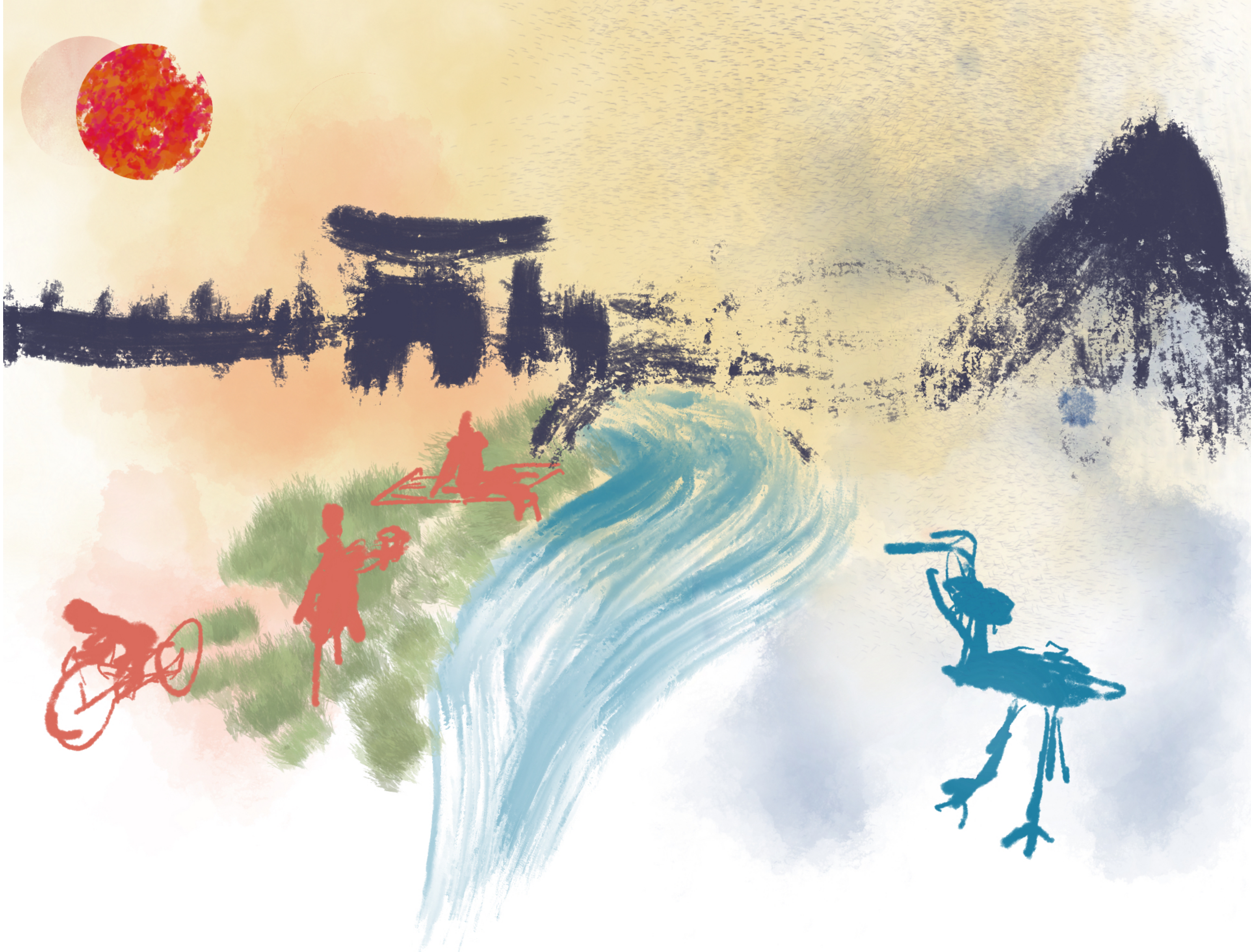

Sponge Design

A Study on Comprehensive Sponge City Design Approach

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Sponge design: a study on comprehensive sponge city design approach

Master thesis submitted to Delft University of Technology
in partial fulfilment of the requirements for the degree of
in Water Management

Faculty of Civil Engineering and Geosciences

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To be defended in public on the 27th of July 2020

An electronic version of this thesis is available at http://repository.tudelft.nl/.

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Acknowledgement

Sponge City is a complex concept, covering knowledge not only in water management field, but also urban planning, spatial management, governance, etc. Understanding such concept and trying to propose an improved Sponge City design approach are challenging. Therefore, I am deeply grateful for the time and the opportunity that I can dive into research on Sponge City concept, get involved into a sponge city planning project and communicate with sponge city practitioners. I am thankful to those contributors and supporters, with whom the thesis work can be possible.

First of all, I would like to express deep gratitude to the thesis committee with five members from diverse backgrounds, who kindly and professionally steer me throughout the research, and provide constructive suggestions. A big thank you to Frans. Thank you for offering me such a valuable opportunity to work together in a sponge city project and providing help no matter when I got stuck in the work. I have learned a lot from you, not only academic knowledge, but also the way of thinking and reasoning, as well as the passion towards work, etc. I really enjoy the time working with you, especially the conversations during lunch time. Chris, thank you for the communications during meetings of the China Europe Water Platform (CEWP). You inspired me a lot and provides valuable insights to Sponge City. Lisa, thank you for the constructive feedbacks you gave along the thesis progress and suggestions on thesis reporting. Qinghua, thank you for the help and advice that you always kindly offered during the thesis work. Weijun, thank you for the time you invested in me and the perspectives you shared based on your abundant practices in sustainable water management.

I would also like to thank the three interviewees, Ran Zhu (P1), Binlong Shu (P3) and another anonymous participant (P2), for sharing your insights and experiences. I am thankful to the working partners of Qinhuai project, AZI, LOLA, and NHRI. Two particular co-workers I would like to thank are Simon and Liang. Thank you for the impressive work you have done. I really enjoy the time working with you and learned a lot from you. Thanks to Deltares for financial and technical support. My sincere thanks to the support and encouragement from Deltares colleagues: Toine, Gerald Jan and other fellow interns. Thanks to my friend Changxu, who kindly helped me to know more about deep learning method, so that I could apply it to rainfall pattern analysis.

I am grateful to my friends and classmates in the Netherlands who cared me, inspired me and always supported me, especially when COVID-19 messed up our patterns of life. I would like to thank Haoyue, Nathan, Diana, Shu-chen, Ilias, Xinzhu, Siyuan, Zixi for caring me and exchanging thoughts with me during the thesis time. I appreciate those insightful conversations and enjoyable time with you.

Thanks to the thousands-of-kilometre distance between Delft and my hometown Tongling, which enables me to think out of the box to critically review the sponge city paradigm. Such long distance also makes the care, support, encouragement from my friends in China more precious. Thank you, my friend Zhixian, Shiming, Zhenghao, and Yijiang.

And finally, to my parents and grandmother, the gratitude cannot be fully expressed by words. Thank you for unconditionally support me and care me. Dedicated to the memory of my grandfather, who always believed in my ability to overcome every obstacle and would be proud of what I have achieved.

Preface

I grow up in Tongling, a small city by Yangtze River. Beautiful waterscapes and fun water activities are my special impressions to this water town in the South Yangtze region. However, severe flooding events in summer also deeply rooted in my memories. The top-down promotion of 'Sponge City' construction was initiated in year 2014, when I was a freshman, aiming to mitigate damage of flooding and other water issues. The first time I was involved in a sponge city research project was in my sophomore year. The part I was working on was using a hydraulic model to evaluate the effectiveness of sponge measures. When I presented the results, what one professor from structure engineering commented on my work impressed me a lot. He questioned the benefits of constructing on-surface sponge measures with vast investments instead of simply enlarging sewer pipes. I was not confidant to answer the question based on the knowledge I was equipped with then. However, during studying master programme of water management in TU Delft, especially during the course Water Management in Urban Areas, I started to re-think what "Sponge City" really means and how it can contribute to a more liveable urban environment. That is one of the motivations I started this thesis research.

During the thesis research, I intensively feel 'modern' Chinese cities should learn from the nature and learn from the history. Cities should adapt to water, retain & detain water, as well as manage water in an integrated manner, instead of discharging water as quickly as possible. Sponge City is only the starting point of sustainable urban water management in China; To harmonize water and city, much more need to be studied and tested. Importantly, the mindset of governors, practitioners and the public should be changed; and more experiences are to be accumulated and learned from city to city, from nation to nation.

Flood destroys ancient bridge in east China, a photo taken on July 7, 2020
Source: http://www.xinhuanet.com/english/2020-07/07/c_139194709_2.htm

Suzhou Scenery (1985), a Chinese ink wash painting by Wu Guanzhong

送人遊吴

杜荀鹤

君到姑苏见，人家尽枕河。

古宫闲地少，水巷小桥多。

夜市卖菱藕，春船载绮罗。

遥知未眠月，乡思在渔歌。

See a Friend Off to Wu

Du Xunhe

I see you to Ku-su.
Homes there, sleeping by the stream.
Ancient palace, few abandoned spots.
And by the harbor, many little bridges.
In the night market, lotus, fruit and roots.
On the spring barges, satins and gauze.
Know, far off, the moon still watches.
Think of me there, in the fisherman's song.

Translated by J.P. Seaton

Abstract

Water is cherished as treasure in traditional Chinese culture and expected to stay in harmony with human. However, the disharmony between water and urban life is looming especially after over thirty-year rapid urbanization in China with notable global climate change. Faced with water-related issues, e.g. flooding, water pollution, water shortage, etc., Government of China initiated a so-called Sponge City Program (SCP) in 2014 for constructing 'sponge-like' water-resilient cities. Nevertheless, challenges and gaps lie in practice of SCP, one of which is that an operationalizable design approach of a sponge city to realise its multiple objectives is neither available in current guidelines, nor thoroughly studied or proposed in recent literatures.

The aim of this master thesis was to formulate an improved approach, as well as to improve planning & design framework for supporting integrated sponge design process and enhancing the involvement of various stakeholders. Literature study, the study of current guidelines and sponge plans of Nanjing, and interviews with sponge city practitioners were performed to evaluate current Sponge City (SC) concept and assess SC planning & design practice. Analysis of SC concept development showed that SC has been evolving from a term mainly describing measures with ecological benefits towards a more inclusive urban development paradigm, considering not only water ecology, but also water safety, water environment and water resource. Analysis on SC practice identified the gaps in current SC water management contents, including a lack of design method for calculating storage capacity against pluvial flooding, ignorance of extreme drought assessment, missing groundwater management, etc. Challenges that might impede comprehensive sponge city planning & design process were also enumerated, including data availability and accessibility, the bond between SC and other sector plans, etc.

Based on the identified challenges and gaps, improvements on current planning & design practices were given and a new design approach was proposed, including changing collaboration method, introducing a co-design workshop and using a sponge design toolbox to facilitate planning & design process. The approach provided a method to calculate the required sponge capacity for not only preventing flood damage but also mitigating water shortage in dry spells, as well as quantifying other co-benefits. The improved design approach was tested by a case study in Nanjing, in the Qinhuai District sponge city planning project. Case study results showed that most steps in the proposed design process were successfully taken in Qinhuai project, and the toolbox was able to facilitate planning and design of sponge measures to have functions not only for pluvial flooding prevention and control, but also for water shortage mitigation, ecological benefits and other day-to-day values. The design process also demonstrated the collaborative contribution to a sponge city plan from water managers, water engineers and landscape architects. Therefore, the new design approach can contribute to a more integrated SC planning and design.

摘要

在中国传统文化中，水被视为财源的象征，人和水应和谐相处。然而，在中国三十多年快速的城市化进程中和显著的全球气候变化影响下，水与城市生活之间的矛盾正在日益凸现。面对如洪涝灾害、水污染加剧、水资源匮乏等问题，2014年中国启动了海绵城市建设试点工作，致力于建设像海绵一样具有水弹性的城市。目前，海绵城市在实践中还面临着许多挑战，例如，现有的指南并未提供用以实现海绵城市建设的多重目标的具体设计方法，近期的文献也鲜有关于海绵城市设计方法的详细研究或提议。

本硕士论文旨在完善海绵城市规划和设计的框架，并提出更优的设计方法，同时，增强各个利益相关者的参与度。基于对相关文献、南京市海绵城市指南和规划的研究以及对相关从业者的采访，本文阐释了海绵城市的概念，并对现有的海绵城市规划和设计做出多方位的评价。对海绵城市概念的分析表明，海绵城市已经从描述具有生态效益的措施的术语演变为更具一种综合性的城市建设的模式，以解决城市水生态、水安全、水环境和水资源等问题。此外，对海绵城市实践的分析揭示了当前水管理方面的不足，包括缺失计算调蓄能力的方法，忽视极端干旱的情况，以及缺乏对地下水的管理等。同时，本文还列举了海绵城市规划和设计过程中可能遇到的困难，包括关键数据的可用性和可访问性，海绵规划与其他规划之间的衔接性问题等。

基于实践过程中已发现的困难和不足之处，本文提出了新的设计途径，例如调整多专业之间的协作模式，引入多方参与的研讨会，以及使用特定的软件工具箱来辅助规划设计等。这种设计途径包括了对所需海绵容量的计算方法，它不仅能满足内涝防治和缓解旱季缺水的需求，还能用于量化各方面的效益。本文以南京市秦淮区海绵城市规划项目为例，对改进后的设计途径进行了验证。研究结果表明，新的设计途径中包含的大多数举措都得以在该项目中成功应用。其中，海绵设计软件工具箱的使用对海绵措施的规划和设计起到辅助作用，使城市具有防御内涝和应对水资源短缺的能力、以及生态效益和日常价值等。设计过程还展示了水管理者、水工程师和景观设计师之间相互配合，在海绵城市规划项目中所做出的贡献。由此可见，本文所提出的新的设计途径有助于综合性的海绵城市规划和设计过程。

An old map of Qinhuai area (1910). Many ponds (in dark green) in the city disappeared due to campaigns and urbanization.
Source: http://218.2.231.251:8080/MonumentDistribution/BeautifulJiangsu/histroymap/index.html

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Glossary

Amenity
The quality of being pleasant or attractive, agreeableness. A feature that increases attractiveness or value, especially of a piece of real estate or a geographic location.

Detailed control plan
Detailed control plan is prepared to control land use, intensity of use and spatial environment, as the basis for urban planning management, and to guide a detailed construction plan.

Detailed construction plan
Detailed construction plan is to guide the design and construction of various buildings and engineering facilities, which needs to follow its detailed control plan.

Non-point source pollution (NSP)
Pollution resulting from many diffuse sources, in direct contrast to point source pollution which results from a single source. Non-point source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, etc.

Point source pollution (PSP)
A single identifiable source of air, water, thermal, noise or light pollution.

Public–private partnership (PPP)
A cooperative arrangement that involves government(s) and business(es) that work together to complete a project and/or to provide services to the population.

Public sponge (facilities)
Sponge city measures installed in urban public spaces (e.g. park, plaza, alongside roads, etc.), especially differentiated from the measures constructed in Xiaoqu, where the outdoor public spaces are collectively owned by residents.

Runoff coefficient
A measure of the amount of rainfall that is converted to runoff.

Return period
Refers to how often an event occurs. A 100-year storm refers to the storm that occurs or is exceeded on average once every hundred years. In other words, its annual probability of exceedance is 1 per cent (1/100). A 50-year storm is the storm expected to occur once every 50 years or has an annual probability of exceedance equal to 2 per cent (1/50).

SDF curves
Storage-Discharge-Frequency (SDF) curves presents relationships between storage capacity and discharge capacity under certain return periods of runoff events.

Sponge capacity
The volume of sponge measures to be capable of preventing and control flooding under (extreme) storm events as well as mitigating the impact of drought during dry spells.

Sponge City (SC)
A sponge city is a 'spongey' city structured and designed to absorb and capture rainwater and utilize it to reduce floods. As a form of a sustainable drainage system on an urban scale, it aims to achieve sustainable hydrological cycles and maintain or restore the city's 'sponge capacity' through multi-disciplinary efforts. In this thesis the concept of building such sponge cities is written as Sponge City (or SC in short).

Sponge City Programme (SCP)
The national program initiated by the central government of the People's Republic of China in 2014 for constructing 'sponge-like' water-resilient cities.

Source control
The control of runoff at or near its source.

Sponge design
Planning and design that implement Sponge City concept, including developing planning principles and design strategies using Sponge City concept, sponge measure sizing process, sponge measure type selection, sponge spatial arrangement and design management train, etc.

Sponge effect
The maintenance and restoration effects of natural hydrological characteristics achieved by implementation of Sponge City concept.

Sponge measures
Structural and non-structural measures that can be designed to restore natural hydrological features and contribute to ecological services.

Xiaoqu
小区, literally micro district, is a typical Chinese model of residential area, which is often enclosed by a wall, with the entrance gate being guarded.

Chapter 1 Introduction

Many countries are faced with water-related issues, e.g. flooding, water pollution, water shortage, etc., which are resulted from rapid urbanization, climate change and inappropriate urban planning (Nguyen et al., 2019). In order adapt to environmental changes and natural disasters, People's Republic of China (PRC) initiated in 2014 a so-called Sponge City Program (SCP) for constructing 'sponge-like' water-resilient cities (MHURD, 2014a).

The Sponge City concept aims to achieve sustainable hydrological cycles and maintain or restore the city's 'sponge capacity' through multi-disciplinary efforts and coordination with techniques such as infiltration, detention, retention, purification, reuse, drainage and other LID measures (MHURD, 2014a). Started with thirty diversely-featured pilot cities, State Council set ambitious goals to promote Sponge City Concept all over the country: 20% of the urban areas should absorb, retain, and reuse 70% of the annual rainfall volume by 2020 and by 2030, the percentage shall reach 80% (GOSC, 2015).

1.1 Research background

As the very first holistic Integrated Urban Water Management (IUWM) strategy implemented in a developing country with rapid urbanization, SCP holds promise for application in other developing countries (Wang et al., 2018). Although the idea of integrated urban water system design and inter-disciplinary contribution is proposed in national guidelines, there is no doubt that challenges and gaps lie in practices of SCP, given which the strategy of 'learning-by-doing' has to be followed by China (Jiang et al., 2017). Such difficulties on implementation could be summarized into four categories (see Table 1), i.e. technical, institutional, financial, and social aspects based on recent literatures (Chan et al., 2018; Jia et al., 2017; Jiang et al., 2018; Li et al., 2017; Nguyen et al., 2019; Xia et al., 2017).

For example, one of the challenges and gaps is: certain national standards concerning infrastructure operation and management do not accommodate Sponge City concept yet (Chan et al., 2018). Sponge City guidelines, including one at national level (MHURD, 2014a) and a few at city level between 2015 and 2016, are rather general without consideration of diverse regional or local conditions (Dai, van Rijswick, Driessen, & Keessen, 2017; H. Li et al., 2017). Additionally, as an important component in sponge city design and construction, current performance indicators system is not effective enough to reach multiple objectives, such as pluvial flooding, pollution prevention, etc. (Che et al., 2015; Dai, Jiao, Ding, & Shen, 2018). Insufficient guidance and design standards as well as knowledge gaps may result in poor planning and implementation of sponge cities (Li et al., 2017).

Given the fact that Sponge City is a complex concept with the interconnection amongst many disciplines, e.g. spatial design, urban ecology, urban water management, etc. (Dai et al., 2017), sponge planning and design should consider not only sponge measures per se, but also urban water system planning, green space planning, ecology and water environment and so on. There are some literatures that discussed SCP planning or design through cases of city, university campus, neighbourhoods, etc. (Hu et al., 2019; Min, 2019; Zhang, Di, & Zhou, 2017), but most of them do not adopt an integrated approach that involves water system management, multi-functions of ecological systems, spatial planning, etc.

Moreover, institutional demarcation of responsibilities may impede inter-department collaboration. Chinese urban water systems are not systematically managed by one or two agencies; on the contrary, multiple departments are separately in charge of water matters (Zhao, 2015). Therefore, the Sponge Office[1] finds difficulties to communicate with other departments, for example, to proceed trans-department data exchange (Cai, 2016; Sun, 2019).

Therefore, an operationalizable design approach of a sponge city to realise its multiple objectives is neither available in current guidelines, nor studied or proposed in recent literatures. Under such context, this thesis aims to: Firstly, understand current Sponge City concept, planning & design contents and process, especially in-depth

1 Sponge Office is a governmental organization which specifically responsible for overall coordination, supervision and assessment, guidance and promotion of the sponge city construction. Sponge Office is usually under Housing Bureau at city level, for example, in Shanghai, Nanjing, Hangzhou, etc. In other cities such as Beijing and Shenzhen, Sponge Office is attached to water authority.

analyse sponge city (technical) planning & (engineering) design framework and their implementation as well as the calculation methods; Secondly, evaluate current planning & design practices and reveal challenges and gaps; Thirdly, formulate an improved sponge city planning and design approach and improve planning & design framework for supporting integrated sponge design process and enhancing the involvement of various stakeholders.

Category	Aspects	Challenges	Reference
Technical	Guidance	• Some standards concerning infrastructure, operations and management systems do not accommodate Sponge City concept.	Chan et al., 2018
		• In need of comprehensive and clear guidelines and training.	Li et al, 2017
	Spatial heterogeneity	• Variety of Chinese cities' features requires customization for different cities and regions.	Li et al., 2017
	Spatial limitation	• As a densely-populated country, land in China is highly valuable, especially in developed urban areas, that would limit sponge measures installation.	Li et al., 2017
	Indicator	• Imbalanced focus on certain indicators (infiltration, source control), but lack of focus on indicators of pluvial flooding.	Dai et al., 2018
		• Lack of comprehensive evaluation indicators which take flood mitigating, pollution prevention, etc. into consideration.	Che et al., 2015
	Data	• Lack of monitoring performance data.	Li et al., 2017
		• Data availability and accessibility.	Cai, 2016
	Model	• Lack of self-produced software (models and knowledge) and hardware (devices and materals) which suit local circumstance.	Li et al., 2017; Jiang et al, 2018; Sun et al., 2019
		• Complexity of models impedes the multi-disciplinary collaboration.	Cai, 2016
	Maintenance	• Difficulties of maintenance for public agencies.	Li et al., 2017
	Plant	• Risks of transforming urban greenery for runoff control purpose.	Zhang, 2016
		• For Jinan City, sponge species are barely available since it requires water-resistance in summer and coldness-resistance in winter, and drought resistance in spring and autumn.	Mi, 2017
Institutional	PPP	• Not clear responsibility divisions for PPP projects and no complete evaluation scheme.	Mi, 2017
		• There are no specific laws governing PPPs, and there is no independent PPP regulating agency in China.	Li et al., 2017
	Responsibility	• Sponge office is under housing bureau, while the original stormwater reuse and black water treatment are taken in charge of by civil gardening bureau; Meanwhile, the responsibility division of different departments is not paid attention to.	Sun, 2019
		• The division of authorities hampers data collection, low degree of free, updated and digitalized data.	Cai, 2016
Financial	Investment	• Substantial investment needs and a lack of reliable financing schemes and experience also provide a huge challenge for China.	Zevenbergen, et al., 2018
	PPP	• Challenges in public–private partnership.	Li et al., 2017
	Sustainability	• The impression is that Chinese cities move from one government supported paradigm to another, without bothering too much about the sustainability of their investments after the end of the projects.	van Dijk & Zhang, 2019
Social	Involvement	• Lack of public involvements	Mi, 2017
		• An effective policy is required to encourage the private sector to involve into the project management and become the main player in the program.	Liang, 2018
	Education	• To achieve public outreach goals and shift public perceptions, a complete education program involving the technical training of municipal staff and lessons in sponge city concepts for the public are in demand.	Li et al., 2017
	Aesthetics	• The public (managers) views on aesthetics shall be shifted from "landscape in order" to more nature based.	Hu & Li, 2015

Table 1 Encountered challenges in sponge city implementation (Cai, 2016; Chan et al., 2018; Che et al., 2015; Dai et al., 2018; Hu & Li, 2015; Jiang et al., 2018; Li et al., 2017; Liang, 2018; Mi, 2017; Nguyen et al., 2019; Sun, 2019; Sun et al., 2019; van Dijk & Zhang, 2019; Xia et al., 2017; Zevenbergen et al., 2018; Zhang, 2016).

1.2 Scientific contribution

As research on Sponge City is still in early stages in China, this thesis can contribute to deepening the understanding of current SC theories and practices through novel visualization and analysis methods of mapping current planning & design contents and framework. Importantly, vagueness or confusions of SC concept scope and indicators, VCRa in particular, are clarified in this thesis. Gaps and challenges in the implementation of SC theories, especially in planning & design, are explored in this thesis, not only by literature and guideline study, but also by listening to voices from current SC practitioners with various backgrounds. Comprehensively understanding SC concept as well as gaps and challenges in practices can facilitate the progress of paradigm shift concerning sustainable urban design and integrated water management. Study on improving planning and design approach in this thesis not only helps maximize SC co-benefits at early stages of practical projects, but also arises the awareness of enhancing inter-disciplinary and inter-departmental cooperation in the implementation of a more sustainable urban development paradigm. This thesis also facilitates to enhance mutual understanding between water management and other disciplines with respect to Sponge City. Suggestions on SC principles and design strategy can help to refine national and local guidelines in the future. This thesis sets an example of exploring how to make sustainable urban water planning and design in a more integrated manner, including the use of a toolbox and multi-disciplinary collaboration. This improved SC approach was verified in a real case of urban water planning in Nanjing, which can be further applied and tested in other cities.

1.3 Research questions

In order to cope with the challenges mentioned in Section 1.1, there are three main research questions to be addressed in this thesis:

1. **How to evaluate current Chinese SC planning & design framework?**
   In order to propose improvements to planning and design approach, current theories and practices must be understood. As SC covers a wide spectrum of disciplines, stakeholders, sector plans, technical guidelines, etc., SC planning and design framework requires an understanding of the meaning of 'Sponge City' concept, contents in sponge city guidelines and plans, the gaps in current SC theories and practices when compared with equivalent concepts in other countries, etc. Therefore, a set of relevant sub-questions are listed below:

   1.1 How do the concept and terminology of Sponge City develop?
   1.2 What are the gaps when comparing Sponge City with other related concepts such as LID, SUDS, WSD, etc.?
   1.3 How are SCP projects designed in literatures?
   1.4 What aspects are contained in sponge city planning and how to assess them?
   1.5 How are indicators downscaled in sponge city planning and design?
   1.6 How do different stakeholders, especially administrative authorities involved in projects?

2. **How to assess and design the required sponge capacity to mitigate pluvial flooding, as well as water shortage during dry spells?**
   According to Sponge City's philosophy, sponge measures should be equipped with the capacity of mitigating pluvial flooding by temporarily storing runoff, as well as mitigating water shortage by reusing stored stormwater during dry spells. However, no corresponding design approach of such sponge capacity is reflected in current guidelines or practices. Therefore, answering research Question 2 would contribute to designing a well-functioned sponge system. Relevant sub-questions are:

   2.1 What is the current storage capacity calculation method?
   2.2 How to estimate required storage capacity for pluvial flooding prevention and control?
   2.1 How to assess required recharge during dry periods?

3. **How to improve the current SC planning & design framework to support multi-disciplinary involvement and realize multiple objectives of SC?**
   As mentioned before, SC planning and design are complex process with consideration of various sector plans, such as urban water system planning, green space planning, ecology planning, etc. Additionally, many authorities are involved in different phases of SCP projects. Therefore, a comprehensive sponge design approach needs to be supported by a planning & design framework which outlines the coordination mechanism of different sector plans and involvement of various authorities throughout project phases. To answer this question, the following sub-questions are to be explored:

   3.1 What aspects in current framework that challenge the implementation of a comprehensive design approach?
   3.2 How to enhance inter-disciplinary cooperation in sponge design process?

Chapter 2 Research approach

2.1 Overall research approach framework

Figure 1 gives an overview of the research approach. In order to address the research questions, this thesis follows a stepwise method of 'information collection' – 'analysis' – 'improvements' – 'verification'. Firstly, information of Sponge City concept and current sponge city planning & design practices will be collected through literature study, the study of current guidelines and sponge plans, and interviews with sponge city practitioners. Generic information on the SC concept will be confronted with practice, by studying specific information in SC implementation in Nanjing. Secondly, the collected information will be analysed in order to evaluate the gaps in current SC integrated water management contents and challenges that might impede comprehensive sponge city planning & design process. Thirdly, improvements on current planning & design practice will be given and new design approach is to be formulated. Finally, the improved design approach will be tested in a case study in Nanjing, in the Qinhuai District sponge city planning project.

2.2 Relationships between research approach and research questions

More detailed explanations of the research approach are provided in this section, including the contents of each step and how they correspond to research questions. It should be noted that some research questions or sub-questions can be directly answered by a single content, whereas others need contributions from multiple contents.

First step is to understand sponge city planning & design by guideline & plan study, and interviews, and discover the gaps and challenges in current SC planning & design. This is the theme of Chapter 3 of this report.

First of all, answering research questions (RQs) should be based on a clear understanding of Sponge City concept. In Section 3.1, a literature study will be presented starting with an overview of 'Sponge City' terminology development and concept evolution (RQ 1.1). Then, Sponge City guiding principles and design criteria are introduced based on the SC guidelines at national levels and at Nanjing City level. Moreover, insights of gaps in sponge design can be revealed by comparing Sponge City concept with other concepts, such as LID, SuDS, WSD, etc. (RQ 1.2). Some typical cases in recent literatures will be summarized in order to acquire more understanding on how planning and design in SCP projects are made (RQ 1.3).

Current sponge city planning & design are presented in Section 3.2, where various aspects contained in sponge city planning are summarized (RQ 1.4), especially the indicator that can calculate required storage capacity (RQ 2.1). Section 3.2 maps current planning & design framework following two axes: spatial scales and project phases. On one hand, sponge city plans are made at different administrative levels with indicator downscaling mechanism (RQ 1.5) and coordination of different sector planning; On the other hand, roles of various authorities (RQ 1.6) are visualized along project phases.

Three semi-interviews with sponge city practitioners are introduced and analysed in Section 3.3 at five angles, i.e. scoping, indicators, storage & discharge, interdisciplinary collaboration and implementation challenges. Such analysis will help deepen the understating of current Sponge City planning and design process. Additionally, challenges in current design approach that are discovered in previous chapters can be verified by the interviews. Those challenges and gaps can indicate where to improve current sponge design approach and planning & design framework (RQ 3.1).

Based on discovered gaps and challenges identified in Chapter 3, an improved Sponge City design approach is to be proposed in Chapter 4, including improvements on vision & scope of SC, planning principle, sponge design process, integrated water management, and (technical) planning & (engineering) design framework. Two important components in improved sponge design approach are integrated design process and integrated water system analysis. Integrated water management in SC should consider multiple water aspects, including pluvial flooding, water shortage, and groundwater. An improved organizational cooperation of sponge design approach is suggested for stimulating inter-disciplinary contribution to such complex design process (RQ 3.2). Based on the improvements on those two components, a detailed stepwise sponge design procedure will be proposed, including necessary contents in each step of sponge design, especially how to select and arrange sponge measures with required storage capacity.

The proposed design approach needs support from simulation tools. In Chapter 5, an overview is to be presented on functions and applicability of available tools. Three types of tools are required to facilitate proposed design approach, i.e. hydraulic model, hydrologic model and Planning Support System (PSS). Hydrologic models are able to estimate the required sponge capacity for pluvial flooding prevention (RQ 2.2) and drought effects mitigation (RQ 2.3); hydraulic models can simulate flood hazard map before and after sponge interventions; these models to evaluate sponge effects of flood mitigation; Scientific challenge in the use of these models is the formulation of representative design storms. Inter-disciplinary involvement can be stimulated by using PSS in co-design workshops for enabling knowledge, expectation, preference, etc. to be considered in sponge planning and design process (RQ 3.2).

In Chapter 6, the proposed design approach will be tested in a case study in the Nanjing Qinhuai District SC planning project. An overall discussion chapter (Chapter 7) will evaluate the application of proposed approach in the case study, assess the limitation of the proposed design approach, and discuss this thesis research approach as well.

2.3 Analysis methods

Analysis methods of three components are explained in this section, including literature review, interview and planning & design framework evaluation.

2.3.1 Literature review

Literature review is performed to analyse SC concept development following the chronological method. As SCP is initiated in the year of 2014, which is a line that separates literature sources into two groups: before year 2014 and after year 2014. Before 2014, the term 'Sponge City' had not been coined, therefore the search strategy is to search 'Sponge' AND 'City' in title, abstract or keywords on CNKI[2]; After year 2014, search strategy is changed to 'Sponge City' AND ('Concept' OR 'Essence' OR 'Interpretation' OR 'Review') [3] in title. Papers with high downloads are retrieved. Some other literatures published before 2014 are discovered and added when reading other review papers, as those literatures do not include 'Sponge' in title, abstract, or keywords, or even unavailable on CNKI platform. The retrieved sources are organized in the order of time and analysed based on the essence of Sponge City concept claimed in those literatures, i.e., what does Sponge City means. Sponge City definition given by authors with their different backgrounds are also mapped in a figure to illustrate the variation of interpretations.

2.3.2 Interview

The interviews with SC practitioners aim to explore current planning & design practice and challenges & gaps in implementing SC concept. Semi-structured interviews (SSI) are selected, during which a few predetermined questions are asked while the rest of the questions are not planned in advance. The advantages of using this method are:

1. On the one hand, prepared particular questions can be covered by SSI; On the other hand, unexpected or unknown concerns or insights are be discussed as well;
2. Flexibility of SSI allows two-way clarification and discussion on complex topics;
3. Broad and open-ended questions are allowed, e.g. personal opinions on SCP progress (Wilson, 2014).

2 CNKI (China National Knowledge Infrastructure) builds comprehensive China Integrated Knowledge Resources System, including journals, doctoral dissertations, masters' theses, proceedings, newspapers, yearbooks, statistical yearbooks, eBooks, patents, standards and so on. Website: https://www.cnki.net/.

3 The concept groups of searching are all in Chinese, i.e. '海绵' AND '城市' before 2014, and '海绵城市' AND ('概念' OR '本质' OR '解读' OR '综述').

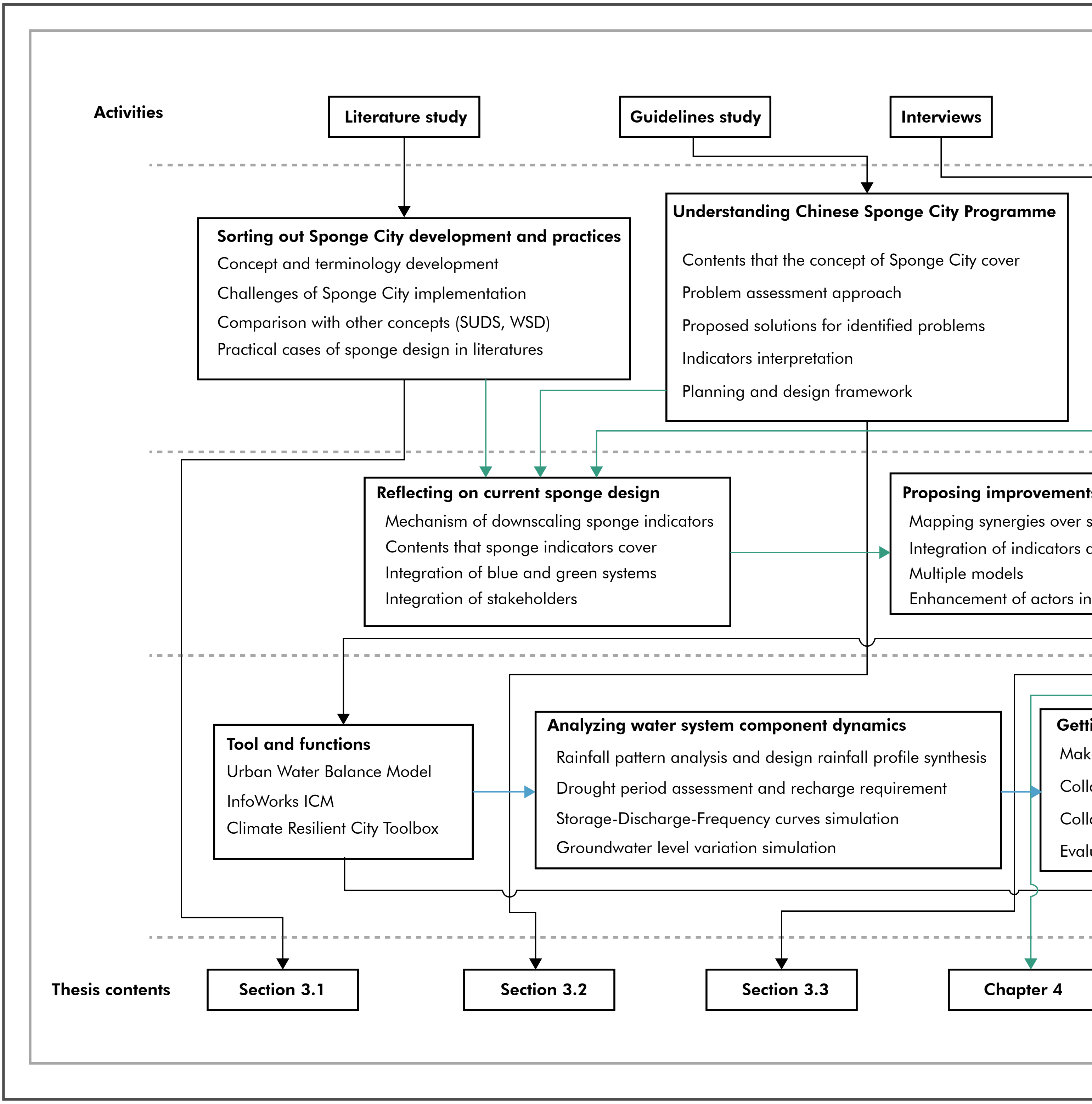
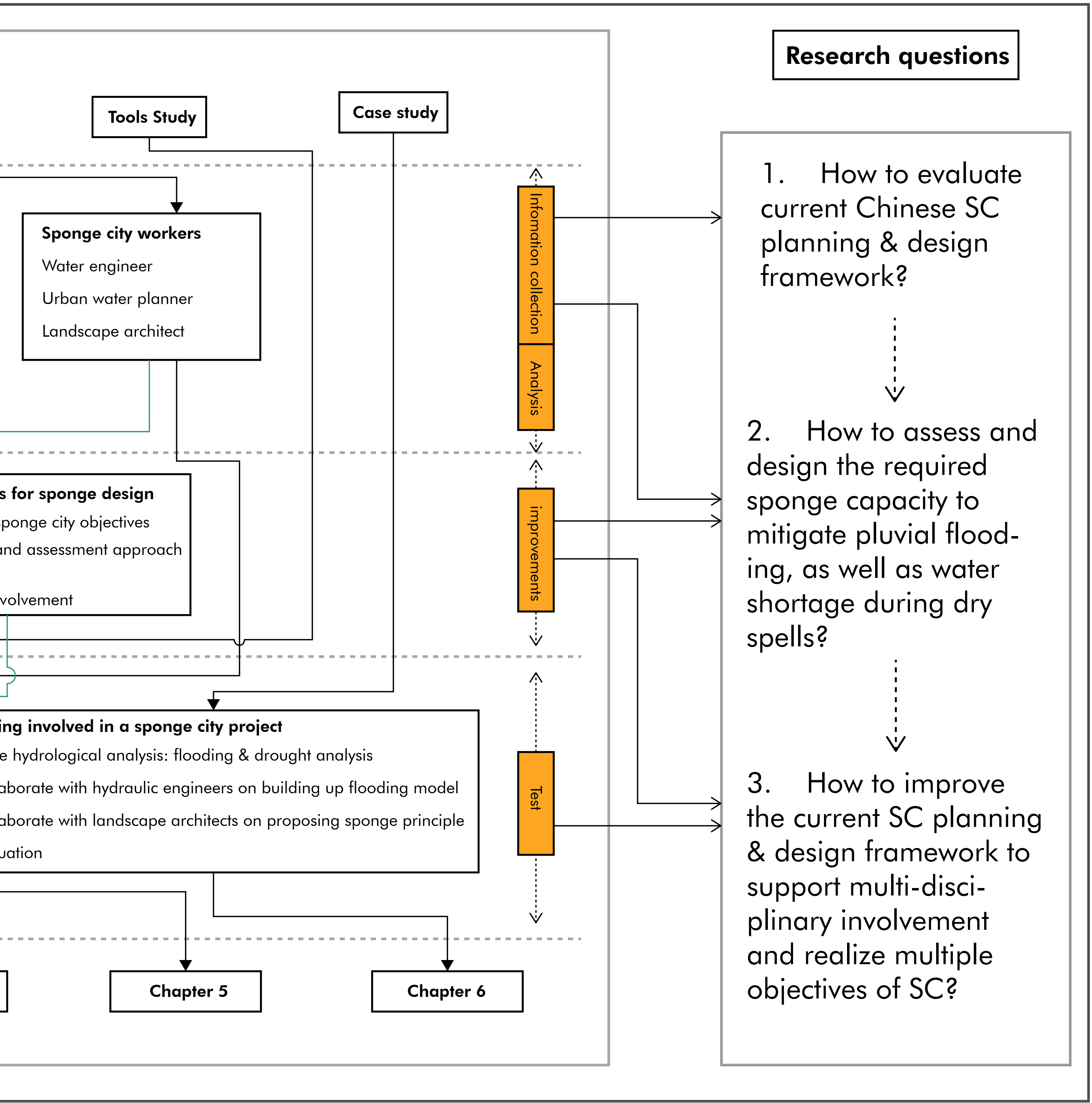


Figure 1 Research approach framework


Tools Study
Case study
Sponge city workers
Water engineer
Urban water planner
Landscape architect
s for sponge design
ponge city objectives
nd assessment approach
volvement
ing involved in a sponge city project
e hydrological analysis: flooding & drought analysis
aborate with hydraulic engineers on building up flooding model
aborate with landscape architects on proposing sponge principle
uation
Chapter 5
Chapter 6
Infomation collection
Analysis
improvements
Test
Research questions
1. How to evaluate current Chinese SC planning & design framework?
2. How to assess and design the required sponge capacity to mitigate pluvial flooding, as well as water shortage during dry spells?
3. How to improve the current SC planning & design framework to support multi-disciplinary involvement and realize multiple objectives of SC?

Three interviewees are from different backgrounds, i.e. hydraulic engineering, urban water planning and landscape design, so that insights of planning & design practices can be obtained from different disciplines' perspectives. Some common questions were asked, such as their experiences and roles in sponge city projects, their opinions on indicators, etc.; While other questions are based on their backgrounds and depending on unknown or unexpected concerns during the interviews. Such manner can help obtain information of their participation in SC and attitudes towards SC indicator system, as well as other unexpected topics depending on their backgrounds.

2.3.3 Planning & design framework

Implementation of the Sponge City concept has two dimensions. The first one is the technical aspect, including the underlying technical principles, indicators, the (technical) planning and (engineering) design. The second one is the planning process, with all the parties that are (to be) involved, their interactions, the administrative steps to be taken in the planning and design process. Together this creates a two-dimensional planning & design framework.

SC sector plans at various administrative levels are closely connected to each other and to other sector plans, such as flood defence plan, green system plan, etc. Therefore, considering the top-down featured SC planning mechanism, a spatial scale axis is used to help map the downscaling process of SC plans and the connections with other relevant plans at various administrative levels.

The administrative steps in implementation of SC concepts include appraisal of SC requirements by multiple governmental departments. In other words, different authorities are (to be) involved to assess the fulfilment of relevant requirements, especially SC performance indicators, throughout the project phases. Therefore, a temporal scale is another important axis to visualize the involvements of various authorities during SC planning & design process.

In summary, mapping spatial scales (administrative divisions) and temporal scales (project phases) helps to organize the contents and to visualize the processes. Hence, those two main axes are used to map planning & design framework.

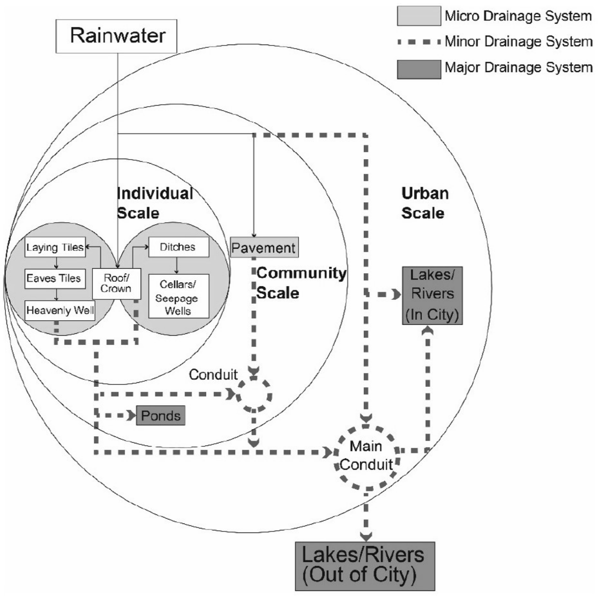
Chapter 3 Analysing Sponge City concept and design

3.1 Understanding Sponge City concept and principles

3.1.1 Brief overview on Chinese water management history

Cherished as treasure in Feng Shui theory [4] (Jie, 2006) , water shapes morphology of dwellings; and it is rooted in Chinese philosophy, expected to stay in harmony with human (Sun, 2016). Drainage and storage are both reflected in traditional urban planning and design for enabling inhabitants living with water.

Ceramic sewers, known as the earliest drainage system in China, were found to discharge runoff dated back to Longshan Period (ca. 2600-2000BCE) (Xu, 2012). The transition of stormwater management from solely drainage to a combination of drainage and rainwater harvesting occurs between Tang dynasty (618-907CE) and Song dynasty (960-1279CE). The Fushou drainage systems, built up in Song dynasty, combined drainage and storage infrastructures (Che, Qiao, & Wang, 2013), which can be regarded as the prototypes of modern urban stormwater management systems (Cun, Zhang, Che, & Sun, 2019). The hierarchy of traditional Chinese drainage and stormwater management systems are shown in Figure 2, including building features, artificial lakes and canals, etc. (Cun et al., 2019).



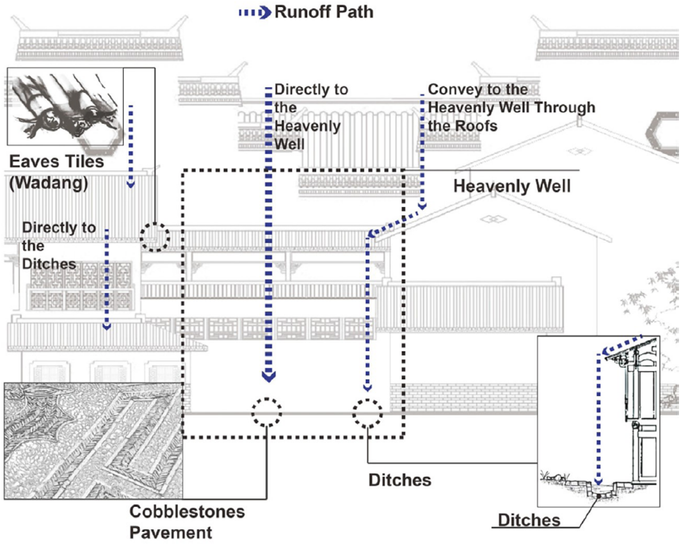


Figure 2 Left: traditional Chinese drainage and stormwater management systems; Right: Micro drainage system in courtyard complex (Cun et al., 2019)

Following an accelerated global trend of paradigm shift from adaptation to control in twentieth century, especially as the development of concrete technology opened up new construction possibilities (McCormack, 2001), China's water resource management is dominated by engineering projects (Liu et al., 2013). The mindset of water resource management is technology- or structure- oriented with weak capacity in governance, which lacks solid policy analysis and participatory and informed decision-making (Jiang, 2015). Such mindset is also embodied in flood mitigation strategy. In over 90% of Chinese cities, traditional engineering infrastructure (i.e. floodgates, concrete infrastructure and oversized drains) are employed as mitigation measures to drain urban discharges as quickly as possible to downstream outlets (Chan et al., 2018). As for water quality management, wastewater treatment has not been emphasized until the 1990s when environmental deterioration became serious in Chinese urban areas (Zhao, 2015); Research and practices on urban water reclamation were officially promoted at the beginning of this century (Xu, 2018).

4 风水(Feng Shui), literally Wind-Water, is a set of Chinese geomancy theory.

However, discharge as quickly as possible may not be panacea. The disharmony between water and urban life is looming especially after over thirty-year rapid urbanization in China and notable global climate change. Much less permeable pavement, fading natural and artificial lakes, lagged-behind standards, etc. escalate the occurrence of urban flooding (Wang, Yan, Huang, & Zhou, 2012). According to an investigation carried out by Ministry of Housing and Urban-Rural Development (MHURD) in 2010, 137 of 351 Chinese cities suffered more than 3 flooding events during the period from 2008 to 2010 (Wu Che & Zhang, 2019). On the other hand, the Ministry of Water Resources (MWR) of China stated that there are more than 400 cities short of water supply and 110 cities facing severe water shortage situation (Li, Li, Fang, Gong, & Wang, 2016). Moreover, polluted water discharged to surface waterways and groundwater exert severe impacts on public health and ecology (He & Xing, 2006; Sun et al., 2016). Faced with above-mentioned and other water related issues e.g. aquatic habitat degradation, groundwater decline and depletion, China needs integrated and comprehensive solutions, involving not one single department but multiple departments (Yu et al., 2015).

Under such context, Chinese central government initiated a so-call Sponge City Programme (SCP) in the year of 2014 for constructing 'spongy' water-resilient cities. Sponge City's first official debut was on at the central urbanization conference in December 12, 2013, where President Xi Jinping introduced the "construction of Sponge City with natural storage, natural infiltration and natural purification" (MHURD, 2014a). MHURD released the first technical guideline of Sponge City construction (MHURD, 2014b). The first batch of 16 pilot cities were released by Ministry of Finance in April, 2015 (MF, 2015) and second batch of 14 were announced 2 years later (MF, MHURD, & MWR, 2016). General Office of the State Council (GOSC) published guiding opinions on Sponge City construction for local governments, mentioning the general goal - "through sponge city construction, minimize the impact of urban development on ecology to locally absorb and utilize 70% of the rainfall"[5] (GOSC, 2015). A trial version[6] of governmental document proposed performance indicators from six aspects[7] to guide the evaluation of SCP construction (MHURD, 2015). The request of compiling local Sponge City planning was published by MHURD in March, 2016, which set general principles of downscaling Sponge City indicators to city level (MHURD, 2016). The official national evaluation standard (MHURD, 2018) was released for guiding sponge effect evaluation in year 2018.

3.1.2 Concept development

Looking back to the development of the word 'sponge', it appeared in urban design and stormwater management fields before the official SC programme had been initiated.

Yu and Li (2003) claimed wetlands alongside rivers are like sponges, regulating the abundance and scarcity of river water as well as mitigating the damage of flooding and drought. Dong and Han (2011) proposed technical schemes and assessment indicators of stormwater management for building an eco-sponge city. Mo and Yu (2012) raised the concept of building urban green sponge based on blue-green solutions in a case study of Yizhuang, Beijing, aiming to realize co-benefits of flooding prevention, resource recovery, waterscape construction via source control and on-site infiltration. Jiusan Society proposed in the year of 2011 the concept of building a spongy city and improving city's ecological restoration capacity (Wu & Guan, 2018). Apparently 'sponge' is related to ecology restoration and flood mitigation in studies before 2014, as different objectives are focused on.

The terminology of Sponge City is officially explained, including conceptual illustrations of the objectives, in *Technical Guidelines for Sponge City Construction-Low Impact Development of Rainwater System Construction (Trial)* (MHURD, 2014b):

> *"Sponge City means cities are like sponges, with good 'resilience' in adapting to environment changes and handling natural disasters, which are able to absorb, retain, infiltrate and purify water, if necessary, release and reuse water… Sponge City construction approach: 1. Protect original urban ecosystems; 2. Restore and rehabilitate ecology; 3. Low impact development[8]…*

5 The timescale is: by 2020, more than 20% of the urban built-up area will meet the target requirements; by 2030, more than 80% of the urban built-up area will meet the target requirements.

6 There is no final version of this document yet.

7 Six aspects in performance evaluation, namely, water ecology, water environment, water resource, water safety, system & implementation, appearance (水生态、水环境、水资源、水安全、制度建设及执行情况、显示度).

8 LID mentioned here refers not to the original focus of LID which is on using site design to minimize impervious areas and

Sponge City construction should integrate LID[9], urban stormwater sewer systems and excess stormwater runoff drainage systems[10]." (MHURD, 2014a)

As how the title is named, this technical guideline emphasized on how to build up low impact development stormwater management systems, which contributes to pollution source control and runoff peak flow reduction.

Explorations of the Sponge City concept's essence started booming in literatures since Sponge City programme was initiated in the year of 2014. Interpretations of 'sponge' or 'sponge city' proposed in some papers are summarized in Figure 3, with backgrounds of the first authors. Apparently, the vision of 'sponge' or 'sponge city' varies amongst different disciplines and even from the same disciplines.

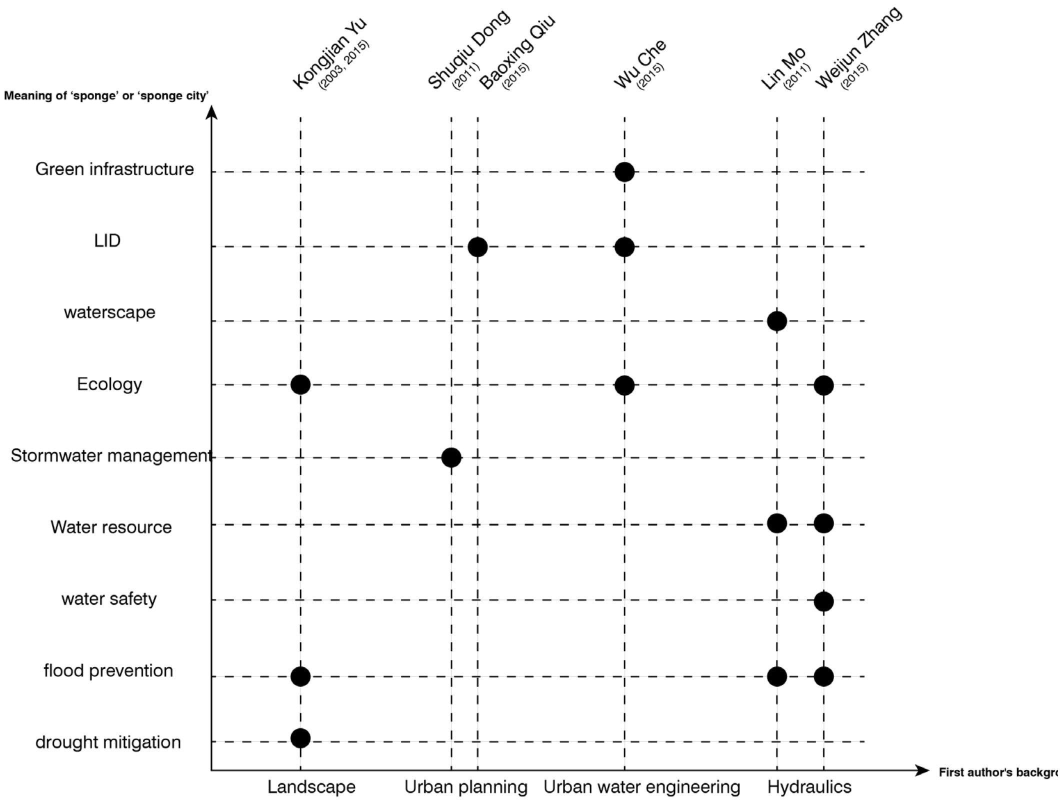


Figure 3 Sponge City meaning given by authors with different backgrounds

Qiu (2015) states that Sponge City follows LID model with adaptation and harmonization to the nature. Che[11] et al. explain the scope of LID that mentioned in the technical guideline, including source control measures, mid-way conveyance and end-of-pipe measures. They claim that the concept, principle, and technical scheme of Sponge City matches LID in broad prospective as well as GSI (green stormwater infrastructure) and WSUD (water sensitive urban design), though many details and contents are LID in narrow terms (Che et al., 2015). Yang and Lin (2015) admit no matter in the guidelines or in official propaganda, LID design of small or medium scale seems to be emphasized, however, the comprehensive meaning of Sponge City is not conveyed effectively. Yu et al. (2015) elaborate the essence of Sponge City from the eco-service point of view, which claim that building a hydro-ecological infrastructure across spatial scales and combining multiple types of specific technologies is the core of a "sponge city".

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retain natural areas, but the combination of source, mid-way and end-of-pipe measures.

9 LID here, and in many other places in the guideline refers to narrow meaning of LID, which is about source control (Che et al., 2015). LID measures are smaller on-site measures to maintain pre-development site characteristics or to reduce the impact of urban development at the source (Dietz, 2007; Prince George's County, 1999).

10 Excess stormwater runoff drainage systems include natural water bodies, multi-functional storage volumes, flooding pathway, etc.

11 Wu Che is one of the major drafters of *Technical Guidelines for Sponge City Construction-Low Impact Development of Rainwater System Construction (Trial)*.

However, Zhang (2015) argues that Sponge City is not equal to LID or waterscape engineering projects, instead, it is about urban water safety and water ecology protection and reinvention, which incorporate water resource management, flood prevention, urban ecology rehabilitation, etc. Che and Zhang (2016) proposed "three combo" concept in Sponge City, namely combination of source and end-of-pipe, combination of aboveground and underground, and combination of green and grey. Wu and Guan (2018) concluded that Sponge City theory focuses on green solutions at the beginning, whereas subsystems in stormwater management should be treated in an integrated way, without separation of green and grey infrastructures.

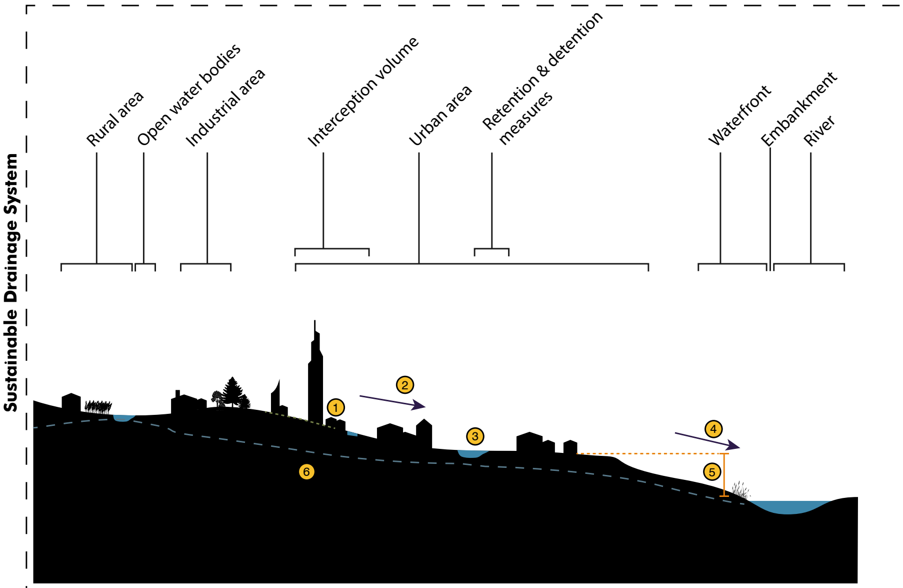
After years of development and enrichment, Sponge City concept become more inclusive and step closer to an integrated urban water management strategy incorporated in urban planning and designing according to the definition given in Sponge City evaluation standard (MHURD, 2018). The terminology of Sponge City is then further elaborated, including objectives of water ecology, water resource, water environment, water safety, water culture, etc.

> *"Through urban planning and construction management, getting hands on 'source control, process control and system management', comprehensively adopt 'infiltration, detention, retention, purification, reuse, drainage' and other techniques, systematically coordinate water quantity and quality, ecology and safety, scatter and cluster, green and grey, landscape and functionality, above-bank and below-bank, aboveground and underground, mitigate the impacts on original natural hydrologic characteristics and damage on water ecology exerted by urban development, make city works like a 'sponge' with good 'resilience' in adapting to environment changes and resisting natural disasters, etc., in order to achieve a urban development paradigm of natural storage, natural infiltration, natural purification, which contribute to co-benefits such as urban water ecology restoration, urban water resource recovery, urban water environment improvement, urban water safety guarantee, urban water culture revitalization, etc." (MHURD, 2018)*

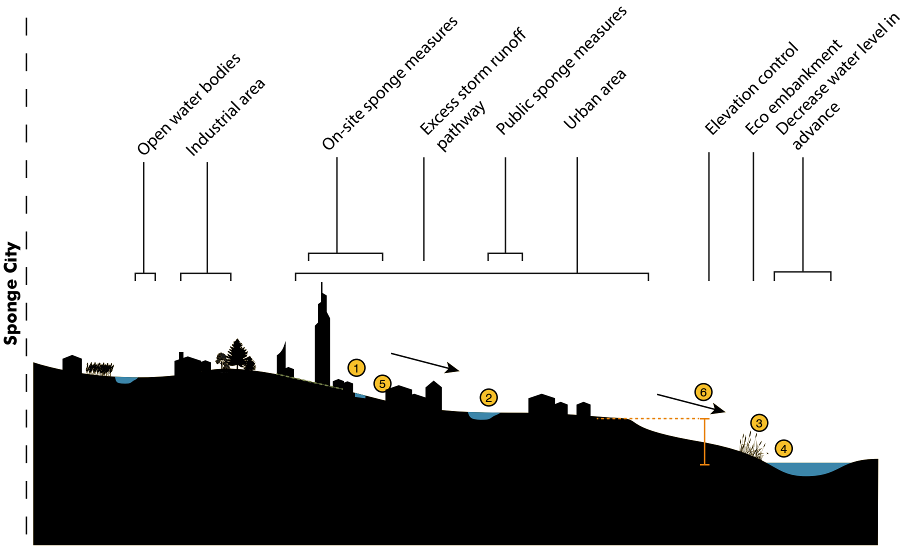
3.1.3 SC concept principles & design criteria

As Sponge City concept is still developing, the planning principles evolve from non-specific in national guideline (MHURD, 2014a) to relatively more specific at local level (Nanjing Municipality, 2018). 'Planning before construction, priority on ecology, safety first, adapting to local conditions, and coordinated development' are the five principles proposed in national technical guideline, while in Nanjing Sponge City guidelines (NPNRB, 2018b) those are transformed to: 'Priority on planning; Priority on ecology; Adaptation to local conditions; Holistic construction; Equal emphasis on construction and management'. More detailed information of those principles in Nanjing SC guidelines can be found in Annex A.

Design criteria of sponge city are shown in Figure 4 with a conceptual model of sponge measures (Nanjing Municipality, 2018; NPNRB, 2018b). Nanjing sponge city guidelines set planning & design objectives on runoff volume control, pluvial flooding prevention, ecological restoration, fluvial flooding prevention, blue spaces, non-point source pollution mitigation, etc. Corresponding design criteria, required by various indicators, are proposed in Nanjing SC guidelines and Nanjing City SC sector plan (Nanjing Municipality, 2018; NPNRB, 2018b). Sponge interventions are classified into source control (e.g. bioretention systems, porous pavement, green roof, etc.), mid-way conveyance (e.g. vegetation trench, infiltration trench, etc.), end-of-pipe storage measures (e.g. constructed wetland, ecological embankment, rainwater detention pond, etc.). VCRa, one of the performance indicators, are used in guidelines to determine storage volume for ecological and water quality treatment purpose. General guidance of sponge design on different land types, i.e. residential areas, roads, public space, water, are given on preferred sponge measures and precautions of design. However, holistic planning and design process that fits SC multiple objectives, including pluvial flooding prevention, ecology restoration, etc., are not available in Nanjing SC guidelines (NPNRB, 2018b).



