

Enlightenment From Ancient Wisdom And Experience Of Urban Canal System Against Urban Waterlogging

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Abstract: This paper researches on the causes of the urban waterlogging after rainstorm, and studying on wisdom and experiences of urban canal system against urban waterlogging in ancient China. It is shown that urban canal system was of organic and multi-functions, being titled as “the blood circulation of city” and that rivers were as the trunk drainage canals, with great density and section for flood passing, tremendous storage capacity, and perfect management. The Forbidden City and Ganzhou are two examples. Enlightenment from ancient wisdom and experiences will help us to solve urban waterlogging problems.

Keywords: Rainstorm; Waterlogging; Urban canal system; Density; Section; Management; Storage capacity

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1 Introduction

Cities emerged in China about six thousand years ago. There were many magnificent cities in ancient China, such as, Changan and Louyang in Han and Tang Dynasties, Beijing in Ming and Qing Dynasties, and so on. Urban canal system in ancient China is valuable heritage of urban culture.

Crowned as “the blood circulation of city”, urban canal system in ancient China had a standardized

form based upon a loop of moat around the city and a network of canals running inside,(Figure 1.) and it functioned in many ways. Such as Supply of Water, Water Borne Transportation, Irrigation and Aquaculture, Military defense, Drainage system for floods and domestic waste, Flood storage and mitigation, Fire fighting, Shelter from storms, Landscaping and recreations, Environment Tempering, and so on. Urban canal system was compared to the blood circulation system of man, because of the significant functions that it carried out^[1].

As urbanization developing, urban canal system of ancient China gradually disappeared. In recent 20 years, many cities in China suffered from waterlogging after rainstorm.

For example, from July 21 to 22, 2012, a torrential rain fell in Beijing, which killed 77 people, affected more than 1.6 million people and caused huge economic losses. The lives of ordinary people have been seriously affected. The urban drainage has once again become one of the focal points of social concern.

According to the statistics of the Department of state Housing and Urban and Rural Construction from 351 cities between 2008 to 2010 about waterlogging, there are 213 cities suffering inundation, which being of 62% of the total number^[2].

This paper is going to discuss how we are able to be enlightened from the wisdom and experience of urban canal system in ancient China against urban waterlogging.

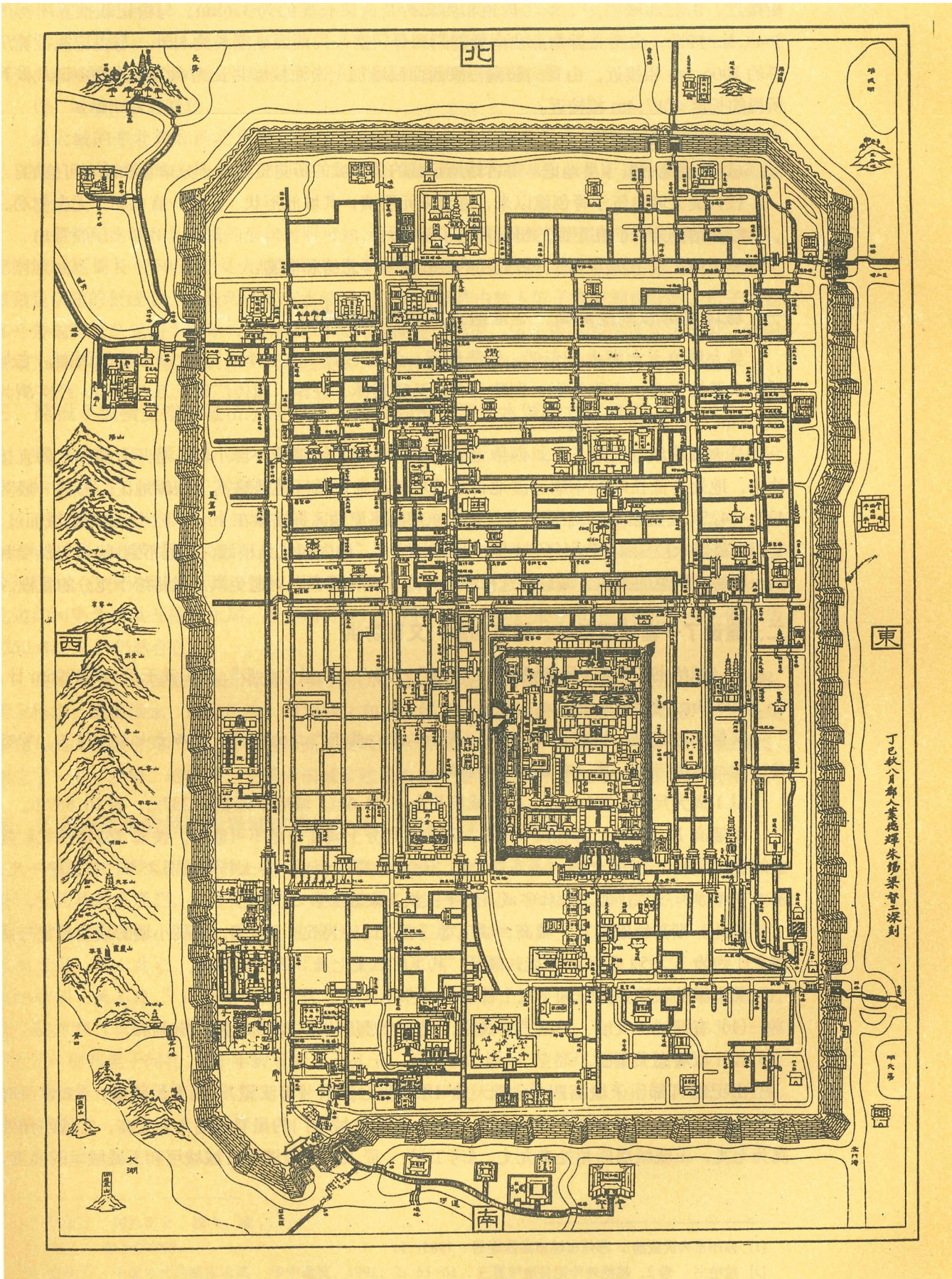


Figure 1. Plan of Suzhou(from stele engraved with map of Pingjiang Prefecture)

2 The factors contributed to the increase of urban waterlogging

2.1 Urban construction making rivers, canals narrowed, and flood level rising and the risk of waterlogging going up

Guangzhou is one of the examples of urban construction encroaching on flood rivers and waterways in the Pearl River Delta.

