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# Research on Urban Green Rainwater and Flood Infrastructure System

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***Abstract:***

Small and medium-sized cities in low latitudes account for a large proportion of the world, which is characterized by rainy weather and a population of less than 2 million. Such small and medium-sized cities are vulnerable to rain and floods. Taking this as the research object, this paper analyzes the development development of rainwater management and expounds the latest technology of new rainwater and flood management. Based on the in-depth analysis of the formation mechanism and characteristics of water-logging in small cities, this paper puts forward the construction plan of urban green rainwater and flood infrastructure system, which puts forward the construction of infiltration, collection GSI planning and design strategy of rainwater comprehensive utilization mode in multi-functional community with integrated discharge function. Practice has proved that the urban green rain and flood infrastructure system can achieve good results in the field of rain and flood control.

***Keywords**: Rain and flood management; city; Security pattern; infrastructure; system*

## I. INTRODUCTION

According to the white paper on global urban rain and flood disasters issued by UNESCO in 2020, more than half of the world's cities have experienced water logging to varying degrees, and the impact and scope of flood disasters have gradually expanded year by year. During the development and construction of some cities, lakes and ponds are buried and river courses are cut straight, which leads to the blocking of the circulation route of rainwater natural infiltration. The problem of water-logging and ponding in cities under heavy rainfall is becoming more and more serious [1]. Take China as an example. In southern China, heavy rainfall occurs frequently, flooding occurs in many places, and a small number of people are killed or missing due to the disaster which as shown in Fig 1. These situations show that rain and flood disasters have become one of the most important natural disasters in cities all over the world, but the ability of cities to resist rainstorms and manage rain is obviously insufficient. In the context of disaster normalization, the climate and flood problems faced by small and medium-sized cities are becoming more and more serious, and the demand for rain and flood management is prominent.

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(a)Urban rain disaster in China

(b) Urban flood disaster America

Fig 1: Urban rain disaster and flood disaster

Aiming at this situation, this paper puts forward the rainwater and flood management method based on green rainwater infrastructure, introduces the green rainwater infrastructure theory, and puts forward a rainwater and flood management system that can make up for the problems of limited load capacity and difficult transformation of gray infrastructure, so as to achieve the goal of sustainable development of the city in a more ecological way.

## II. DEVELOPMENT AND CURRENT SITUATION

### 2.1 Development

In response to the city's rainwater problem, Western developed countries have introduced "Stormwater management" concept. However, due to different regional background, environmental basis and urban problems, countries have different research priorities in rainwater and flood management. Rainwater and flood management systems formed according to their own urban characteristics have their own similarities and differences, and rainwater and flood management methods and technologies are also quite different in terms of adaptation scale and control objectives. The United States is the first country in the west to introduce modern rainwater and flood management concept as early as the 20th century In the 1950s, a relatively perfect urban "rain sewage diversion" drainage system has been established, but it is also difficult to control the overflow exceeding the pipeline load in case of rainstorm, and the rainwater is directly discharged into the water body without treatment, which is easy to cause water pollution. In order to solve this problem, the US government has promulgated a series of bills to manage urban water pollution. The promulgation of the clean water act in 1982 opened the prelude to the management of urban rain and flood in the United States [2]. The concept of best management measures (BMPs) was put forward in this period and applied to control agricultural non-point source pollution. However, BMPs adopt the end centralized treatment of rainwater, which does not quickly solve the problem of urban rainwater, and the investment cost is high, which is difficult to popularize. In view of this deficiency, the concept of low impact development (LID) is proposed, which aims to manage the source, transmission and

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confluence of rainstorm through small and decentralized technical measures, so as to maximize the utilization of rainwater resources. Different from the drainage and water purification measures with high cost and high maintenance cost, lid is more economical and applicable, simple construction, and can mobilize the participation of the whole people [3]. It is a rain and flood management method that can be widely popularized.

In the 1990s, Britain put forward the concept of sustainable drainage system (SUDs). Suds has changed the characteristics that the traditional urban drainage system only pays attention to "discharge", incorporated the water quality, biological, ecological and other factors and the sustainability of rainwater discharge into the optimization of urban drainage system, and achieved the goal of reducing flood and water pollution from the source to the end. At the same time, the Australian government put forward the rainwater treatment concept of water sensitive urban design (WSUD) for "urban flow syndrome". Its core content is to protect, repair and manage urban rainwater management, sewage management and water supply management as a whole. It not only protects natural water systems such as rivers, lakes, streams and wetlands, but also adds landscape design to rain and sewage treatment to increase ecological benefits [4]. In the 20th century, New Zealand put forward the new concept of low impact urban design and development (liudd) in the research of "sustainable urban investment and development project". Integrating urban design into lid concept does not place too much emphasis on technology, but on reducing the impact of human activities on the environment through low-intensity natural development and planning.