Number	Target	Criteria
1	Water quality treatment (Volume interception)	90% of average annual rainfall or the first 10-15 mm of rainfall depth
2	Watercourse protection	Maintain greenfield runoff for rainfall event with 50% annual probability (once-in-2-year)
3	Site level of service	Maintain on-site flooding at less than 3.3% annual probability (once-in-30-year event)
4	River flood protection	Maintain greenfield runoff for 1% annual probability event (once-in-100-year 6-hour event)
5	Building flood protection	Maintain floor slabs above 1-1.5% annual probability flood level
6	Groundwater table control	Maintain groundwater level below 1% annual exceedance probability



Number	Target	Criteria
1	Runoff volume control	VCRa ranges between 60% and 85% based on local conditions around China (ca. 10-30mm of rainfall depth)
2	Pluvial flooding prevention	Match return period requirements from flood control code (e.g. once-in-50-year event for Qinhuai district, Nanjing)
3	Ecological restoration	Obligatory requirement: ecological embankment ratio 80% (for Nanjing)
4	Fluvial flooding prevention	Match return period requirements from flood control code (e.g. once-in-200-year event for Nanjing)
5	Blue space	Water surface ratio reaches 11.4% for Nanjing
6	Non-point source pollution mitigation	Suspended solids reduction ratio more than 50% by sponge measures for Nanjing

Figure 4 Conceptual model and design criteria of SuDS and Sponge City

3.1.4 SC approach in literature

Practical Sponge City cases concerning planning and/or design in literatures were found by searching 'sponge design implementation' or 'sponge city design' or 'sponge city planning' in Chinese at CNKI. Limited pieces of papers focus on Sponge City design approach, of which seven literatures were selected to study on their scope and methods (see Table 2). Most of cases comply design criteria stated in the national technical guidelines, which emphases on runoff volume, rate and quality control, as well as the indicator VCRa. Besides above-mentioned sponge targets, Q. Yang and Li (2019) use Aquacycle[12] to quantify co-benefits of groundwater recharge and stormwater discharge reduction during selecting design alternatives, and stormwater reuse rate of 3% is mentioned in a neighbourhood sponge design of Tianjin City (Zhang et al., 2017). Zhenjiang old district design, not like other design with design storm ranging between 10 mm and 30 mm, determines a storage target of 80.5mm for purposes of both flooding prevention and pollution mitigation, through combination of on-site LID measures, huge piping systems (4000 mm) and end-of-pipe treatment facilities (Hu et al., 2019). Moreover, Liu, Li, and Shi (2018) proposed a layered strategy model for sponge design from city scale to site scale.

12 Aquacycle is a daily urban water balance model which has been developed to simulate the total urban water cycle as an integrated whole and provide a tool for investigating the use of locally generated stormwater and wastewater as a substitute for imported water alongside water use efficiency. Source: https://toolkit.ewater.org.au/Tools/Aquacycle

City	Scope	Design approach	Reference
Suining	Neighbourhood design alternative selection based on water quantity	• Use Aquacycle to quantify water balance for each alternative. • Compare results from perspectives of annual runoff volume, annual groundwater recharge and annual stormwater discharge.	Yang & Li, 2019
Zhenjiang	Top-level design for an old district based on multi-objective	• System assessment for identifying flooding and pollution issues facilitated by PCSWMM modelling. • Determine design targets: VCRa = 94.5%, design storm depth = 80.5mm. • Propose system plan: combination of on-site LID measures, large multi-functional pipes (DN4000) and end-of-pipe water treatment facilities.	Hu et al., 2019
Jinan	Research on sponge effects of sponge measures in Shandong University campus	• Use SWMM evaluate runoff volume reduction, peak rate delay & mitigation, and runoff water quality improvements after applying sponge measures.	Ming, 2019
Tianjin	Sponge City top planning design for the city of Tianjin	• Tianjin housing and construction committee issues an official notice regulating SC projects from set-up to completion and evaluation. Sponge City should be necessary in contract of leasing land; when assessing construction drawings, competent authorities should pay attention to lowered green ratio, pervious pavement ratio and sponge volume per thousand square meter pavement.	Zhang et al., 2019
Hunchun	Scale Strategy Of Sponge City Design with adaptation to Water Environment	• Master planning scale: 1. Use InfoWorks ICM to assess rainfall-runoff process facilitate structural plan of landuse; determine vertical planning principle and make city catchment subdivision; 2. Specify schematic sponge control index (i.e. VCRa) • District level: 1. Consider topography and morphology, landuse, ecology to specify indicator downscaling requirement; advice on green size and spatial distribution; measure green space for subzones 2. Specify VCRa for each subzone considering implementation difficulties, footprint and other factors. • Site level: 1. Consider slope, building density, green ratio, hardness, etc. 2. Design with nature, consider local feature and original fibre. 3. Use LID to reduce runoff to reach VCRa targets.	Liu et al., 2018
Jilin	Sponge campus design	• Sponge design elements include unquantifiable (spatial design) and quantifiable (LID facilities) aspects: 1. Specify VCRa; 2. Analyse sponge spatial planning; 3. Build flood hydro-dynamic model using infoworks ICM; 4.Optimize LID measures to meet target indicators; 4. Design drainage system based on models iteratively; 5.Overall evaluation	Liu et al., 2017
Tianjin	Neighbourhood sponge design (Incorporate Sponge City concept into construction drawings)	• Keep existing green spaces and apply LID. Set targets: VCRa 80% (design storm 29.5 mm), runoff pollution control rate 65%, reuse stormwater rate 3%.	Zhang et al., 2017

Table 2 Cases from literatures about sponge city projects (Hu et al., 2019; Shengjun Liu, Jin, & Wu, 2017; Liu et al., 2018; Min, 2019; Yang & Li, 2019; Zhang et al., 2017; Zheng, Yu, Wu, Li, & Lyu, 2019)

3.1.5 Relevant design paradigms, concepts and approach

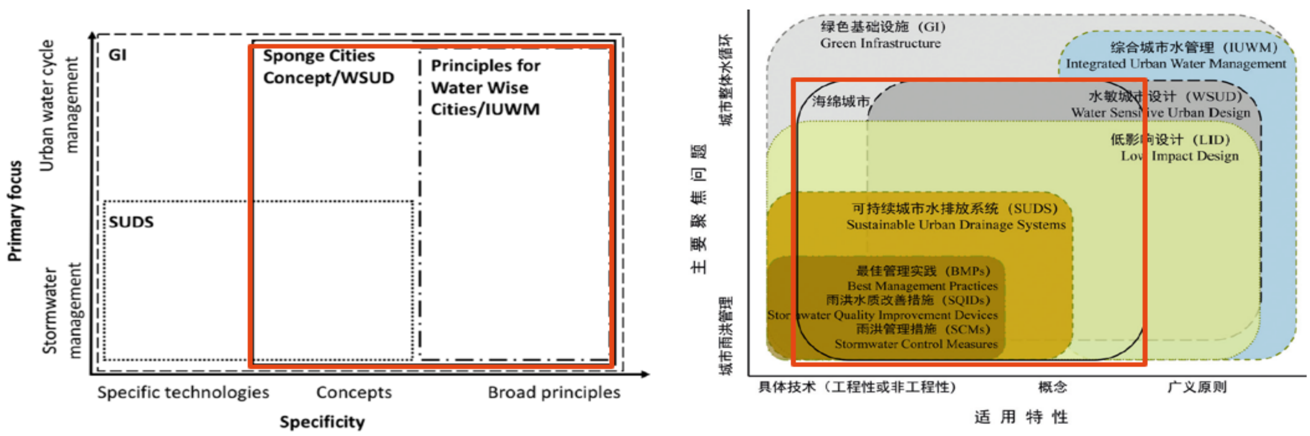


Figure 5 Sponge City interpretations. Two figures share the same axes and the red frames are the scopes of Sponge City identified in two literatures. Left figure: Zevenbergen et al. (2018), right figure: Sun et al. (2019).

As a complicated and on-going refining concept, Sponge City might be interpreted differently (Figure 5). Therefore, before diving into details of Chinese sponge city planning & design, more insights can be gained by reviewing other equivalent or similar design paradigms originated from other countries, e.g. Low Impact Development

(LID), Sustainable Drainage Systems (SuDS)[13] and Water Sensitive Design (WSD)[14]. Principles and design criteria of SuDS will be introduced in order to compare with Sponge City. The spatial scales and design process of WSU planning is also included to shed light on sponge city planning. Moreover, the principles of Dutch planning with water will be elaborated to understand how to make more sustainable design considering both spatial planning and water management. Two relevant concepts, i.e. four-component vulnerability framework and Three Point Approach (3PA) are introduced, which will be used to evaluate current planning & design contents in Section 3.2.3. Additionally, PRIMO-chain approach for good governance is explained as well.

LID

The term Low Impact Development (LID), widely used in the USA, means a comprehensive technology-based approach to managing urban stormwater with small and cost-effective on-site measures in order to emulate 'natural' hydrology of pre-developed site or to reduce the impact of urban development at the source (Dietz, 2007; Fletcher et al., 2014; Prince George's County, 1999). LID measures include green roofs, bioretention systems, porous pavement, etc.

SuDS

In the UK, Sustainable Drainage System (SuDS) aims to 'minimise the impacts from the development on the quantity and quality of the runoff, and maximise amenity and biodiversity opportunities' (Woods-Ballard et al., 2007). The three-way concept includes quantity, quality, and amenity & biodiversity. The SuDS Manual (Woods-Ballard et al., 2007) proposed design criteria for hydraulic, water quality, amenity, ecology and sustainability aspects. General principles are listed below.

Hydraulic

1. *Ensure that people and property on the site are protected from flooding.*
2. *Ensure that the impact of the development does not exacerbate flood risk at any other point (either upstream or downstream) in the catchment of the receiving watercourse.*

Water quality

An appropriate management "train" of SuDS components should be implemented to effectively mitigate the pollution risks associated with different site users/ activities.

Amenity

1. *Health and safety.*
2. *Visual impact.*
3. *Amenity benefit.*

Ecology

1. *The use of native planting.*
2. *Locating SuDS in or near non-intensively managed landscapes (where possible), e.g. close to*
3. *Natural pond and wetland habitats.*
4. *Retaining and enhancing natural drainage systems.*
5. *Creating a range of habitat types.*
6. *Including a shallow, aquatic bench in pond designs (i.e. a maximum depth of 0.45 m depth below the permanent water level, with a minimum width of 1 m).*
7. *Implementing an appropriate maintenance and management plan.*

Sustainability

SuDS should be considered within a holistic science-based framework of sustainability

A conceptual SuDS model based on SuDS technical report (Wilson, Bray, & Cooper, 2004) is illustrated in Figure 4, which listed relevant detailed criteria for storage sizing design and where interventions are probably take place. It is worth noting that storage types are clearly explained in the SuDS manual (Woods-Ballard et al., 2007), which are classified into four categories, namely interception storage (ca. 5 mm), long-term storage, attenuation storage and treatment volumes (ca. 10-15 mm). The required long-term storage volume is normally calculated by the difference between runoff volume from development sites and that from greenfield sites under certain rainfall event (e.g. 100-year, 6-hour event). Moreover, subsurface soils and groundwater are taken into consideration in SuDS, including the criteria for groundwater table control (Woods-Ballard et al., 2007). Unlike Sponge City with a typical top-down policy implementation mechanism, implementation of SuDS is a piecemeal, bottom-up approach essentially relying on local "SuDS Champions" (Lashford et al., 2019).

13 Sustainable Urban Drainage Systems (SUDS) was believed first coined by Jim Conlin of Scottish Water to describe stormwater technology in 1997, after which 'urban' in the term was omitted by some parties, referring to Sustainable Drainage Systems (SuDS) (Fletcher et al., 2014).

14 In the Auckland region, WSD represents the best practice approach for stormwater management (Lewis et al., 2015).

WSUD

Water Sensitive Urban Design (WSUD) is particularly used in Australia, which refers to a 'philosophical approach to urban planning and design that aims to minimize the hydrological impacts of urban development on the surrounding environment' (Lloyd, Wong, & Chesterfield, 2002).

WSD

By considering uniqueness of New Zealand environments and elements from similar design paradigms including WSUD, LID and SuDS, Water Sensitive Design (WSD) is used in Auckland region to guide land use planning and land development, with a specific focus on stormwater and freshwater management (Lewis et al., 2015).

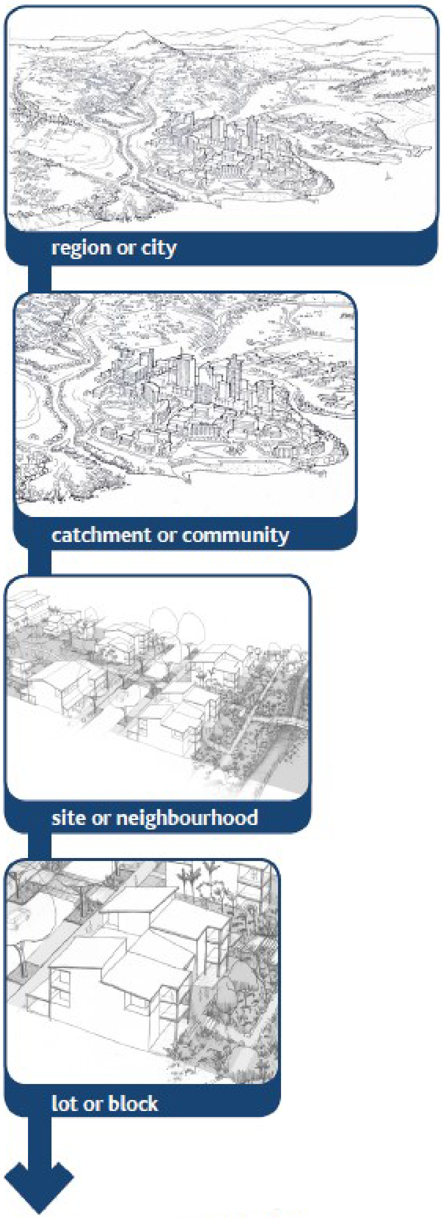


Figure 6 Spatial scales in WSD (Lewis et al., 2015)

The definition of WSD is:

"An approach to freshwater management, it is applied to land use planning and development at complementary scales including region, catchment, development and site. Water sensitive design seeks to protect and enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities." (Lewis et al., 2015)

Four guiding principles are proposed in WSD, which are listed ad below:

1. Promote inter-disciplinary planning and design;
2. Protect and enhance the values and functions of natural ecosystems;
3. Address stormwater effects as close to source as possible;
4. Mimic natural systems and processes for stormwater management (Lewis et al., 2015).

WSD principles are applied and discussed at various planning scales (see Figure 6) of the 'region' (in this case the Auckland region), the 'catchment' (or community), and the 'site' (or neighbourhood) scale (Lewis et al., 2015). Promoting WSD outcomes at the complementary planning scales helps to balance development with supporting ecosystem services (Lewis et al., 2015). A recommended design process specific for stormwater management is shown in Figure 7.

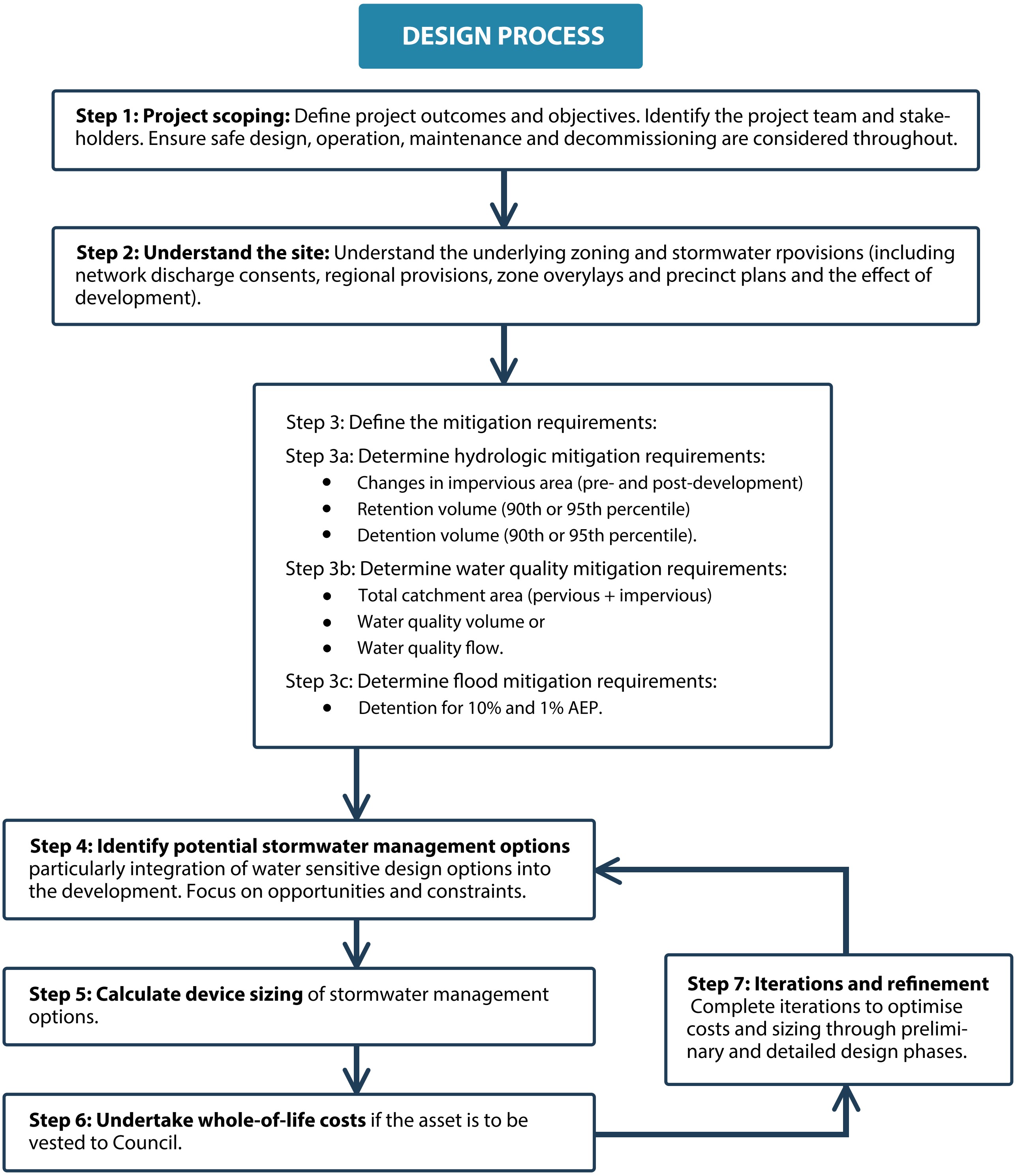


Figure 7 A recommended design process specific to stormwater management in WSD. (Cunningham et al., 2017)

Dutch planning with water

Water management is of evident influence on the spatial planning in a region and vice versa (van de Ven, 2016). Some key Dutch water management & spatial planning principles are listed as follows:

1. Safety first
    - No building in flood-prone areas

- Make space for dikes and facilities
- Prioritize 1. Retain 2. Store 3. Drain water
- Create retention areas and emergency flooding areas
- Retain water in the ground
- Multi-functional land use
- Make space for groundwater quality

2. Never shift problems ('Niet afwentelen')
    - Never shift problems to your neighbours/downstream
    - Never shift problems to the future
3. Water flows from clean to more dirty land use
    - Two network strategy
4. Keep clean water clean
    - Clean versus polluted watercourses
5. Make water fun
    - Keep water visible
6. Build water positive
    - Prevent sealing surfaces

(van de Ven, 2016)

Four-component vulnerability framework

The four-component vulnerability framework includes threshold capacity, coping capacity, recovery capacity, and adaptive capacity (de Graaf et al., 2007). Specifically, threshold capacity is the ability that a system is able to prevent damage up to a certain level (e.g. levee, pumps, etc.); Coping capacity is the ability to reduce damage if a disturbance exceeds the threshold (e.g. emergency and evacuation plans); Recovery capacity refers to the capacity of a society to recover to the same or an equivalent state as before the emergency (e.g. reconstruction of buildings and dikes); Adaptive capacity is the capacity to cope with, and adjust to uncertain future disturbance (climate change adaptation measures). Using such four-component vulnerability framework can help assess water and climate related vulnerability of urban areas and develop more complete water management strategies to reduce vulnerability (de Graaf et al., 2007).

Three Points Approach (3PA)

Three Points Approach (3PA) is a method to help decision making process of urban flood risk management in the context of climate change (Fratini et al., 2012). The three points in Figure 8 represents three domains where different aspects can be valued by stakeholders: The first point focuses on technical optimization of water system, where certain return periods are to be met by threshold capacity following design standards; The second point is dealing with extreme climate conditions where water experts, urban planners, etc. discuss solutions to maximize coping and recovery capacity and increase adaptation capacity to future changes; The third point emphasizes on day-to-day values to increase the quality of inhabitants' daily life, where stakeholder involvement in decision making process is crucial.

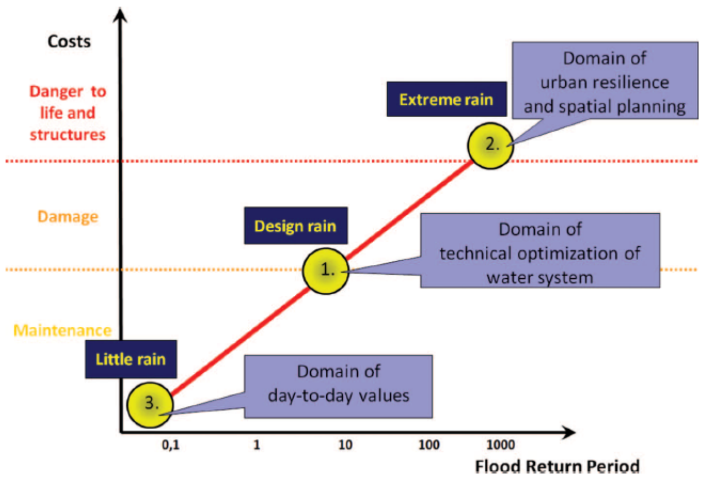


Figure 8 Three-point approach (Fratini et al., 2012)

PRIMO-chain approach

PRIMO-chain (in Dutch called BRUHO-keten) stands for a series of governance aspects related to each measure (van de Ven, 2016):

- Policy (Beleid)
- Regulations and Legislation (Regelgeving)
- Implementation capacity, execution capacity (Uitvoering)
- Maintenance, enforcement, performance evaluation (Handhaving)
- Organisation and financing (Organisatie en financiering)

Proposed measures can be assessed by the governance aspects in PRIMO-chain. If any of those aspects is insufficiently covered or not available, there would be uncertainties or challenges in implementation, operation and maintenance of any proposed measure (van de Ven, 2016).

3.1.6 Discussion

It can be concluded that Sponge City has been evolving from a term mainly describing measures with ecological benefits towards a more inclusive urban development paradigm, considering not only water ecology, but also water safety, water environment and water resource. Although the concept scope of Sponge City has been debated throughout these years, the integrated essence of this term does catalyse inter-disciplinary dialogues, including disciplines such as water management, landscape architecture, urban planning, ecology, and so on. Such dialogues help the growth and spread of Sponge City 'brand'. It is rather important that practitioners explicitly express what they mean by the term 'Sponge City' and for what purposes 'Sponge City' is expected to achieve before moving to the phase of planning and design. Authorities should also promote academic research on developing a ubiquitous Sponge City definition and concept scoping. On the other hand, comprehensive directions could be given by central government so that the guidelines – instead of directives – enables cities flexibly to carry out their own versions of Sponge City and allow for tuning the approach to local climate and spatial conditions.

More insights can be found when comparing Sponge City (SC) with other design paradigms or planning principles. In the very first SC technical guideline (MHURD, 2015), LID design for small or medium rainfall events seems to be emphasized, whereas SC concept contains not only source control but also mid-way and end-of pipe measures. SC and SuDS contain some common targets and management train; however, SC does not pay attention to subsurface & groundwater, neither amenity & biodiversity, especially health and visual impact are missing in guidelines. The scope of SC concept is close to WSUD and WSD concerning integration of sustainable water management with urban planning and design. In SuDS, WSD and Dutch planning with water, one common principle is mentioned: never shift problems from one place to another. It is expressed as 'ensure that the impact of the development does not exacerbate flood risk at any other point' in SuDS, 'address stormwater effects as close to source as possible' in WSD and 'never shift problems' in Dutch planning. However, such principle does not appear in Chinese SC guidelines. Additionally, WSD principles are applied and discussed at various planning scales, whereas Nanjing SC plans at various planning scales have similar principles without much changes from city guidelines.

As for water systems, SC highlights water surface ratio in development sites and ecological embankment compared to SuDS, however, calculation method of storage for large rainfall events is not mentioned in current guidelines, and most importantly groundwater is missing. It should also be noted that scenarios of climate change are not considered in current Sponge City design. Differences between SC and SuDS also lie in storage sizing design. Storage is not clearly defined in national technical guideline (MHURD, 2014a), though on-site storage and public sponge[15] are distinguished in Nanjing SC planning (Nanjing Municipality, 2018). On-site sponge sizing is based on an indicator (VCRa) which is for ecological and water quality purpose. Methods of sponge sizing calculation for pluvial flooding target are missing. A reflection on SC versus four-component vulnerability framework, the 3PA and the PRIMO-chain approach is presented in Section 3.2.3, after understating the planning & design contents in Nanjing City.

15 Public sponge in Nanjing sponge plan refers to storage capacity provided by public green areas, which are designed to be around 10-30 mm.

In line with guidelines, cases in literatures commonly pay attention on water quantity and quality in sponge design, especially using VCRa as an overall guiding indicator. However, a key water system component groundwater is missing in most cases. LID measures are designed for small rainfall events and no surface storage for pluvial flooding prevention and control under extreme rainfall events is assessed or designed.

Moreover, another difference between SC and SuDS is the implementation mechanism. SC is promoted by top-down policies whereas SuDS takes a bottom-up approach essentially relying on local "SuDS Champions". Such fundamental difference probabily cause sponge design practices rely much on upper guidance, while the motivation of seeking their own SC versions at bottom is limited.

3.1.7 Summary

No doubt that Sponge City is a revolutionary paradigm in terms of both Chinese urban development and water management. However, SC is still in its infancy phase and undergoing exploration of best practices from concept to planning & design.

The scope of SC concept extends LID and SuDS and is closer to WSUD and WUD. Compared with relevant concepts from other countries, there still are some components missing in current Chinese SC guidelines. Missing parts include subsurface and groundwater, amenity and biodiversity, climate scenarios. Moreover, 'never shift problems' or other close expressions is not included in current SC guiding principles.

In the next section, contents and process of sponge city planning & design in Nanjing will be studied, through which more insights can be found.

3.2 Studying planning & design practice

3.2.1 Sponge City planning contents

Sponge City is a complicated concept, integrating knowledge from various disciplines, e.g. integrated urban water management, landscape architecture, urban planning, transport, etc. Nevertheless, water is the core of a sponge city. Guidelines and sponge city sector planning hitherto commonly categorize sponge city assessment and solutions into four themes, namely water safety, water ecology, water environment and water resource. For those cities with significant water related historical or social values, water culture is also considered in their sponge planning and design. Following paragraphs will detail sub-themes, problem assessment and solutions under those five themes in current sponge city practices. It should be noted that the study is based on governmental documentation of Nanjing City (Nanjing Municipality, 2018; NCMEDRI, 2019; NNNTDCAC., CSUS., & PCSNJ, 2016; NPNRB, 2018b; THUPDI, 2019). It is assumed that similar structure of planning and design holds true for other Chinese sponge cities, despite that weights of five water aspects are different due to varieties of local conditions.

The overview of water-related contents in sponge planning is shown in Figure 9. Next to the 'core' of Sponge City, there is a ring containing five water themes, each of which has different sub-themes in the next ring. Problem assessment approaches are listed in the ring next to sub-themes. The outermost ring includes solutions for tackling issues under each theme.

Since there is no official definition for those five themes, self-proposed definition will be stated first, followed by problem assessment methods and solutions. Emphasis is given to water safety, water environment and water ecology.

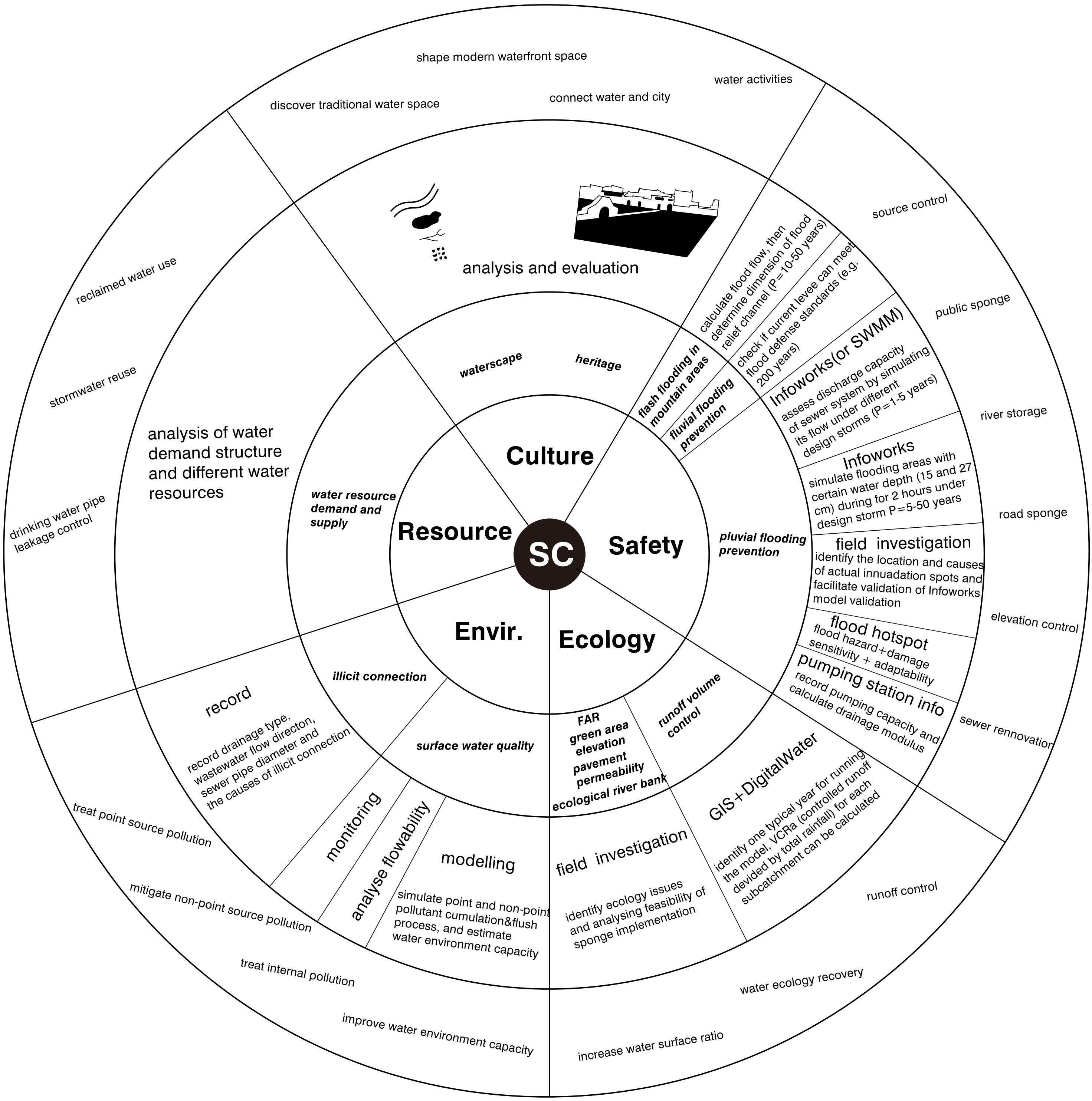


Figure 9 The overview of water themes, assessment approach and solutions in SC planning of Nanjing

3.2.1.1 Water safety

Definition

Water safety refers to water-related hazard issues that occur in the human living environment and economic development, which is commonly treated as water quantity safety. For example, water safety includes pluvial flooding, fluvial flooding, flash flooding in Nanjing SC planning.

Problem assessment

Urban flooding issues in Nanjing are categorized into fluvial flooding, pluvial flooding and flash flooding in mountain areas. The assessment for fluvial flooding is proceeded by analysing historical flooding causes and current flood defence capacity. Flash flooding is not assessed in detail in Nanjing SC planning, whereas the calculation of flash flood control facilities is based on return period of flood flow. Pluvial flooding assessment is paid more attention, including sewer system assessment, flood hazard simulation, etc.

Nanjing aims to improve its storm sewer systems to handle rainfall events with 3-5 years return period[16]. Therefore, InfoWorks ICM model is employed in the Nanjing city SC sector plan (Nanjing Municipality, 2018) to assess which parts of current storm sewer systems should be renovated to meet 3-year return period criteria. Drainage catchments and pumping station capacities are assessed as well. Historical flood hotspots and flood risk map are shown in city planning (Nanjing Municipality, 2018), while models are used to simulate flood hazard and risk maps at district level (NCMEDRI, 2019; THUPDI, 2019). Jianye District sponge plan (THUPDI, 2019) models flooding hazard under scenarios of storm events with 5, 10, 50 years return periods, and calculated flood duration of areas with water depth of 15 cm (assumed as threats to traffic) and 27 cm (assumed as threats inhabitants' property). Such analysis approach refers to the requirements in national code of pluvial flooding prevention (MHURD & GAQSIQ, 2017) (see Table 3). It should be mentioned that design storm profiles used for flood hazard simulation are either SCS II with a middle peak or the design storm distribution recommended by Jiangsu Province with a peak at 75% of total duration (Nanjing Municipality, 2018; NCMEDRI, 2019; THUPDI, 2019). There is no design storm profile available that suits Nanjing's local climate condition (Nanjing Municipality, 2018).

Type	Return period (year)	Surface inundation design criteria
Megalopolis	• 100	1. The ground floor of residential, industrial and commercial buildings is flood-proof; 2. Water depth in one land of roads shall not exceed 15 centimetres.
Mega city	• 50-100	
Large city	• 30-50	
Medium and small city	• 20-30	

Notes: 1. The return period can be used in storm intensity formula determined by annual maxima method. 2. regular inhabitant population: megalopolis more than 10 million, mega city between 5 million and 10 million, large city between 1 million and 5 million, medium city between 0.5 million and 1million, small city less than 0.5 million; 3. The code does not include specific inundation time. Each city shall determine inundation duration based on its own condition.

Table 3 Design criteria of pluvial flooding prevention and control (MHURD & GAQSIQ, 2017)

Solution

Nanjing SC plan proposes an ideal drainage system which consists of LID, storm sewers and excess stormwater drainage. Thus, the solution for tackling water safety issues is a combination of source runoff control, storage & discharge, and elevation control. Sponge components such as source control measures, public sponge, river sponge, road sponge, elevation control and sewer innovation are proposed as detailed solutions. It is worth mentioning that source control is corresponding to the storage volume calculated by VCRa for development sites. Public sponge in Nanjing sponge plan refers to storage capacity provided by public green areas, which are designed to be around 10-30 mm. Road sponge means road can be used as 'flooding pathway' with temporary storage capacity. It is regulated in national code (MHURD, 2017) that roads can work as sponge for no longer than

16 Return period is the average time interval between occurrences of a hydrological event (rainfall or flow) of a given or greater magnitude, usually expressed in years (Woods-Ballard et al., 2007). For example, a once-in-fifty-year event will have an annual exceedance probability of 0.02.

12 hours and shall discharge to water body, pipes or other sponge facilities nearby, roads at the downstream[17] of sewer systems are preferred rather than main roads, etc. River sponge means water level in the rivers are (to be) manoeuvred to be 0.1-1.2 metres lower in advance of heavy storms to receive runoff. Elevation control is to manipulate site elevation 1.5 metres higher than maximal water level in watercourse and critical infrastructure level higher than surrounding roads or surface. However, if the whole system can cope with 50-year flooding is not thoroughly evaluated in Nanjing SC plan.

3.2.1.2 Water ecology

Definition

Water ecology means the quality of the ecosystem in urban water environment, including pond, lakes, cannels, rivers, etc., as well as ecology of embankments.

Problem assessment

Assessment of water ecology includes water surface ratio, ecological embankment length, VCRa, floor area ratio (FAR), etc. VCRa is an essential indicator in sponge planning, design and evaluation, so it will be explained in the following paragraphs.

Volume Capture Ratio of annual rainfall (年径流总量控制率, VCRa) is an indicator meaning volume percentage of a certain rainfall depth, which is used to represent how much percentage in total stormwater volume is intended to be retained by sponge measures for ecological reasons. Calculation method of VCRa is shown below.

Sort the daily precipitation data in ascending order and exclude rainfall events whose 24h rainfall depth is less than 2 mm. Then the VCRa is derived based on Equation 1 (MHURD, 2014a):

$$VCRa(\%) = \frac{\sum_0^i h_{i(i<D)} + \sum_i^n h_{D(i>D)}}{P}$$

Equation 1 VCRa calculation

Where P is total annual precipitation (mm), h_D is the design rainfall depth (mm), h_i is the actual 24h rainfall depth (mm); i is the sequence number of daily rainfalls, and D is the particular sequence number corresponding to certain design rainfall depth.

An illustration of VCRa calculation method is given in Figure 10.

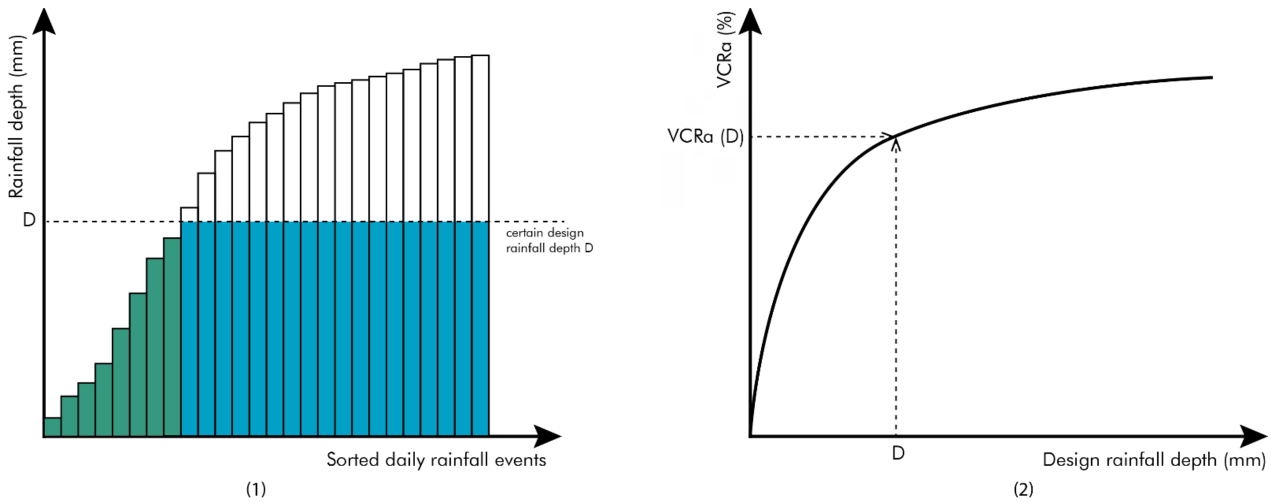


Figure 10 Illustration of VCRa calculation.

17 *Code for design of outdoor wastewater engineering* (MHURD & GAQSIQ, 2017) states downstream roads are used as temporary storage, instead of upstream. The possible reason for this counterintuitive statement is that 'quick drain' is still the main model in Chinese cities, so downstream roads serve as an end-of-pipe storage measure.

For a certain design rainfall depth D (mm), the first term in the numerator of Equation 1 means the total depth of daily rainfall events with depth less than D (as green area indicates); the second term in the numerator in Equation 1 means that if daily rainfall events with depth higher than D, count their depth as D and sum them up (as blue are indicates). Therefore, VCRa for design rainfall depth D can be calculated by the sum of green and blue area divided by the total area. Then one point can be plotted on the figure with design rainfall depth as x-axis and VCRa as y-axis. Calculate an array of design rainfall depth, then a VCRa-design rainfall depth curve can be derived.

Note that VCRa is a similar index to water quality volume (WQV) proposed in water sensitive design (Cunningham et al., 2017), which means total volume of rainfall events that deliver the majority of the stormwater pollutants during a year. VCRa is set as 75% to 80% in Nanjing, corresponding to design storm depth around 25 mm. In Auckland, WQV takes value from 90th%ile of 24-hour storm event (approx. 25 mm). A rational method is used for calculating required sponge volume V (m^3):

$$V = 10 \times DS \times C \times A$$

Equation 2 Sponge volume calculation

Where DS is design storm (mm), C is runoff coefficient, A is catchment area (hectare), 10 is for manipulating units.

It is important to notice that no matter it is called VCRa or WQV, both indices are set for storing runoff of small rainfall events in order to reduce runoff pollution or for stormwater reuse purposes. VCRa is NOT an indicator for designing sponge measures against pluvial flooding (Lin, Liao, & Ding, 2019; Wang, Ding, Cheng, & Li, 2015). This point will also be verified by interviews in Section 3.3.

It should be clarified that VCRa for design purpose and VCRa for current situation analysis are two different concepts, which is sometimes confusing. The former one is related to target rainfall depth, the calculation of which only uses historical precipitation data (MHURD, 2014a), whereas the latter one is actually referred to rainfall runoff control ratio, meaning the ratio between controlled rainfall volume (through infiltration, retention, detention, etc.) and annual average rainfall volume (MHURD, 2018). The later one equals to one minus runoff coefficient (1-C_t[18]) in practice. Inconsistence of VCRa definition in guidelines of 2014 and 2018 might lead to confusions.

Solution

Water ecology rehabilitation strategies include creating more water surface, increasing ecological embankment ratio and source control (quantified target through VCRa).

3.2.1.3 Water environment

Definition

Water environment refers to surface water systems whose quality are affected by point, non-point source or other types of pollution from urban activities.

Problem assessment

Surface water and groundwater quality should comply the requirements in national standards (GAQSIQ & SAC, 2017; MEE, 2002). Water environment issues in SC are water quality issues normally caused by combined sewer discharge, illicit connection, runoff pollution, water stagnancy, etc. Therefore, analysis is performed concerning current drainage system type (combined or separate), wastewater flow direction, pipe diameters and illicit connections. Water quality monitoring results are used to reflect temporal and spatial patterns of water environment issues. Moreover, water quality models are applied to simulate the load of point and non-point source pollution accumulation and flush, as well as water environment carrying capacity. Then the required non-point

18 C_t = total runoff via the sewerage (excluding the base flow) / total precipitation on entire drainage basin

source pollution reduction rate can be simply determined by the formula below according to Nanjing sponge plan (Nanjing Municipality, 2018):

$$Non - point\ source\ reduction\ rate = \frac{point\ source\ pollution\ load\ +\ non - point\ source\ pollution\ load\ -\ water\ envrionment\ carrying\ capacity}{non - point\ source\ pollution\ load}$$

Equation 3 Calculation of NSP reduction rate

While, sponge effects on pollution reduction is calculated by the formula below according to national sponge technical guideline (MHURD, 2014a):

$$Non - point\ source\ pollution\ reduction\ rate = VCRa \times average\ pollution\ reduction\ ratio\ of\ sponge\ measures$$

Equation 4 Effective NSP reduction rate

Solution

Water environment treatment includes mitigation of (non-) point source pollution, treatment of internal pollution, and improve water environment carrying capacity. Point pollution can be mitigated by three measures: 1. Promoting the construction of separate sewer systems; 2. Increasing water quality standard of wastewater treatment plant outflow; 3. Increase interception ratio of combine sewer systems. Water quality treatment train, also mentioned in SuDS, contains source control, midway control and end-of-pipe treatment. Other measures include proper dredging and cleaning water bodies, ecological rehabilitation, water recharge, etc., which can reduce pollution and enhance water environment self-purification capacity.

3.2.1.4 Water resource

Definition

Water resource in Nanjing sponge plan includes water demand from different industries and supply from different water sources, e.g. surface water, groundwater, reclaimed wastewater, and stormwater reuse.

Problem assessment

Analyse water demand structure and different water resources.

Solution

Measures can be taken to more efficiently use water resources, for example, reducing pipe leakage, using reclaimed wastewater, reusing retained stormwater, etc. Corresponding quantified targets are through indicators of pipe leakage ratio (PLR), reclaimed water use ratio (RWUR) and stormwater reuse ratio (SRR).

3.2.1.5 Water culture

Definition

Water culture means culture which is related to local traditional water activities, historical heritage of watercourses or waterfront spaces, etc.

Problem assessment

Analyse and summarize waterscapes, water history and heritages in Nanjing. Identify problem areas and areas with opportunities to retrofit traditional water features to stimulate cultural identity and awareness of the relation between the history of the city and the waters in and around the city.

Solution

Four strategies are considered to revitalize urban water culture: 1. Discover traditional water spaces; 2. Shape modern waterfront spaces; 3. Connect water and city; 4. Water activities. The detailed explanation of each strategy is presented in Annex A.

3.2.1.6 Indicators

The overview of main indicators at city level in Nanjing sponge planning is illustrated in Figure 11. Similar indicators can be found in district and neighbourhood sponge planning. These nine indicators can be classified into two categories, obligatory and recommended. It seems indicators cover all themes except for water culture, however, return period requirements proposed in water safety do not provide practicable sponge design criteria and/or procedures.

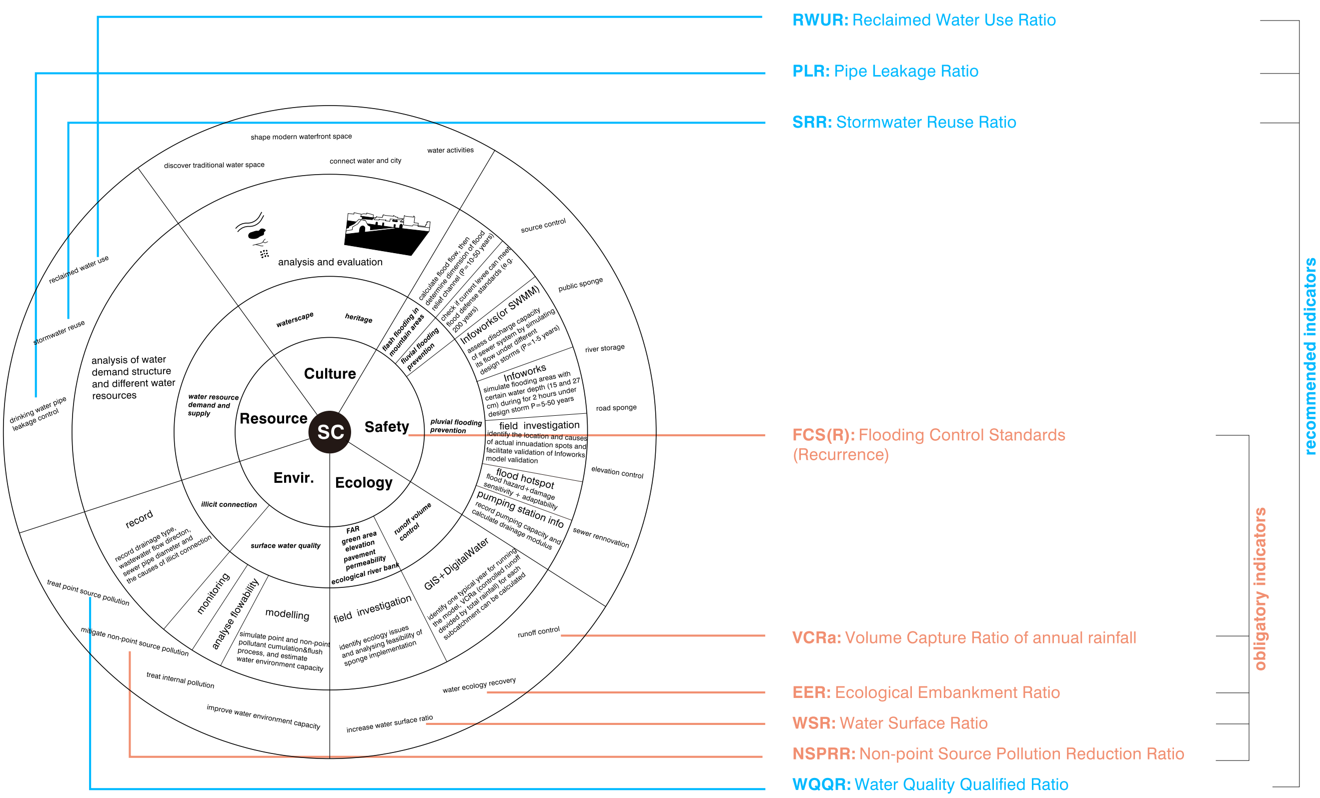


Figure 11 Obligatory and recommended indicators in Nanjing SC planning

It should be noted that indicators in SC sector plan at various administrative levels are different from indicators required in detailed control planning. The latter ones are imposed to land developers to make sure low impact development, including obligatory indicators (VCRa, NSPRR and WSR) and recommended indicators (lowering green ratio, pervious pavement ratio and green roof ratio). More in-depth explanation on the roles of indicators during planning & design process will be provided in Section 3.2.2.

3.2.2 Planning and design framework

Although SC planning and design framework is proposed in the national technical guideline (MHURD, 2014a), shown in Figure 53 (in Annex B), it is not clear how such system works in practice, especially when involving different sector plans and authorities. Therefore, actual planning and design system was investigated by studying documents of Nanjing SC at different administrative levels and relevant literatures (Nanjing Municipality, 2018; NPNRB, 2018a, 2018b; Shen, 2016). Such system is organized following two important axes: spatial scale and project phases (see Figure 12).

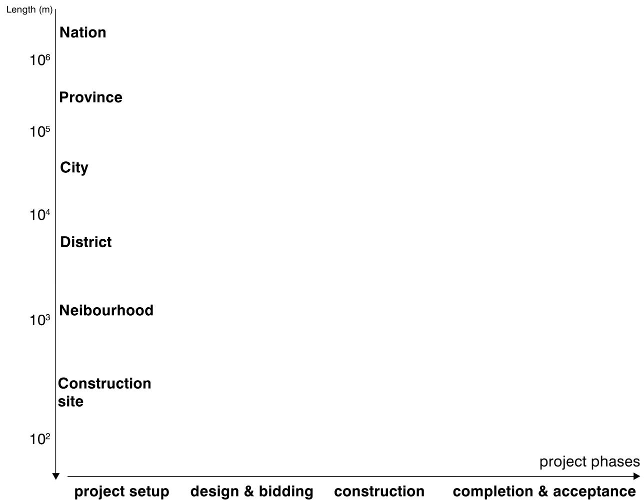


Figure 12 Two axes in sponge city planning & design framework

The analysis result of sponge planning and design system is illustrated in Figure 13. Figure 14 is the legend of the planning & design framework. The framework describes three components, i.e. planning, project and responsible authorities. Three coloured frames represent different types of planning, i.e. master planning, detailed planning and sector planning. The blue line and the green line represent the connection of different planning concerning water and green systems. Coloured bullets stand for different authorities, which take responsibilities of supervision and/or management in different project phases. For example, Sponge Office (in pink), together with Natural Resource (in yellow) & Planning Bureau or Transport Bureau (in purple)[19], is responsible for checking whether (preliminary) design of the project fulfils SC requirements before the construction project planning permit[20] is issued by Natural Resource & Planning Bureau (Nanjing Municipality, 2018; NPNRB, 2018a, 2018b). Analysis of the framework is conducted from three aspects: the relationship between sponge planning and other planning, the downscaling process of SC requirements and authority involvements in projects.

Firstly, the framework shows that SC plan is NOT independent, but interweaved with urban master plan and other sector plans. Sponge planning integrates output from spatial planning, water system planning, flood control planning, green system planning, ecology protection planning, etc. For example, protection spaces around watercourses, which cannot be used as development land, are drawn in blue line planning[21](WAB, NRPB, & NWPDI, 2019) for preventing flooding in buildings next to water, improving water environment quality, and rehabilitating ecology of water bodies. Such planning lines work as land use boundaries and set spatial restrictions to land development projects. SC sector plan also refers water safety targets, water basin division, pumping capacity and other information to flood control planning (Nanjing Water Authority, 2018). As proposed in national guidelines (MHURD, 2014a), sector planning should reflect SC concept, for example, water system planning, green system planning, flood control planning, and transport planning, Although current version of Nanjing green system plan (2013-2020) has not included SC concept yet, whereas the most recent design standard for urban residential green in Nanjing (NQTSB, 2017) reflects SC concept by setting principles, and requires 30% lowered green surface for stormwater retention. Flood control planning (Nanjing Water Authority, 2018) suggests to comprehensively adopt measures of infiltration, retention, detention, purification, reuse, discharge, etc. However, quantified planning of storage in Nanjing is not included in flood control planning. On the other hand, SC sector plan also gives suggestions to other sector plans, i.e. flood control plan, green space plan, and road plan, for better implementing SC concept. SC sector plans suggest flood control plan to maintain proper urban water surface and restore urban water bodies, such as restore occupied or filled trenches and ponds[22], enlarge

19 If the project is about transport, the Transport Bureau is responsible for design check-up (Shen, 2016).
20 The construction project planning permit: 建设项目规划许可.
21 Blue line, one of sector planning lines, which sets the boundary of landcover of water. Sector planning lines, including blue for water, green for ecology and environment, purple for heritages, red for roads and blocks, etc., are used to protect public resources and stimulate sustainable urban development (Wu & Li, 2010).
22 Thousands of canals, trenches, ponds and other water bodies are filled or occupied after 1950s due to campaigns and urbanization (Liu & Han, 2014).

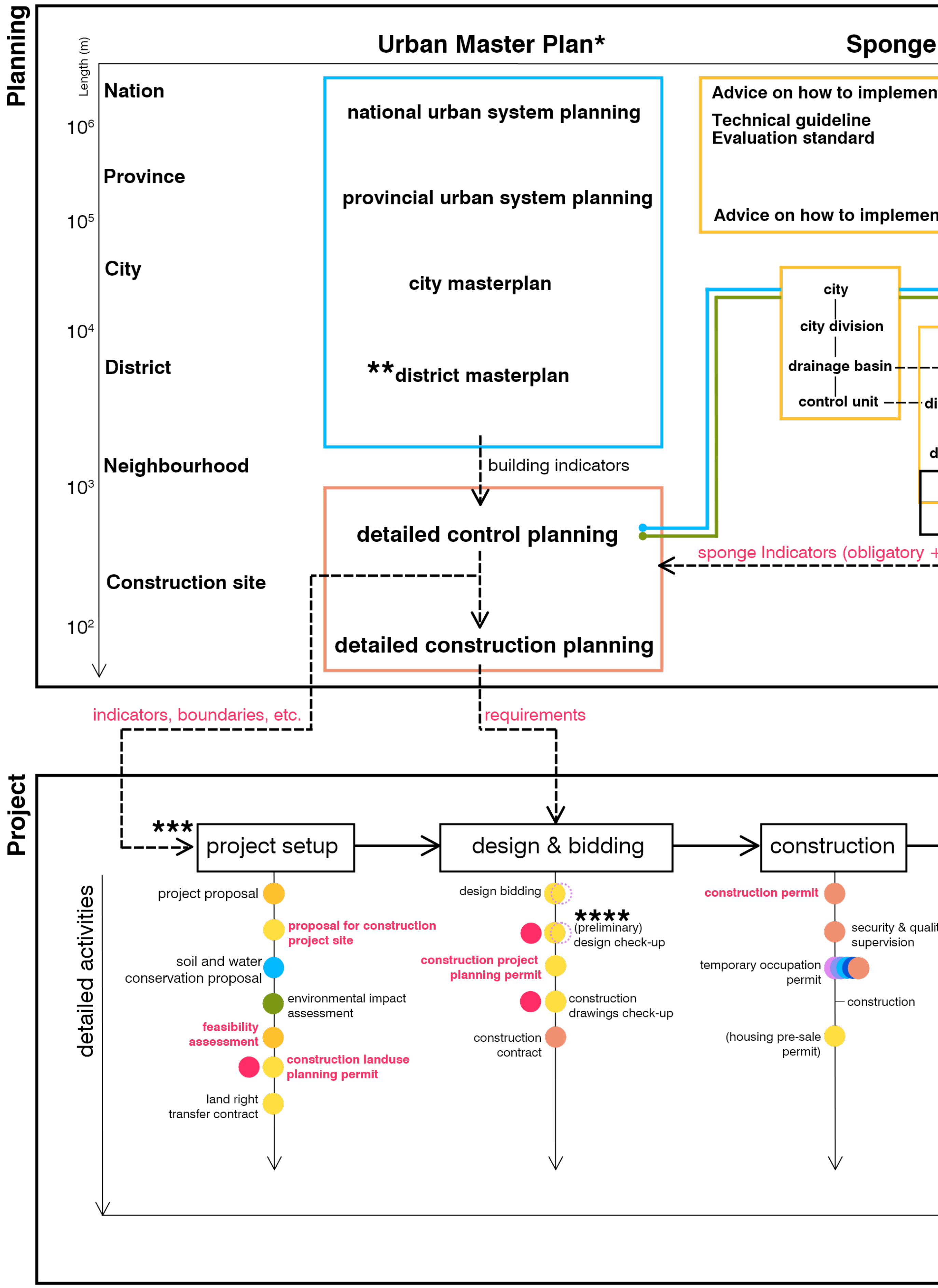
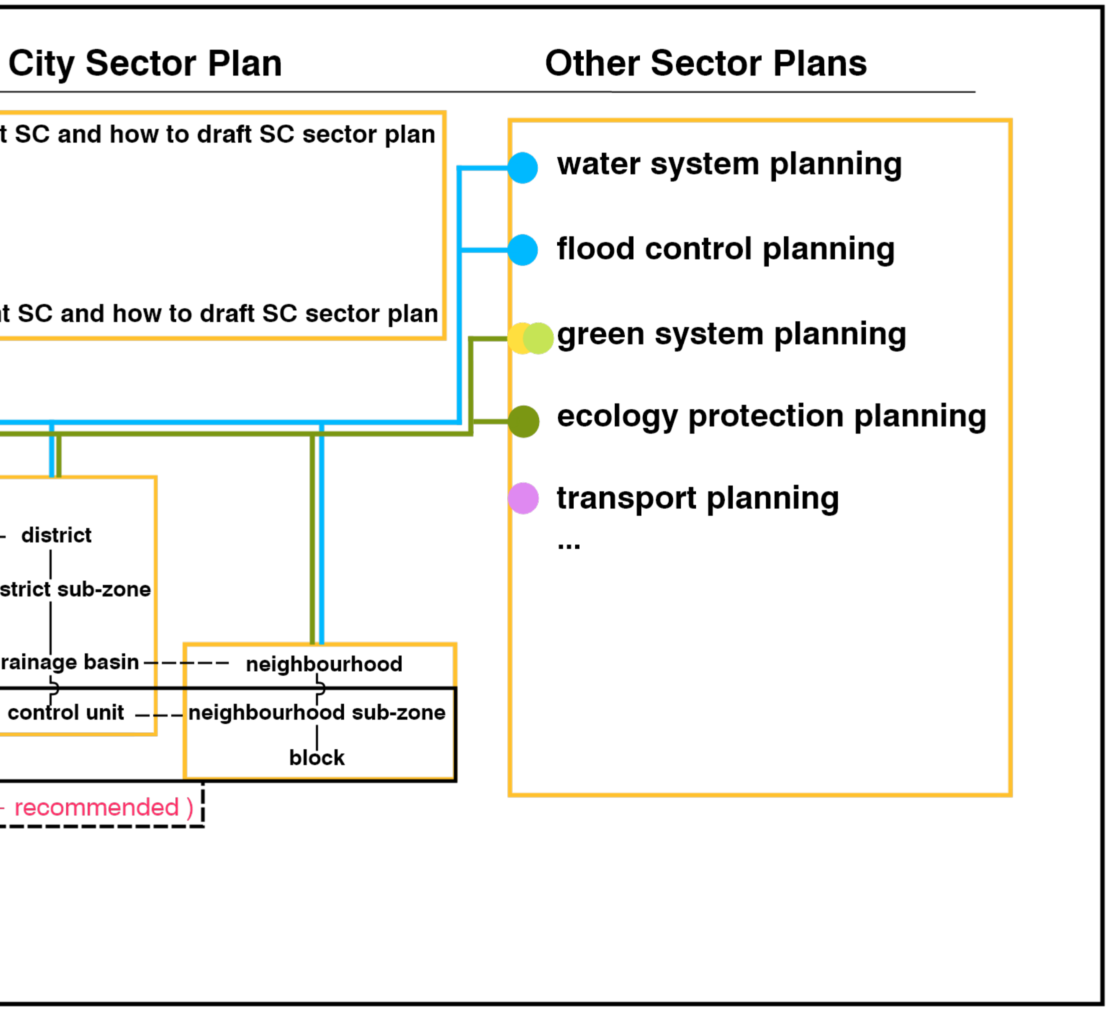
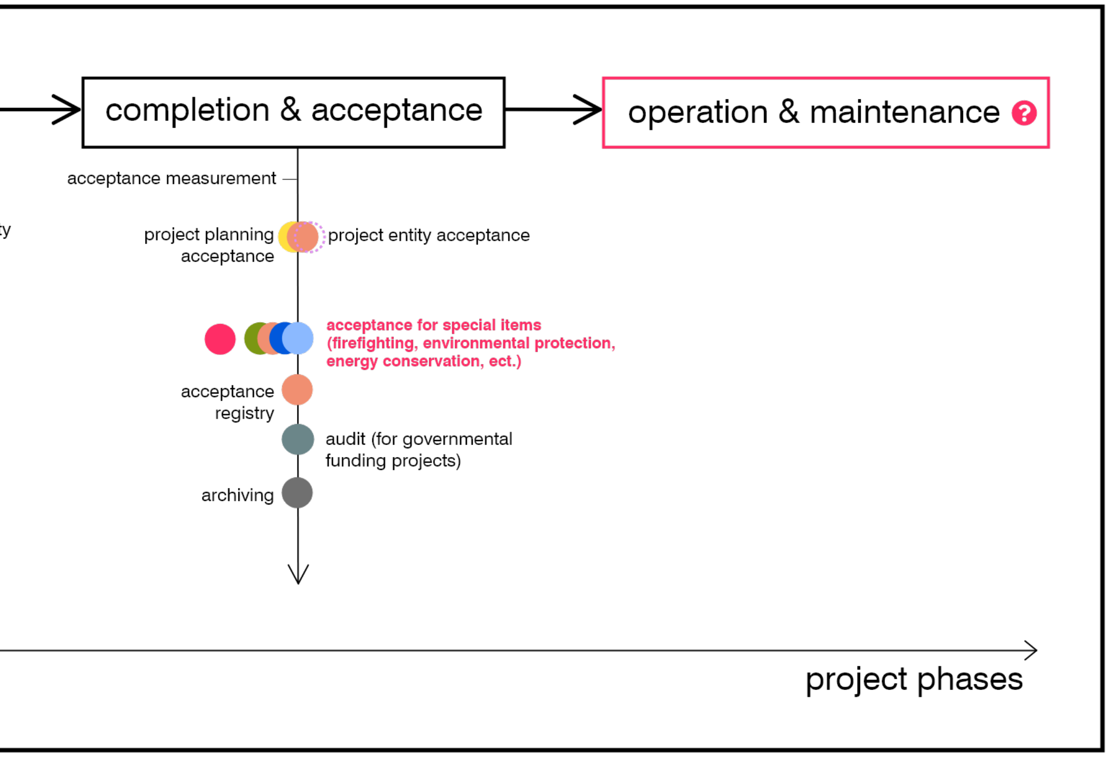


Figure 13 Self-summarized sponge city planning & design framework (based on Nanjing City)


City Sector Plan
Other Sector Plans
t SC and how to draft SC sector plan
t SC and how to draft SC sector plan
water system planning
flood control planning
green system planning
ecology protection planning
transport planning
...
district
strict sub-zone
rainage basin
control unit
neighbourhood
neighbourhood sub-zone
block
recommended)


completion & acceptance
operation & maintenance
acceptance measurement
project planning acceptance
project entity acceptance
acceptance for special items (firefighting, environmental protection, energy conservation, ect.)
acceptance registry
audit (for governmental funding projects)
archiving
project phases

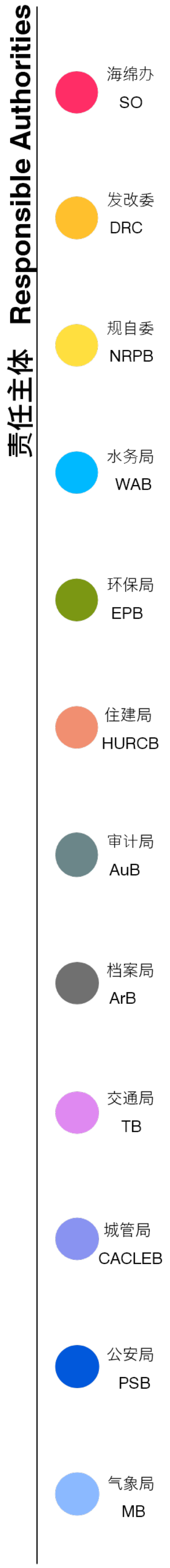

责任主体 Responsible Authorities
海绵办 SO
发改委 DRC
规自委 NRPB
水务局 WAB
环保局 EPB
住建局 HURCB
审计局 AuB
档案局 ArB
交通局 TB
城管局 CACLEB
公安局 PSB
气象局 MB

Figure 14 The legend of the planning & design framework

urban lakes, etc. (Nanjing Municipality, 2018).

