

## **WATER SYSTEM AND URBAN FORM OF GUANGZHOU IN TIMES OF CLIMATE CHANGE**

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### **ABSTRACT**

The Pearl River Delta is the most economically dynamic and densely populated region of China since 1980s. Guangzhou is the central metropolis and historical riverfront city of the Pearl River Delta. Being a typical subtropical city, Guangzhou is facing increasing climate-related crises, such as flooding due to sea level rise, extreme storms and precipitation. It is urgent to search for a compact, integrated, sustainable and highly-efficient mode of development in the process of rapid urbanization. Vulnerable environment and ecosystem requires new perspective and strategy for future planning and urban design. The relationship between water system and urban form is one of the key components to solve the conflict. This paper takes Guangzhou as the study case, uses the layer approach and typological way to analyze the relationship between urban form and the river landscape with special focus on human interventions.

This paper first gives a brief introduction of the context of Guangzhou, especially focusing on its superior conditions as a port city. Second, it investigates the relationship of water system (Pearl River, canal system, lakes and wetlands), infrastructure (flood-defense, drainage system and transportation) and urban form (land use, urban fabric, street pattern, waterfront space and buildings). The analysis aims at defining on which aspect the city could develop in a sustainable way to cope with the conflicts between different layers as an integrated unit. Then the paper gives an overview of current water-related problems and initiatives of urban planning. Finally, this paper analyzes the transformation trend and common rule for subtropical cities with similar features.

By analyzing the specific transformation features and rules of the waterfront urban form of Guangzhou, this paper aims at providing some solutions and strategies of smart growth and sustainable development for Guangzhou and the whole Pearl River Delta. Furthermore, the conclusion could be the starting point of searching for a resilient, adaptive and sustainable way to solve the common contradiction of water and city in global subtropical delta regions.

**Keywords:** Guangzhou, Water System, Urban Form, Infrastructure, Climate Change, Subtropical Delta Region

### **DISCUSSION**

Currently, there has been a growing concern about how to develop a sustainable urban form which could strike the balance of density, size, configuration, energy and quality in subtropical cities, especially when vulnerable environment and climate change pose increasing problems on urban development. However, most research has focused on urban form itself and the transformation rule. From a historical perspective, the water system has been playing a multifunctional role on urban form transformation, such as water supply, navigation, tourism, ecosystem as well as cultural and

economic carrier. However, water related problems including flooding, water pollution, land subsidence and declining waterfront are the threat and also could be new opportunity for urban regeneration. An interdisciplinary method with the combination of hydraulic engineering and sustainable urban growth could be the breakthrough of inventing a new perspective on future urban planning.

This paper uses a “Layer Approach”<sup>1</sup>(Fig. 1), which includes three major layers: Landscape Layer, Infrastructure Layer and Urban Occupation Layer, with special focus on the relationship and interactions among different layers. Layer approach can help actors to broaden the scope for finding solutions, a broadening in space, subjects and time. The Water system, the most dynamic element in the landscape layer, is emphasized as one of the most flexible and influential factors functioning in the transformation process of urban form.

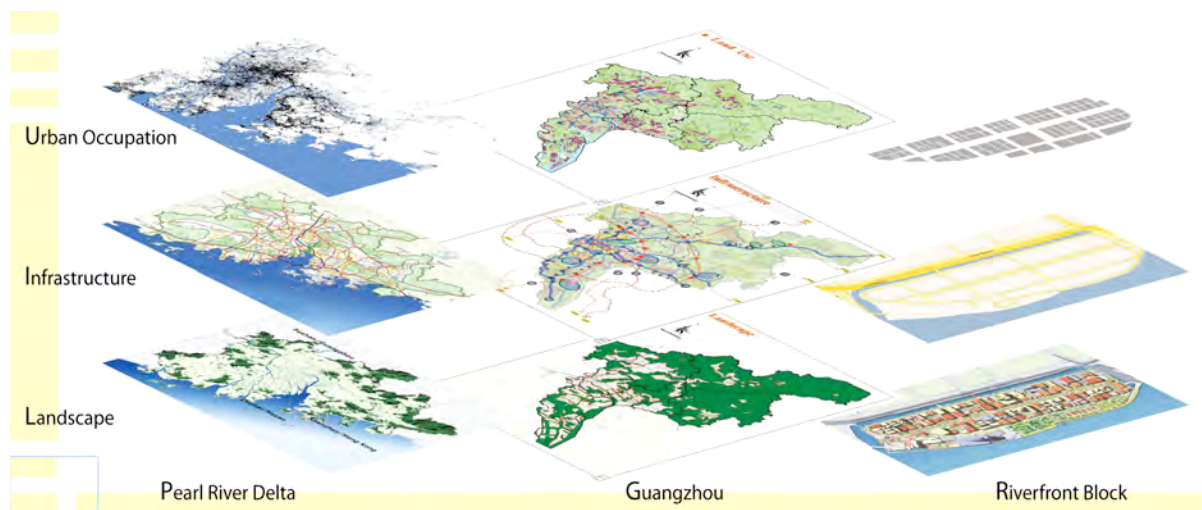


Figure 1: Layer Analysis of Guangzhou, Pearl River Delta

### Relationship of Water and City - Site Selection and Traditional Ecological Pattern

Guangzhou is the political, economic and cultural center of the Pearl River Delta. It is also the transportation hub and an important historical port city in southern China. The stable and prosperous development can be traced back to the initial landscape and city site selection more than two thousand years ago.

