

# Flood and Waterlogging Disaster Management System in Shenzhen River Basin

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**Abstract:** In recent years, "see the sea" in the rainy season has become a high frequency event in cities. Urban flood and waterlogging which are increasing day by day has influenced residents' lives seriously especially in large cities with high population aggregation. As a coastal city with low altitude, Shenzhen, where has a high requirement for the urban drainage system, not only has to face abundant in rainfall but also has to cope with the tide. In this paper, the disaster reduction systems such as rainwater collection, drainage system, flood storage and detention basin, reservoirs and pumping station in the Shenzhen River basin are analyzed and the operation effect is studied. In general, the flood management system of overall planning, emergency scheduling, preparation before flood, key area on duty, and post-rain response has achieved a high level and played an active role in disaster prevention and reduction. The conclusions that Shenzhen River basin has a complete and efficient system of urban flood and waterlogging management, the rainwater collecting and discharging system can meet the requirement of the city and modern design concepts of blocking, storing, draining, pumping, scheduling which have effectively reduced the disaster have been come.

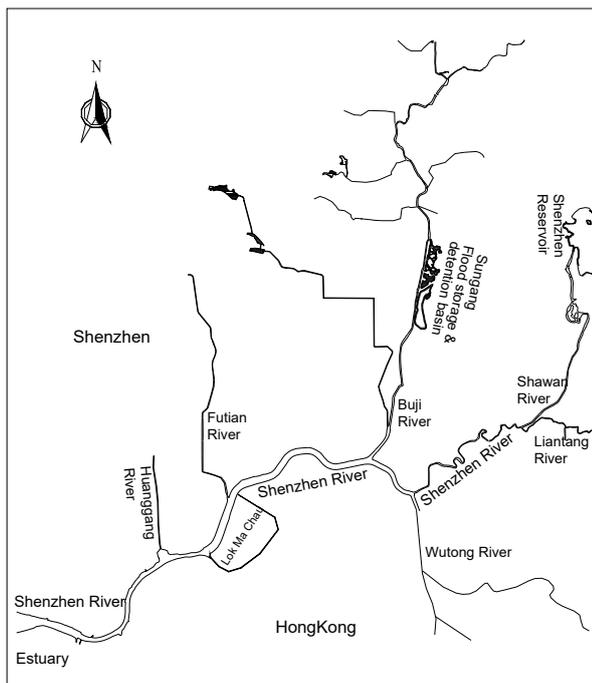
## 1 Background

With the development of domestic cities, they are changed that the degree of urbanization has gradually increased, the population has been concentrated in cities, the urban area has become larger and larger, and resources such as rivers, lakes and water pools with accumulated water and flood control functions have been crowded and the natural ground that can seep water gradually becomes a cement floor that is impervious to water. Lakes are a natural buffer against flood disasters (Xi-jun Lai, 2017) and reservoirs are an important part of the modern flood control system (Rao En-ming, 2014). In order to deal with the flood and waterlogging problems, new water conservancy projects are constructed (Liu Bao-jun, 1999). With the weather change (T Haer, 2017; Y Hirabayashi, 2013) and economic development (SHI Fang-bin, 2006 ; Shao W., 2017), flood and waterlogging, which occurred mainly in coastal areas with low altitude in the past (Aerts J.C.J.H.,2014), often occur in inland cities and cause serious economic losses (Su Boni,2015; Winsemius H.C.,2013 ).

Compared with many historic inland cities, Shenzhen is a vibrant "youth". As a frontier of reform and opening up, Shenzhen which has a subtropical maritime climate with abundant rainfall and rainy seasons has a resident population of 12.52 million expanded rapidly in the short

term. It is a rainy season from April to September every year. Annual rainfall is about 1933mm and the tropical cyclones (typhoons) invade 4-5 times every year on average. Owing to sparse vegetation in the city, there are few lakes and water pools which are impossible to store rainwater and lead to the phenomenon of "water catchment". At the same time, the city has a low altitude and small fall head that makes the rainwater is difficult to discharge (Zhang Li-hong, 2017). It is the focus of municipal waterworks that how to find the method to match the municipal flood control facilities and the climate of heavy rainfall in the coastal areas.

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**Figure 1.** Shenzhen River Basin

The Shenzhen River is the boundary river between Hong Kong and Shenzhen. Most of the densely populated and highly developed Luohu District and Futian District belong to the Shenzhen River basin. The middle and lower reaches of the Shenzhen River basin, which is close to the end of the drainage collection system with small fall head, large development intensity, high degree of modernization, flat terrain and dense population, is the center of the city which is easy to cause waterlogging that is also a common problem in coastal cities.

