Building climate resilience and water security in cities: Lessons from the sponge city construction of Zhengzhou, China

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Chinese government launched the “sponge city program” in 2013 to deal with waterlogging and floods in urban area. It aims to reduce the negative impact of rainwater at its source, enhance rainwater infiltration and prevent or reduce runoff generation. Zhengzhou was selected as the provincial sponge city pilot city in Henan province of China in 2016. River system not only provides water resources for cities to meet the needs of human’s survival and development, but also be a typical “sponge body” of the city (a natural discharge channel) to guarantee urban flood control safety. Zhengzhou carried out the planning of river system improvement project which mainly includes thress aspects: water surface expansion planning, revetment ecological restoration planning and waterscape and water culture construction improvement planning. Zhengzhou also expand green space area and adopt green infrastructures which achieved good ecological and environmental benefits also have positive impacts on improving the sponge city construction.

Key Words : *Sponge city, river system, green space, green infrastructure, urban water-logging and flood*

1. Introduction

Due to the extreme precipitation events caused by climate change and the rapid development of urbanization, surface water flooding is the most serious water problem faced by many cities around the world. However, traditional drainage method, which aims to reduce the peak rainwater flow by diverting the runoff to the detention basin areas, has been unable to load the huge amount of water brought by heavy rainfall. In order to solve this problem, Chinese government launched the “sponge city program” in 2013 to deal with these challenges. It aims to reduce the negative impact of rainwater at its source, enhance rainwater infiltration and prevent or reduce runoff generation. River system and green space system, as important “sponge bodies” of sponge city construction, play a significant role in rainwater management.

This paper clarified the concept and developme of sponge city in China and analyzed the sponge city construction in Zhengzhou city through reading literature and news, collecting government policy information and making telephone interview with relevant personnel. In the end of the paper, discusses about the role and function of river system and green space system during the construction of sponge city were made and the importance of both system in reducing the risk of urban flood and waterlogging was pointed out.

2. Sponge city

Sponge city is a new generation of urban stormwater management concept, which means that the city has good flexibility in adapting to environmental changes and coping with natural disasters brought by rainwater, which can also be called “water elastic city”. Different with the traditional urban rainwater management, sponge city refers to the city will work as a sponge that absorbs water when it rains heavily and releases water when it is short of water.

(1) Concept of sponge city

According to the social and economic differencies, rain flood patterns in foreign countries are classified into different categories. Sustainable Urban Drainage system (SUDs) in the UK focuses on solving urban rainwater problems. Water Sensitive Urban Design (WSUD) in Australia focuses on wastewater and water supply by comprehensive means. Low Impact Urban Design and Development in New Zealand (LIUDD) emphasizes to reduce the environmental impact through water pollution management. The Seattle Public Utilities' Low Impact Development (LID) program in the United States is to build an ecosystem based, source control oriented and sustainable development rainwater and flood management system. Although there are differences in the management systems of rainwater and floods, in general, it is through the deep management of rainwater and sewage to reduce the environmental impact. The concept of sponge city in China is mianly learnt from the LID program in the United States. At the same time, it also focuses on ecological development in combination with LID and green infrastructure construction. The surface runoff will be dispersed through natural infiltration, and rainwater will be purified by biological path and stored to strengthen rainwater reuse.

Traditional urban construction mainly adopts impervious pavement. In case of heavy rain, the drainage mainly relies on the gray facilities which include pipes, canals and pumping stations. Building sponge city needs to change the main planning and design concepts from "rapid drainage and centralized terminal control" to "slow discharge and slow release" and "source dispersion control", so as to avoid flooding and effectively collect rainwater. Futhermore, according to the Technical Guidelines for Sponge City Construction (Trial Implementation)[1], priority should be given to green measures, which include grass ditch, water seepage brick, rainwater garden, depressed green and etc. to organize rainwater drainage. There are three main construction approaches of sponge city: ecosystem protection, ecosystem restoration and LID. The core guiding ideology of sponge city is the concept of LID. There are a series of LID facilities could be adopted based on different conditions of cities. According to Technical standard of sponge city construction system in Henan Province[2], Table.1 shows the suggestions for selection of various facilities of sponge city in different land types.