In ancient China, an important theory of site selection for cities was propounded by Master Guan (700BC). His main idea is “To select a site for a capital, either at the foot of great mountains or on the broad plains; neither too high to get water supply, nor too low to avoid extra drainage works.” Based on this planning culture, Guangzhou is located near the intersection of three major rivers (East, West and North Rivers) of the Pearl River Basin (Figure. 2). The geographical pattern of Guangzhou is featured by vast hinterland both towards the inland and the sea. The Historical city center was built up on the flood plain between Baiyun Mountain in the north and the sea (current Pearl River) in the south for good water and geological conditions, shaping an ecological spatial form of “Mountain-City-River” (Fig. 3).



Figure 2: Pearl River Basin

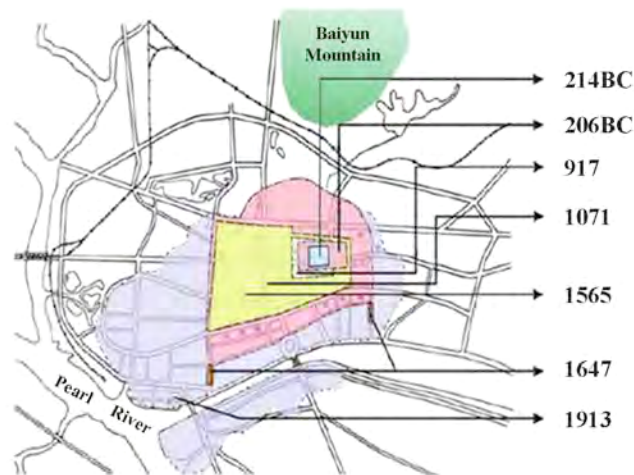


Figure 3: Urban Growth and Traditional Spatial Pattern  
Source: Adapted from a Historical Map

### Change of Spatial Pattern

Together with the expansion of the urban area, many problems seriously restricted the potential of urban development regarding the aspects of environment, transportation and land capacity. The strategy of developing new urban areas somehow increased the dependence on the city center because of the fragmental functions. The action raised the economic land value and intensified the strength of real estate development in the historical city center instead of releasing the traffic pressure. The urban renewal projects have changed the traditional urban fabric and cultural identity, which lowered the integrated value of historical city.

In 2000, Guangzhou expanded the municipal boundary by including Panyu district in the south and Huadu district in the north as parts of the city. The adjustment removed the restriction of the development towards southeast and north, and Guangzhou has become a coastal city. This action greatly changed the spatial pattern of Guangzhou from "Mountain-City-River" to "Mountain-City-River-Agriculture-Sea" (Fig. 4)<sup>2</sup>. However, opportunities and threats coexist by intervening in the elements of different layers.

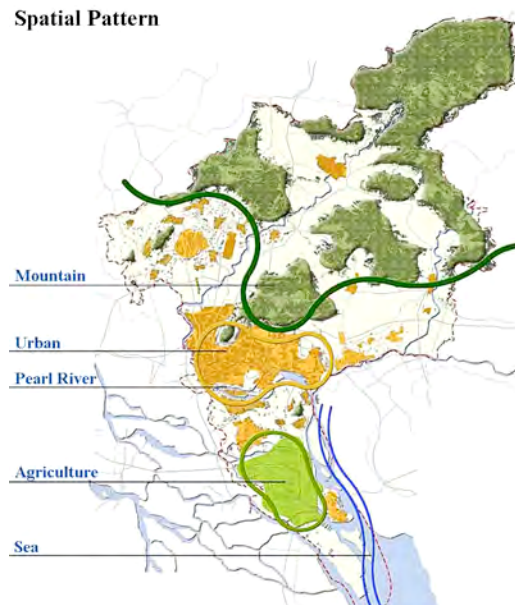


Figure 4: New Spatial Pattern of Guangzhou

Source: Guangzhou Urban Planning Bureau, Guangzhou Strategic Planning of Urban Development, 2000

### Water Typology and Layer Analysis

The Water system, which is considered as the most dynamic element in the landscape layer, is playing an increased important role in structuring urban form and influencing infrastructure. Developing from a coastal city to a riverfront city and now back towards the sea again, the relationship between city and water is changing because of both natural processes and human intervention. The Water elements in the water system which are mainly discussed in this paper are three major types: the Pearl River, canal network, lakes and wetlands.