With the development of urban construction, more and more buildings occupied the rivers in Guangzhou. The Dashatou port built in the 1960s stretched 100 m into river more than it was before 1949. The people's Bridge was built in 1967, it making the river surface near Shamian narrowed by 60m.

In the early 1980s, the White Swan Hotel was built and filled with a section of the north bank of White Goose Pool (south bank of Shamian), which affected the inner port of White Goose Pool^[3]. As a result, the nine rivers near Guangzhou have been narrowed, among which the width of the Sanzhi Xiang waterway was 446m in the 1950s, 284m in the 1970s, 162m in the 1970s, and the narrowing rate being 36%^[4]. The ground elevation of the Long Embankment in Haizhu Square Section of Guangzhou is only 1.8m. After 1960, the flood water level reached 2m many times, so it was often inundated. When the flood water level was 2.24m in June 1959, the flooded area of Liwan was 0.3km², 472 streets and alleys were inundated, and the water depth being 0.6m. If the flood water level rises to 2.50m, 872 streets, including the commercial center, will be inundated in Guangzhou. Due to the narrowing and silting of flood rivers (such as the river bed of Sanzhi Xiang waterway has changed from 6 m to only 2 m)^[5], the flood water level of Zhujiang River in Guangzhou has a rising trend, which makes the risk of urban flood rising. In 1994, serious waterlogging occurred in Guangzhou due to poor flood discharge. In addition to the narrowing of rivers, that elevated bridge piers from Yuexiu North to Shawan Grand Hotel built in recent years were located in Donghaochong, which seriously affected the flood discharge, was also an important reason. As a result, the water flooded people's breasts in the Provincial Party School area of Huanghua Road, and the residents in Triangle City and nearby were flooded many times, and the losses were serious. The phenomenon of encroaching on flood channels also existed in Shunde, Foshan, Shenzhen and other cities in the Pearl River Delta.

2.2 As urban rivers, lakes, ponds and depressions being filled up, urban canal system losing the function of drainage and storage

Urban canal system of the ancient China is composed of moats, canals, lakes and ponds inside and outside the city. It has ten functions. Unfortunately, the precious heritage left to us was damaged in urban construction. With the construction of highway and railway, the position of urban canal system in transportation is greatly reduced, and the defense function of modern city is no longer important. Filling the moats, canals and lakes has become general mood of urban development. There are few lakes in the city, urban landscape has no characteristics, there being no charm, urban environment and microclimate being deteriorating, and getting worse. That the streets become rivers after rainstorm happens in hundreds of cities from south to north, with few exceptions.

The examples of filling urban water bodies were abundant in modern times. More typically, more than 1000 ponds were filled up in Chengdu. In 1958, the Inner Jinshui River, which was built in the Tang Dynasty and has a history of more than 1,000 years, was so filled that it caused serious losses of Chengdu in the flood on August 17, 1983.

Wuhan is also a typical example. Wuhan is divided into three towns by the Yangtze River and Hanjiang River. The average elevation of the urban area is 24m, the average annual water level of the Yangtze River in flood season is 25.38m, and the highest flood water level is 29.73m. In the middle of the 20th century, there were more than 300 lakes and each lake being of 100 mu of water surface (6.67hm²) in Wuhan. Historically, due to the construction of land around the lake, the lake water surface has plummeted. There were still 100 lakes in the city in 1949. Later, Boli Dangzi, Xiaodong Lake, Tea Port, Dusi Lake and other 8 lakes were completely filled, now there are only 27 lakes. The capacity of the surviving lakes is also shrinking sharply^[6].

Serious waterlogging was often caused by rainstorm in Wuhan during flood season, and the sharp decrease of water body in the city was the main reason. On July 21, 1998, there was a torrential rain in Wuhan, 90% of the enterprises in the three towns being affected, 1,183 enterprises without production, and 509 enterprises with half production, finally with a cumulative direct loss of more than 51.7 billion yuan^[7]. Fortunately, some cities attached importance to the protection and utilization of water bodies, and reduced the flood

disaster. Due to poor management and poor drainage, 60% of the houses in Lingbi County, Anhui Province, were flooded by a rainstorm in July 1990. From March to May 1991, according to the planning requirements of “renovating and dredging the river around the city in an all-round way”, the renovation was completed. During the flood in 1991, the flood discharge in Lingbi County was unobstructed, and there was basically no loss in the city^[8].

2.3 Urbanization flood effect aggravating waterlogging

The increase of urban waterlogging is also closely related to the effect of urbanization flood effect. Urbanization makes the natural watershed change rapidly, making the original permeable vegetation and soil become impermeable artificial buildings, and making most of the rainfall can not enter below the ground cushion, and forms the surface runoff, which increases the flood volume of rainstorm and flood, increasing the discharge, advancing the peak time and accelerating the process of flood fluctuation. It is the main characteristic of urbanization flood effect. It makes the capacity of the original drainage and flood discharge system smaller, thus aggravating the flood disaster in the urban area^[9].

2.4 The rising sea level making drainage to be difficult in coastal cities and posing a serious threat of tidal disaster

The rise of the sea level is a positive result of global warming. Considering the different degrees of surface subsidence in the three deltas, the relative sea level calculated by 2050 is 40~50cm in the Pearl River Delta, 50~70cm in Shanghai and 70~100cm in Tianjin. For the shore section of Guangzhou, when the sea level rises by 50cm, the current situation of the biggest storm surge once in 50 years will become once every 10 years, while in the Yangtze River Delta, the once-in-a-century storm surge will become once every 50 years, and the threat of marine disasters to the city will be more frequent^[10].

Historically, the Yangtze River Delta and Shanghai have been threatened by storm surges. The Typhoon No. 7 in 1962, the highest water level of Huangpu Public Park was 4.76m, half of Shanghai was inundated, the depth of water being 0.5~0.7m, the loss reaching 500 million yuan. In the past 100 years, there have been 12 annual floods in the process of tidal level rising in Shanghai, including 1900, 1905, 1915, 1921, 1931,

1933, 1939, 1944, 1962, 1974, 1981, and 1991. The height of flood control wall on the Bund of Huangpu River is built according to the biggest flood in 10 centuries. If the sea level rises by 0.5m, the standard of dike will be reduced to once in a hundred years, and the ability to resist disasters will be significantly reduced.

