Using Nature to Reshape Cities and Live with Water: An Overview of the Chinese Sponge City Programme and Its Implementation in Wuhan

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Summary

Wuhan, located in central China, is well-known as the “city of one hundred lakes” and has abundant water resources and extensive water systems. However, water management and waterlogging prevention in Wuhan is challenging. Wuhan has suffered from waterlogging for years mainly due to the low-lying built-up area and the uneven distribution of precipitation. Rapid urbanization has exacerbated waterlogging. The sharply shrinking size of natural lakes caused by land expansion reduces the regulation and storage capacity of the lakes. As sewage pipes and stormwater pipes are mixed and misconnected, the sewage water is discharged into urban water channels, resulting in water pollution that deteriorates the water management system. It is urgently needed to develop an effective system for water management and waterlogging prevention.

The concept of the “sponge city” was developed in 2013 to address urban water management challenges in China and rebuild a harmonious relationship among people, water and city (read more in Part 1). The sponge city concept refers to a way of urban management that allows cities to resolve urban waterlogging, improve water storage and discharge capacity, enhance water quality, and alleviate heat island effects through nature-based and grey solutions, by applying the concept’s six technical measures - "infiltration, retention, storage, purification, utilization and discharge".

Wuhan is one of the sponge pilot cities in China. The target of the Wuhan Sponge City Programme is set as 20% and 80% of the urban area should achieve the sponge city requirements by 2020 and 2030 respectively and absorb 60%-85% of the annual rainfall. The sponge infrastructures applied in Wuhan include nature-based solutions, such as rain gardens, grass swales and bio-retention facilities, and grey infrastructure, such as permeable pavements, infiltration trenches, and rainwater storage modules. In 2015, Wuhan started to implement the sponge city demonstration project, which consists of two demonstration areas and 288 pilot projects. The construction of demonstration projects attracted CNY 11 billion (EUR 1.4 billion) of investment from both government funds and social investments. Hundreds of sponge projects across the city have been in construction to date (read more about case studies of sponge projects in Part 3).

So far, the Wuhan Sponge City Programme has achieved great success and showcased the great ability of waterlogging prevention and the potential of nature-based solutions. In the summer of 2020, Wuhan experienced multiple rounds of intense, record-breaking precipitation during the long-lasting rainy season, but no serious waterlogging occurred. Waterlogging issues in Wuhan have been alleviated significantly after implementation of sponge projects.

Several key points lead to the success of the Wuhan Sponge City Programme:

1. Applying whole-process management in waterlogging prevention;
2. Integrating sponge projects in Wuhan Comprehensive Planning with the collaboration of different city departments;
3. Developing localized strategies and technical standards;
4. Establishing a fund-raising mechanism and attracting social participation for risk- and benefit-sharing.

Part 1 Overview of Chinese Sponge City Programme

1.1 Urban Water Management Challenges in China

Since the 1980s, China has witnessed rapid urbanization, a sharp growth in urban population and a dramatic expansion of urban land. The rapid development of cities tends to bring serious water issues. Large areas of absorbable green space in growing cities have been converted to impermeable pavements. The urban stormwater drainage systems in Chinese cities are considered insufficient, as the construction of current drainage systems in some cities, like Beijing and Wuhan, can be traced back to the Qing Dynasty[1]. Those drainage systems are seriously degraded and cause severe water pollution in rivers, streams and other water bodies. It is also estimated that the drainage systems in half of all Chinese metropolises do not meet the national flood prevention standards[2].

Figure 1.1 Historical Flooding in Wuhan (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

China is also particularly vulnerable to floods. It experienced 15 floods from the year 2004 to 2014[3]. Floods usually lead to severe property damage and loss of life, and according to statistics, up to 1% of annual Gross Domestic Product (GDP) is washed away annually[4]. The extreme storm events are even increasing due to climate change, with more and more frequent flooding events. To resolve urban water issues and adapt to climate change, China has raised the urban water management challenges as a priority for national development, exploring shifting the paradigm from the conventional engineering-based approaches to a holistic and systematic nature-based model for urban water management[3,5].

1.2 Chinese Sponge City Programme

Inspired by concepts used worldwide, including “Low Impact Development” (the USA), “Water Sensitive Urban Design” (Australia), “Sustainable Urban Drainage Systems” (the UK) and “Low Impact Urban Design & Development” (New Zealand), the “sponge city” concept was developed in China to reshape the relationship between people, water and the city. In 2013, Chinese President Xi Jinping pointed out that cities should be built to retain rainfall and make use of natural forces to accumulate, infiltrate and purify rainwater like a sponge in a new type of urbanization[6]. Since then, the concept of “sponge city” has gradually entered the public view.

In 2015, the State Council of China issued the Guideline on Promoting the Construction of Sponge Cities[7] (hereinafter called “National Guideline” for short), which would enable urban areas and infrastructure, like parks, streets and buildings, to “act like sponges”. The sponge city concept refers to a way of urban management that allows cities to naturally absorb, store and purify rainwater to resolve waterlogging issues, prevent urban flooding, improve water storage and discharge capacity, enhance water quality, and alleviate heat island effects through nature-based and grey solutions.

According to the National Guideline, the sponge city programme sets the targets at 20% of the urban area that should be constructed to meet the sponge city standards of absorbing and utilizing 70% of the rainfall in situ by 2020 and 80% of the urban area by 2030. To meet the targets, six measures - "infiltration, retention, storage, purification, utilization, and drainage" - are taken to minimize the impact of urban development and construction on the environment. The construction of sponge cities should emphasise conservation, restoration and rehabilitation of original urban ecosystems to build “resilience” for cities. Preserving rivers, lakes, wetlands, ponds and other aquatic ecosystems as well as forests and grasslands to the maximum extent possible and maintaining the natural hydrological characteristics are the basic requirements for sponge city construction. Three principles are pointed out in the National Guideline: adhere to the ecology and natural cycle; adhere to guiding and developing through planning; and adhere to governmental guidance and social participation.

The municipal governments are suggested to follow the guideline and establish their sponge city work plan and standards. The construction of sponge cities shall be carried out in both new urban districts and old city districts in coordination with the renovation of dilapidated buildings and shantytowns.

Guided by the Ministry of Housing and Urban-Rural Development (MOHURD), the Ministry of Finance and the Ministry of Water Resources, the Sponge City pilot programme selected 16 pilot cities in 2015, followed by another 14 pilot cities in 2016.

Figure 1.2 Pilot Cities in Chinese Sponge City Programme

List of pilot cities:

2015 (16 cities): Qianan, Baicheng, Zhenjiang, Jiaxing, Chizhou, Xiamen, Pingxiang, Jinan, Hebi, Wuhan, Changde, Nanning, Chongqing, Suining, Guian New Area and Xixian New Area.

2016 (14 cities): Beijing, Tianjin, Dalian, Shanghai, Ningbo, Fuzhou, Qingdao, Zhuhai, Shenzhen, Sanya, Yuxi, Qingyang, Xining and Guyuan.

To support the construction of sponge cities, the national government offers funds for pilot cities to start the programme in the initial three years: CNY 400 million (EUR 51 million) per year for each city, CNY 500 million (EUR 63 million) for each provincial capital, and CNY 600 million (EUR 76 million) for each municipality directly under the central government. In general, the national fund equals 15-20% of the total cost of sponge city construction. A 10% incentive subsidy is given to the local municipal government if social investment from other sources funded a certain proportion of remaining costs.

As the National Guideline suggests, firstly, the municipal governments are encouraged to actively promote various fundraising methods and establish a collaborative mechanism to share risks and benefits between the government and social capital (capital from private enterprises and state-owned companies). Funds raised from social capital are separate from national funds. This mechanism allows the market to play a role in the allocation of resources under the supervision of the local municipal government. For instance, public-private partnerships (PPP) and franchising are ways to encourage social capital to participate in the investment, construction and management of sponge cities. PPP can reduce the expenditures on construction and relieve fiscal pressure for the government and also bring innovative designs and operations management to improve the quality of the infrastructure[8]. Under the franchise granted by local governments, social capital should be responsible for the design, fundraising, bidding for construction and operation of the project within the agreed terms of the partnership. The right to use assets and the management right will be transferred to the municipal government or entrusted to authorized companies after the expiration of the contract. Secondly, at provincial levels, governments should increase investments in sponge city construction, and at city levels, municipal governments should prioritize the construction projects of sponge cities in their annual financial budgets and construction plans. Finally, governments at all levels should stimulate financial institutions, like banks, to increase credit support and provide mid- and long-term loans for sponge city projects.

The MOHURD, the Ministry of Finance and the Ministry of Water Resources jointly assess the performance of sponge cities each year and the Ministry of Finance adjusts the amount and payment schedule of the allocated funds on the basis of the evaluation results. According to the Sponge City Performance Evaluation Index System[9,10] published by the Ministry of Housing and Urban-Rural Development in 2016, the evaluation is divided into four grades. Cities assessed as "excellent" will be allocated with full funds and be rewarded by 10% of the fund. Cities at "good" and "qualified" levels will both be given full funds but "qualified" cities will be given a postponed payment of 30% of the fund of next year. "Disqualified" cities will be applied to the withdraw mechanism with a withdrawal of all allocated funds and a postponed allocation of all funds of the following year. The evaluation includes seven indexes from all aspects: use and management of funds, the collaboration between government and social capital, cost compensation and guarantee mechanism, quantity of outputs, quality of outputs, project benefits, and technology routes. Apart from the index system, six indicators, including water ecology, water quality, water resources, water safety, institutional setup and implementation, as well as display, are used for assessing project benefits. The Assessment Standard for Sponge City Construction[11], a clearly defined national standard for the evaluation of the sponge effect, came into force in August 2019 after public notification in 2018. The standard looked into the assessment items and methods in different aspects, containing volume capture ratio of annual rainfall, urban water quality, urban heat island effect, etc.

