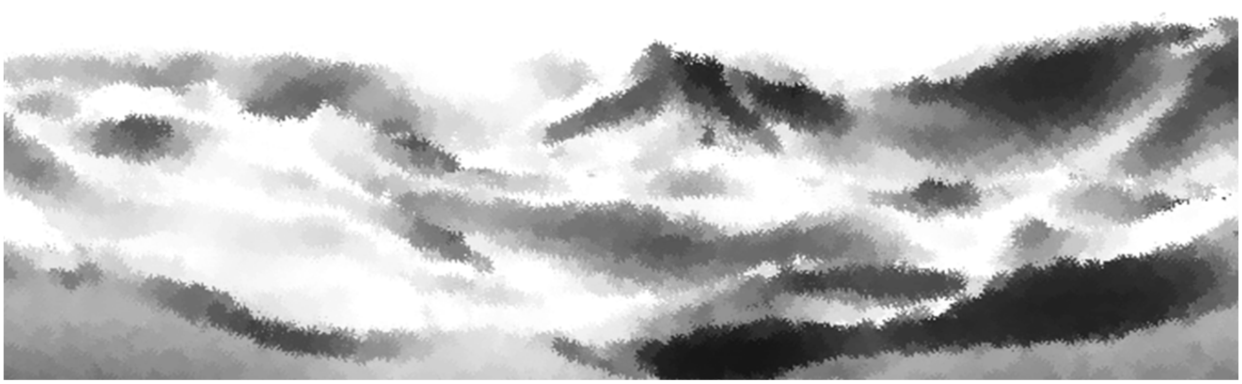
Landscape Design Strategies for Urban Stormwater Management in northern China

An analysis and comparative study of six Chinese stormwater management projects

Li Xin

Institut für Freiraumentwicklung
Leibniz Universität Hannover



Landscape Design Strategies for Urban Stormwater Management in northern China

An analysis and comparative study of six Chinese stormwater management projects

Von der Fakultät für Architektur und Landschaft der

Gottfried Wilhelm Leibniz Universität Hannover

zur Erlangung des Grades

DOKTOR DER INGENIEURWISSENSCHAFTEN

Dr. –Ing.

genehmigte Dissertation

von

von M. Sc. Li Xin

geboren am 14.11.1982

P.R. China

Hannover, Germany [2016]

Supervisor: **Prof. Dr.-Ing. Martin Prominski**

Institut für Freiraumentwicklung

Leibniz University of Hannover, Germany

Second Supervisor: **Prof. Dr.-Ing. Bettina Oppermann**

Institut für Freiraumentwicklung

Leibniz University of Hannover, Germany

Date of final exam: 21.06.2016

Sponsorship: Li Xin held the scholarship offered by China Scholarship Council

Eidesstattliche Erklärung

Vor- und Zuname: ______________________________

Geburtsdatum: ______________________________

Geburtsort: ______________________________

Hiermit erkläre ich an Eides statt,

- dass ich die vorgelegte Dissertation selbständig und ohne unzulässige fremde Hilfe angefertigt und verfasst habe, dass alle Hilfsmittel und sonstigen Hilfen angegeben und dass alle Stellen, die ich wörtlich oder dem Sinne nach aus anderen Veröffentlichungen entnommen habe, kenntlich gemacht worden sind;

- dass die Dissertation in der vorgelegten oder einer ähnlichen Fassung noch nicht zu einem früheren Zeitpunkt an der Ruhr-Universität Bochum oder einer anderen in- oder ausländischen Hochschule als Dissertation eingereicht worden ist.

[Unterschrift] ORT, DATUM

To People who I love and love me

Acknowledgement:

Firstly, I would like to appreciate my supervisor Prof. Dr.-Ing. Martin Prominski. He gave me a chance to let me have an opportunity to see how the world is amazing. In each meeting I can feel his respect, consideration, understanding and support, and also I perceive his tolerance and wisdom. His explanation and guidance is the key to overcome the uncountable challenges in my studying period.

Secondly, I also want to thank my second supervisor Prof. Dr.-Ing. Bettina Opperman. Her suggestions can often hit my points of my research, and at the same time show me how beautiful the research is. In talking with her about my research I often am stimulated to an in-depth thinking and strong motivation.

I am particularly grateful to my colleges, including Dipl.-Ing. Verena Butt, Corinna Haberkorn, Dipl.-Ing. Anna Schwinge, Dipl.-Ing. Christiane Kania , M.sc. Vilja Larjosto, Dipl. Ing. Susanne Zeller, and others. They provide me many specific supports and assistances which I will never forget. Their help and kinds make me to adapt very well in Hannover and deal with many tough times.

Here, I also would like to thank my friends, Dr. Catherine Atkinson and Dr. Joy E. Reid. They give me a key to open a specific door, through which I am watching a beautiful and amazing English-writing world. They investigate many time and patience to improve my writing skills. I will keep their help in my mind in my life and never forget their expectation.

I also want to appreciate Prof. Dr.-Ing. Wang Xiangrong and Prof. Lin Jing. Their passion and thinking for landscape design deeply influences on my understanding on this field. I am very honoured and lucky to study from them in the one of the top design teams in China. The experience cultivates me a strong motivation and determination to continue to pursuer my dream when I study in Germany.

Finally, thank to 1.3 billion Chinese people because of their contribution to my scholarship and also appreciate China Scholarship Council for their organization and truth.

Abstract:

On account of the unpredictable climatic characteristics and ecological hazards in northern China, the need for green stormwater management systems is being seen as more urgent. However, due to rapid urbanization, the perception of landscape in the context of stormwater management has been underestimated, leading to low quality of stormwater management system, open spaces and public indifference to rainwater issues. Based on a review of the theoretical background and investigation results, the six cases examined here of different features of stormwater management in northern China were collected as research objects and assessed in terms of three aspects, namely stormwater management system, open space quality and landscape perception. Two main research methods were employed in this study: project descriptions and questionnaires designed specifically for this research. Stormwater management function can significantly influence open space quality, and it can also combine with open space quality to contribute to a higher degree of landscape perception. Based on the conclusions verified in this research, a new standard of high-quality stormwater management is proposed, combining coherent structure and legible context. Coherent structure implies that the logical order of design components (e.g. water bodies, streets, and squares) and their rhythmic dimensions allow viewers to understand the stormwater management functions. Legible context means that a viewer recognises the hierarchical relationship of these components, based on the overall coherent structure, and appreciates the rich, detailed and distinctive landscape features, such as colours, materials and textures. In particular, as far as stormwater management system is concerned, the components, including the water body, of stormwater management systems, should be connected to each other coherently and integrated into the whole functional process. The legible context of open space quality has a corresponding relationship with the coherent structure of stormwater management system, and is required to highlight functional focus and interweave visible components in order to accentuate the landscape features of stormwater management system. This combination of stormwater management system and open space quality is able to benefit landscape perception in two ways, namely understanding the whole functional system, and increasing the attractiveness of landscape detail. There are two strategies proposed: 1) a new evaluated system of stormwater management established by analysing expert and public opinion on the three aspects, stormwater management system, open space quality and landscape perception; 2) a series of specific design recommendations to raise the coherence and legibility of stormwater management systems and to integrate them in the context of urban stormwater management. Most importantly, due to the huge potential of stormwater management in China this research can benefit the scenario of "Sponge Cities" and contribute to its success in the future.

Key Words: Stormwater management system, Open space Quality, Landscape Perception, Stormwater Water Management, Sponge Cities

Zusammenfassung:

In Anbetracht der unvorhersehbaren klimatischen Eigenschaften und ökologischen Gefahren in Nordchina wird die Notwendigkeit "grüner" Regenwassermanagementsysteme als zunehmend wichtig angesehen.
Dennoch ist die Wahrnehmung der Landschaft hinsichtlich des Regenwassermanagements im Zuge der rasanten Urbanisierungsprozesse unterschätzt worden. Dies hat zu gestörten Gewässerhaushalten, geringer Qualität öffentlicher Räume und einem Desinteresse der Öffentlichkeit an dem Thema Regenwasser geführt. Aufbauend auf theoretischen Grundlagen und Forschungsergebnissen werden in der vorliegenden Arbeit sechs Fallstudien untersucht, die unterschiedliche Herangehensweisen an das Regenwassermanagement in Nordchina zeigen. Die Untersuchungsobjekte wurden hinsichtlich dreier Aspekte zusammengestellt, nämlich Gewässerhaushalt, Qualität des öffentlichen Freiraums und Landschaftswahrnehmung. Zwei Hauptmethoden wurden für diese Studie herangezogen: Projektbeschreibungen und eigens für diese Untersuchung erstellte Fragebögen. Der Gewässerhaushalt kann, mit Bezug auf seine Funktion des Regenwassermanagements, die Qualität des öffentlichen Raumes signifikant beeinflussen. Kombiniert mit hochwertigen öffentlichen Freiräumen kann er zu einer verbesserten Wahrnehmung der Landschaft beitragen.
Auf Grundlage der in dieser Arbeit belegten Rückschlüsse wird ein neuer Standard für ein qualitativ hochwertiges Regenwassermanagement vorgeschlagen, das eine kohärente Struktur mit einem lesbaren Kontext verbindet. Eine kohärente Struktur bedeutet, dass die logische Anordnung der Gestaltungskomponenten (z.B. Gewässer, Straßen und Plätze) und ihre rhythmischen Dimensionen es den Betrachtenden ermöglichen, die Regenwassermanagementfunktionen zu verstehen. Ein lesbarer Zusammenhang bedeutet, dass die Betrachtenden die hierarchische Beziehung dieser Komponenten erkennen, und auf Grundlage der umfassenden kohärenten Struktur, die vielfältigen, detaillierten und spezifischen Eigenschaften der Landschaft genießen, so wie z.B. die Farben, Materialien und Oberflächen. Sofern der Gewässerhaushalte betroffen ist, sollten insbesondere die Komponenten der Regenwassermanagement-Systeme, einschließlich dem Gewässer, kohärent miteinander verbunden sein und in den gesamten Funktionsprozess integriert sein. Der lesbare Zusammenhang des öffentlichen Raumes steht im engen Verhältnis zu der kohärenten Struktur des Gewässerhaushalts und ist notwendig um die funktionalen Aspekte zu betonen und sichtbare Komponenten zu verweben, um die Funktion der Landschaft als Regenwassermanagementsystem zu betonen.
Diese Verbindung von Gewässerhaushalt und Freiraumqualitäten kann die Landschaftswahrnehmung verbessern, nämlich das Verständnis des gesamten funktionalen Systems, und die Attraktivität der

landschaftlichen Details steigern. In dieser Arbeit werden zwei Strategien vorgestellt: 1) Ein neu ausgewertetes System des Regenwassermanagements auf der Grundlage der Expertenanalyse und der öffentlichen Meinung hinsichtlich dreier Aspekte, und zwar Gewässerhaushalt, Freiraumqualität und Landschaftswahrnehmung sowie 2) eine Reihe konkreter Gestaltungsempfehlungen um die Kohärenz und Lesbarkeit des Regenwassermanagements zu verbessern und sie in das städtische Regenwassermanagement zu integrieren. Durch das große Potenzial des Regenwassermanagements in China kann diese Arbeit insbesondere einen Beitrag zu dem Szenario der "Sponge Cities" leisten und zu dessen zukünftigen Erfolg beitragen.

Stichworte: Gewässerhaushalt, Freiraumqualität, Lanschaftswahrnehmung, Regenwassermanagement, Sponge Cities

Tables of Content

Chapter 1 Introduction

1.1 Research problem statement

Opportunities and challenges always co-exist because the one can be transformed into the other. Such a transformation process constitutes a turning point – one that is driven by challenges and stimulated by opportunities. It can be observed that every country or city will one day arrive at a turning point of some kind. China, as an industrial nation and the world's largest developing country, is now reaching a turning point in urban development. Northern Chinese cities, particularly the larger ones, are experiencing water crises and suffering from a deterioration of the ecological environment due to rapid urbanization. Driven by these challenges, the call for greater public participation in, and attention to, rainwater issues as well as more public demand for better open space quality could become so vociferous that they will bring about a turning point in the development of these cities. It is proposed that new ideas for stormwater management that combine improved open space quality with increased landscape perception can make a valuable contribution to coping with such a point.

Traditionally, stormwater management is defined as relating to the efficient management and control of water resources, including precipitation, within a specific hydrological circle (Wanielista and Yousef 1993: P. 3). Research insights have been applied to various fields, including agriculture, urban rainwater management and flood management. Aimed at dealing with the above-mentioned challenges, the present study concentrates on proposing a new strategy for urban rainwater management, interpreted from three aspects, namely stormwater management system, open space quality and landscape perception. In contrast to other studies in this field, this research interprets the principles of urban stormwater management more comprehensively and proposes that a stormwater management system ideally be treated as a multi-layered system which provides both a stable stormwater management system as well as the high open space quality that other research focuses on. However, based on distinctive landscape features employed in stormwater management systems, this research combines these two aspects and introduces the concept and assessment of landscape perception, which is intended to stimulate the public into appreciating stormwater management systems.

First of all, with a view to clarifying the motivation for this research, Chapter 1 specifically addresses three challenges currently faced by northern Chinese towns: poor stormwater management system, the decreasing quality of open space and low levels of landscape perception. In particular, the low quality of stormwater management system embraces three main issues, namely, water pollution, urban floods, and the very mixed quality of stormwater management projects in northern China. At the same time, rapid urbanization is also accompanied by a low quality of open space, which fails to provide recreational value, pleasure from contact with nature and increasing cultural values in urban areas. This section also refers to the concept of "Smart Cities" and points out the lack of awareness of how to interpret this concept.

1.1.1 Poor stormwater management system

In terms of water crises, northern Chinese cities have similar problems to other cities in China. In particular, most Chinese cities have been suffering from low efficiency of urban stormwater management system during the last two decades, including water pollution (Wu et al. 1999), urban flooding (Yu 2010b), shortage of water (Jiang 2009), and lowering of the water table (Hu et al. 2005). Here, the research concentrates on two main problems: water pollution and urban flooding.

1.1.1.1 Water pollution

Pollution is a major issue in the field of water management in China. It includes industrial pollution caused by dumping wastewater directly into urban water bodies (Dasgupta et al. 2001; Wang et al. 2008); Non-point Source water (NPS) pollution mainly caused by the first flush of rainwater runoff (Li et al. 2007; Yan et al. 2013); and pollution caused by the overuse of commercial fertilizer and animal manure etc. in agriculture and animal husbandry (Puckett 1995; Zhang et al. 2004).

In particular, Non-point Source water pollution derives from traffic route runoff, including railways, roads and transportation corridors (Wei et al. 2010; Zhang et al. 2003a; Zhang et al. 2003b); the deposition of atmospheric pollutants (Shao et al. 2006; Zhang et al. 2010); and waste deposits from coal mines (Liu and Diamond 2005; Wang and Ongley 2004). The NPS pollution is receiving more attention in society in general, because it is reported that the pollution from agriculture and NPS pollution accounted for 81 percent of nitrogen and 93 percent of phosphorus in total water pollution in China (Ongley et al. 2010).

Additionally, ecological hazards resulting from the eutrophication of water bodies also frequently occur in China. Urban stormwater runoff is treated as one of the major reasons for eutrophication (Ren et al. 2008). In the last two decades, because the rainwater runoff, carrying various pollutants, is generally discharged into urban water bodies without treatment, this problem has rapidly spread throughout the majority of urban water bodies in China, for example in Dianchi Lake (Li et al. 2005; Zheng and Wang 2002), Lake Taihu (Xu et al. 2010; Zhu 2008) and West Lake (Pei and Ma 2002).

1.1.1.2 Urban flooding

In the theory of urban floods, there are two unpredictable climate features in northern Chinese cities: uneven rainfall distribution and extreme precipitation patterns (see section 4.1.1). They lead to a strong possibility of frequent floods in summer (Wu et al. 2007). For example, on July 21st, 2012, a huge flood hit Beijing, causing the death of 80 people and 1.265 billion Euros in direct economic loss within twenty hours (Er and Tian 2012; Tian and Ni 2013). The threat of urban floods affects not only the cities in northern China, but also southern Chinese cities. For example, from July 16th to 18th, 2007, a sudden urban flood in Chongqing killed 93 people with ten people missing, and 4.450 billion Euros of direct economic losses (Er and Tian 2007: 8). On

July 18th and 19th, 2007, 37 people died, and over 167 million Euros of direct economic losses were caused by a flood in Jinan (Er and Tian 2007: 8). Apart from these unpredictable factors, there are also other reasons, such as ineffective decentralized drainage systems combined with extreme rainfall events, ecological degradation and fragmented greenways (Yan et al. 2013).

At the same time, these cities are also facing the challenge of shortage in the urban water supply (Jiang 2009). Statistical data has proved that in China only six percent of the world's fresh water has to satisfy 20 percent of the global population (Yu 2010b); in 1999 the country's water deficit had already reached 967 million cubic meters (Zhao et al. 2006); more than 660 cities have almost reached a critical level of water shortage (Qiu 2010; Yu 2010b). The water shortage in the north of China is particularly serious. For example, before 1999, the risk of water resource shortage in Beijing was evaluated at the lower to middle level, while after 1999, the evaluation showed the risk was at a high level (Liao et al. 2013). Apart from climate change and topographic features, other major reasons for water shortage include water body shrinkage, lower water tables and the breakdown of healthy hydrological cycles (Yan et al. 2013).

1.1.1.3 Diverse quality of stormwater management projects

Due to the low quality of stormwater management system and an increasing awareness of the importance of decentralized water treatment concepts, the managers of Chinese cities have also shifted their attention away from urban water engineering systems towards interdisciplinary cooperation and multiple methods. However, the quantity and quality of water projects is rather low and limits the effects of stormwater management projects. Table 1 shows almost all significant urban stormwater management projects in China. Based on the review of literature and the author's own investigations, it can be shown that relevant water projects and research in China are just beginning and are of a far lower standard than in Western countries, particularly in Germany.

The main reasons for this are the absence of interdisciplinary cooperation, insufficient political guidance, the underestimation of the need for green decentralized stormwater management, and the isolation of the stormwater management systems from the surrounding environment. For instance, the investigation shows that the majority of northern Chinese projects are more or less ecologically isolated from urban green corridors in the context of urban open space system. As a consequence of such disconnection, Jack Ahern writes that isolated core areas in non-supportive landscape matrices become smaller over time due to disturbances to the connecting corridors (Ahern 2002: p.51).

Table 1: Significant urban rainwater projects in China

Location	Name	Type	Designer	Area
Tian Jing	Zhangjiawo New Town	Urban Resident Zone	Atelier Dreiseitl	Master plan=180ha,
Tian Jing	Cultural Park	Urban Park	Atelier Dreiseitl	90ha
Pingdingshan	Development master plan of City of Pingdingshan	Master Plan	Atelier Dreiseitl	2872ha
Beijing	LID/GSI Project of the Ecological Oriental Sun City	Urban Resident Zone	Che Wu	Master plan=200ha
Beijing	Beijing Olympic Park	Urban Park	Sasaki	84.7ha
Beijing	Yongyou Software Park	Industrial Park		341 hm²
Hong Kong	Wetland Park	Diversity of wetland ecosys-tem, Water conservation		61ha
Harbin	Qunli Strom Water Park	Wetland restoration	Turenscape	34ha
Shanghai	Giant Interactive Group Headquarters	Rain Water Adaptive Strategies	SWA Group Los Angeles Office	18.2ha
Beijing,	Shuangzi Community	Technological consolidation	Chinese Ministry of Science and Technology	2 hm²
Beijing,	Guyue Community	Technological consolidation	Chinese Ministry of Science and Technology	11 hm²

So rather than being seen largely as technological instruments, sustainable stormwater management projects need to be observed in a landscape site, on an urban scale, and to be seen also as green corridors with an ecological function. In brief, the challenges of low quality of stormwater management system can be discussed on two scales: 1) on the urban scale, a flexible and resilient urban water management system has not yet been built, and citizens still suffer from water pollution and urban flooding; 2) on the landscape project scale, although projects with decentralised stormwater management concepts have been built, the differing quality, small quantity and technological limitations of these projects have not created social, ecological and cultural values compared to the projects in Western cities. Therefore, these challenges generate the significant question as to how the stormwater management system of individual projects can relieve the stress of urban water crises and produce more values such as the quality of open space and landscape perception.

1.1.2 Shortcomings of "Sponge Cities" theory in China

The concepts of "Sponge Cities" and "Smart Cities" have common goals, such as increasing the inhabitants' well-being by sustainable approaches. Today, both of the concepts could be embedded in the processes of Chinese urban planning and design, however, the theoretical bases of the two concepts in China are not mature enough yet. The rise of Smart Cities opens new windows of opportunity for those of us confronted with the current challenges of urban environments. Historically, ideas relating to "smart cities" were first initiated at a gathering named "SMART95" in Toronto (Gibson et al. 1992). In 2008, this concept was reinterpreted and expanded by Samuel Palmisano, the president and CEO of IBM, who believes that a future city will be a place which can create better services via close cooperation between conventional infrastructure systems and digital and telecommunication networks (Palmisano 2008). Subsequently, a series of related ideals were proposed on the basis of this concept, such as "smart government", "smart mobility" and "smart water conservancy" (IEEE Smart Cities 2009; Wang et al. 2013a). In 2009, Wen Jiabao, the ex-premier of the People's Republic of China, officially proposed the concept of "Perceiving China" based on "The Internet of Things" (IoT), which is one part of the "smart cities" concept (Jiabao 2009). Faced with these ideas and changes, the Chinese Academy of Engineering (CAE), a celebrated national academy, regards "Smart Cities" as one of the major national large-scale engineering projects in the publication named "The Report of the Medium and Long Term Science and Technology Plan and Strategy of China". This report constitutes a systematic plan for the period until 2030 and sets out the roadmap for future Chinese technological development (Wang and Guo 2013). In this published report the smart cities have been evaluated on the level of the national development strategy.

There is no explicit and global definition of a smart city. Regarding ways of establishing "Smart Cities", two opposing viewpoints are being discussed: the bottom-up and top-down approaches. Bottom-up means that centralized technological systems should not be regarded as the "panacea" of urban planning. From a broader perspective, governments should pay attention to common sense, different kinds of affordable technology, and innovative design (Townsend 2013). In contrast, people who support the top-down approach claim that collecting and analysing "big data" and advanced technological networks can contribute towards truly smart cites (Wladawsky-Berger 2013). The present research argues that whichever one of the two approaches (or both of them) prevails, the move towards "Smarter Cities" will develop into a major trend, but obviously, much still has to be done before the ideal "Smart City" can be achieved.

Turning now to "Sponge Cities", one aspect of this concept is water management. The concept of "Sponge Cities" has been developed in the Chinese urban water management with the aim of fighting the water crises by means of decentralized water treatment systems (Su et al. 2014). The concept of "Sponge Cities" also includes such important characteristics as flexible and resilient landscapes, well-maintained ecological systems, and effective cooperation between engineers and designers. This concept, with its capacity for cooperating with the digital technologies of the smart city, can bring huge benefits for cities facing the threats of natural disasters or climate change. The term "Sponge Cities" was first used at the beginning of the millennium with two different meanings. The "Sponge Cities Effect" proposed by demographer Bernard Salt is defined as the effect that results from a large town with an attractive way of life being able to "soak up" the people living in the surrounding area, as in the case of Horsham in Australia (Salt 2004). This effect is often referred in the discipline of urban policy. For example, Margaret Alston indicates that one of the main reasons leading to this effect is the inequality of regional policy since rural inhabitants have less access to social resources, such as education and health (Alston 2000: p.31). At almost the same time, the term of "Sponge Cities" also started to be used in stormwater management research. For instance, the research into water balance in the Indian city of Hyderabad regarding irrigation and agriculture uses this term as the title, although the author did not explain its meaning (Van Rooijen et al. 2005); Kongjian Yu and Dihua Li used the physical features of sponges as a metaphor to describe the ideal ecological functions of natural rivers which have degenerated due to rapid urbanisation (Yu and Li 2003: p.139). Nevertheless, the combination of "Sponge Cities" and holistic urban planning are not considered in this book. Recently, the research into urban stormwater management has started to integrate broader disciplines and issues such as urban traffic systems, networks of green infrastructure, land usage and regional planning. From this perspective, proposing "Sponge Cities" as an alternative perspective for an attractive urban future is a necessary step and also reflects the tendency towards integrating urban strategies, specifically for Chinese cities confronted with the imbalance of urban water resources Therefore, a large amount of research now pays more attention to the different approaches for constructing "Sponge Cities" and is now exploring their implementation in China, discussing for example the cooperation between green infrastructure and pipe networks for water drainage in the Shougang industrial zone (Shuqiu and Zhigang 2011). Lin and Yu propose organising urban water resources and green systems as a principle resource in establishing "Green Sponges", which decentralize water treatment systems, prevents urban flooding and retains rainwater as well as providing a waterscape (Lin and Yu 2012). There are also many new insights that have been developed in parallel research across the world. For instance, Ignacio Bunster-Ossa suggests that one of the best perspectives on "Sponge Cities" might be to build resilient and integrated systems that include "a giant water retention, filtering and recycling structure". Then there is the discussion of the projects by the Water Remediation Technology Company and Buckminster Fuller (Pickett et al. 2013: p.305). Owing to the huge efforts currently being undertaken by academic researchers and practitioners, the concept and perspectives of "Sponge Cities" have been officially proposed by the Chinese Government. Jinping Xi, the Chinese president since 2013, appealed to town planners and architects to "establish 'Sponge Cities' employing high capabilities of natural retention, permeability, and purification" on December 31st, 2013 (Yang and Guangsi 2015: p.60). Some months later, the Chinese Ministry of Housing and Urban-Rural Development published a "*Technical Manual for Establishing Sponge Cities – Construction of Low Impact Development in Stormwater Management system*" (2014). This manual indicates that "Sponge Cities" need to be very resilient in order to address the changes in environment and climate or to confront the threats of natural disasters. More specifically, rainwater should be absorbed, retained, penetrated and purified in the city for meeting future needs (Ibid., p. 4). With this perspective, the manual discusses four aspects, namely, design on a landscape scale, planning on an urban scale, maintenance and engineering construction. The discussion of these four aspects is related to the concept of Low Impact Development and attempts to outline tangible solutions in different design tasks, such as streets, parks and drainage systems on a landscape and urban scale (Ibid., p. 6). However, Yang Yang and Guangsi Lin (2015) find fault with the fact that this manual concentrates mainly on technological details, while failing to establish a concrete theoretical basis for "Sponge Cities". This shortcoming might weaken the potential of "Sponge Cities" and lead readers to believe, falsely, that the concept of "Sponge Cities" only relates to the concept of Low Impact Development. The present research argues that the research of "Sponge Cities" in China is still at an early stage, and the development of related theories is as yet very inadequate. Consequently, the proposed technological and design details, which lack the guidance of a strong theoretical basis, may have a negative impact the innovative and comprehensive nature of Chinese "Sponge Cities". This research argues that stormwater management system should be implemented together with other open space functions, to achieve a truly liveable urban space for inhabitants. Additionally, another critical aspect, -public awareness, is also completely ignored in the manual by the ministry, as will be discussed in the following section.

1.1.3 Decreasing open space quality

Rapid urbanization impacts greatly on the Chinese population structure and existing urban structures and at the same time opens up both new perspectives for the future as well as presenting unprecedented challenges. According to the latest official statistical data, the total Chinese urban population had reached 731 million by the end of 2013, which is 19.3 million more than in 2012. The Chinese urbanization level rose to 53.73% in 2013 (Li 2015). Rapid urbanization has two main consequences. The first is that an increasing number of citizens are demanding a higher quality of life from their residential environment. The second is that the value of open space quality is now decreasing in three respects: in terms of size, the available natural resources and cultural heritage (Yu et al. 2008b). For instance, because of the rapid urban expansion, numerous communities and urban parks with few and low-quality open space systems built in recent years have contributed to the worsening water crises and the decrease of citizens' well-being. It can be seen that open space systems not only provide a liveable space for inhabitants. In terms of urban rainwater issues, the cooperation of engineering systems and green infrastructure is also an important precondition for establishing a sustainable and effective stormwater management system. Therefore, the study of open space systems in the present research mainly focuses on two aspects, namely public infrastructure and nature pleasure.

First, the fast-growing residential zones and their surrounding environments, urban parks for example, lack a satisfying public infrastructure (Song 2012). They fail to attract citizens and bring them more recreational value, which results in fewer outdoor recreational activities and a reduced experiencing of the landscape. In particular, there is still plenty of room for improvement in the type, distribution, quantity, artistic value, maintenance and functional diversity of the public infrastructure in residential zones and urban parks. The limited financial investment, short production cycles and the low level of democracy in the design process etc. possibly cause these disadvantages. But a new question also arises from the status quo as to how public infrastructure combined with green open space systems can play a more important social role and produce a higher quality of open space.

Second, most communities and urban parks are equipped with little green infrastructure, but with huge numbers of rigid and ordered landscape elements that are not sustainable and provide little enjoyment of nature such as large paved surfaces with little shade. As already mentioned, the citizens have urgent demands and the huge expectation that they can gain satisfying recreational values from the surrounding urban open space. However, for the reasons mentioned above, landscape design has turned out to be a decorative art, one that serves to fulfil the urban greening index, while ignoring inhabitants' demands. As a consequence of this, the green landscape in most communities and urban parks cannot convey a higher quality of natural enjoyment (Bai 2000; Wang 2010). Additionally, because water treatment design and landscape design are traditionally considered as two distinctive fields, even on an urban scale. Thus, one finds that stormwater water management is now separated from the planning of green elements in most urban projects. For this reason, the green elements fail to contribute positively to both the stormwater management system and the scenic landscape. So, when considering stormwater management and the enjoyment of nature, the question emerges as to how designers can produce a high and distinctive enjoyment of nature for inhabitants on the basis of interaction between stormwater management and green elements (Zhang 2006; Zhang and Zhang 2002).

In addition, the historical identity of open spaces has also disappeared in the wave of rapid urbanization. Local cultural features fail to be preserved or to be treated as distinctive landscape elements that can greatly help the public to identify with them. A homogeneous urban landscape without unique cultural features results in open space systems that fail to stimulate inhabitants' feelings and common memories, and also cannot continue to develop local cultural and historical identities (Yu et al. 2008b).

1.1.3 Low level of landscape perception

One's perception of the landscape is regarded as the cognitive feeling and emotion that is engendered when observing, understanding and appreciating one's environment (Pocock 1972). Research in this field argues that because of the three mental activities involved here – observing, understanding and appreciating – landscape perception is closely related to human thinking and behavior (Reed and Jones 1978). Other researchers, with a different understanding of landscape perception, imply that the public's appreciation of waterscapes can be driven, for example, by the quality of a landscape's stormwater management (Dreiseitl 2013). The present study reviews this field of research in order to clarify how the theory of landscape perception has developed, and how it is relevant for the study of stormwater management (see section 2.3).

Unfortunately, due to the low quantity and quality of urban stormwater management systems in China, the significance of landscape perception and the need to intensify this experience fail to be considered in most cities. As a result, despite being aware of the threat it faces from natural disasters, the Chinese public is not truly concerned with urban rainwater issues and participates little in related agendas. More seriously, because this low level of landscape perception is contributing to a lack of awareness of urban rainwater management, thus leading to a huge and long-term waste of water resources, the low level of public awareness of rainwater issues counteracts the continued efforts of experts and public administration (Chen et al. 2007; Cheng et al. 2009). To illustrate this: in March 2013, 16,000 dead pigs were found in the Huangpu River, a drinking water source in Shanghai. It is reported that some butchers threw the dead pigs into the river illegally, in order to escape handling costs (Shannon and Meulder 2013). It is inconceivable that such a large-scale action went unnoticed, yet it was not reported.

Herbert Dreiseitl argues that a higher quality of landscape design – one that makes the principles of stormwater management visible – can attract more attention to, and thinking about, the value of water resources. Developing such an awareness relies on creating landscapes with a high aesthetic value that are both functional and sustainable (Dreiseitl 2013: p.74). It is argued in the current study that the uniqueness of an urban environment is produced by interweaving human activity, politics, economy and culture. In turn, a well-designed environment can also change individual relationships within society, stimulate public participation in rainwater issues and act as a catalyst to give impulses for sustainable social reform.

Positive public awareness stimulated by environmental design can, if encouraged, constitute an important element in the Chinese Smart City. An attractive and perceptible landscape can increase public participation, and, most crucially, produce motivation and strength for the goals of "Sponge Cities". Although there are many ways of training people to understand environmental processes, such as through the media and school, landscape-based design can also play an important role through stimulating the inhabitants' landscape perception and influencing their consciousness of urban water issues. In sum, the above-mentioned problems motivate this research to propose research questions in which the relationship of the stormwater management system, open space quality and landscape perception will be discussed and evaluated in order to enrich the theory and interpretation of "Sponge Cities".

1.1.5 Academic gap

As shown above, low efficiency of stormwater management system and the generally low quality of open spaces in Chinese cities are the main challenges at present. However, a key to dealing with these two problems is landscape perception in the context of stormwater management, because the research on landscape perception has proved that environmental change closely correlates with human mentality and behaviour. Similarly, a successful management of urban environmental infrastructure can also facilitate an understanding of the surrounding environment. However, little research focuses on the relationship between stormwater management function and landscape perception. In particular, the review of literature has shown that although a large number of studies on green stormwater infrastructure in China has already been published, including conference proceedings (Jensen 2008; Stokman 2008b; Wang and Zong 2008), academic dissertations (Zhang 2013; Zhao 2012; Zhen 2010) and articles (Wu et al. 2007; Yu et al. 2008a), there is little research on the theoretical relationship between stormwater management system, open space quality and landscape perception in academic fields and landscape practice. From this particular perspective, no research on stormwater management in northern China has been published, although this region is suffering from water crises, low quality landscape practices and low levels of public awareness of rainwater issues.

In conclusion, poor stormwater management system and low-quality open spaces have stimulated the application of various concepts in China, such as LID and “Smarter Cities”, or “Sponge Cities”. However, in the view of stormwater management, these concepts weaken public perception and ignore the public’s desire to participate in urban construction. So far, most research has failed to combine the three aspects to find a new solution which can benefit future Chinese cities.

1.2 Research questions

Based on the discussion above, this research aims at dealing with the following problems:

1.) **What are the qualities of contemporary northern Chinese stormwater management projects in terms of stormwater management system, open space quality, and landscape perception?**

2.) **Which recommendations can be made regarding design strategies to raise the quality of future stormwater management projects in urban landscapes of northern China, taking into consideration stormwater management system, open space quality and landscape perception?**

First of all, six significant cases with a well-managed stormwater management system will be identified and examined, and these cases will be discussed with a view to determining how a decentralized water treatment system can achieve water balance and a high quality of open space.

Subsequently, in terms of stormwater management, its appearance, namely open space quality, can raise people's interest and attention, and thus stimulate unique perception of a landscape that is distinctive from other landscape systems. In every case study the open space will be assessed to find out the characteristics and rules which can influence landscape perception.

The three components – stormwater management system, open space quality and landscape perception – are on different levels of abstraction, with landscape perception being much more abstract than the other two components. In terms of the relationship of stormwater management system and open space quality, open space quality can be influenced by visible functions of stormwater management system. And it is very clear that a good stormwater management system is one of the common goals for open space systems and stormwater management system. Because of the broad meanings of the two fields, this research does not intend to focus on all aspects of their intersection. This research argues that the relationship of stormwater management system and open space systems, such as the role of stormwater management system in producing and enhancing open space quality, needs to be clarified and explained. Additionally, stormwater management system and good quality open spaces are considered as the basis and prerequisite of effective landscape perception. A high degree of landscape perception in connection with stormwater management can be stimulated in a specific open space equipped with attractive landscape elements and understandable stormwater management function. Based on the case studies, the research then proposes a series of recommendations regarding stormwater management system, open space quality and landscape perception. These recommendations are expected to facilitate the fulfilment of concepts such as "Smart City" and "Sponge City" in respect of stormwater management.

1.3 Significance and goals

This research is of significance: following the national political tendency, this research is a necessary supplement to the concept of the "Sponge City" for building flexible and resilient urban open space systems, and is also expected to expand the perspective of "Chinese Smart Cities" which can positively transform economic achievements into citizens' well-being. At the same time, the current research is also expected to give new stimulus for planning models regarding landscape perception in the context of stormwater management as a vital part of the "Sponge City".

The present research aims to develop specific recommendations in terms of design which can raise the quality of future stormwater management projects in northern China. In doing so it has three goals. First, it intends to support designers in taking full advantage of stormwater management systems to build a stable relationship between stormwater management system, open space quality and landscape perception, thus producing greater benefit in terms of social values.

In particular, the construction of such a relationship is expected to produce a better understanding of the three components, and to create new fields of knowledge to benefit design practice. Because of their ecological deterioration, most urban areas have built either artificial scenic landscapes which have little ecological value and undermine the local stormwater management system, or landscapes that lack sufficient green recreational amenities. The present study tackles this disadvantage by means of connecting between the function and aesthetic value of stormwater management. It also intends to improve the 'legibility' of water management systems through better landscape perception, thereby raising public awareness of rainwater issues.

The second goal is to stimulate more citizen participation in the affairs of water protection. Based on the above mentioned discussion regarding "Sponge Cities", the behaviour and attitudes of citizens who lack awareness of the need to cherish water resources produce the kind of society that wastes water resources. An increasing individual understanding of water challenges can result in stronger public opinion – one that provokes more discussions and reflection in the entire society, and also inspires more frequent cooperation between citizens, decision makers and landscape architects in order to counter the above-mentioned water crises. The research had proven that individual consciousness of rainwater issues can be developed through publicity and education and be inspired by a coherent and legible landscape. Thus understandable and perceptible landscape systems that cooperate with stormwater management systems are needed because they can bring about a long-term positive influence on public awareness and stimulate greater citizen participation. However, one point should be mentioned here, namely that a good atmosphere of citizen participation not only relies on the efforts of landscape design. It must also be assisted and cultivated by local government and other social groups. In terms of urban design, because it was difficult to define and evaluate public participation in the investigation and because the landscape systems in the majority of the Chinese cases have different qualities, the recommendations regarding how to establish understandable and perceptible landscape systems are significant for citizen participation.

The third goal is to expand existing theories. Kongjian Yu's theoretical research and planning practice mainly concentrate on the regional planning scale, giving rise, for example, to the "Theory of Ecological Security Pattern" (Yu et al. 2009), while Che Wu has paid more attention to technological approaches on the project scale (Che 2011). Although his research has recently turned to an integrated approach, his studies still address the rainwater issues from a technical perspective. In comparison with these, the present research focuses largely on stormwater management systems on the project scale with a specific focus on the particular relationship between ecological systems on the one hand and open space quality and landscape perception on the other.

Chapter 2 Research Background

2.1 Review of research and practices of stormwater management system

This section reviews stormwater management in Western countries and China from a historical and modern view, including previous research and practices in the area of stormwater management system. The review below shows that the development of stormwater management from ancient to modern times has also been a process of pursuing a well-managed stormwater management system.

2.1.1 Review of stormwater management in western cities

2.1.1.1 Historical review of engineering facilities

Technologically limited the first attempts at stormwater management had to use basic materials and primitive tools to obtain water from local wells. Only local water bodies could be used to build basic infrastructures, washing possibilities and to make irrigation available to people (Prowse et al. 2007). Particularly, the streets connecting the ancient residential areas could be used for rainwater conveyance (Angelakis et al. 2005; Frankfort 1950). For example, the relics of Athens city built in 500 B.C. and the archaeological excavations in Pompeii and Herculaneum in Italy show that ancient people often used wood and rock to build simple linear structures which were used as forms of primitive stormwater management (Waterfield 2005). However, with the growth of ancient cities, water played an increasingly important role in urban development, including business, fortification, navigation and agriculture. Therefore, people started to intensively invent and develop a series of new technological instruments in order to meet the demands of the growing cities. Moreover, new materials used in the establishment of urban infrastructures, such as baked clay, also gave people an increasing number of choices in the building of suitable stormwater infrastructures (Hopkins 2007). More complex conveyance systems, instruments of water storage and engineered capture, etc., have been applied within the urban area or houses since the medieval period (Large and Petts 1996; Pandey et al. 2003; Roberts and Cox 2007).

In the 17th century, the Industrial Revolution was initiated in Great Britain and quickly spread throughout Europe. Several important inventions not only brought about breakthroughs in manufacturing processes and science, but also gave rise to closer considerations of urban health, aesthetics, and recreation. These breakthroughs also promoted the development of urban stormwater management (Akan and Houghtalen 2003; Giroud 1983). Traditional forms of animal and human labour, and the generation of energy by water or air such as through water wheels or wind mills (Loucks and van Beek 2005), were generally replaced by steam and fossil fuel energy (Mokyr 1999). These breakthroughs also boosted a series of huge water conveyance projects, stream straightening, underground pipe covering, reservoirs and storage and linear canal networks (Kelso 2004). The popular application of fossil fuel energy and insufficient urban health facilities resulted in water pollution which posed a high risk to public health. At the end of the 17th century, urban managers in western countries initiated some large-scale projects focusing on countering water pollution, improving water quality, and drain rainwater (Al Radif 1999; Alvim-Ferraz et al. 2006). Previously isolated sewer pipes were then built and connected to each other within urban areas (Novotny et al. 2010).

Due to widespread water pollution mainly caused by fossil fuel energy and insufficient urban drainage systems, urban managers in the middle of the 19th century became aware of the importance of countering water pollution, improving the quality of water consumption, and draining rainwater via large scale urban sewer systems (Al Radif 1999; Alvim-Ferraz et al. 2006; George and Nielsen 2000). An example of this is the Fen Project of Back Bay in Boston (Egan 1990; Miller 2001). At the end of 19th century, there was massive financial investment in technological engineering aimed at alleviating the pollution of excreta and faecal matter (Szreter 1999), for instance, the introduction to water-flushing toilets linking with fast conveyance systems (Quitzau 2007); wastewater treatment which mainly includes septic tanks and leaching fields in the United States (Stewart 1986; Steyer et al. 2006), and the development of Imhoff Tanks which were underground storage units for collecting and dealing with sewage in Germany in 1906 (Scott et al. 2010; Van 2008).

However, it has been shown that the artificial water conveyance systems are related to various problems (Burns et al. 2012; Li et al. 2007; Massoud et al. 2009; Stokman 2008b; Wilderer and Schreff 2000; Yan et al. 2013), such as the flood hazards in many western countries, including the U.S.A. (Novotny 2009), England and Wales (Wheater and Evans 2009), Australia (Tony 2006) and Germany (Beneke 2003). The social criticism and reflection on these rigid and mono-functional systems has forced landscape practitioners and managers to focus on producing urban sustainable concepts and theories (Ahern 2007; Jiahua and Houkai 2010; Woolley 2003) The Clean Water Act (CWA) by the U.S. Congress in 1972 (Adler et al. 1993; Poleto and Tassi 2012), and the Water Framework Directive (WFD) enacted by the European Parliament in 2000 (Borja et al. 2004; Muxika et al. 2007) have inspired a shift from protection and consumption of water resources to restoring urban ecological systems and improving the water recreational function (Novotny 2003). Driven by this development, new technological approaches have been applied, including secondary treatment stages in sewage systems, mandatory nitrogen removals (Hulth et al. 2005; Mulder 2003), control of non-point pollution (Havens et al. 2003; Novotny 1995), and nutrient removal from point and non-point sources (Kronvang et al. 1995; Van Drecht et al. 2003).

2.1.1.2 Modern landscape practices and theories of stormwater management

With the increasingly intensive need for sewer systems in human habitats, rigid and mono-functional sewer networks have become generally less suitable for dynamic urban development

(Stokman 2008a). They are associated with high maintenance and installation costs, high rainwater runoff, nonpoint pollution sources (NPS), decreases in urban vitality, limited water availability, ecological deterioration, and do not promote water protection (Burns et al. 2012). In combination with climate change, these weaknesses of the sewer systems cause flood hazards or unbalanced urban water resources in many countries. This has triggered widespread criticism and deeper reflection in both public and professional domains (Frederiksen 1996; Gleick 1993). Landscape practitioners and researchers have started to look at implementing sustainable strategies, and are also aware that urban ecological systems should be restored and preserved through interdisciplinary research and cooperation (Hough 1995; Jiahua and Houkai 2010). Various discussions and a large amount of research has been produced as a result of these reflections and criticisms, and thus for nearly two decades many theories and concepts have been proposed, for example, the United Kingdom's Sustainable Urban Drainage Systems (Butler and Parkinson 1997; Mitchell 2005; Poleto and Tassi 2012), Australia's Water Sensitive Urban Design (Wong 2006; Zhang et al. 2013), Canada and U.S.A 's Low Impact Design (Bowman and Thompson 2009; Li et al. 2014) and Best Management Practices (McBroom and Zhang 2011; Urbonas and Stahre 1993) and Green Infrastructure or Blue-green Infrastructure (Benedict and McMahon 2002, 2006) or Green Stormwater Infrastructure (Kessler 2011; Valderrama et al. 2013). This research and exploration was achieved by multi-disciplinary cooperation, including landscape architecture, construction technology, urban ecology, and public education, etc. (Yu et al. 2008a). Therefore, in the most recent decades, a number of projects have adopted various and efficient methods of rainwater treatment, which have been successfully implemented in accordance with the above-mentioned theoretical achievement and specific geophysical conditions. Table 2 shows seven typical German projects investigated by the present author. In addition to the German projects, due to the geographic conditions and for historical reasons, the Netherlands have provided large amounts of inspiring practices as well. For instance, "Waterplan 2" project was initiated by Rotterdam City Council and Holland Water Board. This project, with a total area of 319 km2, has four goals, namely preventing flooding, providing clean water, establishing an attractive city and introducing a decentralized sewer system. In this project, urban facilities were built for temporally storing rainwater and stimulating public activities in dense residential zones (Hoyer et al. 2011: p.56). Another example is the DWR Headquarters in Amsterdam designed by Atelier Dreiseitl, covering a total area of 0.2ha. This project takes advantage of a large basin for meeting various needs, such as toilet flushing, receiving and storing rainwater, and increasing open space quality (Dreiseitl and Grau 2009: p.36). Still, there are many more relevant projects, which have enlightened the author and the present research, but which will not be presented here.

