

Sustainable Improvement of Urban River Network Water Quality and Flood Control Capacity by a Hydrodynamic Control Approach-Case Study of Changshu City

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Abstract. Water environment of urban rivers suffers degradation with the impacts of urban expansion, especially in Yangtze River Delta. The water area in cities decreased sharply, and some rivers were cut off because of estate development, which brings the problems of urban flooding, flow stagnation and water deterioration. The approach aims to enhance flood control capability and improve the urban river water quality by planning gate-pump stations surrounding the cities and optimizing the locations and functions of the pumps, sluice gates, weirs in the urban river network. These gate-pump stations together with the sluice gates and weirs guarantee the ability to control the water level in the rivers and creating hydraulic gradient artificially according to mathematical model. Therefore the flow velocity increases, which increases the rate of water exchange, the DO concentration and water body self-purification ability. By site survey and prototype measurement, the river problems are evaluated and basic data are collected. The hydrodynamic model of the river network is established and calibrated to simulate the scenarios. The schemes of water quality improvement, including optimizing layout of the water distribution projects, improvement of the flow discharge in the river network and planning the drainage capacity are decided by comprehensive Analysis. Finally the paper introduces the case study of the approach in Changshu City, where the approach is successfully implemented.

1. Introduction

The Yangtze River Delta has favorable natural conditions, good geographical conditions, solid economic base, advanced science, technology and culture education, with convenient land and water transportation. It is the most economically advanced region in China. There are complex river network, abundant precipitation, and rich water resources. Water environment of urban rivers suffers degradation with the impacts of urban expansion[1]. Some urban river channels were occupied in the process of urbanization. A large number of sluice gates make the urban river network be isolated. The sludge and contaminants in the urban river continuously deposited. Few of water functional areas could meet the water quality standard. Many urban rivers were polluted and the aquatic environment deteriorated[2-3]. Therefore, the water environment of the river network regions to be improved urgently.



The purpose of the hydrodynamic control approach for urban flood control and water environment improvement is to apply the solutions for the occupied city river, the deterioration of the water environment, the slowly velocity of river network, poor water quality and other difficult problems in Yangtze River Delta. Urban river water environment is an important element for peoples life. The river system in Changshu City is typical urban river network in Yangtze river delta[4]. It faced all the above problems and additional flood control problem. The paper introduces the hydrodynamic control approach which combining urban flood control with water environment development. It can realize almost all of the rivers flow smoothly in Changshu city, the reliable protection of the flood containment and the improvement of the river water ecological system.

2. Methodology

The approach can effectively improve the urban water environment and enhance urban flood control capacity. The basic ideas and the key techniques are listed below.

2.1 Basic ideas of improvement the urban river network

Step 1: Identify the clean water sources.

The water sources should be sufficient and the water quality should be much better than that in the urban rivers, i.e. the water in Yangtze river. Also, the selection of the water sources is according to its locations in the drainage basin and regional river network. The water sources are diverted into city by pump station or by water level differences.

Step 2: Water intake and outlet routes.

The selection is according to the landform, river system pattern and the existing urban clean water channel. There are usually more than one water intakes and outlet. The major rivers are usually chosen as the intake or outlet channels. The water level in the intake channel is higher than the outlet. The water level differences are created by the existing gates and weirs artificially. The pump-sluice stations are planned in the intake and outlet, which are helpful for flood control and create the hydraulic gradient.

Step 3: Estimation of the water-recycling rate in demand in the urban river network.

The maximum water-recycling rate of the river network can be estimated according to the urban river storage capacity and the capacity of the pump for water intake. The total urban river storage capacity can be calculated by the hydrodynamic model.

Step 4: Making the river flow smoothly by creating water level difference artificially.

The water levels in the river are planned and arranged according to the hydrodynamic model. Sluice gates and weirs are controlled to create water level differences. Avoiding to use the pumps in the urban area. Some weirs may be built to control if there is no existed gate. Water flow smoothly by the hydraulic gradient.

Step 5: Improvement of water quality sustainably.

The flow velocity increases in the urban rivers, which increases the rate of water exchange, the DO concentration and water body self-purification ability. The water quality improves day by day.

Step 6: Improvement of the flood control capacity.