1.3 National Guidance on Municipal Sponge City Plans

To promote the construction of sponge cities, in 2016, the MOHURD published the Temporary Provisions on Specialized Planning of Sponge City Programme[12] to guide municipal government and planning sectors on the compilation of sponge city plans. In accordance with the Provisions, the municipal sponge city specialized plan is the foundation of the sponge city construction programme and an important part of urban planning. The municipal sponge city plan is suggested to follow the principles in the National Guideline to minimize the impact of urban development on the natural environment.

The municipal sponge city plan can be formulated separately or with the urban comprehensive plan. The sponge city planning area should be, in principle, consistent with the city planning area (designated in the urban master plan by the municipal government). At the same time, the sponge city plan should adhere to the urban comprehensive plan, and should take account of the integrity of the rainfall catchment area and the ecological elements, such as mountains, water, forests, croplands and lakes. While compiling or revising the urban master plan, the core index of sponge city programme - volume capture ratio of annual rainfall - should be incorporated into the comprehensive plan.

In addition, the municipal urban and rural planning department should collaborate with other departments, including construction, municipal administration, gardening and water affairs departments to consolidate the municipal sponge city plan, ensuring the municipal specialized plans, like urban roads and green space plans, are consistent with the sponge city plan. After approval, the sponge city special plan is published by the municipal government. Relevant planning data and survey data as requisite background materials, such as meteorological, hydrological, geological, and soil materials, should be collected prior to the compilation of the sponge city plan. In the process of compiling sponge city plans, listening to and accepting the opinions from relevant departments, experts and the public extensively is important.

Additional Reading

The organisations or responsible departments undertaking the sponge city plans should be qualified in urban and rural planning and should engage in the planning work within the scope permitted by the qualification.

The content of the sponge city specialized plan should contain:

1 Overall evaluation of the construction condition of the sponge city: analyse urban location, geography, economic and social status, rainfall, soil, groundwater, underlying surface, drainage systems and hydrological situation before urban development to identify existing problems in water resources, water environment, water ecology, water security and other aspects.

2 Determine the objective of sponge city construction and specific indexes: the objective is mainly the volume capture ratio of annual rainfall, defining the short- and long-term goals of the required area and proportion, and addressing the index system referring to the national evaluation guidance - Sponge City Construction Performance Evaluation and Assessment Method.

3 Propose the overall idea of sponge city construction: define the implementation path according to local conditions. The old urban area should be problem-oriented, focusing on solving the problems of urban waterlogging, rainwater collection and utilization, and the treatment of black and odorous water bodies. New urban areas and various industrial parks should be target-oriented, giving priority to meeting targets for the protection of the natural ecological background and reasonably controlling the development intensity.

4 Propose guidelines on the zoning of sponge cities: identify background conditions of ecosystems, such as mountains, water, forests, croplands and lakes, address the natural ecological space pattern of the sponge city, and define the protection and restoration requirements. According to the present situation, delimit the construction area of sponge city and propose the construction guidelines.

5 Implement the sponge city construction control requirements: divide the objective and indicators of the rainfall capture into four categories – water ecology, water environment, water safety and water resources.

6 Address suggestions on linking planning measures with relevant specialized plans.

7 Clearly define the priorities in the short-term: put forward the construction requirements in different stages.

8 Propose safeguard measures and implementation suggestions.

Other relevant documents like texts, drawings and descriptions should be included in the sponge city plan, including the following planning maps:

1 Status map (including elevation, slope, underlying surface, geology, soil, groundwater, green space, water systems, drainage systems and other elements).

2 Natural ecological spatial pattern of sponge city.

3 Sponge city construction zoning plan.

4 Sponge city construction control map (designate categorized indexes, like the volume capture ratio of annual rainfall, in different subregions).

5 Layout of water-related infrastructure in sponge city construction (urban drainage and waterlogging control, combined sewage overflow pollution control, rainfall storage and other infrastructures).

6 Sponge city construction plan by stages.

In 2014, the MOHURD published the Technical Guide for Sponge City Construction[13] to support the implementation of municipal sponge city programmes. The Technical Guide guides the implementation of the sponge city concept in the process of planning, design, construction and maintenance at all levels. Also, the Technical Guide instructs the coordination among urban planning, water affairs, road traffic, gardening and other relevant departments to supervise the construction of sponge cities (See Figure 1.3).

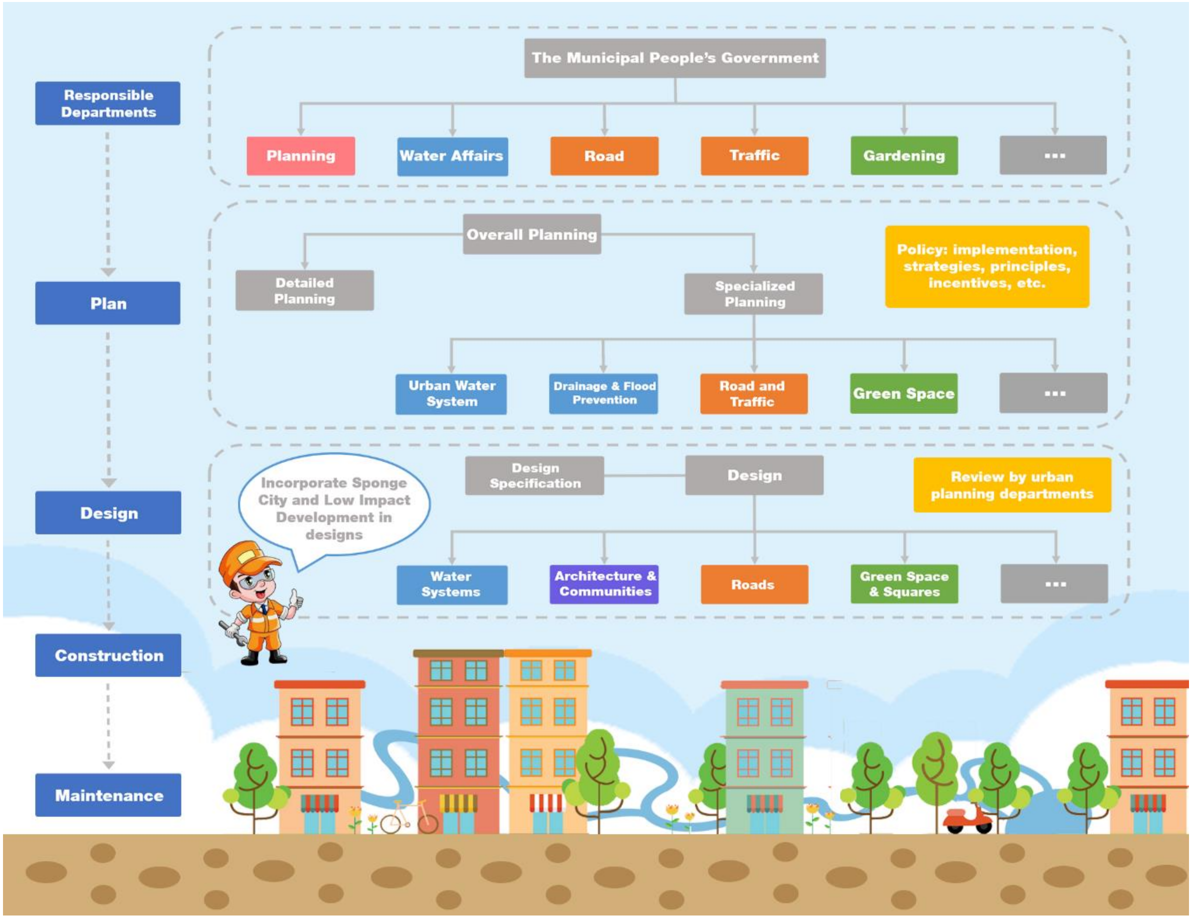

Figure 1.3 Coordinating Different Departments in the Municipal Sponge City Programmes

The MOHURD also published a catalogue of technology and products[14] that can be applied in sponge city construction. The catalogue lists various technologies, such as aquatic microbial bio-activation technology and stormwater collection and reuse systems, and products, such as planting bags for green roofs and permeable pavements. Technical consulting companies, including private companies, state-owned companies and universities, are enclosed in the catalogue as well.

Part 2 Overview of Wuhan Sponge City Programme

To start the initiative of sponge city construction, Chinese Sponge City Construction Programme selected 30 pilot cities in 2015 and 2016. Wuhan was among them. Municipal governments are suggested to follow the sponge city guiding package provided by the national government and establish their sponge city work plan and standards. The package is essential in the planning and design of sponge city projects, including the National Guideline, index systems[9,10], technical guides[13], and others.

It is not too complicated for cities to adopt the national guiding package in their municipal sponge city programme. However, since different cities vary significantly in their hydrological, geographical and meteorological conditions, applying the uniform guiding package would be problematic. Thus, the implementation of national guidance must be context-specific and accommodate flexibility for the localized goals and technical measures according to the municipal environmental and social-economic situation.