### The Pearl River

The Pearl River (Guangzhou part) has experienced great transformation throughout history, which was extremely obvious in the period of Ming and Qing Dynasties (more than 1000 years ago). The transformation rule shows that the north part of the Pearl River continued moving towards south while the south part stayed relatively stable, the width of the Pearl River has narrowed gradually (Figure. 5). Some research and statistics show that the width of the Pearl River was 1500m in 400s, 1400m in 900s, 900m in 1209, 700m in 1369 and 500m in 1850, and recently the narrowest width of the Pearl River is only 180m near Haizhu Bridge.<sup>3</sup> The natural process of sedimentation along the north bank and the land reclamation activities both promote the rate of urban space developing towards the south across the Pearl River.

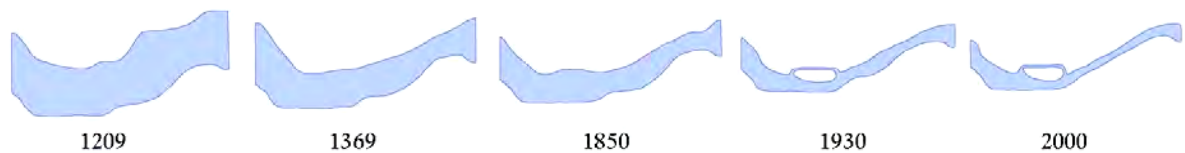


Figure 5: Transformation of the Pearl River

### Canal Network - Historical Development of the Canal Network

Master Guan put forward a theory of the construction of urban canal network: "In a sage's work on his capital planning, city is built on the flat and steady land, fertile and rich, backed up by mountains and served by rivers and lakes. Well-formed drainage system is set up inside the city, ensuring a smooth drainage into rivers."; "to ditch on the high lands and to dike on the lows". Crowned as "the blood circulation of city", the urban canal network in Guangzhou had a standardized form based upon a loop of moat around the city outside the city wall and a network of canals running inside, and it functioned in many ways (Fig. 6).

Guangzhou has established the canal network since 1200s for the functions of navigation, drainage and water supply. The canal network was constructed according to the landscape feature. Rain and waste water was drained through many ditches to the six major canals, and then it was diverted to the east and west moats and finally discharged into the Pearl River. The whole water system could largely enable the city to avoid the flooding problem with smooth connection as the blood circulation, so that the government initiated several dredging activities to maintain the network. However, the situation became worse when several canals were covered up for urban construction in recent decades.

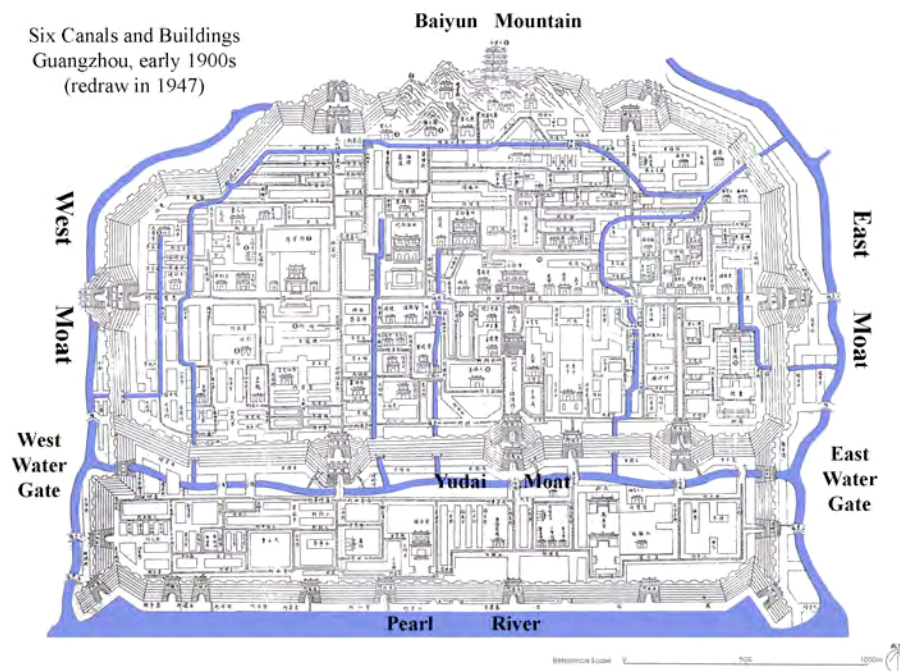


Figure 6: Canal Network of Guangzhou in 1900  
Source: adapted from historical map

### Functions of Canal Network

The significance of the canal network can be concluded in several aspects concerning economic, social, environmental and cultural value.<sup>4</sup>

#### 1) Water Supply, Irrigation and Aquaculture

In ancient times, the sources of water supply came from wells and urban canals. Wells ensured the supply of drinking water while canals provided water for domestic, agricultural and manufacturing use. This explains why many historical cities settled along a big river.

## **2) Navigation**

As a historical port city, canals and moats in Guangzhou were open to boats for navigation. The convenience of transportation stimulated the commercial development and foreign trade. Several commercial streets accumulated along the river and canals. However, after cars prevailed in Guangzhou as well as the accumulation of sedimentation, the function of navigation has sharply declined since 1920s.

