem 2: Rapid urbanization**

Since the 1990s, a tremendous change in the population has been taking place in China. For the whole city of Hangzhou, the total population grew from 5.8 million in 1990 to 9.4 million by the end of 2017, resulting in a population density around 554 people per kilo square in spite of the rapid expansion of the urbanized area size in the meanwhile. Rapid urbanization also results in shrunk natural water bodies and increasingly fragmented natural water system in this area, where a rich history dealing with water and a close relationship with water are well-known.

**Inappropriate land use and loss of natural water network**

The city of Hangzhou belongs to the subtropical monsoon climate, and it has an uneven distribution of rainfall over the year. The concentrated periods of precipitation include Mei-yu, which usually takes place from May to July, and typhoon rainstorms, which occurs from August to October. The annual precipitation is around 1,100 mm. Moreover, due to geographical reason, the city needs to discharge the water from the hilly area in the west which is also the area with most precipitation.

People who live in this area have been maintaining a commensal relationship between water disasters, which, however, has been changed since the country has been chasing an economic development by leaps and bounds, during which the ecological environment has become one of the expendable figures. It is indicated that according to a survey among 351 Chinese cities done by the Ministry of Housing and Urban-Rural development of the People's Republic of China, 62% of these cities experienced flooding between 2008 and 2010.

Thousands of high-rise buildings were built along the main water infrastructure occupied the space for the natural water body and turned it into the asphalt with impermeability of water.

**A hard-engineered way of flooding control**

In recent forty years, a complete and concrete dyke was built along the river for 200-year flooding. Previous dense canal network in the city became narrower and shallower, losing their capacity for transportation. Some of them were canalized and the quality of water got worse and worse. As a result, the previous busy waterways became smelly and dirty rivers in the city.

With the loss of natural water network and respect of nature, the frequency of flooding is going higher and higher. As a fast and efficient way, a hard-engineered way of flooding control has been used in order to meet the demand of rapid growth of the city. It works properly in the short time. However, it is lack of resilience and the most important it demolished the most beautiful historic and cultural features of this area made the city lost its own characteristic and identity.





FIG. 2.8 (above) City growth  
Source: edited by author based on plan of Hangzhou over the years.

FIG. 2.9 (right) Population change of Hangzhou and percentage of urban population of whole China  
Source: edited by author based on data from Hangzhou statistical information net and Qinyi Zhang.

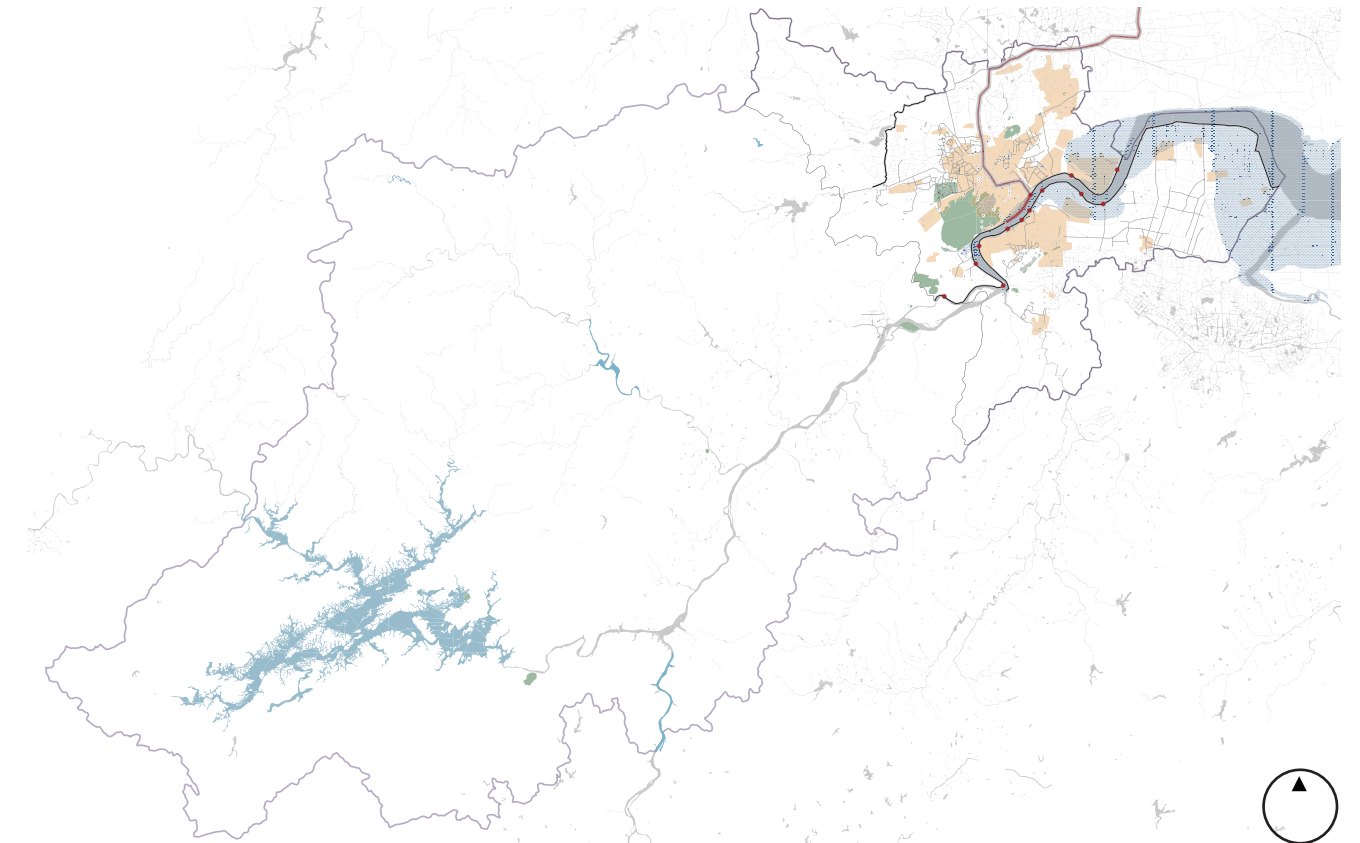
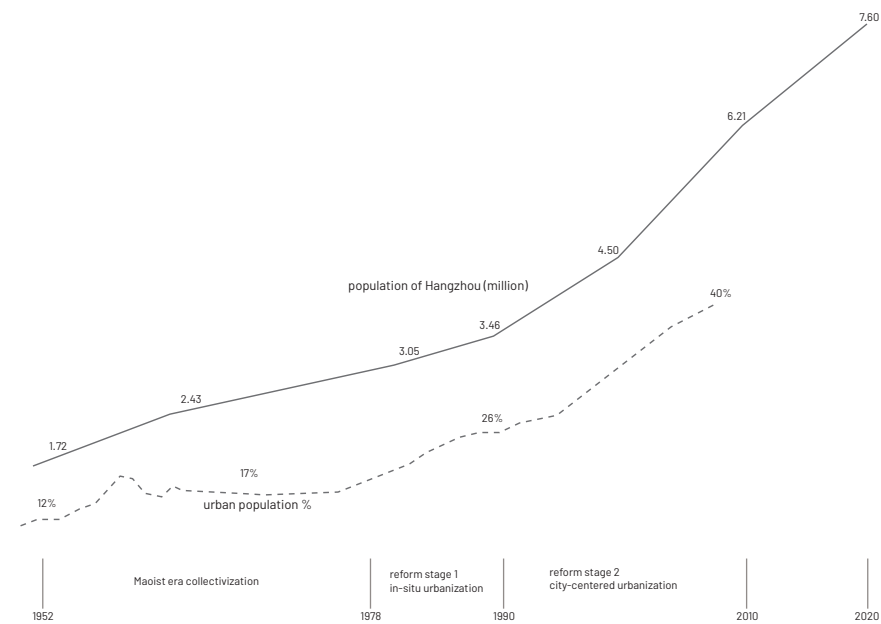
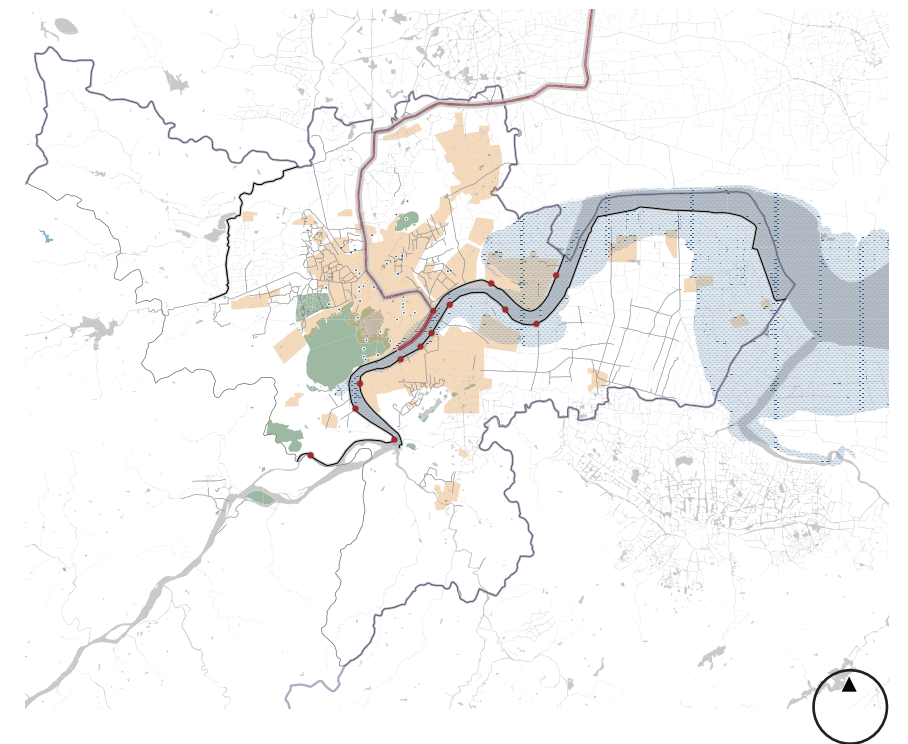
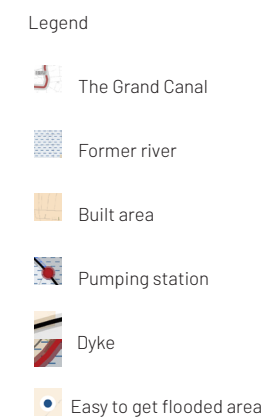


FIG. 2.10 (above) A hard-engineered water management method and its effect  
Source: edited by author based on GIS data.  
(right) Hard engineered water management method in the city centre of Hangzhou  
Source: edited by author based on GIS data.





Excessive rainfall as an unpredicted threat for the city

The city has been facing and fighting with extreme natural disasters for centuries like typhoons, rainstorms, and tides. Due to the climate change recently, the possibility of flooding caused by the intense rainfall becomes increasingly higher in some cities, especially in the delta area, and this trend is taking place in higher frequency and more cities. Apparently, the current highly engineered city is not ready for the upcoming climate change.



FIG. 2.11 Severe flooding in the city is threatening safety of citizen's life and property.  
Source: Chinanews.

2.3 – Problem statement

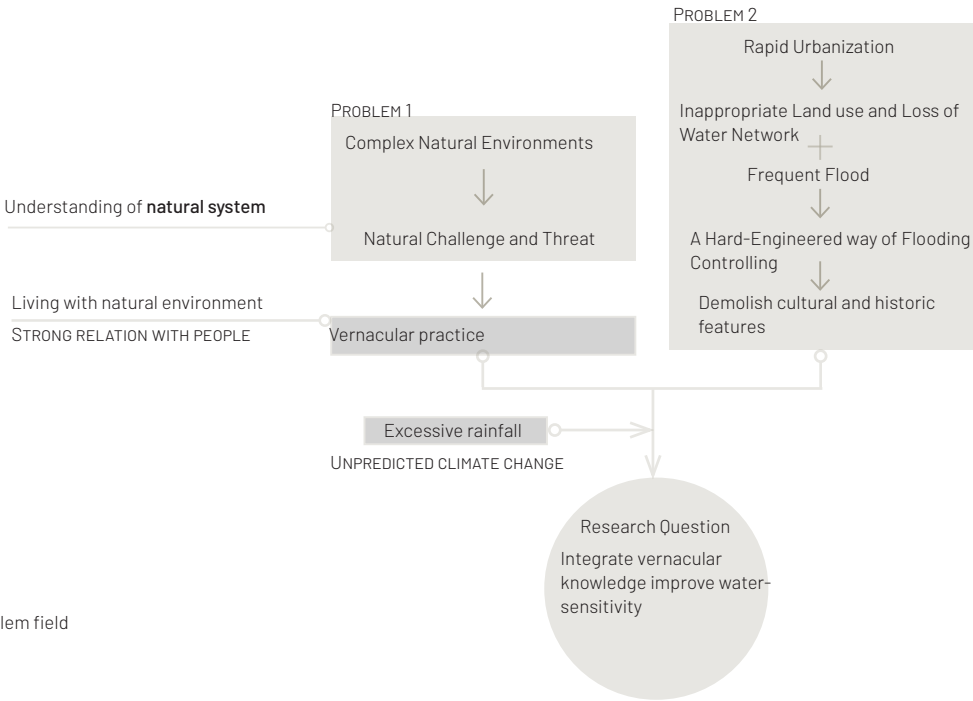


FIG. 2.12 Diagram of problem field  
Source: edited by author

Due to its specific location in the Yangtze river plain, Hangzhou is dealing with the water issue for centuries. To support daily life and protect themselves from flooding threats, people who live in this area have been maintaining a close and intelligent relationship with water. **The interaction between nature and human activities formulated its unique water management infrastructure in different scales.**

However, the growth of population led to the competition for land between human and water in the limited space. Moreover, rapid urbanisation and inappropriate land use have taken place of the previous dense waterway network. With the trend of increased occurrence of flooding, modern engineering approach of water management is being challenged.



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### 3 – Hypothesis

Is it possible to apply lessons and principles learned from vernacular water-management practices in the current urban context and towards a water-sensitive urbanizing delta for Hangzhou?

### 4 – Objective and Research questions

What lessons can be learned from historical-vernacular water-management practices for water-sensitive development in Hangzhou?

Furthermore, what are the possibilities (and to what degree) can they be applied in the contemporary urban context?

FIG. 4.1 1. Mulberry fish pond in Taihu Lake basin  
Source: photo by Hui Zeng [online] available at: <http://weibo/tarticle/p/show?id=zwenzhang> [accessed on 25 March 2018].  
2. Historic watertown Wuzhen  
Source: photo by Mafengwo [online] available at: <http://www.mafengwo.cn/> [accessed on 25 March 2018].  
3. Ancient weir  
Source: [online] available at: [http://www.china.com.cn/culture/txt/2008-06/26/content\\_15893566.htm](http://www.china.com.cn/culture/txt/2008-06/26/content_15893566.htm) [accessed on 25 March 2018].

#### Research questions:

1. What are the important water infrastructures in Hangzhou?
2. What are the characters of two different watersheds? What are the task and solution of dealing with water issues?
3. What lessons and principles could be learned from examples according to two different watersheds?
4. Besides water mission, what kind of extra values could be learned from these examples?
5. What is the existing natural system and urban system in Hangzhou? What are the problems and potential?
6. How to apply lessons and principle in the contemporary urban context and add extra value for the built environment?

#### Methods:

- Mapping
- Literature review
- Statistics
- Reasoning
- Archive
- Ancient painting
- Chinese poem
- Visionary images



# 5 – Relevance

This thesis has both scientific and societal relevance. In recent years, the trend of the increased occurrence of flooding is threatening people’s daily life and property security. It is urgent to find alternative solutions based on the local socio-cultural background.

## Scientific relevance

From the academic point of view, the research aims to contribute to the discussion by rethinking the ancient method integrating with recent theories which have strong connections with one of the EMU topics ‘Constructing the Sustainable Delta City’. This topic addresses the necessity of urban and landscape architectonic design of a new balance between urbanized area and landscape and will consider the development of landscape-structures in the city as well as of urban settlements in the landscape.

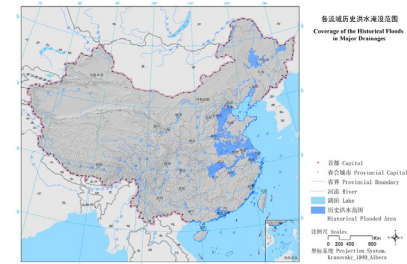
Moreover, this study is also aligned with the theme Delta Urbanism under the Urbanism Research Program, which focuses on developing new approaches to balance urbanization, development, agriculture, environmental and ecological qualities. This study could provide a different perspective of the example in a different landscape and historical context of Yangtze River Delta in China, and this study is expected to test the process of turning theories into practice by considering the local history and socio-cultural background.

For other researchers in the same field, Kelly Shannon and Bruno De Meulder published their research outcome Water Urbanisms: East (Meulder, 2013). In the book, they decided the vast Asian world and its rich cultural heritage hold great lessons for the revered role water once held in its ancient cartography, history, mythology, festivals, cities and everyday life (Shannon & Chen, 2013). Waterways were important for transportation, defence, and livelihoods; they also imposed respect.

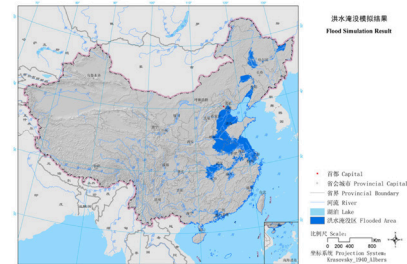
As a former master student Collage of Architecture and Landscape of Peking University, the author has been influence by Prof. Kongjian Yu and his theories. His recent study about ‘sponge system in territory scale: ecological security pattern’ (FIG 5.1) also shows the importance of research in the YRD (Yu, 2016).

## Societal relevance

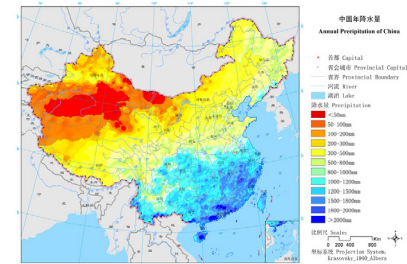
In recent years, the trend of increased occurrence of flooding is threatening people’s daily life and property security. For instance, the city centre of Hangzhou faced severe flooding after strongest rainstorms over forty years. The intensity of rainfall reached 191.3mm/d. Around 1,563 houses got flooded. And the rainstorms caused traffic paralysis. And there were 533 places had ponding which one of the deepest reached 1.5 meters. More than 150 cars shut down in the flood. Both the West Lake and the Grand Canal reached their alarm level. For the Grand Canal, it even overflowed into the city which aggravated the flooding. For the whole city, more than 210,000 of citizens were affected and caused economic losses of more than 3,460 million Euros.



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1. Coverage of the historical floods in major drainage  
Source: Turenscape [online] available at: <https://www.turenscape.com/project/detail/4650.html> [accessed on 25 March 2018].
2. Flood stimulation results  
Source: Turenscape [online] available at: <https://www.turenscape.com/project/detail/4650.html> [accessed on 25 March 2018].
3. Annual precipitation of China  
Source: Turenscape [online] available at: <https://www.turenscape.com/project/detail/4650.html> [accessed on 25 March 2018].



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1. Flooding in Hangzhou, 2007  
Source: photo by Hui Zeng [online] available at: <http://weibo/tarticle/p/show?id=zwenzhang> [accessed on 25 March 2018].
2. Flooding in Hangzhou, 2007  
Source: photo by Mafengwo [online] available at: <http://www.mafengwo.cn/> [accessed on 25 March 2018].

6 Theoretical Framework

7 Research Structure

8 Research Approach

# 6 – Theoretical framework

This research was directed by the problem of building an integrated method towards a water-sensitive approach into a discussion on how the city of Hangzhou could be planned in a way that environment could be adaptive against flooding. Moreover, in this research, design plays a role between knowledge and the lessons from ancient practices, understandings about the situation. However, the way to integrate principles requires support by three key theories which include landscape urbanism, landscape as infrastructure, and complexity systems.

## Landscape Urbanism as theoretical foundation

*Charles Waldheim:*

The theory of landscape urbanism provides a way of reading urbanism through the lens of landscape (Waldheim, 2016). It argues that by using **landscape as a medium** of design and intervention in the city, a horizontal integration in terms of social, ecological and economic performance in the city could be developed, which helps to generate a responsive and flexible structure.

In this horizontal field of urbanization, landscape has a newfound relevance, offering a multivalent and manifold medium for the making of urban form, and in particular in the context of complex natural environments, post-industrial sites, and public infrastructure (Waldheim, 2006). This theory provides a vital hint in the design of Hangzhou to emphasis the importance of landscape as a carrying structure.

*Kelly Shannon (water urbanism):*

A descriptive landscape urbanism could involve from the careful reading of layered narratives, contested territories and a ‘designerly’ investigation of potentials. The existing logics of landscapes (including its historical layers and ad-hoc daily appropriations) could be recognized at different scales and connected to new (infra) structure. Moreover, specific logics from the ‘junkyard’ of existing landscape could be stressed and new interventions with structural capacities could reformulate reality. She emphasises the importance of understanding the site including historical and daily activities. This perspective could be valued as the advocate of learning from the history.

And for another importance function is landscape urbanism strategies could become powerful tools for negotiation between different actors and within the ‘contested territories’ of 21st century cities.

## Landscape as infrastructure as design approach

The main concept of landscape as infrastructure is landscape as a system.

Landscape as infrastructure reflects on the change of relationship between urban economy and environment, from separated to inseparable. Belanger redefined infrastructure as a collective system of hard technology, biophysical resources, agents and services (Belanger, 2013).

Gerdo Aquino indicates two landscape-based systems are appropriate as programmatic overlays on these infrastructural systems (Hung et al, 2011).

- (1) a ubiquitous pedestrian system: when residential diversity increases, it needs to improve transit and equal access to open space for social and cultural activities.
- (2) natural systems: water, vegetation, soil and habitat and their latent potential to operate within a broader, more connected distribution network.

What is infrastructure? Hung interpreted it as ‘the basic facilities, services, and installations needed for the functioning of a community or society’ ((Hung et al, 2011).

In addition to the temporal, decentralized, and multifunctional characteristics that define landscape infrastructure is further comprised of a set of attributes relating to form function, and time, all of which have a cumulative effect benefiting the greater whole.

## Complexity system as main research approach

System theory has been widely used natural sciences to observe and measure change, structures and processes (Huggent 1983).

Both systems thinking and analysis in landscape studies, focusing on the complex interaction between man and nature, provided the framework to evaluate forms, functions, and dynamics of natural, agricultural, and urban areas. (T.K. Bacchin 2015)

From a functional perspective, the system behaviour is subject to its degree of isolation, closeness or openness (Huggent 1983).

In this way, systems theory addresses the influence posed by the environment in the discrimination of structural units and the notion of the interchange between the unit/ system of analysis and its adjacent areas. (T.K. Bacchin 2015)

The most important concept is considering system is form by its components and their relationships which is very helpful for understanding how system works and finding the possibility of further change.

7 – Research structure

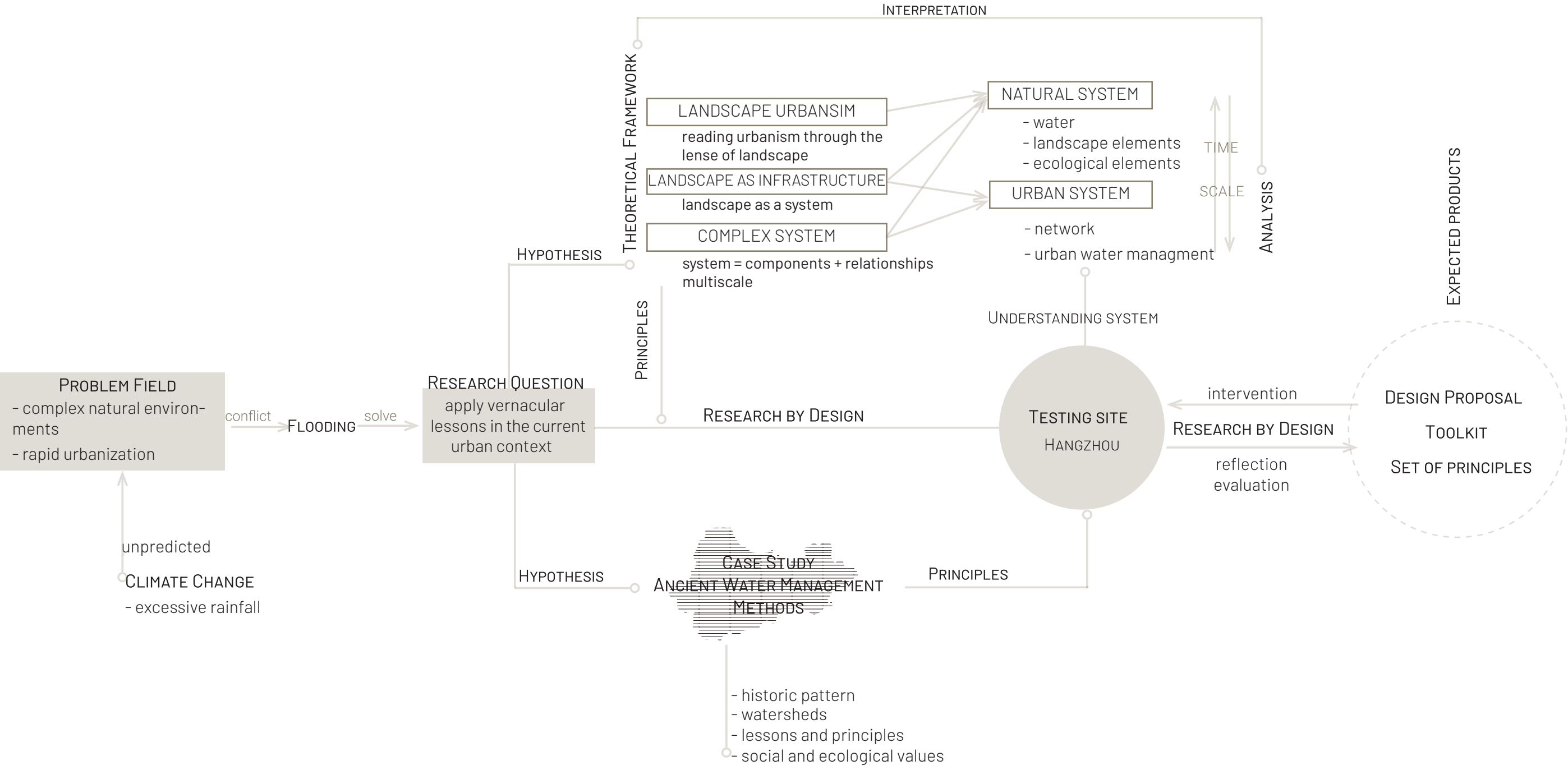
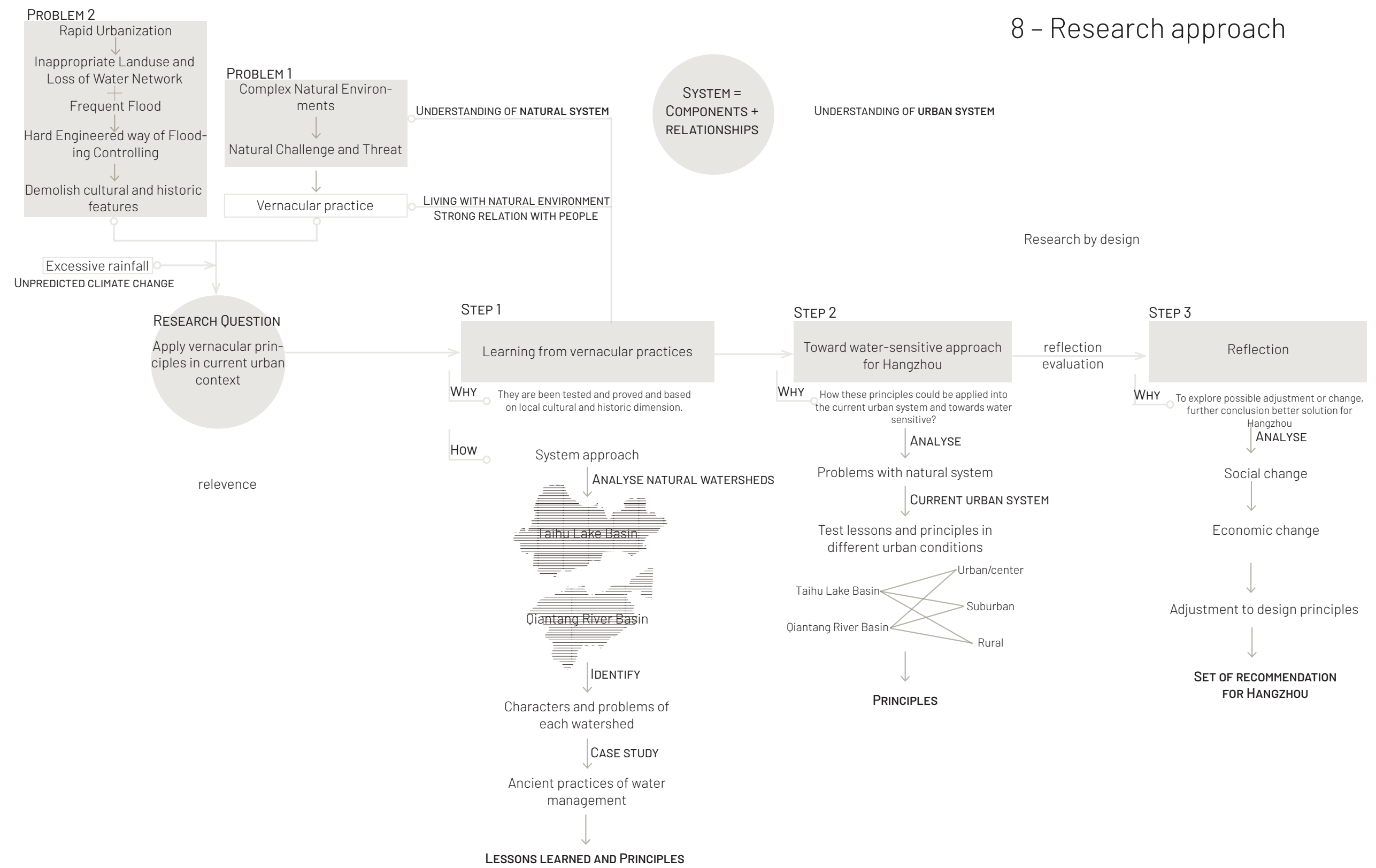


FIG. 6.1 Research structure  
Source: author

8 – Research approach



PART 3

# Learning from vernacular water management practices

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9 Water system in Hangzhou

10 Taihu Lake Basin

10.1 Taihu Lake Basin

10.2 Example one - Yu area

10.3 Example two - ancient city of Hangzhou and Wuzhen

10.4 Principles

11 Qiantang River Basin

11.1 Qiantang River Basin

11.2 Example three - Xiaoshao Plain and Eastern Zhejiang Canal

11.3 Example four - Weir system

11.4 Example five - Beitang (pond) system

11.5 Principles

12 Conclusion



# 9 – Water system in Hangzhou

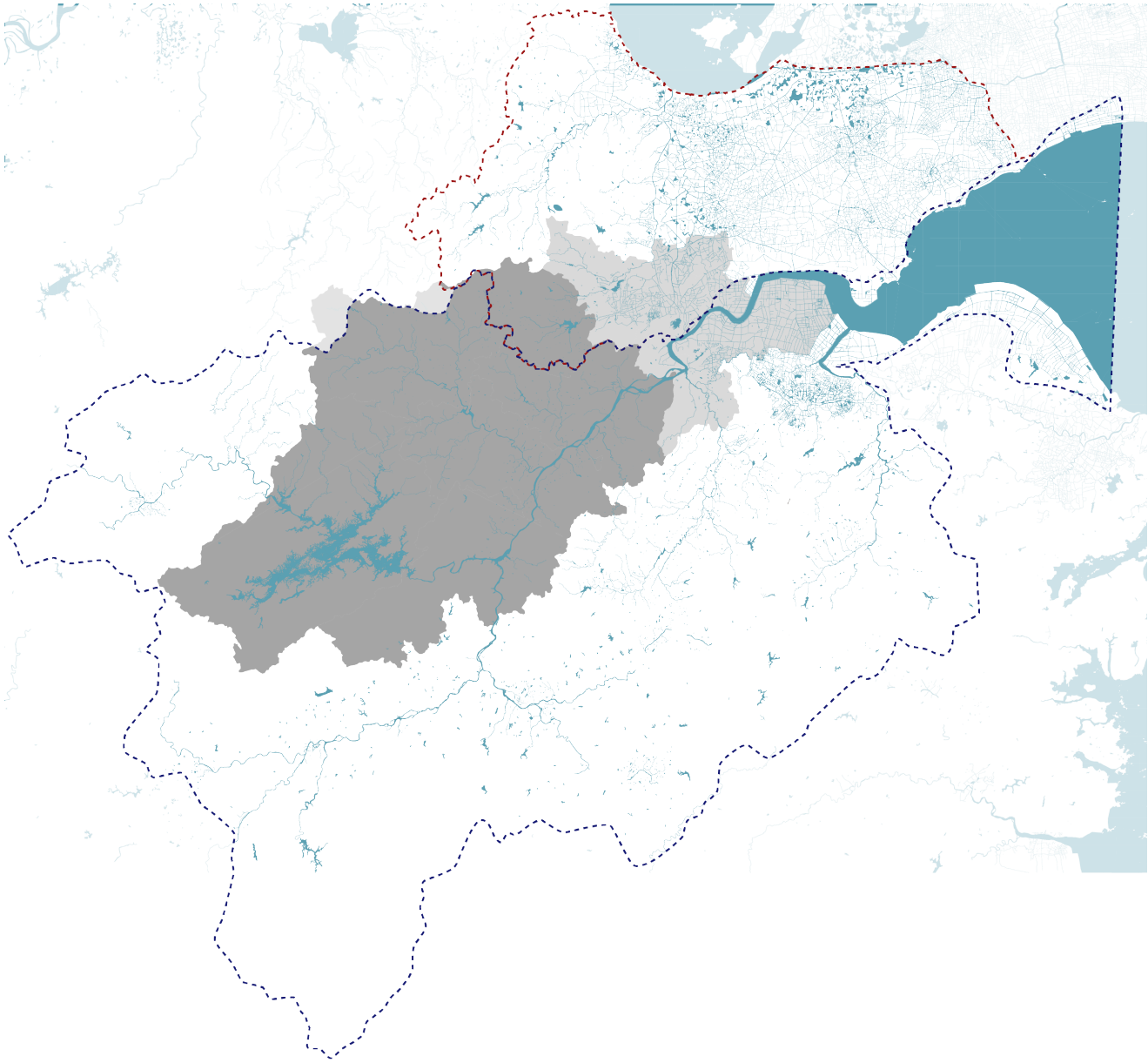


FIG. 8.1 Natural watersheds of Hangzhou  
Source: author based on GIS data



FIG. 9.1 Sub watersheds of Taihu Lake Basin  
Source: author based on GIS data



FIG. 9.2 Subl watersheds of Qiantang River Basin  
Source: author based on GIS data

The city of Hangzhou belongs to two main natural watersheds. The first is the area of the city centre, which is located in the northeast part and belongs to the plain area of Taihu Lake basin as a portion of Yangtze River Delta. The rest of the city belongs to downstream and river mouth of Qiantang River which has its strong influence on the formation of the city.

Two main watersheds have completely different water conditions because one is river basin and the other is lake plain. This differ from the natural system might leave distinctive marks on the methods of water management for dealing with various water problems.

In this section, the exploration will be delivered according to these two natural watersheds. It will start with a quick overview of two watersheds and come with several typical examples to tell the story of the area and the relationship between nature and human activities. In the end, system, strategies, and principles will be concluded as lessons learned from the vernacular water-management practices. They will be tested the suitability and possibility of application in the next part.



10 – Taihu Lake Basin

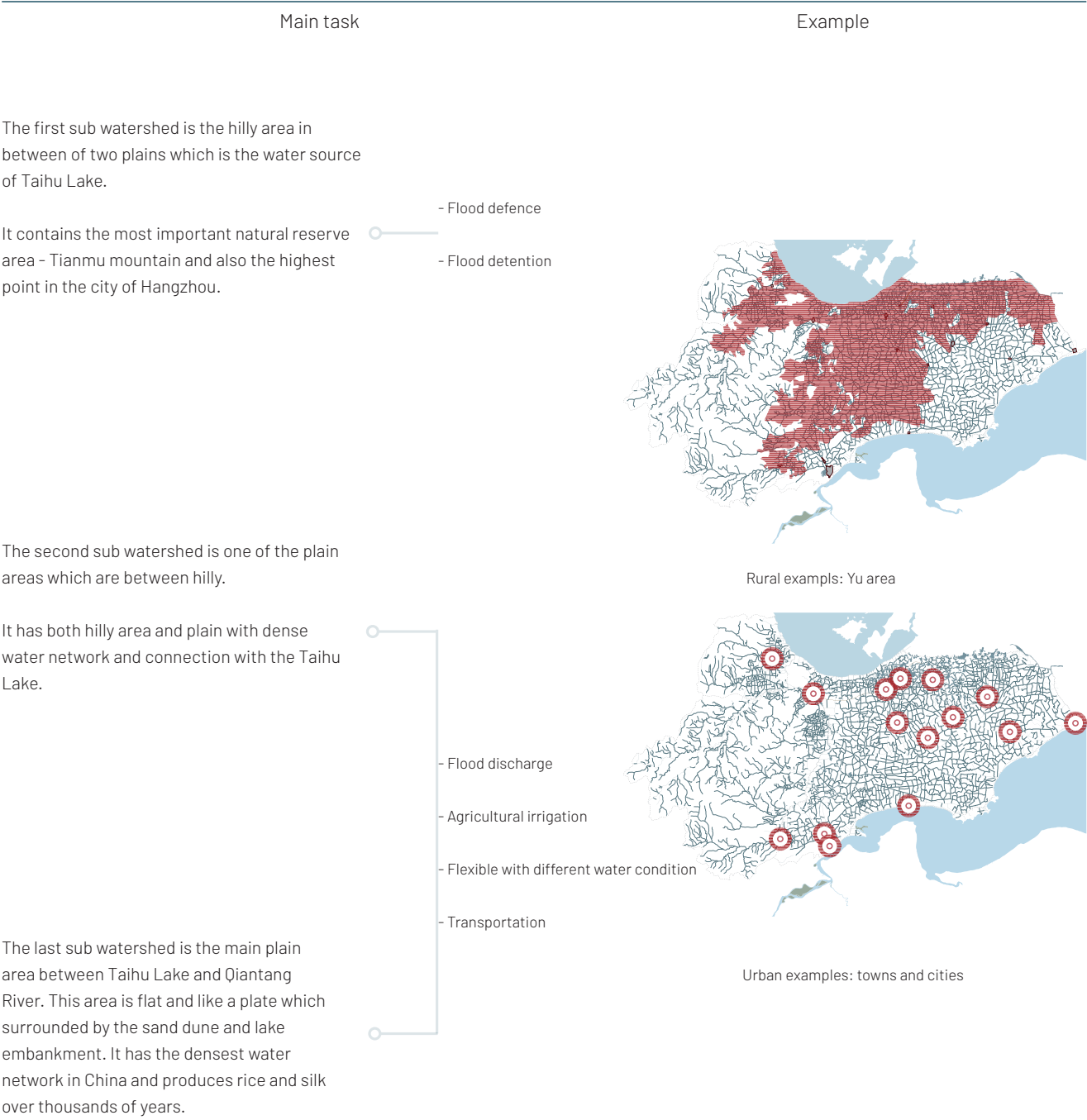
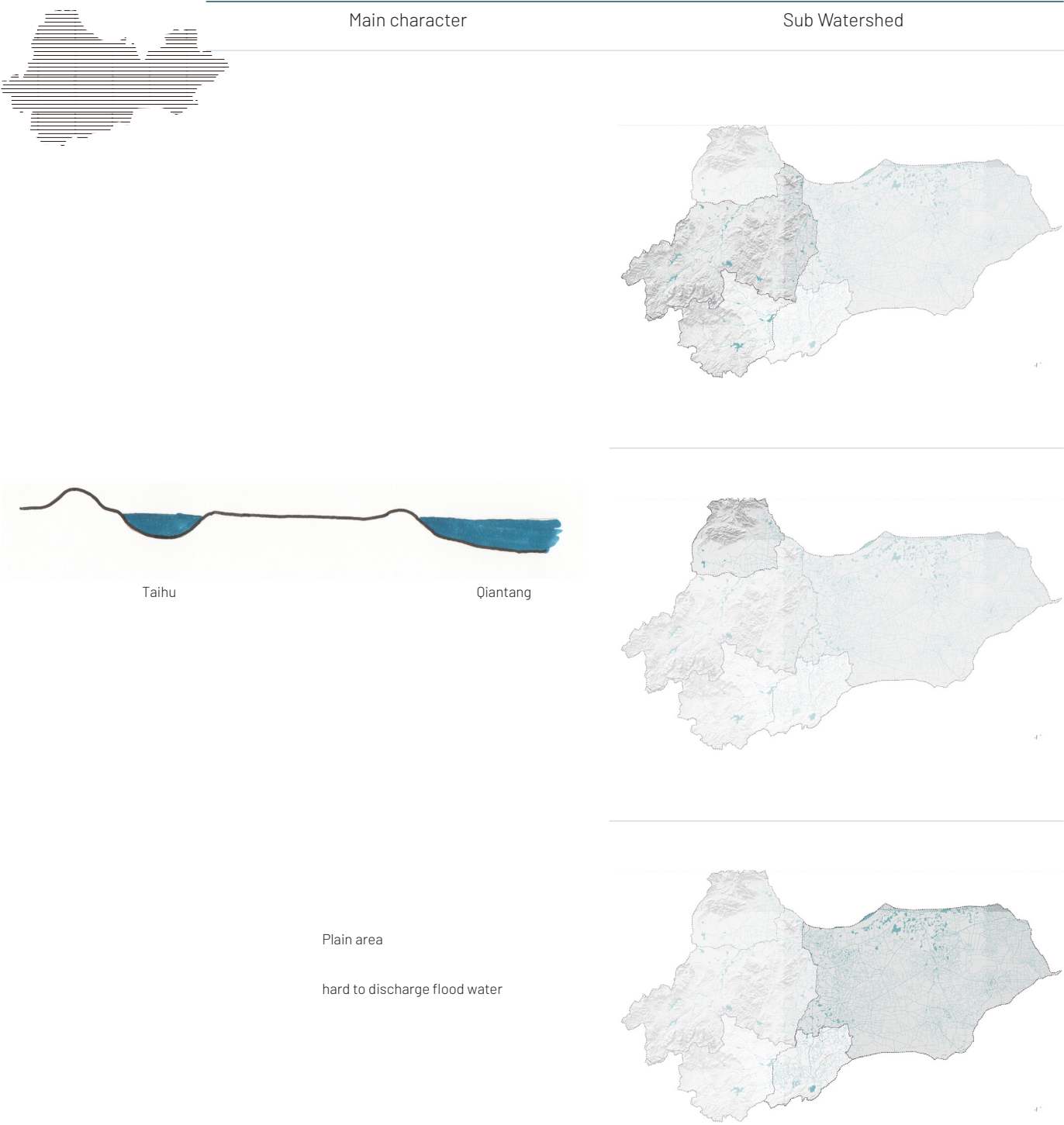






FIG. 10.1 First impression of Taihu Lake Basin  
Source: author



2

### 10.1 – Taihu Lake Basin

Having a subtropical monsoon climate, Taihu Lake Basin (FIG 10.2.1), is the area between two river mouths of Yangtze River and Qiantang River. The concentrated periods of precipitation include Mei-yu, which usually takes place from May to July, and typhoon rainstorm, which occurs from August to October. The annual precipitation is around 1,100 mm. The topographic trend in this area (FIG 10.4) is gradually decreased from west to east. The west part is a mountainous and hilly area where comes the water, while the central part is plain and low land. The elevation of the plain area is around 4-8 meters and the lowest area is around 2.5-4 meters. All sides facing water have seawall or river bank as defence. However, as a result, these geographical conditions formulate the characters of multiple lakes and make the immense amount of canals and waterways which are all connected together. All small elements contribute to building a system of water which functions as a water storage, irrigation, and flood water discharge. This area has a long history of water management practices, by which the alluvial area is wisely turned into a rich and fertile place by people there.

The northeast part of Hangzhou belongs to the south part of Taihu Lake Basin (FIG 8.1). It has three sub watersheds in the area. From west to east, the first watershed is a small plain area located between two hilly areas. The second has two rivers coming from the mountainous area which runs into Taihu Lake. The last one is famous for its highly dense water network and the Grand Canal.

FIG. 10.2 1. Map of Taihu Lake Basin  
Source: Chinabaike [online] available at: <http://www.chinabaike.com/article/sort0525/sort0521/2007/20070715141092.html> [accessed on 13 March 2018].  
2. South part of Taihu Lake Basin and Hangzhou  
Source: Baike [online] available at: [http://tupian.baike.com/a2\\_18\\_21\\_01300001332647134562219898164\\_.jpg.html](http://tupian.baike.com/a2_18_21_01300001332647134562219898164_.jpg.html) [accessed on 25 February 2018].