Table 2: Information about investigated projects in Germany

Location	Name	Area (ha)	Designer	Concept of rainwater treatment
Hamburg	Trabrennbahn Farmsen	15.1	Kontor Freiraumplanung Möller Tradowski, Hamburg	Open conveyance systems are the key feature; the whole system reflects the site's identity as a harness racetrack (Hoyer et al. 2011)
Hannover	Kronsberg	160	ifs, Ingenieurgesellschaft für Stadthydrologie mbH; Atelier H. Dreiseitl	The whole residential area relies on a hollow-and-trench soakaway system to collect and convey rainwater.
Berlin	Kirchsteigfeld, Potsdam	60	Krier and Kohl	The combination of a stream, green land and green roofs contributes to a powerful drainage system that provides flood protection.
Stuttgart	Arkadien Housing Estates	1.5	Atelier Dresseitl	Drainage systems were built for rainwater recycling, plantings delay rainwater runoff; multiple ways for filtering rainwater.
Ostfildern	Scharnhauser Park	140	Janson & Wolfrum	Two systems, south-facing slope and Scharnhauser park, were built and employ various methods, including swales, trenches and retention basins.
Stuttgart	Hohlgrabenäcker	16.7	diem. baker GbR; Plastatt Johann Sener	The application of green roofs, cisterns, and pervious pavements to reduce costs.
Winnenden	Arkadien	3.4	Atelier Dreiseitl	Drainage systems convey rainwater into central water body and open space system, thereby establishing an attractive waterscape.

The new term of "water urbanism" coined by Kelly began to attract more attention (Shannon et al. 2008). The principle of "urbanism" was generated during the period of the Urban Reform Movement (Shannon and Meulder 2013) which had concentrated on "charities" and "commons", and then was increasingly developed and extended by a huge number of architects, urban planners, social scientists, landscape architects, and sociologists (Mostafavi and Doherty 2010; Shannon and Meulder 2013; Waldheim 2006). The introduction to "urbanism" into the various fields also drove further reflection about vast and complex western cities (Wirth 1938), for example, landscape urbanism, ecological urbanism, new urbanism, unitary urbanism, etc. As Louis Wirth wrote, "as long as we identify urbanism with the physical entity of the city... and proceed as if urban attributes abruptly ceased to be manifested beyond an arbitrary boundary line, we are not likely to arrive at any adequate conception of urbanism as a mode of life." (Wirth 1938: p.4-5). As far as the relationship of these urbanisms goes, Kelly Shannon wrote, "all [these sub-urbanisms] are in the end only a variation on urbanism with a certain emphasis… water urbanism surely is one of the articulations of landscape urbanism" (Shannon and Meulder 2013: p.6-7) .

2.1.2 Review of stormwater management in China

2.1.2.1 Historical review of engineering facilities

The term of "hydraulic civilization" coined by the German-American historian Karl A. Wittfogel, implies that any agricultural system has to establish a huge centralized management or power in order to supply the most important two national requirements: "production" (irrigation) and “protection” (flood control) (Jazairy 2011), for example, the oriental civilization (Ancient Egypt, Mesopotamia, China, and India). This theory was further developed in Wittfogel’s book “*Oriental Despotism*” (Wittfogel 1981). In the case of China, Robert D. Kaplan pointed out that “China combines an extreme, Western-style modernity with a "hydraulic civilization" that is reminiscent of the ancient Orient: thanks to central control, the regime can, for example, enlist the labour of millions to build major infrastructure” (Kaplan 2010: p.22-23).

The historic events and tales which were written and handed down showed that rivers and lakes were symbolically represented as seniors, mothers, armies, gods or governors in the Chinese culture. They always had an intimate relationship with the surrounding population because water has facilitated the growth and conflict of tribes since the very beginning of Chinese culture (Jiang 2003). The theory of “hydraulic civilization” demonstrates the significant differences between western countries and China (Li 2000a).

The establishment of hydraulic projects improved primitive centralized power (Li 2005), and the earliest one can be traced back to around 2000 B.C (Wu and Ge 2005). The frequent flood disasters inspired many grandiose projects, such as the Zhengguo Canal constructed 246 B. C. (PingSong 2013; Zhan 2011).

However, due to various reasons, modern sewer systems were not established in the majority of Chinese cities until the middle of the 20th century (Liu 2013; Xia 2012). There are several reasons for this, including low financial investment, frequent dynasty changes and war damage, an underestimation of the huge potential of the industrial revolution, and cultural and political background issues (Hai 2009; Wang 2008). Hence, the modern concept of water management in China came out much later than that in Japan and western countries (Cheng et al. 2007). Aiming to clarify the historical context of stormwater management in China, the most important achievements of the ancient water management in the ancient cities are reviewed on the basis on archaeological findings (Yu et al. 2007) (Table 3).

Table 3: Construction progress of water management based on the archaeological findings

Dynasty	Materials and structures	Location	Sources
The Neolithic Age (2600 B.C.- 2100B.C.)	Choosing higher topography, pottery pipe	Relics of ancient city ,Huaiyang County, Henan province	(Yu et al. 2007);(Yingqiao 2005);
Xia (2100 B.C. - 1600 B.C.)	Pottery pipe including straight formation and curved formation	No Relics	(Hou 2004); ;(Wu and Ge 2005)
Shang (1600 B.C.- 1100 B.C.)	Drainage ditch composed of wood and stone	Yanshi City ,Henan Province	(Yu et al. 2007)
Western Zhou Dynasty (1100 B.C.- 770 B.C.)	The different-diameter pipe	Pingyao Ancient City, Shanxi Province	(Liu 2007b);
The Spring and Autumn (770 B.C. - 221 B.C.)	The different-diameter pipe, slope composed of cobble on the street	Linzi Ancient City, Shandong Province	(Huaibei Museum 2010); (Liu 2007b); (Zheng 2003); (Li 2005b)
Qin Dynasty (221 B.C. - 207 B.C.)	Pottery pipe, open well and closed conduit, drainage system	Mausoleum of the First Qin Emperor, Xian City, Shanxi Province	(Li 2005a);(Yu et al. 2007); ;(Wang and He 2001);
Western Han Dynasty (206 B.C. - 25 A.D.)	Pottery pipe; open well and closed conduit; drainage system	The Changle Palace, Xian City, Shanxi Province	(Xu 1991); (Li 2002);
Tang Dynasty (618 A.D. - 907 A.D.)	The brick underground railway; the huge area of drainage ditches; cooperation with open well and underground railway; huge numbers of roadside trees	Chang'an Ancient city, Xian City, Shanxi Province	(Li 2012); (Li 1995); (Song 2008)
Song and Yuan (960 A.D. -1368 A.D.)	Brick, Slab stone	Dongjing City, Kaifeng City, Henan Province, Relics in Beijing	(Sun 2011); (Qian 1999)
Ming and Qing (1368 A.D. - 1840 A.D.)	Brick, Slab stone, semi-open underground trench system	Forbidden City, Beijing	(Han 2011; Wu 2003); (Zhao 1980)

From 2600 B.C. to 2100B.C. (the Neolithic Age), the first urban structures were constructed for basic drainage demands. Primitive tribes took advantage of topography and simple channels to drain the rainwater, sanitary water and waste water. In the late Neolithic Age, vitrified-clay pipes for water conveyance were found in the vestige of the ancient city of Ping Liangtai.

After the Neolithic Age, the Xia dynasty (2100 B.C. - 1600 B.C.) and Shang dynasty (1600 B.C.- 1100 B.C.) started to observe nature and proactively reformed the surrounding environment of the residential areas (Hou 2004). The accumulated knowledge inspired people to develop a new perspective on water management (Wu and Ge 2005). More advanced and diverse vitrified-clay pipes were found in the palace of the Shang dynasty, including straight and curved pipes. These different pipes were connected together for long distance conveyance. Additionally, artificial water basins were built inside and outside of the cities, retaining the rainwater and supplying the daily demand (Yu et al. 2007).

During the period of the Western Zhou Dynasty and the Spring and Autumn Dynasty (1100 B. C.-221 B.C.), systematic drainage systems, connecting with wells and local pools, were used in ancient buildings (Li 2005b; Liu 2007b). The wastewater and animal faeces were discharged away via these systems (Huaibei Museum 2010). The important cities installed lots of dedicated discharge channels including water inlets and outlets, water channel systems, all of which were built with huge stones. Pipes with non-uniform diameters (0.23-0.26m small diameter, 0.27-0.33m large diameter, 0.35-0.45m length) were also found (Yu et al. 2007). The reason for designing pipes with variable diameters is the quick assembly. In this period every underground water pipe line was made up of three pottery pipe lines (Li 2005b; Zheng 2003) (Figure 1).

Figure 1: Three different pipes of variable diameter combined together were used as water conveyance lines (Wang 2006)

In 221 B.C., the Qing dynasty, the first imperial dynasty in China, a water infrastructure system was built to meet the requirements of the operation of the whole empire (Li 2005a; Zhang 2005). For instance, drainage pipes with open well and closed conduits in the relics of the Mausoleum of the First Qin Emperor and in the Epang Palace were found (Wang and He 2001; Yu et al. 2007).

The Western Han dynasty (206 B.C. - 25 A.D.) not only inherited much technological knowledge from the Qing dynasty, but also developed it further, including advancing the water conservancy projects, building more reservoirs on establishing multi-functional urban hierarchical water networks (Li 2002; Xu 1991). In the Tang Dynasty (618 A.D. - 907 A.D.), the urban scale, living standards and the density of population increased very quickly which meant that the water infrastructure also had to expand greatly (Li 2012). Intensive drainage ditches were found where a brick underground channel was built. An open well and an underground channel were connected together, which created a complete urban drainage system (Li 2012). Urban managers also began to be more concerned about urban water issues, for example huge numbers of trees were planted along the streets which could decrease the rainwater runoff and offer a high landscape aesthetic performance (Li 1995; Song 2008).

In the Song dynasty (960 A.D.- 1279 A.D.) and the Yuan dynasty (1279 A.D.- 1368 A.D.), some new planning strategies countering waste and rainwater were proposed (Qian 1999; Sun 2011). For instance, Liu Yi, who was in charge of planning the local urban environment, had systematically investigated the local streets and urban construction of the Gan city. He then decided to build a 12,600 m long channel system which contained two urban discharge channels named “Fu” and “Shou”. This system contained six outlets which connected with the Gong River and the Zhang River (Han 2011; Han and Huang 2013; Li 2010). Most importantly, it connected with water bodies outside the urban area, cooperating with open wells and closed conduits, and established these two channels as a hierarchical water system improving public health, decreasing urban flood and boosting the local economy (Han 2011; Han and Huang 2013; Li 2010).

In the Ming (1368 A.D.-1644 A.D.) and Qing dynasties (1644 A.D.-1921 A.D.), the previous planning concepts implemented since the Tang dynasty were advanced further, i.e. urban constructions (Chen 2010; Wu 2003), the establishment of urban sewage systems (Song 2014), and the completion of urban water networks (Han 2011). Moreover, the two dynasties also established many underground sewage systems using huge stones and pig coppers (Zhao 1980). These findings have shown that water management in Chinese stormwater management history was at its peak in the Qing dynasty (Wang 2011).

2.1.2.2 Modern landscape practices in stormwater management in China

Certainly, traditional methods and technology would not be able to deal with the modern challenges in relationship to climate changes and rainwater flood. It can be observed that modern Chinese cities are suffering from a series of urban water crises and ecological degradation, such as urban flooding, water shortages, pollution of water resources, decreasing underground water, etc. (Stokman 2008b; Yu et al. 2006b). Although a series of research projects have been initiated in the last decade, more or less concerning with urban rainwater issues, only a few projects and theories are concentrating on restoring a harmonious relationship between nature and people (Che et al. 2013; Dong et al. 2007). Positive examples are the "Theory of Ecological Infrastructure Security Pattern ", proposed by Kongjian Yu (Qiang et al. 2005; Zhu et al. 2005). He argues that on the regional scale the safeguarding of natural, biological, cultural, and water issues, should be integrated via cooperation with ecological planning methods and the Geographical Information System (GIS) (Yu et al. 2009) . This security pattern has been applied into several real projects: the "Growth Pattern of Taizhou City Based on Ecological Project", which focused on several goals, including the restoration of abiotic processes which aims at the integration of stormwater management, natural hierarchical water systems, biotic processes and cultural processes (Min et al. 2005; William 2012; Yu et al. 2005); the "National Linear Cultural Heritage Network Project", which concentrated on the integration of ecological networks and greenway systems in order to balance the conflicts between nature and people (Qiang et al. 2005; Yu et al. 2009); the "National Ecological Security Patterns" which established systematic conservation guidelines including water conservation, flood containment and management (Shannon and Meulder 2013; William 2012; Yu 1996); and the "Beijing Ecological Infrastructure Demonstrated the Significance of the Security Pattern" which aimed to balance the urban and rural water sources for the sake of prohibiting the urban flood through improving the quality of the existing water features, retaining rainwater and recharging the aquifer (Yu et al. 2010; Yu et al. 2009).

As far as urban and landscape design is concerned, some water projects in China concentrating on rainwater issues have emerged in the last decades (Yu 2001). Particularly Turenscape founded by Kongjian Yu has proposed and finished several such exemplary projects (Turenscape 2015). For example, "Qunli National Urban Wetland Park Project" (see case study section 4.2) which concentrates on restoring and improving the original urban wetland in the intensive residence zone through collecting rainwater and recharging aquatic plants (Yu 2012), "Tianjin Qiaoyuan Wetland Park Project", which aimed to offer an urban park combining with a high aesthetic performance through retaining and purifying rainwater (Liu and Yang 2012).

Other research directions concentrate more on the cooperation with water engineering technology and green stormwater infrastructure on the small scale, compared to "Ecological Infrastructure (EI) Security Pattern (SP)". The achievement of Professor Che Wu is significant in this field. He argued that interdisciplinary cooperation is needed to deal with urban water crisis, including engineering, urban planning, landscape architecture, urban ecology, etc. (Ding 2004). Specifically, he recommends transferring the greater experience of western water management to China (Che et al. 2012), implementing strategies of urban recycled rainwater and decreasing Nonpoint Resources Pollution as well as greater cooperation between urban planning and technological engineering (Che and Li 2011).

Additionally, some projects adapting the advanced principles of stormwater management are inspiring Chinese landscape designers. For example, Atelier Dreiseitl, who insists on interdisciplinary design practice, particularly integrating art, landscape design and urban hydrology (Dreiseitl et al. 2001; Geiger and Dreiseitl 2001). They have designed five water projects across the design scales in China. There are two urban master planning projects: "Tianjin Cultural Park project in Tianjin" (Dreiseitl and Grau 2009; Grau 2009) (see case study section 4.4); "Hua Ming New Town project in Tianjin"; one residential project, "Zhangjiawo New Town project in Tianjin" (Dreiseitl and Grau 2009) (see case study section 4.3); one river restoration project is "Feng-Chan River Restoration in Tianjin" (integrated within Zhangjiawo New Town project); and "one industrial regeneration project in Changchun" (Dreiseitl 2015). Additionally, there are other municipal water projects relying on water technological engineering to rainwater. For example, since 2000 the German Federal Ministry of Education and Research and the Chinese Ministry of Science and Technology have initiated a program, named "Research and demonstration of stormwater management and technological application in Beijing Urban area" (Bai 2005; Yu et al. 2006a) (see case study section 4.6.1). Through assistance of this program, a series of exemplary projects, such as Guyue Community and Shuangzi Community (see case study section 4.6.3 and 4.6.4), were built, aiming to display the advantages of the technological infrastructure of the stormwater management (Zhang and Ding 2003). This section reviewed stormwater management in Western Cities and China from historical perspective and also gave separately a specific view on the modern practices of stormwater management system in China. Based on the above mentioned description, the historical stormwater management addresses mainly two issues, water supply and flood runoff for the two regions. And due to the deterioration of urban environment, urban managers also have to consider how municipal sanitary can be achieved through urban sewer lines. With the development of technology and science, the interdisciplinary cooperation and interaction has improved on the stormwater management system which can have more perspectives and alternatives.

2.2 Research review of open space quality

There is no doubt that open space research on China has grown quickly over the past two decades for various reasons, for example because of climate change, urban ecological degradation, and the decreasing quality of life (Ebi and Burton 2008; Maruani and Amit 2007; Xie et al. 2012). The range of research has also expanded hugely into various fields, for example urban open space, agricultural land, suburban areas, and villages, etc. (Brander and Koetse 2011; Cho et al. 2008); and by fulfilling the requirements of interdisciplinary cooperation, multi-dimensional perspectives of open space systems have also been established, including the regional, urban and site scales (Maruani and Amit 2007). So, from the enormous amount of research it is rather difficult to extract several suitable preferences regarding open space quality in order to assess open space systems in this research. It is obvious that the functions of a stormwater management system can influence aspects of open space quality to a certain degree, and is also clear that urban open space systems provide a fairly broad number of functions, stormwater management being just one of these. Cooperating with stormwater management can produce a sustainable stormwater management system and livable space, both of which Chinese urban inhabitants require. Therefore, this research concentrates mainly on the interrelationship between stormwater management system and open space quality. On the basis of the case investigations and a broad research review, this research has chosen two main aspects of open space quality to be used as research objects, namely public infrastructure and nature pleasure. There is a particular reason for selecting these two, as stated in section 1.1. These two issues are important challenges in China in connection with the decrease in open space quality (see section 1.1.2).

- **Public infrastructure**

Three aspects of public infrastructure in the open space assessment are often discussed in the published research, including convenience, maintenance, and aesthetic value (City of Zube and Moore 2013). It can be seen that the outstanding sharing, accessibility and accommodation of public infrastructure encourage people to use and increase the attractiveness of the urban environment, and thus perform a high convenience. The published research argues that a high quality of convenience needs to employ several strategies, including encouraging the sharing of infrastructure(City of Stirling 2008) and having an access to the accommodative recreational infrastructure in an urban area (Seeland and Nicolè 2006). Because of the permanency of public infrastructure, the diversity and distribution are also important preferences in order to increase recreational experiences (Airola and Wilson 1982; Crawford et al. 2008). Additionally, there is a consensus that a successful maintenance, which can improve landscape attractiveness and the assessment and implementation of maintenance (Zube and Moore 2013), is necessary to be achieved in the view of urban managers (Council 2010; Mohammed 2006; Schabel and Dwyer 1985). By these reasons, the assessment of maintenance quality does not only involve with public infrastructure, but also cover whole landscape components, such as, plants, vegetation and other components (Mohammed 2006). The recreational value as main function of the public infrastructure is also discussed (Schabel and Dwyer 1985). Based on landscape preferences, the investigation and design description on the public infrastructure of Chinese projects are also undertaken according to the three aspects, namely convenience, maintenance and aesthetic value.

- **Nature pleasure**

Natural elements in the urban open space can stimulate landscape users' interest, imagination and exploration (Moore and Lackney 1993). Clare Cooper Marcus argues that the increase of sensory stimulation in the urban environment can be directly contributed by natural elements, and believes that the choice and design of plants could change people's perception on landscape design and urban environment (Marcus and Francis 1997: p.281). Due to the flexibility and versatility of the urban environment, the diversity, patterns, species, and colors of natural elements are discussed in the landscape assessment of this present research, and can greatly influence the landscape aesthetics and human perception (Hendriks et al. 2000). For example, Rachel Kaplan and Stephen Kaplan propose that plant diversity without clear patterns or rules could bring an extreme complexity of landscape experience. However, if there is a mutual relationship between diversity and patterns in plant design, a landscape coherence can be produced (Kaplan et al. 1989). Additionally, because the contrast of colors and shape can produce a great visual stimulation, it is important to balance between the contrast and complexity in open space systems (Litton 1968; Magill and Litton 1986). Therefore, Arthur W. Magill also states "[Plant] color is one of the 'dominance elements'---form, line, and texture are the others--which express forcefulness in landscape analysis" (Magill and Litton 1986: p.46). Following these arguments, the subsequent research started to concentrate on the color contrast between landscape components (such as building and public infrastructure) and the surrounding environment (Bishop 1997). The assessments about nature pleasure in the related research provide inspirations for constructing case study in this research, for example, the analysis of the Zhangjiawo Community emphasized on the color contrast between building style and green plant systems.

As far as accessibility, it is often mentioned in the open space assessment to combine other factors for discussing landscape quality, such as convenience (Airola and Wilson 1982; Stirling 2008; Zube and Moore 2013). In specific, the accessibility is a significant aspect, because an outstanding accessibility of public infrastructure encourages people to use and increase the attractiveness of the urban environment, and thus perform a high convenience. The published research argues that a high quality of convenience needs to employ several strategies, including encouraging the sharing of infrastructure (Stirling 2008) and having an access to the accommodative recreational infrastructure in an urban area (Seeland and Nicolè 2006). Because of the permanency of public infrastructure, a high accessibility to reach public facilities is considered as an important aspect for increasing open space quality (Airola and Wilson 1982; Crawford et al. 2008).

2.3 Research review of landscape perception

This section reviews the research background and theoretical basis of landscape perception. Because the scientific knowledge about landscape perception begins from ancient philosophical debates on the relationship between beauty, aesthetics and knowledge, the discoveries of the Greece era and philosophers' discoveries are introduced as an important motivation for modern related research. Subsequently, the differences and similarity of landscape perception between the West and China are also referred from different perspectives in order to discuss challenges and possibilities of investigation on German projects. Additionally, since the philosophical debates cannot offer scientific methods and tools for the research on landscape perception, cognitive science started to receive more attention and developed since the 1970s. Through the review of historical development of cognitive science, six theories and hypotheses are introduced because they significantly inspire the assessment of landscape perception.

2.3.1 Research background of landscape perception

The definition of the term "perception" in the Oxford English dictionary (2014) has two aspects: the first is that people have an ability to see, hear, or become aware of something through the senses; the second is the way in which something is regarded, understood, or interpreted. This explanation reveals the high potential that an attractive landscape has to inspire a visitor's perception and to influence their awareness and behaviour through the stimulation of their senses. The ability to perceive the surrounding environment is extremely necessary for living organisms striving for survival on this planet, particularly for human species (Slovic 1987). Human perception has been recognized as an innate inherited capability since ancient times. In particular, the question of how the accumulated sensory experience affects human cognitive activity has broadly been discussed on the basis of a certain understanding of the natural environment. For this reason, a series of ontological questions were proposed in the times of ancient Greece, which greatly influenced the development of modern philosophy, including the research of landscape perception.

2.3.1.1 Philosophical discussion of perception

One of the main focuses of modern philosophers is the relationship between “thinking and being” (Silverman 1977). This research argues that the “turning point of modern philosophy” represents a human natural instinct which pursues the balance of the psychological inner and physical outer world (Long 1982: P.310). Regarded as an integration of natural elements, art, cultural heritage and social development, landscape design is ineluctably interwoven within this psychological field. Landscape design becomes an extension of human inspiration which is characterised by two distinct natures: one is an inner psychological nature, and the other is an outer physical nature. This perspective suggests that landscape assessment establishes a strong correlation between these two natures through convincible methods and tools. The philosophical work on perception in the Greek era is treated as a starting point in metaphysically and scientifically bridging between these two natures.

The philosophical theories on perception prevailing during that period in Greece focused on how to understand the environment to gain “true knowledge”. For instance, Plato accepted Socrates’ perspective in which knowledge is a process and result of recollection rather than pure learning, observing and studying (Cary and Burges 1859; Hubler 2007), and also concluded that knowledge comes universally from the objective (Hubler 2007). Additionally Plato introduced the “four levels of knowledge” in his book, named *The Republic*, and divided cognitive activity into two types: visibility and intelligibility (Cross and Woozley 1966). Each type is again divided into two types. Visibility is composed of representation and opinion, whereas intelligibility is made up of reasoning and “knowledge” which is defined as the understanding of ideas by the means of the Socratic Method (Barry 2013). Theatetus refuted the view of Socrates on cognitive activity, and claimed that knowledge is nothing but perception (Fine 2003; Modrak 1981). In brief, a consensus has been reached since ancient Greek times that perception inspired by the various visible aspects of nature greatly influences human being’s intelligence and their understanding of this world.

The study of the interaction between perception and the environment was continued by many later philosophers. Their research inspired the establishment and development of subsequent related disciplines, such as social, cognitive and environmental science and philosophy. For example, Gottfried Wilhelm Leibniz, in the early 17th century, believed that people can receive “small perceptions” without awareness. His theory influenced the research of Ernst Platner who coined the term of “Unbewußtseyn” (unconsciousness) (Nicholls and Liebscher 2010). Current research on unconsciousness is starting to combine with the research on landscape perception (Nassauer 1995), for example, the relationship between the environment and human behaviours in Gibson's Theory (see section 2.3.3.3). Subsequent philosophers have also contributed significantly to the further development of perception from distinctive views between the 17th and 18th centuries. Although they were not able to give persuasive evidence in a scientific way, their debates generated a sustained motivation for the development of subsequent research on landscape perception. This fruitful endeavour has provided a theoretical basis for the human-environment sciences, and has also directly and indirectly influenced the establishment of several theories about landscape perception, which have been adopted in this research, such as the Prospect Refuge Theory, Biophilia Hypothesis, and others referred to in the next section.

2.3.1.2 Chinese classical philosophy about perception

Compared to classical western philosophers who concentrated on perceiving nature and its physical characteristics, ancient eastern philosophers seemed to focus more on perceiving the correlation of elements in an invisible connection through mental activities (Goh and Park 2009). For example, the ancient Greeks proposed five classic elements, including, earth, water, air, fire and aether, which has had a significant influence on the western cultural and philosophical development (Major et al. 2015). The "elements" in ancient Greece were regarded as the smallest units or divisions which form the whole world (Father and Spirit 2015). In comparison, Chinese philosophy and indigenous religions also proposed five elements, named Wuxing, which stem generally from the senses and distillation of human past experience and from perceiving natural phenomena. Wuxing includes wood, fire, earth, metal, and water, which are conceptual and represent universal laws, including mutual generation and mutual conquest. Being a part of the traditional Chinese civilization, they influenced various aspects of society and culture, including human perception of the living environment (Li et al. 2006). Based on this cultural wealth, Kongjian Yu started to concentrate on the Chinese ideal model of living habitats and what environmental setting would be suitable for the Chinese (Yu 1990). He proposed that, since Chinese culture started to develop, various factors forced them to share a common reflection on the environment. These factors include other human species, but also the geographical basin, including edge, enclosure, measure, and corridor factors. These have influenced the development of the Chinese civilization, from the philosophical perspectives, including Wuxing and Fengshui principles (Yu 2010a). Because of these cognitive differences in landscape perception, there is an inevitable question of whether or not the lessons learned and experience gained from German exemplary stormwater management systems can be used in Chinese projects. The upcoming section tries to answer this question with a broader perspective.

2.3.1.3 Transformation of knowledge and experience

This study selected seven German projects from the published research and related reports (Dreiseitl and Grau 2005). The selection condition was that the investigated projects employed sustainable concepts of decentralized rainwater treatment in combination with green infrastructure and public facilities. The investigation into the German cases aimed to provide inspiration for enquiry in the Chinese case study. Therefore, the collected German projects had to fulfil the two following requirements: highly efficient and comprehensive stormwater management principles and a high open space quality.

There are two major questions posed in the investigation, namely if it is possible to compare German and northern Chinese projects in terms of stormwater management system and open space quality, and how the lessons of German projects can be used to facilitate this research. Although there are differences in the understanding of the environment between the West and China as mentioned above, it is assumed in this research that, in terms of these issues, the differences have become less due to the effects of globalization. However, at the same time, it is clear that there are still many significant obstacles in the transfer of knowledge and experience. Therefore, in this research the two issues will be discussed separately. The first issue of differences will be discussed from two points of view, difficulties and possibilities. The second issue is answered on the basis of the discussion of the first issue.

- **Differences of landscape preferences**

There are two different opinions about cross-cultural landscape preferences in current research. One opinion maintains that landscape preferences between investigated cross-cultural groups are distinctly different (Yang and Brown 1992; Zube and Pitt 1981). Based on these studies, it is argued that the challenges in transferring the knowledge and experience have at least three aspects, including climate features, urban environment, and design quality.

First of all, different climate features between Germany and northern China lead to a significant difference of landscape experience. For instance, German monthly precipitation is higher on average than northern Chinese monthly precipitation (Xu et al. 2004). This research argues that this difference of average monthly precipitation has a significant influence on the quality of landscape perception, such as the numbers of plant species, the quality of maintenance and human recreational activities. Secondly, as mentioned above, the whole of China is involved in a quick and comprehensive urbanization, in which the processes of re-distributing social resources are uncertain and intensive due to its complexity and opacity. Compared to the intensive social and urban changes in China, German social development, including urban development, is relatively smooth. As a result of this, human perception of the living environment in Germany can maintain a more steady level than Chinese perception of an uncertain environment. In terms of this research, German cases are built in the context of urban open space systems while the green open space systems within Chinese study cases have rather few relationships with their urban green networks. The related information was introduced in the background of every Chinese case (see case study in Chapter 4). In terms of design quality in China, due to high numbers of visitors and specific public requirements in the area of public open space, related organizations have had to struggle to maintain a high quality of green infrastructure, and designers have had to reduce the numbers of green infrastructures and to enlarge the area of urban squares as well. However, German projects do not have such stresses and challenges. Therefore, because a comprehensive comparison might cause an obvious or potential investigating bias and draw questionable results, such a comparison of landscape perception between Germany and China projects will not be made in this study. The focus here will be placed mainly on Chinese study cases.

- **Comparison and similarity**

The investigation of German cases indeed broadens the perspective of this research and improves the Chinese case studies. Firstly, the investigation of German cases drove this research to have a comprehensive consideration of the influence of natural conditions. An example of this is the investigation on Kronsberg, which is a sustainable neighbourhood in Hannover (Rumming 2004). Before it was built, related hydrogeological research had been undertaken and showed that traditional stormwater management methods could massively influence natural rainwater treatment systems in this region. It was also estimated that the soil in Kronsberg has a low infiltration rate (Kathrin 2006). Therefore, the concept of stormwater management in Kronsberg considers rainwater as an important landscape element (Akinyemi 2009). It adopts a decentralized water system through a network of “soakaways” in order to harvest rainwater and delay release (Kathrin 2006; Pathak 2002). However, although the community has a highly efficient water treatment system, the rainwater within Kronsberg is not collected for building an attractive waterscape. Based on these lessons, this research asks the following question in the Chinese cases: *how can landscape design combine with natural conditions in order to perform a balance between a high efficiency of water treatment and a high quality of open space*. Therefore, in the investigation of every Chinese case, a relationship between hydrological and climate features was achieved and combined within each case study. Secondly, the fact is that the quality and quantity of German stormwater management projects are higher than those of Chinese projects. Therefore, the seven German projects which provide rich and diverse types of water treatment systems for this research have established a high standard for Chinese stormwater management systems, such as the combination with public open spaces and water drainage systems in Scharnhauser Park, the connection between waterscapes and trench systems in Arkadien Winnenden, the combination of intensive plant groups and the building of rainwater treatment systems in the Arkadien Housing Estate, the drainage networks along the roads in Kronsberg. In brief, this research combines the experience of the investigation of German projects with Chinese case studies with the expectation that this study will support research on other Chinese related projects.

2.3.2 Research about perception in Modern Times

Previous philosophical ideas referring to perception have contributed to the rise of modern environmental science. Environmental science provides related theories and hypotheses for the research of landscape perception and part of them has been adopted in this research. However, before the adopted theories in this research are introduced, it is necessary to review this relationship with respect to cognitive science.

First of all, the research on landscape perception has benefited indirectly and directly from "cognitive science", which was coined by Christopher Longuet-Higgins in 1973 (Hünefeldt and Brunetti 2004; Longuet-Higgins 1987). The development of cognitive science in the twentieth century cannot only provide the necessary scientific tools, but can also start to combine the art, science and philosophy. This combination creates a new theoretical alternative to the relationship between human beings and the environment at this beginning stage of research into landscape perception. Similarly, the research of landscape perception has also been significantly influenced by environmental psychology, coined by Will H. Ittelson in 1964 (Halpern and Voĭskunskiĭ 1997; Ittelson 1964). Environmental psychology focuses mainly on the relationship between environmental components and human action (Canter and Craik 1981; Halpern and Voĭskunskiĭ 1997; McSpadden 1999). It started to develop through interdisciplinary research in the middle of the 20th century, such as the research of geography and sociology in relation to the evaluation of environmental conditions on democracy politics (Langdon 1966; Lowenthal 1967). Due to the more attention on this relationship, and also due to the changes of social structure, the urban renewal movement in the late 19th century, landscape architects', planners' and architectures' knowledge and roles were challenged by unfamiliar spatial dimensions and different physical environments compared to the traditional design scale when their design focus shifted from gardens to urban areas (Langdon 1966). Because of the consequences of this shift for cultural heritage, environmental pollution and increasing energy demands, the relationship between the natural environment and human beings has received increasingly more attention (Haney and Knowles 1978; Holdren and Ehrlich 1974; Turk 1972), and has stimulated research into environmental perception. It should be mentioned that the research scale of landscape perception is narrower than the research scale of environmental perception, but the preferences and cultural information contained in the landscape environment are more complicated and dynamic than interior environment and rural environments (Kaymaz 2012). Environmental perception is generally defined as "a cognitive structure of the reality" (Pocock 1972: p.115), which means that people possess an ability to explore, understand, receive and reserve information from the surrounding environment (A Dictionary of Geography 2004). The results of this research have been applied in broad fields (Gärling and Golledge 1989; Lowenthal 1972; Parsons 1991), including urban planning and landscape architecture (Lapka et al. 2008; Rishbeth 2001), interior environments (Suresh et al. 2006; Yildirim et al. 2007), geographical science (Aitken et al. 1989; Zhou et al. 2003), human health and cognitive science (Maller et al. 2008; Parsons 1991). Due to these broad applications and the in-depth research, several related theories and hypotheses have been proposed, and in part collected in order to contribute to the theoretical basis of this research.

2.3.3 Adopted theories about landscape perception

This research focuses on landscape perception, based on related research on landscape architecture and planning (Lynch 1960; Soini 2001). Several theories and hypotheses of perception in previous research which developed in modern times have been chosen as the theoretical basis of this research. They derive from modern advanced technical tools and from past psychological experience and are dramatically expanding the research range of landscape assessment.

2.3.3.1 Prospect Refuge Theory

This theory was proposed in 1975 in the book named *the Experience of Landscape* by the English geographer Jay Appleton. In this book, Jay Appleton argues that human beings' perception of art (including landscape design) and animals' reaction to the environment are "an acquired preference for particular methods of satisfying inborn desires" (Appleton 1975: p. 237). As Jay Appleton argues in another book, *The Poetry of Habitat*, the satisfaction from aesthetics which can be generated by a human habitat is actually an inherited biological requirement of human beings, and this requirement has been developed by our evolutionary experience (Clamp and Powell 1982; Ruddell and Hammitt 1987). He continues to indicate that long-term evolutionary processes have caused a psychological orientation in human beings which spontaneously generates pleasure and satisfaction from perceiving the surrounding landscape (Appleton 1978). Human beings and other animal species have a common biological requirement to understand their surrounding environment in order to gain prospects (opportunities) and safety (refuge) (Verderber 2009). In terms of landscape design, this theory predicts which characteristics of open space systems can be appreciated by human beings and be attractive for other animal species. These main characteristics include high places with broad and unobstructed views, several specific places for refuge, water elements, and intensive plant growth and the presence of few dangerous species (Verderber 2009). Furthermore, some more specific preferences regarding the general rules for choosing refuge sites are also proposed, for instance, selecting a position on the edge of a place, where living species are protected from the rear (Ruddell and Hammitt 1987), or finding places which shelter human beings and animals from being attacked by dangerous animals and human beings (Appleton 1975; Tveit 2009). In fact, although there are no decisive scientific conclusions which can prove this theory in the discipline of human aesthetics, Prospect Refuge Theory still has a significant influence on the study of environmental psychology (Kaplan and Kaplan 1989), and also enriches the practices of landscape design, as can be seen in the gardens of the Bloedel Reserve on Bainbridge Island in Puget Sound, designed by Richard Haag (Hudson 1993). In this case, designer established a series of sculptural things to express the constancy of specific concepts, including Prospect Refuge Theory. In addition, the designer prefers to stimulate public to “read” these gardens by their own eyes. Richard Haag believes and want to present in this garden that Prospect Refuge Theory is the one of many concepts which human beings share to respond our circumstance (Saunders et al. 1998: p.50-52). This theory is also broadly applied within the study of landscape preferences, because the key words of this theory, namely “prospect” and “refuge”, can be assessed through the observers’ feelings (Kaymaz 2012), as shown by the analysis of landscape preferences in urban landscapes (de la Fuente de Val et al. 2006; DeLucio and Múgica 1994) and individual perceptions of landscape scenery (Gimblett et al. 1985).

As Don Luymes and Ken Tamminga indicate in their study, “Prospect Refuge Theory provides a theoretical framework for understanding the human ecological dimensions of environmental design” (Luymes and Tamminga 1995: p.391). This present research argues that landscape designers need such an “understanding” of the preferences of landscape users, because the users also have strong requirements to understand their surrounding urban environment. The mentioned understandings of landscape architect and users about their circumstance are significant, especially for the present research, because this theory supports the idea that the aesthetic value of open space system, produced by a specific landscape structure (predictable and understandable), should be considered as a precondition of a high quality of landscape perception.

2.3.3.2 Biophilia Hypothesis

The Biophilia Hypothesis indicates that human beings have to explore and understand their living environment. Edward O. Wilson, in his book *Biophilia*, suggests that the a consequence of bio-evolution brings an “innate tendency to focus on life and lifelike processes” for human beings (Gullone 2000: p.293). Wilson defined *Biophila* as a force that pushes humans to affiliate with others life forms (Kellert 1995), and wrote that “In short, the brain evolved in a biocentric world, not a machine regulated world. It would be therefore quite extraordinary to find that all learning rules related to that world have been erased in a few thousand years, even in the tiny minority of people who have existed for more than one or two generations in wholly urban environments.” (Wilson 2007: p.250). In recent years, relevant studies on landscape architecture and planning have already incorporated this hypothesis, for example, the influence of visual impact on human psychological and physiological changes (Grinde and Patil 2009; Hartig et al. 2011). Based on this theory, it is understood that there is an instinctive motivation to stimulate human beings to notice, observe and understand their surrounding environment.

2.3.3.3 Theory of Affordances

According to Gibson's Theory interaction allows people to understand the function of their surrounding environment through the accumulation of collective memories. James Jerome Gibson argues that this theory contributes to the study of visual perception within various fields, including cognitive science (Garbarini and Adenzato 2004), human-computer interaction (Bickhard 2001), interaction design (Hartson 2003), and perceptual psychology (Reed 1986; Shaw and Bransford 1977). The term "affordance", coined by Gibson himself, means "the complementarity of the animal and the environment" (Gibson 1977: p.56). This theory states that features of an environment are perceived by animals and offer them the chance to interact with these, and that affordance is not a property of an environment, but rather one of an animal's capability (Chemero 2003; Maier and Fadel 2003). Adapting different ecological approaches, this theory links with other theories on the visual perception of landscape architecture, for instance, landscape assessment and the description of children's playgrounds (Fjørtoft and Sageie 2000; Heft 1988), the methodology and concept of landscape ecology (Farina 2006), landscape aesthetics and human behaviour (Heft 2010; Kaplan 1988). Although the function of stormwater management is often covered under the aesthetic value of open space systems and is hardly noticed by people, the research above shows that the function of stormwater management can still be understood by people through explicit structures and visible components.

2.3.3.4 Gestalt Effect

Gestalt Effect which continues to develop the Theory of Affordances was established by German psychologists, Kurt Koffka, Max Wertheimer and Wolfgang Köhler in 1910 (King and Wertheimer 2005; Wertheimer 1938). The term "Gestalt", from the German word "*die Gestalt*", contains two meanings, namely "form" and "shape" (Perls et al. 1951). The Gestalt Effect is the capacity of human perception on the whole form of a substance, rather than its components. Although its achievements are rarely related to the design field (Behrens 1998), this theory has a great influence on modern art and building design, particularly on landscape design and planning, such as the interpretation of aerial photography in landscape ecology (Antrop and Van Eetvelde 2000); critical views on the landscape assessment (Bowden 1984; Carlson 1993); improvements of human attracted perception on the forest landscape (Gobster 2001); research on the digitally conducted design experiments in transitional landscapes (Kamvasinou 2006); combinations of landscape elements for visual quality (Nassauer 1980); auditory settings in landscape design and planning (Hedfors and Berg 2003). The theory suggests that the combination of components can stimulate more intensive landscape perception than individual components do, and therefore project descriptions in this research emphasize the influence of the whole landscape systems on inhabitants' landscape perception, rather than focusing only on individual landscape elements.

2.3.3.5 Collative-Motivation Model

The Collative-motivation model and Information Processing Theory (see section 2.3.3.6) concentrate on the processes of perception with specific preferences. David E. Berlyne established the Collative-motivation model in the 1970s and states that the characteristics of a dynamic environment, such as unfamiliarity, complication, unpredictability and incompatibility, can be regarded as a process of discovering action and information conveyance (Kaymaz 2012; Konečni 1978). Wohlwill proposes two concepts that support this model: 1) the arousal potential, which relates to nervous systems and has three sources, namely psychophysical properties, ecological stimulus, and collative factor; 2) the hedonic response linked to the human experience and the outcome of two separated parts, reward and average systems (Wohlwill 1976). An inverted U-shape drawn by Berlyne showed that the medium degree of arousal potential can occur at the point of highest reward value, and can receive an increasing average value when it is far away from the medium degree (Partridge and Rowe 1994). These concepts of the model are introduced and developed within the field of landscape theory, for instance, the relationship between visual landscape and emotional well-being (Ulrich 1979), the analysis of urban design aesthetics and natural landscape (Nasar 1987b, 1994; Ulrich 1983), assessment of traffic safety and landscape (Mok et al. 2006; Nasar 1987a), or the study of environmental aesthetics (Ataov 1998; Nasar 1992). The design of questionnaires and project investigations are ideologically inspired from this theory, such as the question orders about the visible function in questionnaires.

2.3.3.6 Information Processing Theory

This theory initiated by S. Kaplan and R. Kaplan is a significant evolutionary method closely connected with landscape preference and human well-being (Maulan et al. 2006; Zube et al. 1982). This theory states that the information we gain from our experience of the environment and life becomes a vital part of our memory and inspires our development of the world. Aiming to grasp more, people have to understand and continually explore their surrounding environment, and pay more attention to organizing and maintaining the information received from the understandable environment, and they should also be willing to share and exchange this information (Kaplan et al. 1998). As "information hungry creatures", people prefer to make sense of the environment in the pursuit of safety, and therefore the capability of understanding the surrounding environment is significant for human species survival on this planet (Maulan et al. 2006). Regarded as a stimulus, landscape can directly and indirectly influence human beings' emotions and feelings (Kaplan and Kaplan 1989), such as aesthetics which is a reflection in the human brain of reality (Kaplan 1988). Assuming that environmental preferences can be measured and evaluated in order for people to better receive information from an environment (Kaplan 1975), this theory suggests that a reasonable spatial organization and moderate amount of information contained within a particular environment (such as appropriate landscape diversity and observation), can convey positive feelings and attractive information for observers (Kaplan et al. 1998). In Kaplan's theory, four vital preferences are built on the basis of the results of numerous case studies: coherence, relating to order and organization is achieved through repeating a theme, similar texture, and appropriate contrast; complexity, referring to the diversity of a system, encourages an exploration; legibility, concerning a cognitive map and the distinctiveness of a system, can be achieved through landmarks, focal points, spaciousness, and recognizable textures, etc. Examples of related case studies include those of Appleyard (1976) and Lynch (1960), who focused on the urban legibility (Gärling and Golledge 1989); mystery, inspiring exploration as well as complexity, which encourages people to gain more information through exploration of the system, particularly from landscape (Kaplan et al. 1998; Kaplan 1975; Schauman 1988; Stamps III 2004). A body of the research was achieved, such as adapting multi-dimensional scaling (MDS) to evaluate one of the landscape preferences that is mystery (Gimblett et al. 1985), and improving the landscape assessment in rural landscapes through computer technology (Lynch and Gimblett 1992). Additionally, the coherence and complexity of a landscape can be quickly understood through a two-dimension picture, whereas the legibility and mystery need to be understood long-term, generally in an unconscious way, through three-dimensions (Herzog and Bryce 2007; Kaplan et al. 1998). With regard to landscape architecture, this was developed and transformed into subsequent research areas, such as the landscape assessment of rural landscapes (Brown and Itami 1982), connecting between landscape assessment and management technology in the visual landscape (Brown et al. 1986), describing frameworks and models about the hiker behavior in the forest reaction (Deadman and Gimblett 1994), analyzing visual resources (Herbert 1981), etc. (Lynch and Gimblett 1992; Tveit et al. 2006; Wright et al. 1984). These research areas introduce and transform coherence and legibility in the assessment of open space perception, while complexity and mystery are not treated as main preferences. The main reason is that coherence and legibility can be directly interpreted and measured with respect to landscape assessment through methods of social investigation. Complexity and mystery are more difficult to measure and clarify in comparison. Apart from this reason, this present research proposes that in terms of stormwater management concept legibility and coherence are more fundamental conditions to keep high efficient functions and low economic cost. This research introduce coherence and legibility to evaluate landscape perception, because the essence of coherence relating with order and organization of landscape infrastructure components is inextricably bound with the functional system of the landscape, whereas the legibility regarding to context of landscape (point, line and dimension) has a strong connection with the visual quality of individual landscape components.

