Research on Design Methods of City Sponge Greenway in North China Based on the Quantification of Landscape Performance——Case Study of Lakeside Greenway Park, Qi` an, China

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Abstract: The annual rainfall in North China is less than normal and the rainfall is concentrated. Rainstorms frequently occurs and the annual evaporation is large, which cause serious flood and water shortage problems. Meanwhile, the problem of rain flood in urban areas also bring serious ecological security and ecological quality hidden troubles.
Therefore, it is of great significance to alleviate the problem of urban rain flood and improve the ecological quality of the city by using the sponge greenway in the city as the ecological buffer.
The location of the research is in Qi`an which was the demonstration city of sponge construction in North China. The project aimed to construct a series of inner-city sponge greenway systems in order to alleviate the pressure of urban rain flood and enhance the ecosystem service function through plants and water transformation in green space.
Firstly, by analyzing the climatic characteristics of North China and the situation and characteristics of rain flooding in northern urban areas, the research discusses the necessity of the construction of sponge greenway in the urban areas of North China.
And on this basis, according to the current site condition, aiming to reducing the pressure of urban rain flood and improve regional ecological service function and obtaining the most benefits of water resources, ecological environment and social economy，the design methods of the city sponge greenway mainly included as followed:
1) Analyzing urban terrain and natural environment, combing the urban runoff direction.
2) Adding rainwater management measures, combing with terrain to delay and save water runoff.
3) Increasing regional plant species, to shape different plant habitats and restore regional ecological environment.
The research put forward the design methods based on the instructions of landscape performance series (LPS) proposed by Landscape Architecture Foundation in USA. The LPS was intended to quantify outcomes of landscape solutions in environmental, economic and social aspects. Then, research focused on one sponge greenway project in Qian`an——the East Side Green Belts of Qian`an Lakeshore East Road, by using the SWMM (Storm Water Management Model) for quantitative analysis, the research proves the main benefits were as followed:
1) The sponge greenway has better efficiency in controlling total runoff, peak flow and delaying peak time. A case of once 1-year of rain as an example, the project reduced runoff 13030 m3, reduced the flow rate by 2.31 m3/s, and delayed the peak time of 118 minutes.
2) The sponge greenway can effectively solve the problem of rainwater storage and utilization. The project used the water storage module to reduce the demand for irrigation water of

381,100 m3 per year, and reduce the maintenance cost of the park more than 876,530 yuan per year.
3) The sponge greenway provides a more diverse ecological environment, increasing the richness of species and restoring the ecological role of the region. The project design wetland, woodland, paddy field and other ecological environment, add more than 15 new plant species, and restore the habitat environment of various animals.
Keywords: *North China, Sponge greenway, Design method, Landscape performance, Quantitative analysis*

1. Foreword

In recent years, the progress of urbanization in China caused more and more serious degradation phenomenon of hardening city underlying surface. It leads to frequent phenomenon of urban waterlogging, which has brought the serious crises and challenges to the development of the city.

To solve these kinds of problems, in the '2014 Key Point Work', Ministry of National Housing and Urban Development determined "the urge to speed up the distributary transformation of rain and wasted water to improve the level of city drains, to greatly push forward the low impact development mode, to accelerate the policy measures of construction of the sponge city "; From 2014 to 2015, the first announced batch of 16 urban construction pilot cities began to be built, with a planned investment of 30 billion yuan in three years and a construction area of over 400 square meters[1]. In May 2016, the second batch of 14 cities were announced, with each city receiving 1.2 to 1.8 billion yuan of policy investment. The construction of sponge city has attracted the attention of social media and the masses.

From the construction results in the past two years, the construction of sponge cities in China has achieved some good effects. The pressure of flood control and drainage was greatly relieved in many cities in plain areas. [2] However, it should also be noticed that the construction of China's sponge system started late and it is more concentrated in urban areas. In North China, especially north shallow mountain range, city not only face to their own internal drainage pressure, but also to carry on the surrounding mountain flood discharge pressure, which leading to its rain flooding is more serious, its special surroundings environment required a more scientific and efficient rain flood management system.