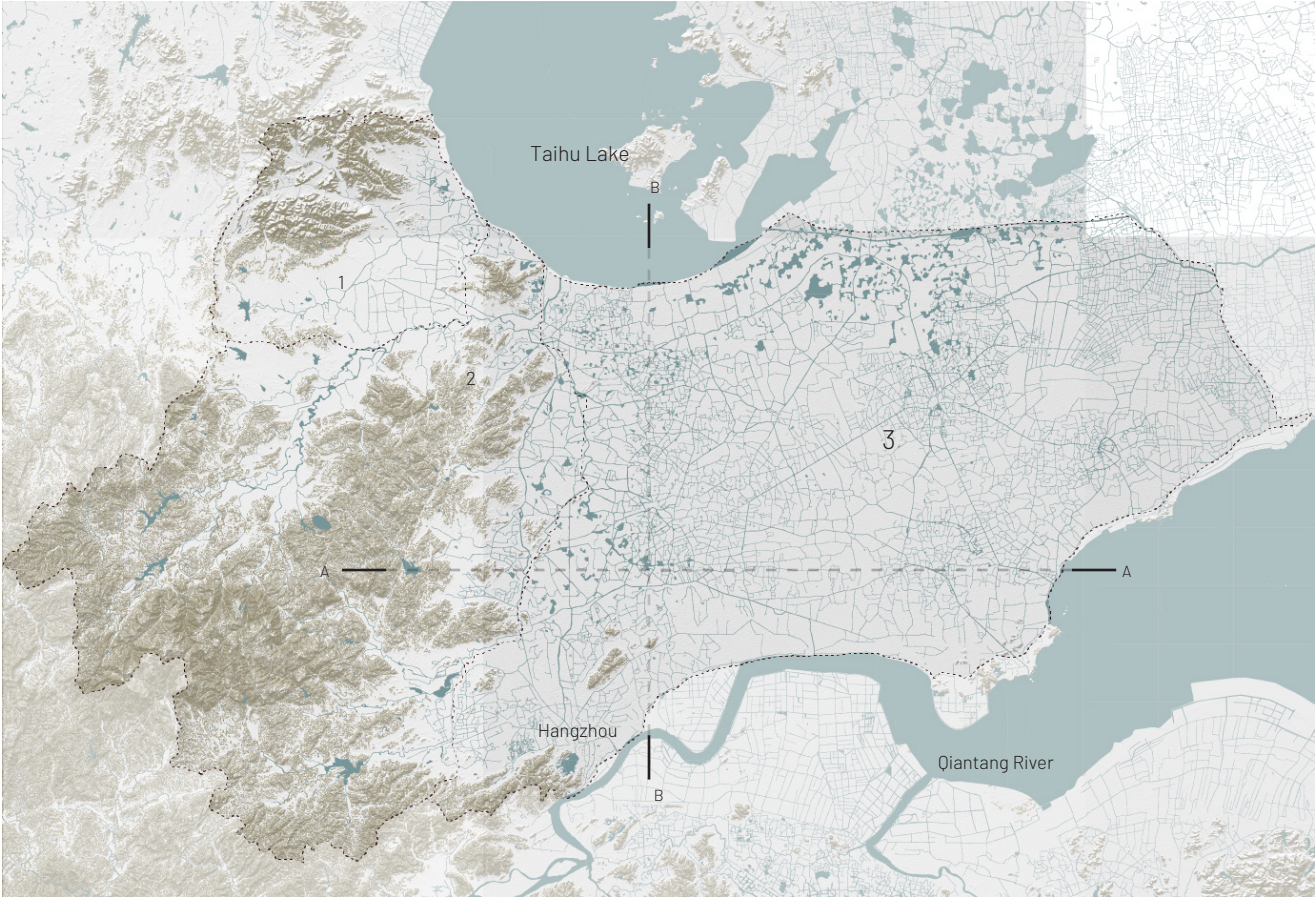


FIG. 10.3 Current condition of water and topography  
Source: edited by author, according to GIS data

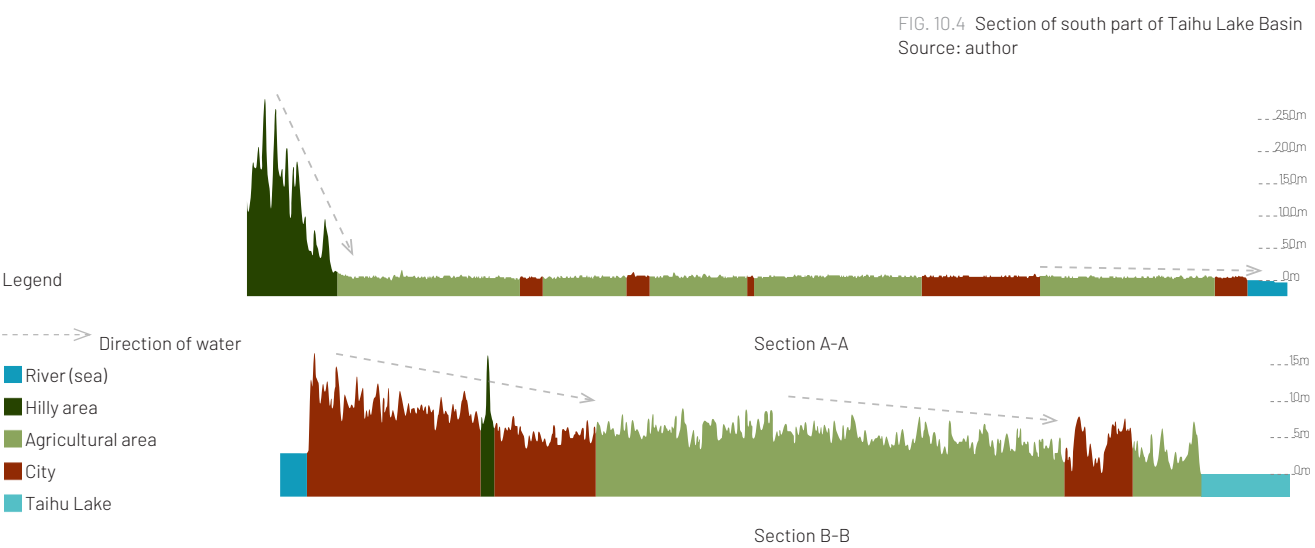
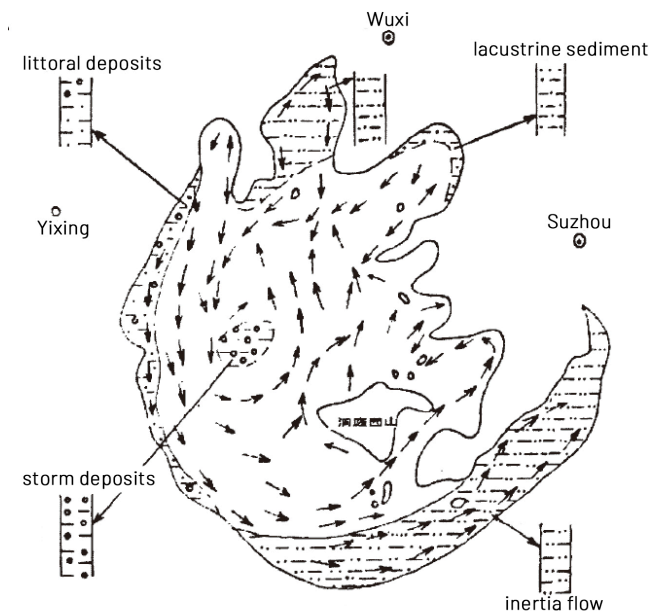


FIG. 10.4 Section of south part of Taihu Lake Basin  
Source: author





Due to its water flows, the south bank of Taihu Lake was formed by the movement of sand and also brought fertile soil for further agricultural development. With the comparison of bank shape from three sub watersheds (FIG 10.6), the conclusion could be drawn that sub watershed 1 and 3 share the similar character of canals and are connected to the lake. Take sub watershed 3 as an example to explore how this phenomenon occurs and what is the function of these canals.

FIG. 10.6 (left) Flow of water and classification of sediment of Taihu Lake  
Source: edited by author, according to Qin Zhou and book Taihu 1993

FIG. 10.5 (below) Different bank shape along Taihu Lake  
Source: edited by author, according to Google Earth



Section of bank

Sub watershed 1



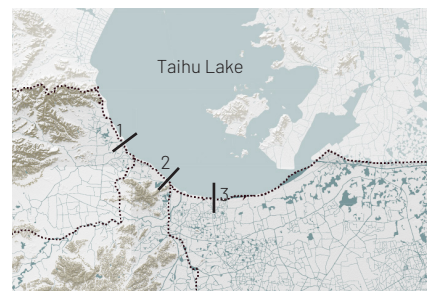
Section of bank

Sub watershed 2



Section of bank

Sub watershed 3



Map of location



FIG. 10.7 Complete map of Zhejiang Province (1773-1841)  
Source: Library of Congress [online] available at: <http://lcnc.loc.gov/gm71005029> [accessed on 13 March 2018].



- city
- pond/ lake
- waterway
- island
- watershed

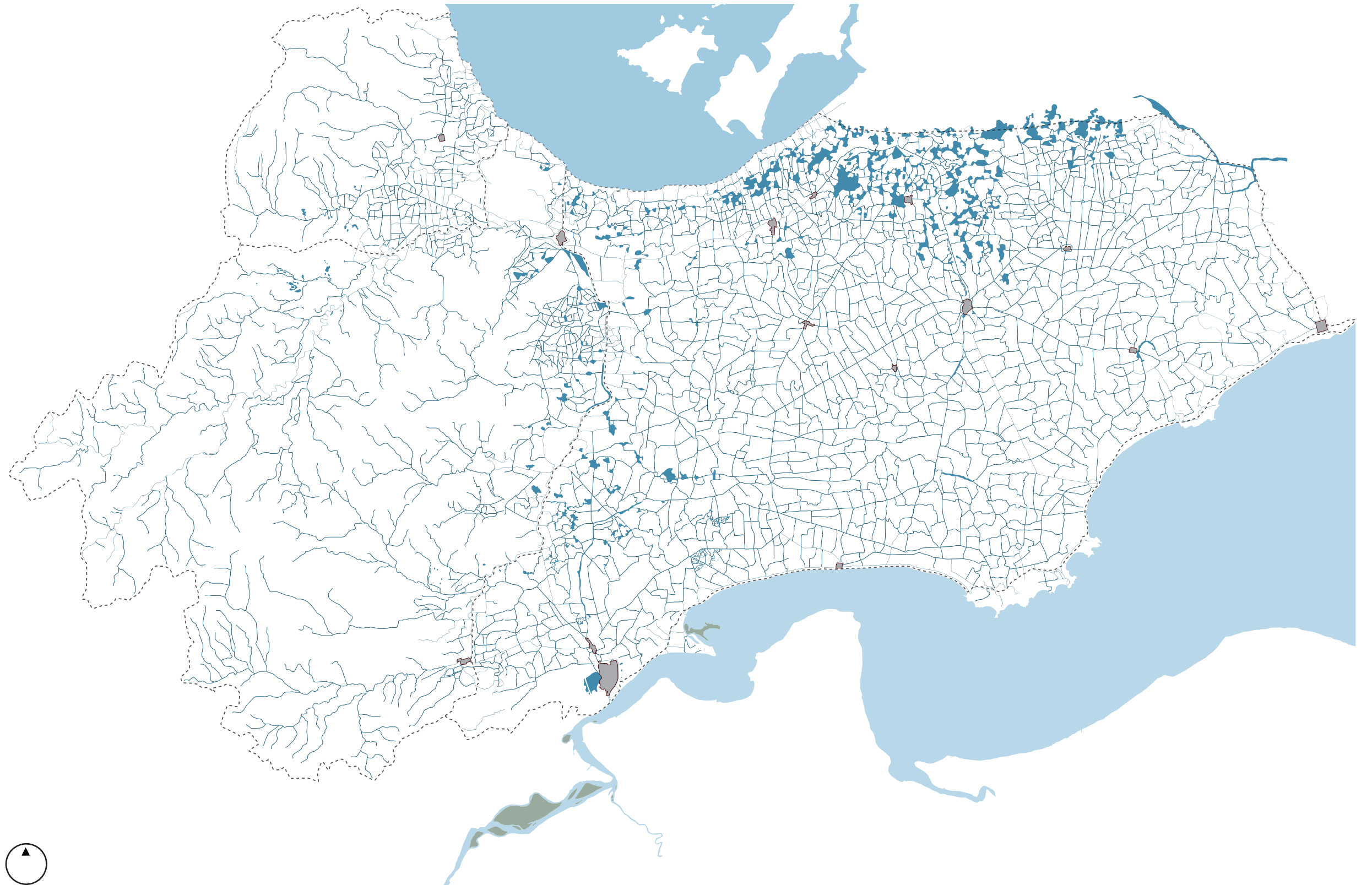


FIG. 10.8 Map of water and cities in 1957  
Source: edited by author, based on map prepared by  
Army Map Service





city

waterway

FIG. 10.9 Map of water and cities in 2016  
Source: edited by author, based on GIS data

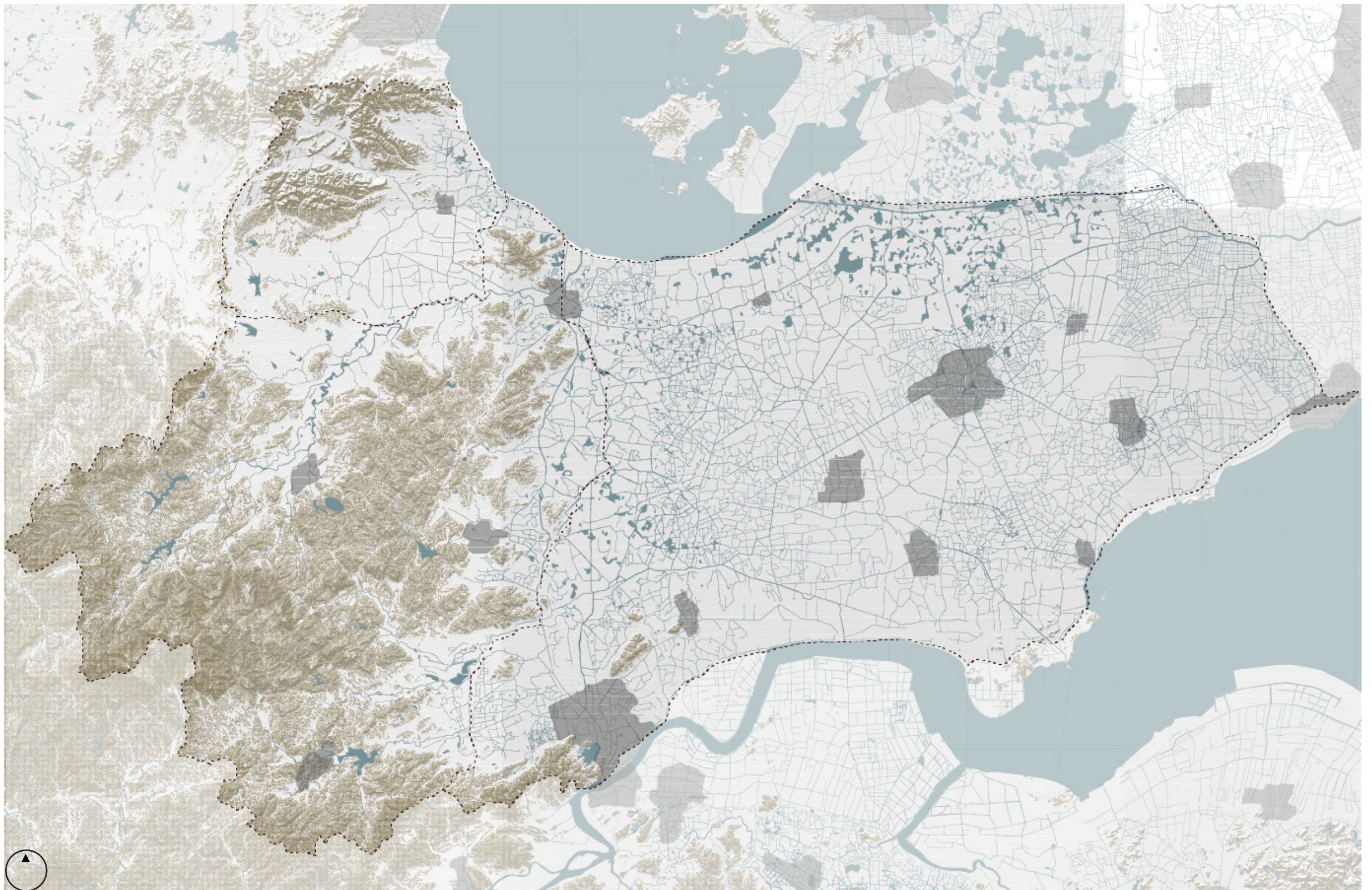






FIG. 10.10 Drawing of water village (1302)  
 Source: Drawn by Mengfu Zhao, The Palace Museum  
 [online] available at: <http://www.dpm.org.cn/collection/paint/230286.html> [accessed on 25 March 2018].

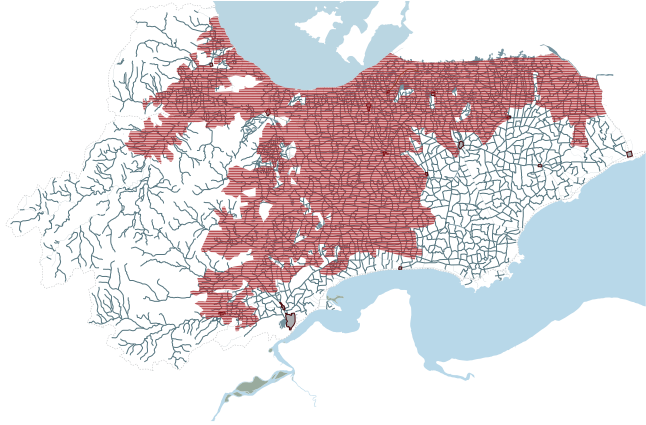


FIG. 10.11 Location of Yu area in Taihu Lake basin  
Source: edited by author, based on map prepared by Army Map Service

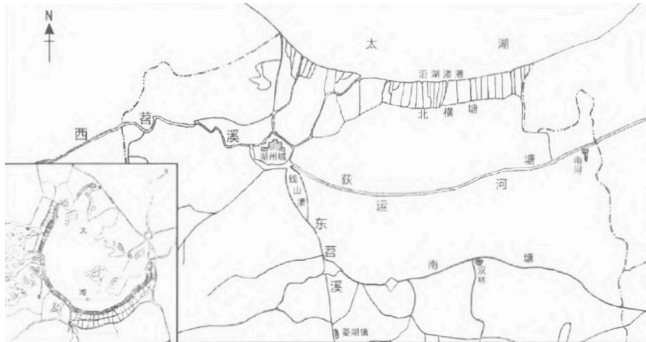


FIG. 10.12 Water system along south bank of Taihu Lake during Tang and Song Dynasty(618-907)  
Source: Local chronicles of Huzhou, 1982

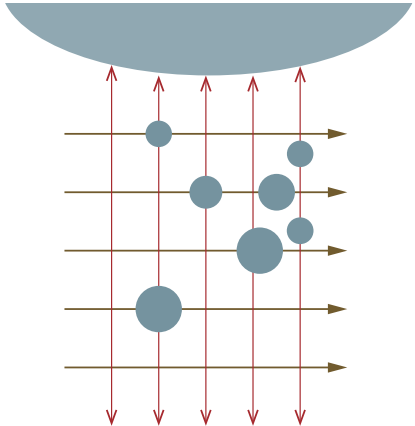


FIG. 10.13 Diagram of grid water network  
Source: edited by author

## 10.2 – Example one – Yu area

Scale: Regional

History: 6th century to now

Feature: Agricultural land with dense water network in the plain area of Taihu Lake Basin

Challenges: Flood discharge and agricultural irrigation

The first example is a typical agricultural land form – Yu spread in the plain area of Taihu Lake Basin.

It has a water defence system with two layers. The first layer is about its grid water network along the south bank of Taihu Lake (FIG 10.16). This system has two main components. One is waterways 溇(Lou) which are in the direction of north-south. During the wet season, it is used for discharging extra water from the fields into the lake. On the contrary, it is used to get fresh water for agricultural irrigation from the lake in the dry season. The width of this waterway is similar as canals (FIG 10.15). And the other type of waterways is 塘(Tang) which are parallel with lake bank in the direction of east-west. It has the function of defence flooding, discharging extra water from the hilly area to the east and transportation since it also connects 溇(Lou). That's how it comes to this grid water network and the whole system of water management method in the original marshland.

The landscape of the grid and dense waterways was by a poem was described like “五里一纵浦（溇港），七里一横塘” which means both directions of east-west and north-south have a waterway every 2 kilometres. For waterways of different directions not only create the dense together but also have their own function under different conditions.

From the ancient map of Zhejiang Province (FIG 10.7), it could be considered as reflection of dense water network in the area between Qiantang River and Taihu Lake. Furthermore, the scale of cities could be read from the map since ancient Chinese cities had wall and moat around them. A famous drawing drew by Mengfu Zhao during Yuan Dynasty(around 1302) called ‘the drawing of water village’(FIG 10.10). It shows the landscape of village near Taihu Lake. Houses located in the higher land which are surrounded by trees. And it also shows the initial relation between water, land, and settlements.

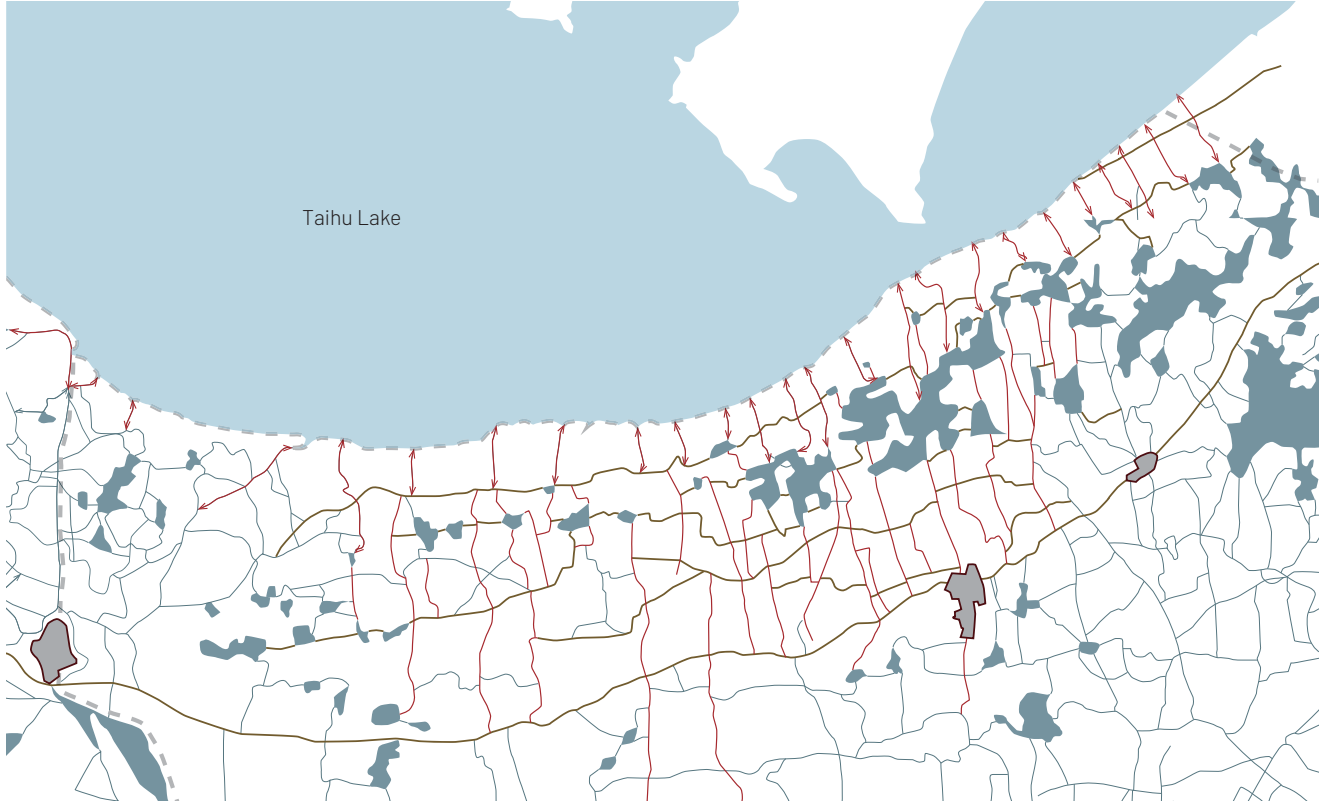


FIG. 10.16 Belt of grid water network along the south bank of Taihu Lake  
Source: edited by author, based on map prepared by Army Map Service

- city
- pond/ lake
- north-south waterway
- east-west waterway
- waterway

FIG. 10.14 Section of 溇(Lou)  
Source: edited by author

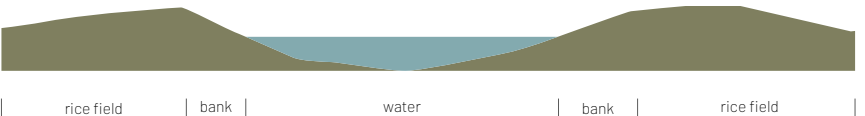
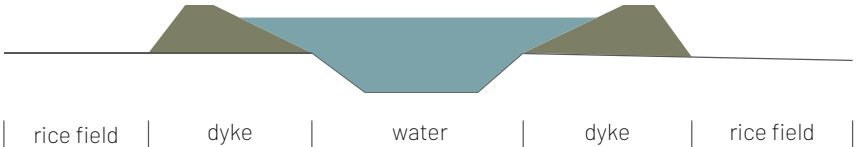
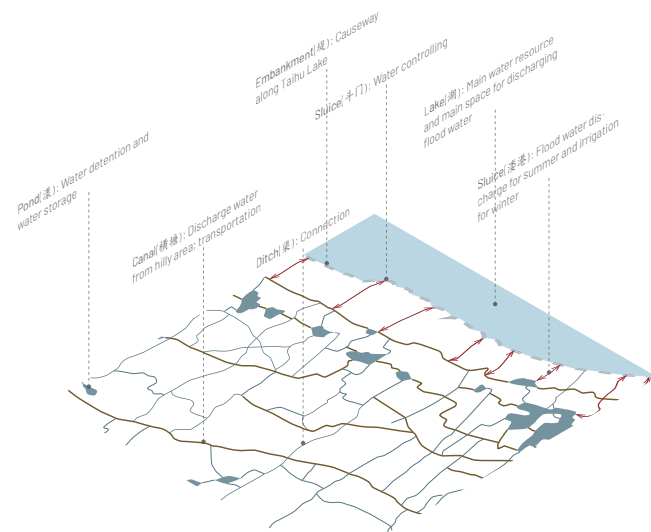


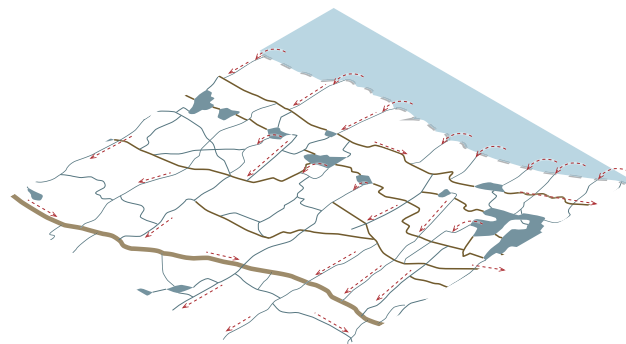
FIG. 10.15 Section of dyke structure of 塘(Tang)  
Source: edited by author



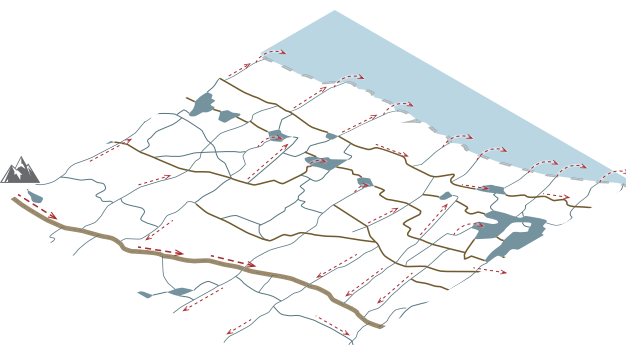




1 Function of different elements



2 Direction of water flows in dry season



3 Direction of flows in wet season

FIG. 10.17 Diagram of grid water network  
Source: edited by author

## The waterways and Yu field system in Taihu Lake plain

The system consists of Taihu Lake, embankment, canals, ditches, pond and sluice.

**Taihu Lake (湖 Hu):** Taihu Lake is the main water resource for the area and also plays an important role in taking the flooding water discharging.

**Embankment (堤 Ti):** Embankment is the causeway along the Taihu Lake which is created by sedimentation.

**Canal (塘 Tang):** The direction of this canal is east-west and it's deeper than any other canals due to its main function for discharging flooding water to the east to reduce the pressure of Taihu lake. It has also been used as important transportation way in the area.

**Canal (漾 Lou):** These canals are mainly directly connected to Taihu Lake. And they all have sluice at the connection with lake. There were around 72 canals in the past, which only 27 remain.

**Ditch (渠 Qu):** Ditch is the most important connection of all different elements. The efficiency is dependent on the depth and width of ditch.

**Pond (漾 Yang):** Pond is small water surface which has different function under different water condition. It could be water storage or flood water detention.

**Sluice (陡门 Doumen):** Sluice is the devices of water controlling. The existing ones are made of several pieces of wood (FIG 10.18).

For dry season:

Use the water from Taihu lake for agricultural irrigation.

For wet season:

Discharge flooding water into small ponds or Taihu Lake. And discharge water from hilly area to Huangpu River to the east.



FIG. 10.18 Wooden sluice  
Source: cropped from document [online] available at: <https://v.qq.com/x/page/p0373uhq0sv.html> [accessed on 25 March 2018].

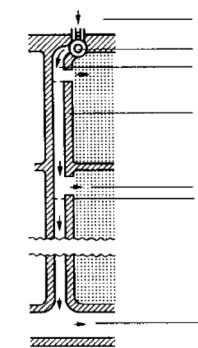
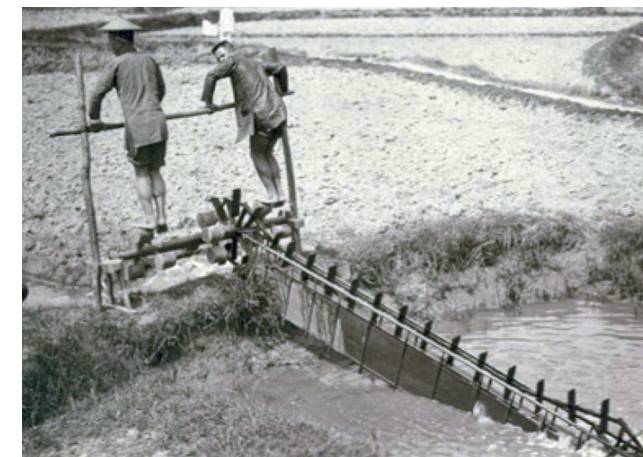


FIG. 10.19 Water discharging and irrigation as a group work  
Source: Fei, 2001



In the ancient rice agrarian society, the phenomenon of a team working and clear labour division was described by Hsiao-tung Fei in his book of 'Peasant Life in China: A Field Study of Country Life in the Yangtze Valley' (Fei, 1939).

For instance, the small town Fei studied also belongs to the Taihu Lake basin, which is famous for its silk production. For men, their responsibility is fieldwork, which includes irrigation, discharging flood water, sow, and harvesting. The main part of the work was done in a group. Especially the most important part is related to water. For water discharging or irrigation, it depends on low tech device - wood wheel which requires manpower. As is shown in FIG 10.19, one Yu field as one water management unit and each small pieces of a field will be worked by a group in order.

On the other hand, women stay at home. Besides housework and taking care of kids, their main job is to make silk and silk production.

It is not expected that the income of men and women are quite similar. As a result, this stable working pattern made Taihu Lake Plain one of the richest area in China.



FIG. 10.20 Different works in charge of men and women  
Source: cropped from document [online] available at: <https://v.qq.com/x/page/p0373uhq0sv.html> [accessed on 25 March 2018].

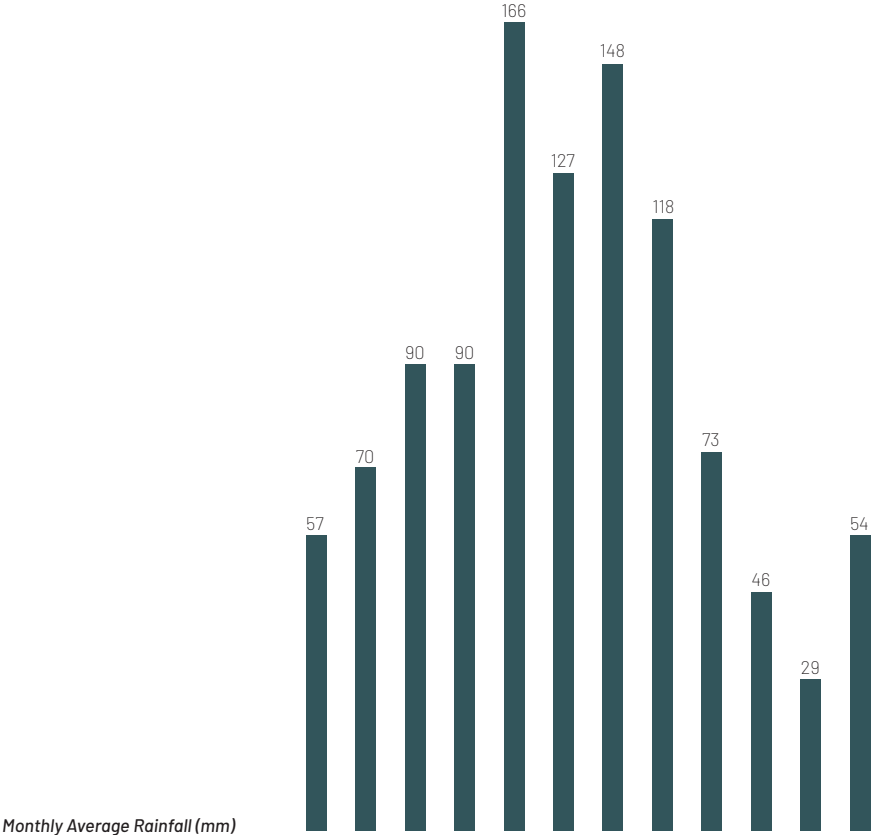
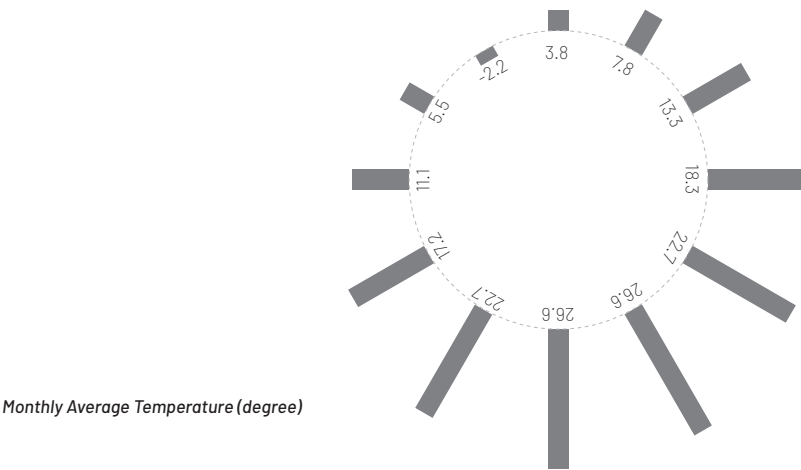
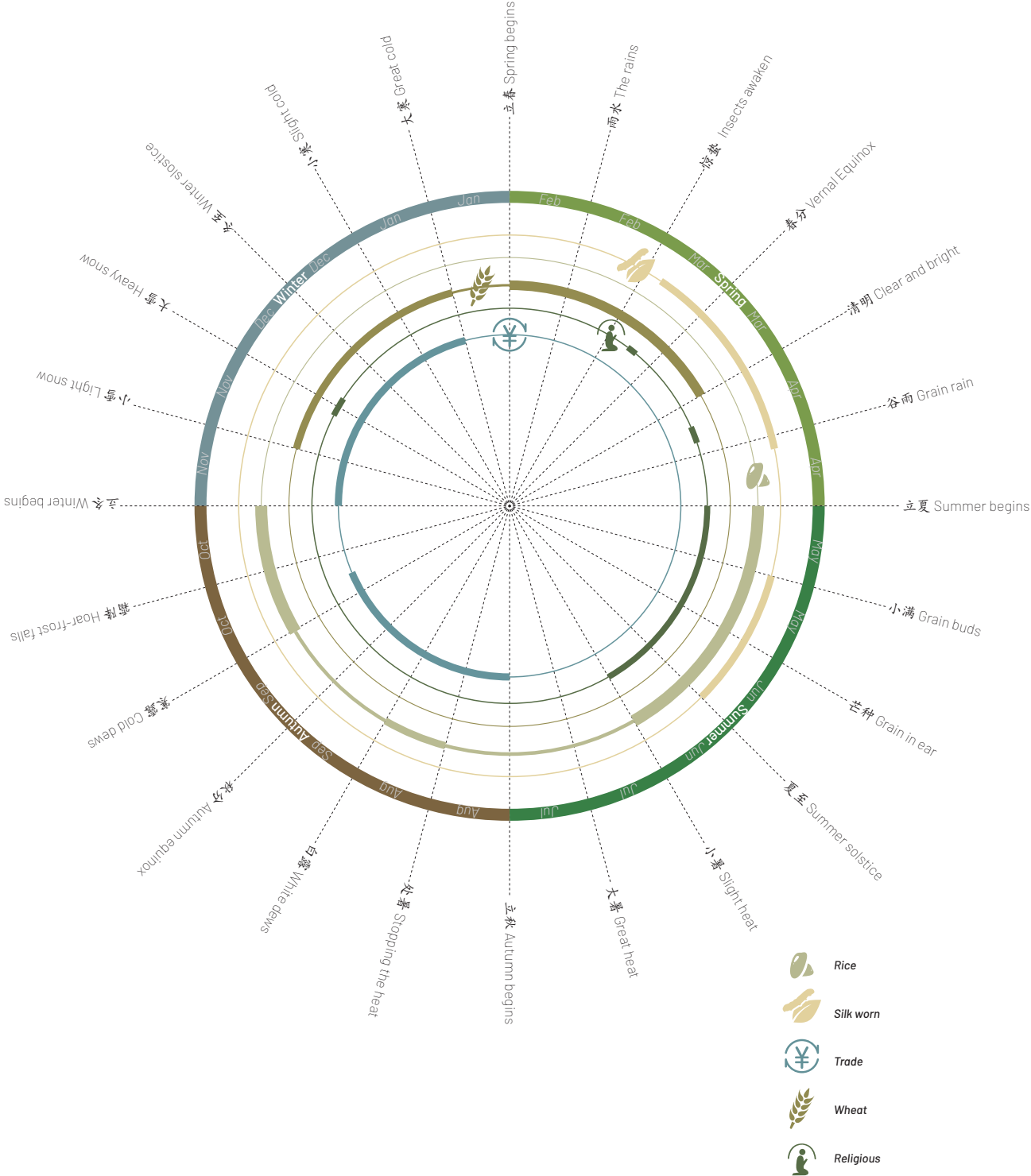


FIG. 10.21 Activities according to the 24 solar terms  
Source: edited by author based on data from Fei





Yu field

The second layer of example one is zoom into the grid made by the water network. And it has two different performances according to different water conditions.

The first one is under the condition of the previous water management method function well. Although flood creates big damage to the agricultural field, it brings fertile soil which is vital for agriculture. People there started to build a structure with three different levels of a field which could keep out water from outside and connect to inland waterways.

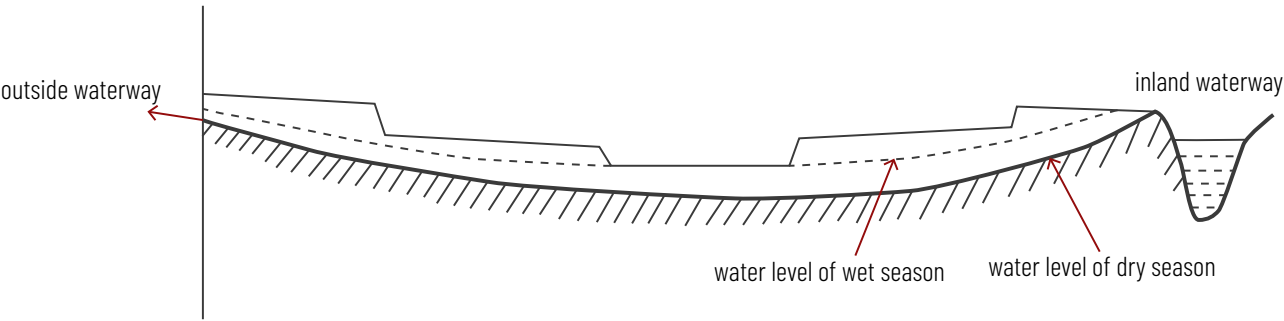


FIG. 10.22 Section of Yu structure  
Source: edited by author, based on Qing Zhou

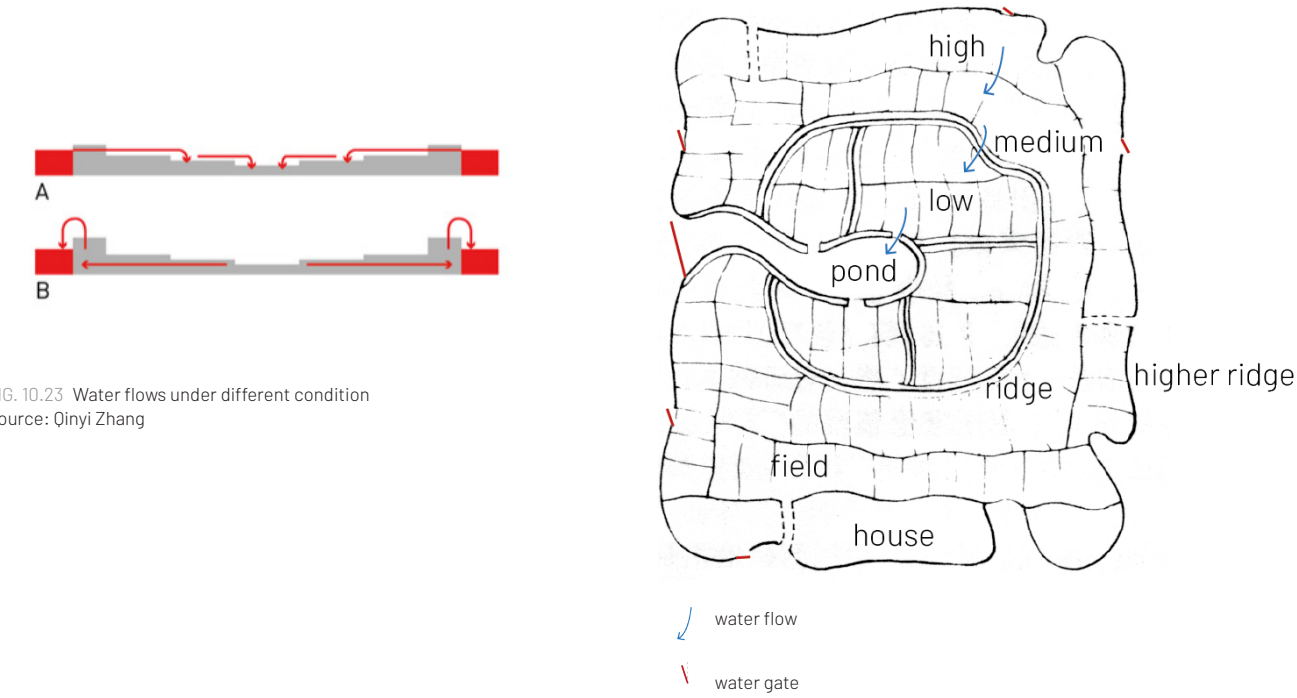


FIG. 10.23 Water flows under different condition  
Source: Qinyi Zhang

FIG. 10.24 Structure of Yu  
Source: edited by author, based on Pwsannong

Mulberry fish pond complex

The second one appears when the previous water network could not discharge floods. Since rice and other crops could not survive floods. People started to dig fish ponds in low land which is easy to get flooded. They used the dug out soil as the material to consolidate the embankment which later became the place to cultivate mulberry trees. In this way, it creates a whole complex of ecological system.

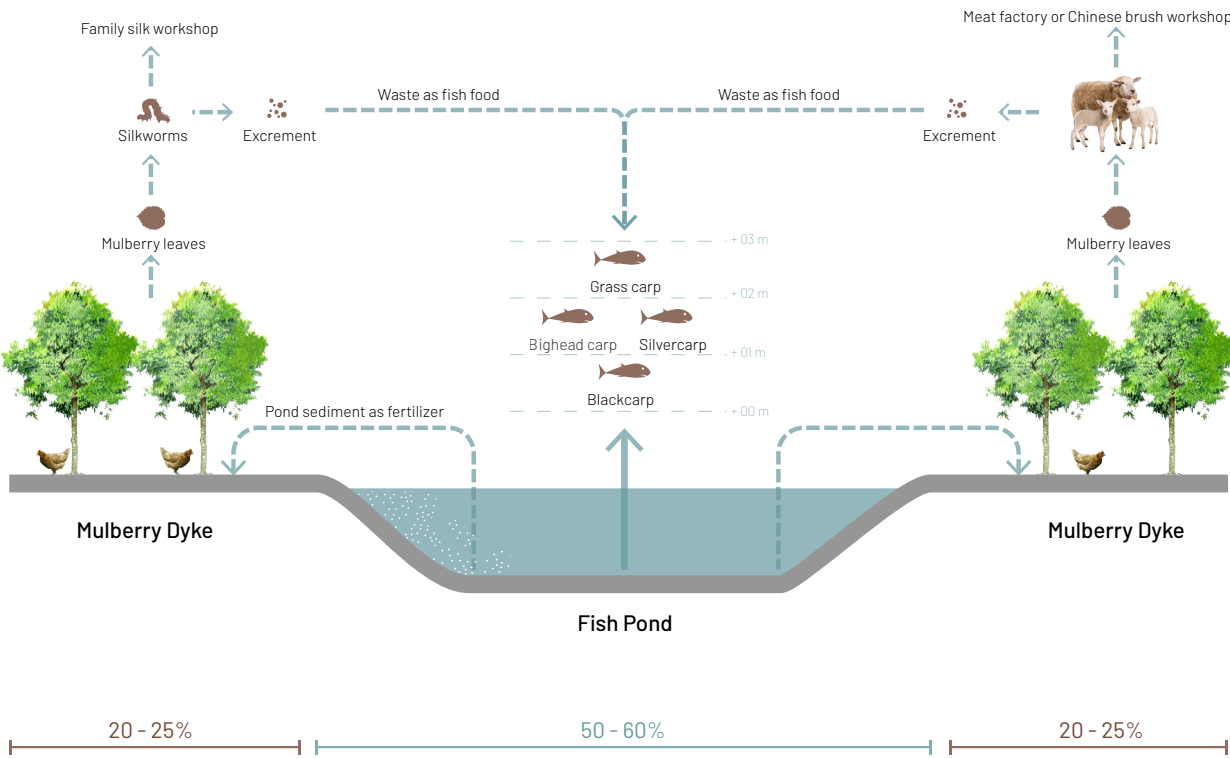


FIG. 10.25 Ecological flows of mulberry fish pond complex  
Source: edited by author



FIG. 10.26 Fish pond in Huzhou  
Source: News.cn [online] available at: [http://www.xinhuanet.com/photo/2017-05/16/c\\_1120977433\\_3.htm](http://www.xinhuanet.com/photo/2017-05/16/c_1120977433_3.htm) [accessed on 14 March 2018]







FIG. 10.29 (part of) Along the River During the Qingming Festival, (1085-1145)  
Source: Painted by Zeduan Zhang, the Palace Museum [online] available at: <http://www.dpm.org.cn/collection/paint/228226.html> [accessed on 26 March 2018].



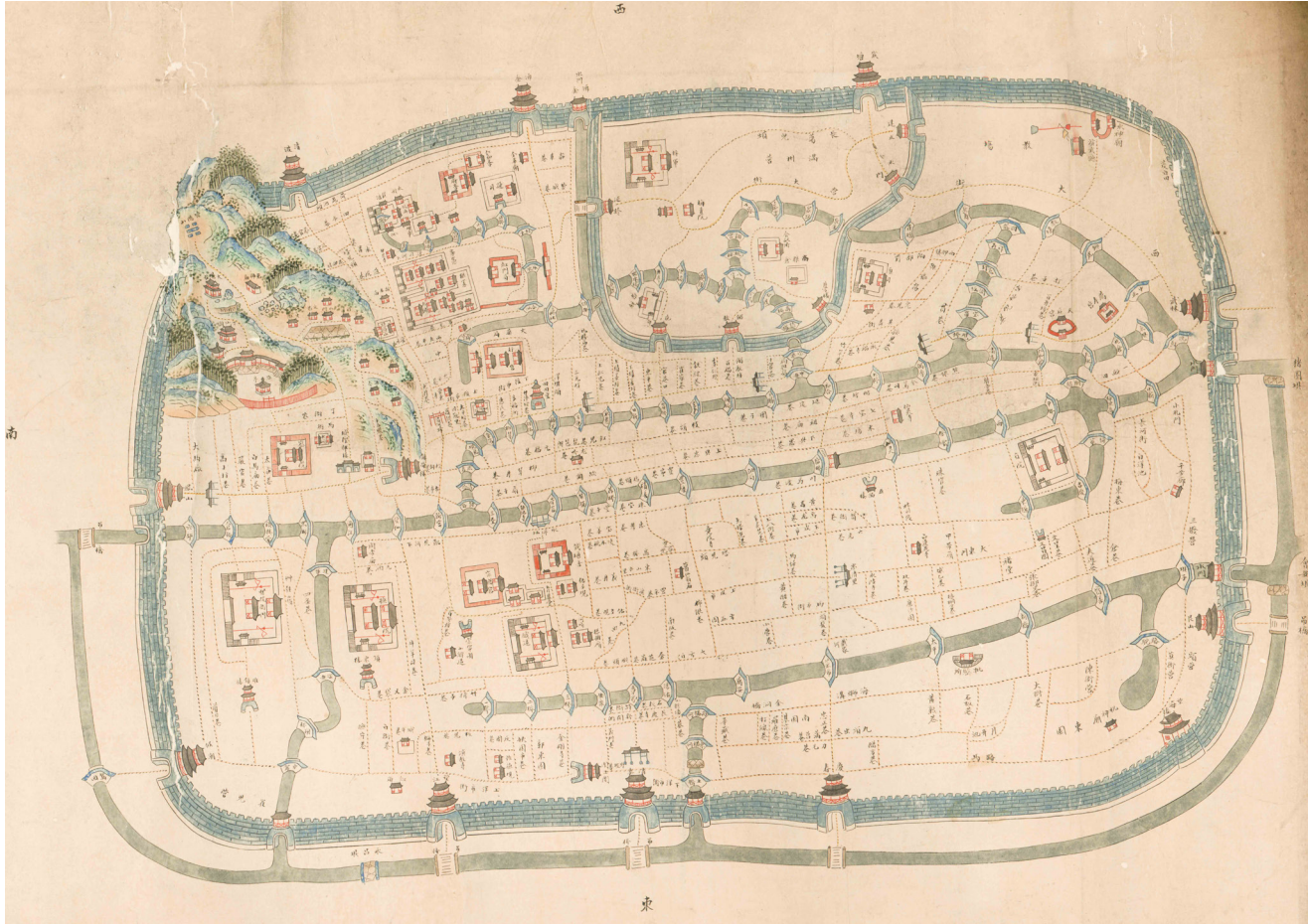


FIG. 10.30 Hydrographic Map of Hangzhou, Capital of Zhejiang Province (1864-1874)  
Source: Library of Congress [online] available at: <http://lccn.loc.gov/89691149> [accessed on 12 February 2018].