The rain and flood management system model is shown in Fig 2.

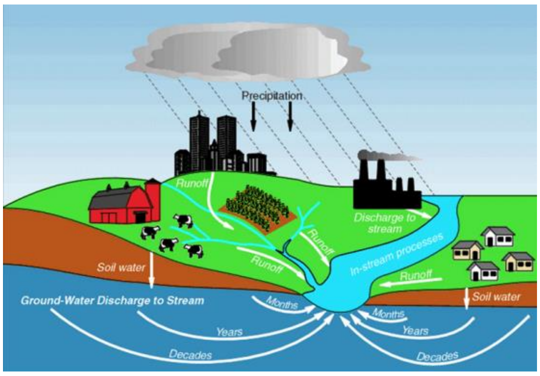


Figure 2: Model of Rain and flood management system

China's rainwater and flood management technology system is mainly based on the code for outdoor drainage (Chinese national standard: gb50014-2) is the core of the construction. The technical system at this stage mainly aims at flood control and drainage, and has not systematically formed rainwater utilization, pollution reduction and other rainwater and flood management concepts. At present, China's rainwater and flood management system is based on sponge cities, and researchers try to use low impact development technology (LID) in cities to change this phenomenon. The administrator tries to use the theory of urban ecology and urban regeneration to apply the characteristic small landscape and regional

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vegetation to the city, so as to build the urban ecosystem.

2.2 Present situation

After decades of development, the rainwater and flood management system has formed rainwater and flood management methods and measures suitable for different regional characteristics. Among them, it is recognized by the academic community that the design concept of multi-scale and multi-level green rainwater and flood management system: BMPs and lid in the United States advocate using some scattered and small rainwater retention facilities to share the rainwater load of urban gray infrastructure and control the water quality of the basin, Make up for the shortcomings of the traditional drainage system. However, if the rainwater management only focuses on the rainwater problems of small-scale sites and public spaces, it is likely to cause greater problems on the watershed scale, such as mountain torrents, debris flows and so on. From the experience of rain and flood disaster management in some developed countries, the development trend of rain and flood management has gradually changed from small-scale control to large-scale comprehensive management, and the content of rain and flood management pays more and more attention to comprehensiveness. The city itself is composed of multiple watersheds. The role of small-scale rainwater facilities is limited and can not take into account the whole urban area. This requires us to explore a multi-scale rainwater and flood management system and adopt different levels of rainwater and flood management measures according to different scales (cities, regions and sites) [5]. In addition, WSUD in Australia and liudd in New Zealand also advocate the combination of rainwater treatment and landscape design, taking social and cultural factors into account, enriching the level and connotation of rainwater and flood management and better guiding the construction of green infrastructure.

The evaluation system matches the green rain and flood management system: its content includes design stage evaluation, monitoring evaluation and economic value evaluation. The scale of the evaluation object includes watershed scale, urban scale and site scale. The evaluation method is appropriately selected according to the conditions of the object. The final result of the evaluation can be used as the acceptance standard of the rain and flood management project, and can also be used as the basis to improve the deficiency of the rain and flood management project [6]. In order to ensure the effective implementation and promotion of the evaluation system, it is necessary to formulate and improve the policies and regulations of rain and flood management and clarify the functions of managers in the process of rain and flood management performance evaluation.

## III. DESIGN OF RAIN AND FLOOD MANAGEMENT SYSTEM

3.1 Design concept

The traditional way of rainwater and flood system to improve water safety is mainly to increase the diameter of rainwater pipe canal or heavy rain pipe canal and other engineering measures, without considering the integrity and complexity of regional rainwater and flood system. The rain and flood management system proposed in this paper takes green as the starting point and takes solving the rain and