Secondly, performance indicators play important roles in the downscaling process of SC requirements. SC guidance are provided at national and provincial level, while sponge planning at and below city level specify its own sponge analysis and strategy. Administrative regions are divided into smaller subzones for downscaling SC requirements. For example, SC city plan has four scales of subzone, i.e. city, city division, drainage basin, and control unit; SC district plan adapts drainage basins and control units proposed in the city plan to be district and district subzones; Similar mechanism holds for neighbourhood plan. Then, indicators are downscaled with the divisions at various scale (city-district-neighbourhood), meanwhile ensuring objectives can still achieve when values at lower-level units are aggregated to upper-level units. Obligatory indicators (VCRa, NSPRR and WSR) and recommended indicators (lowering green ratio, pervious pavement ratio and green roof ratio) are assigned to each control unit in detailed control planning and must be respected by land developers during land lease process and following design and construction phases.

Thirdly, different authorities are involved in administrative examination and approval to make sure projects achieve SC requirements. Sponge Office and/or other related authorities shall check dimensions, types, layouts and other elements of sponge design and construction, and especially appraise those performance indicators, before issuing any planning or construction permits. Those administrative assessment and permits concerning SC requirements are shown in pink colour next to 'detailed activities' arrows in Figure 13.

It must be noted that operation and maintenance of sponge facilities are faced with challenges in current sponge practices. Some authorities are responsible for evaluating sponge performance, however the official entity for maintaining public sponge facilities is neither clearly stated in sponge guidelines nor involved explicitly in its planning. As for projects of private developers, themselves are said to be responsible for operation and maintenance (Zhu, 2020).

3.2.3 Current SC planning & design evaluation

Water is the point of departure in SC planning & design, which can be reflected by those five 'water' themes. Indicators play important roles in guiding and evaluating sponge designs, however indicators proposed in current plans are not sufficient for comprehensive considerations of water system components, flood protection, water surplus and deficit, amenity and biodiversity.

Applying Three Points Approach (see Figure 8) to analyse water safety in sponge design, it can be found that little rain is controlled by VCRa design, and sewer systems of 3-5 year return period of design rainfall are aimed to achieve in SC planning as an technical optimization (Point 1). However, design for more resilient to future changes (Point 2) by additional water conveyance and storage is missing in Nanjing sponge planning, though

50-year return period flooding prevention target is required. Moreover, the day-to-day values (Point 3), such as aesthetics, recreation values, etc., are not taken into consideration in current SC planning & design. Therefore, Point 2 and 3 are not addressed in current SC approach.

From vulnerability framework point of view (de Graaf et al., 2007), current SC planning & design enhances threshold capacity by increasing discharge capacity, improving storage capacity, intercepting runoff pollution to reduce impacts on ecology & environment, etc. Coping capacity is also planned to be increased by building flood early warning system, emergent discharge pathways and back-up of water supply source and other supplies, etc., whereas emergent plans for vulnerability of water ecology and environment are not included in SC sector plans. Recovery capacity of a society to recover to the same or an equivalent state as before the emergency (de Graaf et al., 2007) is not taken into consideration in SC planning as well. As discussed in Section 3.2.1, sponge interventions are designed based on current problems assessment without consider future disturbance. Therefore, SC planning should consider building adaptation capacity to cope with uncertain future disturbance, e.g. climate change, population growth, landscape change, etc.

PRIMO-chain approach can be used to assess the weaknesses in governance aspects of SC measures. Two critical issues are from aspects of Regulation and Maintenance in SC: 1. The regulations of flood prevention and control are weakly implemented in SC planning & design. Although the return period requirements are set in the national standard and required in SC plans, whether proposed sponge interventions can fulfil those requirements are not sufficiently evaluated. Moreover, regulations on groundwater management criteria are not available. 2. There is no clear responsibility of maintenance and performance evaluation.

Therefore, six crucial gaps of SC integrated water management contents are:

1. There is no method of sponge sizing calculation for pluvial flooding target;
2. Storage capacity and discharge capacity are both important and must be considered in an integrated way;
3. Extreme drought condition is not included in sponge design;
4. Groundwater management is missing;
5. No design rainfall profile based on local climate;
6. Day-to-day values are not paid attention.

Current SC planning & design framework are faced with challenges and gaps to support a comprehensive sponge design approach, which are listed as follows:

1. The bonds between SC and other sector plans are not strong. SC concept is not well incorporated into green space, road and flood control design.
2. Sponge city division may conflict with administrative management unit and spatial planning control unit (Zhou, 2015), which would hinder the consistency of hydrologic and ecologic system when making designs.
3. Current indicator downscaling mechanism cannot well connect sponge sector plan and projects and does not fulfil all

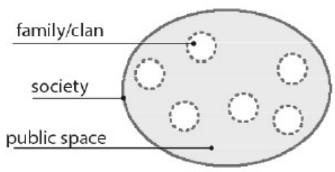
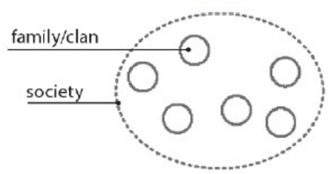
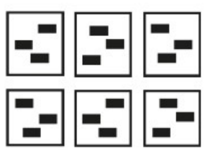
	Spatial value system	*Morphology*	*"Place" is*
Historical European urban model			public (e.g. street, square)
Contemporary Chinese urban model (*xiaoqu*)			enclosed (e.g. courtyard)

Table 4 Spatial value system and morphology of historical European city and of Xiaoqu (Capitanio, 2018)

SC objectives. Specifically, flood prevention and control are not reflected in land development project designing, and discharge is still the major strategy for water safety (Yang & Lin, 2015).

4. The collective ownership of public space in Xiaoqu makes sponge construction hard to proceed in such gated community. Limited green space and high building density may challenge sponge construction in Xiaoqu as well. Conceptual model of Xiaoqu can be found in Table 4.
5. The current framework lacks a comprehensive approach to all components of the PRIMO-chain. For example, there is no clear monitoring responsibility.
6. Data availability and accessibility are concerns for making system analysis and sponge designs, as there are no public data sharing platform or official data sharing mechanism in current framework.
7. There is no clear maintenance responsibility.
8. There is no clear local stakeholder involvement mechanism in SC planning and design.

3.2.4 Summary

Section 3.2 presents an overview on: 1. What water-related themes SC contains, 2. What SC's obligatory and recommended indicators are, and 3. How the SC planning & design system is functioning.

There are commonly five water themes in SC, namely water safety, water ecology, water environment, water resource and water culture. Structured analysis and solutions under those five categories are proposed in SC planning at city, district and neighbourhood level in Nanjing. Indicators can be categorized into obligatory and recommended ones, functioning in sponge city planning as well as in sponge design of individual projects. Definition, calculation and limitation of VCRa are explained in depth, in order to clarify its actual meaning and function in sponge design. Misconceptions of the VCRa occur where it is treated as an overarching metric for flood protection in current sponge planning and design. Current SC planning & design mechanism and process are illustrated in a framework (see Figure 13), mapping the connections amongst various urban master plans or sector plans across spatial scales and authorities' involvement along project phases. Evaluation of current planning & design system is provided concerning gaps in contents as well as challenges for comprehensive design approach.

3.3 Listening to sponge city practitioners

3.3.1 Introduction

Semi-structured interviews were conducted with Sponge City practitioners from three different disciplines, in order to approach and reflect current practices from a variety of perspectives. Those interviewees are:

- P1, a water engineer from Ewaters[23],
- P2, a water planner at a Chinese design consulting institute[24],
- P3, a landscape architect from CAUPD[25].

Three interviewees were engaged into Sponge City practice throughout recent years, though project phases they were involved in are different. P1 experienced conceptual design and detailed design, mostly the former one. P2 was active in drafting Sponge City sector planning and providing on-site technical consultancy, while P3 participated through design untill construction on some urban park and watercourse projects.

Five themes were designed in advance: personal experiences with Sponge City, indicators of Sponge City, design approach, customized questions, and overarching remarks. For each interviewee, some themes or sub-themes are raised differently due to their variety of backgrounds. Annex N gives an overview of interview topics (Table 9), followed by full contents of interview transcripts in Chinese and highlights in English.

In the following section, perspectives of interviews are filtered to fit the research scope and further analysed.

23 P1 was working at Ewaters when the interview was performed. Ewaters is based in Shanghai with extensive local, as well as international experiences in the planning, design, and construction of sponge cities and integrated water resources engineering management services (visit website).

24 The interviewee requested to keep anonymous in this thesis to protect personal privacy. Identifying features in the interview transcript of this participant were removed.

25 P3 was working at China Academy of Urban Planning & Design (CAUPD) when the interview was performed. CAUPD, attached to Ministry of Housing and Urban-Rural Development, is one of the drafters of national Sponge City guidelines.

Some points from interviewees will be referred to in the next chapters.

3.3.2 Interview results

Five aspects are highlighted in the analysis of the results:

1. Scoping of Sponge City
2. Indicators
3. Storage and discharge
4. Interdisciplinary collaboration
5. Challenges of implementation

3.3.2.1 Scoping

P2 organized the trajectory of Sponge City development, which reflects the pattern found on concept development in previous chapter. In Chapter 3, it is concluded that Sponge City evolves from a concept with emphasis on source control and focusing on ecological indicator VCRa in 2014's technical guideline towards a more integrated water management concept in 2018's evaluation standard. P2 says:

> *"When the SC pilot project just initiated, people were confused with the sole official reference, the SC construction technical guidelines (trial). People might think SC is equal to LID or it does similar things as LID does. Such situation lasted for one year… Around the end of 2015, the Ministry (MHURD) thought planning was not only about downscaling indicators. Public pressure was also high, especially in 2016, when lots of places were flooded under summer storms. Thus, the Ministry turned to problem-oriented solutions, that is solving problems instead of focusing on indicators. The article of Linwei Zhang et al.[26] extended the scope of SC from residential area to city level."*

P1 mentioned a dilemma sponge cities are faced with, which is about relationship between sponge and flood control. P1 said:

> *"The relationship between Sponge and flooding control is not sorted out clearly. SC is now in an awkward situation. Flood control departments (water authorities) is commonly in charge of 'fluvial flooding prevention and pluvial flooding discharge' and SC would passively propose some indicators and targets, however, the flooding issues are expected to be solved by flood control departments in practice. As for sponge planning, the major work is solving small initial storm runoff. Housing Bureaus (in charge of SC) is not capable or competent to proceed flood control, although related flood control indicators can be proposed in SC planning. The coordination between those two is not very smooth despite of overlapping areas in both SC planning and flood control planning."*

From history point of view, P3 stated that sponge city is not a brand-new concept, but already exists in previous practices. For example, farmers have a set of decent methods to irrigate crops: Runoff from the high lands are accumulated in ponds, which act as sponges, so that water in ponds can be used in irrigation. 'It (Sponge City) is a reinforcement of the concept', P3 said:

> *"We have to solve the problems of waterlogging, water quality, and water resources in our cities as much as possible by combining the consideration of local conditions and our existing knowledge."*

3.3.2.2 Indicators

Three interviewees were all asked about questions of indicators, especially VCRa. P1 admitted that VCRa is the major indicator in design and in appraisal, while there are no corresponding indicators[27] for flooding control. P1 also expressed opinions on the reason why flooding indicator is not included in the requirements at site scale:

> *"Water safety must relate to larger area, such as a sponge city subdivision. If a developer gets a piece of land for housing development, it is unlikely to ask him/her for a water safety target."*

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26 浅析海绵城市建设的顶层设计 (Zhang et al., 2017)

27 In some cities' sponge planning, flood control requirement is referred to planning of fluvial flooding prevention and pluvial flooding discharge (e.g. 50-year return period for Qinhuai, Nanjing), however it does not provide explicit storage requirements to site development.

P2 evaluated current indicator system and agreed that rigidly downscaling all indicators from city level to block level would restrict design process, which was the reason why indicators were classified into two categories, obligatory ones and recommended ones. Considering Chinese different climate, for example, some cities have very intensive thunderstorms, peak runoff rate control might be more important than runoff volume control from P2's point of view. There used to be a peak runoff rate reduction ratio, but it is hardly used and assessed now according to his statement. To tackle this peak runoff issue, P2 said:

> *"First of all, it is necessary to make breakthrough techniques. You must have technical support in order to have a basis for policy. Otherwise, people will not be able to implement it. It's could be tools, models or techniques. Such method must be with low cost, otherwise the cost of implementation will be too high."*

P2 also mentioned, after knew Dutch planning with water, the principle 'Never Shift Problems' could be reinforced in China.

From a landscape architecture point of view, P3 expressed compliments on setting indicators for urban park design. P3 thought it would be beneficial to let parks take sponge functionalities, but P3 also claimed that it was worth thinking the question: whether or not those indicators are determined scientifically and to what extent by setting those can solve problems. Even indicators are given, local spatial conditions still need to be considered, P3 said.

3.3.2.3 Storage and discharge

P2 addressed that stormwater management system was widely accepted in China, which is a triplet management train, including source control in neighbourhood, drainage systems and excess stormwater management. P2 claimed the objectives and measures of source control are now clear, except for peak runoff control; There is also a Chinese design approach to guide design of sewer drainage systems; However, the gap lies in excess stormwater management. Although in flood control standards there are requirements for return period, flooding pathway, etc., no approach available to guarantee the system can be, say, once-in-50-year flood-proof. He also believed storage capacity must be increased, probably in public space outside of Xiaoqu. "It is a blank space in China", he admitted, "storage and discharge are both necessary and must be combined". P2 said the gap can be filled by Storage-Discharge-Frequency curves (SDF curves, detailed information in Section 5.2.1.2). P2 added, "regulations on discharge should also be improved, … for example, our interception ratio of combined sewer system can be further increased". He highlighted the importance of peak runoff reduction considering storms with high intensity in some Chinese cities.

According to P1, current sponge cities is still aimed to address small rainfall, though requirement for flood control is proposed in Sponge City. This is much related to the fragmentation of Chinese department responsibilities; Housing Bureau, which Sponge Office mostly belongs to, does not have competence or abilities to promote flood control projects, which are used to fall on Water Authority's shoulder. P2 mentioned such fragmentation issue as well:

> *"Because (flood control) is not your (Housing Bureau's) business, you may not even think about it. Sometime if you would like to integrate them (storage and discharge), but you are not capable to do so."*

3.3.2.4 Interdisciplinary collaboration

P1 took a design of residential area as an example to explain interdisciplinary collaboration based on personal experiences (Figure 17 (1)).

> *"Such designs include building external design, water-heat-electricity underground design and landscape design. Usually we base our design on subsurface networks. It is beneficial for us to cooperate with landscape designers. We make a draft design and landscape designer will refine the draft, followed by sponge performance assessment by us."*

P1 also briefly explained how designs are appraised by authorities. P1 mentioned drawings and models or calculations will be reviewed by Sponge Office, after which appraisal permit would be issued. After reviewed by

Sponge Office, designs would also be checked by civil and landscape departments. After the design passes all checks, project then can move to next design phase. However, there is limited multi-departmental communication, for example through participatory activities like workshops, in China.

P3 explained the collaboration process from personal perspective. Much more interactions between water and landscape seems to be found based on the description of P3. Maybe it is because the projects P3 is involved in are more about relatively large urban parks and watercourse, which require more interdisciplinary cooperation from the beginning.

> *"Generally, we work together since the conceptual design phase, from the overarching ideas to each sector planning, with the combination of landscape, water conservancy and water ecology. It is not independent. Therefore, there are many dialogues amongst us. We work as a team from planning to construction drawing and construction."*

P3 agreed such collaboration would be beneficial for both sponge functionality and landscape visualization.

> *"Yes, definitely, I think. One point is the mutual understanding between disciplines, and another is collaboration when projects are landed. Moreover, I think landscape needs to know more about how many problems sponge can solve, how to solve problems by combing landscape and sponge. Sponge (sector) needs to think how to, at the same time apply measures to solve problems, merge (measures) into landscape in a more natural and ecological manner. Large grey infrastructures should be avoided as much as possible. More ecological measures are preferred to solve ecology problems."*

P2 shared opinions on the question: if there is a chance to introduce collaboration mechanism into guidelines.

> *"Basically, no. Because it is not a technical issue, it is about negotiation mechanism. Say if it is written in the guide or the standard, it can only be written as opinions shall be collected from multiple parties, strengthening coordination and consultation, and reaching consensus, right? In principle, this can only be the case. When it comes to negotiation, who will take a step back can only be based on negotiation situation. From my perspective, basically when we found a conflict, the first thing is to respect the professional opinions of the structure discipline. Safety first."*

P2 also revealed different voices on current SC practice from other fields:

> *"Objections are from different disciplines. For example, greening and gardening is worried that polluted storm runoff would hurt plants' growth if green areas are lowered; people from hydraulic/hydrology fields have concerns about VCRa"*

3.3.2.5 Challenges of implementation SC concept

Three interviewees all expressed their positive attitude towards sponge progress so far. P2 said the concept was now well-known by the public, though the ambition set in 2015 - by 2020, more than 20% of the urban built-up area will meet the target requirements – found difficulties to meet by the end of this year. P1 also spoke high of some projects in some cities during 5-year sponge development.

There is no doubt there are concerns on current challenges of sponge city construction, as mentioned by interviewees. Such challenges are summarized in Table 5. Some challenges verify similar findings from analysis in previous sections. Important challenges are:

1. The scope of SC is not clearly defined at the top level;
2. Data are difficult to obtain;
3. Lack of indicator of pluvial flooding prevention;
4. Visual impact is not paid attention in design.

Challenge	Quote	Interviewee
Scoping	• The functions of sponge are not defined clearly at the top level, which causes difficulties of implementation at lower levels.	P1
Local climate	• (Guyuan) has particularly long cold days and few warm days. Altitude there is relatively high and it is lack of water.	P2
Client awareness	• Client must be equipped with relevant knowledge…at least should know to make what requirements.	P2
Visual impacts vs. functionality	• Designers did not draw such designs (e.g. lowering green) before, and the construction staff did not do such things. In this case, a number of projects has relatively strong functionalities, but poor landscape appearance.	P2
	• Some sponge facilities have nice landscape effects, while functionality is poor.	P3
Data	• Data are difficult to get in projects which are not commissioned by government departments…There is no public platform where people can acquire data. Data are still confidential.	P1
	• The basis (data) for modelling is not solid…First reason is that as-built drawings are not well-managed. Usually what you get from archive room is construction drawings...The second reason is about geomatics. It can be accurately measured in theory, but there are often problems in reality, especially in older communities. • Apart from those on-site techniques, the measurement of certain parameters is another issue.	P2
Tool	• You must have technical support in order to have a basis for policy. Otherwise, people will not be able to implement it. It's could be tools, models or techniques. Then this method must be a low-cost, otherwise the cost of supervision will be too high.	P2
Indicators	• Lack of indicator requirement for pluvial flooding.	P1
	• Peak reduction might be more important than VCRa considering high intense storms in some places in China.	P2
	• Lack of explicit and scientific indicators between sector planning and project level.	P3
Institutional barrier	• Because (flood control) is not your (housing bureau) business, you may not even think about it. Sometime if you would like to combine them (storage and discharge), you are not able to do so.	P2
Construction, operation & maintenance	• There might be conflicts in operation and maintenance. Housing bureau may get the funding for construction but leave the projects to greenery departments to maintain. • Construction might cause inconvenience to the elderly; property management responsible parties are not missing; the greenery maintenance is poorly managed, etc. (in old district).	P1

Table 5 Challenges in sponge city projects mentioned by interviewees

3.3.3 Discussion & summary

In this section, interviews with three sponge city practitioners are summarized based on the research scope. More insights are gained in terms of Sponge City development, indicators, relationship between storage and discharge, interdisciplinary collaboration and the challenges of implementation. Statements from interviewees verify some findings from Section 3.1 and 3.2.

The dilemma of bridging sponge city and flood control was revealed by two interviewees, which indicates that the vision and scope of Sponge City should be further clarified. What the role and functionality of sponge city are and how sponge city plan is related to other sector plans should be re-considered.

Principles of current sponge city paradigm should be refined, especially from perspective of functionality vs. visual impact, 'never shift problem', interdisciplinary collaboration, etc. Indicator system is of concern to all three interviewees. P2 claimed that climate characteristics required some Chinese cities to focus more on peak runoff reduction, which is vital in the line of thinking when refining sponge design strategy.

3.4 Chapter summary

This chapter studies current SC planning & design practices based on revelant literature study, guideline & plan study of Nanjing, and interviews with three sponge city practitioners. The terminology development of 'Sponge City' and different interpretation of SC concept is analysed in literature study. By comparing SC concept with other relevant design paradigms, differences can be found concerning design principles and criteria. The study of Nanjing SC planning is done by mapping SC planning & design contents, as well as planning & design framework. Based on the understandings of contents and framework, gaps can be found in SC integrated water management and challenges are identified in current planning & design framework to support a comprehensive sponge design. Moreover, interview results verify some findings in literatures study and analysis of SC guidelines & plans; the interviews also disclose additional challenges with respect to SC scoping, the relationship between storage and discharge, interdisciplinary collaboration in planning & design, etc.

Chapter 4 Improving Sponge City design approach

After sorting out Sponge City concept development and design methods in practices (see Section 3.1), understanding current sponge city planning and design processes (see Section 3.2), and listening to sponge city practitioners' perspectives (see Section 3.3), this chapter will reflect on findings from previous chapter and propose improvements on sponge design approach.

4.1 Vision and scope

Sponge City is one of the city visions which sketches an ideal balanced relationship between urban development and the environment. Water, as an essential element in Sponge City concept, is aimed to be managed in an integrated way for creating a more secure, liveable, efficient and sustainable urban life. According to the latest national official definition (MHURD, 2018), the ambition of promoting Sponge City is to:

"Make city works like a 'sponge' with good 'resilience' in adapting to environment changes and resisting natural disasters, etc., in order to achieve a urban development paradigm of natural storage, natural infiltration, natural purification, which contribute to co-benefits such as urban water ecology restoration, urban water resource recovery, urban water environment improvement, urban water safety guarantee, urban water culture revitalization, etc. " (MHURD, 2018)

However, the scoping of Sponge City is in an ill-defined situation. Although governmental documents claim the objectives of Sponge City include dealing with urban water safety, this aspect is not seamlessly incorporated in SC planning & design process. Compared with other design paradigms in other countries, missing components in SC concept are amenity & biodiversity, subsurface & groundwater, recovery capacity to after emergent events and adaptive capacity to future disturbance (e.g. extreme flooding or drought events). Based on findings from Section 3.2, the metric VCRa is used to guide planning and designing sponge measures, but it is an ecological indicator. Section 3.3 reveals a dilemma of bridging sponge city and flood control due to administrative responsibility fragmentation. Sponge city indicator requirements (VCRa, WSR and NSPRR) can be readily imposed to site development projects because assessments on those indicators are required for land developers in order to acquire construction permits from relevant authorities. But the water safety target is faced with challenges of operationalization. Sponge Offices which are attached to Housing Bureaus do not have competence or capacity to set requirements for solving flooding issues, because flood control is under the responsibility of Water Affair Bureau (or Water Conservancy Bureau in some cities).

Therefore, given above-mentioned gaps and challenges, it is important to refine SC concept and clarify the scope of Chinese SCP at national level in the future. Two essential questions have to be answered: 1. What is the relationship between Sponge City and pluvial flood control; 2. How to properly bridge sponge city planning and pluvial flooding control planning.

4.2 Sponge contents & synergies

It can be found in Section 3.2 that sponge sector plans at various level in Nanjing all follow the similar structure: from problem statement, analysis towards solutions concerning five water themes (see Figure 15). Similar to the three-way concept (quantity, quality and amenity & biodiversity) in SuDS, five water themes (see Figure 9) in SC can be summarized into three categories: quantity, quality and culture. Water environment and ecology are related to water quality improvements, whereas water safety and water resource are dealing with water quantity surplus and deficit issues.

Despite of separately treated in sponge city plans, there are synergies amongst those aspects which can be mapped to enhance the understanding of Sponge City concept and to support developing Sponge City panning & design strategies.

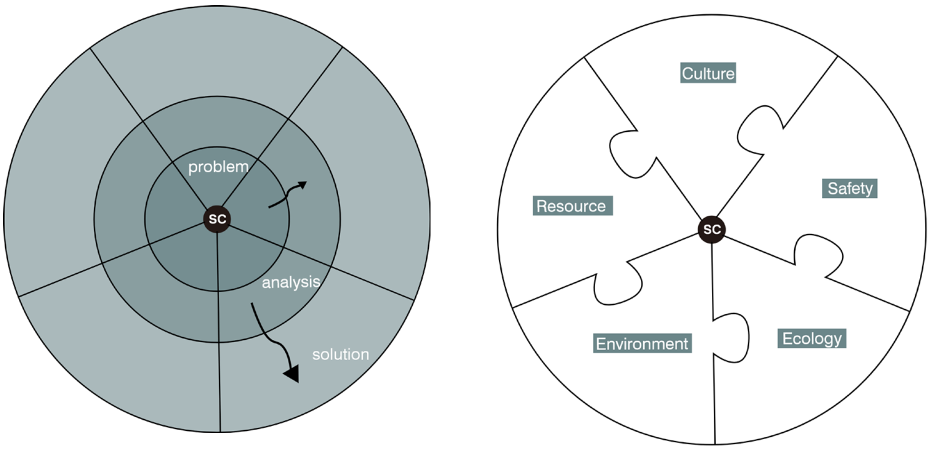

Figure 15 Structure of sponge city sector plan in Nanjing City

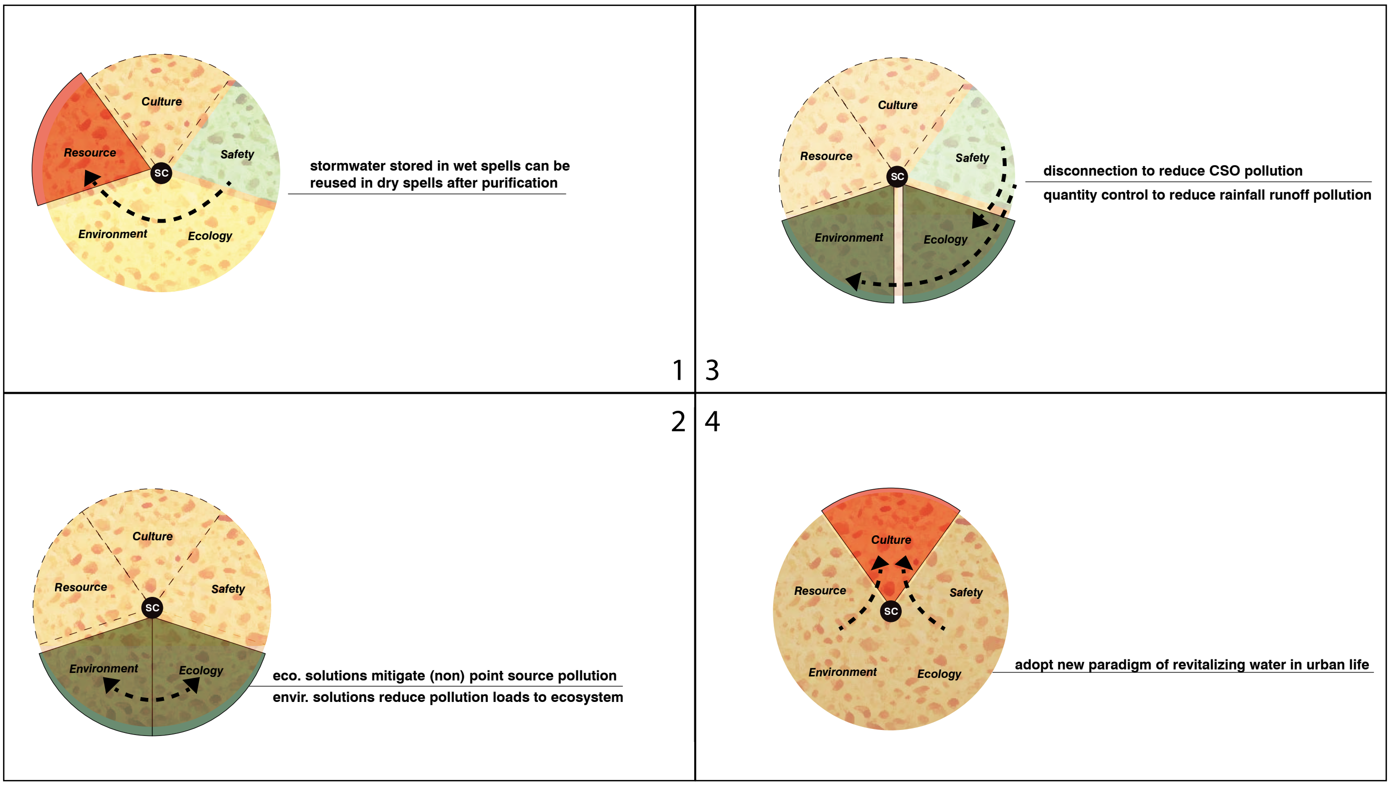

Figure 16 Synergies across five water themes in sponge city

Synergies illustrated in Figure 16 are:

1. Stormwater stored in wet periods can be reused in dry periods after water quality improvements by sponge measures.
2. Sponge measures used for ecology rehabilitation can mitigate point and non-point source pollution; measures used for improving water environment can also reduce the pollution loads to ecosystem.
3. Sponge measure for reducing runoff volume or rate can result in disconnection of catchments to sewer systems, which helps to alleviate CSO pollutions; Quantity control measures can intercept runoff pollution, which is beneficial for ecology.
4. Incorporating water management into urban planning and design can help to revitalize water as an essential culture element in urban life, as well as secure the water safety in historical streets.

Those synergies present the co-benefits of sponge measures, which indicates that multi-functional sponges are significant to efficiently solve multiple issues under the context that limited urban spaces (both aboveground and underground) are available in many Chinese cities. Additionally, such synergies highlight the importance of building a sponge system instead of separate sponges, in other words, sponges must be arranged comprehensively to achieve multiple objectives, benefits and ecosystem services. Therefore, sponge capacity should not only serve for flood prevention or ecology rehabilitation, but also take consideration of water shortage in dry spells.

Day-to-day values (e.g. social, historical, aesthetic, recreation, etc.) can be held in planning & design synergies so that sponge interventions are able to improve the quality of life. As functionality and visual impacts are not balanced in some current projects (Anonymous, 2020; Shu, 2020), SC planning & design can include a water amenity focus into its scope. Sponge measures not only need hydraulic and ecological functions, but also harmonized visual appearance to fit into local environment and inhabitants' daily life.

Moreover, groundwater management, as a missing component in current guidelines and plans, can enhance synergies of water resource, water safety, water environment and water ecology. As an essential element in urban hydrologic cycle which would affect land subsidence, surface water level, drinking water source depletion & quality, and/or flooding issues, groundwater should be monitored, analysed and/or modelled in order to seek for a more integrated solution to solve urban water issues.

It should be highlighted that to operationalize these synergies not only requires more integrated technical water management, but also needs involvement (awareness, acceptance, participation, etc.) of different stakeholders, including planners, designers, officials, etc. from various disciplines, as well as local inhabitants and/or NGOs. Knowledge, preference, expectations, and perspectives from stakeholders can contribute to planning and designing sponge interventions so that multiple objectives of SC can be achieved with co-benefits, eco-services and daily values.

In summary, sponge multi-functionality, connectivity, daily values, and groundwater should be paid extra attention in the contents of SC approach. In order to operationalize synergies of SC contents, stakeholder involvements are necessary.

4.3 Sponge planning principles

Based on study of current sponge city practices and interview analysis, as well as the synergy analysis, here proposed some complementary planning principles, which can be added to current principles in guidelines for contributing to a more comprehensive approach to urban water management in the context of a sustainable urban environment.

1. **Never shift problems**
   Do not shift either water quantity or water quality issues from one area to another, or shift problems to the future. Discharge is shifting water quantity load from upstream towards downstream, which should be avoided unless it is necessary. Water quality pollution should be prevented in the first place; if impossible, a water treatment train of source control, midway conveyance and end-of-pipe treatment can be considered.

2. **Design for resilience**
   Future changes or uncertain disturbance, e.g. climate change, landscape change, are recommended to be considered in planning phase. Planning & design of sponge interventions should also aim to minimizing damage under extreme weather conditions by increasing its coping and recovery capacity. Moreover, sponge measures can be designed in a more flexible and sustainable manner (e.g. amphibious building, aquifer thermal energy storage, sustainable building materials, etc.) so as to adapt to future changes or uncertain disturbance (e.g. sea level rise, resource depletion, etc.).

3. **Respect local conditions**
   Sponge city strategies should be based on local conditions concerning climate, catchment, culture, society, etc. For example, cities with heavy storms with sharp-peaked rainfall in summer should pay attention to retention & detention measures to reduce and delay peak runoff, whereas cities in semi-arid climate and collapsible loess soil condition could apply surface storage measures for stormwater resource reuse.

4. **Arrange sponges systematically**
   Systematic sponge measure arrangement requires first a comprehensive understanding on water and spatial systems, which means occupations, networks and subsurface, especially groundwater system, are to be assessed before doing sponge design. Sponge design should consider connectivity of different sponge measures and their multi-functions to meet planning objectives. Connection through different spatial and temporal scales is to be considered for a coherent water management policy. Specifically, in different spatial context, planners/designers should consider the connections amongst different types, sizes and functions of sponge interventions. For example, an urban wetland (at catchment scale) should be designed to cope with more extreme flooding events, whereas rain gardens (at site scale) are to be designed to prevent and mitigate runoff close to source. Moreover, temporal scales should be considered to consistently manage urban water. Forward-looking water plans are usually on different horizons (e.g. 50 years) compared to other plans, such

as urban spatial plans (e.g. 20 years), economic development plans (e.g. 5 years), environmental protection plans (e.g. 100 years), etc. Therefore, SC planning should consider long-term construction goals, in order to achieve required sponge capacity step-by-step.

5. **Make sponges attractive**
   Sponges are not mono-functional measures purely for solving water-related issues, but should create tangible and intangible values such as visual impacts, amenity landscape benefits, interaction with local inhabitants, harmony with surroundings, etc. It is particularly important to ensure that such values are integrated into the overall design from an early stage (Woods-Ballard et al., 2007).

6. **Bring relevant stakeholders around table**
   As an urban planning and design paradigm with interdisciplinary knowledge and interests involved, sponge city cannot be planned and designed only by urban planners or water managers. It is essential that relevant stakeholders should be involved in the planning phases to maximise sponge city benefits.

7. **Good governance**
   Good governance principle can be operationalized by applying the PRIMO-chain approach to sponge city planning. The approach should fit the local Policies and Regulations, the capacity to Implement and Maintain facilities should be there, as well as the Organization and financing structure.

Above-mentioned principles can close some crucial gaps in current sponge planning & design. Generally, Principle 1 to 5 aim to provide guidance on more integrated and sustainable design of urban water management; Principle 6 is about stakeholder involvement in the planning phases, whereas Principle 7 is about governance aspect. Specifically, Principle 1 and 2 provide more sustainable water management strategies, including the priority of storage capacity, increasing coping, recovery and adaptive capacity. Principle 3 is already included in current Nanjing SC plans, but it is further elaborated here using two examples with different climate conditions. Principle 4 aims to increase integration of sponge design, including water and spatial systems analysis, sponge measure connectivity and consideration of spatial & temporal scale connection. Principle 5 highlights tangible and intangible values of sponge measures in planning & design. Principle 6 is to enhance stakeholder involvement, while Principle 7 creates the 'soft' context for successful implementation of the SC approach.

4.4 Sponge design process

4.4.1 Integrated urban water management in SC

Analysis in the previous chapter reveals gaps in planning & design of SC integrated urban water management (Section 3.2.3). Solutions to closing these gaps can be by introducing SDF curves, drought analysis, groundwater modelling, rainfall pattern analysis and sponge design for values (social, recreation, aesthetics, etc.) in the planning phases.

Storage and discharge are exchangeable: stormwater runoff that cannot be discharged needs to be stored temporarily in the system; whereas runoff has to be discharged if there is a lack of storage capacity (van de Ven, 2016). By calculating SDF curves of a study area, the relationship between storage capacity and discharge capacity under different return periods can be determined, based on which total sponge size and target discharge capacity can be decided. Therefore, gap 1 and 2 can be solved by using SDF curves in sponge design. Drought analysis can be performed to identify what are the historical extreme drought events and how much recharge in theory is able to mitigate the drought effects, so that Gap 3 can be closed. Groundwater modelling is to provide information for groundwater modelling (Gap 4). Local rainfall pattern analysis helps to synthesize reasonable design rainfall profile for flooding simulation (Gap 5). Moreover, day-to-day values should be considered in conceptual design or preliminary design phase (Gap 6), during which perspectives can be collected and exchanged with from local stakeholders.

4.4.2 Stakeholder involvements

Another challenge in current sponge design practice is that there are limited stakeholders involved in the design process. The stakeholder involvement in sponge design process that interviewee P1 mentioned (Zhu, 2020) can be simplified in Figure 17 (1).

In order to provide a solution to estimating required sponge size matching design criteria and involving relevant stakeholders to collaboratively communicate on sponge measure planning, an improved sponge measure design approach is proposed as in Figure 17 (2). Firstly, water engineers calculate required sponge capacity and landscape architects (or urban designers) analyse available urban space for potential interventions. Secondly, a pre-selection stage can be performed jointly to shorten the list of potential sponge measures considering local conditions. Thirdly, a participatory co-design workshop can be organized for triggering discussion of sponge measure arrangement amongst relevant stakeholders, e.g. urban designers, water engineers, civil engineers, local inhabitants, experts, governmental authorities, etc. During the co-design workshop, participants are to be engaged to share knowledge, expectation, preference, etc., and make contributions to sponge measures selection and arrangement (van de Ven et al., 2016). The conceptual phase of design is particularly timely opportunity for such co-design workshops (McEvoy, 2019). Finally, model simulation is used by water engineers to evaluate effectives of revised sponge design; other aspects such as environmental impact assessment, cost benefit analysis, etc. might require involvement from other disciplines.

4.4.3 Comprehensive sponge design process

As mentioned before, there is no recommended holistic planning and design process that fits SC multiple objectives in guidelines, neither at national level nor at Nanjing city level. Current sponge design pays attention on performance indicators Figure 18, especially using VCRa as a guiding metric, which is not sufficient to support its multi-objectives.

Following similar structure of the design process recommended in WSD for stormwater management (Cunningham et al., 2017), proposed sponge design process is shown in Figure 19, considering proposed sponge planning principles (Section 4.3) and additional SC planning & design contents (Section 4.4.1). Such design process can not only be applied to sponge city planning design, but also can be used in individual sponge projects at smaller spatial scales, though steps may differ depending on specific cases.

The first step is to define sponge project objectives and expected deliverables, as well as identify design team and make stakeholder analysis to understand the responsibility division and cooperation mechanism. The second step is pre-design preparation for collecting relevant information or requirements from standards, plans, guidelines, etc., and necessary available data. Step 2 also includes a vulnerability scan to assess problems of those five water themes (Section 3.2.1) in the project area. Step 3 starts with analysing water system, infrastructure, land use, etc., in order to assess the risk-prone areas and available spaces for sponge interventions. Water system analysis, including simulation of SDF curves, drought analysis, groundwater modelling can contribute to setting sponge capacity requirements, whereas spatial availability analysis can help sponge pre-selection. Based on local conditions, e.g. climate, soil types, site analysis, design principles can be set for determining sponge interventions. As required in guidelines, planning area should be divided into subzones. Therefore, catchment division is included in Step 3. Governance aspects related to each sponge measure can be analysed by PRIMO-chain, which facilitates assessment of measures concerning implementation, operation and maintenance aspects (van de Ven, 2016). The targets of storage capacity, recharge requirements, investment, water quality, heat stress mitigation etc. are set in Step 4 based on guidelines and standards, as well as water system analysis. Those requirements, together with spatial analysis and PRIMO-chain analysis, facilitate to make a pre-selection of sponge interventions (Step 5) which follows design principles. Then, a co-design workshop can be organized involving relevant stakeholders to discuss on sponge interventions design (Step 6), during which the types and locations of sponge measures will be revised or specified (Step 7). Finally, the effectiveness (hydraulic, ecological, financial, etc.) of selected measures from co-design step will be evaluated through model simulation and performance indicators (Step 8).

The calculation of target sponge capacity and sponge measure design will be elaborated with the toolbox introduction in Chapter 6. The improved design process is tested in case study in Chapter 7.

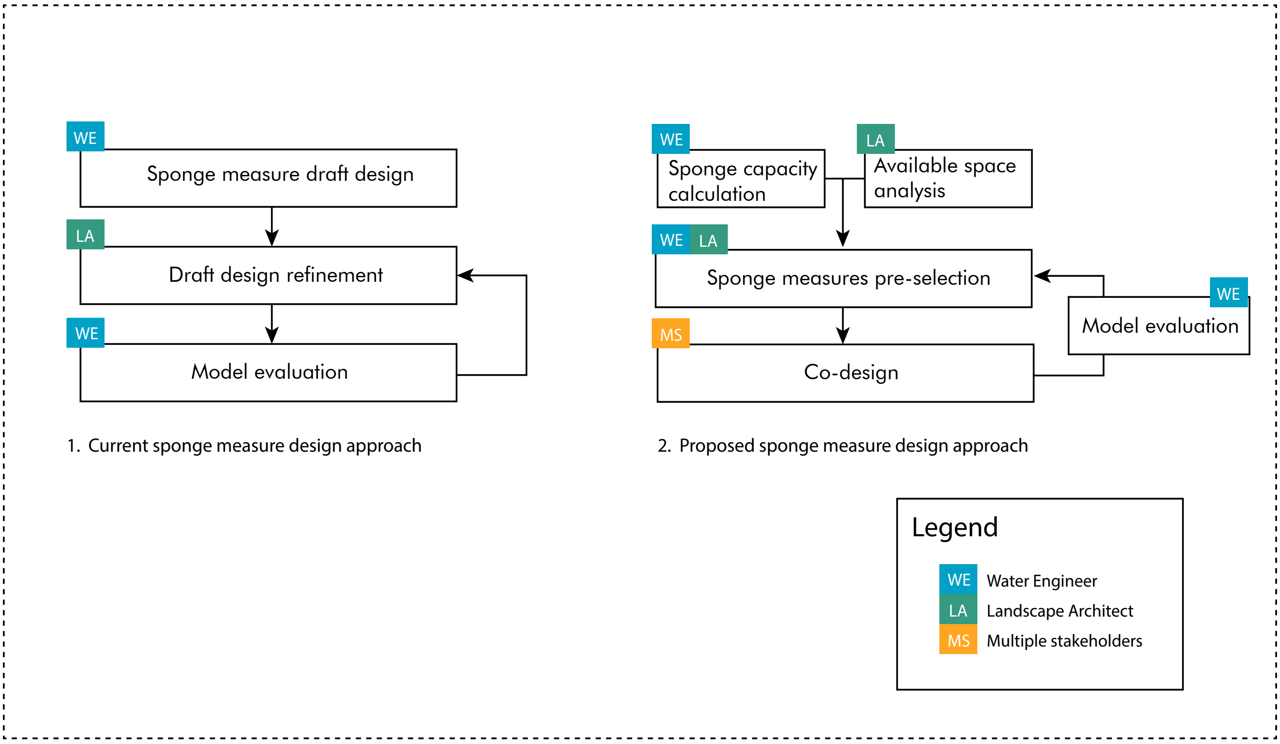

Figure 17 (1). Current sponge measure design approach; (2). Proposed sponge measure design approach

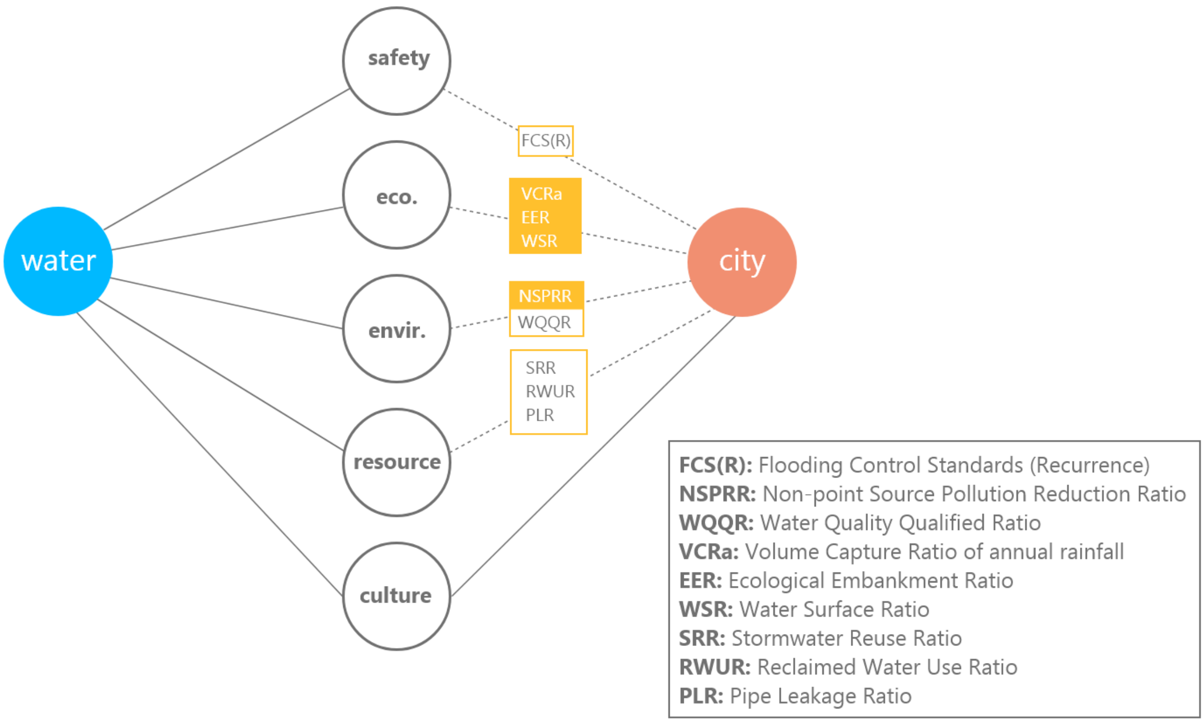

Figure 18 Current sponge design deploys performance indicators in water systems to intervene urban development

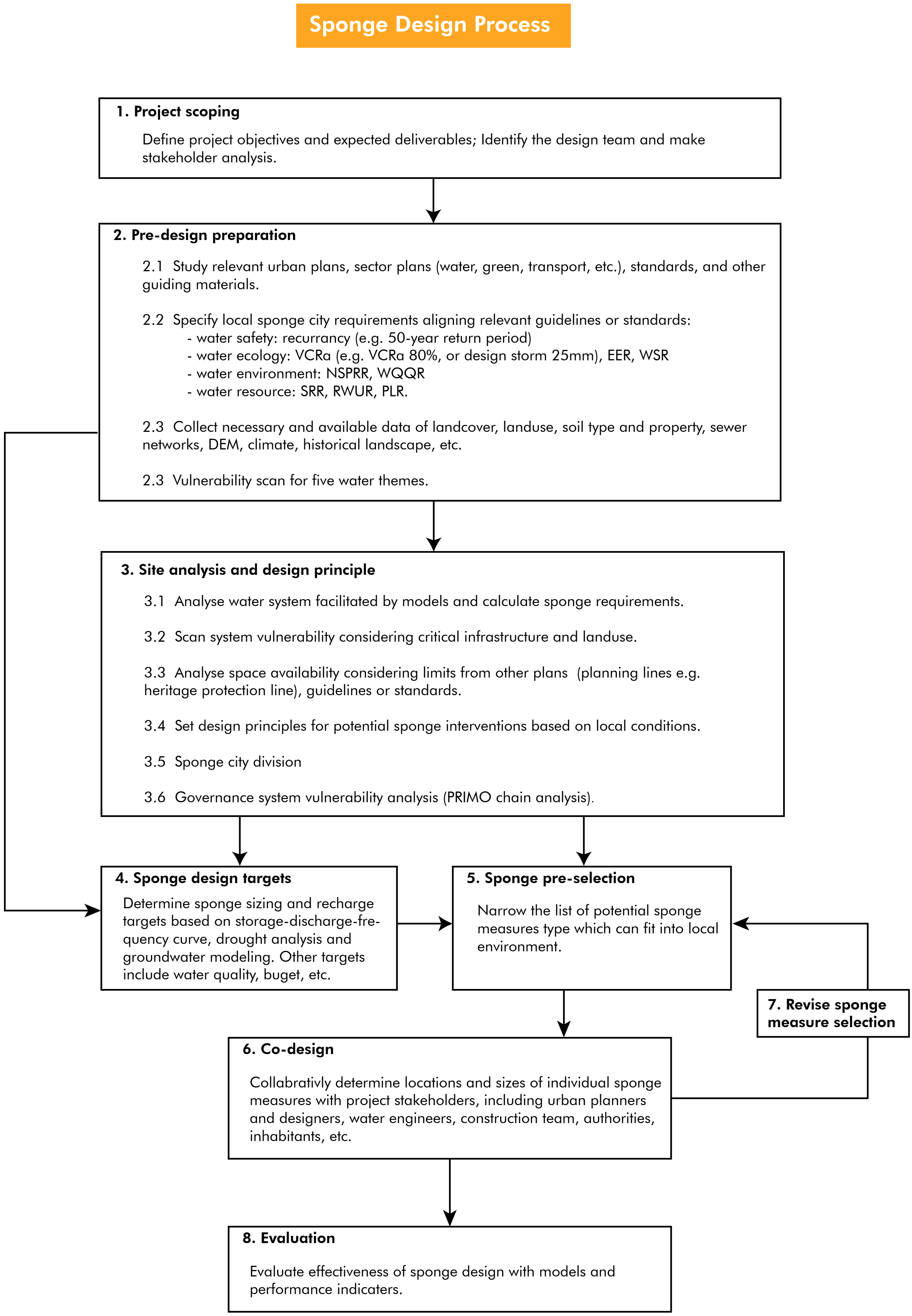

Figure 19 Recommended sponge design process

4.5 Improvements on planning and design framework

Corresponding to the identified eight challenges in Section 3.2.3, improvements on current sponge planning & design framework which can support sponge design process are given as follows:

1. **Consistency over sector planning.**
   Sponge city and flood control sector plan should agree on the same principle (i.e. retain & detain water before discharge) when dealing water safety issues and collectively determine required storage & discharge capacity. Urban spatial plan can reserve spaces for public sponges or preserve water bodies/greenfield as natural sponges based on storage requirements. Ecological and environmental planning should prevent pollution at the first place. Greenery and parks sector plan can set proper principles for suitable plant types, green multi-functionality, porous pavement in the park, lowered green, etc., in order to coordinate sponge planning. Groundwater management should be paid attention in the light of SC concept. The arrangement of sponge measures should consider groundwater pollution prevention and groundwater table control.

2. **Principle for different scales can be differentiated.**
   Current sponge city scales are mainly for downscaling indicators and for project management, without consideration of eco-system consistency. Additionally, regional or catchment interventions are not well-considered in current guidelines. Clear principles at various spatial or hydrological scales like in WSD (see Figure 6) would provide a baseline to planners and designers so as to make sponge designs at various administrative levels.

3. **SDF curves can be used in design to determine required storage capacity given a target discharge capacity.**
   By using SDF curves, storage and discharge are both considered when designing a flood-proof system. Meanwhile, SDF curves can be an instrument for triggering discussion between Sponge Office and Water Authority.

4. **Impose flood prevention requirements to land developers.**
   Xiaoqu can take more responsibility to reduce runoff volume and rate on site, instead of shifting flooding problems to surrounding roads, or other municipal pubic areas. Imposing requirements to land developers in the design & construction phases can ensure flood prevention interventions be implemented and maintained.

5. **Specify responsibility of monitoring on urban water system components as well as sponge measures' performance.**
   Monitoring urban water system components such as groundwater table, CSO, soil moisture, etc. can provide information on system behaviour and facilitate calibration and validation of modelling in the design process. Water quality and quantity performance, as well as eco-services and other additional values of sponge measures should be monitored in order to assess whether sponge measures are well-functioning as designed and when maintenance may be needed. Such understandings on measure performance help to make better sponge design in the future. The responsibilities of monitoring should be specified.

6. **Enhance trans-department data exchange process and make data transparent to the public.**
   Data are very essential to make system assessment and affect reliability of model results. Making data transparent would stimulate research and studies on SC planning and design, which benefits the growth of this concept.

7. **Specify maintenance responsibility.**
   Maintenance is important for measures to be well-functioning. The responsibility of maintenance is strongly suggested to be specified and agreed by relevant parties in the sponge planning.

8. **Introduce a co-design workshop in planning and/or design phase.**
   As sponge measures involve interests of various stakeholders, it is necessary to bring them around the table in SC planning or preliminary/conceptual design phase to trigger the discussion of sponge interventions. Such workshop could also facilitate the conversation amongst authorities, inhabitants and designers, etc. It will help build mutual understandings based on each stakeholder's request, insights, preference and so on.

The improved planning & design framework is illustrated in Figure 20. Point 1-4 are about improvements on planning & design contents, whereas point 5-8 are about improving organizational aspects of planning & design process.

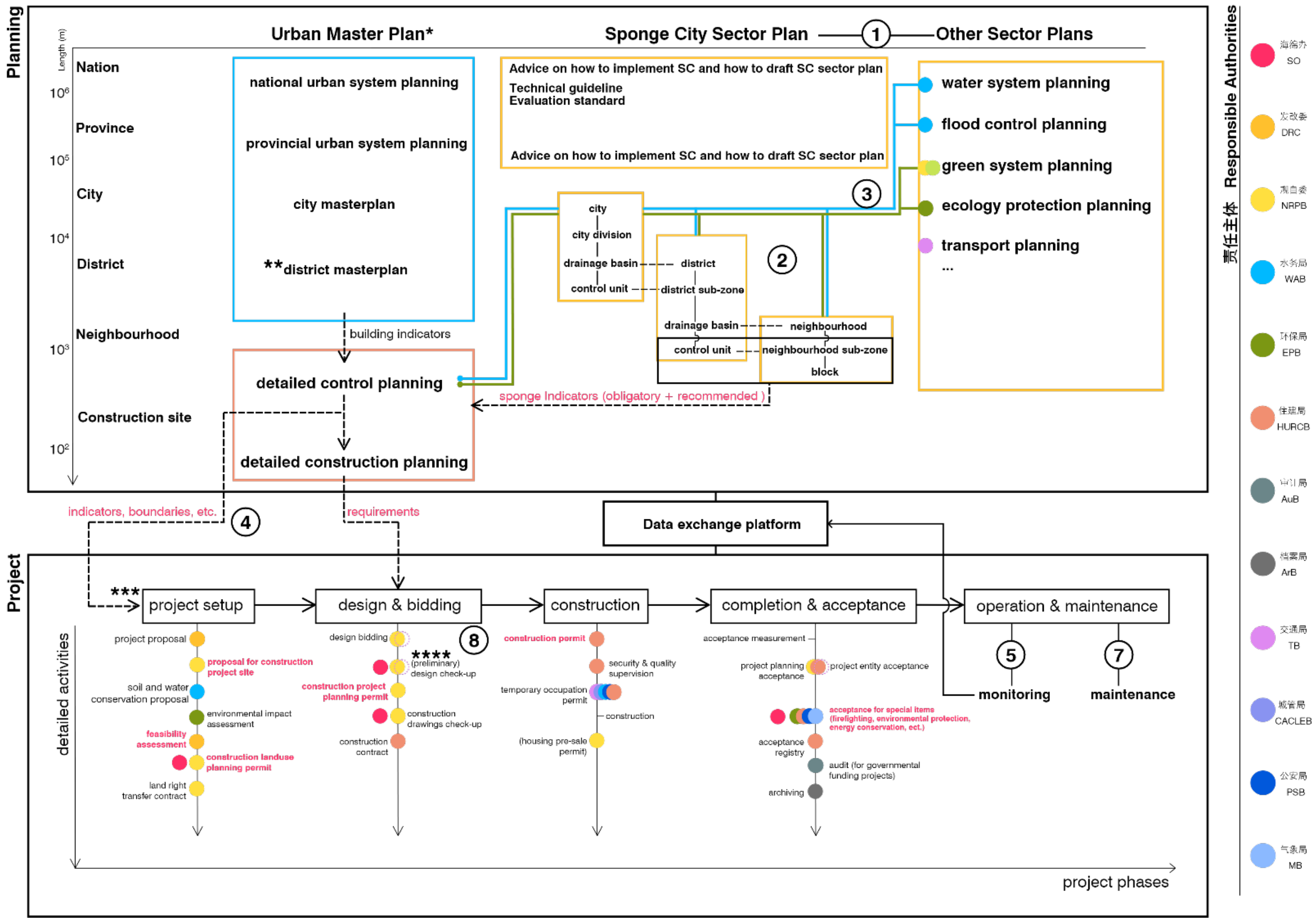

Figure 20 Improvements on planning & design framework

4.6 Chapter summary

Based on the findings from literature study, planning & design system study and interviews, this chapter proposes improvements on sponge design approach at five angles: SC scoping, sponge contents & synergies, sponge planning principles and design strategies, sponge design process, sponge planning and design framework. Improvements on current planning and design practice are given following Sponge City philosophy of integrated water management and integrated planning & design process.

Chapter 5 Assembling a sponge design toolbox

5.1 Model overview

Simulation models are tools; tools are needed to operationalize sponge design in practice. When designing (or re-designing) an urban water system, models can be used to mimic reality and provide predictions on different scenarios. A number of models, no matter free conceptual models or complex commercial packages, are developed for supporting SuDS, WSD, and other equivalent urban (water) design paradigms. Figure 21 gives an overview on functions and applicable spatial scales of popular tools.

It is very important to note that using tools in Sponge City should consider their functions and limitations, especially in the context of project objectives. In the context of sponge city modelling, InfoWorks ICM, SWMM, Delft 3D FM Urban, MIKE, or other hydraulic models can be deployed to simulate hydraulic load of sewer system and assess sewer drainage capacity. Moreover, it can model flood hazard under extreme rainfall conditions for providing information to sponge design; it can also model flood hazard under the scenario where sponge interventions are applied, so that the effectiveness of sponge design can be evaluated. However, one main drawback of these individual models is the exchange of mass and other information between subsystems cannot be modelled (Zhu et al., 2016).

Therefore, new types of model are required to support the SC planning process, in addition to the hydraulic models. Firstly, hydrologic models can provide guidance to water resource management (Marshall, 2014) with simulation on water storage at each component and water flows between components. In SC planning, hydrologic models can be used to estimate sponge capacity (required storage volume and recharge rate), as well as to simulate groundwater table dynamic. Secondly, Planning Support System (PSS), one type of planning support tool, is able to provide communicative and analytical support to co-design workshops (McEvoy, 2019). PSS refers to 'geo-information based tools intended to support planners in planning tasks such as information handling, communication and analysis in planning processes' (Vonk & Geertman, 2008).

Moreover, these models are to be applied in a different order to draft an integrated urban water management plan in cooperation with other disciplines and stakeholders.

5.2 Three models and calculation methods

Three types of tools, i.e. hydraulic model, hydrologic model and PSS, can facilitate SC integrated urban water management in planning & design phases. In this thesis, three tools are selected into the toolbox to support SC planning of Qinhuai District, including Urban Water Balance Model (UWBM), Climate Resilient City Toolbox (CRCT[28]), and InfoWorks ICM.

5.2.1 Urban Water Balance Model

Urban Water Balance Model (UWBM), a conceptual lumped multi-reservoir model for urban water balance modelling, is able to dynamically simulate dominant hydrological processes (Zhang, 2019). The UWBM model, written in Python language, was released by Deltares in 2019 as open source software[29] (Deltares, 2019).

28 Climate Resilient City Toolbox, previously named as Adaptation Support Toolbox, is developed by Deltares to support the collaborative planning of adaptation measures for a more resilient and attractive environment. For more information, please visit: https://www.deltares.nl/en/software/adaptation-support-tool-ast/

29 For more information on the model introduction, assumptions, calculation methods, etc., please visit: https://publicwiki.deltares.nl/display/AST/Urban+Water+balance+model

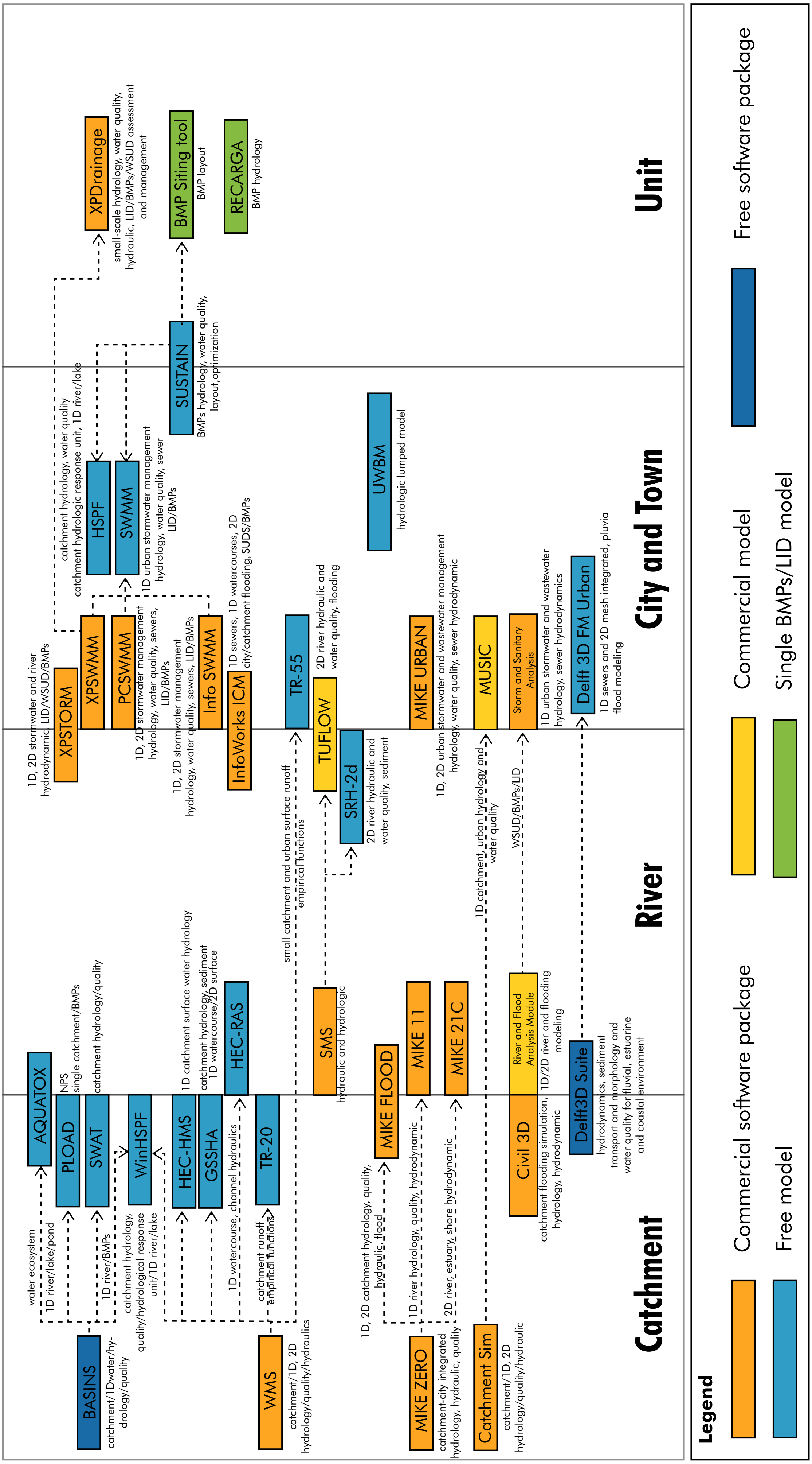

Figure 21 Models that can be used in sponge city adapted from (Cai, 2016)

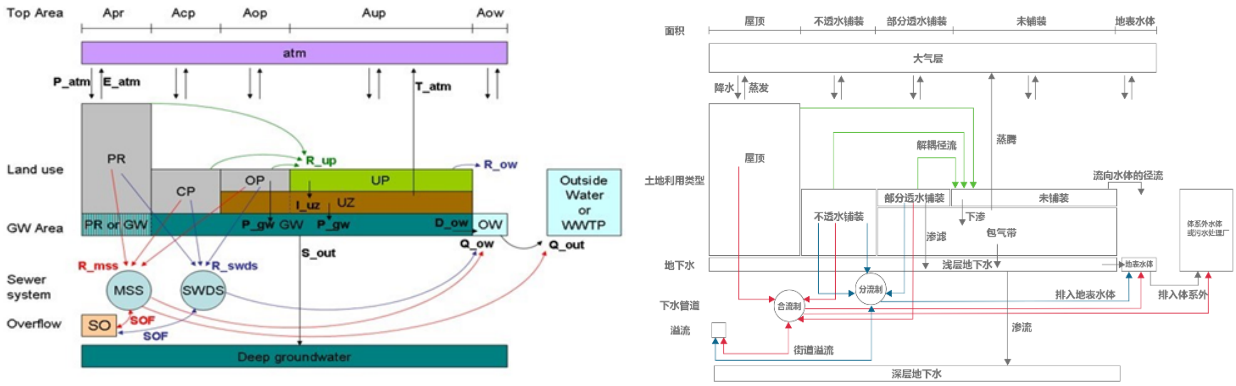

Figure 22 Left: schematic overview of UWBM, retrieved from: https://publicwiki.deltares.nl/display/AST/Urban+Water+balance+model#UrbanWaterbalancemodel-1Generaldescription; Right: self-translated Chinese version

The UWBM simulates the water balance components, as shown in Figure 22, over a long period of time, so that the dynamics of each component can be studied. To this end, the UWBM takes long, multi-annual historical rainfall data as input - preferably including the series of daily potential evapotranspiration - which is a big advantage because all kinds of different initial conditions in all parts of the urban water system are taken in to account (Deltares, 2020). Another advantage of using a water balance model is that both model building and model calculations take much less time (Deltares, 2020), compared to detailed hydraulic models, like SOBEK, SWMM, InfoWorks, MIKE-urban, etc. UWBM can provide users dynamic information of water flows among components (see Figure 22) with a rather quick speed.