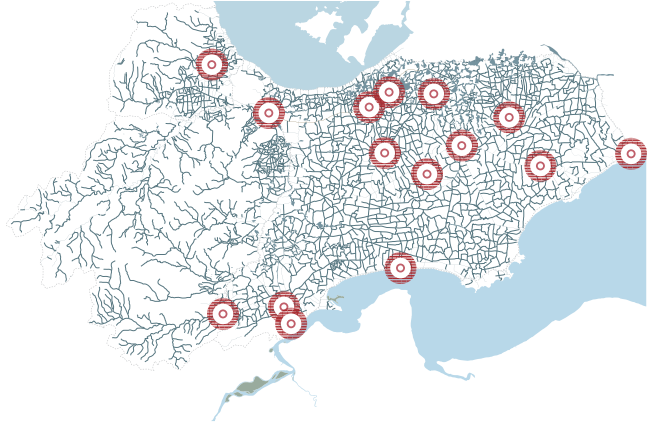


FIG. 10.32 Towns and cities in the Taihu Lake basin  
Source: author

### 10.3 – Example two – ancient city of Hangzhou and Wuzhen

The second example is about the city. In ancient China, cities were always protected by wall. As Marco Polo mentioned in his book (B & Yule, 1904):

*The position of the city is such that it has one side a lake of fresh and exquisitely clear water, and on the other a very large river. The waters of the latter fill a number of canals of all sizes which run through the different quarters of the city, carry away all impurities, and then enter the Lake; whence they issue again and flow to the Ocean, this producing a most excellent atmosphere. By means of these channels, as well as by the streets, you can go all about the city. Both streets and canals are as wide and spacious that carts on the one and boats on the other can readily pass to and fro, conveying necessary supplies to the inhabitants.*

Both from his description and drawing of the landscape, it follows the two network strategy (Tjallingqi, 2010).

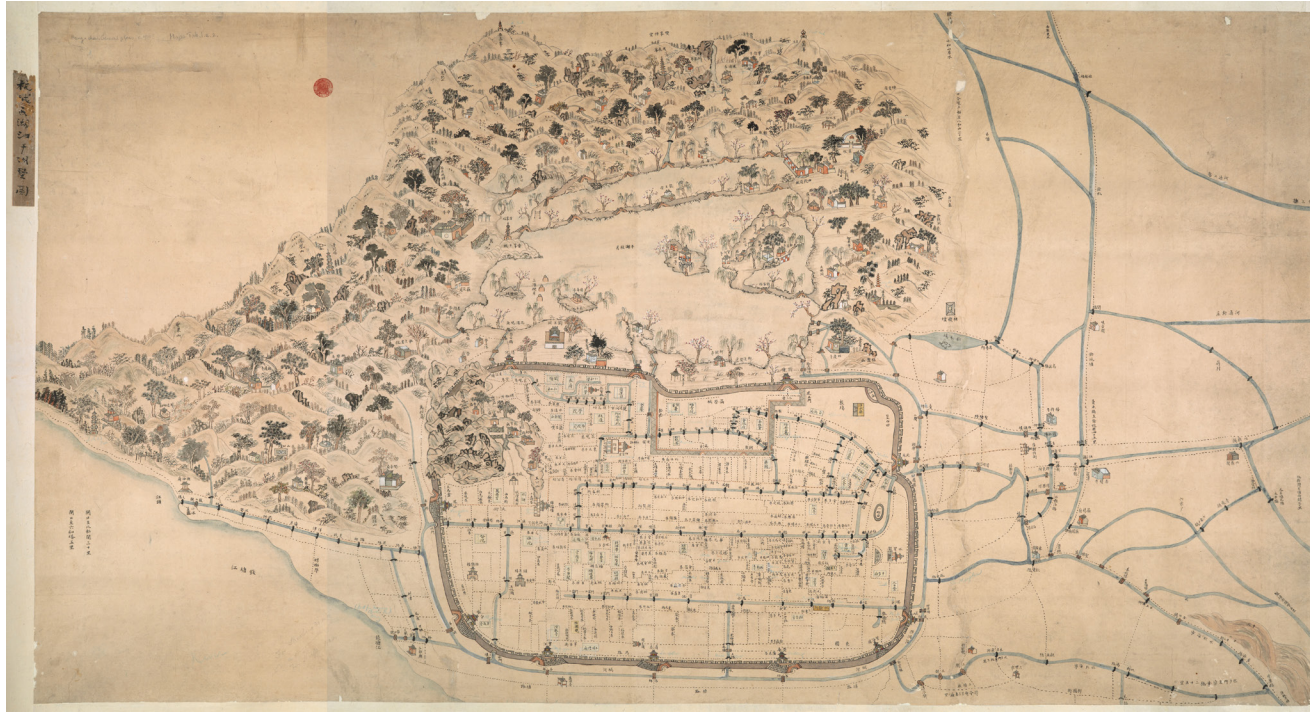


FIG. 10.31 Landscape of Hangzhou (1716-1727)  
Source: British Library [online] available at: [http://explore.bl.uk/primo\\_library/libweb/action/dlDisplay.do?docId=BLL01004856239](http://explore.bl.uk/primo_library/libweb/action/dlDisplay.do?docId=BLL01004856239) [accessed on 12 February 2018].





FIG. 10.34 View of the main canal in Wuzhen  
Source: Ctrip, pictured taken by Kun Zhang

A similar view could also be read from the famous painting of Along the River During the Qingming Festival (FIG 10.28). It shows the flourishing scenery along the street and canals in the Northern Song Dynasty.

Since ancient Hangzhou city exists only in archives, this example will be explored one of the water towns **Wuzhen** in the Taihu Lake Basin which has a history over thousand years.

**Two network of mobility system in ancient Town of Wuzhen**

Similar as the ancient city of Hangzhou, the town of Wuzhen has well integrated two networks of mobility and still function well nowadays.

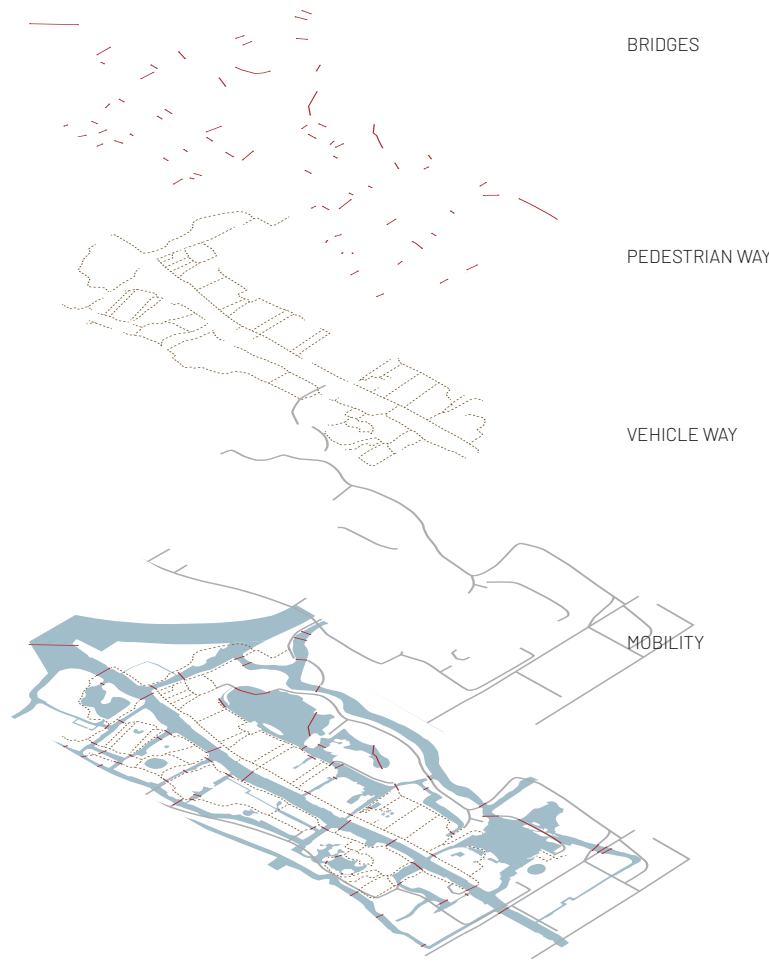


FIG. 10.33 The mobility system of Wuzhen  
Source: author

**Water management system in ancient Town of Wuzhen**

The ancient town of Wuzhen is one of the existing water towns which we could read the ancient method of water management and transportation. It is located along the Grand Canal in the part from Hangzhou to Jiaxing. So the first element of the water management is the connection with the Grand Canal because it's also the main entrance to the town. Then the town is surrounded by south and north moat which separated the settlement with the field. But the moat also has the function of agricultural irrigation. As the main axis of the town, the main canal is the main space for all activities and it's even more important than streets on the land. Between the main canal and moats, there are several small canals and lakes which work as a collector of water around them. In the end, the whole water management system is shown below (FIG 10.34).

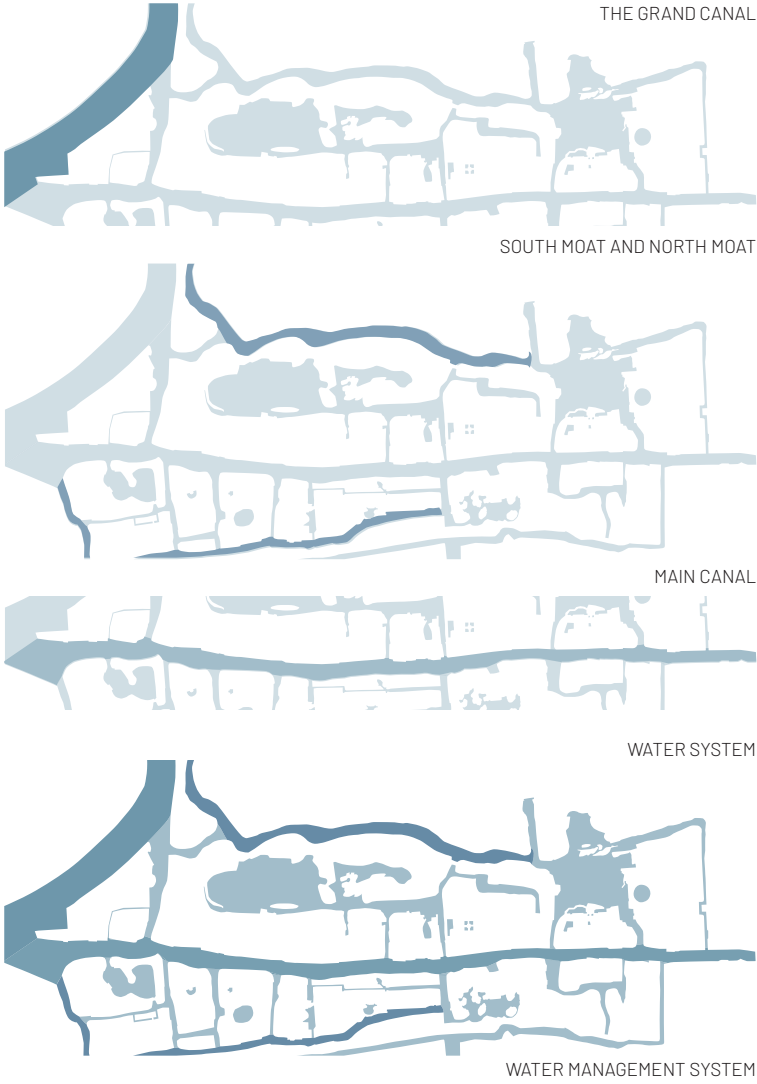
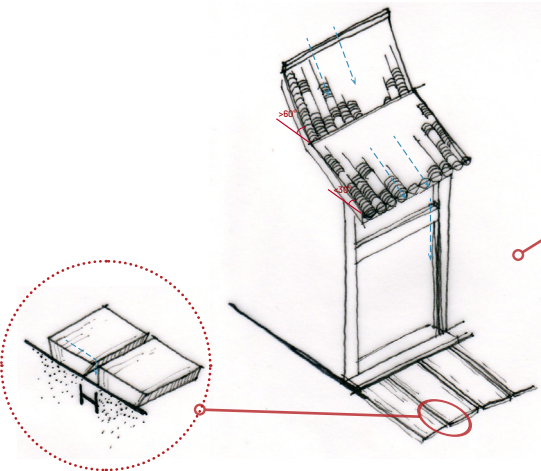


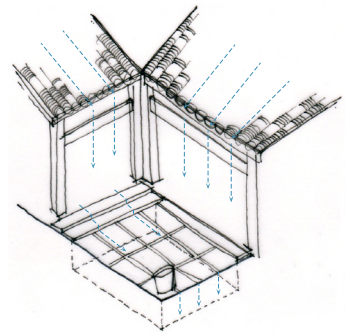
FIG. 10.35 Different elements in the water system of Wuzhen  
Source: author



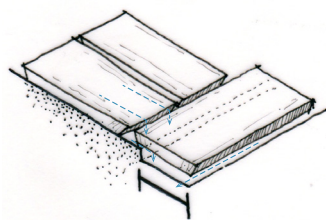
## INDIVIDUAL HOUSE



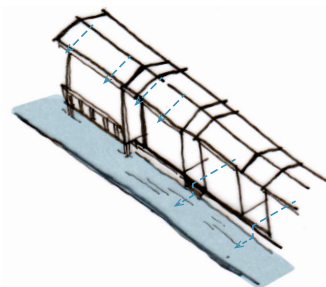
## COURTYARD



## STREET



## CANAL



## Small details of water management in Wuzhen

Apart from the water management of the whole town, there are also small-scale details and methods dealing with water hiding in the ancient town of Wuzhen.

### For individual house:

The degree of the roof leads the water go into the courtyard in the house. The courtyard is usually the lowest place in the house where residents dug a hole in certain depth for temporary water storage or a water vat is always put in the courtyard for rainwater collection. It represents the collection of water and wealth in Fengshui.

### Street:

The street is also an important part of water discharging element in the system. First, the pavement is in the shape of inverted trapezoidal which provides space between pavement for water to keep the street clean. Second, along with each street one or both side will have blind drainage to connect from individual house and canal.

### Canal:

Canal collects water from the roof of the house and street. And it also connects to main canal or river for further discharge.



Roof tiles show direction for rain water to drop.



Space between pavement to keep it clear when it rains.



Water well in the courtyard connects the culvert to the main river.



Courtyard as a space for extra water, and water vat uses for storage.



Pavement along the street.



Pavement in the courtyard.



Well-connected canal system in the town.



Close relationship with water.

FIG. 10.36 Practices about water management in small scale of Wuzhen  
Source: edited by author



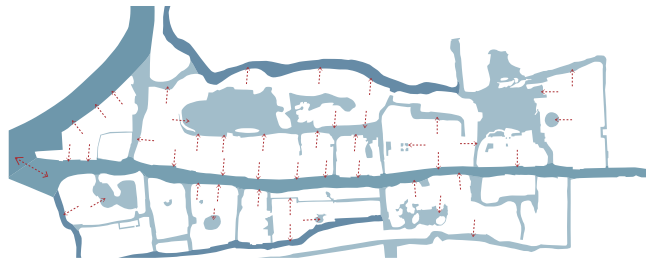


FIG. 10.37 The water management system of Wuzhen  
Source: author

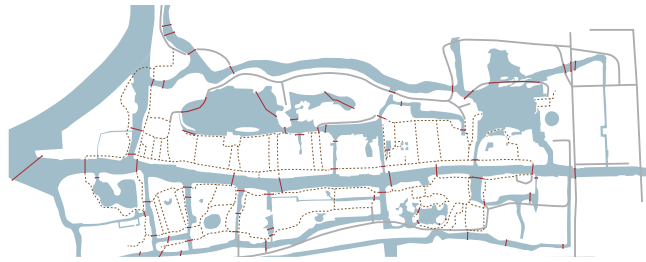


FIG. 10.38 The mobility system of Wuzhen  
Source: author

### Lessons learned

#### System and strategies:

Main water system of Wuzhen

Intersection of two network, water and mobility (water also as part of the mobility)

#### Principles:

New development of urbanization should locate in higher place for safety reason.

Space for water is an important element in flooding defence system in the plain area.

Space between pavement could increase permeable rate.

External water storage could be installed in the building or underground.

Street could be used as an external waterway for flood water discharge.

Water storage could also be applied with a group of house

Public space could be design for water detention and water storage and increase greenery.

#### Strength:

The well-connected water system has a clear structure of main connection, main canal, two moats, small connection and lakes. The main canal works as the main axis of all activities including water management, transportation, economic activities and connection to the Grand Canal. Small canals work as connector which link moats and the main canal. Lakes of different size are evenly spread in the town as collector of water around and also provide public space and recreation function for the town. The well-connect water system helps the town with water management and water resource management which connects field around the town.

Inside the water system, small scale water storage and management in the building and along the street also contributes to it.

The appearance of water creates micro climate with better living environment for inhabits and close relationship between human and water.

The combination of two network increases the connectivity and accessibility for the area. The network of waterway and street created the connection - bridge as an important spot for activities. Bridges and space along the canal work as public space for retail and other small business.

Well functioning water management system could promote the development of local economy and creates unique culture with close relationship of nature.

#### Weakness:

In the town of Wuzhen, water system has dominant position which causes a bit disconnection with the mobility system of the regional scale. For now, tourism becomes the main economic income for the town.

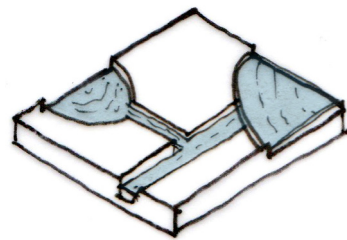
#### Possible apply area:

The water system of Wuzhen provides another composition of flooding defence system.

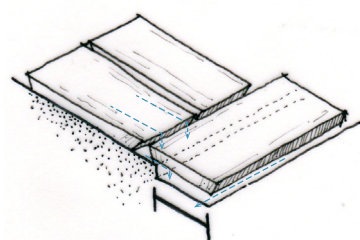
It could be applied in the planning of new development with the requirement of flooding defence.

The small scale intervention about individual buildings, street could be used not only in new development but also in the regeneration project.

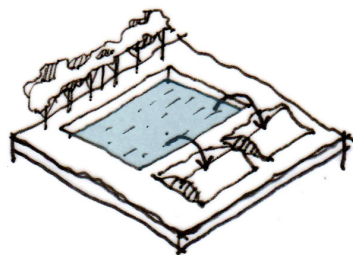
10.4 – Principles



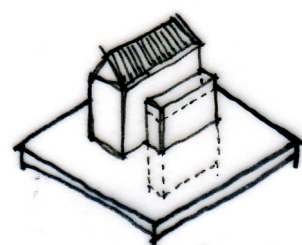
Space for water is an important element in flooding defence system in the plain area.



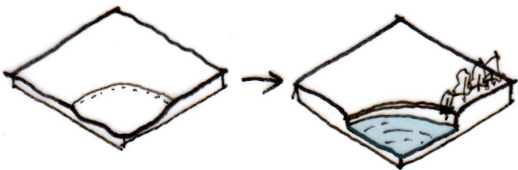
Space between pavement could increase permeable rate.



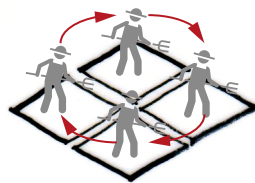
Soil extraction for other purpose, like dyke maintenance, fertilization.



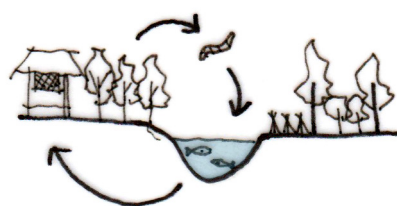
External water storage could be installed in the building or underground.



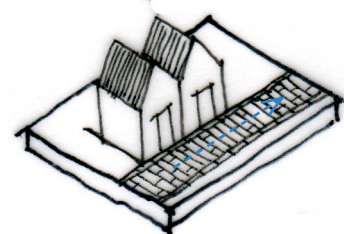
Lower land which easier to get flooded could be used as flood detention area and water storage area.



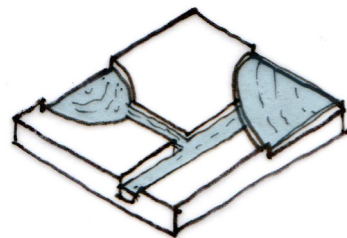
Water management as a collective work.



Reuse of ecological waste into other use like sedimentation recycle.



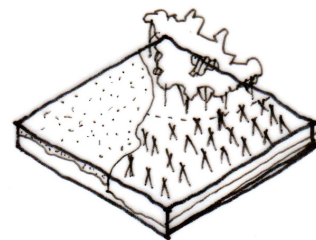
Street could be used as an external waterway for flood water discharge.



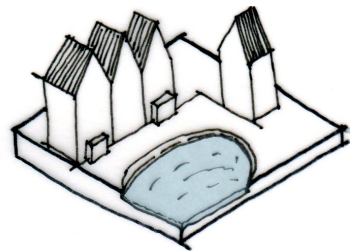
Ditches and canals play as main connection between different water resources.



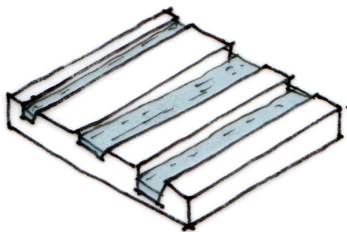
Changing ground level could be applied for different types of plantation which needs different water conditions.



Make use of different soil types for plantation design.



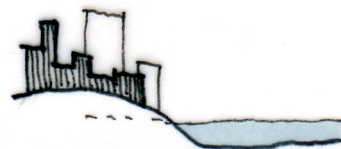
Water storage could also be applied with a group of house.



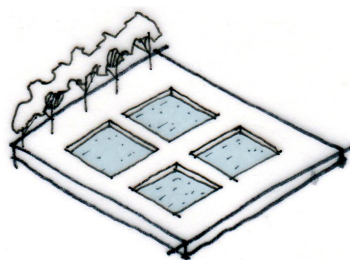
Widen or deepen ditches could improve sufficiency of flooding water discharge and capacity of transportation.



Changing ground level could be applied for different types of plantation which needs different water conditions.



New development of urbanization should locate in higher place for safety reason.



Public space could be design for water detention and water storage and increase greenery.

11 – Qiantang River Basin

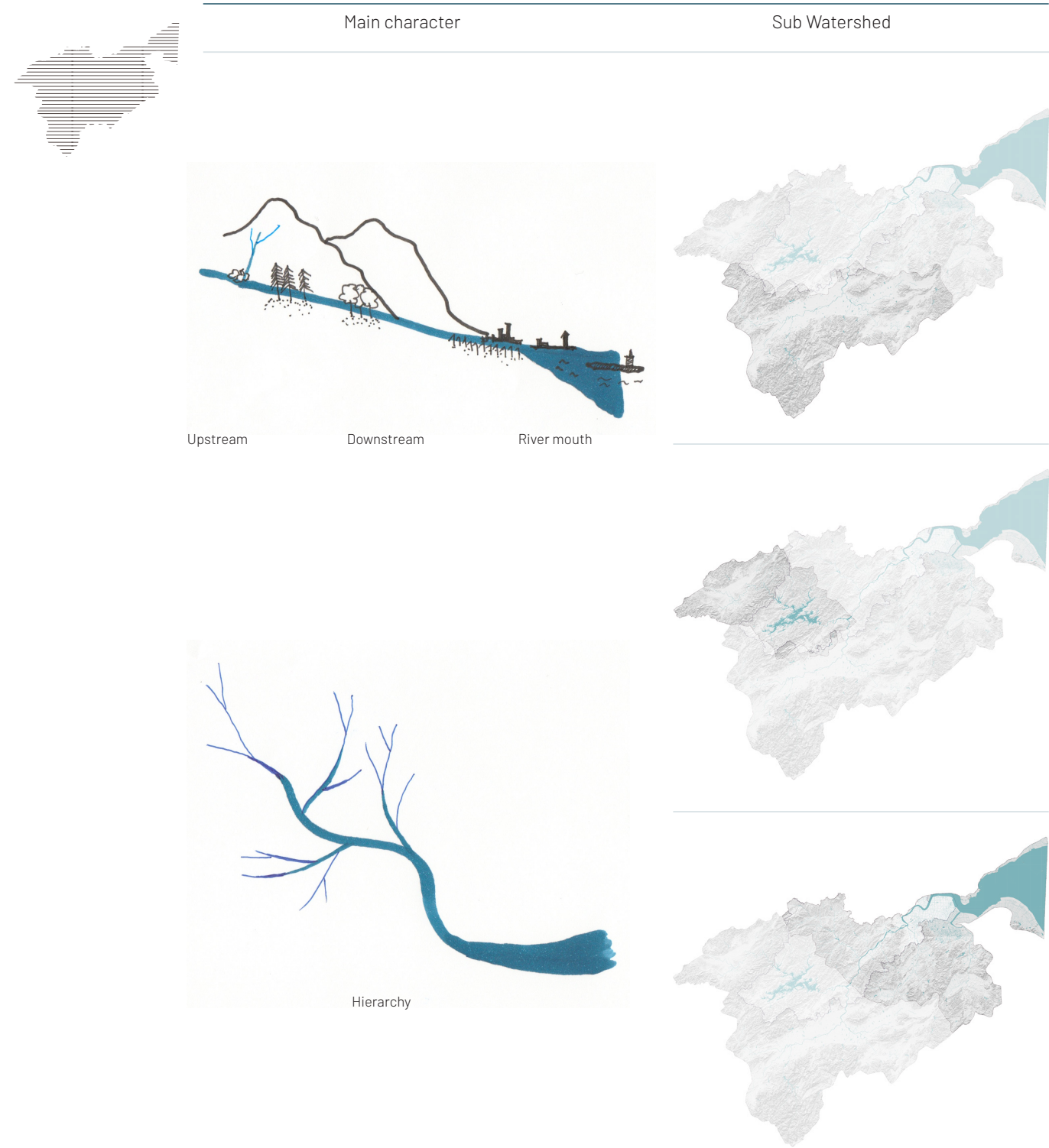






FIG. 11.1 First impression of Qiantang River  
Source: edited by author

FIG. 11.2 Evolving edge of Yangtze River Delta  
Source: edited by author, base on Catherine Seavitt Yangtze River Delta Project[online] available at: <https://scenariojournal.com/article/yangtze-river-delta-project/.html> [accessed on 26 February 2018].

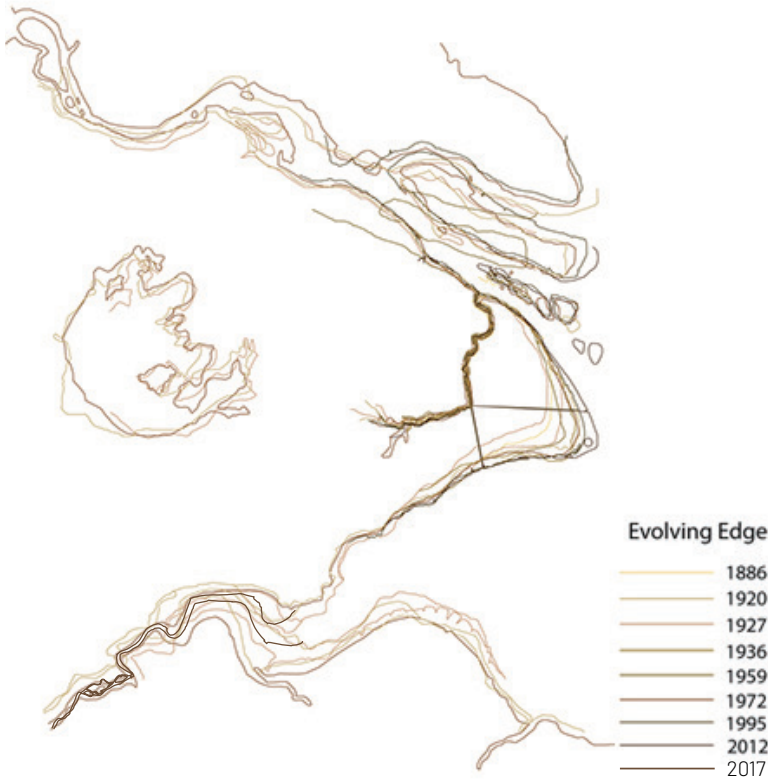


FIG. 11.3 Liuhe Pagoda and Qiantang River Bridge  
Source: QQ news [online] available at: [https://news.qq.com/a/20100623/001989\\_7.htm](https://news.qq.com/a/20100623/001989_7.htm) [accessed on 12 February 2018].



FIG. 11.4 Sub watersheds in the Qiantang River Basin  
Source: edited by author based on GIS data

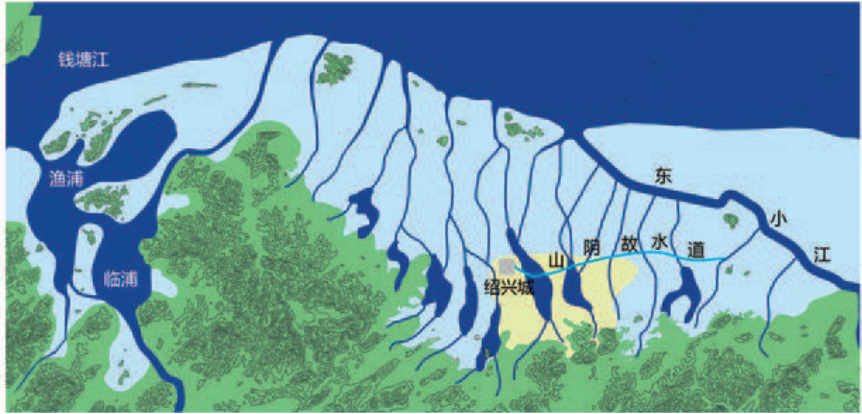
### 11.1 – Qiantang River Basin

Qiantang River Basin is close to the southeast coast of China and belongs to subtropical monsoon climate. It separates the city into two sides. It is the mother river of Hangzhou, also took efforts of generation to control its risk from its unique tidal bore. The tidal bore in Qiantang River brings salty water

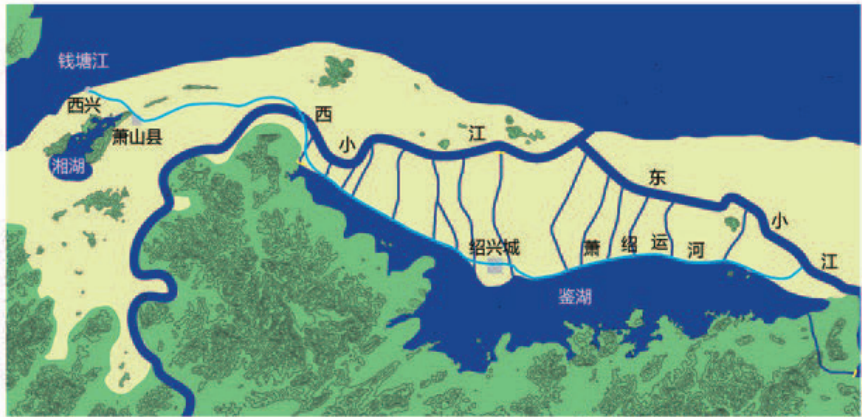
Qiantang River and the Hangzhou Bay are known as the world's largest tidal bore. Tidal bore brings strong wave to threaten the safety of people and property, and also brings a lot of salt water which causes salinity of water and soil. Moreover, with the sand brought by waves, it's been difficult to fully use the function of transportation along the river especially the part downstream of the river.

Examples will be explored from two different types of landscape. One will be Weir and Beitang system in hilly area. The other will be Xiaoshao plain close to the river mouth of Qiantang River.





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FIG. 11.5 Historical change of Xiaoshao Plain  
Source: Wei Guo

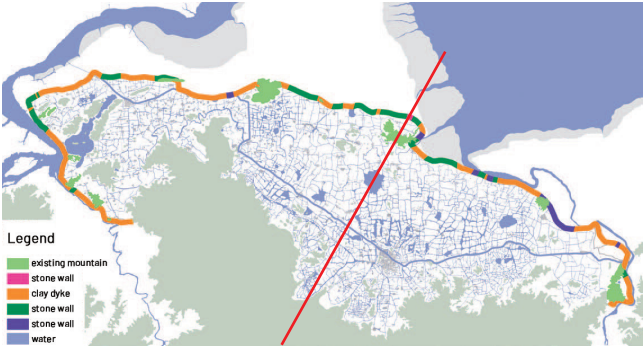


FIG. 11.6 Types of sea wall in the Xiaoshao Plain  
Source: Wei Guo

### 11.2 – Example three -Xiaoshao Plain and Eastern Zhejiang Canal

This example is combined with two parts. The first one is the evolution of the water system in Xiaoshao plain polder reclamation area.

The plain is located in the river mouth of Qiantang River, suffering from the tidal bore and soil salinization which had been marked as swampland. By building the hydraulic system over the years, it becomes one of the richest and important areas in China thanks to the Eastern Zhejiang Canal.

The hydraulic system includes seawall, dykes, rivers (ditch, canals), reservoirs, weirs, and sluices. The hydraulic system has different layers of flooding protection. The first layer is the seawall to prevent salt water to come in. Then, it has a man-made reservoir for storing the fresh water comes from the mountains. Together with sluice, canal, and ditches, they are a complete flood defence and water resource management system.

Qiantang River and the Hangzhou Bay are known as the world's largest tidal bore. Tidal bore brings strong wave to threaten the safety of people and property. And it also brings a lot of salt water which causes salinity of water and soil. Moreover, with the sand brought by waves, it's been difficult to fully use the function of transportation along the river especially the part downstream of the river.

Local resident created an old water way along the man-made lake around 140-1010.

Different types of landscape in short distance has edge effect, so wetland has high biological diversity and healthy ecological system (FIG 11.8 &11.9).

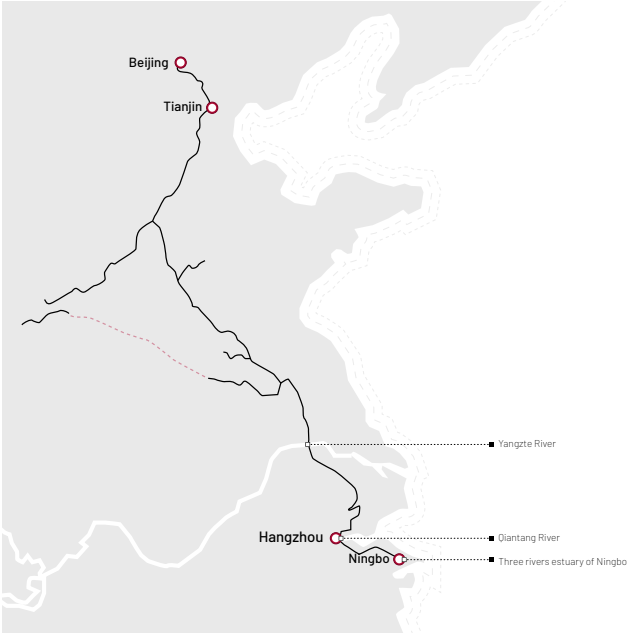


FIG. 11.7 Location of Eastern Zhejiang Canal  
Source: author

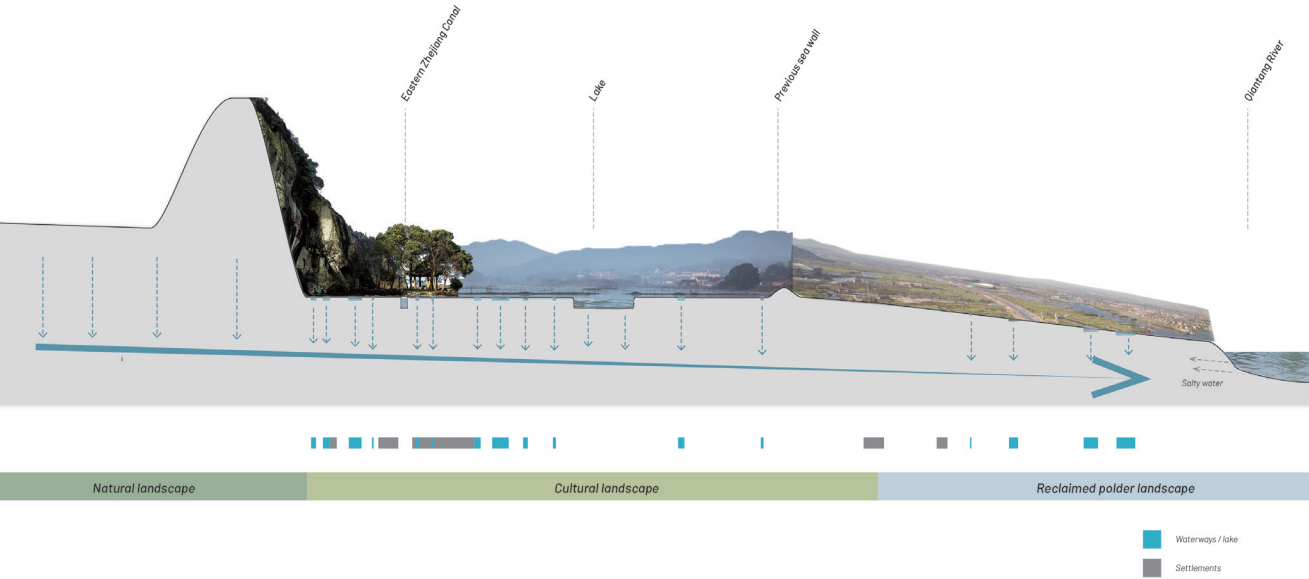
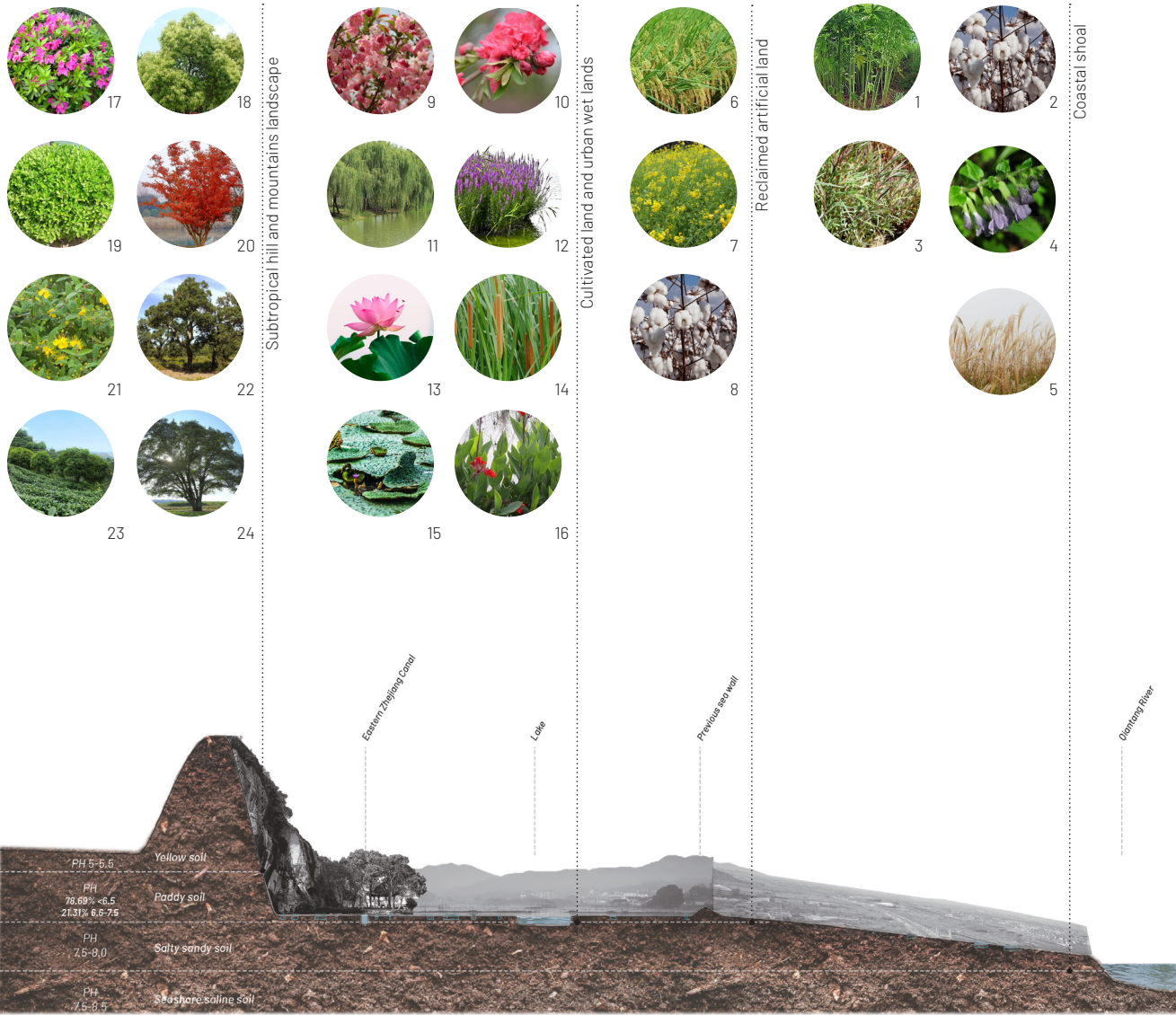


FIG. 11.8 Section of landscape change  
Source: author



- |   |  |
|---|--|
| 1 <i>Corchorus capsularis</i> L.  | 15 <i>Euryale ferox</i> Salisb. ex Konig et Sims |
| 2 <i>Gossypium</i> spp  | 16 <i>Canna glauca</i> L.                        |
| 3 <i>Artemisia halodendron</i> Turcz. ex Bess.                            | 17 <i>Rhododendron pulchrum</i> Sweet            |
| 4 <i>Meehania henryi</i> (Hemsl.) Sun ex C. Y. Wu                         | 18 <i>Cinnamomum camphora</i> (L.) Presl.        |
| 5 <i>Phragmites communis</i>  | 19 <i>Buxus megistophylla</i> Levl.              |
| 6 early seasonal rice   | 20 <i>Acer palmatum</i> Thunb.                   |
| 7 <i>Brassica napus</i> L.  | 21 <i>Hypericum monogynum</i> L.                 |
| 8 <i>Gossypium</i> spp  | 22 <i>Quercus variabilis</i> Bl.                 |
| 9 <i>Malus halliana</i> Koehne  | 23 <i>Camellia sinensis</i> (L.) O. Ktze.        |
| 10 <i>Amygdalus persica</i> L. var. <i>persica</i> f. <i>duplex</i> Rehd. | 24 <i>Ulmus pumila</i> L.                        |
| 11 <i>Salix babylonica</i>  |  |
| 12 <i>Lythrum salicaria</i> L.  |  |
| 13 <i>Nelumbo nucifera</i> Gaertn.  |  |
| 14 <i>Acorus calamus</i> L.   |  |

FIG. 11.9 Section of soil and habitat change  
Source: author



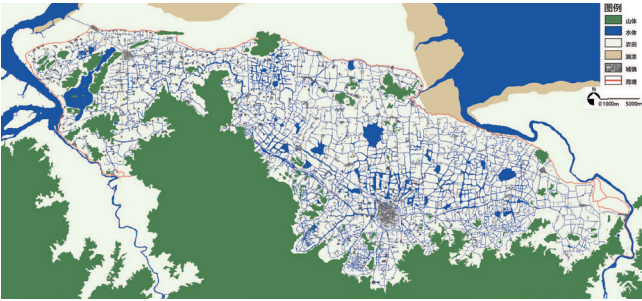


FIG. 11.10 Relationship between settlements and water of Xiaoshao Plain  
Source: Wei Guo

**Lessons learned**

**System and strategies:**

Hydraulic system for polder landscape

Canal as main transportation method

**Principles:**

Sluice as the main elements to connect rivers with different water levels and it's important for water transportation.

New development of urbanization should locate in higher place for safety reason.

Soil extraction for other purpose, like dyke maintenance, fertilization.

Space for water is an important element in flooding defence system in the plain area.

**Strength:**

The hydraulic system has different layers of flooding protection. The first layer is the sea wall to prevent salty water to come in. Then, it has a man-made reservoir for storing the fresh water comes from the mountains. Together with sluice, canal and ditches, they are a complete flood defence and water resource management system.

The connection of Eastern Zhejiang Canal to the Grand canal promotes economy and culture for Xiaoshao Plain.

Different types of landscape in short distance has edge effect, so wetland has high biological diversity and healthy ecological system.

**Weakness:**

The dense water network was occupied by the new urban development. Modern mobility reduce the importance of water transportation.

**Possible apply area:**

The hydraulic system of polder landscape has similarity of Dutch polder landscape and could be applied in low land.

The principle of water system and settlement could be applied for new development

The water system could be connected with green space to create green blue infrastructure for the future city.

The existing water system could be redesigned as urban wetland.



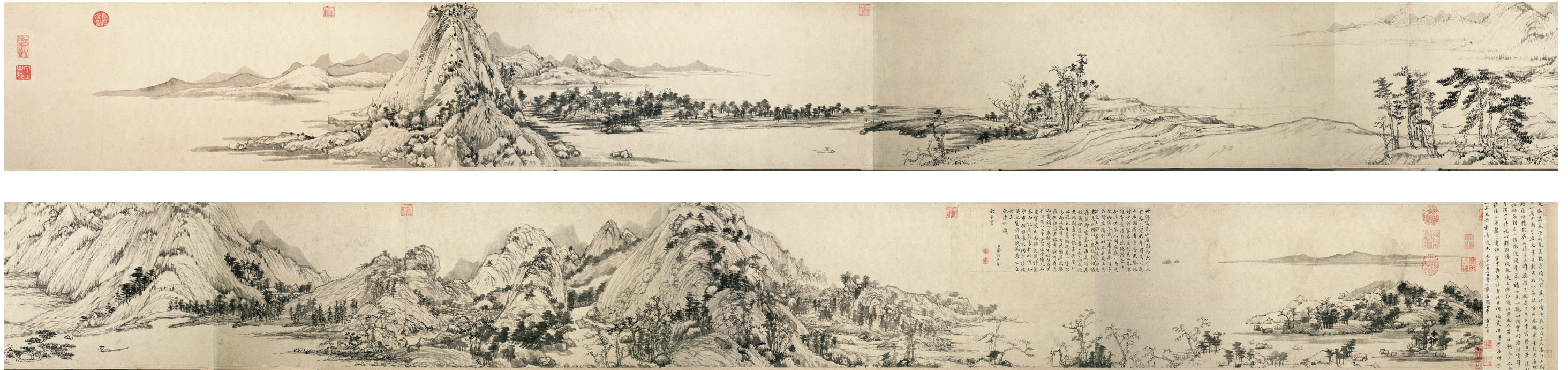


FIG. 11.11 (part of) Dwelling in the Fuchun Mountains  
(1348-1350)  
Source: Painted by Gongwang Huang, National  
Palace Museum in Taipei [online] available at:  
[http://www.npm.gov.tw/exh100/fuchun/ch\\_02\\_1.html#t00](http://www.npm.gov.tw/exh100/fuchun/ch_02_1.html#t00) [accessed on 26 March 2018].



