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## Enlightenment of Foreign Theories of Sustainable Storm Water Management to Sponge Cities in China

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# Enlightenment of Foreign Theories of Sustainable Storm Water Management to Sponge Cities in China

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**Abstract:** With the promotion of sponge cities in China, foreign theories of sustainable rain and flood management similar to sponge cities has also begun to attract attention from all sectors of society. In China, sponge cities are developing continuously. However, people's doubts about sponge cities are rising because of people's low understanding of sponge cities, some problems in the construction process of sponge cities, and the results so far are not significant. This paper makes a comparative study on the foreign theories of sustainable rain and flood management and sponge cities.

## 1. Introduction

At present, the development of global urban water environment is facing severe challenges. In order to cope with the problem of urban rain and flood, many countries have carried out sustainable rain and flood management according to their own national conditions, and introduced relevant regulations and design methods, including the Low Impact Development in United States, Water Sensitive Urban Design in Australia, ABC Water Plan in Singapore, and Sponge Cities in China. Compared with these countries, the practice of sustainable rain and flood management in China started late. At present, the construction of sponge cities is still in the primary stage, the technology is not mature enough, the management is not perfect enough, and there are many other problems. Foreign sustainable rain and flood management has a long history, rich experience and relatively mature technology. These successful experiences can be used for reference in the construction of sponge cities in China.

## 2. A summary of foreign theories of sustainable rain and flood management

Foreign research on rain and flood management has developed for nearly a century, and its theory has been relatively advanced. However, due to the different historical stages, economic and social backgrounds, regional and cultural foundations and ecological environment of each country, the management system of rain and flood disasters formed by each country is also different. Three most representative theories abroad, namely Water Sensitive Urban Design, Low Impact Development and the ABC Water Plan of Singapore, are selected to elaborate in detail.

### 2.1. Water Sensitive Urban Design—hereinafter referred to as WSUD

WSUD originated in the 1960s. It combined the urban design with the management, protection and preservation of urban water cycle to ensure that urban water cycle management respected the natural water cycle and ecological process. Water sensitive cities were Australia's improvements to traditional development practices, including water treatment and site landscape design. It layered stress on reducing the negative impact on natural water cycle and protecting the health of water ecosystems through holistic



analysis of urban planning and design. It took urban water cycle as a whole and integrates rain and flood management, water supply and sewage management.

### *2.2. Low Impact Development—hereinafter referred to as LID*

LID developed in the late 1990s from the Best Management Practices in the United States. BMP was proposed in 1972 to control non-point pollution. LID means Low Impact Development, which was called low impact development by some people. It referred to a rainwater management method based on the principle of simulating natural hydrological conditions and adopting the concept of source control to realise rainwater control and utilisation. The goal of LID was to maintain the hydrological balance of a site before and after development by means of infiltration, filtration, storage and evaporation of rainwater. The characteristic of LID was that its development had a low impact on the original environment, and tended to manage rainwater by soft engineering through vegetation treatment in the site, which was designed in combination with the hydrological environment of the site.

### *2.3. Active, Beautiful, Clean Waters (ABC Waters) Programme —hereinafter referred to as Singapore ABC*

Singapore ABC was launched jointly by Singapore National Water Authority and Public Utilities Bureau in 2006. The official definition of ABC was "transforming existing drainage ditches, rivers and reservoirs with single functions and poor practicability, combining urban landscape, integrating surrounding land development, creating lively and beautiful streams, rivers and lakes, and creating more liable and sustainable waterfront leisure and community activity space".

Compared with LID and WSUD, Singapore ABC started late. Moreover, through Singapore's domestic development theory, its system theory was more comprehensive on the whole, its vision was longer, its humanistic feelings were more prominent, and its development goals were more focused on the development environment of the whole city. It combined the water environment and urban development of Singapore as a whole, and played a great role in the participation of non-governmental organisations and the public. Initially, in order to diversify the water supply, Singapore adopted a number of water management methods to deal with the country's water crisis. With the development of cities, Singapore has gradually shifted its focus from water management to the integration of catchment areas and urban space. Because of the limited space, the urbanisation process posed a higher challenge to the city's function and carrying capacity. The Singapore Bureau has created an integrated rain and flood management system that included source solutions, path solutions and destination solutions. With the acceleration of urbanisation and constant consideration of water management methods, Singapore had a better view on water management and urban design. The Singapore ABC was launched in 2006. It aimed to transform Singapore's water structure so that it could surpass the only functions of flood protection, drainage and water supply before. By integrating Singapore's water resources, urban parks and leisure facilities, building a "blue, green and orange" comprehensive system, it created a vibrant urban development space that could enhance social cohesion.