## **3) Military Defense**

In combination with the city wall, city moats outside the city wall in the urban canal network were set up for the sake of military defense. Functioning as an important military defense fortified construction, a moat with certain depth and width can resist enemy's attack efficiently.

## **4) Drainage System and Flood Mitigation**

The subtropical climate feature of Guangzhou is mainly reflected as intensive precipitation during summer seasons. Besides, Guangzhou is located at the flood plain only several meters above sea level. There are many sources of flooding: mountain floods from the north; water from the three branches of the Pearl River Basin; high tides of the Pearl River in the south; as well as extreme storms, typhoon and high precipitation. Therefore, a good canal network is able to drain the rain water and domestic waste water to the Pearl River. During high tide period, canals can also function as water storage for flood mitigation.

## **5) Recreation and Microclimate Adjustment**

In hot and humid summers, the presence of water brings down the temperature of waterfronts to a certain extent. Thus, the microclimate of urban area is tempered and modified. Waterfront landscape is also an attractive name card which embodies the cultural identity of the historical city.

### **Artificial Lakes and Wetlands - Construction of Artificial Lakes**

Since 1958, four major artificial lakes (Lihua Lake, Dongshan Lake, Liwan Lake and Lu Lake, (Fig. 7) <sup>5</sup> were constructed on low-lying land for water storage and flood mitigation. Combined with some water infrastructure as sluices and connected to the canal system, these four lakes have mitigated the flooding risk of Guangzhou efficiently. According to the weather forecast, the monitoring center can open the sluices through a computer control system during the low tide period of the Pearl River to lower the water level of the lakes. On the contrary, when there are storms and the water level of the Pearl River rises, the monitoring center will close the sluices between the Pearl River and the canal system, and open the sluices between the lakes and canal system to store extra water. This method not only accelerates the process of water drainage but also prevents the back flows of the Pearl River. Besides, the artificial lakes contribute a lot to the ecosystem and provide recreational parks for residents and tourists.

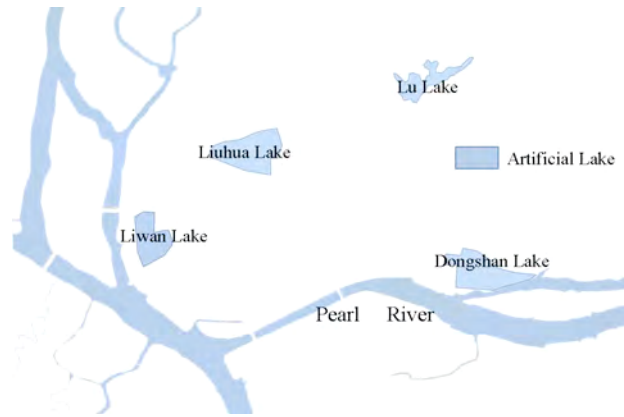


Figure 7: Artificial Lakes Since 1958

### Wetland Ecosystem

The Wetland ecosystem has several ecological values as water storage, climate adjustment, water purification and biodiversity conservation, etc. The extraordinary growth rate of urbanization and industrialization is at the expense of the loss of massive areas of wetlands. The area to the northwest part of Liwan Lake used to be a farmland and a wetland a century ago. There were densely distributed canals connecting to the large wetland system on the low-lying flood plain. Residents built dikes around the wetlands to plant litchi trees on the dike and to develop fish farming. Unfortunately, this kind of self-recycling ecosystem has been replaced by urban land use at an alarming rate.

### Layer Relationship and Interaction - Infrastructure and Urban Form

Regarding the dynamic interactions between different layers, the effective approach to solve the conflicts is to seek an integrated, compact and sustainable combination of landscape (especially water system), infrastructure and urban form. The infrastructure layer (both the water infrastructure and the transportation system), however, is now mainly functioning in reorganizing the water system and reintegrating the urban form as a whole (Fig. 8).