The Pearl River Delta and Hanjiang Delta in Guangdong Province are typhoon prone areas. Typhoon No. 6903 on July 28, 1969 made the tide level of Mayu Station in Shantou City reach 3.10m. The urban area of Shantou was inundated and the water depth being 1~3 m. On July 1, 1981, typhoon surge made the water depth of Shantou city reach to 0.1~0.5 m, and causing heavy losses. On September 9, 1983, Typhoon No. 8309 made the high tide level of 2.63m above the plane of the Pearl River appearing in Nansha Town, outside Humen. In this storm surge, 137 people were killed and injured in Panyu City, a lot of area of Guangzhou was inundated, and the water depth of the streets being about 1m. On July 18, 1989, Typhoon No. 8908 made the tidal level of Chiwan Station reach 4.69m, the depth of water in Zhuhai was 0.5m, half of Macao being inundated, some streets of Dongshan District and Xiaxiguan Commercial District of Guangzhou being flooded. The total loss in the Pearl River Delta was 1 billion yuan. In the old city of Guangzhou, there are 4.25km² urban areas below 1.4m of the plane of the River, 13.01km² urban areas below 2.4m, and 27.22km² urban areas below 3.4m. If the sea level rises by 0.7m, the typhoon surge once in 20 years will make the water level reach 3.1 m, about the area of 20km² in Guangzhou will be inundated, the economic loss will reach more than 20 billion yuan. The sea level will rise and will reduce the urban drainage capacity and aggravate the urban waterlogging disaster^[11].

2.5 The frequency of typhoons landing on China's coast will increase by 1.76 times in this century, and the storm surge disaster being going to be more serious

Global warming, rising tropical ocean surface temperatures and falling pressure increase the chances of typhoons. It is studied and speculated that after heating up 1.5 °C in the middle of the 21st century, the frequency of typhoons in the North Pacific in the second half of the 21st century is twice as high as that at present. The frequency of typhoons landing on China's coast will increase by 1.76 times, and the typhoon surge disasters will be more serious^[11].

2.6 Excessive exploitation of groundwater causing land subsidence and aggravation of waterlogging disaster

The land subsidence caused by overexploitation of groundwater mainly occurs in the plain area. Shanghai, Suzhou, Wuxi, Changzhou, Tianjin and so on have this problem among them the ground of Changzhou City having subsided for 0.7m. The average subsidence around Tanggu between 1959 and 1985 reached 94mm per year^[12], and Fuyang City being more serious, with a subsidence of 277mm in 1987 and now an average of 453mm per year^[13]. There is no doubt that the subsidence of the ground will increase the threat of flood disasters to city.

2.7 Modernization making cities more vulnerable to floods, and the loss of secondary disasters caused by floods being more serious

Urban modernization is the goal that people pursue. However, modern cities, especially large cities, are becoming increasingly vulnerable to flooding. The reasons are as follows: (1) the central management function of mastering the lifeline of the national economy is highly concentrated in the big cities. (2) the cities are increasingly dependent on water, electricity, gas, communication, transportation and other lifeline engineering systems, (3) the cities are developed underground to alleviate the contradiction between traffic, commerce and lack of living space, the power system of high-rise buildings is often placed in the basement, and underground space is the weak link of water prevention. (4) the finance of high-speed operation, circulation and production economic departments are increasingly dependent on communication networks and computer networks^[14]. Therefore, once the city suffers from flood, its direct economic loss is of course huge, and the indirect loss caused by the disorder of normal society, economy and life order will be much greater.

2.8 The urban waterlogging relating closely to drainage pipeline section sediments in Beijing, which reflecting the disadvantages of modern urban drainage design and management

Since the second half of 2007, *Li Haiyan*, a professor at the School of Environment and Energy Engineering of Beijing Institute of Architectural Engineering, has investigated the deposition of sediments in rain water drainage pipeline in Beijing^[15]. *Li Haiyan* wrote a

paper entitled *the investigation and study on sediment deposition in rain water (drainage) pipeline in Beijing*: “there are the sediment in nearly 80% of rain water drainage pipelines in Beijing, the thickness of sediment in 50% of rain water drainage pipelines account for 10% ~50% of the diameter of the pipelines, and the thickness of sediment in the individual pipeline accounts for more than 65% of the diameter of the pipeline. More importantly, these sediments can pollute the water quality of urban water systems. The rougher the inner wall of rain water drainage pipe, the greater the resistance to water flow. The sediment in cast iron pipe with the same diameter is more than 50% less than that in reinforced concrete pipe. At present, the rain water drainage pipelines in most cities of China are reinforced concrete pipelines. Lack of garbage management is also an important reason for the sediment in rain water drainage pipeline. In addition, there are many infrastructure maintenance and renovation projects, such as pavement in the old residential area, which will increase the total amount of particles entering the drainage pipeline. At present, *the Interim Measures for the Administration of Urban Municipal drainage facilities in Beijing* were issued in early 1986, 23 years ago, and have seriously lagged behind the rapid development of urban construction in Beijing. The backwardness of this design technology and the backwardness of management are the important causes of urban waterlogging.

3 Wisdom of urban canal system in Ancient China

Urban canal system is the great creation of ancient China, which embodies wisdom of ancient Chinese. This system is organic, not mechanical, with multi-functions, being an important infrastructure to avoid urban waterlogging in ancient China.

As the blood circulation of city, urban canal system is of significance in urban development as follows:

- (1) Urban site stabilizing;
- (2) Urban industry and commerce developing;
- (3) Living environment improvement;
- (4) Urban features forming^[1].

4 Experience of urban canal system in ancient China

By way of the research on the cases of capitals, i.e. Changan in Sui and Tang Dynasties, (Figure 2.)

Dongjing (Figure 3.) in Northern Song Dynasty, Dadu in Yuan Dynasty(Figure 4.), Beijing in Ming and Qing Dynasties(Figure 5.), the Forbidden city(Figure 6.) in

Ming and Qing Dynasties, important conclusions on six aspects are obtained. Among them, three finds are as follows^[16].