The following section gives an overview of Wuhan Sponge City Programme to elucidate the implementation of the project and how the sponge city programme and nature-based solutions work collectively to address waterlogging issues and urban water management challenges. This part is formulated following the structure of the Technical Guide[13] with further descriptions about the achievements and finance of Wuhan sponge city projects. Let us now move on to Wuhan and discover the reasons behind the challenges of Wuhan water management and waterlogging prevention.

2.1 Background and Primary Problems

Wuhan, the capital city of Hubei Province, is well-known as the “city of one hundred lakes” located in central China. Wuhan city occupies a total of 8494 km^2 with 812km^2 of built-up area. The abundant water resources and extensive water systems shape beautiful landscapes and nice city views and make the city liveable. The water systems, consisting of 165 rivers, 166 lakes, over one hundred water channels and hundreds of reservoirs, cover 25% of the entire municipal area. Two main rivers, the Yangtze River and Han River, merge here on the floodplain. Wuhan is also one of the most populated metropolises in China with nearly 11 million residents, thus, ensuring a good urban living environment is critical.

Figure 2.1 East Lake, Wuhan, China (Stephen Fang / Unsplash)

However, water management and flood prevention in Wuhan is challenging. Predominantly due to its geographical location and unevenly distributed precipitation, Wuhan has suffered from waterlogging for years[15]. The built-up area of Wuhan is located in the low-lying area and the elevation of the urban area is usually lower than the flood level. The annual precipitation of Wuhan is 1257mm, with 70% of the rainfall falling in April to September. The flood season of the Yangtze River and its tributaries coincides with the rainstorm period, which restrains urban discharge capacity. In most times, the rainfall was pumped to the outer river by pumping stations during the long-lasting flood season.

Additionally, urbanisation has reshaped the urban landscape, changed the natural hydrological process and exacerbated waterlogging[16]. The high intensity of urban development, refilling of lakes, and over-hardening of the underlying surface caused by concrete pavements make the waterlogging issues and flood prevention situation worse. The size of natural lakes has shrunk by nearly 70% from the 1950s to 2013[17,18] through the urbanisation process, resulting in reduced regulation and storage capacity of the lakes.

In 2016, Wuhan witnessed the largest flood event since 1998[16]. The total rainfall from the 30th June to 6th July reached 560.5mm, which hit the record of Wuhan's weekly precipitation[15]. The water level in the Wuhan section of the Yangtze River rose rapidly from 3rd to 7th July, reaching a peak of 28.37m, the fifth-highest historical record in Wuhan. The serious waterlogging affected at least 1 million people in Wuhan and 15 people died from the flood. The event also directly caused a severe economic loss of CNY 5.3 billion. Waterlogging, thus, has a heavy impact on citizens' life.

On top of the waterlogging issues, water pollution caused by urbanisation also deteriorates the water management system. Sewage pipes and stormwater pipes are mixed and misconnected, resulting in incomplete sewage collection, and thus the sewage water is discharged into the urban water channels, forming black and malodorous water bodies. Besides, the overexploitation of groundwater and the heat island effect are also problems that need to be addressed in urban management. Therefore, it is urgently needed to develop an effective system for water management and waterlogging prevention.

Figure 2.2 Waterlogging in Wuhan (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

2.2 Principles & Requirements

As one of the first batch of sponge pilot cities, the Sponge Cities programme therefore became the primary means used in Wuhan to address its water management problems. After consulting the National Guideline and design guidelines from Beijing, Nanning and Shenzhen, Wuhan released the Guideline for Wuhan Sponge City Planning and Design (Trial) (hereinafter referred to as "Wuhan Guideline") in 2015[19]. The guideline was jointly compiled by Wuhan Planning and Research Institute, Wuhan Municipal Water Affairs Bureau, Wuhan Municipal Land resources and Planning Bureau, Wuhan Urban and Rural Construction Committee, Wuhan Municipal Landscape and Forestry Bureau and other municipal departments. The planning principles for sponge city projects in Wuhan are consistent with the National Guideline: adhere to the ecology and natural cycle; adhere to guiding and developing through planning; and adhere to governmental guidance and social participation.

On the basis of these national sponge city planning principles, the Wuhan Guideline specifies several basic requirements for sponge city construction. The planning and construction of sponge cities should follow the concepts of natural absorption, natural infiltration and natural purification; pay attention to the protection and restoration of original urban ecosystems such as rivers, lakes, wetlands, channels, ditches, etc.; and emphasize low impact development, making use of the six technical measures - "infiltration, retention, storage, purification, utilization and discharge".

To take the local conditions into account, Wuhan sponge city planning and design should comprehensively consider drainage needs, prevention of waterlogging and water pollution, and rainwater utilization. The planning and design of all newly-built, reconstruction and expansion projects in Wuhan shall include the low-impact development and sponge city construction concepts. The sponge city - low impact development facilities should be planned, designed, constructed and used simultaneously with the project construction. Effective coordination among various engineering measures with low impact development should be carried out to reserve as much urban green space as possible, increase the permeable ground, and store rainwater in situ for reuse.

The Wuhan Guideline also points out that all engineering facilities with low impact development shall be consistent with stormwater drainage facilities and the municipal drainage system, and shall not reduce the design standard of the municipal rainwater drainage system. All engineering facilities with low impact development should be coordinated with the surrounding environment and pay attention to the landscape effect. The planning and design of the low-impact development facilities shall be coordinated with relevant departments such as the general plan, landscape, architecture, water supply and drainage, structure, roads and economy of the project to maximize the comprehensive benefits. In addition, during the process of sponge city - low impact development, attention should be paid to the special control of non-point source pollution, to avoid polluting groundwater and surrounding water bodies.

2.3 Objective and Construction Goals

Under the guidance of Wuhan Guideline and the Wuhan Comprehensive Planning[20], Wuhan compiled the Specialized Plan of Sponge City in Wuhan (2016-2030) (hereinafter called “Wuhan Plan”)[21] with the goal to strengthen the planning and management of urban planning and construction. The objective of Wuhan Sponge City Construction complies with the National Guideline which set up the objective as 20% and 80% of the urban area should achieve the sponge city requirements by 2020 and 2030 respectively.

In addition to the main objectives, Wuhan has set up four construction goals for sponge city programme based on the local condition to alleviate waterlogging problems:

1 Light rain shall be able to seep through the ground
2 Heavy rain shall not cause waterlogging
3 To lessen water pollution
4 To alleviate heat island effect

To accomplish the construction goals, Wuhan has defined the principal construction requirements as follows: The sponge projects must achieve 60%-85% (17.6-35.2mm/d) of the volume capture ratio of annual rainfall, achieve a capacity to resist 50-year storm effectively (303mm/d), and eliminate black and malodorous water bodies to meet water quality standards[15].

2.4 Planning

In this section, we look deep into the Wuhan Plan[21] to understand the top-level design and strategies used to promote the implementation of Wuhan sponge city programme. The foundation of the Wuhan Plan includes national policies and regulations, municipal regulations, national standards, sponge city technical guides and relevant municipal plans.

2.4.1 Concept and ideas

The overall concept of Wuhan sponge city construction is the systematic and whole-process controlled water management with a combination of blue, grey and green infrastructure and a combination of engineering and non-engineering measures[15]. The Wuhan sponge city programme has also established a multi-level system based on the runoff process with a double orientation of problems and targets (see Figure 2.3). The runoff process starts with precipitation as the source and finishes with the outflow of water from rivers. Problem-oriented strategies should be applied with systematic governance in the existing built-up area; target-oriented strategies should be applied with high standards of control and construction in the new development area.

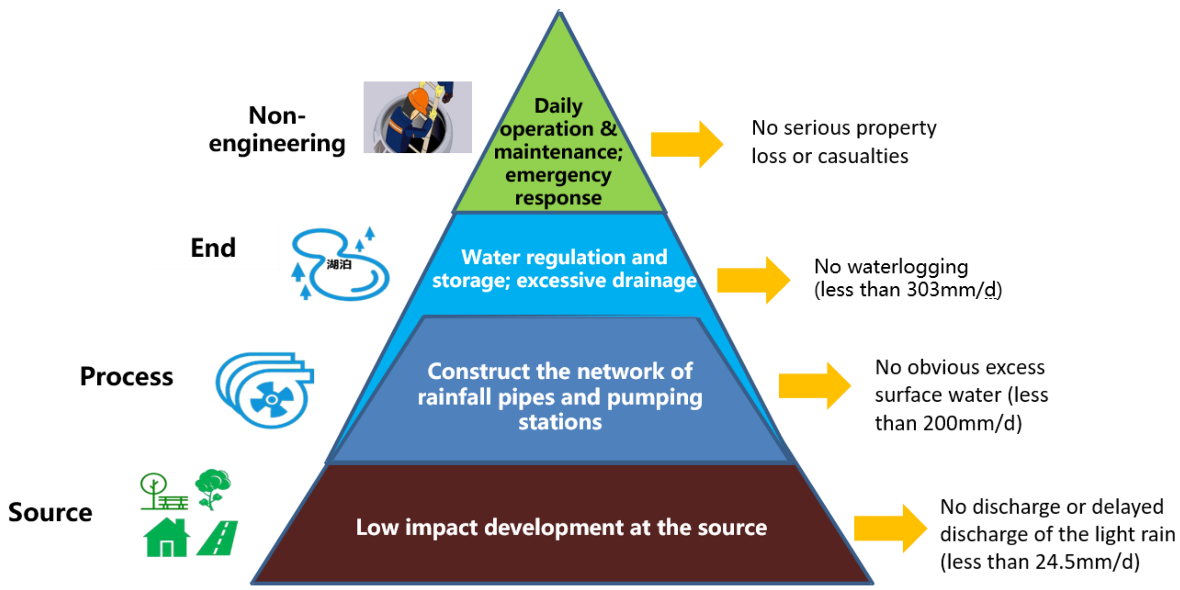

Figure 2.3 The management ideas of sponge city construction (adapted from KANG Dan 2020[15], permissions from the Wuhan Urban and Rural Construction Bureau)