2. Current Situation of Rain and Flood Management in North China

North China includes Beijing, Tianjin, Hebei, Henan and Shandong provinces and cities [3] (fig. 1), which in includes many important administrative, economic, industrial and tourism cities in China. Due to the warm temperate continental monsoon climate in North China, summer is hot and rainy, winter is cold and dry, and the spatial and temporal distribution of rain resources is extremely uneven. Although the annual rainfall in North China is usually lower than the normal level, the rainfall time is mainly from July to August of the flood season, and the precipitation

in the flood season accounts for 45% to 65% of the whole year, which lead to frequent rains in the rainy season and large annual evaporation in the dry season, resulting in serious floods and water shortage, such as:

In May 2014, severe rainstorms occurred in Qingdao, Shandong Province, causing 18 deaths and 3 injuries [4].

In 2016, <2016 national natural disasters basic situation> [5], nearly 90% of the national 31 provinces nationwide county-level administrative region affected by different degree of natural disasters, including Hebei, Shandong and other cities of North China flood disaster.

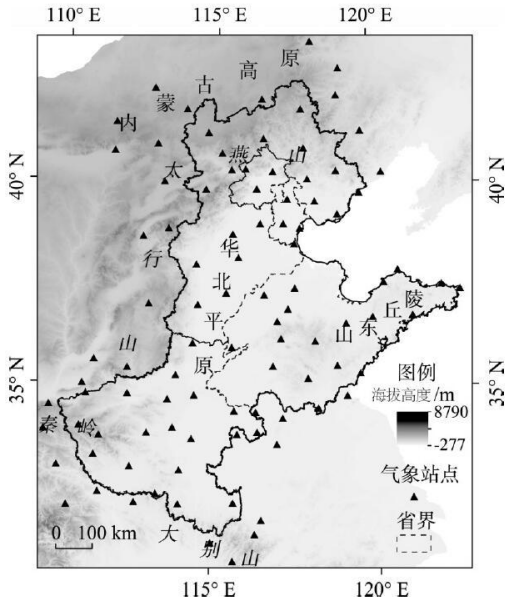

Figure.1 The location of North China and the distribution of meteorological stations [3]

According to geographical conditions, North China is divided into five plates. In the northern region, the terrain is undulating and undulating. The terrain is inclined from south to north. Most of them are above 1000m, with annual precipitation between 340 and 450mm; Annual precipitation in the central region is 500~800mm; the eastern region is mainly hilly and mountainous, with annual precipitation of 600-900mm; the annual precipitation in the western region, mainly in the Taihang mountains, is between 400 and 800mm; the southern region consists of Tongbai mountain and Dabie mountain, with an altitude of around 800m and annual precipitation of 1000-1300mm [3].

Northern Yanshan piedmont region is relatively low rainfall, but due to the complex topography, thin soil cover, low vegetation coverage rate, the lack of buffer between mountains and plains section, the city become more vulnerable to the threat of mountain flood discharge in water catchment, especially in recent years appeared the phenomenon such as frequent rainstorm, flood season ahead, further aggravated the severity of the rain flood damage in North China. [6]

3. Necessity and feasibility of sponge greenway construction

3.1 Necessity Analysis

In the northern part of China, the foothills fluctuate, and cities are often coupled with ridgelines and valleys to carry a large amount of flood and water. Part of natural mountain water confluence connects with the city in the form of river channel, and part of it forms external runoff under high intensity rainstorm to enter the urban area. Due to topographical reasons, there are many definite and continuous routes of water confluence between mountain and city. This confluence route is deterministic and continuous in time and space (fig.2). Runoff treatment based on these paths tends to better results. At the same time, as a linear greenbelt open space, greenway has better coupling with the definite linear flood water exchange route, and its construction is necessary. [7]