2.4 Assessment of stormwater management in study cases

2.4.1 Water management system

This research concentrates largely on how visible functions of stormwater management systems influence on landscape value. Although stormwater management has lately been defined as belonging to landscape architecture (Hoyer et al. 2011), current water treatment methodologies fail to propose an explicit way of transforming engineering systems in order to create a landscape that the observer can appreciate, and also fail to recognize the intrinsic connection between stormwater management system and urban landscape contexts. More recently, Kelly Shannon and Bruno De Meulder have argued that one's perspective on stormwater management system should be broader and can be advanced by more interdisciplinary cooperation (Shannon and Meulder 2013). In their book, *Water Urbanisms 2*, they claim that stormwater management should be discussed in an urban context, taking history, culture and time scale into account (p.4-9). However, the book contains few discussions about specific strategies and detail towards site design. The present research aims to explore more possibilities for developing a broad, integrated view.

Based on Gibson's Theory, landscape function can be understood by people due to the innate human capability given by biological evolution. The explanation of the Information Processing Theory shows that people can understand, receive, preserve and share the features of a particular environment through the arrangement of landscape settings (Kaplan et al. 1998).

The research discussed above proposes that there are indirect or direct relationships between understanding functions of landscape system and patterns of green infrastructure components. In this research the assessment of stormwater management system is performed from two aspects: green infrastructure, artificial water facilities (Table 4).

Table 4: Assessment of stormwater management system in this research

Components	Categories	Evaluated aspects	Goals
stormwater management system	Green infrastructure	Natural water body Plant system	Description and conclusion
	Artificial water facilities	Terrain change Conveyance systems on the ground Water storage infrastructure Technological engineering	

The assessment of green infrastructure concentres on the influence of natural water bodies and plant systems on the whole water treatment system. The assessment of artificial water facilities involves four aspects: change in terrain height, conveyance systems on the ground, water storage infrastructure and technological engineering. The four categories are often found in the projects as effective methods to restore the ability of local stormwater management system, such as changing terrain height is to collect rainwater in a natural way; conveyance systems are often built to concentrate rainwater into water storage infrastructure; simple or complex technological engineering systems are often established as well for fulfilling public requirements when green infrastructure components cannot work. This research proposes that most landscapes were modified by these four aspects in order to establish a more efficient water treatment system. This assessment of stormwater management system does not only concentrate on the stormwater management system of landscape projects, but also on the influence of their modification of ecological sustainability and open space quality.

2.4.2 Open space quality

Stuart Echols and Eliza Pennypacker emphasise "education", which they regard as one of the functions of a stormwater management system (Echols and Pennypacker 2008). The meaning of "education" has three aspects: the "ideal to learn" relates to the designer's artistic narrative embedded in the landscape; "ways to learn" refers to signage and recreational facilities, and "context to learn" concentrates on three aspects: visibility, gathering and interactivity of stormwater management components. The conclusions of their study have provided the present research with plenty of inspiration, while there are still significant differences in approach. First, this research has a much less discussion about the relationship between function, aesthetics, and education; second, the authors consider signage as a means of "educating people", while the present research does not; third, the importance of the five functions of stormwater management, namely education, recreation, safety, public relations, and aesthetic richness are treated equally in their research. However, the present study propose that a successful stormwater management system and open space quality are the main preconditions for an outstanding landscape perception, which in turn can contribute to a high quality of public relations and education. Therefore, a distinctive logical relationship has been established between stormwater management system, open space quality and landscape perception. Similarly, the research had not paid any attention to the question of signage. Additionally, other research also discusses how stormwater management systems can influence a user's emotions and behaviour. For example, the projects designed by Herbert Dreiseitl as well as his research have inspired the present research to explore the role of open space quality in stormwater management systems. He proposes that the combination of function and landscape value are necessary to produce a harmonious atmosphere that allows citizens to reflect on the value of water resources (Dreiseitl 2013: p.74).

Table 5: Assessment of open space quality

Components	Categories	Evaluated aspects	Goals
Open space quality	Public infrastructure	Usage of spaces; Maintenance condition; Aesthetic value	Description and conclusion
	Nature pleasure	Area, diversity and colour of plant systems; Dimension and dynamic of waterscape	
	Accessibility	Boundary and walking environment	

As mentioned above in the review of open space quality, the open space quality of the six case studies has been assessed from three categories, namely public infrastructure, nature pleasure and accessibility. These aspects have further been detailed in Table 5. First, the categories, aesthetic value, maintenance condition and the usage of spaces are also involved in the evaluation of public infrastructure. This research argues that if various public infrastructure components have a high aesthetic value, keep a well maintenance condition and have a high usage rate, they can then contribute to a higher open space quality and can stimulate more landscape perception. Nature pleasure focuses on two aspects, namely plants and water bodies which are of essential visual value in an open space system. Additionally, the accentuation in the assessment of open space quality is another important parameter, like explicitness in the assessment of stormwater management system. The landscape features of stormwater management should be accentuated in order to increase the attractiveness of open space and, at the same time, to receive the notice and appreciation of human beings.

In addition, the accessibility means that the designer should provide a convenient way for landscape users to access components of stormwater management in order to observe the process of water treatment. The concept of stormwater management with such high accessibility should remove the unnecessary boundaries and obstacles surrounding the infrastructure components of stormwater management systems, and stimulate more people to observe the landscape systems. Therefore, the accessibility can be treated as one of preconditions of achieving legibility. Additionally, the way to access the water treatment system mainly relies on walking. Related published research regards walking as an efficient way to stimulate more landscape perception because it can connect between the physical environment and psychological cognitive processes through sighting, measuring, reading, and merging (Jacks 2004). As Jams Hillman wrote “As we walk, we are in the world, finding ourselves in a particular space and turning that space by walking within it into a place, a dwelling or territory, a local habitation with a name” (Hillman et al. 1980: p.3), Therefore, aiming to examine the quality of legibility, the consideration with respect to “accessibility” is also added in the landscape evaluation of the case studies as Table 5 shows.

2.4.3 Landscape perception

This dissertation argues that there is a relationship between landscape perceptions, open space quality and stormwater management system on both a theoretical and practical level (see section

1.2). A high landscape perception of stormwater management systems should be based on two foundations, stormwater management system and open space quality. First, Herbert Dreiseitl indicated that a high open space quality of stormwater management systems can bring more attractiveness. It can also inspire a better understanding about the value of water resources (Dreiseitl 2013: p.74). The public perception can be stimulated by a high open space quality promoted by the function of visible components. Second, the stormwater management system actually involves cultural, social, recreational, and ecological values.

- **Coherence and legibility**

Additionally, there are two key words which have been implied in the theoretical background, namely coherence and legibility (Table 6). S. Kaplan and R. Kaplan in the 1930s proposed four aspects of landscape preferences, namely complexity, legibility, coherence, and mystery (Kaplan et al. 1998). Based on the explanation about coherence and legibility in the Information Processing Theory (see section 2.3.3.6), this research argues that the two aspects have an intimate relation with stormwater management system and open space quality.

Table 6: Assessment of landscape perception

Component	Parameter	Aspects	Goals
Landscape perception	Coherence	Stormwater management system	Explicit structures
	Legibility	Open space quality	Accentuated set of landscape elements; high accessibility

Kaplan believes that coherence is related to an objective explicit structure with order and rhythm achieved by the set of landscape elements. In terms of open space quality, the order and rhythm of visible components of the stormwater management system can have an influence, and in the view of landscape perception the stormwater management system with visible function is the precondition of a high landscape perception. As coherence is considered as an important parameter in the assessment of landscape perception, it will be discussed and evaluated in all six cases. According to Kaplan’s theory, legibility is about a subjectively understandable context with wisely accentuated landscape elements. Promoted by the explicit structure of stormwater management systems, the accentuated open space quality can produce an attractive landscape and stimulate more landscape perception. Similarly, the legibility is also evaluated in every case.

2.5 Conclusion

This chapter reviewed the theoretical development of stormwater management system, open space quality and landscape perception. The review details the development processes of stormwater management in the West and China, and discusses their connection and cooperation. In terms of open space quality, according to the problem statement, the following three landscape preferences were considered, namely public infrastructure and nature pleasure. The theoretical review of landscape perception is based on philosophical achievements since ancient Greek times and later philosophical developments on perception. The attitude of Chinese traditional culture on perception was also referred to in order to explore the differences in understanding the concept of perception between the West and China. This research also expanded on a broader perspective of this issue to discuss the challenges associated with transmitting the knowledge of stormwater management in Germany to China. Six theories and hypothesises related to cognitive science were chosen and introduced in this research, which provide a theoretical basis for the assessment of stormwater management.

Chapter 3 Research Methodologies

3.1 Constructing the theoretical basis

The research questions basically have two goals, firstly that of evaluating the northern Chinese projects and secondly that of proposing recommendations that can broaden the perspectives of social groups tackling the current challenges and produce new visions for the future (see section 1.2). In order to reach the second goal, the first one has to be obtained by undertaking specific empirical research revolving around the Chinese cases in question. Performing the landscape assessment and data analysis also requires theoretical support. Certainly, an important precondition of empirical research is that it can be conducted logically, supported by reviewing past theoretical achievement. The review in this research indicates that stormwater management systems that maintain a stable stormwater management system and produce high open space quality can gradually influence a landscape observer's perception, and thus change their attitudes towards urban rainwater issues within a landscape context (see section 1.3). The theory review also took into account insights into the challenges identified earlier in order to select landscape preferences for each of the three components –stormwater management system, open space quality and landscape perception –and to explore the influence of the three on each other (see section 2.4). Thus, the theoretical basis is constructed according to the roles of the three components in this research by establishing a series of landscape parameters and providing theoretical support for interpreting the relationship of the three components to each other.

- **Stormwater management system:**

Chapter 2 mentioned that in the reality of stormwater management system in China generally results from two aspects, namely green infrastructure and low-quality artificial water facilities. The biophilia hypothesis and theory of affordances indicate the theoretical relationship between the functions and scenes of a landscape system. Therefore, this research has chosen the landscape preferences mentioned above on account of their close relationship to stormwater management system and then used them in each of the project descriptions, reflecting the current challenges and theories.

- **Open space quality:**

to prove the influence of open space quality on how a landscape is perceived, the current study has also taken note of the prospect refuge theory, which indicates that the high aesthetic value of stormwater management systems is a precondition for realizing a high level of landscape perception (Ruddell and Hammitt 1987). As mentioned in Chapter 2, three aspects of open space quality, namely public infrastructure, nature pleasure and accessibility, were selected for analysing their roles and influence on landscape perception in each case.

- **Landscape perception:**

The above discussion about the relationship between stormwater management system and open space quality has to be pursued further. To answer the research questions two more steps are necessary with regard to the theoretical basis: choosing preferences used in evaluating landscape perception and building up an investigation method.

1) Preferences used in evaluating landscape perception: In this present research, the coherence and legibility in the information processing theory are introduced. The discussion about coherence in each project concentrates more on the assessment of the whole functional system of stormwater management from a broad perspective; and the legibility focuses here on the assessment of open space quality in terms of scenic impressions. Coherence explores the relationship between stormwater management system and open space quality. Legibility focuses on how the scenic landscape as a water treatment system's image exerts its influence on landscape perception. Additionally, because the relationship between element and system needs to be interpreted, this research considers the arguments of gestalt theory, in other words how the public is capable of recognizing the uniqueness of a landscape. Going a step further, this recognition can assist people in understanding a landscape system's coherence with regard to the stormwater management system (see section 2.3.3.4).

2) Methodology of investigation: This present study inspired by other published research chose empirical methodology containing both quantitative and qualitative methods to deal with the research questions, which are introduced in following sections.

3.2 Case study analysis

This research chose and investigated seven German projects by way of expert-based project descriptions. Because there are huge differences between German and Chinese society, culture and urban environment, this research does not directly compare German and Chinese projects, but rather takes advantage of the experience and knowledge gained from the investigation of German projects to benefit and improve the analysis of the Chinese cases. In the Chinese study cases, the investigation employed empirical methodology, combining qualitative (expert-based project description provided by direct observation) and quantitative methods (questionnaires with polar questions). Because of the importance of case study for this research, this empirical methodology is emphasized and its detailed information is explained in the following sections.

3.2.1 Choosing cases in China

The investigation of seven German projects has contributed to the Chinese case study by providing a broad perspective and a background of experience for the Chinese case study (see section 2.3.1.3). This perspective contributed to the selection of the Chinese cases. These have a good reputation and as a whole represent the typical characteristics of stormwater management systems in northern China. Six typical projects in northern China were selected (Table 7). More detail information will be illustrated and explained in Chapter 4.1.

It should be mentioned that the Zhangjiawo Communities and Tianjin Cultural Park were designed by a German landscape architecture office, Atelier Dreiseitl. These projects concentrated on creating a landscape with a high aesthetic value and eco-friendly features, to 'transform a dynamic and fluid water element into a positive and beautiful landscape through using intelligent and aesthetic ways' (Dreiseitl 2013). Qunli National Wetland Park, which was designed by Turenscape, a China-based company, received the international ASLA award in 2012. Its concepts and principles are discussed fully in the case study. The rest of the northern Chinese projects such as Guyue and Shuangzi Communities are also intensively covered (Kang and Zhai 2014) .

Table 7: Significance of stormwater management projects in the selected projects

Name	Location	Project significance
Qunli Wetland Park	Harbin	One of the 37 natural wetland parks in China; 2012 ASLA Professional Award; the First Urban Flood Park in China
Zhangjiawo Communities	Tianjin	One of the most successful community projects in China, employing the concept of water-sensitive design
Tianjin Cultural Park	Tianjin	One of the most important public spaces in Tianjin and located next to landmark buildings.
Yongyou Software Park	Beijing	The largest industrial complex in Asia; one of the most successful rainwater harvesting systems in China
Guyue Community	Beijing	An exemplary project for rainwater harvesting in Beijing
Shuangzi Community	Beijing	See Guyue

During the period of investigation in China, the empirical method of questionnaires was employed. Additionally, this research designed a series of customized strategies for the questionnaires, as explained later.

3.2.3 Empirical research

Empirical methodology is defined as "research based on experimentation or observation (evidence)" (Hani 2009), which provides in-depth and broad perspectives and which enable us to observe the structure of our world directly or indirectly using quantitative (experimentation) and qualitative (observation) methods (Cohen 1996; Hughes 2006). The two different methods–experiment and observation–derive from a fundamental question in Greek Philosophy, namely "What is knowledge?" (Steup 2008). Empirical methodology can provide two different ways of gaining knowledge from a dynamic situation, namely comparing the research objects in quantitative or qualitative analysis (Hani 2009). In terms of landscape assessment, quantitative and qualitative data in empirical research can be collected in various ways, including on-site surveys (Brunson 1991) and online surveys (Roth 2006). Quantitative methods involve analysing and evaluating the relationship between humans and the environment using quantitative data collected in various ways, including questionnaires for determining the preferences of members of the public (Sayadi et al. 2009) and extracting data from the existing literature and other sources (Amir and Gidalizon 1990). The research using qualitative methods focuses on establishing non-quantifiable landscape preferences using one or more of three main methods: participant observation (Swaffield and Foster 2000), direct observation (Appleton 1994) and in-depth interview (Scott and Shannon 2007).

The current research employed two different survey methods, namely expert-based project description and public-based questionnaires. Specifically, the expert assessment was achieved qualitatively by case description on the basis of direct observation by the author. Public opinion was assessed quantitatively by undertaking survey questionnaires, as will now be discussed in more detail.

3.2.3.1 Cases study description: project characteristics

This research employed the method of expert's direct observation to achieve project descriptions. Within the context of qualitative methods, direct observation is able to provide a large number of evidence with direct experience for such description, which cannot be given by participant observation (Pauly 2010). The method has different specific ways to collect investigation data for meeting various research backgrounds, such as interviews and on-site investigation (Scott et al. 2009; Sleegers and Brabec 2014; Yu 1995).

It is worth noting that the case study in the current study gains considerable inspiration from the research of Frank Sleegers and Elizabeth Brabec which concentrate on the aesthetical value of linear infiltration systems. They adopt the method of expert-based description, which contains several specific steps, such as choosing landscape parameters from published literature, selecting data formation and types, choosing study cases in German and USA and evaluating chosen parameters in qualitative and quantitative ways. This present research adopts similar strategies while there are also several significant differences in these steps, for example, this research proposed the landscape preferences produced by the emerging challenges, concentrate on Chinese cases and combines two distinct methods, namely qualitative evaluation with author' view and quantitative assessment with questionnaire survey which is discussed in the latter sections.

In brief, this current investigation produced amounts of literal data and photographical documents. These data can be used to evaluate the stormwater management system in each case according to aforementioned landscape preferences of stormwater management system and open space quality. The conclusions can provide ideas for the evaluation of landscape perception and deduce its degree about coherence, legibility and others preferences of landscape characteristics.

3.2.3.2 Case study construction: questionnaires

The method of conducting questionnaire surveys to analyse public or expert opinions quantitatively is applied in a large number of research studies. The main approach for collecting data is questionnaires with polar questions (Múgica and De Lucio 1996).

For the questionnaire survey, the present research was greatly inspired by published research, in particular by that of Marta Múgica and José Vicente De Lucio (Múgica and De Lucio 1996). These scholars employ a mixed questionnaire method, composed of polar questions within the chosen interview sites. The present research adopts a similar approach. However, because of the differences in the research questions, the present research has developed unique strategies in certain details, reflecting the peculiarities of each study case. The approach used here embodies four aspects that now need to be discussed, namely questionnaire strategies, improvements and challenges, the visible function of stormwater management system and open space quality. The first and second aspects are about the preparation for the questionnaire and difficulties encountered when using it, and the third and fourth aspects discuss the polar or yes-no questions.

- **Questionnaire strategies**

1) Selecting interview sites:

Selecting interview sites is an important part of the preparation. Because interview sites were chosen in much frequented areas the investigator is able to contact more respondents. Choosing interview sites also needs to consider the quality of the stormwater management system, since the surrounding landscape helps to jog the respondent's memory and to recall previous landscape experiences. Therefore, a successful interview site involves more participants and facilitates the explanations that the investigator needs to give before undertaking the formal questionnaire survey.

There are three rules about choosing interview sites: they need to be selected before distributing the questionnaires; the interview sites should be located in much frequented areas; in addition, an interview site should be located in a place where the observer has a better view of elements in the stormwater management system than elsewhere in the same project; and last but not least, all questionnaires must be completed within the interview sites.

2) Selecting respondents:

According to the Theory of Affordances, understanding the environment is an important human instinct, which may be influenced to a greater or lesser degree by social background, but can never be removed entirely. Moreover, S. Kaplan and R. Kaplan's Information Processing Theory indicates that the capacity to understand a specific landscape can be increased by frequent visiting. Thus to reach the goal of the investigation, this research needed to interview respondents who knew the investigated project well. There are two specific requirements for selecting the individual respondents: the length of time they have dwelt in the area and where they live, since these both relate to visiting frequency. In order to qualify, respondents were required to have lived near the parks or in the communities for at least one year. Specifically, in terms of Yongyou Software Park, because it is a working environment, the requirement is that the working time should be more than one year. Based on Kaplan's theory, human perception of a landscape's legibility cannot be acquired in a short period or after a few visits; the visitors need to have observed a landscape for a long term (Kaplan et al. 1998; Kaplan 1975).

In order to determine whether the respondent qualified or not, this study employed verbal interviews with two steps. The first one is to ask questions about where he or she lives, namely "*Do you live in this community?*" or "*Do you live nearby and where exactly?*" Regarding visiting frequency, the questions were "*How often do you visit this park?*", and about the length of dwelling time: "*How long have you lived here in this community?*" or "*How long have you lived near this park?*" The second step is to clarify the meaning of stormwater management systems, in case respondents did not understand the questionnaires due to the terminology used there. So, further questions were for example: "*Do you know what "stormwater management" means?*" and "*How do you understand this term?*" If a visitor did not know the meaning of stormwater management, a brief explanation would be necessary: "Stormwater management is a method of dealing with large amounts of rainwater using landscape elements and technology."

- **Improvements and challenges**

Improvement strategies: This research aimed to interview respondents and select respondents who were as diverse as possible. However, because of the aging population in China, many people who appeared in the parks or communities were retired or aged. They enjoyed going outside accompanied by a younger person or participating in collective public activities. The younger generations have a faster pace of life and have to spend more time at work. Thus, in the cases studied the periods of visitor flow were different and unpredictable, thereby increasing the difficulty of collecting samples.

To deal with this challenge the investigator prolonged the investigation time as much as possible. The investigation ran from 6:30 am to 19:30 pm every day or was prolonged further according to a project's specific situation, thereby making sure that each day's peak periods of visitor flow were covered by the investigation. As mentioned above, the interview sites were chosen in areas much frequented by people in order to meet more respondents. The author tried to talk to every respondent walking cross this interview site and at the same time select respondents with different backgrounds. However, even so, it was truly difficult to balance the different social groups in each project.

Challenges of urban parks: In terms of investigating urban parks, one thing is worth emphasizing: This investigation's goal was to determine whether landscape users who often visit the park understood and appreciated its stormwater management system. This goal had two aspects: firstly, the local habitants who had visited the park a few times or never at all were not targeted by the research; and secondly, this research focuses only on interviewing landscape users who often visit the interview site. Therefore, it was the perception of the qualified landscape users who were directly able to reflect on a stormwater management system's degree of coherence and legibility that was most important for this investigation. Additionally, in view of the fact that people with different social backgrounds might have different landscape preferences, it was important to address respondents with diverse backgrounds. However, it seemed that certain social groups seldom visited the some of sites studied, even when they lived near the project. For instance, Qunli Wetland Park has fewer landscape visitors than other urban parks nearby, and most of the visitors were not local inhabitants. In Tianjin cultural Park most landscape visitors are young white-collar workers who often walked through the park because they just wanted to cut across it to get to their workplace. Additionally, these young workers had higher educational levels than the older local people. So it was difficult to obtain an even spread of age and educational background.

Challenges in the communities: The first challenge was the number of qualified respondents. The rapid development of the Chinese economy and the huge scale of urbanization are leading to highly mobile populations and to high levels of temporary migration (Goldstein and Goldstein 1985). The challenges result in unpredictable issues. For instance, although the high-grade villas in the Zhangjiawo Communities were sold many years ago, the majority of homeowners do not often live there; in contrast, the Guyue and Shuangzi Communities were built more than 10 years ago and a large number of rooms are rented short-term to young people who work nearby. Such situations increase the difficulty of conducting an investigation significantly.

In terms of gender, in the Zhangjiawo and Guyue Communities the numbers of investigated male were generally lower than those of the females. Reason for this is that most of the retired women have more free time and enjoy having a chat or doing some recreational activities, whereas few retired men have such interests. As regards average age, it was hard to find qualified younger people in the Zhangjiawo communities because the communities are located in a suburban district far from commercial areas and the university. Therefore, the communities were mostly composed of people in the 30-40-year age bracket and the 40-50-year age bracket.

Challenges in Software Park: In terms of educational levels, in Yongyou Software Park a large number of employees have worked for this company for less than one year due to high fluctuation levels in this software field. Moreover, as regards basic demands on the educational level and age range, the majority of respondents had obtained bachelor degrees or higher and were not in the above 50 + year age range.

- **Explanations in the questionnaires of how stormwater management systems function**

The questionnaires pose four questions in respect of how stormwater management systems function (Appendix A). In fact, these questions themselves illustrate the process of landscape perception, including noticing and understanding. The first question – "*Where did you learn about the meaning of stormwater management?*" – And the second question – "*What are your favourite kinds of movement on this site?"* **–** allow respondents to recall relevant knowledge they have learned previously as well as the landscape experiences they have gained from the local environment. The first two questions aim at emphasizing the theme of the questionnaires and facilitate understanding the subsequent questions. The third question – "*Did you gain knowledge from the surrounding environment about how stormwater management works?*" – relates to "noticing", which is the precondition for understanding. When answering this question, most of the respondents wanted to look round at the interview site's surroundings and tried to recall how they had perceived the landscape in terms of rainwater treatment. This question also focuses on the "understanding", which is the one result that can indicate whether they had noticed the functions of the stormwater management system. The fourth question – "*Have you become more concerned about urban rainwater issues since you have been living here?*" – intends to assess whether the attitudes of local inhabitants are changing due to being influenced by this "understanding".

- **Open space quality of stormwater management system as dealt with in the questionnaires**

Similarly, there are four questions focusing on open space quality. The first question is "*Which is your favourite landscape element?"* and the second question is "*Which landscape components should be improved?"* The first two questions, which address positive and negative opinions, were intended to correct any unfair or extreme answers given by the respondents and decrease the bias as much as possible. The third question – *"When evaluating the aesthetic value of the stormwater management system with a score of 1 to 5, which score do you give?"* – aims to ascertain the extent to which the public appreciate stormwater management systems. The last question – *"Do you think the project will become a classic one, compared with similar projects in China?"* **–** enquires into what the local inhabitants expect of the project.

Chapter 4 Case Studies

The six Chinese projects collected in chapter 3 are evaluated and discussed in this chapter, namely Qunli national wetland park in Harbin, Zhangjiawo community and Cultural Park in Tianjin, Yongyou Software Park, Guyue and Shuangzi Community in Beijing. Table 8 shows the basic information of each project, such as geographical location, scale, weather features and their social value. This chapter aims to achieve evaluation and explanation with respect to three aspects, namely stormwater management system, open space quality and landscape perception, on the basis of published documents and this author's direct observation.

4.1 Analysis of geographical conditions

Three cities were involved, namely Harbin, Tianjin and Beijing, and six Chinese projects have been selected as show in the figure 2: Qunli Wetland Park, Zhangjiawo Communities, Tianjin Cultural Park, Yongyou Software Park, Guyue and Shuangzi Communities. Because all the cases are located in northern China, they have similar climatic and geographical conditions. However, there are some different details among the six cases.

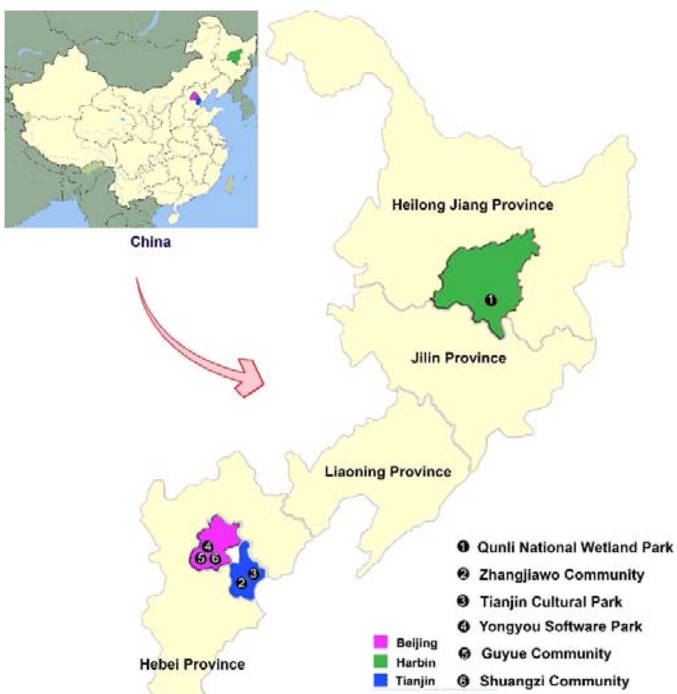
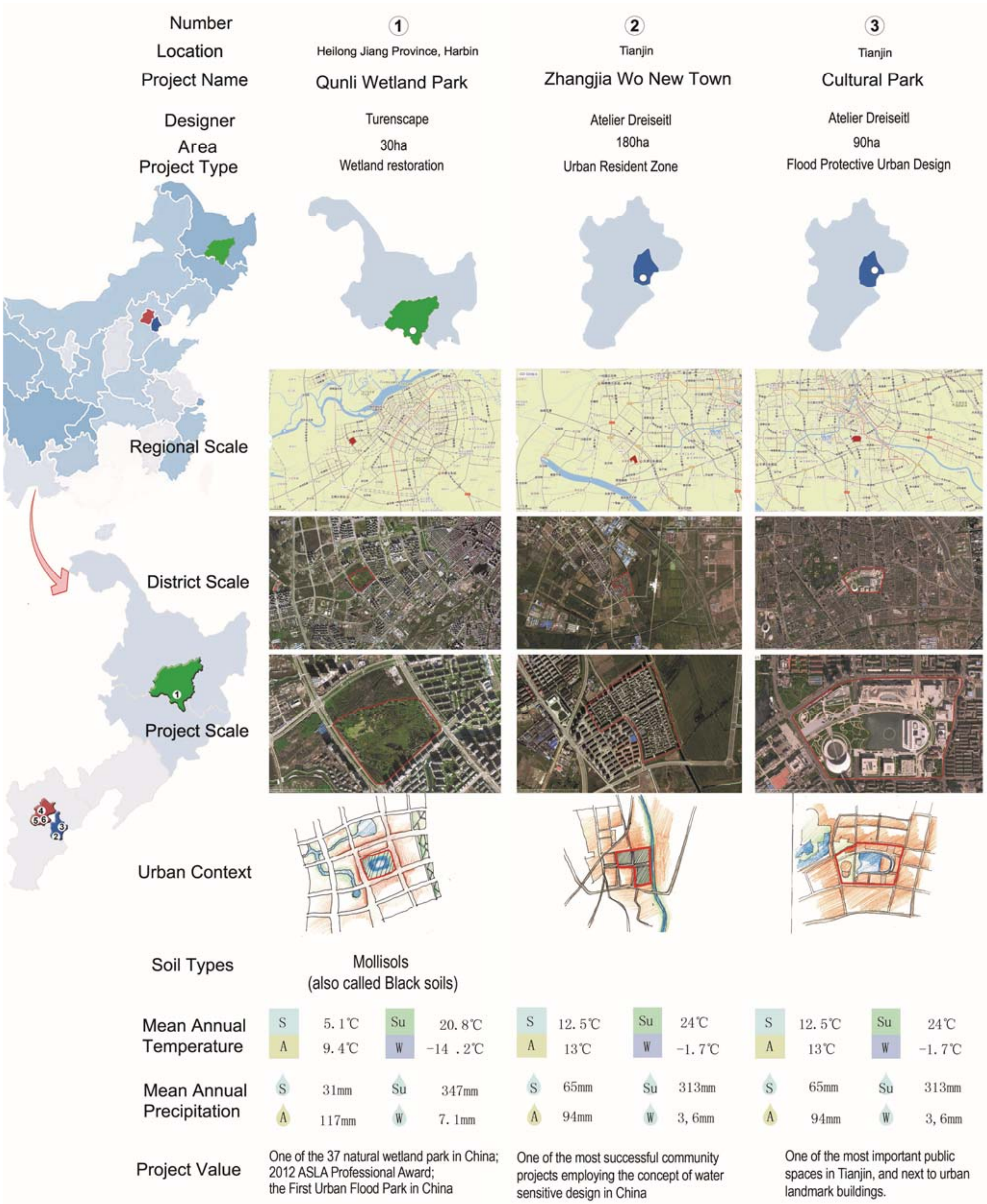


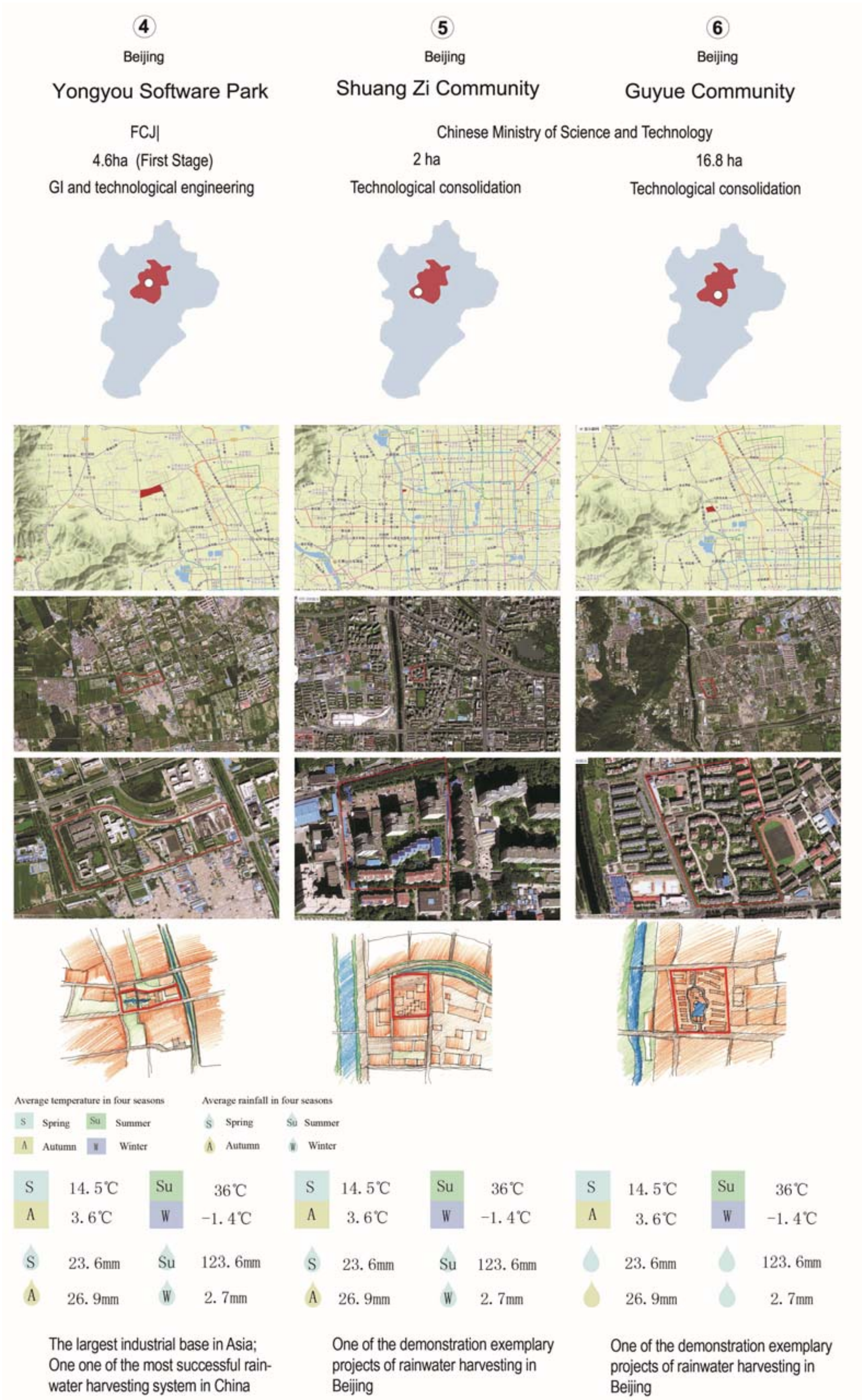
Figure 2: The locations of Six Study cases in Northern China

In particular, the local climatic conditions have distinctive features and can dramatically impact on the present urban structures, and the geographical features can influence the stormwater management system. Because of the importance of these conditions, the six cases are dealt with geographically and thus also in terms of similar local climatic conditions, starting with the northernmost case, followed by the two cases in Tianjin, and finishing with the three cases in Beijing.

Table 8: The basic information of Six Study cases in Northern China



Number	1	2	3
Location	Heilong Jiang Province, Harbin	Tianjin	Tianjin
Project Name	Qunli Wetland Park	Zhangjia Wo New Town	Cultural Park
Designer	Turenscape	Atelier Dreiseitl	Atelier Dreiseitl
Area	30ha	180ha	90ha
Project Type	Wetland restoration	Urban Resident Zone	Flood Protective Urban Design
Regional Scale			
District Scale			
Project Scale			
Urban Context			
Soil Types	Mollisols (also called Black soils)		
Mean Annual Temperature	S 5.1℃; Su 20.8℃; A 9.4℃; W -14 .2℃	S 12.5℃; Su 24℃; A 13℃; W -1.7℃	S 12.5℃; Su 24℃; A 13℃; W -1.7℃
Mean Annual Precipitation	S 31mm; Su 347mm; A 117mm; W 7.1mm	S 65mm; Su 313mm; A 94mm; W 3, 6mm	S 65mm; Su 313mm; A 94mm; W 3, 6mm
Project Value	One of the 37 natural wetland park in China; 2012 ASLA Professional Award; the First Urban Flood Park in China	One of the most successful community projects employing the concept of water sensitive design in China	One of the most important public spaces in Tianjin, and next to urban landmark buildings.


4
Beijing
Yongyou Software Park
FCJ|
4.6ha (First Stage)
GI and technological engineering
5
Beijing
Shuang Zi Community
2 ha
Technological consolidation
6
Beijing
Guyue Community
Chinese Ministry of Science and Technology
16.8 ha
Technological consolidation
Average temperature in four seasons
S Spring
Su Summer
A Autumn
W Winter
Average rainfall in four seasons
S Spring
Su Summer
A Autumn
W Winter
S 14. 5℃ Su 36℃
A 3. 6℃ W -1. 4℃
S 23. 6mm Su 123. 6mm
A 26. 9mm W 2. 7mm
S 14. 5℃ Su 36℃
A 3. 6℃ W -1. 4℃
S 23. 6mm Su 123. 6mm
A 26. 9mm W 2. 7mm
S 14. 5℃ Su 36℃
A 3. 6℃ W -1. 4℃
23. 6mm 123. 6mm
26. 9mm 2. 7mm
The largest industrial base in Asia; One one of the most successful rain-water harvesting system in China
One of the demonstration exemplary projects of rainwater harvesting in Beijing
One of the demonstration exemplary projects of rainwater harvesting in Beijing

The six cases could have been grouped together as design types, namely parks and residential zones; however owing to the great differences within the design types, this approach did not seem feasible. The descriptions of the climatic and geographical conditions will be explained in the respective sections in the following chapters. Generally there are three specific climatic features in Northern China, namely four distinct seasons, uneven rainfall distribution, and extreme precipitation patterns.

4.1.1 Climatic conditions in study cases

4.1.1.1 Four distinct seasons

Due to the higher latitude, the period of summer and spring have moderate temperature suiting outdoor recreational activity, whereas the winter and part of autumn are freezing cold, which results in the earlier dormancy of the herbaceous plants. Particularly, Harbin has the longest winter season and also has the lowest temperature among the three cities (Song et al. 2012; Sun 2013).

4.1.1.2 Uneven rainfall distribution

Another climatic feature refers to the amount of the precipitation occurring in the summer, which is different from the average rainfall distribution in the four seasons in the Southern Chinese cities (Li et al. 1998; Zou et al. 2008). For example, approximately 80 percent of precipitation falls during the period of three months in Tianjin City (June, July and August). This precipitation causes a series of consequences, particularly frequent urban floods. Due to the overloading of urban municipal water management caused by instantly conveying huge volume of rainfall, the public health and security are thrown into dangerous situation in the rainy season. More relevant detail with respect to uneven rainfall distribution are introduced in each studied project.

4.1.1.3 Extreme precipitation pattern

This feature means that the huge intense rainfall occurs during a short period and it is significant for local regional, because it increases the possibility of urban flood. This characteristic which combine other climate features has considerably impact on the urban construction and landscape quality in Beijing and Tianjin (Che et al. 2007).

4.1.2 Analysis of soil types in study cases

4.1.2.1 Soil feature of Harbin

Harbin located in the Northeast China Plain has 9 kinds of soil types, 21 kinds of subclasses, and 25 kinds of soil species. Mollisols, also named Black Soils, are spread out in the outskirts and 12 counties (towns) in Harbin. This soil type includes 2 subclasses, namely black soil and meadow black soil; and also has three kinds of soil genus: clay, sandy, and meadow. The soil type on the

Qunli Wetland Park belongs to the meadow black soil type, which have a loose texture, high soil porosity, and poor water permeability (Harbin Statistics Bureau 2014).

4.1.2.2 Soil feature of Tianjin

Tianjin has 6 types of soil types, including mountain brown soil, aquic soil, and seashore saline soil, etc. There are 17 kinds of subclasses, 55 soil genus, and 459 kinds of soil species. The original soil types on the Zhangjiawo New Town and Cultural Park are loamy Fluvo-aquic soil, which can have a strong water retention capacity (Tianjin Shi Zhi Office 2007).

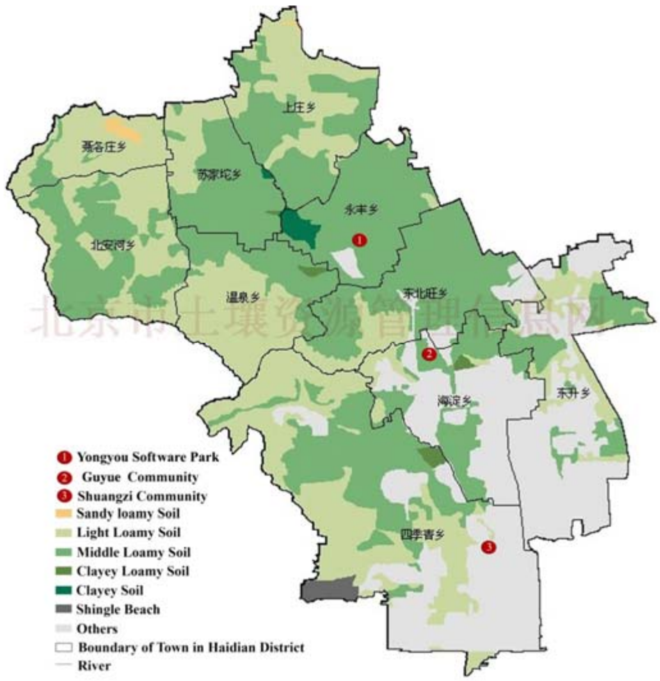


Figure 3: Distributions of soil types in Beijing (Zhao 2009)

4.1.2.3 Soil feature of Beijing

The distribution of soil types in Beijing is complicated, due to geographical conditions (Figure 3). The soil types of the Beijing city consists of 9 soil types, 20 kinds of subclasses, 64 soil characteristics. The soil type of the Yongyou Software Park and Guyue Community, which is wide spread in Beijing, is the middle loamy soil which is able to store the water very well, but has low drainage capability. For the Shuangzi Community, the mixed soil types on this project are too complicated to determine components of the soil.

4.1.3 Urban hydrological condition in study cases

4.1.3.1 Urban hydrological condition in Harbin

Harbin locates in the Heilong Jiang Province, which is in the humid, sub-humid, and semi-arid climate zone, and which has 12 kinds of wetland types. The Statistical data in 2002 shows the province has 6 million hectares of natural wetland and 2 million hectares of constructed wetland (Turenscape 2009a). Because of various reasons, such as the development of agriculture, climate change, and uneven precipitation pattern, the quality and quantity of wetlands are rapidly shrinking. The shrinking wetlands cause urban ecological deterioration, low biodiversity, decreasing recreational value, etc. In particular, Harbin has 0.13 million hectares of wetlands, and has already established 2 natural wetland parks before 2010, namely Taiyang National Island Wetland Park, and Baiyu Natural Wetland Park. Compared to them, the third one constructed in 2011, namely Qunli National Wetland Park is playing a more important role, because of being located in the core zone of the future urban development.

4.1.3.2 Urban hydrological condition in Beijing

Haidian District of Beijing is the one of fourteen suburban districts of Beijing. Three study cases in the Haidian District are involved, namely Yongyou Software Park, Guyue and Shuangzi Community. Although Haidian District has relatively an abundance of water resources, the consequences caused by water pollution and urban rainfall runoff are gradually rising. There are 10 rivers systems crossing through Haidian District, which have the total length of 119.8 km (Sun 2012). Contributed by this natural resource, the regional available surface water resources can provide 170 million cubic meters for the whole city (Liu 2007a). However, the water crisis, including the deterioration of water quality, the shortage of water supply, and frequent urban floods are still unfolding. In particular, the water quality in northern Haidian, such as Nansha River, Wuyi Channel and Youyi Channel exceeds V class which can only be used for irrigation (Liu 2007c).

4.1.3.3 Urban hydrological condition in Tianjin

In terms of the surrounding hydrological situation of study cases in Tianjin, there are about 300 tributaries in the upstream of Hai River, include Nan Yun River, Zi Ya River, Da Qing River, Yong Ding River, Bei Yun River. They are named "Drainage System of Hai River" (Su 2013). Tianjin is located at the junction and estuary of the five tributaries. Due to the special geographical condition, Tianjin enjoys a more complex and intensive river water networks than the majority of Chinese cities. Additionally, Tianjin has also an own drainage system which is called "Jie River". Historically the abundant water resources have been a great advantage for economic development, growth population and the advancement of the urban area. However, due to climate changing and the construction of plenty of dams on the upstream of Hehai River, the water flowing into the river system of Tianjin are reducing annually in recent 30 years (Fan 2011). The decreasing of water input was considered as one of significant reasons which lead to the urban water shortage.

4.2 Qunli National Wetland Park in Harbin

4.2.1 Background and introduction

This project is located in Harbin which is the largest city of the Heilongjiang Province (Figure 4a). The Sub-provincial city with the total area of 53km² is on the southeast edge of Songnen Plain. According to 2011 population census, the Sub-provincial city has 9.93 million inhabitants (Wang et al. 2013b). The climate categories of the city are a Cold-Temperate Zone with semi-humid continental monsoon climate. The urban area reaches 10 km². The city is constituted by 10 counties, and eight districts. Qunli natural wetland park is located in Daoli District (Figure 4b-c). The total number of population in this district has reached 0.9 million inhabitants. Average annual precipitation is 500-600 mm, and the rainfall amounts of three months (July, August and September) account for 70 percentages of the total annual rainfall (Xu 2011).