Table 1. Urban Canal System Of Five Captial Cities in Ancient China

Order	Dynasty	Captial	Area(km ²)	Length of Cancals(km)	Section of drainage cancals(m ²)	Density of drainage canals(km/km ²)	Total(m ³)	The average storage capacity m ³ /m ³
1	Tang(618.A.D.—907.A.D.)	Chang'an	83	37	28	0.45	592740	0.0714
2	Northern Song(960.A.D.—1127.A.D.)	Dongjing	50	77.4	372.48 28.88	1.55	1852.230	0.37
3	Yuan(1271.A.D—1368.A.D)	Dadu	50	50.225	238.875 147	1	1999580	0.3999
4	Ming and Qing(1368.A.D—1911.A.D)	Beijing	60.2	64.27	238.875	1.07	1935290	0.3215
5	Ming and Qing(1368.A.D—1911.A.D)	The Forbidden City	0.724	5.8976	312	8.3	118560	1.637

4.1 The density of drainage canals and their section for floods passing being two key factors for waterlogging control design

The density of drainage canals of Changan City was only 0.45km/km², and it's section for floods passing being only 28m².The drainage system of Dadu in Yuan Dynasty was better than that of Changan in Tang Dynasty. It's density of drainage canals is 1 km/km², and it's section for flood passing was 147m² and 238.9m² respectively which being 5.25 times and 8.5 times of that of Changan in Tang Dynasty respectively. The drainage system was of a higher level in Beijing in Ming and Qing Dynasty, it's density being 1.07km/km², and the section for flood passing being 238.9m². The drainage system of Dong Jing was well planned and designed, four rivers passing through the city, it's density of drainage canals being 1.55km/km², which being 3.5 times of that of Changan in Tang Dynasty, and it's section being 372.48m², which being 13.3 times of that of Changan in Tang Dynasty. The best example of drainage systems is of the Forbidden city in Ming and Qing Dynasties, it's density of drainage canals being 8.3km/km², which being 18.4 times of that of Changan in Tang Dynasty, it's section for flood passing being 312m², 11 times of that of Changan in Tang Dynasty.

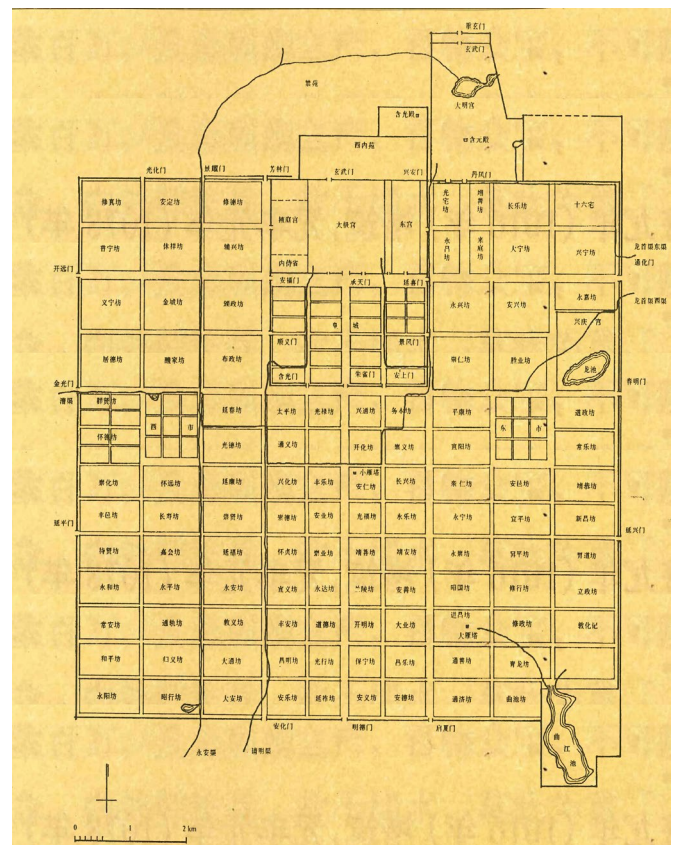


Figure 2. Plan of Changan City in Tang Dynasty. (from Fu Xiniang as the chief editor. Architectural History In Ancient China. Vol.2 Beijing: China's Building Industry Publishing House, 2001:318)

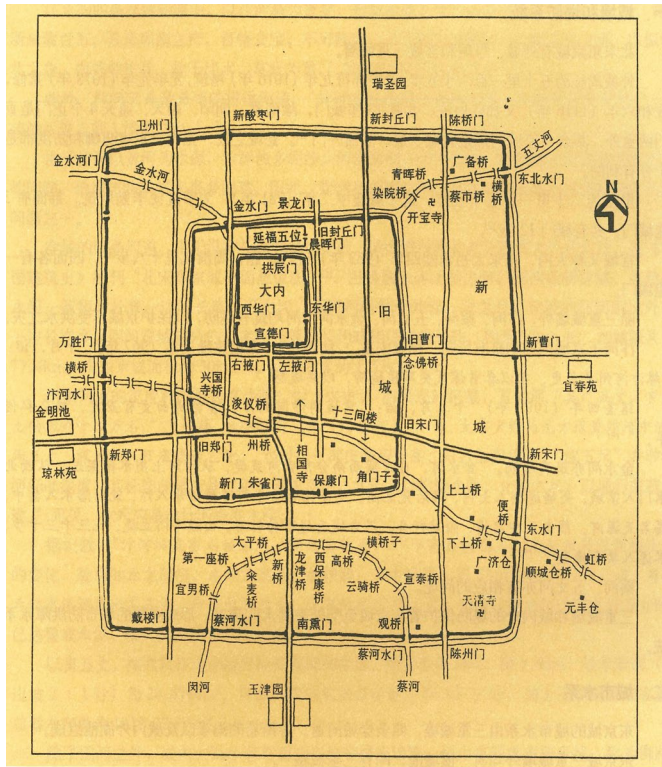


Figure 3. Plan of Dongjing City in Northern Song Dynasty (from Guo Husheng. *Dongjing in Northern Song Dynasty*. [J]Architects, 1996(8):79)