Table.1 Suggestions for selection of sponge city facilities in various land types

Technology type	Facilities		Land use types				
			Architecture and community	Urban roads	Green space and square	Urban water system	Cultural monuments
Infiltration	Pervious pavement		Suitable	Suitable	Suitable	Could be used	Could be used
	Green roof		Suitable	Not suitable	Not suitable	Not suitable	Not suitable
	Depressed green		Suitable	Suitable	Suitable	Could be used	Could be used
	Bio-retention measure	Simple type	Suitable	Suitable	Suitable	Could be used	Not suitable
		Complex type	Suitable	Suitable	Could be used	Could be used	Not suitable
	Seepage pond		Suitable	Could be used	Suitable	Not suitable	Not suitable
Retention	Regulating pond		Suitable	Could be used	Suitable	Could be used	Not suitable
	Regulating pool		Could be used	Could be used	Could be used	Not suitable	Could be used
Storage	Wet pond		Suitable	Could be used	Suitable	Suitable	Not suitable
	Rainwater wetland		Suitable	Suitable	Suitable	Suitable	Not suitable
	Impounding reservoir		Could be used	Not suitable	Could be used	Not suitable	Not suitable
	Rainwater tank		Suitable	Not suitable	Not suitable	Not suitable	Not suitable
Purification	Vegetation buffer zone		Suitable	Suitable	Suitable	Suitable	Not suitable
	Initial rainwater drainage facilities		Suitable	Could be used	Could be used	Could be used	Not suitable
	Artificial soil infiltration		Could be used	Not suitable	Could be used	Could be used	Not suitable
Drainage	Grass swale		Suitable	Suitable	Suitable	Could be used	Could be used
	Seepage pipe		Suitable	Suitable	Suitable	Not suitable	Could be used

(2) Development of sponge city

In order to establish a scientific and reasonable urban drainage system, and deal with the internal and external disasters caused by climate change, the concept of "sponge city" was first proposed in 2012 Low Carbon City and Regional Development Science and Technology Forum in April 2012. In 2013, general secretary Xi Jinping stressed in his speech on China's urbanization conference that China should build a sponge city with natural accumulation, natural infiltration and natural purification. In October 2014, the promulgation of Technical Guidelines for Sponge City Construction (Trial Implementation) refined and combed the concept of sponge city. Meanwhile, other relevant policies and standards for sponge city construction were issued. In October 2015, the General Office of the State Council issued the Guiding Opinions on Promoting the Construction of Sponge City[3], pointed out that the construction of sponge city can effectively control rainwater runoff, and realize a series of urban development modes including natural accumulation and natural infiltration. In 2015 and 2016, two batches of sponge city pilot cities were publicized respectively. In 2017, Premier Li Keqiang's government work report clearly defined the development direction of sponge city, so that sponge city construction is not limited to pilot cities, but all cities should strive to development spone city construction.

3. River system and green space system

(1) River system

In the process of urban formation and development, urban river, as an important carrier of resources and environment, is related to the survival and development of the city. Systematic sponge city construction can effectively solve the problems of urban water ecology, water security, water environment and water resources. As an important part of urban natural ecosystem, urban river has the functions of flood control, drainage and rainwater storage. Strengthening urban river management is an important part of water conservancy work in sponge city construction. It plays an irreplaceable role in restoring urban water ecology, improving urban water security, improving urban water environment and conserving urban water resources. In the aspect of water ecology, the degradation of urban river ecosystem is a global ecological environment problem, and the protection and restoration of river ecosystem is the basic requirement of sponge city construction. In terms of water security, urban river is the main framework of sponge city, which connects buildings with residential areas, urban roads and urban green space, forming a scientific urban flood control and drainage system. In terms of water environment, urban rivers are the main places and channels for storing and discharging rainwater runoff, and are the basic conditions for realizing the functions of retention, infiltration storage and purification of flood water in sponge cities. In terms of water resources, urban rivers are the base of water conservation and regulation, which play a positive role in ensuring the water resources carrying capacity of sponge cities.

(2) Green space

As the main carrier of sponge city system construction, urban green space system is not only responsible for the image publicity of urban greening and beautification, but also the core embodiment of rainwater ecological restoration ability in the rainwater circulation system of LID. In the sponge system, the planning of urban green space system focuses on controlling the surface flow of rainwater, the peak value of flow in rainy season and the pollution degree of surface runoff. Therefore, under the requirements of sponge city system construction, the planning requirements of urban green space system become more detailed and strict. Therefore, the planning layout, structure scale and construction status of urban green space system will also reflect the rationalization degree and implementation quality of sponge city system planning and construction. Under the background of sponge city, the interaction among urban green space, urban environment and urban space should be considered comprehensively when designing green space system. Meanwhile, striving to store, purify and utilize urban rainwater through urban green space sponge without affecting the overall layout of urban planning is also needed to be paid attention on.

According to the current classification standard of urban green space in China, green space in cities can be divided into five categories: park (green space), nursery, protective green space, attached green space and other green space[4]. In the sponge city system, these five different types of urban green space respectively assume the corresponding role and function (shown as Table.2).