The management ideas of sponge city construction contain source reduction, process control, end regulation and disaster response, simultaneously implementing the six technical measures to reduce flood risk. At the source, sponge infrastructures in different aspects - urban roads, architecture and communities, green space and urban water systems - adopt the concept of low impact development in practice. Source reduction, which is the base of this governance system, can efficiently deal with the light rain (less than 24.5mm/d). Process control mainly targets relatively heavier rainfall (less than 200mm/d). The construction of stormwater pipe networks and pumping stations at this level is to reduce excessive surface water and prevent waterlogging. However, when the rainfall reaches a larger amount (200mm - 303mm/d), the regulation and storage capacity of lakes can leverage the potential for end regulation. Excessive rainfall and water drainage can be dealt with by regulating the lakes. The top of this hierarchical system is non-engineering measures, which integrate daily operations and maintenance with emergency response to effectively respond to extreme flooding events. The periodic overhaul of sponge facilities, pipe networks and pumping stations, such as drainage tests and pipe dredging, ensures smooth operation of infrastructures and disaster response. No serious casualties and property loss should occur during the extreme rainstorm event.

2.4.2 Integrating the sponge programme into urban plans

The Wuhan sponge city programme is not a construction project that exists separately from other urban plans but is interdependent with them, especially the Wuhan Comprehensive Planning[20] and the ecological planning framework. It also needs the cooperation of different departments, such as water affairs, landscape and road traffic, to be planned and implemented.

The Urban Comprehensive Planning and Ecological Planning Framework in Wuhan

In 2010, the Wuhan Municipal Government issued the Wuhan Comprehensive Plan (2010-2020). The city is planned into the urban development area (3261 km^2) and the agricultural and ecological development area. The urban development area focuses on financial, commercial, industrial, residential, recreational and other urban functions. The agricultural and ecological development area emphasizes the conservation of mountains, forests, water, wetlands, farmlands and other ecological resources, which are the ecological security barriers of Wuhan.

Four zones are designated in Wuhan in order to accomplish and implement the Wuhan Comprehensive Plan:

1. Prohibited construction areas: rivers, lakes, wetlands and surrounding control areas, embankments, first-grade protection areas for drinking water sources, mountains and surrounding control areas, surface subsidence areas, underground mineral deposit areas, core areas of scenic and historic sites, core areas and buffer areas of nature reserves, and core areas of ecological green wedges. In principle, any urban development and construction activities are prohibited.

2. Restricted construction areas: secondary protection areas for drinking water sources, flood storage and detention areas, non-core areas of scenic and historic sites, non-core areas of ecological green wedges, forest parks, ecological public welfare forest areas, basic farmland protection areas, underground cultural relics burial areas, etc. Construction should avoid restricted areas.

3. Suitable construction areas: areas that are suitable for urban development and construction but have not yet been built, and are priority areas for urban development. The development mode, scale, intensity and construction sequence should be determined scientifically and rationally according to the resource and environmental conditions.

4. Built-up areas: the existing urban built-up areas. The existing areas should focus on structural adjustment and functional optimization, improving infrastructure, and enhancing the urban environment and intensive development.

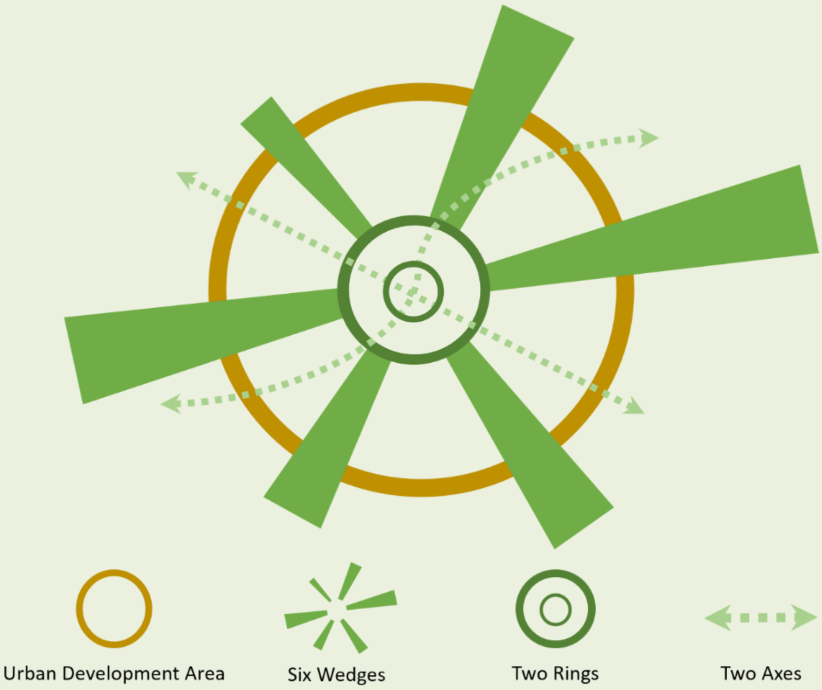

Figure 2.4 Wuhan ecological planning framework (adapted from Wuhan Comprehensive Planning (2010-2020)[20])

Proposed in the comprehensive planning in 2010, Wuhan ecological planning framework put forward the "1+6" urban development pattern and the overall ecological framework - "Two axes, two rings, six wedges, and multiple corridors" (see Figure 2.4).

- "1+6" pattern refers to 1 central urban district and 6 new urban districts within the urban development area
- Two axes: mountains and rivers (the Yangtze River and Han River)

- Two rings: an inner ring formulated by the protected forest belt connecting 6 large parks, 27 small and medium parks and 5 low-density construction areas and an outer circle located outside of the central urban district within the urban development area.
- Six wedges: 6 lake districts, consisting of parks, lakes, wetlands, forests, agricultural fields, recreational areas, etc.
- Multiple corridors: multiple ecological corridors connected with the six wedges.

The spatial pattern of the sponge city aligns with the Wuhan ecological planning framework (see box) to integrate the construction of sponge projects into the urban framework. The sponge city spatial pattern is similar to the urban ecological plan but replaces the two axes with T-shape axes of the Yangtze River and Han River and multiple corridors with waterlogging sites. Therefore, the sponge city spatial pattern is called “T-shape axes - two rings - multiple spots - six wedges”.

Furthermore, the sponge city programme has delineated blue and green areas for conservation and protection of natural ecosystems in Wuhan. The blue protection zones include 189 km^2 of river sections and riparian buffer zones along the Yangtze River and Han River, 32 km^2 of major urban open channels and protected areas, and 166 lakes jointly protected by the Wuhan Lake Protection Regulations[22]. The green protection zones consist of parks and reserves, farmland, forests, natural reserves, wetlands, mountains, water source reserves and other ecologically sensitive areas in the agricultural and ecological development area. In all protected areas, construction activities are prohibited or restricted. Besides, regarding the urban development area, Wuhan sponge city programme has planned to construct diverse types of urban parks and gardens to eliminate inner waterlogging, build communal parks in areas with dense populations, build stormwater facilities in the urban protection forest belt and surrounding parks, and construct artificial vegetation and a forest belt to improve ecological function. The programme has delineated 19 km^2 of urban parks, 64 km^2 of protective green areas near highways and expressways, 37 km^2 of protective green areas near railways, and 37 km^2 of protective green areas for major municipal parks and facilities. All construction work requires effective collaboration between various departments and enterprises.

2.4.3 Wuhan sponge city construction index system

The Wuhan sponge city construction index system was published to set the goals and target values for sponge projects. Because the four categories of technical performance evaluation for comprehensive water management (water ecology, water environment, water resources, water safety) were recommended by the national government, Wuhan has adjusted the indexes according to its municipal context (Table 2.1). Those indexes are the core indicators of sponge performance and waterlogging prevention and later become the standard reference for the design of sponge infrastructures in Wuhan.