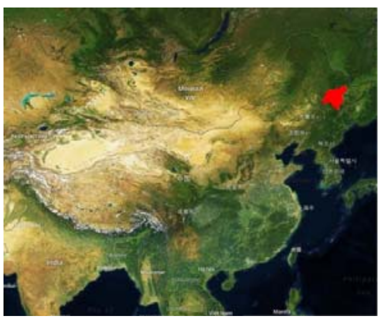


Figure 4a: Location of Harbin
(Map data: Google, Digital Globe)

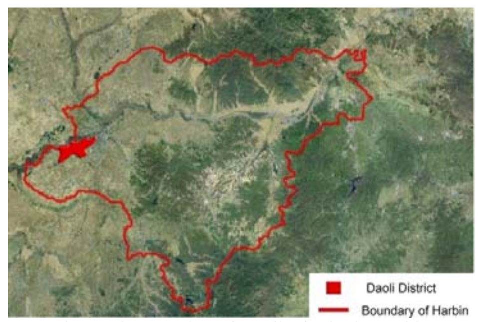


Figure 4b: Location of Daoli District in Harbin
(Map data: Google, Digital Globe)

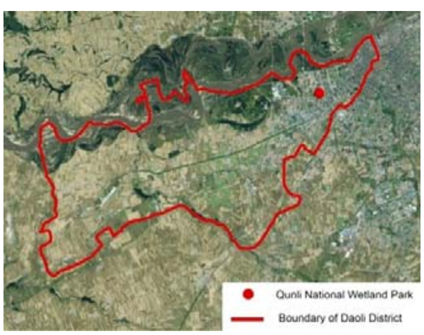


Figure 4c: Location of the Park in the Daoli District
(Map data: Google, Digital Globe)

Figure 4d: Qunli National Wetland Park
(Map data: Google, Digital Globe)

The wetland had once been called “Swan Pao” with a one hundred year history. During the last decades, the original wetland had lost its valuable ecological merits due to the urban sprawl. In 2009, Beijing Turenscape accepted the commission to restore the original wetland and build a new wetland park. In 2011, the new Wetland Park with 0.3 km^2 areas was completed and is named as “Qunli National Wetland Park” (Figure 4d), serving for ecological conservation purposes and rewarded by State Forestry Administration of the People's Republic of China.

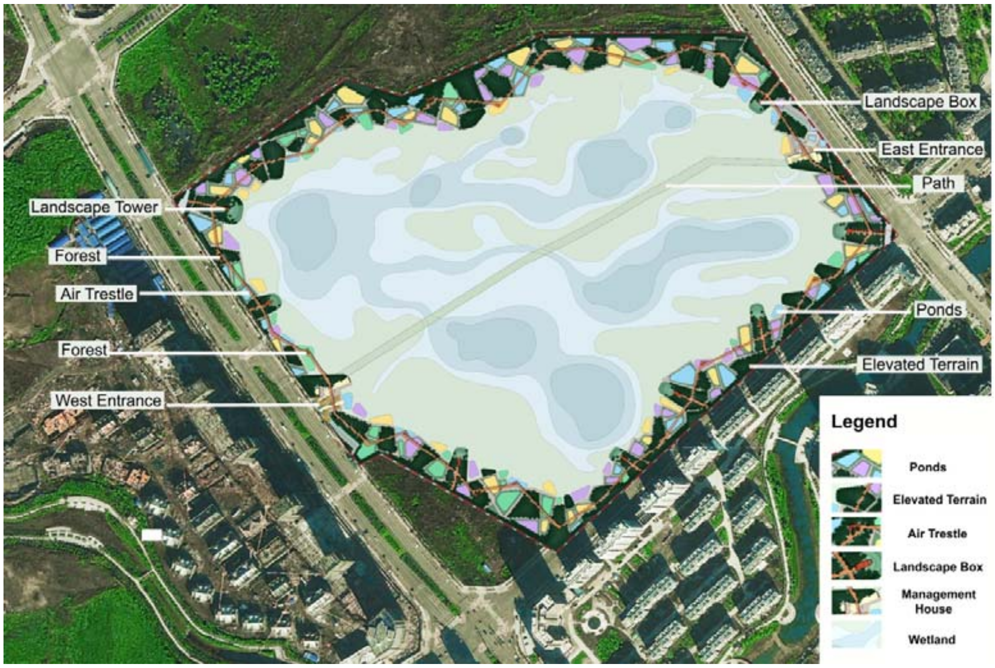


Figure 5: Plan of Qunli National Wetland Park (Drawn on the basis of Turenscape 2009a and Google map)

4.2.2 Design challenges and responds

Being similar to other northern cities, Harbin is also confronted by a series of water challenges, such as distinctive annual rainfall precipitation, uneven rainfall distribution, and extreme precipitation patterns, like other northern cities (Figure 6). The unstable and low annual precipitation contributes to the decrease of urban water storage. The growth of commercial and resident zones has also resulted in the decrease of wetland areas (Yu 2011). By these reasons, the designer had to solve four design challenges (Turenscape 2009b: p.5): 1) how this wetland park with high ecological value can coordinate with urban development; 2) how this park can overcome the issues of water loss, and can retain sufficient water to recover the biological habitat; 3) how the design can improve the biological system; 4) how the design can establish a comfortable environment for the reproduction of various species.

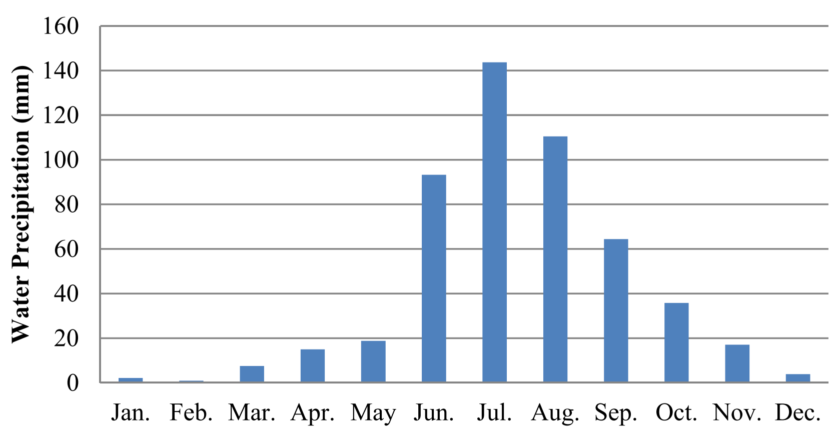


Figure 6: Uneven rainfall distribution in Harbin (Wang et al. 2013b)

The most challenges have been well responded by a series of strategies which have been proposed in the planning context:

1) This original wetland invaded by urban facilities had not an ecological connection within the surrounding urban open space system. The design restores the ecological system of the wetland and finds alternative solutions dealing with the conflicts of the urban development.

2) It is necessary to find comprehensive solutions to handle the insufficient water storage such as introducing recycled water and increasing the efficiency of rainwater harvesting. Figure 7 shows the processes and components in the stormwater management.

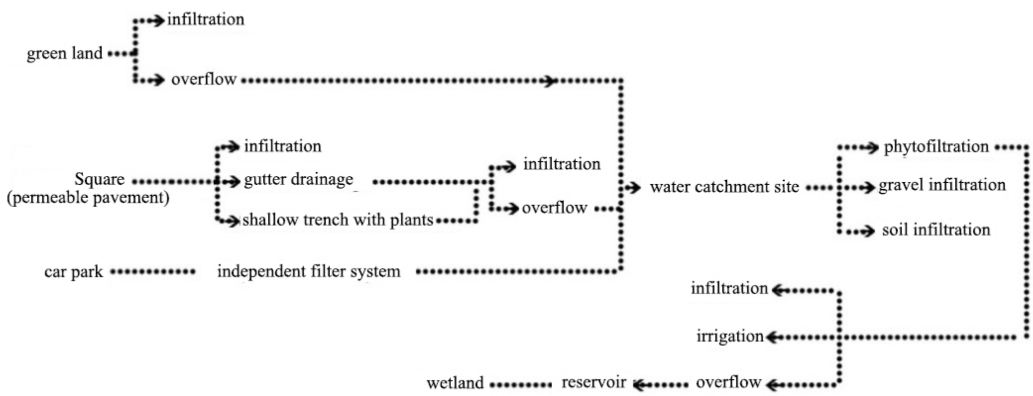


Figure 7 Processes and components of Stormwater Management in the Park (Drawn on the basis of Turenscape 2009a)

3) The invasion of commercial and residential land as well as human disturbances result in wetland shrinkage, ecological degeneration, and insufficient water storage. Therefore, the design principle of the park concentrates on recovering natural habitats in order to establish the structure of the ecosystem and to prevent from natural ecological deterioration.

4) In the paradigm of Chinese urban development, the maintained methods and monitoring system of the park will be established, aiming to stabilize the functionalism and growth of the new wetland park.

4.2.3 Analysis of investigations

4.2.3.1 Description and personal evaluation of stormwater management system

- Description of stormwater management system

1) Natural infrastructure:

Aiming to achieve water balance ecologically, the designer adopts a series of measures including improving the hydrological system and promoting ecological diversity. First, Figure 8 a-c shows the previous terrain condition and the comparison between “Swan Pao” and the existing park. These photographic documents show that regarding the hydrological system, the previous wetland with water bodies has been transformed into a new wetland landscape.

Figure 8a Previous terrain in the summer of 2003 (Map data: Google, Digital Globe)

Figure 8b Previous terrain in the winter of 2006 (Map data: Google, Digital Globe)

Figure 8c Establishment of the Park in 2011(Map data: Google, Digital Globe)

Aiming to prevent from extremely climate event, such as water loss and rainfall overflow, the design concept sets three levels of buffer zones in order to retain more rainfall and to improve the ecological habitats on the basis of the previous hydrological systems. Based on computer simulation, the park can store the total 71906 cubic meters of rainwater in regular situation, and 137675 cubic meters in extreme rainfall events (Li 2013). Additionally, aiming to enhance the ecological value, the rainfall collected from roads or squares will initially retain in the two levels buffer zones, and each level aims to deal with different rainfall runoff in each season (Figure 9) (Yu 2010b) . Therefore, the rainwater can flow into the central wetland when mounds and pond overflow (Turenscape 2011). Generally, the amounts of precipitation in regular rainfall events can only be able to refill part mounds and ponds.

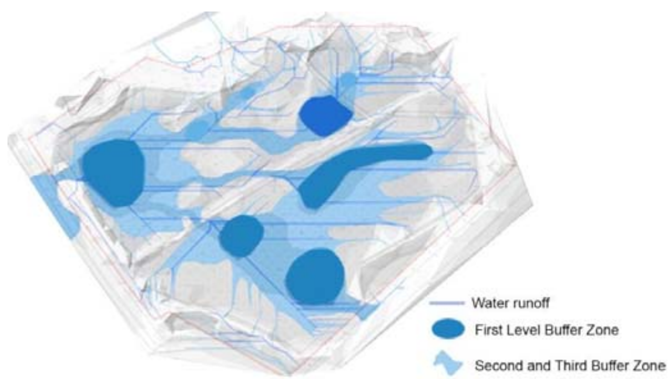


Figure 9 Buffer Zones and route of water runoff (Turenscape 2009a)

Second, in terms of plant systems, the park has various plant species, including several white birches, about 9 kinds of shrubs and herbs, and above 14 kinds of aquatic plants (Yu and Song 2009). The various plant species contribute to the establishment of a biologic chain, the decrease of rainfall runoff, the infiltration of the toxic substance within rainfall, and the increase of the natural hydrologic cycle. In the view of plant distribution, there are two distinctive plant patterns, the semi-natural plant pattern which still need to be intensively managed by workers and natural plant pattern which only need to be maintained extensively (Figure 10a-c). In particular, the herb plants grow naturally and intensively in the margin of mounds and pond which maintains local ecological value.


Figure 10a: mounds and ponds


Figure 10b: Semi-natural plant patterns


Figure 10c: Natural plant pattern

2) Artificial water facilities:

The wetland park does not adopt a powerful engineering system in its stormwater management; instead it takes full advantage of the green infrastructure and changes in terrain height. In particular, aiming to efficiently collect rainfall, the designer changes the previous terrain in different locations: 1) aiming to prevent from the disturbance of the surrounding commercial zone, an elevated terrain is built at the margin of wetland park (Figure 11); 2) aiming to collect the rainwater, the different terrain changes are made at the periphery of the wetland; 3) the designer builds a series of water ponds with a high ecological value and water storage.


Figure 11: Elevated terrain in the Park entrance


Figure 12: Pump station in the Park

In terms of the conveyance system, there are also three ways to carry the rainfall. First, the rainfall on car parks and squares can either be collected on the nearby sunken green land, or be infiltrated through permeable pavement on the ground. Second, there are short shallow ditches which are built on the periphery of the park without convey rainwater to sunken green land. Third, every pond on the periphery of the wetland can also collect rainwater through a sloped terrain. In sum, the wetland park does not have an intensive long-distance conveyance system, but rather relies largely on many small decentralized water treatment systems. Even so, there is a pump station in the park which is built to connect recycling water factories in order to refill the wetland in the dry summer (Figure 12). The park cannot maintain the ecological diversity, if the refill water could only rely on the rainwater collection.

- Personal evaluation of stormwater management system

The whole park has a high capability of retaining rainfall which can maintain the ecological system through natural ways. Nevertheless, the visible function of stormwater management which visitors can be able to observe is not obvious. There are three main reasons: 1) the permeable processes of rainwater at the margin of the wetland park, 2) elevated terrain in the area between the margin of the park and periphery of wetland, 3) and the mounds and ponds. First, at the margin of the park the permeable materials and the sunken green land can absorb rainwater with a high efficiency. Even when the rainfall on the squares or car park overflows, the existing ditches can still alleviate the overflow burden. Because of the high absorption capability of the natural wetland it is not necessary to build particularly long and powerful conveyance facilities to transport rainwater to the wetland. Second, the designer takes full advantage of terrain changes to facilitate rainfall concentration. The rainfall either is conveyed by slopes of green land, or flows into ditches or sunken green land. Therefore, ditches linking the wetland are built. Third, the ponds at the periphery of wetland are next to the road and are the boundary between people and wetland. The designer did not build a huge and united natural water body. Instead, many small ponds with organic shape are arranged in a ring around the wetland. Every pond can also be considered as a small, but multi-functional decentralized water treatment system.

Additionally, the stormwater management system in this park also relies largely on the extremely high greening rate and hydrological system. However, in the view of visible function, the processes of water treatment are dispersed. The function is rather difficult to be detected and noticed by the eyes of non-professionals.

In terms of explicitness, there are four mentioned factors, namely intensive decentralized water treatment, terrain changes, multi-functional ponds and the preservation of the hydrological water system. The park relying on these advantages has achieved a decent ability of stormwater management system. Nevertheless, this ability does not bring a truly distinctive landscape with the explicit structure of stormwater management. Therefore, the public has not an awareness of the rainwater collection at all, but rather believes the water in the ponds is refilled by other resources. The main reason is that the park with the dispersed decentralized water treatment does not build a clarified landscape representing stormwater management.

4.2.3.2 Description and personal evaluation about open space quality

- Description of open space quality

1) Public infrastructure:

The park has several categories of public infrastructure with a distinctive style, including park management house, air trestle, landscape box, landscape tower, and twisty road (Figure 13 a-e) (Yu 2013). These facilities have artistic value and are built by sustainable materials, such as stone and wood. They also provide the different landscape perspectives for visitors. Most importantly, these facilities allow people to have a broader view to watch the landscape within the park (Figure 14). The maintenance relies mainly on manual work, while the efficiency is low (Figure 15).

Figure 13a: Management house


Figure 13b: Air trestle


Figure 13c: Landscape box


Figure 13d: Landscape towers


Figure 13e: Twisty road


Figure 14: Broader view

For instance, there is sole toilet in the park which is closed for a long time because of disrepair (Figure 16). Additionally, a lack of plant maintenance undermining the open space quality has already influenced the effect of water treatment because the large area of soil is not fully covered by the plants (Figure 17).In the view of space usage, there are two distinctive space types, public space and wetland. All recreational facilities are built in the public space, while the wetland cannot be accessed by public. In particular, the public space has not a large square offering the public activity. However, the landscape trestle, tower and box can provide rich vertical variation for different landscape experiences.


Figure 15: Maintenance workers in the Park


Figure 16: Sole toilet in the park


Figure 17: Lack of plant maintenance

2) Nature pleasure:

In terms of nature pleasure, the plant system within the park consists of two distinctive types (Figure 18). The first type of plant system can be found in the public space. The plant pattern is semi-natural and frequently maintained by workers. The second type is a distribution with natural patterns. Various plants are naturally set within the wetland and have little human disturbances. Additionally, the colours of plant pattern from May to October are dominantly green (Figure 19).

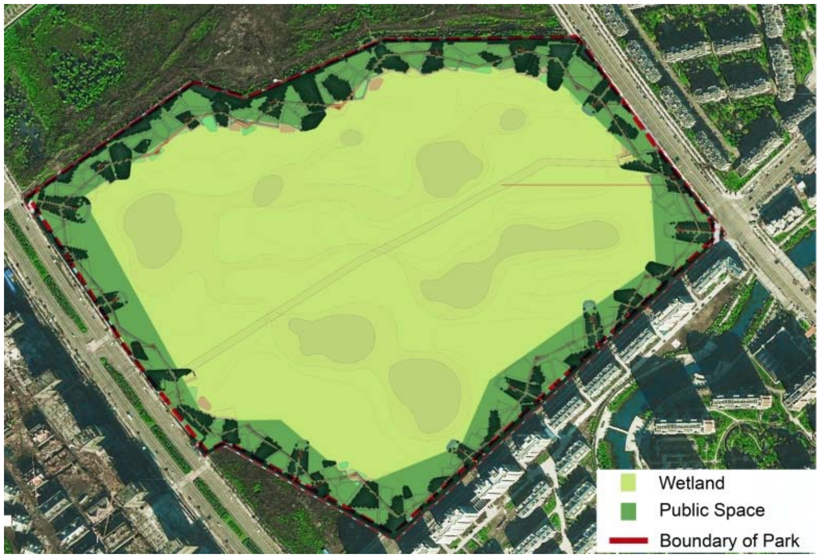


Figure 18: Two space types in the park (Draw on the basis of Turenscape 2009a and Google map)

Figure 19: Seasonal changes of plant system (Turenscape 2009a)

To connect between the first and second plant pattern, the mounds and ponds can be regarded as the bridge. Due to the high growing plants in the wetland, the ponds are the only few visible water bodies. They are next to the roads or trestles and combine the natural plant patterns to produce a small and static waterscape. Other water bodies hide behind the reeds and cannot be seen by public's eyes, even when they are standing on the air trestle.

3) Accessibility:

In terms of accessibility, the pedestrians can freely enter the park and become observers and users. There are not obvious obstacles between the outside and inside of the park. Instead, the two distinctive spaces are only marked by pavements with different materials and colours (Figure 20).

Figure 20: Boundary of the Park: the gravel road of this park connects to the public pavement on the left side without

In the view of the pavement system within the park, the curved paths on the elevated terrains are interwoven with each other, and the visitors cannot go into the wetland. These restriction factors result in certain degrees of inconvenience when visitors are walking in the park.

- Personal evaluation of open space quality

The investigation on open space quality establishes a bipolar evaluation among regular visitors. On the one hand, the park produces a rare landscape among regular urban parks and might be a favourite park for them. On the other hand, in terms of perception on rainwater management, this author has an opposite view. This discussion will analyse the reasons from both sides.

First, the park promotes several landscape experiences. In particular, the landscape facilities with special artistic shape increase the open space quality and offer visitors different viewpoints. People can overview the whole landscape when standing on these facilities. These facilities themselves also turn out to be a remarkable landscape of this park. Second, the species and patterns of plant system surrounding the public space are various which can produce an attractive landscape. The combination between water and plants in the huge area of green space also strengthens the open space quality which is also valuable for the modern Chinese urban context.

The opposite evaluation indicates that the park fails to meet the public needs. First, the lack of considerable maintenance has already influenced the visiting experience. For example, the toilet is out of repair; and the soil is bare due to the lack of plants. Second, aiming to protect the ecological value, the design adopts a series of methods, including decreasing the area of public spaces, and the limitation of access to the wetland. Third, the landscape context of the wetland is lack in visual stimulus because of monotonous colour and landscape textures. In particular, the major water body is covered under the reeds and then people cannot see it, resulting in less attractiveness, and then decreasing nature pleasure to a certain degree.

Figure 21a: Surrounding urban park

Figure 21b: Surrounding urban square

Figure 21c: Few visitors visiting the park

In sum, although the park with its flexible and resilient landscape has an enormous potential of aesthetic value, there still is visual fatigue and less attractiveness to a certain degree. In particular, because of the emergence of aged society in the Chinese cities, also including Harbin, the increasing number of aged people needs more space for recreational activities. Therefore, the majority of local residents prefer the surrounding regular parks and squares to this wetland park because these public space can provide a sufficient space (Figure 21 a-b). Figure 21c shows the low vitality of this park. The photos explain the difference of the numbers of visitors among the three urban parks, two of which are nearby the wetland park, at a same time period. The wetland park has less vitality than others, which is further discussed in the upcoming discussion with respect to the coherence and legibility of stormwater management.

In sum, as far as accentuation is concerned, although the park has impressive landscape experiences for the local residents, the problems mentioned in the section about open space quality show that the landscape features representing stormwater management are not truly accentuated. The limited numbers of visible functional components are another important reason. In particular, the wetland provides a waterscape with intensive plants. Among the layers of the natural landscape, the ecological values are more important than the explicitness and accentuation of stormwater management, instead this waterscape and the process of stormwater management system are lack of scenic accentuation in terms of landscape value because they are difficult to be observed.

4.2.3.3 Analysis of landscape perception

- **Coherence and legibility**

1) Coherence:

The discussion on the explicitness and accentuation shows that the park fails to provide a strongly coherent landscape experience of stormwater management. Although the stormwater management also provides repetitive themes such as the decentralised water treatment facilities and slope terrain, these repetitions are not transformed to be a landscape with coherent context of stormwater management. First, the water treatment relies on permeable materials and sunken green land. The processes allow rainfall to infiltrate into ground with less surface runoff. Therefore, it is difficult to notice the slight processes. Second, the elevated terrains at the public space can allow rainfall to flow in the ditches or ponds. However, this method fails to reach an outstanding coherence of the stormwater management system, and then it is difficult to allow the public to easily perceive coherent information with respect to rainwater management.

2) Legibility:

The environment does not represent a fully legible structure of stormwater management. The legible landscape should contain remarkable and distinctive features of stormwater management in the environment. Wetland landscapes as the central design focus of the park is also a vital component of stormwater management. As mentioned above, due to less accentuation of the wetland landscape, the distinctive features have been buried in the dense and intensive reed, which means that visitors seem to enjoy a natural landscape and are unable to recognize the function of stormwater management. Therefore, the homogeneous wetland landscape cannot offer strongly legible information for residents.

4.2.4 Introduction to questionnaires

The investigation and questionnaires have been investigated five days from 22nd to 26th in 2013. The total numbers of 38 respondents have been chosen when they were visiting the park. The qualified respondents should live in communities surrounding the park.

Table 9: Basic information of involved respondents

Items		Numbers
Valid Questionnaires		38
Gender	Male	13
	Female	25
Dwelling period (Year)	1-2	8
	2-3	12
	3-4	12
	4 and above	6
Education background	Secondary school and below	10
	Higher education	12
	Bachelor degree	9
	Master Degree or above	7
Average age	20-30	10
	30-40	6
	40-50	10
	50+	12

The participators include 13 men and 25 women among the valid questionnaires. There are 10 respondents in the 20-30 age group, 6 respondents in the 30-40 age group, 10 respondents in the 40-50 age group, and 12 respondents above 50 age group (Table 9).

The questionnaires were undertaken within the public space nearby the entrance of the park. Additionally, Table 10 shows the statistic results about questionnaires of the wetland park. The most important question of the questionnaire about visible function is "*Did you gain knowledge from the surrounding environment how the stormwater management works?*" and another question directly related to open space quality is *"Please evaluate the aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?"*

Table 10: Content of questionnaires and answers of respondents

Categories	Questions	Answers	Results
Stormwater management system e	How long do you spend outdoors in this park per week?	Less than 1 hour	12
		1-2 hours	10
		2-3 hours	4
		3-4 hours	2
		Longer than 4 hours	10
	Where did you learn the meaning of stormwater management?	Media	7
		Surrounding environment	5
		Neighbourhood	4
		Others	10
		Not at all	12

	What is your favourite kind of activity in this site?	Walking	18
		Sitting	4
		Overlooking	14
		Don't Care	2
	Did you gain knowledge from the surrounding environment how the stormwater management works?	Yes	14
		No	24
	Have you become more concerned with the urban rainwater issues since you have been living here?	Yes	36
		No	2
Open space Quality	Which landscape element would be your favourite?	Plant borders	14
		Peaceful rainwater pond	6
		Broad lawn	6
		Rainwater square	0
		Shady path	12
	Which landscape components should be improved?	Water body	16
		Plant system	14
		Road	4
		Lawn	4
	Please you evaluate the aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?	Very high (5 Points)	10
		Quite high (4 Points)	18
		Moderate (3 Points)	8
		Quite low (2 Points)	2
		Very low (1 Points)	0
	Do you think the project is going to be an exemplary case, comparing with other similar projects in China?	Yes	24
		No	0
		Not Sure	14

4.2.5 Final conclusion

The urban development in Harbin with the influence of climate change and quick urbanization is confronted by enormous challenges, including urban floods, water pollution, or ecological degeneration. These challenges together are a threat to the public safety and undermine citizens' well-being. Therefore, under this circumstance the designer has specific motivation to explore a new alternative design principle. Qunli National Wetland Park is one of the best examples.

The evaluation of this section contains three main components, namely stormwater management system, open space quality, and landscape perception. In the view of stormwater management system, the green infrastructure plays a dominant role. Two responds are given by the design approach, including the innovation of water bodies and the improvement of plant systems. First, the innovation includes the transformation of the previous green wetland and the establishment of mounds and ponds in order to fulfil the potential of water storage of wetland. Additionally, the chosen plant species are naturally distributed in the park, which can establish a natural broad shelter against surface runoff, and a natural infiltration network for water pollution. Second, the plant patterns are divided into two distinctive types according to space categories, namely public space and wetland. These two different plant patterns are connected through the landscape management of mounds and ponds.

The setting of artificial infrastructure components in the communities also contributes profoundly to the ecological value of the park. Aiming to prevent from human disturbance and to facilitate rainwater collection, the designer has elevated the terrain at the margin of the park and dug the mounds and ponds at the periphery of the wetland. These terrain changes and the application of permeable materials also contribute to the intensive distribution of decentralised water treatment systems with the function of water conveyance and storage. The characteristics of stormwater management systems efficiently maintain the efficiency of stormwater management system; instead, this maintenance needs a pump station which can refill the wetland in the dry season. Thus, the distinct landscape features of stormwater management are difficult to be found.

In terms of open space quality, the public infrastructure with unique artistic formation can bring a different visiting experience for visitors. However the lack of efficiency in the maintenance work decreases this visiting pleasure. Additionally, the park has two distinctive space types, namely public space and wetland. Due to the priority of ecological value, the public space has been largely limited in order to stimulate the development of ecological habitat. In the view of nature pleasure, the features of plant patterns have also two distinctive types in different space categories, namely semi-natural plant pattern and naturally growing plant group. The connection of two categories is made by mounds and ponds, which can be seen by visitors.

The author's evaluation indicates the local residents have a sense of division about the park. This research summarised the main viewpoints of the two opposite aspects. First, the park has a high aesthetic value, created by the artistic formation of terrain and facilities, overviewing platforms, various plant species, and the rare natural landscape. Correspondingly, the park has also profound disadvantages in views of open space quality, for example, the maintenance problems, limited public space, homogeneous landscape context in the wetland, or invisible water bodies, and others. These disadvantages are also the part of reasons that this park has less visibility resulting in a relative lower vitality.

As far as landscape perception is concerned, the explicitness and accentuation have also received a low evaluation. In particular, the explicit structure of stormwater management is covered in the impressive natural landscape and is hard to be perceived. The impressive natural landscape overgrows the "fragile" and "thin" legible layer of stormwater management. Therefore, visitors do not have an awareness of the existing water treatment systems. Based on the discussion on the explicitness and accentuation, the landscape of the wetland park cannot convey the strong coherent information and legible context of stormwater management.

Finally, the questionnaire shows that 70 percent of the residents give a negative answer to the most relevant question with respect to visibility of stormwater management system, "*Did you gain knowledge from the surrounding environment how the stormwater management works?"*

For another most relevant question about open space equality, "*Please evaluate the aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?*" the most respondents chose the middle range of the five-point grade. In sum, compared to other urban parks, the park still has huge aesthetic and ecological value, and also has a huge potential to improve the coherence and legibility of stormwater management

4.3 Zhangjiawo Communities in Tianjin

4.3.1 Background and introduction

The Zhangjiawo New Town is located in Tianjin, a metropolis in northern China. The city has an important economic and politic status, because it is one of the five National Central Cities of the People's Republic of China (PRC). It has a common border with the Beijing Municipality and is the largest coastal city in north-eastern China. Tianjin's perimeter measures 1,290 kilometres, comprising 153 kilometres of coastline and 1,137 kilometres of land borders. The urban surface area measures 11,917 square kilometres (Figure 22b) (Liu 2012; Wiki 2014).

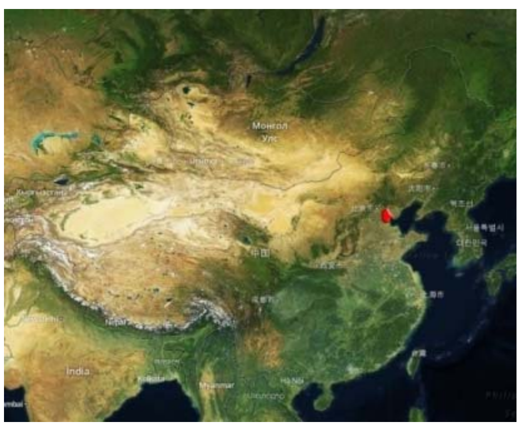


Figure 22a: Location of Tianjin
(Map data: Google, Digital Globe)

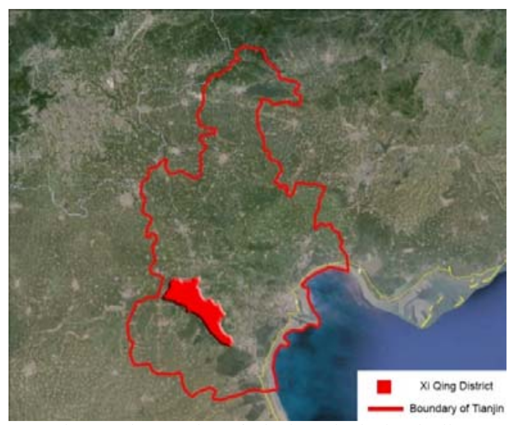


Figure 22b: Location of Xi Qing District in Tianjin
(Map data: Google, Digital Globe)

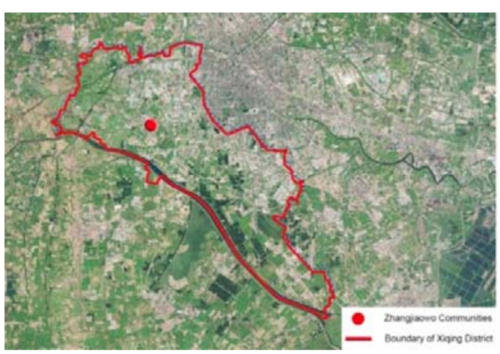


Figure 22c: Location of the Zhangjiawo Communities
(Map data: Google, Digital Globe)

Figure 22d: Zhangjiawo Communities
(Map data: Google, Digital Globe)

Xiqing District, which is the one of the eighteen districts in Tianjin, is located in the southwest of Tianjin and on the lower reaches of the Hai He River. It measures 48 kilometres from south to north and 11 kilometres from east to west. The district's surface area is 571 km^2 and covers 4.92 percent of the total area of Tianjin (Figure 22b).

The Zhangjiawo New Town, located in the middle of the Xiqing District of Tianjin, was completed in 2008 (Figure 22c-d). The total project area is 180 hectares. The Shanghai Wisepool Real Estate Co. Ltd. commissioned the German landscape Company Atelier Dreiseitl and its design team to construct a new landscape that incorporates the function of a rainwater management system as well as a recreational area and to improve this district's ecology.

4.3.2 Design challenges and responds

Figure 23 and Table 11 shows that Tianjin's rainfall distribution concentrates on three months, namely June, July, and August, which means that in summer the precipitation is far greater than in the other three seasons. As the tables and statistics show, Tianjin's climate has three weather traits, namely distinctive annual rainfall precipitation, uneven rainfall distribution, and extreme precipitation patterns. At the same time, Tianjin is going through a water crisis, including urban floods, shortages in the urban water supply and a lowering of the water table. These challenges have caused unpredictable economic losses and continue to threaten citizens' safety.

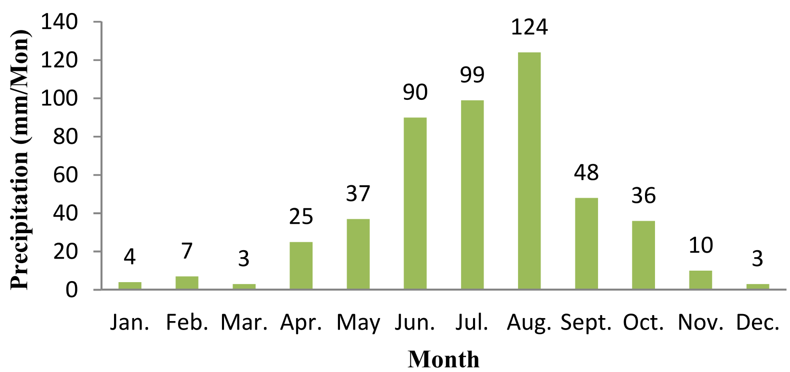


Figure 23: Monthly rainfall distributions in Tianjin in the from 2005 to 2011 (Li et al. 2012)

Apart from these climatic and geophysical factors, the commissioned designers also faced several other challenges. The first one was how to establish a new community and yet preserve its vernacular identity. The majority of Chinese communities are built in an exotic style, thereby deviating from local traditional styles and sustainable methods. The second one was how to establish an integrated design concept to maintain the social function of the Feng Chan River, namely irrigating farms, which among other things meant preventing brackish seawater from pushing up the river and improving the river's social value for the local communities. Here, due to its importance for the communities, it is worth introducing this river briefly. It is located in the east of communities and was used to irrigate local farms. In 1950, the local people began to build a new river channel and the construction was completed until 1950.

Table 11: Average precipitation during the four seasons in Tianjin from 1985 to 2009 (Li et al. 2012)

	Spring	Summer	Autumn	Winter
Precipitation (/mm)	67.3	352	82.9	9.1
Percentage (%)	13.16	68.85	16.21	1.78

Therefore it is named as "Feng Chan River", which means that it could bring more fortune and lucky. After accomplishing the first and second challenges, the third challenge, which should actually have been solved at the very beginning, was to decide how the river and the community can be combined with each other as a landscape entity. To summarize, in view of the crisis in Tianjin, the social responsibility shouldered by landscape architects pushes designers towards conceiving new integrated design perspectives, seeking design concepts that can improve the stormwater management system on an urban scale.

Figure 24: Plan of the Zhangjiawo Communities (Dreiseitl 2008)

Figure 24 shows that the Zhangjiawo Communities are made up of three communities constructed in three phases. The Feng Chan River and the Rui Xin communities are adjacent to the Zhangjiawo communities.

These expectations have motivated the communities to become a resilient landscape, and a water-sensitive design concept. The project focuses on improving the regional stormwater management system through landscape management. The design description shows that most of the issues were considered in the design concept. As the designers explained, the design principle of the Zhangjiawo Communities has already responded to the challenges. The designers proposed a design incorporating recreational areas and accessibility, thus essentially realising the concept of “liveability” (Dreiseitl 2008).

Figure 25: Dirty water before 2008 (Dreiseitl 2008)

Figure 26: Polluted water at present

In terms of the Feng Chan River, ecological strategies were adopted in the design concept for the river to prevent the water from becoming brackish. The designers anticipated that the river could be transformed ecologically from a polluted river into a clean one (Figure 25). The research shows that the designers proposed effective ways to tackle these challenges, and local residences have proved that with the efforts of designers, this river was clear again for a short period and the water quality of this river had been improved significantly. However, the designers perhaps are not aware of that the river water is being polluted again by upstream industrial sewage discharge after several years. Figure 26 shows the water quality at present. This polluted river influences the communities’ ecological systems and threatens public health. Therefore, inhabitants prefer to live as far away from the river as possible. A long iron fence has been erected between the river and the community. The river has turned into a dangerous and unpopular place. In brief, the communities have been built in a complex urban context with multiple ongoing issues. Even so, some goals have still been achieved within the communities. The designers should be given credit for their sensitive and persistent efforts to create resilient landscapes. But it cannot be denied that the polluted river with its pungent smell has lost the social value that it had for a short while.

4.3.3 Analysis of investigations

4.3.3.1 Description and personal evaluation of stormwater management system

- **Description of the stormwater management system**

1) Green infrastructure:

In terms of historical environment, earlier water canals have been preserved and transformed into an artificial pond. This project did not create any new natural water bodies due to the soil’s high permeability. The plant systems are connected closely with the waterscapes.


Figure 27: Dense linear vegetation groups along the roads


Figure 28: Continuous green spaces combining shrubs and aquatic plants


Figure 29: Aquatic plants growing on a semi-natural bank


Figure 30: Water park is based on the old water canals


Figure 31: Remaining old canals are reshaped to function as reservoirs


Figure 32: Drainage using gradient on the main road


Figure 33: Drainage using gradient on a secondary road

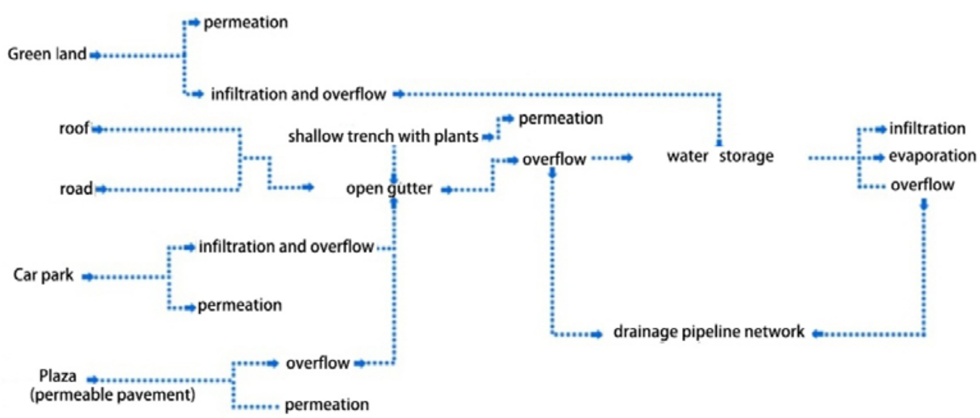


Figure 34: Rainwater management system combining artificial facilities and green infrastructure

All of them can largely be categorized into three groups, namely orderly, rhythmic arrangements of shrubs parallel to the roads, groupings of different native plants in the central open spaces and aquatic plants in the water catchment area: 1) The linear plant groups along the roads help to remove pollutants introduced by the rainfall, by slowing down and retaining rainwater (Figure 27). This group, composed of densely planted shrubs, can be seen in all streets of the communities. 2) There is a green open space in the central area of each community. The high numbers of flourishing plant species in these green spaces have been combined with aquatic plants in the central water catchment. Through this combination, the plant systems, linking two distinct spaces, cultivate a diverse ecological system and develop a continuous green space

(Figure 28). 3) The combination of the green spaces and the dense aquatic plants helps to reduce the levels of nitrates and phosphorus in the water in order to offer a sound biological habitat. Thus both are also a vital part of the landscape elements for stormwater management and form an ecological habitat (Figure 29).

2) Artificial facilities:

The communities' artificial facilities supply a well performing water management system and at the same time result in low maintenance costs. Four main artificial facilities are involved: 1) Aiming to respond to the local identity, the designer has preserved the existing environmental framework and did not change a lot of terrain features. The functions of old facilities have been changed following the requirements of the design concept, so that the old canals are now used as a water park and reservoirs (Figure 30 and 31); 2) the drainage gradient is used on the streets in the communities as an important above-ground rainwater conveyance method. To prevent hydroplaning, the shallow trench systems or fluted gutters are laid along both sides of the main roads in order to not impede vehicles (Figure 32), whereas on the secondary roads the open gutter systems are located in the middle of street (Figure 33); 3) rainwater runoff in shallow trench systems can either be discharged directly into decentralized urban water systems or be retained in the water catchment. Some canals located in the central area have been redesigned and integrated in water parks in the three communities. The remaining ones located elsewhere are now used as open reservoirs. 4) As far as engineering instruments are concerned, the communities' stormwater management system does not rely largely on complex technology. Apart from necessary engineering solutions such as impermeable technology under the central water catchment, the communities have applied an open and green stormwater management concept with low technological requirements in the new park. Figure 34 shows the combination of artificial facilities and green infrastructure from the view of the stormwater management system. In brief, it was possible to develop the water storage and conveyance system functions by preserving the existing canals and by means of the necessary technological engineering.

- **Personal evaluation of stormwater management system**

The water-sensitive design adopted in this case provides new means of obtaining a resilient landscape. The combination of low-technology infrastructure and the high number of plant species enables the stormwater management to deliver a satisfying performance and maintain the stormwater management system. Responding to local identity and geographical features, the design principle does not focus on basins, which would probably have resulted in high maintenance costs and a loss of local identity. Instead it uses large numbers of local plant species in a variety of ways. The designers used different plant groups to connect the water facilities. The strategy provides a considerable ecological resilience and potential for adaptation.

As far as artificial facilities are concerned, the design principle did not significantly change the whole terrain, but rather preserved the existing geographical features and facilities. The designers also endowed the landscape with new meaning. For example, preserving the obsolescent canals was aimed at retaining more rainfall, and thus decreasing the financial costs and increasing the ecological benefits in a sustainable way. Their preservation also links to the local identity, because the obsolescent canals represent a piece of local history. In the case of the waterscapes, the water is replenished by means of the conveyance systems. In order to collect as much rainwater runoff as possible, conveyance systems are laid out on all streets. Combined with plant beds, permeable bricks and drainage outlets, they can temporarily retain rainwater in the first stages of peak periods of precipitation. Thus the drainage gradient is sufficient to act as one of the main components of this system, allowing the runoff to contribute to the waterscape. The water storage connected to this drainage gradient links with the green spaces to develop buffer zones, and to play a more significant role in the stormwater management systemand ecological system. In particular, this link provides the ecological basis for maintaining a suitable habitat for various bio-species and to create a resilient landscape for receiving excess rainwater. Therefore, the combination is also a key part in the communities' water management. The design strategies allow the communities to get rid of their dependence on complex engineering solutions. In sum, the design principles and their implementation offer a new and appropriate perspective on stormwater management system with a clear structure of stormwater management for dealing with the design challenges mentioned above.

In sum, all the communities display a highly explicit landscape, in which the essence of stormwater management is accentuated distinctively. In this way, people can observe and trace the process of rainwater management. As the description of stormwater management system has shown, the communities provide a visible system of stormwater management, which has contributed to good stormwater management system. How this system influences explicitness can be summarized in four points: 1) the connection between the shallow trench systems or gutters and the waterscape work visibly and can be observed. 2) The former canals have been transformed visibly into a the part of stormwater management system – a function that is underlined by the dense groups of plants in the canals; 3) Plant beds are set along the main traffic routes, which displays openly the rainwater flowing towards the waterscape; 4) The processes of collecting rainwater can be observed. Still, there are two disadvantages that need to be improved. First, there are not many plant beds alongside the trench systems, which mean that people do not notice the processes of rainwater infiltration. Second, some shallow trenches connect directly with sewage drains, causing confusion and a lack of clarity about how the trench system actually functions.

4.3.3.2 Description and personal evaluation of open space quality

Description of open space quality

1) Public infrastructure:

The design and aesthetic value of public infrastructure highlight two categories, namely outdoor recreational equipment and service facilities, including pavilions and shallow drainage trenches or gutters. 1) These communities provide adequate recreational facilities, particularly for children. Such equipment is also located in the squares in front of buildings to allow children to have easy access (Figure 35 a-c). 2) There are two kinds of pavilions to be found in the communities. The first one is established near buildings in order to provide a semi-private space for people who want to rest or communicate (Figure 36). The other kind is built in the central water park, in which visitors have a good view on the water park. In particular, every pavilion has a different shape, potentially making it a distinctive landmark (Figure 37). Additionally, the systems of shallow drainage trench are made in a distinctive colour, different to that of the road surface. In this way, they add more details and variations to the roadside and enable people to notice this distinctiveness.


Figure 35a: Climbing wall located in front of building


Figure 35b: Recreational facility located between buildings


Figure 35c: Small kindergarten set between buildings


Figure 36: Communication space in the landscape pavilion


Figure 37: Distinctive pavilion in the central area


Figure 38: Open gutter in secondary road connected to central waterscape

Green infrastructure as the framework for landscape spaces in the communities are further defined by the high numbers of plants used to create different spatial experience. Three spatial categories are involved: shrub beds alongside the roads, small squares or plazas with semi-private spaces laid out near buildings, and central open spaces combining waterscapes and plant groupings. First spatial category is that there are two road systems in the communities. Serving to provide access for the fire brigade and motor vehicles, the main roads are equipped with shallow trench systems and are accompanied by plant beds with dense shrubs arranged lengthwise. The various sections of the main roads display different shrub patterns.


Figure 39a: Small square composed of vegetation and wooden benches


Figure 39b: Landscaped square with stone stools and trees near the road


Figure 39c: Vegetation, single trees and benches contribute to an ordered landscape


Figure 40a: Linear waterscape in first phase-community


Figure 40b: Waterscape in second-phase community


Figure 40c: Waterscape in third-phase community

The secondary road has two main functions, namely to provide recreational space and to enable accessibility. Some recreational facilities and trench systems are laid out on these streets. Rainwater can flow above ground through the trench systems of the secondary roads directly into the waterscape (Figure 38). Second spatial category is that small squares that connect with roads and surround the buildings are also built for public activity. Each square is unique and equipped with different landscape amenities and spatial features, leading to a high recognition value (Figures 39 a-b). The third spatial category is that the central open space is the geographical heart of the community. Two spatial types are involved, namely the waterscape and the natural green landscape. The waterscape space is framed by paths and further shaped by aquatic plants distributed in a natural way. Figure 40 a-c shows how the different waterscapes in the three communities are framed by plant systems. Within this continuous space, the landscape offers various spatial types, sufficient public amenities, and high accessibility and has thus become vital space for public activities.