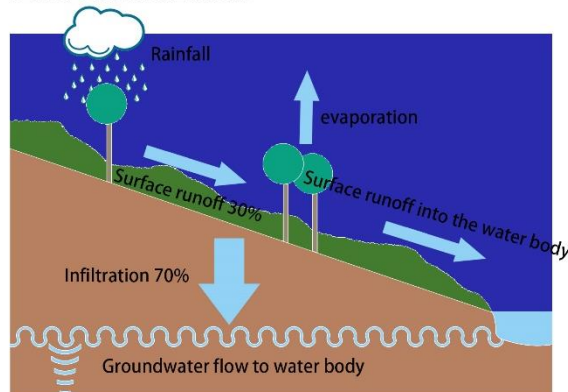
## **3. Theory of Sponge Cities in China**

### *3.1. Background*

After decades of urbanization, China is facing various crises, such as water shortage, water pollution, floods, urban water logging, the decline of groundwater level, the loss of aquatic habitat and so on. Urban problems are very serious. Especially with the increase of urban waterproof pavement and the decrease of available green space, urban water logging problem is becoming more and more serious. Over the past 20 years, many large and medium-sized cities in China have been frequently attacked by water logging disasters. In 2012, serious water logging disasters occurred successively in Beijing, Nanjing, Wuhan, Nanchang and Changsha, causing heavy casualties and property losses. In June 2012, rainstorms occurred in Yichang, which affected more than 200,000 people. The frequent occurrence of such serious urban waterlogging not only threatened the safety of life and property of urban residents,

but also seriously affected the normal development of urban economy. In the face of such internal and external problems, China urgently needs to adopt some "solution" to alleviate this series of water problems, and sponge cities theory emerges as the times require.

#### Before urbanization



#### After urbanization

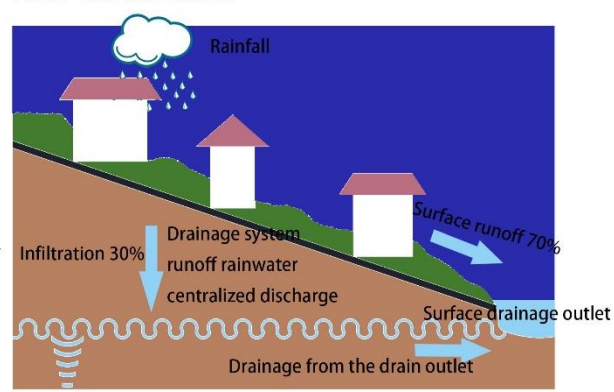


Figure 1 Comparison before and after urbanization (Picture source: made by author)

### 3.2. Definition

As the name implies, sponge cities refers to a city that has good "flexibility" in adapting to environmental changes and coping with natural disasters like a sponge. It should absorb, store, seep and purify water when it rains, and release and utilize the stored water when needed.

### 3.3. Process

In the early urban construction, China emphasized the adaptability, green ecological concept and sustainable development, which coincided with the concept of sponge cities. Before 2012, the concept of eco-resilient city similar to sponge cities appeared in China. In April 2012, the concept of sponge cities was first proposed in the Forum on Science and Technology of Low Carbon Cities and Regional Development 2012. In April 2015, the first batch of sponge cities experiment projects were determined, and in April 2016, the second batch of sponge cities pilot projects were determined. After three years of construction plan, the second batch of sponge cities experiment will soon usher in results testing.

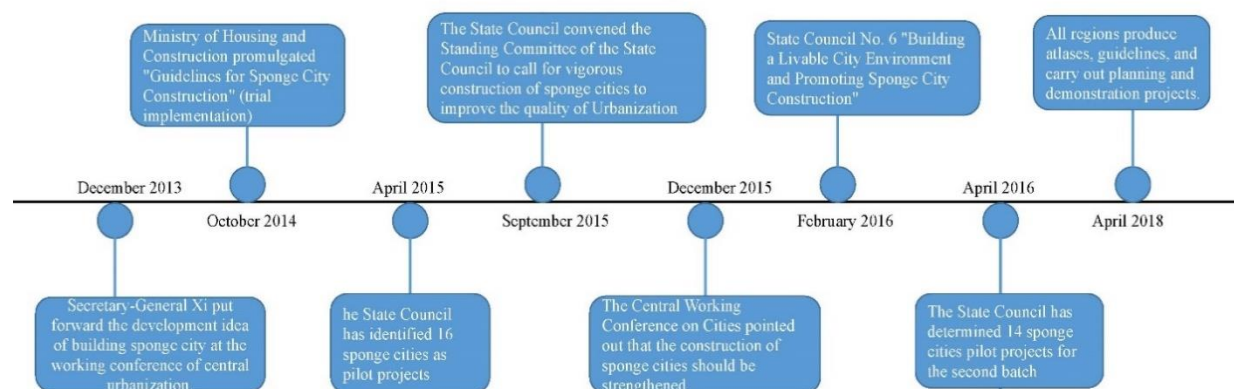


Figure 2 Process map of sponge cities in China (Table source: made by author)

## 4. Comparisons of Foreign Theories of Sustainable Storm Water Management and Sponge City Theory in China

### 4.1. Theoretical contents

As the theoretical content has been introduced in detail in the previous paragraph, this paragraph focuses on the similarities and differences of the theories.