Table.2 Five categories of green space in China and their role in sponge city.

	Role in sponge city
Park green space	-Diverse layout with large scale. -As a rainstorm garden, it plays an important role in controlling rainwater runoff, delaying flood peak time and controlling peak flow.
Productive green space	-Have clear ecological function requirements. -Play the role of auxiliary development of sponge city.
Protective green space	
Attached green space	-The most widely distributed and scattered category green space. -Can be used as the main carrier of rainwater runoff flow control in the small and medium-sized areas of the city in a decentralized way.
Other green space	-Could be used as a carrier to balance the relationship between the urban green space and the external environment of the city, and can be used to explore the preliminary development of LID.

4. Sponge city construction of Zhengzhou

(1) Current situation and main characteristics of water resources in Zhengzhou city

Zhengzhou, the capital of Henan Province, is located in the center of the Central Plains. It is adjacent to the Yellow River in the north, Songshan Mountain in the west, and Huanghuaihai Plain in the East and south. It belongs to the monsoon climate of north temperate zone, with an annual average temperature of 14.3 ℃ and an average precipitation of 640.9mm. The rainfall in Zhengzhou city is mainly from June to September, but less from January to April (shown as

Fig.1) [5]. Between 1998 and 2018, the maximum rainfall in Zhengzhou city was 954 mm in 2003 (shown as Fig.2) [6]. The rainfall time distribution is very uneven, and the annual rainfall is less. There are 35 rivers in the territory, which mainly belong to the Yellow River system and the Huaihe River system. The section of Yellow River flow through Zhengzhou city is 150.4km long[7]. Huai River system accounts for the most of the area of Zhengzhou city. The main rivers are Suoxu River, Qili River, Chao River, Jinshui River, Xionger River, Jialuzhi River and etc. Futhermore, from the perspective of spatial distribution, most of the water resource in Zhengzhou city is distributed in the southwest.

Fig.1 Precipitation of Zhengzhou city in 2018

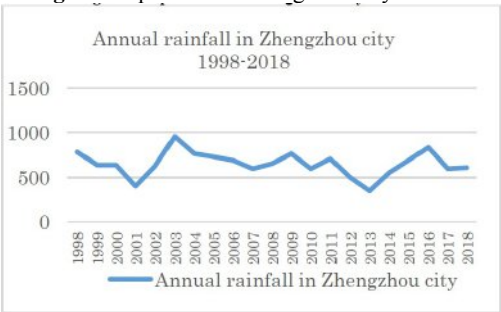

Fig.2 Annual precipitation inZhengzhou city 1998-2018

(2) Change of Zhengzhou under urbanization

In the early 1990s, the urbanization of Zhengzhou city has started. During this period, the rivers in Zhengzhou city had abundant water with good water quality. Most of the rivers were formed by natural scouring and the influence of human activities on the rivers was not significant. Since the 21st century, the urbanization of Zhengzhou city has been accelerating. Economic development has stimulated a large influx of population into cities, but also stimulated the expansion of urban construction land. With the passage of time, the area of impervious surface in Zhengzhou city has been expanding continuously (shown as Table.3). The reduction of length and area of river system and the increase of pollution have damaged the ecological regulation of rivers and increased the risk and frequency of urban flood disasters [8].

Table.3 The area and proportion of four types of land use in 1998, 2002 and 2016 of Zhengzhou city

Types of land use	Indicators	1988	2002	2016
Impervious surface	Area(km2)	178.88	911.19	2335.51
	Proportion (%)	2.4%	12.24%	31.37%
Vegetation coverage surface	Area(km2)	4580.38	5264.04	4599.56
	Proportion (%)	61.51%	70.69%	61.77%
Water body	Area(km2)	192.09	112.29	78.70
	Proportion (%)	2.58%	1.51%	1.06%
Other	Area(km2)	2494.85	1158.68	432.43
	Proportion (%)	33.51%	15.56%	5.80%

However, different with river system, in 1948, the greening scale of Zhengzhou was very small, and the greening of the city had not been carried out (shown as Table.4) [9]. Since the late 1990s, Zhengzhou green space construction has not only made a breakthrough in quantity, but also has a significant change in the concept of planning and design [10]. Zhengzhou puts forward the slogan of "green city" and "garden city". At the same time, with the development of economy, the environmental problems of Zhengzhou city are becoming increasingly prominent. Calling for green and yearning for a fresh and harmonious living environment have become the theme of this era.