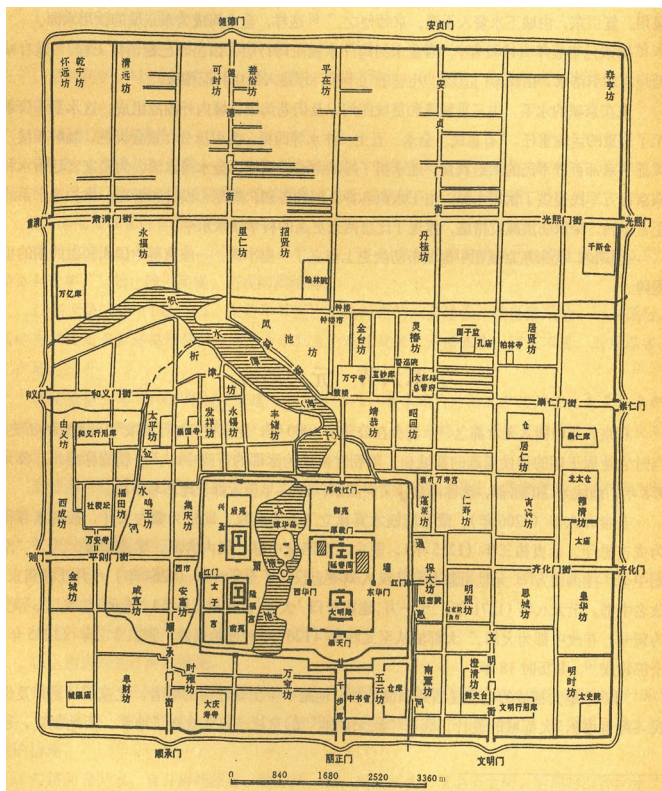


Figure 4. Plan of Dadu City during the period of Zhi Zheng(1341. A.D.-1368.A.D.) inYuan Dynasty.(from Ma Zhengling. *Historical Geography of China's Cities*. Jinan: Education Publishing House of Shandong, 1998:227)

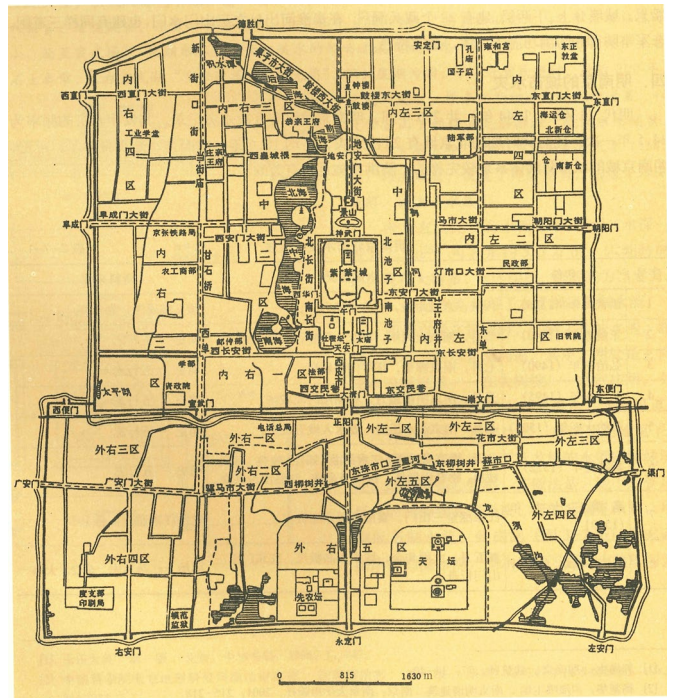


Figure 5. Plan of Beijing City at the first year of Xuan Tong Reign, 1909 in Qing Dynasty. (from Ma Zhengling. *Historical Geography of China's Cities*. Jinan: Education Publishing House of Shandong, 1998:239)

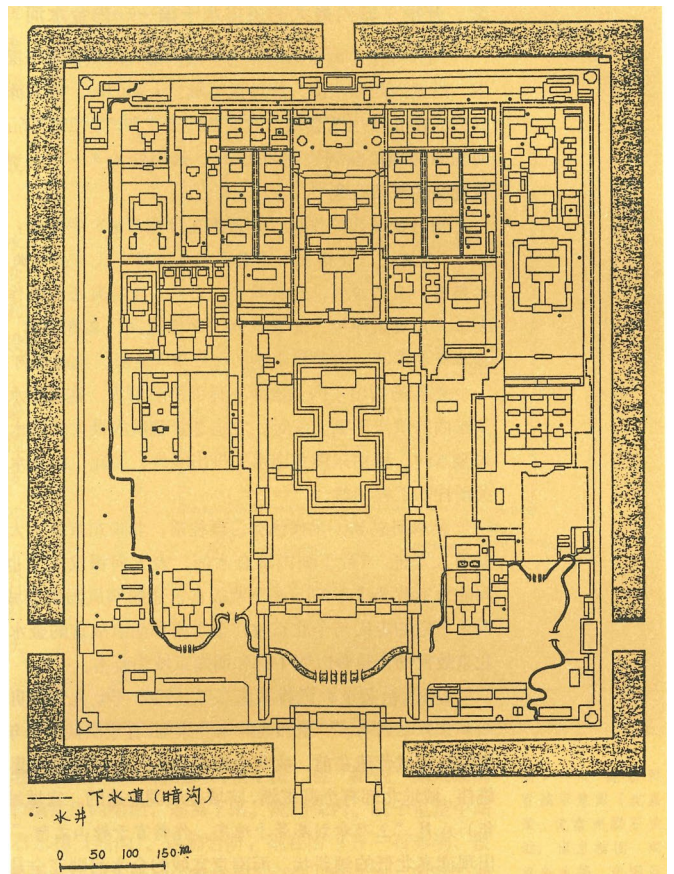


Figure 6. Plan of drainage trunk canals in the Forbidden City in Ming and Qing Dynasties (from Yu Zuoyun. *The Palaces In The Forbidden City*.)

4.2 The total storage capacity of the urban canal system being the key factor of prevention from waterlogging

The area of Changan in Tang Dynasty was 83km^2 , and the total storage capacity of its urban canal system being 5927400m^3 , i.e. the average capacity of the city being only $0.0714\text{m}^3/\text{m}^2$. The area of Dongjing in northern Song Dynasty was about 50km^2 , and the total storage capacity of its urban canal system was $18,523,300\text{m}^3$, the average capacity of the city was $0.37\text{m}^3/\text{m}^2$, which being 5.2 times of that of Changan in Tang Dynasty. The area of Beijing in Ming and Qing Dynasties was 60.2km^2 , and its total storage capacity of urban canal system was $19,352,900\text{m}^3$, the average capacity was $0.3215\text{m}^3/\text{m}^2$, which being 4.5

times of that of Changan in Tang Dynasty. The area of Dadu in Yuan Dynasty was 50km^2 , its total storage capacity of urban canal system was 19995800m^3 , the average capacity was $0.3999\text{m}^3/\text{m}^2$, which being 5.6 times of that of Changan in Tang Dynasty. The area of the Forbidden city in Ming and Qing Dynasties was 0.724km^2 , and its storage capacity of Tong Zi River was $1,185,600\text{m}^3$, the average capacity was $1.637\text{m}^3/\text{m}^2$, which being 23 times of that of Changan in Tang Dynasty, and 5.1 times of that of Beijing in Ming and Qing Dynasties, and 4.4 times of that of Dongjing in northern Song Dynasty, and 4.1 times of that of Dadu in Yuan Dynasty. That is why there has been no water logging in the Forbidden city for 600 years since it was constructed. Attention must be pay to the storage function of urban canal system. The sufficient storage capacity of urban canal system is the key factor to avoid urban waterlogging. This scientific discovery can be used as important references for contemporary urban flood control.