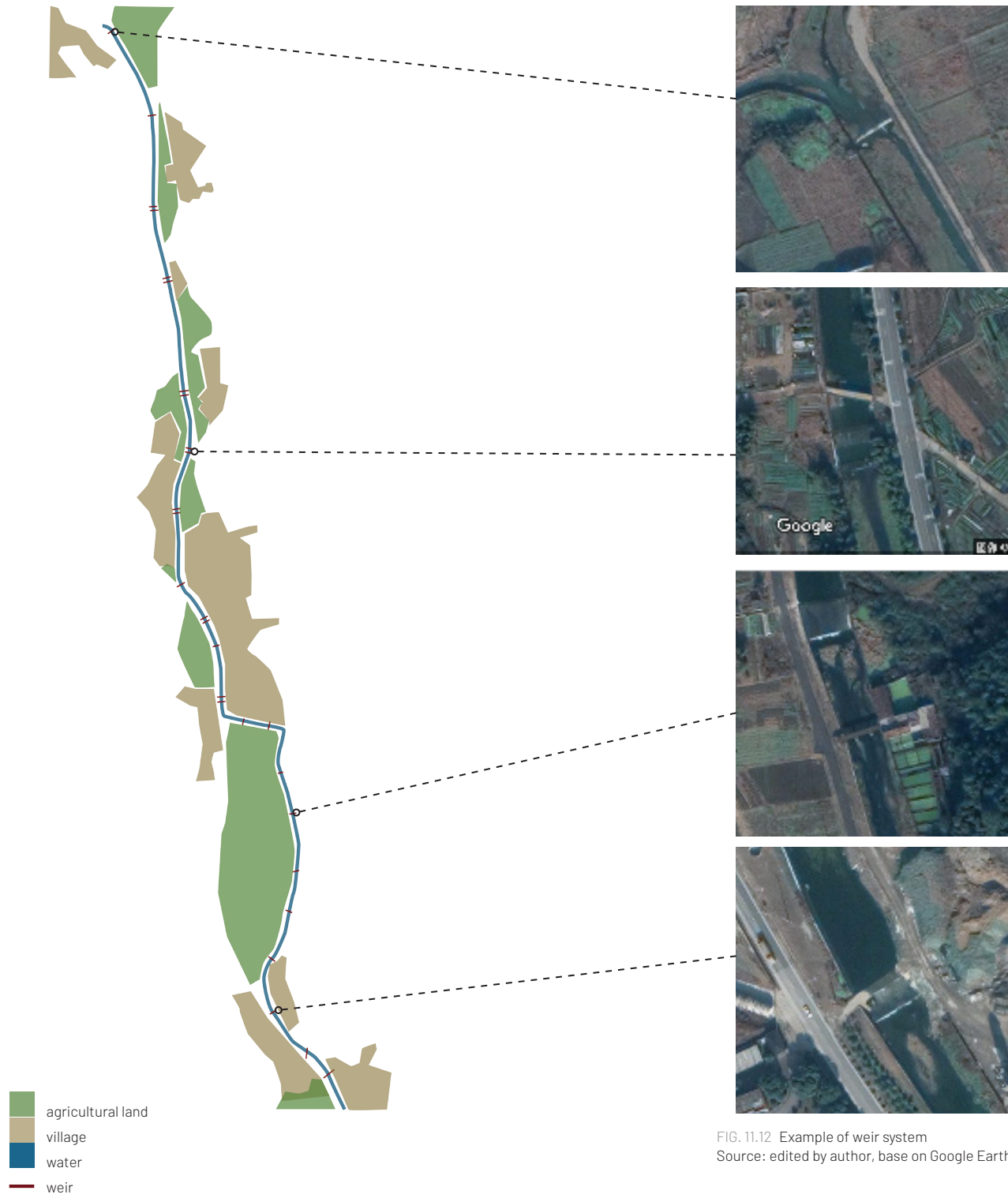


FIG. 11.12 Example of weir system  
Source: edited by author, base on Google Earth

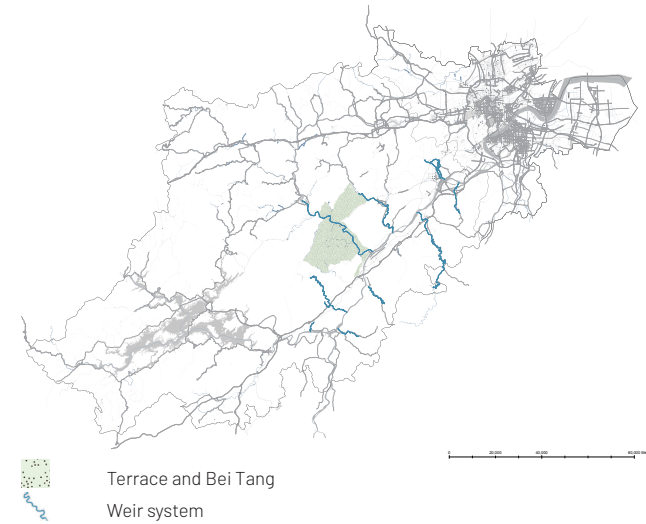


FIG. 11.13 Location in the Qiantang River Basin  
Source: edited by author, based on GIS data and Google Earth

### 11.3 – Example four –Weir system

The painting of 'Dwelling in the Fuchun Mountains' shows the beautiful scenery along Qiantang River (FIG 11.11). Weir as a low intervention device could reduce the big influence on the landscape itself.

Weir is a small scale dam made by stones and bricks. The main function is to change the speed of water flow along the river in the hilly area. The small dyke not only works as a block but also provides overflow in the wet season. So the speed of water slows down before it meets the dyke and creates a certain size of the water surface, making it safe and easy to get access to water.



FIG. 11.14 Example of weir system  
Source: edited by author, base on Google Earth



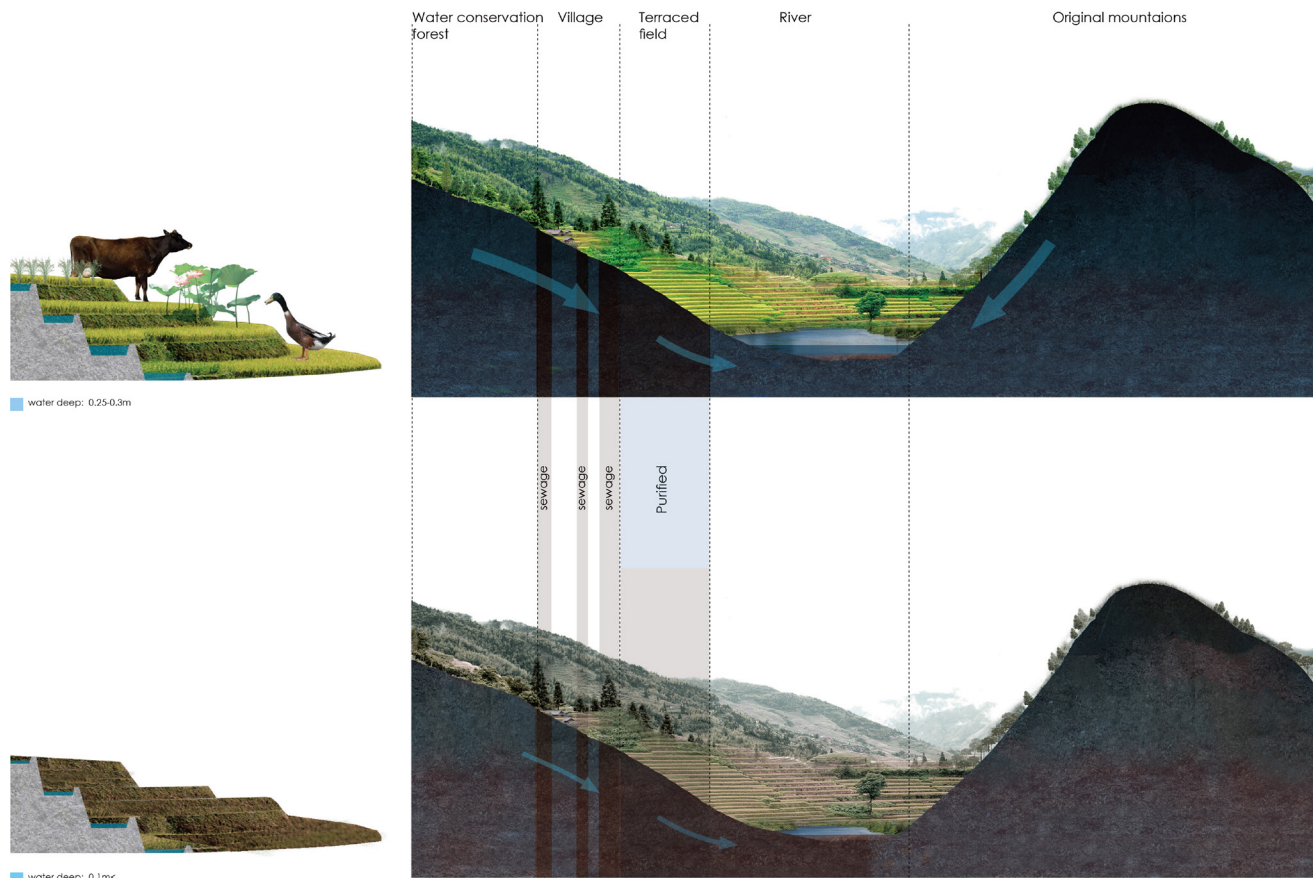


FIG. 11.15 Diagram of typical terrace with pond system  
Source: edited by author, base on diagram of HKU of Ning'er program

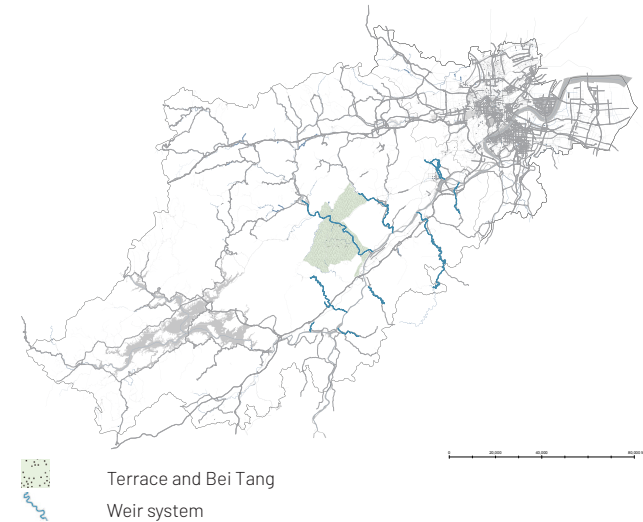


FIG. 11.16 Location in the Qiantang River Basin  
Source: edited by author, based on GIS data and Google Earth

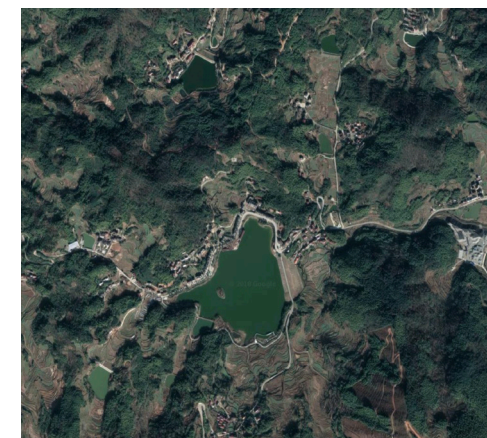


FIG. 11.17 1. Terrace with Beitang  
2. Terrace with Beitang  
Source: Google Earth

#### 11.4 – Example five -Beitang (pond) system

Beitang is one type of small water surfaces between terrace or close to terrace. It means farm pond, which has water surface between 1 meter square to 2 hectometre square. It needs to be filled with water for more than four month per year.

It started to appear in the hilly area of western part of Zhejiang Province in Song Dynasty. The main reason of started to terrace construction was the contradiction between limited plain area and fast growth of population. In the year of 1,175 only, there was 2,100 Beitang built in the western part of Zhejiang Province.

One of the best way to turn mountain into arable land is to build terrace. Then the problem of irrigation for the dry season arises due to the uneven precipitation over year. To solve this problem, local farmers started to build man-made ponds as medium or small scale water infrastructure in between of terrace for water storage and purification. This method worked because this area has tattered land form, abundant precipitation and dense water.

By comparing the normal terrace and Beitang system (FIG 11.6), Beitang plays an important role in the dry season for regulating the humidity for the soil and part of the function for irrigation. Also the landscape of Beitang combines ponds, field, forest, sewage and pathway. With the whole system, it could function not only as water storage, but also water purification and protection of biodiversity.

As this example in the Qiantang River basin, field is surrounded by diverse vernacular plantation and forest. The main purpose is to irrigate field and infiltrate rain water. Moreover, it has the fish culture and recreational function. It has high ecological service value until now.

**Lessons learned from Example four and five**

**System and strategies:**

Weir system: changing speed of water to increase accessibility to river

Beitang system: irrigation, rain water storage and water purification

**Principles:**

Water could be stored in the spot for infiltration.

Make use of the natural flows.

Make use of the soil type with less permeability for water storage.

Weir structure could be built by simple materials like local stones.

Weir could be used as devices of changing the speed of water and water storage infrastructure.

Water flows could be visible for public space and create close relationship with human.

Space along water infrastructure creates public space for local residents.

**Strength:**

Weir system is one of the vernacular device for changing the speed of water and increasing the accessibility to water, while Beitang system plays as main infrastructure for irrigation for the terrace in the hilly area. Both make use of local material and local character. Together with reservoirs, they form the whole irrigation system in the hilly area of Qiantang River Basin.

Beitang has high ecological services value with the its multifunction as storage, fire protection, infiltration and recreation.

**Weakness:**

The initial devices are made of simply but poor materials with less stability and could resist strong flood. Small scale devices have limited benefited area(buffer zone) around them. To increase or maintain the high ecological services value, the connectivity of them needs to be improved.

**Possible apply area:**

Weir device could be applied in the urban water landscape with height for changing the speeding of water and create different forms of water.

Existing big Beitang could be considered as part of the green blue infrastructure for the future city.

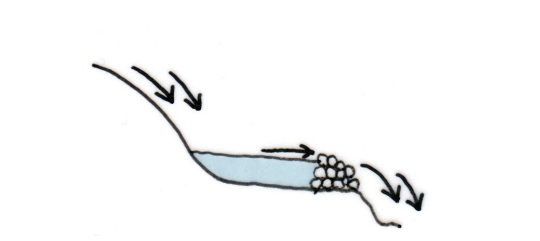
Exisiting Beitang could be transferred into wetland to build a Beitang-wetland system for field.

The principle of water storage at spot could be applied into urban neighbourhood to re-design the public space into temporary water storage space like water square and increase the space for rain water storage for the building itself.

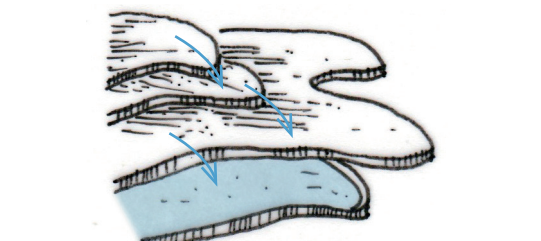
Beitang could also be connected with the existing river, lake stream, low land and ponds and combine a complete rain water management system and purification system.



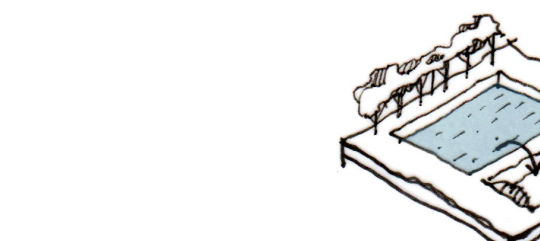
11.5 – Principles



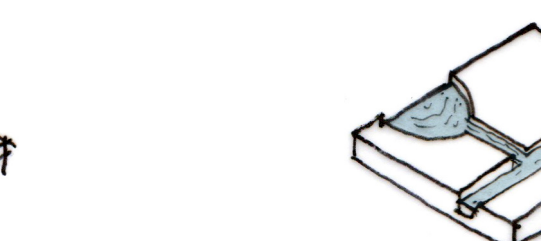
Weir could be used as devices of changing the speed of water and water storage infrastructure.



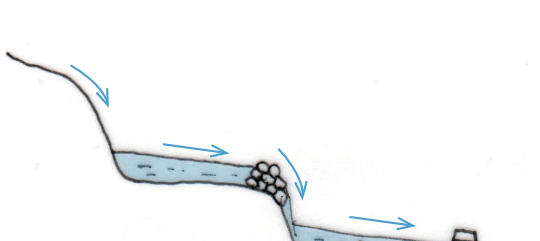
Make use of natural flows.



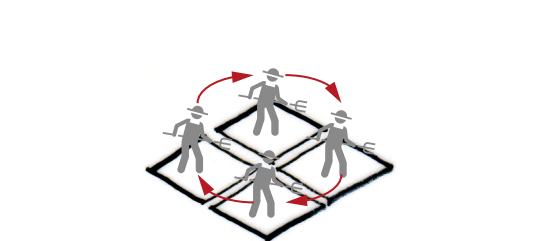
Soil extraction for other purpose, like dyke maintenance, fertilization.



Space for water is an important element in flooding defence system in the plain area.



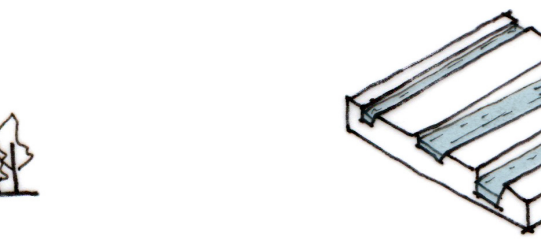
Weir could be built by simple materials like stones.



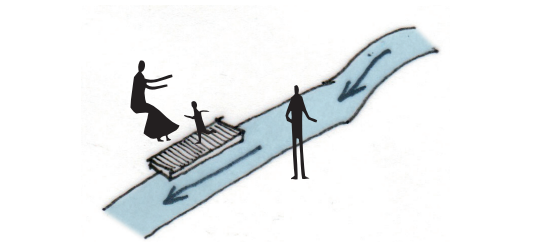
Water management as a collective work.



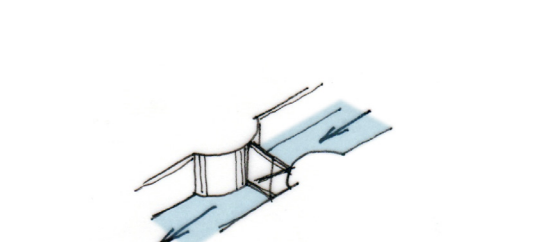
Reuse of ecological waste into other use like sedimentation recycle.



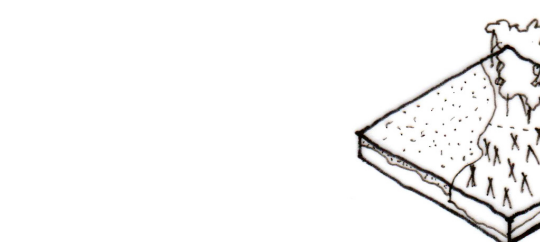
Widen or deepen ditches could improve sufficiency of flooding water discharge and capacity of transportation.



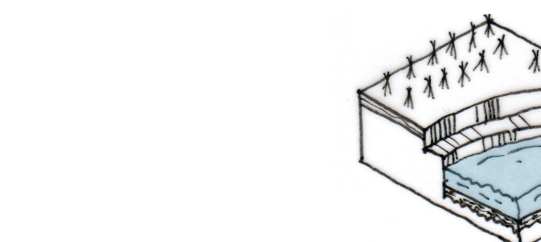
Water flows could be visible for public space and create close relationship with human.



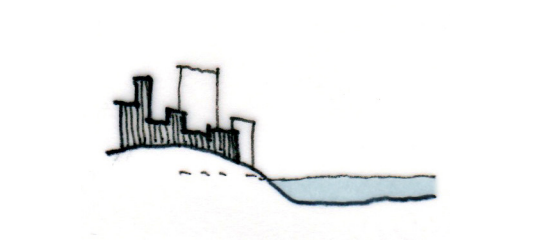
Sluice as the main elements of connecting rivers with different water levels and it's important for water transportation.



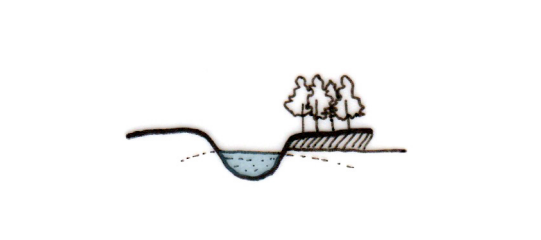
Yellow soil, red soil and clay has less permeability than other soil types.



Make use of the soil type with less permeability for water storage or small ponds.



New development of urbanization should locate in higher place for safety reason.



Different types of landscape in short distance could create edge effect to improve biodiversity.



Space along water infrastructure creates public space for local residents.

## 12 – Conclusion

## 12.1 – Well-connected water system

All three examples of Taihu Lake irrigation and discharging system, the water town Wuzhen and Xiaoshao Plain have a well-connected water system. However, their compositions vary from each other due to their special locations in the whole watershed and different water problems.

For irrigation and discharging system in Taihu Lake plain, it consists of dense and grid water network together with ponds and fields as mediator under different water conditions to distribute the risk of flooding and drought.

For the water town Wuzhen, the water system used to be the main mobility system. It is composed of main canal and surrounded by two moats. Small canals work as connector between main canal and moats, while lakes and ponds as extra water collector in the grid of main canal and small canals.

For the Xiaoshao plain, it has an extra protection due to its location of the river mouth. The sea wall cut off salty water and Jianhu lake for fresh water storage. The initial lake was split into small pieces due to the pressure of population growth. However, the Eastern Zhejiang Canal has been kept since then.

In conclusion, both location natural condition and historic, cultural background are important in the process of water system for flood defence.

## 12.2 – Low impact intervention of dealing with water problem in small scale

Small scale practices like Yu field and fish pond in the plain area show the principles of low impact intervention dealing with different water levels, and provide high ecological service value. These principles could be applied in the process of building urban wetland both for ecological value and recreational value.

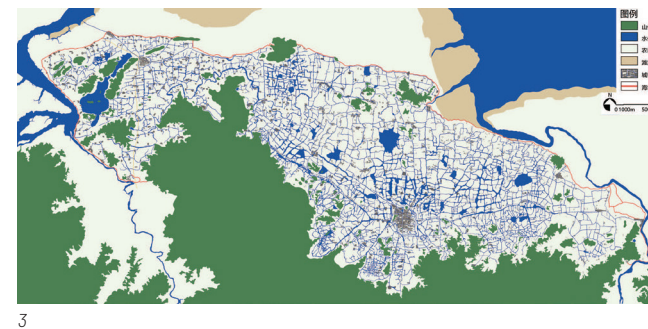
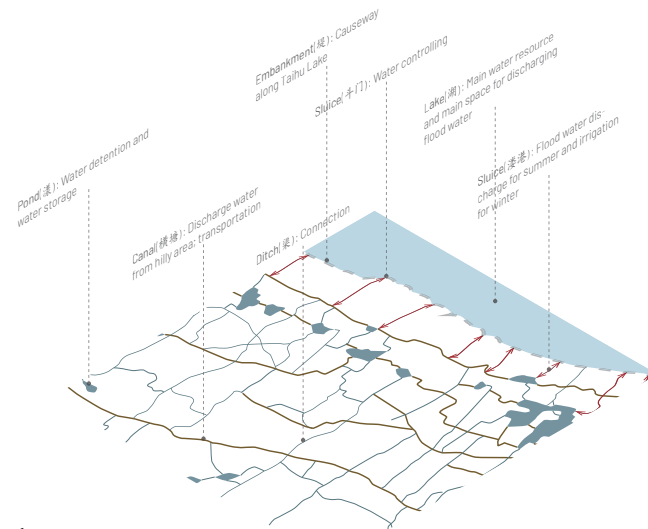


FIG. 12.1 1. Irrigation and discharging system of Taihu Lake Plain  
2. Water town Wuzhen  
3. Xiaoshao Plain  
Source: edited by author



FIG. 12.2 Old picture of transferring rice from Taihu Lake plain to Capital Beijing through the Grand Canal  
Source: cropped from video of Tengxun

Other example like the impressive detail in water town Wuzhen could be considered as principles for both new development and regeneration project to provide communities with better living space.

Last but not the least, two low impact intervention in the hilly area could work together for to improve water resources management and offer productive and ecological values with water which has different water levels or streams in the hilly area.

### 12.3 - Well-functioning water system could promote the development of economy and culture

Well-functioning water system could not only protect the safety of life and property, but also promote the development of economy and culture. The plain area of Taihu Lake is famous for its rice and silk production. Xiaoshao Plain took advantage of the connection from Ningbo port, and became one of the richest places in China. Thanks to the flourishing economy and stable society, there are lots of famous painters, poets and calligraphers from this region.

## 12.4 – Social change effects on the relationship between human and water

High maintenance requirement is necessary for the dense water network. Water management used to be considered as a group work and it was crucial for the productivity of farm land.

With the changing of population structure and increasing of technical level, the relationship between human and nature are not as close as before. The importance of these system has been forgotten.

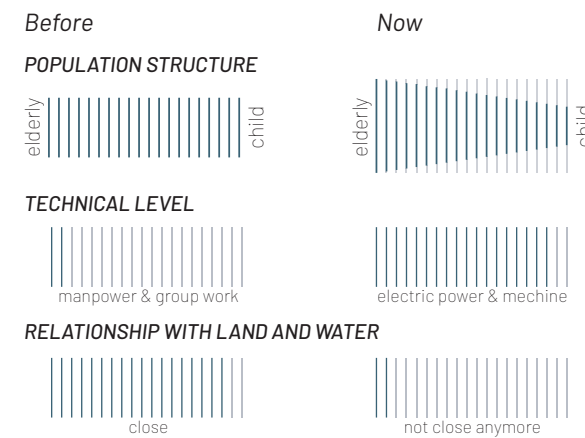
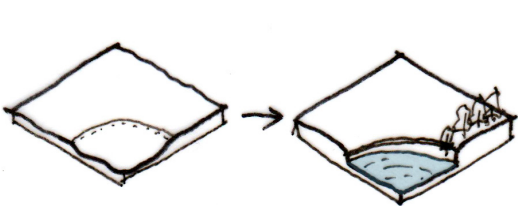


FIG. 12.3 Diagram of difference between  
Source: edited by author

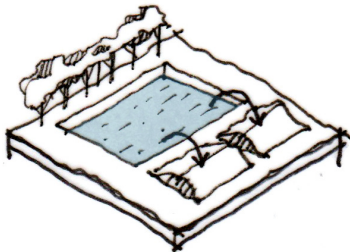


12.5 – Principles

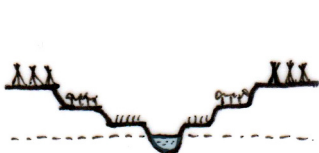
Principles for the natural environment



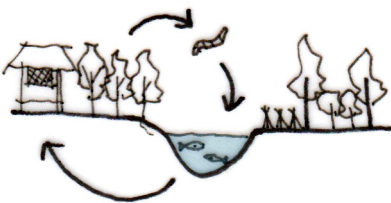
Lower land which easier to get flooded could be used as flood detention area and water storage area.



Soil extraction for other purpose, like dyke maintenance, fertilization.



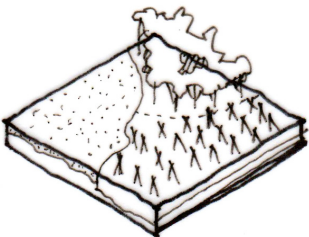
Changing ground level could be applied for different types of plantation which needs different water conditions.



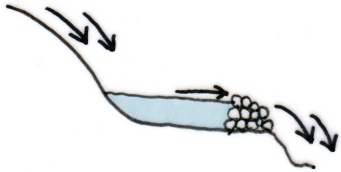
Reuse of ecological waste into other use like sedimentation recycle.



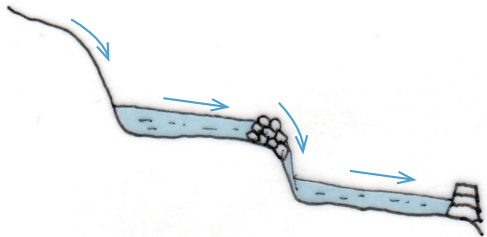
Changing ground level could be applied for different types of plantation which needs different water conditions.



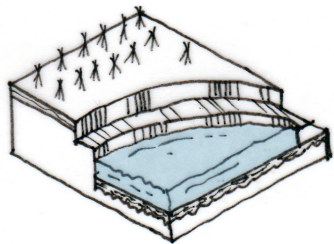
Make use of different soil types for plantation design.



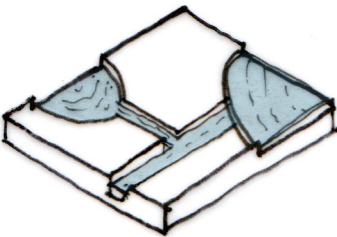
Weir could be used as devices of changing the speed of water and water storage infrastructure.



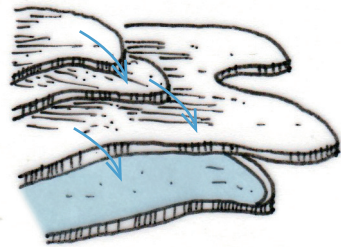
Weir could be built by simple materials like stones.



Make use of the soil type with less permeability for water storage or small ponds.



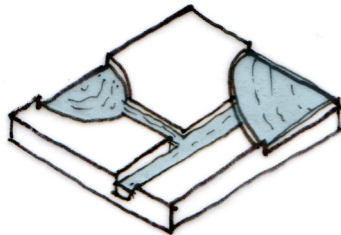
Ditches and canals play as main connection between different water resources.



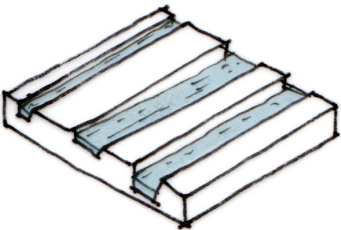
Make use of natural flows.



Different types of landscape in short distance could create edge effect to improve biodiversity.

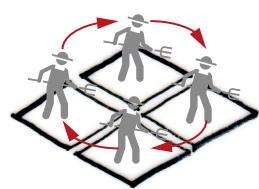


Space for water is an important element in flooding defence system in the plain area.

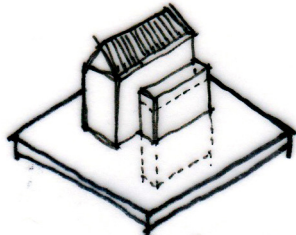


Widen or deepen ditches could improve sufficiency of flooding water discharge and capacity of transportation.

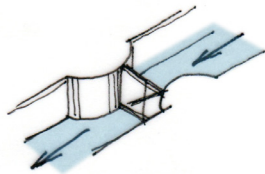
Principles for the urban environment



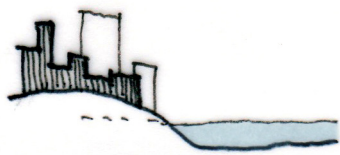
Water management as a collective work.



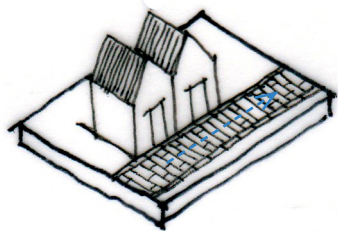
External water storage could be installed in the building or underground.



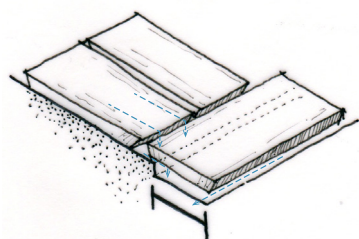
Sluice as the main elements of connecting rivers with different water levels and it's important for water transportation.



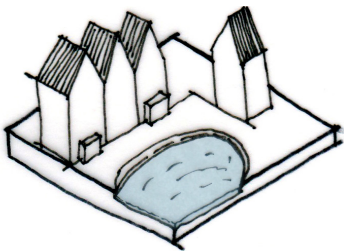
New development of urbanization should locate in higher place for safety reason.



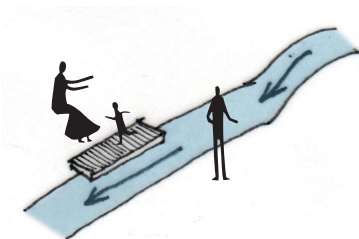
Street could be used as an external waterway for flood water discharge.



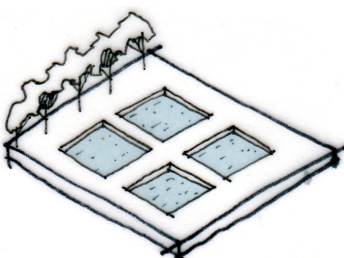
Space between pavement could increase permeable rate.



Water storage could also be applied with a group of house.



Water flows could be visible for public space and create close relationship with human.



Public space could be design for water detention and water storage and increase greenery.



PART 4

# Toward a water sensitive urbanizing delta for Hangzhou

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13 Analysis of water problems and potentials in Hangzhou

13.1 Natural system

13.2 Urban system

14 Exploring possibilities

14.1 Highly urbanized area

14.2 Rural area

14.3 Semi-urban area

# 13 – Analysis of water problems and potentials in Hangzhou

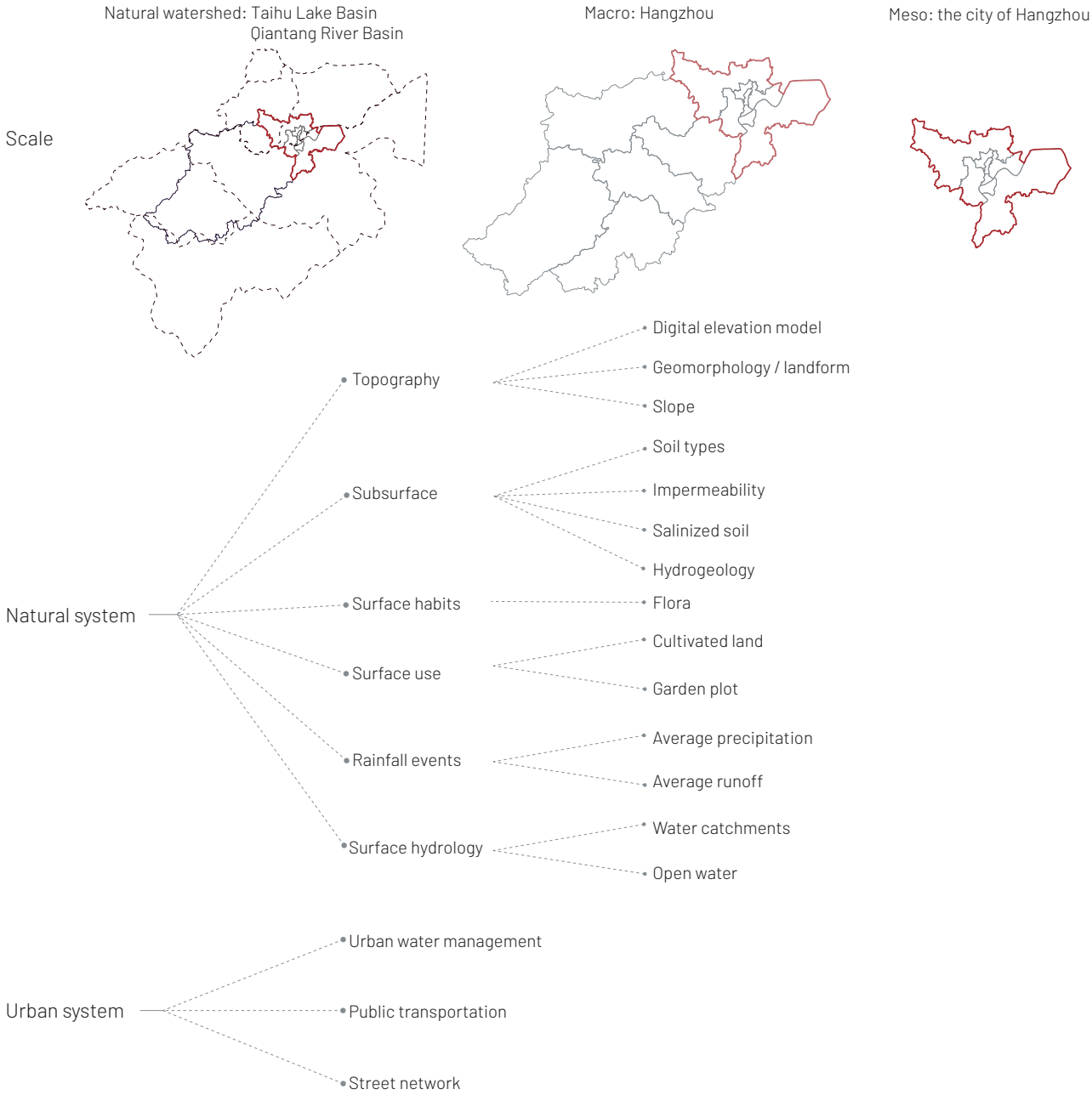


FIG. 12.4 Diagram of research structure of chapter 13  
Source: author

In this section, the water problem will be localized in the city of Hangzhou. The exploration will focus on two systems: natural system and urban system.

The first part starts with the complex natural system of Hangzhou. As mentioned before, Hangzhou belongs to two natural watersheds. And in the previous part, the vernacular water-management practices have been explored according to these two natural watersheds. Different water problems arise during the process of research. Meanwhile, a problem could be seen as a potential opportunity from another perspective. In this part, the current water problems under the high speed of urbanization which causes conflicts between two systems will be explained in different layers and different scales (FIG 12.4) .

In the second part, the design exploration will be initial proposals with the testing areas under different urban contexts based on different problems and potentials which are been explained in the first part. The aim is to use design as a tool to explore the possibility of using lessons learned from vernacular practices in the contemporary urban condition.



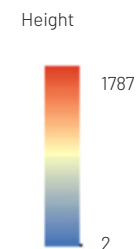
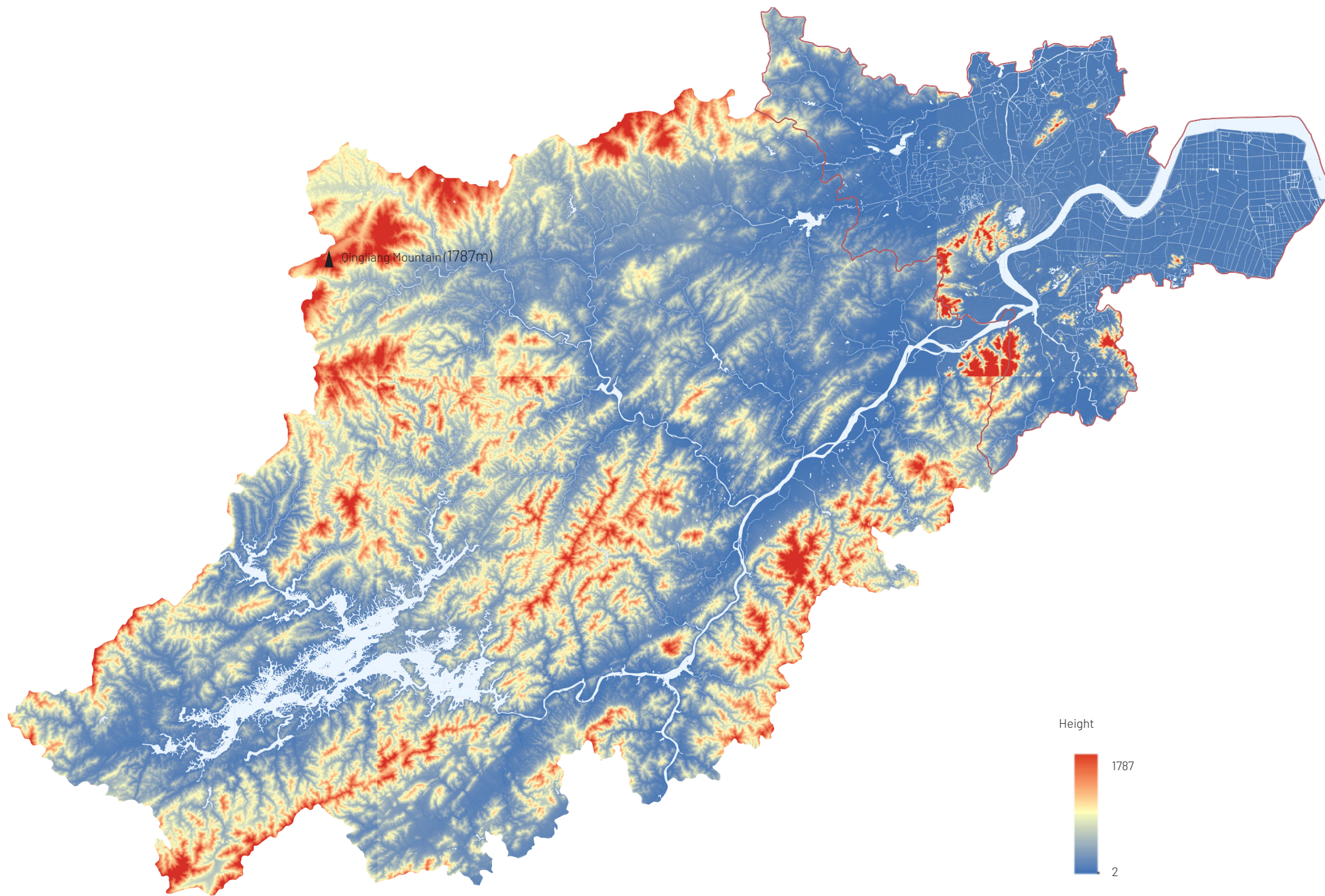


FIG. 13.1 Topography  
Source: edited by author based on DEM

## 13.1 – Natural system

### 13.1.1 – Topography

The main topography of Hangzhou descends gradually from southwest to northeast. The highest point is Qianliang Mountain which is 1787 meters locates along the board of Zhejiang Province and Anhui Province.

Six landform types of Hangzhou:

1. The northern part of Mount Tianmu is medium and low mountainous area. The Tianmu Mountains in Lin'an County are tall and straight, stretching over 200 kilometres. There are around ten mountain peaks more than 1000 meters, and there are nearly 10 peaks above 1,500 meters, such as Qingliang Mountain at an altitude of 1,787 meters, Longtang Mountain which 1,586 meters and 1479 meters for the East Tianmu Mountain. There are many igneous rocks in this area. The top of the gorge is shallow and flat. The slopes are steep and upright, and the valleys are narrow and deep. The huge boulder is lying in the creek bed. The water is rushing, the water resources are abundant, and there are almost no stream accumulations on the bank.
2. The western and south-western parts of Yuling, Baijishan, Qianligang is medium and low mountainous areas. It is also a mountainous stretch with numerous peaks and clouds. It is also a hilly rush, the valley is narrow and deep, and the streams are rushing. There are very few sediments on both sides of the stream.
3. The southern Longmen medium and low mountainous areas. This area is located on the southeast side of the fault line from Longmen to Cailanggang, west to the southwest end of Jiande, and near the west, east to the Xiaoshan hill region. There are many igneous rocks in the area, and there are developments in the sediments of mountains and rivers.
4. Central medium and low mountainous areas. The rocks in this area are mainly sedimentary rocks, and the sediments and flowing water deposits are all relatively developed.
5. The Fuchun River valley and the Tiaoxi River valley along the hilly area. There is a large area of low hills and gentle slopes, the pluton deposits are well developed, and the soil and soil layers are generally deep.
6. Eastern water network, coastal plain area. The district is located east of the Hangzhou City and Yuhang Town, including the Hangzhou-Jiaxing-Huzhou Plain in the north of the Qiantang River, and the Xiaoshao Plain in the south of the city. Due to the constant change of rivers and rivers, the age of soil formation is young, the soil is in the stage of desalination and de-calcification, the organic matter content is low, and nutrients are poor.





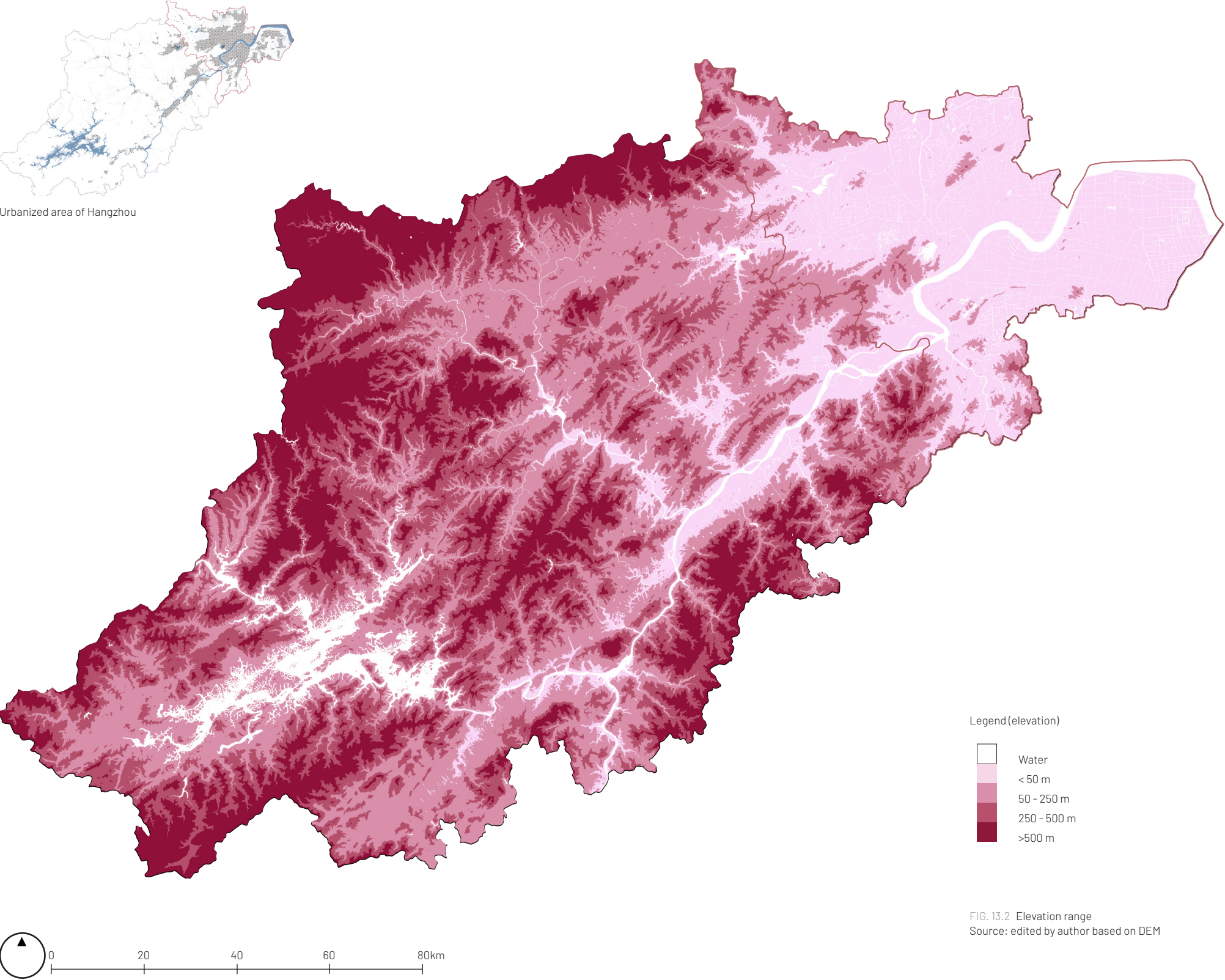


FIG. 13.2 Elevation range  
Source: edited by author based on DEM

Geomorphology / landforms

The topography of Hangzhou is complex, with six types of landforms such as mountains, hills and river valleys, water networks, coastal plains, river, and lakes. Among them, there are 12.05 million mu in the middle and low mountains (>500 meters above sea level), accounting for 47.7% of the total area, and 1.58 million mu in the high hills (250-500 meters above sea level), accounting for 6.2% of the total area. Low hills(elevation of 50-250m) have an area of 2.95 million mu, accounting for 11.7% of the total area. River valley plain (<50m above sea level) has 4.13 million mu, accounting for 16.3% of the total area. There are 1.38 million mu of lowland plain area with water network, which accounts for 5.5% of the total area. The coastal plain has 1.15 million mu, accounting for 4.5% of the total area. The area of the water body is 2.049 million mu, accounting for 8.1% of the total area.

Table of the portion of landforms:

	Water body: lake, river	8.1%	
	< 50 meter: river valley plain, lowland plain with water network, and coastal plain	16.3% 5.5% 4.5%	26.3%
	50 - 250 meter: low hills	6.2%	
	250 - 500 meter: high hills	11.7%	
	>500 meter: middle and low mountains	47.7%	

Problems and potentials:

The area with most problems related to water like floods belongs to the plain areas which include river valley plain, lowland plain with water network and coastal plain. Coincidentally, these areas have high overlap with the urbanized area which has less permeability due to the pavement and asphalt for the infrastructure.

To solve this problem, the lessons learned from vernacular water-management practices could be applied in order to give an alternative solution other than hard-engineered method in small scale. For instance, the Yu field with different levels of the ground could be applied to the regulation of canalized rivers for increasing both accessibility and biodiversity.



FIG. 13.3 Middle and low mountains: Qianliang Mountain, the highest mountain in Hangzhou, has a beautiful landscape with stone, pine tree and clouds.  
Source: Mafengwo [online] available at: <https://www.mafengwo.cn/sales/2360839.html> [accessed on 26 March 2018].



FIG. 13.4 Low hills: Tea plantation in the low hills surrounded by forest. The raw of tea follows the contour line of altitude creates a certain type of landscape with its own pattern and aesthetic beauty.  
Source: Getty image [online] available at: <https://www.vcg.com> [accessed on 26 March 2018].



FIG. 13.5 River vally plain: A view like Chinese landscape painting of a fish man and his wife fishing with a wooden boat in the upstream of Qiantang River.  
Source: Mswweekly [online] available at: <http://www.mswweekly.com/show.html?id=93939> [accessed on 26 March 2018].



FIG. 13.6 Low land plain with water networks: The Grand Canal as one of the most important waterways in China, still plays an important role of transportation and remind people of the close relationship with water in the past times.  
Source: Ifeng [online] available at: <http://wemedia.ifeng.com/58223210/wemedia.shtml> [accessed on 26 March 2018].



FIG. 13.7 Water body: Xianghu as second biggest lake in Hangzhou locates in Xiaoshao Plain.  
Source: Sohu [online] available at: [http://www.sohu.com/a/229975460\\_349129](http://www.sohu.com/a/229975460_349129) [accessed on 26 March 2018].



FIG. 13.8 Coastal plain: Xiaoshao plain has a range of diverse of landscape from coastal plain of Qiantang River, to famous water town.  
Source: China shaoxing jianhu institute [online] available at: <http://www.jianhu.so/picinfo.php?id=115> [accessed on 26 March 2018].





