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Sponge City Construction Based on Comprehensive Watershed Management

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Abstract:

With the development of society, water problems caused by traditional urbanization have become increasingly serious. Sponge urban construction has begun to emerge, based on the sustainable concept, to improve the urban water system. In the urban renovation, however, designers and builders often do not consider the scope of the watershed comprehensively, which is easy to cause certain harm to the upstream and downstream cities. Therefore, it is significant to carry out innovative design of sponge city based on comprehensive watershed management. Based on the overall view of the basin system, this study puts forward improvement measures for the construction of sponge city, and uses SWMM model to simulate the flow and other parameters, and finally analyzes the benefits. The results show that: (1) The construction of the new sponge city can improve the drainage status of the city and the basin. The peak displacement effect can reach 20%, the peak reduction is about 65%, and the slope of the drainage curve slows down. (2) Implementing new measures of sponge city construction can improve the level of system ecology. The system ecological coefficient is increased from 0.65 to 0.78, the efficiency improvement rate can reach 20%, and the water quality improvement rate can reach 14%. This study provides some measures and ideas for the regional coordinated development of sponge city construction, which is conducive to sustainable development.

Keywords: Sponge city, comprehensive watershed management, regional coordinated development, sustainable development.

1. Introduction

With the rapid urbanization process, the traditional urban construction uses a large number of hard pavement and impervious ground, which seriously affects the natural water circulation system of the city. Urban waterlogging, river pollution, water shortage and other problems are becoming increasingly prominent, which brings great challenges to the life of urban residents and the sustainable development of cities.

In this context, the concept of sponge city came into being. Sponge City takes a series of ecological measures, so that the city can be like a sponge, absorb, store and purify rainwater when it rains, and release it when needed, to effectively improve the urban water problem.

The integrated basin management considers the management and protection of water resources on a larger scale. As a complete ecosystem, the utilization and protection of water resources should consider the relationship between upstream and downstream, left and right banks, surface and groundwater. Through comprehensive watershed management, the sustainable utilization of water resources can be realized, the ecological environment can be protected, and the coordinated development of regional economy and society can be promoted.

2. Literature Review

2.1 Sponge City

The concept of sponge city was first proposed in China, aiming to solve the problem of urban water resources management by means of natural accumulation, natural infiltration and natural purification. In recent years, sponge city construction has been widely concerned and practiced in the world. Many countries and regions have begun to formulate and implement policies and plans related to sponge cities. For example, China launched the sponge city construction pilot work in 2015, selected a number of cities for pilot, and achieved certain results. These policies and plans provide institutional guarantee and technical guidance for sponge city construction [1].

Sponge city construction involves a variety of technologies and measures, including permeable paving, green roofs, rain gardens, wetland parks, etc. These technologies and measures have been widely used in different cities and regions, with remarkable results, and are constantly optimized and improved. For example, permeable paving technology can effectively reduce surface runoff and increase rainwater penetration [2]. Green roofs can reduce urban heat island effect while absorbing rainwater [3]. At the same time, there have been many successful sponge city construction cases at home and abroad. For example, the construction of “garden city” in Singapore, the “low impact development” (LID) model in the United States, and several pilot cities in China (such as Shenzhen, Wuhan) have all achieved remarkable results in the construction of sponge cities [4]. These cases provide valuable experience and reference for other cities.

2.2 Integrated Basin Management and Small Basin System View

Integrated watershed management considers the management and protection of water resources on a larger scale. As a complete ecosystem, the utilization and protection of water resources should consider the relationship between upstream and downstream, left and right banks, surface and groundwater. It is necessary to formulate a scientific and reasonable comprehensive plan to consider the development and utilization of water resources, ecological environmental protection, flood control and disaster reduction and other factors. For example, the comprehensive management plan of major rivers such as the Yangtze River Basin and the Yellow River Basin has been implemented for many years and has achieved certain results [5]. These plans provide scientific basis and action guidelines for integrated watershed management. On the other hand, the comprehensive management of small watershed is based on the basic principles of comprehensive management of large rivers and rivers, taking small watershed units of 1~10km2 as the management objects, and on the basis of comprehensive planning, reasonable arrangements are made for agricultural production and other industries, and comprehensive soil and water loss control measures are laid according to local conditions, so as to realize the protection, improvement and rational utilization of natural resources.