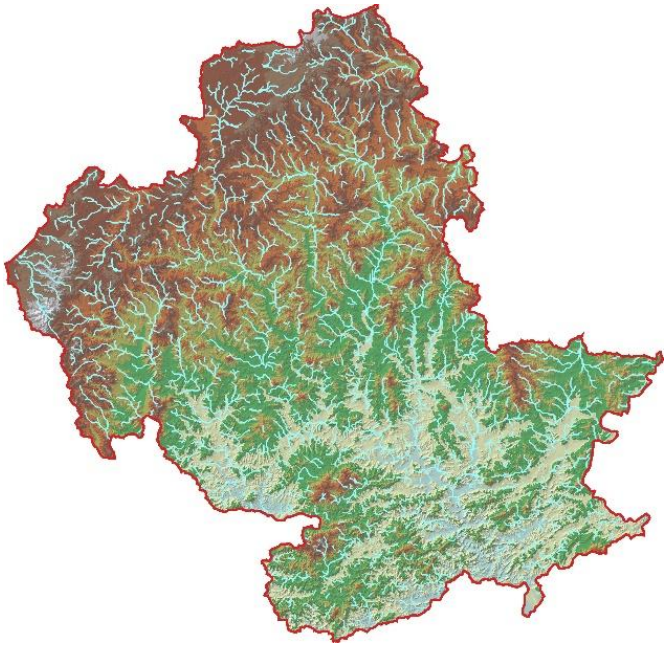

Figure.2 Catchment line in some cities in North China (Author draw)

3.2 Feasibility Analysis

By the Chinese way of sponge of city construction, including the low impact development facilities pay more attention to deal with runoff in the process and the source, such as planting Grass Swale, Sunken Green Space, Bio-retention ponds etc. These facilities undoubtedly have the characteristics of small scale, high quantity and diversified construction modes, which are basically consistent with the linear construction mode of green corridor and green road. It also in good agreement with the geographical conditions of multi-valley and multi-ridge in mountainous areas in North China. From this point of view, the greenway has great potential in the control of rain and flood. Therefore, the construction of sponge greenway in the mountainous cities of Northern China is feasible. [8]

4. Sponge Greenway Construction Strategy

4.1 Research Project

On April 2, 2015, Qian`an was established as the first batch of pilot sponge cities by the ministry of housing and construction, the ministry of finance and the ministry of water resources. Qian`an is the only pilot sponge city in the northern shallow mountainous area of North China. It is located at the southern foot of Yanshan mountain and on the bank of Luanhe river (fig.3). Qian`an is typical warm temperate continental monsoon climate in North China plain, dry in spring and winter, rainy in summer and autumn, uneven distribution of rainfall, mainly from June to September in summer. The annual average temperature of Qian`an is 11.5 degrees. The annual average precipitation is 711.9 mm. The geographical conditions and climate of Qian`an have typical characteristics of North China. [9]

In this study, the greenway park on the east side of lakeside road in Qian`an was selected as the research object.

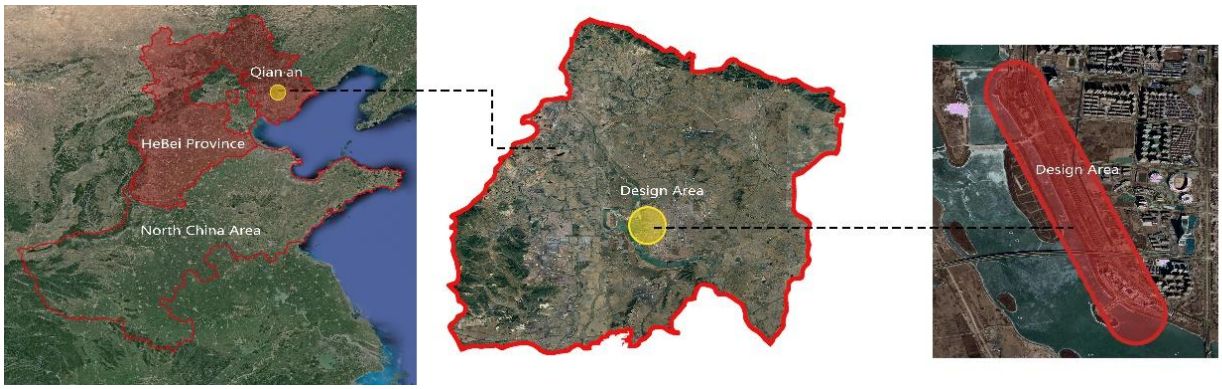

Figure.3 The location of the research project in Qian`an in North China (Author draw)

4.2 Regional Status

The planned area of the research project is 164.14 hectares, including two external rain-flood management planning areas and one core design area. The project requires that, in addition to solving its own rainstorm and flood problems, two external lands on the north and the east side should also be reduced to the rainwater runoff from the site. The two external plots of land cover 91.6 hectares and 45.8 hectares respectively.