The UWBM is used in three different ways, with three different sets of inputs, as shown in Figure 23: a Simple Run to study the dynamics of flows and water stocks, a SDF Run to generate Storage-Discharge-Frequency (SDF) curves and a Complete Run to calculate the performance indicators of various adaptation measures. Based on temporal dynamics of unsaturated zone soil moisture simulated from Simple Run, a drought analysis can be performed to estimate recharge requirement for prevent drought damage. The groundwater level exceedance probability can be calculated using Simple run results, based on which decisions can be made to select target groundwater level for avoiding subsidence problem or high/low groundwater table issue. SDF curves can be generated by SDF module of UWBM, which support identifying required storage capacity for a selected discharge capacity under a target flood return period. Complete run is able to simulate effectiveness of all potential sponge measures by calculating performance indicators, e.g. runoff reduction factor, groundwater recharge, and evaporation. These calculated indicators are imported to CRCT for estimating the effects of co-designed sponge intervention scenario.

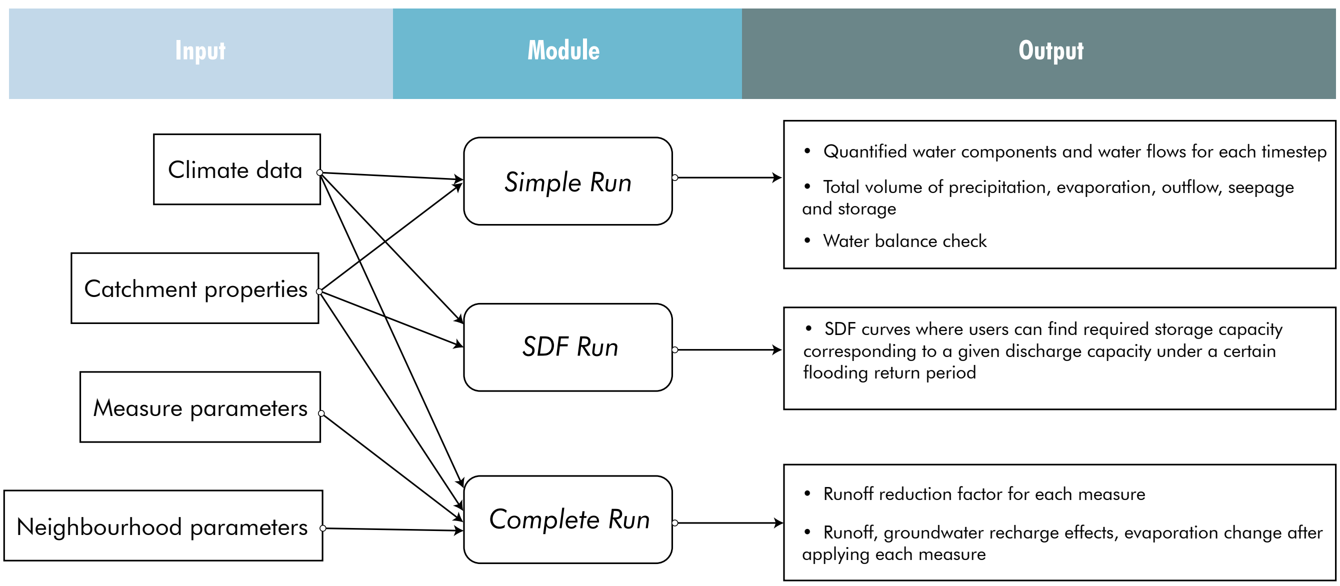

Figure 23 Input and output of UWBM modules

SDF curves, drought analysis method and some key performance indicators (KPIs) will be explained in detail in the next paragraphs.

5.2.1.1 Water balance dynamic analysis (Simple Run)

The Simple Run can simulate dynamics of flows and water storage, including soil moisture and groundwater.

Simulated root zone soil moisture variation can help study agricultural drought events. There are a number of drought indicators and indices that help define drought events, two of which are explained in Annex C. Drought characteristics can also be derived from time series of observed or simulated hydrometeorological variables using Threshold Level Method (Van Loon, 2015). A pre-defined threshold level (in case study θ_{50}[30] is used) can be used to calculate dynamics of soil moisture deficit. Exceedance probability of soil moisture content deficit is to be derived for identifying extreme drought events. The mitigation of moisture deficit can be assessed by adding certain amount of rainfall during the selected extreme drought timespan as a representation of irrigation recharge. That amount of 'recharge' is used as one of sponge capacity requirements, which indicates how much storage should be designed to irrigate unpaved areas during dry spells.

Additionally, Simple Run is able to model dynamics of groundwater table level. Exceedance frequency distribution of groundwater level against time will then be calculated, based on which the decision on what target groundwater level to be maintained can be made.

5.2.1.2 Storage-Discharge-Frequency curves (SDF Run)

As an add-on module of UWBM, Storage-Discharge-Frequency (SDF) Curve takes climate forcing (precipitation & evaporation) and catchment properties as inputs, and then produces relations between storage capacity and discharge capacity of an area under certain runoff return periods. The specific storage capacity – in mm or m^3/ha – is calculated by multiplying open water area in the model with the rise of water level, then divided by the total project area. The obtained figure of SDF curves is the basis of estimating the required storage capacity in an area in view of the existing or future stormwater discharge capacity. Involved actors are enabled to work on conceptual design based on the information of required storage and discharge that SDF curves provide.

To explain the use of the SDF curves let us take SDF curves of Nanjing's Qinhuai District as an example (see Figure 24). The abscissa of the curves represents discharge capacity, which is water flow that drained out of the system. Normally, discharge capacity equals total pumping capacity in a district-sized area; as it is not allowed to shift problems to downstream areas, this capacity is limited to a level that can be handled without problems (is acceptable for) the downstream system. In water sensitive design this discharge capacity is of the set to 'not exceed predevelopment discharge rates' (Cunningham et al., 2017). The ordinate of the curves means storage capacity in mm, which is storage volume spread over entire study area. The lines, labelled as return period X years, represent the relation between storage capacity and discharge capacity of the water system that is exceeded once every X years. The orange lines indicate when discharge capacity is 300 mm/d and storage capacity is 80 mm, the system would be capable of handling once-every-20-year runoff event without causing flooding. Evidently, the larger the discharge capacity is, the less storage capacity is required to achieve the same probability of exceedance, which verifies the point that 'storage and discharge are both necessary and must be combined (in thinking)' (Anonymous, 2020). It is also worth mentioning that storage capacity calculated out of VCRa method can be compared with the storage capacity for pluvial flooding prevention. When VCRa is 87%, the design storm depth is 44mm, which has a return period of 0.2 years (= occur or is exceeded at least 5 times per year on average). The storage out of VCRa method is rather small (see light blue line with label '0.2yr'), that is not enough to prevent pluvial flooding during any significant storm events.

30 θ_{50} is the mean between the wilting point and the field capacity.

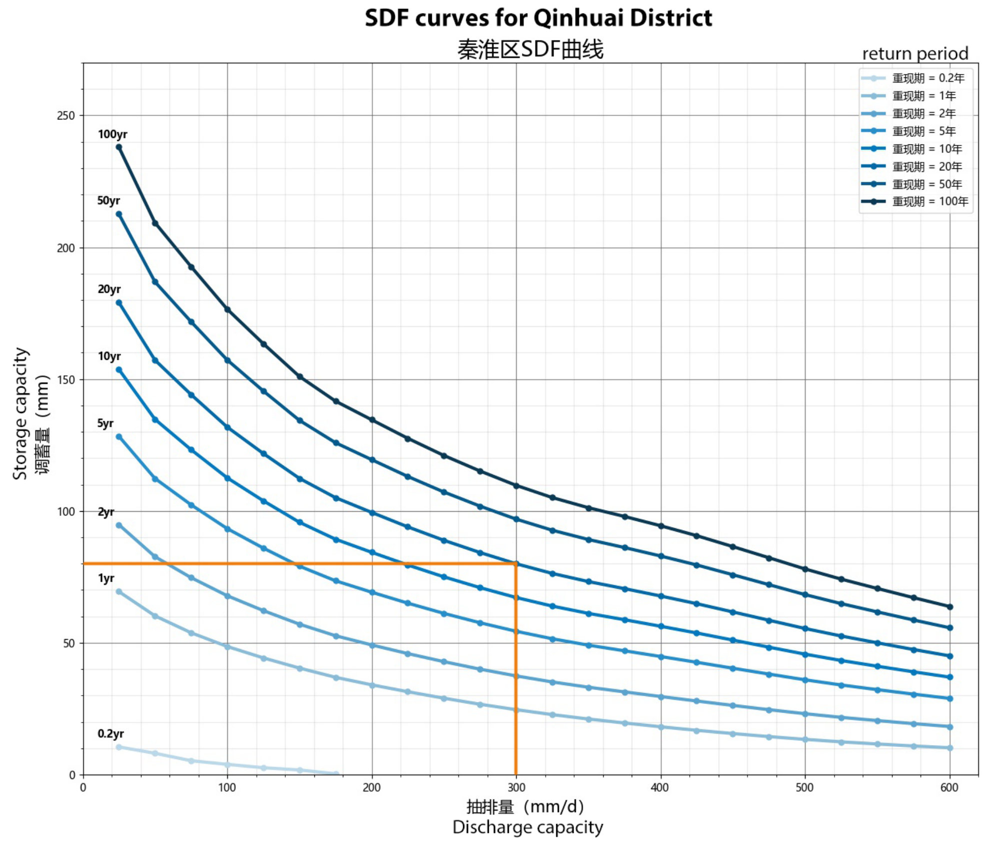

Figure 24 SDF curves for Qinhuai District

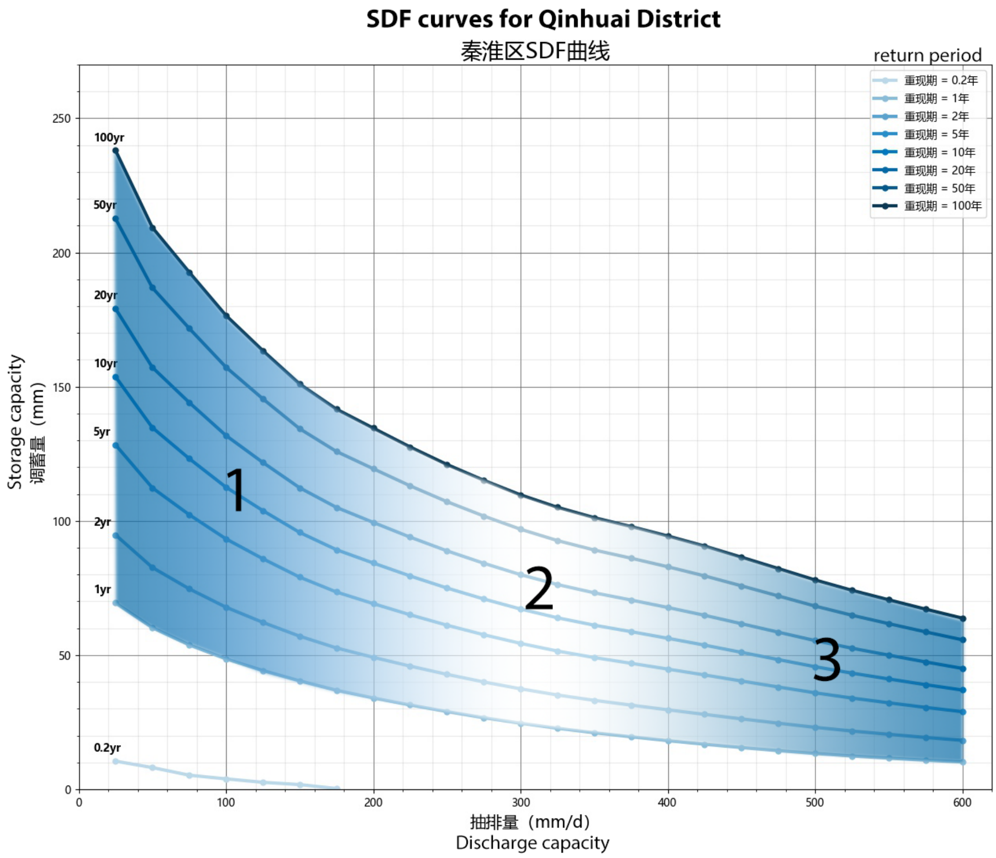

Figure 25 Three zones in SDF curves

Determining required storage capacity should first agree on acceptable runoff event with a certain return period of exceedance. For example, Nanjing City sets target for old district to be once-in-50-year flood-proof, which means return period should select 50 years. Next step is to find the combination of storage capacity and discharge capacity. There are three zones in Figure 25, labelled with 1, 2, and 3. Generally speaking, zone 1 and 3 are not proper for making selections. Zone 1 requires high storage capacity, which is not realistic due to high investment and space requirements; Zone 3 requires a huge discharge capacity renovation, which is not possible as well, because larger discharge means both larger sewer system and pumping station should be installed, and the hydraulic load at downstream is drastically increased to an unacceptable level. Moreover, such high discharge capacities are very hard to realize in a flat area, where hydraulic gradients are very small. Therefore, storage and discharge combination in zone 2 is normally considered as a reasonable option. Additionally, when determining the discharge capacity of a district, not only current pump capacity should be considered, but also the projected pump capacity should be taken into account if there is a reconstruction, demolition or renovation plan in the near future. If the receiving river is heavily loaded by the combination of all the pumping stations of all the districts, it would be wise to reduce the pumping capacity and bring it more in line with the natural, predevelopment drainage load of the river. This selected storage capacity (mm) is multiplied by project area to find the storage capacity target value (m^3) for the whole area.

The impact of climate change and land use changes on the SDF curves can be studied in a sensitivity analysis. In order to assess the SDF curves, the UWBM uses long time series of rainfall and potential evaporation, in combination with numerous parameters related to land use and subsurface drainage characteristics. By modifying these inputs, the sensitivity of the assessed storage capacity can be shown. SDF curves can also reflect climate and land use change scenarios. An example from a study in Xiangtan, Hunan province is shown in Figure 26 (van de Ven et al., 2020).

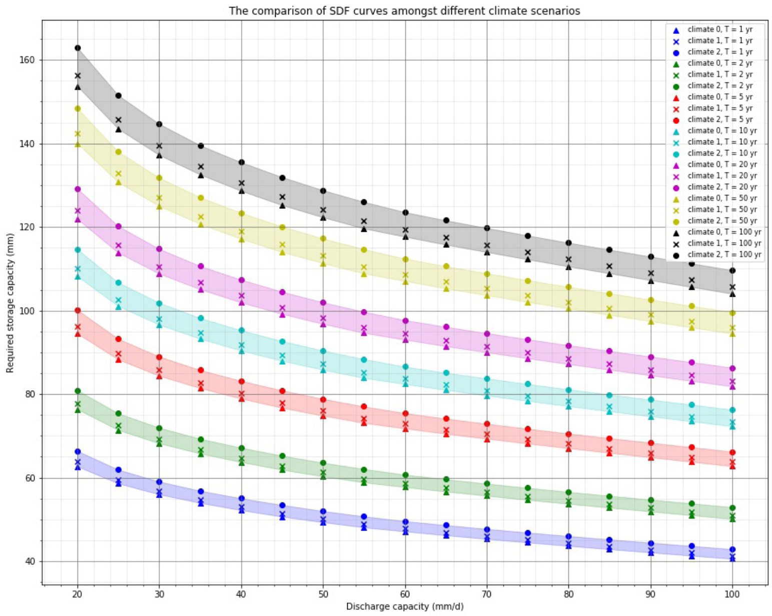

Figure 26 Future scenario of climate change. Retrieved from: Pre-feasibility study of confirmed ecosystem-based adaptation measures for Xiangtan. Source: van de Ven et al. (2020).

5.2.1.3 Performance indicators assessment (Complete Run)

The UWBM is used in Complete Run mode to assess the key performance indicators (KPIs) for each of the sponge city ecosystem-based adaptation measures included in the CRCT. These indicators include the runoff reduction factor, the expected additional groundwater recharge and irrigation recharge (the latter is not yet included in the CRCT). For detailed explanation of KPIs in UWBM, please refer to Annex D.

5.2.2 Climate Resilient City Toolbox (CRCT)

Climate Resilient City Toolbox (CRCT) enables multiple stakeholders in a co-design workshop to select certain sponge interventions (adaptation measures), draw them onto project area and see the estimation of effectiveness and costs prompt (van de Ven et al., 2016). Since climate, geographical features, soil type, land cover, etc. are diverse in different cities, a customized CRCT that fits local conditions should be prepared. Such customization requires a series of calculations. Required storage capacity derived from SDF curves is used for setting the target value of storage volume in CRCT. KPIs are calculated for all possible measures in project area, then results are processed and shown in the CRCT, so that quick estimation of selected measure effectiveness can be performed during co-design workshop. Moreover, local map layers (e.g. ESRI areal map, flood map, etc.) could be incorporated into CRCT for providing participants information on spatial context, flooding hazard, etc.

The user interface is shown in Figure 27. There are three panels in CRCT. Users can use left panel to set project properties and targets, as well as select sponge measures from a ranked long list of adaptation measures. The middle panel is map view, on which users can choose a preferred layer to draw measure contours. The right panel gives users results of estimated performance.

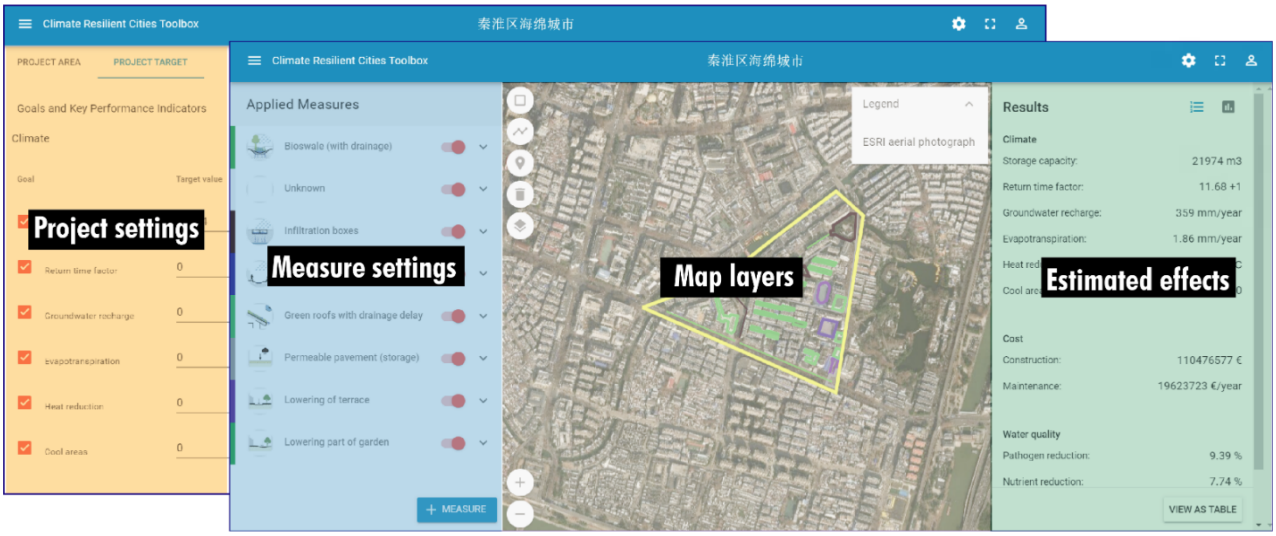

Figure 27 User interface of CRCT

A Chinese version of CRCT was built for an application in Xiangtan, Hunan Province, PRC (van de Ven et al., 2020). Xiangtan Climate Resilient City Toolbox (XCRCT) is a customized version of the planning support tool, developed for The Xiangtan Low-Carbon Transformation Sector Development Program (van de Ven et al., 2020).

5.2.3 Hydraulic simulation models

Hydraulic simulation models are abundantly available for the analysis of urban drainage systems. In the case study InfoWorks ICM is used to perform hydraulic calculations. InfoWorks ICM, developed by Innovyze, is 2D surface flood modelling, water quality simulation, application of SuDS measures, etc. (HRWallingford).

Before running the model, it is very important to carefully select reasonable design storm profile to ensure the reliability of modelling results. The calculation method for design storm with a short duration (< 3 hours) is available in national technical guideline, and Chicago rain is recommended for determining storm profile (MHURD & CMA, 2014). Such short design storm is used in designing storm sewer system (MHURD & GAQSIQ, 2014). Yet, pluvial flooding assessment requires 3 to 24 hours design rainfall input for urban flooding prevention and control (MHURD & GAQSIQ, 2017). There are only a few cities that published calculation methods for composing storm profile with long duration (e.g. 24 hours) (MHURD & GAQSIQ, 2017; Nanjing Municipality, 2018). Therefore, local rainfall pattern analysis should be performed in order to compose a design storm profile to run flood modelling. Cumulative frequency distribution of rain duration vs. deviation to constant rain can be calculated to provide insights on peak's location. Different types of rainfall patterns can be conceptualized, so that the distribution of historical rainfall events over those patterns gives indication on what is the most frequent pattern in the area. More details on how to analyse rainfall pattern and synthesize design storm profile will be presented in Section 6.3.1.

5.3 Timeline of using tools

The timeline of using tools in sponge design toolbox is shown in Figure 28. Firstly, UWBM is used to generate SDF curves, make drought analysis and model groundwater level, based on which requirements on performance indicators can be set and used later in co-design sessions. Hydraulic modelling or water quality modelling can be performed in parallel to simulate flood hazard and water quality, so that designers can select possible sponge interventions. Then CRCT is to be applied in a co-design workshop to further identify problems and specify sponge interventions at conceptual design level. Finally, the hydraulic models are used to evaluate hydraulic and water quality performance of sponge interventions in the phase of detailed design.

5.4 Chapter summary

Following on the proposed holistic sponge design process to achieve an integrated urban water management, several tools are needed to support the analysis of the water system and the design of a Sponge City concept. This chapter dives into the sponge capacity calculation method, sponge measure design process and models that can support sponge city projects. Functions of three tools, UWBM, CRCT and hydraulic models (such as Delft 3D FM Urban, InfoWorks, SWMM, etc.), and how they can be used in sponge design are explained in this chapter.

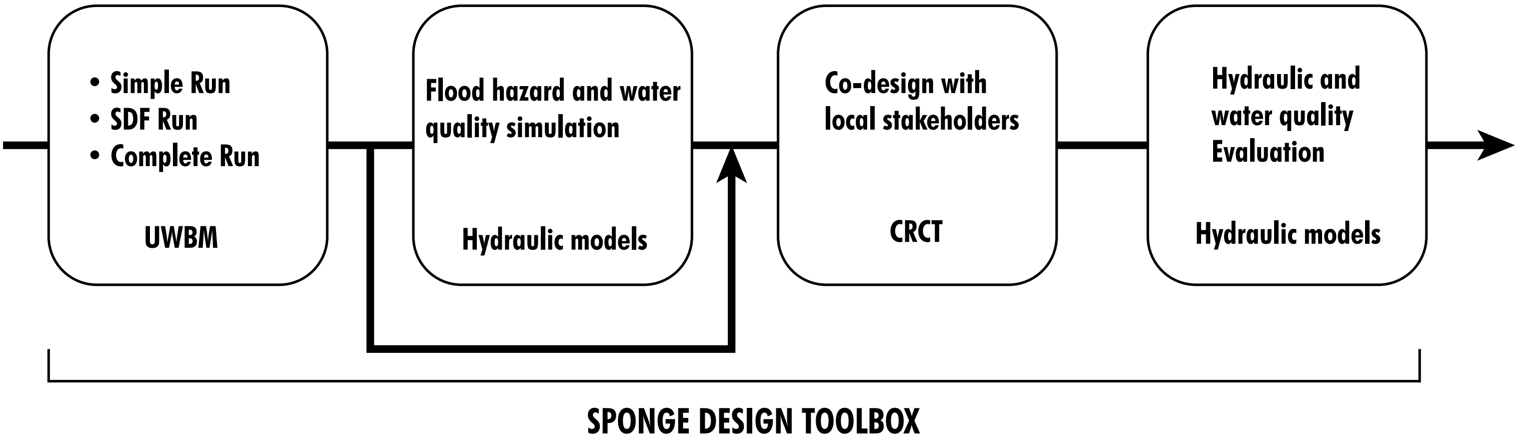

Figure 28 Timeline of using tools

Chapter 6 Testing the new approach: case study Nanjing Qinhuai District

6.1 Introduction

For testing the new approach to Sponge City planning and design, this study could use an ongoing SC planning project in Nanjing.

After elected as one of the pilot sponge cities in Jiangsu Province, Nanjing City initiated planning work at various administrative scales aiming to tackling urban water-related issues following Sponge City concept. The project is to make a Sponge City plan (2020-2035) for Qinhuai District. Based on status quo of Qinhuai district and future development visions, this planning project aims to construct a reasonable structure of sponge city system, coordinating urban spatial plans and other sector plans.

6.1.1 Planning area

Served as capital of ten kingdoms, dynasties, and republic, Nanjing witnesses drastic changes along the history and rapid urbanization over last decades. This river city with renowned water heritage and waterscape is situated at Yangtze River Delta, which has a humid subtropical climate and is influenced by the East Asian monsoon (Mao, Wu, Pei, He, & Liu, 2012). Heavy precipitation in summer, combined with other factors such as urban landcover change, low topography, etc. cause frequent flooding hazards in Nanjing City (Nanjing Municipality, 2018).

Qinhuai District is located in the south of Nanjing main city, with palace heritages clustered in northwest and old canal networks interweaved in urban landscape. Less densified areas are mostly in south and east of Qinhuai. The total area of the district is 49 km^2. The location and landcover of Qinhuai are shown in Figure 29.

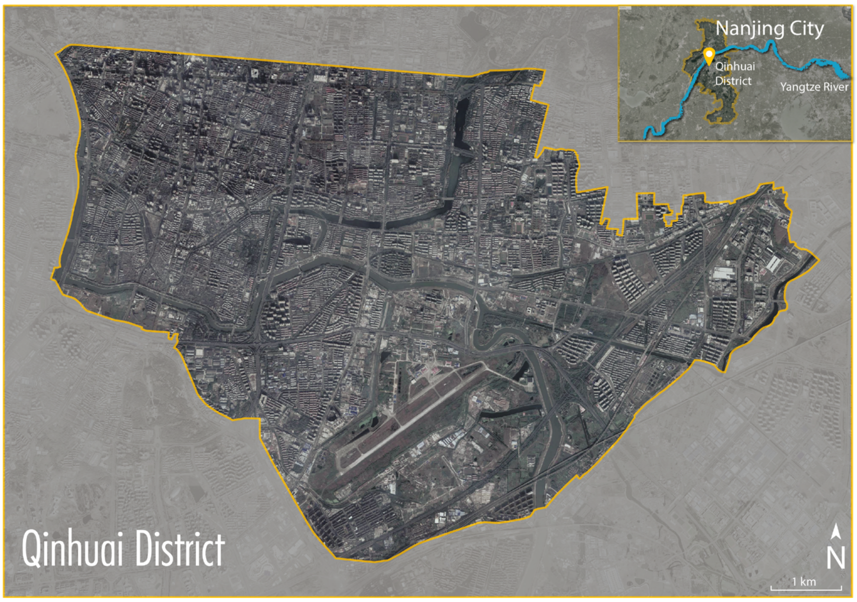

Figure 29 The location and aerial picture of Qinhuai District

6.1.2 Objective

The objective of this case is to make a SC plan for Qinhuai District, through which sponge interventions are deployed to contribute to solving water quantity and quality issues, meanwhile, to have co-benefits such as mitigate urban heat island, revitalize water culture, etc.

6.1.3 Project roadmap

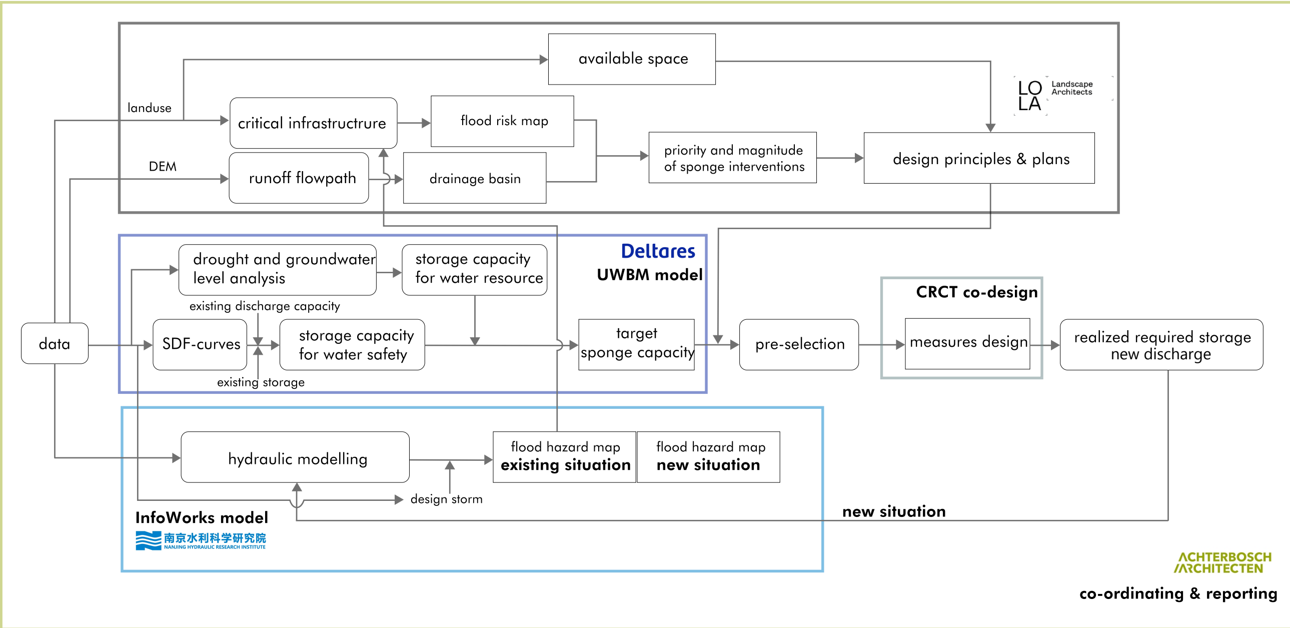

Figure 30 Project roadmap

There are four parties in the design team: AchterboschZantman International (AZI), Deltares, LOLA Landscape Architects (LOLA) and Nanjing Hydraulic Research Institute (NHRI). The project roadmap of this ongoing project is shown in Figure 30, which indicates again that sponge design requires efforts from different disciplines.

The study was done under the Deltares component of the project, as shown in Figure 30. In this chapter the new SC planning and design approach will be applied and tested, often in cooperation and consultation with the other project partners. In Chapter 7, experiences will be evaluated in order to identify the strengths and weaknesses as well as the barriers when introducing this new approach to practice.

A side-note to the project was the hindrance caused by the COVID-19 pandemic (WHO, 2020) that impeded communication between the Dutch and Chinese counterparts and reduced the original plans for co-creating plans with the local experts and authorities.

6.2 Pre-design preparation

6.2.1 Relevant plans

As shown in the current planning & design framework (see Figure 13), sponge city should take consideration of urban spatial plans, economic plans, other sector plans, etc. Concerning sponge city planning for Qinhuai District, relevant plans are listed below, ranging from national level to district level.

1. Ministry of Housing and Urban-Rural Development, "Sponge City Construction Technology Guide-Low Impact Development Rainwater System Construction" (Trial)
2. Implementation Opinions of the General Office of the Municipal Government on Promoting the Construction of Sponge City
3. Code for Urban Drainage Engineering Planning" (GB50318-2017)
4. Technical Specifications for Construction and Community Rainwater Utilization Engineering (GB50400-2016)
5. Guidelines for the Construction of Sponge City in Jiangsu Province
6. Nanjing City Sponge City Planning and Construction Guide
7. Nanjing City Master Plan (2011-2030)
8. Nanjing Qinhuai District Urban Master Plan (2013-2030)
9. Nanjing City Sponge City Sector Plan (2016-2030)
10. Nanjing City Land Use Master Plan (2006-2020)
11. Nanjing Ecological Red Line Area Protection Planning (2014)

12. Comprehensive Planning of Drainage and Waterlogging Prevention in Nanjing City Centre (2015-2030)
13. Nanjing City Flood Control Planning Report (2013-2030)
14. Outline of the 13th Five-Year Plan for National Economic and Social Development in Qinhuai District
15. Specifications for the Special Plan for the Sponge City of Nanjing Honghua-Airport Area (2015-2030)
16. Qinhuai District Green Space System and Greenway Slow Moving System Planning Research
17. Qinhuai Soil Control and Remediation Plan (2017-2020)

These plans were studied, and relevant elements were included in the data analysis for the SC plan. For example, *Nanjing Qinhuai District Urban Master Plan (2013-2030)* gives an overview of current and planned land use, sewer systems, historical protection areas, and other information of Qinhuai District; *Nanjing City Flood Control Planning Report (2013-2030)* sets flood protection requirements for districts and critical infrastructures; Requirements of SC indicators and SC division are proposed in *Nanjing City Sponge City Sector Plan (2016-2030)*, where corresponding information on Qinhuai District can be collected; *Nanjing Ecological Red Line Area Protection Planning (2014)* identifies vulnerabilities of eco-systems in Nanjing, based on which vulnerable areas in Qinhuai District should be planned with rehabilitation and protection measures.

6.2.2 Local sponge city design indicators

Sponge city indicator requirements of Qinhuai District inherited and customized based on Nanjing City planning are shown in Figure 57 (in Annex E), with the same structure as Figure 18, where obligatory indicators are coloured with orange.

6.2.3 Data availability

Category	Contents	Details
Climate	Precipitation	2009-2018: hourly
	Evaporation	2009-2018: daily
Soil	Soil type and infiltration capacity	Based on soil investigation of Jiangsu Province
Urban master plan	Land-cover & land use	2015 and 2030: JPEG files
	Sewers layout	
	Pumping station location	
	Heritage protection area	
Water system components	Sewer information	data of length, node elevation, pipe diameter acuqired from Water Authority
	Pumping station	Current and in planning pumping station location and capacity
Elevation	Degital Elevation Model	DEM file for Qinhuai District
Detailed control plan	Land use & control indicators	CAD files for Qinhuai District

Table 6 An overview of important available data[31]

Data plays an essential role in current situation assessment, sponge capacity calculation and sponge intervention evaluation. Table 6 gives an overview of important available data. Monitored data of groundwater table, soil moisture, etc. are not available, which means calibration and validation of modelling are not able to perform. It also should be noted that longer series of climate data (e.g. 30 years of hourly rainfall data) would improve result reliability of hydrologic modelling.

31 Currently there is no official provincial or city-level climate change scenarios that can be referred to. At national level, *China's National Assessment Report on Climate Change, the third version* (The Committee for Compilation of China's National Assessment Report on Climate Change, 2015) gives prediction of climate change on East PRC Region, where Nanjing City is located in.

6.2.4 Vulnerability scan for 5 water themes

Detailed analysis process about five water themes of Qinhuai District are not the focus of this thesis, hence only key problems are summarized in Annex M. As this thesis is focused on the new elements in the approach to SC planning and design, the analysis is emphasizing on:

1. The analysis of the local water system and its challenges;
2. The assessment of the required storage and drainage capacity;
3. The development of representative design storms for hydraulic modelling;
4. The application of the design principles to create a SC plan.

The following sections follow the same structure as proposed sponge design process in Figure 19.

6.3 Site analysis and design principle

6.3.1 Rainfall pattern

Based on 10-year rainfall data of Qinhuai District, local rainfall pattern could be analysed. Average annual precipitation is 1245 mm, with larger portion in June, July and August (see Figure 58 & Figure 59 in Annex F). Compared with hourly rainfall series of The Hague, Qinhuai has much higher rainfall intensity, especially in summer (see Figure 31), which indicates that sponge strategy should emphasize on detention and retention to mitigate peak flow rate of runoff and control runoff volume to avoid high flooding risk at downstream.

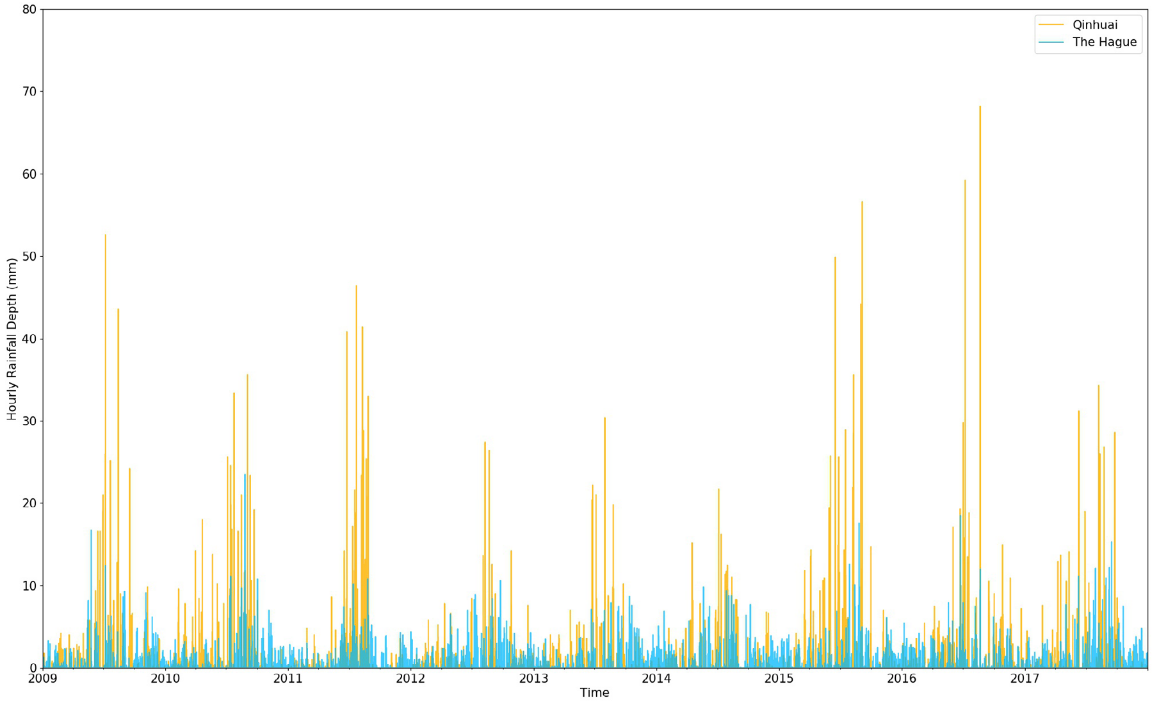

Figure 31 Hourly rainfall depth of Qinhuai District vs. the Hague

In order to develop a design storm profile that fits actual condition of Qinhuai, typical peak location of rainfall events can be studied.

There are 578 rainfall events identified by the criteria that: 1. Two events should be separated by at least a 6-hour dry period; 2. Rainfall events with depth smaller than 2 mm are discarded. A cumulative frequency distribution of rain duration percentage vs. deviation to constant rain[32] (see Figure 32) can shed light on whether rainfall peak mostly happens in the first half or second half. Purple line represents the medium of rainfall events, which has deviation value of 0.12 at 50% of total duration. It means the cumulative rainfall depth is 0.62 at half time, which indicates that more volume of storm happens in the first half compared to the second half. This result could mean an early peak pattern in Qinhuai area; however, more precise analysis was performed by manually

32 A constant rain means rainfall events with constant intensity, so at 50% total rainfall duration, cumulative depth is 50% of total depth. If an event has a deviation value of 0.1 at half time of total rainfall duration, it means the cumulative depth is 60% of total depth at half time.

checking storm profiles.

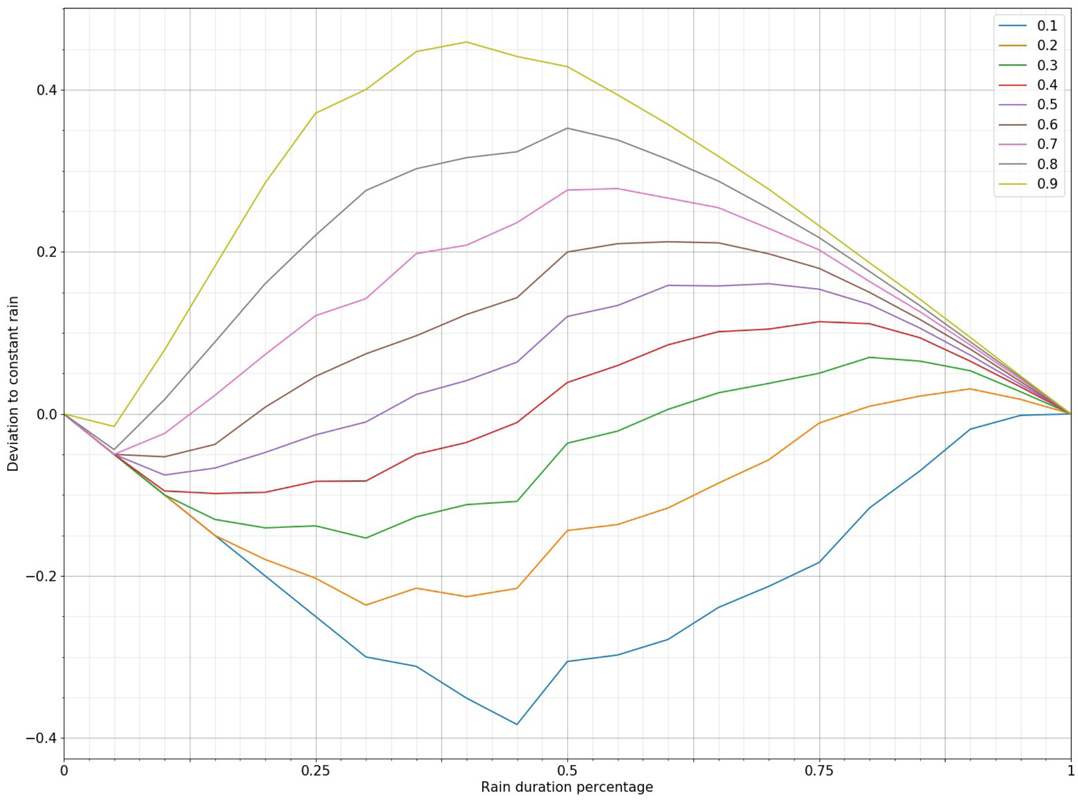

Figure 32 Cumulative frequency distribution of rain duration vs. deviation to constant rain

The heaviest 300 rainfall events as well as heaviest 200 rainfall events with more than 24-hour duration are manually categorized into those 7 classes (see Figure 33). Evidently, the most rainfall events are with peaks (either single peak or double peaks) in front and/or middle part. This conclusion can be used to compose a design storm profile which has more rainwater volume in front part.

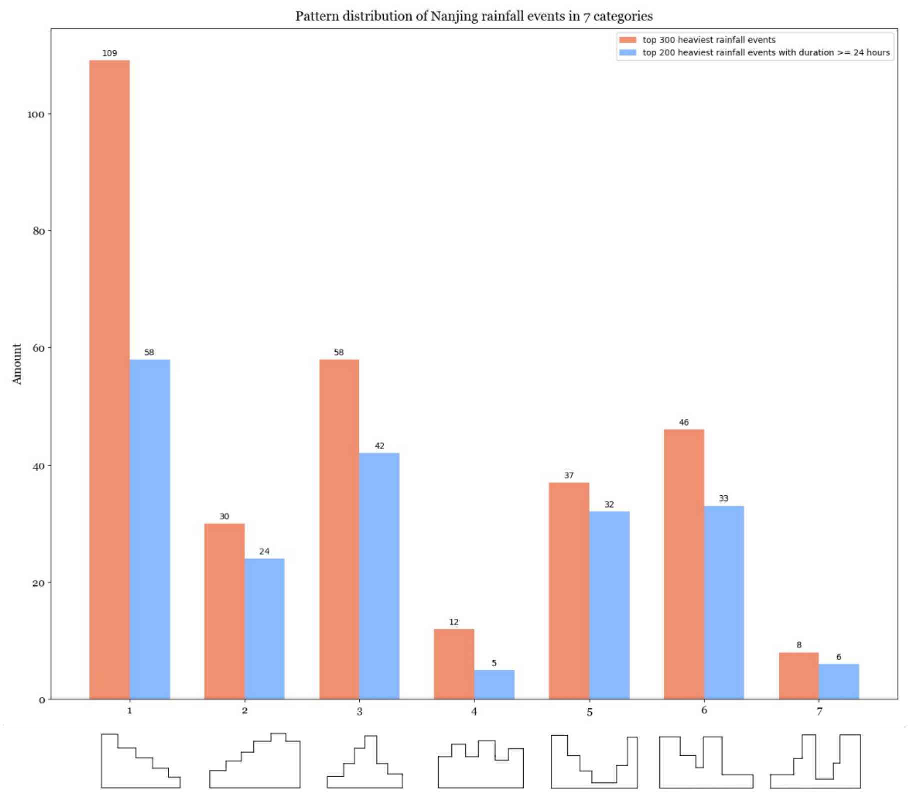

Figure 33 Distribution of rainfall pattern over 7 categories

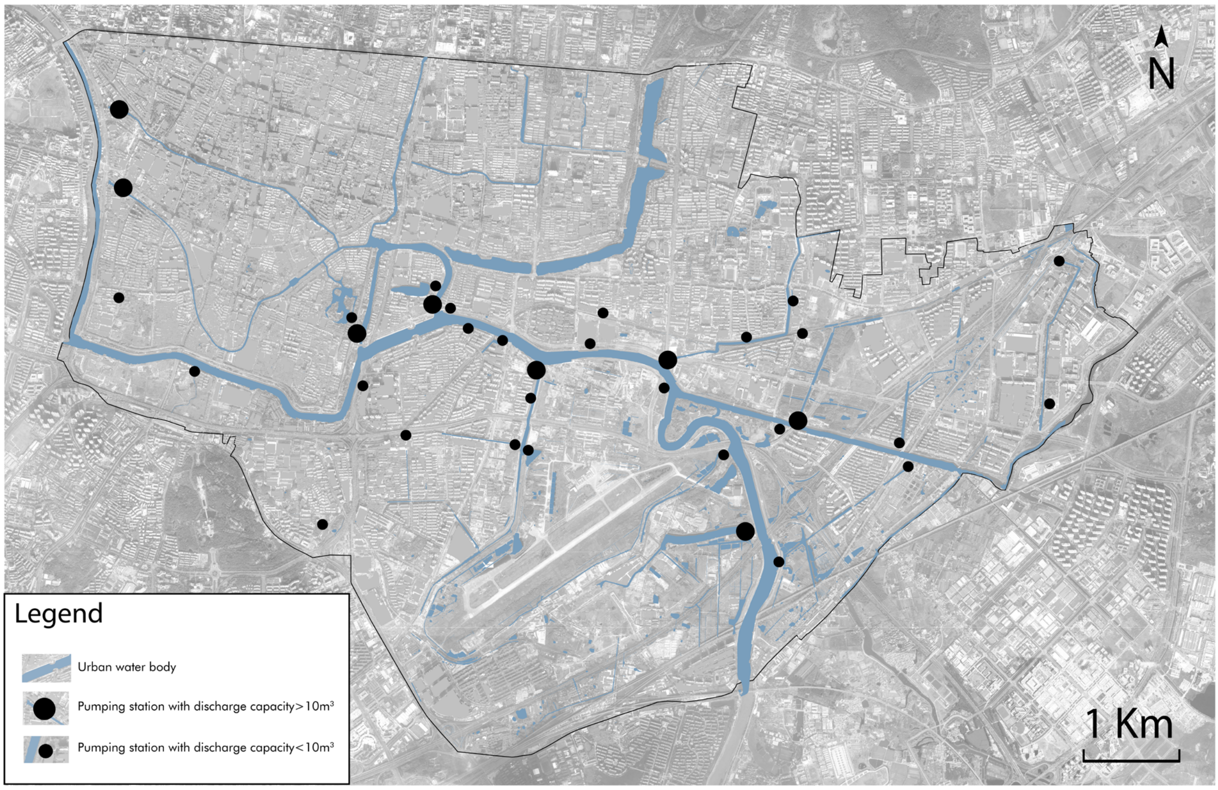

Figure 34 Surface water networks and pumping station locations

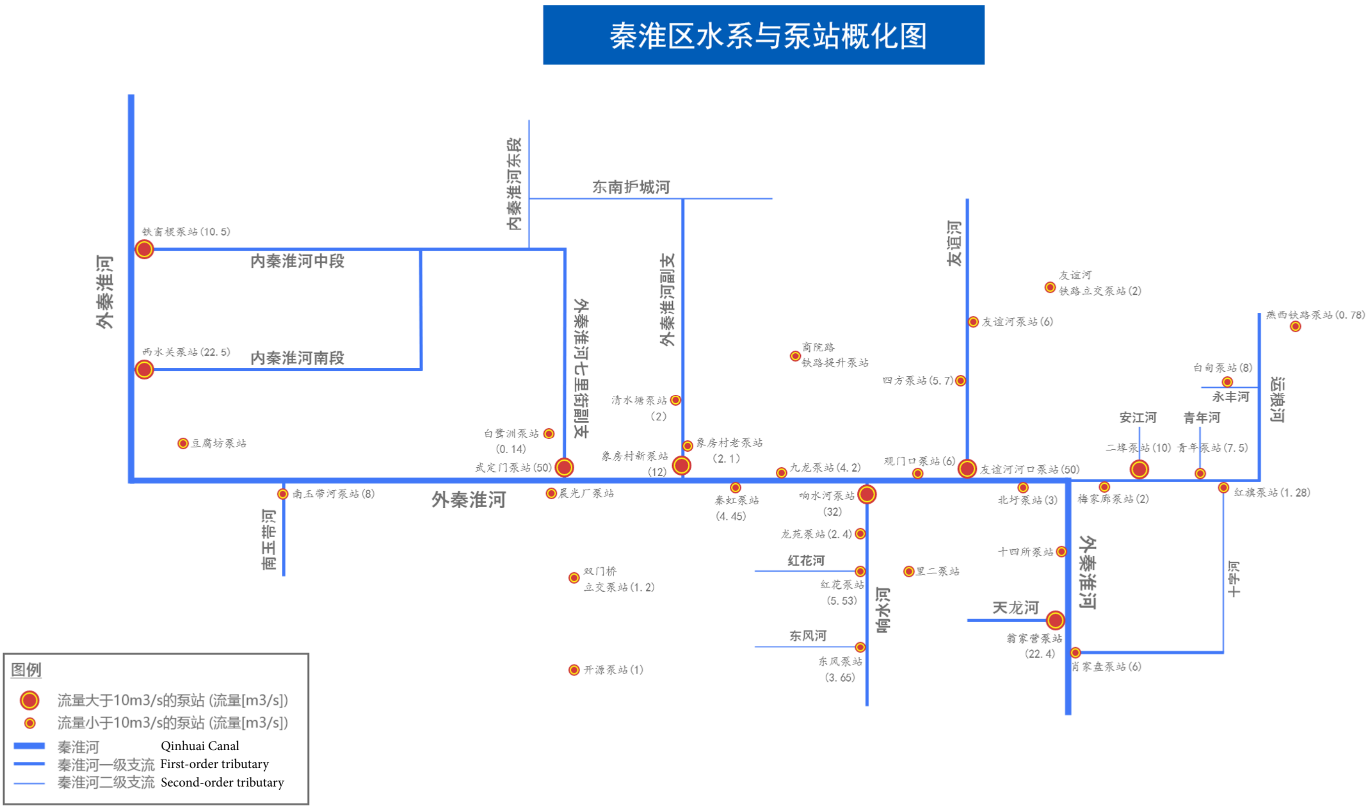

Figure 35 A schematic overview of canal networks and pumping stations

Moreover, the possibility of artificially classifying rainfall pattern is tested by a fully connected machine learning method (see Annex G).

6.3.2 Water system & pumping stations

Surface water networks and locations of pumping stations are shown in Figure 34. Figure 35 illustrates a schematic overview. Big dots represent pumping stations with more than 10 m^3/s capacity; while small dots represent those with less than 10 m^3/s capacity. Total discharge capacity of Qinhuai District is 387 mm/d.

6.3.3 UWBM modelling

After raw data processing, input data for UWBM modelling are listed in Table 8 (in Annex H). The simulated dynamics of open water level, groundwater level and soil moisture together with rainfall series are shown in Figure 62 (in Annex H).

SDF curves for Qinhuai District (see Figure 36) are generated for supporting determining required sponge capacity against pluvial flooding.

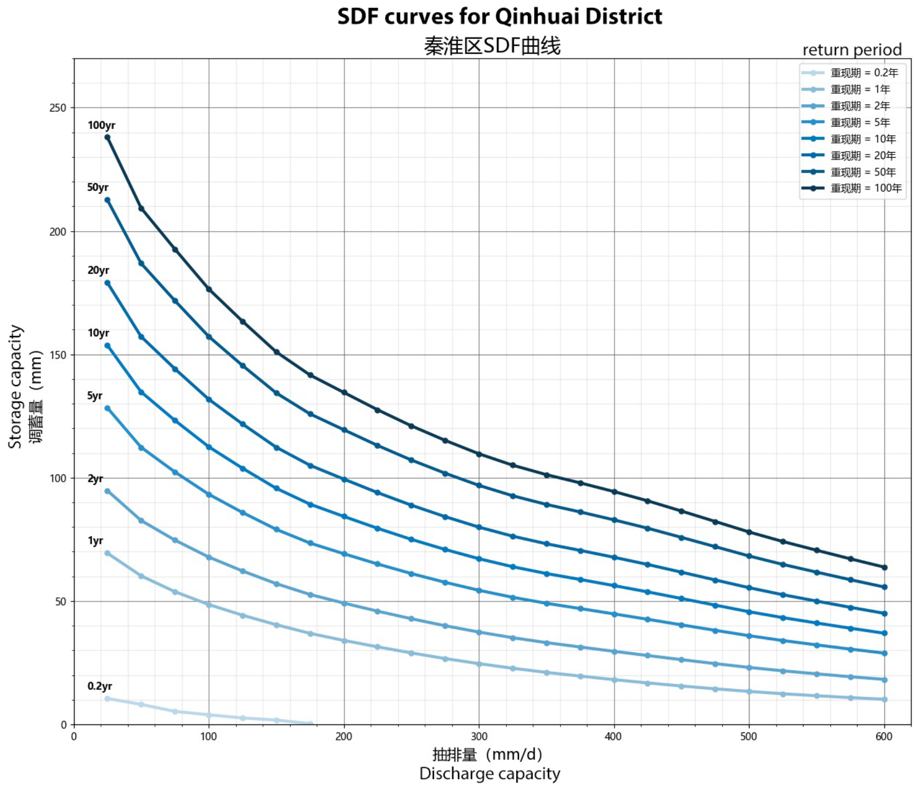

Figure 36 SDF curves of Qinhuai District

6.3.4 Flood vulnerability scan

i. Design storm

Design storms for testing sewer capacity and assessing flood hazard are different. Design storms with short duration (e.g. 3 hours) under short return period are used to assess sewer drainage capacity and those with long durations (e.g. 24 hours) under long return period are used to assess flood hazard.

Nanjing sponge city plan (Nanjing Municipality, 2018) gives design storm depth under various return period for different duration. The depth of 24-hour design storm with return period of 50 years is 283.8 mm, whereas depths of 3-hour storm with return period of 1, 3, 5 years are 51.3 mm, 71.7 mm, 94.1 mm, respectively. As recommended by MHURD and GAQSIQ (2017), Chicago storm is used to generate design rainfall profiles (see Figure 63 in Annex I).

Based on rainfall pattern analysis in the previous section, a storm of 24 hours with early peak can be a good candidate of design storm in flood simulation. An actual rainfall event beginning at 18:00 on December 14th, 2009 and ending at 17:00 on December 15th, 2019, as it lasted for 24 hours and most volume of rain fell in the first half. Storm profile of the event is proportionally scaled up to 283.8 mm to be a design storm (see Figure 37).

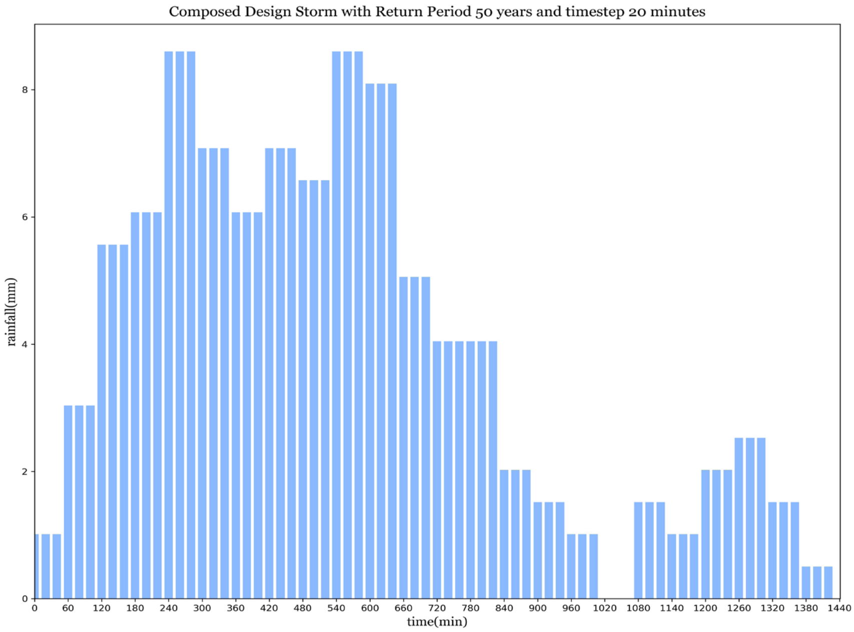

Figure 37 Composed 24-hour design storm with return period 50 years

ii. InfoWorks modelling

Taking inputs of design rainfall, sewer system information, water level in rivers, DEM and pumping station operation information, InfoWorks ICM was used by NHRI to simulate hydraulic loading of sewer under 1, 3, 5 year return period and inundation area[33] under 50 year return period. The results are shown in Figure 64 (in Annex J) and Figure 38, respectively.

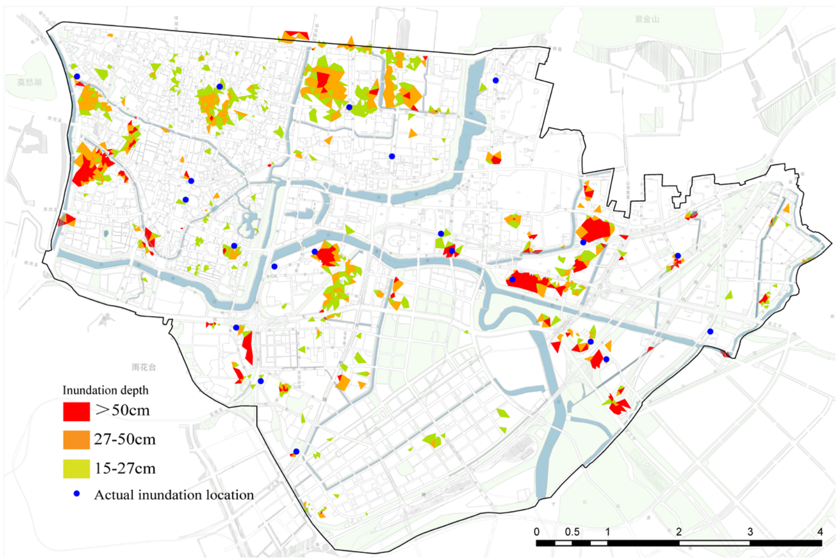

Figure 38 Inundation areas under design storm of 50-year return period. Credit: NHRI

33 Inundation area is defined by the area with more than 15 cm water depth that last for more than 2 hours (MHURD & GAQSIQ, 2017).

iii. Flood risk and priority & magnitude of sponge interventions

The flood hazard map illustrates flood-prone areas, but not all areas are exposed at the same level of damage risks. For example, the same flood level would exert much more impacts on a commercial street than a green-field. Therefore, flood risk should consider both simulated flood hazard areas and their occupation types (see Figure 39). Once the flood risk map is generated, priority of watersheds to have different magnitude of sponge interventions can be analysed. As Figure 40 shows, the watersheds with critical flood risk should be considered to have high priority of sponge interventions.

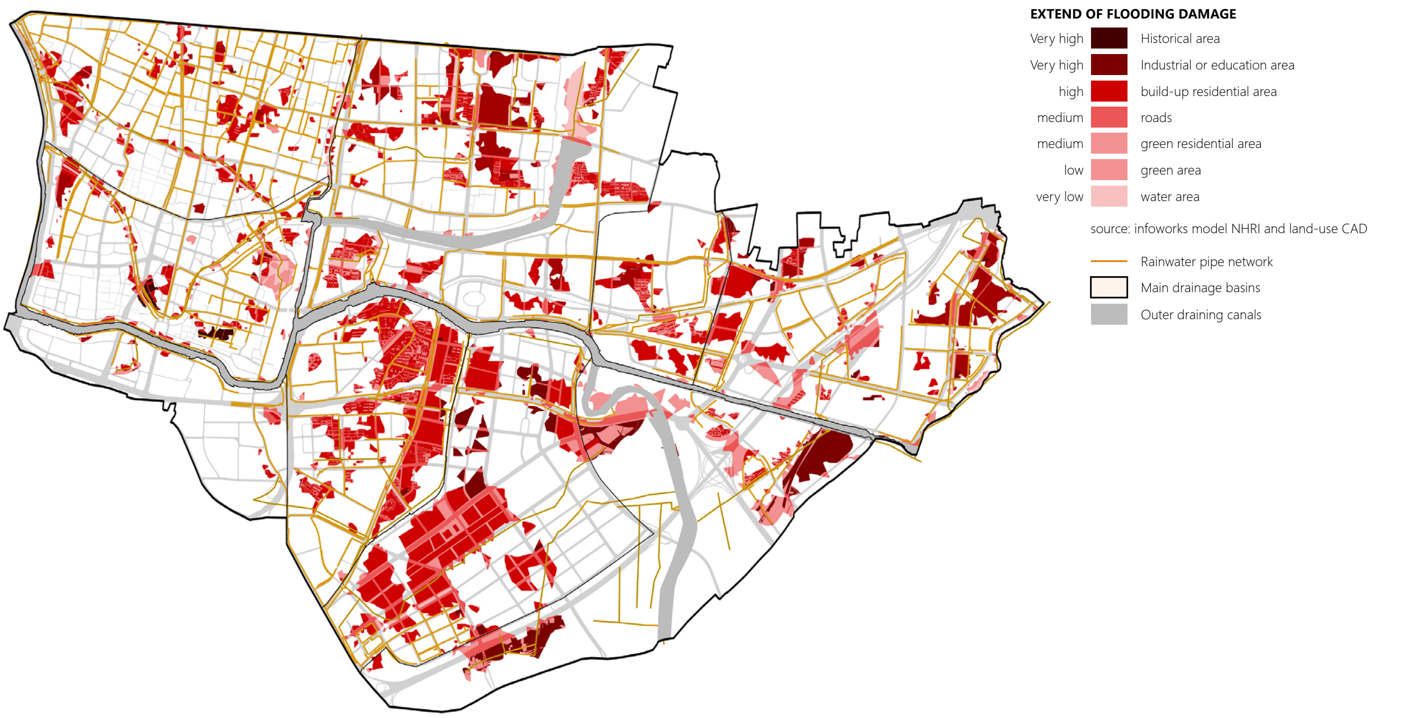

Figure 39 Flood of critical infrastructures, credit: LOLA

Figure 40 Priority of drainage basins and magnitude of sponge interventions, credit: LOLA

iv. Space availability

LOLA team also studies on space availability for sponge interventions. Vacant infrastructural green spaces (see Figure 41), public green spaces and neighbourhood spaces, rooftop, etc. can be considered to design sponge measures, while historical protection areas are restricted to make sponge interventions.