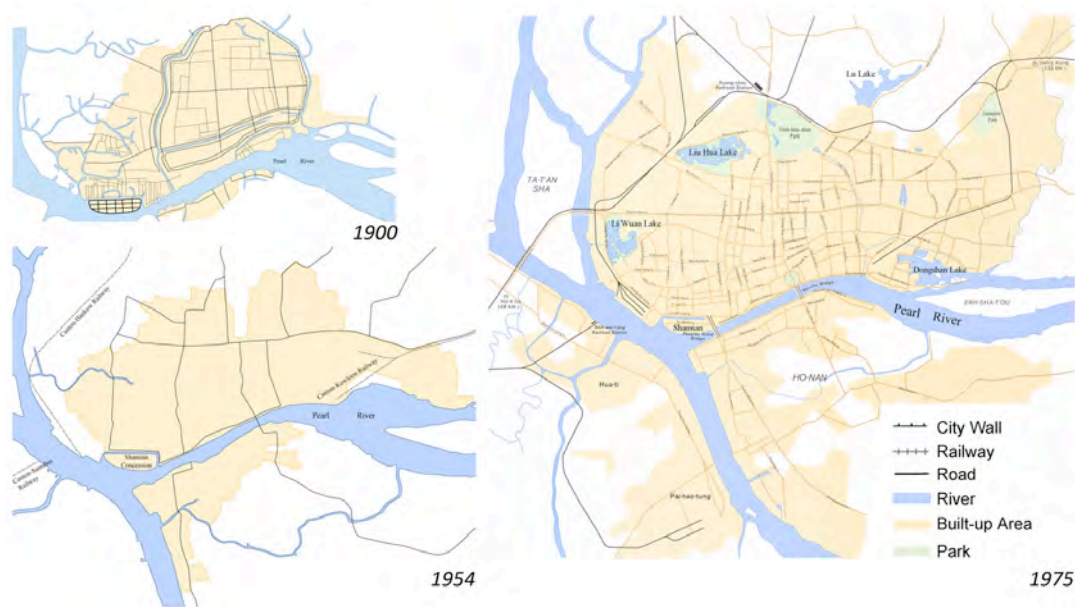


Figure 8: Change of Relationship between Layers

On the one hand, water infrastructure promotes economic development and enhances riverfront beautification, such as the Long Dike and West Dike along the north bank of the Pearl River. The original road construction was kind of a by-product of the wharfs and dikes. In 1886, the local government built the Tianzi Wharf, following a road with the length of 1500m was first constructed near the wharf. Continuously, a new dike road was built from the west moat gate to the east moat gate at the beginning of the 20th century, with the length of 800m and the width of 16m. It was not until 1911 that this dike road was extended to Shamian Concession with a total length of 960m.<sup>6</sup> The construction activities spurred the economic bloom by attracting various investments. Correspondingly, a great number of new architectures emerged as landmarks with a combination of Chinese and Western styles along the Pearl River.

On the other hand, however, rapid urbanization and new patterns of transportation have changed the traditional urban fabric since the 1920s. Newly-built roads and bridges across the Pearl River, railways and subways substantially replaced the navigation function of the river. Moreover, industrial land use has been moved outside the old city center gradually. Many wharfs were abandoned and the original prosperous riverfront has encountered depression. There is a growing concern about the passive impact of the infrastructure in recent years. The most representative example is the elevated road above the original canal, which greatly breaks the continuous space order. A collage city is taking shape with interventions in different stages of development (Fig. 9).

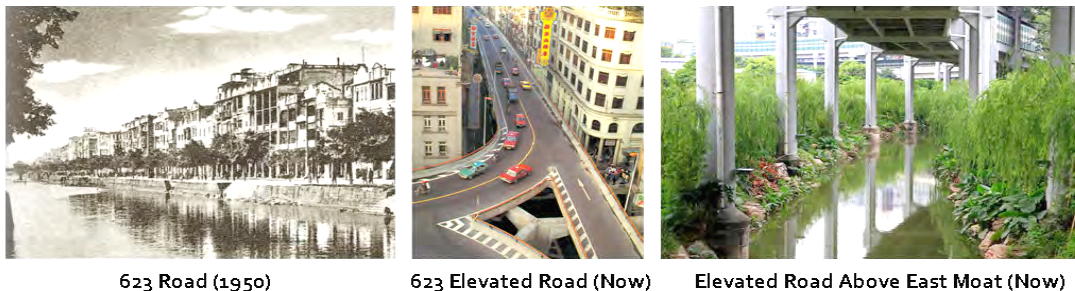


Figure 9: Change of Canal Landscape

### Urban Transformation and Port Dynamics

Guangzhou is a prosperously developed port city in China with the vitality over 2000 years. The special urban pattern with the integration of commercial and port city reflects the importance of water system in economic development and urban growth. Ming and Qing Dynasties are the most prosperous periods for commercial and trading development as well as urban construction. In 1757, the national government closed Min, Zhe and Su Customs, leaving Yue Customs in Guangzhou the only one for foreign trade in China. The speed of land reclamation towards the Pearl River was relatively high. Several wharfs and ports were built along the river, following the dike and road construction. The most famous example is the Shisan Hang foreign trade district along the Pearl River near Shamian Concession. It was not until the Opium War that the leading status of Guangzhou port was replaced by Shanghai while the position as the center of foreign trade was replaced by Hong Kong.

From the historical perspective, the direction of urban expansion of Guangzhou has a corresponding relationship with the location of ports (Fig. 10).<sup>7</sup> The main development direction is from northwest to southeast towards the estuary of the South China Sea. Thus, the development axis of Guangzhou is also moving towards east. This kind of port-oriented development mode could indicate and guide the direction of future planning.