4.3 Great attention having paid to the management of urban water system

Generally speaking, the management of drainage facilities in the capitals of the past dynasties was poor in Chang'an City in Tang Dynasty and better in Dongjing City in Northern Song Dynasty, but it being better in the early years of Song Dynasty and slightly worse in the later. The drainage system of Dadu City of the Yuan Dynasty was well managed. During the Ming and Qing Dynasties, the drainage system of Beijing was well managed in the Qing Dynasty, the system was perfect, and the reward and punishment were clear. Every early spring, it was necessary to dredge the rivers

in the Forbidden City, which had been formed in the Ming Dynasty and used in the Qing Dynasty to make the drainage system in the city unobstructed and give full play to the role of drainage and flood discharge, which being the best in management.

5 The historical experience against waterlogging of the Forbidden City in Ming and Qing Dynasties

The most elaborate and scientific part of urban canal system is the Forbidden City's drainage system.

The Forbidden City is the imperial city of the Ming and Qing Dynasties. The plan (Figure 6.) is rectangular, with a length of 961m and a width of 753m. The perimeter is 3,428m and the area is about 0.724km^2 . Its historical experience against waterlogging is as follows.

(1) A moat, wide and deep, was built around the citywalls.

(2) Excavation of the largest drainage canal in the city -- the inner Jinshui River.

(3) A number of drainage trunk channels and branches were set up to form a drainage network.

(4) Ingenious surface drainage was adopted.

(5) The design and construction of drainage system were scientific and accurate, so it was strong and durable.

(6) The drainage system was well managed.

The Forbidden City in the Ming and Qing Dynasties was surrounded by Tongzi River, and the Jinshui River ran through it. The two rivers were about 6km long, and the river density reached $8.3\text{km}/\text{km}^2$, which being comparable to that of Suzhou in the Song Dynasty (it being $5.8\text{km}/\text{km}^2$ in the Song Dynasty^[1]). The drainage system of the Forbidden City in the Ming and Qing Dynasties was designed scientifically and perfectly, the drainage method being ingenious and effective, the canal system being large in capacity, and becoming the most perfect example of all the cities in ancient China. There are more than 90 courtyards in the Forbidden City, and the buildings being of high density. If the drainage system is not good enough, there will certainly be a record of inundation. However, since the completion of the Forbidden City in the 18th year of Yongle Reign (1420), it has been 600 years. There has been no record of waterlogging, and the drainage system has been used and effective all the time^[17]. This is not only a miracle in the history of urban construction in China, but also in the history of urban construction in the world.

6 Another example of flood and waterlogging control, Ganzhou

Ganzhou locates on the upper reaches of Ganjiang River where being confluence of Zhang River and Gong River.

6.1 Yang Junsong, the master of Fengshui, selecting the city site and constructing the tortoise city Ganzhou (Figure 7.)

YANG Junsong, the master of Feng Shui, selecting the city site and constructing the tortoise city of Ganzhou.

Yang Junsong chose the urban site and build up Ganzhou city with the idea of a tortoise against the current, the head of the turtle being the southern Gate, it's tail being at confluence where being called Gui Wei Jiao (the corner of the turtle tail) until today, it's legs being the Gates on both eastern and western city walls facing the rivers. As a result, Ganzhou was constructed into an unshakable iron city with three direction boundaries surrounded by water^[18].

6.2 The advantages of site of Ganzhou are as follows:

Zhang River, Gong River and their tributaries provide with water transportation. It contributes to the development of Ganzhou for that it's site is situate on confluence and a hub of both water transportation and land communication^[19].

Surrounded by water on three directions, Ganzhou became an iron city of solid defence, it being easy to have vast basins and hills of three River valleys under it's control.

There are much level land on the southern of Ganzhou for the purpose of urban development. The area of the city was about 1km² in Tang Dynasty (618-917). The city opened up to south and it's area was more than 3km² in the Five Dynasties. Later, the city continued to develop to the south, and it's suburban area built is of 18km² in 1988.

Though the location of Ganzhou has three virtues, it also has a disadvantage, i.e. being liable to flood disasters.

Site of Ganzhou situates on the basin surrounded by mountains, it's city walls facing water in three directions. The terrain of northwest in the city is higher, 120 to 125 meters above sea level, it's northeast, east and southeast being lower, with elevation of 100 to 106 meters. For the ground along rivers, the terrain is only 97 meters above sea level. The surface of Ganzhou

appears as a back of turtle with higher at the centre and lower all around.

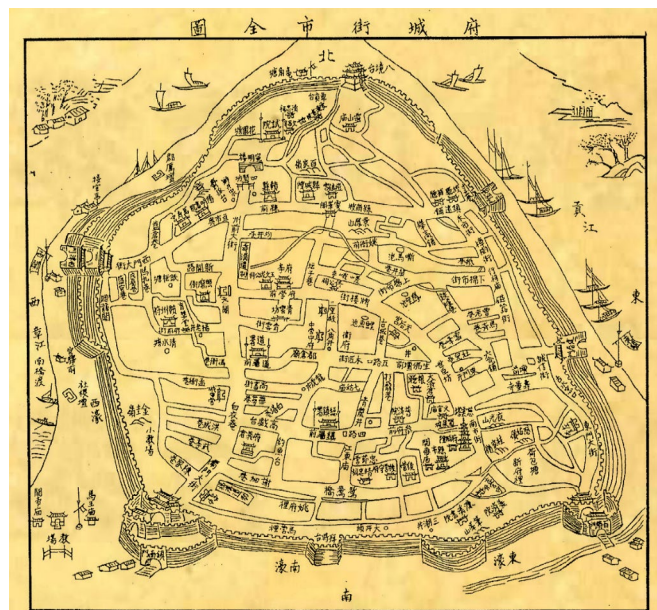


Figure 7. Plan of Ganzhou City from *Gan County Chronicle* (compiled in the 11th year of Tongzhi, 1872)