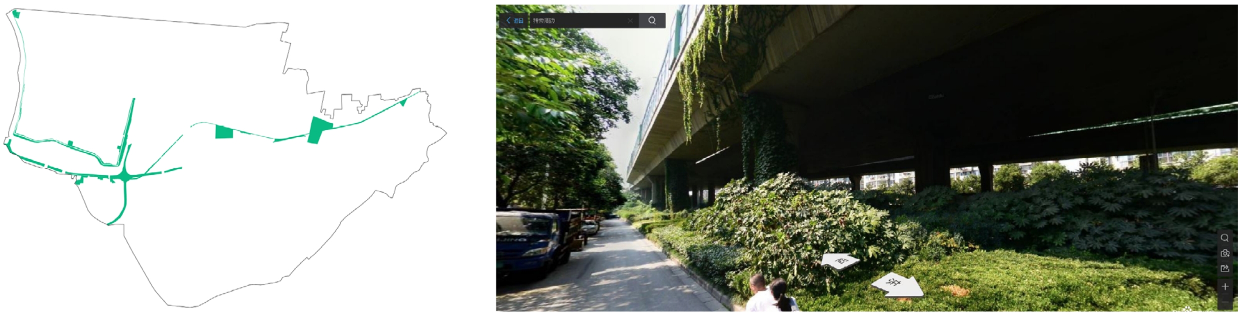

Figure 41 Vacant infrastructural green spaces (left); an example: elevated highways, credit: LOLA

6.3.5 Design principles

Current sponge design strategy in national guidelines and Nanjing sponge plans includes source control, storm sewer systems and excess runoff drainage system. However, discharge still dominates in design for water safety in practice according to literature study and interviews. Source control measures and public sponges are planned for 10-30 mm which only accounts for resisting small and medium rainfall events in Nanjing. Sponge strategy for cities like Nanjing with humid subtropical climate should pay more attention to creating storage, especially detention capacity. Because solely relying on discharge of sewers and pumps would result in risk of flooding downstream, whereas detaining water before slowly releasing it would help to reduce peak flow with relatively small impacts to downstream and have water resource and water quality benefits at the same time. Therefore, some design strategies, beyond the management train already proposed in guidelines, can be added to Nanjing sponge city:

1. Storing stormwater on-site by retention and detention capacity are preferred in sponge design
2. Connectivity of sponges should be well-designed to convey stormwater to from one place to another if on-site retention/ detention is not possible
3. Sponge type selection should consider site condition, such as land use, soil type, mobility, etc.
4. Sponge sizing should consider not only water surplus but also water shortage under local climate.

Considering the additional strategies and Qinhuai local spatial conditions, three design principle are proposed:

1. **Retain & detain first**
   Retention and detention are essential in delay peak flow and control runoff volume. Storage can lead to other co-benefits such as mitigate non-point source pollution, groundwater recharge, drought mitigation, stormwater reuse, etc.
2. **Hierarchical intervention priority** (see Figure 42)
   The priority hierarchy of sponge interventions are: 1. Public green space sponges; 2. Vacant infrastructural space sponges; 3. Residential green space sponges; 4. Temporary small road sponges; 5. Green roof sponges. Public spaces have huge potential to be transformed to sponges whereas residential green spaces in old Xiaoqu are very limited and collective ownership of public space in Xiaoqu would impede sponge transformation. Green roofs on the bottom of the list because slopes and areas of most rooftops are not suitable for sponge construction.
3. **Multi-functional blue-green infrastructures** (see Figure 43)
   Blue-green measures in sponge city should have co-benefits concerning ecology, water safety, recreation and urban heat island.

6.3.6 Sponge city division

As Qinhuai District has diverse topography, functioning zones, soil type, etc., it is necessary to divide the administrative area into smaller pieces for better hydrologic modelling and customized sponge measures design as

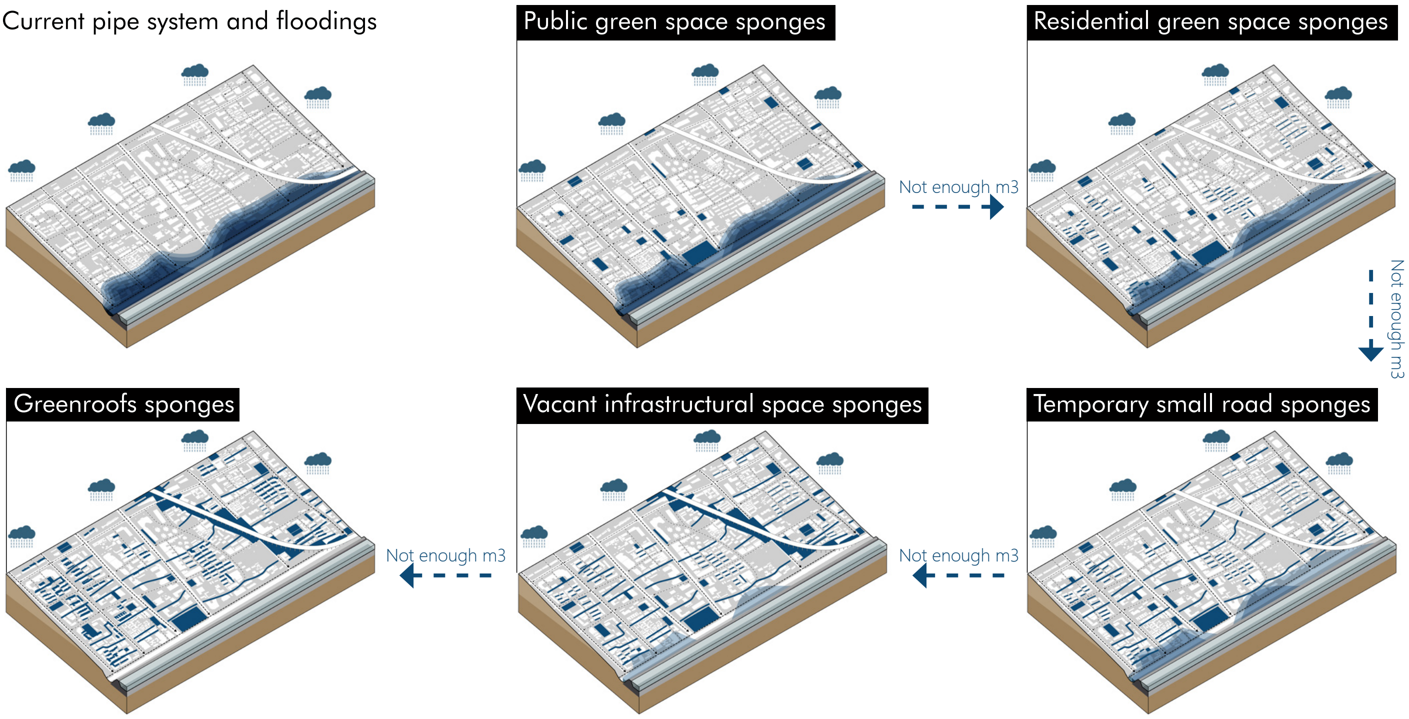

Figure 42 Layered sponge intervention priority, credit: LOLA

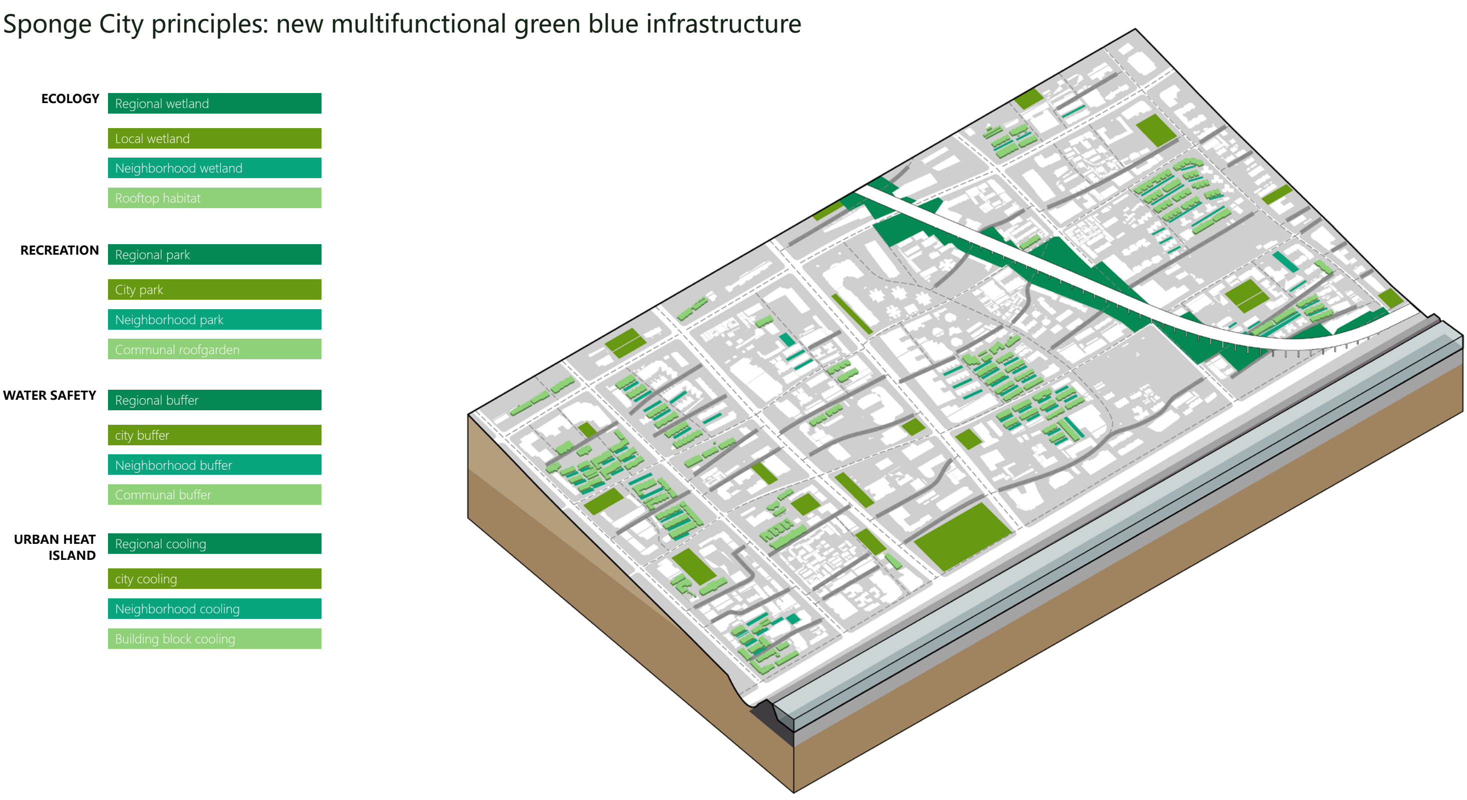

Figure 43 Multi-functional green blue measures

well as management purposes. Considering pumping station distribution, sewer drainage basin divisions, land use, soil types and administrative divisions (different neibourhoods), the sponge city division is shown in Figure 44. The division method can be found in Figure 65 (in Annex K). SDF curves are separately generated for each subzone, which means storage requirements differ from one subzone to another (see Annex L).

In order to provide different sponge strategies for distinct urban topologies, Qinhuai District is divided into four types, based on sponge city division. Those four types of topologies are shown in Figure 45. Type 1 is old city centre, featured by highly densified commercial/historical areas; Type 2 has historical parks, commercial and residential areas; Type 3 is less densified with more green and blue spaces and infrastructure like main roads; Type 4 is an abandoned airport which is planned to be developed. In Qinhuai project, test cases are designed with different strategies for each of those four distinct. Test case 1 will be introduced in Section 6.6.

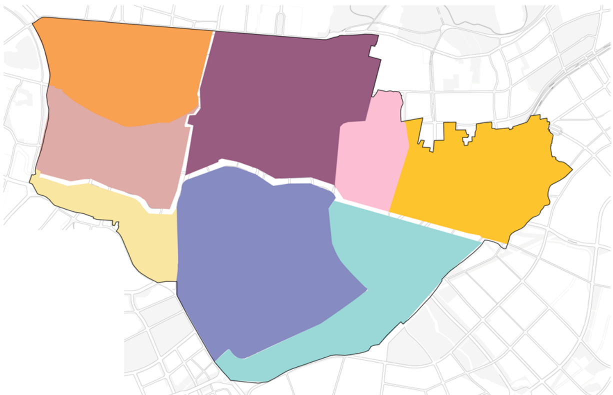

Figure 44 Sponge city division

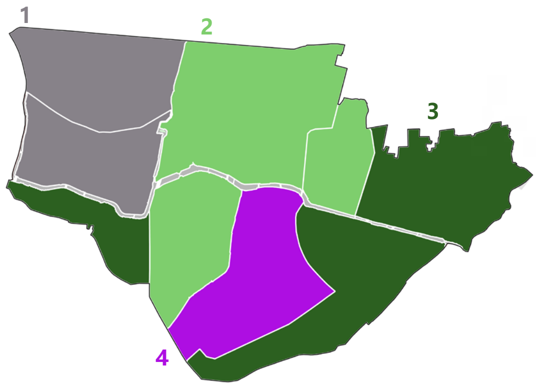

Figure 45 Four types of topologies in Qinhuai District. Credit: LOLA

6.4 Sponge capacity requirements

6.4.1 Required storage capacity

When discharge capacity keeps current condition (387 mm/d), the required storage capacity is 86 mm (see Figure 46), which means storage measures with total effective volume of 4,214,000 m^3 are required for preventing and controlling once-every-fifty-year pluvial flooding. Storage requirements for each subzone can be found in Annex L. These storage depths are set as storage capacity targets in designing sponge measures.

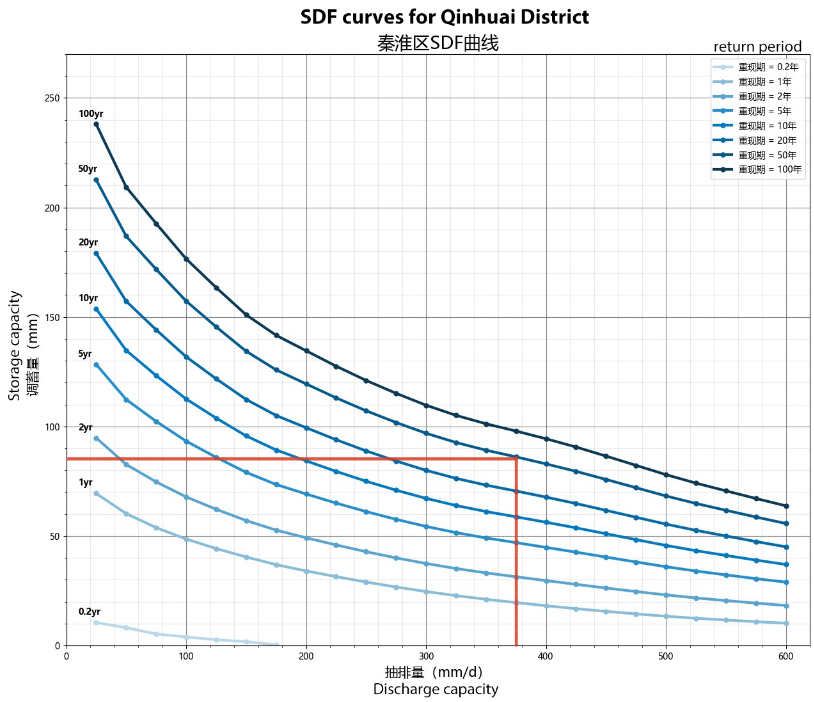

Figure 46 Selection of required storage capacity for Qinhuai District

6.4.2 Drought analysis

The indicator method of assessing drought periods that Qinhuai District has historically gone through is presented in Annex C. The following paragraphs will introduce how to estimate irrigation capacity to mitigate drought impacts on soil moisture.

Setting threshold level of soil moisture at root zone as θ_{50} (104.5 mm in this study), which is the average of field capacity and wilt point, the dynamics of moisture deficit can be calculated using UWBM. Drought events are separated if moisture deficit reaches zero. The exceedance distribution of extreme moisture deficit against return periods is illustrated in Figure 47.

The most severe drought event (which happens once in ten years) took place in the duration of 2012-05-01 to 2012-08-04 (see the yellow line in Figure 48). By adding 0.15 mm/hr into original rainfall series, the deficit during that drought period is significantly reduced (see the blue line in Figure 48). This additional represents a hypothetical 3.6 mm/d recharge over entire catchment. Considering that unsaturated zone is only under unpaved area, 3.6 mm/d irrigation recharge are effectively meaning 0.72 mm/d over unpaved area[34]. The total effective recharge is 68mm considering 95-day drought duration.

Therefore, recharge of 0.72 mm/d or 68 mm in total can help mitigate the most severe drought event, which can be supported by reusing stormwater that are stored in sponge measures during wet spells.

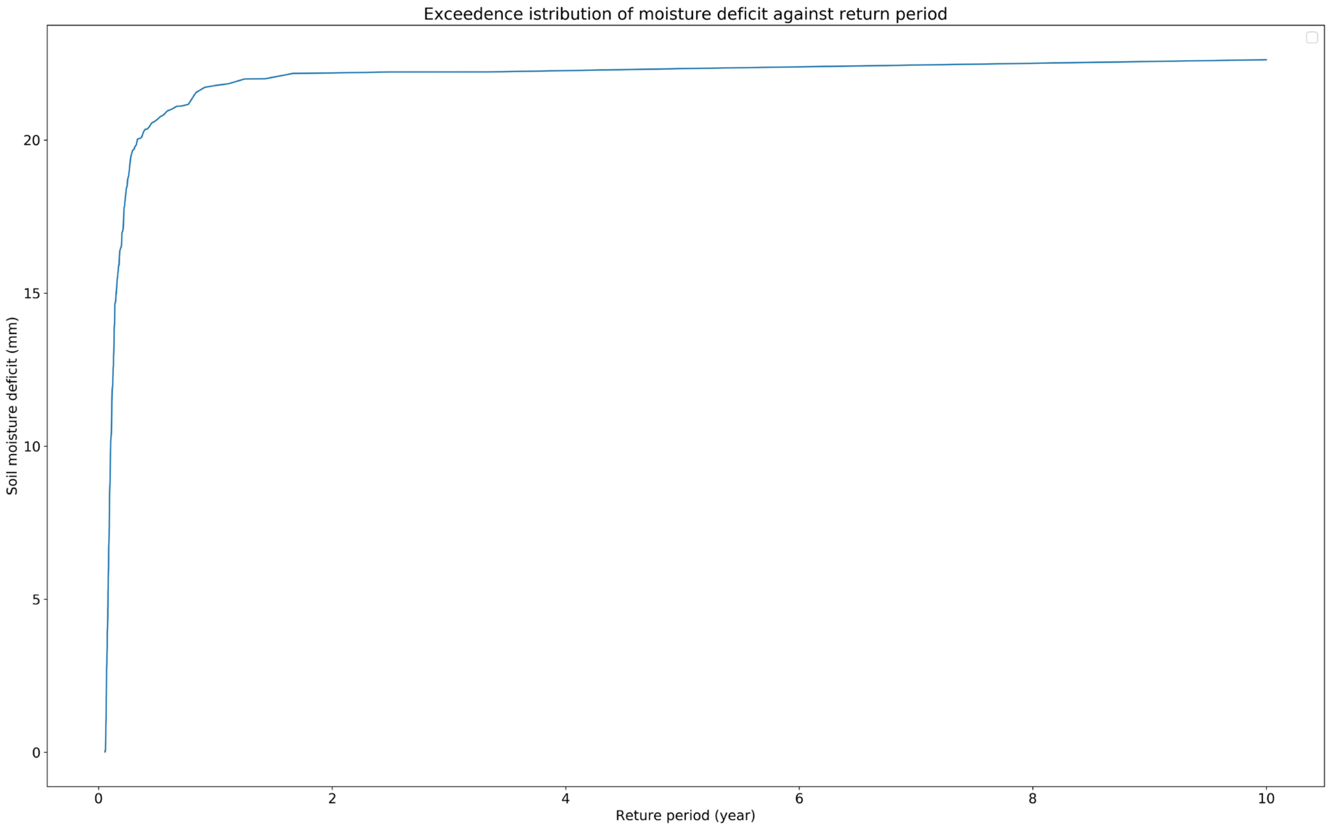

Figure 47 Exceedance distribution of extreme moisture deficit against return period

34 Note that unpaved ratio is 0.2. If 3.6 mm/d recharge takes place over entire catchment, the effective recharge on unpaved area is 3.6*0.2 = 0.72 mm/d, assuming recharge on other landcover becomes runoff and is drained away.

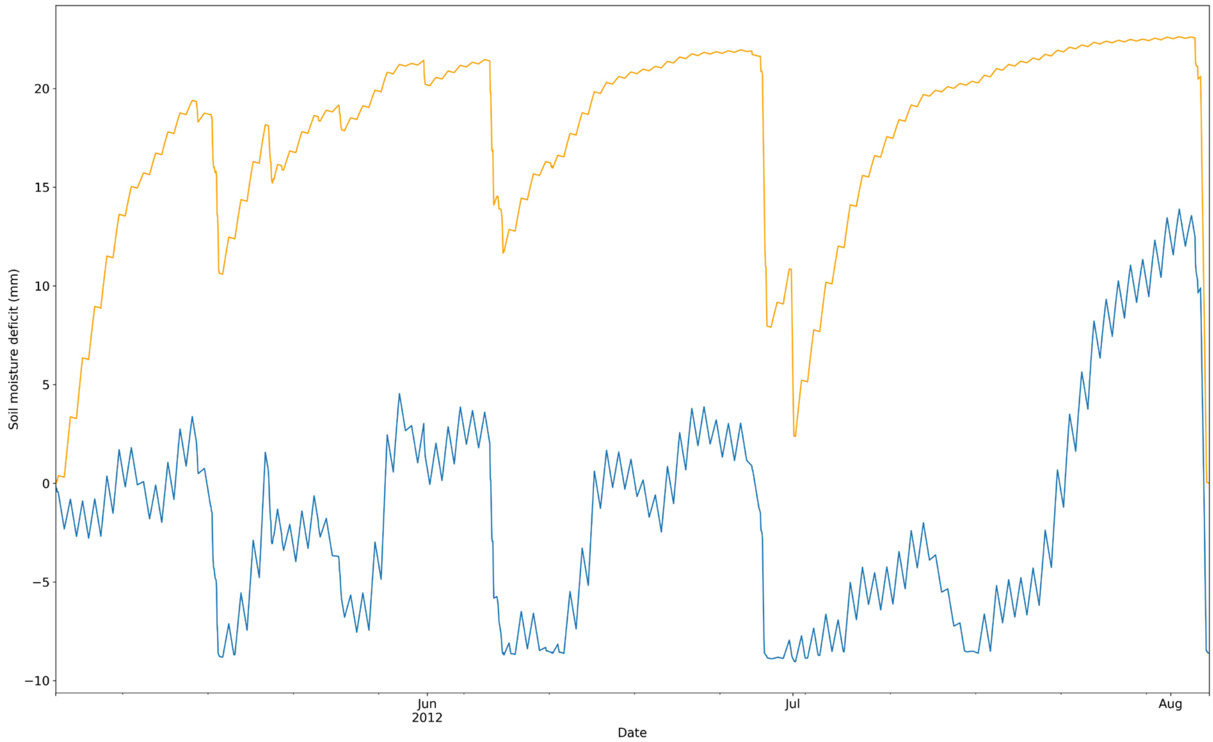

Figure 48 Soil moisture deficit before adding recharge (in yellow) and after adding recharge (in blue).

6.4.3 Groundwater level

An exceedance frequency distribution of groundwater level against time was derived from dynamic results of UWBM (see Figure 49). For example, for 40% of the time, groundwater level is higher than 1.6 m[35]. Based on this kind of curve, planners can choose a certain groundwater level to control. However, as mentioned before there is not monitored data concerning groundwater table available, which means this analysis is not supported by calibration and validation. Moreover, available information in this project are not sufficient for making decisions on groundwater management or setting groundwater recharge target in CRCT.

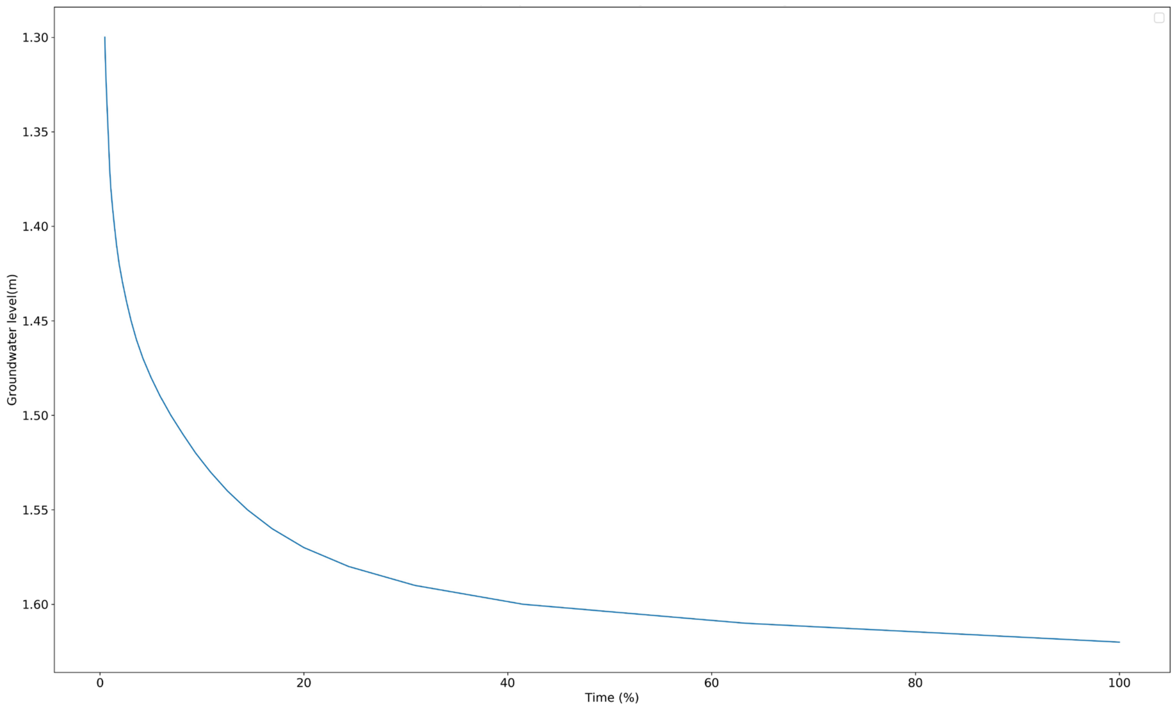

Figure 49 Exceedance frequency distribution of groundwater level against time.

35 It means the distance between groundwater table and surface level is less than 1.6 m.

6.5 Sponge pre-selection

Based on planning principles, a bundle of sponge measures is selected for four typical urban topologies considering space availability and planning restrictions (see Table 7). Table 7 also includes the expected responsible authority in Nanjing for each of the adaptation measures and the bureaus that are possibly (to be) involved in planning, design, implementation and maintenance of these facilities in a more co-ordinating way. Clearly, the introduction of multiple sponge solutions is not in the hands of a single bureau but requires co-ordination with others as well as with representatives of the local population and businesses. It underpins again that a collaborative co-design workshop with relevant stakeholders is needed.

Sponge measures	Old City Centre	New built - airport area	Historical park, commercial / office and residence	Infrastructure (main roads)	Main responsible authority in Nanjing (in theory)	Possible co-ordinating authorities	Remarks
Fountains, water facades	Less or not applicable	More widely applicable	applicable in some situations	Less or not applicable	greenery&parks bureau	housing and urban&rural development bureau	
Green facades	Less or not applicable	More widely applicable	applicable in some situations	Less or not applicable	housing and urban&rural development bureau	greenery&parks bureau	for heat stress and landscaping
Creating shade (trees, overhangs…)	Less or not applicable	More widely applicable	applicable in some situations	Less or not applicable	greenery&parks bureau	city administration and comprehensive lao enforcement bureau; transport bureau	for heat stress and landscaping
Adding trees to street-scape	Less or not applicable	More widely applicable	applicable in some situations	More widely applicable	greenery&parks bureau	city administration and comprehensive lao enforcement bureau; transport bureau	for heat stress and landscaping
Rain garden	Less or not applicable	More widely applicable	applicable in some situations	Less or not applicable	greenery&parks bureau	city administration and comprehensive lao enforcement bureau; housing and urban&rural development bureau	tree-pit bioretention cells
Gravel layer (infiltration trench)	Less or not applicable	More widely applicable	applicable in some situations	More widely applicable	transport bureau	housing and urban&rural development bureau	
Bioswale (with underdrainage)	Less or not applicable	More widely applicable	applicable in some situations	More widely applicable	greenery&parks bureau	city administration and comprehensive lao enforcement bureau; housing and urban&rural development bureau; water affairs bureau	
Storage by extra freeboard	More widely applicable	More widely applicable	More widely applicable	Less or not applicable	water affairs bureau	development&reform comission; housing and urban&rural development bureau	
create extra surface water (m2)	applicable in some situations	More widely applicable	More widely applicable	Less or not applicable	water affairs bureau	natural resource & planning bureau; environmental protection bureau; development&reform comission; housing and urban&rural development bureau	
rainwater detention pond (wet pond)	applicable in some situations	More widely applicable	More widely applicable	Less or not applicable	water affairs bureau	housing and urban&rural development bureau; natural resource & planning bureau; environmental protection bureau; development&reform comission	
Water square	Less or not applicable	More widely applicable	applicable in some situations	Less or not applicable	housing and urban&rural development bureau	water affairs bureau; city administration and comprehensive lao enforcement bureau; development&reform comission	
Urban artificial wetland	applicable in some situations	More widely applicable	More widely applicable	Less or not applicable	water affairs bureau	housing and urban&rural development bureau; natural resource & planning bureau; environmental protection bureau; development&reform comission	
Remove pavement & plant green	More widely applicable	applicable in some situations	More widely applicable	Less or not applicable	transport bureau	greenery&parks bureau; housing and urban&rural development bureau	
Bioretention cell	applicable in some situations	More widely applicable	More widely applicable	applicable in some situations	greenery&parks bureau	city administration and comprehensive lao enforcement bureau; housing and urban&rural development bureau; water affairs bureau	
Rain barrels / rain tanks	More widely applicable	More widely applicable	More widely applicable	Less or not applicable	housing and urban&rural development bureau		
Urban agriculture	Less or not applicable	applicable in some situations	Less or not applicable	Less or not applicable	housing and urban&rural development bureau	city administration and comprehensive lao enforcement bureau; greenery&parks bureau	
Lowering garden / park / green belt	applicable in some situations	More widely applicable	applicable in some situations	applicable in some situations	greenery&parks bureau	housing and urban&rural development bureau	
Infiltration boxes	More widely applicable	More widely applicable	More widely applicable	More widely applicable	water affairs bureau	housing and urban&rural development bureau	
Drainage-Infiltration-Transport (DIT) drains	More widely applicable	More widely applicable	More widely applicable	More widely applicable	water affairs bureau	housing and urban&rural development bureau	in combination with subsurface (DIT) drainage for groundwater level control
Permeable pavement	More widely applicable	More widely applicable	More widely applicable	More widely applicable	transport bureau		
Green roof (extensive)	applicable in some situations	applicable in some situations	More widely applicable	Less or not applicable	housing and urban&rural development bureau		
Green roof with drainage delay	applicable in some situations	More widely applicable	applicable in some situations	Less or not applicable	housing and urban&rural development bureau	water affairs bureau	
Water roof ('blue roof')	applicable in some situations	More widely applicable	More widely applicable	Less or not applicable	housing and urban&rural development bureau	water affairs bureau	
Rainwater harvesting system	applicable in some situations	More widely applicable	applicable in some situations	Less or not applicable	water affairs bureau	housing and urban&rural development bureau	
Trenches along roads	Less or not applicable	More widely applicable	applicable in some situations	More widely applicable	water affairs bureau	greenery&parks bureau; housing and urban&rural development bureau; city administration and comprehensive lao enforcement bureau; transport bureau	
Lowering roads('hollow road profile')	More widely applicable	More widely applicable	More widely applicable	More widely applicable	transport bureau	water affairs bureau; housing and urban&rural development bureau	

Table 7 Sponge measure selections for four topologies and responsible authorities for implementation and maintenance.

Legend

- Less or not applicable
- applicable in some situations
- More widely applicable
- housing and urban&rural development bureau
- environmental protection bureau
- greenery&parks bureau
- transport bureau
- water affairs bureau
- development&reform comission
- city administration and comprehensive lao enforcement bureau
- natural resource & planning bureau

6.6 CRCT co-design

XCRCT was used by LOLA team to design test cases. One example area in urban topology type 1 is shown in Figure 50. By adding sponge measure combination of biological retention tanks, infiltration boxes, water square, hollow roads and lowered garden, the test area can reach 102 mm storage requirements (return period of 50 years) and have co-benefits such as groundwater recharge (0.71 mm/d in average), runoff control and runoff pollution mitigation, etc. (see Figure 51). Such measures in old city centre aim to not only mitigate flooding and drought, but also to improve urban ecology and environment, especially biodiversity. Blue and green spaces in water square and lowered garden, with aesthetic appeal, can create opportunities for social interaction and recreation activities, which enhance day-to-day values of those measures in addition to their hydraulic or ecological functions.

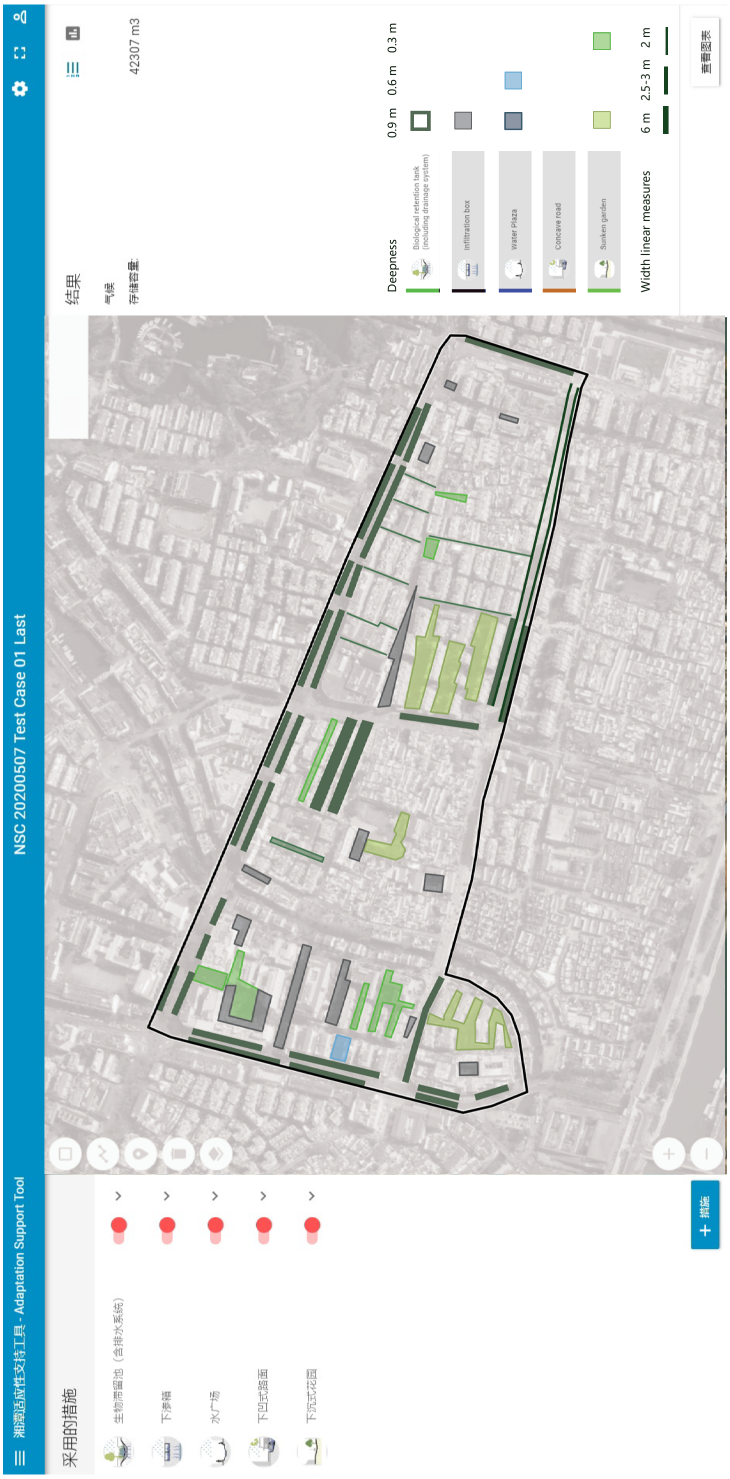

Figure 50 Sponge interventions of a test area in topology 1. Credit: LOLA.

6.7 Evaluation by InfoWorks model

The flooding situation after sponge capacity of Qinhuai District is shown in Figure 52. Compared with current flood hazard map of current scenario in Figure 38, the inundation areas are significantly less. Some of the remaining modelled inundation areas may result from incomplete input of sewer pipes in model configuration. For example, sewer pipes in area 7 and 8 are not included in the model building due to the lack of data, which means the stormwater ponded in those areas cannot be drained by the pipes in the model.

result

CLIMATE AND COSTS | CO BENEFITS

Measures	surface	Storage capacity (m3)	Increase coefficient of runoff recurrence period (+1)	Groundwater supplement (mm / y)	Evaporation (mm / y)	Reduce heat (C)	Cool place	Construction cost (yuan)	Maintenance cost (yuan)
Biological retention tank (including drainage system)	9537.51	3338	0.6	43	1	0.07	0	4291880	193135
Infiltration box	16,657.13	15477	1.26	156	0	0	0	94945649	30192716
Water Plaza	980.28	735	1.01	0	0	0.01	0	24262043	2620301
Concave road	5690.5	1707	0	0	1	0	0	1024290	138279
Sunken garden	23389.21	21050	2.63	61	3	0	0	3508382	210503

result

CLIMATE AND COSTS | **CO BENEFITS**

Measures	surface	Reduce pathogens (%)	Reduce nutrients (%)	Absorbed pollutants (%)
Biological retention tank (including drainage system)	9537.51	2	2	2
Infiltration box	16,657.13	4	3	4
Water Plaza	980.28	0	0	0
Concave road	5690.5	0	0	0
Sunken garden	23389.21	3	1	3

Figure 51 Estimated performance and co-benefits of sponge interventions of a test area in topology 1. Credit: LOLA.

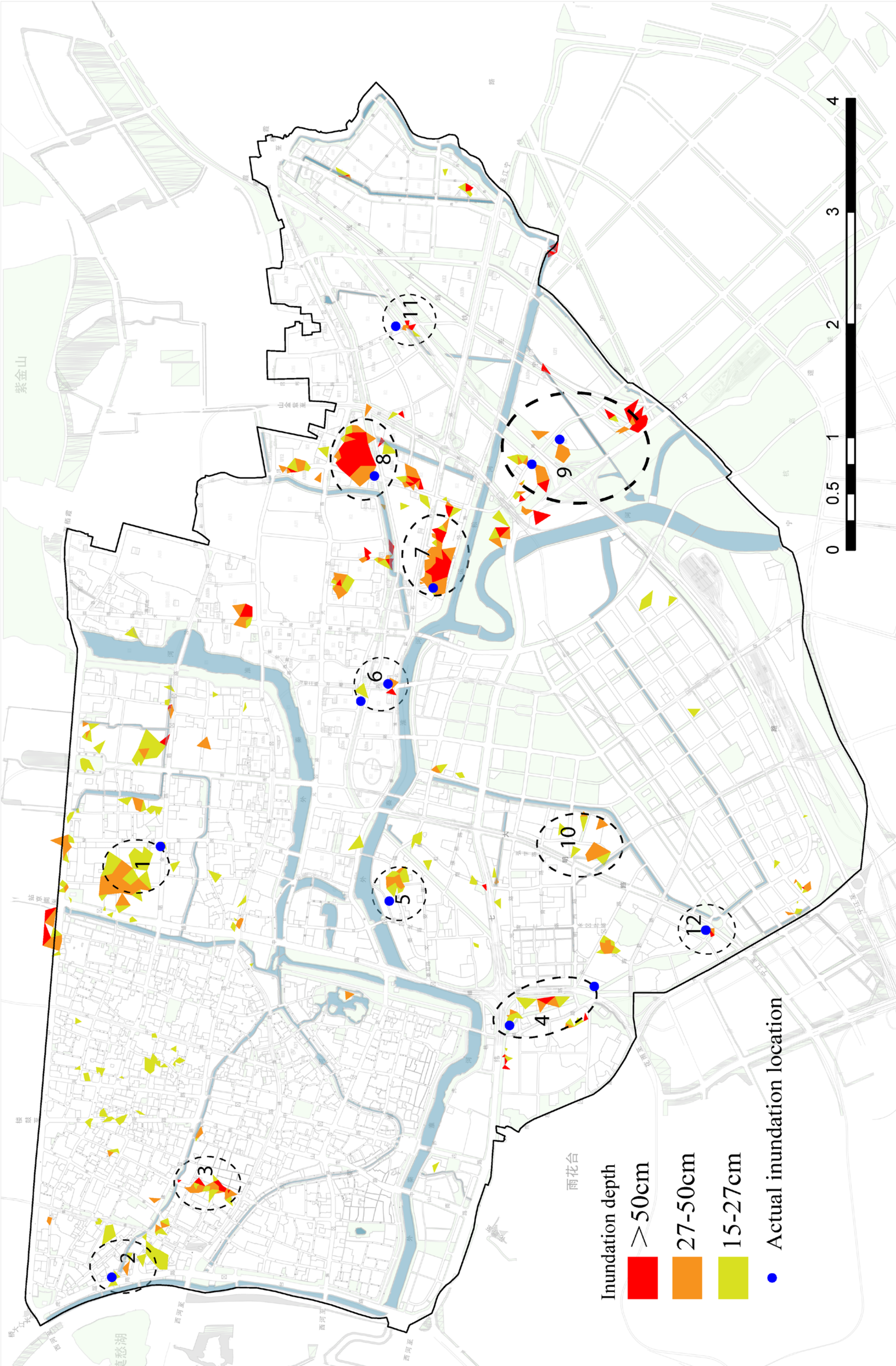

Figure 52 Flood hazard map after sponge volumes are added. Figure credit: NHRI & AZI

Chapter 7: Discussion

This chapter firstly evaluates the new improved sponge design approach based on the Nanjing Qinhuai District case study; Secondly, the limitation of this new improved approach is discussed; Thirdly, the methodological approach followed in this thesis is discussed.

7.1 Evaluation of improved sponge design approach

The case study adopts pre-proposed sponge design approach, including proposed design process, sponge capacity calculation method, localized planning principle, and importantly, the multidisciplinary contributions.

7.1.1 Design process & sponge capacity calculation

The case of Qinhuai sponge city planning follows most of steps in the design process (Figure 19), while some steps are hard to take. In this section, the proposed sponge design process in the case study is evaluated stepwise to discover the values and limitation of the approach. Please refer to Figure 19 in Page 44 for your understanding of this evaluation.

Step 1 and 2 are successfully performed, except for the stakeholder analysis. Available information is not sufficient for a comprehensive stakeholder analysis in Nanjing, though overviews are presented concerning the governance roles of different Nanjing bureaus during different project phases (see Figure 13) and theoretical responsibility of authorities in implementing various sponge measures (Figure 42).

In step 3, Urban Water Balance Model and InfoWorks in sponge design toolbox are able to analyse water systems and facilitate to calculate sponge capacity requirements. UWBM models the dynamics of water components (open water level, groundwater level, and soil moisture contents) and provides information for determining sponge capacity targets (by SDF curves and drought analysis); SDF method have been applied in some studies (Kuijk, 2014; Molenaar, 2015; Zhang, 2019) . Since there is no monitoring data available in this project; hence, calibration and validation of modelling results cannot be performed. Moreover, it is assumed in UWBM, as a lumped conceptual model, that properties of the whole catchment and climate conditions are spatially homogeneous, which is not the case in the reality. Therefore, results of UWBM have a certain level of uncertainty, which could affect reliability of sponge capacity targets. Data availability also exerts impacts on InfoWorks modelling in the project. As mentioned in Section 6.7, incomplete data input of sewer pipes might be the reason why there still some severe flooded areas after required storage capacity is applied. Additionally, insufficient and inaccurate data of land level, river cross-sections and pump station operation conditions affect flood hazard modelling results as well. At Step 3.4, localized design principles are developed by the design team involving water managers and landscape architects based on analysis of water and spatial system. At Step 3.5, catchment division is done by comprehensively considering discharge capacity distribution of pumping stations, sewer drainage division, land use types, soil types, and administrative divisions. By doing so, the conflicts between sponge city division and administrative management unit or spatial planning control unit can be prevented. Moreover, insufficient background information of sponge city governance in Nanjing cannot support a thorough governance system vulnerability analysis (PRIMO-chain analysis) in the case study.

At Step 4, the water system dynamics simulated from UWMB are used to set sponge design targets. Substantial amount of required storage capacity (86 mm for the whole district) is derived from SDF curves for pluvial flooding prevention of 50-year return period. Despite of the fact that huge storage volumes are needed, there are still enough spaces, either above ground or underground, available for implementing sponge interventions, as the example case shows in Section 6.6. Drought analysis can give an estimation of how much irrigation recharge is required for mitigating extreme soil moisture drought of soil moisture contents. Based on that amount of required irrigation recharge, sponge measures can be designed to store stormwater during wet spells and reuse the water in the dry spells. It should be noted that such Threshold Level Method (Van Loon, 2015) uses constant threshold level to derive moisture deficit without consideration of natural seasonal variation of moisture contents, which may give biased results of drought events identification. It uses simplified method of adding continuous rainfall with constant intensity to mimic the effects of artificial irrigation during drought events, while the situation in the practice is more complicated considering dynamic recharge, inflow and outflow of stormwater in storage measures, etc. As UWBM is a lumped model, soil moisture is assumed to be the same over entire catchment area, which is spatially diverse in reality. Therefore, this method gives an estimation of required recharge which can be used as a criterion to select sponge measure to mitigate extreme drought damage, however, more accurate dynamic modelling is needed for designing detailed dimensions of sponge measures to realize required recharge capacity. As for groundwater management, whether simulated groundwater level variations are able to support decision making of controlling groundwater table is not tested by the case study due to unavailable monitoring data. Additionally, limited monitoring data of water quality hinders problem assessment and evaluation of sponge measure effectiveness.

During sponge pre-selection process at Step 5, the design team shortens the list of potential sponge measures based on water and space systems analysis in previous steps. The applicability of pre-selected measures in relation to urban topology is studied as well, which provides guidance for following design steps. However, due to spatial restrictions in Qinhuai District, the types of sponge interventions in Qinhuai District are very limited. Structural changes cannot be made in public spaces (e.g. removing pavement to plant green) and interventions cannot be proposed in private properties (e.g. green roofs).

The co-design workshop is not able to be organized as planned in the project, which means the perception and contribution of local stakeholders are not available for evaluation. According to the workshop in Xiangtan City (van de Ven et al., 2020), the XCRCT can be successfully applied into the planning & design of two pilot areas of sponge city, but the feasibility of such planning support toolbox in Nanjing and other cities should be further studied. The landscape architecture team uses XCRCT tool to make a conceptual design of an example area, the estimated performance of which indicates available spaces can still achieve the storage capacity requirement, together with other co-benefits and values. However, as mentioned before, the water quality and groundwater targets are difficult to set due to data availability issues, therefore, the performance of sponge measures cannot be thoroughly evaluated. Moreover, before using the toolbox, the parameters in CRCT should be tailored based on local catchment properties. Since this process is not included in the project scope, an alternative is to use XCRCT, which was customized to Xiangtan City, in the Qinhuai project, assuming both areas share similar climate and catchment similarities. However, such assumption may lead to systematic errors of modelling results.

InfoWorks model is used in many cases to evaluate sewer hydraulic load and flooding hazard after adding required storage capacity into current scenario (Nanjing Municipality, 2018; THUPDI, 2019). Instead of implementing sponge measures individually, InfoWorks model in Qinhuai project takes a simplified method that using initial loss to represent the storage capacity of sponge measures, which definitely exerts impacts on results. The results show a significant reduction of inundated areas due to the introduction of storage volume, however, there still are severe flooded areas, which might be resulted from incomplete sewer pipe input in the model configuration. Model calibration and validation cannot be performed due to limited data, which makes model results less reliable.

Additionally, the case study fails to include future scenarios, e.g. climate change, population growth, in the planning and design process. On the one hand, there is no localized future scenarios available for Qinhuai District; on the other hand, the awareness of decision makers to consider adaptive capacity of sponge city has to be aroused.

To sum up, most of the improved planning and design contents are performed successfully by the case study, which indicates it can be applied to improve SC integrated water management, while the data availability significantly affects reliability of model results, which underlines the importance of monitoring data (Li et al., 2017). It is found that there is limited information to support adaptive capacity building, and the awareness of such capacity should be aroused. Moreover, the contribution of co-design workshop is claimed necessary in literatures (Jiang et al., 2018; van de Ven et al., 2016), and is also proven valuable in Xiangtan sponge city planning practice (van de Ven et al., 2020) and other co-design workshops for climate resilience planning (McEvoy, 2019; McEvoy, van de Ven, Brolsma, & Slinger, 2019; McEvoy, van de Ven, Santander, & Slinger, 2019). In the case study, the necessity of having such co-design workshop also rises up. Hindrance of making sponge designs in overlapping areas in hand of different departments (public space, road, etc.) and private properties, as well as the gaps in acceptance of sponge design principle requires a participatory workshop to trigger the discussion amongst designers, different authorities, local inhabitants, etc. However, this case study is not able to include co-design results due to the COVID-19 pandemic.

7.1.2 Planning principles

The principle 'retain & detain first' was not well-accepted by decision makers from relevant authorities, since the concept of 'never shift problems' is not widely known and accepted in China and 'quick drain' model is still believed to be the solution against pluvial flooding. Such obstacles would restrain the application of Sponge City concept in planning and design.

As mentioned in the previous section, the space restrictions limit the diversity of sponge measures concerning intervention types and locations. Therefore, more political and social participation could be involved in the co-design workshops to explore the possibility to make sponge interventions not only for mono-functions, but also for day-to-day values (Fratini et al., 2012).

7.1.3 Multi-disciplinary contributions

In the case study, four parties work closely on sponge city planning principles, sponge measures selection, develop design strategies based on site analysis results, etc. Instead of linear collaboration method between water management and landscape architecture (Zhu, 2020), this case study demonstrates the valuable process of multi-disciplinary cooperation, which contributes to making a sponge plan with attention on water safety, ecology, recreation, culture, etc. The importance of such multi-disciplinary contributions is also mentioned in literatures (Xia et al., 2017; Xiang, Liu, Shao, Mei, & Zhou, 2019). This study can set as an example of organizing sponge planning and design through multi-disciplinary efforts, and it is promising to involve more disciplines in planning and design process, e.g. urban planning, transport, subsurface, etc.

7.2 Limitations of the new sponge design approach

Based on the evaluation of the case study, limitations of the new sponge design approach are listed as follows:

1. **Data availability**
   The new approach requires sufficient spatial and temporal data to support water system analysis, which might not be available currently in Chinese cities.

2. **Model uncertainty**
   Sponge design toolbox, integrating three types of models which are intrinsically linked and have various assumptions, has uncertainties from model conceptualization, input and calibration process (Nguyen, Ngo, Guo, & Wang, 2019).

3. **Planning & design contents**
   The proposed design approach adds methods of storage sizing for pluvial flooding prevention, drought analysis and groundwater level analysis to current planning & design contents, but improvements on current water quality assessment methods and biodiversity enhancement are not proposed.

4. **Spatial applicability**
   The new approach is only tested for Qinhuai District, Nanjing City, where flooding issues are dominant in wet season. The application results of this approach to other cities with different climate conditions and catchment properties are uncertain. For example, in cities with semi-arid climate, the use of detailed hydraulic modelling may not be necessary, since water shortage is more important issue rather than flooding, which means drought model or stormwater reuse model is needed. Therefore, the toolbox, process and focus of planning should adapt to different cases in specific.

5. **Stakeholder involvement**
   The new approach assumes that co-design workshop participants need and are open to discuss together on sponge design. However, limited researches are available to assess the opportunities and constraints of having sponge city co-design workshops in China. Therefore, the results of applying this new approach to Chinese cities are uncertain.

6. **Multi-disciplinary collaboration**
   The design approach is structured based on disciplines of urban water manage and landscape design. However, some steps might differ in practices if the project involves other disciplines. The collaboration mechanism for more disciplines during the planning and design steps (before co-design) is not given in the new approach.

7. **The role of SC planning**
   The approach expects that SC plan acts as a lightening-rod to help co-ordinate and integrate current urban water management systems (Chan et al., 2018), while if SC planning has such role in practices is questionable.

8. **Limited materials used in analysis**
   The new approach is proposed based on the analysis of challenges and gaps in Nanjing SC planning & design guidelines and plans. In other cities, the challenges and gaps might differ from the city of Nanjing, which means the design approach needs to be customized based on local conditions.

9. **Limited PRIMO-chain governance evaluation**
   Good governance considering all aspects of PRIMO-chain is important for supporting SC concept implementation (Xia et al., 2017). To some degree, we were able to evaluate the sponge design approach to urban water management in the light of existing and new policies and regulations. However, we were not in the position to evaluate the local capacity (expertise, skills) to implement, operate, monitor and maintain the measures that we have included in our plan, nor did we have the possibility to evaluate the organization and financing of this new approach to urban drainage and water management.

10. **Limited guidance on building adaptive capacity**
    Building adaptive capacity is missing in current SC design approach. The new approach proposes a principle of 'design for resilience to increase adaptive capacity and mentions future scenarios (e.g. climate change and landscape change) can be considered when calculating SDF curves to determine required storage capacity. However, more detailed methods on how to assess current adaptive capacity and how to increase adaptive capacity are not included in this approach.

In future research, the feasibility of the new design approach can be assessed by more applications in Chinese cities, and exploration on how to plan and design a sponge city to reach multiple objectives with multi-disciplinary efforts can continue.

7.3 The methodological approach

This thesis research followed a stepwise method of 'information collection' – 'analysis' – 'improvements' – 'verification', in order to understand current Sponge City concept and its implementation, evaluate gaps in current planning & design practices, propose a new improved design approach and test the approach via a case study. Three analysis method, i.e. literature review, interview and planning & design framework, were designed to understand current SC concept and implementation.

Through analysis of recent literatures concerning SC concept essence, the pattern of terminology development was able to be found. However, there is a limited number of literatures and governmental materials which study the essence and interpretation of SC concept, as SCP was promoted by the government recently. Hence, such literature study may not reflect the complete picture of SC concept development. Cases in literatures that are summarized in this thesis are not enough to understand SC planning & design for different cities and different land types.

Semi-structured interviews with three SC practitioners with diverse background shed light on difficulties of implementing SC concept in practice from different disciplines' point of view. One of the limitations of the interviews is that the three interviewees were involved in limited SC projects and project phases, which means three interviews cannot cover enough questions on different types of SC projects in different cities. Moreover, other disciplines, for example transport, ecology, economy, etc., were not engaged in the interviews. In other words, the qualitative analysis of the interviews with the three SC practitioners are not sufficient to reflect all problems in current SC concept and practice and cannot be supportive to make comparisons amongst different disciplines. More stakeholders from more disciplines and/or authorities are needed to be interviewed in the future to have a holistic understanding on SC design, implementation and governance.

Specific information were studied in this thesis concerning planning & design contents and process in SC implementation of Nanjing City. The evaluation through the study of SC planning & design framework in Nanjing can shed light on gaps and challenges, which indicated potential improvement for the new SC approach. However, SC implementation situation in other cities might differ from Nanjing, which means the new improved SC approach proposed in this thesis should adapt to local conditions.

Chapter 8: Conclusions & recommendations

8.1 Conclusions

Driven by three key research questions, this master thesis dives into a research on theory and practice of Chinese Sponge City Programme (SCP) with a focus on planning and design phases.

Sponge City has been evolving from a term mainly describing measures with ecological benefits towards a more inclusive urban development paradigm, considering not only water ecology, but also water safety, water environment and water resource (Figure 9). The scope of current SC concept extends LID and SuDS and is closer to WSUD and WSD. However, missing components in current Chinese SC guidelines include subsurface and groundwater, amenity and biodiversity, climate scenarios. Moreover, 'never shift problems' and other principles of Dutch water management are not included in current SC guiding principles. Current storage capacity calculation method in SC practice is mainly done by indicators or empirical index. Using the ecological indicator VCRa to calculate storage volume for controlling small and medium rainfall is proposed in guidelines and widely applied in practice. However, there is a lack of operationalizable sponge capacity calculation method to mitigate flooding and drought issues in current SC approach.

Sponge city planning bridges water management and urban development planning using indicators to guide and evaluate interventions. Indicators are downscaled with the divisions at various scale (city-district-neighbourhood). Obligatory indicators and recommended indicators are distributed to each control unit in detailed control planning and must be respected by land developers during land lease process and following design and construction phases. However, indicator system proposed in current national or local guidelines and current design process are not sufficient for comprehensive considerations of water system components, water surplus and deficit, amenity and biodiversity, as well as enhancement of stakeholder involvements and good water governance. The crucial gaps of current SC water management and challenges of planning & design framework to support comprehensive design were identified (as listed in Section 3.2.3). Inter-disciplinary cooperation varies amongst different SC projects based on interview results; some projects have more inter-disciplinary cooperation than others. Different authorities are involved in administrative examination and approval to make sure projects achieve SC requirements. Sponge Office and/or other related authorities shall check dimensions, types, layouts and other elements of sponge design and construction, and especially appraise those performance indicators, before issuing any planning or construction permits. But during this examination and approval process not all aspects of the PRIMO – chain for good water governance are covered.

Therefore, it is necessary to propose an improved sponge design approach, complementary to current indicators system, to provide supports for making integrated planning and design. The proposed new approach includes improvements on contents and process of SC planning & design, facilitated by the proposed sponge design toolbox containing a hydrologic model (e.g. UWBM), a hydraulic model (e.g. InfoWorks) and a Planning Support System (e.g. CRCT). Required sponge capacity can be calculated by this new approach. The obtained SDF curve from UWBM is the basis of estimating the required storage capacity in an area in view of the existing or future stormwater discharge capacity. Involved actors are enabled to work on conceptual design based on the information of required storage and discharge that SDF curves indicate. The Threshold Level Method can be used to calculate dynamics of soil moisture deficit. The mitigation of moisture deficit can be assessed by adding certain amount of rainfall during the selected extreme drought timespan as a representation of irrigation recharge. That amount of 'recharge' is proposed to be used as one of sponge capacity requirements, which indicates how much storage should be designed to irrigate unpaved areas during dry spells. Inter-disciplinary cooperation can be enhanced by the proposed design approach as well, during which water engineers, water managers and landscape architects can separately work on site analysis, then jointly develop design principles and make sponge intervention pre-selections. Theoretically, a co-design workshop is needed to trigger discussion, understanding, knowledge exchange and other communications amongst different stakeholders and disciplines. The challenges encountered in planning and design sponge measures, due to spatial restrictions and acceptance of the principle 'never shift problems' (and, consequently, 'retain & detain first') by decision makers, verifies such need of a participatory co-design workshop. Inter-disciplinary cooperation is also required for good water governance. Not only the technical and spatial aspects of the sponge design process ought to be addressed in the planning process; also, the 'soft' side – policies, regulations, expertise, skills, organization, financing mechanisms – need to be in place for a successful implementation of the sponge city approach.

To sum up, the new design approach can contribute to a more integrated SC planning and design.

Based on the thesis research process and results, those three key research questions can be answered:

1. How to evaluate current Chinese SC planning & design framework?

   Based on the study of national and local guidelines and planning materials of SC in Nanjing, the planning & design framework can be illustrated using two axes: spatial scales and project phases. Connections between SC plans and other sector plans, the downscaling process of indicators and responsibility of various authorities during project phases are mapped in the framework. Challenges and gaps of Current SC planning & design framework to support a comprehensive sponge design approach are assessed based on the framework as well.

2. How to assess and design the required sponge capacity to mitigate pluvial flooding, as well as water shortage during dry spells?

   Sponge capacity calculation methods are not available in guidelines, neither in current sponge city planning & design. The criterion of pluvial flooding prevention is proposed by certain return period but no design criteria concerning water shortage. SDF curves are able to support the design of required sponge capacity for pluvial flooding by finding required storage volume after determining discharge capacity and selecting target return period. As for water shortage mitigation design, the soil moisture drought analysis by UWBM can be performed to estimate required irrigation recharge. Both of storage volume for pluvial flooding prevention and irrigation recharge for drought mitigation can serve as design objectives of sponge measures.

3. How to improve the current SC planning & design framework to support multi-disciplinary involvement and realize multiple objectives of SC?

   Improvements are proposed at two angles, i.e. planning & design contents and organizational aspects of planning & design process. Eight improvement suggestions corresponding to the eight challenges/gaps are listed in Section 4.5.

8.2 Recommendations

Sponge city is a completely new concept to China. Its implementation at all levels of governments requires substantial efforts from multiple disciplines to make it thrive. Not only water managers should take responsibility to explore best practices of sponge design approach, other disciplines, such as landscape architects, transportation managers, economists, contractors, policy makers, etc. ought to work together and communicate more on systematic planning and design of sponge projects. Earlier stage SC concept cut in, more co-benefits the design will bring. As the new improved sponge design approach is only tested by one single project, the strength and weakness can be further studied through more applications to other cities and to other spatial scales. Here are some recommendations for future researches concerning modelling, institutional, and other aspects to improve sponge design approach:

1. Data is essential. Available and accessible data to the public would benefit sponge city studies and development.
2. More stakeholders should be involved in sponge planning & design, not only various bureaus, departments and offices from various authorities, but also local inhabitants, NGOs, etc.
3. Sponge Office and other departments could collaborate more in making sector plans, so that the consistence of different plans can be enhanced. In order to better bridge sponge city planning and other sector planning, more leading competence can be given to Sponge Office.
4. Cities with different climate and catchment properties should explore their own sponge measure design strategies that fit into local conditions.
5. Cities with similar climate as Nanjing should realize that the volume of required storage for pluvial flooding prevention is indeed substantial – as they regularly receive very extreme rainfall volume – every piece of land should be carefully planned and maximize its multifunction following SC concept.
6. More efforts should be spent to explore how to make Xiaoqu take more responsibility of flood runoff mitigation.
7. Models in proposed calculation method of required sponge capacity should be calibrated based on local conditions.
8. Both decision makers and designers should know what the essence of SC is to avoid paying too much attention or having

misunderstandings on indicators.