The core design area is the greenway park on the east side of lakeside road in Qian`an. The greenway is distributed as a belt, and the topography presents a gentle slope trend of high north and low south. The west side of the core design area is the park green space, the east side is the commercial, residential and education scientific research land, and the north side is the residential land. The total area is 26.74 hectares.

The greenway park on the east side of lakeside road in Qian`an building as a demonstration project, the designer positioning it to become water management as the core of urban open space, in addition to solve the problem of sites around the city rain flood, designers also want to solve the lack of municipal road slow system within the field and energy loss.

4.3 Construction Strategy

And on this basis, according to the current site condition, aiming to reducing the pressure of urban rain flood and improve regional ecological service function and obtaining the most benefits of water resources, ecological environment and social economy，the design methods of the city sponge greenway mainly included as followed:

1) Analyzing urban terrain and natural environment, combing the urban runoff direction.

Based on the analysis of the urban elevation of Qian`an, the whole city presents a topographic trend of high north and low south. At the same time, the Luan river passes through the center of the city of Qian`an. The runoff at the foot of Yanshan mountain through Luan river exerts great pressure on the urban area of Qian`an.

By analyzing the runoff path of Qian`an(fig.4), it mainly includes two confluence paths: First one is the north end to undertake village and town land catchment of the sand river; second one is the leading direction of the city is the mountain water confluence towards the Luan river.

It can be seen from the urban runoff analysis that the subpath covered by each section of the catchment path and the area of the catchment area are different. Combined with different water catchment area, land type, and path map of water confluence line, different types and grades of sponge greenway design methods are proposed.