2) Nature pleasure:

This section on the visible landscape discusses two components that relate to nature pleasure: the vegetation systems and the waterscape. The arguments show that the plant groups and the waterscape have raised the open space quality within the communities.

Figure 41a: Landscaping in a public entrance

Figure 41b: Landscaping in a private entrance

Figure 42a: Jujube trees in the communities

Figure 42b: Fruits of jujube tree

Communities' sustainable concept envisages a high rate of green coverage. Most community areas, such as public space, service facilities and even walls are covered by vegetation and shaded by trees. For instance, at both sides of the public or private entrances of most buildings, several groups of green bamboo grow and sway in the wind. Behind the bamboos, the walls, also covered by climbing plants, are a colorful background (Figure 41 a-b). As mentioned above, the diversity of local plant species and their appropriate distribution also needs to be highlighted. Most species, including many kinds of shrubs and some trees are concentrated in the central community's open space to create a green space.

Second, the waterscapes in the community centres with their luxuriant plant growth have a significant influence on the open space quality of the communities due to their large sizes and central location. There are also other advantages that raise the attractiveness, including highly dense aquatic plants, the continuous green spaces, the connection to the drainage systems and recreational facilities. For instance, because the dense reeds are naturally distributed within corners of the water body, the waterscape displays more dynamic change and attractive details. Due to the high numbers of reeds, the plant groups in the central landscape create spatial links with the waterscape, resulting in a pleasant atmosphere. Finally, aiming at removing the flood threat and at the same time maintaining quality and attractiveness, the open trench systems with their distinctive colours and textures connect visibly with the water body, which is thereby replenished. In brief, the relatively large waterscape with its various spatial types is combined with elaborately chosen and carefully maintained plant groups. This combination is the main basis of the open space quality.

Figure 43: Landscape of Feng Chan River

3) Accessibility:

Although there are physical boundaries between urban landscape and the communities, high accessibility within the communities is nevertheless guaranteed. Due to security and privacy requirements, most Chinese communities are enclosed by walls or iron fences, and are isolated from the social environment as much as possible. There are only two main gates, one for visitors, and the other for residents. The visitors' identity cards have to be checked by guards. However, within the park the designers use two kinds of roads to connect open spaces within each Zhangjiawo Community. Linking the two kinds of roads, the shady paved or wooden paths are also laid out in the central green landscape and waterscape.

- **Personal evaluation of the open space quality**

The description of the amenities takes two evaluation dimensions into account: how the public experiences the public infrastructure in each of the communities (benches, plazas, pavements and pavilions etc.) and the evaluation of the open space in all three communities. First, the investigation has shown that the communities' highly convenient landscape management provides the following advantages: the amenities are well distributed, highly accessible and have distinctive styles. These features contribute to the pleasant and vibrant atmosphere of the open spaces. The smaller spaces adjacent to the roads, paths and buildings create a complex spatial landscape with areas of seclusion and mystery. Second, when viewing the open spaces of all three communities as a whole, one can conclude that the three main spatial categories are smoothly connected and merge into each other on account of the plant groups, roads, paths and drainage systems. In this way, the different layers and features of the public space are distinctive and identifiable.

The beneficial influence of plant groups on the open space quality can be attributed by their biological diversity and dense distribution. These advantages not only produce a dynamic natural landscape by adjusting the microclimate, cultivating flourishing ecological habitats, and creating pleasant, colourful scenes; they also decrease the threat of flooding from the beginning of the heavy rainfall and the contaminated first flush of rain, and, importantly, allow more rainwater to be absorbed into the ground. So the continuous green space systems are significant for the ecological systems and landscape value. As another component of this continuous space, the waterscapes with their ample and appropriate dimensions harmonise well with other landscape features such as the aquatic plants, public infrastructure and other spatial categories, thus providing a peaceful and pleasant landscape experience. Such waterscapes demonstrate how stormwater management systems function. In addition, the roads and paths provide high accessibility, thus allowing people to observe the landscape freely and appreciate it.

In term of accentuation, as shown by the description of open space quality, the strong accentuation of the stormwater management in these communities relies on five different kinds of contrasting strategies: 1) the contrast of material, for example between that used in the shallow trenches and the neighbouring plants; 2) the colour contrasts, as in the red pavements of the shallow trenches; 3) the contrast in dimensions such as the spatial difference between linear spaces and the central open space; 4) the contrast in distribution such as the restrained plant patterns versus the natural landscape; 5) additionally, the designers have endowed every space category with distinctive landscape features, allowing people to establish a distinctive individual cognitive map. However, the functional connection between the waterscapes and green spaces are not particularly accentuated, although the green spaces are considered as secondary buffer zones when the water catchment is overflowing.

4.3.3.3 Analysis of landscape perception

- **Coherence and legibility**

1) Coherence:

The legibility and coherence of the communities is outstanding, due to the contribution of a visible functions of stormwater management system (referring to explicitness) and high open space quality (relating to accentuation). The discussion of the explicitness and accentuation indicated that the stormwater management landscape does not estrange the two preferences.

The relatively high coherence is mainly attributed to the visible functions of the stormwater management in these communities, which produces a repetitive, orderly and rhythmic landscape. This coherence is also influenced by accentuation. For instance, in a smaller scale, the shallow trench systems with their distinctive colour and carefully arranged vegetation on every road repeatedly reappear as a design theme in this case. People can recognize this theme's repetitiveness with their own eyes, and can infer that this whole theme continues to reoccur out of their view. Similarly, viewing the three states communities as a whole, they are applied there in general with the same design theme. Although each community has its own distinctive landscape features, people still can predict the basic style and common features of the three communities, even if they only visit one or two of the communities. At the same time, the whole three communities have also a united landscape styles. Additionally, the accentuation highlights the focus of the stormwater management system and contributes to a complete mental image which can trace the processes of rainwater treatment.

2) Legibility:

In terms of legibility, the communities have not established a remarkable iconic landscape, such as the landscape towers in Qunli Wetland Park, or the artificial lake of Tianjin Cultural park. However, the design concept takes advantage of distinctive contrasts to inspire people to “draw” up their own cognitive map of the stormwater management system. The information and meaning of its functions is conveyed to the residents who already have a detailed cognitive map.

However, there are some points that need to be improved. The description of explicitness shows that more plant beds should be added to the trenches and that these systems should not be connected directly with the sewage systems. In terms of coherence, more plant beds could be considered as a strongly repetitive element that strengthens the theme visually. The disconnection from the sewage systems would reduce the lack of clarity about their function and allow the landscape of the shallow trenches to be more coherent. Additionally, the communities are isolated from the surrounding urban landscape, which also decreases the value and influence of legibility and coherence on the surrounding social environment. The polluted river harms the communities’ open space quality considerably. So the communities with a good balance between stormwater management system and open space quality score well in terms of legibility and coherence; however, there are still points that can be improved.

The stormwater management system has an explicit and coherent structure in this case study: it contributes significantly to achieving the rainwater collection, conveyance and storage as a system and at the same time manages to increase the landscape value. The waterscape is not only the main focus of each landscape; it also plays a vital role in the rainwater management system. The combining of both roles contributes to increasing the landscape perception with respect to rainwater management. In sum, the interaction of these landscape components with one another establishes a well-balanced basis for the inhabitants to perceive the landscape.

4.3.4 Introduction to questionnaires

The investigation and questionnaires on the Zhangjiawo Communities in Tianjin lasted four days. A total of 31 questionnaires were completed. The 26 valid questionnaires involved 16 men and 10 women respondents. Due to the aforementioned reasons, it was difficult to meet younger people (20-30). There are 10 respondents in the 30-40 age group, 6 respondents in the 40-50 age group, and 10 respondents in the 50 and above age group (Table 12).

Table 12: Basic information about respondents involved

Items		Numbers
Valid Questionnaires		26
Gender	Male	16
	Female	10
Dwelling period (Year)	1-2	5
	2-3	10
	3-4	8
	4 and above	3
Educational background	Secondary school and below	7
	Higher education	3
	Bachelor degree	8
	Master Degree or above	8
Average age	20-30	0
	30-40	4
	40-50	12
	50+	10

The first stage of the investigation focused on choosing the interview sites and preparing the questionnaires. Based on the initial investigation, the main interview sites were located on the roads with trench systems and paths near the waterscape because they contain the most visible information about stormwater management. Additionally, the basic qualification of target groups is that they should have lived in the communities for at least one year. According to the statistics, the important question regarding visible function, namely "Did you gain knowledge from the surrounding environment how the stormwater management works", received 20 positive answers. In terms of the question about open space quality, namely "Please evaluate the aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?" 10 respondents offered grade 5, 15 respondents give grade 4, and one respondent chooses grade 3 (Table 13).

Table 13: Content of questionnaires and answers of respondents

Categories	**Questions**	**Answers**	**Results**
stormwater management system	How long do you spend outdoors in this community per week?	Less than 1 hour	6
		1-2 hours	4
		2-3 hours	0
		3-4 hours	4
		Longer than 4 hours	12
	Where did you learn the meaning of stormwater management?	Media	6
		Surrounding environment	10
		Neighbourhood	9
		Others	1
		Not at all	0

	What is your favourite kind of activity in this site	Walking	14
		Sitting	8
		Overlooking Viewing the landscape	0
		Don't Care	4
	Did you gain knowledge from the surrounding environment how the stormwater management works?	Yes	20
		No	6
	Have you become more concerned with the urban rainwater issues since you have been living here?	Yes	18
		No	8
Open space quality	Which landscape element would be your favourite?	Plant borders	8
		Peaceful rainwater pond	6
		Broad lawn	4
		Rainwater square	2
		Shady path	6
	Which landscape components should be improved?	Water body	10
		Plant system	12
		Road	0
		Lawn	4
	Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which scores do you give?	Very high (5 Points)	10
		Quite high(4 Points)	15
		Moderate(3 Points)	1
		Quite low(2 Points)	0
		Very low(1 Points)	0
	Do you think the project is going to be a classical, comparing with other similar projects in China?	Yes	16
		No	4
		Not Sure	6

4.3.5 Final conclusion

All three communities provide a well-functioning water management system, which combines plant systems and facilities with low technological requirements. In terms of stormwater management system, this analysis is able to answer the first part of the research question. The communities provide a resilient landscape as a result of a water-sensitive concept. Due to low technological requirements and the combination with green infrastructure, the investment costs for the stormwater management system have been reduced to a minimum, while efficiency has been increased. In brief, the communities have a capacity to provide new means of achieving stormwater management system in a sustainable fashion.

These practical and visible strategies have also contributed to some concrete advantages in terms of open space quality. By outlining the discussion, the response to the second part of the research question can be highlighted. The communities have achieved two vital components, namely public infrastructure and nature pleasure. The public infrastructure and buildings frame the open space in the communities. As a result of this, the open space systems can be categorized in distinctive spatial types, and have developed coherent, distinctive, and recognizable green spaces. In terms of nature pleasure, the high density, diversity and appropriate distribution of plant groups have been highlighted. The advantages of waterscape have also been discussed, such as this integration between the waterscapes and plants significantly increases the performance in terms of aesthetical value.

The achievements of stormwater management system and aesthetic value considerably increases the evaluation of explicitness and accentuation. The above description pointed out that high accessibility facilitates the public's appreciation of a landscape. The explicitness has been greatly influenced by the trench systems and waterscape. The discussion listed four main points: visible functioning of the trench systems, the connection between the trench systems and the water catchment, the combination between plants and trenches, and the waterscape's function. These points released that the practical and visible features are two basic requirements of a high explicitness. The evaluation of accentuation replies on five contrasting ways in this case, including materials, dimension, colours, distribution, and finally highly distinctive space features. These contrasting strategies contribute to a high accentuation physically on the vital components of stormwater management, and also psychologically on facilitating the establishment of individual cognitive map. This mental map can allow respondents to have a more distinctive understanding on functionalities of stormwater management. Finally, based on the analysis above, people can easily notice, appreciate and trace the processes of stormwater management.

The evaluation on the coherence and legibility of stormwater management has been made on the basis of the conclusion of four landscape preferences, namely explicitness and accentuation. They offer a relative higher coherent and legible landscape of stormwater management in the communities. The visible function (referring to explicitness) contribute to the coherent features of water management, including repeated, ordered, rhythmic, whereas the performance of legibility is influenced by the preferences of open space quality (accentuation), including materials, dimension, colours, and distinctive space features. However, the boundaries between legibility and coherence are always blurred and muddled. For instance, the accentuated landscape also provides a visual focus that highlights the construction of a coherent landscape because this focus guides peoples' attention to the more meaningful landscape components.

Iron fences and wall enclose the boundaries between the social surrounding urban environment and the communities. Because of water pollution, Feng Chan River, as an important boundary and ecological bridge, cannot play its role at all. In the view of urban context, the surrounding environment of the communities lacks a high quantity and quality of stormwater management infrastructure. Streets, communities, and even broader environment rely only on undeveloped sewer lines to remove rainfall. They have not sufficient recreational and green amenities as well.

The discussion on questionnaires shows more detail information and significant data. The public replies to the question about visible functionalities, namely*" Did you gain knowledge from the surrounding environment how the stormwater management works?*" show that there are only 6 respondents (20%) gave negative answers. Another question, namely "*Please evaluate the* *aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?"* displays that at least 60 percentage did not grade 5 points. This research suggest that there are five main disadvantages which have decreased the public evaluation, including lack of interesting details in the trench systems, connection directly with urban sewer lines, polluted river water, and unspecified functional connection between waterscape and green open space.

In brief, the Zhangjiawo Communities provide a new possible solution to answer the research question referring to stormwater management system, and perception. They are different from the National wetland park in Harbin, which adopts open space quality natural-predominant strategies; from the Tianjin Cultural Park and Yong You Software Park, which are equipped with the engineering systems for water treatment and also from Guyue and Shuangzi communities in which the engineering collaboration are a main solution.

4.4 Tianjin Cultural Park

4.4.1 Background and introductions

The Tianjin Culture Park was established in the Hexi District of Tianjin City (Figure 44a-b) and is located in a dense commercial and residential urban zone (Figure 44-c) between the City Opera House and City Hall (Figure 44-d).

Figure 44a: Location of Tianjin (Map data: Google, Digital Globe)

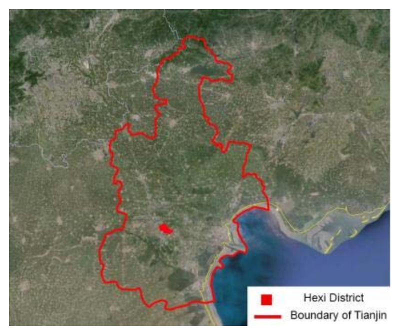


Figure 44b: Location of Hexi District in Tianjin (Map data: Google, Digital Globe)

Figure 44c: Location of the Cultural Park in Tianjin (Map data: Google, Digital Globe)

Figure 44d: Plan of Tianjin Cultural Park (Map data: Google, Digital Globe)

The whole project, covering approximately 0.9 km2, was expected to play an important role in public recreational activities. The client, namely Tianjin Government, commissioned Atelier

Dreiseitl Company to create the landscape design for this site. The whole project was completed in 2012. This region's landscape previously included a huge area of natural lake with polluted wasteland. Clearly it was necessary to look ahead and envisage a new blueprint for the future (Dreiseitl 2008).

4.4.2 Design challenges and responses

The climatic features in northern China mentioned above always exert their influence on urban planning strategies and represent a potential threat to citizens' safety. These features include high annual precipitation, uneven rainfall distribution, and extreme precipitation patterns. These geophysical challenges and the current water crisis have resulted in a strong social call for change, which drove the governors to consider a decentralised stormwater management concept. For this reason, a project must adopt a water-sensitive concept for being realised.

The designers attempted to establish a memorable park with complete stormwater management system, providing a satisfying educational platform, suitable space for public activities and recreational value. Nevertheless, there were several challenges that had to be dealt with before the park could be constructed. 1) Because the park is located within an intensive commercial and residential zone, it was worthwhile for the designers to consider how to organise traffic systems in such a way as to produce more public convenience and foster communication. 2) The second challenge was to create a design concept that would appeal to the public and at the same time enhance the cultural atmosphere. 3) The third challenge was how to accentuate the new local identity by combining stormwater management and public amenities.

In terms of the second and third challenges, it was only when these ecological considerations were combined with the need to express the specific local identity that the design concept was able to break up the fundamental boundaries and conflicts between "soft" ecological functions and "hard" artificial instruments and between the wish to create a landscape pleasant for people and a dynamic and sustainable ecological system. Confronted with these challenges, the designers provided integrated design strategies, such as a circular traffic system, recreational infrastructure in various types of space, and the construction of a new and sustainable hydrological strategy that was able to strengthen the local identity as well.

4.4.3 Analysis of investigations

4.4.3.1 Description and personal evaluation of stormwater management system

The designers modified the landscape elements in the existing environment in order to create a new, iconic landscape. In terms of the rainwater management system, the influence of artificial facilities used in this project to achieve stormwater management is now greater than that of the green infrastructure components. The urban park, with the help of the engineering instruments, now meets the basic demands of stormwater management system, including the improvement of water quality and the prevention of flooding.

- **Description of the stormwater management system**

Two main aspects of a rainwater management system were discussed in Chapter 2, namely green infrastructure and artificial water facilities. Figure 45 shows how the artificial facilities in the Cultural Park participate in the water management processes.

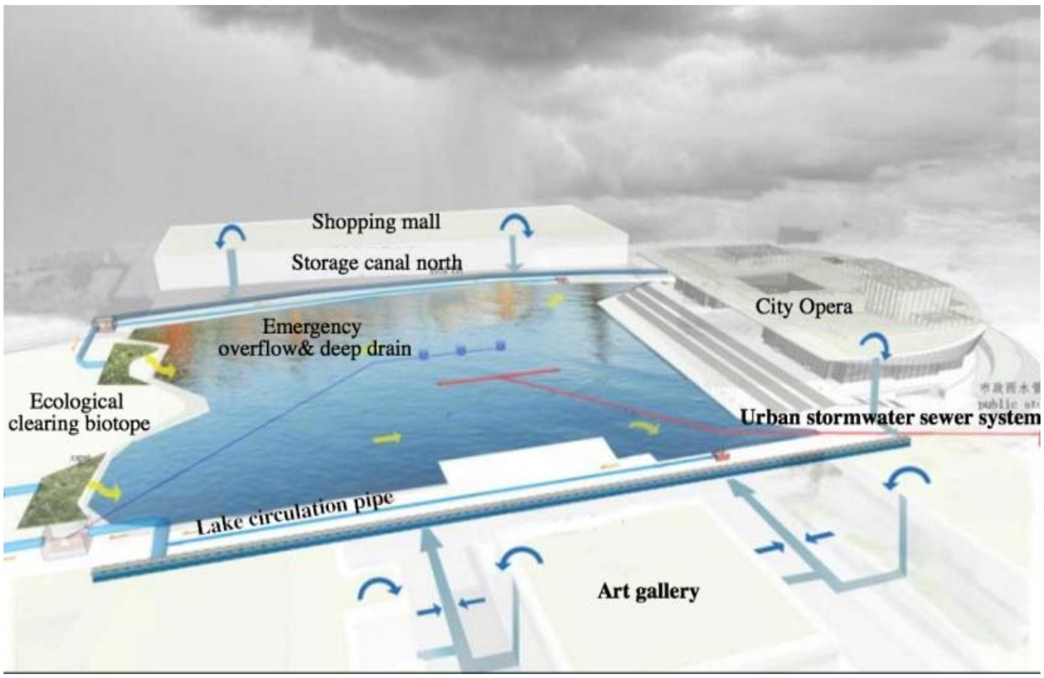


Figure 45: Park employs engineering systems for facing flood threat (Dreiseitl 2012)

There was a natural lake in the original terrain. This was not preserved in the new design, since this lake was polluted and had no viable ecological system. Figure 46 a-d shows how the terrain changed. The terrain modifications were intended to build a new, vibrant waterscape and to establish a well-functioning rainwater management system. Finally, the park plan shows that this new artificial lake, covering about 20 percent of the whole park area, has been built between the opera and green landscape as the park's functional and geographical heart (Figure 47).

Figure 46a: Existing terrain in 2008 (Map data: Google, Digital Globe)

Figure 46b: Constructing Cultural Park in 2009 (Map data: Google, Digital Globe)

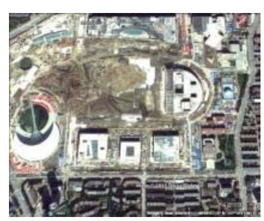


Figure 46c: Constructing Cultural Park in 2011 (Map data: Google, Digital Globe)

Figure 46d: Establishment of Cultural Park in 2012 (Map data: Google, Digital Globe)

The banks of the central lake, adjacent to the ordered plant groups, are planted with grass and a diversity of plants (Figure 48). This landscape includes large numbers of aquatic plants, shrubs, and several kinds of trees. The rainfall in this area either seeps into the central lake after infiltrating the soft bank or permeates into the soil. The landscape reveals much information about the ecological water cycle.

The water loss from evaporation and leakage is faster than rainwater refill (Dreiseitl and Grau 2009). So the practical strategy was proposed of employing engineering works to replenish the water body and maintain the waterscape. The instruments include a skimmer, recycled water circulation, and greywater conveyance systems. In case of extreme weather, additionally, an emergency overflow outlet has also been built in the lake. The relevant reports about the system's performance have not yet been published, however local news media have praised its ability to prevent urban floods (Wei 2013; Wu and Yang 2014).

Figure 47: Plan of Tianjin Cultural Park and City Opera House (drawn on the basis of Dreiseitl 2012 and Google map)

Figure 48: Natural landscape in Cultural Park

Figure 49: Bare soil of the plant beds on the promenade

As Figure 49 shows, the soil in the plant beds on the banks of the waterscape is not yet covered by vegetation. In addition, no swale or gravel trenches were established in the park as a means of conveying rainwater runoff. Consequently, lacking treatment, rainfall containing contaminants flushes off the roofs and streets and runs into the water catchment. The plant beds can decrease the rate of surface runoff, but remove very little of the contaminated substances in the rainfall runoff, meaning that the water quality is not as a high as it would be if it were treated.

At present, the main means of replenishing the lake relies only on collecting rainwater and conveying recycled water from a water treatment plant outside the park. The weather statistics show that the dry seasons are far longer than the rainy months, which means that there is not enough rainfall to support the waterscape. Therefore, a conveyance system needs to be built for transporting additional water.

- **Personal evaluation of stormwater management system**

In brief, aiming to remove the threat of flooding, the designers changed the original terrain, looking for an effective and suitable water strategy. The landscape elements such as the green bank are a supplement to the engineering water systems. The engineering constructions, such as the conveyance systems and the emergency overflow, play a significant role in maintaining the stormwater management system. In particular, the artificial lake is designed as a spatial bridge between the Tianjin Opera House and the park's natural landscape. However, the disadvantage is that the water management lacks an efficient infiltration and conveyance system. Assuming that an open trench system could be built, the rainfall from the roofs and streets could be conveyed by an open swale, and then either flow into the central lake or permeate the trench system's gravel (Dreiseitl 2012). To sum up, the project's stormwater management performance has turned out to be efficient and satisfactory.

4.4.3.2 Description and personal evaluation of open space quality

- **Description of open space quality**

1) Public infrastructure:

The quantity and categories of the facilities in this park meet the basic public needs. The main practical amenities, including benches, steps, and wooden paths, are mainly distributed around the central lake. In addition, some art works have also been built in order to highlight the cultural atmosphere, for instance, visitors can see an array of sculptures arranged on the promenade in front of the different buildings (Figure 50). At the same time, the park also provides sufficient public spaces, in case citizens want to hold urban festivals or ceremonies (Figure 51).

The spaces of this park are outlined by landscape elements, such as plant beds, trees, and, sculptures on the promenades in order to create various space categories for an enjoyable experience: a series of small squares, semi-private spaces, and linear spaces divided by belts of trees. The promenades themselves are also divided into different spatial types by linear plant beds (Figure52).

2) Nature pleasure:

The plant patterns fall into several categories, including roadside trees, solitary landscape trees, flower and lawn strips and aquatic plants (Figure 53a-c). The array and distribution of plants are elaborately designed in order to emphasise the central lake waterscape and to keep the balance of spatial types (Figure 54).


Figure 50: Sculpture in Cultural Park


Figure 51: Sufficient space for public activity


Figure 52: Changes of space on promenades created by plants


Figure 53a: Roadside trees


Figure 53b: Solitary landscape trees


Figure 53c: Flowers, grass and aquatic plants

Figure 54: Visitors' viewing sites of the waterscape (Map data: Google, Digital Globe)

The central lake is visually emphasized by public infrastructure, spatial categories, and plant patterns. Aiming to add more detailed design, some plant beds with flourishing plants are also set in the water (Figure 55). For instance, aquatic plants such as lotus flowers grow naturally in the lake. Additionally, the plant groups in this landscape are well maintained (Figure 56 a-c).

Figure 55: Lotus and plant beds in the waterscape

Figure 56a: Removing waste from the water

Figure 56b: Watering trees

Figure 56c: Watering roadside trees

3) Accessibility:

The requirement of high accessibility was responded to by erecting a circular promenade and open borders to the park. The park borders on a commercial zone with many office buildings and aims to deal with the challenges of a high rate of visitors. Two strategies were adopted, allowing the park to be integrated into the urban context. The park is accessible from the nearby streets (Figure 57).

Figure 57: Open access to park behind the opera

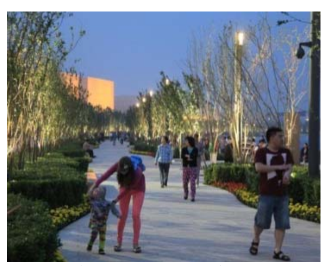


Figure 58: Convenient communication space (Dreiseitl 2008)

Figure 59: Visitors enjoying full view of waterscape

Everyone can walk freely into the park and across to another urban block or just take a break in the park. Second, a circular promenade has been built, and is complemented by a considerable number of shady paths. This openness and the circular promenade lead to high accessibility.

- **Personal evaluation of open space quality**

The sculptures and other amenities have a highly aesthetic value with different graceful shapes, and have a certain degree of attractiveness. In addition, the whole park contains distinctive spatial types connecting with the promenade, which are expected to develop into a communicative and pleasant public space with rich potential for social functions (Figure 58).

Figure 60: Simple plant landscape on the promenade

Figure 61: Easier accessible water landscape

In response to public demands, the series of squares creates a pleasant atmosphere for public activities. In addition, the promenades themselves also have rhythmic space changes created by plant beds, and at the same time they connect spatially with the central lake by long steps that allow people to enjoy a full view of the waterscape (Figure 59).

The plant groups were designed to accentuate the landscape axis; however, this also results in a decrease of plant diversity and a restriction of plant arrays on the promenades to a certain degree (Figure 59). Additionally, plants are selected carefully to improve the open space quality as much as possible. However, the aesthetic value of the plant patterns is not impressive, because of the reduced plant diversity and orderly nature of the plant arrangements.

As a vital component of the park, the dynamic waterscape in the centre of the park has become a landscape focus, and a crucial part of the park's stormwater management. Indeed, water can strongly impact on the visitors' emotions and perceptions. In particular, plant beds on the water surface, aquatic plants, as well as the huge dimension and dynamics of the water expanse can produce seasonal changes and a strong landscape impression. On the other hand, due to its huge dimensions, the waterscape can probably cause visual fatigue when people stand on the bank and experience the waterscape. But in general the local inhabitants like staying in the park and sitting next to the lake for communication, contemplation, and recreational purposes, since such a waterscape still holds a strong attraction for them (Figure 61).

As far as the cultural context is concerned, the buildings include a museum, an art gallery and a library and thereby introduce a cultural atmosphere to the park. However, the cultural identity needs to be built into, and fully integrated within, the landscape concept.

All in all, the case also shows that even if explicitness receives a low evaluation, the sophisticated accentuation of the stormwater management components can result in a good evaluation. There are two main strategies which aim to highlight the water body in this case: the first one is to guide the visitors' attention to the waterscape. It could be seen that the sculptures and open borders attract people to visit and walk in the park. Their attention and gaze eventually fall on the central lake since it is highly accentuated by spatial management, plant distribution, and road design. The second one is the contrast of dimension and materials. For building an exciting and dynamic landscape, the green land with its variety of plants and the opera house have been placed at opposite side of the lake. The designers have opposed the "soft" green infrastructure covering a limited area and the “hard” landscape with its huge dimensions. This contrast also achieves a balance among the landscape components. The two distinctive methods contribute to accentuation of the water body.

4.4.3.3 Analysis of landscape perception in Tianjin Cultural Park

- **Coherence and legibility**

This park is equipped with a concise stormwater management structure with clearly ordered space types and a landscape formation which can inspire people to understand the function of stormwater management. However, regarding details the park does not present a coherent context.

The central lake can contribute significantly to enabling people to complete their mental maps of a stormwater management system. Human emotions such as imagination, perception, and appreciation are stimulated when faced with such a significant component of a stormwater management system. However, the quality and quantity of visible landscape components in the stormwater management system does not attain an ideal level and, consequently, the legibility does not receive a high evaluation. People find it hard to appreciate the waterscape’s aesthetic value, and also do not truly grasp the significance of the central lake in relation to the stormwater management in a short space of time. Another aspect is that the waterscape’s huge size, accompanied by a lack of attractive details, might cause visual fatigue.

In sum, as far as coherence is concerned, the order and rhythm of the landscape components are not elaborately designed in this case. People find it hard to establish a cognitive map to perceive the stormwater management system as a whole if they do not visit or stay in the park frequently and over a long period. The good accentuation results from significant attractive landscape components such as the artificial lake. This leads to a positive atmosphere, so that the central lake can inspire individuals or interview groups to “read” the legible details. The landscape axes as a visual focus create a significant spatial contrast between the waterscape and ‘hard’ park components.

4.4.4 Introduction to questionnaires

A total of 26 questionnaires were filled in, 13 women and 13 men. Regarding the age of respondents, the questionnaires involved 10 respondents in the age bracket 20-30 years, 4 respondents in the group 30-40 years, 4 proponents in the age bracket 40-50 years, and 8 respondents older than 50 (Table 14).

Table 14: Basic information of respondents involved

Items		Numbers
Valid questionnaires		26
Gender	Male	13
	Female	13
length of residence in the district (years)	1-2	3
	2-3	12
	3-4	5
	4 and above	6
Educational background	Secondary school and below	9
	Higher education	3
	Bachelor's degree	3
	Master's degree or higher	11
Average age	20-30	10
	30-40	4
	40-50	4
	50+	8

Based on the preliminary investigation, the wooden path connecting to the park's green landscape was chosen as the interview site (Figure 62). The vital components of the stormwater management can be seen when people stand on this path. The significant qualifications of the target group were that they should be local residents living in this district rather than visitors or employees.

In terms of questionnaire results, Table 15 displays the statistical details of the questionnaire result with regard to the two vital components, namely visible function and open space quality. There are 16 positive and 10 negative replies to the question, namely "*Did you gain knowledge from the surrounding environment about how the stormwater management works"*. In response to another question, namely "*Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score do you give?*", 2 respondents gave the best grade, 12 respondents gave 4 points, 7 respondents chose grade 3, and 5 respondents awarded grade 2.


Figure 62a: Interview site nearby waterscape connects with semi-natural landscape (Drawn on the basis of Google map)


Figure 62b: Interview site in the Cultural Park


Figure 62c: Landscape surrounding the interview site

Table 15: Content of questionnaires and answers of respondents

Categories	Questions	Answers	Respondents
stormwater management system	How long do you spend outdoors in this park per week?	Less than 1 hour	6
		1-2 hours	10
		2-3 hours	4
		3-4 hours	1
		Longer than 4 hours	5
	Where did you learn about the meaning of stormwater management?	Media	6
		Surrounding environment	9
		Neighbourhood	9
		Others	1
		Not at all	1
	What is your favourite kind of movement in this site?	Walking	13
		Sitting	5
		Looking	6
		Don't Care	2
	Did you gain knowledge from the surrounding environment about how the stormwater management works?	Yes	16
		No	10
	Have you become more concerned with the urban rainwater issues since you have been living here?	Yes	16
		No	10
Open space quality	Which landscape element would be your favourite?	Plant borders	13
		A peaceful rainwater water body	4
		A broad lawn	3
		A rainwater square	3
	Which landscape components should be improved?	Shady path	3
		Water body	10
		Plant system	6
		Road	6
		Lawn	4
	Please evaluate the aesthetic value of the stormwater management system with a score from 1-5.Which score do you give?	Very high (5 points)	2
		Quite high (4 points)	12
		Moderate (3 points)	7
		Quite low (2 points)	5
		Very low (1 points)	0
	Do you think the project is going to be a classical, comparing with other similar projects in China?	Yes	6
		No	1
		Not Sure	19

4.4.5 Final conclusions

As mentioned above, the weather challenges and local water crisis continue to impact on the vernacular history and the physical environment in the area of the Tianjin Cultural Park. Three aspects of these issues have been considered, the path network design, the improvement of the recreational infrastructure, and the restoration of local ecological systems.

The strategies have been fully described and discussed in the section on the stormwater management system and open space quality. The stormwater management system relies greatly on the engineering collaboration. The collection of rainfall from the street and ground takes advantage of the sloping terrain, which allows rainwater to flow into the lake without the need for any particular purification.

In terms of open space quality, three points are emphasized: 1) the quality and quantity of recreational infrastructure involves two main components: public infrastructure and the management of open spaces. The park's public infrastructure meets basic public demands. In particular, although the sculptures standing on the promenade are not truly impressive, they still attract people to walk in the park and accentuate the cultural atmosphere. The distribution of space is on three levels, namely the finer square in front of the buildings for public activities or ceremonies, the linear spaces on the promenade for appreciating the waterscape and the huge lake as a landscape axis. These dimensional levels produce a pleasant atmosphere for communication. 2) Two vital preferences have been discussed in this section with respect to open space quality. Specifically, the restricted arrangements of the plant and the limited numbers of species create low landscape values. On the other hand, the waterscape is accentuated through the management of plant species. The waterscape's attractiveness is the main pillar of the park's open space quality. 3) Apart from the large size of the waterscape, the park's cultural identity has not been integrated into the stormwater management landscape due to the loose integration of the landscape components.

The open boundary and circular promenade guarantee high accessibility. Nevertheless, the high accessibility does not lead to a high explicitness, while it still has an advantage, namely the park's landscape focus, the waterscape. The functions of the stormwater management system, negatively affected by the weak explicitness, are not displayed visually by means of interesting and observable landscape details. Legibility is improved by the waterscape's huge dimensions as a significant component of the stormwater management, whereas coherence suffers from the lower marks for explicitness.

Additionally, the questionnaire shows that 38 percent of the respondents answered the question in the negative, namely *did you gain knowledge from the surrounding environment about how the stormwater management works*. In the surrounding environment, the second question – regarding open space quality, namely *Please evaluate the aesthetic value of the stormwater management system with a score from 1-5.Which score do you give* – received five points only twice, four points 12 times, and less than four points 12 times. The design description and the evaluation by members of the public show that among the six northern Chinese cases, the Tianjin Cultural Park remains at a middle level regarding visible function and open space quality.

4.5 Yongyou Software Park

4.5.1 Background and introduction to Yongyou Software Park

The three remaining cases, namely Yongyou Software Park, the Guyue community and the Shuangzi Community are located in Beijing, the capital of the People's Republic of China (PRC). Yongyou Software Park is located in the Haidian District of this metropolis (Figure 63 a-d).

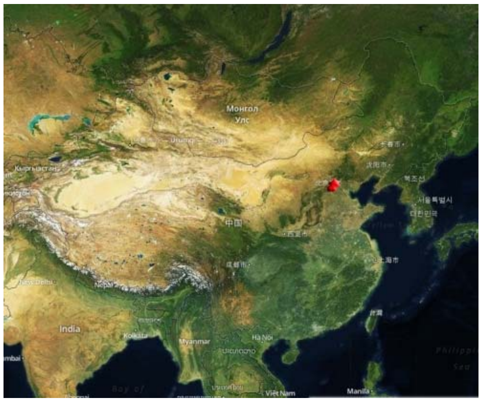


Figure 63a: Location of Beijing (Map data: Google, Digital Globe)

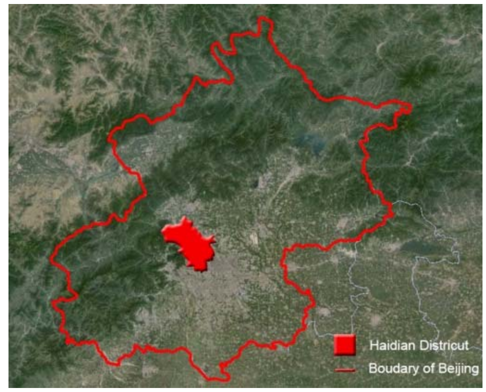


Figure 63b: Location of Haidian district in Beijing (Map data: Google, Digital Globe)

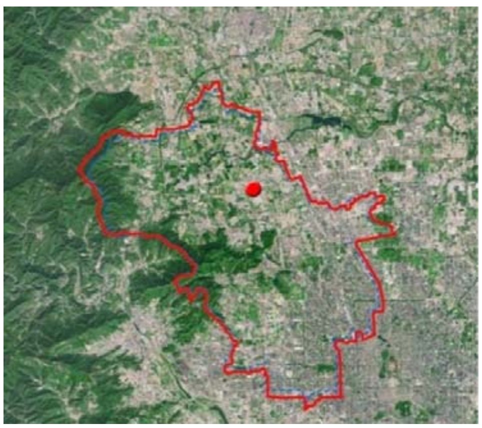


Figure 63c: Location of the Yongyou Software Park (Map data: Google, Digital Globe)

Figure 63d: Yongyou Software Park (Map data: Google, Digital Globe)

Beijing, with a total area of approximately 16410 km^2, is surrounded by Hebei Province and borders on Tianjin City. Based on the latest demographic statistics, the population of Beijing exceeded 21 million in 2013, which is 0.45 million more than in 2012 (Xia 2013). Figure 64 shows the changes of demographic population in Beijing between 1979 and 2012. The local climatic features are similar to those of other northern Chinese cities, with distinct seasonal climatic changes, uneven rainfall distribution, and extreme precipitation in certain months (Xie and Wang 1995). In particular, the statistics of the monthly rainfall distribution in Beijing shows Beijing's rainfall concentrates on the three summer months (Figure 65).

Haidian District with its total area of 426 km^2 is one of the sixteen districts of Beijing. The demographic census in 2010 showed that there are 3.2 million permanent residents living in this district, which is 1.4 million more than in the census in 2000. The annual population growth rate has reached 3.9% (Li and Lin 2011). In terms of water resources, compared to other districts in Beijing, Haidian has more abundant water resources and encompasses the largest area of water in Beijing (Liang et al. 2012). The lakes include Kunming Lake, Yuyuan Tan, Fu Hai and the Shuang Zhuang Reservoir. The water diversion canal systems are made up of Jing Mi, Chang He, and Yong Ding. They play a significant role in terms of the urban landscape, water supply, and farm irrigation. Even so, being similar to other districts, Haidian has still gone through various water crises.

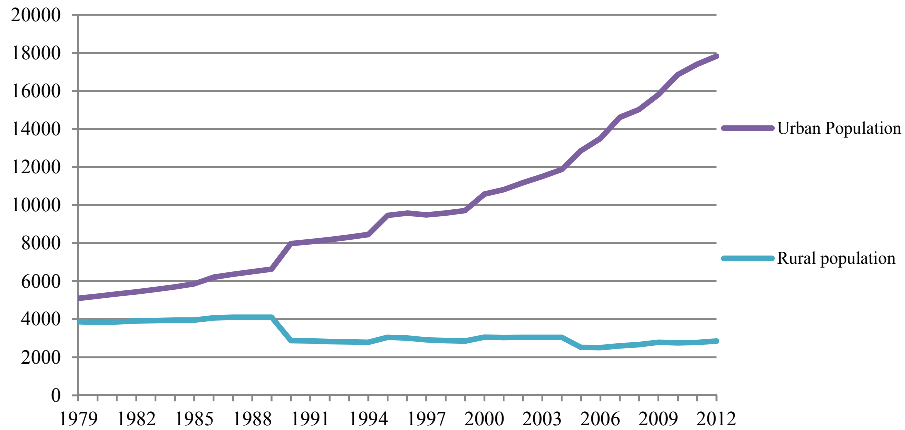


Figure 64: Increase of Beijing Population from 1979 to 2012 in thousands (Beijing Municipal Bureau of Statistics 2008)

Therefore, the three cases in Beijing (Yongyou Software Park, Guyue Community, and Shuangzi Community) have a common goal to improve the local stormwater management system. Regarding Yongyou Software Park, the owner of Yongyou Software Co., Ltd. (formerly UFIDA Software Co., Ltd.), established in 1988, is a prestigious software company. Within a rapid development during the past 25 years it has already built a broad technological background and has a solid financial basis, so they are also establish a complicate engineering energy system for achieving a good stormwater management system. The company governors believe that this integrated strategy not only contributes to the local stormwater management system, but also can enhance their brand value. The systematic water and energy management applied in the investigated zone has three vital components; a pumping system fuelled by geothermal energy, and integrated rainwater management engineering, and an energy conversion system (Yongyou 2013).

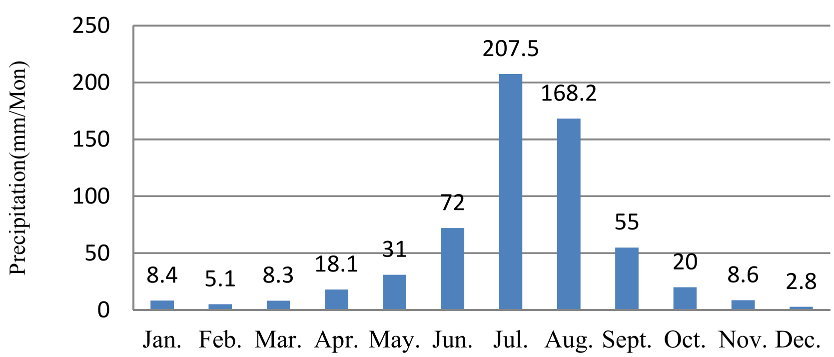


Figure 65: Average monthly rainfall distributions in Beijing from 2005 to 2010 (Guo, Liu et al. 2011)

From 2003 on the company commissioned Zhang Yonghe, a prestigious architect and chief designer of Atelier FCJZ and the dean of the Architecture Faculty at MIT, to design new company buildings and environments in the first phase.

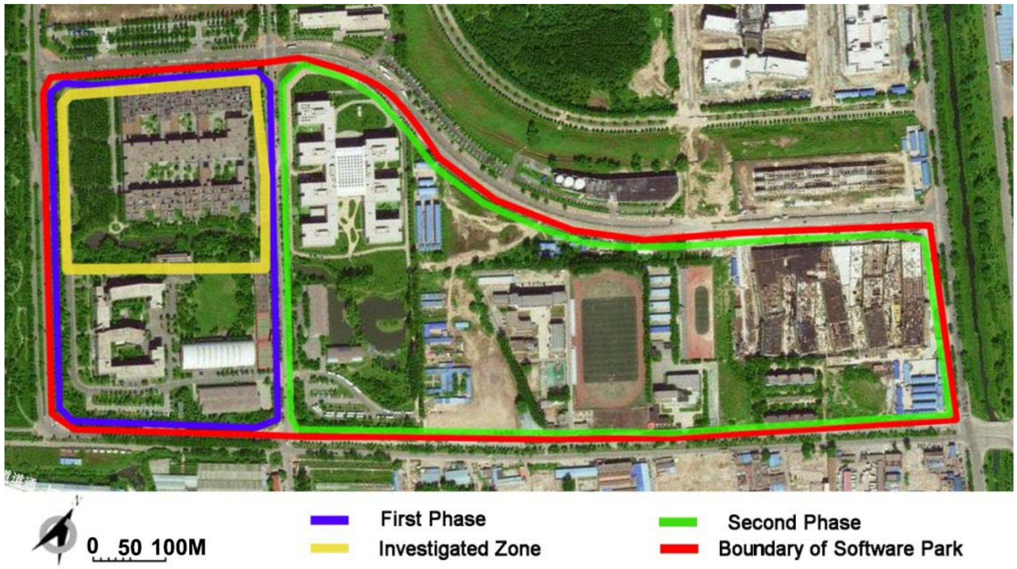


Figure 66: First and second phase of UF Soft R&D Centre (Drawn on the basis of Google Map)

The new software park is required to meet the integration of social values, corporate culture, and the functions of water management (Zhou 2008). This first phase, which was constructed over less than two years, from 2005 to 2007, covers an area of approximately 46122 m^2, and the building area is 15,347 m^2 (Frontmedia 2008). The second stage with a total construction area of 67,869 m^2 has come into service since 2011. Both stages are equipped with a rainwater management system (Figure 66).

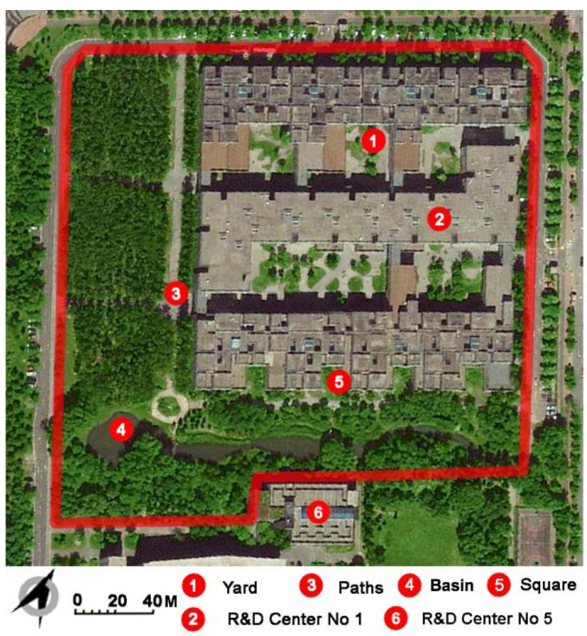


Figure 67: Courtyard of the UF Soft R&D Centre No. 1 (Drawn on the basis of Google Map)

The research will largely focus on the first phase, namely UF Soft R&D Centre No.1 (Figure 67). The main reasons are that a complete and typical stormwater management system has been built in the Centre No. 1 and urban design also has a distinctive design style and a characteristic landscape identity which significantly influences the stormwater management.