Table.4 Transformation of tree's number, green space area and coverage in Zhengzhou

Year	Number of trees	Green coverage (hm^2)	Green coverage rate (%)	Per capital public green space area (m^2)
1948	77	0	0	0
1976	1280000	2466	36.23	
1985	1790000	2400	35.25	2.31
2001	8450000	4468	34.51	5.73

(3) Regulations and policies which related to Sponge city in Zhengzhou city

Zhengzhou city was selected as the provincial pilot city of Henan province in 2016. The Zhengzhou Sponge City Planning and Construction Management Guidelines which established by Zhengzhou Municipal People's Government in 2018 is mainly made based on a series of regulations and policies[11], including Notice on the construction of urban drainage and waterlogging prevention facilities[12], opinions of the State Council on strengthening urban infrastructure construction[13], guiding opinions of the general office of the State Council on promoting the construction of spong city[14], technical guide for sponge

city construction -- construction of low impact development rainwater system (Trial) and etc. The basic principles of Zhengzhou Sponge City Planning and Construction Management Guidelines are consistent with the basic principles of Guiding opinions of the general office of the State Council on promoting the construction of sponge City. The purpose of this guidance is to determine the planning and control objectives of sponge city construction in Zhengzhou city, and to clarify the content, requirements and methods of urban planning, engineering design, construction, maintenance and management with low impact on the construction of development rainwater system.

The goal of sponge city construction is to deal with the relationship between green space, permeable surface and gray buildings. Zhengzhou Sponge City Planning and Construction Management Guidelines (Trial Implementation) put forward the goal of Sponge City Construction in Zhengzhou city which mainly include four goals, including:

- Overall objective

The goal is that by 2020, more than 25% of the built-up area of the city will meet the national target requirements. By 2030, more than 80% of the built-up area of the city will meet the national target requirements.

- Total annual runoff control objectives

As Technical guide for sponge city construction -- Construction of low impact development rainwater system (Trial) which was established by China Ministry of Housing and Urban Rural Development in 2014 stated that because runoff pollution control objectives and rainwater resource utilization objectives can be achieved through runoff total amount control, the total runoff control can be selected as the primary planning and control objective in the construction of low impact development rainwater system[15].The total control rate of annual runoff in Zhengzhou city is 75%, and the control rate of annual runoff in specific construction projects is subject to the indicators determined in the regulatory detailed planning. Based on specific conditions of different areas in Zhengzhou, the specific index of total runoff control rate index of sponge city construction in different areas of Zhengzhou is shown as Fig.3 below.

- Runoff pollution control objectives

The total annual suspended solids (SS) removal rate of rainwater runoff in the construction project area with low impact development is controlled by 40% - 60%.

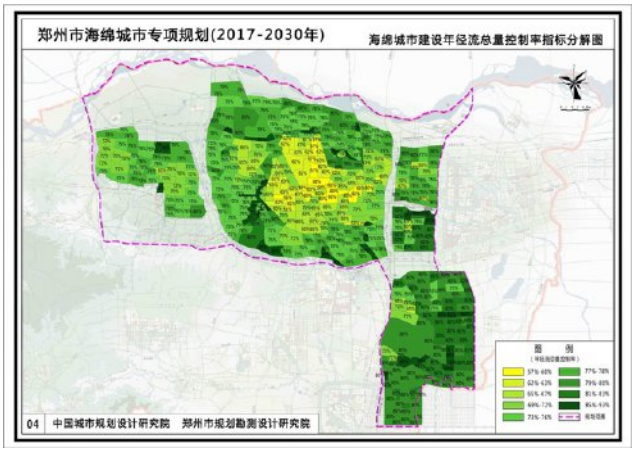

Fig.3 Specific index of total runoff control rate index of sponge city construction in different areas of Zhengzhou city.

- Runoff peak control objective

The principle of runoff discharge in the newly-built area is not to cause serious impact on water ecology and water safety. The peak value of runoff generated after development shall not exceed that before development. When the area is reconstructed, the reconstructed runoff shall not exceed the original runoff.

In addition, in order to standardize the standard of sponge city planning and design scheme, establish sponge city planning technology evaluation system, and comprehensively promote the planning and construction of sponge city in Zhengzhou city, Key Points of Planning and Design of Sponge City Construction Project in Zhengzhou (Trial) was established by Zhengzhou Urban and Rural Planning Bureau in 2018[16].

(4) Sponge City Specailized Plan in Zhengzhou city (2017-2030)

The main contents of Spong City Specialized Plan in Zhengzhou city (2017-2030) include[17]:

- Comprehensively evaluate the construction conditions of sponge city, identify the existing problems in urban water resources, water environment, water ecology, water security and etc.
- Determine the target and specific index of sponge city construction, put forward the index system of sponge city construction.
- Put forward the general idea of sponge city construction, and determine the implementation path of sponge city construction according to local conditions.
- Construct the natural ecological spatial pattern of sponge city, delimit the construction area of sponge city, and put forward the construction guidelines.