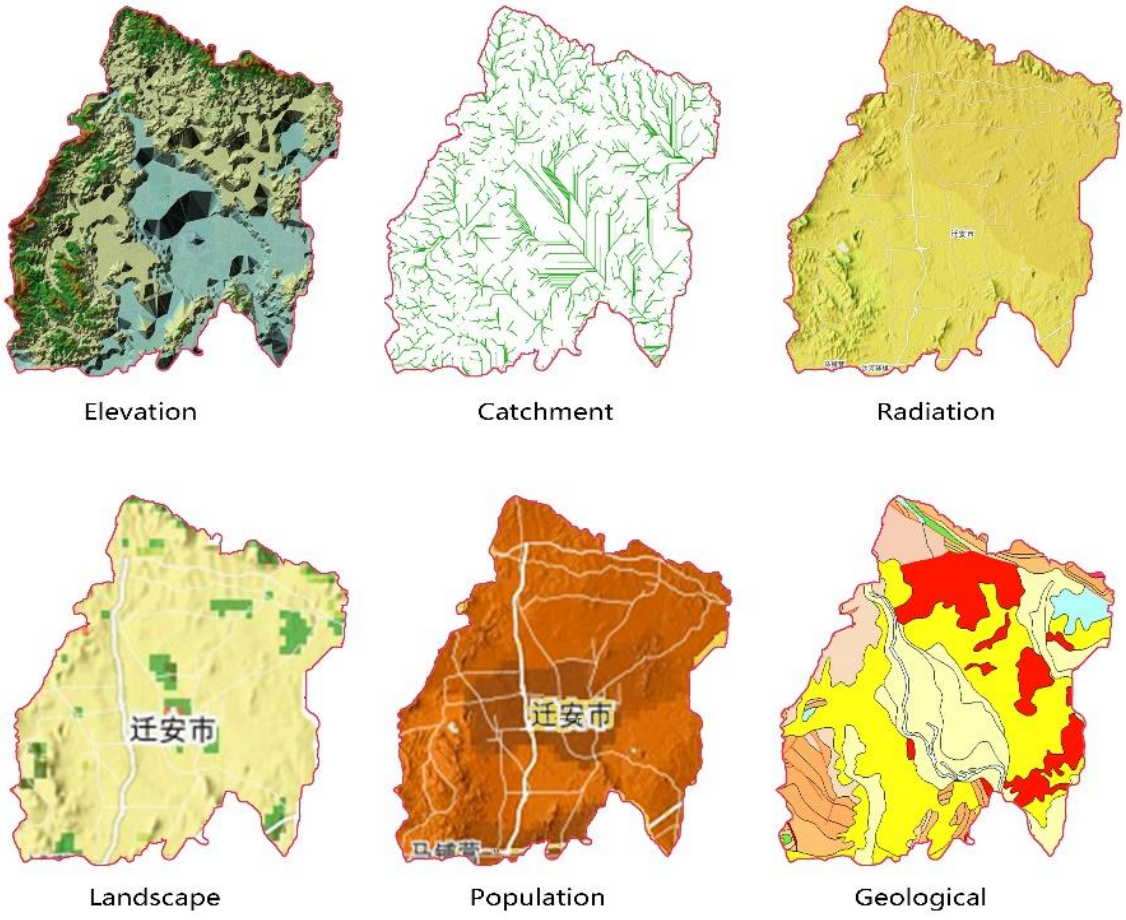

Figure.4 The analysis of Qian`an (Author draw, Internet data)

2) Adding rainwater management measures, combing with terrain to delay and save water runoff.

Many low-impact development measures are proposed in the technical guide for sponge city construction in China, [10] such as: initial abandoned well, grass swale, sunken green space, biological detention pond, water tank, etc. These rainwater management facilities have different functions and adapt to different environments. (fig.5)

On the one hand, these rainwater management measures form a low-lying space through topography treatment, regulating and storing runoff flow, and reducing runoff discharge. On the other hand, many rainwater management measures have formed a complete sponge circulation system by adjusting the topography to adjust the runoff path in order to increase the length and area of runoff flow in green area, and increase the seepage water.

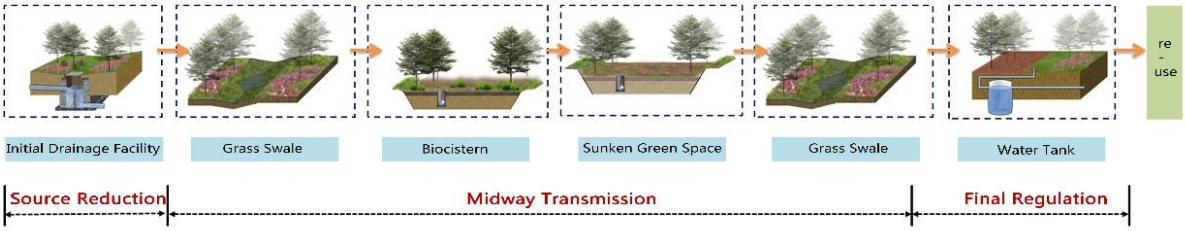

Figure.5 Low-impact development measures with different functions. (Author draw)

3) Increasing regional plant species, to shape different plant habitats and restore regional ecological environment.

Different setting of rainwater management measures to establish function often leads to the change of environment view in a region with different rain fall. Therefore, not only landscape factors should be considered in plant selection, but also its ecological habits should be analyzed to comprehensively consider its ecological value and viability. For example, more deep-rooted plants are often designed in the transmission system. With numerous roots and luxuriant branches and leaves, plants can better form biofilms, which are conducive to absorbing, transforming and degrading pollutants in rain water. It can also play a better role in purifying the management measures of transmission rainwater; the sunken green space chooses more plants that are dry and wet to ensure the long-term landscape effect of rainy season and dry season. (fig.6)