Sponge city theory	Abbreviation	Major countries	Origin cause	Origin time	Definition	Emphasis	Time to date
Water Sensitive Urban Design	WSUD	Australia	Rainfall is scarce in Australia, where arid or semi-arid areas account for more than 70% of the land area and more than a third of the land is covered by deserts.	1960s-1980s	Water environment management of natural water	Emphasis on urban planning and design methods	About 60 years
Low Impact Development	LID	The United States	Control non-point source pollution	In the late 1990s	It is a rainwater management method based on the principle of simulating natural hydrological conditions and using the idea of source control to realize water control and utilization.	Emphasis on source control	About 30 years
ABC Water Plan (A stands for activity, B stands for beautiful, C stands for clear)	ABC Water Plan	Singapore	THE SOURCE OF RAIN is not guaranteed, it can only meet about 20% of the water demand	In 2006	ABC is an optimized water resources management strategy, which aims to transform sewers, ditches and reservoirs into dynamic, beautiful and clear rivers and lakes. The goal is to integrate the environment, water bodies and communities to create a dynamic and sustainable urban development space with social cohesion.	In the early stage, the storage of water resources was emphasized, and in the later stage, the integration of catchment canal and urban space design was emphasized.	Thirteen years
China's Sponge Cities	Sponge cities	China	The urban waterlogging is serious	In 2012	It means that the city has good "flexibility" in adapting to environmental changes and coping with natural disasters like a sponge. When it rains, it absorbs water, stores water, soaks water, purifies water, and releases the stored water when it needs it and makes use of it.	Emphasize the role of the city itself	Seven years

Figure 3 Sponge City Theory Collection (Table source: made by author)

#### 4.1.1. Similarities

(1) There are many theoretical commonalities between foreign sustainable rain and flood management and sponge cities in China. For example, their water treatment methods are the same in essentials while differing in minor points, using rainwater gardens, green infrastructure and so on.

(2) The development of their theoretical content was towards a more integrated goal. With the continuous development of time and the acceleration of urbanisation, the theory of rain and flood management will become more perfect. Theories of the rain and flood management have begun to rise to a more "comprehensive" level, the thinking of specific theoretical objectives has risen from the original single goal to the urban system, and the theoretical content of thinking has also changed from simple and single to complex and pluralistic. For example, with the continuous improvement of the theory, the theoretical goal of low-impact development technology is to extend gradually from maintaining the hydrological environment and surface and groundwater quality control before site development to maintaining the integrity of aquatic life resources, ecosystems and receiving water ecosystems, and then to protecting natural resources, biological resources and ecological resources. After the accumulation of previous water management methods and the continuous learning of successful experience from other foreign countries, the current theoretical objectives of Singapore ABC have become relatively more integrated. From the perspective of the overall urban environment, it hopes to build a thriving urban development space full of social cohesion. Australia's WSUD was the earliest theory of development. It has been nearly 60 years since its origin. Its strategic goal was also from the initial pollution control to the combination of urban water cycle and urban design. Among them, the object of rain and flood management has changed from single to multiple, and the management goal has also risen from maintaining the health of water quality to creating a liable city, so as to enhance the flexibility and adaptability of the city.

(3) The process of theoretical development started from the problems faced by the city in order to find a rain and flood management model that adapted to its own characteristics.

(4) The scope of application of the theory was wider and wider, and there were more and more interdisciplinary related to it.

#### 4.1.2 Differences

(1)The emphasis of the theories are different. The initial principle of low impact development and sponge city construction are ecological priority. They have been emphasising the maintenance of the original natural hydrological function, so that the site can maintain the original hydrological function after being developed. Singapore ABC emphasises the overall environment of the city. It puts forward a comprehensive system of blue, green and orange, hoping to build a green water, blue sky, ecologically liable home city. WSUD emphasises the cooperation between urban planning design and landscape specialty.

(2)The process of theoretical objectives are different. The United States tried to solve the problem of water pollution in the 1980s. Now their theory focuses on occasional water logging, wetland ecological restoration, and waterfront landscape. At present, the problem of water pollution in sponge cities in China is still very serious, so the problem of water pollution occupies a larger weight. Singapore ABC has solved the problem of water supply. In recent years, it has shifted its goal to the integration of catchment areas and urban space recreation. WSUD in Australia has shifted its goal from initial sewage treatment to the integration of urban water cycle and urban design.

(3)The degree to which the theoretical audience considers the public is different. American LID pays attention to the degree of public participation in the formulation of work flow, formulates detailed explanations and public participation plans, and actively guides the bottom-top principle. Singapore ABC also attaches great importance to the role of private institutions and residents. It has done a good job in maintaining management and public education by incorporating the PPP model into written plans. WSUD in Australia has been in the process of transformation, and has made some corresponding strategies to support community participation. Comparatively speaking, there is a slight gap in public participation in sponge cities in China. It neither made oral propaganda nor put it on the written agenda.