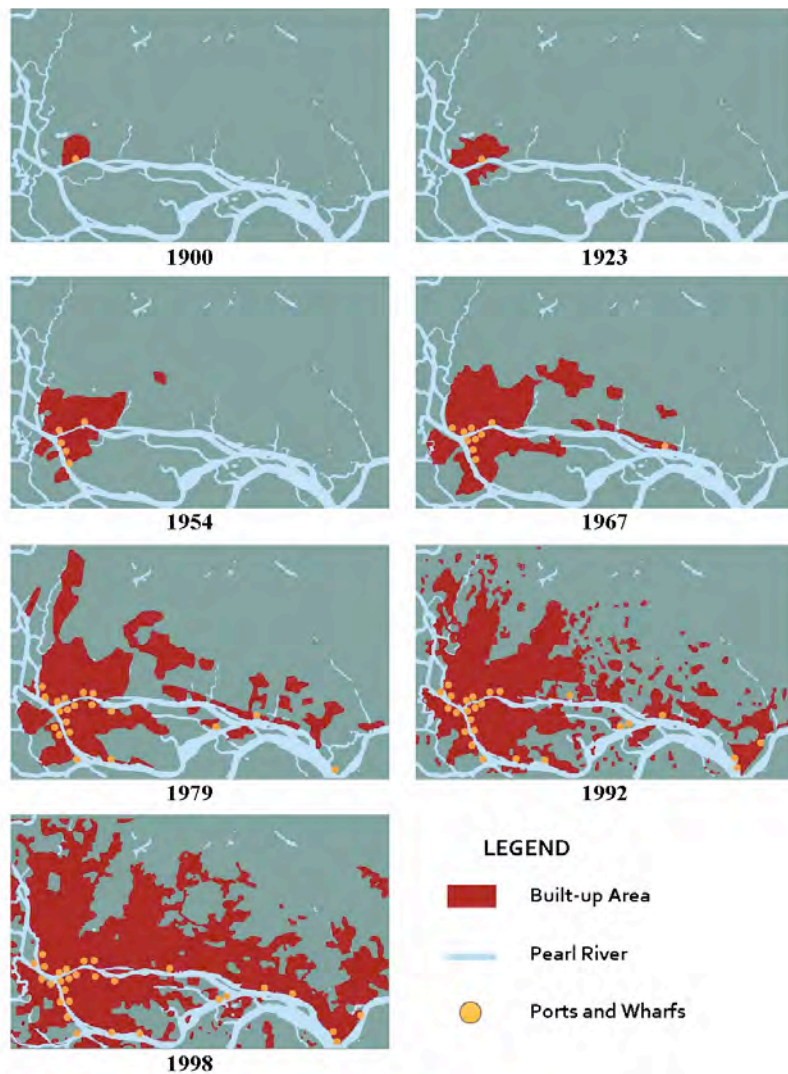


Figure 10: Transformation of Port and City

### Subtropical Feature of Waterfront Urban Fabric

The recession of the Pearl River changed the relationship between water and city to a larger extent. Both the spatial form and the street patterns have close connection with the Pearl River and the canal network. Because of the prosperous navigation of the Pearl River, the development of the riverfront area maintains a corresponding direction with the Pearl River. Therefore, roads in the east-west direction have a higher density and more convenient connections. In contrast, in the north-south direction, roads are relatively less, many of which are perpendicular to the Pearl River. For one thing, this kind of arrangement can enhance the convenience of the Pearl River navigation; for another, it can adjust the microclimate by introducing the river wind to the city in the hot summer season (Fig. 11).

For the area in Xiguan Plain,<sup>8</sup> the natural water network somehow determines the direction of road network. Xiguan area used to have plenty of farmlands and wetlands before Qing Dynasty with a dense canal network. The formation of the streets and lanes is more or less related to the rivers and

dikes. So the streets and lanes are developed parallel to the river, showing the feature of curve and various directions, resulting in the anomalous fragmented neighbourhood.



Figure 11: Urban Fabric along the Pearl River

### Contradictions of Water System and Urban Growth - Climate Change and Flooding

In recent years, climate change has posed increasing problems on urban development and spatial pattern. Especially in subtropical delta cities as Guangzhou, the climate sensitivity has triggered a series of issues. The direct consequence of climate change is the sea level rise. According to the Inter-governmental Panel of Climate Change (IPCC), the global mean sea level rise is projected as 49cm and the predicted range is between 20cm and 86cm.<sup>9</sup> Regional responses could in fact differ substantially, owing to regional differences in heating and circulation changes. Tides, waves and storm surges could also be affected by regional climate changes. The magnitude of the mean sea-level rise in the Pearl River Delta between 1990 and 2030 was predicted as 30cm with an annual rising rate of 5cm.<sup>10</sup> Occupying vast land below sea level, Guangzhou and the whole Pearl River Delta are greatly threatened by the estimated consequences of climate change (Fig. 12).