- Implement the management and control requirements for sponge city construction, decompose the annual runoff control rate target, and put forward the management and control requirements.
- Put forward suggestions on connection of planning measures and relevant special plans.

The goal of the plan is to build Zhengzhou city into a sponge with the functions of water absorption, water storage, water purification and water release, improve the capacity of urban flood control, drainage and disaster reduction, improve the urban ecological environment and relieve the pressure of urban water resources.

The plan includes six classification index:

- Water ecology:

100% of the natural water area is maintained. By 2030, the proportion of ecological shoreline will reach more than 80%. The heat island effect in the urban built-up area has been alleviated. The average temperature in summer in the sponge city construction area is not higher than that in other areas in the same period, or it shows a downward trend compared with that in the same historical period (excluding the impact of natural temperature change).

- Water safety:

The design return period of waterlogging control in urban area and aviation city is once in 50 years, and that in other planning areas is once in 20 years. The flood control standard of the planning area is once in 200 years.

- Water environment:

The annual reduction rate of total SS is more than 50%.

- Water resources:

In 2030, the utilization rate of rainwater resources will reach 5%, and the recycling utilization rate of sewage will reach 60%.

- Water culture:

Improve the urban water landscape, make full use of water space, inherit traditional water culture, and improve the living ecological environment.

- System construction:

Establish a perfect system and mechanism, and issue relevant documents, including: planning and construction management and control system, blue line and green line protection system, investment and financing mechanism construction, performance appraisal and reward mechanism, and relevant systems to promote industrialization.

As the planning mentioned that a natural ecological spatial pattern of two belts(the wetland ecological belt along the Yellow River and the ecological landscape green belt of the main canal in the middle route of the South-to-North Water Transfer Project), three areas(ecological conservation area, ecological buffer area and sponge construction area), ten corridors(ten river corridors) and multiple nodes(the core node of sponge city construction with regional function built by the original low-lying wetland, important river nodes, large open space, etc) will be build (shown as Fig.4). According to the Sponge City Specilized Plan in Zhengzhou city (2017-2030), river system plays an important role in mitigating the risk of urban floods and waterlogging. The characteristic of Zhengzhou sponge city is to combine water system and green space system to construct a complete sponge system, that aims at solving the rainwater problem and improving flood control and drainage.

Fig.4 Natural ecological spatial pattern of two belts, three areas and multiple nodes.

5. Ecological Water System Project in Zhengzhou city

River system is a natural discharge channel, which is of great significance for urban flood control safety and is a typical sponge body of the city. However, The expansion of urban land, especially the construction of roads, has reduced the connectivity of river systems in Zhengzhou city. The Third Meeting of the Standing Committee of the 14th Zhengzhou Municipal People's Congress deliberated and passed the Comprehensive Improvement Project Plan of Ecological Water System in Zhengzhou metropolitan area in 2014[18]. The plan proposes that through engineering and non-engineering improvement measures, the ecological water system of Zhengzhou metropolitan area will be formed into a healthy water ecosystem, so as to improve the city grade and the quality of life of citizens. The planning mainly includes three aspects: water surface expansion planning, revetment

ecological restoration planning and waterscape and water culture construction improvement planning.

(1) The Project of Ecological Water Cycle around Zhengzhou city

Zhengzhou city is located in the middle and lower reaches of the Yellow River. In recent years, due to the shortage of surface water resources and the reduction of water volume of the Yellow River which was caused by the undercutting of the Yellow River channel, as well as the large-scale exploitation of groundwater by people, the groundwater level drops. Meanwhile, with the gradual improvement of the ecological water system pattern, the water demand of river course is increasing year by year, but the water supply is far from meeting the future demand. The urban ecological water system urgently needs to add new water sources.

"The terrain of Zhengzhou city is high in the southwest and low in the northeast, and most of the rivers originate in the southwest, and finally flow into the Jialu River in the northwest of the city" said by relevant people of Zhengzhou Water Bureau. The water system around the city is to transport the water from the northeast to the southwest. Because it is against the terrain, pumping stations must be set along the way. Using the Yellow River water which come from Niukouyu Yellow River Diversion Project as the water resource, two-stage pumping stations are built in Putian Lake and Chao River. The water is lifted to the upper reaches of Huama Canal, Baishiguntan Canal, Chao River, Shiqili River, Shibali River, Xionger River and Jinshui River through the pumping station and water transmission pipeline, and finally flows into Putian lake through Qilihe river (shown as Fig.5). After the completion of the project, it will provide a reliable water source for the ecological water system of Zhengzhou city, effectively curb the over esploration trend of groundwater, realize water resource conservation and efficient recycling, improve the river ecology, enhance the environmental value of waterfront land, increase the scale of urban water surface and water body, adjust the local microclimate, and improve the ecological landscape environment of urban rivers[19].