(4)The way of management is different. The United States is a federal state. As far as the federal government is concerned, it has a unified governing body, the U.S. Environmental Protection Agency. Therefore, any policies, plans or activities related to water resources management should be implemented in accordance with regulations of NEPA. However, the water resources in the United States are owned by the states, and the management of water resources is basically carried out by the states.

The federal government is mainly responsible for macro-management planning, supervision and coordination. The specific management of water resources is the responsibility of the water management departments of each state, and is guided by the legislation and mutual agreement of each state. This is a way of combining administrative region management with watershed management. Singapore ABC, Australia and China are dominated only by government agencies to manage and develop contents.

#### 4.2. laws and policies

In terms of legal and policy support, foreign sustainable rain and flood management has been developing for a longer time, and the support of laws and regulations and related policies are also better. However, although China has developed relatively late, the government's support is strong, so it is being constantly improved.

WSUD: Australia has the longest history of development. In its infancy, the government launched a campaign of "Treating the Yalla River with an open hand" in 1980, calling for public awareness of environmental protection. In the following process, with the development of water-sensitive cities in Australia, laws and regulations have been constantly improved. At the beginning of the transition period, the Victorian Government first drafted the Best Practices Guide. In the growing stage of maturity, the best practices guidelines have been formally compiled by the whole country and various states as the design guidelines for water-sensitive cities. In addition, the local government has also launched a rainwater quality compensation strategy and formulated a strict compensation policy for fear of the economic burden on land developers caused by technological transformation. In the stabilisation phase, the Australian Federal Government has set up a new government management department-"Vigorous Victoria Office", advocating the creation of "Vigorous Melbourne, Vigorous Victoria".



**LID:** LID technology originated mainly in the United States. And it is now mainly popular in the United States and Canada. The United States is a federal state. National-level LID technology is under the responsibility of the US EPA. Each state has a design manual to guide its LID engineering practice. The US Federal Government Environmental Protection Agency (EPA) is responsible for compiling national LID guidance documents. In 1999, the Department of Environment and Resources in Prince George County, Maryland, launched the first LID design manual, Low Impact Development Design Strategies: an Integrated Design Method. In 2003, the Department of Housing and Urban Development officially published Low Impact Development Practice Report. In 2004, the U.S. Department of Defense released the "Low Impact Development: Unified Facilities Standards". In 2010, the U.S. Environmental Protection Agency defined LID as the green water infrastructure of the 21st century.

**Singapore ABC:** In 1963, the Public Utilities Bureau, which was subordinate to the national water administration, was established to take charge of the development, utilisation and protection of water resources in Singapore. In 2001, Singapore Public Utilities Authority was integrated into a unified water management organisation. In 2006, it began to implement the overall planning of water environment in the central region and the Urban Guidelines of the "Vigorous, Beautiful and Clean". In 2010, the Public Utilities Bureau launched the ABC Urban Waters Landscape Design Certification Scheme. In 2010, it launched the ABC Urban Waters Professional Program because of the rapid growth of talent demand. In 2017, it added ABC Water Certification Gold Scheme to the 2010 Urban Waters Landscape Certification Scheme.

**Sponge cities:** In October 2014, the Ministry of Housing and Construction issued the Guidelines for the Construction of Sponge Cities in China. In 2015, it identified the first batch of six sponge city experiment projects. In 2016, it identified the second batch of 14 sponge city pilot projects. In 2018, atlas guidelines were compiled in succession in all parts of the country. Although only six years have passed, it was extremely rare for them to issue policies so quickly and determine the time interval between pilot projects so quickly. This fully proved our government's strong support for sponge cities. However, due to the short development time of sponge cities in China, many laws and policies are not perfect. With the continuous development of sponge cities in China, our country should learn from foreign rain and flood management and constantly improve relevant policies, such as ABC in Singapore supports the projects of water professionals.