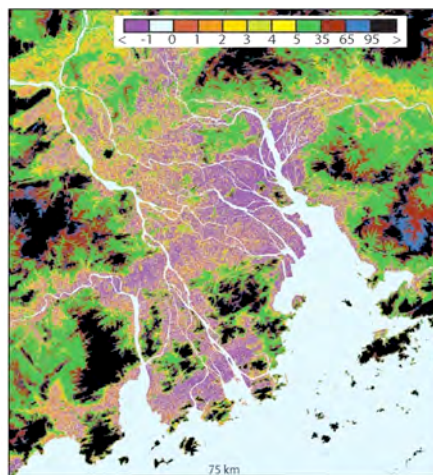


Figure 12: Elevation of the Pearl River Delta (Purple Area below Sea Level)  
Source: NASA's Space Shuttle Endeavour during the Shuttle Radar Topography Mission in 2000

Another impact of climate change of Guangzhou is the increasing ratio of extreme climate events. Guangzhou has a distinction of wet season in summer and dry season in winter. The recent extreme climate event occurred on 7 May, 2010. Three successive days of intensive precipitation caused serious inundation problems and enormous economic loss. The statistics show that the rainfall during three days reached a quarter of the annual precipitation amount of Guangzhou. Both the inefficient drainage system and the threat of climate change are the major causes for flooding.

### **Inefficient Urban Drainage System**

As one of the most important water infrastructures, the inefficient urban drainage system is the root of the flooding problem. The principal reason is that the current drainage system can no longer adapt to landscape change and urban development, and the conflict is becoming more obvious for many reasons.

#### **1) Land Use Change**

Usually, rainfall is collected by canals and lakes and then discharged into larger rivers or seas, while it is partially absorbed by soil and flows into the rivers through underground runoff. In the past, soil and reservoirs could store large amounts of water. However, along with the rapid urbanization, most of the wetlands, green space and natural ponds disappeared. The current situation is, about 90% of the rainfall relies on the drainage system.

#### **2) Low Standard of Design**

The current drainage system of Guangzhou remains unchanged over 20 years. Among 6000km of the drainage pipes in the city center, 83% of which have the standard of one-year return period for flooding, and only 9% can reach the requirement of two-year return period, and the rest has only half-year return period.

#### **3) Mix of Rain and Sewage Water**

Only 15% of current drainage pipes in Guangzhou are able to separate rain water from sewage water. Apart from those in the city center, many ditches are seriously polluted and blocked without smooth connection with the canal network.

#### **4) Elevation of Drainage Pipes**

Most of the land elevation along the Pearl River is between 6.5~9.0m above sea level, and the elevation of current drainage pipes is between 4.2~6.5m, while the tide level of the Pearl River is among 4.3~7.0m. Considering the trend of sea level rise, current drainage pipes are below the high tide level of the Pearl River, thus the river water could possibly flow back to the drainage pipes during high tide period.

### **Water Pollution**

The problem of water pollution means that both surface water body and underground runoff, are quite a common feature in most developing countries along with the process of rapid urbanization and industrialization. Contaminated water in Guangzhou is mainly discharged into the Pearl River, threatening human health, ecosystem, biodiversity as well as the image of the city. The dredging activities are accompanied by the demolition of illegal buildings along canals, which aims at guaranteeing the functions of flood mitigation, navigation, recreation, irrigation and drainage.

### **Land Subsidence**

Underground water exploitation is the major reason for land subsidence, and the construction of high-rises in Guangzhou has accelerated the rate of land subsidence. Moreover, the construction of metro lines and high speed railway increases the risk. The growing rate of land subsidence and the trend of sea levels rising double threaten the low-lying land. The increasing distance between water levels and the land elevation creates the possibility of sea water intrusion in coastal areas and aggravates the risk of flooding.

### **Focus of Current Urban Planning - Water System Reorganization**

In 2005, the "Canal System Planning in the City Center of Guangzhou"<sup>11</sup> defined the overall guidance of building reservoirs in the north and sluices in the south of Guangzhou. Two more artificial lakes (Baiyun Lake and Haizhu Lake) are under construction with the integration of ecological parks, functioning as water storage, flood mitigation and recreation.

Guangzhou has 231 canals in the city center with the total length of over 913km, while 121 of which are included in the restoration project. Guangzhou has spent around 7 billion US dollars in recent two years to improve water conditions with the goal of no sludge and stench. The water quality in 121 canals and streams with a total length of 388 km has been greatly improved. A total of 30 sewage treatment plants were constructed to increase the city's sewage treatment capacity by 2.25 million tons a day.

### **Infrastructure Improvement**

Guangzhou is suffering from the flooding problems caused by the upstream water from North and West River. At the same time the city is bearing the risk of flooding from the Pearl River (Guangzhou part) in the south, the Xiliu River and mountain are flooding in the north. The Current flood defense project is based on the standard of a 200-year return period along the Pearl River and a 50~100-year return period along the Xiliu River. The flood defense system is combined with water reservoirs, forming an integrated water infrastructure.