(2) River lake connection project

The main ways to discharge the floods caused by heavy rain or large precipitation in urban area are several rivers, including Jinshui River, Xionger River, Qili River, Dongfeng Canal and etc. However, there is an obvious dilemma existed which refers to the narrow rivers and canals. Once there is a rainstorm, a large amount of rainwater in the urban area will be discharged into these rivers and channels in an instant, resulting in the rapid rise of the water level of the rivers and channels and all the rainwater outlets will be submerged. This will make it difficult to discharge the rainwater into rivers and canals. When the large amount of rainwater stay in the urban area for a long time, the waterlogging will occur. Furthermore, in addition to the urban rainwater, in case of heavy rain, the mountain torrents in the western mountainous areas will also flow into the urban area along the terrain, which to a certain extent increases the flood discharge burden of several rivers and canals in the urban area.

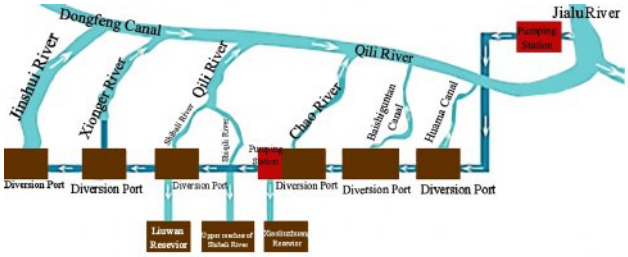

Fig.5 Direction of flood discharge through river system in urban area of Zhengzhou city

For urban flood discharge, Zhengzhou Ecological Water System Planning adopts the idea of flood interception, diversion, discharge and storage. In the early stage of the huge flood, drainage is the main method, while in the later stage of the huge flood and the middle-scale and small-scale flood, drainage and storage will be combined[20]. Based on the comprehensive improvement project plan of ecological water system in Zhengzhou metropolitan area, in the aspect of river lake connection project, the existing and new planned independent, low water source guarantee rate and weak survival capacity single river, lake and regional water area are incorporated into the existing large water system of Zhengzhou city through technical engineering methods such as water source project and river-lake connection project, forming a water system network with hydrodynamic characteristics with multi water source guarantee[21]. In this way, it is conducive to the formation of a living river system context that meets the concept of "three networks in one" of flood control network, water resource allocation network and ecological network(shown as Fig.6) [22]. After all the rivers in Zhengzhou city are connected, the urban rainwater can flow smoothly into the main stream of Jialu through each branch river and flow out of the city safely and then flow into Huai River that will finally

flow into the sea (shown as Fig.7).

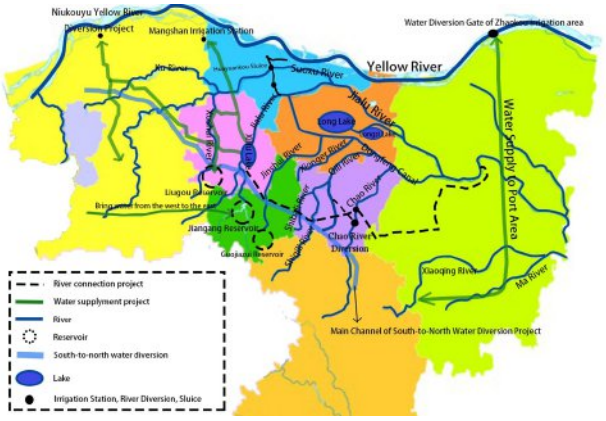

Fig.6 Comprehensive improvement project planning of ecological water system in Zhengzhou metropolitan area.

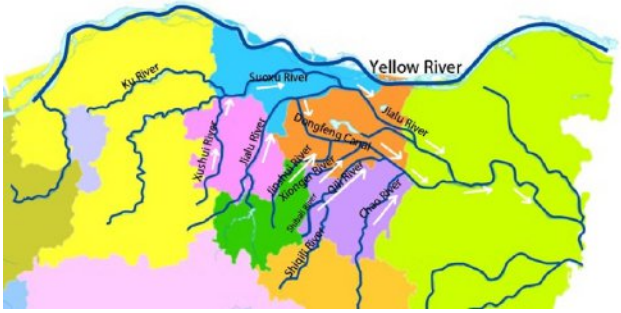

Fig.7 The direction of flood discharge through river system.