time	Enacting agency	Enactment of regulations	Main content of related policies
2014.10.22	Ministry of Housing, Urban and Rural Construction	Technical Guidelines for the Construction of Sponge Cities, Construction of Rainwater Systems for Low Impact Development (Trial Implementation)	It put forward the basic principles of sponge city construction, that was, influencing the development of rainwater system construction, planned the decomposition and implementation of control objectives and its technical framework, and defined the content, requirements and methods of the construction of low-impact development rainwater system in the process of urban planning, engineering design, construction, maintenance and management.
2014.12.31	Ministry of Finance, Ministry of Housing, Urban and Rural Construction, Ministry of Water Resources	Notice of the Ministry of Finance, the Ministry of Housing, Urban and Rural Construction and the Ministry of Water Resources on the Pilot Project of Central Financial Support for Sponge City Construction	It clearly pointed out that the central government would grant special fund subsidies to the pilot projects of sponge city construction for a certain three-year period, and the specific amount of subsidies would be determined in different grades.
2015.04.02	The State Council	Action Plan for Water Pollution Prevention and Control State Council No. 41 Document in 2015	It clearly pointed out that we should actively implement the low-impact development and construction mode, construct the rainwater collection and utilization facilities combining stagnation, seepage, storage, use and drainage, and build hardened pool surface in new urban areas, and its permeable area should reach more than 40%.
2015.10.11	General Office of the State Council	Guiding Opinions on Promoting Sponge City Construction (State Council No. 75 Document in 2015)	It pointed out that urban construction should be summarized to minimize the impact of urban development and construction on the ecological environment, and 70% of the rainfall should be digested and utilized in situ. By 2020, more than 20% of urban built-up areas will meet the target requirements. By 2030, more than 80% of the urban built-up areas will meet the target requirements.
2015.12.10	Ministry of Housing, Urban and Rural Construction and State Development Bank	Notice on Promoting Development Finance to Support Sponge City Construction	This notice required the State Development Bank, as a development financial institution, to make sponge city construction a key area of credit support and better serve the national economic and social development strategy. All levels of All levels of housing construction departments in urban and rural areas should take the State Development Bank as the key cooperative bank, strengthen cooperation with it, enhance the financial security of sponge city construction projects, make full use of credit funds, and help the construction of sponge city.

Figure 4 Policies existing in sponge cities (Picture source: made by author)

#### 4.3. Design goal

WSUD: From the functional point of view, the goal of water-sensitive cities in Australia pays attention to the ecological function of rainwater measures, and takes the water as the core. Specific objectives include "water quality", "water quantity", "maintenance" and "water supply". The goal of "water quality" includes multiple objectives of reducing pollution load and environmental protection. The objective of "water volume" includes the control of runoff duration, flood frequency, peak discharge and total runoff. The goal of "maintenance" includes the maintenance of sensitive areas and the curing of natural drainage systems. The goal of "water supply" includes reducing the demand and supply of drinking water and sustainable recycling.

LID: The goal of low impact development in the United States is to start from a functional point of view. Initially, it focused on solving the problem of non-point source pollution. With the continuous improvement of technology and the increasing problem of urbanisation, its design goal has gradually expanded from maintaining the hydrological environment and surface of a single site before development and controlling groundwater quality to the integrity of site aquatic life resources and the ecosystem, and received the integrity of the water system, and then to the protection of natural resources, biological resources and ecological environment. There are four main design objectives of site LID, including site runoff value, peak runoff, runoff frequency and duration, and water quality. The establishment of the first three objectives should fully consider the whole rainwater circulation process, while the water quality control objectives mainly consider the runoff of waterproof surface and the treatment of rainfall pollutants.

Singapore ABC: ABC Water Plan, from the urban perspective, aims to give full play to the potential of water bodies to improve water quality and quality of life. It hopes to turn the city into a garden and a water city. The meaning of the ABC Water Plan is "positive, beautiful and clean". It aims to create beautiful and clean streams, rivers and lakes, have postcard-like beautiful community space for everyone to use, so that urban residents can have a better life.

Sponge cities: Sponge cities in China start from the planning level and pay attention to the safety and ecological problems of cities. Its specific objectives include total runoff control, peak runoff control, runoff pollution control, utilisation of rainwater resources and so on. Among them, because the specific situation of different places is different, it can choose one or more objectives as planning control objectives according to the actual situation. Generally speaking, the total runoff control can be chosen as the primary planning control objective for the construction of low-impact development rainwater system in different regions. However, the annual total runoff control rate is generally regarded as the control target for the total runoff control. Runoff control rate corresponds to the design of rainfall. Specific methods can be consulted in the Guide.

In comparison, from the perspective of goal setting, WSUD and LID are from the functional point of view, sponge cities in China are from the urban planning level, and ABC in Singapore is from the urban human settlements environment. As far as the specific content of the target is concerned, the water is the core of WSUD, the total runoff is the core of sponge cities in China, and the waterscape landscape design is the core of ABC in Singapore. From the point of view of target evaluation criteria, LID, WSUD and sponge cities in China have similar evaluation criteria. They are all in an ideal state. The runoff discharge after development and construction takes the runoff discharge close to the natural landform before development and construction as the standard. The standard of ABC in Singapore has always been to create a more beautiful natural environment for human settlements and to maintain and surpass it.

#### 4.4. Flow of work

WSUD: The process of WSUD design work is clear and strict. The content of the workflow covers design criteria, approval process, design evaluation, results requirements, etc. Workflow embodies three characteristics: systematic, hierarchy and standardisation. According to the working flow chart of WSUD, two nodes can be observed, namely, conceptual design scheme and deepening design scheme. Both schemes need to be submitted to the committee to discuss whether they meet the water-sensitive



WSUD requirements. Once it does not meet the requirements, it is returned to redesign the plan, re-execute, and repeat the cycle until it meets the requirements before compiling the construction implementation document. In the process of evaluation, first, it is necessary to evaluate the design drawings of each water-sensitive measure according to the standard WSUD Engineering Technical Regulations. Second, it is necessary to apply SWMM modelling software to measure water quantity.