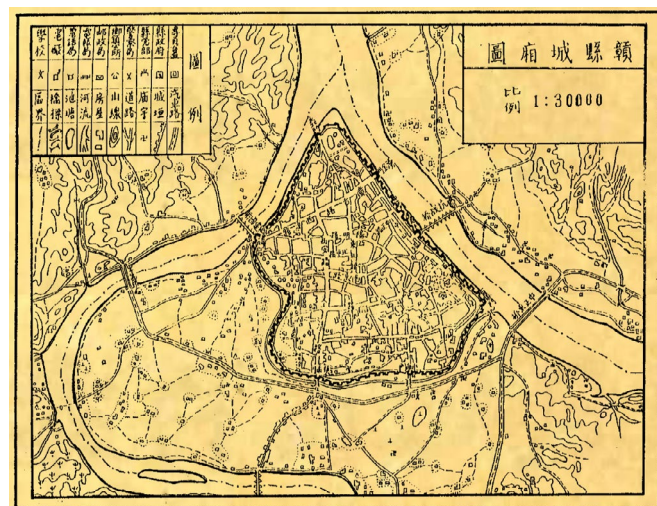


Figure 8. Plan of City and Suburb of Gan County (*new Chronicle of Gan County*, 1946)

According to the information of hydrometric station, the highest water level of Zhang River of Ganzhou above warning water level(99.0m) is of twenty-six years every twenty-eight years, as to that of Gong River, above warning water level(97.50m) being of twenty-five years every twenty-eight years^[20]. During the flood season, the water level of rivers is higher several meters above the urban ground and the life and property of the urban inhabitants are in danger. The most important issue Ganzhou facing is how to protect the city from flood damage and waterlogging.

6.3 Facing serious flood hazard, a flood control system being set up to keep the flood from rivers in check and to store and drain heavy rainfall to avoid waterlogging

The flood control system of Ganzhou was composed of citywalls, moats and canals, which called Fushougou, being urban storage and drainage systems.

Situated on subtropic area, Ganzhou has plentiful precipitation. It's maximum rainfall for twenty-four hours is 200.8mm(May 16th,1961). Ganzhou would suffer waterlogging after rainstorm without perfect drainage system. Rainstorms always happen during high-water season, escape canals can not discharge flood to the rivers for their water levels being higher than that of urban ground. During flood season, flood of rainstorm should be stored in storage system with enough capacity. Otherwise, inundation will occur. Liu Yi, the water conservancy expert, took up the post of the governor of the prefecture in Xi Ning Period (1068-1077) in Song Dynasty, planning and constructing both drainage system and storage system i.e. Fu Gao and Shou Gao^[21]. Fu Gao and Shou Gou have been undertaking both storage and drainage tasks of Ganzhou since that time on.

Everything is never plan sailing. After Xi Ning Period, the residents occupied the canals and built up houses upon them, Fushougao being obstructed and

water being unable to pass through, people in the city suffering from inundation. Local officer gave orders to remove the obstacles and to dismantle the illegal houses, and Fushougao functioned normally as before. After maintenance in Tong Zhi the Eighth to the Ninth years (1869-1870) of Qing Dynasty, plan of Fushougou was drawn (Figure 9.). It's total length is about 12.6km, about 1km of which being the length of Shou Gao, another 11.6km being that of Fu Gou^[22].

6.4 Fushougao having been still playing an important role against waterlogging

Fushougao was maintained from 1953 to 1957, and 7.3km canals being restored, which being about 58% of the total length. There are nine drainage outlets in the old town, among them, six of which, belonging to Fushougao and still in use. The outlets are covered with wooden gates, their axle being at upper reaches. When the water level of the river is lower than that of the canals, the force of discharging can open the gates. On the contrary, the running water of the river may close the gates and block the high level water to flow backwards to inundate the urban area. Nowadays, the wooden gates have been changed into iron gates^[22].

To avoid water-logging, Fushougao connects a lot of ponds and lakes, and having enough storage capacity to avoid inundation after rainstorm (Figure10., Figure11.)^[23].

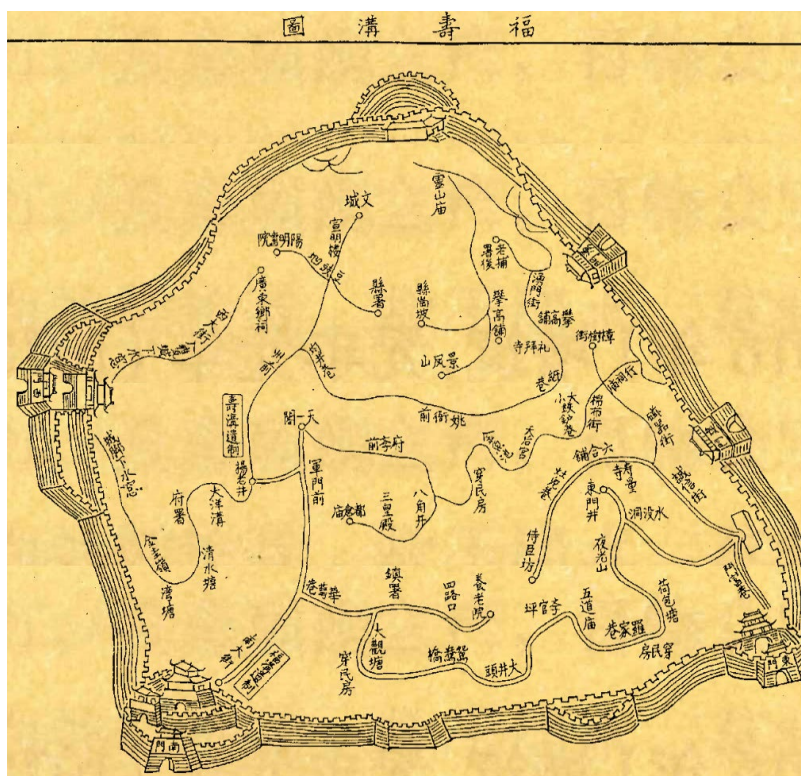


Figure 9. Plan of Fushou Gao in Ganzhou from Gan County Chronical (compiled in the 11th year of Tongzhi, 1872)



Figure 10-1. Plan of Ganzhou City in 1872.