Table 2.1 List of Wuhan Sponge City Construction Index System (adapted from WPDI, 2016[21])

Index Type	No.	Index Name	Category	Index Value		Notes
				2020	2030	
Water Ecology	1	Water retention rate of natural lakes	Concept	100%	100%	
	2	Volume capture ratio of annual rainfall	Concept	20% area reach standards	80% area reach standards	Zoning by construction
	3	Proportion of natural shoreline of rivers and lakes	Measure	≥50%	≥80%	
Water Environment	4	Proportion of water bodies meeting quality standards	Target	80%, and no black and odorous water	95%, and no water below grade 5 (V standard)	
	5	Reduction of non-point source pollution in the upper part of watersheds	Measure	≥50% (Calculate by TSS*)	≥50% (Calculate by TSS)	
	6	Number of combined sewer overflows	Measure	≥10 times/year	≥10 times/year	Mixed flow outlets
Water Resources	7	Utilization rate of rainfall resources	Measure	Consumption of rainfall is not less than 5% of tap water	Consumption of rainfall is not less than 5% of tap water	Introductory
	8	Utilization rate of regenerated wastewater	Measure	≥20%	≥20%	Introductory
Water Safety	9	Flood control standard	Target	Resist 200-year storm event	Resist 200-year storm event	
	10	Waterlogging control standard	Target	Resist 20-year storm event	Resist 50-year storm event, 100-year storm event for key areas or facilities	
	11	Rate of discharge pumping station meeting standards	Measure	85%	100%	
	12	Levee compliance rate to the standard length	Measure	100% for the main levee, 90% for back levee	100% for the main levee and back levee	
	13	Rate of stormwater main pipes (canals) meeting standards	Measure	70%	95%	
	14	Proportion of permeable hardened pavement in new projects	Measure	≥40%	≥40%	

Note: TSS* = Total Suspended Solids

2.4.4 Zoning

The entire sponge city construction area covers 3261km^2 in the urban development area of Wuhan. As one Chinese idiom said "applying appropriate medicine according to the symptom", it is important to adopt problem-oriented strategies. Likewise, the purpose of zoning is to classify different zones, determine the construction routes and indexes, and form the sponge city zoning maps for Wuhan on the basis of the water-related problems in each district. Therefore, the goal and sponge indexes of each subregion should be differentiated from other subregions.

The rules of zoning take consideration of primary issues, area size, distribution of liability and drainage outlets. The following three levels are established for delineation of sponge subregions: The first level is divided by the outlet of the river, focusing on the coordinating management of external flood and waterlogging and capacity building of waterlogging prevention. The second level considers the receiving water body, focusing on the coordinating management of drainage and dispatch. At the third level, the construction characteristics, drainage system, water issues and administrative management of the area are considered, with the emphasis on the coordination of construction and management. As a result, Wuhan delineated 4 main sponge districts and 171 subregions in total in the sponge city planning area.

The municipal sponge city construction guidelines suggested that the overall construction goals for new projects should be stricter than renovation projects, so the indexes should be set differently (Table 2.2). Table 2.3 and 2.4 show the designation and adjustment of different goals for volume capture ratio of annual rainfall in different zones. Those indexes demonstrate how the planning maps (for volume capture ratio of annual rainfall) are formulated.

Table 2.2 Controlling indexes[21]

Index name		Value	Control type
Ratio of permeable pavements	New projects	≥40%	Mandatory
	Renovation projects	≥30%	Introductory
Ratio of depressed green areas	New projects	≥25%	Mandatory
	Renovation projects	≥25%	Introductory
Utilization rate of rainfall resources		≥5%	Introductory
Ratio of green roof		≥30%	Introductory

Note: Utilization rate of rainfall resources = Usage of rainfall resources / total usage of tap water

Table 2.3 Adjusted values of volume capture ratio of annual rainfall in architectures and communities[21]

Characteristics	Adjust values in various land-use types						
	Residential	Industries	Public management and public service	Business service	Public infrastructure	Logistics and storage	Transportation infrastructure
Renovation	0	0	0	-5%	-5%	0	-5%
New	+5%	+5%	+5%	-5%	0	+5%	-5%

Table 2.4 Adjusted values of volume capture ratio of annual rainfall in urban roads[21]

Road width of boundary lines （m)	Adjust values	
	Renovation projects	New projects
10≤B＜20	-5%	0%
20≤B＜40	0%	0%
B≥40	0%	+5%

2.4.5 Safeguard measures

Concerning the discrepancy between planning and implementation in real-life, Wuhan introduced strategic safeguard measures to ensure the completion of sponge city projects. As suggested by the Wuhan Plan, a whole-process control mechanism should be established. In combination with the demonstration project, the municipal government should refine the Management Measures for Wuhan Sponge City Construction[23], and formulate policy documents with clearer responsibilities and more rational routes. To better implement the sponge city concept, relevant governmental sectors are required to develop an annual evaluation system and to summarize the problems experienced during project implementation. Another measure is to link sponge city construction with the awarding of governmental honour for companies and institutions and set the promotion of sponge city construction as a prerequisite for all administrative units. Meanwhile, developing policies for active publicity, open information and public monitoring allows social supervision of the construction of sponge cities.

It is important to discover an effective and sustainable financial security system for the sponge city programme. The municipal and district governments are encouraged to establish a special investment fund used for construction or subsidy and reward of sponge city projects and explore a mechanism to link stormwater fees and the sponge sites.

2.5 Design

To implement the Wuhan Plan, sponge city projects are being developed on the ground, focusing mostly on waterlogging prevention at the preliminary stage of construction, from 2015 to 2020. The Design Guide for Wuhan Sponge City Construction[24] was published in 2019 and suggested that with the objective of preventing waterlogging in the urban areas, various measures and strategies have been utilized collectively.

As part of the Wuhan urban comprehensive ecological plan, 166 lakes were designated in the conservation plan to ensure the water regulation and storage capacity of the lakes, particularly during the flooding season. Grey infrastructure is applied for flood prevention and process control, including the construction of embankments to prevent external water flooding and the repair of pipes and pumps to increase water discharge capacity. Green and blue infrastructure plays a key role in waterlogging prevention. Source reduction strategies, like “infiltration” and “retention”, are combined with low-impact development, to reduce the drainage of rainfall and relieve drainage pressure on the urban pipe networks. The Wuhan sponge city programme also implements non-engineering strategies for daily operational management and maintenance. The management measures emphasize the regular maintenance of pipes and pumping stations and emergency response to enhance disaster response capacity and reduce the property loss and casualties to the maximum extent.

Figure 2.5 The rain garden in Huazhong University of Science and Technology, Wuhan (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

Sponge Infrastructures

The sponge infrastructures are suggested to be designed under the guidance of the national technical guide for sponge infrastructures. The sponge infrastructures used in Wuhan sponge projects include rain gardens, green roofs, permeable pavements, grass swales, bio-retention facilities, depressed green spaces, pervious concrete pavements, constructed wetlands, rainwater-fed wetlands, infiltration-removal wells, infiltration basins, infiltration manholes, infiltration trenches, rainwater storage modules, pervious asphalt pavements, vegetation buffer zones, wet ponds, artificial soil infiltration facilities and ecological embankments.

The design of sponge infrastructures in each project should be applied according to the different sponge indexes to maximize the sponge effects. Table 2.5 illustrates how the six technical measures are incorporated into the design of sponge infrastructure while fulfilling the sponge goals.

Table 2.5 The Framework of National Building Standard Design System for Sponge City Construction (adapted from MOHURD, 2016[25])

	Sponge infrastructures	Infiltration	Retention	Storage	Purification	Utilization	Drainage
Nature-based solutions	Green roofs						
	Sunken green areas						
	Infiltration ponds						
	Bio-retention facilities						
	Grass swales						
	Rain gardens						
	Stormwater wetlands						
	Wet ponds						
	Retention ponds						
	Detention basins						
	Vegetation buffer zone						
Grey solutions	Permeable pavements						
	Underground rainwater tanks						
	Water storage modules						
	Seepage wells, seepage pipes, seepage canals						
	Rainwater drainage facilities						
	Rainwater purification facilities						
	Green area irrigation						
	Artificial soil filtration						

2.6 Project Implementation

Hundreds of sponge projects were being implemented while the compilation of local sponge technical standards was underway. Figure 2.6 showcases the project timeline and the current progress of the Wuhan sponge city programme.