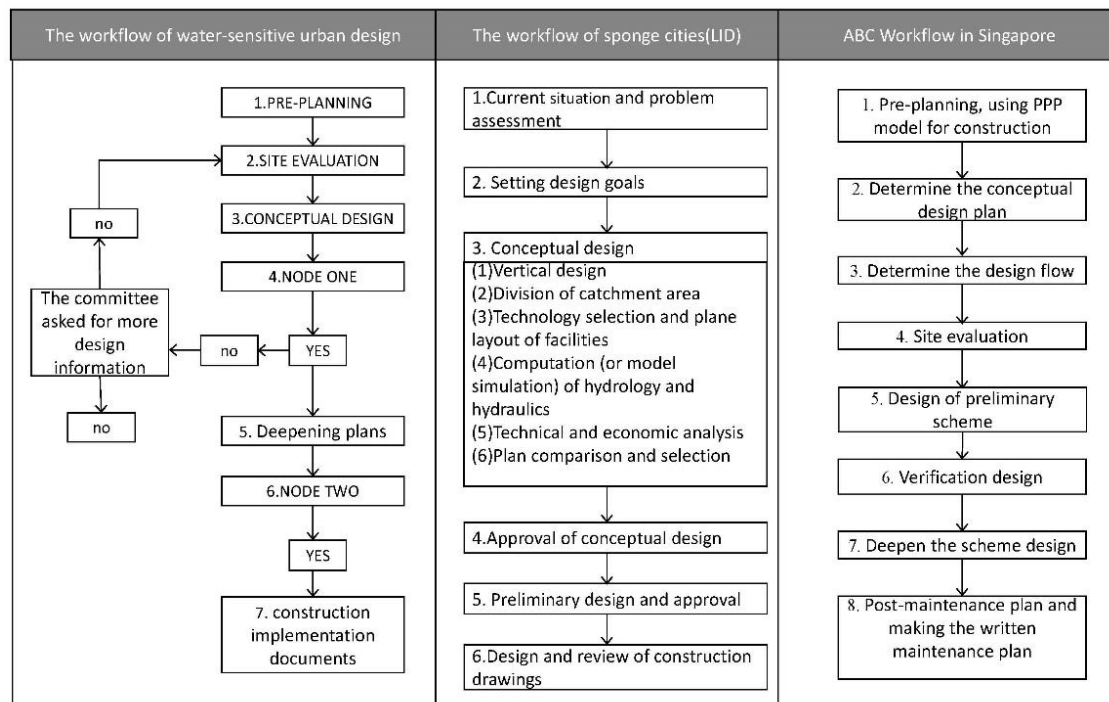


Figure 5 (Table source: made by author)

LID: American LID, from a macro perspective, has two workflows, NEPA and EIS. For any policy, plan or activity related to water resources management, it shall carry out environmental assessment in accordance with the provision of NEPA, and prepare one of the assessment reports of CE (category of exemption), EA (environmental assessment) and EIS (environmental impact report) according to the severity of the environmental impact of the programme. Only after the relevant impact on the environment has been determined and assessed can it be allowed to pass. From the point of view of EIS workflow, it pays more attention to public participation. In the early feasible meeting, it pays attention to public promotion, and after the later drafting is completed, it pays attention to public comment participation. From the point of view of the work flow of water design, it has two characteristics: clarity and hierarchy. The work flow includes the evaluation and analysis of LID site, the determination of rainfall events, the determination of LID site design objectives, the formulation of non-structural site planning strategy and technology, and the determination of the preliminary and final plan of LID site planning.

Singapore ABC: According to technical measures, the work flow can be divided into vegetation depression, biologically detained marsh and biologically detained basin. However, these three workflows are similar in general, ranging from site evaluation in the early stage, to the determination of conceptual solutions, and then validation design. After the design passes, the design is deepened. It is worth mentioning that Singapore ABC has set up the maintenance plan as a workflow, which clearly states that it needs to develop a written maintenance plan. All projects designed and completed must be certified by ABC Water Project.

Sponge cities: According to the technical measures, the work flow of sponge cities can be divided into two categories: ecological restoration and low impact development. Among them, the low impact

development workflow directly adopts the workflow of the American LID. From pre-planning to site evaluation to project design, it is a simple talk about the rut. It only proposes to coordinate with the majors of gardens, roads, drainage, architecture, but it does not put forward how to link up and how to cooperate. Moreover, it only mentions in some paragraphs that it needs to meet the relevant requirements of urban master planning and special planning, and does not specify in detail how the requirements should be met or which one of the specifications is. The drawbacks reflected in the process are that the evaluation criteria in the process are not clear and strict. The first is that it does not specify which criteria should be strictly followed to strictly enforce the standard assessment. The second is that it can be seen in many places in the guide that software test simulation is only performed when conditions permit. This shows that the work flow of sponge cities in China is not strictly implemented.