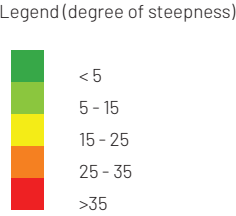
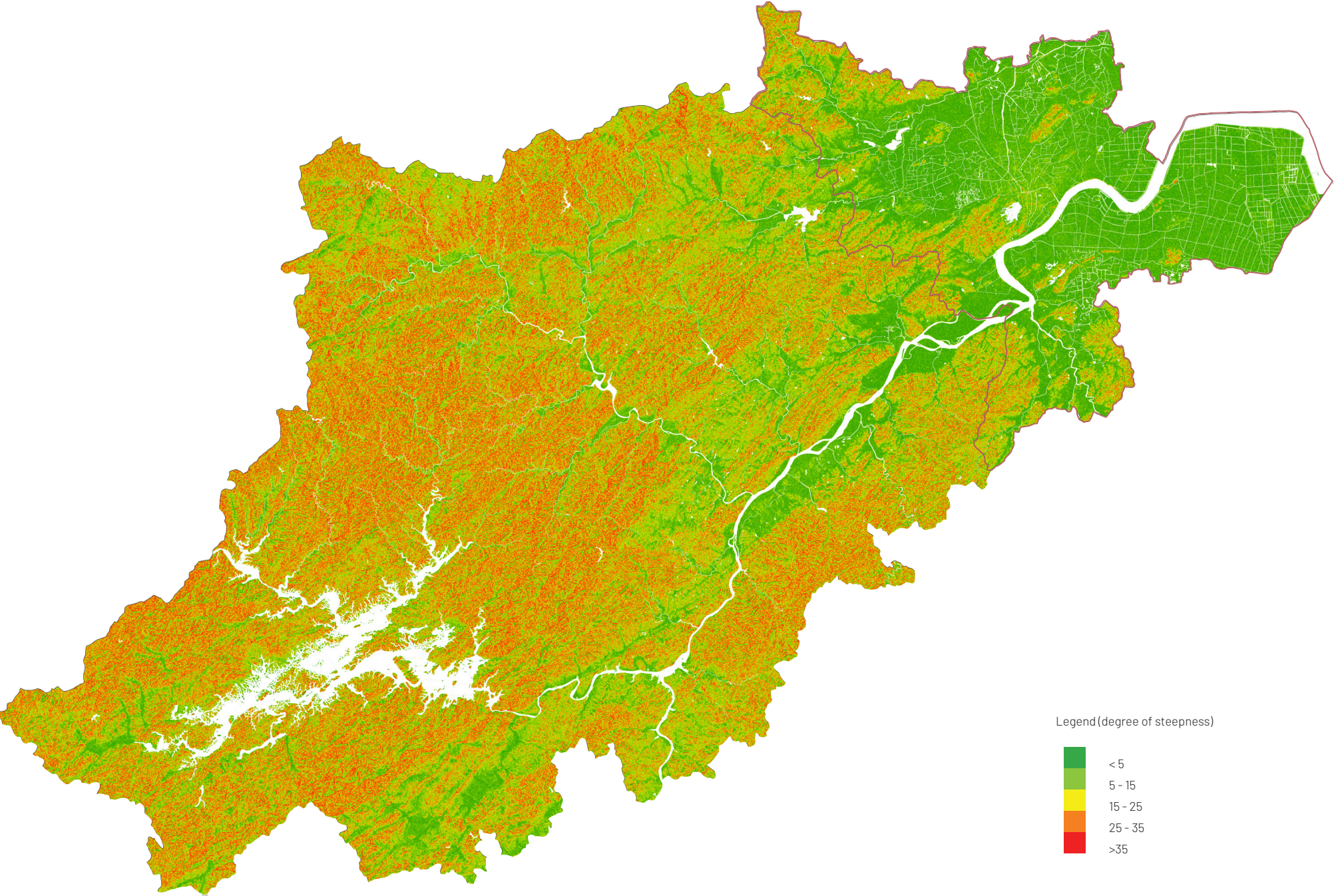


FIG. 13.9 Slope range  
Source: edited by author based on DEM

Slope

Due to the complex topography and different types of landforms, both altitude and slope change dramatically in Hangzhou.

There are 47.2 % of land is over slope 25 degrees. According to ‘Code of vertical planning on urban field (CJJ 83-99)’ which published by Ministry of Housing and Urban-Rural Development of the People’s Republic of China in 1999, the steepness of land greater than 25 degrees is not suitable for urbanization.

Slope (degree)	Percentage (%)
>45	6.30
35-45	17.30
25-35	23.60
15-25	16.30
5-15	9.70
<5	26.90

Problems and potentials:

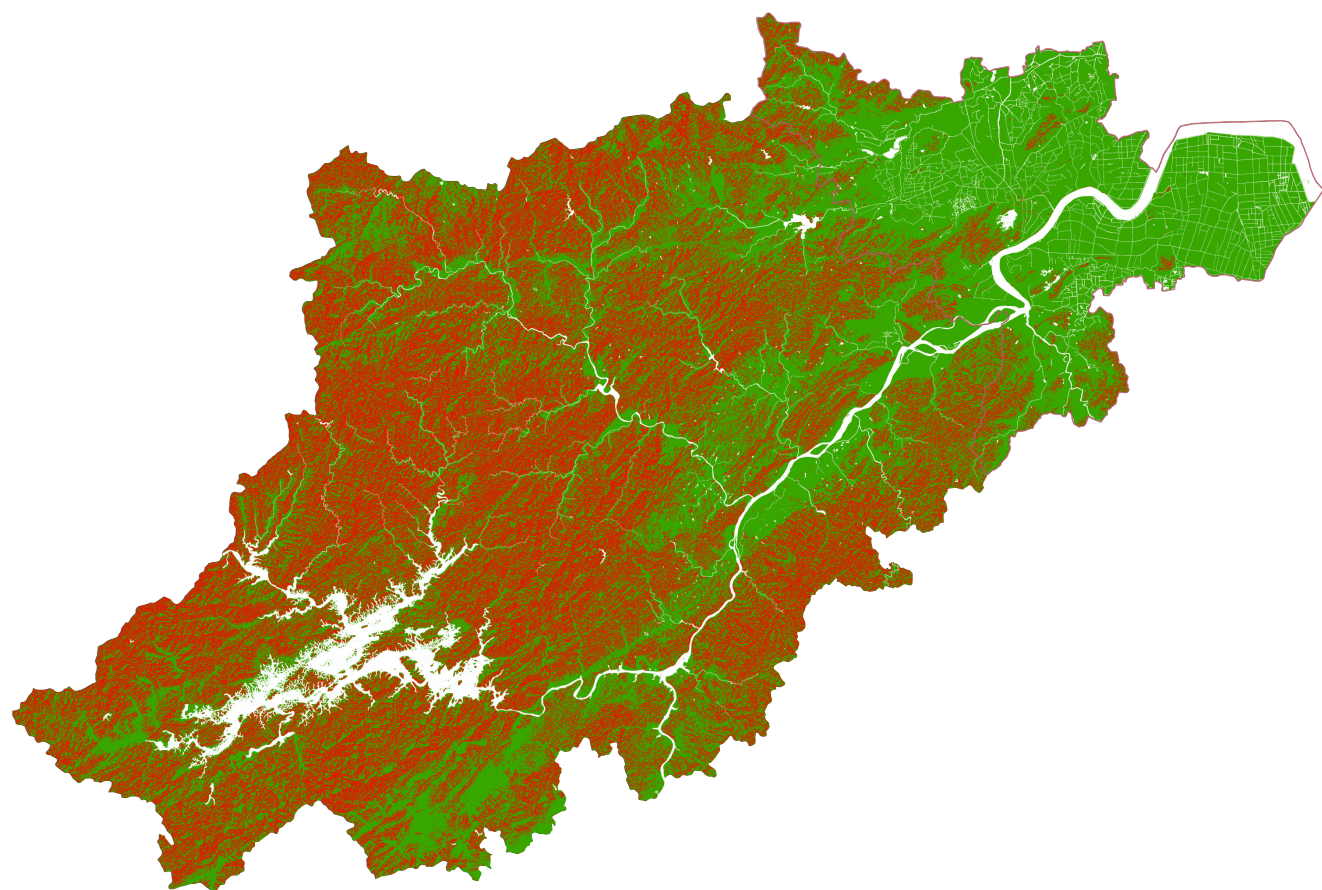
For the area which steepness of land is greater than 25 degrees, the cultivation needs to be controlled in a certain percentage. The main task is to maintain soil and water for prevention mountain torrents and landslide caused by extreme and heavy rainfall on open land.

Nowadays, it is popular to investigate organic tea plantation in high hills for both high quality of growing environment for tea and high quality of tea production. The lessons learned from Beitang system could be applied in the planning of production and agricultural plantation. Instead of mono-function tea plantation, a new type of plantation with various species and small water bodies could be introduced to farmers. By introducing various species and small water bodies, it will enhance biodiversity and improve the quality of space for possible future tourists to enjoy the beauty of landscape and tea itself.



FIG. 13.10 Mudslide happened in Linan county on May 7th, 2016  
Source: Media China[online] available at:[http://media.china.com.cn/tpzs/2016-05-07/720818\\_7.html](http://media.china.com.cn/tpzs/2016-05-07/720818_7.html) [accessed on 26 May 2018].

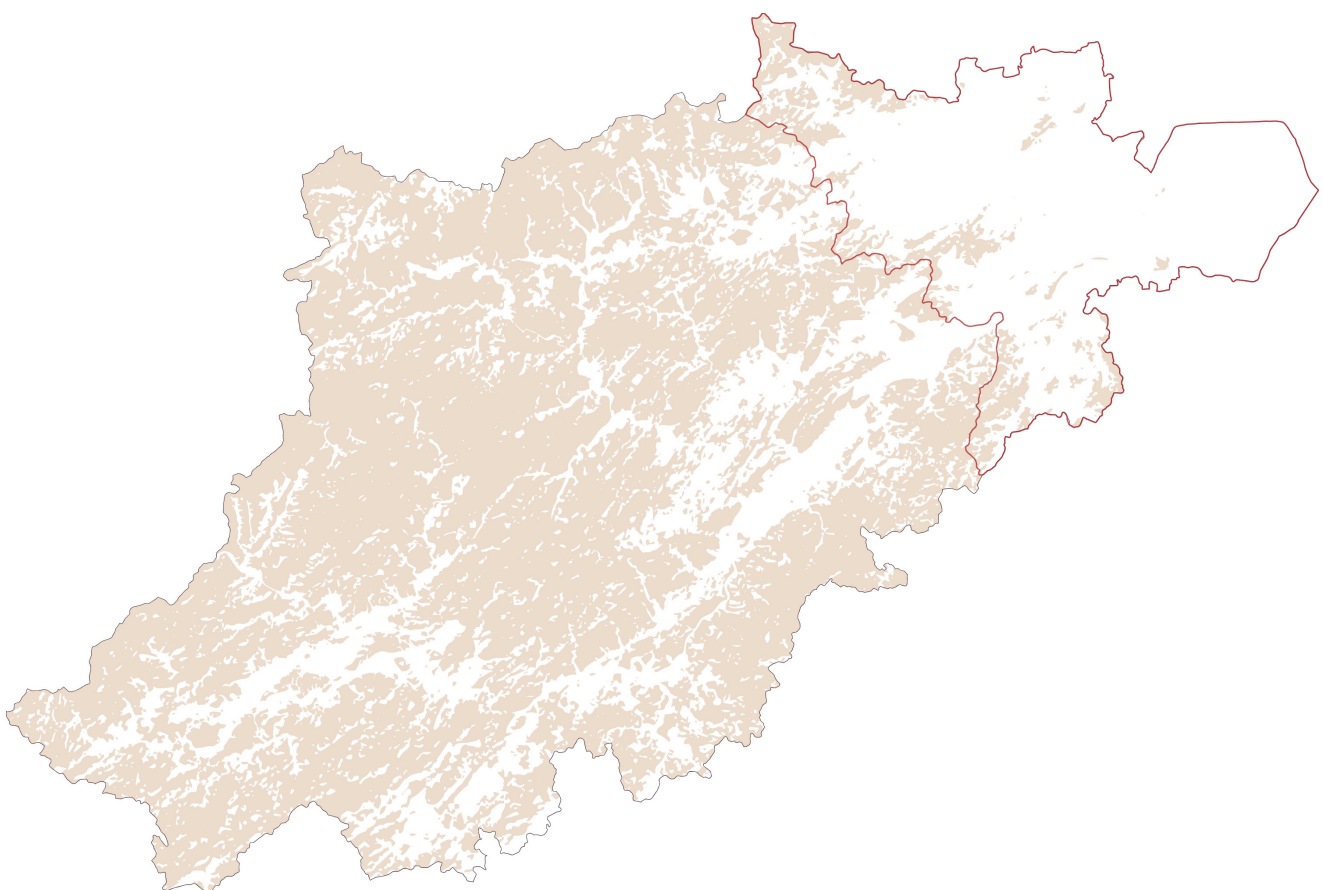




Legend



FIG. 13.11 Slope greater than 25 degree and less than 25 degree  
Source: edited by author based on DEM



Legend



FIG. 13.12 Slope greater than 25 degree  
Source: edited by author based on DEM





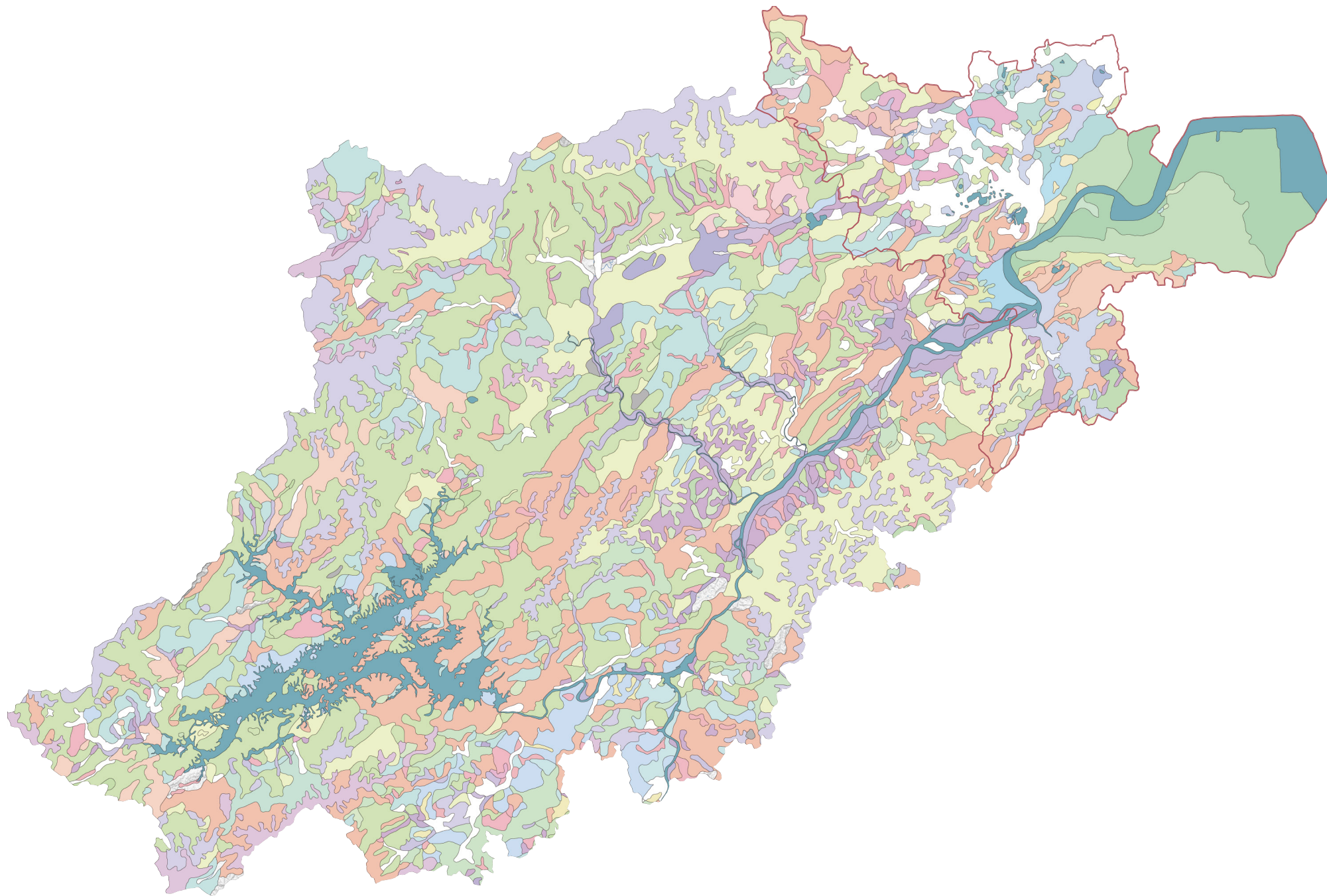


FIG. 13.13 Soil types  
Source: edited by author based on data from Prof. Mingkui Zhang from Zhejiang University

### 13.1.2 – Soil

#### Soil types

There are 11 main types of soil in Hangzhou which are red soil, yellow soil, purple soil, rendizina, coarse soil, rocky soil, alluvial soil, mountain meadow soil, moisture soil, seashore saline soil and paddy soil.

Red soil locates in the hilly area which altitude is around 600 - 700 meters.

Yellow soil locates in the medium and low mountainous area which altitude is higher than 650 - 700 meters.

Purple soil locates in the hilly areas, however, it has the problem of poor vegetation cover and serious soil erosion.

Coarse soil locates on the peak and steep slope of small hills.

Rocky soil locates on the steep slope of hilly area.

Alluvial soil locates on both sides of the new floodplain of rivers.

Mountain meadow soil main locates in grassland.

Moisture soil locates along the coastal area, near water network, plain area and streams.

Seashore saline soil locates on the mud of Qiantang River.

Paddy soil formed from all types of soil under the cultivation of rice after long time. It is the most common soil in Hangzhou.

#### Problems and potentials:

#### Impermeability

Soil type with less capacity of water absorbing

They are urbanized area, red soil, yellow soil, purple soil, rendizina, coarse soil and rocky soil.

#### Salinized soil

Salinized soil locates mostly along the coastal plain of Qiantang River which includes two types. One is seashore saline soil, and the other is moisture soil which is after the process of desalination but still has thinned fertile layer.





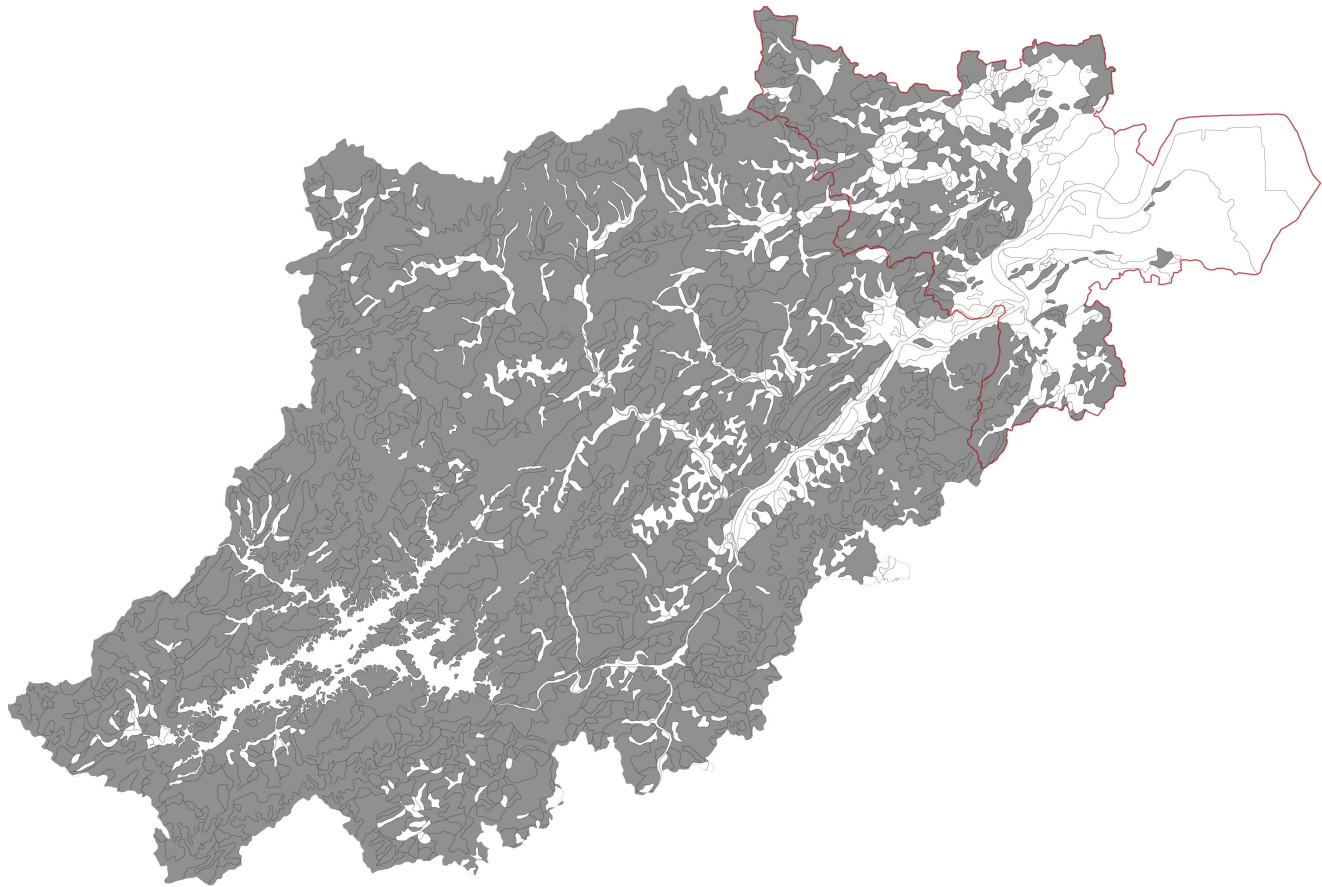
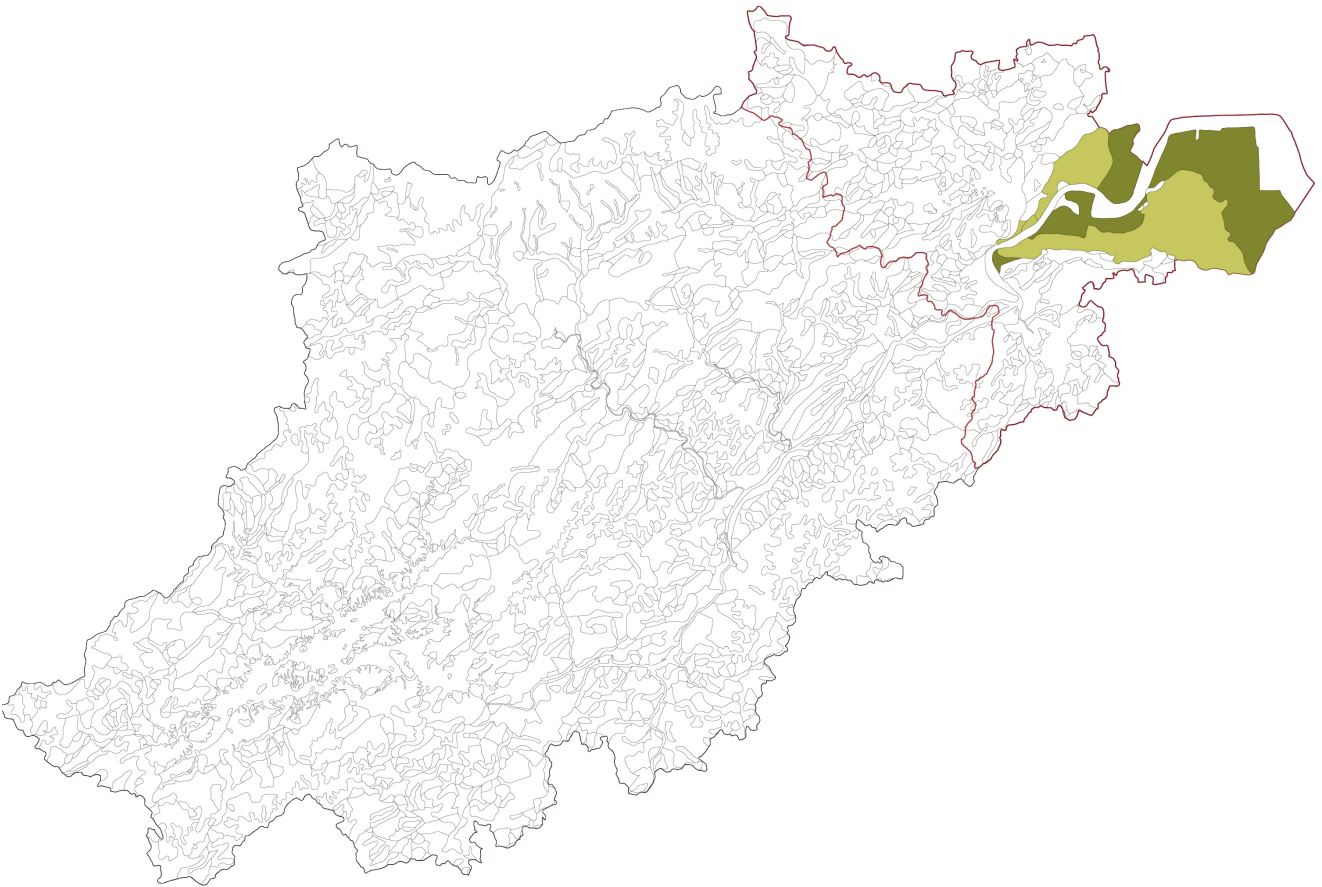


FIG. 13.15 Urban square and asphalt  
Source: Sina news [online] available at: [http://k.sina.com.cn/article\\_6372044474\\_p17bcdaeba020002txv.html](http://k.sina.com.cn/article_6372044474_p17bcdaeba020002txv.html) [accessed on 26 May 2018].



Legend  
Area with less permeability

FIG. 13.14 Soil types with less capacity of absorbing water  
Source: edited by author based on data provided by Prof. Mingkui Zhang from Zhejiang University



Legend  
Seashore saline soil  
Moisture soil

FIG. 13.16 Soil types with less fertile for cultivation  
Source: edited by author based on data provided by Prof. Mingkui Zhang from Zhejiang University



长江三角洲地区水文地质图

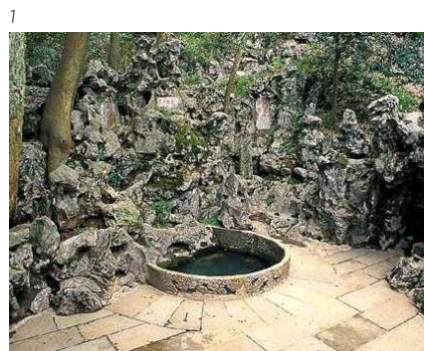
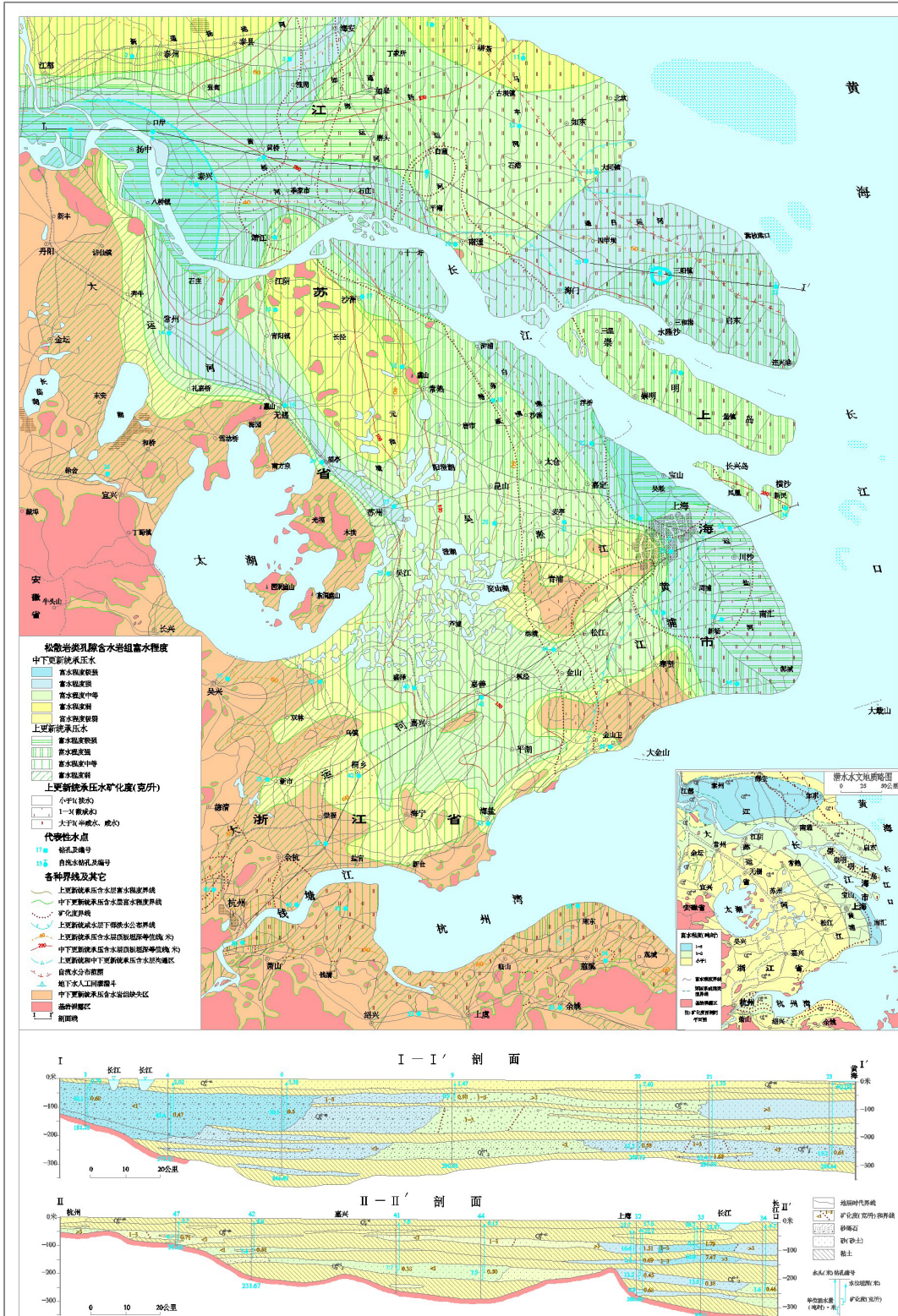


FIG. 13.18 1. Dreaming of the tiger Spring  
Source: National geological archives of China [online] available at: <http://www.hzcn.com/news/hzjd/126202158411463FF57F90AK0J7366.htm> [accessed on 26 May 2018].  
2. Dragon well Spring  
Source: Sina [online] available at: [http://blog.sina.com.cn/s/blog\\_6839d5770100j3xp.html](http://blog.sina.com.cn/s/blog_6839d5770100j3xp.html) [accessed on 26 May 2018].  
3. Jade Spring  
Source: Lofter [online] available at: <http://xujian195300.blog.163.com/blog/static/37272630201091264438363/> [accessed on 26 May 2018].

FIG. 13.17 (left) Hydro-geology map of Yangtze River Delta  
Source: National geological archives of China [online] available at: <http://www.ngac.cn/EDefault.aspx> [accessed on 26 March 2018].

## Hydro-geology

From the hydro-geology map, the ability of maintain water in the plain area is different from low to medium. As for the hilly area on the south, the bed rocks was exposed. Natural springs exist in well-preserved natural environment.

Groundwater in Hangzhou can be classified into loose rock pore water, carbonate rock fractures – cave water, bedrock fissure water, and red clastic rock pore fissure water.

There are many springs in Hangzhou. As early as the Xinyi Period (9-23), Quanting used to be the place name of Hangzhou. Ming Chenghua's "Hangzhou Fuzhi" refers to the five springs of Hu Runquan, Longjing, Yuquan, Guo Pojing, and Wu Shanquan as the "holy water of Hangzhou". According to modern instrument tests, these five springs are still among the best in the city's groundwater resources.

1. Dreaming of the tiger Spring. Brewing Dragon well tea with spring water from dreaming of the tiger Spring is most beneficial to the dissolution and leaching of effective chemical components and biochemical components of Dragon well tea.

2. Dragon well Spring. The exposed standard elevation is 100 meters above sea level. It is a bare cracked karst water. The spring flows out of the north-north-east fault of the Chuanshan Formation limestone with a flow rate of 0.50 liters/second, a pH value of 7.2, and a total salinity of 280 mg/l. , Free carbon dioxide 25 mg / l, total hardness 14.5 German degrees, is a heavy calcium carbonate water.

3. Jade Spring. The exposed elevation is 25 to 30 meters above sea level. It is pore water, and the spring flows out from the gravel layer of the sub-sand in the front of the Holocene alluvial fan and is replenished by karstic water from the Carboniferous fissures in the Lingyin area. The flow rate is 5 to 10 liters/liter. Second, pH 7.4, total salinity 205 mg/l, free carbon dioxide 15 mg/l, total hardness 10.4 German degrees, is heavy calcium carbonate type water.



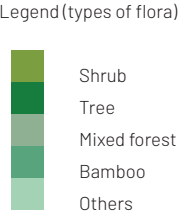
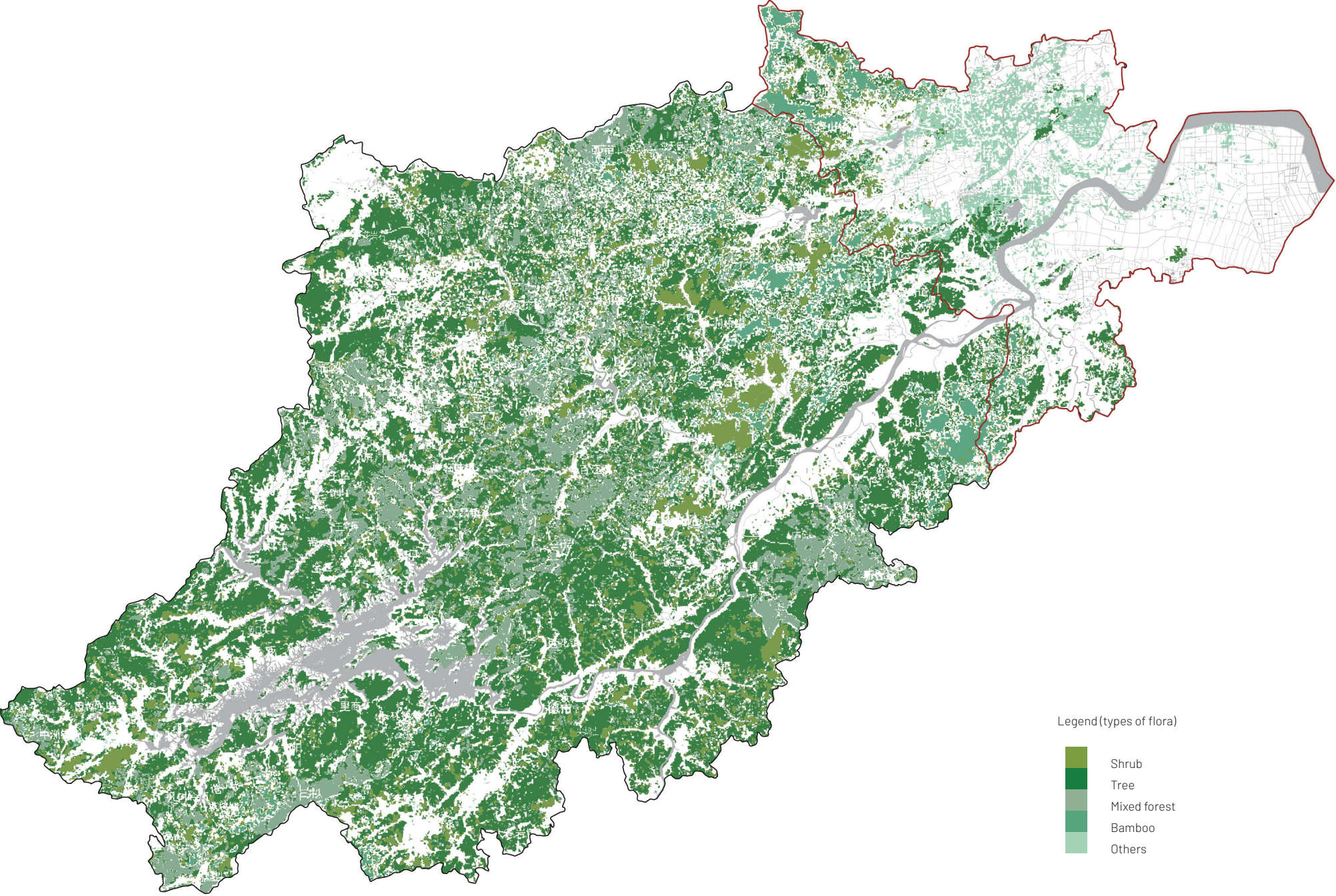


FIG. 13.19 Flora types  
Source: edited by author based on data of China geology census, down by Hangzhou Planning Bureau

13.1.3 – Surface habits

Flora

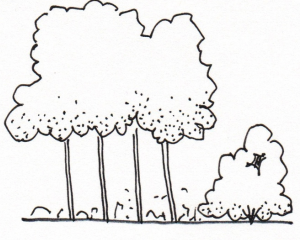
Hangzhou locates in the central of subtropical evergreen broad-leaved forest vegetation belt.

There are more than 1200 kinds of plants identified and confirmed in Hangzhou, belonging to 155 families. Among them, there are 20 families and 39 species of ferns, 8 families and 49 species of gymnosperms, and 127 families and more than 1,100 species of angiosperms.

Vegetation types and function:

Tree:

- Regulate water
- Tree nursery
- Recreation



Shrub:

- Regulate water
- Soil protection
- Recreation



Grassland:

- Regulate water
- Soil protection
- Recreation



Mixed forest:

- Regulate water
- Habitat for animals
- Recreation
- Micro climate



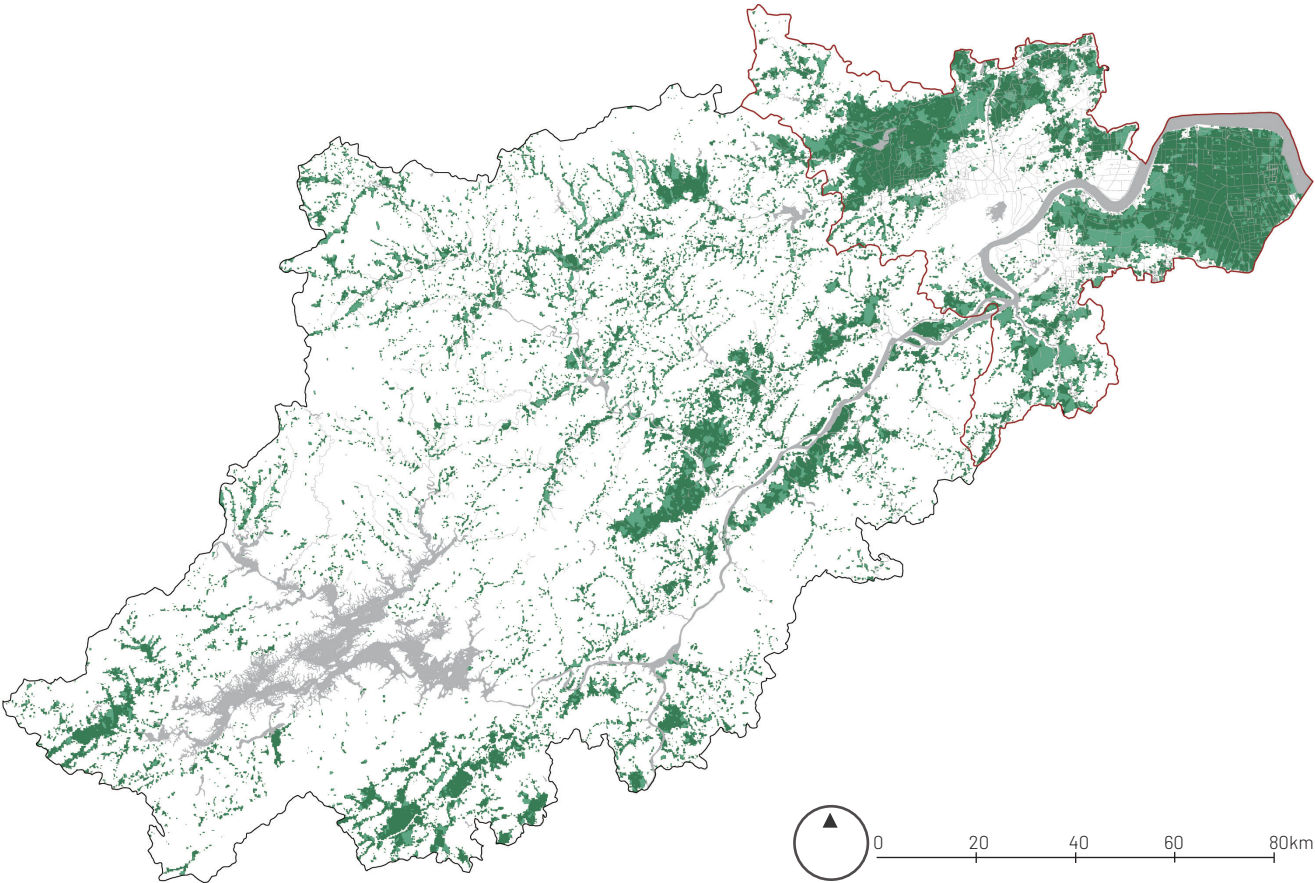
Wetland:

- Regulate water
- Water purification
- Habitat for birds, fish
- Recreation





Arable land



Legend (arable land)

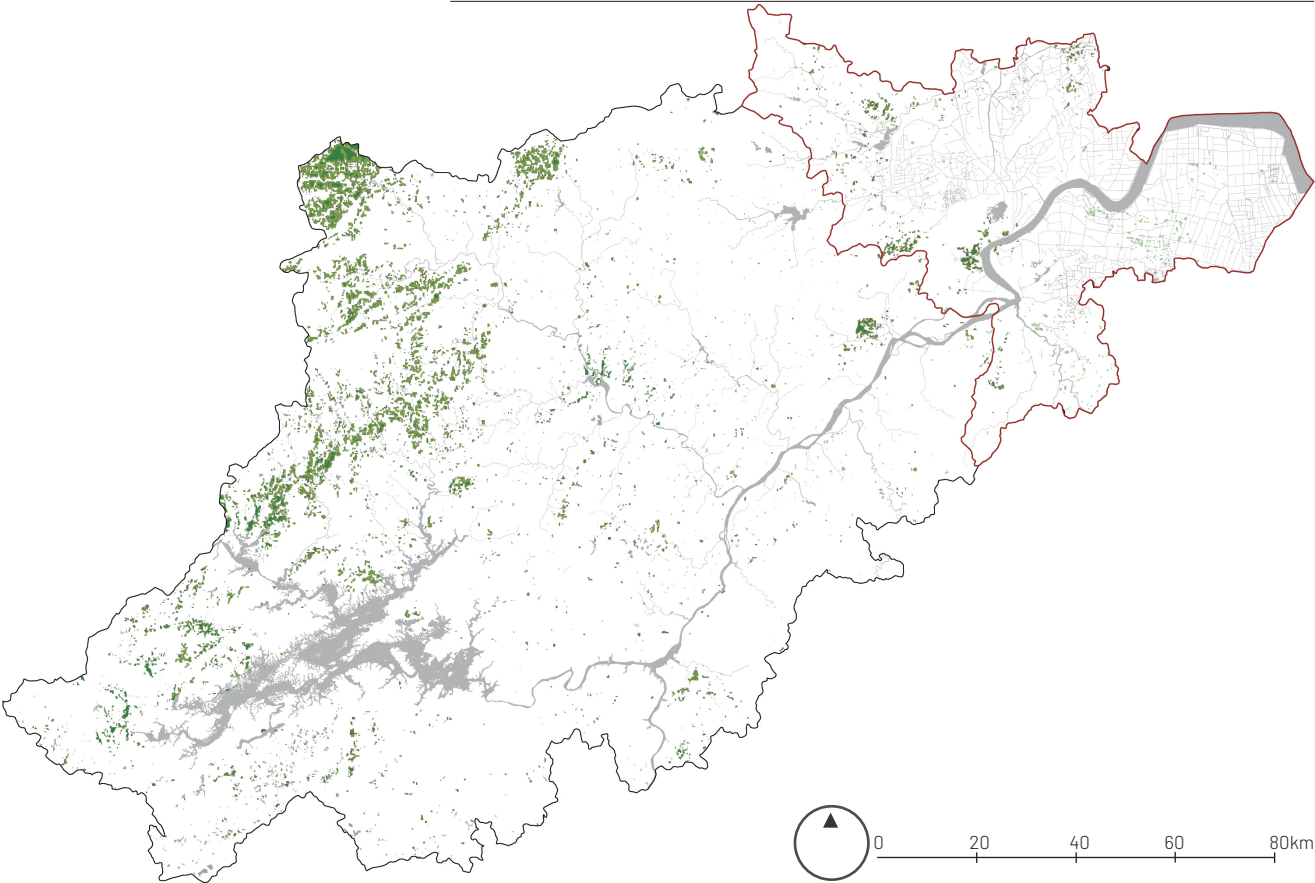
- Cultivated land
- Non-cultivated land

Arable land has been categorized into two types due to their condition. The first type is cultivated land. In cultivated land, the paddy field area is 640.07 square kilometres, and the dry land area is 439.02 square kilometres. The cultivated land is mainly distributed in flat areas below 50 meters above sea level and below 2 degrees above the slope. The area of cultivated land distributed over a slope of 25° is 16.56 square kilometres. The other type is non-cultivated land which is been transformed into other uses. In non-cultivated farmland, the garden plot area is 615.60 square kilometres, the grassland (mainly refers to the abandoned land) is 107.72 square kilometres, the forest land area is 176.51 square kilometres, the aquaculture water surface area is 110.43 square kilometres, and other land area is 40.24 square kilometres.

FIG. 13.20 Arable land  
Source: edited by author based on data of China geology census, down by Hangzhou Planning Bureau

13.1.4 – Surface use

Garden plot



Legend (garden plot)

- Nursery
- Mulberry
- Fruit
- Tea
- others



1



2

FIG. 13.21 Garden plot  
Source: edited by author based on data of China geology census, down by Hangzhou Planning Bureau

FIG. 13.22 1. Tea plantation  
Source: zszs [online] available at: <http://travel.zszs.cn/2012/04/19/105311.htm> [accessed on 26 May 2018].  
2. Fruit plantation  
Source: gdcgy [online] available at: <http://www.gdcgy.com/display.asp?id=547> [accessed on 26 May 2018].



Average precipitation (1956-2000)

The average precipitation per year is 1,400 mm. But it has the character of uneven distribution in space and time.

By looking at the rainfall over the year, it mainly focuses during summer time, and winter time is with least precipitation.

The maximum annual precipitation on record is 2919.3 mm in 1999.