9. Incorporating sponge requirements into detailed control planning makes it onerous to downscale VCRa, WSR and other indicators even to the block level, which may restrain innovations in design. More flexibility can be given to local level, enabling more diverse sponge solutions. On the other hand, the question to what extent using indicators is helpful to design process should be studied.
10. Sponge city is a long haul which needs stepwise planning strategy. Capacity building and learning by doing (and evaluating) are essential components of the introduction, not only for the planners and designers, but also for the constructors, operators and maintenance staff for the new sponge city measures.

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Annex

A. Planning principle and water culture strategies

Translated planning principles in Nanjing (NPNRB, 2018):

1. **Priority on planning**
Update the concept of urban planning and construction, insist equally on ecological measure and engineering methods, combine 'green' measures and 'grey' facilities to realize transformation of urban drainage from 'quick discharge, end-of-pipe concentration' to 'slow release, at-source dispersion'. In the process of preparing all levels of the city and related professional plans, fully implement the requirements of the sponge city construction, rationally plan and lay out the city's Low Impact Development system, scientifically formulate the relevant control goals and indicators of the sponge city, and serve as the planning conditions for the land right transfer.

2. **Priority on ecology**
Strictly manage the urban blue and green lines[36]; strengthen the protection and construction of rivers, lakes and green areas; actively adopt natural drainage methods; make full use of the city's ability of natural accumulation, infiltration and purification of stormwater, and enhance the natural restoration and circulation capacity of urban water ecology.

3. **Adaptation to local conditions**
Combined with the urban function layout, hydro-geological conditions, water environment needs, and infrastructure conditions of different areas in Nanjing, in the construction process of urban roads, squares, parks, green spaces, buildings, etc., the functions, cost, and landscape effects of various types of sponge facilities are comprehensively considered according to local conditions, reasonably adopting different engineering measures and ecological techniques.

4. **Holistic construction**
Newly developed urban areas and newly constructed projects strictly implement the simultaneous design, simultaneous construction, and simultaneous operation of sponge facilities and main projects in accordance with the control objectives and indicator requirements of the sponge city; sponge city construction in old city areas combines road renovation, shantytown renovation, Xiaoqu[37] renovation, drainage improvements, flooded area transformation, and watercourse renovation, etc.

5. **Equal emphasis on construction and management**
Strengthen the management of sponge city construction, fully consider the overall, complex and long-term nature of sponge city construction, establish a project back-up system, and promote the construction of urban related infrastructure in a scientific and orderly manner to avoid major demolition and large-scale construction. Strengthen the transfer and maintenance of established sponge facilities, actively build a sponge city information supervision platform, improve the evaluation system, implement supervision responsibilities, and give full play to the comprehensive benefits of completed sponge facilities.

Translated water culture strategies (Nanjing Municipality, 2018):

1. **Discover traditional water spaces**

   1) Maintain the accessibility of historically protected areas and traditional streets & markets:

      Accessibility should be considered when renovating historical buildings or district in at waterfronts. For historical buildings, the priority of consideration is to transform them to public buildings for public services; For traditional districts of water town, the transformation is advised to combine with local blocks for public activities.

   2) Protect historical relics related to water:

      Protect water related heritage, such as harbour, river quay, bridge, weir, etc., which are unique historical elements in water towns and should be conserved intact. Riverfront cultural sceneries are retrospective to people concerning the history of Water Towns in South of the Yangtze[38]. Retrofit riverfront areas with functionality adjustment. Present those areas with historical cultural values as well as new functions.

36 Lines with different colours are used to divide different land types. Blue lines are protective boundaries of water bodies, whereas green lines are protective boundaries for ecology and environment. Source: *Urban Planning Principles* (Z. Wu & Li, 2010)
37 Xiaoqu (小区), literally micro district, is a typical Chinese model of residential area, which is often enclosed by a wall, with the entrance gate being guarded. Inhabitants collectively own and have the right to manage public space in the Xiaoqu they live.
38 Water Towns in South of the Yangtze (Jiangnan): 江南水乡.

2. **Shape modern waterfront spaces**

   1) Planning and construction of city centre near the river:
   Promote cross-river development and develop city centre along the riversides further across the river, which can enhance connection between old and new districts with cross-river transport, and efficiently allocate resources for both river sides. Original riparian factories, warehouse, etc. could be relocated to construct squares, green spaces, wetlands, etc.

   2) Construct an open space with a river as its skeleton:
   Ensure the dominant role of open water spaces, so that the whole city can benefit from river sceneries, activities, ecology, etc.

   3) Enrich orderly opposite and in-depth landscape:
   Consider rhythm changes of contours with coordination amongst buildings, mountains, water bodies and landmarks. Coordinate morphology of both riversides, and create in-depth landscape of river, city and bridge.

   4) Build an urban fabric dominated by the river:
   Adopt methods of inheritance, blend, replacement, connection, etc. to enhance the integration between river and old & new urban fabrics. Conserve and create river fabrics considering riparian lines and accessibility.

3. **Connect water and city**

   1) Enhance the integration of water bodies and urban areas:

   Conserve as much water bodies as possible, clean watercourses and recover old canals.

   2) Enhance the connection between water and banks, banks and land:

   Balance between flood control and water closeness. Reserve land near water by moving floodwall inland. Build ecological embankments.

   3) Enhance the integration of bridges and urban areas:

   Combine bridges with buildings and streets to enrich spatial forms.

4. **Water activities**

   Combined with the characteristics of Water Towns in South of the Yangtze, create diversified activities related to water and develop event water culture, including dragon boat racing, model airplane competition, triathlon and so on.

B. Planning & design framework proposed in national SC guideline

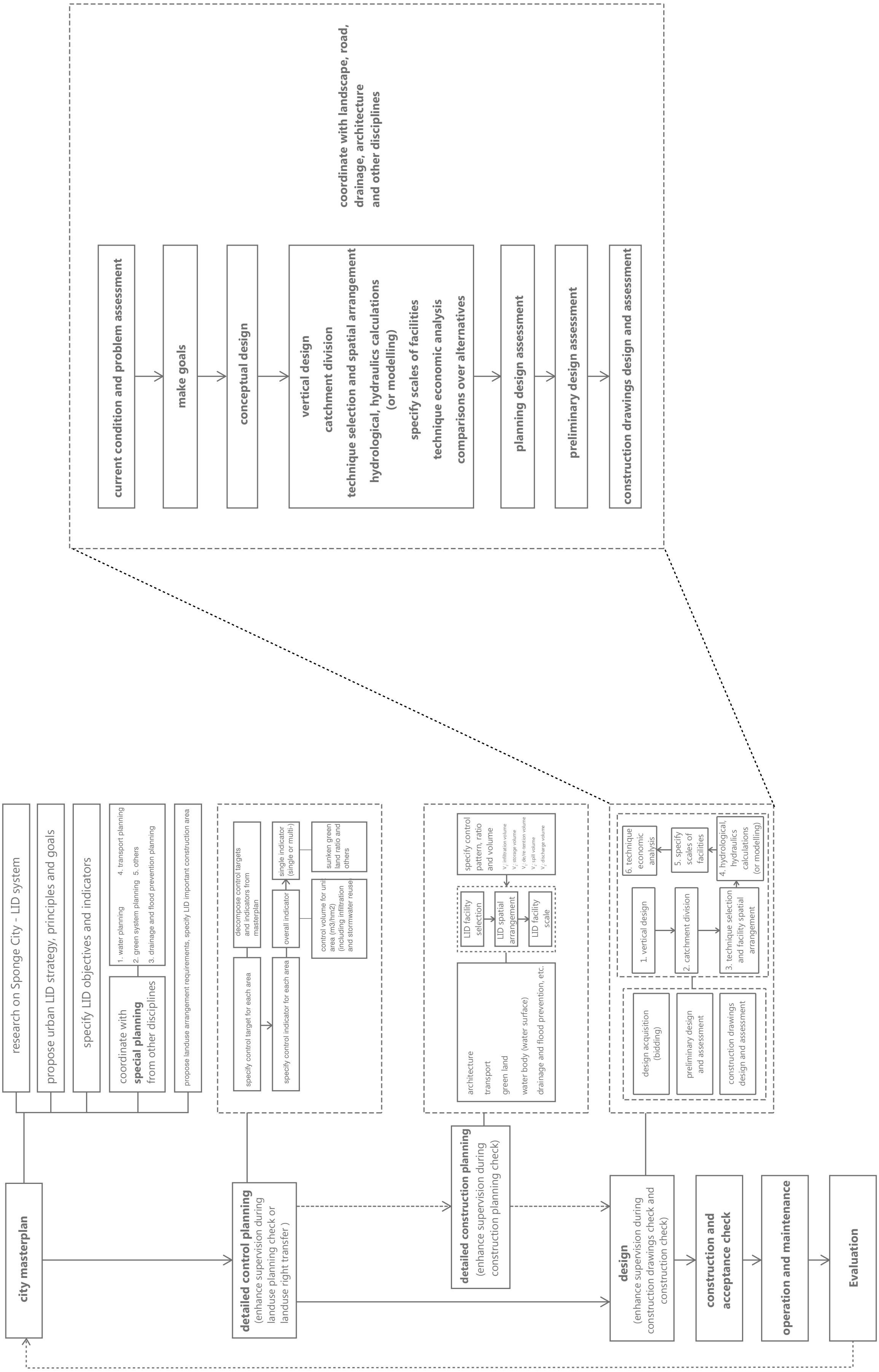


Figure 53 Proposed planning and design framework in sponge city national technical guideline (MHURD, 2014a)

C. Drought indices

Wilhite and Glantz (1985) proposed four definition of drought:

- Meteorological drought: Usually expressions of precipitation's departure from normal over some period of time. Reflects one of the primary causes of a drought.
- Hydrological drought: Usually expressions of deficiencies in surface and subsurface water supplies.
- Agricultural drought (or soil moisture drought (Van Loon, 2015)): Usually expressed in terms of needed soil moisture of a particular crop at a particular time.
- Socio-economic drought: Definitions associating droughts with supply of and demand for an economic good.

The first three types could be classified as environmental indicators, whereas the last one as a water resource indicator (Hisdal & Tallaksen, 2000).

However, Hisdal and Tallaksen (2000) claim drought studies have been suffering from the lack of consistent methods for drought analysis. Handbook of Drought Indicators and Indices (WMO & GWP, 2016) gives an overview of a number of drought indicators and indices concerning their ease of use, input parameters, etc. Indices of meteorological and agricultural drought are selected in this thesis considering data requirements and ease of use, which are Standardized Precipitation Index (SPI) and Soil Moisture Anomaly (SMA). Detailed information of these two indices are shown below, retrieved from WMO and GWP (2016).

Meteorology	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Standardized Precipitation Index (SPI)	13	Green	P	Highlighted by the World Meteorological Organization as a starting point for meteorological drought monitoring
Soil moisture	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Soil Moisture Anomaly (SMA)	25	Yellow	P, T, AWC	Intended to improve upon the water balance of PDSI

Green: Indices are considered to be green if one or more of the following criteria apply:

- A code or program to run the index is readily and freely available
- Daily data are not required
- Missing data are allowed for
- Output of the index is already being produced operationally and is available online

Note: While a green 'ease of use' classification may imply that the indicator/index may be the easiest to obtain or use, it does not mean it is the best for any given region or locality. The decision as to which indicators/indices to use has to be determined by the user and depends on the given application(s).

Yellow: Indices are considered to be yellow if one or more of the following criteria apply:

- Multiple variables or inputs are needed for calculations
- A code or program to run the index is not available in a public domain
- Only a single input or variable may be needed, but no code is available
- The complexity of the calculations needed to produce the index is minimal

Figure 54 Information of SPI and SMA, retrieve from (WMO & GWP, 2016)

SPI (Standardized Precipitation Index) is highlighted by WMO as a starting point for meteorological drought monitoring. The SPI is a powerful, flexible index that is simple to calculate using only precipitation data (WMO, 2012). Detailed calculation process is explained by McKee, Doesken, and Kleist (1993). SPIGenerator programme, developed by University of Nebraska-Lincoln, can be used to calculate SPI for each month and identify drought periods. The more negative SPI is, the more extreme drought the area is suffering from.

SMA (Soil Moisture Anomaly), as defined in Equation 5, is implemented in the Copernicus European Drought

Observatory (EDO, 2019), and used for detecting and monitoring agricultural drought conditions.

$$SMI = 1 - \frac{1}{1 + (\frac{\theta}{\theta_{50}})^6}$$

$$SMA = \frac{SMI_t - \overline{SMI}}{\delta_{SMI}}$$

Equation 5 SMA calculation

where SMI is daily soil moisture index, θ is the daily soil moisture and θ_{50} is the mean between the wilting point and the field capacity, SMIt is the decade average SMI for the t of the current year, is the long-term average and δ_{SMI} is the standard deviation. According to this definition, the anomaly values are expressed as units of standard deviation.

Soil moisture is very essential for the growth of plants (EDO, 2019). SMA represents the deviation to normal condition of soil water content. The more negative SMA is, the drier the condition that plants would suffer.

i. SPI

SPIGenerator programme simulates monthly SPI and dry periods (see Figure 51). However, the result from this method has rather coarse time resolution, which can be hardly supportive for sponge design.

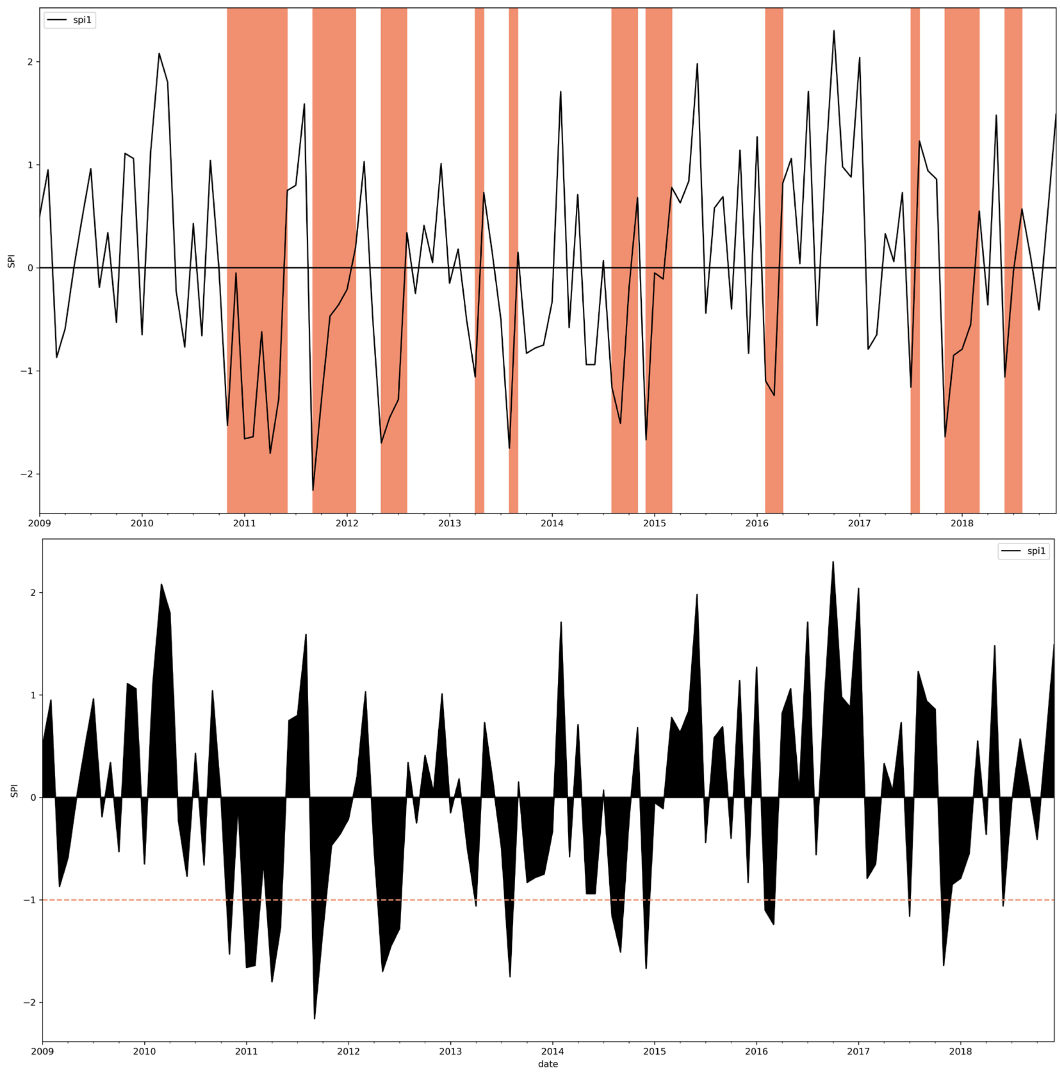
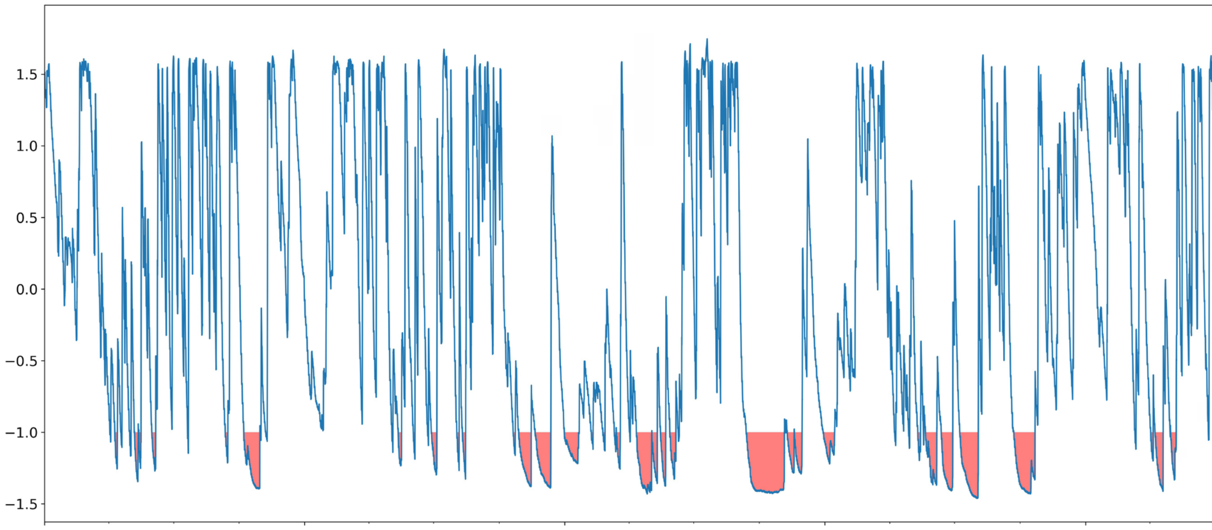


Figure 55 Monthly SPI (upper); Identified dry periods (lower)

Figure 56 SMA dynamics of root zoon soil moisture



ii. SMA

A long series of SMA dynamics can be calculated based on soil moisture contents in the root zone (see Figure 56). By setting the threshold of -1.0, the degree of drought can be visualized. If SMA index is low for a long time span, it might be a signal of critical drought event, such as couple of months around September, 2011. Measures can be taken for preventing such events happen in the future.

D. Key performance indicators in CRCT

Runoff reduction factor

The runoff reduction factor is an indicator for the expected reduction of the runoff volumes and peak flows due to the application of an adaptation measure in the project area, as compared to the original extreme discharge events. For a more complete description please see the link as below:

https://publicwiki.deltares.nl/display/AST/Calculation+of+runoff-factor\.

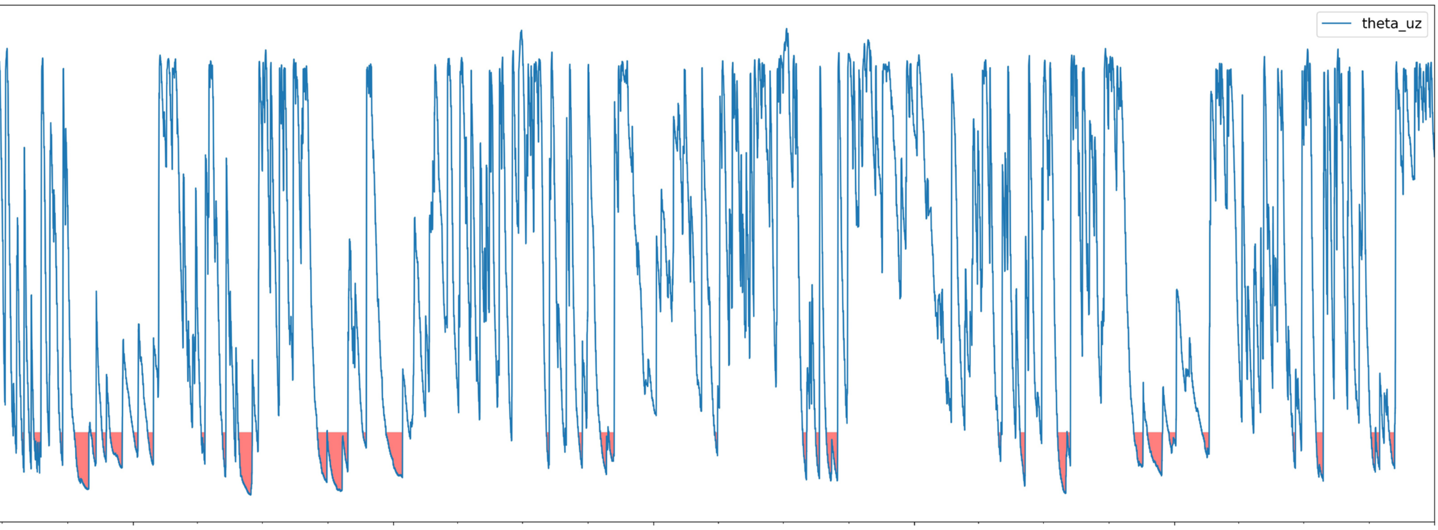
The effectiveness of applied measures could be assessed by runoff reduction factor, which indicates the reduced frequency of runoff impacts. The runoff reduction factor is derived by calculating the averaged factors of the changes of return periods for a pre-defined set of runoff depths (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 30, 40, 50 mm). It should be noted that the factor is based on the measure inflow area, the normative runoff factor from the entire project area (F_{tot}) is calculated using transformation formula:

$$F_{tot} = \frac{A_p \cdot e^{\left(\frac{A_{mi} \cdot \ln(F_{meas})}{A_p}\right)} + \frac{Perc_{RA}}{100} \cdot (A_{tot} - A_p)}{A_p + \frac{Perc_{RA}}{100} \cdot (A_{tot} - A_p)}$$

with:

F_{tot}	Factor for total area
F_{meas}	Factor for measure inflow area
A_{tot}	Total area
A_p	Paved area
A_{mi}	Measure inflow area
$Perc_{RA}$	Runoff from the rest of the area, estimated as a percentage from the runoff from paved area

Equation 6 Transformation formula of runoff reduction factor, retrieved from https://publicwiki.deltares.nl/display/AST/Calculation+of+runoff-factor



Groundwater recharge

Groundwater recharge is essential for an area that is suffering from groundwater resource depletion, land subsidence or drought events (Jia, Hou, Wang, O'Connor, & Luo, 2020). Setting target groundwater recharge values could deploy detailed groundwater modelling, which is interpretative for investigating groundwater system dynamics and understanding local flow patterns, as well as human interference (Zhou & Li, 2011).

Other indicators, including evaporation, construction & maintenance costs, and water quality, are not elaborated in this thesis. For more detailed information, the public documentation of CRCT could be referred to.

E. Required SC performance indicators in Qinhuai District

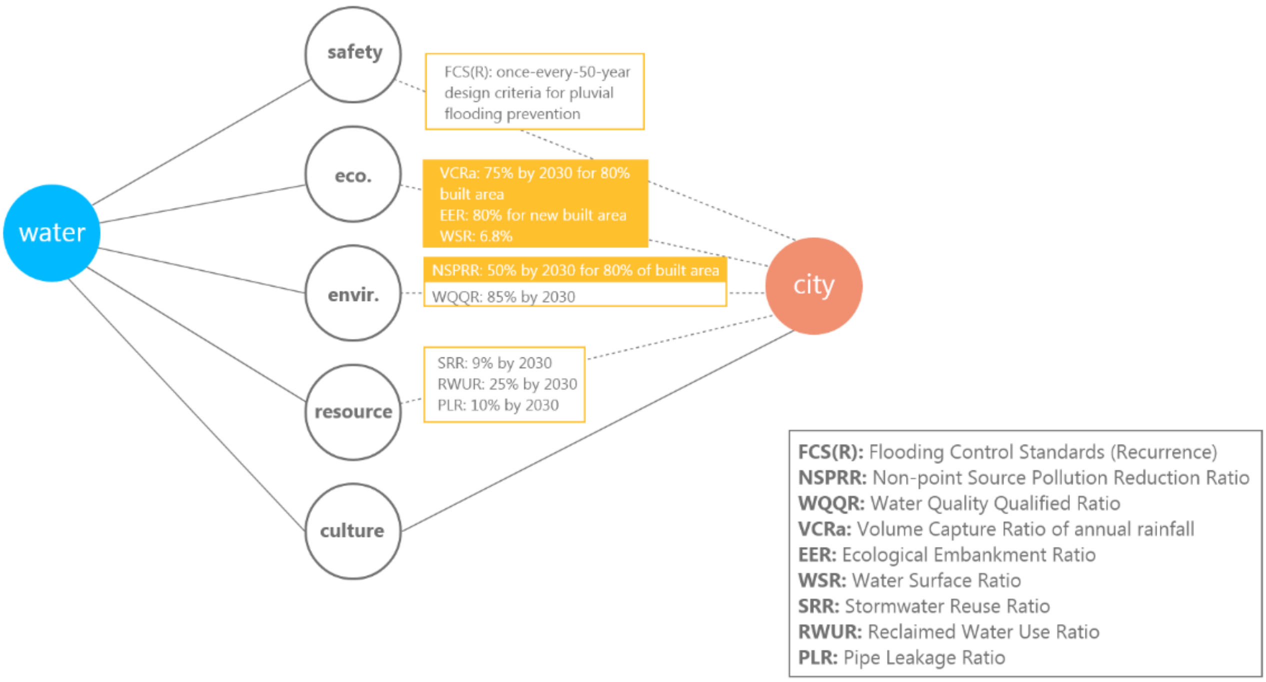


Figure 57 Indicator requirements for Qinhuai District

F. Temporal Distribution of Rainfall in Qinhuai District

Figure 58 Heatmap of precipitation over 10 years

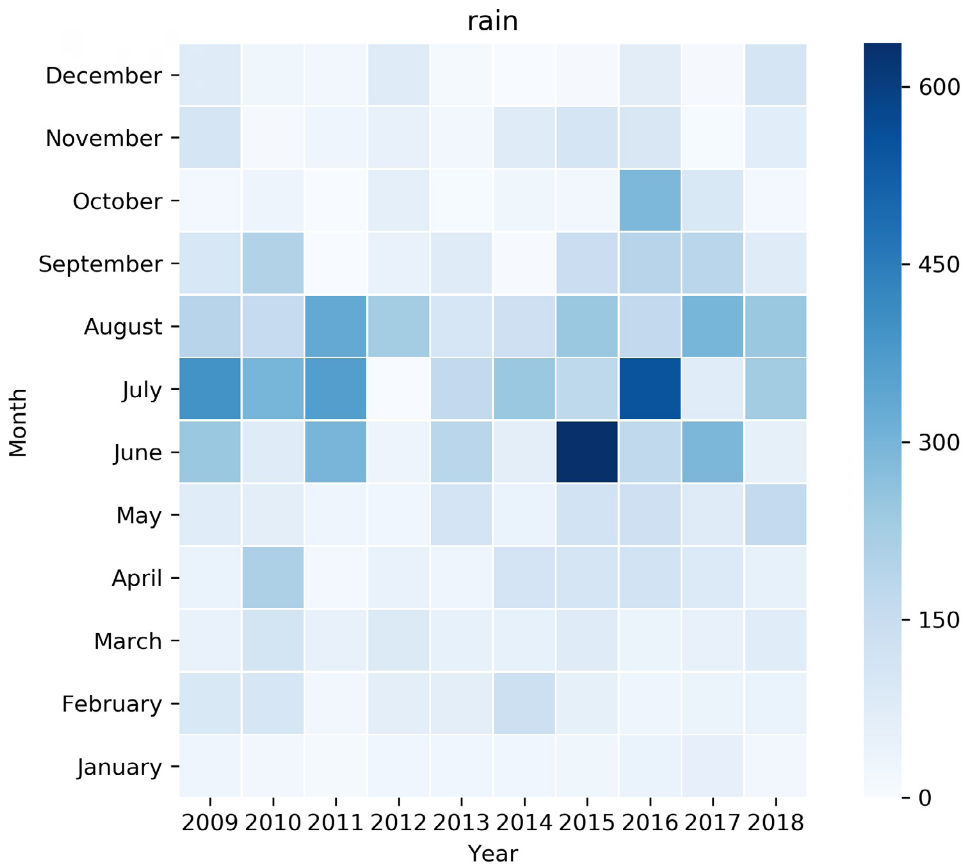


Figure 59 Monthly sum of precipitation (in mm) over 10 years

G. Fully connected neural network for rainfall pattern classification

300 classified rainfall events are randomly divided into two categories: training (220 events) and evaluation (80 events).

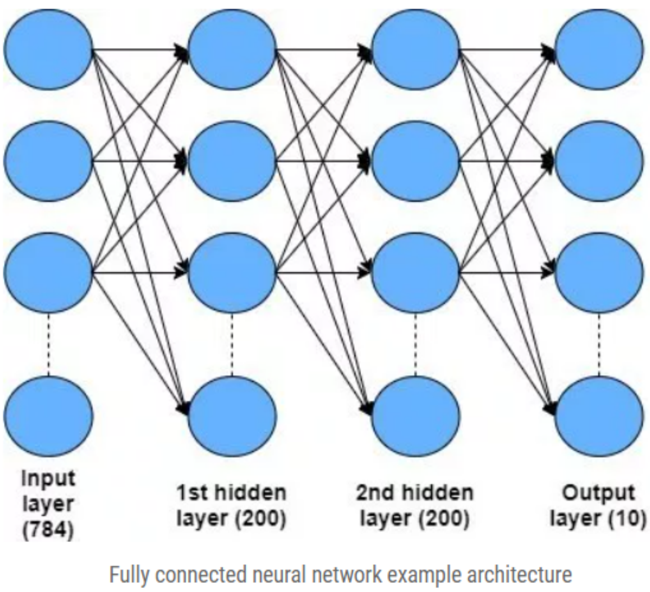


Figure 60 Fully connected network example architecture, retrieved from https://adventuresinmachinelearning.com/pytorch-tutorial-deep-learning/

The goodness of machine learning prediction is shown in confusion matrix[39] (see figures below). Class 1 and 3 are well-distinguished while class 7 is mostly mistakenly classified. One of the reasons for poorly performed deep learning method is because the number of training data is limited, which means 10-year rainfall series are not supportive for such method.

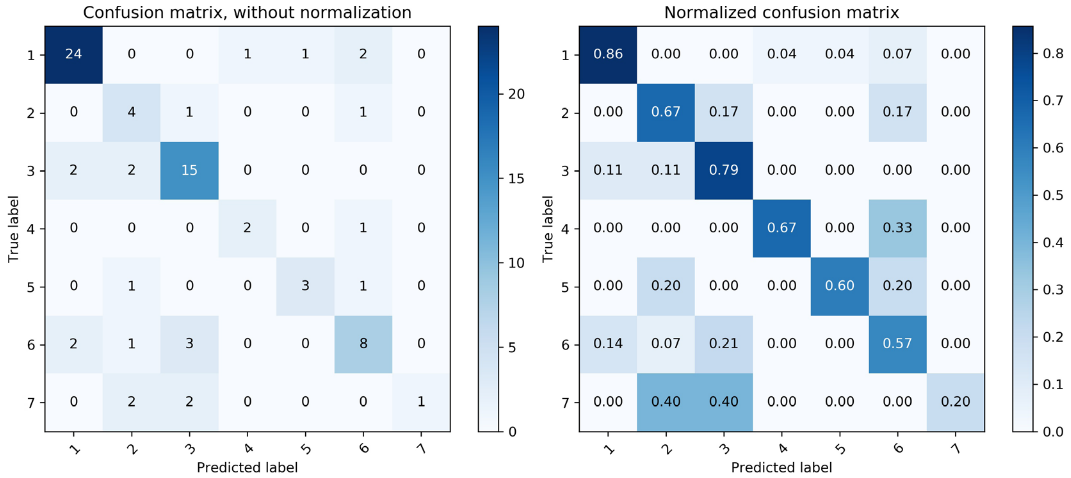


Figure 61 Confusion matrix without normalization (left), and with normalization (right)

39 A confusion matrix, also known as an error matrix, is a specific table layout that allows visualization of the performance of an algorithm. Each row of the matrix represents predicted classes while each column represents actual classes (or vice versa).

H. Input data and dynamics of key water components

Category	Contents
rainfall	2009-2018 hourly
evaporation	2009-2018 hourly derived from daily data
total area	49 km2
paved roof	0.18
closed paved	0.12
open paved	0.46
unpaved	0.2
open water	0.04
soil type	17
target open water level	1.6 m
discharge capacity	387 mm/d
storage capacity of storm water drainage system	2 mm
storage capacity of mixed sewer system	9 mm
rainfall intensity when swds overflow occurs on street	16 mm/hr
rainfall intensity when combined overflow to open water occurs	6 mm/hr
interception storage capacity on unpaved	20 mm
infiltration capacity on unpaved	43.2 mm/d
drainage resistance from groundwater to open water	50 d
constant downward flux from shallow groundwater to deep groundwater	0.25 mm/d
hydraulic head of deep groundwater	3 m
vertical flow resistance from shallow groundwater to deep groundwater	1000 d
part of urban paved area with storm water drainage system	0.3

Table 8 Input data for UWBM modelling

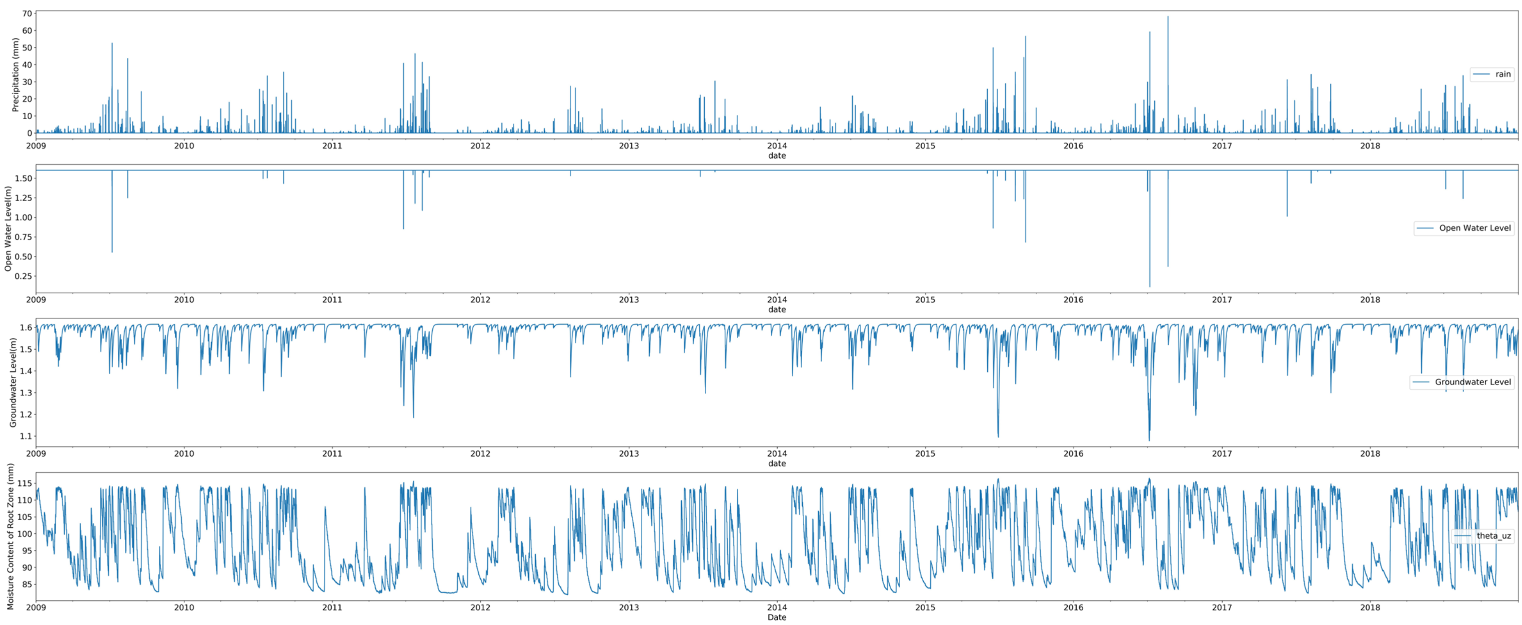
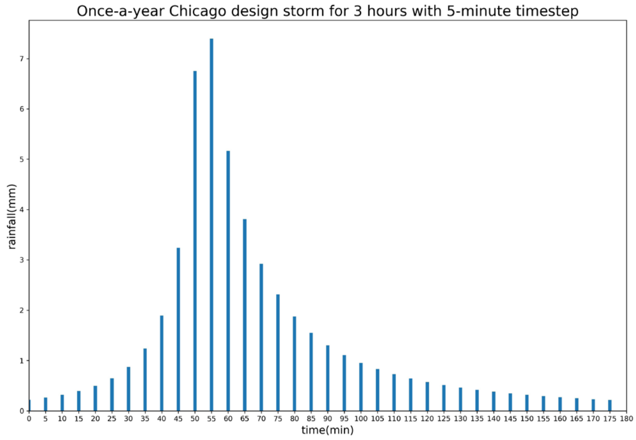


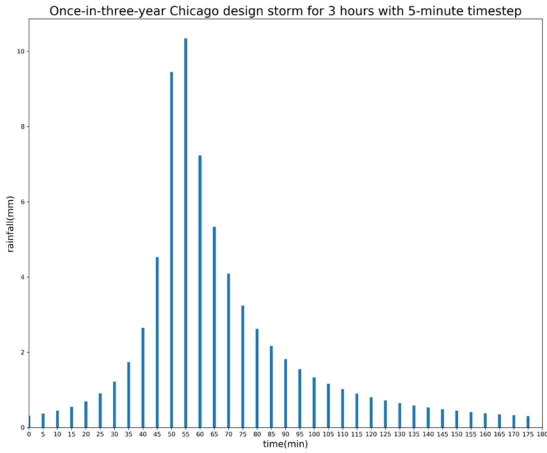
Figure 62 Simulated key water components dynamics (from top to bottom: precipitation, open water level, groundwater level, soil moisture contents at root zone)

I. Chicago storms

(1)



(2)



(3)

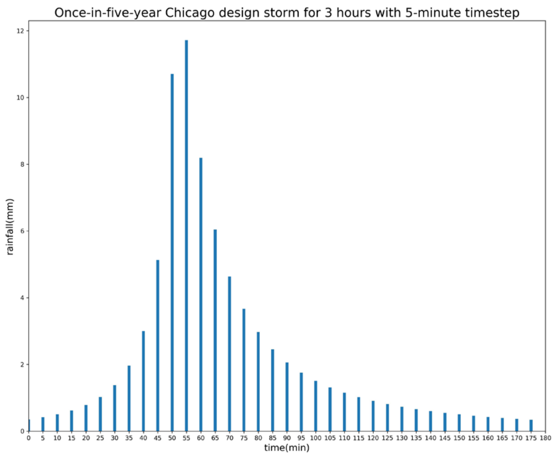
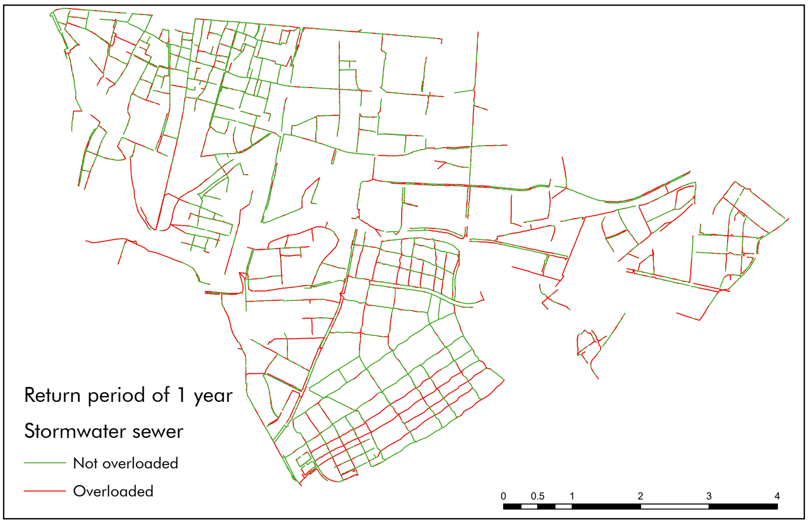
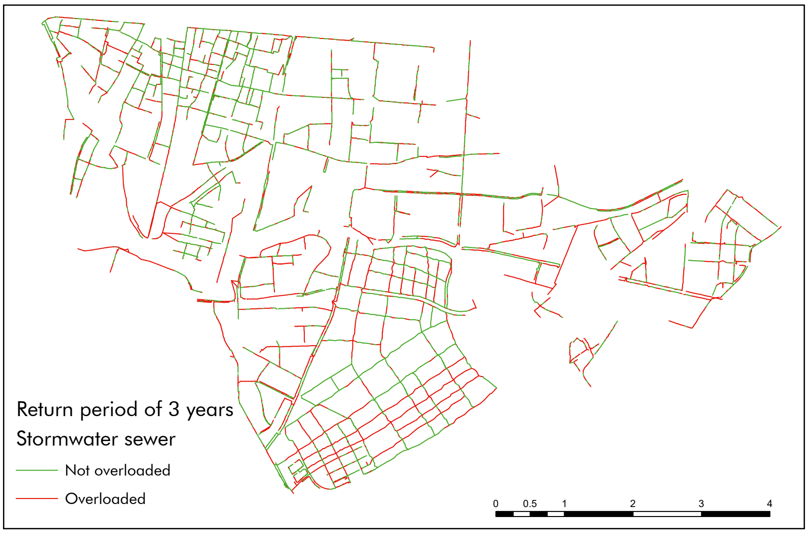


Figure 63 Designed Chicago storm with return period of (1) 1 year, (2) 3 years and (3) 5 years

J. Sewer pipes hydraulic load





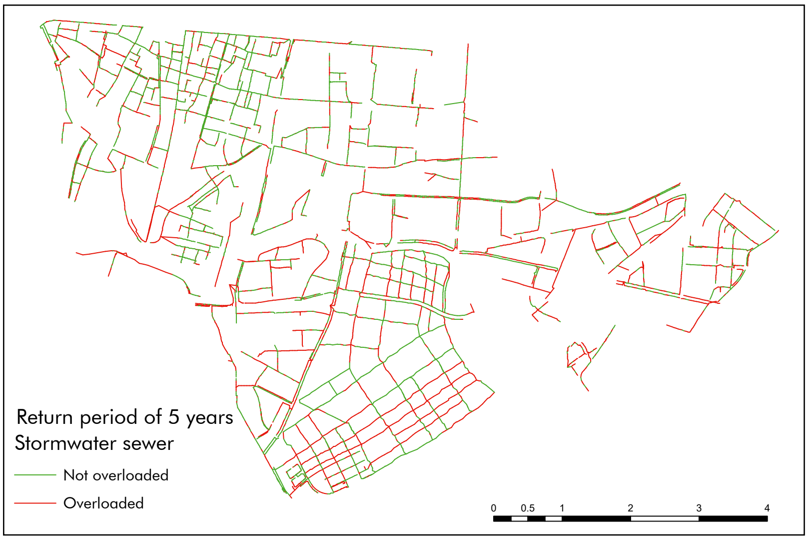


Figure 64 Sewer pipes hydraulic load. Credit: NHRI

K. Sponge City division in Qinhuai District

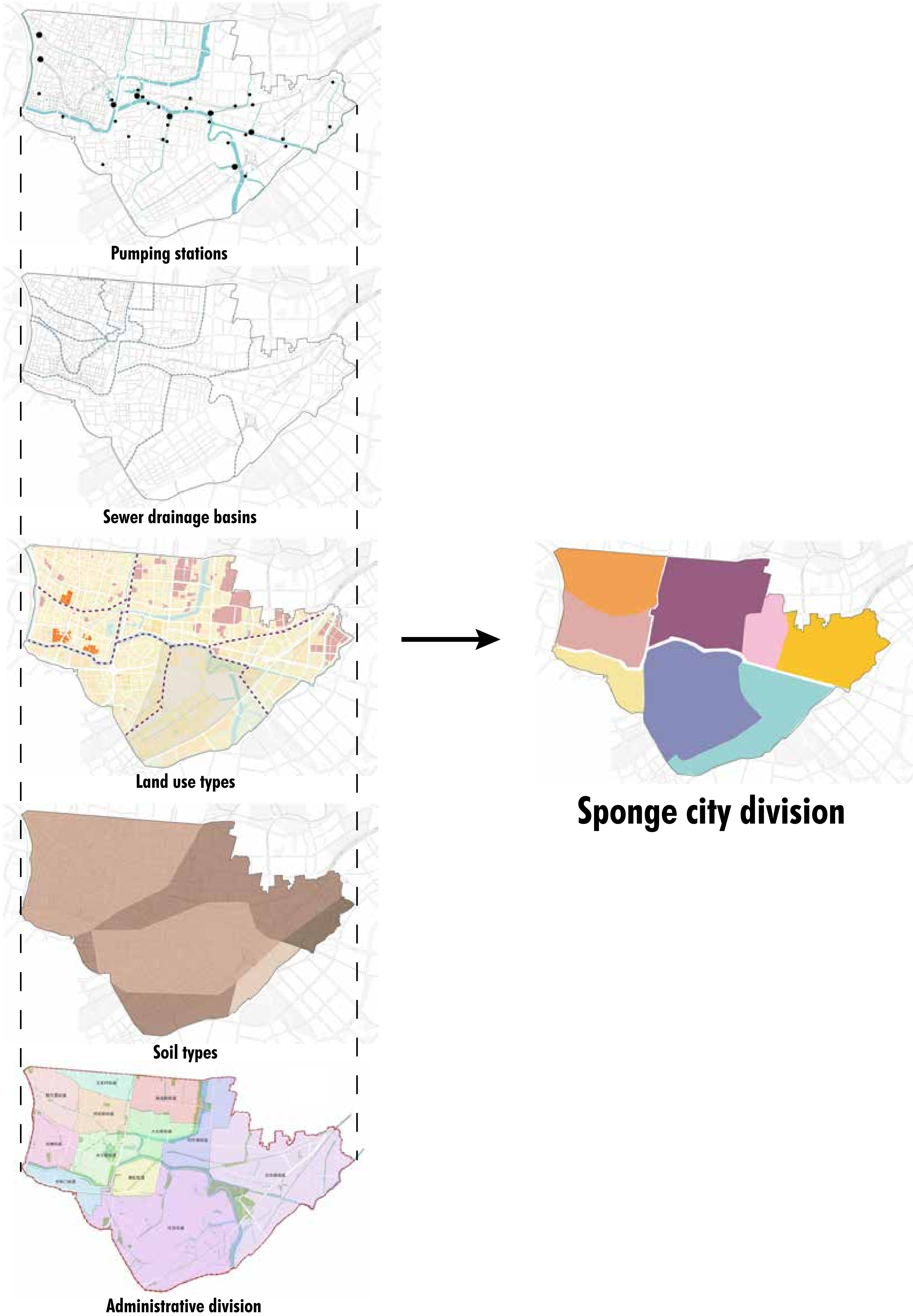


Figure 65 Sponge city division method in Qinhuai District

L. SDF curves for each subzone

Area: 576 ha
Required storage capacity: 97 mm
Storage volume(depth = 1m): 56 ha
Discharge capacity: 242mm/d

② **Old City South Area** 老城南片区
Area: 440 ha
Required storage capacity: 102 mm
Storage volume(depth = 1m): 45 ha
Discharge capacity: 242 mm/d

③ **Zhonghua Gate Area** 中华门片区
Area: 235 ha
Required storage capacity: 91 mm
Storage volume(depth = 1m): 21 ha
Discharge capacity: 294 mm/d

④ **Yueya Lake Area** 月牙湖片区
Area: 907 ha
Required storage capacity: 103 mm
Storage volume(depth = 1m): 93 ha
Discharge capacity: 242 mm/d

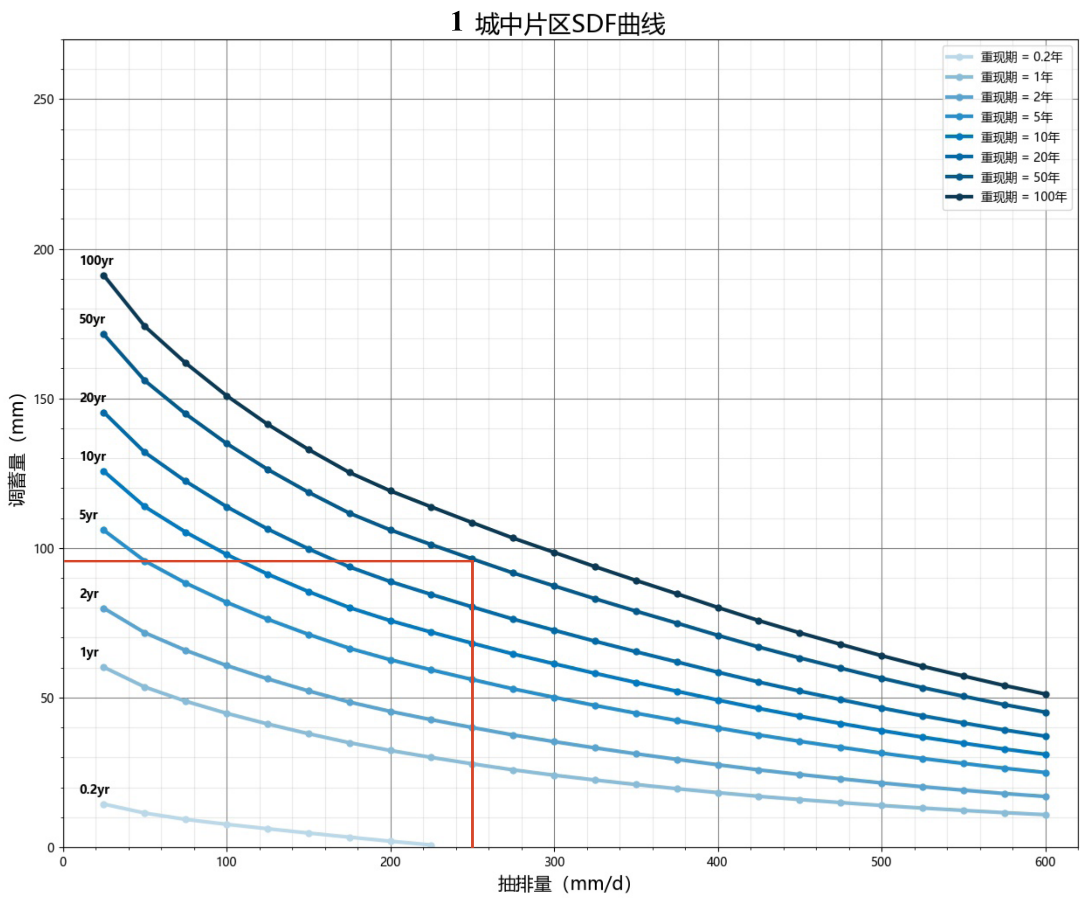
⑤ **Qinhong Area** 秦虹片区
Area: 438 ha
Required storage capacity: 86 mm
Storage volume(depth = 1m): 38 ha
Discharge capacity: 354 mm/d

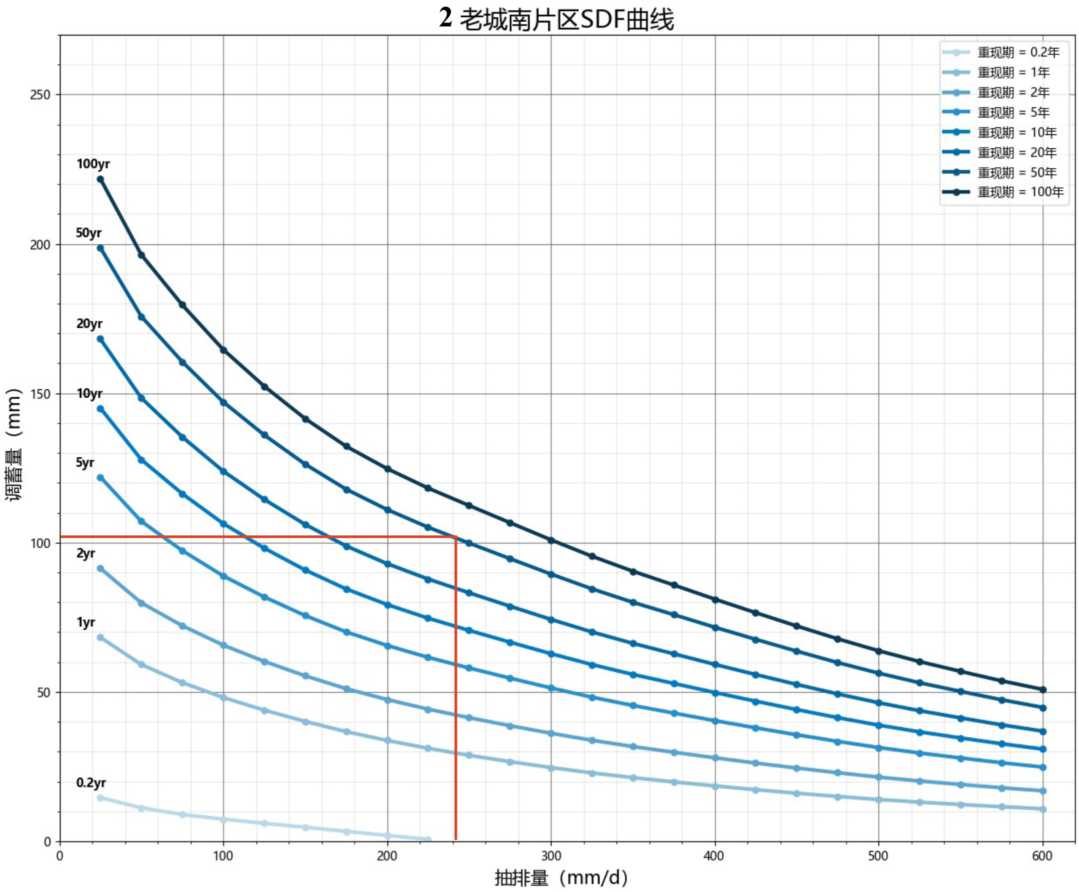
⑥ **Guanghua Road Area** 光华路片区
Area: 257 ha
Required storage capacity: 83 mm
Storage volume(depth = 1m): 21 ha
Discharge capacity: 420 mm/d

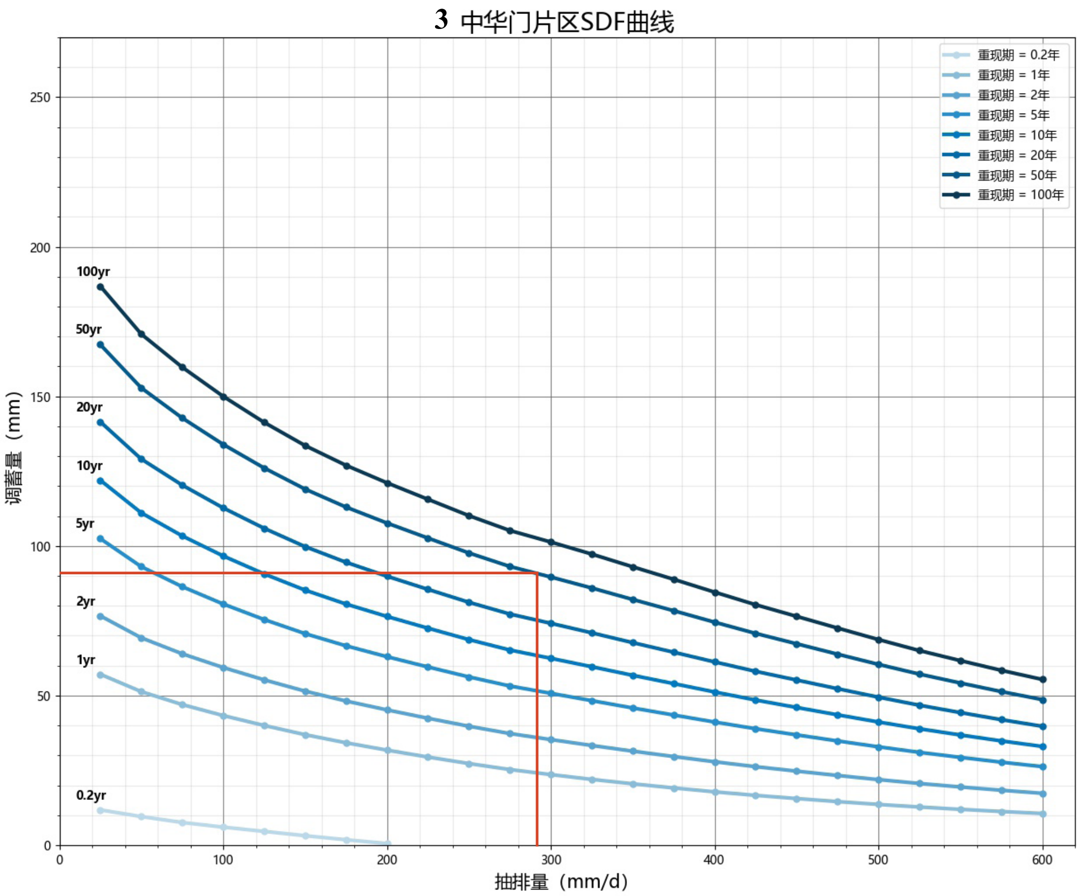
⑦ **South New City Area** 南部新城片区
Area: 616 ha
Required storage capacity: 86 mm
Storage volume(depth = 1m): 53 ha
Discharge capacity: 354 mm/d

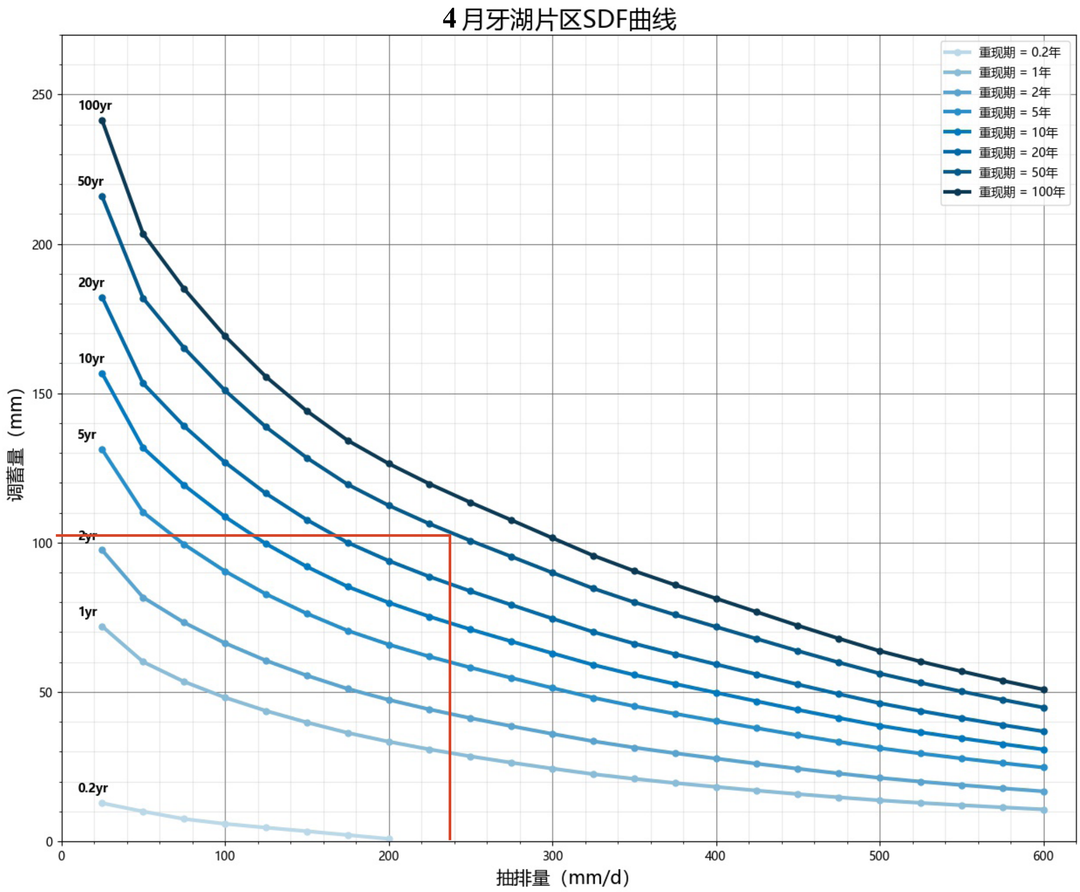
⑧ **East City High-tech Area** 城东高新片l
Area: 619 ha
Required storage capacity: 89 mm
Storage volume(depth = 1m): 55 ha
Discharge capacity: 356mm/d

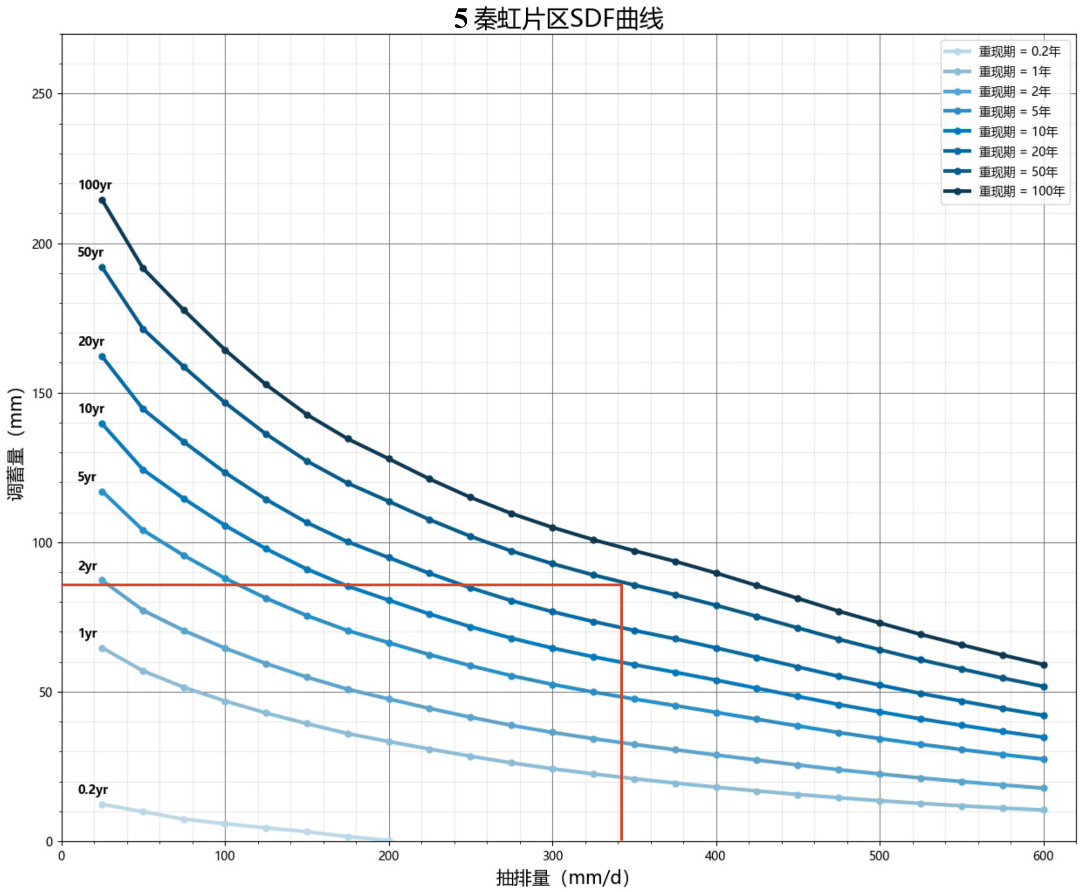
⑨ **Qiqiaoweng Area** 七桥瓮片区
Area: 637 ha
Required storage capacity: 75 mm
Storage volume(depth = 1m): 48 ha
Discharge capacity: 430 mm/d