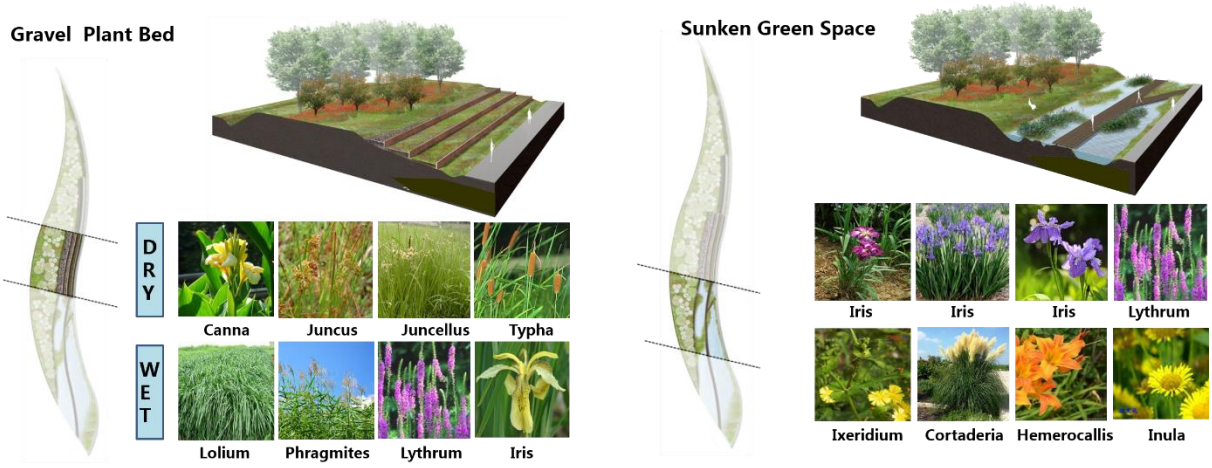

Figure.6 The plant selection in different water management meansures. (Author draw)

5. Landscape Performance of Sponge Greenway

Landscape performance series (LPS) was proposed by Landscape Architecture Foundation in USA. The LPS was intended to quantify outcomes of landscape solutions in environmental, economic and social aspects. By using the SWMM (Storm Water Management Model) for quantitative analysis, the research proves four main benefits were as followed:

5.1 Runoff Control

According to the corresponding relationship between the annual total runoff control rate and the designed rainfall, China is divided into five zones as shown below(fig.7). The control rates of annual runoff amount in each district are given as follows:

Ⅰ area (85% to 90%); Ⅱ area (80% to 85%), Ⅲ area (75% to 85%), Ⅳ area (70% to 85%), Ⅴ area (60% to 85%). Qian`an region is located in the Ⅱ area.

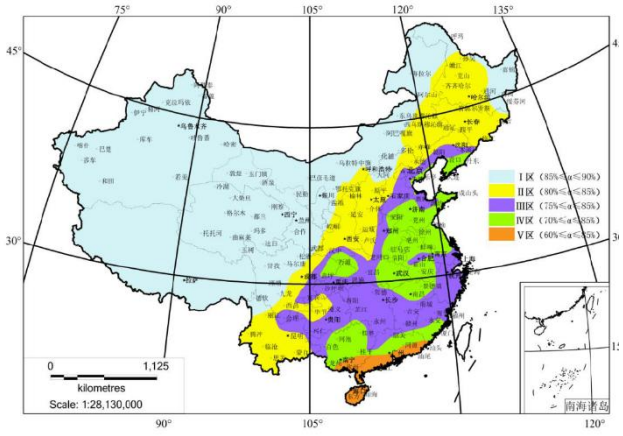

Figure.7 Zoning map of annual runoff control rate in mainland China [10]

Based on the rainfall data(Tab. 1), designers could make a preliminary plan and analysis it by SWMM(Storm Water Management Model) to verify whether the requirements are met.