## 2 Urban flood control and drainage master Plan

### 2.1 Layout principles

The main function of the urban drainage system is to divert the collected rainwater to the urban flood control system such as rivers and lakes that is a process of collecting and discharging.

Urban drainage which is the system of collecting rainwater and flood control project which is the system of discharging are related to each other and become a closed system. The layout and project of flood and drainage should take into consideration of different natural and human factors such as topography, geology, urban land planning and transportation network. The drainage project conforms to the law of water flow which is the principle of high water with high drainage and low water by pumping. Rainwater in the low-lying area is retained and strong drainage and pumping are required. Therefore, the pumping station is arranged at the point where it is easy to gather rainwater and it is close to the containment area that would reduce the pumping area. In combination with the river management project and the flood control engineering

system, the storage lake project will be set up in accordance with the requirements of low-impact development and construction.

At present, the urban drainage standards in Shenzhen: urban central areas (including Futian, Luohu, Nanshan Districts) can effectively cope with heavy rains of no less than 50 years; other urban areas can effectively cope with heavy rains of no less than 20 years.

The urban rainwater pipeline network system is the engineering of collecting rainwater in the urban construction area; the river system is the main project and the confluence area of urban rainwater. The terrain where is higher than the drainage level in the discharge area and has self-discharge conditions is meeting the requirements of urban rainwater discharge and no problem of flooding. The drainage pumping station is set up to meet the discharge requirements of the rainwater in the area where the local conditions do not meet the self-discharge.

General requirements for project construction:

(1) Mountain flood interception engineering system: the flood interception project is excavated along the contour line on the periphery of city development and construction area, so that the mountain flood can not enter the urban area. The design flood standard is generally used once in 20 to 50 years and increased according to the importance of protected object. Rainwater utilization facilities using low-impact development technology are constructed to realize the control of rainstorms in the development and construction community.

(2) According to the principle of nearby emission into the river, the rainwater drainage pumping station is setting up in the area where the self-discharge requirement is not met. At the same time, it makes full use of low-impact development technology to control and use rainwater from the surface in order to reduce the surface runoff coefficient, flood peak and flood volume caused by urban development and construction.

(3) Closed drainage facilities are set up surrounding the area where below the ground such as the sinking plaza, subway station, underground parking lot and rainwater pumping stations are constructed in the sinking squares.

(4) It is utilized of certain ecological technologies and storage space to control the convergence speed and utilize rainwater.

### 2.2 Drainage project overview

In Shenzhen there are 310 rivers, which are divided into 7 large areas named Shenzhen River Basin, Maozhou River Basin, Longgang River Basin, Guanlan River Basin, Pingshan River Basin, Western Coastal Region (including the small rivers directly into the sea in Pearl River Estuary and Shenzhen Bay) and Eastern coastal Region (including Dapeng Bay and Daya Bay). And 90 rivers directly run into the sea in all.

Following the management principle of high water with high drainage and low water by pumping, Shenzhen has built 110 rainwater drainage pumping stations with a

total pumping capacity of 572m<sup>3</sup>/s and a total installed capacity of 40,000 kilowatts.

### 3 Causes of waterlogging in Shenzhen River basin

Shenzhen is located in the coastal areas with low latitudes. The main causes of the waterlogging are the topographical factors, the gully factors, rainstorm factors and the tidal factors.