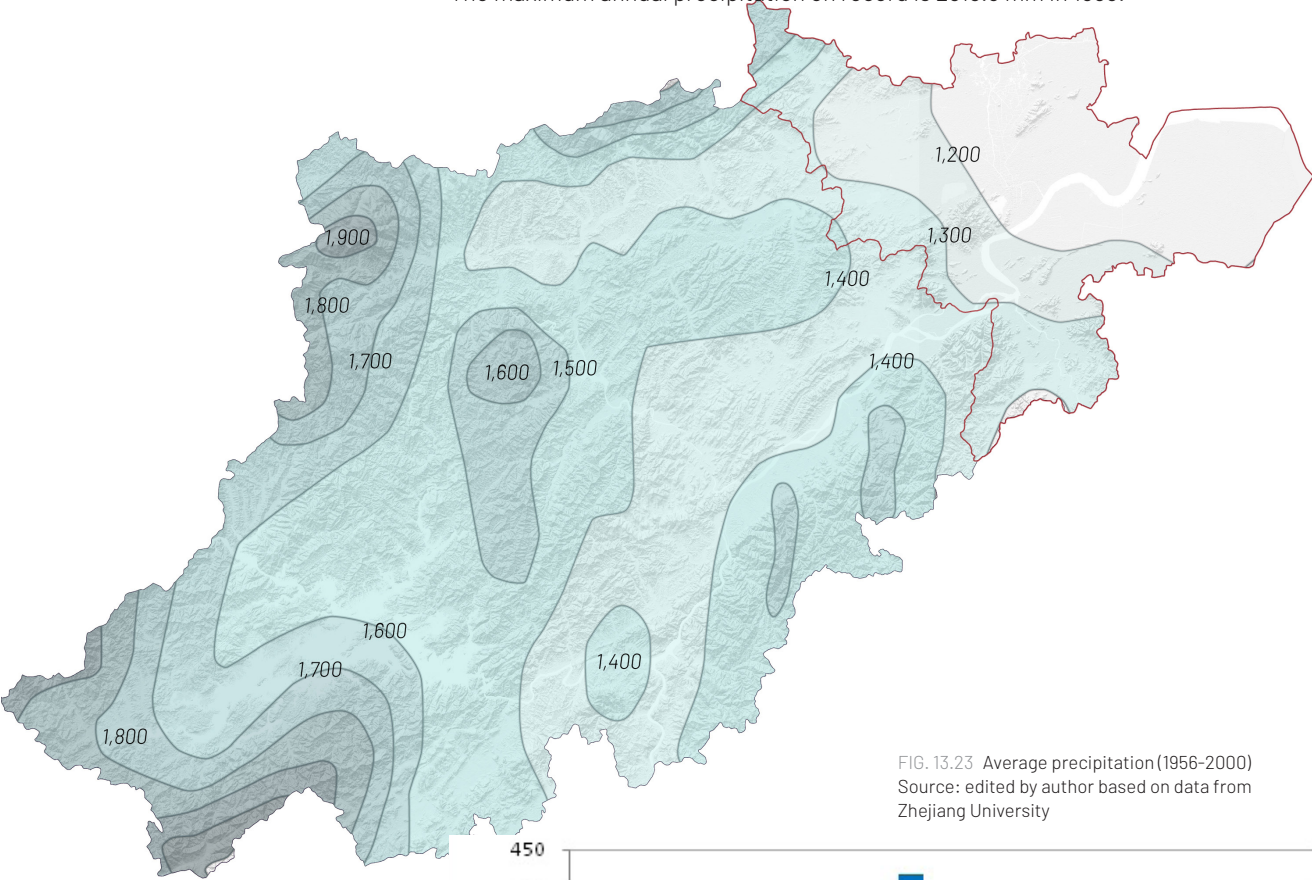


FIG. 13.23 Average precipitation (1956-2000)  
Source: edited by author based on data from Zhejiang University

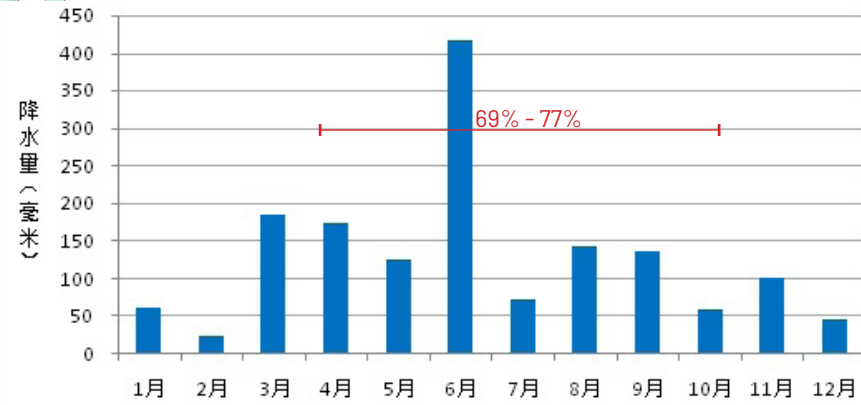


FIG. 13.24 Precipitation of 2017  
Source: Hz-sw.news



13.1.5 – Rainfall events

Average runoff

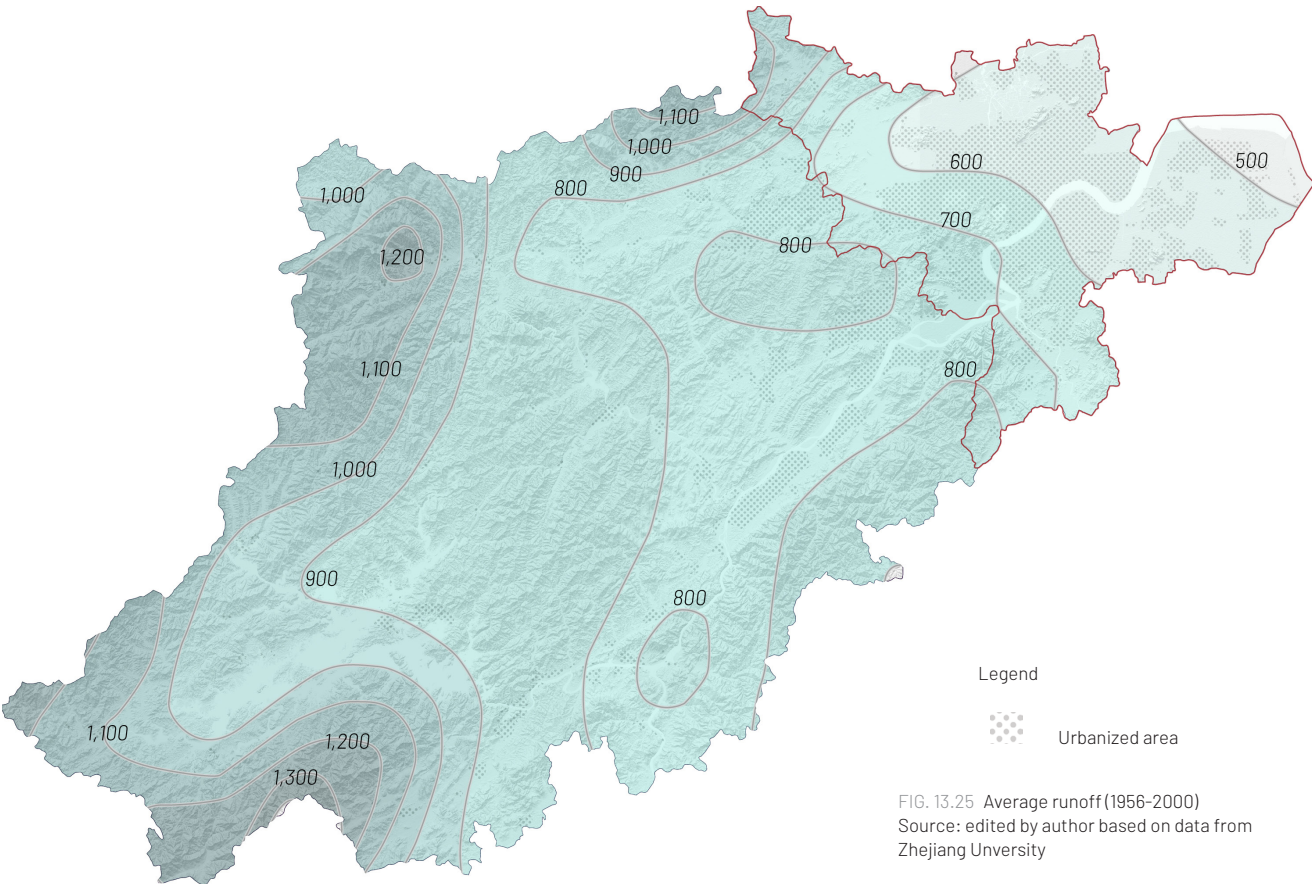


FIG. 13.25 Average runoff (1956-2000)  
Source: edited by author based on data from Zhejiang University

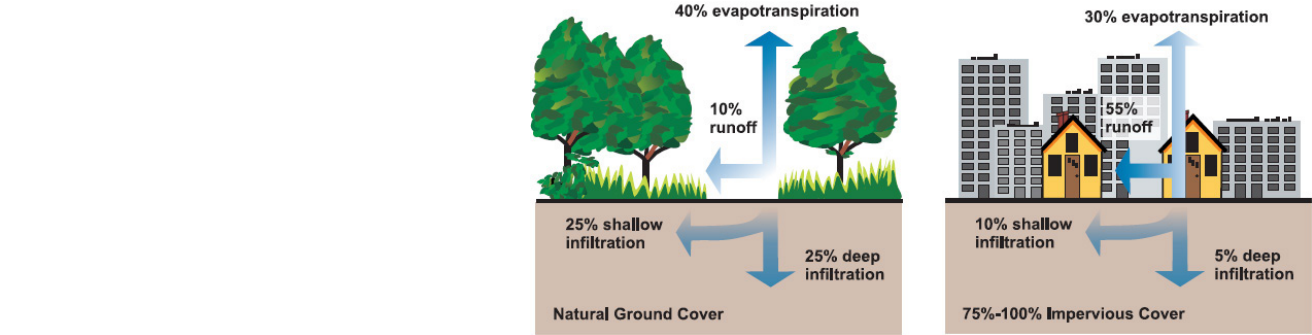
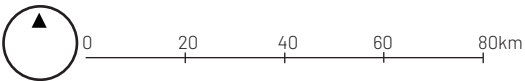


FIG. 13.26 Relationship between impervious surfaces and surface runoff  
Source: U.S. Environmental Protection Agency, Washington, D.C. "Protecting Water Quality from Urban Runoff." Document No. EPA 841-F-03-003



Water catchments

The city of Hangzhou belongs to two main natural watersheds. The first is the area of the city centre, which is located in the northeast part and belongs to the plain area of Taihu Lake basin as a portion of Yangtze River Delta. The rest of the city belongs to downstream and river mouth of Qiantang River which has its strong influence on the formation of the city.

Two main watersheds have completely different water condition because one is river basin and the other is lake plain. This difference from the natural system might leave distinctive marks on the methods of water management for dealing with various water problems.

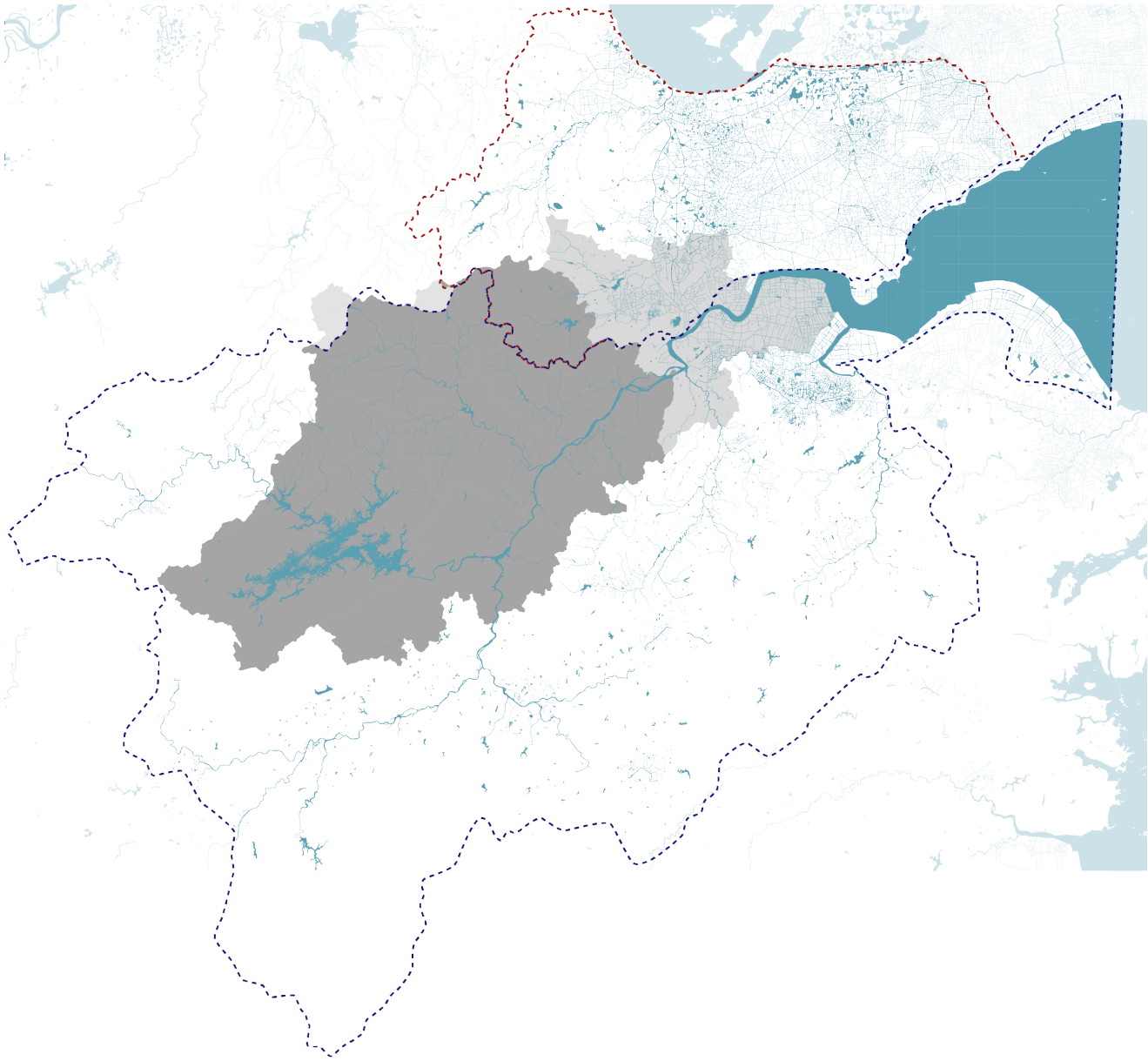


FIG. 13.27 Natural watersheds of Hangzhou  
Source: author based on GIS data

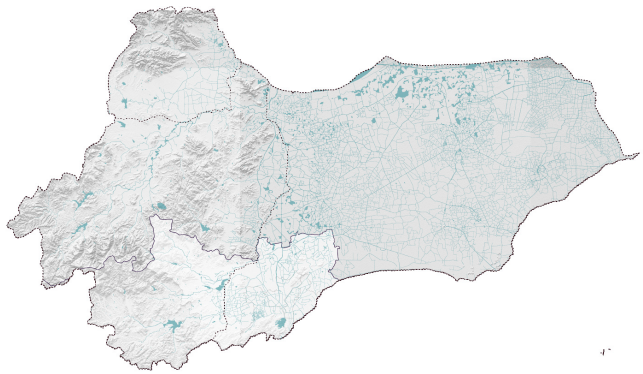


FIG. 13.28 Sub watersheds of Taihu Lake Basin  
Source: author based on GIS data



FIG. 13.29 Subl watersheds of Qiantang River Basin  
Source: author based on GIS data



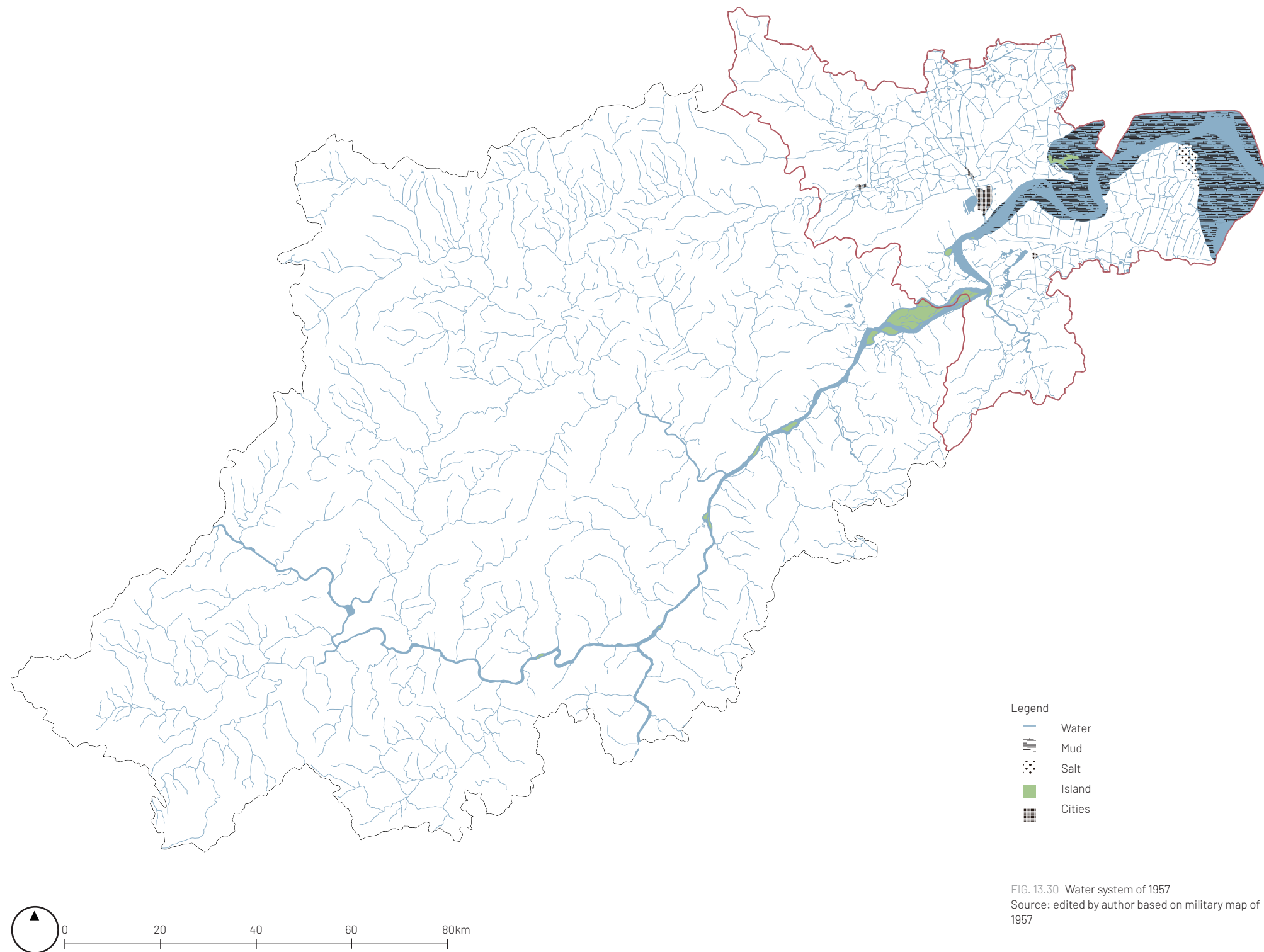


FIG. 13.30 Water system of 1957  
Source: edited by author based on military map of 1957

### Water system in 1957

The map shows the water system of 1957 from an old map made by US military.

It is considered as the basic water condition before urbanization.

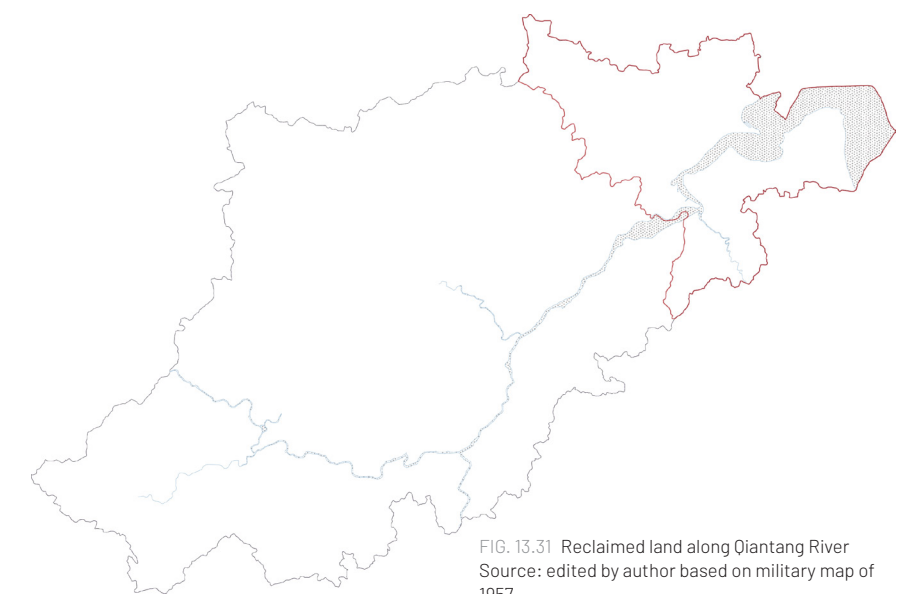
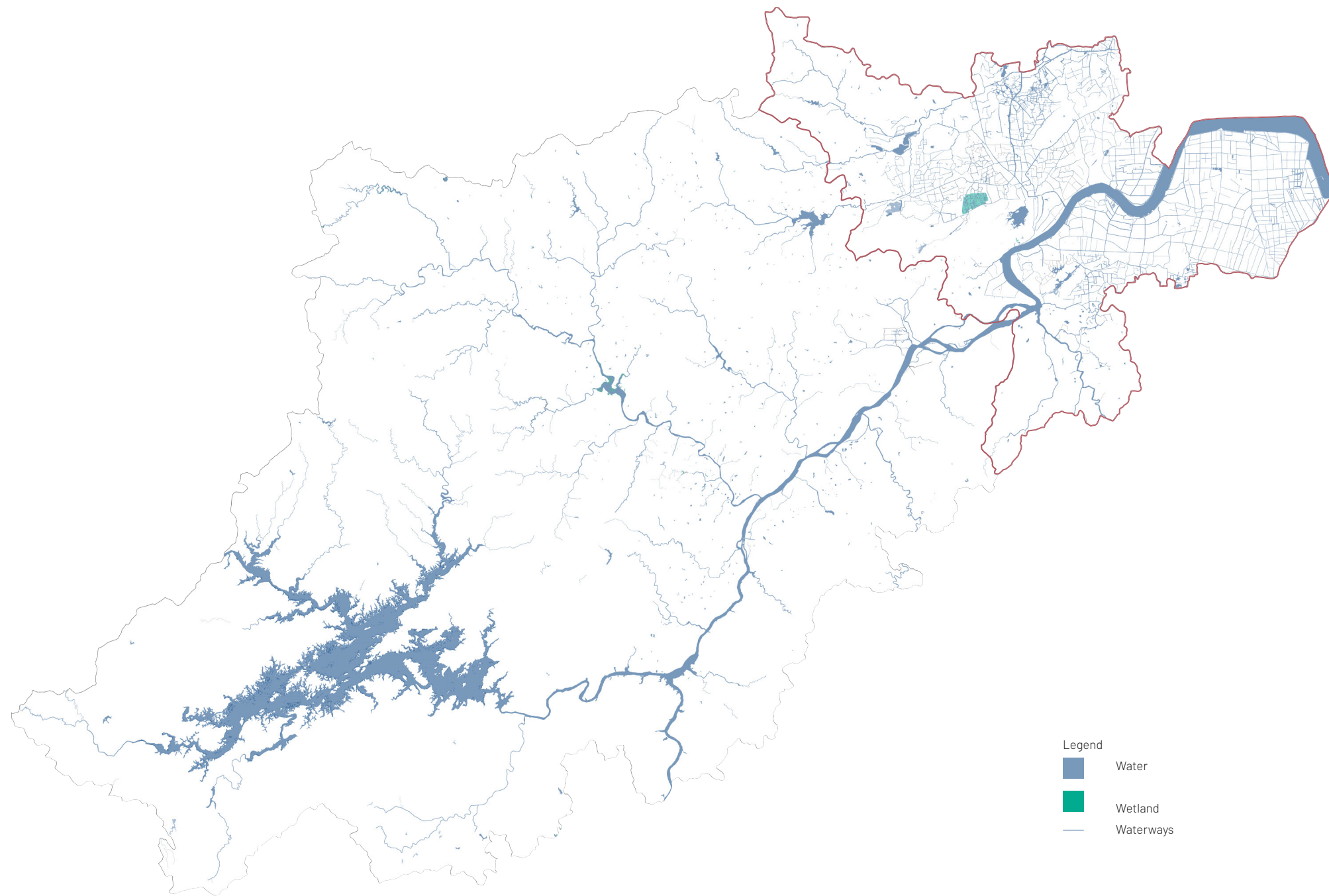


FIG. 13.31 Reclaimed land along Qiantang River  
Source: edited by author based on military map of 1957



Legend

- Water
- Wetland
- Waterways

FIG. 13.32 Current water system  
Source: edited by author based on military map of 1957

### Current water system

Comparing the map of the water system in 1957 and current water system, in general changes could be explain as the reason of human.

### Problems and potentials

Huge hydro-power station Qiandao Lake has been built in the 1970s which creates big water surface with nice environment.

The waterways in the city have been occupied by the need for development and also canalized.

The plain along Qiantang River has been reclaimed and grid waterways replaced the previous organic streams.

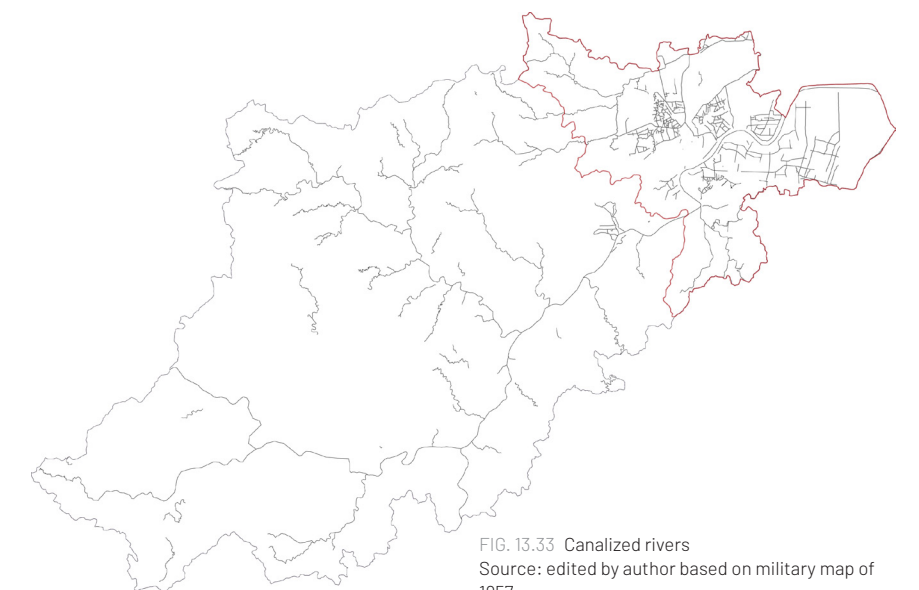
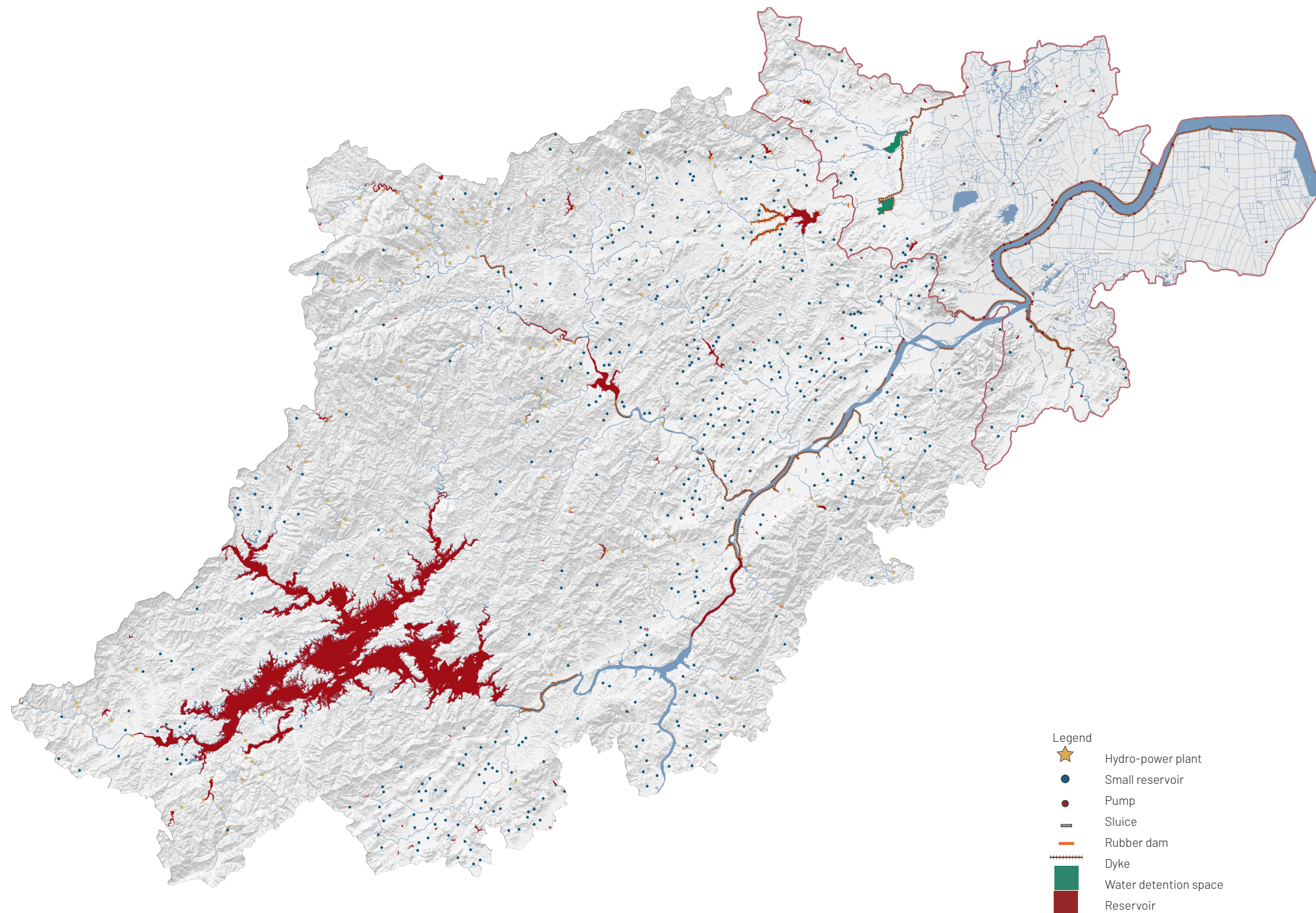


FIG. 13.33 Canalized rivers  
Source: edited by author based on military map of 1957



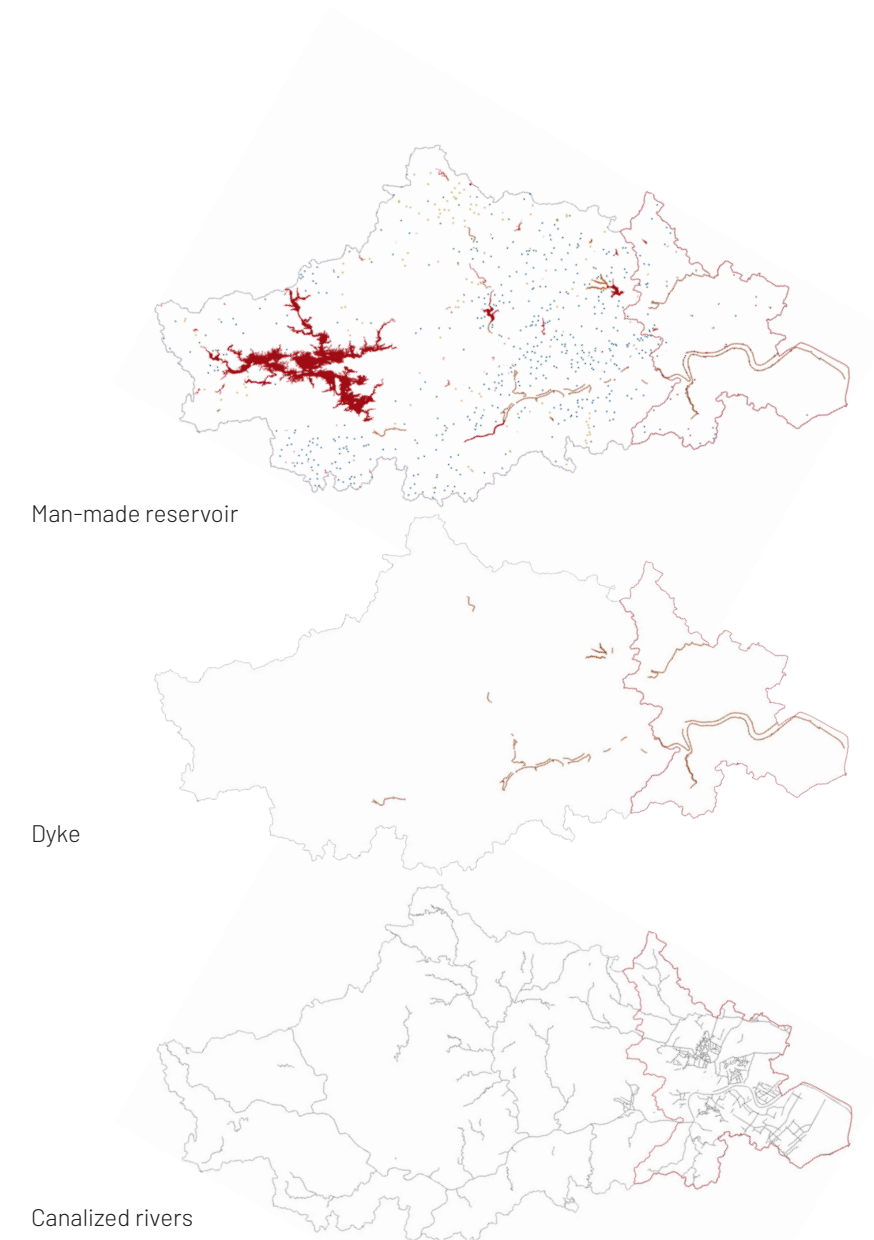


- Legend
- ★ Hydro-power plant
  - Small reservoir
  - Pump
  - Sluice
  - Rubber dam
  - Dyke
  - Water detention space
  - Reservoir

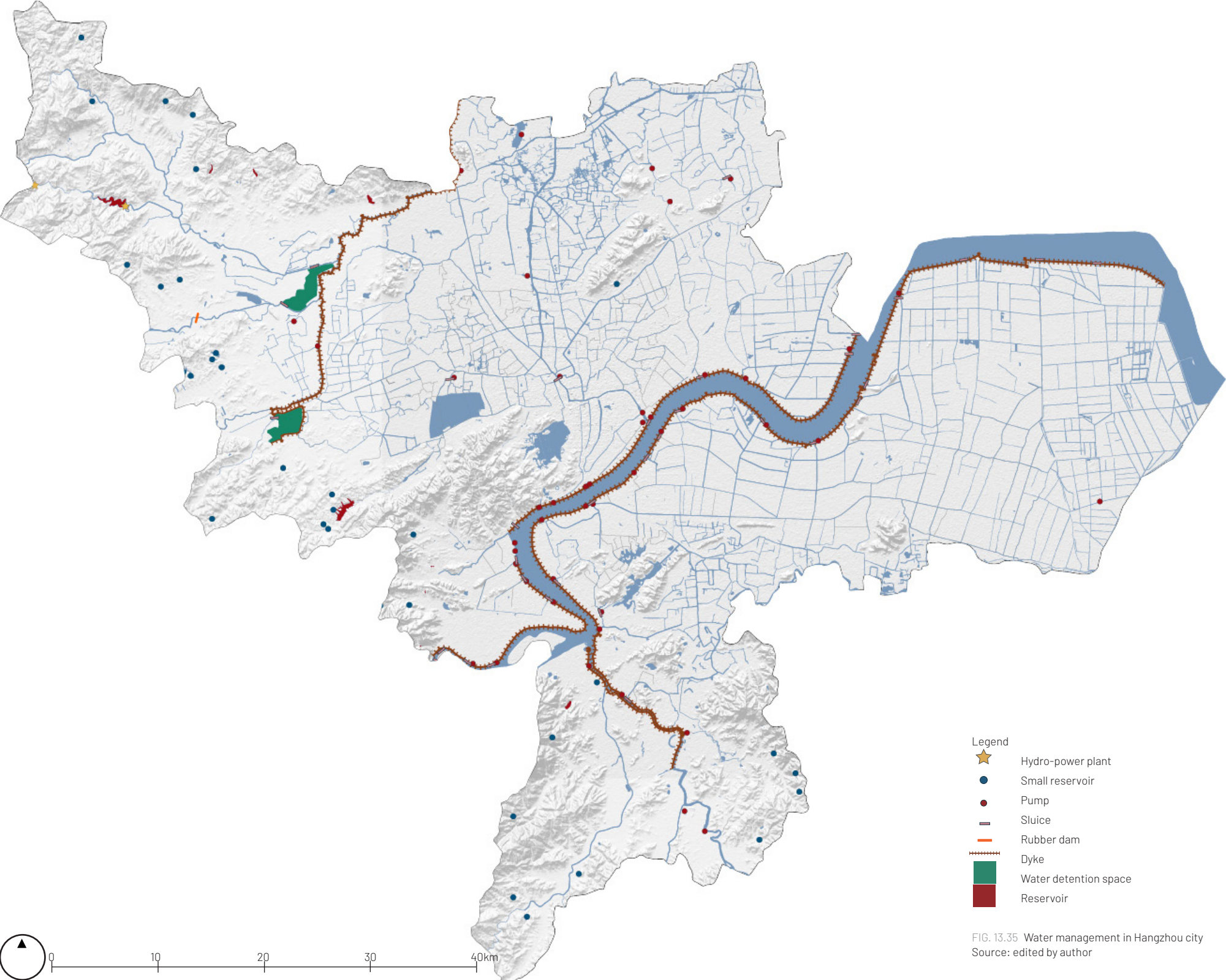
FIG. 13.34 Water management in Hangzhou  
Source: edited by author

## 13.2 – Urban system

### 13.2.1 – Urban water management system



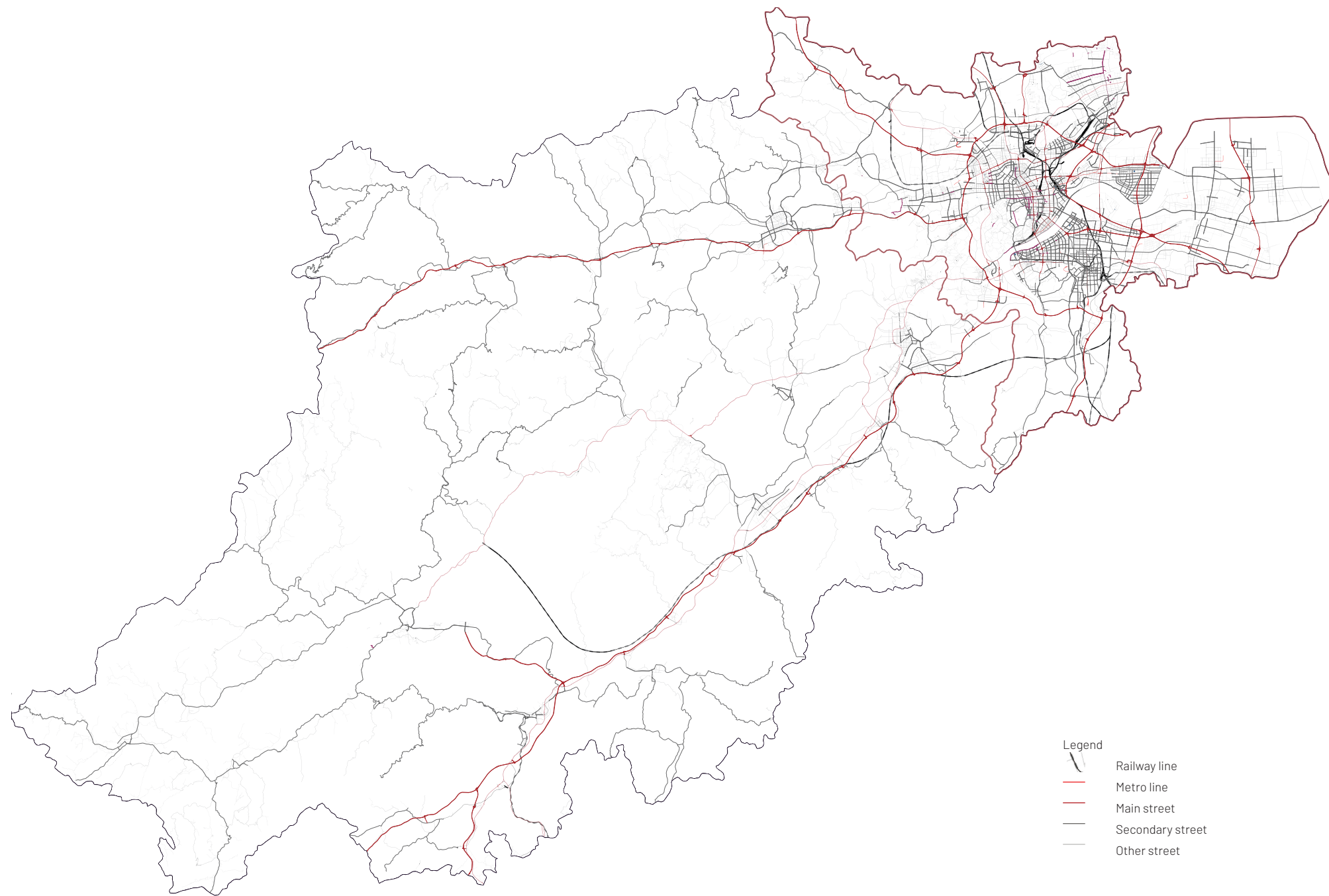




- Legend
- ★ Hydro-power plant
  - Small reservoir
  - Pump
  - Sluice
  - Rubber dam
  - ⋈ Dyke
  - Water detention space
  - Reservoir

FIG. 13.35 Water management in Hangzhou city  
Source: edited by author










- Legend
-  Railway line
  -  Metro line
  -  Main street
  -  Secondary street
  -  Other street

FIG. 13.36 Public transportation and street network in Hangzhou  
Source: edited by author based on GIS data

### 13.2.2 – Public transportation and street network

Mobility is analysed in the city scale and city centre scale through main transportation infrastructure. In general, mobility is highest in the city centre, with a trend to increase towards the small cities along the Qiantang River for both railway and highway.

This direction will be even more enhanced by the new plan of expansion along the Qiantang River.

The accessibility of a place in Hangzhou is depending on different transportation methods.

#### 1. Vehicle:

Due to tremendous amount of vehicle, the policy which has been made by the municipality limits 20% of the vehicle in certain area. But still, traffic congestion happens everyday.

#### 2. Bus or metro:

The city has a well-developed bus network. However, the efficiency of travelling with bus has been influenced by the heavy traffic on the road. As for metro, two have been finished and eight more are being constructed.

#### 3.Train:

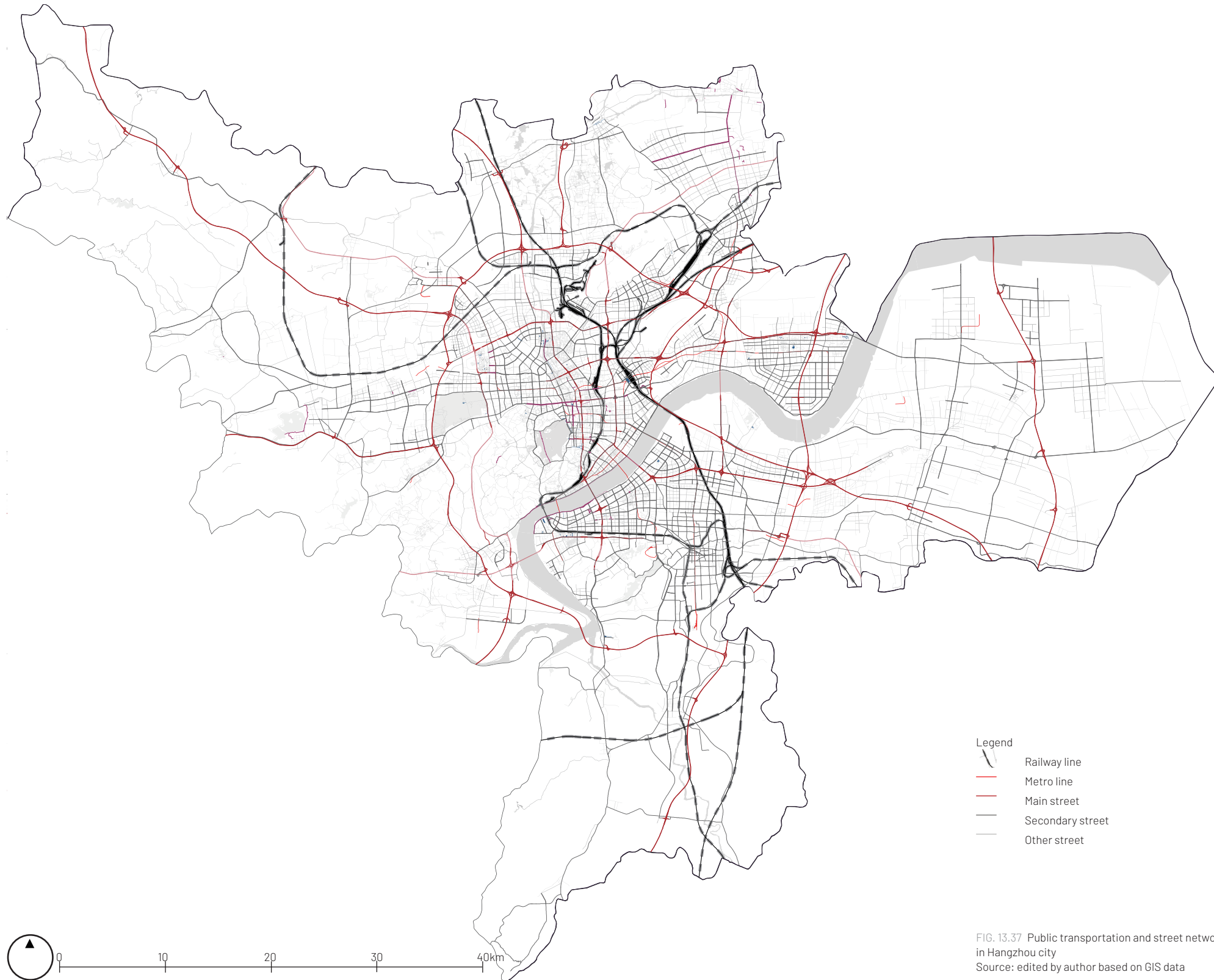
With the development of high-speed railway, it is possible for residents who live in small towns in Hangzhou commute to the centre within half hour. However, train lines create physical barrier in both city centre and rural areas.

#### 4. Bike:

Hangzhou is the earliest city which promoted sharing bikes in China. Bike parking spots could be easily found in the city.

#### 5. Foot:

In the scenic area of West Lake, footpath has been thoroughly planned and well connect. But for other place, it is hard to go around without vehicle or public transportation.