The water management in Guangzhou is a series of projects including pollution source control, canal dredging, sewage treatment and water diversion. Since 2009, the water management institute has invested over 135 million US dollars on reconstructing drainage pipes. There are 228 low-lying areas in the city center with serious flooding problems. The major task is to dredge and enlarge drainage pipes and establish pump stations. This way of water management is especially brought up according to the specific conditions of Guangzhou and the Pearl River Delta. Many water infrastructures as sluices are used to adjust the water level in the canals and lakes due to high and low tides of the Pearl River. Water purification is involved during the whole process to improve the water quality and environment.

### **Waterfront Revitalization and Integration**

The aim of water management is not only for the water treatment itself, but also for integrating the surrounding environment and ecosystem, at the same time linking urban fabric with historical and cultural value. Therefore, urban planning should attach equal importance to safety and city beautification, for the benefit of environmental, social and economic development.

There are plenty of cultural heritages along the Pearl River, such as Xiguan Mansion, arcade streets, contemporary architecture conservation district in Shamian Concession and the Western style of architectures along the dike road. All of these nodes stand for the historical image and cultural

identity of the city. They represent the prosperous history of Guangzhou as a port and commercial city, and they also identify the close relationship between water and city.

Instead of navigation, the Pearl River is mainly functioning as a name card for tourism with many landmarks on both sides. Recent planning is focusing on riverfront revitalization with the idea of adopting an integrated developing mode. The new axis of Guangzhou with several projects and mixed land use is an integration of the functions of modern CBD, high-quality residential districts, riverfront recreation, tourism, sustainable ecosystem and convenient transportation.<sup>12</sup>

## CONCLUSION

A Subtropical city has a more vulnerable and sensitive ecosystem especially when climate change and rapid urbanization have both intensified the conflicts in recent years. In order to deal with the dynamic changes of water system and urban form, two types of solutions are proposed, namely mitigation and adaptation. While mitigation tackles the causes of climate change, adaptation copes with the effects of the phenomenon. This paper puts more effort on adaptive possibilities which aims at reducing vulnerability by building and strengthening existing coping strategies. Therefore, the research and planning should be based on local landscape conditions, taking historical and cultural values into consideration, thus to provide guidance for infrastructure and urban design with the key points of ecological resilience and climate adaptation.

The typical spatial pattern of Guangzhou and subtropical climate feature the influence of urban form at different levels, including land use, street pattern, open space and architectural style. The close relationship between water and city identifies the urban pattern and development mode as port-oriented and water-structured urban fabric. The ecosystem of Guangzhou should be considered as an open system, so that the organization of ecological elements should be merged into a larger spatial context. Urban planning should attach equal importance to safety and city beautification, for the benefit of environmental, social and economic development. Future planning should also consider the coordination of water system, infrastructure and urban patterns in the Pearl River Delta Region for better allocation of energy and resources.

Adopting a “layer approach” model, urban planning should fully respect the landscape conditions (water network, land subsidence, ecosystems and biodiversity) as the basic layer. Urban form could be reorganized and optimized by integrating more sustainable, flexible and efficient water landscape and infrastructure. Meanwhile, the importance of the infrastructure layer (flood defense and transportation) as a medium should be reinforced to adjust the relationship between landscape layer and urban occupation layer. Layer analysis can help planners to build an interdisciplinary perspective on the strategies of sustainable development. The relationship and interaction among different layers is the most significant and dynamic issue which could be the breakthrough for most problems of urban development.

## ACKNOWLEDGEMENTS

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## ENDNOTES

1. Layer Approach was first applied by McHarg (1976), adopted and developed in the 1980s in the Netherlands on spatial planning, often mentioned in planning and design documents, but never elaborated in a systematic way.
2. Guangzhou Urban Planning and Design Survey Research Institute, From "Mountain-City-River" to "Mountain-City-River-Agriculture-Sea"—Ecological Oriented Planning of Guangzhou.
3. Junjing Li, "Transformation of the Pearl River (Guangzhou Part)," *History of South China*, no. 3 (1990):58.
4. Qingzhou Wu, *Research on Flood Defense of Chinese Ancient Cities* (Beijing: China Architecture & Building Press, 1995).
5. Capacity of water storage in four artificial lakes: Liuhua Lake: 1.15 million m<sup>3</sup>; Liwan Lake: 0.51 million m<sup>3</sup>; Dongshan Lake: 2.5 million m<sup>3</sup>; Lu Lake: 1.12 million m<sup>3</sup>.
6. Xia Zhou, *Transformation of Guangzhou Urban Form* (Beijing: China Architecture & Building Press, 2005).
7. Jianqiang Yang and Chao Luo, "Reservation and Redevelopment of Warf Area in the Rear Channel of the Pearl River" (presentation, annual convention of the Conference on Chinese Urban Planning, Dalian, China, September 19-21 2008).
8. Xiguan refers to the low-lying flood plain in Liwan District of Guangzhou, which used to be outside the west city gate in Ming and Qing Dynasties. The area has a dense canal network, and flooding has always been a serious problem in history.
9. Climate Change 2001 - IPCC Third Assessment Report.
10. Chinese Academy of Science, *The Influence and Strategy of Sea Level Rise on Coastal Economy of Guangdong Province*, 2002.
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