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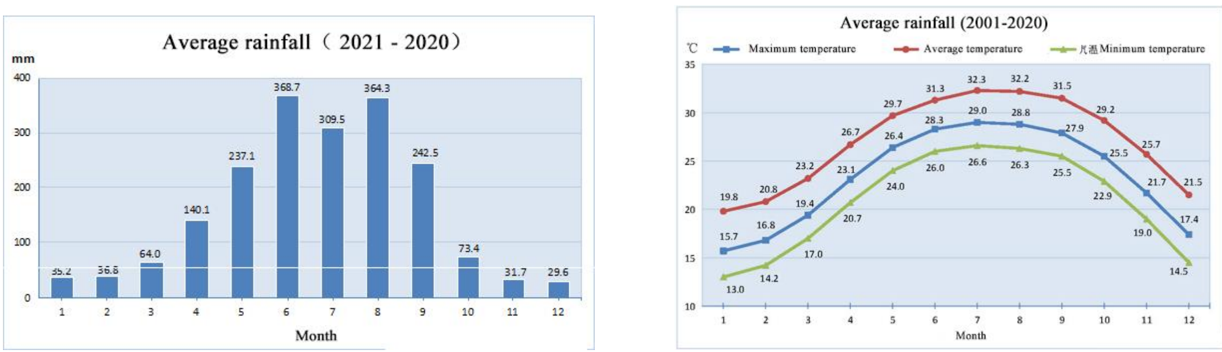
flood problem as a priority in the process of urban development. Reserve runoff channels before urban development and construction, guide relevant construction work with systematic planning, ensure high starting point planning, high standard construction and high-level management, and gradually realize a green rainwater and flood management system with resistance, resilience and adaptability.

3.2 Requirement analysis

Taking Guangming District of Shenzhen, China as the research object. The causes of rain and flood of the object mainly include the following three points:

(1) There are more extreme rainfall in the city: Guangming district is located in the area where coastal typhoons frequently land at low latitudes, and rainstorms occur frequently under the influence of coastal mountain geomorphic belt, frontal rain and typhoon rain. According to the statistics of rainfall data in the last ten years, there were 30 rainstorms (100.1 ~ 250 mm) and 70 rainstorms (50-100 mm) from 2001 to 2020 The proportion of rainstorms was high, and the maximum daily rainfall reached 247 mm / d. According to the 48 year rainfall data of Shiyan Reservoir in Guangming District, the annual average precipitation in Guangming district is 1600 mm, and the distribution is uneven. The rainfall is mainly concentrated in the flood season, of which the precipitation from April to October accounts for 87.5% of the annual precipitation 6%.The above data is drawn as shown in Figure 3 with data processing software.




(a) Average rainfall

(b) Average temperature and pressure

Fig 3: Rainfall statistics of Guangming district (2001-2020)

(2) Low lying terrain: the upstream area of Guangming district is built along the mountain, with a large catchment area, bringing flood pressure; The middle and lower reaches are low-lying and supported by the tide level. During the flood season, the rainwater in some areas cannot be discharged by gravity, which is easy to form regional waterlogging.

(3) The hardening surface standard is low: with the rapid development of urban construction, many flood detention areas such as ponds and paddy fields are developed into urban construction land, and the surface storage capacity and ground permeability are reduced, resulting in the increase of flood peak flow

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and the advance of flood peak. The current construction standard of drainage facilities is low, the scale of drainage pump station is not enough, the river flood control is not up to standard, and the high-speed development and construction in the built-up area seriously destroys the original drainage system. Once there is strong extreme weather exceeding the standard, it is very easy to form serious flood problems.

3.2 System Design

"System" is a whole with special functions composed of interacting and interdependent individuals with some kind of connection. The academic session has a clear definition of green infrastructure system a multi-functional ecological network composed of all natural, semi natural and artificial green spaces and open spaces, which provides essential basic support and services for natural life systems. This ecological network is composed of two parts: Network Center and connecting corridor, forming the basic framework of GSI system. Among them, the network center is the hub of the whole network, mainly referring to large areas of nature reserves, such as forests, parks, farmland, wetlands, etc. The connecting corridor is a linear channel for biological energy transmission and a link connecting various centers. It mainly refers to various linear rivers, streams, green belts and other open spaces.

The working flow of green rain and flood management system is shown in Fig 4.