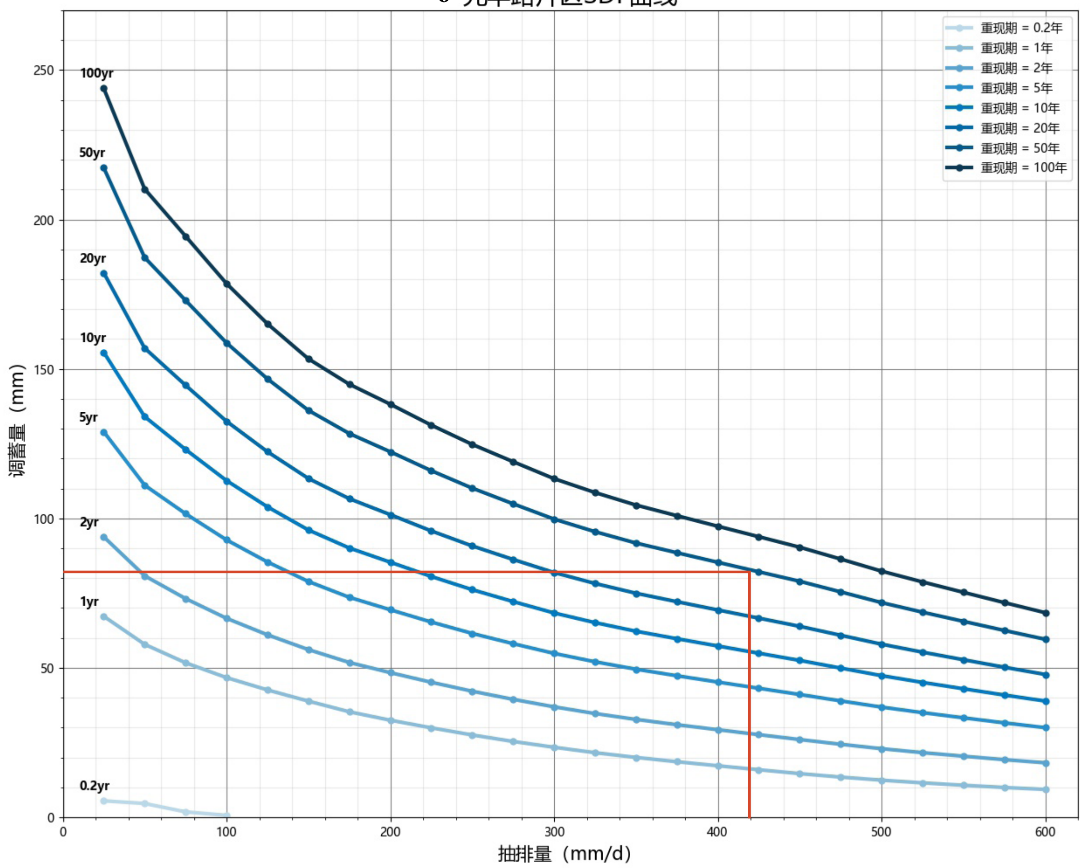

2 老城南片区SDF曲线
重现期 = 0.2年
重现期 = 1年
重现期 = 2年
重现期 = 5年
重现期 = 10年
重现期 = 20年
重现期 = 50年
重现期 = 100年
100yr
50yr
20yr
10yr
5yr
2yr
1yr
0.2yr
调蓄量（mm）
抽排量（mm/d）
0
50
100
150
200
250
0
100
200
300
400
500
600


3 中华门片区SDF曲线
重现期 = 0.2年
重现期 = 1年
重现期 = 2年
重现期 = 5年
重现期 = 10年
重现期 = 20年
重现期 = 50年
重现期 = 100年
100yr
50yr
20yr
10yr
5yr
2yr
1yr
0.2yr
调蓄量（mm）
抽排量（mm/d）
0
50
100
150
200
250
0
100
200
300
400
500
600

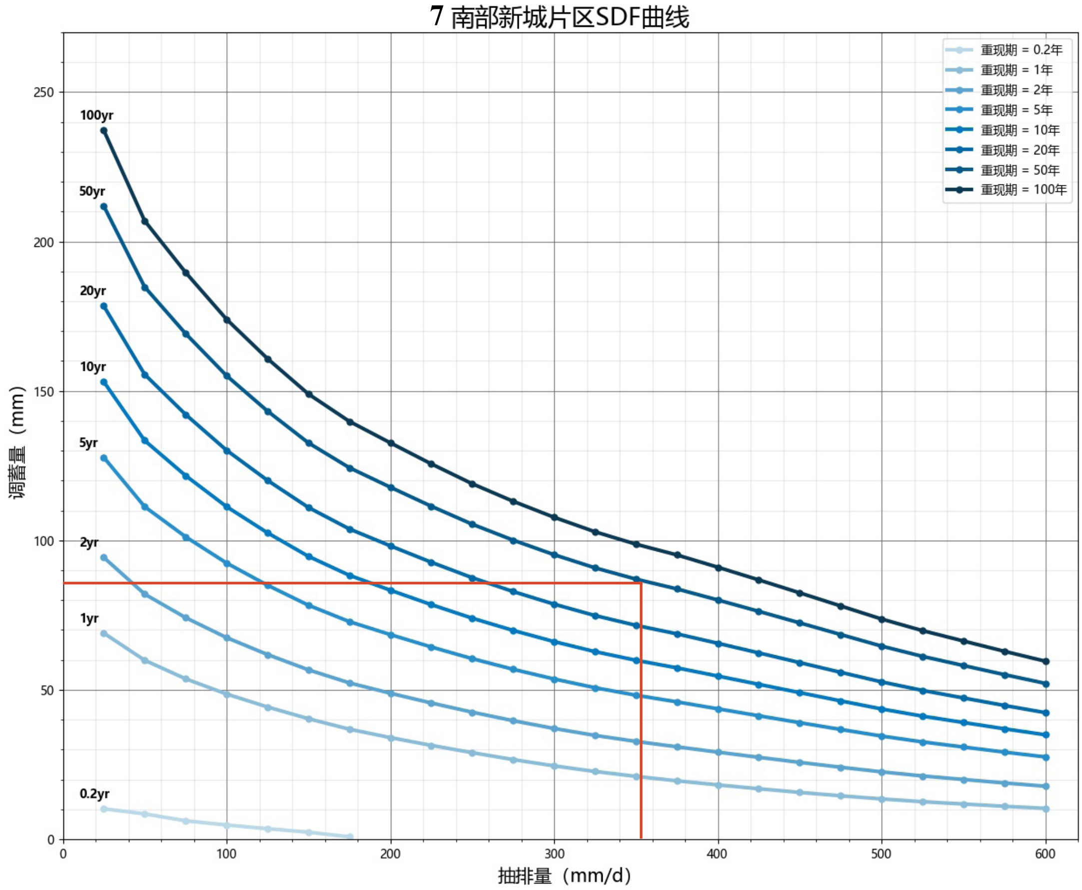

4月牙湖片区SDF曲线
调蓄量（mm）
抽排量（mm/d）
100yr
50yr
20yr
10yr
5yr
2yr
1yr
0.2yr
重现期 = 0.2年
重现期 = 1年
重现期 = 2年
重现期 = 5年
重现期 = 10年
重现期 = 20年
重现期 = 50年
重现期 = 100年

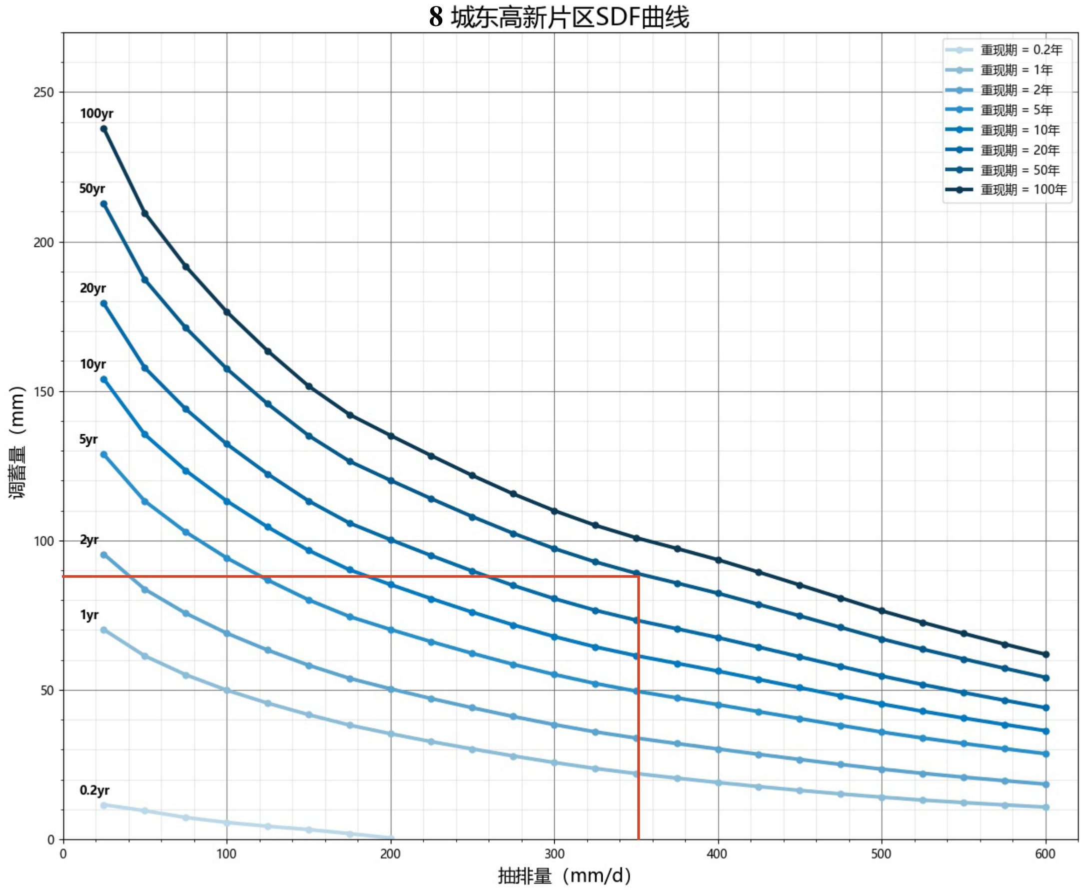

5秦虹片区SDF曲线
调蓄量（mm）
抽排量（mm/d）
100yr
50yr
20yr
10yr
5yr
2yr
1yr
0.2yr
重现期 = 0.2年
重现期 = 1年
重现期 = 2年
重现期 = 5年
重现期 = 10年
重现期 = 20年
重现期 = 50年
重现期 = 100年

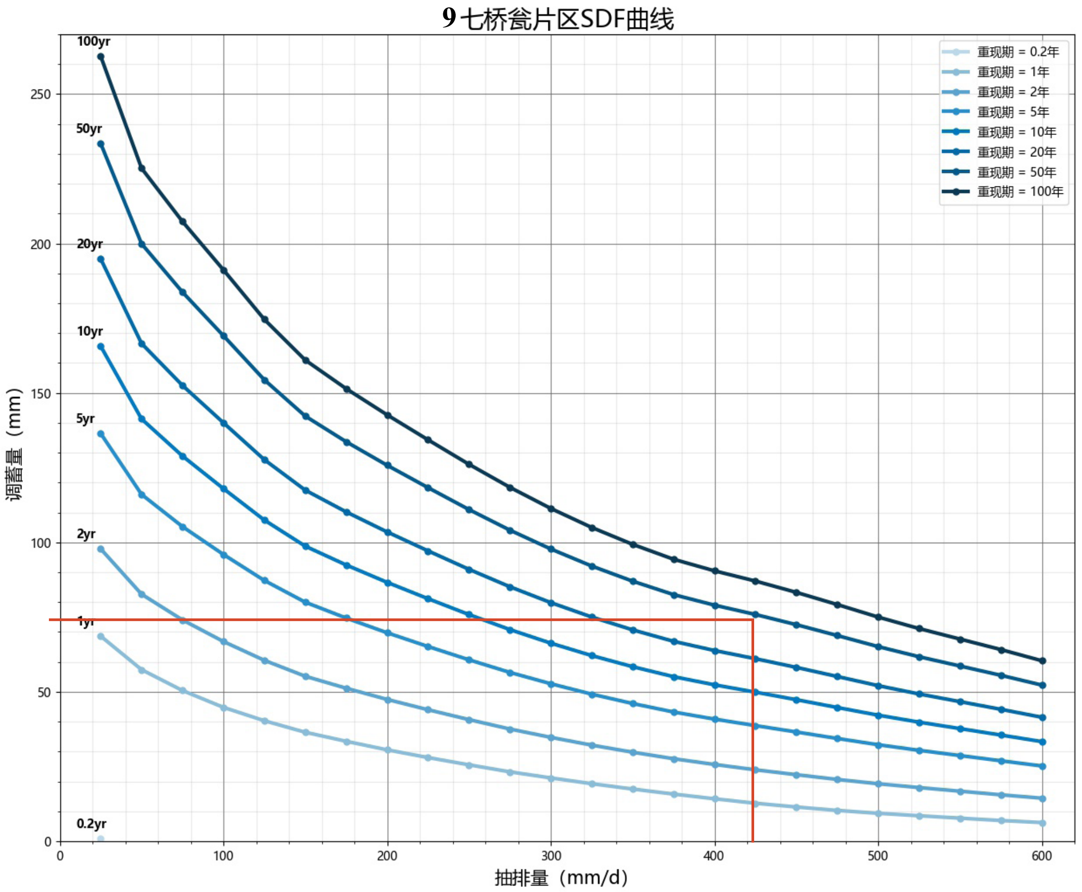
6 光华路片区SDF曲线



7 南部新城片区SDF曲线




8 城东高新片区SDF曲线
重现期 = 0.2年
重现期 = 1年
重现期 = 2年
重现期 = 5年
重现期 = 10年
重现期 = 20年
重现期 = 50年
重现期 = 100年
100yr
50yr
20yr
10yr
5yr
2yr
1yr
0.2yr
调蓄量（mm）
抽排量（mm/d）


9 七桥瓮片区SDF曲线
重现期 = 0.2年
重现期 = 1年
重现期 = 2年
重现期 = 5年
重现期 = 10年
重现期 = 20年
重现期 = 50年
重现期 = 100年
100yr
50yr
20yr
10yr
5yr
2yr
1yr
0.2yr
调蓄量（mm）
抽排量（mm/d）

M. Vulnerability scan for 5 water themes in Qinhuai project

i. Water safety

1. Increasing imperviousness of rapid urbanization causes more runoff volume and higher runoff rate.
2. Sewers were designed for return period 0.5-1 year, which is lower than standards (3-5 years).
3. Blue and green areas are shrinking due to urbanization, which weaken system storage capacity.

ii. Water ecology

1. Average value of rainfall runoff control ratio is 38%.
2. Hard banks in Qinhuai account for 64% of total length.

iii. Water environment

1. Water quality was tested as Class V[40] in six out of seven cross-sections of Qinhuai canals during 2015-2019.
2. Water quality of groundwater at two test points both give Class V results during 2015-2019.
3. Non-point source pollutants are estimated to be 1718-ton SS/year, generated from runoff over pavements.
4. Point source pollution mainly happen along Yongfeng River, which are resulted from combined sewer overflow and illicit connection problems.

iv. Water resource

1. Pipe leakage ratio in Nanjing is above 16%.
2. There is almost no stormwater reuse practices in Qinhuai District.

v. Water culture

Water culture should be protected and developed, such as palaces of Ming dynasty, imperial canals, old city walls, Yunliang River (canal for food transportation in history), etc.

40 Surface water and groundwater quality have five classes: I, II, III, IV and V. Class V represents the worst quality.

N. Interview transcripts

Interviewee	Date & setting	Themes	Subthemes
P1	**15/02/2020 Voice call**	Personal experiences	• For which cities and in which phase you participated in Sponge City programme • Sponge City strategies in different cities
		Indicator intepretation	• Water safety: pluvial flooding prevention • Water ecology and environment: VCRa • Water resource
		Model	• Model selection and in which phase models are used • Data and monitoring
		Coordination with other parties	• Cooperation with other disciplines • Decision making for sponge design
		Overarching remarks	• Evaluate Sponge City programme • Sponge City implementation • Operation and maintenance
P2	**10/03/2020 In-person**	Personal experiences	• For which cities and in which phase you participated in Sponge City programme • Sponge City strategies in different cities • Difficulties of trans-disciplinary cooperation
		Indicator intepretation	• Downscaling mechnisms • Limitations of indicator approach in sponge design • Improvements of indicators • Difficulties in Sponge City projects implementation
		Model	• Application of models in Sponge City projects • Hypothetical application of SDF and AST in Sponge City projects
		Stormwater management	• Storage and discharge • Water shortage • Adjustment of strategy concerning Chinese climate
		Overarching remarks	• Sponge City progress
P3	**05/05/2020 Voice call**	Personal experiences	• For which cities and in which phase you participated in Sponge City programme • How to cooperate with other disciplines
		Indicators and requirements	• Will indicator limit landscape design • Water shortage and groundwater recharge
		landscape design	• Plants • Interation and visulization of water • Sponge measure connectivity • Ecological embankment • Design theory
		Sponge City and landscape	• relationship between sponge design and landscape design
		Overarching remarks	• Evaluate Sponge City hitherto • Difficulties

Table 9 An overview of interview topics

1. Interview full transcripts (In Chinese)

第一部分

日期：2020年2月15日
参与者：P1（被采访者，黑色文字），陈诗扬（采访者，蓝色文字）
总时长：50分钟

之前我们聊过，就是说你做过大概十个左右的海绵城市，然后这些海绵城市他们做的标准，或者说他们做的目标上差异大吗？

我们是做过国内大概10多个城市跟海绵有关的，从规划方案和设计都会有，主要还是做规划的方案比较多。然后其实因为对国内来说，海绵城市的专项规划就是最上面的纲领性的文件，你在规划里面就要给出这个城市的设计目标。不管是海绵，其实在做海绵城市，因为它是一个综合性的内容，像国内从整个全国来看，它提出的要求有4个，里面两个最重要的两个，一个就是水环境，还有一个是水安全。当然不同的城市，它的水安全和水环境这些方面的指标是不一样的。然后国内对他在海绵城市这是统一这个指标是年径流总量控制率。 每个城市的年龄的总量控制率是不一样，这是一个大的指标是不一样的。然后他的目标这一块他肯定也各有侧重了，但是一般的城市来说，这4个方面都要提目标的，只不过说的提的目标的要求，先后和重要性是不一样的。有的城市像南方它可能没有那么缺水，它可能水资源的目标就比较小。然后但他水污染比较严重，他可能在水环境这要求比较高。然后有的城市它可能会存在一些内涝的风险，他它的水安全的目标就会稍微高一点。

好，我们就从这4个方面来就是讲就是水安全，是城市内涝问题，这个方面国内是用什么方法解决，是通过防洪排涝吗？还是说有一个别的规划方案？

国内其实现在海绵和防洪排涝的关系并没有梳理得很清楚，他们之间的关系是怎么协调的，没有梳理得很清楚，就海绵现在在有些城市的地位还是比较尴尬的。总体上来说，防洪排涝的责任主要还是由防洪部门来解决，而且海绵这边会被动地提一些指标和目标，但是在那个实践上面肯定还是由防洪、内涝部门来解决。你再提单独海绵这块，其实可能最主要的还是在源头这一块要求。 就海绵规划来说，主要还是在源头这一块解决一些小的初期雨水的径流污染的一个问题，以这个为主。其他的说只能说是配合着去提指标，因为海绵现在你不管是规划的部门也好，还是后面去执行的部门也好，它的地位其实是比较尴尬的，就算你提了一些防洪排涝的要求，你也没有能力或者说配套的职位，还有一些手段去推行后面的这一系列的工程。因为国内是有专门的防洪部门排涝部门的，他水利局他水利局和住建又不是又不是同一个局，所以就说这些的工作目前国内其实还是由防洪排涝的水利局、水务局职级单位来完成。

就是说海绵城市是由住建部主管对吧？然后防洪排涝是水利部门，然后他们两个没有衔接在一起？

理论上是要衔接的，但是据我们了解国内衔接的情况况并不是很好，现在只是说海绵城市的专项规划会提出防洪排涝的要求，防洪排涝的规划里面也会有一些关于海绵的内容，但是实质上的衔接其实做得并不是很好。

防洪排涝他们解决内涝的方式就是通过增加泵站和管道这类是吗？

对，他们有自己的传统的，或者说他们常用的一些防洪设施、预警系统什么，他们当然也会有自己的水利这一块的一系列的系统和设施，都会有他们的解决方案的。然后洪水和涝水也是分开的，涝水这块可能又是由市政这块去解决的，所以也不一定完全都先衔接上了，有每

个城市跟行政的职能划分也有关系，每个城市也不完全一样。目前我们了解到的大多数城市，它的海绵办都是隶属于住建局下面的，但也有一些城市它不是属于住建局的，有些可能也会有极少数的属于规划，或者是其他的管理局都有可能。

好。那说到水生态和水环境，VCR主要是解决上水生态上的问题，对吧？

水生态它主要是相对城市内的湖泊这一块，水体这块它有一个要求。之前我不是也跟你说过吗，国家出的标准里面是有对应的，就是这些的。这些方面的要求研究和可能控制率应该是属于水环境（有误，应为水生态）这一块的指标要求，因为荷兰那边的目标我不是很清楚，因为当时章总之前一直都是拿新西兰和澳洲那边的去跟我 们去讲的，然后国外的话它是在海绵城市的指标那边就有一个有单独的一个指标，是对应泄洪需求的，或者说防洪排涝这个需求的。但是国内的话现在只有一个年径流总量控制率，最多再加上一个ss削减率还不是完全强制的。 所以就这块它没有对应的指标。所以后面整个体系就跟不上了。

还有一个水资源上它具体的怎么要求，我看指标上面也没有提，他只是说污水再生利用率。

对，他就是水资源的再生利用率，每个城市可能会有它雨水的再生资源利用率。 其实没在做海绵之前，国家也在推，比如说你小区做蓄水池，蓄水池雨水用作循环利用、浇洒绿化什么之类的都算，包括雨水桶这种的都算。有些地方也是把放进去了。

然后我们就说一下模型，在模拟内涝上选取模型是有哪些限制因素？会根据甲方的要求选吗？还是你们比较有自由度？

比如说这块我们公司吗？据我了解，一般甲方不会有特别的要求，因为我们对接的甲方一般都是像如果做防洪排涝这块很多可能是水利局、水务局，然后本地的一些设计院，然后主要是这些单位，然后他们对模型这块一般没有太大的要求说你一定要用什么模型，没有这方面。他们最多只是说你需要给我提供什么样的核心成果，他不会对你选择模型的选择有具体的要求，我了解到的好像很少。 常见常用做内涝模型的也就那几种。

海绵城市的模型选择会有不同吗？

据我了解，国内其实在做海绵城市模型这块的话并不是特别多。还是偏少的。有个别城市它是要有模型要求的，但是也不是很多，但他们好像也没有特别强制。国内模型的发展水平其实并不是特别高，这个你也知道。然后一般国内现在其他的设计院用的最多的还是SWMM。

这个模型在比如说所以他们在海绵城市在哪个阶段会使用，最初的规划阶段？还是说后面有可能会用到?

是这样子，因为其实我们公司接到的这种海绵城市模型的任务都是在考核阶段接到的。这个城市它面临海绵城市的考核了，那么住建部可能对这些试点城市是要有要求的。然后他要求你对有些项目做模型的评估和校验，所以也会所以他需要外面的一些其他这种公司来配合做模型方面的工作。是这样子的。除了我们这种情况，还有一些我刚才跟你说到的，有一些城市它我了解到的，好像福建那边好像就是说你大于多少公顷以上的小区，你在提供海绵城市设计阶段，你就要提供模型报告。这个有的是在设计阶段的。

所以你们遇到的主要是在考核阶段用的对吧？

对，我们现在接到的项目基本上都是在考核阶段用的。然后还有一些可能试点城市主要试点城市比较多，然后他们可能出于一些宣传什么的目的，然后加分，然后又想要有的模型这块。

像我们之前湘潭那个项目里头，模型分析它内涝风险，这种会经常遇到吗？

那个不算单个项目的， 我们做了整个城市的一个内涝风险，做了一个比较粗的整个湘潭市的内涝风险。

做考核的时候，数据都是水利部门会给你们对吧？

甲方去负责收集这些相关的资料，因为国内你的这些数据也是散落在不同的部门的。不是都在一个部门的。

那会有一些数据比较缺吗？

当然会存在这种，但是我们相对要好一点，因为我们一般接到这些项目都是政府部门委托给我们这个项目，那么他们去内部协调就会比较容易。但是像有些个别的项目，不是政府部门是其他的单位业主委托 给我们的话，那些就会比较困难。因为你比如说他住建局也不一定能搞到水利局的资料。就气象局的数据也很难要，就跟在湘潭的时候做项目，你也知道。国内情况就是这个样子。他没有一个公开的平台让大家都可以获取数据，这数据还是保密的。

那就是参数率定上 ，我看海绵城市规划里头也说需要监测数据，对做出来的很多设施进行监测，国内有做到吗？

有的像试点城市都是要求做海绵城市监测的。

你们做考核的时候会用到这些监测的数据吗？

要的，要监测数据，来支撑模型的率定。监测数据有两种，一种是直接验证，就直接用监测数据去验证，这个海绵效果有没有达标，要么就是用到模型里面，通过模型的率定验证来看一下它的海绵效果没有达标，一般是这两种。

在用这些模型模拟的时候，他设计暴雨的选择有什么要求吗？

国内一般用的都是短历时一个，长历时一个，然后可能有些项目会做典型的暴雨，再做一两个，一般是这样的。

长一时是多长？24小时一般。现在还没有一个规定说是要做，要做多久是吧？

这是自己选择的。也不完全是吧。因为好像是参考本地的防洪排涝的要求的。有些地方它比如说防洪排涝的要求是50年一遇，24小时。然后有些它根据城市的等级，它的要求是不一样的。好像现在海绵这块水安全这一块是参考防洪排涝的标准。

那就是你们模型做的比较多的是那种小尺度的海绵，还是说会有整个城市？

低影响开发是吗？不用管其他的防洪排涝要求？不管的，小尺度的，比如说一个小区一个公园，一个学校这样评估。

行，还有一个问题跟其他部门的跟其他专业和其他部门协调的问题。 因为你们做的都是考核阶段，如果是在设计阶段，像我们做湘潭那个，是我们做出来的模型结果要交给下一个部门去进行设计吗。你了解这个过程，就是说是先做的模型，来给下面设计部门一些参考，还是说设计部门先做设计，然后我们在用模型进行校核？

他是这样子的，国内比如说一个小区，它的室外设计，它可能有建筑这块的室外设计，然后

它水这块要看水暖电，可能要看看地下管线这块的设计，然后再的话就可能是室外的绿化这块又归属于景观去设计。 然后海绵这块是新加进来的。一般来说我们可能是先以水暖电的规划是设计为基础，因为他们要排线布线什么之类。他们有他们的标准和要求。在他们的基础上，我们和景观最好的是和景观一起合作，去做设计，然后我们一般会做一个方案，然后景观把我们的方案深化，然后用这个方案再去评估它的一个效果这样子。

所以大部分时间都是和景观专业一起做室外的这种景观设计？

对，因为国内的海绵全是是低影响开发，主要还是在绿化这一块，绿化水体这一块做一些，做一些道路，然后所以这块国内原先基本上还是属于绿化的，属于景观去做这块。

最后的设计方案的选择和决定是政府部门主导的吗？还是委托的设计院之类？

有些单位它可能是，海绵这个东西，反正对于政府这块，他不管你这个东西是不是有海绵。因为现在是设计院去做，有些比如说这种方案，它是市政的部门去做的，有些可能是景观去做的，但是不会管你是哪个去做的，但你只要最终提交上来，图纸要由海绵办审核，包括你的模型报告，如果有要求模拟报告或者说计算过程的话，海绵办会给你审核。然后还有专门的海绵办有专门的审图的人去审核，审核完了之后好像就去拿审图证。然后再去，有的比如说方案阶段，先提交一版方案，方案海绵办审核之后，然后把这个图再交给市政那边，市政那边的审图的人再去审核，他交给景观那边再去审核。整个的审图流程，全部过了之后再进入下一个设计阶段。然后有一些地方它是海绵的审图和景观什么那些市政的审图并到一起去了，有些还是分开在两个部门的也要走两次审图。

海绵的审图是审查什么？是他具体的设计吗？还是说多大尺寸？

因为一般来说城市有海绵城市专项规划，它就会给你每个区有对应的指标，那么每个区，在理论上在控规里面要给区的不同的分再分小区，然后再给出不同的指标。比如说开发商新拿到一个楼盘之后，他要有一个应该叫什么土地特征，还土地规划证什么的，他拿证之前他就要承诺你块地能达到多少控制率的目标，那么他知道这个目标之后，他就得按照这个目标去设计。VCR就比如说80，你就按照80去设计，然后他就可能会去找他的设计团队去做这个事儿。做了方案设计之后，提交给海绵办就审。你现在这个方案能不能达到80%的控制力目标就是这样。

就是说主导的因素还是VCR是吧？

看它每个区的控规的指标定的到底是什么。如果他指定了一个VCR，然后那就只看了，如果他要定了污染物，就再看一下污染物。如果他可能定了什么雨水资源利用率，都有可能的。但是最主要的一定要卡是VCR，其他的是看各个城市的要求。

VCR，他在绩效海绵城市建设、绩效评价与考核指标里头是放在水生态里面，然后但是现在是不是很多城市都用当成一个总的总的控制指标一样，然后对这个指标进行分解？

因为你分解到单个项目的时候，是不会给他提出你的水安全的指标的，因为你像什么水安全这些的指标，或者说什么水体的指标，肯定是对一个大一点的层级，至少是一个海绵管理分区去提这个目标的。像我刚才说的，你比如说一个开发商，他只拿到一个小区的用地，他就不可能给他再提水安全的指标。

他就不用管最少是可能30年一遇的内涝能不能抵抗，他就不用担心这个指标会不会过去？

对，因为我之前也跟Frans解释过，国内的防洪的要求不是不是靠源头的海绵设施去解决的。因为你这个目标只有70%，你就算到90%，他也就几十毫米，这个雨量是很小的。

对，因为VCR指标是是关于水质的，是关于水生态的，他解决不了内涝的问题。 所以在海绵城市里头，内涝好像都是由另一个水利或者水务部门来解决。

海绵会提这个指标，但是这个指标的话工程实际上还是有。对，你刚才说的些部门。

因为在荷兰这边，他可能是通过调蓄跟管道排水泵站抽水相结合，它就灰绿设施相结合，但是好像是现在在海绵设施海绵建设中，就存在灰绿割裂开的局面，就是绿色的东西只做低影响开发的源头，然后灰色的来解决防洪和排涝的问题。是像这样一个情况吗？

灰色也有，我不知道荷兰那边，荷兰这块你像泵站这块的工程， 荷兰这块跟海绵这块它是有一个专门的部门吗？ 我不清楚他们具体部门是什么，但是因为他们做设计的时候都会把调蓄跟排水结合在一起考虑，就不会说只看调蓄或者只看排水。

我觉得不单纯是技术上的问题，跟中国的职能体系体制也是有关系的。不同局的关系它是泾渭分明的。一般不太会去交叉对方的职权范围。所以说在海绵推出来之后，好像定的地位很高，但实际上并没有给他很大的权力，所以就比较被动。

之前说我看到有些地方政府它海绵办的就是主任是市长还是什么？感觉他们（海绵城市项目）地位比较高？

你们应该是那种试点城市，它试点城市因为它有各种各方面的原因，市长挂名的，因为对市长有政绩，然后国家试点也是一个很大的荣誉。然后也会给予很多配套的资金。但是在实际的操作过程当中也不一定好，国家试点会稍微好一点，因为他的名头大，然后他也有资金，就好去协调这个事情。再往下一点，其他各个城市做起来就会比较被动。

现在是不是只有30个试点城市？其他城市有过要求做吗？

他是这样子的，国家有国家试点，然后每个省也有省试点。但是也没有说的都有。还是试点城市还是相对比较少。以前都说2020年实现海绵城市百分之多少的要求。

我查了一下，好像也没有看到关于他们海绵城市试点做了绩效的一个评估的报告。目前还没有，是看不到的，网上你是看不到的，他没有公开，没有公开我们都看不到。他结果也没有公开，就是说哪些试点已经达到实现了目标。但好像成绩出来了，第1批试点的成绩已经出来了，好像。有吗？但是有没有网上公开我还真不清楚。 我看了一下住建部的，他们官网好像没有通知评价他们是不是达成目标。好像反正这个事情他们一直都在拖，比原先的计划都晚了很久，第1批是别晚了快一年晚了，将近一年才去验收什么的。所以都比较慢，然后可能既然第1批试点下来，好像效果也都不是很理想，有可能。所以现在可能住建部也有其他的要求，也不是很清楚。上一次有住建部的专家来看过现在，住建部包括新出的评价标准，又提出了一个新的，就要求对一个排水片区做整个的建设监测和评估的一个流程，它是分区为单位。现在他就是对监测这块还有评估这块，它是要求按典型排水片区为单元去做这个事。是把城市划分成排水片区，然后每个片区来看它的效果吗？他要求典型排水片里面你挑一个，符合他的要求的典型排水片区去做这个事。这块感觉部里面在思考这个问题，反正太那个（具体）的我也不是很清楚。

还是回到之前模型在就在选择那些海绵选项的时候，比如说什么生物滞留池，或者说什么调蓄池塘，会用模型来做这些选，就是给它们排序，哪个是比较优选的一些方式，然后提供给决策者吗？会有提交几个方案都提交，可能会根据业主的要求，可能会提交几个方案。

就是像我们湘潭做的那样的流程，在国内是不是不常见？你说哪个流程？我们先做一个大概的海绵的尺度，然后交给景观或者交给那些设计部门，让他们设计成景观元素，然后再放到

一个workshop里面一起讨论。不会workshop一起讨论的，国内没有这种交流的习惯，各部门各做各的都是这样子的。

所以最后方案敲定还是主导是在设计部门对吧？就是说景观他们想把这个设置成什么形式？是主动权在哪。因为现在审图的是要求景观要审，市政要审，然后海绵要审，主动权在哪我也很难讲。我也不是很清楚，可能每个项目会不一样。

然后一些大的方面的问题，这些指标就能不能满足我们最初对海绵城市构想的一个要求。比如说年径流总量控制率，他只是一个特别小的一个尺度，它只是20，30多毫米，用这个指标能不能规范海绵城市建设的尺度？

这个问题非常难回答。 但是，指标肯定是有效果的，有它的效果。至少在控制初期雨水径流污染这块他肯定是有用的。但是，你说他能不能完全实现这个目标？因为你不是也讲过海绵城市的目标，国内也是大体还是分了水安全、水生态、水环境的。年径流总量控制率，只是水生态当中的一个，你水安全的话，它有防洪排涝的目标，然后水环境的可能他有水体质量的要求，然后其他的也有其他的目标。我不可能说一个VCR就能实现所有的目标，这个也很难办。

所以现在的建设还是以结果为导向， 他们审查部门就只看大部分，只看年径流总量控制率指标，来判断还能就是建设的好坏，对吧？ 总体上它来说是这样的。

还有一个就是在分区的过程中，我看过比如说南京是看过他们的南京市的海绵城市的规划，他们把他们城市分成了不同片区，然后每个片区对指标分解，但是分解的时候就很奇怪的是他们把老城区划分的控制率比较低，然后那种没开发的新区划分的比较高。在我看来就比较奇怪。因为老城区它水安全水生态的任务应该是更大，但是他反而把控制率划的比较低。你有遇到过这种情况吗？

在老城区是他的需求是会比较大，但是老城区的建设难度也大，所以我们这边也是把老城区的目标定的比较低的，也要考虑建设难度和建设成本，一个新城区他在新规划的时候，它是一张白纸，你想怎么画就怎么画。但是老城区它都已经建成了，然后像国内这种老城区，它可能还存在着拆迁的问题，然后业主交流沟通的问题，还有它的绿地率都是偏低的，建筑密度偏高，这种你都很难去做海绵的。

所以还是在城市的总体指标上会被平均了，如果老城区比较低的话，新城区很高，如果做试点城市的话，他们就总体的VCR可能还是比较高。是不是这样有利于达到成绩？

每个城市他划分试点区的时候，他可以自己选，一般几平方公里都可能会有。然后最开始做试点的时候，很多人是选择老城区，你因为觉得老城区存在的问题比较大，他们也提了一些方法，但是实际下来效果都不好。 这个效果不好，可能是技术上的问题，也有可能很多方面的问题。你比如说老城区住了很多年纪大的人，给他们施工的时候也很困难，然后后面有些可能没有物业，你绿化的维护也有困难，很多方面的问题大家发现下来老城区的建设效果都比较差，很难实现当初的目标。所以现在大家都想把试点区尽量的选在新城区，这样子，操作的效果比较好，难度也比较低，比较好管控。 他开发商拿地的时候，他就给指标要求，这样他就比较好管，对吧？ 是开发商拿地的时候，政府就会提着个海绵VCR多少。对。不然拿不到用地许可的。还是挺靠源头的。然后有的城市是会给补贴的，多少钱一平方好像是这样。

然后还有关于指标另一个指标，比如说ss削减率，他这个东西要怎么模拟，我感觉这个指标有点虚啊？地表上的那些沉积物他怎么能模拟他的削减？然后怎么去验证它是削减了那么多？

一般比如说像有的小区做地表的径流污染的监测，整个小区进来的污染物大概是多少，那小区的出口那边再装一个比如说SS检测，然后再看一下。是指雨水管道内的吗？对，就整个小区出口那块。是的，然后还有地下 。地表的也有，他地下的也是来自地表。他如果你测小区我刚才说的那种，还有测单个设施的话，它就是设施的。 进口测一个，出口测一个。也是污染去处。小区的是测他们管雨水管道内的ss的变化量，还是说他在地表上监测地表径流里头SS有多少？因为你要测一整个小区你只能测小区出口的雨水排出口的污染物，没有办法测地表的。而且你测地表也没有用，你要考虑污染物经过设施，因为它设施过滤什么处理之后，它会再进到盲管，盲管你在接到市政管道，所以他处理后的水应该还是从市政管道出来。

模拟的时候会直接去用软件去模拟它吗？还是说具体监测数据为主。

都有用，模拟的也有检测，但是监测的话误差会比较大。所以一般还是配合着模拟做。

如果监测的不准确的话，模拟就可靠度不是也很低？

对。模拟监测的时候，它可能存在着比如说监测数据不够连续，因为你需要多个检测数据才好去模拟这个事，但是你用模拟的话一些断断断续续的监测数据也是可以用的。反正总体来说，监测的可靠性都不高。

然后还有一个指标叫下凹式绿地利率对吧？

有的城市有用，但这个不是强制性的，不是每个城市都有。

但它用面积率来做下凹绿地有没有规定深度？

不在这个比例里面扣，它可能每个城市它有标准图集或者是导则吗，然后他可能会对你下凹绿地的深度有要求。

行，我大概的问题就差不多。然后你还有什么评价吗？

国内海绵总体来说的，这个存在着挺多的问题，这个问题是从上而下的。这上面他海绵这块它的职能就不是很清楚，下面在落实的时候也不是很好落实。但是，15年国家推海绵现在都已经快5年了，肯定还是有进步的，有些城市做得还是有些项目做得还是可以的，要一个长期的过程，不可能那么快。

所以说还是职能划分上，职能上的紊乱，导致它实施起来没有效率？

这个职能事情我是觉得职能肯定是占了一个挺大的因素，但也不完全是这样。你技术的发展，因为国内像现在设计水平、设计阶段其实已经挺大提到了，很多设计院都能够在设计这一块做得比较好了，但是在施工这一块还是很欠缺的，然后在后面可能在运营维护这边也是欠缺的。因为像国外他们推这种东西，它是整个技术体系都一起发展的。然后在去推这个事情，它推的过程也会比较慢，不像国内，因为中国做事情都是先干了再说。 所以肯定会有很多的问题。

说到运营维护的话，海绵城市现在的运营维护是在哪个部门他们负责还是说那些开发商他们负责？

如果是开发商的项目，肯定是开发商自己运营维护。像市政道路上的项目可能很难说绿化或者环卫这些部门去运营维护，就现在运营维护谁来维护也是一个问题，也会存在纷争的问题。住建局可能拿了钱是吧，他施工完了，但他又不管，运营维护要让市政这边弄，也有不情愿的地方。

我差不多问题就结束了。

第二部分
日期：2020年3月10日
参与者：P2（被采访者，黑色文字），陈诗扬 （采访者，蓝色文字）
总时长：80分钟

第一方面的问题是您在做海绵城市的一些经历，然后关于对海绵城市认知在您和您所处的单位或者行业上一个变化的过程。

第1个小问题是您参与过海绵城市的那些阶段，比如说从规划一直到实施，然后到最后考核，您参与的比较多的是哪些阶段？

第1次接触到具体的项目，应该是2015年，国家第1批海绵城市试点，当时去的是四川省的遂宁市，主要的工作，一个是编海绵城市专项规划，第2个是做现场的技术咨询服务。到了2016年，就去了宁夏固原，第2批海绵城市试点，当时的工作是一个是申报实施方案的编制，第2个是申报成功之后，专业规划的编写，第3个就是固原后期的一些项目前期的策划和对接，比如现场的技术服务，海绵城市的建设评估方案，国家就搞了两批。所以您做的比较多的是规划和评估方向的方案。对吧？对，大部分都是规划方向。然后15年的时候还去过鹤壁，河南省的，他也是第1批海绵城市试点城市。做过鹤壁的改造项目的设计，然后遂宁也做过，遂宁第1年的所有的设计都是打包我们做的，我们跟别人合作。基本上就是我们出方案，他们出施工图。

在您参与的这些城市中，他们建设海绵城市的方式上差异大吗？能不能做到因地制宜，实现他们的目标？（就）您参与的一些城市（而言）。

刚开始试点的时候，大家确实比较迷茫，那个时候的依据，你经常拿到的海绵城市建设技术指南（试行），那个时候大家可能就都等同于低影响开发，或者主要做的都是低影响开发的事情。这种时间大概持续了有一年，那一个时期我是觉得因为一个是国内争议比较大，大家讨论也比较活跃，比如说15年编专项规划的时候，那个时候还没有专项规划编制暂行办法。因为对于在国内来说，我们编规划的话，基本上以前的规划都会有一个大纲，或者就编制大纲的东西，或者有一个提纲或者有一个办法，就是你拿到那个项目的时候，你会知道，大概要分成7章还是8章，主要的内容是包括是什么东西，但是那个时候只是说要编专业规划，这个专业规划包含哪些内容，要解决什么问题大家都不太清楚。我的感觉是那样，因为最开始大家有的都是指南，从低影响的角度，大家觉得规划的意义不太大。低影响就是一个指标指导性的一个建设，所以那个时候15年的时候，大多数的专项规划都是一个分指标的过程，市里面跟一个大数，然后分到各个片区，各片区再分到各个地块，因为通过城乡规划的编制体系，这样你只有落到控规里面，才可能往下继续得到实施和落实吧。否则的话，有可能就没人管，主要的原因就是你要没进控规就没有进现有的规划建设程序。相当于是有这么一个东西，但是没有落实到部门的事权，因为你落到控规了就有一个专职的部门，比如规划局他就会发放这个指标，然后他会监督他的实施和完成的情况。

大概是在15年后期，部里面就觉得规划不只是分指标，这是部里面的，另外一个社会上，好像压力也挺大，特别是2016年，海绵试点了一年之后的，夏天好像雨很大，很多地方都淹了，有标题性的就是海绵城市，什么出现严重内涝这样的，特别是武汉了什么半米一米深这

种，所以到了16年的时候，我觉得部里面他可能就转向了一个问题导向了。 就是说你有什么问题，你就解决什么问题，就别光盯着那个指标了，别光在小区里面弄点什么下城市绿地这些东西。然后再往后就出来了源头减排、过程控制、末端治理。第1次提出来，我不太清楚是啥时候提出来，好像是章林伟他们在给排水上发了一个文章的时候提出来的。他们联合在的一个杂志上发了一篇叫海绵城市顶层设计的一个文章，大概有10来个作者。就是这样的话，相当于把海绵城市从一个低影响开发，从一个小区内部的建设，往城市层面来扩展。当时暂行办法出来之后，也是说解决4个水问题，生态、环境、资源和安全。 但是后来我是觉得生态这一块，从现在来看，比如说我们现在部里面写十四五水务发展的话，他就这三个水了，水安全保障、水环境治理、水资源利用。就生态当时从我们弄的时候来说的话也会有一点困惑。第1个，他会跟环境这两个搅不清，说也弄不清。另外一个，如果是抛掉我们前面说的山水林田湖大海绵的基底，大生态来说的话，后面的生态就是现在说的生态河道了。对，尺度太小了。你要能列工程的话就是这样。比如说低影响开发，它其实也有生态功能是吧？但是那个东西你就不好列了，他开发相当于有综合的功能。可能跟这些东西都有相关。因为按照我们以前编规划的话，你前面目标、战略或者是措施，最后就是任务，要对应到项目你这样才能落实，弄的时候就不好列项目了，包括低影响的话，当时列到小区上去就统计多少个小区多大面积，然后有的时候可能就按照面积估一个钱，大概需要多少投资。

大概那样一年过了之后，我是觉得加上部里面这样的一个指导，大家基本上都是走向一个因地制宜的这样一个状态。就几个表现，第1个就是不再死扣指标。2015年的时候，如果你现在倒过去找好多城市本的指标都分到小数点后面两位数，有点特别机械的那种感觉。当时我们就觉得没有太大必要，对吧。你比如说比如说我们在遂宁的时候，我们就给它分成几个档，基本上就是什么3580就这样。这是我们当时给他分的档的意思，就跟容积率一样，你比如说国内常见的容积率，1.0、1.2、1.5、1.8、2.0，你要说非弄个1.75也不是说不行。

那个阶段因为大家也比较迷茫，不知道做什么。当时就知道分指标，就比分指标谁分的精确，然后这个阶段我觉得出现小数点后面的很多都是原来是环境专业出来的，他们比较擅长于计算，然后他算完之后，他觉得要么是自己觉得说比别人更精确，让我觉得他就应该这么精确了。但是从现在来看，基本上大家没有当时那么执着，我看基本上分指标都分到大数了，再出现小数点后面的基本上没有。然后档也不会太多了。就像刚才说的就像容积率一样，1.0、1.2、1.5、1.8、2.0就这样了。大家都比较比较轻松一点的话。

第2个就是刚才说的更加针对那个问题，比如说像遂宁，他们当时有内涝的问题，他们就通过解决内涝的问题，然后获得了群众的极大的认可。包括后面为什么部里面就比较推遂宁拿到了奖励资金。这个也是个很重要的原因。后面要是说到就按照以前邓小平说的，黑猫白猫抓到老鼠好猫是吧？就说，你说一千道一万，你做这么多事情之后有没有效果？所以他当时我觉得他主要是把那几个内涝点的事情解决了，所以在16年的时候，他就是出现了一个不同的局面。在好多城市，在老小区，甚至国内有一个城市老干部联名写信反对市政府改造这种公共建筑。因为比如说15年我们刚开始搞海绵城市的时候，选了很多都是工业。为什么选呢？第1个，从建筑类型来说，我们也要全覆盖，都要有它。第2个，工业相对来说它的绿地、面积啊，开场的空间比较大，相对来说好弄一点。第3个就是比如说弄工业，政府掏钱会好掏一点，因为有的地方就会出现，你要政府说给小区改造别的老百姓会有意见，平常就给他改，不给我们改。就是像这样一些反对。遂宁他就通过解决内涝的问题，结果出现了好多小区之后，他们统计起来可能有上百个小区给市里面海绵办写信，主动提出要求给他改。后来他也思路进一步拓宽了，刚开始的时候他可能主要是比如说解决内涝的事情，包括后面他也解决水环境的事件，他解决内涝的事情。他就附带着按照现在的说法，他当时叫海绵+嘛，就是我们的意思也是你都是进人家小区了，你别就光这干这一件事，人家要有别的事情不方便，你也一道给他收拾了。它的排水不畅他把管道修了，路面破了，把路给恢复了。然后好的小区原来绿化不行，要么就是给他做一下景观，要么就是老小区它有个停车难的问题，就是把绿化在里面给他增加一些停车的功能。然后还有一些小区，比如说照明没有或者照明坏了，

路灯不亮，外立面什么东西就基本上弄完之后，按照咱说的就是焕然一新。所以他后来弄得比较成功，老百姓比较认可，然后领导也比较满意。

比如说到了固原，固原年均降雨量不到400毫米。它是黄土高原干旱半干旱地区，当时我们在那提出来16个字，优先利用、调蓄排放、生态净化、适度入渗。他那个地方是湿陷性黄土地区，所以当时我们去了之后，他们跟我重申的事情，就是我们这个地方是湿陷性黄土，我们这个地方水不能下渗，但是咱们又给了这么一个指标，到了16年的时候会比15年会好一点，就是你别的事情可以做，就视野更宽了，但是你这个事情不能不干。 不像16年先一上来就先把这个小区给改了，他16年的时候就变成别人要干，这个小区还得该改还得改。这样的话就碰到这个难题，所以后来我们给他建议的就是优先利用，结合他水资源比较短缺，然后适度入渗、生态净化、调蓄排放。他那边现在雨水收集的设施做的还是比较多的。用在灌溉或者是？他那边有地下的，地上的量比较多，但是单个的容积比较小，大多数都是一立方米的。可能比荷兰的还会大一点，我看AST上面写的是240还是多少？是什么？雨水罐。基本上大多都是200~300左右。很多小区到后面就是一个雨水立管下面就一个。第1年弄的时候，弄完了第2年一看，老百姓还是比较认可，因为那个地方第1个确实比较缺水，然后小区里面绿化也需要水。然后第2个就那地方经济不太发达，有的人可能出于节省费用的问题，也出来提桶水，或者是把碗什么东西拿出来下面洗。

到了第2年的时候，我们也发现雨水收集设施有个什么问题，不便于利用。第1年的只是为了控制径流，从这个出发，然后采用雨水利用的这种形式，但是在实际使用发现一个问题，当时箱子都搁在地上，然后出水口肯定是在下面了，基本上就这样。接水非常的不便，到了第2年开始就给所有的新建的上面都做上架子了，比如说架个半米高，这样的话以后大家接水用水、雨水利用更加的方便了。

就是雨水桶。对，第1年是桶就直接就出在地上了，他收集屋顶、屋面雨水。那时候大家洗个碗都是趴在地上。像这种他是在设计过程中，它的自主主权比较大的，是吗？不依靠于规范上规定的水资源利用率多少来扣指标。我就说一说我们的指标是怎么来弄的，可能现在大多数都是这么弄的。当时第1年分指标的时候，我们就把那个指标分成两类，一类是叫约束性，还有的叫建议性还是怎么的，可能就分成两类。对。

因为刚开始分指标的时候，就是从指南里面，他有好多指标，比如径流控制率，什么下沉式绿地率，什么透水铺装利率就这些。我们后来当时就想有一些它是属于措施性的，我们觉得他应该是引导性。然后像径流控制率，这个是目标性，是属于达标的。这个也是相当于是从我们国家的控规编制里面，来得到一些启发，他那里面也是这样。因为当时我们想我如果从一个全市的角度，我不可能对你每个小区了解的那么仔细，然后对于一些措施性的指标控制的这么死，你通过一些方式的组合，你觉得更加的合适，或者你有更有一些自己的倾向的话，只要能满足目标就可以。 像在遂宁的时候，控制性指标只有一个，就是年净流总量控制率。但是到了固原，是两个，还有一个与水资源利用率，跟他当地的水资源紧缺状况，以及他湿陷性黄土这样的一个地质特征是相匹配的。总体来看的话，海绵城市在中国是一个不断思考、循序渐进，向前发展的这样的一个过程，包括目前我觉得他也还是在不断的发展和完善过程中。

还有一个各个部门和不同专业背景的机构，他们在配合方面，协作方面的情况是不是能做到互相协调来共同完成海绵城市建设，有没有遇到一些困难？

不同行业对这个事情的认识，或者说出发点不同之后，他提出的想法或者是建议，还是存在比较大的差异，或者有的时候就产生了冲突。比如说下沉式绿地，开始的时候园林部门反对

声音很大，他们就觉得这个东西进去了之后会把他们的植物给淹死。另外一个可能也是跟中国的国情有关系，中国的雨水可能会比较脏，他觉得水进来会把他们植物给弄死了。像重金属什么的。所以配合他们园林部门，后来还接受了吗？还是比较抵触？怎么解决这个问题？可能最后还是看是谁主导这个事情，谁主导谁说了算。因为比如说像小区内的这些改造，基本上都是建设局在主导。很多地方都是单设的园林局，相当于这个项目就是我的。我干的话你只能提反对意见，但是你没有决定权。在这种反对声不少，但是因为他不是在那个决策里面，他不能参与决策。你要去上网去搜杂、期刊里面有很多人反对，主要是园林的。我们之前也看到了水利的主要的质疑的就是年径流总量控制率。

现在是大多数都是在住建部门下面负责海绵实施项目？对。比如说跟交通部门协调的时候，或者跟园林部门协调的时候，他们怎么推进这个事？比如说做一条路，准备说把两边的铺装改成透水铺装，然后加一些生物滞留池。但是那边的交通部门就反对声音很大，就是怎么协调好这个部门之间的利益冲突的问题？

你这个说的还真是一个比较典型的，因为假如我们说小区的话，他就没有那么多，你要是说到路的话，他路上的绿化就是归园林局管。

对，车行道又归交通部门管，然后他会限制你就是要给路让多少米。如果就多个部门之间冲突了，我们会不会在以后海绵城市的指南或者规范里头会提到他们，指导他们怎么协作？

我觉得基本不会。　　因为这个的话，我觉得他不是个技术问题，他是一个协商机制的事情。你要是说到时候在指南里面或者规范的写，只能说是多方征集意见，加强协调协商，达成共识，是吧？原则性的话只能是这样。具体到时候协商的时候谁让一步，只能看协商的时候情况。这个里面原则按照我的理解啊，基本上我们原来在发现这种冲突的时候，第一是要尊重结构专业的意见，安全是第一的。比如说我在固原的时候，我说渗下去，他说渗下去会塌陷，房子会倒，我就得问他，我说我离你那个房子地基多远？三米还是多少对吧？比如最后他告诉我三米以外可能是安全的。有可能是他们行专业里面一个经验，也有可能确实是有这方面的比较规范明确的规定，但是我们不是他那个行业的，我首先是有尊重的，也有可能你研究完了之后，不用三米只要两米也够了。这个可能就是下一步再去优化的事情了。所以现在规范里头不能明确说怎么协商，因为看你冲突点在哪，是吧？就具体对你冲突不一样，你基本上我觉得安全第一搁到哪都没有问题。你比如说房子，他说房子归他，比如说你那个路，假如说他地基他要是什么密实度要按照多少，他说那地方不能渗水，渗下去导致他路面会开裂的话，你就没办法，你只能尊重他。对吧？在安全抛开之后，剩下的现在他们就是说功能和景观是要并重的。因为有一段时间把这个功能看得比较重，特别是刚开始的时候，那个时候就出现了一批，就是说15年试点的那一批，城市里面干了一批的，有点叫照猫画虎那个东西，因为那个时候大家谁都不知道，比如说看到下凹式绿地，在那个书上看到图片了，对吧？以前也没有画过。设计人员没有画过图，施工人员也没干过这样的一个东西，这样的话就出现了一批功能比较强、景观比较差的这样的一些项目。你比如说下凹式绿地或者植草沟是吧？你要是按照景观的，它是坡度深度，它有一个比较好的衔接。因为第1年刚上来的时候，市政的就是给排水的人为主，这帮人都是搞工科出身的，第一可能他美感就不足，第2个他搞景观的经验基本上没有。他再加上施工单位，你说跟植草沟那个东西在图上可能不太好表达，可能就是一个意象的意思，主要是靠施工单位，施工单位他以前没搞过，施工单位现在主要是以民工为主，这样的话他就是用锄头或者是铲子或者小扒机，有的确实勾出了，但是非常的难看。所以说还是得在设计和施工的时候要加强不同背景的（协作）。所以后来我们就说这个东西属于一个精细化设计、精细化施工、精细化管理的事情。道理很简单，要做好比较难，大家要在小处下功夫，这跟咱们以前的建设有点不太一样，以前咱们那个项目都是什么大长高都是这样，都是追求一个规模的效益，它都在细微之处，你看这第1年真的是这样出现了这种现象。第2个有一种功能也没做好，也那个原因还是属于一个装猫画虎的状态，

比如说需要一个溢流口是吧，当时16年我们去看，15年那一批的时候干了一年，有些项目溢流口搁在那一个汇水片区最高的地方，口是有的，他那个口估计从来不会进水吧。对。所以后来就提出来了，要重视竖向组织，它跟供水不一样了，它就是重力流了。不是你说从哪进他就从哪进。

我们再聊聊指标的方面，在我看到的一些文献里头，从设计然后一直到考核，都很重视这个指标。然后这样我想了解的第1个是这个指标是如何从比如说从省一直分解到社区，甚至到街道的过程？

省是没有的。省只有一个指导意见是吗？省会出一个指导意见，但是省是没有指标的。 因为中国的城乡规划编制，那个条例里面，城市总体规划、分区规划、控制性详细规划分成控规和详规，它体系作用在绝大多数的市，比如说地级市，它就是两级法定规划，一个是城市总体规划，另外一个是控规，分区的话可能像上海、北京这种特大城市才会出现了，总规里面会给整个城市确定一个指标或者是目标。然后在总体规划里面，他还要确定一个片区的，比如这个城市可能划成20个片区，但是反正这个片区，现在也说了，也要尊重社会属性，也要尊重自然属性。经常也为分区打架，来一专家说你会的分区划的不对。但是现在分区还是靠根据它的汇水功能来划的吗？还是会综合考虑一些什么土壤、土地利用这些社会功能，还是说？主要是依据汇水。主要就是依据汇水，然后我他那里面说的自然和社会是那个，自然属性是你地形地貌造成的这样的一个流域片区；社会属性，就是你上了排水管网之后，你有可能在边缘去或者说局部改变它原有的这样的一个排水方向的一个事情。所以他就是说要有遵循这个。但是这个东西就是你刚才说的，比如说跟他城市用地的布局，你可以做适当调整的。也不是说完全就是一个自然的，就是你这种排水的分区是吧。因为你比如说城市有这个组团，你就差那么一点，你就不过去了，是吧？这个也有点太激烈了。对这个争议比较大。我就碰到过画一个分局来一个专家说，他画的不对，又来一个，又不对。就有一段时间特别强调排水分区，就觉得划好排水分区是你指标分解的基础。如果你这个基础都没有，你这指标肯定分的是不对的。然后基本上在总规里面会确定一个大数，然后确定若干个片区的数，可能跟城市规模会有关系，跟城市的布局有关系。若干个有可能是20个，也可能是30个，甚至在有些地方之后，就是为了协调或者是平衡矛盾，分成一级分区10个，二级分区35个，后来我都给你了，就这样的。然后下一个法定规划不就是控规了吗。拿到控规的时候，你就会到那里面去找，也有一部分城市直接把指标就落到控规编制单元。 比如说他城市要编30个控规，它的总规里面直接就给了30个数，30个数字到每一个控规，这样的控规你就不用去找你是哪个流域分区，否则的话你可能拿到一片控规10平方公里，有2/3在这个流域，1/3在那个流域。

我也看了一些的他们地方的规划，像比如说南京市他们先区分它们每个区的一些指标，然后再把每个区分排水或汇水区，然后每个汇水区再分不同级别的小地块，然后每个地块给他具体的指标，最后不管是南京市的规划，还是到他们排水分区的规划，都里头给的数都特别详细。但是这样的分解指标的方式会不会影响到或者限制到一些设计的过程？比如说如果我特别小的地块就给它限定死了，下沉绿地多少，然后绿色屋顶多少，然后 VCR多少的话，会不会限制它的景观设计，因为设计是一个创造的过程，如果你给他太多限制的话，会不会影响他的景观设计？

是这样，我的理解跟你一样。所以当时我们在那个城市做的就是给他分成强制性和引导性的，我觉得哪些措施性的指标，你都不能给他约束。或者你给他一个比较低的门槛，让它有比较大的一个发挥空间。我当时跟他们说的那个意思，比如说我为什么要搞约束性指标，让你有这个意识，你要优先采用透水铺装，优先采用绿色屋顶下沉绿地，对吧？这个绿地不要死抠，你要一死抠机械的那就没意思了，对吧？我跟你分指标的时候，我连你小区的总平的图都没有，我怎么能给你限定死，你就绿色屋顶就25%了，是不是？有可能你就出来一看你

全是小高层，有可能你绿色屋顶就是0。

然后还有一个问题，就是现有的指标体系中有哪些指标您觉得需要调整，或者哪些方面需要补充指标？就现有的我们就不说哪些多余了，有哪些需要调整或者需要增加的？

还没想到这个问题。如果跟荷兰这边或者是跟欧盟这边对比，或者说有一些国内没有提到过的指标，或者是国内过多强调的一些指标，但是可能没有那么必要。我觉得这样的人第1个想到的就是那天Frans说的那个，还要进一步强化“肥水不流外人田“。是原则上不要转移问题吗？他不是说1.5升每秒每公顷是吧？对。如果是对照他的原则，我们现在尺度还是有点松。什么尺度？排水还是可以很多。另一方面你要不排多就涉及到调蓄要增加很多问题。就是看你的理念什么，他的逻辑就是那样，你家的不要的东西你就不能往外扔，你不好办是你自己的事情，你不好办，你也给他办了。

你就说到这个，我就想起来环卫现在固体废物法里面有点关系，但那个东西现在给我们造成很大困难，他就是固体废弃物，特别是危废，法律面是规定的不能跨行政区域转移。比如说上海原来就出现过垃圾不好处理，然后找人用船拉到江苏去倒了。这个东西跟别的还不一样，它是违法的。所以现在我们住建部在组织有一个地方搞那种城市连绵带、城市密集地区、重大环卫设施共建共享的（时候）就碰到这个难题。这扯远这跟他没关系。但是意思上有点相近是吧？虽然水没有那么大的危害性。对，你要更严格。

另外一个就是年径流，这个总量现在是有了。原来以前有个峰值的指标，很少有地方在分在用在考核。是不是也因为他不好定值？就是不好把它具体化要减多少才算减峰值？我觉得那个东西大家最大的问题是不好去考核。就打个比方，AST他为什么最后能搞下去？我觉得最根本的原因就是他有简便的小公式。就三个数两个数，是个人都能给你算出来。如果你说这个东西你要先建个模型，要花30万，三个月建了个模型才能算出来。相当于你评估的成本太高了，社会是承受不了这个成本的，所以最后我觉得只好放弃，没办法用。就打比方，我给你下指标，说你峰值要给我削50%，你也不知道削了多少，我也不知道怎么去评估你到底削了多少，这事咱俩就没法去较劲了。没有一个公认的尺度。咱俩能达成一致，就是说你算的这个数我能认。而且现在每个地方做的也不一样，对吧？每个地方用的模型也不一样，然后做模型的方法也不一样。基本上我还没碰到一个地方在考核。这个也是鹤壁市我看它有一个模型的一个报告，他就是说用了InfoWorks做，然后高风险内涝区减少了多少。那个是这样的。比如说在别的城市也有这样的，项目做完了，他为了展示他的效益的时候，因为你模型都建了，他顺带就把它给算出来了，明白吧？他也知道有这个事情，但是他在做那个事的时候，是没有盯着峰值削减的目标去做的。你做这个事情他是有多个产出的。对。到最后他评估的时候，他为了展示他的很多的产出，所以他把这个事情（做了）。你的意思是从开始设计的时候，他没有把峰值削减当成一个目标，是吧？就是在设计的之前也没有人告诉他要削减多少。设计的时候他也没有特意为这个事情去做什么。因为成本问题或者因为？最后为什么会有效果，是因为那些设施它是多功能的，它自然就带有效果。后面就是因为它确实有这个东西，但是你为了把这个事情展示的更好，是吧。把他的所有的效果都展现出来了。因为你知道吗？不是所有的项目都算到模型的。对，就有一些。但是所有的项目都考核年径流总量控制率，是不是？他怎么实现的？就是他那里面有一个大家能接受的简便的公式，可能有很多人说公式不对，或者是说不妥，至少不妥。但是他不管妥不妥，八九不离十你能算出来，对吧？你对于峰值来说可操作性，你连个八九不离十的这个东西都没有。后面峰值您看来会改进他们会规范他吗，在以后的项目里面还是会很难？首先在技术上要突破，你要技术上有支撑，政策上才能有依据，不然的话他又没办法去执行了。就是工具、模型或者有技术。然后这个手段必须是一个低成本的手段，否则的话你的监管的成本就太高了。对，而且学习成本也很高。当时我是觉得这个指标还是很重要的，对于中国就是峰值这个值，对峰值削减，他甚至有可能比径流控制率还要重要。但这个是水安全角度上，削减是防止内涝，是