The workflow of water-sensitive city mainly embodies systematisation and hierarchy, and is designed separately by site size. However, each site is to achieve the sustainable management of catchment area from the source-process-end three control stages. The work flow and design method of sponge cities in China adopts different design methods according to different types of reference objects, which are divided into four parts: building and district, urban road, urban green space and square, and urban water system.

#### *4.5. Technical measures*

**WSUD:** The core technology of WSUD is BMP (Best Management Practices), Bmp is usually divided into the structural Bmp and the non-structural Bmp. Structural BMP refers to control pollution and flooding problems in the process of rain and flood by using a variety of treatment technologies and facilities. Non-structural BMP refers to achieve the goal of rain and flood management through non-technical means such as management, system or education. BMP mainly includes demand management, roof water collection, rainstorm collection, sewage treatment reuse, serious pollutant capture equipment, sedimentation tank, grass or vegetation depression, gravel filter, biological retention system and other measures.

**LID:** Low-impact development technology in the United States is a green rainwater infrastructure that can be fully promoted only after many years of engineering practice at the grass-roots level. Its main implementation means include: 1. roof rainwater system 2, rainwater storage system 3, grass planting ditch 4, rainwater garden 5, concave green space 6, permeable road 7, green street. In terms of technology development and management, each of them has its own responsibilities. The EPA of the United States is responsible for the LID at the national level, and there are design manuals to guide the practice of LID projects in various states at the local level. These design manuals provide specific guidance for local governments and communities in developing green infrastructure.

**Singapore ABC:** Singapore ABC is mainly divided into catchment elements, treatment elements, transportation and storage elements. The catchment elements mainly include artificial places such as squares, building structures, vehicle roads and pedestrian corridors. Catchment is the most important factor. Its main type is natural wetland. Among them, water landscape design is the main one. It adopts the bio-soil engineering technology and roof greening engineering, the design of depression and buffer zone, and the design of biological detention land. The elements of transport and storage refer to Singapore's rainwater network. ABC Water Design Guide gives a detailed description of these facilities.

**Sponge cities:** The main core technical measures of sponge cities in China are the restoration technology of water ecological sensitive areas and low impact development technology. Rehabilitation technology of aquatic eco-sensitive areas is relatively imperfect, while low-impact development technology mainly refers to foreign low-impact development technology, which is relatively mature. Low-impact development technology can be divided into three categories according to its main functions: detention and storage technical measures, permeation and transportation technical measures and storage and reuse technical measures. Low-impact development technology includes a number of different forms of low impact development facilities, including permeable mat formation, roof greening, grass planting ditch and sunken green space. The technical measures of the guide give a detailed table on how to select technical measures, and point out how to choose the best combination method for a

single measure, the principle of combination and the calculation method for the scale of technical facilities. For example, the guideline for the selection of facilities provides a list of the necessary selection of low impact development facilities and a list of the selection of low impact development facilities for various types of land use. For example, the principle of selecting single or combined low-impact facilities is as follows: 1. The applicability of each facility conforms to the permeability of site soil; 2. It corresponds to the planning control objectives; 3. It can control the cost well. For example, the scale of technical facilities is divided into six different types of algorithms, and each algorithm gives a detailed formula calculation. Generally, there are three algorithms: volume method, flow method and water balance method.

Technical measures are the priority among priorities. Domestic and foreign theories have introduced the technical measures in detail from the micro aspect. However, compared with us, foreign technological measures are more mature. The LID in the United States is based on micro infrastructure, and has strict requirements and mature calculation algorithms in rain pattern design and water volume design. The government of Singapore participates strongly, and its infrastructure is relatively perfect, mainly focusing on rainwater quality and waterscape landscape design. WSUD mainly lay stress on the method of urban design. It has developed for a long time in terms of technical measures, and has been mature through continuous improvement. China's development is relatively late, and its technological measures are basically based on the LID of the United States. Therefore, China's technological measures are relatively developing. The introduction of the detail drawing of technical measures in the guide is more detailed, which needs to be redesigned according to China's actual national conditions and local conditions. Moreover, in the process of the pilot, we need to constantly adjust and modify according to the feedback results to achieve the design objectives of our sponge cities.

#### *4.6. Maintenance management*

**WSUD:** In terms of policy, the cost budget should be considered from the early stage. Australia has set up a CRCWSC platform to help formulate policies, share data, translate its research into supportive tools and actions, and provide an accessible general platform for the general public.

**LID:** On the macro level, one of the five core principles of low impact development is education and maintenance, mainly government support and public participation. It includes providing sufficient funds for the practice and maintenance of rainwater management technical measures, and teaching people how to apply rainwater management technical measures to private field areas and reach legal agreements to ensure long-term implementation and maintenance. On the micro level, each state manages it separately, and most of them have issued guidance documents such as low impact development technology manual. For example, Arizona's Southwest Green Infrastructure and Georgia's Rainwater Management Manual of Coastal Rainwater Supplement to Georgia, which describes in detail how to maintain and manage these low impact technical measures.