#### (1) Topographical factors

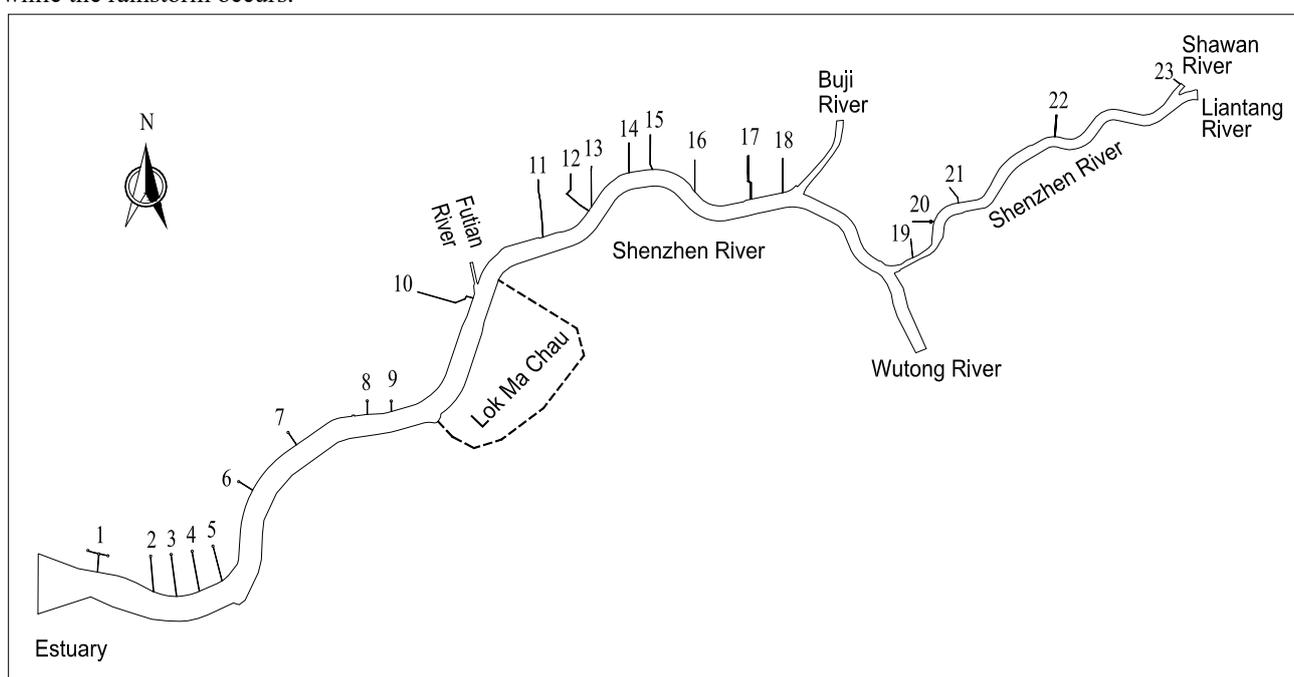
**Terrain.** As a coastal city, southern Shenzhen has a low elevation that is lower than the multi-year average high tide level of the sea which makes the rainwater cannot be discharged and forms the water accumulation while the rainstorm occurs.

**Development and construction.** In the process of urban development and construction, there is a lack of scientific vertical planning which leads to the later exploited regional terrain higher than the early exploited region with the lower design standards of drainage network resulting in the backflow and intrusion in partial old town.

#### (2) Fallen leaves and road garbage

A large number of fallen leaves and road garbage blocked the gully.

When the rainstorm occurs especially during the typhoon, the rain accompanied with strong wind is heavy causing a lot of fallen leaves which will be flushed into the rainwater sluice along with the road garbage that blocks the trash rack and the anti-mosquito gate, causing



**Figure 2.** Schematic diagram of the distribution of rainwater discharge outlets along the side of Shenzhen

the rainwater can't be discharged in time. It has become one of the main factors in the occurrence of waterlogging.

#### (3) Heavy rains

Heavy rains are concentrated and intensive that lead the floods easily formed.

The distribution of rainfall in time and space is extremely unbalanced in Shenzhen located in the southeast coastal area. Rainfall often comes in the form of heavy rain in flood season accounting for more than 80% of the total rainfall of the whole year and in summer it is mostly hit by typhoon which is easy to form heavy rain and flood disaster.

#### (4) Flood and tide encounters

The middle and lower reaches of the Shenzhen River are affected by the tide that increases the risk of flood disasters.

### 4 Shenzhen River flood discharge systems

The drainage system of the Shenzhen River basin consists of pipeline (culvert), reservoir, flood storage and detention basin, pumping station, emergency scheduling and river to complete the flood control.

#### 4.1 Pipeline (culvert) projects

In Shenzhen there are 23 outlets directly discharged into the Shenzhen River which is the terminal of the drainage system and undertakes the work of rainwater discharge of the basin. Among them, there are 12 discharge pipes and 9 rectangular discharge culverts, 2 pumping stations discharge outlets. Close to the right bank of the Shenzhen River estuary having 9 drainage outlets within 3.8km is the bonded area where the rainwater is discharged directly into the Shenzhen River through a short collection pipeline. The middle and upper reaches of the river are mainly rectangular drainage culverts without anti-backflow gates except for the pumping stations where the self-flowing and pumping switching

gates are set. The distribution of rainwater discharge outlet along the side of Shenzhen is shown in Fig2 and the characteristic is shown in Tab1.