4.5.2 Design challenges and responses of Yongyou Software Park

In recent years, huge potential challenges regarding rainwater have emerged. In particular, Figure 68 shows that Beijing population concentration has distinctive features, such as a dense and uneven population distribution. In particular, it shows that the approximate density of Haidian's resident population, 7617 people per km^2, lies the second highest in Beijing. The 1.8 million urban inhabitants account for 86.3% of Haidian's population, and the average population density in 2013 is 1289 per km^2 (Xia 2013).

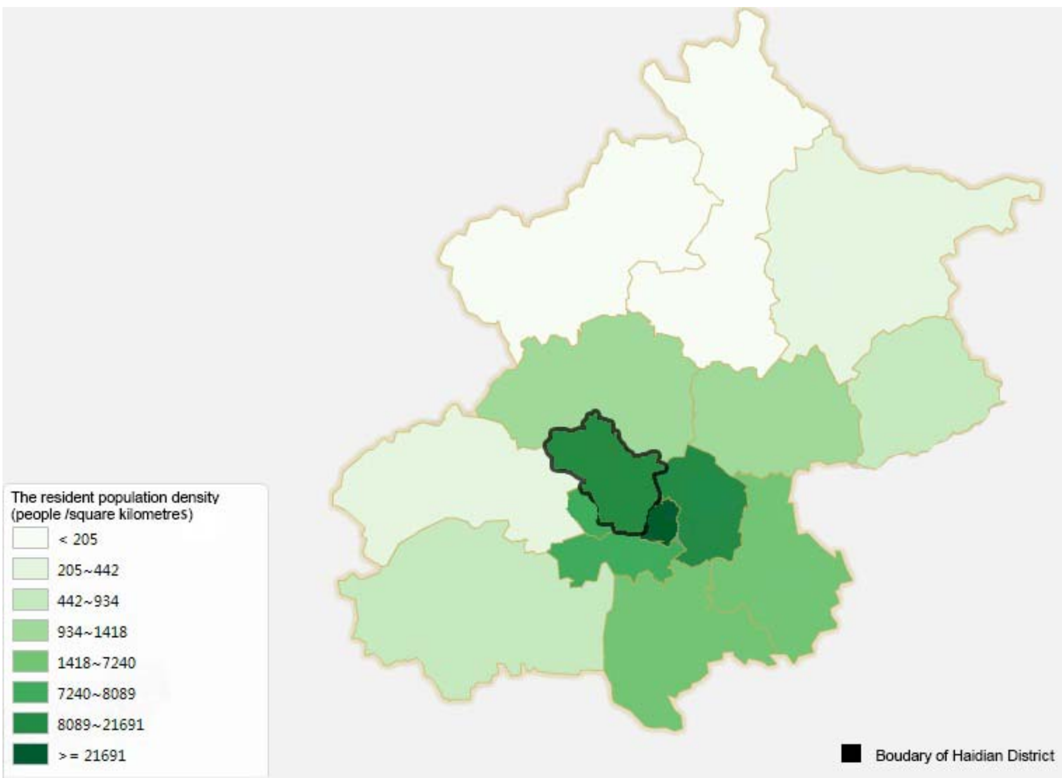


Figure 68: Uneven resident population density of sixteen districts of Beijing, including Haidian in people per square kilometres (Xia 2013)

Thus the chosen cases in this research are being confronted with the common demographic challenges, and increasingly so. A dense population interweaves with the impact of climatic features, inadequate financial investment and inappropriate urban planning perspectives, which are already generating new challenges. The challenges have caused an overburdening of the basic infrastructure, serious pollution, and a blindly repetitive urban construction. Consequently, the water crisis, which leads to an overloading of the municipal sewer systems, frequent urban floods, shortages of water and ecological deterioration, has resulted from rapid urbanization, attributable to the predominant concept of the priority of economic development over the environment. For example, on July 21st, 2012, a huge flood hit urban zones of Beijing, causing the death of 80 people and direct economic losses amounting to nearly 1.3 billion Euros within twenty hours (Er and Tian, 2012; Tian and Ni, 2013).

These consequences drive governors and experts to reconsider the existing strategies, and to look forward to new alternatives that can respond effectively to the crisis by way of a decentralized stormwater management. For this reason, the stormwater management system of Yongyou Software Park is expected to be equipped with a highly efficient water treatment system and good open space quality. In addition, the designer had to concentrate on other practical requirements as well, such as the establishment of a pleasant atmosphere, communication spaces, and accentuating the company's identity.

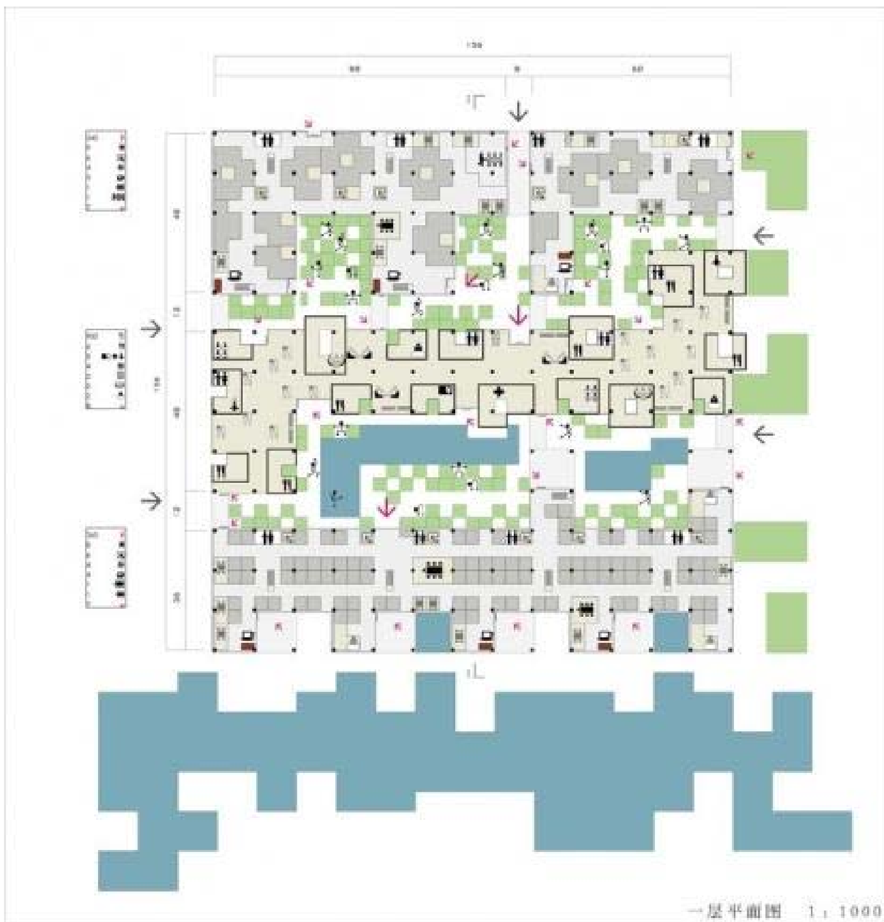


Figure 69: The 'fabric building' and its open space systems laid out in a grid system (Zhang, 2008)

The new design principle is proposed on the basis of a large number of investigations into working models. Considering the ways in which programmers typically work, including flexibility, spontaneity and independence, the designers adopted the concept of a "fabric building" (or "mat building"), which focuses more on socio-programmatic activities (i.e. social and work activities), with the aim of inspiring more social interaction at work, of interweaving the exterior and interior environments of generally low buildings, and of producing a unique visual identity.

Aiming to meet the requirements, the whole project follows the concept of "fabric building" and is constructed on the basis of "an accurate grid", and creates more flowing open spaces in order to meet the social function, namely "social-programmatic" ones (Zhang, 2008) (Figure 69). All buildings have only three stories, aiming to deal with different employees' working types in a regular software project. Three kinds of facade designs convey symbolically visual signs that are echoed in the pavements of the adjacent courtyards and squares (Figure 70 a-b).

Figure 70a: Pavement and building surface in the yard

Figure 70b: Pavement and building surface in the square

More detail will be discussed in the paragraphs on open space quality. As far as the outdoor environment is concerned, two courtyards have been created between the main buildings in order to offer a convenient communication space. In order to create a healthy working atmosphere, fresh air, sunshine, and scenic landscapes are necessary. Therefore, the roof terrace, adequate lighting, and a linear water basin with dense plants have been included in the design proposals.

4.5.3 Analysis of investigations

4.5.3.1 Description and personal evaluation of stormwater management system

- Water management of the UF Soft R&D Centre No.1

In order to make the following description and evaluation easier, this section will include an introduction to the specific type of stormwater management in this project. The technological system includes three components: 1) rainwater collection, penetration and drainage system, 2) subsurface wastewater infiltration system, and 3) gravel layers for infiltration (Figure 71).

First, due to the differences in terrain height, the rainwater that is collected in an area of 1.5 hectares can flow into the water basin. The rainfall on the ground flows into the technological rainwater collection system. After a series of treatments to remove polluted substances, the rainwater is eventually collected in the basin.

Second, being similar to onsite wastewater treatment systems (OWTSs), the subsurface wastewater infiltration system also plays an important role. The original model was developed in Japan. Being continually innovated, the method has been applied worldwide (Chen and Yang, 2002). The classic treatment processes are generally performed by a series of underground ponds. There are generally four typical main components, the septic tank, capillary penetration-discharging band, a water storage pond, and a clean water pond. In this case, the wastewater from the buildings can be pumped into four capillary penetration systems through a septic tank and grid as the initial infiltration process. After the treatment through natural filtering performed by the capillary penetration and discharge band, the wastewater retained in the water storage ponds has become recycled water. Finally, the recycled water is concentrated in the clear storage ponds for car washing, for use in the waterscape and other purposes.

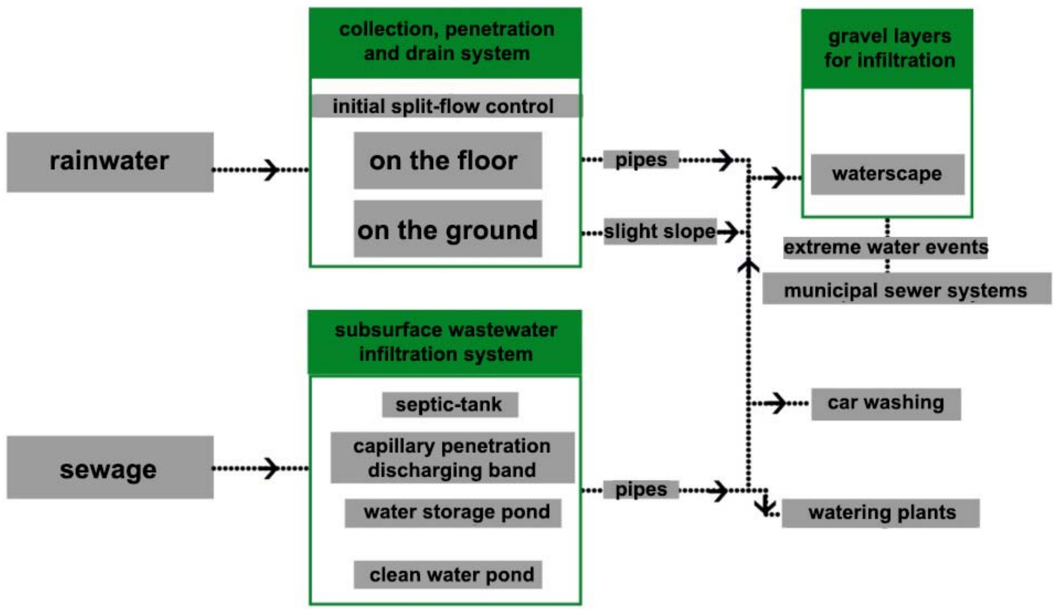


Figure 71: Relationship of three components (Drawn on the basis of Yongyou 2013)

Third, since it receives rainwater and recycled water, the basin needs to be equipped with a water filtration strategy which reduces water eutrophication. Gravel layers aim to take advantage of the physical features of gravel for improving water quality. The rainwater collection, penetration and drain system will be discussed with regard to the natural infrastructure, and the others will be mentioned in connection with technological solutions. The three systems combine with other engineering units and aim to build a pleasant working atmosphere with low ecological impact. The social value and landscape quality will be discussed in the following sections.

- Description of stormwater management system

1) Green infrastructure:

In terms of the waterscape, the linear water basin, with a length of 225 meters, is located between the first research building block No. 1 and the fifth research building block No. 5. Dense aquatic plants, green banks and plant systems construct an intensively planted waterscape (Figure 72). The public infrastructure, including benches, wooden viewing platforms and bridges, also contribute to improving the waterscape value. Water replenishment derives largely from rainwater and recycled water, as mentioned above. The rainwater can flow into the basin after infiltration in nature ways. The recycled water produced by a wastewater infiltration system is conveyed into the basin through pipes. Because of less maintenance, it has been observed that the basin water is eutrophic (Figure 73). The official documents show that the water cycle for infiltration through the gravel layer should last five days.

Figure 72: Natural landscape of the basin

Figure 73: The basin's eutrophic water

Figure 74: Space categories of the UF Soft R&D Centre No. 1 (Drawn on the basis of Google Map)

Figure 75: Plants in the courtyards

The dense plant systems contribute to efficient rainwater penetration and infiltration. For this purpose and landscape quality, different space types are equipped with distinctive plant patters. The open space has mainly four components, courtyards between buildings, buffer zones surrounding the basin, the linear space linking the courtyards as well as the basin and the plants of the waterscape (Figure 74).

First, each courtyard (125meters × 32meters) is ornamented with several trees, grass planting pavements and geometrically shaped sunken green land (Figure 75). Rainfall concentrates on this sunken land and penetrates into the ground. Second, the linear space linking the basin and the buildings offers a green coverage (Figure 76). The sycamores as roadside trees are set alongside the buildings, and at the other side there are shrubs so the aquatic plants of the basin produce a continuous green belt along the linear space for improving ecological functions. Designers manage to increase the area of permeable zone, such as building small areas of green squares with clusters of shrubs next to the entrances of the buildings (Figure 77).


Figure 76: Linear paths and green space


Figure 77: Small square next to the entrance of the building


Figure 78: Reeds as dominant elements in the waterscape


Figure 79: Shady green space

Third, the designers have arranged natural green components around the basin to develop a strong network of green infrastructure, including dense aquatic plants, trees and a natural bank, and have developed a buffer zone with a width of 10 to 15 meters. The buffer zone can play its role in case of extreme weather. Vegetation and tree groups covering this buffer zone combine with the dense and flourishing aquatic plants next to the research building centre No 1 (Figure 78). Compared to this side, the plant system growing on the other side of the buffer zone, mainly including trees and turf grass, provides a green shelter (Figure 79). Fourth, the reeds are the dominant aquatic plants in the basin. The four aspects show that the exterior environment is already equipped with a high green coverage rate, which nourishes the biological habitat and provides a complete natural water cycle.

2) Artificial water facilities:

This project adopts four methods, namely modifying terrain, building conveyance systems, technological engineering and maintaining water storage. The significant modification of terrain is to establish the basin for replacing previous terrain, namely a natural pond (Figure 80 a-d). In addition, the elevation of green land was changed to be relatively lower than paths and squares, which allow rainwater to flow into the basin. The conveyance systems were built for dealing with different situations and adopted two methods: 1) the rainwater and wastewater in the building, UF Soft R&D Centre No. 1, are collected and conveyed into several underground layers, and then retained in the basin as waterscape; 2) rainwater in the outdoor environment either seeps into the ground or flows unrestrictedly into the basin via the green spaces; 3) in terms of water storage, there are two methods of maintaining water in this project, namely the basin and the underground penetration and drainage system. They delay rainwater discharge into urban sewer networks, improve natural hydraulic systems and cultivate the ecological systems efficiently; 4) the energy conservation system plays an important role as well.

Figure 80a: Previous terrain in 2003 (Map data: Google, Digital Globe)

Figure 80b: Constructing the Park in 2005 (Map data: Google, Digital Globe Digital Globe)

Figure 80c: Constructing the Park in 2006 (Map data: Google, Digital Globe)

Figure 80d: Establishment of the Park in 2011 (Map data: Google, Digital Globe)

The investment in the above technological systems might not contribute a clear financial return. The financial investment in the stormwater management has reached 200 million Yuan. In terms of recycling rainwater, the annual goal for collecting rainwater lies theoretically at 12000m3, which would save approximately 64,000 Yuan per year. For the underground wastewater filtration system, the total financial investment was 1.4 million Yuan. The maintenance costs mainly include operational costs and energy consumption, generally reaching about 50,000 Yuan per year. The official documents also draw a comparison of costs between this system of recycled water supply and the traditional method, replenishment via tap water, which clearly shows that the value of the water management is more on the social and ecological level, rather than on a financial level.

In sum, the designers have established an effective and comprehensive water management system combining landscape design and engineering. The natural bank has reached high green coverage and coordinates with artificial facilities, for example by cooperating with the energy conversation systems. However, the maintenance of landscape elements in this project is not at a high level. For example, some plant groups are sparse and loose and need to be maintained more carefully. And the eutrophic basin water should receive more attention, as mentioned above.

- Personal evaluation about stormwater management system

A highly efficient water management has been established. The investigation shows that the water basin has the significant function of connecting the green infrastructure system with the technological equipment. The aquatic plants are linked with the two basin banks. The green infrastructure components, including aquatic plants, vegetation, trees and grass, integrate within the water management engineering systems. However, the plant maintenance is not at a high level for financial reasons. Even so, the careful terrain elevation supports the functions of the plant systems in achieving natural rainwater treatment. Moreover, the terrain changes are an economic and efficient method of removing or preventing waterlogging. The water storages comprising underground drainage water tanks have met the requirements of the water management. Since the water systems have been in operation, waterlogging has rarely occurred.

However, the visible functionalities of the rainwater infrastructure are not impressive and hardly recognizable. The natural infrastructure on the ground uses physical properties such as permeation, slight slopes, and underground soil filtration, to obtain low-cost and sustainable water treatment. The artificial systems, being buried underground or covered by buildings, are responsible for the collection, conveyance, and storage. The two distinctive systems have one common characteristic – that their operations are not easily perceived.

In addition, the network of the stormwater management system produces functional explicitness to a certain degree. However, parts of the network are buried and cannot easily be observed by the public. Thus, the processes for dealing with grey water are difficult for employees to observe and recognize. The water basin constitutes the main focus of the open space and the core of the visible rainwater treatment components, and the connection between this basin and the other components is fragile. Consequently, people have difficulty in understanding how the rainwater management system operates as a whole, too. So to sum up, although the whole solution, linking the green infrastructure and the technological components produces highly efficient rainwater treatment, this interlinking does not actually mean that all components are well integrated. Therefore, in terms of the visible components, their functions and features do not achieve high explicitness.

4.5.3.2 Description and personal evaluation of open space quality

Public infrastructure and nature pleasure are focused on, whereby the former discusses three aspects, namely aesthetic value, maintenance conditions, and spatial patterns, and the latter focuses on the management of natural elements, waterscape and plants.

In addition, the designers introduced the concept of Computer Graphics (CG) into this project, and defined three independent layers of open space systems, namely the terrain system, the texture mapping system, and the plant system (Zhang, 2010). For this reason, the landscape components – benches, bridge, and other public infrastructure using plant groups –uniquely echo the architectural themes of this software company, resulting in rich seasonal changes. The mapping system, which includes two components, public amenities and building surface, will be mentioned in the discussion of employee infrastructure. Historical components are not included, because there are no distinct historical features that have been preserved.

- Description of open space quality

1) Public infrastructure:

The investigated environment has three main kinds of recreational facilities: wooden benches, paths and a viewing platform (Figure 81 a-b). In addition, the surface of the building echoes the pavement formation and symbolizes a programmer’s general work status (Zhang, 2010).

Figure 81a: Bench on the square

Figure 81b: : Wood viewing platform

Figure 82: Semi-private space

There are three spatial categories in the investigated area, namely the courtyards between the office buildings, the buffer zones surrounding the basin and the space connecting courtyards and waterscape. People can relax or hold short informal meeting in these spaces. The buffer zones of the waterscape along the basin provide employees with a quiet semi-private space (Figure 82).

2) Nature pleasure:

Various plant arrangements produce a dynamic landscape, changing from season to season due to the various plant species, and with the basin water body which is the pillar of the open space. The low water quality, however, decreases its scenic quality to a certain degree. The basin is 225 meters long, and the width ranges from 6 to 26 meters. The buffer zone provides a green linear landscape with recreational space.

3) Accessibility:

This landscape's high accessibility is important for meeting the requirements of the fast-paced software industry, with its need for intensive communication among the employees. In terms of accessibility to the park, since an atmosphere conducive to work is necessary, external visitors on foot cannot cross between the first and second phase areas of the UF Soft R&D Centre nor can they enter the park directly due to the iron fences erected on two sides. For the employees working in the first phase area, it is convenient to gain access to the UF Soft R&D Centre No. 1. In addition, the designers have established efficient and convenient communication between the interior of Centre No.1 and the surrounding environment, which was investigated. So it can be seen that the designers have managed to establish high accessibility for the employees by means of the landscaping and the building components and layout, except for external visitors. Nevertheless, this restriction is necessary and understandable.

- Personal evaluation of the open space quality

The open space quality is considered a functional and aesthetical extension of the interior space, which means that the landscape system echoes the architecture's unique qualities. In fact, the landscape design concept closely responds to the designer's architectural narrative. In particular, the uniqueness of the landscape design stems from the clients' requirements and consists, as mentioned, of three layers, namely terrain systems, texture mapping systems, and plant systems. The open space quality is also influenced by other three aspects. The pavements in the two courtyards and the patterns of the facades have distinctive features representing the symbolic impression of a computer graphic map. On the other hand, benches, paths and platforms lack clear features. Every space category is outlined by plants and pavements. Actually, the visible features of stormwater management are not truly highlighted. In addition, the low-level maintenance of the waterscape and the plants has a detrimental effect on the open space quality.

The waterscape is also well highlighted by means of the management of the landscape elements. The basin can be considered as a spatial connection, recreational focus and vital component of the stormwater management system. In reality, the first two functions dominate over the last one, with the result that the basin's landscape does not fully represent the features and details of the stormwater management system.

The open space quality could be excellent compared to similar cases in China. However, in terms of the stormwater management system, its landscape features are dominated by the distinctive design style, and are consequently difficult to recognize. For example, the designer introduces the three aspects of the CG concept (a kind of high-level computer language, named C for computer and G Graphics) for the landscape design, thus developing the three levels already mentioned. However, the concept of stormwater management is largely realized through individual and rather subtle landscape elements, rather than through the combination of visible and accentuated or symbolic landscape elements.

In sum, the features of the stormwater management system are not fully accentuated. As shown in the design description, the designers paid more attention to the spatial arrangements and the layout of the components with respect to the overall architectural design. They were less concerned with the landscape value and functions of the visible stormwater management component. For example, the landscape focus is not enhanced any further since the waterscape fails to contribute explicitly to the water management system, due to the lack of visible conveyance systems and its limited size. The conveyance systems are not accentuated as the design description shows, which probably cause incomplete cognitive map in terms of landscape perception.

4.5.3.3 Analysis of landscape perception

- Coherence and legibility:

This park fails to organise the landscape components in such a way as to construct an easily observable system, which allows people to understand the operation of the stormwater management system readily. Additionally, the landscape components employed in the stormwater management system do not represent landscape features in their own right, with the result that the landscape value of the stormwater management is ignored as mentioned above.

The legibility has also been influenced by the applied strategies. Here, the way in which the green infrastructure network operates within the stormwater management is estranged from the design focus. Unlike the accentuation in Qunli Wetland Park and the oversimplification in Tianjin Cultural Park, here, the landscape system as a functioning part of the rainwater management does not present an impressive landscape with a distinctive water treatment process. The distinctive buildings and open spaces as well as the design language replace the water basin as the focus of the design concept and the functional focus. So since legibility is limited, time, attention and patience will be the key to grasping the legibility, presumably only for a public that is interested in such landscape components. The degree of landscape perception could possibly be raised when the employees have established a mature mental map of the whole stormwater management system. Certainly, short visits to phase 1 area of the park will present difficulties in recognizing and appreciating the processes of the stormwater management system.

4.5.4 Introduction to questionnaires

A total of 40 employees, 22 male and 18 female, participated in the questionnaires. Among these respondents, there were 24 respondents in the 20-30 age group, 14 respondents in the 30-40 age group, and 2 respondents in the 40-50 age group. There were no respondents in the 50+ age group; the reason for this was discussed in Chapter 3 (see section 3.2.3.2) (Table 16).

Table 16: Basic information of involved respondents

Items		**Numbers**
Valid Questionnaires		40
Gender	Male	22
	Female	18
Working period (Year)	1-2	21
	2-3	18
	3-4	1
	4 and above	0
Education background	Secondary school and below	0
	Higher education	0
	Bachelor degree	29
	Master Degree or above	11
Average age	20-30	24
	30-40	14
	40-50	2
	50+	0

Table 17: Content of questionnaires and answers of respondents

Categories	Questions	Answers	Respondents
stormwater management system	How long do you spend outdoors in this park per week?	Less than 1 hour	8
		1-2 hours	13
		2-3 hours	11
		3-4 hours	4
		Longer than 4 hours	4
	Where did you learn the meaning of stormwater management?	Media	12
		Surrounding environment	4
		Neighbourhood	0
		Others	20
		Not at all	4
	What is your favourite kind of activity in this site?	Walking	26
		Sitting	6
		Overlooking	8
		Don't Care	0
	Did you gain knowledge from the surrounding environment how the stormwater management works?	Yes	15
		No	25
	Have you become more concerned with the urban rainwater issues since you have been working here?	Yes	16
		No	24
Open space quality	Which landscape element would be your favourite?	Plant borders	17
		Peaceful rainwater pond	2
		Broad lawn	6
		Rainwater square	1
		Shady path	14
	Which landscape components should be improved?	Water body	20
		Plant system	4
		Road	6
		Lawn	10
	Please you evaluate the aesthetic value of the stormwater management system with a score from 1-5., Which scores will you give?	Very much (5 Points)	9
		Quite high(4 Points)	27
		Moderate(3 Points)	3
		Quite low(2 Points)	1
		Just a little(1 Points)	0
	Do you think the project is going to be a classical, comparing with other similar projects in China?	Yes	10
		No	0
		Not Sure	30

The first stage of the investigation focused on choosing the interview sites and preparing the questionnaires. Based on the initial investigation, the main interview site was located on the roads with trench systems and paths nearby the waterscape, because they contain the highest numbers of visible components of the stormwater management system. Additionally, the basic qualification of the target group was that respondents should have worked for this company for at least one year. The vital question of visible function, namely "*Did you gain knowledge from the surrounding environment about how the stormwater management works",* received 15 positive answers. As far as the question regarding open space quality was concerned, namely "*Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score do you give?"* 10 respondents gave a grade 5, 15 respondents gave grade 4 and one respondent chose grade 3 (Table 17).

The interview sites were chosen on the paths and courtyards surrounding the UF Soft R&D Centre No 1 according to spatial types. However the basin as the largest visible area of water management cannot be seen directly when people are standing in the courtyards. Slight terrain changes can also be found in the courtyards. The questionnaire only targeted employees who have been working here for more than one year. In reply to the question *"Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score do you give?"* 9 respondents offered a grade five, 27 respondents chose grade four, 3 respondents chose grade three, and only 1 respondent chose grade two.

4.5.5 Final conclusions

The investigation and analysis of Yongyou Software Park indicate that the open space system with high quality fails to stimulate a high level of public appreciation and perception of stormwater management. The proposed solution have improved the local stormwater management system, and provided relief from the emerging water crisis to a certain degree. Three systems have been coordinated, namely the rainwater collection, penetration and drainage system; the underground wastewater infiltration system; and the gravel layers for filtration. This cooperation between green infrastructure and the engineering systems has established a highly efficient water treatment management system.

In terms of stormwater management system the description and evaluation mentioned that although most processes of water treatment take place underground, an important role is still played by the visible components of the stormwater management system, such as the water basin, plant beds and sunken green land. Nevertheless, these components' visible functions are difficult for employees to notice because the green infrastructure features are not obvious.

The evaluation of the open space quality is complex because the architectural and landscape design concepts have produced strong personal designs, providing a distinctive visual experience of the buildings and forcing the landscape system to echo the design concept. So although the green components of stormwater management are functionally related to the engineering system, the relationship does not develop a clear and visible landscape setting for the stormwater management

.

The evaluation of the stormwater management system indicated that the visible functions are difficult for people to notice and the discussion of the open space quality points out that the features of the stormwater management do not stand out from the rest of the environment. Although the park provides high accessibility, the low levels of explicitness and accentuation still cause difficulties in traceability. Therefore, in terms of coherence and legibility, the distinctive design language with the strong and distinctive building concept and the obscure landscape with its limited visible functions result in a relatively low assessment of the coherence and legibility.

To sum up, Yongyou Software Park has adopted a complex stormwater management system and a very distinctive design concept. The cooperation between the green infrastructure components and the engineering systems contributes to highly efficient water treatment systems and at the same time results in limited visible functions. So although the designers have managed to produce high open space quality, the visible functions fail to stand out from the surrounding landscape and have difficulty in stimulating people's landscape perception of stormwater management.

4.6 Guyue and Shuangzi Communities in Beijing

4.6.1 Background and introductions

Guyue and Shuangzi Communities are representative projects equipped with technological engineering to achieve highly efficient decentralized water management. The projects' backgrounds need to be traced back to the early 90s. With the increasing threat of urban floods, the organizations responsible drew up a long-term agenda, and then several rainwater projects and research were undertaken, such as the programs "Key to water resources development and utilization – researching rainwater flooding" and "Technological research and extensive experiments relating to urban rainwater application in Beijing" in 1997 (Kang and Zhai 2014). Significant achievements were obtained on the basis of the further research and programs. For example, the distribution and quantity of rainwater resources have been investigated for the first time. At the same time, more research achievements, such as determining the rainwater quality, influential factors and varying patterns, have also been made. Most importantly, it was the first time in Beijing's history that the change of rainwater quality had been traced and detected successfully. The achievements and lessons gained by the two projects provided an explicit strategically goal for dealing with urban rainwater issues. In 2000, with the support of the Ministry of Science and Technology of The People's Republic of China and the German Federal Ministry of Education and Research (BMBF), a four-year project named "Application and control of rainwater floods in Beijing urban area" was launched as one of Beijing's "248 Major Innovation Projects" (Zhang and Ding 2005). In total, seven universities and companies were involved: University of Duisburg-Essen, BDC Dorsch Consult, DHI-WASY GmbH, GEP Ltd., UFT Engineering Ltd., Technical University of Berlin, and I.B.B. Ltd. Within four years, five models of stormwater management and five different representative rainwater projects had been built (Li 2000b; W. et al. 2009). Figure 83 shows the four projects in the Haidian district, two of which have been chosen as study cases. The fifth project is in another district of Beijing and does not show in the map.

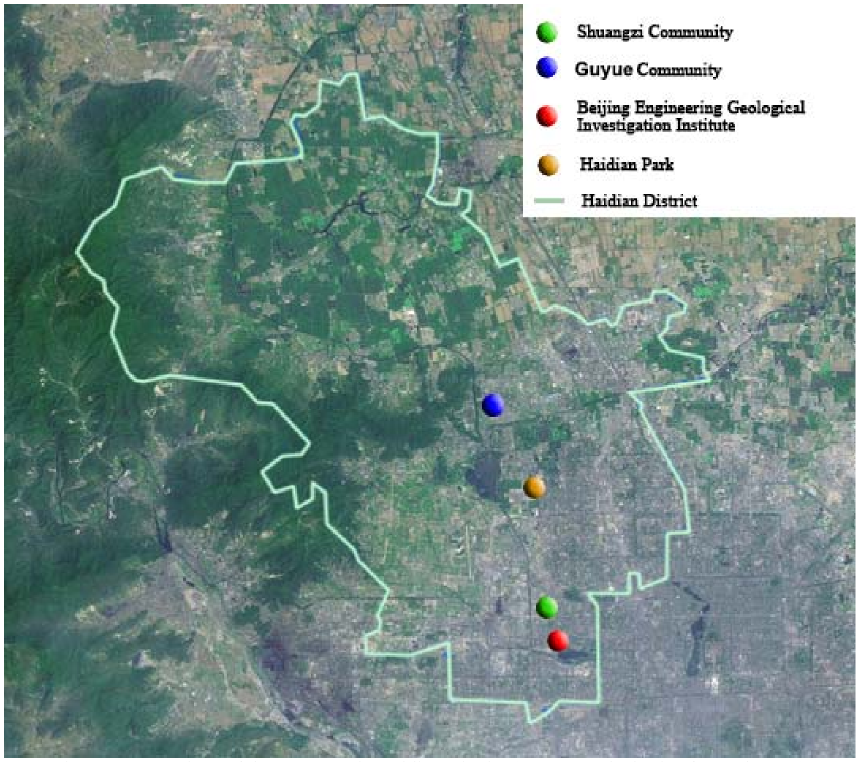


Figure 83: Locations of the programs in Haidian District (Drawn on the basis of Google Map)

1) The Tianxiu Community, located in one of Beijing's new towns, is made up of four parts or smaller communities: Guyue Community, Anshe Community, Hetangyuese Community, and Chengxiu Community. Among them, the Guyue Community has been chosen as the project's experimental focus. The engineering system built in the community has a large artificial lake that aims to provide two functions: as a scenic landscape and for rainwater retention. The main lake is largely replenished with recycled water, which is specially treated, and with rainfall collected from the buildings, paved surfaces and roads. After primary treatment, this is pumped into the artificial lake or used to recharge the groundwater (Zhou 2011).

2) The project of the Beijing Engineering Geological Investigation Institute in the old town zone covers 3 hectares (including 1 hectare overbuilt, 1.8 hectares of courtyard, and 0.2 hectares of green land). Due to the intensive housing coverage and the large area of impermeable surfaces, groundwater recharging technology was adopted as the main solution. The engineering system is similar to that of the Tianxiu Community. Construction began in June 2003 (Ding 2005).

3) Shuangzi Community located in a new town zone has a total area of 2 hectares (including 0.46 hectares overbuilt, 1.04 hectares of roads and paved areas, 0.5 hectares of green land). A sewage water treatment system has also been built with the aim of increasing the efficiency of rainwater reuse. Paths, including permeable pavements and sunken green land, have been laid out in this community. Recycled water is retained for use in the dry season. The system produces up to 200 tons of recycled water per day, realizing zero discharge of wastewater. The rainwater is recycled to flush public toilets, wash cars and water plants (Wang 2015).

4) The Water Conservancy and Hydroelectric Power Training School occupies 4 hectares and started to operate in 2003. The rainfall is collected from the pavements and playground and then concentrated in an impounding reservoir in order to be used in different ways, such as flushing toilets and watering plants.

5) Haidian Park is an important public space in Beijing. The total area of the designated zone is 38 hectares, including a road system with 2.18 hectares and an artificial lake with 2.32 hectares. Groundwater recharge technology, filtration wells and underground drains are all employed in this park.

Due to the limited time and financial support, this research chose two typical community projects as study cases from among these five projects, namely those of the Guyue and Shuangzi Communities. The reasons for this choice are based on three points of consideration: first, the investigation of the Guyue Garden and Shuangzi communities is a good supplement to, and comparison with, the other investigated Chinese projects; second, the two projects also have a significant practical value because they demonstrate how rainwater issues can be dealt with in a dense space or how stormwater management can be combined with public recreational activities; third, and most importantly, the two projects have landscape features typical of many Chinese communities.

In particular, when investigating the Guyue community, the main research scope concentrates on the environment surrounding the artificial lake with the most obvious features of the stormwater management system in this community.

4.6.2 Design challenges and responds

The motivation for tackling the challenges of stormwater management derives from two planning perspectives: how to implement urban stormwater management systems in the future and the appropriate technological solution in individual cases. In terms of developing future urban perspectives, the Guyue project has three research missions, reflecting the above-mentioned challenges. Firstly, the research aims to broaden the existing perspective by providing a concrete basis for improving widespread implementation of stormwater management in urban contexts and for ensuring their acceptance by the public; secondly, after acceptance and implementation, the governors can grasp the chance to deal with rainwater issues on a cross-border scale. The Guyue and Shuangzi Communities are vital parts of this agenda. At the same time, the project also has challenges, for example, to determine within the relatively limited area which technological solution can suitably be used in the Shuangzi community to reduce public open space. For the Guyue community, its challenge is to decide how to balance the large artificial lake with the demands for public services.

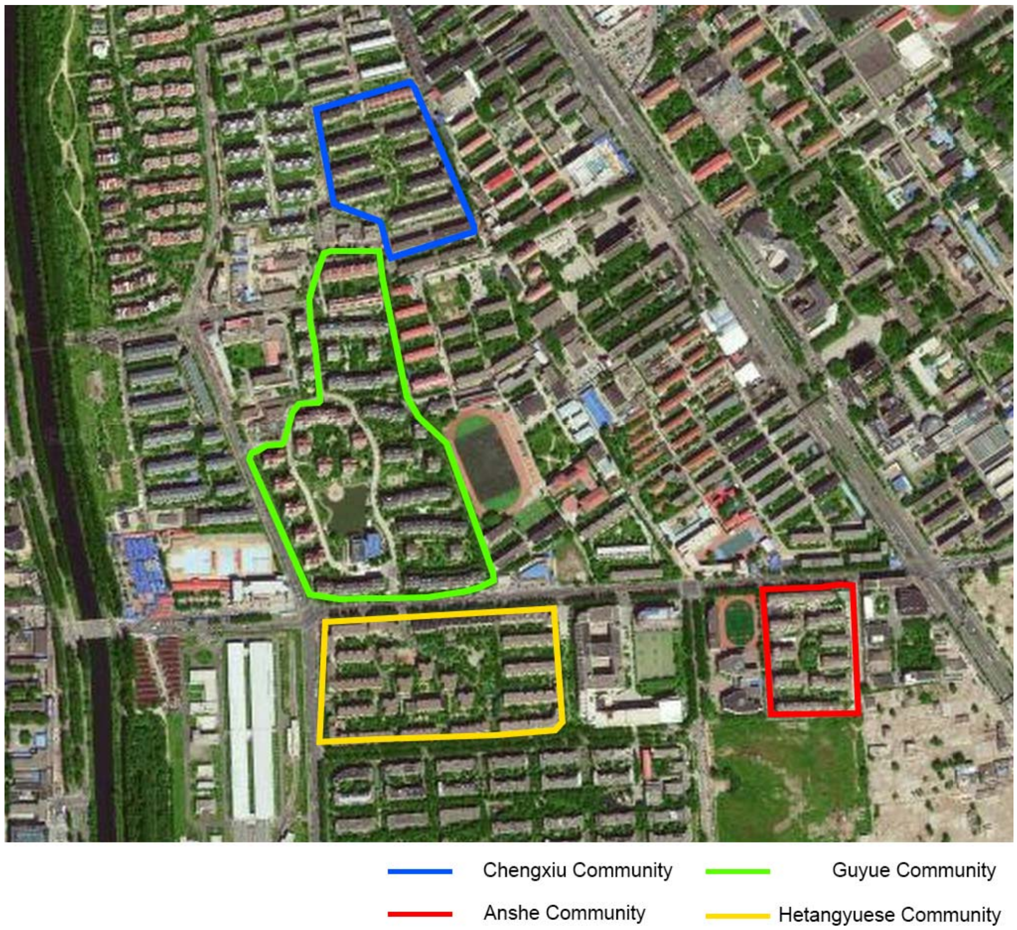


Figure 84: Four components of Tianxiu Community (Drawn on the basis of Google Map)

The achievements and experience of the program named "Application and control of rainwater flooding in Beijing urban area" have contributed to a very large number of projects, including, a total of 1355 rainwater utilization projects initiated between 2004 and 2010 (Gao 2014). However, obstacles still exist and problems such as low maintenance standards and the lack of public awareness of rainwater utilization have increased. In view of the challenges faced by the Guyue and Shuangzi communities, the response of Guyue was to build an underground garage under the artificial lake in the Guyue community, with the aim of providing the necessary public services while saving space; and the response of the Shuangzi Community was to lay down permeable bricks to increase water infiltration and reduce public space.

In addition, one explanation is worth mentioning. The reason for introducing the two projects in one chapter is that they are profoundly similar, specifically in terms of the stormwater management concept. In addition, as mentioned above, the strategies of two cases regarding stormwater management were innovated by one program initiated by the same official organizations. So the two projects employ similar methods and have common problems, as will be mentioned below. Therefore, they are analysed in one chapter due to these common points. At the same time, the two projects have several different landscape features which can stimulate a distinct perception of local residents living in the two communities, which is also worth analysing together for comparing.

4.6.3 Analysis of investigation into the Guyue Community

The whole Tianxiu Community covers 168 km^2, and the average plot ratio is 1.17, the greening rate (the percentage of green space in an area) lies at 39%. The community consists of four parts, namely Guyue Community, Anshe Community, Hetangyuese Community, and Chengxiu Community (Figure 84). The Guyue Community started to operate in 2003 and covers approximately 16.8 hectares (Figure 85).

Figure 85: Plan of Guyue Community (Drawn on the basis of Google Map)

4.6.3.1 Description and personal evaluation of stormwater management system

- **Description of stormwater management system**

As the investigation has shown, the stormwater management system mainly relied on an engineering system (Figure 86). Although the stormwater management has proved highly efficient, it still introduces another practical problem. The green infrastructure and artificial water facilities will be discussed in this section. Due to the engineering system's long-term operation, its maintenance work also will receive considerable attention.

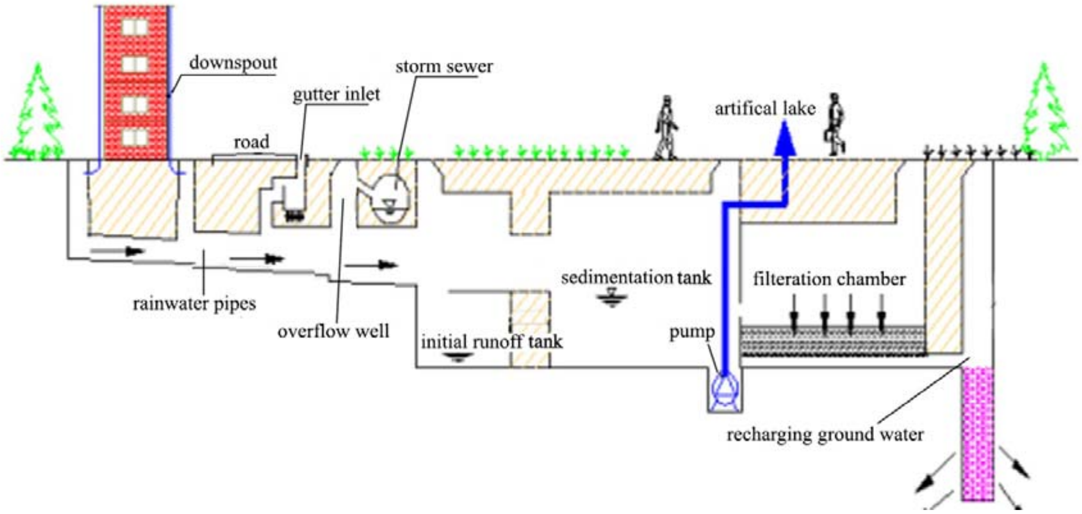


Figure 86: Processes of rainwater treatment in Guyue Community (Zhang and Ding 2005)

1) Natural infrastructure

A huge artificial lake has been built, and most of the plant landscape has been laid out in an orderly manner. Various categories of plant species can be found, such as aquatic plants, turf grass, shrubs, herbaceous plants and many trees (Figure 87). Although the whole community has a high greening rate, it is difficult to find plant groups with natural distribution. Most plants are to be found in the courtyards between the buildings, whereas the numbers of plant species surrounding the lake is relatively low (Figure 88).

Figure 87-a: Shrubs and herbaceous perennials

Figure 87-b: Trees and grass

Figure 87-c: Aquatic plants

2) Artificial water facilities

The artificial water facilities have three vital components, the artificial lake, rainwater collection and the water treatment components. The major engineering systems, such as the conveyance pipes and the sedimentation tank, are below ground. The artificial lake, with a total area of 5944 m^2, is located near the park's south entrance. It is connected to the engineering system through a short shallow ditch, which conveys pumped water from an artificial hill into the lake.


Figure 88: Fewer plants around the waterscape


Figure 89a: Shallow ditch


Figure 89b: Artificial lake with water outlet

As in the case of the Yongyou Software Park, the whole system can also be divided into two parts: the visible set of stormwater management components above ground and the underground technological instruments. There are two significant terrain changes that facilitate the rainwater management, the slopes of the raised promenade and the artificial lake. Additionally, there are two means of conveyance that contribute to the stormwater management system: 1) the rainfall and sewage are conveyed through underground rainwater pipes; 2) There is a very short ditch at the corner of the lake which conveys recycled water into the artificial lake after being pumped from the underground tank (Figure 89a). Water storage is conducted in an underground sedimentation tank and the artificial lake itself. The tank serves to retain recycled water temporarily and replenishes the lake via the pump, the water is first conducted, into an artificial hill and then via the short, shallow ditch into the lake (Figure 89b). However, few people know what kind of water it is and where it comes from. The rainfall is collected from the buildings, paved areas and roads. Underground pipes convey the rainfall into the sedimentation tank. The first flush tank (called the initial runoff tank in the diagram) has been built to prevent secondary pollution by the initial rainfall. The general way is to discharge such rainwater directly into the urban sewage system. In view of the prevailing uneven precipitation patterns, engineering experts have established overflow wells which connect the system to the urban sewage system. Only when the system is overloaded, in the event of extreme rainfall, is the rainfall released to the centralised urban sewage system. The recycled water can also recharge the groundwater after the necessary treatment. In sum, tackling the rainwater challenges relies largely on a centralized system, and the efforts have actually achieved good results.