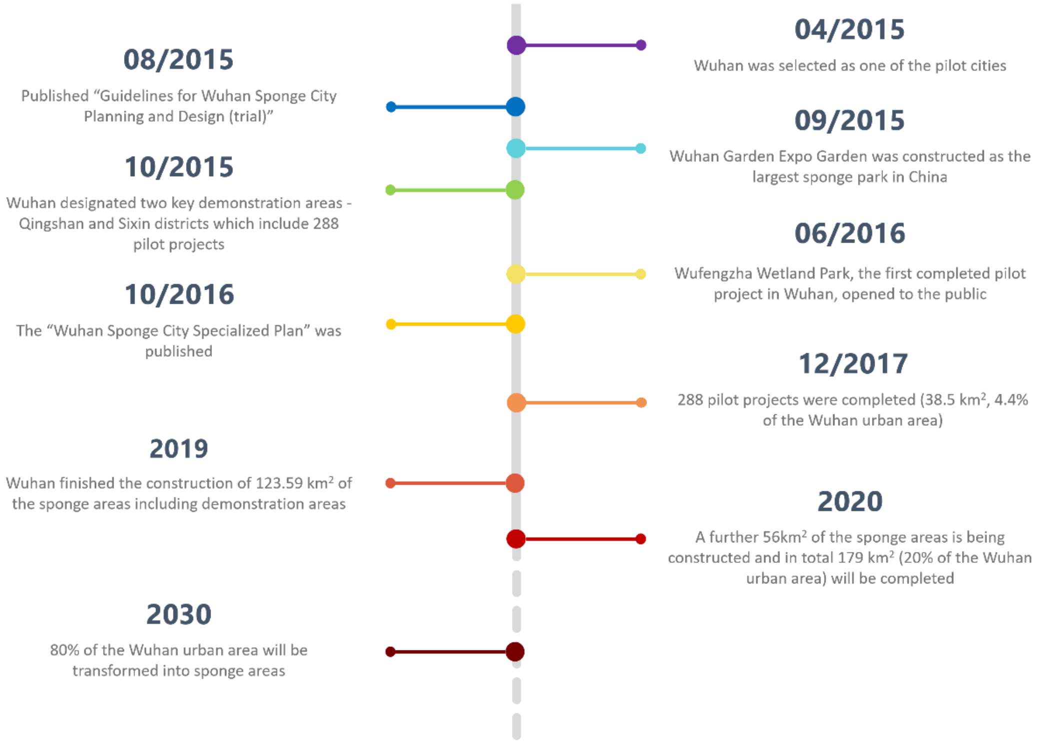

Figure 2.6 The timeline of the Wuhan Sponge City Programme

Demonstration Projects

To initiate the citywide sponge city projects, Wuhan implemented demonstration projects of sponge city construction in 2015 and issued "Wuhan Sponge City Pilot Implementation Plan" in 2016. A "2+N" mode was designated for sponge demonstration projects to construct 38.5km^2 of sponge-like areas. "2+N" mode refers to the two demonstration areas, Qingshan (23 km^2) and Sixin (15.5 km^2), and 288 pilot projects with the emphasis on the renovation of the old town area and development of the new city area. The pilot projects consist of various types, such as roads, green space and residential quarters. Started in 2015, the construction of demonstration projects lasted for three years and attracted CNY 11 billion (EUR 1.4 billion) of investment. Case studies in the demonstration areas, such as Nangan Channel Sponge Project - the first PPP (public-private partnership) project in Wuhan, and the Gangcheng No.2 Middle School (Figure 2.7) which has achieved great success, are analyzed in Part 3. Demonstration projects as the prototype of sponge city construction accumulated experience and laid the foundation for promoting larger-scale construction across Wuhan city.

Figure 2.7 Before and after sponge construction of demonstration project – the Gangcheng No.2 Middle School in Qingshan district, Wuhan (Kang Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

The success of demonstration projects has proved the potential of nature-based solutions and grey solutions in urban water management and waterlogging prevention. Sponge construction has realized the natural absorption, purification and utilization of rainfall through various sponge infrastructures, enhancing the harmonious relationship between water and city. After the completion of demonstration projects, sponge projects have been implemented across Wuhan city. See more details about sponge projects and their achievements in Part 3.

2.7 Operation and Maintenance

Wuhan sponge city projects are operated and maintained both by the government and enterprises, depending on the main responsible body of each project. To comply with and implement the national technical guide, Wuhan released The Technical Guide for Operation and Maintenance of Sponge City Infrastructures in Wuhan Residential Quarters (trial)[26] in 2017. Key points of this technical guide include that the sponge infrastructures should be maintained and supervised regularly by their owners or entrusting parties; the owner of sponge infrastructures should develop a standard manual for operation; and that the maintenance personnel should record the maintenance status of the infrastructure and evaluate annually. Specific requirements for the operation and maintenance of each sponge infrastructure are also specified in the document, which serves as the standard reference for sponge infrastructure.

2.8 Achievements

Until 2020, Wuhan sponge city construction programme has achieved a series of results. Practically, the standardization and localization of sponge technologies throughout the sponge city construction process is critical. Wuhan finished the compilation of local technical standards in 2019 and also encouraged enterprises to establish sponge construction standards.

The Wuhan Sponge Science Museum was built in the Qingshan demonstration area to introduce the implementation of the Wuhan sponge city programme to the public in the form of stories, photographs, videos and models. Citizens in Wuhan can get to know what the sponge city is and what role the sponge city plays in urban development through the visit.

To efficiently manage data and monitor sponge projects, a citywide sponge city monitoring and evaluation platform has been developed. The platform integrates sponge maps, information management, real-time monitoring and performance evaluation into one system. Moreover, Wuhan sponge city programme has fostered development of the sponge industry. The industry alliance of Wuhan sponge city has been established and expanded to gather teams relevant to research, design, construction, and product development. The sponge industry has so far formed a number of achievements, including 58 patent applications and authorization materials, 4 sets of professional software and 5 local sponge city implementation methods[15]. The sponge industry also shows great potential in green building materials with the construction of several new production lines for sponge city building materials which facilitated the development of the Wuhan green building materials industry.

The performance of 2020

In the summer of 2020, Wuhan has showcased the great ability of flood control and waterlogging prevention developed from the construction of sponge cities[15]. Wuhan suffered from multiple rounds of intense precipitation during the rainy season of 2020. The rainy season lasted from June 8 to July 19, in total 42 days, which is the longest rainy season in this century, and cumulative precipitation was 1.3-2.1 times more than other years. In some areas of Wuhan, the total amount of the rainfall in the rainy season was 1109.5mm. The daily precipitation even reached 472.3mm and the hourly precipitation reached 88.3mm. The flood level of the outer river was more than 4m above the average elevation of the urban surface, which could potentially inflict severe flooding in Wuhan. On July 7, the Yangtze River reached the warning line of 27.30 m, and was close to exceeding the protective safety level. However, on 12th of July, the flood peak, which was 28.77m ranking the fourth in history, went through Wuhan “quietly”. No serious floods occurred in Wuhan thanks to the multi-level flood prevention and water management system.

Although the heavy rainstorm event in the summer of 2020 caused serious flooding and property losses in most provinces in Southern China, Wuhan, whose rainfall amount in the rainy season of 2020 ranked the first among metropolises, has not seen serious waterlogging and floods. The occurrence of some waterlogging points in the urban area did not cause a serious impact on the city and could be effectively dealt with.

Compared to the storm event in 2016, despite a strong rainstorm hitting Wuhan again, the construction of sponge projects effectively increased the discharge capacity and efficiency[15]. The number of waterlogging points reduced from 162 to 30 (more than 90% of the waterlogging points disappeared when rain stopped). The maximum duration of waterlogging shortened from 1 month to 6 hours and the area of waterlogging points was significantly reduced. The impact of waterlogging on traffic and the public was greatly alleviated, which demonstrated huge potential and capability of the sponge city programme.

Figure 2.8 The Sponge infrastructures in Wuhan (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

2.9 Finance

The construction of sponge city projects is costly, thus, there has to be an effective fund-raising and allocation mechanism to attract investment and distribute funds. As one of the sponge pilot cities in China, Wuhan received national funds of CNY 500 million (EUR 64 million) each year from 2015 to 2017, as the financial support to implement the municipal sponge city construction. The Municipal Government of Wuhan is responsible for receiving the national funds, preparing municipal funds, inviting social investment, allocating funds to the district government, and setting up management regulations for the use of funds. District governments, the main responsible bodies for project implementation, get funds from the municipal government and arrange their own funds for sponge projects. The Wuhan municipal government also encourages the participation of social capital and the application of the PPP model. For example, demonstration projects constructed without government investment are rewarded 30% of the fund if they started before October 2015 and 15% if they started after that date[23].

2.10 Lessons Learned and Future Visions

2.10.1 Successful experiences

The Wuhan Sponge City Programme has obtained experience in many regards. The success of the sponge programme depends on the systematic and whole-process controlled water management. The combination of non-engineering measures and engineering measures, which include blue and green infrastructure to “let nature do the work” and grey infrastructure to reduce excessive rainfall, constitutes the top-level design of sponge cities as well as coordination with other urban plans, realizing the integration of multiple planning programmes.

Sponge city construction requires collaboration between government and different departments, rather than being a duty for one single department. The programme has clearly defined responsibilities for every engaging department and has established a specific leading group for Wuhan sponge pilot projects, which consists of leaders from different participating departments. Wuhan municipal and district governments coordinate the construction of sponge cities. The Municipal Urban and Rural Construction Bureau is responsible for the overall planning and promotion of the sponge city programme. The Municipal Gardening Bureau takes charge of the implementation of the sponge city concept in green space projects, while the Municipal Water Affair Bureau takes responsibility for the implementation of the sponge city concept in the water-related projects. The Municipal Planning Bureau is accountable for sponge city management control and project acceptance.

Localization is another reason behind the success of the sponge programme. Due to different natural and social-economic conditions in different cities, identical strategies would not lead to the same results. The implementation of sponge city projects must be context-specific. The localized strategies applied in the programme include but are not limited to the sponge index system for the design of sponge infrastructures and zoning, the local technical standards throughout the entire project process from planning, design, and implementation to maintenance, and the development of the local sponge industry union. The Wuhan sponge monitoring and evaluation platform is another illustration of the localization strategy, which has been established to integrate information management, monitoring and performance evaluation into one system. Since the programme allows the local government to address water management challenges, strong national policies, fiscal and regulatory mechanisms and clarified national technical standards also back up the implementation of sponge projects.

A cost analysis[3] conducted by the University of Leeds showed that the use of sponge measures with a focus on nature-based solutions in Wuhan sponge city demonstration areas have saved around CNY 4 billion (EUR 509 million) compared to the conventional approach to upgrade the drainage system based on grey infrastructure. This reveals the potential of nature-based solutions.

Going down to the specific projects in Wuhan, the implementation of sponge projects have enlightened deeper application of the sponge city concept and replication in other cities. The Nangan Channel sponge project, namely the first PPP project in Wuhan, is a good example. The project reused recyclable resources, like the industrial wastes generated in iron production, to achieve sustainable development. Meanwhile, the project exported experiences learned by telling stories about Wuhan’s water management and by communicating with other cities, experts and well-known enterprises about the PPP model, sponge technology application and other aspects. It also invited experts for technical consultation and cooperated with research institutes for research and standard formulation to enhance the application capability of sponge technology. As a result, this project accumulated rich and useful materials for the formation of sponge city construction that can be used for reference and replicated in Wuhan.