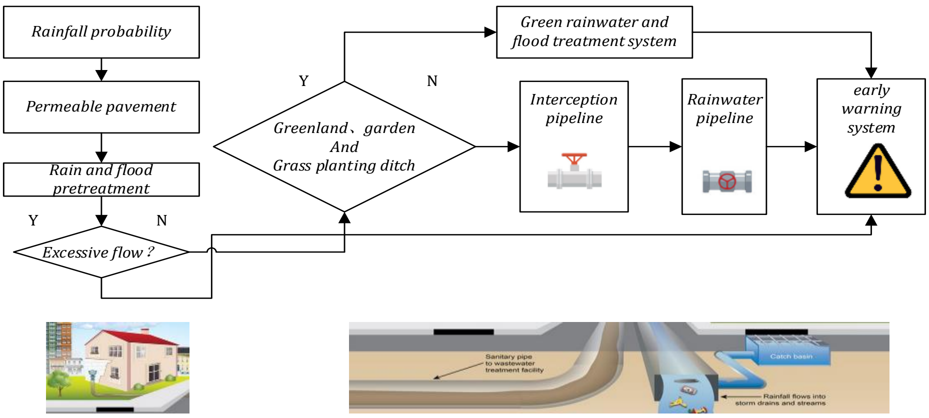


Fig 4: Green rain and flood management system

Green rainwater infrastructure is an important part of GSI system. The implementation of rainwater infrastructure needs to be combined with water body and green space, which is inseparable from the support of a large number of green spaces. Therefore, the construction of GSI system cannot be separated from GSI system, and the whole GSI ecological network needs to be taken into account. Based on this, the GSI system based on rainwater and flood management should be composed of three parts: parks, forests, farmland and other large-area natural green space is the network center of the whole system, and the good permeability of soil can promote rainwater infiltration. Linear spaces such as rivers, wetlands and roads are runoff transport corridors, which can retain rainwater runoff [7]. When the two are difficult to connect, the green rainwater infrastructure scattered in the whole network will play a role, bear the rainwater runoff that

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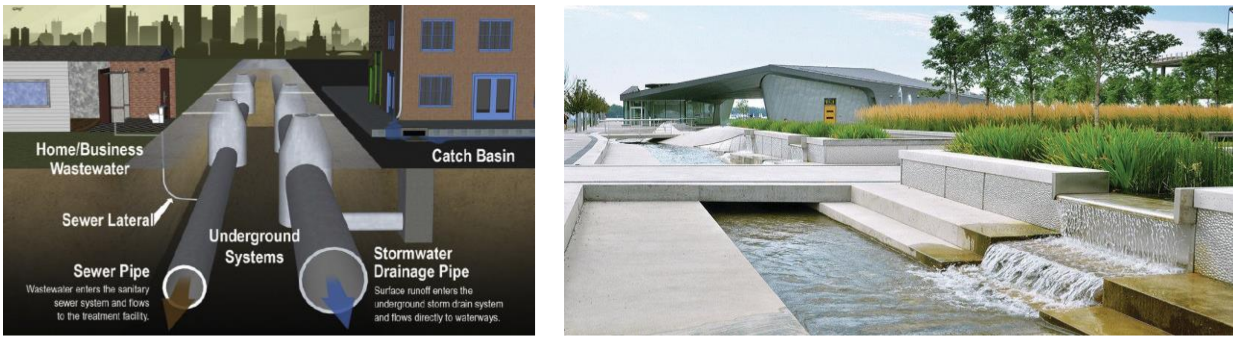
is difficult to load by urban gray infrastructure and blue infrastructure, and store and transmit the initial rainwater runoff. The artificial ecological treatment system can also filter, separate and transform water pollutants, and realize recycling after rainwater purification.

3.4 Design of road GSI and drainage system

GSI (green infrastructure system) is the core of this design system. GSI refers to an interconnected green space network, which is composed of various open spaces and natural areas, including greenways, wetlands, rain gardens, forests, local vegetation, etc. these elements form an interconnected, organic and unified network system. The system can provide the starting point and end point for wildlife migration and ecological process. The system itself can naturally manage rainstorms, reduce the harm of floods, improve water quality and save urban management costs.

A variety of green rainwater infrastructure can be arranged in the green space between the motor vehicle separation belt and the non motor vehicle lane and the sidewalk, and connected with the municipal pipeline of the city to reduce the surface runoff, reduce the scouring of rainwater on the pavement and further reduce the road pollution. In the rain and flood management of the parking lot, grass planting bricks with good permeability shall be used to replace the concrete pavement as far as possible. When the space is large, some low trees and shrubs can be planted at intervals to create a good urban landscape.