吧？对。因为你看现在从降雨量分布来看，荷兰就是欧洲这一块，它海洋性气候，雨非常的均匀，你看下一天雨下10毫米，咱们一定要下一天雨下100毫米，说不定一个小时给你下100毫米，一搞就是强对流天气了。所以我们这边水安全的这方面的需求比他严峻的多了，你要他下这点雨的话，我们现在的设施根本不会出现任何问题。

然后在考核阶段，您参与过一些海绵城市上的考核，对吧？考核阶段会遇到哪些他们当地做的困难的地方。就是他们做起来比较困难，或者指标上解读比较困难，或者是在设计施工上存在一些困难的地方，或者是考核出来发现它效果不大好的。有这种情况吗？

比如说像固原那边，现在部里面就反映做出来的项目，数量很多，没有精品。这个东西的话，可能跟几个方面都有关系。第1个他先天不足，他那地方气候就比较差，我16年在那地方是五一了，桃花都已经开了，桃花比这边开的晚一个月，还下冰雹。他冷天特别长，暖和的天比较少。本来海拔也比较高，水又非常的缺乏。所以，先天不好。第2个，你比如说，我在遂宁的时候，现在局长走了，他当时跟我说做事情东家还是要上心，说东家不上心，都靠你们设计施工的肯定是干不好的。他说你看我们好多项目都是小设计院干的，他说你看这个效果干得挺好。他就是说做这个工程，说七分靠东家三分靠工匠。确实当时在遂宁的时候，他们有那么一批干部，第1个他非常的认真，你要想蒙混了，那打马虎眼他也是接受不了的。第2个他们确实很聪明，善于学习。那个东西是个新东西，其实对于我们来说也是个新东西，对吧？可能比他稍微好一点，但他也在学，跟他就会在主动的想，海绵城市该建的什么样该解决什么问题。相反在固原他们就会缺这样（的意识），所以导致先天就不好。第2个后天干的时候又没人管，所以说部里面反应的就是说，你得要有一批能懂这个的能管得住的人。虽然你是有设计的、有施工的、有监理的，你不能当甩手掌门，你要再甩手掌柜，可能大家都糊弄一下。对。你的意思就是跟家里装修一样。要看上层指导。所以至少你要知道提什么要求，对吧？比如拿过来说什么都好，肯定他，对吧？谁也不想多费脑子多花时间。

下一个方面是关于模型，您觉得在海绵城市哪个阶段需要模型，然后需要哪些功能的模型，现在的模型能不能满足海绵城市建设的需要，首先，哪些阶段需要模型？

在规划阶段用过模型，设计阶段也用过模型。但是我用模型的目的都是做一个结果反馈，不是用模型来指导设计或者是规划，相当于我出一版方案，然后建模，用模型来评估它的实施效果。你首先要建模，我现在要出一版方案，你是想知道哪个阶段也需要是吧？对。这个事情我觉得哪个阶段都可以用，但是什么模型，还有问题。比如说模型在国内有两帮人争议，包括我们院里面，一帮人就是模型无用论，一帮人就是模型万能论。我觉得模型它肯定是有科学根据的。现在在中国为什么会有这么大的争议？可能就是因为基础不足，因为它需要数嘛，是吧？你数没有你让模型能干啥？是不是？就是说你支撑的越充足，你给的信息越多，模型做出的答案肯定是越科学、越准确、越精确。现在国内很难达到这个阶段。对。很多比如说微观模型，微观模型一般就是用在单个的项目上，但是在项目上的话，如果是新一点的小区，可能还好一点，我们通常都能找到CAD的图纸，这样的话基本上是能建个模的。然后老小区呢，假如说确定要建模，因为不是每个小区的建模，他要没有这个的话，我们会让甲方去找勘测的再测一遍。但是就是这样的话，它这个基础还不是太好。你看第1个原因就是中国的竣工图把得不严。往往你在档案室拿到那个是施工图、是个设计图。他在施工过程中可能出现多次变更。对于设计院来说，最后他再出一版竣工图，他是要收费的。比如说他不出竣工图是2.2个点，带竣工图是2.7个点，要多0.5个点。他还要再修改一版图纸，然后再上交再存档。有的时候他可能是没给这个钱，有可能是没签这个合同。有的时候很有可能就施工单位就把原来那个图改就交了，也可能他没改就交了，反正这个也不太清楚。

第2个就是说测绘这个事情，如果是通过测绘的，理论上是能够测准，但是现实中也会经常有

问题，特别是比较老的小区，经过一次，有的多次改造之后，那些管子他测他也蒙。很难测是吗？还是测的不准确。比如说在路上一到拐弯的地方，它就犯迷糊，谁跟谁连了它就有点搞不清楚了。用的主要是物探，然后也可以下人工下去看。

一个可能是客观条件比较复杂导致的。第2个也有可能甲方对他的要求不够高。因为以前测绘的图交完了之后，有没有人跟你较劲了。你这个东西测的准不准，按照我们说测绘能测80%是准的就不错了吧。反正来说去中国的技术比较差，这是一个现场的技术比较差，另外一个就是那里面需要一些参数，那些支撑也非常的少。比如说你模型里面，你要说渗透率是吧，初始渗透率多少，后面稳定渗透率是多少是吧？你像我们在有些地方就做过双环入渗实验，在那画一条曲线，可能刚开始的时候一个小时能渗个100毫米，后面一个小时可能就有10毫米，是吧？理论上就是说你只有在这个地方做了这个实验，你才能获得一个比较准的数。假如说你没做的话就没有。这个事情就是这样。如果你是做一个小区，它就比较费劲，对吧？你找别人来就干这一个事情了，一个小区里面给你扣几下，这个你就会涉及到费用怎么出什么问题，是吧？像在遂宁，当时我们就是说，因为第1年的所有项目都给我们打包了几十个项目，我就说这个事是要做的，然后他就委托一家把那几十个都做了，这个就比较顺了，你要是单独是为了一个来弄的话，你想现在这个东西他不可能是个人行为，他可能是公司行为，公司要签合同，你可能这一个他只要个几百块钱，但是你这都不够费这劲。有时候很简单的事情你就是办不了。现在操作起来肯定各种各样的问题。所以他们有的比如高校里，他们有学生，他们就自己买双环渗透仪，自己去弄。其实自己弄当时也是可以。但是这个东西，你要是说如果别人给你建模的话，一般模型公司他不会给你搞这事的，对吧？因为比如说我了解的模型公司里面它主体的人员，还是搞计算机的。通常比如说10个人里面有两三个学给排水的，然后六七个都是搞编程的。他们肯定是没有这个概念的。因为我觉得模型是个好东西，也是一个发展趋势，以后我们肯定也是向往这个方向发展。

谈谈荷兰这边的模型，SDF以及AST，谈谈他们在海绵城市中的适用性。现在做过两个项目，在国内湘潭现在在做的南京的。就用在设计阶段，用SDF指导他设计多少的调蓄量，然后用AST来指导不同行业背景的人一起讨论哪些措施放在哪里？然后措施是多大？你觉得这种（工具）在海绵城市中在中国推广的话会有一些困难吗？

我只能说我现在的感受啊，他后面还要给我个案例，我用一用有可能会有不同的感受。我现在觉得它不适合这个项目层面。因为通常在国内来说，项目层面的模型就是个机理模型，他这个不是个机理模型，即使他把SDF搁到里面去了，我也很难想象。比如说我按照重现期两年一遇或者是三年一遇，我设计的管道，那个S怎么跟那个D平衡，D可能会是很大的。我按照室外排水设计规范套出来的，我的排水能力会很大的。因为小区我现在不用算，中国的雨水小区出来至少是400（毫米）的，　400的管子一天能排好几万吨水。它可以做成小时。他做个小时就是这个问题。我们现在的规定的调蓄量是日降雨量，你不能调整小时，你调成小时的原理就不对了。存在调蓄跟排水它时间上不对称？就是刚才说到那个事情，如果用他1.5升/秒/公顷，我给他算了一点，1.5升/秒/公顷是什么概念？1万平米一天只能排100多方，你看我那400的管子，这300的管子一天排1万方都没问题。就是数量级中间差好几个零，你那个东西对我一点约束都没有。他不说中间取一段吗？我肯定是在你那两部两侧。没有关系，就算你按现在的现状的规范来设计它的排水，你也可以确定一个调蓄的量，可以找到它调蓄的量。是可以找到一个。那个量可能会很小，会比你海绵的十几毫米还小。

这个困难除了这个时间上的尺度不一样，还有一些别的困难吗？就接受度上（而言），比如说AST用在国内，各行业一起来讨论（海绵）摆在哪能解决他们行业之间冲突的问题吗，就像我们之前谈的那个。

如果在项目层面我觉得没那么复杂，其实按照咱们通常来说都是比如说多方案或者是有个方案征求各方意见是吧。我不知道来一个东西，咱们大家一起在上面排兵布阵会是什么样的一个结果。你觉得他适合在多大尺度？控规，几平方公里的尺度。在控规的时候，他有的时候会给你一个意象图就相当于总平图这样的一个东西。上面只是写的用地性质，比如总规层面就是这样，控规它会告诉你这个地块里面容积率、绿地率这个东西是多少，然后在这个基础上，按照国内就是说如果你再给他费用的话，他能给你做一张，相当于我们叫意象图叫什么来着？能把你房子给你摆上。因为要有那个东西，你就上面就好圈，不然的话你就没法圈。现在你的规划图上是没法圈的。你圈现状还行，规划啥都没有，没法圈。

这个SDF你觉得可以用在控规里头，比如说指导这一个区，他总共需要多少调蓄的量吗？我觉得可以流域。这个层面可能是比较合理。大概是多大尺度？你觉得比如说拿秦淮区去做例子，你觉得做一个秦淮区的用SDF，再分排水片区，给每个排水片区再定一个调蓄量的指标。我首先觉得我流域没有多大的概念，多大的流域都可以。但我觉得它可能会要设一个下限，就缩小一下就不用做了。就不要再无穷无尽的分到每一个地块里去了。打个比方，比如说长江流域我觉得都可以用。你比如说长江口，你流量控制多少上面湖泊需要多少调蓄。你同样移植到赣江，那也是可以用的。在干旱地区或者像固原这种地区也可以使用吗？我觉得也是可以使用的。因为只要他原则、理念大家能接受，这是可以的。

好。我们进入最后一个话题，就是海绵城市技术指南也讲它是追求一种现代的雨洪管理体系。我们就谈谈现在中国的雨洪管理的思路。因为现在海绵城市的他调蓄量可能是解决中小型降雨。你觉得有必要把中小型降雨范围再扩大成那种暴雨，像上次Chris向我们展示的，从0年、5年，然后10年有20年、50年、到200年，有现在海绵城市可能就是0~1年的调蓄量，但您觉得可能扩展到后面10年一遇20年一遇。

如果是从雨洪管理这个角度，从城市层面是有必要的。他现在说的十几毫米中小降雨与还是源于 LID来的。

比如说小区层面，它是不是也有必要去扩展一下，它也有可能存在内涝风险，如果只靠1-3年一遇的管道的话不能解决内涝问题。

我可能只能说一说现在的状况是什么样。中国小区出现内涝的不太多，或者说比较少。现在通常看到的内涝主要是在道路上。小区出现内涝的确实是因为自身条件不行，四面都比他高基本上都是这种状况。现在按照城市竖向规划规范里面，小区的场地的地坪，他肯定是有一个点，要比周边的道路要高20厘米以上。就是在中国的竖向设计上，建设用地要比周边的至少一个点要高的，也就意味着他那地方不太会积水，他得有高差的。他有积水他就会流到路上去，所以现在经常一积水会路上会有这个问题。

如果道路上你觉得有没有必要考虑这种调蓄跟排放结合的这种思路？

所以我是觉得随着标准提高，肯定是调蓄容积也要增加，但是他有可能不会像荷兰一样就搁在每个小区。他有可能是搁在小区之外的公共空间，有可能是需要道路边上建一个调蓄池。也可能是在某个片区周边要建一个什么湖泊水塘什么东西，现在我觉得国内还是没有的。

你觉得怎么协调这个和现在已有的设施呢，比如说防洪排涝的一些设施怎么协调好，海绵城市它强调的调蓄的量跟防洪排涝里头说的那些排放和调蓄的措施。

我可能回去还得再研究这个事情。这种矛盾可能是不太会有的。比如说现在大家可能能够比较接受的，雨洪管理系统三套，第1个就是源头的小区里面，第2个就是管道的，第3个就是超标的。现在源头上基本上搞的差不多了，我觉得比基本上清楚了，是吧？要管一些什么东西？目标是什么？方法、手段都有了。刚才提到了峰值可能没有控制好，但是基本上都有了大的。管道的更完善了，是吧？以前都是从苏联学来的，但那个东西里面可能是不是有需要改进的地方？经常管道设计的是不是准的？有没有跟西方国家他们这些理论做一个对比？因为我们上学的老师就按照这个教的，但是不管他对不对，那个东西他现在基本上是成体系的。可能要做的话也是个完善的事情。但是现在超标的东西，超标洪水系统，基本上是不能说空白，是起步阶段或者是理论阶段。你肯定发现国内的规范有一个内涝防治标准，对30年50年是吧？你问他怎么做不知道。你画了行泄通道你保证有水过来嘛，也不知道。行泄的说话多年一遇的雨地上水有多深，你知道吗？也不知道。可能会跟SDF衔接上，通过三套系统总的能达到，比如说他说的一百年一遇的，我觉得应该是这个概念。不能把100年一遇或者250年都关在小区里面，对吧？荷兰有可能能关得住，中国真关不住。

那就涉及到气候差异的问题。你觉得就和中国跟荷兰，中国当然有些地方降雨也比较少，那些比如说南京这种江淮地区降雨比较强烈，短时间降雨比较大的这些地方的气候跟荷兰这边降雨的差异会导致我们在海绵城市设计上有哪些区别呢？

最大的差异还是不均匀性。我们峰值太高了，导致的结果如果反过来就是说我们要更加注重峰值的控制。

控制是指调整调蓄的功能还是说调整排放或者是两种结合？怎么来达到调蓄？因为我们国内的峰值比这边要大很多，能借鉴（荷兰）这边的，依靠调蓄来控制这些峰值吗？

我觉得排和调都要，按照水利上叫蓄排结合。以前我们可能是从城建的角度，过分关注于排了，因为那些水体那些湖泊都不归城建系统管，它都是水利部门的东西。对吧？因为跨行业首先它就不是你的地盘，估计也没想过要弄那个事情，有的时候你可能想要把它搁到一起，但你也搁不到一起。不是一家管，就是有部门分割的问题。其实调蓄肯定是要增加的，但是我觉得在国内的排放的标准也还可以适度提高，也不是说我们排放现在就已经做到位了。像咱们的合流制溢流一样，虽然我们现在也截留了，但是我们截留倍数还不够。所以也不能完全跟荷兰这边一样，因为毕竟我们峰值太大了？反正是要削峰。咱们一天下100毫米，太多了。年年都会有。甚至一天能下200毫米。他这地方多绵绵雨，他一年下800，我觉得七八月份可能也就100毫米。从10月份开始，（气象图上荷兰）都看不见有雨，可能就10毫米8毫米的吧，北京可能就是五六百毫米的雨，就在那三个月就下来了。

说到这个问题，我最近也在思考，中国降雨就主要分布，比如说南京为例，梅雨季节、台风雨、夏秋对流雨等等，剩下的时间可能降雨比较少，然后土壤干旱或者城市缺水问题可能又比较突出。有没有可能我们会在入渗或者是雨水利用上，再给一些规定说，把雨季的水截留下来，然后用在旱季灌溉这个方面，你觉得有没有可能，或者我们有没有可能想出一个评估干旱的指标？比如说地下水补给。

比如说啊在南京，你比如冬天不下雨，空气确实干燥一些，但是好像也没有带来什么危害。你要说更湿润一点，是不是也可以？但是南京你要是冬天湿润一点，大家觉得更阴冷了吧。我说雨水收集利用在大多数地区是不适宜的，除只有那少数地方，比如像固原那种真的缺水。因为雨水收集利用的效益，投入产出比很低。比如说南京这个城市，它可能雨水量比较多，但不存在缺水的问题，当然可能水质上比较差。有没有可能是说他利用雨水来进行灌溉，或者是进行别的一些功能来达到它的效益。雨水利用从资源的角度，它的利用效率、投

入产出比是很低的。你比如说你投100块钱，你能收获多少？雨水资源，你跟水利部门投100块钱，建个水坝比的话，差的太多，从经济上不合算，除非就是说那种他真的很缺水。如果比如说学校啊像大学这种他们设计雨水，然后给他们用。用一些很低成本的方式来设计雨水。最低成本，就是这种地表式设计是最低成本。只要有地就行了。可能卡就卡在经济这一块。如果经济上可以的话（就可以）。如果北京除了雨季峰值比较大，它干旱的时候，会有一些负面影响吗？比如说从植物生长和对生态上。他是那样，因为当时我们算那个的时候也去问过，他植物也是。你不下雨，中国的植物他也落叶了。中国主要是落叶植物，对吧？冬天基本上不用浇水。也不是说绝对不叫它会有个春灌，他发芽之前是要灌一次。这个不是太好弄。比如说你要说弄去灌溉的话，在城里面你可能还浇浇花，要弄到农村就基本弄不过去了。水利用就是这个问题。空间上不具备，时间也不匹配，对吧？说着这边一堆水资源那边很缺水。怎么过去呢？

然后一个问题是海绵城市它的定位的问题。比如说现在已经有黑臭水体治理，然后防洪排涝的一些工程，您觉得在未来海绵城市它定位上，会有一些变化吗？他怎么跟现在有这些项目相协调？

借鉴一次讲座的标题叫要统筹推进海绵城市黑臭水体排水防涝工程。如果是从标题来看的话，这三个事情不是独立的，它是有关联的。你觉得海绵城市会把它另外两个工程包括进去吗？我觉得从推进工作的角度，不会拿一个东西把所有的东西都一个箩筐打进来，不同时期要有不同的重点，老说一件事情，国家也不一定会重视，是吧。

行。最后一个问题就是你评价一下，海绵城市的进展不足，未来的调整。

概念已经被熟知了，但是从完成任务的角度，2020年实现20%建成区达到海绵标准有困难。

第三部分

日期：2020年5月5日
参与者：P3（被采访者，黑色文字），陈诗扬 （采访者，蓝色文字）
总时长：42分钟

我就先从您做海绵的经历开始讲。作为景观背景，您参与过哪些城市，然后做过海绵项目哪些阶段？

我是从16年做三亚的一个公园，它是在一个河道边上，是一个15公顷的城市公园，当做一个海绵体来打造的，也是个海绵示范的项目。然后一直到陆陆续续到这几年三四年的时间，做了贵阳，然后在现在去做河道，大概做了基本以河道为主，以城市公园为这种海绵体为载体来做。基本上是从方案一直到施工图再到落地，这么几个阶段。

主要是公共海绵为主是吗？有涉及什么小区、住宅那种海绵或者海绵改造吗？

公共的城市空间。

在这些阶段跟哪些其他专业的合作比较多？

一般还是跟水务的这块专业合作比较多，因为它会涉及到一些水体净化，水循环和水生态这块的工作。

你们合作的流程一般是怎么样的？是在一起工作吗？

一般是从方案阶段就在一起，从总体的思路，然后到各个专项，但是都不是完全脱开的。景观和水利、水生态，包括海绵往往是结合在一起做的，它不是一个独立的东西。所以沟通还是比较多，在方案包括在后期施工图以及后面实施都是作为一个团队。

这种合作是只是你们公司内部比较方便，还是其他项目你了解也会这样？

一般都是大型的项目，包括这种景观其实是一个比较综合的一个专业，很明显的一个特点，就是各专业的这种协作，所以说海绵这块水利跟景观合作的会比较多，我觉得是国内都是这种情况。一般你要做大的海绵体系，或者跟水相关的都是景观跟水利，而且他招标的时候都是需要有资质的，所以还是很普遍的合作模式。

关于海绵城市指标方面，你们作为景观背景是怎么应用的一些指标？

指标其实更专业的还是在水利这一块，作为景观，可能跟他有些对接，但是毕竟还是不是特别专业的海绵的这块研究，但是我可以结合一个例子，在三亚，三亚丰兴隆生态公园。这块是在它的一个两河交汇口，总面积大概是15 公顷。然后考虑到他当地的蒸发量，近30年来平均的蒸发量是2344毫米，但是他年平均的降雨量是1522毫米，但是它是分布不均匀的，就是雨旱季就特别特别明显。导致雨季的时候，内涝特别严重，旱季的时候，但是淡水又是一个缺乏的状态。他现在公园他既然是考虑到两个方面，一个是作为一个海绵体，他需要去吸收或净化周边社区，周边一定区域的这种市政管网的水先进入到公园的海绵，然后进行一个吸收净化，再排到它邻近的河道里，到雨季的时候，它实际上达到了一个削峰错峰的作用。公园的汇水面积他就做了7.2公顷，所以基本上就占到了公园的一半。然后它能够吸收整个周边雨水管网的汇水面积大概是31.3公顷，然后有效径流面积是在25公顷。之前也是这个数据都是和水单位合作，德国的公司汉诺威，他们提供的一些数据。

他们提供完数据之后，你们进行设计的时候有哪些方法、途径？

景观这个都是一起设计的，我们只是在景观上更多还是配合他。指标还是他们定，然后景观上还是跟他们协作，我怎么把他这些水利的这些指标满足，同时又结合景观设施做，比如说它有一些跌水的，它是一个曝氧的一个过程，也是一个净化的过程，所以在景观上我们会做一些高差的处理。然后还有一些大水面，大水面它本身要缺乏这种流动，还需要设循环。本身它水体也需要进行一个净化，实际上也是海绵很重要的一个工作，就是你把水吸收进来了之后，你还得还需要稍微净化一下，然后再排出去。所以说净化这块会提一些需求，但是具体的指标是水专业去测算的，然后它会反提需求，比如说我们就设多种样式的这种图案，多种水生植物的净化面积，包括还会设一些这种除磷池、除氮池，这个都是在地面上的，这些池子也实际上是露出来。在地面上也会跟我们景观结合，我们做什么形状上面种什么植物。植物包括肯定除了景观考虑之外，还要考虑他对氮、磷这些吸收净化作用比较好的，比如说我们在三亚芦苇这些用的比较多。

做设计的时候可能会遇到那种指标会限制你设计吗？比如说有的地块它就必须要求下沉率低

多少？

没有，我们认为我们认为公园里能够承担海绵这个部分的功能是非常好的。然后我们国家其实国内也在走这个方向，包括海绵提的一些这种下沉式绿地，包括植草沟，包括透水铺装，实际上是各大公园，现在全国都是在用这个理念，现在不管什么公园城市、公园社区也好，基本上都是首先是这种雨水花园、雨水沟，这种透水砖、透水混凝土这些材料。实际上他这些条件对整个公园的设计我觉得还是有好处的。

这些下沉式设计会影响景观植物的生长吗？做设计的时候会考虑吗？

对，这个是会。尤其是在我们考虑下沉式（设计）在雨季的时候，可以淹没的区域。实际上还会选择一些环境抵抗能力比较强的树种。但是一般的话也得看气候条件，有的地方它淹没的时间，比如两三天的话，可能也没事，淹的时间久的话，他可能就要选别的植物。还是有所考虑的。

这种净化水质的功能对植物选取有哪些要求？ 比如说想解决初期雨水冲刷的带来的污染物，会在挑选的时候特意选一些净化能力强，结合一些土壤过滤设施吗？

会的。就拿三亚的项目来说，实际上它初期雨水，是先到管网里头，接到我们的一个调蓄池，地下的。先接到地下的一个调蓄池，经过沉淀，然后沉淀的污水会直接接入到污水管网，然后剩下溢流出去的会进入到下一个溢流池。溢流池进行一个沉沙，然后水基本上就还好了，初期的污染物基本上都移除掉了。然后下一个沉淀之后，就是这个水抽出去再进入我们植物除磷、除氮或者地面的生态调蓄池。生态调蓄池上面包括它这种沙子的土壤，更容易吸收污染物，包括上面会一些这种植物，吸收一些微量元素，氧化的这些东西，这个都会有，但是它前端还是我们的三亚项目前端还是设置了一些雨水调蓄的设施，再进入到生态净化的设施。

关于可视性跟互动性，就是我看国内很多海绵项目它做的水的可视性比较少，很难见到像欧洲这边比较多的水广场水屋顶，国内这种现象有什么原因吗？或者说你了解有些项目会考虑到水的可视性跟互动性吗？

我觉得是这样。首先我们国家幅员辽阔啊，咱们北方气候很不一样，南方地区我觉得可视性和互动性的水的利用还可以比较多，但是在北方因为它气候原因，干燥，包括它水资源缺乏，另外它养护起来也很贵。所以在北方一般我们做景观还是比较少。因为包括像看北方的河道常年都是缺水的。但是在南方实际上还是有这部分考虑的。包括尤其是三亚特别热的气候，亲水的包括喷泉、旱喷广场这些，都是有设计。然后像上海这一块，其实也是像滨江、海滩那块，滨江东岸那一块，实际上也是有很多水景的设置。我觉得还是有的，但是国内可能还是考虑养护，包括气候条件，这几个是比较大的方面，再一个（方面）一般设浅水，然后深水的话可以结合国内的一些安全规范来设计。浅水指的是哪些水体？ 那种互动性的还是很浅的水池。几十公分。

还有一点就是你刚刚谈到，先是把水通过管道汇集到沉砂池，然后再溢流口进到下一个。在你们做海绵的时候，是怎么考虑这种海绵设施之间的连接，形成一个海绵体系？

实际上我刚才说的海绵设施是针对整个周边地区雨水汇过来的一个大海绵体系。然后这些设

施实际上它是一个必要的生态雨洪调节的，包括净化的一些设施。如果没有这些设施的话，它的指标有些是满足不了的，包括进来之后出去的水它水质可能就达不到（标准），所以这些海绵这块实际上是重要的一个设计内容，包括在这个项目里头它投资也比较大，但是是放在一个地下的空间。所以说它是一个必需的，但是同时它不能影响景观。当我们在设计的时候，就把它安到地下去了。然后另外公园本身有一些这种屋顶绿色屋顶流下来的水，下边会按照坡度引导到植草沟，再到下凹式绿地，然后再通过引导到我们景观水体。本身公园里头也是有一些小海绵的体系。我刚才说的设施那一块，实际上是针对更大范围的周边地区的。然后公园本身的这些地表的水或者径流，实际上它都可以做到海绵的吸收消纳，包括净化。

在小海绵跟大海绵，他们之间会用生那种生态廊道、绿色廊道来连接来组织吗？在景观上。

我个人觉得廊道实际上是指在一个比较大尺度的这种视角下语境下去谈的一个词。然后就是说你聚焦到一个小的场地里头，他就没有廊道的概念。如果说廊道的话可以对一个城市来讲，或者对朝阳区来讲。我们现在做的在朝阳区坝河沿线，它本身就是一个蓝绿空间，那么它实际上是承担着重要的防洪排涝的这种功能。所以我们在设计的时候，把它作为一个合理的生态廊道来打造，不仅仅是绿，同时在水方面是考虑的比较多的。我们会根据下游它有一个防洪指标的限制。所以它必须消纳一定的雨季来的洪峰量，会在廊道周边一些大的绿色空间里头，把它作为一个蓄滞洪区，一个大海绵体。我觉得在这种时候下谈廊道还是比较有意义的。然后河道周边把原来的一些绿色空间整合起来，形成一个湿地公园的形态。但是实际上它有一定消纳（功能），包括比如说湿地公园就可以像我们刚才说的三亚那样，还可以吸收周边的地表径流、初期雨水净化，同时它也是个景观体，同时它也能够承担河道一定的防洪功能。 还是跟尺度有关。 对。

像这些公共海绵，我在不同地方海绵专规里看到，对他的要求好像还比较少，大部分都是对地块进行指标分解，公共海绵是在专规里他是一个什么样的地位？

这个尺度就超出了我的认知。但是我们院有个水务院，其实他们也在做整个海绵的规划，但是我觉得这个还是一层一层的，分尺度来做的。就像河道对吧，刚才说的河道、湖泊，然后再到绿地空间再到社区，它可能是一种一层层的，包括街道，每个层级他都有他的海绵体系。

你们在接到这种公共海绵项目的时候，在指标上会有什么要求吗？还是说拿到之后再自己定指标？

现在我们前两年做的，实际上都没有，国内还没有开始对每个城市做海绵城市的规划，像我们在三亚做的，它是一个试点，不可能有周边的海绵专项规划，而且据我了解现在就像我们今年做的北京的项目，其实也没有海绵的专项规划。因为建设部目前也是在编这些海绵城市建设的指导意见，但是每个城市根据意见去做海绵规划，我觉得这个东西每个城市都没推开，包括落到实体项目的话，他根本没有规划的条件。所以我们做这种东西，就是说尽可能的去多设一些海绵去解决一些指标的问题。但是说上位对他有没有严格的指标，我觉得还没有做到那么细的程度。

解决一些地方干旱问题的话，你们在设计的时候会计算它，比如说要补给多少地下水，或者说要有多少雨水利用，会考虑这些吗？

这个会。就像在三亚，因为三亚确实是实施出来的项目。在旱季的时候它有一个蓄滞洪量。像它水源与水质的保障系统，场地内水面积大概9公顷，绿地面积是15公顷，所以它园内他会考虑一个水资源量消耗量之间的年均差额，它会达到一个13万方。那么从4月到11月汇水区域收集的雨水，因为它4月和11月是它的一个雨季，它可以通过一些蓄水模块进行收集雨水，它这个季节可以满足浇灌和景观水体的一个补水的需求。那么但是12月到第2年的3月份，降水量少了，蒸发量又大了，所以就要进行额外的补水。这个是有计算的，那么包括场地内的调蓄空间，实际上都是经过计算的。

像针对于地下水补给的话，这块有没有考虑？

我们没有说地下水补水，因为我们这个项目可能比较特殊，地下水是咸水，所以说地下水是有隔离层的，要不然植物会受影响。但是我们的补水都是一个是保证景观水，另外一个是保证它公园本身的绿化消耗的用水。地下水一般从大的别的项目来说，可能是一个自然渗透的概念。但是我们做的可能还比较粗，没有对他孔隙度进行一个量化的一个指标性的研究。

刚刚说三亚地下水，我还挺好奇，他是地下是咸水，然后你们用了什么措施控制咸水吗？

它那个地方是在两河，离入海口比较近，所以他三亚这种海边它是一个朝汐的景观，所以他最高水位的时候，咸水就超过了三亚地区的地下水位，所以它地下水是咸的。但是我们上面需要淡水植物的这种淡水环境，那么我们在水系下面铺了一层防渗毯，做到地下水和上面的景观设计的隔离。那么同时我们要考虑防渗毯的抗渗、抗浮的能力，怕地下水的压力把它顶上去。有这么一些考虑。

在做设计的时候会用到一些模型工具吗？在做设计时，你们需要从别的专业得到哪些信息？

像小的公园不需要那么明确的，因为比较简单。像大的流域、河道，是需要这种水动力模型的，包括汇水的模型。但是他这个模型一般。反正我们做坝河的那一块，德国戴水道提供水动力的一些模型，去模拟水流态，哪一块冲刷力比较大，水量、断面都会使用数据模拟。然后如果你周边开辟了蓄滞洪的话，可能河道这边水怎么流到蓄滞洪，然后从哪个闸出，水位的关系，会有这种水的模型。就比较专业了，水利那一块的。做景观的有时候就是对他们提供一些要求，然后水位需要保持多少，然后他去做一些模型设施去做到。反正这个角度上来说也是一个互相合作沟通的层面。

如果做好了河道模型的话，你们是要做的是生态驳岸，还是做哪些设施？

对，会有一些生态驳岸的处理。然后对一些滨水岸线的处理。其实它就相当于一个条件了，对后期的景观设计也比较重要。

这个项目主要是关于驳岸的吗？还是说他会有一些公共海绵的一些设计？

实际上是河道两侧绿地本身就是一个海绵，周边的这些城市建设用地的汇水，或者说至少是地表径流汇流进来。进来之后，它本身那块绿地可以承担一定的海绵功能，进行一定的消纳、滞留、净化，然后再排到河道。它是连在一起的。然后到从绿地到河道之间，还会经过驳岸的这种空间。如果你做生态驳岸的话，它有一些梯级的净化，或者说梯级处理。如果你

做硬质驳岸的话，可能就没有，他可能直接就下去了。可能有些残留污染物也会影响比较多。生态驳岸对河道来说也是一个生态海绵的重要措施。

像我个人经验，很多国内河道两岸都是硬质。现在在海绵里是怎么来进行这种滨河两岸的这种设计？

现在国内做河道都是强调蓝绿一体、蓝绿空间。以前水利建设都是硬质河岸，那个是很死板。现在现在理念都转变了。在河道这块设计的话都是蓝绿交织、生态岸线，重新建立跟自然的这种联系。整个专业理念都在转变。

我不太清楚景观专业怎么进行设计，有什么原则或者是有什么理念支撑海绵设计吗？

景观实际上是在美国是最发达的一个地区，然后很多年了，包括世纪90年代开始就陆陆续续发展到现在。实际上它是一个综合解决复杂问题的一个学科。是他在美国叫景观设计学，在中国叫风景园林学，然后他甚至衍发一个规划的理论叫景观都市主义，那么实际上是对城市建设规划到具体落地实施都很有影响。它能够综合解决一个地区的人的活动、交通、城市的功能片区、生态等多方面的问题。所以景观设计学研究的理论还是比较多的。然后我们做项目的话都是偏向于解决一个综合问题。我觉得你可以说他是没有指导，但是我觉得他的限制东西多，要解决问题更多，所以往往就是切入点就更多。

现在海绵的话还是针对水吗？还是说会有一些交通、社会、文化上一些考虑吗？

文化上可能会有结合，比如说和以前它就是一条航运的河道，做水的时候可能还要跟大运河的这种文化相关。然后像功能上我觉得还是考虑到这种亲水互动，像你说的，尽量还是要满足人的这种需求。然后海绵的话就是一个生态的，我觉得这是一个城市功能的保障。所以景观如果我们做坝河这个项目，海绵是我们很小的一部分，我们有很多问题需要去解决交通问题，解决城市防洪安全问题，解决文化问题，解决功能问题。

像海绵的话，它不是作为一个非常整合型的一个概念吗？主要还是针对水吗？

不是，它只是其中一方面。像我们做三亚丰兴隆，我刚才跟你讲的其实也是那边的一个专项，但我们公园里景观上要解决的问题，这些还要多得多。

您评价一下现在做海您做海绵的整体的感受，觉得哪些地方还需要改进？或者哪些地方您觉得比较值得推荐一些点？

我觉得是海绵这个几个方面，就是从政策上或者说从国家推的角度来说，它是一个正向推的。相关部门制定规范指导意见，各个地区去根据地指导意见做海绵专项规划。我刚才也说了，我觉得可能专项规划研究，像你说的这些指标，我觉得是还没到那么细，或者说它落地，从专项规划到落地之间，缺少这种比较明确的这种科学的研究性的指标，因为这个量太大，包括需要研究的东西也太多。然后从实施的角度来说，我觉得海绵也不是一个新的概念。像我们国家以前像农民他们处理灌溉的水，他们都有一套比较，对他们来说比较适用的方式。以前实际上他们也用到了海绵，村里的池塘实际上也是海绵，上面的山体会下来的，回到池塘里，然后拿池塘里水，去灌溉一样。它实际上我觉得它这个理念在我们国家很早就

有，也是一个利用了很完善的区域。到我们现在社会要去再把它完整弄下来，我觉得是概念的一个强化。我们还是要结合地区结合实地条件，结合我们已有的这种认知，尽可能的去解决我们城市的一些内涝、水质、水资源这些问题。

所以海绵只是解决这些问题中的一种方式？

海绵不是单纯的独立存在去解决解决问题的一个手段，它往往是根据景观结合在一起。因为最终还是一个设施外化出来，你不可能就是一个混凝土的。它是一种景观的形式展现出来的。我认为是这样，他一定要是一个比较生态的或者比较稍微美观舒适一点的这种形态。因为它不可能全部存在于地下，所以他还是一个跟景观结合在一起。不会单独做一套没有景观性的这种海绵设施。

像之前跟一个采访者聊的时候，他提到在国内有些项目海绵功能是有，但是景观性比较差。做的东西都比较粗线条。

对，往往我还觉得有些景观性做得好的海绵设施，仅仅是景观性好，反而是海绵设施的功能比较差。这两种情况可能都会出现。

像解决这种问题的话，还是得加强专业之间的协作吗？

对，我觉得肯定的。一个是学科之间的互相了解，然后包括学科之间落地的时候互相的协作是必须的。而且我觉得景观专业要更加去了解一下海绵到底是能够解决多少问题，应该去怎么解决问题，（并且）跟景观融合。然后海绵也应该去思考怎么以更有效的这种设施途径去解决问题的同时，更好的融入到景观里头，自然的方式，更生态方式展现出来。像这个灰色的大的基础设施，可能还是能少见就少见，能以更生态的办法去解决生态问题是最好的。

像国内的话比较困难的是城市空间比较少，很难摆上很大的海绵。像你们做的话会收到什么限制吗？

还好。其实我们从景观上我们接的都是这种蓝绿空间的项目，我觉得空间不是问题，空间大小都可以做。你小的话你可能解决问题可能就是不会那么复杂。很大的话，就可能周边流域的周边片区的都会去考虑。而且现在国内这种绿地还给人还给自然的理念越来越强。因为我们国家推崇生态文明建设，实际上是这种各级政府执行还是比较到位的，都达成共识了。绿地越来越多，他们可能会拆除一些原来侵占绿地的一些设施去打造成一些海绵空间。空间不是问题。

比如说那些老旧小区，他们往往道路比较狭窄，然后屋顶也不适合改建，像这种海绵改造就非常困难。

只能说是在现有的条件下，因为这个小区的话涉及到是有产权的，有些东西也不是想拆就能拆的。有的小区可能绿地率比较高，有的小区绿地率比较低。我觉得屋顶，尤其是北方的屋顶是做不了海绵设施的，他不可能做一些绿植。收水的话还是靠道路的一些管道，包括楼与楼之间的绿地空间，去进行收集。如果需要加设施的话，可能会在公共区域加一些设施，能做的工作有限，但是想做还是会尽量去做。包括国内在推老旧小区改造，我觉得这可能也是

一个方面，不仅仅是房屋的改建。

我之前做海绵的时候就看到一些，比如说控规里头他会写这个地块有多少指标，是下沉绿地有多少，然后附属水面有多少，这个你怎么看？

我觉得也是要去考虑给你的这些指标是怎么来的。首先你要去想想这些指标到底是不是科学论证过的，就是下沉绿地有多少就能解决多少问题吗？我觉得这个需要去打个问号。再一个如果他给了这些指标，我觉得还是得看现状的空间条件。如果真的是绿地只有一公顷，他要你下沉绿地1.5公顷是做不到。当然可能这个指标也不会这么做。但如果他给的指标是9公顷，你可能尽量也要做成。我觉得看有关手法和设计，我们跟海绵一起结合设计手法去实现，也是能够实现。

2. Interview Highlights (in English)

Part 1

Date: February 15, 2020
Attendees: P1 (interviewee, words in black), Shiyang Chen (interviewer, words in blue)
Total duration: 50 minutes

Experiences in SC projects and differences of objectives amongst cities?

We did around 10 cities related to SC. Our work ranges from planning to designing, most of which are planning. Sponge City is a comprehensive concept that requires 4 aspects. VCRa is the common indicators which varies from city to city. The priority of those 4 aspects are different for different cities. For example, southern cities which are not short of water may set lower water resource targets; if a city has severe water pollution problems, the target of water environment is set higher; and the same holds for water safety, etc.

About water safety, what is the approach to mitigate pluvial flooding issues? Is it via “fluvial flooding prevention and pluvial flooding discharge” (flood control in China)? and how do they coordinate with each other?

The relationship between Sponge and flooding control is not sorted out clearly. SC is now in an awkward situation. Flood control departments (Water Authority) is commonly in charge of “Fluvial flooding prevention and pluvial flooding discharge” and SC would passively propose some and targets, however, the flooding issues are expected to be solved by flood control departments in practice. As for sponge planning, the major work is solving small initial storm runoff. Housing Bureaus (in charge of SC) is not capable or competence to proceed flood control, although related flood control indicators can be proposed in SC planning. The coordination between those two is not very smooth despite of overlapping areas in both SC planning and flood control planning.

Is pluvial flooding handled by solely increasing discharge capacity?

It is done via their traditional methods, e.g. flooding defence, early warning systems, etc. Pluvial flooding and fluvial flooding are separated. Municipal departments (could be under Housing Bureau or water authorities) are in charge of pluvial flooding, so pluvial and fluvial flooding is not well-connected either. Sponge Offices are commonly below Housing Bureau, while a few of them belong to planning departments.

Is VCRa used for dealing with water ecology?

Yes. VCRa is only major indicator. There are no corresponding flooding indicators, the whole SC system is not complete.

How do guidelines require for water resource?

Water resource reuse ratio. Actually, China has been promoting it even before SC initiative.

How would you select models for pluvial flooding and what are the factors affecting model selection?

As far as I am concerned, clients do not have special preference for models. Because our clients are normally water authorities and local design institutes, who do not have requirements on models. Clients require the expected deliverables instead of model type.

How about the models in SC?

The demands for modelling in SC are not that high except for some certain cities. Most domestic design institutes use SWMM.

Which phases in SC projects are usually using models?

The cases Ewaters get are in evaluation phase, for example, when a city is faced with SC evaluation requested by MHURD. Some cities in Fujian Province as far as I know requires modelling report in design phase for residential areas larger than certain hectares. Some pilot cities may do modelling more out of self-promotion purpose.

How is the data availability? Are specific data missing?

That might happen. We usually received cases from governmental departments, so it might be easier for their internal coordination. But other cases contracted by non-governmental clients probably encounter data issues. For example, Housing Bureau may not get data from water authorities and data from meteorological bureau are also difficult to obtain, like in Xiangtan project. Those data are still confidential.

Would you use monitoring data for evaluations?

Yes, we need monitoring data for model calibration. There are two types of monitoring data. One is used for direct validating sponge performance, and the other is used in models for evaluating sponge performance after calibration.

What are the requirements for design storm when applying such models?

Normally one with short duration and another with long duration. Some projects will do one or two typical storms. Requirements are based on local flood control planning.

What is the size of modelling area?

Small size, like a park, a campus, a residential area.

What is the procedure of cooperation with different disciplines? Would it be like the Xiangtan case, we do modelling before handing the outcomes to design institutes?

For example, the design of a residential area includes building external design, water-heat-electricity underground design and landscape design. Usually we base our design on subsurface networks. It is beneficial for us to cooperate with landscape designers. We make a draft design and landscape designer will refine the draft, followed by sponge performance assessment by us.

Does it mean most of time you work with landscape design?

Yes, sponge design in China now are almost LID, mainly about greenery and water bodies. Greenery is previously done by landscape design, so they are involved in SC as well.

Does the final decision on design proposal made by governmental departments or delegated design institutes?

The preliminary design and modelling reports will be checked by Sponge Office before handing over to municipal departments for next check, then turning to landscape departments. If the materials pass all checking procedure, the project will proceed to next design phase. Some cities integrate checking authorities, while other cities still keep them separated.

What is sponge check? Is it about detailed design, sizes or other aspects?

Before developer get the construction permits, developers should promise what indicators or targets they will achieve according to detailed control planning's requirements on their land. If they have the target, e.g. VCRa 80%, developers will find a design team to realize such target. Sponge Office will assess if the preliminary design meets the target.

Is VCRa the dominate factor?

The major one is VCRa, other parameters depend on local requirements.

Is it a phenomenon that most cities treat VCRa as an overarching indicator for guiding SC?

Because if you downscale indicators into project level, it is barely likely to require water safety. Water safety must relate to larger area, such as a sponge city subdivision. If a developer gets a piece of land for housing development, it is unlikely to ask him/her for a water safety target.

So pluvial flooding is addressed by water authorities in practice though SC would mention water safety targets?

Yes.

Is it true that the fragmentation of green and grey infrastructure occurs in SC, meaning that green is used for LID source control and grey for tackling flood issues?

I do not think it is a pure technical problem. It has something to do with Chinese institutional system.

Different bureaus do not cross responsibility borders. Therefore, although SC seems like put on a high rank, but it is not much empowered. That is the reason why the situation of SC is passive.

I heard the leader of Sponge Office is major in some cities, does it feel SC is important?

Maybe that's the case for national pilot cities with relatively sufficient funding and it's easier to coordinate, however the situation for other cities might be passive.

Isn't there only 30 pilot cities? Are other cities required for SC construction?

There are national pilots as well as provincial pilots. But the number of pilot cities are still rather small.

Does workshop-style discussion or negotiation happen in China?

No, there is no such communication tradition in China. Different departments work on their own things.

Are those indicators in SC fulfil the original vision of SC? Can VCRa set sizes of sponge measures?

It is hard to give an answer. But indicators definitely are effective in its own right. At least VCRa can contribute to initial storm runoff pollution control. As for water safety there is flood control target and water quality requirements for water environment. VCRa cannot achieve all targets.

Do now authorities still rely on VCRa to assess sponge performance?

Generally speaking, yes.

There is one point I noticed strange is that the tasks of water safety and ecology for old city districts should be heavier but the targeted VCRa for such areas is relatively low. Did you know this situation?

The targets for old city districts are relatively low because of construction difficulties and costs. New development areas are like blank paper that you can freely sketch on. But old city districts are built up, some of which are faced with demolition and relocation problems, as well as communication issues with house owners. Their green surface ratio is low while building intensity is high, that hinders SC implementation.

Each city can choose its own SC demonstration areas of some square kilometres. At the beginning, many people start with old city districts because they think there are more problems. But it was not well ended. That may result from technical challenges but also other difficulties. For example, construction might cause inconvenience to the elderly; property management responsible parties are not missing; the greenery maintenance is poorly managed, etc. Thus, now people start select pilots in new development areas, which are easier for operationalize and manage SC projects. When developers get the land, targeted indicators are required, otherwise they cannot get land use permit. Some cities also grant allowance for SC construction.

How is the Suspended Solid Reduction Ratio simulated or assessed?

Some places have surface runoff pollution monitoring. The inlet and outlet of storm sewers in residential areas are monitored. Single sponge measure can also be monitored for inlet and outlet.

Is it mainly done by monitoring or modelling?

Can be both. Sometimes if there are big bias in monitoring data, then models are used.

If the monitoring data is not reliable, does it mean the reliability of modelling is also low?

Yes. The inconsistency of monitoring data might happen. But if you can still do modelling using some inconsistent monitoring data. Generally speaking, monitoring does not have high reliability.

What are your remarks on SC?

There are still many challenges of SC in China, which are top-down. The role of SC is not clearly defined from upper level, which results in difficulties of implementation at low levels. But improvements can be seen from these 5-year development of SC. Some projects in some cities are good. This (SC) is a long-term process, which may not be that fast.

Is it true that the fragmentation of governmental functions causes the low efficiency in implementation?

Governmental function is of course a big cause, but it is not the complete picture, technology development (could be another cause). Design capacity has been improved quite a lot and many design institutes are capable of doing good designs, but construction capacity is not that good. Operation and maintenance are lagged behind. Similar concepts are promoted well abroad because the whole technical system is developing together, then concepts are promoted and implemented in slow paces. But China does things first, of course there are lots of issues.

Speaking about operation and maintenance, which parties are responsible for that?

Developers should maintain their own projects. Municipal road projects are difficult to maintained by greenery or environmental projects. There might be conflicts in operation and maintenance. Housing Bureau may get the funding for construction but leave the projects to greenery departments to maintain.

Part 2

Date: March 10, 2020
Attendees: P3 (interviewee, words in black), Shiyang Chen (interviewer, words in blue)
Total duration: 80 minutes

Your experience with SC projects?

I was involved in making SC plan, technical consultancy service, project design for Suining City, Sichuang Province in 2015, one of the first batch SC pilot cities. Also, I participated in transformation project design of Hebi City, Henan Province. I took part in drafting pilot city proposal, and in drafting sector plan for Guyuan City Ningxia HAR, after it was selected as pilot cities in 2016.

When the SC pilot project just initiated, people were confused with the sole official reference-SC construction technical guidelines (trial). People might think Sponge City is equal to LID or it does similar things as LID. Such situation lasted for one year, during which debates and conflicts rose up. The contents and objectives of SC sector plan was not clear. It was thought that if SC is treated as LID, there is not much sense for making planning, as LID is a guiding construction with indicators. Therefore, most

SC sector plan is assigning indicators from city to local blocks. Only through detailed control planning of urban spatial planning system, the indicators can be downscaled, operationalized, and supervised.

Around the end of 2015, the Ministry (MHURD) thought planning was not only about downscaling indicators. The social pressure was also high especially in 2016, when lots of places were flooded during summer storms. Thus, the Ministry turned to problem-oriented solutions, that is solving problems instead of focusing on indicators. After that, source reduce-process control-end treatment was proposed. The article of Linwei Zhang et al. extended the scope of Sponge City from residential area to city level. Interim Provisions for Sponge City sector plan mentioned 4 waters, but for me I feel a bit puzzled on water ecology. That is because: 1. It is mixed with water environment;2. It is not easy to make a project list for water ecology.

Do SC strategies differ amongst cities?

One year after SC was initiated, people adapt Sponge City concept to local conditions. SC programmes then were not only focusing on numbers. Because if people are confused what to do about SC, the only thing is to assign indicators and calculate indicators to more digitals. Moreover, SC became more problem oriented. For example, Suining gained much applause from the public and the official just because they tackled pluvial flooding issues. Since then the minds were opened and SC was extended to Sponge plus in Suining, which means apart from its original objectives, SC programmes also solve other issues in residential areas, such as road renovation, landscape redesign, lighting, etc. Guyuan is another different case with less than 400 mm annual rainfall. Shortage of water resources and collapsibility of loess plateau makes the city select different SC strategy: stormwater reuse is given high priority rather than proper infiltration.

Inspired by detailed control planning system, we divided indicators into two categories: obligatory (for ends) and recommended (for means). By such combination of indicators, flexibility could be given to different block designs.

Difficulties when coordinating and cooperating with other disciplines?

Objections are from different disciplines. For example, greening and gardening is worried that polluted storm runoff would threat plants' growth if lowering green; hydraulic people have concerns on VCRa. However, the decision is usually made by the department who is dominating the project and other departments are not involved in decision making. For example, renovation projects of residential areas are dominated by Housing Bureau, and other bureaus can object some issues while they cannot be involved in decision making.

How to solve such difficulties? Would drafting detailed cooperation mechanism in guidelines a way out?

The detailed coordination mechanism cannot be written in guidelines. The basic principle in my opinion is the safety first, and then functioning is equally important as landscape effects (aesthetics). SC requires delicate design, delicate construction and delicate management. It is easy to understand the principle, but it is not easy to operationalize. SC is different from other previous construction projects which perused scale effects (high buildings, long bridges, etc.). Scrutiny is necessary for SC.

How indicators are downscaled from province to local blocks?

Province will only give instructions without specifying indicators. Master plan sets indicators or objectives for whole city. The city is divided into smaller pieces with respect to social and natural properties. The subdivision is always controversial over different experts. Some cities divided cities into 10 first sub-zones and 35 second sub-zones, so that people can find indicator requirements for local control units. Some cities directly assign indicators to control units to avoid the issue that the control unit is located on two different sub-zones.

Do you think too much indicators for small pieces of lands might restrict landscape design?

Agree. The indicators shall not be stuck on. Recommended indicators could be given a rather low threshold for flexibility of design.

What indicators do you think needs to adjust or add in current guidelines?

The principle 'Never Shift Problems' could be reinforced in China. That reminds me of China's solid waste law, which regulates that solid waste, especially dangerous solid waste cannot be transferred over administrative regions.

The runoff peak flow reduction ratio (RPFRR) was mentioned before, but it is hardly used and assessed now. The biggest problem is that the assessment cannot be easily operationalized concerning time and budget. AST can be successfully promoted just because it is easy and handy to use. The same holds for VCRa. All projects are assessing VCRa because it has acceptable easy formulas which can gives rough answers, though it is criticized by many people. For RPFRR, there is not any operationalized methods for assessment. There should be a support tool for RPRR with low cost. From my perspective, peak reduction might be more important than VCRa considering high intense storms in some places in China.

Do you know any challenges for local officials to implement SC?

Some cities, for example Guyuan, do not have the foundation (climate) for SC construction. Clients also play important roles in implementing SC projects. If clients do not pay attention, only relying on design and construction participants will not work. They should know what are required for SC constructions, just like home interior design.

Which project phases need models? And which models with certain functions are required?

Models can be used in any project phase, but there are debates for using models. Some people think models are useless while some treat them as panacea. The controversy of using model probably results from a lack of sufficient data. The more information is fed to models, the more scientific and accurate results will models give. Insufficient data can be caused by poorly managed and required as-built drawings as well as difficulties of geophysical prospecting for old residential areas. Apart from those on-site techniques, the measurement of certain parameters is another issue. For example, a handful of experiments just for testing infiltration rate as a parameter are difficult to proceed, only if many projects require the experiments so that a company can be contracted to do such. The modelling company will not care parameters that much as most of employee are with programming background. I think modelling is the trend and we will definitely develop towards that.

How do you think the feasibility of applying AST (+SDF) in Chinese SC cases?

Not sure how AST would look like when all parties arranging things on the screen together. It suits for designing some square kilometers area and used to draw on not only current situation but also detailed control planning map. SDF can be used as catchment scale. It is better to set lower boundary, below which such analysis is not a necessity.

Since design storage of SC in current projects are dealing with small and moderate rainfall events, do you think it will be extended to 10 to 20 years events?

10-20 mm storage is originated from LID. Stormwater management in city level is necessary. The pluvial flooding events in residential areas are not that frequent.

For example, do you think the storage capacity in residential area is necessary to increase if 1-3 years sewers cannot handle pluvial flooding?

Based on urban vertical elevation design, the elevation of residential area is higher at least one point of surroundings, therefore roads are usually inundated.

If the roads have higher flooding risks, what do you think about the necessity of combing discharge and storage?

Storage capacity definitely needs increase. But not like in the Netherlands for each households or apartment complex, it may take place in public spaces, such as retention pond alongside roads, or lakes, wet ponds, etc. That is a blank in China currently.

What do you think how to balance SC with other programmes, such as "fluvial flooding prevention and pluvial flooding discharge"? What is the relationship between the storage in SC and the storage in other programmes?

I will keep thinking this question. Conflicts may not happen for SC and others. Three key components in stormwater management, LID, sewers, and excess stormwater. The last one is still in exploration phase in China. It is regulated some area should be 50 years flooding proof, but whether the plans fit the regulation is not clear. SDF may play a role in connecting among three components. But 100-year events cannot be enclosed in residential areas in China.

What adaptation do you think SC strategies should include when learning from Dutch experience considering climate differences of two regions?

Storage and discharge should be combined, and discharge is not ideal, which could be increased. Peak mitigate should be more emphasized considering the intensity of Chinese rainfall events.

Do you think SC will give more guidelines on stormwater resource and drought prevention?

I think stormwater collection is not suitable to most areas, only for areas which are really in shortage of water. Economic feasibility is also a key factor needs consider. How to deal with spatial and temporal unbalance is another issue.

Part 3

Date: May 5, 2020
Attendees: P3 (interviewee, words in black), Shiyang Chen (interviewer, words in blue)
Total duration: 42 minutes

Let's start with your experiences with sponge city. Which sponge cities you are involved in and during which project phases?

I was started with a park in Sanya in 2016, which is 15-hectare urban park by a watercourse. It is a sponge city pilot project. During these three, four years, I did projects in Guiyang, and now turned to watercourses. Generally speaking, I did projects mainly about watercourses, as well as urban park as sponge carrier.

So it is mainly about public sponge? Anything about residential sponge transformation?

Public urban spaces.

During which project phases you worked with other disciplines?

We usually work with people from water sector, because it involves water quality purification, water circulation and water ecology.

What is the normal workflow? Do you work together?

Generally, we work together since the conceptual design phase, from the overarching ideas to each sector planning, with the combination of landscape, water conservancy and water ecology. It is not an independent thing. Therefore, there are many dialogues amongst us. We work as a team from planning to construction drawing and construction.

Regarding the Sponge City indicators, how do you use it from landscape background when doing projects?

In fact, the indicator is more professional in the water conservancy area. As for landscape, it may be somewhat connected with them, but after all, landscape is not specialized in sponge research, but I can take an example. Sanya Fengxinglong Ecology park is at intersection of two rivers, with a total area of about 15 hectares. Taking into account its local evaporation, the average evaporation in the past 30 years is 2344 mm, but the average annual rainfall is 1522 with unevenly distribution especially in the rainy and dry seasons. During the rainy season, waterlogging is particularly severe; However, during the dry season, fresh water is in a state of deficiency. Two aspects are taken into consideration. As a sponge, the park needs to absorb water from municipal pipe network in a certain area, and then absorption and purification takes place, before discharged into the adjacent river. In the rainy season, it actually achieves peak reduction and delay effect. The inflow area of the park is 7.2 hectares, around half of park's size. It can absorb water from 31.3-hectare catchment of sewer networks, and effective runoff area is 25 hectares. The figures are provided by a German Hanover water company.

After being provided data, what would be the approach or method to do designs?

We do designs together. We just coordinate them on landscape architecture. They make indicators and we cooperate with them on how to fulfil the indicators combining landscape facilities. For example, there are some waterfall, which is an aeration and purification process. Therefore, we would do some elevation change. Some large water surfaces which lack of mobility require water circulation. Water needs purification, which is an important task in sponge city. Water needs to be purified after absorbed in to sponges, and then discharged away. So, there are some requirements on purification, but the specific indicators are calculated by water sector. Water sector could also propose requirements to us. For example, we would set multiple patterns of aquatic plants area, N/P removal tanks. Those are above ground. We consider not only landscape effects of those plants, but also their abilities of absorbing N and P. For example, we use lots of reeds in Sanya.

Did you encounter such situation that indicators might limit designing? For example, sunken surface ratio for some blocks.

No, we think it is good to have parks take responsibility of sponge functions. Actually, our country is heading towards that direction, including sunken green, vegetation trench, porous pavement. Large parks or communities around the country basically first consider rain gardens, rainwater trenches, porous bricks, porous concrete, etc. The requirements are beneficial for designing parks in my perspective.

Would these sunken designs affect growth of plants? Is it considered in designing?

Yes, it is. Especially when we consider potential flooding area in rainy seasons. Species with strong environment resistance are selected. But it depends on local climate conditions. Plants are inundated for two or three days in some places are fine, but other types of vegetations would be considered if inundation time is longer.

Concerning water visualization and interaction, from my experiences, it is less frequently seen in China when compared with in Europe, like water squares, water roofs. What could be the reason behind it? Or do you know some projects that would take water visualization and interaction into account?

First of all, our country has vast land with different climate from north to south. I think visualization and interaction can be more used in south; But in north the climate is dry and water resource is scarce, and maintance cost is also high; Therefore, there are few waterscapes in north. Because watercourses in north are lack of water throughout a year. But in south visualization and interaction are taken into consideration. Especially in Sanya with tropical climate, fountain or interaction fountain plaza are used in designing. For example, in Shanghai, there are waterscapes in riverfront, beach areas, east banks. I think there are some considerations on that, but maybe maintenance is also concerned, climate conditions as well. Normally shallow water is set, and deep water should be designed considering safety standards.

When you get public sponge projects, what are the requirements of indicators? Or you set indicators later by yourself?

For the projects in previous years, there is no sponge city planning for each city. What we have done in Sanya is a pilot project, and no sponge sector plan around. As for as I know, the Beijing project we are doing this year does not have sector planning. Each city does not have sponge city planning yet based on the ongoing sponge city construction guidance by Housing Ministry. I think it is not promoted to each city and the planning foundation is not available for projects. So, we are trying to apply sponges to solve indicator issues, but there are no explicit indicator requirements from upper level.

I am not sure about how landscape discipline does design. Is there any principle or theory to support sponge design?

Landscape architecture thrives in the USA for many years, starting from 90s. Actually, it is a discipline for comprehensively solving complicated questions. In the USA it is called landscape design whereas in China it's called landscape & gardening. It also derives a planning theory called landscape urbanism, which affects urban planning and construction. It can comprehensively solve problems concerning human activities, transport, city function division, ecology, etc. So, there are many theories in landscape design. Comprehensive problems are preferred to solve when we do projects. I think you can say there is no guidance of landscape design, but I think there are more to consider and more angles to cut in.

Are sponge city now oriented to water? Or other consideration for example transport, society, culture?

Might be combination with culture. For example, culture could be related to in projects of historical transport canal. As for functionality, I think closeness and interaction with water are considered, as you mentioned, satisfying human needs. Additionally, sponge is ecological, which guarantees city functions. So, if we do Bahe project from landscape discipline, sponge is only small part. We have other problems to tackle, such as transports, urban flooding, culture, functions, and so on.

Sponge is not a very integrated concept? It is mainly about water?

No, it is one aspect. Like Sanya Fengxinglong, what I talked about is only one sector project, but we have to deal with much more issues in park landscape.

Could you please evaluate the general feeling of your experiences in doing sponge projects? Anything to improve? Or Anything you think is worth recommending?

From the policy or national level, it is a positive promotion process. Competent authorities make guidelines, different places make sponge city sector plans following the guidelines. As I mentioned before, I think sector planning study, like indicators you spoke about, is not detailed. Or between sector planning and project implementation, there is a lack of scientific indicators. Too much in it and too much to research. From implementation point, I think sponge is not a brand-new concept. For example, farmers have a set of decent methods to irrigate: Runoff from the high lands are accumulated in ponds, which act as sponges, so that water in ponds can be used in irrigation. I think the theory exists in China long before, and it is commonly used. Now our society wants to do it in a complete picture, which is a reinforcement of the concept. We have to solve the problems of waterlogging, water quality, and water resources in our cities as much as possible by combining the consideration of local conditions and our existing knowledge.

So, sponge is only one of the ways to those problems?

Sponge does not independently exist to be a measure of solving problems, which is usually combined with landscape. Because facilities have to be exposed above ground, they cannot be just concretes. They must be combined with landscape.

Another interviewee mentioned there are some sponge projects with functionalities, but landscape impacts are low.

Agree. Some sponge facilities have good landscape effects but with poor sponge functions. Both conditions exist.

In order to solve this problem, inter-disciplinary collaboration should be enhanced?

Yes, definitely, I think. One point is the mutual understanding between disciplines, and another is collaboration when projects are landed. Moreover, I think landscape needs to know more about how many problems sponge can solve, how to solve problems by combing landscape and sponge. Sponge (sector) needs to think how to, at the same time apply measures to solve problems, merge into landscape in a more natural and ecological manner. Large grey infrastructures should be avoided as much as possible. More ecological measures are preferred to solve ecology problems.

Is it difficult to implement large sponge due to limited urban spaces in China? Do you feel any restrictions?

It is ok. In fact, projects we have been working on are blue-green spaces. I think space is not a problem. Sponge can be done no matter how big the size of space is. If the space is small, there are fewer complex problems to deal with. If the space is large, surrounding catchments might be taken into consideration. Because China is promoting ecological civilization, which is implemented by governments at various levels. The agreement is reached, and there are more and more green spaces now. Sponge spaces can be created by removing infrastructures that occupy original green spaces. Space is not a problem.

From my experiences, there are indicators proposed in detailed control planning on how much sunken green ratio, how much water surface ratio, etc.

I think how the indicators are derived should be considered. First you should think whether those indicators are scientifically verified. Can certain sunken green ratio solve certain problems? I think it needs to be questioned. Given some indicators, I think current space conditions should still be analysed. If the green space is only one hectare, 1.5-hectare sunken green is not possible. Of course, the indicator will not require that. But even if the requirement is 9 hectares, you still have to fulfil it. I think it depends on measures and designs, it can be realized by combination of landscape and sponge.

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