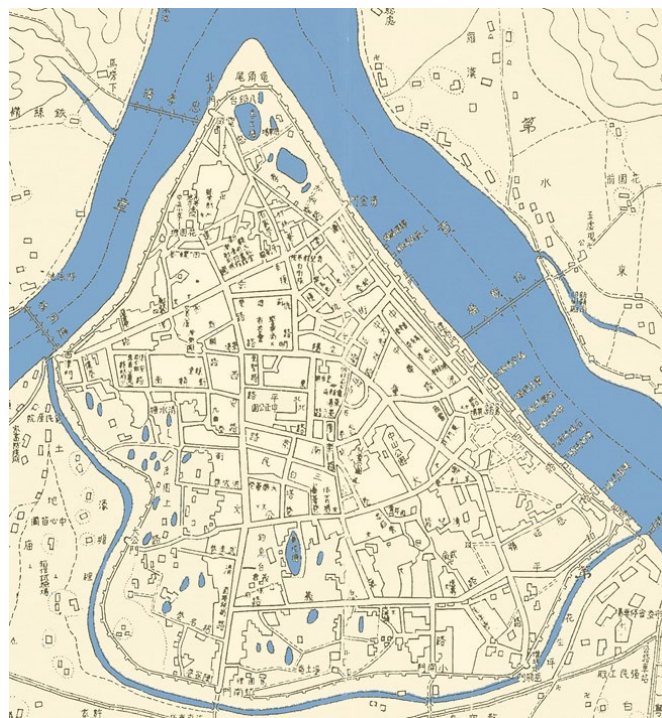


Figure 10-2. Plan of Ganzhou City in 1942

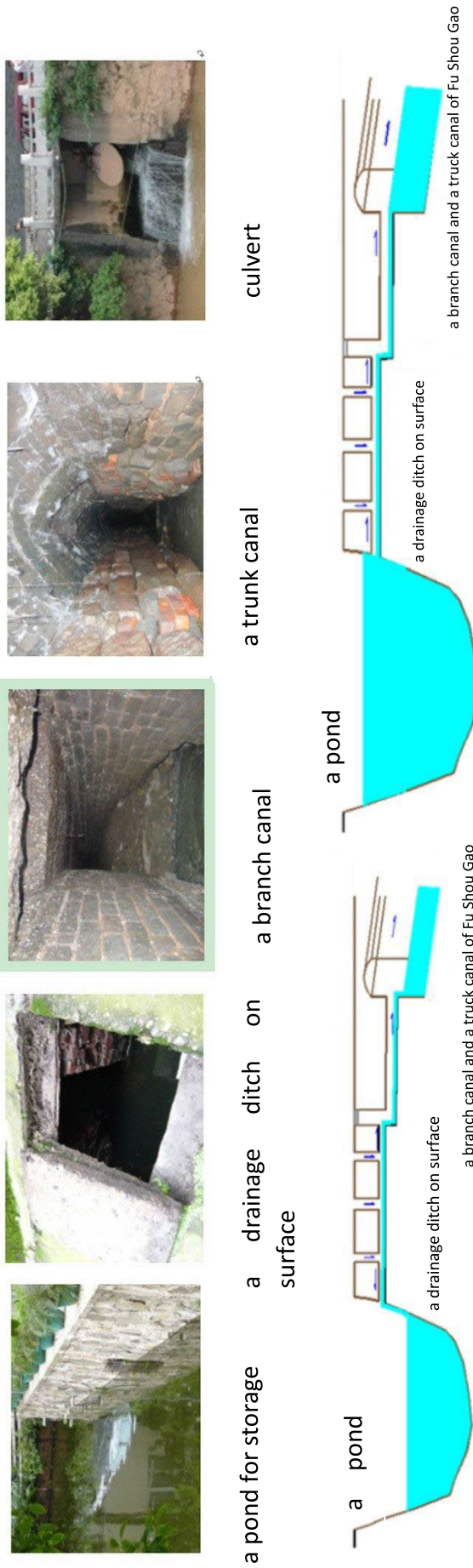


Figure 10-3. Plan of Ganzhou City in 1972.



Figure 10-4. Plan of Ganzhou City in 1980

Figure 10. The evolution of the historical urban area of Ganzhou



A sketch map showing the course of drainage and storage of Fushou Gao in the dry seasons.

A sketch map showing the course of drainage and storage of Fushou Gao in the rainy seasons.

Figure 11. Sketch maps showing drainage and storage functions of Fushou Gao connecting with a lot of ponds and lakes

The master of Feng Shui, Yang Junsong planned and built the tortoise city Ganzhou; Kong Zonghan protected city from flood damage and created the first city Bajing of China; Liu Yi constructed the canal system Fushougao to avoid inundation. Ganzhou becomes the first city of Gun River and state historic cultural city. Ganzhou is an example and a book of city planning and urban construction in ancient China.

There are two distinguishing features of the urban flood control system in ancient China, one is that city walls and moats being a entity of both military defense and flood control engineering, another is that the urban canal system being the blood circulation of city with multi-functions. Ganzhou embodies these features and the great wisdom of ancient Chinese^[24].

During summer in 2010, as many cities facing the water-logging after rainstorms, the inhabitants of Ganzhou were enjoying peace and happiness. The city walls and Fushougao functioned as before, which aroused profound respect and drew wide attention of society^[25].

7 Countermeasures against urban waterlogging

7.1 Strengthening the planning and management of flood rivers and waterways in urban areas, and strictly prohibiting embezzlement and filling in legislation.

7.2 Protection of urban lakes, ponds and depressions to store rainstorm floods and reduce waterlogging disasters.

7.3 Increase the urban water permeable ground and the storage capacity.

7.4 Introduce BMPs(Best Management Practices)、LId(Low Impact Development)、SUDs(Sustainable Urban Drainage System) and WSUd(Water Sensitive Urban Design) both concept, ideas and technology to improve urban water environment and management^[26].

8 Conclusion

With the increase of global population, the overuse of land, forest, water and biological resources, the environment of whole the Earth is deteriorating, and the disaster is becoming more and more serious. The worsening of modern urban waterlogging disaster is related to many factors. Besides natural factors, artificial factors are very important.

The ultimate aim is to set up a new urban canal system with multi-functions to protect the urban habitants to live a save and happy life.

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