(a) Road GSI design (b) real scene of road GSI

Fig 5: Road GSI real map

As shown in Fig 5, urban roads and parking lots are an important channel for rainwater runoff transmission. Due to the high proportion of impervious area, they are also the key areas for rainwater and flood control. In the rainwater and flood management of the road, the pavement with high permeability should be adopted as far as possible to promote the natural infiltration of rainwater.

Drainage system: in view of the above problems, the design concept of water sensitive city is introduced into the drainage system reconstruction project, combining the urban rainwater and flood management with the development of public space, and a GSI system with rainwater collection, treatment and discharge functions is designed according to the design return period standard of rainwater pipes and canals in the central urban area of small and medium-sized cities. In the specific design, 22 drainage sub basins are divided, and several rainwater regulation and storage tanks are set up underground, so that after rainfall, the surface runoff flows through the infiltration facilities such as scattered inflow wells. After entering the rainwater pipeline for collection, it is first discharged into the regulation and storage tank, filtered and purified, and then overflowed into the central lake or municipal pipe network [7].

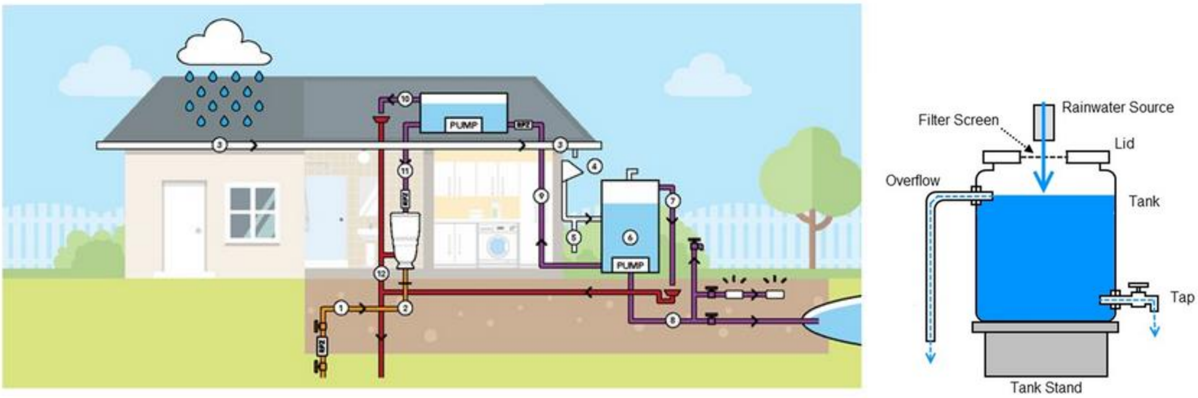



Fig 6: Schematic diagram of drainage system

As shown in Fig 6, the rainwater flowing into the central lake is purified by the circulating system and stored for utilization. Through the series regulation and storage of the regulation and storage tank and the central lake, the drainage system has been able to effectively deal with the impact of continuous heavy rainfall and ensure the safety and ecological environment quality of the surrounding urban areas.

## IV. PRACTICE AND EVALUATION

4.1 Practical verification

The rainfall event in 20210102 lasted for 4 hours from 06:00 to 10:00 on January 2, 2021, with a total rainfall of 72.5% 6mm, the rainfall intensity increases continuously from 6:00 to 7:00, and the runoff also increases. At about 7:00, the rainfall intensity is the largest, and the runoff reaches the maximum. The rainfall intensity decreases gradually from 7:00 to 10:00, and the runoff also decreases slowly.

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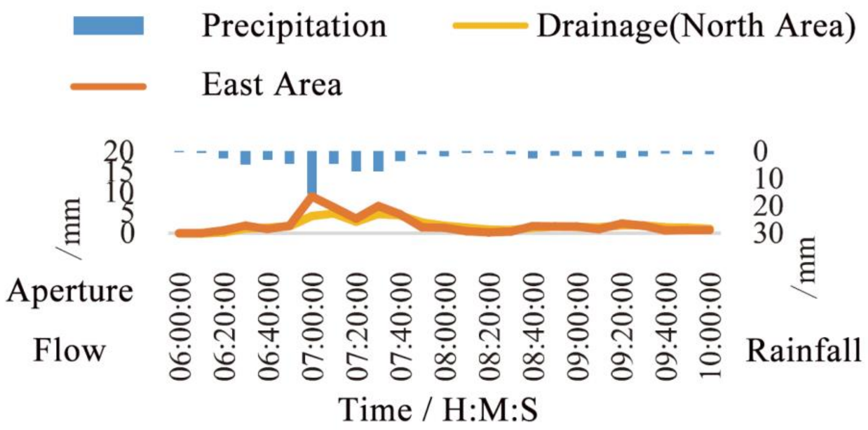