Rainfall Recurrence Period (years)	1	2	5	10	20
Corresponding Rainfall（mm）	30.92	40.20	52.47	61.75	71.03

Tab.1 Rainfall Recurrence Period and Corresponding Rainfall in Qian`an (Author draw)

Take the research project as a sample, the water management system was designed as below(Fig. 8):

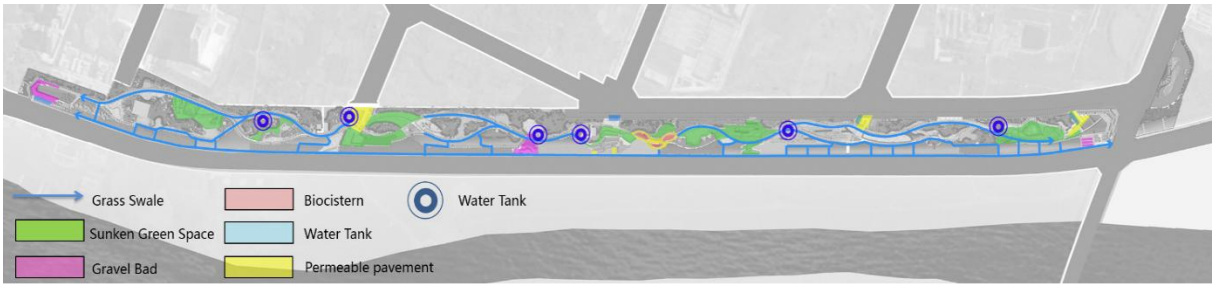

Figure.8 Water management system design in Qian`an Sponge Greenway (Author draw)

Input the data of various rainwater management measures into SWMM for calculation(Fig. 9, Tab.2):

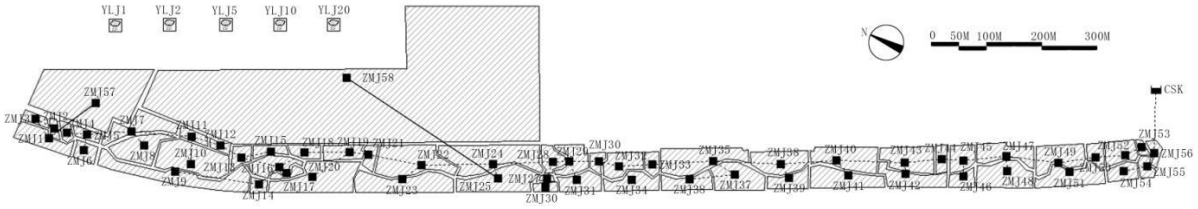

Figure.9 Water management system show in SWMM (Author draw)

Type		Quantities	Unit	Total(㎡)	Proportion
Green Space	Green	183569.2	㎡	217105	84.61%
	Grass Swale	3082.8	㎡		
	Biological detention pond	2592	㎡		
	Sunken Green Space	27861	㎡		
Rainfall Tank	Rainfall Tank	4984	㎡	4984	1.94%
Water	Landscape Water	4207	㎡	4207	1.64%
Building	New Building	240	㎡	2395	0.93%
	Existing Building	2155	㎡		
Road & Square	Pervious pavement	20461	㎡	27907	10.88%
	Impervious pavement	7446	㎡		

Total				256598	

Tab.2 Data of various rainwater management measures (Author draw)

The results show that the sponge greenway has better efficiency in controlling total runoff, peak flow and delaying peak time. A case of once 1-year of rain as an example, the project reduced runoff 13030 m3, reduced the flow rate by 2.31 m3/s, and delayed the peak time of 118 minutes.

5.2 Resource Reuse

The sponge greenway can effectively solve the problem of rainwater storage and utilization. (Fig.10) The project used the water storage module to reduce the demand for irrigation water of 381,100 m3 per year, and reduce the maintenance cost of the park more than 876,530 yuan per year.