2.10.2 Challenges and Future Prospects

Having discussed the successful experience gained through the Wuhan Sponge City Programme, the following section will focus on challenges and further improvements for the programme. The sponge index system of Wuhan was categorized into water ecology, water environment, water resources and water safety, suggested by the national government. However, the system lacks consideration of other factors, especially social aspects.

Although climate change has been considered in the calculation of water drainage capacity and waterlogging prevention, it requires more attention to climate regarding different climate scenarios. Other environmental factors that have not been included in the evaluation of sponge projects include biodiversity, carbon emission reductions and air quality, to mention a few. They could be possibly applied in the multidimensional assessment in the long term. Aside from ecological factors, to ensure the sustainable development of cities, social factors should be taken into account as well, since nature-based solutions offer multiple social benefits. The accessibility to public green areas, mental health, aesthetics, etc., can be potentially included as sponge indicators for environmental and social co-benefit.

The engagement of citizens is sometimes considered in the implementation process of sponge city projects, but it should be strengthened. Public participation and stakeholder engagement is one key component of urban management that could not only fulfil social needs but facilitate project processes and compensate for the conventional top-down management. Local residents should be seen as stakeholders in the sponge city programme and there should be a mechanism for non-governmental stakeholders to be involved in the design and later maintenance of sponge projects. The opinions of property owners, residents and other stakeholders should be fully understood and considered. As one main function for sponge project areas is for recreational activities, such as running and playing sports, the participation of residents can identify their needs, raise awareness of urban nature, and recognise the value of sponge areas[3].

To scale up, the national government should encourage the formation of sponge city networks at both national and international level for open conversations in exchange of experience, good practices and innovations, enabling sponge-related knowledge to be institutionalized[3]. Different sectors should also actively seek more innovative solutions to technological development and governance strategies that support the implementation of nature-based solutions. Opportunities like training, capacity building and research could be given for better implementation and management of sponge projects. Moreover, financial incentives, such as tax deduction, could be offered to ensure social participation in urban green infrastructure and the shared burden of the costs of sponge projects.

In summary, the Chinese Sponge City Programme, which integrates nature-based solutions into cities and leverages the power of nature, is the momentum for moving Chinese cities towards a holistic, nature-based and climate-smart urban water management.

Part 3 Case Studies of Sponge Projects in Wuhan

Case 1 Nangan Channel Sponge Project

Area: 3.84 km^2

Location: Qingshan District (demonstration area)

Participating units: Wuhan Iron and Steel Sponge City Construction Project Investment Co. LTD

Finance: CNY 1.274 billion (EUR 160 million)

Progress: Completed

Background

Nangan Channel is located in an old urban district, involving schools, residential areas, public roads and other public spaces. The high groundwater level, hardening pavement and mixed sewage and stormwater pipes have caused serious waterlogging issues in the area and affected the daily life of the residents[27]. The sponge project in Nangan Channel aims to address waterlogging issues and stormwater pipe systems, but also increase public infrastructure, like green space and parking space, to meet the demands of the residents.

Plan & Design

The main objectives of this sponge project are to capture at least 70% of the annual rainfall, reduce at least half of the non-point source pollution, and resist a 50-year storm effectively[27] (See more details in Annexe). Renovation and dredging of rain and sewage pits were important in the Nangan Channel sponge renovation project. The project planned to identify and differentiate the misconnected rainfall and sewage pipes to rebuild the pipe systems.

This project has constructed various sponge infrastructures, such as bio-retention facilities (Figure 3.1), permeable pavement, underground rainfall storage tank, ecological parking space, etc., in the residential area and other public spaces.

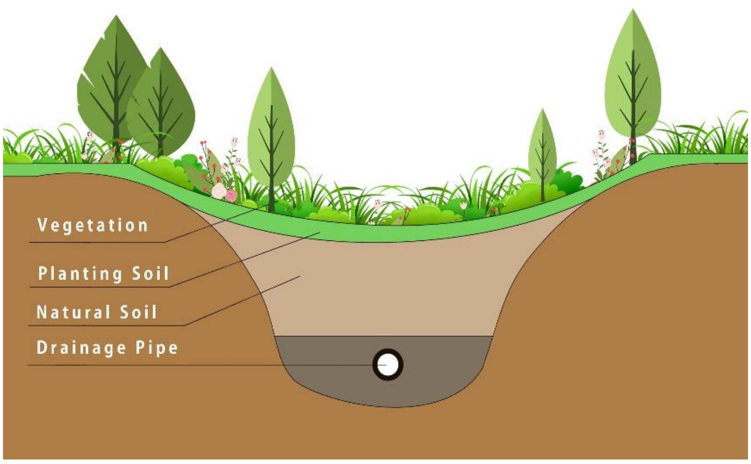

Figure 3.1 Schematic of the bio-retention facility

Public opinion polls were conducted in the residential quarters before renovation. This project also raises funds through the PPP model[28], where only 20% of the funds were from the municipal government.

Results

The project has constructed 12000 m^2 of new recreational areas, more than 1500 parking spots, more than 600 stone tables and benches, renovated more than 7000 rain and sewage wells, finished the construction of 258 distribution systems for stormwater and sewage, solved 9 road problems and finished the renovation of all the rain and sewage distribution systems in public areas. During the project construction, the compilation of the overall design guidance documents "System Scheme" and "One Project and One Policy" of the project was completed. The project also completed the standard guidance of construction work for the construction companies and participated in the compilation of Wuhan sponge city implementation regulations.

Case 2 Qingshangang Wetland Sponge Project

Area: 0.76 km^2

Location: Qingshan District (demonstration area)

Participating units: Water Affair Bureau of Qingshan District; Hubei Design Branch of Pan-China Construction Group Co. LTD

Finance: NA

Progress: Completed

Background

The river channel in Qingshangang area was congested with silt and wastes, which reduced the drainage capacity and water mobility[29]. The sewage outlets were discharged directly into the water body, leading to heavy pollution and eutrophication in the channel[30]. The deteriorated water ecosystem also caused severe biodiversity loss. Moreover, the open space around the area was constructed into shanties and vegetable farmlands, so the landscape quality of the area was extremely poor. Therefore, this sponge renovation project aimed at enhancing the drainage capacity, improving the ecological environment of the area and forming a connected public recreational park.

Plan & Design

The Qingshangang sponge project was designed to capture 85% of the annual rainfall on-site and reduce at least 70% of water pollution[29] (See more details in Annex). To fulfil the targets, it was important to divert the sewage and rainfall pipes and control pollution. The pollution control employed ecological treatments, such as ecological drainage, floating islands, wetland and subsurface wetland, and taking advantage of the 8-meter elevation to treat combined sewer overflows. In the green space along the canal, the sewage water is discharged through sponge facilities rather than going directly into the water bodies. The rainwater can be reused for green areas. As for the water environment, channel dredging was conducted to improve water quality and flow capacity, and aquatic plants were planted to restore the water ecosystem.

Besides, the project integrated sponge design into landscape design with the purpose of enhancing landscape quality[29]. Some streets and residential areas were transformed into sponge-like areas to reduce the pollution at the source. The project has laid out numerous sponge facilities, such as grass swales (Figure 3.2), rainwater gardens and infiltration pavement and rainwater storage modules, in the project area.

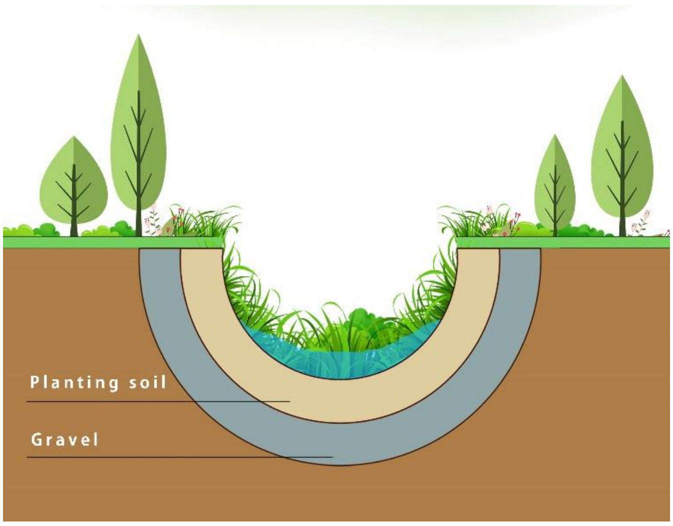

Figure 3.2 Schematic of the grass swale

Results

Through different sponge measures, the black and odorous water bodies were eliminated and the drainage capacity in the catchment was significantly improved, which alleviated the waterlogging issue effectively simultaneously. The main indicators of the sponge project have reached the goal of the annual runoff control rate of 85% and achieved the flood control standard of effectively coping with a 50-year rainstorm[15]. This project is a demonstration project, driving the renovation of surrounding areas. The urban greenways connecting surrounding parks have formed an interconnected landscape pattern, creating a recreational area for citizens[30].