For some cities, there are no gate-pump station around the city. The city may be suffered flood by heavy rainfall. The stations are planned in the outlet of the rivers around of the city to improvement of the flood control capacity. During the non-flood season, these stations can be used to intake clean water or making the water level differences.

2.2 Key techniques

The above ideas are realized by the following key techniques [5].

(1) Site survey. Assessing the conditions and problems of the gate-pump station and rivers by site survey. There are some common problems in the urban rivers. The water almost does not flow in the rivers. Water quality looks not good. Water blackening and stink in some rivers. Some rivers are not

connected. The date of gate-pump stations are different from the books. The scheduling operation of these stations are not intelligent, etc.

(2) Prototype observation. The water level, flow rate and water quality of the urban river are observed synchronously. These data can be used for calibration and verification of the hydrodynamic model. And it also can provide the information for analysis.

(3) Hydrodynamic model. The one-dimensional hydrodynamic model is constructed by InfoWorks RS or InfoWorks ICM, and the model is calibrated with the measured data. The error can be reduced to less than 2cm, and the model can be used to simulate the scenarios closing to the reality.

(4) Scheme analysis. Scenarios are simulated, including the status of the gate-pump station, water level, discharges, velocity, the raising of water level when flooding, etc. A proper scheme for the urban river network are determined. All the rivers can flow or enhance the flow velocity in a certain district.

(5) Site test. According to the scheme, a site test can be conducted by controlling the existing projects and some temporary facilities.

3. Case study of Changshu city

3.1 The current situation of water system

Changshu is under the jurisdiction of Suzhou, in Jiangsu province. It located in the north of Suzhou City, east of Wuxi city and south of Yangtze river. Total area of Changshu is 1264 km². The main urban area is about 60 km², where is the case study area. There are typical river network. Changshu belongs to the Taihu Lake basin. The key rivers are Haiyangjing River, Baimaotang River, Changxu River, Yuanhetang River, Genjingtang River and so on.

There are over 150 rivers, 99 gate or/and pump stations in the urban area and the total length of the river is 159.3km, as shown in Figure 1. There is Mount Yu in the east, Shanghu Lake and Kuncheng Lake in the south. The major problems of the rivers are listed as bellow,

a) Rivers in Changshu are radial water system. The ancient city are in the centre about 2 km². There are 10 divergent key rivers and 3 circular key rivers, as shown in Figure 2. Therefore it is difficult to make all the water in the river flow smoothly.

b) The rivers are lack of external control engineering facilities.

c) It is hard to pump the water into all the urban rivers. Because the large proportion water flows directly from the main river.

d) The river water is turbidity and the sense is poor, because the dredging is not complete and the water is polluted.

e) A large number of the urban rivers are lost or disconnected during the city expansion process.

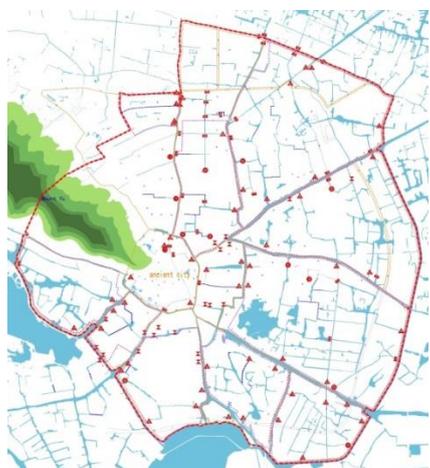


Figure 1 Urban river network of Changshu (red points are gates and pumps)



Figure 2 Key rivers of Changshu city

3.2 Sustainable scheme to improve the urban river network of Changshu

The hydrodynamic model of Changshu consists of 1135 river sections, 790 river reaches adding up to 129km and 281 cross points, which is constructed by the InfoWorks RS software. In the software the gates and pumps are processed with linear object and the corresponding buildings are constructed between the sections. Then the building size information and the corresponding rules should be given in the software. The sub watersheds are determined by the scope of the river boundary and use the side stream object to associate the watershed to the river sections. The model is constructed to create a total of 93 catchments, as shown in Figure 3. The planning scheme in Changshou City consists 3 gates, 7 gate-pump stations and 5 rotated weirs, with the total capacity of $170\text{m}^3/\text{s}$, as shown in Figure 4. The gate-pump faculties are used to control the flood in the flood seasons and to improve the water quality in the non-flood seasons. In the non-flood seasons the gate-pumps are used to pump the fresh water from Yangtze River into the Changshu. The main water diversion channel is Haiyang River, with good and stable water quality, and the maximum pump diversion flow is $30\text{m}^3/\text{s}$. Minor diversion channel is Shanqian River. When the Wangyu River water quality is good, Shanqian River is used as a fresh channel which can provide the flow of $12\text{-}13\text{m}^3/\text{s}$. 5 rotated weirs are planned to enhance the control ability in the city. Together with the planned flood control facility, all the rivers in the city can be controlled artificially. Schemes for the whole and part of the urban area are simulated.