Additionally, the maintenance work and financial investment in the three components needs to be considered: first, the engineering systems have been operating for approximately 15 years. The system's maintenance work has become an ongoing challenge. Recently, reports have increased of residents' complaints and functional breakdowns of the recycled water treatment (Hou 2006). Second, there is an underground garage beneath the water body (Figure 90). Due to the limited amount of land available to the community and the huge pressure exerted by an increasing urban population, it is understandable that the full potential of the land needs to be explored. Nevertheless, the huge financial investment and high maintenance funds will be a continuing challenge for the community for the next 10 years or more. In sum, limited visible function can be found in this community, since there are few components of stormwater management above ground and there is no connection between the green and the artificial infrastructure.

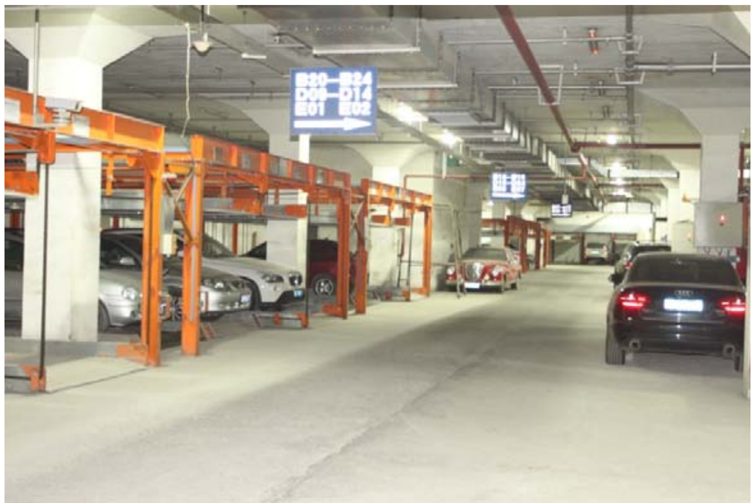


Figure 90: Garage underneath the artificial lake

- **Personal evaluation of stormwater management system**

  Based on the description of the natural and artificial infrastructure, the number of visible functions of stormwater management system is low. Three facts demonstrate this: 1) little participation of the plant systems in the stormwater management; 2) most water treatment processes occur below ground; 3) only few visible components of the stormwater management system can be observed. As regards the first point, an intensive plant system can stimulate landscape experiences. Although densely distributed plants can also contribute to achieving a high quality of stormwater management system to a certain degree, the plant systems have not been considered in this concept of stormwater management, with the result that the plant systems have little influence. Regarding the second point, the description of the engineering systems shows that most processes are performed by underground artificial components and that few people are aware of this. For example, the lake has two main functions. Nevertheless, the interview and observation show that few people know where the water comes from. Most people believe the lake is replenished with pumped tap water. On the third point, the categories and numbers of visible components are limited. So the artificial lake and the short shallow ditch in fact constitute the main two of the very few visible components.

Based on the description and evaluation of the stormwater management system, the whole community provides limited explicitness regarding the stormwater management because of the three disadvantages mentioned in the section on stormwater management system, namely little plant groups, the fact that the water treatment process is largely conducted underground and hence the limited number of visible components. These three disadvantages influence the explicitness significantly. Consequently, the information about stormwater management is fragmentary and incomplete.

Figure 91: Artificial bank of the lake

Additionally, there are other reasons for the low level of explicitness. First, the construction of the underground car park means that the main goal of the artificial lake is now not to recharge the groundwater, but rather to offer scenic pleasure as an “artificial landscape”. The lake’s banks are actually covered with a layer of pebbles set in concrete in order to retain water and prevent water from seeping into the ground. The aim is also to protect the underground car park (Figure 91). So the artificial lake can hardly be viewed by the local residents as a sustainable water facility. Second, the rainfall on the street is collected and flows into gutter inlets. Although the rainwater is in fact collected in the sedimentation tank and eventually replenishes the water body, the system leads to a misunderstanding, giving the impression that the rainfall is being discharged into the urban sewage systems. In sum, the heavy use of technology and the basic nature of the planning arrangements create a significant obstacle to the residents’ understanding of the stormwater management system.

4.6.3.2 Description and personal evaluation of open space quality

- Description of open space quality

1) Public infrastructure:

The communities provide several kinds of basic infrastructure including different pavement types, wooden jetties, pavilions, and various types and sizes of public squares. In this community, there is little stormwater management infrastructure that contributes to the stormwater management system or produces a high open space quality.


Figure 92a: Pavement I


Figure 92b: Pavement II


Figure 92c: Pavement III


Figure 92d: Pavement IV


Figure 93: Wooden jetty with plants


Figure 94: Pavilion with access to underground garage

In particular, the pavements have several kinds of textures, which are used in different squares or plazas and paths (Figure 92). Bordering the waterscape there are a wooden jetty, a pavilion and a public square. The wooden jetty is set at the corner of the lake, and is sheltered by a dense number of plants (Figure 93). The pavilions actually serve as the entrances to the underground garage and also offer the residents shelter from the wind and rain (Figure 94). There are public squares and benches set next to the lake to provide sufficient space and service areas for public activities (Figure 95).


Figure 95: Square nearby the lake


Figure 96: Damage to pavements


Figure 97a: Plaza between buildings


Figure 97b: Roads within the community


Figure 97c: Waterscape

As the investigation shows, these infrastructure components have received maintenance, so they are in fairly good condition. Still, there are some kinds of infrastructure, such as pavements, that have been damaged (Figure 96). Additionally, there are three types of space: the public plazas, the roads and paths, and the waterscape (Figure 97 a-c). Compared to the attractive waterscape, the first two space types are not so appealing and are less frequented by the public.

2) Nature pleasure:

Because of the few plants in the stormwater management system, the system's landscape quality relies largely on the water body rather than on plant patterns. Plant distribution around the lake produces an attractive landscape. However, the number of plants here is limited, does not cover much of the water body and fails to provide rich colour. The community's large waterscape is not typical of the Beijing Communities, because of the increasing land value. Combining green plants growing around the lake, the water surface still offers a dynamic landscape to a certain degree. In sum, the artificial lake as the central landscape element offers quite a good landscape, whereas the inadequate facilities and the limited green land decrease the open space quality.

3) Accessibility:

The community's accessibility is similar to that of other majority communities such as the Zhangjiawo Communities. They are separated from the surrounding environment by boundaries with fences (Figure 98). Only two main entrances are open for residents. People and vehicles can enter the community only after the security guards have checked their identity.

Figure 98: Guyue Community boundary

In terms of internal traffic, the community provides primary and secondary road networks and is also equipped with short or long stone-paved paths connecting the adjacent courtyards or plazas. So the road systems within the community offer good opportunities for looking around and relaxing freely.

- Personal evaluation of open space quality

The way the different components of the stormwater management system fail to cooperate restricts the system's efficiency and also decreases the open space quality for the whole community. As in the case of the Shuangzi Community's landscape features, the engineering systems in the Guyue Community have not been fully transformed into a stormwater management landscape. Thus, with the exception of the waterscape and the shallow ditch, few components of stormwater management are visible. Most vital components are buried underground. The cooperation between the various components is rarely found above ground. So effectively, these connections do not create a distinctive landscape that people can appreciate and remember.

Its simplicity or basic nature is another disadvantage of the open space quality here in two respects: the structure of the stormwater management system, and the individual landscape components. For one thing the function and purpose of the engineering system are too limited and basic. The simple structures and mono-function of the engineering systems exclude the possibility of the system being turned into a landscape that integrates with stormwater management. For another, the aesthetic value of the public infrastructure is mediocre and has no distinctive landscape features. The open spaces have much potential for improvement, i.e. they have the potential for becoming an attractive space, but have not yet achieved this.

Additionally, the waterscape displays greater vitality than the plazas. There are at least four reasons for this: 1) owing to the humid environment and the flourishing shrubs and plants it provides a good habitat for various insects. People suffer stings from insects as they do in the squares between buildings; 2) the lack of additional public infrastructure elements impairs the attractiveness of the small squares or courtyards; 3) the local residents are used to spending time on the square next to the lake; this has become their daily habit; 4) the lake's open space is larger than the others, and the dynamic landscape contributed to by various plants and the waterscape offers a more pleasurable experience. All in all, the plazas and squares, including the larger one next to the lake, still fail to convey the impression of good open space quality.

The features of stormwater management are not accentuated in the context of the landscape system for two reasons, namely the simple structure of the stormwater management and the barely visible connection between its components. For example, the simple and small number of public infrastructure elements can barely meet the basic requirements of public activities, and the several kinds of infrastructure in the stormwater management system are either buried underground or are not highlighted among the landscape elements. Similarly, plant patterns do not combine with distinctive stormwater management components and they are also separated from the stormwater management system. In brief, the stormwater management landscapes components are not managed in such a way as to visually accentuate the functions of stormwater management, thus leading to the situation that local inhabitants are unaware of the stormwater management system when perceiving the landscape.

In sum, the discussion of stormwater management system also provides much evidence to show the need for accentuation. It has been shown that the visibility of the stormwater management functions is low and fragmentary, which mean that people only observe the rainwater treatment processes incompletely. In addition, one rarely finds distinctive landscape features that represent the processes of stormwater management.

4.6.3.3 Analysis of landscape perception

- **Coherence and legibility**

The above evaluation reveals that this community does not have a highly coherent and legible landscape in terms of stormwater management. Because of the ambiguity of its visible function, the community's landscape system does not truly represent a clearly structured stormwater management system that can be observed and easily recognized. Similarly, open space patterns fail to landscape the features of stormwater management. Therefore, viewing the whole community, the environment fails to transfer efficiently valuable information relating to stormwater management to its inhabitants.

4.6.3.4 Introduction to questionnaires

The investigation received 22 valid questionnaires from 13 men and 9 women. The distribution of the residents' age is almost balanced: 7 respondents in the 20-30 age group, 5 respondents in the 30-40 age group, 4 respondents in the 40-50 age group and 6 respondents in the 50+ age group (Table 18).

Table 18: Basic information about respondents involved

Items		**Numbers**
Valid questionnaires		22
Gender	Male	13
	Female	9
Length of residence (years)	1-2	2
	2-3	4
	3-4	10
	4 and above	6
Educational background	Secondary school and below	8
	Higher education	4
	Bachelor's degree	9
	Master's degree or above	1
Average age	20-30	7
	30-40	5
	40-50	4
	50+	6

Table 18 shows the questionnaire statistics. The interview sites were chosen in the area around the artificial lake because the scenic landscape contains more information regarding the stormwater management than any other. The question with respect to visible function, namely "*Did you gain knowledge from the surrounding environment how the stormwater management works",* received 3 positive answers and 19 negative answers. The question relating to function-based aesthetics, namely "*Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score do you give?*", received 1 score of five, 9 with four, 4 with a score of three, 5 scored two and 3 a score of one.

Table 19: Content of questionnaires and answers of respondents

Categories	Questions	Answers	Results
stormwater management system	How long do you spend outdoors in this community per week?	Less than 1 hour	2
		1-2 hours	10
		2-3 hours	4
		3-4 hours	3
		Longer than 4 hours	3
	Where did you learn the meaning of stormwater management?	Media	6
		Surrounding environment	3
		Neighbourhood	4
		Others	7
		Not at all	2
	What is your favourite kind of activity in this site?	Walking	3
		Sitting	6
		Looking	5
		Don't mind	8
	Did you gain knowledge from the surrounding environment about how the stormwater management works?	Yes	3
		No	19
	Have you become more concerned with the urban rainwater issues since you have been living here?	Yes	11
		No	11
Open space quality	Which landscape element would be your favourite?	Plant borders	9
		Peaceful rainwater pond/lake	2
		Broad lawn	3
		Rainwater square	1
		Shady path	7
	Which landscape components should be improved?	Water body	10
		Plant system	5
		Road	3
		Lawn	4
	Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score do you give?	Very high (5 points)	1
		Quite high(4 Points)	9
		Moderate(3 Points)	4
		Quite low(2 Points)	5
		Very low(1 Points)	3
	Do you think the project is going to become a classic one, compared with similar projects in China?	Yes	10
		No	0
		Not sure	12

4.6.3.5 Conclusion of evaluation of Guyue Community

Guyue Community has mainly adopted an engineering system to realize a highly efficient stormwater management, similar to the Shuangzi Community discussed below. Most of the components contribute to improving stormwater management system in the community; nevertheless this is not presented visibly. There are three reasons for this: 1) the quality and quantity of green infrastructure components in the stormwater management landscape is limited; 2); most processes are conducted underground rather than above ground; 3) the categories and methods used in the stormwater management system are limited as well.

From the point of view of open space quality, there are two reasons for the low quality. First, the system's simplicity or basic nature is an important reason in two respects: in the stormwater management structures and in the landscape components. Second, the fragmentary relationship results in a landscape which not being appreciated. The above discussion also mentions the issue of how space is used and gives an analysis with respect to what has been observed.

The well-managed road system offers high accessibility within the community, while the community's boundary restricts the number of visitors, as is the case in other communities. The stormwater management system's explicitness is profoundly influenced by the quality of the visible components. For instance, the inhabitants' knowledge of the stormwater management system is impaired by the fact that the lake lies above an underground car park and that concrete is used in the banks of the lake, making it appear artificial. Consequently, explicitness leaves much room for improvement. Similarly, accentuation also does not receive a high score. The two main reasons were based on the evaluation of the open space quality and reflect the stormwater management's simple nature, and the weak connection between the visible components. As a result of these factors, the information about the stormwater management system available to the public is fragmentary and incomplete.

In terms of coherence and legibility, the community does not provide a sufficiently coherent and legible landscape that allows members of the public to perceive understand and appreciate it. The reasons for this have already been discussed, above all the fact that most processes are conducted underground, that most of the stormwater management system's components play no role in the landscape system, that the plant systems are separated from the stormwater management and so on. These disadvantages result in the low visibility of the stormwater management's infrastructure and the fact that the information is incomplete and not conveyed to the public effectively.

As far as the questionnaires are concerned, the first vital question received only 3 positive answers. The statistical result is lower than in the other cases, except in the Shuangzi Community. The evaluation of open space quality in the second question gained a low value, but still scored higher than the Shuangzi Community.

In short, as one of the six projects investigated here the Guyue community reveals many disadvantages – ones that can also be found in most normal projects in China. By means of the description of the stormwater management system and open space quality, the evaluation shows that the existing open space systems do not produce a high landscape perception of stormwater management.

4.6.4 Analysis of investigation into Shuangzi Community

The whole community, with a total area of 2 hectares, started to operate in 1999 (Figure 99). The community alongside the Shuangzi Canal has been chosen as one of the representative projects in the program of "Application and control of rainwater flood in Beijing urban area". There are about 800 households in this community. The greening rate has reached 39%, and the built-up area amounts to approximately 0.28 hectares. The community is made up of two parts, namely a car park and a residential zone. The car park covers nearly 0.27 ha and is located between the residential zone and the Shuangzi Canal. Additionally, a small artificial hill with a waterfall is situated in the northeast of the community next to the canal.

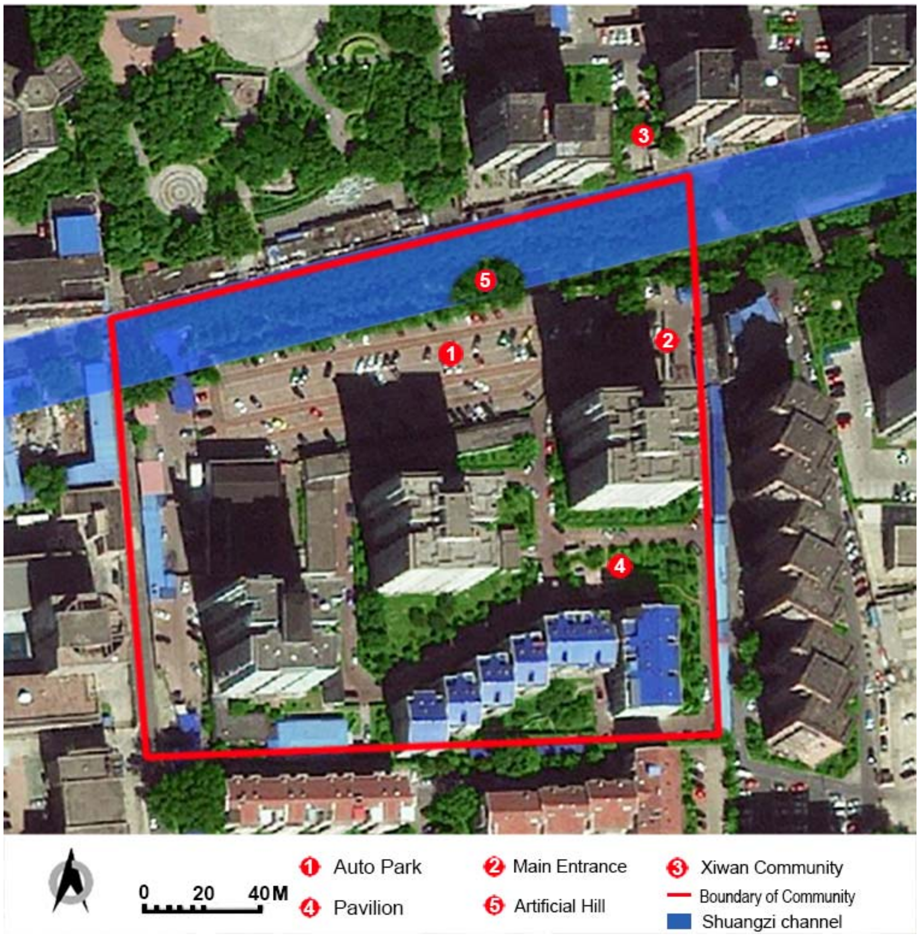


Figure 99: Plan of Shuangzi Community (Drawn on the basis of Google Map)

4.6.4.1 Description and evaluation of stormwater management system

- **Description of stormwater management system**

1) Natural infrastructure:

Because this community is limited in space, a simple but effective engineering system has been adopted (Figure 100). Unlike the Guyue Community this community has no visible water body. Although the Shuangzi canal does not actually belong to the community, the community was allowed to build an artificial hill with a fountain next to the canal. In terms of plants, plant arrangements have been set simply around the buildings (Figure 101). Only at the centre of the community are the plant species richer and the arrangement is not so orderly (Figure 102).

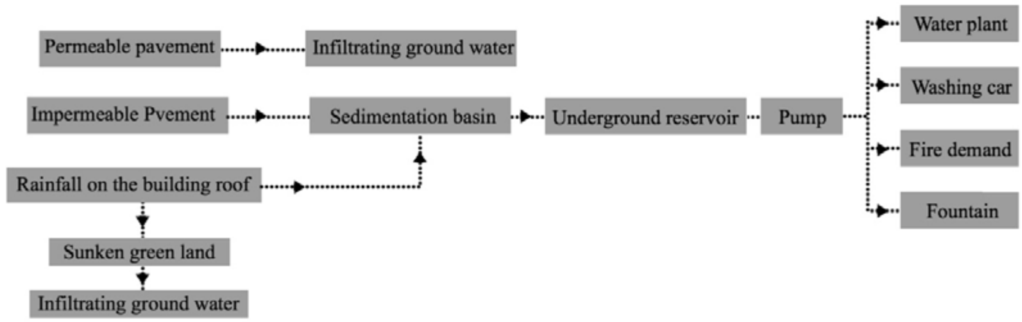


Figure 100: Processes of water treatment in Shuangzi Community

2) Artificial water facilities:

The community does not have the advantage of changes in terrain, nor does it have visible conveyance systems or visible water storage to facilitate rainwater management. As Figure 100 shows, the community has decided on two ways of collecting rainfall. The rainfall on the roofs of buildings is either discharged into sunken green land (Figure 103) or is conveyed to an underground sedimentation tank (Figure 104). The rainfall on the ground also either seeps underground through permeable bricks or flows into the tank. The whole engineering system was designed on the expectation of a stormwater incident recurring every five years (Zhang and Ding 2005).


Figure 101: Plant arrangements


Figure 102: Plant distribution in central area


Figure 103: Sunken green land


Figure 104: Drainpipe and permeable brick paving

- Personal evaluation of stormwater management system

Similar to the Guyue Community, the stormwater management here relies mainly on a simple engineering system. In terms of visible function, this also produces similar issues. Nevertheless, the situation of Shuangzi Community is different from Guyue Community. In the first place, permeable bricks are a significant component in the stormwater management system, and their large number contributes to the stormwater management system considerably. It also meant that the designers did not need to consider involving green infrastructure components in the stormwater management. Bricks may be able prevent from waterlogging and at the same time to save public space. So the community has not built a visible network of shallow ditches. In addition, part of the stormwater management process is conducted underground, similar to the Guyue Community. However, the Shuangzi Community has applied a more compact system with fewer visible components. Thirdly, with its simple stormwater management structure this community benefits from coordinated engineering components, although it fails to benefit from green infrastructure elements. So these three factors have a profound influence on the efficiency of the stormwater management system and the open space quality.

4.6.4.2 Description of open space quality

1) Public infrastructure:

The main public facilities include car park, flushing toilet, single pavilion and artificial hill. These significant facilities have a good maintenance condition as figure 105 a-d shows. In this community, the open space system is mainly divided into two parts, recreational space in front of buildings and car park nearby the main entrance. Due to the insufficient numbers of public infrastructure components in this open space system, less numbers of local habitants use the open spaces for recreational activities in this community for a long time.


Figure 105: Community's main entrance


Figure 106a: Community boundary


Figure 106b: Community boundary


Figure 107a: Car Park

Figure 107b: Toilet using recycled water

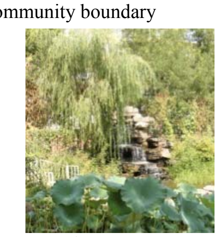


Figure 107c: Artificial hill


Figure 107d: Pavilion covered by plant

2) Nature pleasure:

Plant patterns are ordered and the distribution is restricted. Additionally, in the whole open space system, green land and pavement are distinctively separated by an iron fence, and there is no shade for residents on the pavement. There is an artificial hill on the Shuangzi Canal located between public road and parking lot. On the canal there are intensively nature distributed plants, such as lotus and reeds, surrounding this hill.

3) Accessibility

There is one main entrance for the whole community (Figure 106). Residents who enter to the community do not need to show any identity. The boundaries of this community consist of iron fences (Figure 107). The road system inside the community offers fairly good accessibility.

- **Personal evaluation about open-space quality**

There are two characteristics of the open space system, simplicity and disconnectedness. First, because of less attractive waterscape, plant distribution, and space types, a pleasurable landscape experience is difficult to generate for local habitants. In specific, one kind of permeable bricks with same colour and size are repetitively ordered and paved on the most road area. In addition, the landscape system is fragmented, because individual landscape components do not connect with each other, and then it is hard to have a scenic pleasure when being walking in this landscape system. In sum, the two disadvantages cause a less attractive landscape and little attention as to the stormwater management system.

The features of stormwater management system are not remarkable and blend into the orderly and monotonous landscape. Because there is little public participation and no observable process of rainwater treatment and the open space system is basic and not very attractive, the explicitness and accentuation of the stormwater managmenet system are difficult to notice.

4.6.4.3 Personal evaluation about landscape perception

- Coherence and legibility

The coherence and legibility of the landscape with its features of the stormwater management system are poorly established. For example, the lack of terrain change and the homogeneous pavement bricks produce a landscape that is hardly legible. In addition, the green plant systems have clear layers and structures, but these layers do not influence positively the public's cognitive map as to how the stormwater management system functions. In sum, few local habitants actually notice the coherence of the whole stormwater management and are hardly able to appreciate and 'read' the landscape.

Table 20: Basic information about respondents involved

Items		**Numbers**
Valid Questionnaires		36
Gender	Male	18
	Female	18
Dwelling period (Year)	1-2	5
	2-3	9
	3-4	18
	4 and above	4
Education background	Secondary school and below	12
	Higher education	9
	Bachelor degree	14
	Master Degree or above	1
Average age	20-30	8
	30-40	10
	40-50	8
	50+	10

4.6.4.4 Introduction to questionnaires

This investigation received 36 valid questionnaires, 18 from male respondents and 18 from female respondents. Among these residents, there were 8 residents in the 20-30 age group, 10 respondents in the 30-40 age group, 8 respondents in the 40-50 age group and 10 respondents in the 50+ age group (Table 20).

Table 21: Content of questionnaires and answers of respondents

Categories	Questions	Answers	Results
Stormwater management system	How long do you spend outdoors in this community per week?	Less than 1 hour	16
		1-2 hours	11
		2-3 hours	0
		3-4 hours	6
		Longer than 4 hours	3
	Where did you learn the meaning of stormwater management?	Media	8
		Surrounding environment	1
		Neighbourhood	6
		Others	9
		Not at all	12
	What is your favourite kind of activity in this site?	Walking	5
		Sitting	3
		Overlooking	8
		Don't Care	20
	Did you gain knowledge from the surrounding environment how the stormwater management works?	Yes	1
		No	35
	Have you become more concerned with the urban rainwater issues since you have been living here?	Yes	24
		No	12
Open space quality	Which landscape element would be your be your favourite?	Plant borders	22
		Peaceful rainwater pond	6
		Broad lawn	4
		Rainwater square	0
	Which landscape components should be improved?	Shady path	4
		Water body	4
		Plant system	4
		Road	18
		Lawn	10
	Please you evaluate the aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?	Very high (5 Points)	0
		Quite high(4 Points)	10
		Moderate(3 Points)	16
		Quite low(2 Points)	8
		Very low(1 Points)	2
	Do you think the project is going to be a classical, comparing with other similar projects in China?	Yes	22
		No	8
		Not Sure	6

One question, namely "*Did you gain knowledge from the surrounding environment about how the stormwater management works*"*,* shows that 35 respondents did not know how the system works, and did not receive any information, which is lowest percentage among all cases. Another question, namely *"Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score do you give?"* shows there were no respondents who gave five points. The statistics show that the average scores of this evaluation were also the lowest (Table 21).

4.6.4.5 Conclusions of evaluation of the Shuangzi Community

Regarding its stormwater management system, the community is similar to the Guyue Community. There are two different aspects: first, Shuangzi Community has adopted a relatively simple engineering system to deal with rainwater issues; second, the community has few categories and small amounts of green and artificial infrastructure components. The stormwater management system in the Shuangzi Community is efficient.

However, due to two important aspects, namely the low level of cooperation among the green infrastructure components and the inconspicuous processes of rainwater treatment, but also due to the basic nature and isolation of the stormwater management system, the landscape system does not present the stormwater management system features in a visible and explicit way. In addition, the coherence and legibility of the landscape are not well balanced in this community. Because of its simplicity, disconnectedness, rigidity and repetition, the stormwater management system may perhaps have coherent layers, but it is not easily legible. Similarly, some of the stormwater management components are accentuated and legible, while others are much less attractive and visible. Moreover, the questionnaires show that the evaluation of the Shuangzi Community with respect to stormwater management system and open space quality is low. In brief, although the community deals with the rainwater issues, and adopts a suitable engineering system, it fails to produce high open space quality in its stormwater management system.

4.7 Conclusions of study cases

4.7.1 Conclusions from questionnaires

This section draws conclusions from the three groups of questionnaire data, namely stormwater management system and open space quality. The statistical data, which was collected using vital questions relating to stormwater management system and open space quality, is calculated by a specific mathematical method, the weighted average. In a later section the results from the questionnaires are used to compare the conclusions of the case descriptions.

4.7.1.1 Visible function in stormwater management system

Chapter 3 explained the design concept of the questionnaires and indicated that these two groups of questions relate to two aspects, namely visible function of stormwater management system, and the evaluation of open space quality on an integrated environment. The first aspect aims to determine if landscape users can identify and understand visible functionalities of stormwater management systems, and the second aspect is to gain the respondents' evaluation of open space quality in an integrated environment containing visible and non-visible components of stormwater management systems. Because each interview site has already been selected in advance of each investigation (see section 3.2.3.2), the conclusions of the second aspect are closely related to the achievement of stormwater management components regarding the open space quality.

In addition, the classification of the six Chinese projects has been undertaken on the basis of the evaluation of the questionnaires. In the case of understandable function, the related question is "*Did you gain knowledge from the surrounding environment how the stormwater management works?*" The questionnaire data is evaluated using a weighted average, as Table 22 shows, a positive answer receiving 5 points and a negative answer 1 point.

Table 22: visible function of the six North Chinese projects

	Qunli Wetland Park	Zhangjiawo Communities	Tianjin Cultural Park	Yongyou Software Park	Guyue Community	Shuangzi Community
Yes (5 Points)	14	18	13	15	3	1
No (1 Points)	24	8	13	25	19	35
Value (from 1-5)	2.4	3.8	3.0	2.5	1.5	1.1
Classification	Low visible function	Middle visible function	Middle visible function	Low visible function	Low visible function	Low visible function

In the comparison of the six cases, the ones with less than three points are classified as low visible function; the cases with three to four points are in the group of middle visible function; and the cases with four points or more are the group with the highest visible function. Table 22 shows that the value of the Zhangjiawo Communities has the highest score (3.8 points), while the value of the Shuangzi Communities is the lowest (1.1 points). The result shows that no single case can be valued as having high visible function; the Zhangjiaowo communities and Cultural Park are put in the group of middle visibility, while Qunli Wetland Park, Yongyou Software Park and the Guyue and Shuangzi Communities are grouped as low visibility.

4.7.1.2 Aesthetic evaluation of the integrated environment

The data evaluation of the aesthetic value adopts a similar way to the evaluation method in the section on visible function. The most related question relating to aesthetic value of the integrated environment is "*Please evaluate the aesthetic value of the stormwater management system with a score from 1-5. Which score will you give?*" Because the answers to this question are rated from 5 to 1 points – 5 (Very much), 4 (Quite high), 3 (Moderate), 2 (Quite low), 1 points (not at all) – the assessment of aesthetic value regarding to the integrated environment in the six projects has been done using the weighted average.

Table 23: Evaluation of open space quality in an integrated environment

		Qunli Wetland Park	Zhangjiawo Communities	Cultural Park	Yongyou Software Park	Guyue Community	Shuangzi Community
Statistical data from questionnaires	5 point	10	10	2	9	1	0
	4 point	18	15	12	27	9	10
	3 point	8	1	7	3	5	16
	2 point	2	0	5	1	6	8
	1 point	0	0	0	0	1	2
Average value		3.94	4.34	3.42	4.0	3.14	2.94
Classification		Middle aesthetic value	High aesthetic value	Middle aesthetic value	High aesthetic value	Middle aesthetic value	Low aesthetic value

As Table 23 shows, the six cases are divided into three groups according to the results. The cases with 4 points and above are grouped as high aesthetic value, such as the Zhangjiawo Communities (4.34 points) and Yongyou Software Park (4.0 points); the cases with a value between three and four points are grouped as middle aesthetic value, such as Qunli Wetland Park (3.94 points), Cultural Park (3.42 points) and Guyue Communities (3.14 points); and the cases with less than three points are in the group of low aesthetic value, such as the Shuangzi Community (2.94 points).

4.7.1.3 Conclusions of data analysis

Based on the above calculation, every project receives two kinds of evaluations regarding Visible function and integrated environment (Table 24).The evaluation results indicate how the public perceives the stormwater management system in each case and are used to compare the conclusions of the design descriptions (see section 4.7.5).

Table 24: Value of landscape perception for six northern Chinese projects

	Qunli Wetland Park	Zhangjiawo Communities	Cultural Park	Yongyou Software Park	Guyue Community	Shuangzi Community
Visible function of stormwater management system	Low	Middle	Middle	Low	Low	Low
Evaluation of integrated environment	Middle	High	Middle	High	Middle	Low

4.7.2 Conclusions from project descriptions

This section summarizes the six case study descriptions and extracts four aspects concerning stormwater management system and open space quality as shown in Table 31. Because stormwater management functions interact with open space quality as mentioned above, a corresponding relationship has been recognized between four aspects of stormwater management system and of open space quality. The two groups of four aspects contribute to the conclusions relating to landscape perception in terms of coherence and legibility.

4.7.2.1 Stormwater management system

The present discussion arrives at the conclusion that a well-managed stormwater management plays a critical role in stormwater management by focusing on four aspects (Table 25). As Table 25 shows, every aspect contains two key phrases with opposite meanings. The six cases have been categorized in every group as either positive or negative according to the project description mentioned. The summaries of every group are encapsulated in the concluding characterization of stormwater management system as to explicitness and ambiguity. This research regarded explicitness as a vital parameter for establishing an understandable stormwater management system. The explicitness means that the processes of water treatment should be represented in a visible way without any redundant devices. Ambiguous processes presents an opposite design concept.

Table 25: Four aspects of stormwater management system

No.	Summaries from project description	
1	**Central water body** Zhangjiawo Communities; Tianjin Cultural Park; Guyue Community	**Decentralized water infiltration** Qunli Wetland Park; Yongyou Software Park; Shuangzi Community
2	**Connected components** Zhangjiaowo Communities; Qunli Wetland Park; Yongyou Software Park	**Disconnected components** Tianjin Cultural Park; Guyue Community; Shuangzi Community
3	**Integration of components** Zhangjiawo Communities; Qunli Wetland Park; Yongyou Software Park	**Isolation of components** Guyue Community; Tianjin Cultural Park; Shuangzi Community
4	**Complete process** Zhangjiawo Communities; Cultural Park; Qunli Wetland Park	**Incomplete process** Yongyou Software Park; Guyue Community; Shuangzi Community

- **Water treatment model: centralized or decentralized**

As the investigation shows, high-capacity water storage can provide multiple functions, such as facilitating rainwater collection, nourishing ecological systems, and reducing the stress of urban sewer systems. Therefore, a water body should be expressed as the visible functional center of a water treatment system in order to fully realize it's potential. There are distinctive differences between centralized and decentralized water treatment (Table 26). To fulfill the functional center's potential, it should be located in the geographical and functional center and be linked to a conveyance system in order to perform water storage, recharge underground water and nourish ecological species. The decentralized water treatment used here means that the permeable components of stormwater management, such as permeable bricks and flat green land, are employed in large numbers over huge areas. The system can thus perform efficient rainwater recycling, even when the water storage is not apparent to the outside viewer. Additionally, where space is limited and little financial support is available, sunken green land that serves recreational purposes can also be turned into a temporary water body as a functional center.

Table 26: Differences between centralized and decentralized water treatment

Categories	Processes	Function	Landscape visibility
Central water body as focus	Rainfall flow into water body through slope of terrain, pipes, open ditches	Water Storage; Recharging underground water; Nourishing aquatic plants;	High
Decentralized water treatment	Rainfall permeates into the ground through sunken ground, permeable bricks or green land.	Recharge underground water; Reducing surface runoff	Low

1) Central water bodies:

The Zhangjiawo Communities, Tianjin Cultural Park and the Guyue Community are all equipped with huge water bodies. Comparing these cases, one observes that the water bodies in the Zhangjiawo Communities are located in the central area of each community as a functional core and the center of an efficient conveyance network. Furthermore, these water bodies have more practical functions than the water body in Tianjin Cultural Park. The main reason is that the water body in the cultural park relies merely on sloping terrain to collect rainwater and not on the whole park. Due to high evaporation and low efficiency, the artificial lake has to be replenished through a long-distance conveyance system. The influence of the Guyue Community's water body is the weakest among the three cases, and its potential value is not truly fulfilled because the water body has few typical and strong connections with other components such as green infrastructure solutions and the road network.

2) Decentralized water infiltration:

Qunli Wetland Park, Yongyou Software Park and the Shuangzi Community have adopted decentralized water treatment methods, with the result that they do not have obviously visible water bodies. The wetland in Qunli National Wetland Park has a great capacity to store rainwater, because of the innovation of an existing hydraulic water system. Ponds and elevated terrain also convey rainwater into the wetland core. Additionally, although the basin of Software Park can receive rainwater by means of engineering, the basin has a weaker functional connection with the engineering components. The Shuangzi Community has built a huge area of permeable bricks in order to cope with rainwater runoff, and thus it has a highly efficient rainwater management system despite not having a central water body.

- **Components of stormwater management: connection and disconnection**

These multiple connection methods make use of changes in terrain height, natural infiltration, and ditches etc. However, there are two points which should be highlighted: first, the connection between the functional center and the network's other components should be explicit, and local geographical conditions and rainfall characteristics should be taken into consideration and employed to best effect. Second, engineering systems should be adopted as necessary to increase efficiency and security; however, in most cases the engineering equipment can be replaced by green infrastructure components or other artificial facilities at a lower technological level, which means that designers should build more than one conveyance system; and should continue to place landscape elements around the functional center to achieve and maintain the stormwater management system. Disconnection in stormwater management can be the result of two situations: first, few connection methods are employed, and most components are not interlinked. Second, the functional center is only weakly connected to the other components.

1) Connected stormwater management systems:

The Zhangjiawo Communities, Qunli Wetland Park and Yongyou Software Park have the advantages of combining several systems. The Zhangjiawo communities take advantage of several different conveyance methods such as changes in terrain height, permeable pavements, and ditches. These elements are organized and built around the central water bodies. The different conveyance methods are linked by shallow ditches, which establish a clear structure and a strong visual relationship with the water body. Similarly, Qunli Wetland Park is strongly interlinked, this being achieved by intensive green infrastructure solutions. In Yongyou Software Park, balancing water management is realized by combining high-technology systems and green infrastructure solutions; however, the two different systems are only weakly connected, and the linear basin, as a functional centre, does not have a clear connection with the other components. In this respect, the Software Park is not as successful as the Zhangjiawo Communities and Qunli Wetland Park.

2) Disconnected stormwater management systems:

Examples of disconnected systems can be found in Tianjin Cultural Park and in the Guyue and Shuangzi Communities. They have common disadvantages, namely less green infrastructure participating in the stormwater management. In particular, there is little connection in the Cultural

Park between the promenade and the green infrastructure from the perspective of stormwater management, but the designers take advantage of the changes in terrain height to build a limited conveyance system. In the Guyue Community and the Shuangzi Community, the disconnectedness results mainly from the dominance of underground engineering systems and also from a poor integration of plants.

- **Components of stormwater management and their environment: integration and isolation**

The investigation shows that a comprehensive integration of landscape factors and artificial components into stormwater management systems brings more social and ecological benefits and an improved water treatment. Such a broader integration requires the components that have not yet been integrated into a stormwater management system to be distributed according to the rainwater concept and organized around the functional center. Thus, this kind of integration not only focuses on solving rainwater issues, it also concentrates on interacting with the surrounding environment. Due to plant growth, climate change and human activities, the functions and the degree of integration can also be influenced over time and by the physical environment, thus the integration itself actually becomes dynamic. Therefore, integration is able to produce a more flexible stormwater management system, which can deal with existing and even future rainwater challenges. 'Isolation' here means that all components of a stormwater management system, including conveyance systems and others, are treated in isolation in terms of their function to the environment, which thus operates less effectively.

1) Integration of Stormwater Management:

The Zhangjiawo Communities, Qunli National Wetland Park and Yongyou Software Park are equipped with highly efficient water treatment systems. Their success is largely due to the full integration of diverse components in each project. For example, in the Zhangjiawo Communities, the majority of public infrastructure components are designed to serve as stormwater management systems or to be parts of them. In particular, the efficient conveyance network, continuous green space and central water body combine together to yield a high ecological value. Similarly, the successful stormwater management system in Qunli National Wetland Park is also achieved through integrating natural elements, such as plant systems, and public and private infrastructure components, such as parking lots, small squares, road surfaces and house roofs. Yongyou Software Park employs two stormwater management systems, namely green infrastructure and engineering systems. The combination of components in each system using different methods produces a highly efficient network. However, the fragile connection between the two systems undermines the whole integration in this park. For example, the software park adopted a mixture of engineering and biochemical cooperation to purify the water of the linear basin under normal conditions. However, because this method can produce high maintenance costs, the mechanism of purifying rainwater is rarely turned on, and thus the water quality has declined.

2) Isolated stormwater management components:

The Guyue Community, Tianjin Cultural Park and the Shuangzi Community reach far lower degrees of integration than the above projects. First, all three cases do not fulfil the potential of green systems and rely totally on their engineering systems to overcome rainwater issues. As a result of this, the green and engineering components are isolated from one another and the same is true of the plant groups. The isolation of the three projects leads to a decrease in the flexibility and efficiency of the water treatment. Therefore, potential threats, such as water pollution or overloading of underground engineering systems, rise in rainy seasons, as the above case descriptions mention.

- **Process of stormwater management: complete and incomplete**

The successful operation of stormwater management has one main feature, namely the completeness of the water treatment process with a clearly visible function. This research argues that functional visibility can improve landscape perception. The main reasons are following: firstly, based on the above discussion, underground conveyance systems should be replaced by networks using natural ways above ground, because these clearly achieve higher flexibility and efficiency, as demonstrated by the ditch networks of the Zhangjiawo communities (as a positive example) and by the underground drainpipes of Yongyou Software Park (as a negative example). Secondly, the stormwater management system should build a close relationship between the water body and its other components. The stormwater management systems that benefit from this relationship construct a more suitable conveyance network for the local geographical conditions without requiring too many engineering mechanisms and a large amount of maintenance. Thirdly, as mentioned above, a high landscape perception is closely related to the combination of stormwater management system and open space quality, in which open space quality can be advanced by a high visibility of the stormwater management system. Therefore, high visible function not only achieves a more sustainable stormwater management system, it also offers other potential opportunities.

In terms of a successful rainwater treatment system, the design concept should provide high visibility of the entire process on the basis of efficient functioning and high open space quality. Therefore, landscape architects should meet two basic demands intelligently: rational thinking and artistic intuition. In particular, there are several requirements for a successful complete process. It must rely on the combination of landscape and engineering components, and public serve facilities. Furthermore, the nodes of water treatment process need to have an explicit structure without redundant details in order to present their functions clearly. An incomplete process, resulting from the invisibility and inaccessibility of water treatment processes or an unbalanced concept of stormwater management, can lead to a complex stormwater management system in relationship with fragile connections and low efficiency.

1) Complete stormwater management processes:

The details of the water treatment process in the Zhangjiawo communities are fully visible for local inhabitants, including the collection, conveyance and storage of water. Every node of this system plays its own role. In Tianjin Cultural Park, this park presents a complete and simple, but barely noticeable rainwater collection process due to the unrestricted rainwater runoff on the promenade slope. In Qunli Wetland Park, the designer abandoned the method of traditional long-distance conveyance networks, building instead an intensive green infrastructure to replace the traditional method because the green one can bring a high penetration rate and storage capacity. Therefore, the processes of water treatment, such as unrestricted rainwater runoff, are barely noticeable and difficult to observe.

2) Incomplete stormwater management processes:

Yongyou Software Park, the Guyue Community and the Shuangzi Community are not equipped with complete water treatment processes presented in high visibility. Although the courtyards of Yongyou Software Park represent a clear and complete water treatment process, the park as a whole fails to make its complete process highly visible. The stormwater management system in the Guyue Community relies on engineering mechanisms, such as the connection of a sedimentation basin and underground pipes, which results in parts of the water treatment processes being placed under ground and requires high maintenance costs. In the Shuangzi Community there is a huge area of permeable pavements, which can efficiently absorb rainwater, but it leads to an incomplete rainwater treatment process.

- **Summary of stormwater management system**

This research argues that landscape architects should establish an explicit stormwater management system in accordance with local geographical, climate, and social conditions. In particular, an outstanding explicit structure needs to be constructed by including a significant focus (a water body or centralized sunken land), a powerful linkage network (leading to highly efficient water treatment) which connects and organizes different types of components as an integrated unit and a complete process.

This process can be realized in a highly visible manner by enabling green and engineering infrastructure components to interact. The focus and conveyance systems compose the stormwater management system's functional framework. Based on this framework, the explicit structure can be achieved in order to benefit the local ecological system and facilitate stormwater management system efficiency.

As Table 27 shows, there is an obvious relationship between the results of the questionnaires and project survey. For example, the Zhangjiawo Communities have a successful explicit stormwater management structure because it is equipped with the typical features of such an explicit structure. Correspondingly, its public evaluation is also higher (3.8 points) than the others. Although Tianjin Cultural Park also has an impressive functional center and a complete process, the connections between the focus, the conveyance network and the integration of different components are far more fragile than in the Zhangjiawo Communities, as mentioned above. Its public evaluation is lower (3.0 points) than that of the Zhangjiawo Communities. Both stormwater management systems in Yongyou Software Park, namely the green landscape and the technological systems, are highly efficient.

Table 27: The classification and results of description about visible function

	Zhangjiawo Communities	Cultural Park	Yongyou Software Park	Qunli Wetland Park	Guyue Community	Shuangzi Community
Yes (5 Points)	18	13	15	14	3	1
No (1 Points)	8	13	25	24	19	35
Value (from 1-5)	3.8	3.0	2.5	2.4	1.5	1.1
Classification	Middle visibility of function	Middle visibility of function	Low visible function	Low visible function	Low visible function	Low visible function
Results of description	Central water body	Central water body			Central water body	
			Decentralized water infiltration	Decentralized water infiltration		Decentralized water infiltration
	Connection of components		Connection of components	Connection of components		
		Disconnection of components			Disconnection of components	Disconnection of components
	Integration of components		Integration of components	Integration of components		
		Isolation components			Isolation components	Isolation components
	Complete process	Complete process		Complete process		
			Incomplete process		Incomplete process	Incomplete process

However, due to lack of awareness of the need for the two systems to cooperate and the resultant loss of the functional center (water body) and the lack of a complete process, the functions of stormwater management system are not explicitly represented. This might explain why it received a score of 2.5 in the questionnaires. Compared to Yongyou Software Park, Qunli Wetland Park seems to be equipped with a more explicit structure, while the evaluation of the questionnaires shows that it received a lower value (2.4 points) than Yongyou Software Park. The most important reason is that although the linear basin in the Software Park is not considered as the functional center of the whole stormwater management, it plays a vital role in the landscape system. Compared to the Software Park, the central water body in Qunli Wetland Park plays a significant role as a functional center, but cannot be seen by local inhabitants. In terms of the Guyue and Shuangzi Communities, because both communities do not fully achieve cooperation between the green infrastructure components and the engineering systems, they receive the lowest public evaluation (1.5 points in Guyue Community and 1.1 points in Shuangzi Community).