(3) Water ecological and water landscape improvement project

In the aspect of water ecological and water landscape improvement project, the plan proposes to take the comprehensive improvement of water environment and the restoration of water ecology as the core, and build a water ecological environment system through engineering and non-engineering measures such as the construction of river ecological treatment and artificial lakes, coastal greening, system construction and etc. In order to integrate the concept of sponge city to build sustainable and healthy rivers, it is also necessary to fully tap the regional culture to improve the activation and renaissance of rivers. In the promotion of water view culture, it was integrated with the transformation of urban water system, which could play an important role in inheriting the history and culture of Zhengzhou city and enrich the cultural and historical connotation of the city.

As the Comprehensive Improvement Project Plan of Ecological Water System in Zhengzhou metropolitan area mentioned that this project has huge economic, social and ecological benefits. For instance, it greatly improved the environmental value of waterfront land. According to the preliminary estimation, the value-added benefit of coastal land will be about 105.6 billion yuan after the ecological water system in Zhengzhou metropolitan area is fully improved. The water surface area ratio of Zhengzhou metropolitan area can be increased from 0.93% (of the current situation) to 3.9% (of the planning) [19].

6. Green space system and greenway system of Zhengzhou city

Most of LID facilities, for instance, grass swale, rain garden, wetland, bio-retention measures and etc., are needed to be applied in green space. Hence, green space is also one of the most important component of sponge city. The construction of ecological green space in Zhengzhou has formed the overall structure of "two rings (the ecological landscape belt of the forth rings and third rings in the city), two belts (the ecological green belt along the Yellow River in the north and the green belt of the Middle Route Project of the South to North Water Diversion Project), two lakes (the surrounding green space of Long lake and Xiliu lake), three wedges (green space extending from the forest green belt built in the north, southeast and southwest of the city to the center of the city) and seven chains (Jinshui River, Xionger River, Qili River, Dongfeng Canal, Xushui River, Chao River and Jialu River as well as the protective green space on both sides of the river)" (shown as Fig.8) [23].

Fig.8 Planning map of ecological green space system in Zhengzhou

In the urban green space system, the water green corridor system is an important embodiment of the urban green space system. According to the Master plan of Zhengzhou metropolitan area (2012-2030) [24], the construction of Zhengzhou ecological corridor mainly includes traffic corridor, water system corridor, municipal corridor and group isolation corridor. Among them, the water corridor construction is divided into three levels.

- Grade I: Main canal of the Yellow River and the middle route of South to North Water Diversion

Project. The width of one side green belt is 200 meters.

- Grade II: It mainly includes Yiluo River, Jialu River, Ying River and Shuanghe river which increases the green area of the main urban area. The control width of one side green belt is 50m.
- Grade III: Tributaries and branch canals of main water systems, and the width of one side green belt should be 10-25m.

Zhengzhou strives to create the urban spatial framework and ecological green space framework which should be interdependent to form the point, line and plane pattern of central point, axis corridor and green space group.

Furthermore, decentralized LID facilities need to be linked into a complete system. Greenway and linear green space has positive impact on the connectivity of green space on a macro level by making linkage among all LID facilities which will finally improve the sponge city construction. Forest greenway (with a width of no less than 200m), ecological greenway (with a width of no less than 100m) and recreational greenway (with a width of 30-50m) constitute the greenway system of Zhengzhou urban area.

The greenway system planning of Zhengzhou metropolitan area is planned that by 2035, 7446 square kilometers of Zhengzhou metropolitan area will be built into a greenway network of "one axis, three rivers, three mountains, three rings and five corridors" (shown as Fig.9). According to the main functions, greenways can be divided into four types: ecological protection type, suburban recreation type, waterfront leisure type and urban service type. According to the spatial distribution of resources, greenways in Zhengzhou metropolitan area are divided into three levels. The first-grade greenway is a global greenway connecting the core scenic spots (shown as Fig.9). The second-grade greenway is the greenway between clusters connecting large and medium-sized landscape nodes (shown as Fig.10). The third-grade greenway is a supplement to the greenway network within the cluster (shown as Fig.11).

In 2012, Zhengzhou started the construction of urban greenway, and Zhongyuan West Road was the first route. At present, there are 69 greenways (sections) in Zhengzhou City, with a total length of 3588 km and a total green area of 300 million square meters. A network ecological pattern of "two rings and 31 radiation" has been initially formed. The greenway connects the urban area, counties (cities) and towns of Zhengzhou, connecting parks, parks, country parks, scenic spots and museums into a line.