One of the important contents of comprehensive watershed management is ecological restoration, which aims to restore and protect the ecological function of the watershed through vegetation restoration, wetland protection, and river improvement. For example, ecological restoration projects in the Yellow River Basin have achieved remarkable results in improving water quality and restoring biodiversity [6]. These ecological restoration measures not only improve the ecological environment of the watershed, but also improve the flood control capacity of the watershed. Comprehensive watershed management also includes scientific water resources management, through the establishment of sound water resources management system, reasonable allocation of water resources, to ensure all kinds of water demand in the watershed. For example, the South-to-North Water Diversion Project aims to alleviate the shortage of water resources in northern China by transferring water across watersheds [7]. This cross-basin water transfer project alleviates the problem of regional water resource imbalance to a certain extent.

Sponge city and watershed comprehensive management are important means to deal with urban water problems and watershed ecological environment problems. Although some progress has been made in policy, technology and practice, it is still necessary to further strengthen

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research and practice to explore more scientific, rational and sustainable governance models to cope with the increasingly complex water resources and ecological environment challenges. Therefore, this study chooses the southeast of Tianjin as the research area to carry out the innovative sponge city design combined with the concept of watershed system.

3. Sponge City Construction

3.1 Research Area

In this study, the southeast of Tianjin in North China is selected as the research area.

(1) Landform

Tianjin is located at the eastern foot of Taihang Mountain, which is a sloping plain in the middle and upper part of the foreland alluvial fan. The general trend is higher in the northwest and lower in the southeast. The elevation is between 105 and 65 meters, with a natural slope of 1.3 parts per thousand.

(2) Climate

Tianjin is located in the north temperate zone of semi-arid, semi-humid monsoon climate. It is characterized by an obvious continental monsoon climate and four distinct seasons. The average daily temperature is 14 degrees Celsius; The average annual precipitation is 600 mm, during the same period of rain and heat, the distribution of rainfall within the year is uneven, the flood season (April to September) rainfall is large, rainfall concentration, during the rainfall accounted for about 85% of the annual total, and the flood season rainfall intensity is large, rainfall frequency is high, most of the rainstorm, easy to form flood disasters.

(3) Hydrology

Tianjin belongs to the Ziya river system, its upstream river for the Hutuo River and Fuyang River, flows through the Xianxian hub after the confluence, through the Ziya new River in Tianjin from the lower, in the Binhai New Area into the sea.

3.2 Sponge City Optimization Based on Watershed System View

3.2.1 Design objectives and contents

Based on the watershed system view, considering the overall development of the watershed and the coordinated development of upstream and downstream regions, the facilities of sponge city are optimized as follows:

(1) Reservoir tapping potential. There is no water supply task in the upstream reservoir, the discharge structure can be reformed, the elevation of the spillway can be lowered, and the sluice gate can be added to pre-discharge, so as to ensure that the reservoir does not discharge under a rainstorm in 100 years, and the peak can be cut by 40 m^3/s, increasing the flood storage by 550,000 m^3.

(2) River regulation. Both sides of Tributary 2 and Tributary 3 are currently and planned to expand the land space. The Ziya Water System Planning (2017-2035) proposes to expand the land space, and the regulation range is 2.1 km and 1.5 km respectively from the estuary to the upper reaches, with widths of 5 m and 11 m respectively.

(3) Wetland Park. At present, the new wetland park area is green land and farmland, the planned land type is green land, increase the storage capacity, and add gate control, when the river water level exceeds the threshold, the flood diversion can be carried out, and the flood peak can be reduced by 15 m^3/s.

(4) Low water pumping. Low-water pumping and drainage were carried out in low-lying local areas without old city reconstruction. The low-water area was 3.1km^2, and four rainwater pumping stations were set up, with a total scale of 25 m^3/s.