Figure 3.3 Before and after construction of Qingshangang Wetland Sponge Project (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

Case 3 The Sponge Project in the Gangcheng No.2 Middle School

Area: 0.02 km^2

Location: Qingshan District (demonstration area)

Participating units: Hubei Design Branch of Pan-China Construction Group Co. LTD

Finance: NA

Progress: Completed

Background

The school is located in the low-lying area with low quality of pipes, leading to poor discharge capacity of the internal drainage system and a high risk of waterlogging[31]. The school is at the source of the catchment area with the misconnection of rainwater and sewage pipes and initial stormwater runoff pollution, which cause threats to the water quality in the downstream water bodies[32]. Thus, point and nonpoint source pollution should be reduced at the source. The water consumption of school roads and green space is relatively large. The rainwater recycling and collection can realize rainwater recycling utilization and save water resources. The landscape quality in the school is relatively low, so the environment should be optimized to improve the satisfaction rate of the school.

Plan & Design

In this sponge renovation project, the design standard was comparatively high as the school was a high-risk area for waterlogging. The goal for the annual rainfall capture ratio was 80% and the recurrence interval for storm sewer design was 5 years[31] (see more details in the Annex).

Different solutions were applied to resolve different problems. The project designed the renovation of the misconnected stormwater and sewage pipes to completely separate rainfall and sewage. The stormwater pipes were planned to tackle issues of the blocked stormwater pipes and the poor discharge capacity[31]. Clearing and dredging the open channel was critical for siltation and poor water quality. Regarding waterlogging issues, a storage tank was constructed in the school to collect rainwater and pump it to open channels to increase the water drainage capacity. Moreover, this sponge project planned to replace the current stormwater inlets or construct new ecological rainwater drains to reduce pollution and increase the drainage efficiency[32]. Also, sponge infrastructure, including a rain garden (Figure 3.4), permeable pavement for pedestrians, a pervious playground and parking area, levelled flower beds and ecological dry creek, were built to slow down the discharge speed and reduce the pressure for drainage facilities.

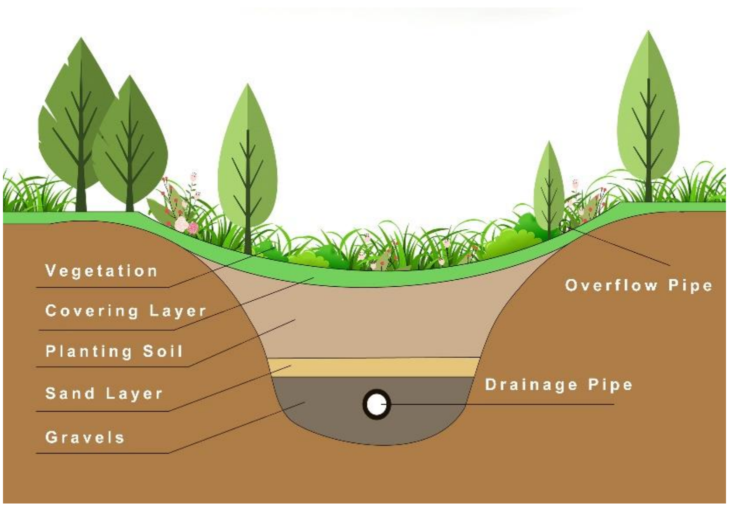

Figure 3.4 Schematic of the rain garden

The project also conducted unified management of sponge landscape patterns to solve the problems of unreasonable landscape layout, the mixed flow of people and vehicles, and poor landscape quality (bare loess). To tackle the issue of the shortage of parking spaces at school, a permeable parking space was built to the west of the table tennis field and to the north of the teaching building[31]. In addition, the project also constructed a sponge publicity board at school for sponge education.

Results

This sponge project has constructed a $400m^3$ rainfall storage tank and 4 water pumps on campus[33]. The collected rainwater can be used for campus greening and road flushing to reuse rainwater. After construction, the waterlogging points would not exceed 15cm and would disappear in half an hour[32]. No waterlogging happened during the storm event in August 2017 when the hourly precipitation reached 113.5mm[15].

Figure 3.5 Before and after construction of the sponge project in the Gangcheng No.2 Middle School (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

Case 4 The Sponge project in the South Lake Area

Area: 1.5 km^2

Location: Hongshan District

Participating units: Wuhan Optical Valley Chinese Science and Technology Park Investment Co., LTD; Wuhan Municipal Engineering Design and Research Institute Co., LTD; China First Metallurgical Group Co., LTD

Finance: CNY 180 million (EUR 22.74 million)

Progress: In construction, to be finished by the end of 2020

Background

The project area is mostly located in low-lying areas, especially in some old residential areas where there was the problem of mixed rainwater and sewage water, and the diameter of underground pipes was too small to meet the drainage design requirements[34]. Seriously silted pipes also existed. Part of the area lacks rain pipe network and outlets, making rainwater accumulate easily and forming waterlogging. Therefore, the objective of this sponge construction project is to separate the previously mixed and misconnected rain and sewage pipelines and to significantly improve the capture ratio of annual rainfall, reduce non-point source pollution, and solve waterlogging problems in the area.

Plan & Design

The sponge construction project involved 18 residential quarters, including drainage network renovation and landscape sponge renovation. The drainage renovation consisted of rainwater and sewage diversion, pipeline dredging, renovation of waterlogging points and seepage discharge pipes. Landscape renovation included a rain garden, ecological parking lot, permeable pavement, grass swales, green roofs and other sponge infrastructures, built according to the main problems of the site[35].

This project aimed at capturing 65% of the annual rainfall and removing 60% of the total suspended solids in the area[34] (see more details in the Annex). Sponge infrastructures were implemented according to local conditions. In some areas, green space was transformed into a sunken green space to absorb rainfall. An abandoned dry pool in the community has also been transformed into a rain garden and replanted with shrubs and turf to form a landscape[34]. As disturbance and construction should be avoided in this urban area with high environmental quality, green roofs (Figure 3.6) are a good choice for “infiltration” and “retention”.

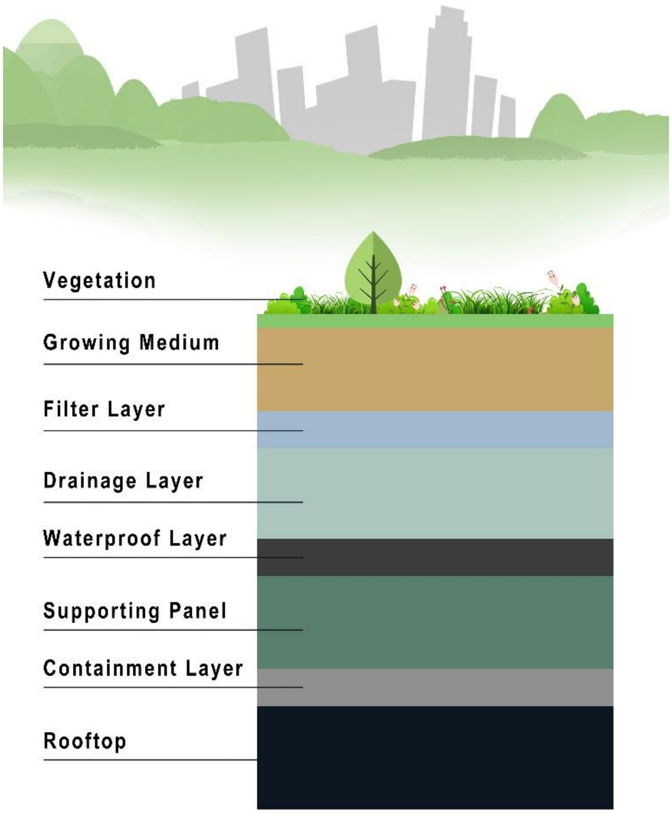

Figure 3.6 Schematic of the green roof

Results

During project construction, rainwater and sewage were separated, the overflow of sewage on rainy days was reduced, and the impact on the downstream sewage treatment facilities was successfully reduced[34]. The project also eliminated waterlogging issues in the area with the construction of new rainwater pipes and gutter inlets[35]. Regarding the landscape sponge renovation, the sponge indexes were effectively improved through the construction of low-impact development facilities. Other results will come out after the completion of the entire project.

Annex: Sponge Indexes of Wuhan Sponge Projects

Project			Case 1	Case 2	Case 3	Case 4
			Nangan Channel	Qingshan Port Wetland	Gangcheng No.2 Middle School	South Lake Area
Sponge Indexes	Water Ecology	Volume capture ratio of annual rainfall	70%	85%	80%	65%
		Ecological shoreline	NA	NA	NA	NA
	Water Environment	TSS[1]	50%	70%	70%	60%
		Others	NA	Diversion rate of rainfall and sewage water: 100% Water quality standard: standard III	Sewage collection rate: 100%	NA
	Water Safety	Flood control	Achieve a capacity to resist 50-year storm	50-year storm	50-year storm	NA
		P[2]	3 years	2-3 years	5 years	New rainwater pipes: 2-3 years; Renovated rainwater pipes: 1 year
		Runoff coefficient	≤0.6	≤0.6	≤0.6	≤0.6
	Water Resources	Rainfall utilization rate[3]	25%	≥25%	≥25%	NA
	Others		NA	NA	NA	The proportion of permeable pavements: 40%

Note:

TSS[1]: The reduction rate of non-point source pollution

P[2]: The recurrence interval for storm sewer design

Rainfall utilization rate[3]: The utilization rate of recycled stormwater in greening irrigation, road flushing and other ecological purposes

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