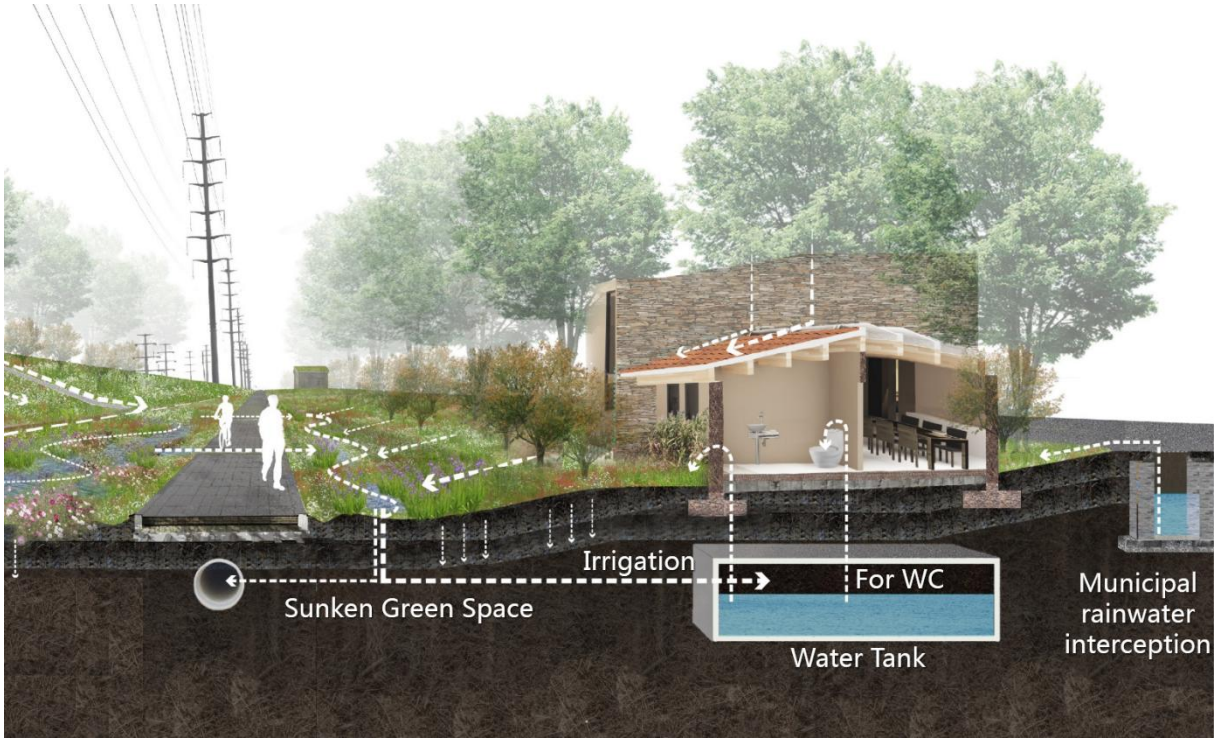

Figure.10 Sample of rainwater storage and utilization in project (Author draw)

5.3 Ecological Restoration

The sponge greenway provides a more diverse ecological environment, increasing the richness of species and restoring the ecological role of the region. The project design wetland, woodland, paddy field and other ecological environment, add more than 15 new plant species, and restore the habitat environment of various animals.(Fig.11)

Figure.11 Project photo in Qian`an (Author)

5.4 Stimulate vitality

The slow walking system in the park ensures the residents' safe travel and complements the infrastructure functions of Binhu East Road. Moreover, the function of infrastructure is put into the green space environment, which increases the comfort level of citizens and brings more popularity to the project. (Fig.12)

The project is surrounded by high-density residential areas with limited attached facilities and recreation facilities, the construction of this park has provided the surrounding residents with a slow walking system for cycling and walking, places for the elderly to exercise and play chess, and gardens for children to play in the water.

The designer has injected new vitality into the site through the outdoor activity function. A good sponge greenway design is not only the end of rain reduction, but also the public's paradise.

Figure.12 Project photo in Qian`an (Project Photographer)

6. Conclusion

In conclusion, the construction mode of sponge greenway should be firstly analyzed based on the environmental location of the construction city to determine its construction necessity and feasibility. Its construction model should also be considered with topography, plants and other elements. The plan should also be simulated and verified before construction. Through the practical verification of the research project in North China, sponge greenway plays a good role in urban runoff control, ecological recovery, resource utilization and regional activation.

7. Reference

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