**Singapore ABC:** On the macro level, the government has been emphasising the sense of ownership of urban residents and cooperation with non-governmental profit-making organisations, and has implemented a series of policies to enhance the maintenance and management of ABC water plan. For example, the ABC Water Project Certification Scheme and the newly added ABC Water Project Gold Scheme. They have inspired private institutions and urban residents to use and manage the measures in a responsible and protective manner. On the micro level, PUB has issued *Sponge City of Singapore - ABC Guidelines*. It describes in detail the key factors that need to be considered in maintenance, the main types are facilities maintenance requirements, specific maintenance lists and so on. *ABC Water Design Features* provides detailed operations on how to design, build and maintain these features. One chapter of *ABC Water Design Guidelines* introduces in detail the construction and maintenance of technical measures at construction stage and after completion.

**Sponge cities:** Macroscopically speaking, the government attached great importance to the maintenance and management of sponge cities. During the period from 2012 to 2018, many localities issued maintenance standards for sponge city construction facilities, such as the "Ningbo Sponge Facility Operation and Maintenance Management Measures" issued in 2018. On the micro level, the

originator of the introduction of the maintenance and management of sponge cities was the guide in 2014. The guidelines not only put forward clear requirements for maintenance management, but also listed the main points for attention, maintenance frequency and risk management of different low-impact development facilities maintenance.

**Comparison:** From the point of view of national support, the world attaches great importance to maintaining green infrastructure, but they adopt different solutions. WSUD mainly integrates data resources to provide a relatively transparent platform for user monitoring and maintenance management. LID and the Singapore advocate people's initiative and lay stress on the public participation. Sponge cities in China are mainly implemented by state compulsion. From the point of view of micro-technical regulations, the maintenance of green infrastructure has been introduced in detail at home and abroad. China is speeding up the pace of sponge city construction.

## 5. Conclusion

From the comparative study between sponge cities in China and foreign theories of rain and flood management, we can find that sponge city construction in China is still in the primary stage, the construction of sponge cities is a long and tortuous process, and our country is making continuous progress, absorbing the essence of foreign theories, and constantly improving our sponge city theory. The following conclusions are drawn by comparing and separating the theories of rain and flood management, hoping to benefit the development of sponge cities in China.

(1) Theoretical contents: By comparison, they are similar.

(2) Related policies: Sponge cities in China have a short history and strong government support. Although the relevant contents are not detailed enough, they are being improved. Because of the great difference of urban water, many places have put forward policies suitable for themselves. Regarding the content of relevant policies, various places have also sought opinions from the society, and strengthened the participation of the people and the public.

(3) Design objective: Theories at home and abroad are much the same. They are all aimed at improving the environment and making people's lives better. From the beginning, the design objectives of our country are multifaceted and omni-directional, so the content is relatively complex. Therefore, it is necessary to quantify and decompose the objectives correctly in the design and implementation, so that the sub-goals can play an active guiding role in each stage.

(4) Workflow: Both at home and abroad are clear and clear. Our previous work process mainly refers to low impact development. However, with the development of sponge cities, China has gradually transformed into a comprehensive and intelligent sponge city. Therefore, it is necessary to keep pace with the times in the process of transformation, and to improve and change the workflow according to the actual needs.

(5) Technical measures: It is introduced in detail both at home and abroad, and they all have corresponding guidelines and specifications to introduce technical measures in all aspects. China's micro-measures are more detailed, but it mainly draws lessons from foreign low-impact development technology. As for rain water network facilities, it is suggested that the idea of ABC water project in Singapore should be used for reference to build the whole city network and realize the South-to-North Water Transfer and ecological balance as soon as possible.

(6) Maintenance management: It is highly valued both at home and abroad. But they have one thing in common is that they attach too much importance to writing, and later maintenance practice is not in place. In the past two years, China has paid more and more attention to the latter maintenance. However, it mainly lies in the policy norms. The first suggestion is to adopt the Singapore ABC idea to strengthen public participation and enhance the sense of ownership of urban residents. The second suggestion is to implement the certification reward and punishment plan and make a strict assessment of the maintenance of the sponge city pilot project. Only when the policy is vigorously promoted, the government is strictly supervised and the people are actively involved, can the post-maintenance work be really put in place.

(7) In addition: As for the supervision and maintenance in the later period, the reality of our country

is that it is difficult to put it into practice. Many design institutes adopt a simple way to deal with the construction design stage. Many project companies do not know how to maintain or even have not done a good job of thinking that needs to be maintained. Therefore, the government should consult with professionals to discuss relevant countermeasures. It can adopt the PPP model abroad, that is, to strengthen the policy punishment in the government, to strengthen the incentive mechanism for training and learning in the professional field, to strengthen the supervision of the masses in the people, and to restrict the rights and obligations of both parties through contracts in the supervision of project companies, so as to strive for the later maintenance and supervision can come true.

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