(5) Urban land runoff control. According to the overall view of sponge city and watershed system, the design adjustment factors and runoff control rate are designed. The runoff control objectives of urban plots are shown in Table 1.

Table 1. Runoff control objectives for urban plots [8]

No.	Land type	Adjustment factor	Annual runoff control rate/ %
P	Public facilities	0.84	70
W	Waters	1.00	-
G	Greenbelt	1.75	90
A	Agricultural land	1.75	90
E	Educational land	0.84	70
T	Transportation land	0.54	55
U1	Water supply land	0.54	55
U2	Water treatment land	0.84	75

3.2.2 Research results and analysis

As shown in Fig. 1, from a small-scale perspective, after system optimization, the peak time of the system is delayed from 25 minutes to 30 minutes, and the peak shift effect can reach 20%. The peak reduction is 40L/s, about 65%, and the peak reduction effect is significant. At the same time, the slope of the drainage curve slows down, and the pressure of the downstream water decreases, which is conducive to the comprehensive management of the basin. Li et al. [3] showed in 2017 that sponge cities can effectively reduce surface runoff and alleviate urban waterlogging through permeable paving, green roofs, rain gardens and other measures. This study is consistent with its findings.

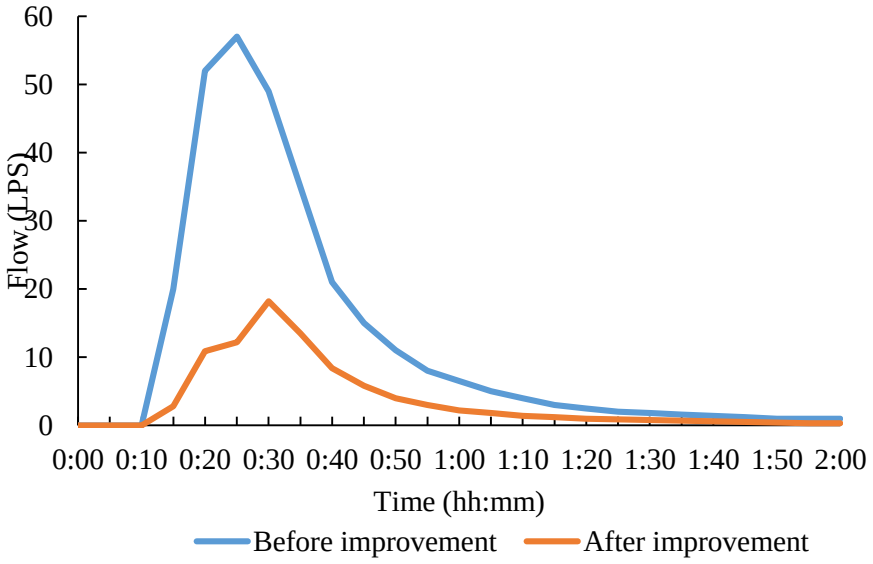

Fig. 1 Flow diagram of catchment before and after optimization

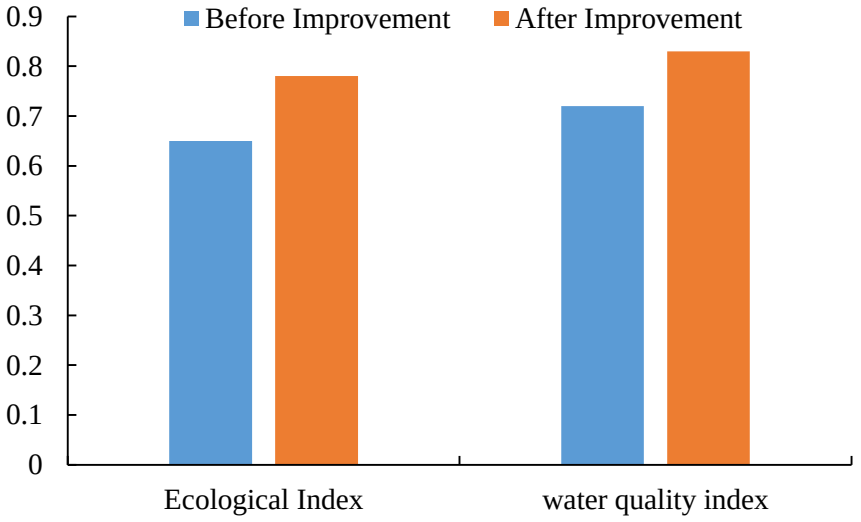

Fig. 2 Comparison of ecological benefits before and after optimization

This study is designed to increase the total area of urban green space and water by 2 km^2, which is conducive to improving the quality of urban ecological environment and increasing biodiversity. At the same time, it can improve the quality of life of urban residents, provide more leisure and entertainment space, and enhance the livability of the city. After system optimization, the ecological coefficient of the system was increased from 65 to 78, and the efficiency improvement rate could reach 20%, while the water quality was increased from 7.2 to 8.3, and the improvement rate could reach 15.3%, with significant effects, as shown in Fig. 2 after normalized analysis. This is consistent with the research results of Li et al. in 2017 [3]. Basin comprehensive management is systematic and comprehensive, considering the development and utilization of water resources and ecological environment protection.

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In this study, measures such as wetland protection and river regulation were taken to prove that comprehensive watershed management can effectively restore and protect the ecological functions of the watershed, which is consistent with Liu et al.'s research results in 2017 [6]. In addition, by comprehensively considering the overall situation of the basin, this study slowed down the drainage rate, reduced downstream pressure, and improved the flood control capacity of the basin, which was also illustrated by Yang et al. 's report in 2016 [5].

4. Conclusion

This paper mainly studies the innovative construction of sponge city based on the holistic view of watershed system, and draws the following conclusions:

(1) After improving the comprehensive management measures of the new sponge city and the basin, the drainage situation of the study area can be improved, and the peak drainage effect can reach 20%, and the peak reduction is about 65%, and the peak reduction effect is significant. At the same time, the slope of the drainage curve slows down, and the pressure of the downstream water decreases, which is conducive to the comprehensive management of the basin.

(2) Sponge city construction based on basin system concept can also optimize basin ecology. The ecological coefficient of the system is increased from 0.65 to 0.78, the efficiency improvement rate can reach 20%, and the water quality improvement rate can reach 14%, the ecological benefits are obvious, and the measures in this study can effectively restore and protect the ecological functions of the basin.

(3) The goal of integrated basin management is to achieve rational allocation and sustainable use of water resources through regional coordinated management. The construction of sponge city has changed from small to large at the scale level, from only taking small areas as the design unit to comprehensive consideration of basin conditions and coordinated regional development, which can effectively alleviate the water management contradictions of upstream and downstream cities in the basin. At the same time, taking the basin as the entry point to carry out the landing of innovative measures of sponge city, can further coordinate the restoration and improvement of regional ecological environment, and is more conducive to sustainable development.

(4) The optimization of sponge city construction and comprehensive basin management have shortcomings while producing benefits. Especially in the aspects of infrastructure transformation and new technology application, the construction of sponge city requires a large amount of capital investment, and this study pays little attention to this aspect. In addition, due to the comprehensive application of various technologies and measures involved in construction technology, the technical complexity is high, the implementation is difficult, and the facility needs regular maintenance and management, and the maintenance cost is high. At the same time, the characteristics and management level of upstream and downstream and surrounding cities and regions should be fully considered in the comprehensive watershed management, which is difficult to coordinate. Therefore, the sponge city based on the concept of watershed system needs to be further verified in the implementation level.

In general, sponge city construction and comprehensive basin management have advantages and disadvantages, which need comprehensive consideration and scientific planning according to specific conditions. By strengthening policy support, technological innovation and multi-party collaboration, the advantages of sponge cities and integrated basin management can be better leveraged to promote sustainable development of cities and basins.

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