**Table 1.** Characteristics of the discharge outlets

NO.	Positon	Shape	Size(m)	Remark
1	0+202	Pipeline	1.95Φ	
2	0+711	Pipeline	1.95Φ	
3	0+970	Pipeline	1.50Φ	
4	1+200	Pipeline	1.60Φ	
5	1+430	Pipeline	1.50Φ	
6	2+290	Pipeline	1.80Φ	without anti-backflow gates
7	2+805	Pipeline	1.00Φ	
8	3+586	Pipeline	1.20Φ	
9	3+775	Pipeline	1.00Φ	
10	5+170	Pipeline	1.00Φ	
11	5+960	Rectangle	2.8×1.8	
12	6+415	Rectangle	2.2×2.2	
13	6+595	Rectangle	2.0×1.2	
14	6+956	Rectangle	1.8×1.4	
15	7+133	Rectangle	1.5×1.5	
16	7+511	Rectangle	2.1×1.0	
17	8+140	Rectangle	8.0×2.0	
18	8+430	Rectangle	2.0×1.2	
19	9+906	Pipeline	0.70Φ	Pump,0.2m <sup>3</sup> /s
20	10+280	Pipeline	1.00Φ	Pump,0.7m <sup>3</sup> /s
21	10+530	Pipeline	1.00Φ	Without anti-backflow gates
22	11+600	Rectangle	8.0×2.0	
23	12+900	Pipeline	0.80Φ	

#### 4.2 Reservoirs

Collecting rainwater treatment system in the Shenzhen River basin is composed by 13 reservoirs, which have a combined catchment area of 84.19km<sup>2</sup> and total storage capacity of 5,600,000m<sup>3</sup> including 1 medium-sized reservoir, 2 small (1) reservoirs and 10 small (2) reservoirs.

#### 4.3 Flood storage and detention basins

In the Shenzhen River basin, there are two flood storage and detention basins: the Sungang storage and detention basin located in the Buji River and the Shenzhen River storage and detention basin located in the upper reaches of the Shenzhen River.

#### 4.4 Pumping station

Besides the old town developed and constructed in the early stage, the waterlogging area is 6.51km<sup>2</sup> mainly distributed along the Shenzhen River and the district between the Buji River and Shenzhen Reservoir floodway. After years of treatment, the flood control

engineering system has been formed and 16 drainage pumping stations have been built with a total discharge flow rate of 71.78m<sup>3</sup>/s.

#### 4.5 Emergency scheduling

When super-standard rainfall occurs, artificial scheduling is particularly important to confront the situation that the rainwater cannot be discharged in time and water accumulation is formed in a short period of time. According to the information technology analysis such as meteorological warning and flood calculation, the storage capacity will be reserved to undertake the rainwater flood by released the reservoir and flood storage and detention basins in advance. Through monitoring and analyzing the river topography, the river channel dredging will be implemented to increase the flood discharge capacity. When water accumulates in low-lying areas, personnel are dispatched to debug, card traffic on-site and orderly organize the discharge work of the mobile pumping station.

#### 4.6 River efflux system

The main stream of Shenzhen River and the tributary Liantang River are boundary-rivers between Shenzhen and Hong Kong. Shenzhen River, belonging to the bay river system, originating from the Niuweiling in the upper reaches of the Huangniuhu reservoir, flowing through the Shenzhen Reservoir and Luohu District and joining the Pearl River Estuary in Shenzhen Bay, locates on the east side of the Pearl River Estuary. The drainage area above the estuary section is 297.36km<sup>2</sup> (the area within Shenzhen is 172.06km<sup>2</sup> and the area within Hong Kong is 125.30km<sup>2</sup>). The average river channel ratio is 1.3‰. In the basin, there are 36 rivers including 1 main stream the length of which is 14.49km, 5 primary tributaries and 30 secondary and tertiary tributaries and the total length of the river channels are 58.54km.

### 5 Conclusions

In Shenzhen urban development is concentrated after the reform and opening up and urban construction is concentrated in a relatively short period of time. As a result, the urban flooding projects are also modern that reflects the characteristics of smart management. The flood control measures such as rainwater collection, pipeline network drainage, reservoir storage, flood storage and detention basin, pumping station, emergency scheduling are used to reduced the impact of rain and flood disasters in the city and it has proved to be effective withstanding the test of several extraordinary heavy rains in recent years in Luohu District and Futian District. When super-standard rainfall occurs, mobile pumping stations are performed by dispatching to reduce the influence of rainwater accumulated as soon as possible.

In general, the flood management system of overall planning, emergency scheduling, preparation before flood, key area on duty, and post-rain response has

played an active role in disaster prevention and reduction. The flood management system has reached a high level and the drainage system basically meets the discharging requirements of urban rainstorm and rainwater in Shenzhen River basin.

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