Fig 7: Relationship between rainfall and drainage

In the 20210102 rainfall event, the total rainfall in the north area is 72.5% 6mm, infiltration amount is 25 928MM, the filling amount is 0.5mm 413mm, runoff 46.5mm 470mm, runoff coefficient 0.5mm 64。The percentage of impervious area in the north area is 41 6%, and the simulated runoff coefficient is 0.5% higher than the reference value of urban comprehensive runoff coefficient 4 ～ 0. 6. It should be too large. The reason is that the rainfall event in 20160701 lasts a long time and the rainfall intensity is greater than the soil regression speed, that is, the soil is saturated for a long time. When the soil is saturated, the rainwater basically does not infiltrate and is transformed into runoff in a large amount, so the runoff coefficient is too large. The total rainfall in the East and west regions is 72.5% 6mm, infiltration amount is 16.5mm 812mm, and the filling amount is 4.5mm 186mm, runoff of 50 030mm, runoff coefficient is 0.5mm 689, because the percentage of impervious area in the East and west areas is 52 7%, and the simulated runoff coefficient results are within the specified value of the comprehensive runoff coefficient of 0 5 ～ 0. 7. It is obvious that the results of the green rainwater and flood management system are good, and the runoff hydrograph of the actual drainage results is basically fitted with the precipitation hydrograph, as shown in Fig 7:

4.2 Visual evaluation

ArcToolbox is an integrated application developed by Environmental Systems Research Institute (Esri). It provides a reference to the toolboxes to facilitate user interface in ArcGSIS for accessing and organizing a collection of geoprocessing tools, models and scripts.In this study, the analysis tools in arctoolbox are used to visually evaluate the urban green rain and flood management function.

The steps are as follows: firstly, the urban green infrastructure patches are vectorized, and the geospatial data and geometric image information of various green patches are obtained through manual recognition and interpretation. Then, the "proximity - multiple ring buffer" tool in the analysis tool in arctoolbox is used to visually express the rainwater and flood management functions at four levels. The coefficient is set according to the rain and flood management scores of various green infrastructure. Through test and adjustment, it is determined that the buffer coefficient of rain and flood management

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scores from 1 to 6 is 350, 300, 250, 200, 150 and 100, and the corresponding visual coefficient is obtained according to the score proportion of technical function, environmental impact, economic impact and social impact.

In addition, the natural patches of non construction land include river water bodies, lakes and ponds, cultivated land and orchards. These patches have good rainwater and flood management ability. The coefficient in visualization is set as the mean value, which is 200. The vegetation form of cultivated land can be classified as ground cover, grass and shrub, which is weaker than other natural patches in terms of rain and flood control and other benefits, so the visualization coefficient is set to 100. Finally, through the visual operation of the platform, we can evaluate and analyze the rainwater and flood management function from the cyberspace structure of green infrastructure through qualitative comparison.

The evaluation results are shown in TABLE I:

**TABLE I. Visualization Coefficient of Urban Green Rainwater and Flood Management**

| coefficient | Type | technical function | environmental impact | economic impact | social impact | Ranking |
|---|---|---|---|---|---|---|
| 350 | Comprehensive Park | 216 | 201 | 369 | 350 | 1 |
| 250 | Roadside green space | 214 | 318 | 321 | 310 | 2 |
| 300 | Protective green space | 100 | 268 | 147 | 216 | 3 |
| 200 | River water body | 145 | 147 | 200 | 187 | 4 |
| 150 | Lake pond | 364 | 412 | 210 | 169 | 5 |
| 100 | Agricultural and forestry cultivated land | 112 | 169 | 195 | 140 | 6 |
| 50 | Agriculture, forestry and orchard | 144 | 248 | 180 | 70 | 7 |

## V. CONCLUSION

The green rainwater and flood management system designed in this paper can adhere to the concept of ecology and natural circulation, ensure the integrity and unity of rainwater catchment area and other urban natural ecological elements, and realize the natural drainage of urban water body, which is suitable for application in small and medium-sized cities. Sponge city is the development direction of urban construction in the future. Green rainwater and flood management system can comprehensively manage and eliminate urban rainwater waterlogging disasters, improve the safety guarantee ability of urban rainwater drainage, and will be more and more widely used.

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