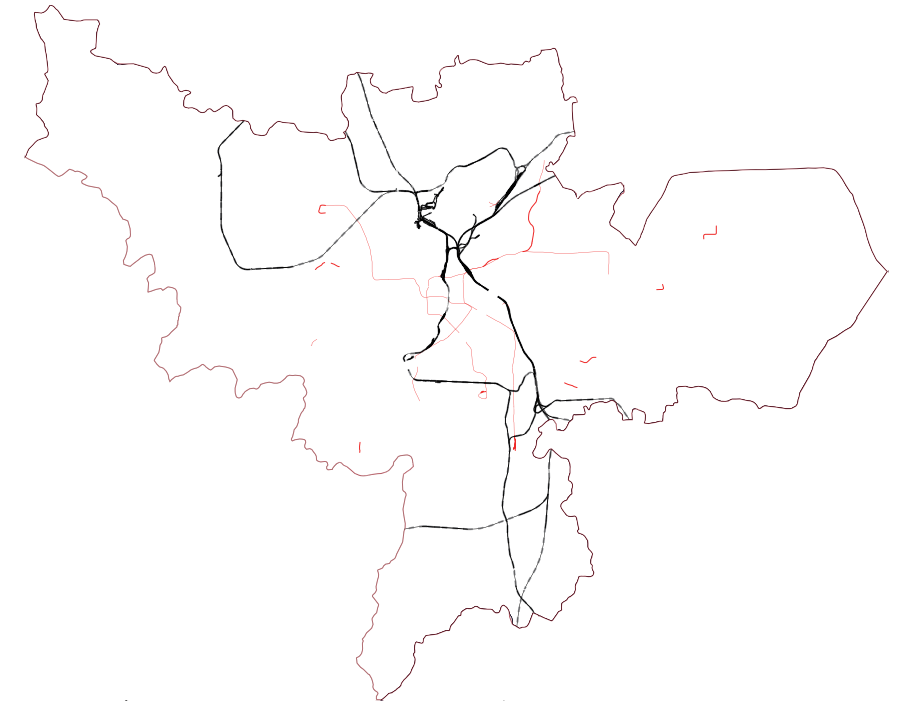
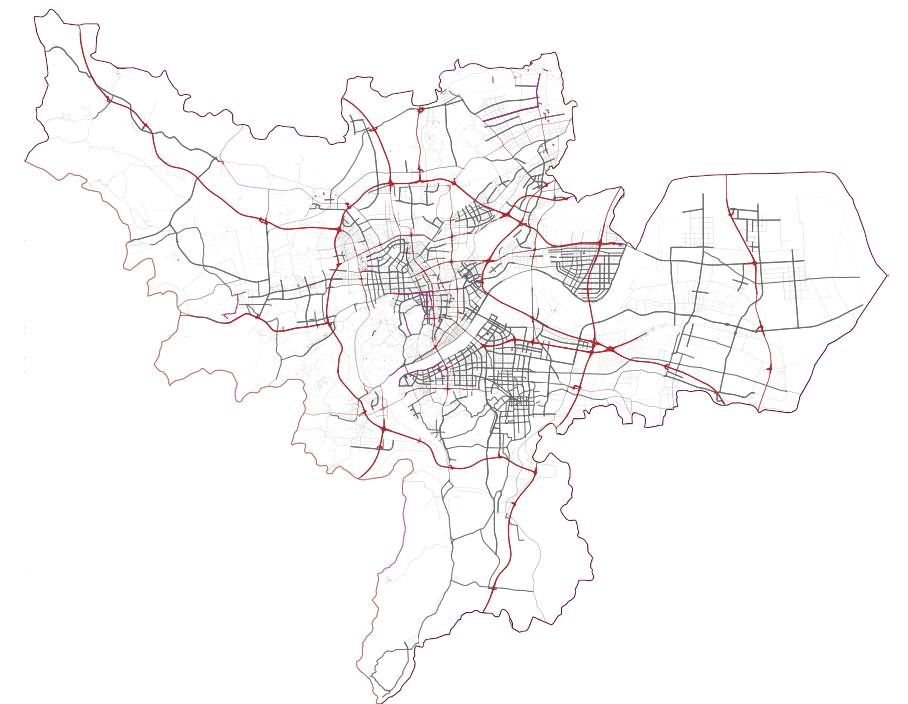
- Legend
-  Railway line
  -  Metro line
  -  Main street
  -  Secondary street
  -  Other street

FIG. 13.37 Public transportation and street network in Hangzhou city  
Source: edited by author based on GIS data

#### Railway and metro



#### Street network with hierarchy





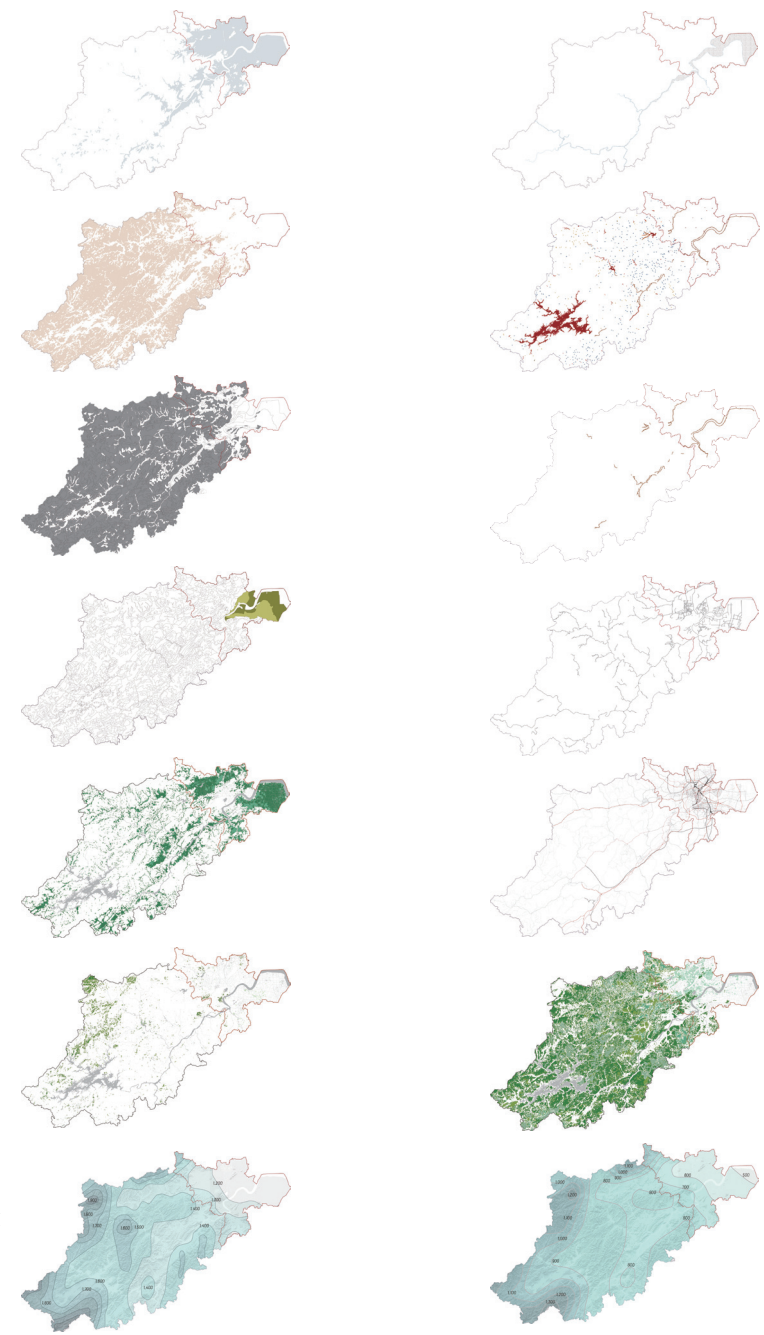
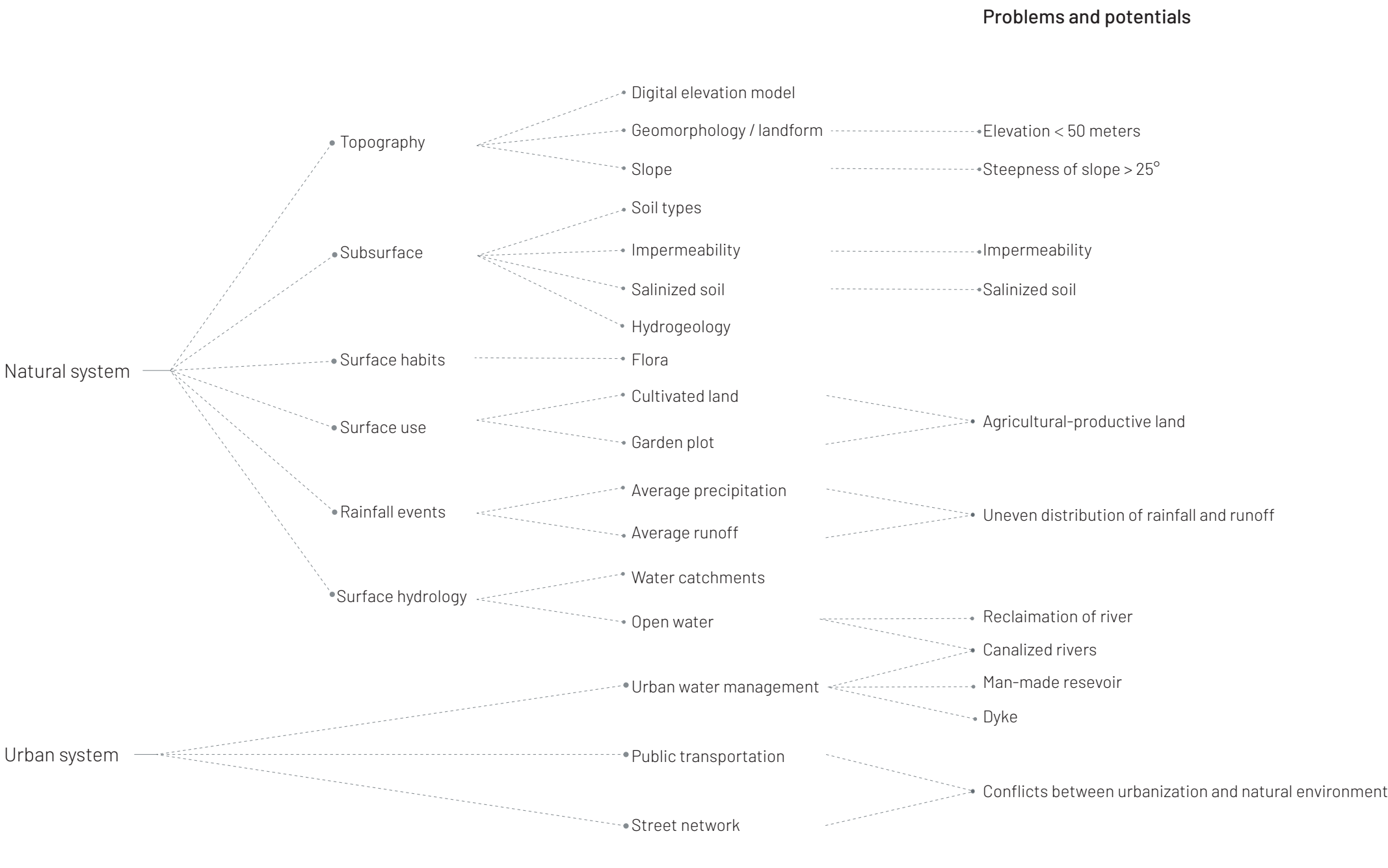


FIG. 13.38 Diagram of synergy  
Source: edited by author

# 14 – Exploring possibilities

In this section, possibilities will be explored as initial temptation of applying principles in the contemporary urban context. The application will use the tool of design exploring the possibility of principles and lessons learned from vernacular water-management practices with the understanding of local water system under the different urban conditions. The process will be based on the problems and potential which are been addressed in chapter 13, and principles will be tested in highly urbanized area, semi-urban area and rural area with corresponding problems and potentials. The outcome would be a set of tool-kit and recommendations for Hangzhou.

One of the most important lessons learned from vernacular water-management practices is in the process of using methods to solve the water issues ecological and social values could be added to the whole environment at the same time.



FIG. 13.39 Vision of the scenery to West Lake  
Source: edited by author

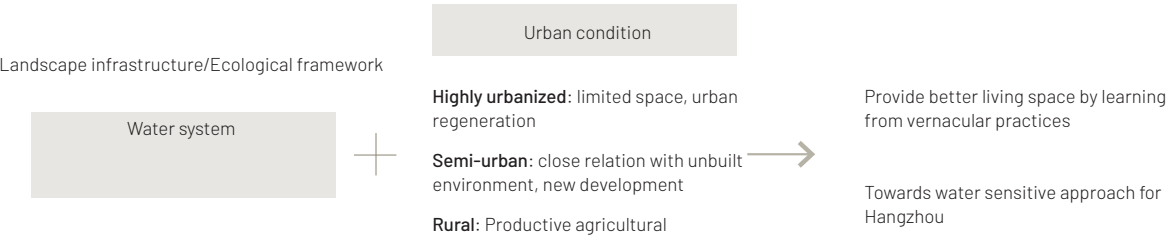


FIG. 14.1 Diagram of design exploration  
Source: edited by author



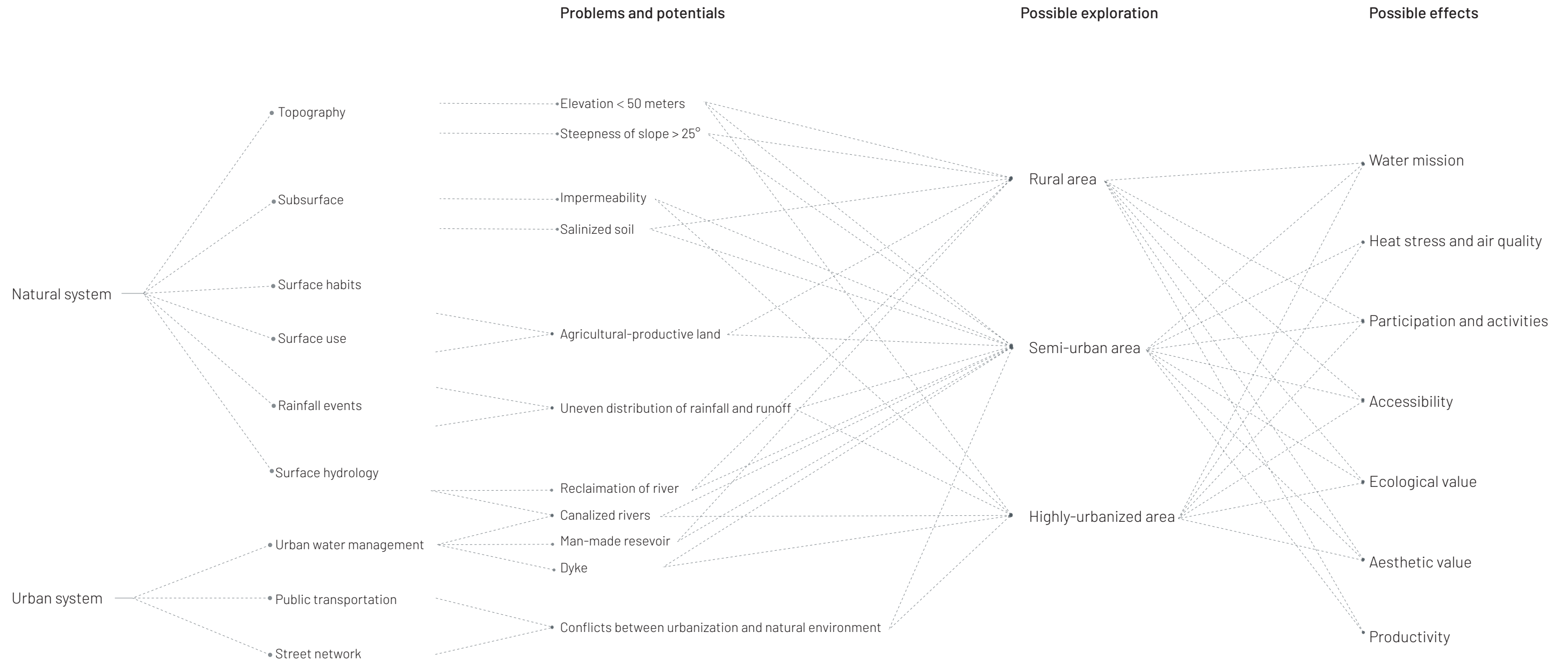


FIG. 14.2 Diagram of the process of design exploration  
Source: edited by author

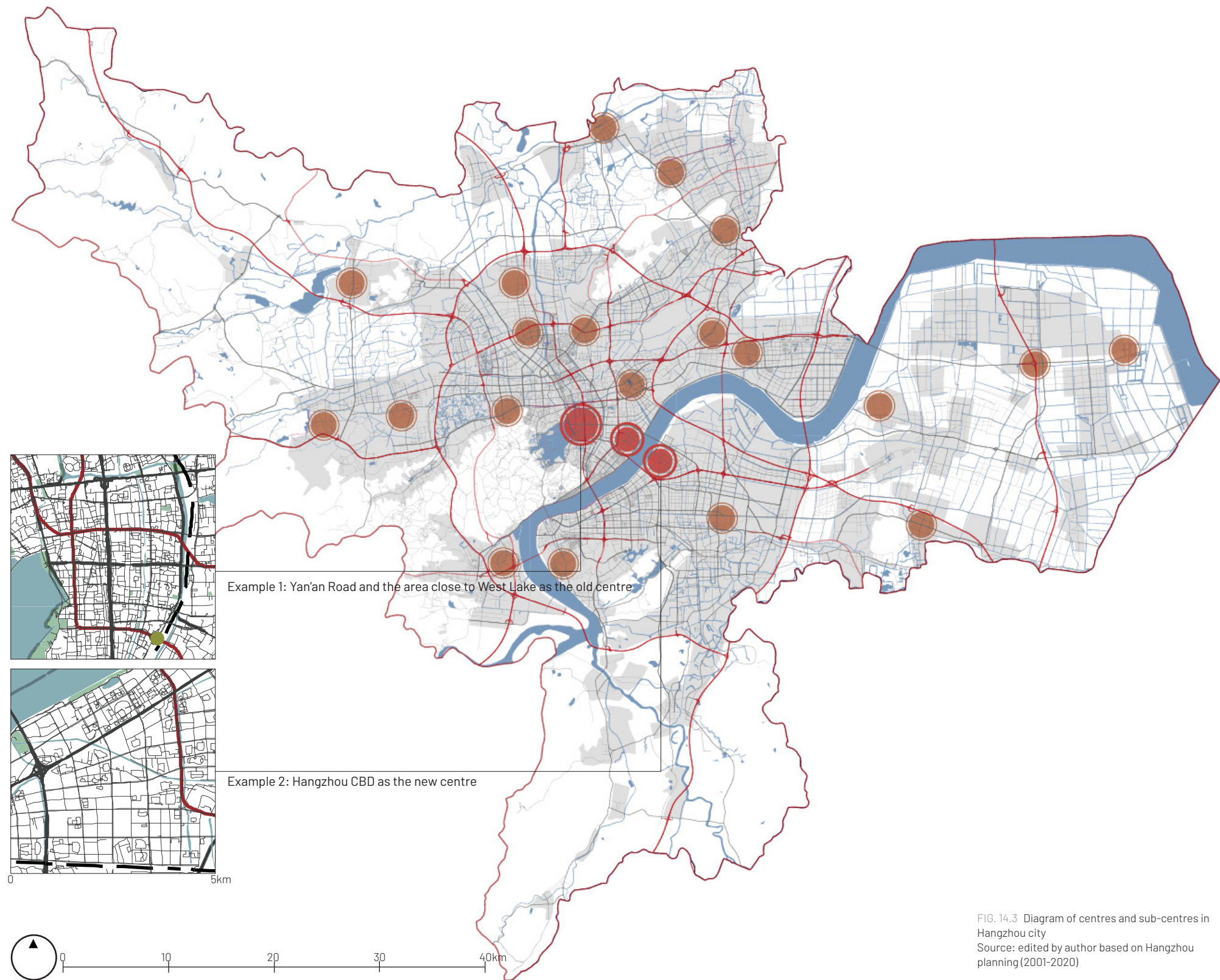


FIG. 14.3 Diagram of centres and sub-centres in Hangzhou city  
Source: edited by author based on Hangzhou planning (2001-2020)

## 14.1 – Highly urbanized area

### Example 1: Yan'an Road and the area close to West Lake as the old centre

It is in the city centre, it is located next to the West Lake and belongs to part of the ancient walled city of Hangzhou.

It's surrounded by the two main water infrastructures in the city as the West Lake and the Grand Canal.

Some neighbourhoods in this area were built in 1980s and in the lack of sufficient water management devices and have high risk of flooding at the same time.

### Example 2: Hangzhou CBD as the new centre

It locates in the newly built centre of Hangzhou at the south bank of Qiantang River.

It has very high density.

### Problems and potentials

**1. High flood risk.** River plain and lowland plain locate in the area which **elevation is lower than 50 meters**. Their geological condition decides their high risk of flooding. The space under the elevated overpass might cause place with higher possibility to get flooded.

Comparing with the previous water network (FIG 14.5), the area of previous city lost **most of the connection** in the direction of east-west. As a result, it is difficult to discharge flooding water in this area, but the only possible method is to depend on urban sewage which might not be efficient enough for extreme rainfall. This might be one of threats for this area.

Another threat hides in the **water level difference** between the West Lake and the Grand Canal (FIG 14.4). The Grand Canal having the lowest water level in the city, works as one of the only rivers for flood water discharging in the city. However, the average water level of the West Lake is around 9 meters as the grand canal around 3 meters. The difference between two water levels reaches 6 meters.

The water level difference has possible threat for the city during the wet season. If the water level of the West Lake gets over the alarm level during the extreme rainfall, it has high possibility of flooding the whole city centre. However, the West Lake has only one water outfall which locates at the northeast corner of the lake. The efficiency of water discharging needs to be improved. And the water level difference needs to be carefully considered during the design.

Moreover, the sluice gate between the Grand Canal and Qiantang River couldn't open for 24 hour per day due to the tidal bore which comes two times per day. It is urgent to find more temporary space for water in the city.



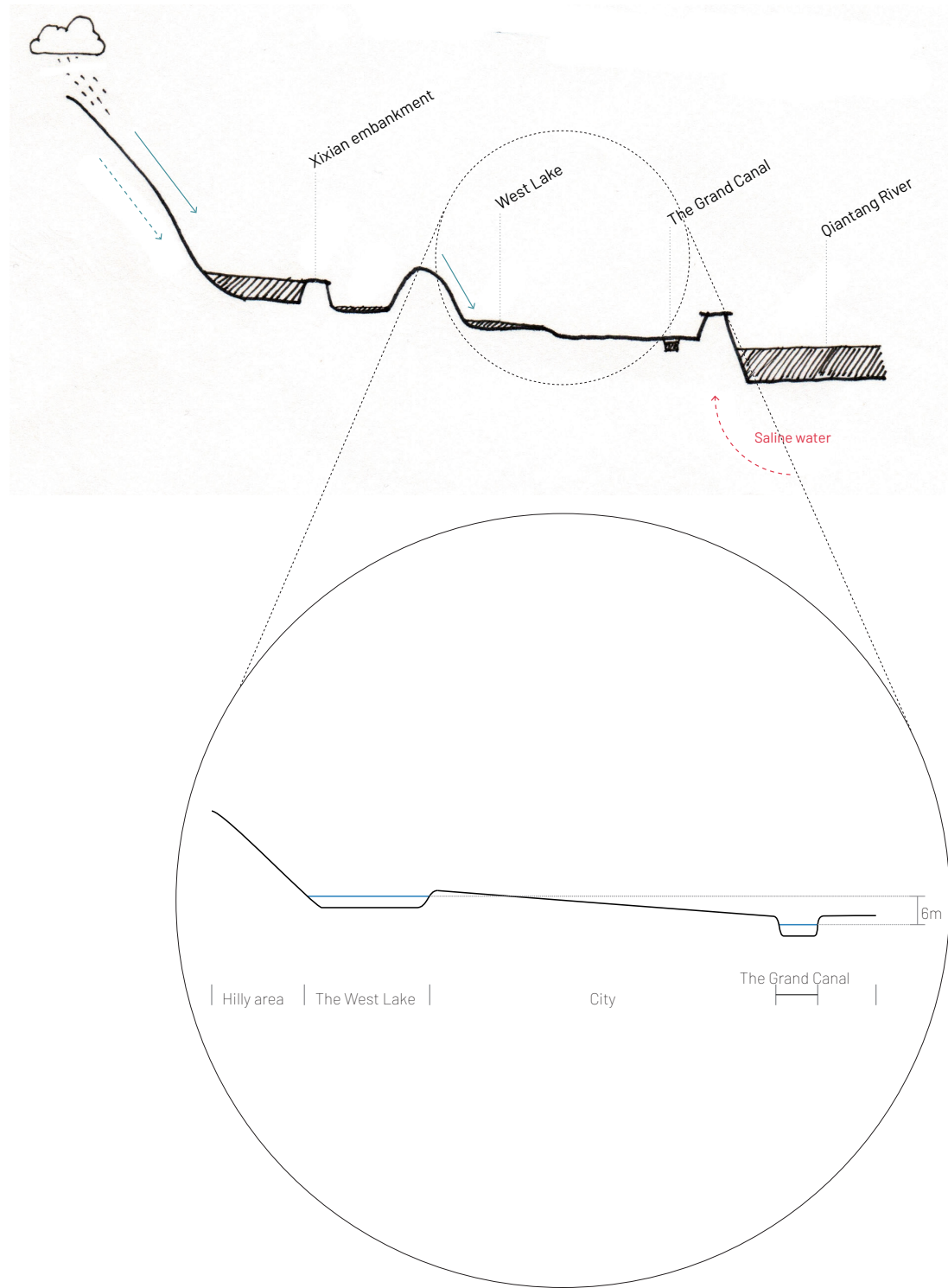


FIG. 14.4 1. Topography and water system  
2. Green space and water system  
Source: edited by author



FIG. 14.5 Historic map of Southern Song Dynasty Water System  
Source: Tengxun [online] available at: <http://zj.qq.com/a/20131009/002915.htm> [accessed on 26 March 2018].

2. **Impermeability.** Both examples are highly urbanized, and lost the ability of absorbing water. Moreover, they both have important infrastructures like railway and metro lines in the areas. Example one is the most important spot in the mobility system of the city as it contains the main railway, two intersect metro lines and elevated overpass. Urban runoff depends on sewage system which has possibility of overflow during extreme rainfall.

3. **Uneven distribution of rainfall and runoff.**

4. **Canalized rivers lack of accessibility.** Compare with the previous waterways, there used to have more waterways between the West Lake and Zhong River. The existing ones are canalized and have less accessibility for residents and tourists.

One of the rivers called Huansha River was covered forty-five years ago and worked as one of culvert for now.

5. **Dyke.**

6. **Quality and accessibility of public space.** In the city, the public space is mainly along the river besides the tourism spot of the West Lake. The lake is surrounded by high-rise buildings along east bank of the lake.



**Principle 1: Use cascading water system for different water level between West Lake and the Grand Canal**

For the problem of different water level between West Lake and the Grand Canal, the lessons learned from weir system in Qiantang River Basin could be applied as cascading water system.

Weir system could be used as devices of changing the speed of water and water storage infrastructure which is suitable for the wet season. Moreover, the material of weir could be very environmentally friendly and could also create nice space for public activities like jogging, bird watching, and other recreational activities.

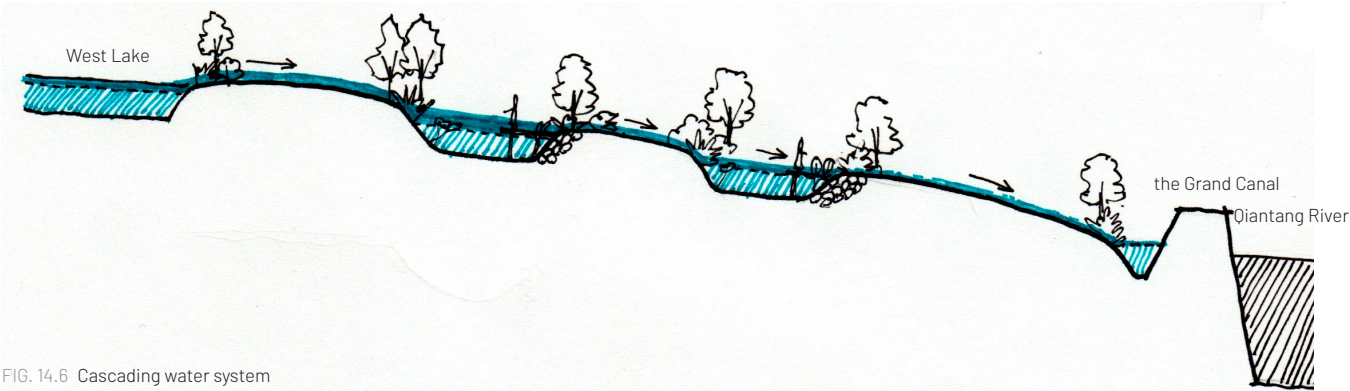
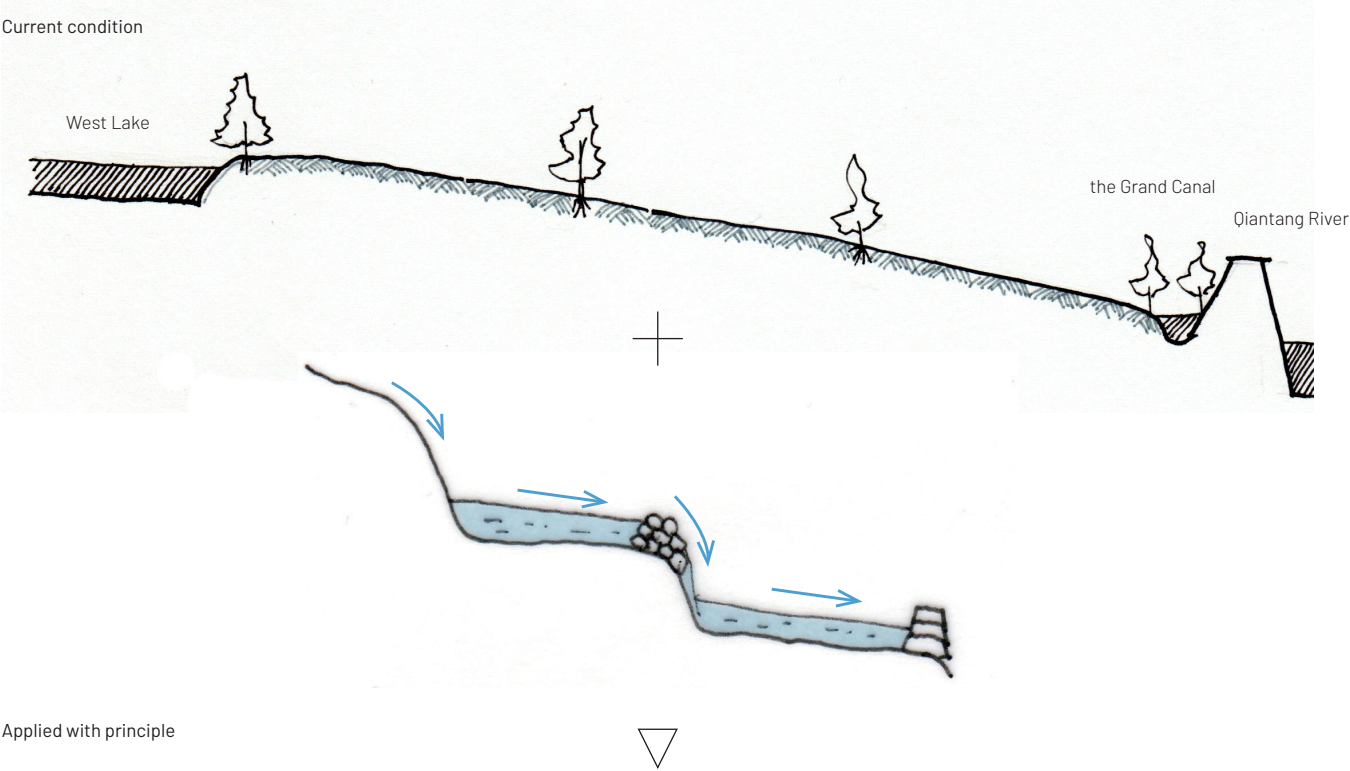
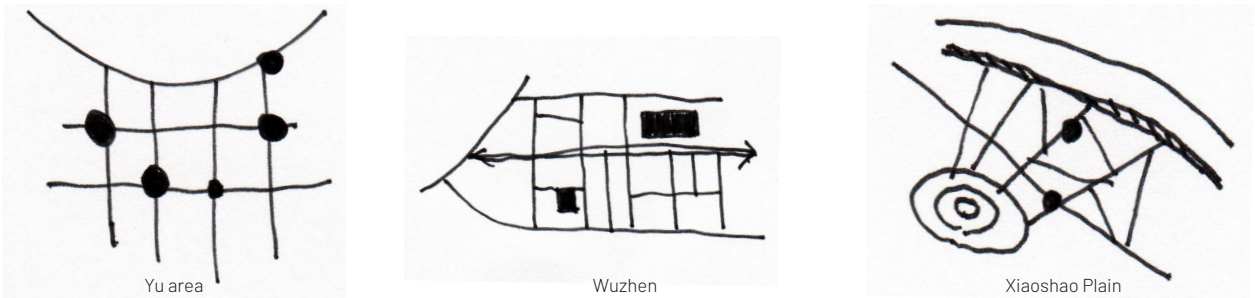


FIG. 14.6 Cascading water system  
Source: edited by author

**Principle 2: Uncover two existing water outlet points for West Lake and re-introduce waterway along the streets to create a well-connected water system**

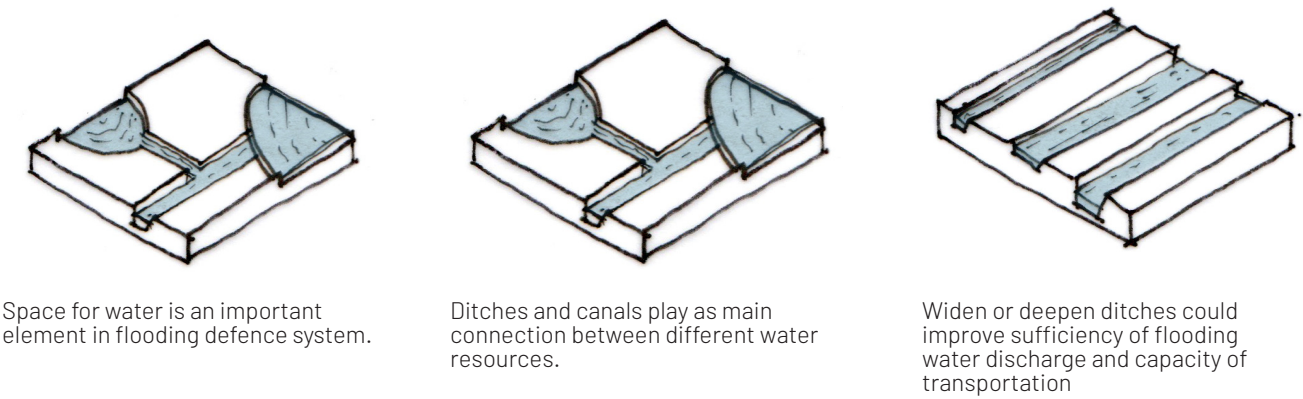
As mentioned before, it's necessary to keep certain speed of water outlet for West Lake for the safety of the whole city. However, only one of the existing outlet is directly connected to a river with a speed of 275 cube meter per second. The other two are connected to city rainwater sewage with only 25 cube meter per second. For this problem, the lessons learned from well-connected water system in Yu area, Wuzhen, and Xiaoshao plain could be applied here.



Learning from these three different types of well-connected water systems, a grid structure and more connections from the lake could be learned from Yu area, and schools and other public space as small 'sponge' could be learned from water town Wuzhen.

Other lessons could be also used in the process of proposing a well-connected water system.

Together with principle 1, locations of changing small weirs for changing water level are considered in the water system as well.







1



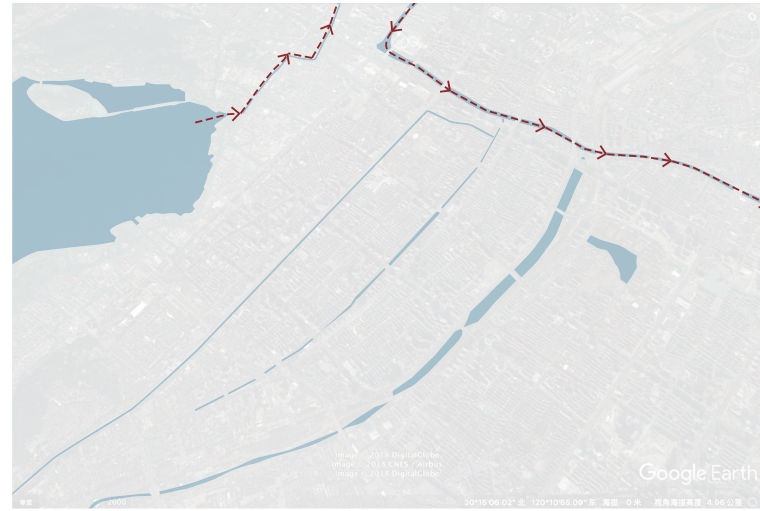
2

--- Previous waterways  
 ◆ Water

FIG. 14.7 1. Water management  
 2. Current waterways and previous waterways  
 Source: edited by author



FIG. 14.8 Proposed new water system with new connections  
 Source: edited by author



**Before:**

Way of discharging water from the West Lake



**New:**

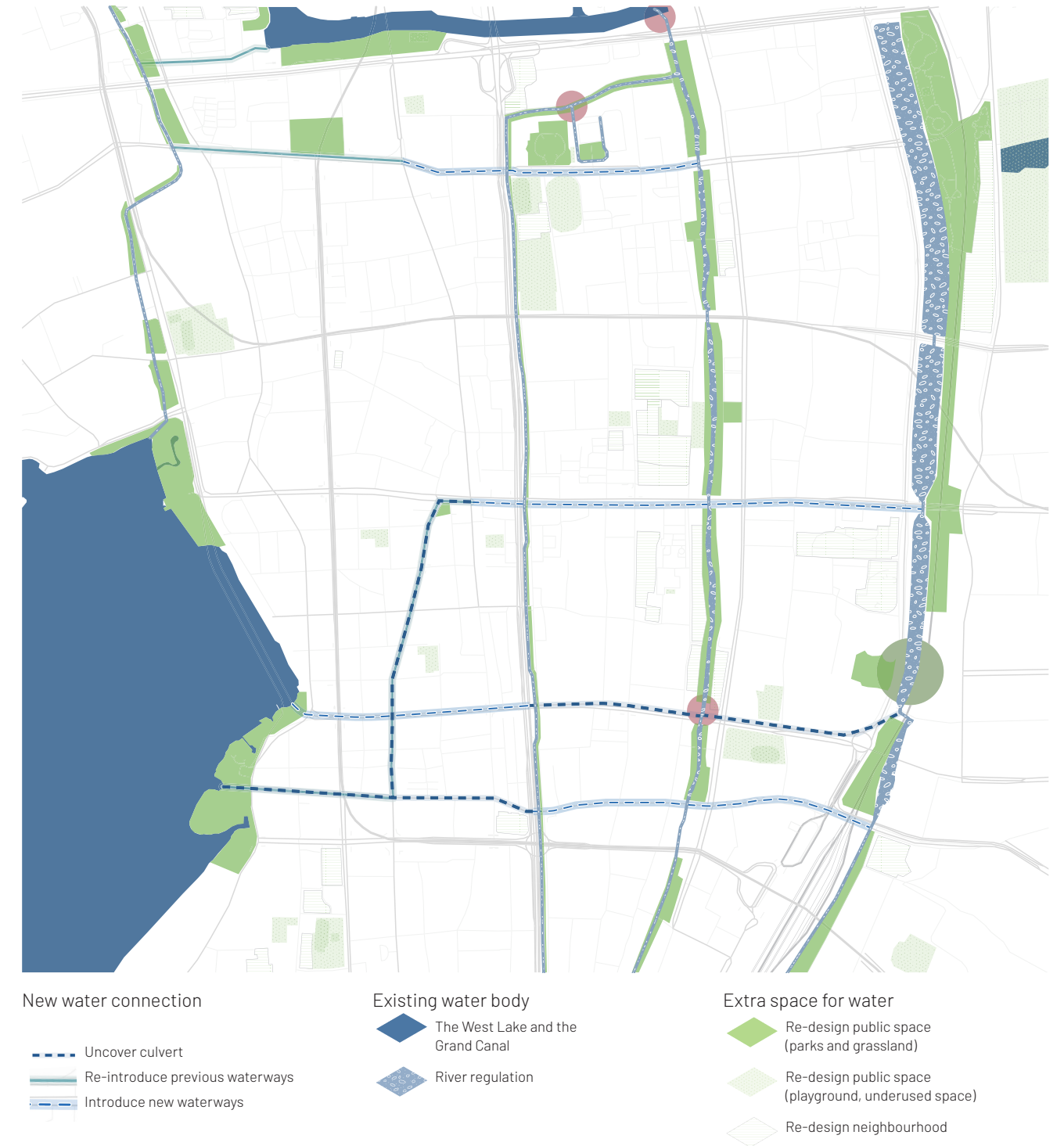
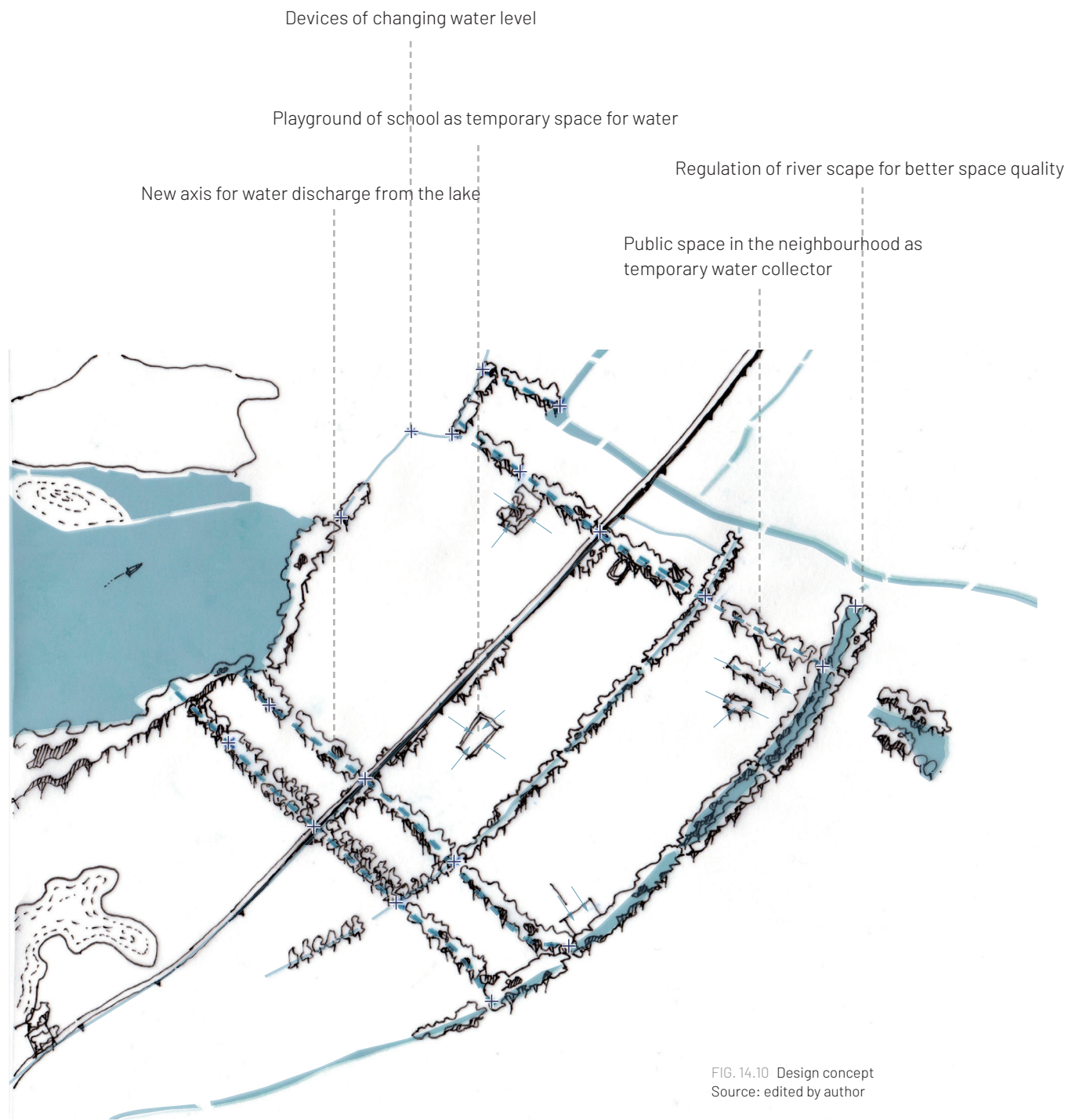
New connection for water system



**Future:**

Ways of water discharging in the future

FIG. 14.9 Design concept  
 Source: edited by author





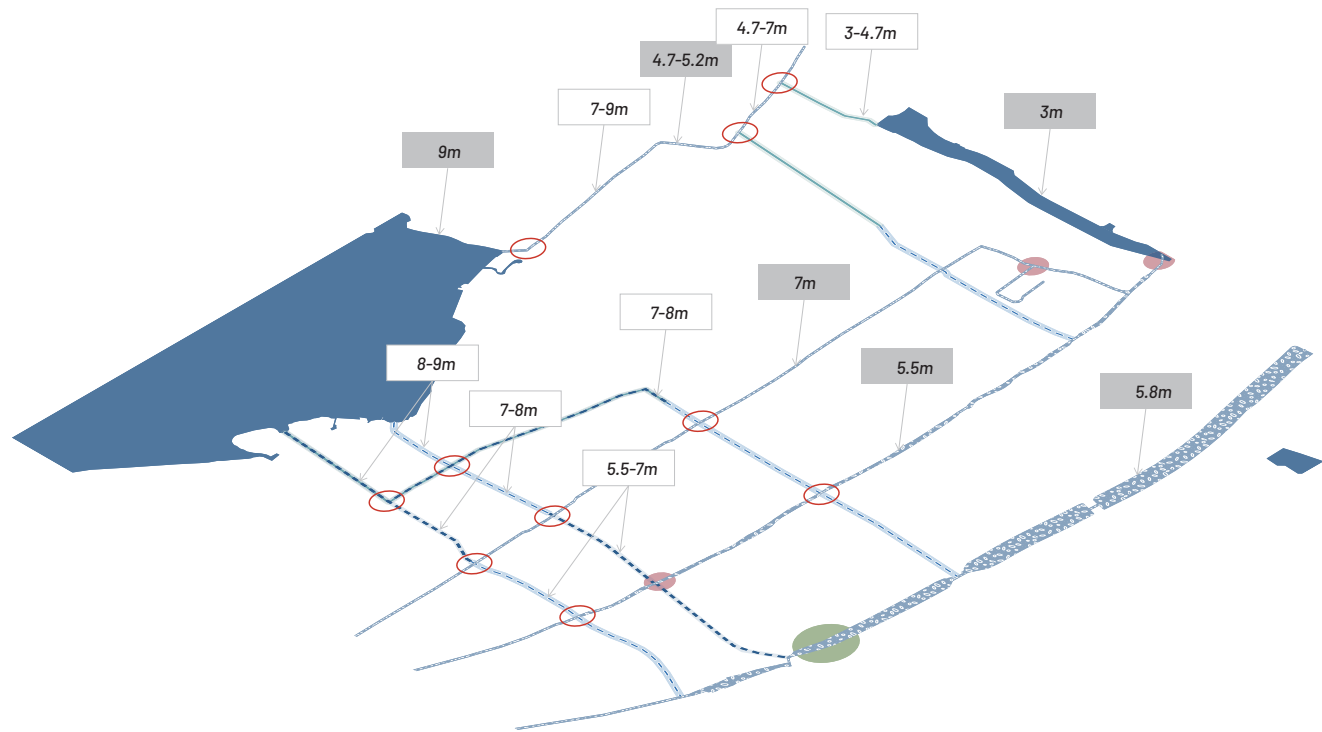


FIG. 14.12 Water system with new connections  
Source: edited by author



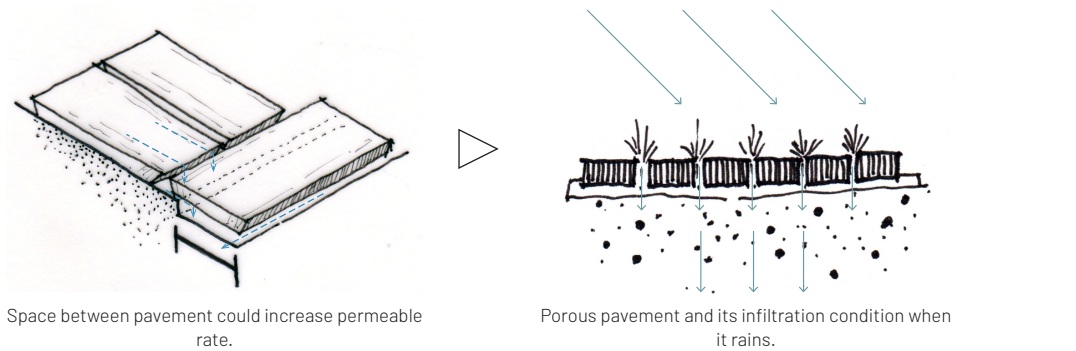
FIG. 14.13 Hydrology and ecology  
Source: edited by author

Principle 3: Increase permeability in old neighbourhood

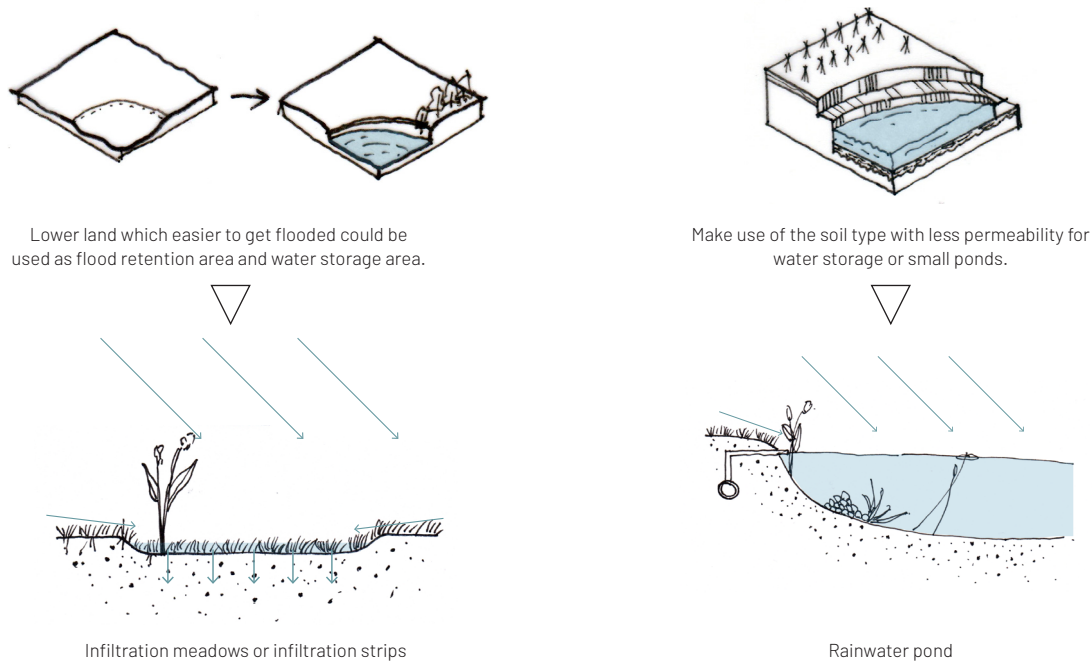
Some neighbourhoods in example 1 were built in 1980s and lack of sufficient water management devices and have high risk of flooding at the same time.