Fig.9 The first-grade green way

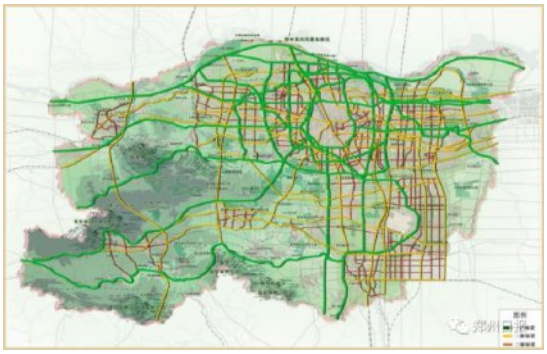

Fig.10 The second-grade green way

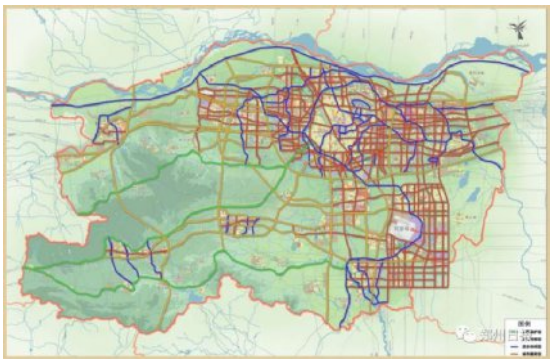

Fig.11 The third-grade green way

7. Discussion and conclusion

According to the statistics of Zhengzhou Urban and Rural Development Bureau, there are 530 sponge city construction projects after the integration of Zhengzhou city. At present, 107 projects have been completed and 42 projects are under construction. The construction of sponge city which has been completed in the central urban area of Zhengzhou, covering an area of 110.8 km^2. Zhengzhou is steadily promoting the construction of sponge city demonstration area. Among them, the public cultural service area and the demonstration area of Long lake area in Zhengdong New District cover a total area of 76.7

km^2. According to the data provided by the Environmental Protection Bureau of Zhengdong New District, the west canal park of Longhu park can collect up to 13000 m^3 of rainwater a year, and the recycled rainwater can be used to irrigate 85% of the green space in the area[25]. Through active exploration in recent years, the regional waterlogging points and polluted water bodies have been eliminated, and the phenomenon of " watching the sea in the city" has been significantly improved. "Through the construction of sponge city, the natural water area of the city has increased year by year, effectively curbing the downward trend of groundwater, and the urban waterlogging and heat island effects have been greatly alleviated." said by relevant people of Zhengzhou Water Bureau.

The construction of ecological water system in Zhengzhou city not only ensures the water supply for the city, but also greatly improves the city's resistance to floods and waterlogging and improve the ecological environment as well. It could provide several experiences to the sponge city construction in the future. In addition, Sponge city construction is a complex system engineering, and cross scale construction strategy is the premise to solve the urban water problem. The construction of sponge city should be undertaken and coordinated from three different levels: macro, meso and micro. Not only should the regional ecological infrastructure be constructed to ensure the water ecological security pattern in the urban area, but also the river and lake water systems in the city should be fully utilized to form a sponge system with local ponding points and catchment areas. At the same time, the construction technology of water ecological infrastructure should be specifically applied to the construction of water collection units such as parks, roads and residential areas. Therefore, starting from the concept of sponge city construction, the approaches of urban river governance are mainly including: build an ecological water network system with river as the framework, optimize the sponge system linked by the river and develop the sponge body with river as the carrier. First of all, the sponge city construction design should be connected with the urban design to control the ecological conditions and build an ecological network (road network, green network and water network are interwoven and connected in series). Secondly, the urban river is taken as the main axis of the system structure to integrate the water space of green land and roads, and to lay out the rainwater drainage system. Finally, the low impact development technology measures are used to strengthen the purification and absorption of rainwater runoff and effectively reduce the total runoff.

As one of the land use types, urban green space is an important carrier of urban ecological environment and landscape, which plays a very important role in maintaining urban ecological balance and improving urban ecological environment quality. In the construction of sponge city, the use of urban green space system to absorb, save, infiltrate and purify rainwater can relieve the huge pressure of urban drainage and sewage treatment. However, the green space area is limited, especially in the extreme rainstorm weather, the "sponge effect" of green space is not obvious, and the control of runoff and flood peak still depends on the urban water network system. This requires the organic integration of urban water network and green network, and the combination of "rapid drainage and quick release" of urban rivers and "slow discharge and slow release" of green space, so as to solve the urban rain and flood crisis.

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