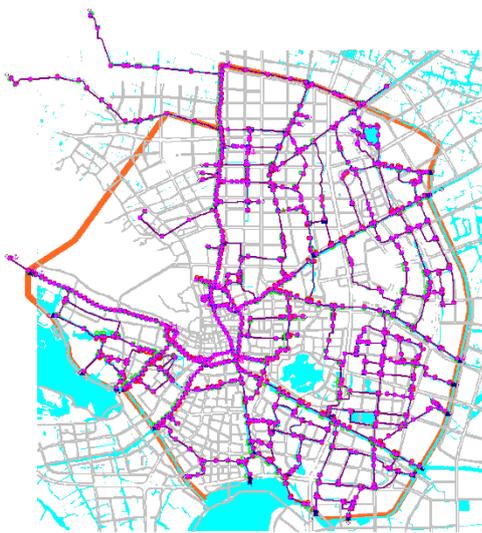


Figure 3 Hydrodynamic mathematical model of Changshu city

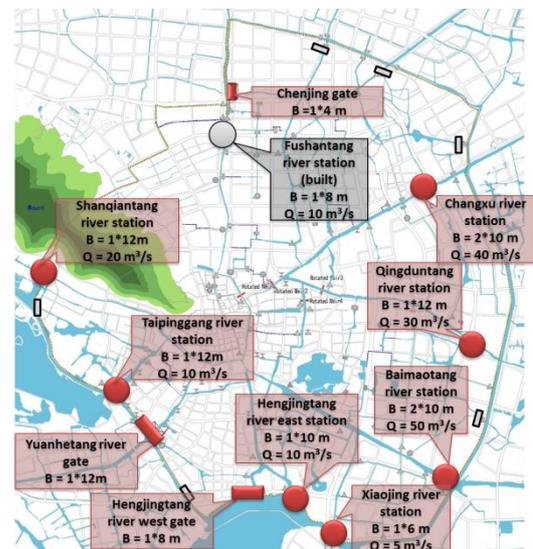


Figure 4 Planning flood control projects (projects can also be used to improve the water environment)

3.3 The implementation effects

Through the establishment of flood control area and control of the regional gates, the following effects can be achieved: a) Flood control standard can be add up to 100 years, the drainage standard can be add up to 20 years. b) Almost all of the rivers can flow. Especially, the flow can increase to $1.5\text{-}2.0\text{m}^3/\text{s}$ in the ancient City region, and the replacement of the whole water can be 2-3 times a day in ancient City region, 3-4 times a day in other areas. c)It can eliminate the black and smelly water in the river completely and improve the river water quality to meet the basic landscape water standard comprehensively.

4. Conclusion

This study shows a hydrodynamic approach to improve the urban river network based on hydrodynamic mathematical model. The hydrodynamic model is one the most significant tools for the improvement of urban water environment and the governance of urban waterlogging. In addition,

urban river network hydrodynamic model can accurately simulate the hydraulic characteristics, such as, water level, flow velocity, and flow pattern of urban river. Meanwhile, it was utilized to analyze the scientificity and rationality of the project, which provided great help on the formulation and implementation of plans

This study reasonably improved the flow velocity and adjusted the water level by use of the existing gate-pumps and some planning projects, creating hydraulic gradients. It realized the comprehensive control of urban water environment.

The self-adjustment and self-maintenance of urban water system can be realized through the hydrodynamic control approach which can both improve urban water environment and manage urban waterlogging at the same time. Therefore, the hydrodynamic control approach, which combined with city flood protection and water environment promotion, is sustainable, economical, and worth popularizing and applying.

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