By increasing permeability in the old neighbourhood, it is also improving the quality of public space and providing recreation space for residents.

The process of increasing permeability has been operated into two parts. The first part is about pavement. As the lessons learned from Wuzhen, it is vital to keep the porosity of pavement.



The second part is to find more space for water when extreme rainfall happens. For the lessons we learned, small ponds could play an important role in water management, and also has its own ecological value and recreational function. So, it is crucial to transform certain area into infiltration meadows or infiltration strips, and some for rainwater pond as buffer area.



Principle 4: Create soft bank and improve accessibility of canalized rivers

As one of the hard-engineered method of water management, all existing rivers are been canalized. As a result, both width and depth are not suitable for heavy shipping, but only some tourism ships. As we learned from the example of Yu field and mulberry fish complex, it is necessary to create soft bank and improve accessibility of canalized rivers.

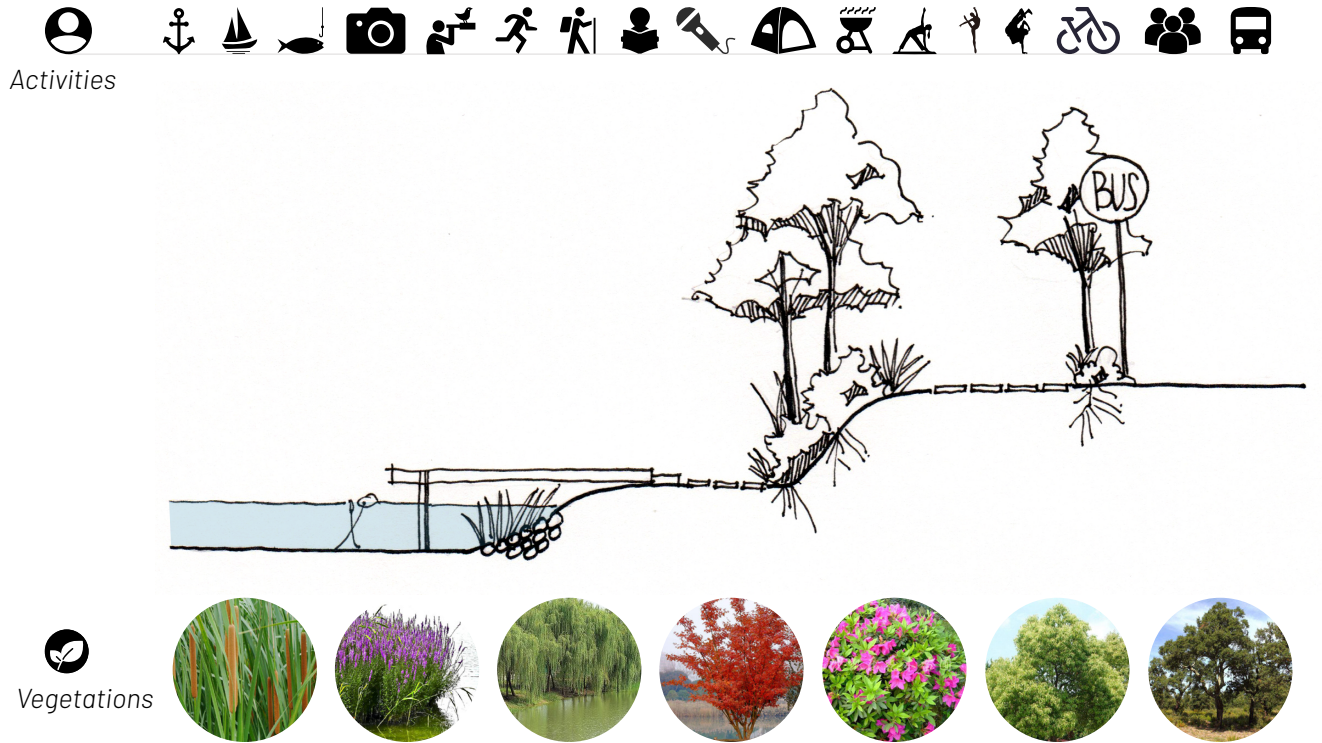
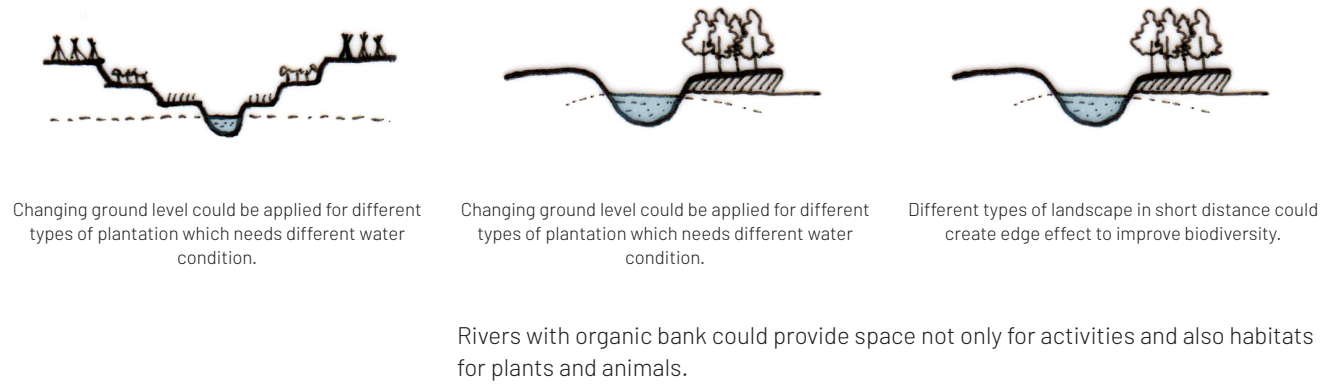


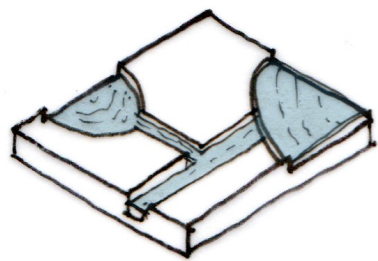
FIG. 14.14 Proposed section of existing river  
Source: edited by author



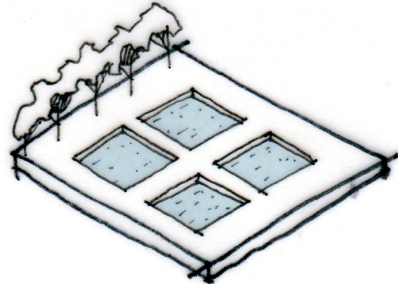
Principle 5: Introduce and re-introduce waterways along the street

As part of the plan of principle 2, these two streets plays an important role of direct extra water from West Lake into above-ground storage or waterway for faster overflow, and also involved with the cascading water system.

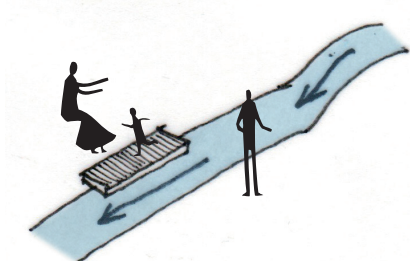
Lessons could be learned from all examples. For instance, by making waterway visible is to private accessible public space, create space for human activities, and add educational values to the space.



Ditches and canals play as main connection between different water resources.



Public space could be re design for water retention and water storage.



Water flows could be visible for public space and create close relationship with human.



FIG. 14.15 (left) Plan for re-introduce waterways along the street  
Source: edited by author  
(right) Vision of the new street  
Source: edited by author

**Principle 6: Besides ecological values, social values could also be added in the process of design or planning**

As we learned from the vernacular practices, Chinese people use twenty-four term as the main calender for agricultural activities. It shows the process of natural law. In the past times, other activities are arranged between busy agricultural periods.

In the contemporary urban context, the relation between human being and natural has been separated by asphalt and concrete boxes. Green space in urban area gives the possibility of getting in touch with 'nature'. Therefore, public space not only provides high quality space for all activities, but also shows the rhythm of scenery changing through seasons and the process of life from birth to downfall.

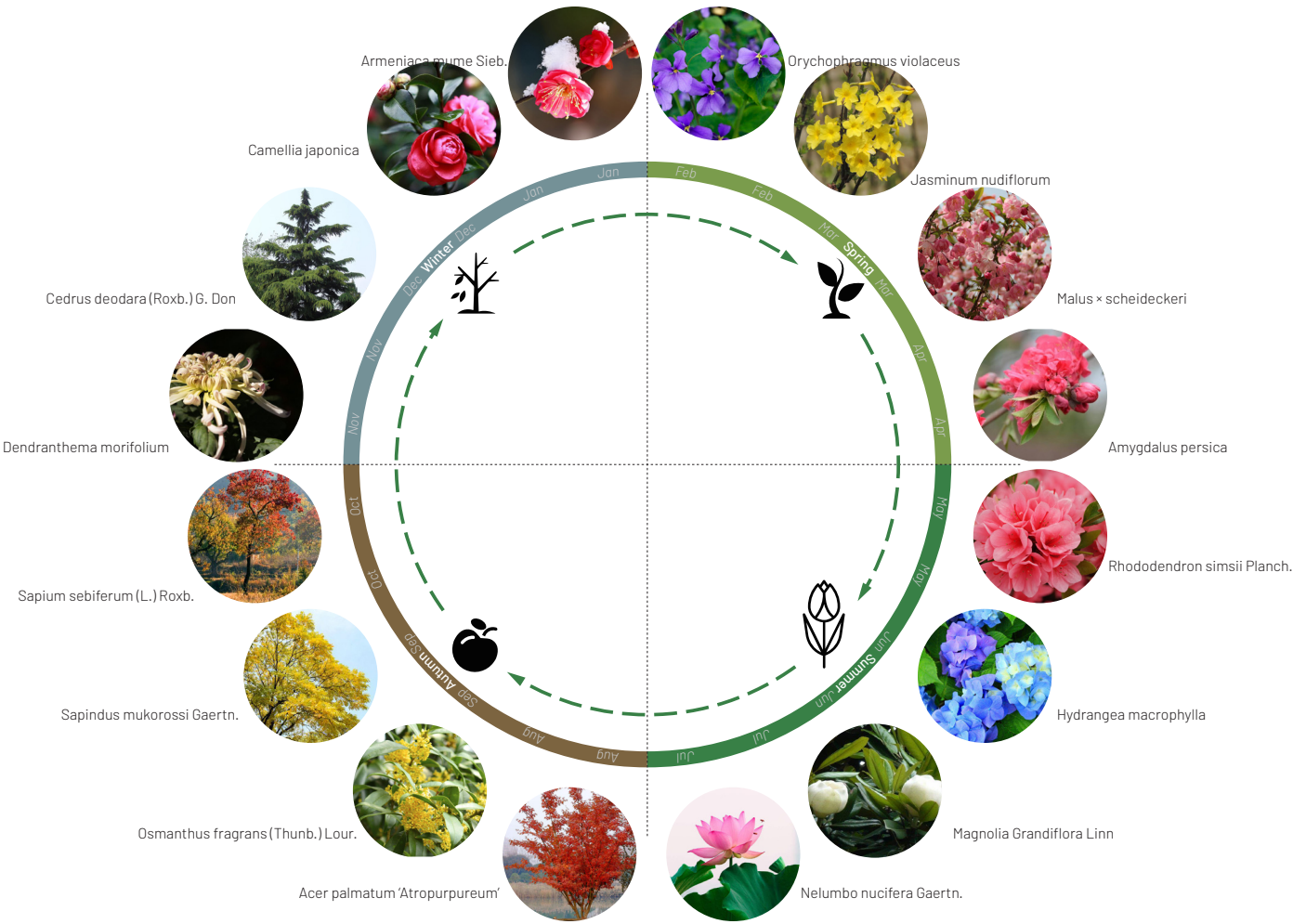


FIG. 14.16 Diagram of seasonal change of plants  
Source: edited by author

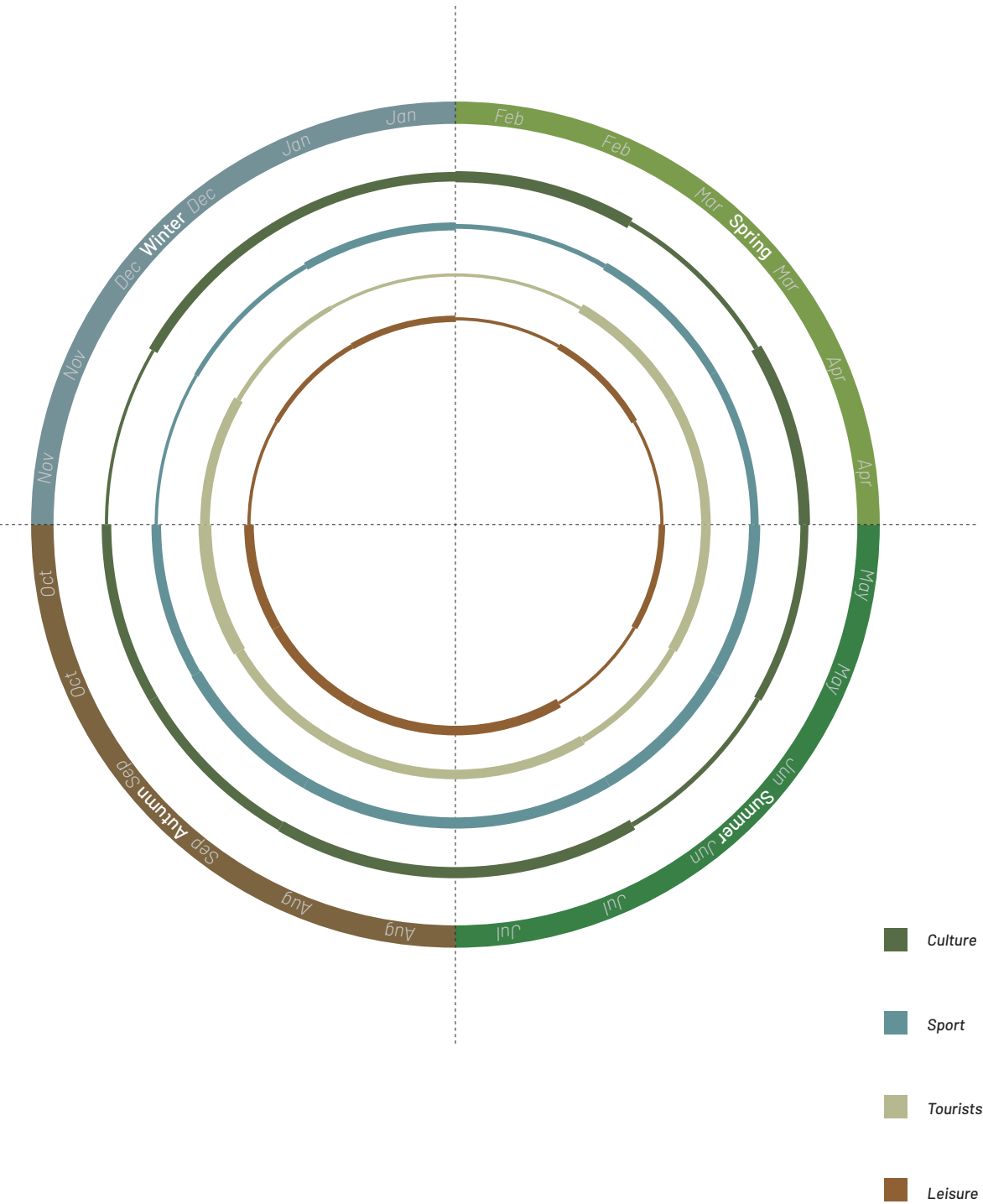
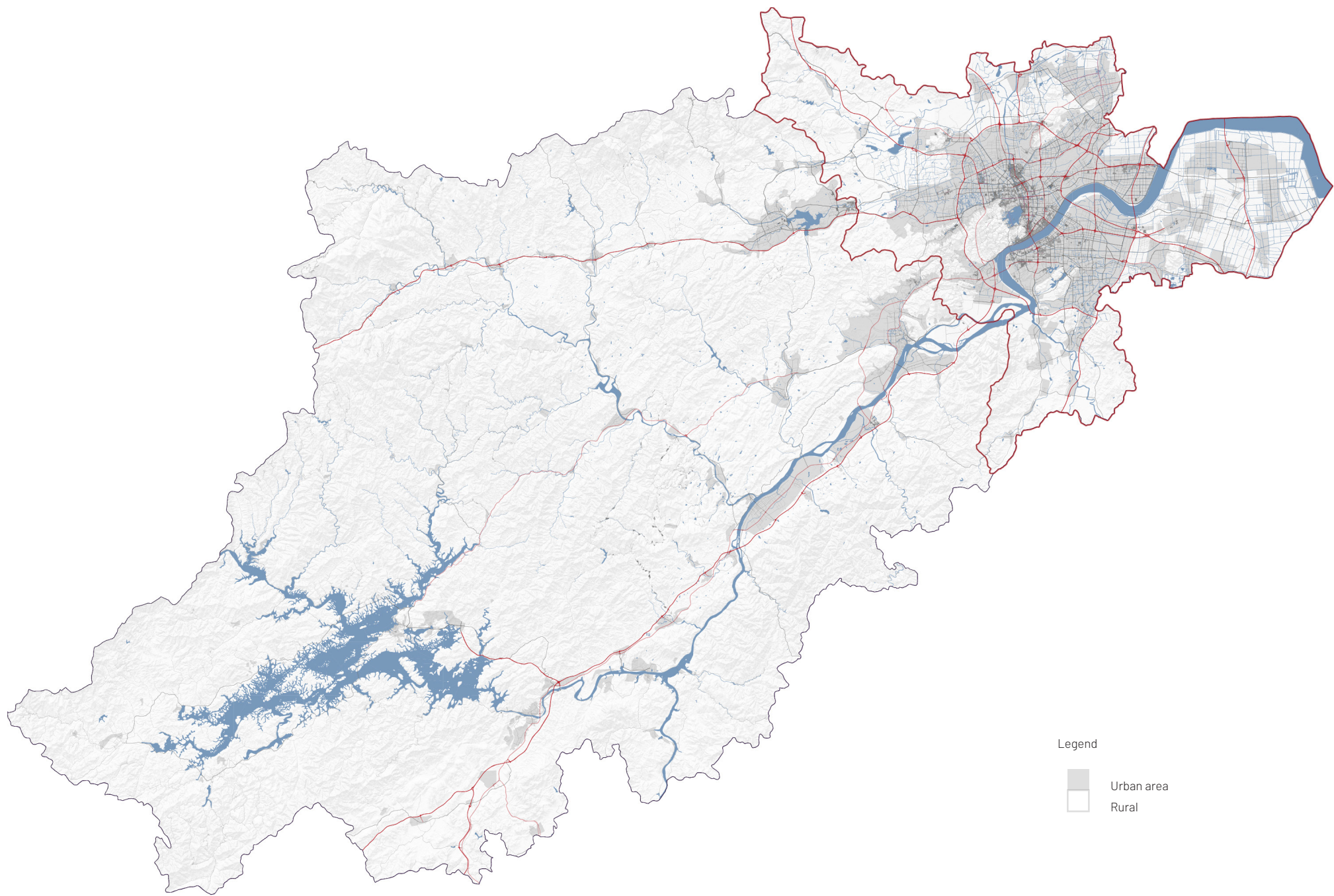


FIG. 14.17 Diagram of seasonal change of activities  
Source: edited by author





14.2 – Rural area

From the map (FIG 14.15), it is clear that urban area locates in the lowland plain and small towns along the Qiantang River. Moreover, two main issues related to the rural area is the land and the water. The Land condition includes elevation, soil types, steepness of slope, its land use. Water condition involves rainfall and man-made infrastructure for changing the natural form of water. Although rural areas have their own specific environmental condition, the main goal is to improve productivities.

Problems and potentials

1. **Productive land in the hilly area.** The main character of the hilly area is gradually increasing terrain. However, water becomes the main problem for agricultural. Different types of man-made water infrastructure have been built during last 60 years, for instance, hydro-power stations, big reservoirs, medium reservoirs and small reservoirs for water storage and irrigation. On the one hand, they contribute a lot to the irrigation. On the other hand, these devices changed the natural flows of water which has a strong impact on the natural environment.

However, the high coverage of forest in the hilly area has its important value for recreational activities.

2. **Productive land along river plain.** Part of the river plain has been reclaimed in the 1970s. Due to its soil and water condition, it limits the option of crops and plants could be cultivated. Moreover, this area is ecological vulnerable land because the mono-function of the fields.

Legend  
Urban area  
Rural

FIG. 14.18 Urban and rural areas in Hangzhou  
Source: edited by author







(up)Diagram of existing Beitang system in Qiantang River Basin  
Source: edited by author  
(down)Possible view for tea plantation  
Source: edited by author



**Principle 1: Apply Beitang system in productive land in the hilly area**

As we learned from the vernacular practices, Beitang system is man-made ponds as medium or small-scale water infrastructure in between of terrace for water storage and purification.

Beitang could be considered as part of the green-blue infrastructure for the future city and transferred into the wetland to build a Beitang-wetland system for fields.

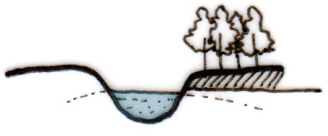
As one of the example, existing Beitang should be kept in the process of developing a new tea plantation field. Beautiful water plants like lotus could be planted in the ponds. Together with forest and tea plantation, Beitang system could be transformed into an attractive spot for recreational activities.

**Principle 2: Wetland as ecological buffer for productive land along river plain**

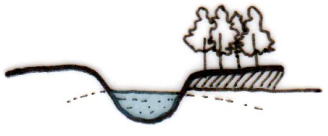
In the man-made reclaimed land along the Qiantang River which suffers from saline water. It is necessary to create wetland as an ecological buffering area for water purification and strengthen the ecological system.



Changing ground level could be applied for different types of plantation which needs different water condition.



Changing ground level could be applied for different types of plantation which needs different water condition.



Different types of landscape in short distance could create edge effect to improve biodiversity.

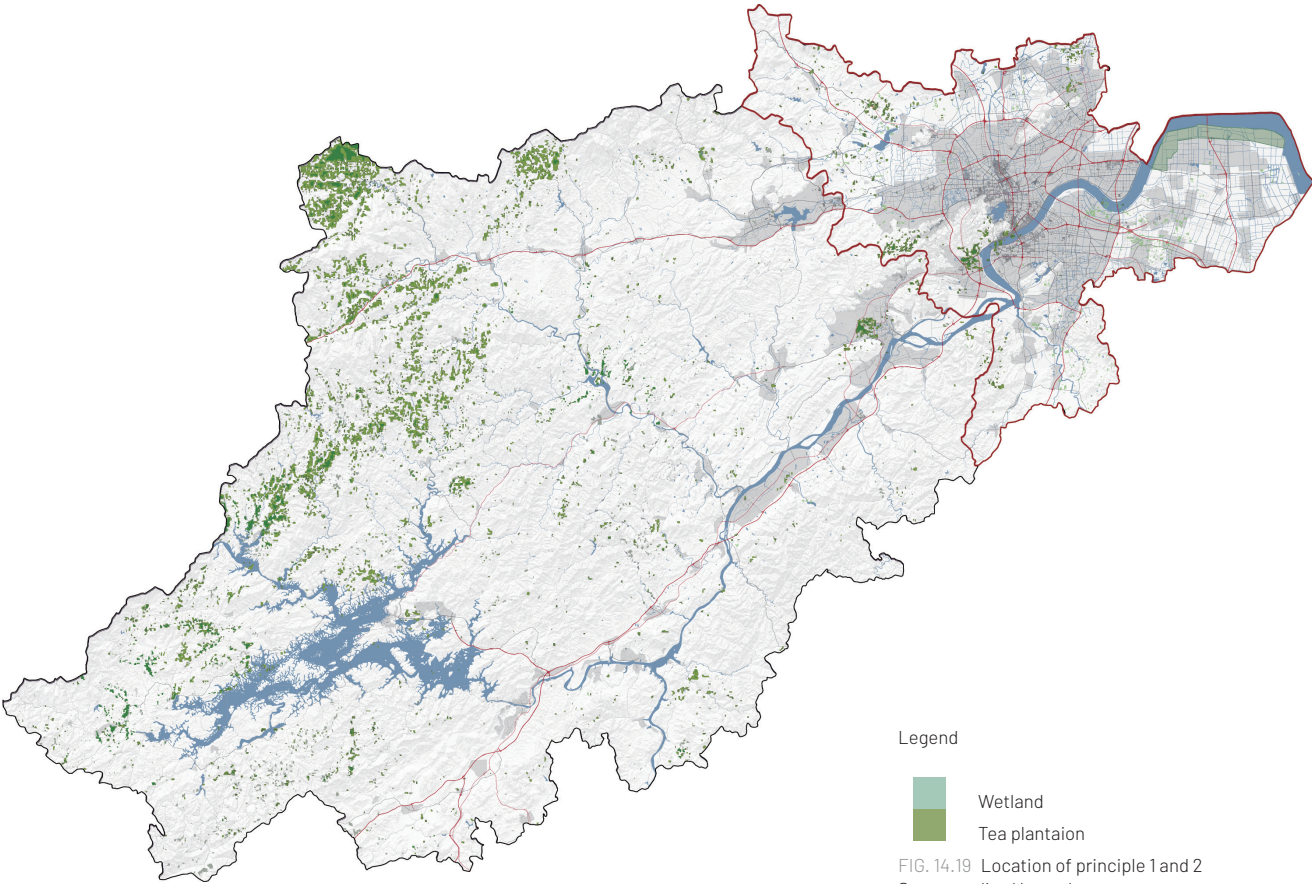
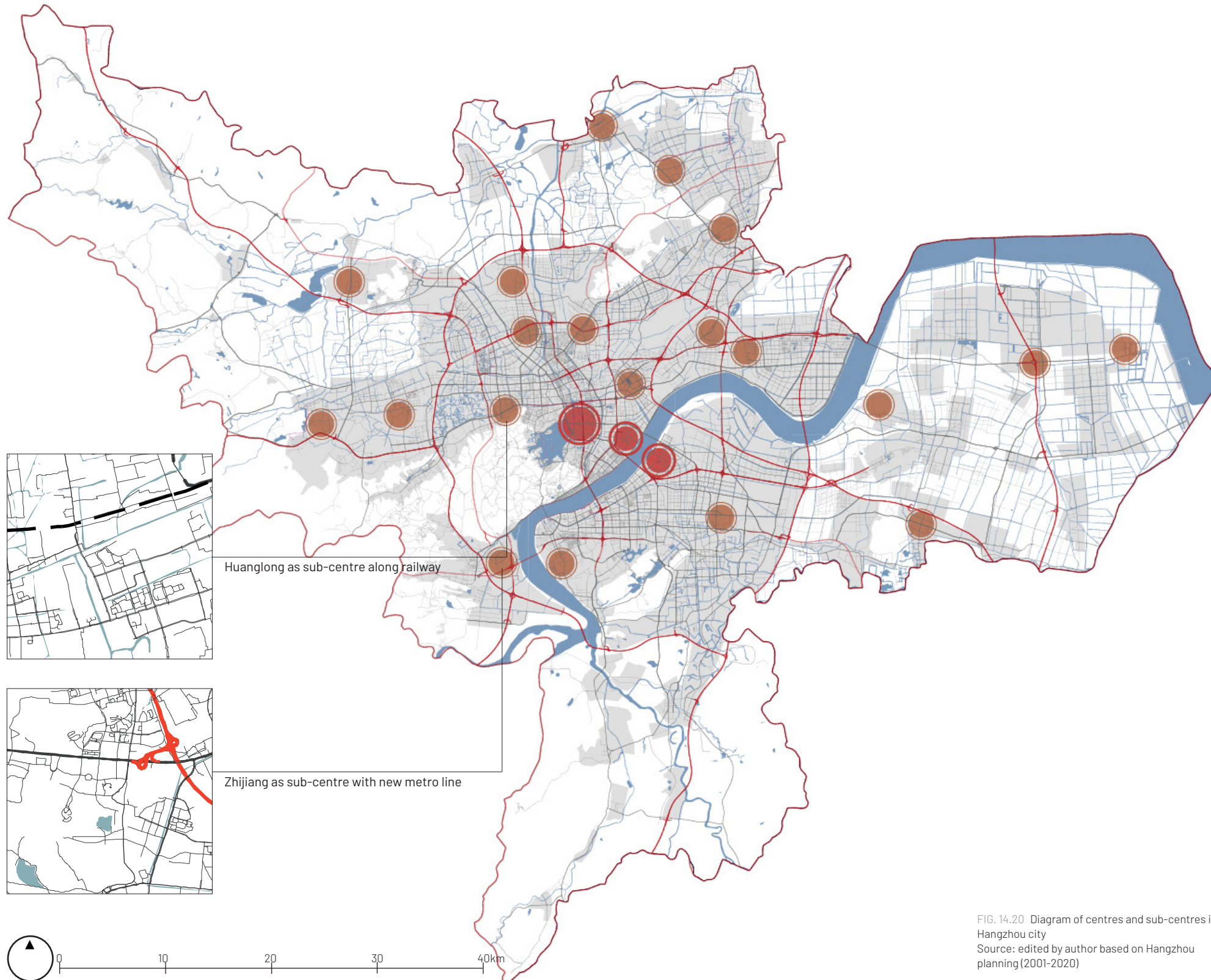


FIG. 14.19 Location of principle 1 and 2  
Source: edited by author





### 14.3 – Semi-urban area

#### Example 1: Huanglong as sub-centre along the main infrastructure

It is located in the edge of the city in the western part. It used to be wetland area. Now it's facing the pressure of high flooding risk from the hilly area to the west and pressure of urban spread. There is a high-speed railway line across the area.

#### Example 2: Zhijiang as sub-centre with new metro line

It is located at the edge of the city along the Qiantang River. There is a high way entry in this area for the ring road of Hangzhou. And in the short future, a new metro line will be built in this area to connect the city centre. Around the planned metro station, new neighbourhoods will be built.

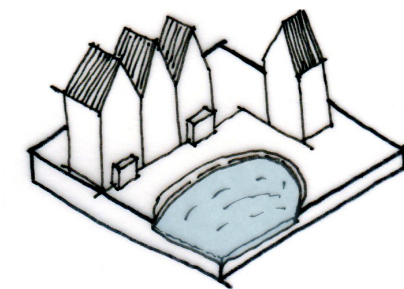
#### Problems and potentials

The semi-urban area is the place with most of the conflicts between natural environment and urbanization. So it contains all problems and potentials from highly-urbanized area and rural area.

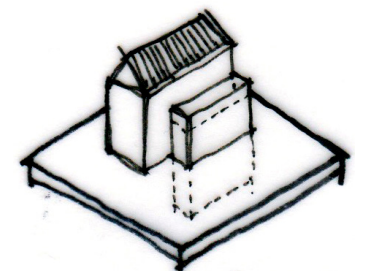
However, the semi-urban area has its own challenge with the new urban development.

#### Principle1: Keep the existing water as the main structure in the new development or buffering ponds between fields and the neighbourhood

Lessons could be learned from Wuzhen.



Water storage could also be applied with group of houses.



External water storage could be installed in the building or underground.

FIG. 14.20 Diagram of centres and sub-centres in Hangzhou city  
Source: edited by author based on Hangzhou planning (2001-2020)

15 Reflection

16 Conclusion

17 General principles

18 Set of recommendation for Hangzhou



# 15 – Reflection

## 15.1 – Research by design

The thesis included the process of research by design. In the first step, lessons and principles are concluded from learning from vernacular practices. Before the whole process of looking for practices, system approach is been used as the main tool to have a better understanding of the water system. However, when implementing the principles and lessons into the application, the method of using design as tool for exploring the possibility and suitability in the contemporary context.

While doing the research, two types of questions are most important. One is how question like how the system works or how to apply the principles. But sometimes the other question of why is more important. As in the process of learning from the vernacular practices, I firstly focus on how the system works and how it functions as a water management method. By comparing three different examples, it seems like they all have the same type of well-connected water system. But actually, when I looked at the reason behind why they did that, I found out they actually have different components according to their own local conditions and cultural background. This helps the author a lot while using the tool of design exploring the possibility.

As one of the most important lessons learned from vernacular water-management practices, it is the fact of the methods they used can not only work as water management, but also bring social, economic, and ecological values for the area. That the reason why respect of water has been shown in all some details. For instance, different types of activities have been arranged according to the 24 solar term which has been invited based on the change of climate and pattern of growth. For the example of mulberry fish pond complex, it is a complete model of decentralized and self-maintained small-scale ecological system which provides food and products for the farmers. In the example of Eastern Zhejiang Canal and Yu area, economic development is the results of successful water management system.

## 15.2 – Reflect on the objective

Main research question:

**What kind of vernacular water-management practices should be explored? What kind of principles and lessons can we learn from? Furthermore, is it possible to apply in the contemporary urban context?**

The results of this research have met the objective through developing the answers for the research questions:

1. What are the characters of two different watersheds? How do people live with water?

The two natural watersheds both have three sub watersheds. Each of them has their own characters and tasks. Examples of vernacular practices in this thesis are illustration based on this understanding.

2. What are the methods still function now or have a important impact on forming the landscape?

All examples have methods which area still function. However, the importance of these methods might be reduced due to the development of technique. For the question of forming the landscape, it is big change for the plain area while it is just low impact methods in the hilly areas.

3.What urgent problems are accumulated from natural disasters and inappropriate land use?

The conflict between two systems is shown as frequent urban flooding and extreme weather.

4.How can we transform the principles from the ancient method into urban design?

By understanding the reason why the specific method works in a specific location with a certain cultural and historic background. It's same for the urban context.

3. What is the limit of the project?

For now, the design exploration is still be tested in small scale. The possibility of applying in city scale or regional scale could be the next step.

## 15.3 – Limits of the project

Due to the short time frame and limited available data, this project has been focus on the understanding of the principles and lessons. And looking for historic data increased the difficulty of this project. However, this project could provide a deep reading of the vernacular water-management practices in Hangzhou which could be used as a solid foundation for future studies.

15.4 – **Next step**

The research aims to contribute to the discussion by rethinking the ancient method integrating with recent theories which have strong connections with one of the EMU topics ‘Constructing the Sustainable Delta City’. This topic addresses the necessity of urban and landscape architectonic design of a new balance between urbanized area and landscape, and will consider the development of landscape-structures in the city as well as of urban settlements in the landscape.

Moreover, this study is also aligned with the theme Delta Urbanism under the Urbanism Research Program, which focuses on developing new approaches to balance urbanization, development, agriculture, environmental and ecological qualities. This study could provide a different perspective of the example in a different landscape and historic context of Yangtze River Delta in China, and this study is expected to test the process of turning theories into practice by considering the local history and socio-cultural background.

For the city of Hangzhou, it is urgent to look for a way to improve the water sensitivity for the city or Yangtze river delta. In recent years, the trend of increased occurrence of flooding is threatening people’s daily life and property security.

In the design exploration of thesis, the author tried to solve the practice problem with the West Lake and the Grand Canal by using the lessons and principles learned from the vernacular practices.

For the next step, it is important to look at the city scale to show both the possibility of regeneration urbanized area and looking for a better way of new development. What is more important, a set of recommendation could be conclude for other cities in the delta region or in the process of urbanization.



## 16 – Conclusion

### 16.1 – Well-connected water system

All three examples of Taihu Lake irrigation and discharging system, the water town Wuzhen and Xiaoshao Plain have a well-connected water system. However, their compositions vary from each other due to their special locations in the whole watershed and different water problems.

For irrigation and discharging system in Taihu Lake plain, it consists of dense and grid water network together with ponds and fields as mediator under different water conditions to distribute the risk of flooding and drought.

For the water town Wuzhen, the water system used to be the main mobility system. It is composed of main canal and surrounded by two moats. Small canals work as connector between main canal and moats, while lakes and ponds as extra water collector in the grid of main canal and small canals.

For the Xiaoshao plain, it has an extra protection due to its location of the river mouth. The sea wall cut off salty water and Jianhu lake for fresh water storage. The initial lake was split into small pieces due to the pressure of population growth. However, the Eastern Zhejiang Canal has been kept since then.

In conclusion, both location natural condition and historic, cultural background are important in the process of water system for flood defence.

## 16.2 – Low impact intervention of dealing with water problem in small scale

Small scale practices like Yu field and fish pond in the plain area show the principles of low impact intervention dealing with different water levels, and provide high ecological service value. These principles could be applied in the process of building urban wetland both for ecological value and recreational value.

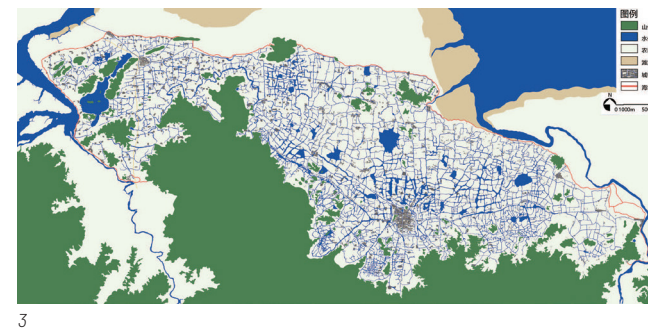
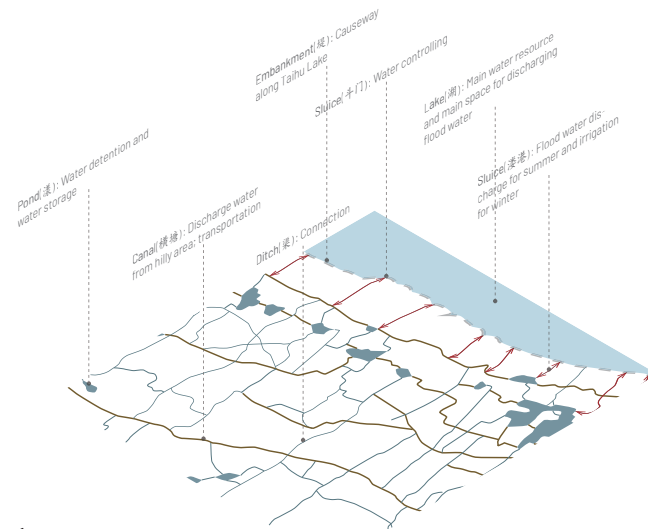


FIG. 16.1 1. Irrigation and discharging system of Taihu Lake Plain  
2. Water town Wuzhen  
3. Xiaoshao Plain  
Source: edited by author



FIG. 16.2 Old picture of transferring rice from Taihu Lake plain to Capital Beijing through the Grand Canal  
Source: cropped from video of Tengxun

Other example like the impressive detail in water town Wuzhen could be considered as principles for both new development and regeneration project to provide communities with better living space.

Last but not the least, two low impact intervention in the hilly area could work together for to improve water resources management and offer productive and ecological values with water which has different water levels or streams in the hilly area.

### 16.3 - Well-functioning water system could promote the development of economy and culture

Well-functioning water system could not only protect the safety of life and property, but also promote the development of economy and culture. The plain area of Taihu Lake is famous for its rice and silk production. Xiaoshao Plain took advantage of the connection from Ningbo port, and became one of the richest places in China. Thanks to the flourishing economy and stable society, there are lots of famous painters, poets and calligraphers from this region.

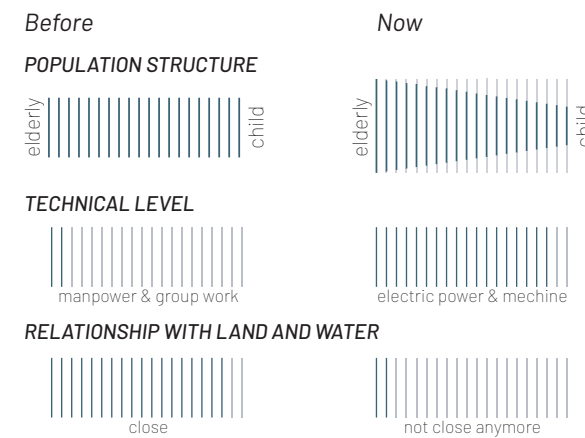


FIG. 16.3 Diagram of difference between  
Source: edited by author

## 16.4 – Social change effects on the relationship between human and water

High maintenance requirement is necessary for the dense water network. Water management used to be considered as a group work and it was crucial for the productivity of farm land.

With the changing of population structure and increasing of technical level, the relationship between human and nature are not as close as before. The importance of these system has been forgotten.

## 16.5 – Successful water management system could bring extra value for the built environment

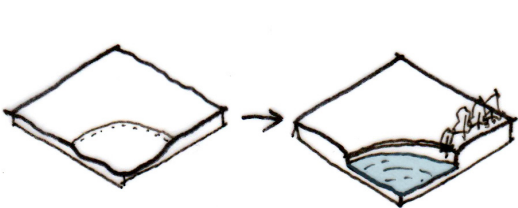
As one of the most important lessons learned from vernacular water-management practices, it is the fact of the methods they used can not only work as water management, but also

bring social, economic, and ecological values for the area. That the reason why respect of water has been shown in all some details. For instance, different types of activities have been arranged according to the 24 solar term which has been invited based on the change of climate and pattern of growth. For the example of mulberry fish pond complex, it is a complete model of decentralized and self-maintained small-scale ecological system which provides food and products for the farmers. In the example of Eastern Zhejiang Canal and Yu area, economic development is the results of successful water management system.

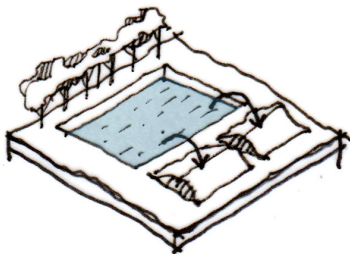


# 17 – General principles

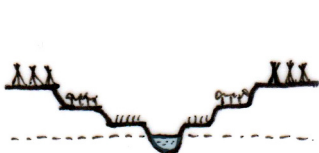
## Principles for the natural environment



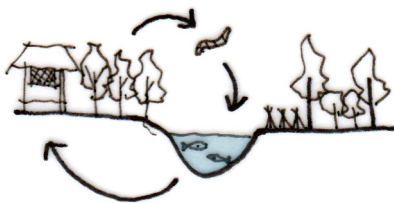
Lower land which easier to get flooded could be used as flood detention area and water storage area.



Soil extraction for other purpose, like dyke maintenance, fertilization.



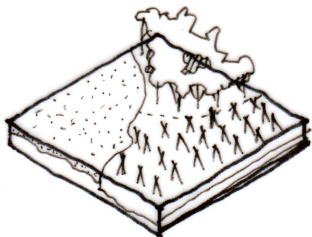
Changing ground level could be applied for different types of plantation which needs different water conditions.



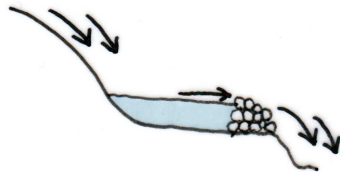
Reuse of ecological waste into other use like sedimentation recycle.



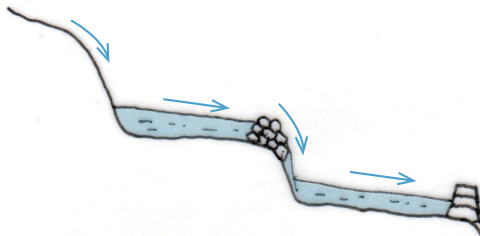
Changing ground level could be applied for different types of plantation which needs different water conditions.



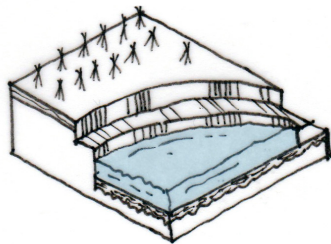
Make use of different soil types for plantation design.



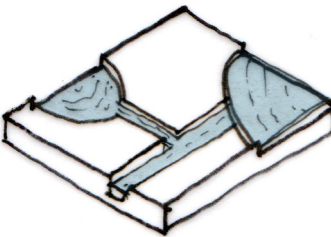
Weir could be used as devices of changing the speed of water and water storage infrastructure.



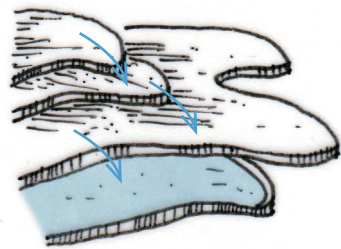
Weir could be built by simple materials like stones.



Make use of the soil type with less permeability for water storage or small ponds.



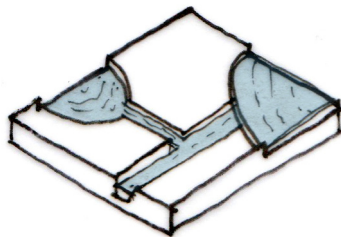
Ditches and canals play as main connection between different water resources.



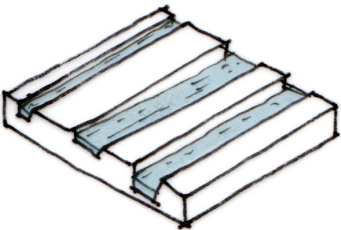
Make use of natural flows.



Different types of landscape in short distance could create edge effect to improve biodiversity.

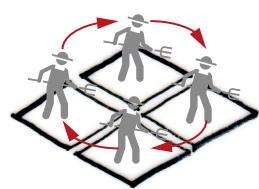


Space for water is an important element in flooding defence system in the plain area.

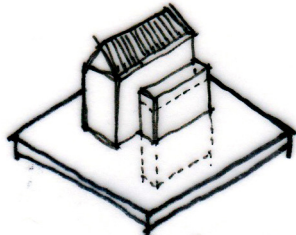


Widen or deepen ditches could improve sufficiency of flooding water discharge and capacity of transportation.

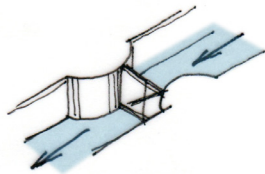
Principles for urban environment



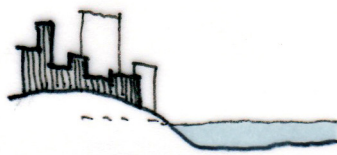
Water management as a collective work.



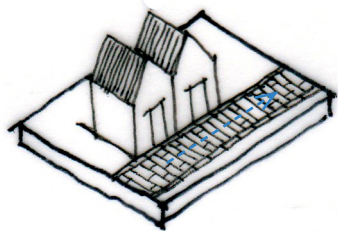
External water storage could be installed in the building or underground.



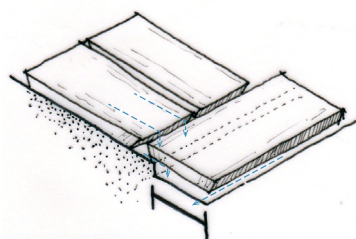
Sluice as the main elements of connecting rivers with different water levels and it's important for water transportation.



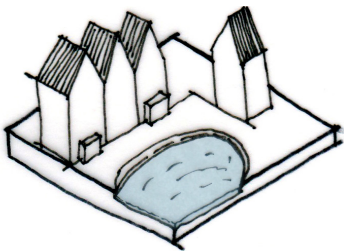
New development of urbanization should locate in higher place for safety reason.



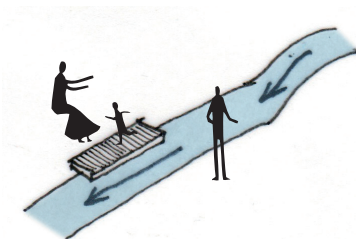
Street could be used as an external waterway for flood water discharge.



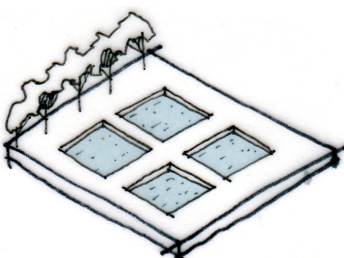
Space between pavement could increase permeable rate.



Water storage could also be applied with a group of house.



Water flows could be visible for public space and create close relationship with human.



Public space could be design for water detention and water storage and increase greenery.



# 18 – Set of recommendation for Hangzhou

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**For highly urbanized area:**

Principle 1: Use cascading water system for different water level between West Lake and the Grand Canal.

Principle 2: Uncover two existing water outlet points for West Lake and re-introduce waterway along the streets to create a well-connected water system in the city centre.

Principle 3: Increase permeability in old neighbourhood.

Principle 4: Create soft river bank and improve accessibility of canalized rivers.

Principle 5: Introduce and re-introduce waterways along the street.

Principle 6: Besides ecological values, social values could also be added in the process of applying principles learned from vernacular water-management practices.

**For agricultural-productive land in rural area:**

Principle 1: Apply Beitang (pond) system in productive land in the hilly area.

Principle 2: Wetland could be applied as an ecological buffer for productive land along river plain.

**For semi-urban area with new development project:**

Principle 1: Keep the existing water as a structuring element in the new development or buffering ponds between agricultural fields and the neighbourhood.

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