The comparison shows that in terms of stormwater management system in the six projects, the conclusions regarding the above four groups agrees with public attitudes. Based on this, Table 28 reveals more detailed information about explicitness and ambiguity. In the Zhangjiawo Communities, the water body's function is strongly promoted by the efficiency of the conveyance network. This network connects many components within the communities through a landscape trench system. The water body and conveyance network contribute to the framework of the stormwater management system and produce an accessible and observable water treatment process. However, the disadvantages are also obvious. The conveyance networks connecting urban sewer systems may possibly cause confusion among observers who want to understand the whole system. Additionally, the connection between the water body and green space is also fragile, as mentioned in the case study. As far as Tianjin Cultural Park is concerned, due to the lack of a distinctive conveyance system, it fails to integrate components into a united system serving the stormwater management system. Qunli Wetland Park has a significant functional center, namely the core wetland, while the huge area of naturally decentralized water treatment undermines the explicitness of the stormwater management. In Yongyou Software Park due to the massive application of engineering systems, the stormwater management has a lower explicitness than in Qunli Wetland Park. In terms of the two projects with the lowest marks for explicitness, the Guyue and Shuangzi Communities, due to the influence of the water body the former is relatively better than the latter.

Table 28: Conclusion regarding explicitness versus ambiguity of stormwater management system

Projects	Explicitness versus ambiguity
Zhangjiawo Community	The water bodies are equipped with a well-managed and visible function; the combination has been strengthened by shallow ditches; a large number of components has been built on the ground surface; a good combination produces a complete and observable water treatment process
Tianjin Cultural Park	The visible function of water body is relatively good; however the combination of the components is weak due to the lack of a visible conveyance system; the main components can be seen, but their functional connection is difficult to recognize; therefore, the visible process of rainwater recycling is complete, but is not easily noticed.
Qunli Wetland National Park	The central wetland has a strong capability to absorb rainwater; the combination is achieved by plants and sloping terrain; the stormwater management components are largely composed of plants
Yongyou Software Park	Fails to uphold the influence/function of central water body; lacks a distinctive conveyance network; most engineering components are invisible; a complete process has been established in the courtyard
Guyue Community	Fails to fulfill the goal and roles of water body; isolated and invisible components; incomplete processes
Shuangzi Community	No water body; lack of obvious conveyance network; isolation of components; few visible components and incomplete process

4.7.2.2 Conclusions about open space quality

There is little research that concentrates on the open space quality of stormwater management systems. Among the relevant studies, Stuart Echols's and Eliza Pennypacker's research, with its concept of "artful rainwater design", is the one of the most important pieces of research (Echols and Pennypacker 2008). This concept's five aspects aim to interpret the meaningful open space quality of stormwater management, namely education, recreation, safety, public relations and aesthetic richness. Stuart Echols and Eliza Pennypacker provide very valuable experience and examples, which have considerably inspired the present research. Based on this experience and these examples, the present research continues to develop and analyze this issue from a distinctive perspective. First, in terms of aesthetic richness, Echols and Pennypacker believe that the aesthetic value of stormwater management systems should be rich in pleasure and beauty on the basis of the concepts of Water Sensitive Urban Design (Whelans et al. 1994: p.282). The present author argues that aesthetic value not merely implies providing beautiful scenic pleasure, but also taking historical tradition and identity into account and establishing a relationship between stormwater management system and landscape perception. This relationship needs to be explored and interpreted in order to provide more social value, as has been the focus of this present research. Additionally, related research also provides plenty of useful experience. For example, Backhaus and Fryd adopted the five parameters of aesthetic value to evaluate twenty stormwater management projects in northern Europe. The five parameters are composed of terrain changes, construction and maintenance, site history and context, stormwater accentuation and water dynamics and the dimensions of water landscapes (Backhaus and Fryd 2013). Its conclusions point out that the lack of design features in landscape-based stormwater management is the main reason for providing the public with a low level of landscape experience. The lack of such features might result from too little awareness of the relationship between design focus and other landscape components connected with the focus, such as channels or plazas (p.52). Their article illustrates a particular evaluation method applied in some of their study cases, which also provides much inspiration for the present research.

Table 29: Four groups of open space quality

No.	Summaries from project description	
1	**Focus highlighted** Zhangjiawo Communities; Tianjin Cultural Park;	**Lack of focus** Guyue Community; Shuangzi Community; Qunli Wetland Park; Yongyou Software Park
2	**Interweaving of visible infrastructure** Zhangjiawo Community; Qunli Wetland Park; Yongyou Software Park	**Isolation of visible infrastructure** Tianjin Cultural Park; Guyue Community; Shuangzi Community
3	**Diversity of landscape** Zhangjiawo Communities; Yongyou Software Park;	**Monotonous landscape** Qunli Wetland Park; Tianjin Cultural Park; Guyue Community; Shuangzi Community;
4	**Articulation of rainwater treatment process** Zhangjiawo Communities; The courtyards of Yongyou Software Park	**Inconspicuousness of rainwater treatment process** Qunli Wetland Park; Tianjin Cultural Park; Guyue Community; Shuangzi Community
	Accentuation of open space quality	**Lack of awareness of open space quality**

Based on these insights, the present author has extracted four key phrases from all the project descriptions of open space quality in the six cases examined here in order to highlight their specific design focuses. The four phrases, each with its opposite, and their relationships are explained below, as has already been done with four other phrases in the summary of stormwater management system (Table 29).

- **Functional focus: highlight and lack of focus**

The conclusions about stormwater management system have shown that a functional centre in a stormwater management system can provide multiple functions, including rainwater storage, recreation, ecological habitat, etc. Based on the current investigation, the projects with a huge water body seem to be easy to produce a more impressive landscape than projects without such a water landscape. Therefore, in projects that have such advantages, appropriately highlighting their focal points can generate a unique landscape experience for citizens. Thus, it is recommended that landscape architects organize different components to artistically emphasise the functional centre using different design elements, such as space, light, sound, green plants and water. Reducing the landscape value of the functional centre could result in a featureless landscape and undermine the attractiveness of the whole stormwater management system. This discussion concentrates merely on these projects because there are only three cases that have built a huge water body area, namely the Zhangjiawo Communities and the Guyue Community as well as Tianjin Cultural Park.

1) Highlighting the functional focus in stormwater management:

The water bodies in the Zhangjiawo Communities and Tianjin Cultural Park are highlighted through different design methods. In particular, in the Zhangjiaowo communities the huge area of water bodies located in the central region are interspersed with large areas of vegetation and aquatic plants. Around each water body there are also some distinctive styles of pavilions and benches servicing the local inhabitants. The central water body in Tianjin Cultural Park is also able to produce an impressive landscape experience through the great contrast between the vast expanses of the waterscape on the one hand and the narrow adjacent public spaces on the other.

2) Lack of a functional focus in the stormwater management:

Although the Guyue Community has a huge area of water body, its water body is not designed as a landscape focus. In particular, the waterscape is combined with few aquatic plants and indistinctive public squares. Thus this community does not take full advantage of its different components to highlight its functional centre.

- **Visible infrastructure: interweaving and isolation**

The interweaving involves connecting the different components of a stormwater management system, and means that the conveyance system surrounding the highlighted waterscape should interweave with each landscape node as much as possible and create clear landscape sequences that are identifiable for landscape users. This interweaving thus lends more pleasure and beauty to the stormwater management system by realizing continuous spaces, rich colors and rhythmic texture. Therefore, when aiming to achieve a high quality of interweaving, clear rules for lying out the landscape elements need to be considered in the design concept. The insulation of visible components can result from disconnected conveyance systems or the fragmentation of the whole stormwater management system.

1) Interweaving of visible infrastructure:

The interweaving in the Zhangjiawo Communities and Qunli Wetland Park has been realized to a greater degree than in other projects. In particular, the stormwater management conveyance systems and the other components in the Zhangjiawo Communities are interwoven in different dimensions by introducing various plant patterns, and then developing continuous green spaces with outstanding stormwater management system efficiency and high attractiveness. The whole Qunli Wetland Park also, which is similar to the Zhangjiawo Communities, employs the method of planting many dense and diverse plant groups, which produce an even larger area of continuous green spaces and rare pastoral scenes for the enjoyment of the local inhabitants. To intensify the interweaving as a whole, the ponds set in a ring around the core wetland connect the wetland and the open space in a natural way. These ponds collect rainwater which flows down the slope of high terrains, and contribute to creating a small area of an adorable and natural waterscape, which produces a unique landscape experience for the citizens.

2) Isolation of visible infrastructure:

The conveyance systems in other projects, namely in Yongyou Software Park, Tianjin Cultural Park, the Guyue Community and Shuangzi Community, interweave with fewer components than the above projects. Although Yongyou Software Park achieves a high level of aesthetic value in its stormwater management system, an intensive interweaving is still not achieved because of the complexity of rainwater concept. In contrast to Yongyou Software Park, different and distinctive spaces in Tianjin Cultural Park are connected with each other around the lake in order to provide sufficient space for visitors and to accentuate the huge waterscape area. Nevertheless, the plant systems are not strongly combined with other components, including the waterscape, resulting in a greater isolation of the individual components.

- **Landscape context: diversity and monotony**

The landscape of stormwater management systems needs to be shaped in diverse ways, employing integrated stormwater management components. The above-mentioned integration or interweaving concentrates on combining and connecting components within the framework of stormwater management in order to achieve high efficiency in rainwater treatment. Assuming this has been achieved, the diversity of components aims to make the integration of these functions manifest in landscape design. Ideally, diversity includes at least three factors: coherent open space types connected by conveyance systems, highly attractive waterscapes and diverse plant patterns. Due to the importance of the water body, its diversity contains additional aspects, such as the dimension and quality of the waterscape, and the distribution, pattern and species of plants. Monotony may arise when landscape features of stormwater management systems are not fully developed, such as indistinctive landscape types and ones that lack dynamic change. In particular, when one kind of landscape element or materials of the same colour or texture is employed excessively over large areas, this probably leads to a decrease in attractiveness.

1) Diversity of landscape:

The Zhangjiawo Communities and Yongyou Software Park have relatively high landscape diversity; for example, there are well-pruned shrubs planted along both sides of the streets and combined with the whole conveyance system. Due to the various species of shrubs used here, this combination produces several different street landscapes, which vary in the different communities or locations. Most of the recreational facilities and parts of buildings are also covered by several kinds of vegetation and shaded by trees. The continuous green spaces in the central communities, containing rich species of shrubs and many recreational facilities, combine with central water bodies and present a diverse landscape. As regards the Yongyou Software Park, a highly diverse landscape, built by rich species and natural plant patterns, contributes to its high ecological value and results in impressive visual stimulation.

2) Monotony of landscape context:

The other projects, namely Qunli Wetland Park, Tianjin Cultural Park, the Guyue Community and Shuangzi Community, have relatively high landscape monotony in terms of the stormwater management systems since most of them employ one kind of design material or element with the same colors and context over huge areas. In Qunli Wetland Park the stormwater management concept is combined with the landscape design as a whole, and employs a large number of plants within the three space types, namely ring ponds, public space with elevated terrain and a wetland core zone. Thus this park develops very compact green systems. However, during the summer season, the dominant plant color within the wetland is green. Additionally, due to the limited area and functional features of the ringed-ponds, they also fail to offer the inhabitants a dynamic waterscape. As regards Tianjin Cultural Park, the diversity of landscape is lower than the previously mentioned projects because there are fewer plants to be found in the public open spaces and on the waterscape. Therefore, a huge area of water body and public space without plant diversity leads to reduced attractiveness and a lack of enduring appeal. In the Guyue Community, there is a lack of distinctive landscape changes and of specific attractions due to the massive application of engineering systems. Similarly, the Shuangzi Community abandons green infrastructures and employs a huge area of permeable bricks of the same color and texture, leading to an exceedingly monotonous landscape.

- **Rainwater treatment process: articulation and inconspicuousness**

To achieve a complete process of rainwater treatment, the landscape architect has to consider another significant question about open space quality: namely, how stormwater management, including the process of rainwater treatment, can be distinguished as a specific landscape from the surrounding environment in order to obtain a distinct and rich landscape experience. The conclusions relating to stormwater management system indicate that a complete conveyance system should connect landscape nodes as much as possible and present its functions explicitly. In doing so, designers can use different means of contrast, including dimension, color and material, etc., to highlight the features and structures of a stormwater management system artistically. An inconspicuous process probably results from an incomplete process of rainwater treatment, inaccessible landscapes, natural permeability and other things. This inconspicuousness can result in less pleasure and beauty, and does not attract the local users' attention to the rainwater treatment processes.

1) Articulation of rainwater treatment process:

The Zhangjiawo Communities and the courtyards of Yongyou Software Park employ a very clear structure of stormwater management system, and at the same time the systems produce distinctive landscape features which can attract people's attention. There is a common point in the two projects: their conveyance systems combine with plants to echo the surface of the buildings, for example the patterns of brick pavements reflect structures in the buildings' surfaces. It is also distinguished from the environment by different contrasts, for example, by the color and materials of the road surface, shallow ditches, and artificial and green infrastructure. Specifically, the conveyance system of the Zhangjiawo Communities, namely shallow trenches, can be identified by its changes in materials and color. The courtyards of Yongyou Software Park develop a meaningful landscape on the basis of an explicit rainwater treatment structure. The two courtyards share the same landscape theme and have a similar setting of landscape components, which allow local people to recognize the processes of the rainwater treatment.

2) Inconspicuous rainwater treatment process:

Because the whole natural rainwater treatment system in Qunli Wetland Park is employed and integrated in a pastoral landscape, it is difficult for landscape users to recognize the system. The conveyance system in Tianjin Cultural Park is also hard to recognize. In spite of the fact that the promenades, regarded as this park's conveyance systems, convey rainwater into the water body, the unrestricted rain runoff on the promenades is hard to notice and performs as a landscape feature. Additionally, because the conveyance of rainwater is achieved by underground drains, the landscape quality of Guyue Community and Shuangzi Community are the worst among the six cases.

Summary of open space quality

This research argues that an accentuated landscaping of stormwater management can be achieved on the basis of the explicit structure of the stormwater management system, and the four above-mentioned aspects contribute to this. In particular, the significant functional center needs to be highlighted as a landscape focus, and then be interwoven with other components into the whole landscape system. The diversity of landscape in a stormwater management system, including its distinctive spaces, the recreational public facilities and a dynamic green infrastructure, improves this system and make it more attractive. Based on this diversity, the conveyance systems and other functional nodes of a stormwater management system can also be distinguished from the surrounding landscape by the different contrasts provided by landscape elements.

Table 30: Evaluation of open space quality in six northern Chinese Projects

		Zhangjiawo Communities	Yongyou Software Park	Qunli Wetland Park	Cultural Park	Guyue Community	Shuangzi Community
Statistical data from questionnaires	5 point	10	9	10	2	1	0
	4 point	15	27	18	12	9	10
	3point	1	3	8	7	4	16
	2 point	0	1	2	5	5	8
	1point	0	0	0	0	3	2
Average value		4.34	4.0	3.94	3.42	3.00	2.94
Classification of cases		High aesthetic value	High aesthetic value	Middle aesthetic value	Middle aesthetic value	Middle aesthetic value	Low aesthetic value
Results of descriptions		Focus highlighted			Focus highlighted	Lack of focus	Lack of focus
		Interweaving of visible infrastructure	Interweaving of visible infrastructure	Interweaving of visible infrastructure	Isolation of visible infrastructure	Insulation of visible infrastructure	Insulation of visible infrastructure
		Diversity of landscape	Diversity of landscape	Monotony of landscape	Monotony of landscape	Monotony of landscape	Monotony of landscape
		Landscaping of rainwater treatment process	Landscaping rainwater treatment process	Inconspicuous rainwater treatment process	Inconspicuous rainwater treatment process	Inconspicuous rainwater treatment process	Inconspicuous rainwater treatment process

The summaries of the open space quality in each project are shown in Table 30. The Zhangjiawo Communities obtained the highest evaluation (4.34 points). Due to the high quality of explicit functional structures, the communities have produced an excellent accentuated landscape for their stormwater management system. Yongyou Software Park gains the second highest evaluation (4.0 points). This research argues that although this park does not have a strong functional center, it still has excellent green systems, which achieve a high quality of accentuated landscape. Qunli Wetland Park has a moderate quality of open space on the basis of its natural rainwater treatment systems, as mentioned above, while the evaluation is lower (3.94 points) than that of Zhangjiawo and Yongyou. There is a gap between public evaluation and research conclusions. The research argues that the park does indeed produce an impressive natural landscape combined with the rainwater treatment system, while less distinctive features of the stormwater management systems undermine the attractiveness of the whole park, which cannot develop an enduring appeal for the citizens.

Additionally, the open space quality in Tianjin Cultural Park scored 3.42 points. Due to the influence of the functional center, the accentuation of landscape in the Cultural Park is higher than in the Guyue and Shuangzi Communities, which have 3.0 and 2.94 points respectively.

Table 31: Conclusion of accentuation versus lack of awareness of stormwater management system

Projects	Accentuation versus lack of awareness of open space quality
Zhangjiawo Communities	Highlighting the landscape focus by accentuating dimensions and landscape elements; the components of stormwater management have been interwoven; the functional structure is innovative due to the various infrastructure and space types; the conveyance systems is integrated in the landscape, and at the same time distinguished from the surrounding environment
Yongyou Software Park	Water body's huge potential regarding its landscape value is not fulfilled; the interweaving has not been fully achieved due to the polarization of the rainwater treatment system; however, the park still provides a green landscape; the components of stormwater management are integrated in the landscape of the courtyards.
Tianjin Cultural Park	Water body is highlighted by means of dimension and contrast; the interweaving is not strong due to little plant participation; however, there is a huge attractiveness for citizens on account of the water body and suitable public space; the conveyance system is not noticeable in the landscape.
Qunli Wetland Park	The core wetland is covered with dense vegetation; the interweaving has been achieved by the dominance of green infrastructure; although the park offers a rare natural landscape, its attractiveness is reduced due to poor maintenance, few plant species, and limited public space; many conveyance systems form part of the landscape, but it is difficult to notice them.
Guyue Community	The water body is highlighted by dimensional contrast; the interweaving of components is weak; landscape attractiveness is reduced by an unclear stormwater management structure; the conveyance systems are made up of underground pipes, which are not part of the landscape.
Shuangzi Community	There is no landscape focus; the whole landscape system is fragile and unattractive; the conveyance system is underground and thus not part of the landscape.

Table 30 shows the summary of open space quality in each project as provided by the design descriptions. The Zhangjiawo Communities attach an accentuated landscape layer onto the explicit structure of their stormwater management system. Yongyou Software Park employs complicated engineering systems and fails to present the whole system in the sense of a landscape. However, this park maintains a diverse landscape, interweaving different landscape infrastructure components. Additionally, the courtyards in this park provide an explicit rainwater treatment structure, which advances the landscape accentuation to a certain degree.

Compared to the Zhangjiawo Communities, Yongyou Software Park does not treat the river as a functional focus, which also causes the accentuation of this software park to be weaker than in the above project. Although the huge artificial lake, which is highlighted as the most important landscape node, profoundly increases the open space quality of Tianjin Cultural Park, the quality of the interweaving, diversity and the inconspicuous rainwater treatment process undermine the attractiveness of the park as a whole. As regards the Qunli Wetland Park, due to the invisibility of the core wetland and the inconspicuous rainwater treatment process, the stormwater management system has no distinguishing landscape features. Although the interweaving produces a highly intensive landscape pattern, the lack of landscape features decreases the attractiveness and fails to present the functions of the stormwater management systems. In the last two communities, namely the Guyue Community and Shuangzi Community, they fail to explore greater potential for stormwater management offered by the green infrastructure. In particular, the Guyue Community, with its huge water body, has a more diverse landscape than the Shuangzi Community and thus greater potential.

4.7.2.3 Conclusions about landscape perception

Based on the Information Processing Theory discussed in Chapter 2, the conclusions relating to landscape perception are discussed from two aspects: the coherent pattern and legible landscape of stormwater management systems. The essence of landscape perception can be grasped from the combination of these two aspects.

- **Coherent pattern of stormwater management**

A system's coherent pattern is closely related to the stormwater management system. It should organize the order of the functions and the spatial rhythm on the basis of functional coherence: 1) the order of functions rationally distributes landscape elements on the ground according to local geographical conditions, and can thus establish an explicit structure of stormwater management. Based on the conclusions about conveyance systems and functional centres referred to in the section on stormwater management system above, component nodes with diverse functions should have a clearly hierarchical relationship to each other in this structure following an coherent order; 2) designers need to organize and regulate the dimension of components according to a spatial rhythm. The order of function and rhythm of space could be the main preconditions for producing an outstanding landscape perception. There are two things worth highlighting here: 1) designers should pay more attention to balance the financial, social, climatic and geographical factors in order to produce a more reasonable and sustainable coherent pattern of stormwater management; 2) a high accessibility is also necessary for encouraging inhabitants to walk, notice and observe stormwater management system.

- **Legible landscape of stormwater management**

This research argues that the legibility of stormwater management has two layers which are closely related to coherent patterns. Kevin Lynch indicates the relationship between landscape legibility and way-finding experience (Lynch 1960: P.3). And Stephen Kaplan continues this notion and proposes that a legible space should be easy to remember and understand, because it is also a well-structured space (Kaplan and Kaplan 1989: p.56). This present research proposes the first layer regarding legibility of landscape is considered as an important prosperity of cityscape, because it cannot only stimulate human perception, such as meeting our visual pleasure demands, but also often allow human beings to produce necessary way-finding experience. Moreover, the first layer can be performed by a high quality of the whole open space system and be sustainably improved from the setting of landscape elements on the coherent pattern, and then it has a strong attractiveness, and can facilitate citizens to understand the whole system.

The second layer concentrates on the individual components to stimulate the memorability to draw the mental map. In particular, both Kevin Lynch and Stephen Kaplan agree that the legible landscape can distinguish from the environment in order to provide a clear identification through colours and clear symbols. Visual sensation could be stimulated by landscape methods solving a significant question, namely how a very memorable function nodes of stormwater management systems can be built.

1) The first layer of the legible landscape:

The first layer could be a "legible landscape hierarchy". A successful perceptible landscape of stormwater management should have a hierarchical relationship, contributed by the whole open space quality, on the basis of its coherent structure. A functional centre, linkage system and sub-branch nodes can constitute an explicit functional hierarchical model. Actually aiming to be well understood by inhabitants, every landscape nodes in each functional node or branch should have their own complete rainwater treatment system. Every branch on different levels should have kept their hierarchical relationship with each other, rather than "overtones of utter disaster" (Lynch 1960: p.5). By this setting, it can provide people a capacity to predict and imagine the structure of entire system, and even when they cannot overlook the whole landscape, such as the stormwater management system in Zhangjiawo Communities.

2) The second layer of the legible landscape:

The second layer focuses on the details and sections of this hierarchical system therefore can be named "legible landscape-element". The notice, appreciation, and perception can be stimulated by the legible landscape context with rich details and distinctive landscape features such as highlighted landscape centre, diverse landscape elements and landscaping processes of rainwater treatment. Every component in the functional branch also should be represented through a similar and repetitive theme in balance of the whole landscape system, for example, they should have a visual connection, such as correlated dimension, landscape setting, similar function, etc. In particular, 1) water body could be considered as landscape focus, for example, a huge area of waterscape and well-managed space pattern could bring a strong memory. 2) Linkage systems should use a visible artificial conveyance network with plant beds, because this network could precisely organize rainwater flowing. By these ways, the visual connection of components could be strengthened. More details or colour can be attached on this system, which can distinguish from the surrounding environment. 3) The connection between components and linkage system should be accentuated for completing inhabitants' mental map. 4) Individual components in every branch, such as square and parking lot, should follow the hierarchical order and rules. They should share a common design theme and similar landscape management in order to facilitate the prediction and imagination.

4.7.2.4 Comparing the conclusions by sketches

In the projects, some landscape components in the six cases were built, such as linkage system (natural or artificial conveyance systems), functional centre (water body), permeable area, and artificial permeable area. Nevertheless, in certain situations they cannot be accessed or not be seen by regular visitors. The most obvious example is the central rainwater storage in Qunli Wetland Park which might ideally keep a high landscape quality, but cannot contribute to a high landscape perception in the reality. Therefore, this present author draws six drawing maps from the memory to compare them and to draw the final conclusion. Certainly,. First, the categories as visual elements are drawn in every project and are represented through different colours (Figure 108-113). If these categories are inaccessible and unobservable, there are no colours on the maps. Based on these, this research gained six maps in the relationship with visual impression of stormwater management systems. In terms of these drawings, they convey clear information about the coherence and legibility of landscape perception.

Based on this comparison, the landscape perception among the six cases has been ordered from highest to lowest. It shows that the evaluation of these maps and the final conclusion are basically accordant.

Figure 108: Drawing map of Qunli National Wetland Park

Although the ringed-ponds provide a clear space structure, the decentralised processes of rainwater treatment and the inaccessible water body result in a vague functional structure and fail to provide a legible landscape context.

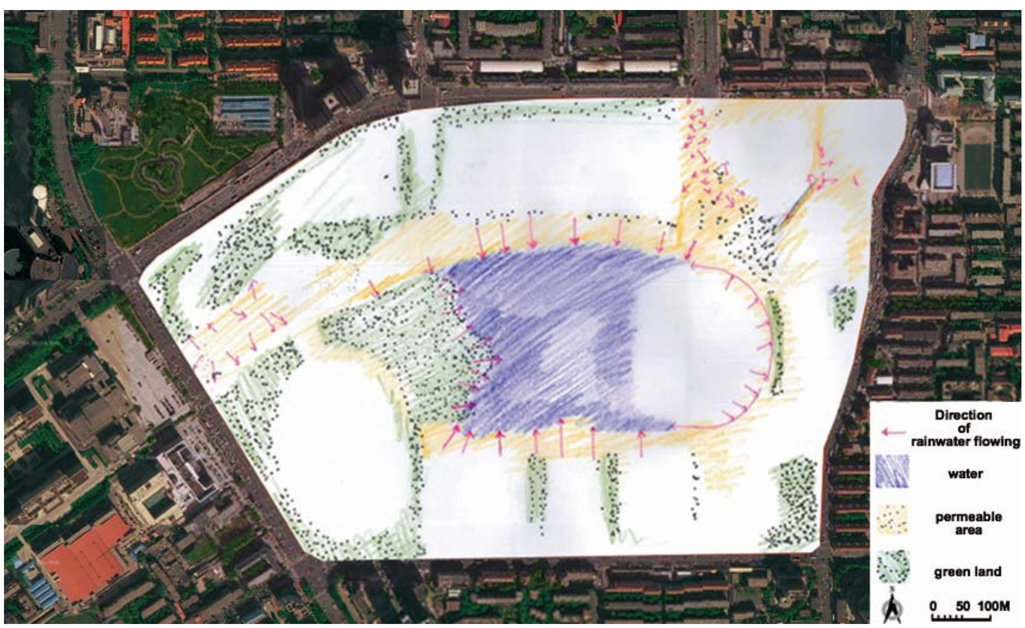


Figure 109: Drawing map of Tianjin Cultural Park

Tianjin Cultural Park provides a simple but clear dimension pattern given by the combination of water body, promenade, and squares. However, this combination does not cover the whole park, which limits the legibility of landscape perception.

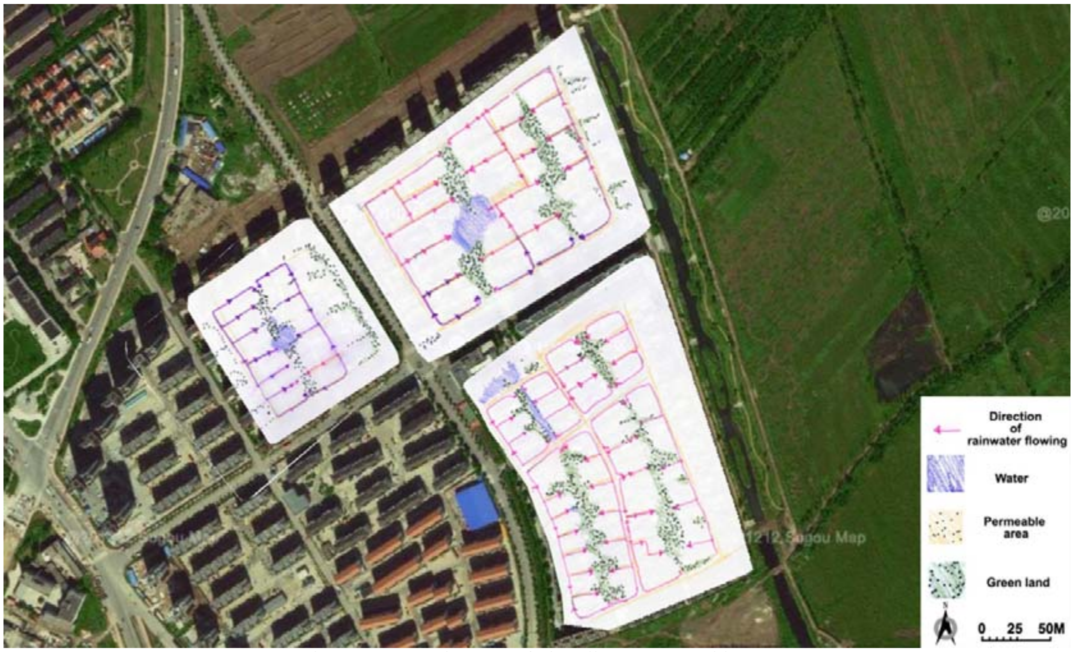


Figure 110: Drawing map of Zhangjiawo Communities

The three Communities have a well-managed coherent pattern and legible landscape context. The explicit structures are coherent surrounding each building. The individual landscape component in each landscape system also represents a distinctive feature on these explicit structures.

Figure 111: Drawing map of Yongyou Software Park

The waterscape does not provide an understandable water treatment process, but rather a scenic landscape. The functions of waterscape are not expressed by a pleasant and visual way. However, intensive green infrastructure and the courtyards with coherent landscape patterns produce certain legible information for the public with respect to the stormwater management systems.

Figure 112: Drawing map of Guyue Community

Figure 113: Drawing map of Shuangzi Community

The maps of the Guyue and Shuangzi Communities represent an exceeding isolation and low quality of landscape patterns, which can significantly undermine the legibility. The Guyue community has more coherent landscape features than the Shuangzi Community. Based on the featureless landscape of the stormwater management system in the Shuangzi community represented in the map, people who are first time visitors to this community can lose their direction. The local inhabitants also perceive less information about the stormwater management system than in other projects.

Chapter 5 Final Discussion and Conclusions

This research set out to explore ideas on how landscapes are perceived regarding stormwater management and on how this relates to stormwater management system and open space quality. The present work has established that cities in northern China have several challenges in common, namely a low quality of stormwater management system, low aesthetic value and a lack of public awareness of the need to protect and conserve water resources – findings that demonstrate how urgent this kind of study is. Two specific research questions were proposed with a view to making recommendations for improving existing urban stormwater management systems in China.

Because of the gap between theory and practice, the relevant backgrounds have been reviewed, including theoretical research and practical projects both in the West and in China. The review of the German projects contributed to the choice of study cases in northern China. The theoretical review drew attention to two crucial points. Firstly, the lack of public awareness about how to manage water resources is closely related to how people perceive a landscape. Landscape perception is influenced by the functions and landscape features of stormwater management systems. Secondly, because of the huge challenges of cross-cultural research, resulting from the differences in the culture and in the social and urban environments, the present research concentrates on six northern Chinese cases and adopts a methodology that combines quantitative and qualitative tools, namely questionnaires and design descriptions. In accordance with this methodology, verified conclusions extracted from the project descriptions have been used to answer the following research questions.

Research questions:

1.) What are the qualities of contemporary northern Chinese stormwater management projects in terms of stormwater management system, open space quality, and landscape perception?

2.) Which recommendations can be made regarding design strategies to raise the quality of future stormwater management projects in urban landscapes in northern China?

Summing up the answers to question 1:

This research has evaluated the study cases using a variety of methods ranging from empirical project descriptions combined with the author's view to questionnaires aimed at ascertaining public opinion. This combination has produced a comprehensive rating system which is able to evaluate the quality of stormwater management system, open space quality and landscape perception from the perspective of stormwater management (see section 4.7).

Summing up the answers to question 2:

It is recommended that stormwater management systems have an explicit structure with visible functional components, since these are able to create a legible pattern in a coherent landscape.

These summaries now need to be looked at in more detail with regard to the individual aspects: stormwater management system, open space quality and landscape perception.

1) Regarding stormwater management system:

Landscape architects need to build a comprehensive linkage system to connect every node in order to produce an integrated functional unit of stormwater management with a visible and complete rainwater treatment process, as defined below.

Stormwater management system in this research has two meanings, one of which is related to the traditional explanation, namely that the rainwater input and output should be balanced. The other sense is a refinement of the first meaning and is regarded here as the foundation for open space quality in the context of stormwater management. This second meaning demands of stormwater management the following. First, well-managed and visible components of stormwater management that replace underground engineering systems should be ordered hierarchically according to geophysical conditions and the design concept, distinguishing between more important and less important elements (see section 4.7.2.1). Second, the hierarchical relationship needs to be based on an explicit functional structure. This explicit structure has four features: a central water body, connections between components, the integration of components into the whole system and a complete rainwater treatment process, i.e. from effective rainwater collection, even during periods of heavy and prolonged rainfall, through retention to purification and recycling. The explicit structures, arranged hierarchically, bring greater efficiency and enable the stormwater management system to tackle the existing water challenges more adequately (see section 4.7.2.2). Such an approach also introduces greater water treatment efficiency, for example by creating a clear structure for transporting rainwater and a functional centre with a huge capacity for storing water. Additionally, it benefits the ecological system as a whole, because the stormwater management structure needs to cooperate more closely with the green infrastructure. A well-functioning structure also provides a solid basis for promoting the open space quality of stormwater management. For example, an explicit structure facilitates the distribution of landscape elements and at the same time makes the system highly characteristic, thus distinguishing it from the surrounding environment. Therefore, the task of establishing an explicit structure with visible and distinctive components should receive much more attention from designers.

2) Concerning open space quality:

A stormwater management system's open spaces should be distinguishable from the surroundings on account of their explicit structures and features. Theoretically, the open space system can be considered as a dynamic integration produced by human imagination and changes in nature, and thus is a significant point in realizing communication between the imagination (landscape perception) and reality (structure of stormwater management).

Thus, it is worth emphasising that the open space quality of stormwater management is understood in two ways. First, from the perspective of landscape architecture, stormwater management needs to press for holistically designed open space systems to be more attractive and to establish a more attractive and pleasing ambience, as the case study of Yongyou Software Park shows (see section 4.5.5). Second, by giving the components of a stormwater management system a clear structure and embedding them meaningfully in the landscape, they are accentuated, thereby increasing the uniqueness of a particular landscape. The designer can achieve this by taking advantage of landscape features such as colour, texture, and dynamics, and of an ordered arrangement of formal qualities such as repetitiveness and contrast, and thus creating a scenic landscape, as shown in the study case of the Zhangjiawo Communities (see section 4.3.3.2). In particular, the water storage body can be regarded as a vital functional node that operates as a recreational, communicative and potentially beautiful space. Additionally, all components of a stormwater conveyance system should be visually interlinked; using plant patterns, material usage and dimensional changes to build a diverse landscape and to produce a rich landscape experience (see section 4.7.2.2). The process of rainwater treatment, supported by the landscape design, is also very much worth being highlighted and displayed because it also produces a unique landscape experience.

The findings of the present research suggest that it is advisable to combine the visible water treatment process with pathways, particularly with sidewalks or promenades. Walking is a good way of experiencing nature and allows the landscape to open up fully before the visitors' eyes. A well-managed landscape setting offers an attractive atmosphere that will encourage inhabitants to walk and observe. In this way, the dimensions, structure, meanings and the interlinking of stormwater management components can easily be converted into a legible language, waiting to be read.

3) Regarding landscape perception:

A legible stormwater management system that benefits from the stormwater management system's explicit nature and an emphasis on open space stimulates landscape perception significantly.

The system needs its function to appear ordered and with dimensional rhythm (see section 4.7.2.3.). Theoretically the appearance of the landscape expresses such function and can be considered as a bridge between stormwater management system (functional unit) and human perception (understandable structure), and at the same time it is the first key to opening up the essence of landscape perception. The ordered function and dimensional rhythm introduce regular sequences of landscape design and predictable changes to the whole stormwater management system. Designers are advised to arrange the different elements and spatial types with a view to composing an overall image and to consider the balance between landscape uniqueness and function.

A legible landscape is the second key and has two layers of meaning. Building up on the basis of the stormwater management system's coherence and ordered character, the first layer requires the designer to consider the whole stormwater management system as a hierarchical system – one that allows visitors to grasp the structure of stormwater management within the overall environment easily and quickly. A rainwater management systems should have hierarchically clear rules and become integral parts of landscape design. If this is done, the Prospect Refuge Theory argues, visitors will receive emotional pleasure from understanding a particular environment (see section 2.3.3.1). The second layer focuses on the comprehensibility of landscape from a personal perspective. Profiting from the landscape value of stormwater management, the attractiveness of scenic landscapes stimulates the inhabitants' appreciation, and at the same time facilitates building a mental map of the area. Such memorized images change continually and improves the inhabitants' awareness of the stormwater management system over time.

In brief, the integration of stormwater management system and open space quality can build a specific landscape with a hierarchical structure for stimulating more intensive landscape perception, and produces a coherent pattern and legible landscape as the essence of landscape perception in the context of stormwater management. Thus the hierarchical relationship provides an understandable structure – one in which people feel comfortable because it satisfies human beings' curiosity about unknown environments. The individual components of stormwater management should also be attractive and integrated into the landscape following the rules of hierarchical relationships. Through the contrast and repetition of various design elements, landscape visitors perceive the information about the local stormwater management system as a result of the highlighted landscape features. Therefore, as discussed above, focusing on how humans perceive individual components and the whole system of stormwater management, this research aimed to bring more attention to understanding and appreciating stormwater management systems.

Research limitation

There are several limitations in this research as well. First, as mentioned in Chapter 3, there are challenges which the investigation had to face in the process of interviewing respondents and collecting questionnaire data, such as the imbalance of social groups in the questionnaire survey. It can be seen that these challenges derive from social situations and cultural factors, for instance, from highly dynamic population mobility and the respondents' different recreational habits. In the present case, time and funds for dealing with these challenges were limited although a considerable effort was made take them into account. In future, when exploring the relationship between human behaviour, urban environments and natural surroundings in the context of stormwater management, it will be necessary to research such projects in greater depth and over a longer period of time. Additionally, the theoretical basis of landscape perception relates to studies of psychology and environmental science. Thus future research of this kind would benefit greatly from cooperating with interdisciplinary research teams as much as possible.

Research Outlook

The proposed goals of creating “Sponge Cities” provide urban planners with stimuli for achieving comprehensive and integrated design when constructing urban stormwater management systems in Chinese cities. However, one of the possible scenarios – unfortunately all too true of developments in China in the past and to be found elsewhere in the world as well – is that magnificent goals and ideals are being held up without providing a sound and broad theoretical basis. The danger is that the concept of Smart Cities will simply turn out to an attractive slogan which appears to mean everything, but in fact means nothing at all. Constructing such a theoretical background is a necessary step, but one that will demand much effort from the entire and considerable patience. Future research needs to focus on how to fulfil the potential and goal of “Sponge Cities”, as this present research.

Although this current research focuses mainly on landscape design on a project scale, it is quite clear that sustainable stormwater management systems on this scale can only be truly influential and effective when incorporated into comprehensive and legible urban systems that link the different projects together. Therefore, looking now on an urban scale, stormwater management systems, if implemented effectively, can serve as an urban “sponge core”, thereby dealing with stormwater peaks more effectively, tackling the rainwater crises and providing more social and recreational value. Flexible and resilient urban open space systems can thus be built as “sponge cities”, constituting an important step towards creating smarter cities. The present research argues that there are three significant steps in this process: 1) a new stormwater management system on the project or site scale, which can be considered as a “green-blue landscape core”, is ideally linked with the surrounding environment through pipes or ditches to maximize its potential. 2) Any surrounding projects that lack stormwater management can be adapted by building sunken green land for retention or a multi-functional infrastructure for both recreation and storing rainwater. If these projects do not have sufficient space, they need alternatively to be linked to existing sponge cores in order to tackle local waterlogging. 3) By means of interdisciplinary cooperation and the participation of policy makers and designers, citizens can be encouraged to participate and find their own ways of reusing rainwater, thereby creating an environment adapted to their taste and needs. As more inhabitants develop an awareness of stormwater management and want to become involved, flexible and resilient urban landscapes will be realized.

To sum up, this study has concentrated on investigating, analysing and evaluating six landscape projects in northern China in order to answer the design question: How can the landscapes of stormwater management systems be designed in such a way that they are understood and appreciated more by the public? Essentially, two significant factors have been dealt with in this dissertation. The first one focuses on investigating and evaluating the current qualities of stormwater management in these six cases. Initially, the motivation and the research background were introduced by discussing the challenges presented by the situation of an ineffective stormwater management system and the low quality of open space systems in northern Chinese cities. Then, the investigation of the six study cases provided an integrated method to gain insight into the present qualities of stormwater management in northern China regarding three specific aspects, namely stormwater management system, open space quality and landscape perception. By investigating and evaluating these three aspects, it has been demonstrated that the six northern Chinese stormwater management projects have failed – some to a greater degree, others to a lesser degree – to produce understandable and appreciated landscapes that present the functions of stormwater management to the public in a legible way – or at least have achieved very unsatisfactory results. The second significant aspect considers which new recommendations can be made on a landscape scale to improve the present situation. The conclusions drawn from the case studies have shown that hierarchical and predictable landscape patterns need to be integrated into the design concept, thereby organizing the functions of stormwater management systems visibly and producing greater aesthetic values. If produced in this way, landscape systems attach legible, coherent and perceptible values to a stormwater management system. Ideally such systems provide new perspectives for the interdisciplinary cooperation and public participation in the further development of "Sponge Cities". They may also trigger off a landscape architect's imagination in seeking solutions to responding to the current challenges and handling them creatively and aesthetically. Furthermore, this research has not only focused on the restricted local scale. A specific aspect of the urban scale has also been highlighted, because this study predicts that the establishment of "sponge cores" is a precondition for achieving flexible and resilient "green and blue" networks. It maintains that, although requiring much time and patience, the perspectives mentioned above are worth striving for, because such sustainable networks are an integral part of "Sponge Cities" and represent a feasible solution for producing unique and ecologically oriented urban landscapes in China.

.

List of Tables

List of Figures

(Where no reference is given, the photograph was taken by the author)

List of References

Adler, R. W., Landman, J. C., Cameron, D. M., (1993), *The clean water act 20 years later*, Island Press
Ahern, J., (2002), *Greenways as strategic landscape planning: theory and application*, Wageningen Universiteit
Ahern, J., (2007), *Green infrastructure for cities: The spatial dimension, a chapter in Cities of the Future: Towards integrated sustainable water and landscape management (V. Novotny, and P. Brown, eds.)*, London, IWA Publishing.
Airola, T. M., Wilson, D., (1982), Recreational benefits of residual open space: A case study of four communities in Northeastern New Jersey, *Environmental Management* 6(6):471-484
Aitken, S. C., Cutter, S. L., Foote, K. E., Sell, J. L., (1989), Environmental perception and behavioral geography, *Geography in America*:218-238
Akan, A. O., Houghtalen, R. J., (2003), *Urban hydrology, hydraulics, and stormwater quality: engineering applications and computer modeling*, Wiley
Akinyemi, E., 'An Approach to Mainstreaming Low Impact Development (LID) Technology in Municipal Engineering Practices', *Low Impact Development for Urban Ecosystem and Habitat Protection*, ASCE, 2009, pp. 1-10,
Al Radif, A., (1999), Integrated Water Resources Management (Iwrm): An Approach To Face The Challenges Of The Next Century And To Avert Future Crises, *Desalination* 124(1):145-153
Alston, M., (2000), Rural poverty, *Australian Social Work* 53(1):29-34
Alvim-Ferraz, M. C. M., Sousa, S. I. V., Pereira, M. C., Martins, F. G., (2006), Contribution Of Anthropogenic Pollutants To The Increase Of Tropospheric Ozone Levels In The Oporto Metropolitan Area, Portugal Since The 19th Century, *Environmental Pollution* 140(3):516-524
Amir,S., Gidalizon,E., (1990), Expert-based method for the evaluation of visual absorption capacity of the landscape, *Journal of Environmental Management* 30(3):251-263
Angelakis, A. N., Koutsoyiannis, D., Tchobanoglous, G., (2005), Urban wastewater and stormwater technologies in ancient Greece, *Water Research* 39(1):210-220
Antrop, M., Van Eetvelde, V., (2000), Holistic aspects of suburban landscapes: visual image interpretation and landscape metrics, *Landscape and urban planning* 50(1):43-58
Appleton, J., (1975), *The experience of landscape*, John Wiley & Sons.
Appleton, J., (1978), *The poetry of habitat*, Landscape Research Group and Dept. of Geography, University of Hull
Appleton, J., (1994), Running before we can walk: are we ready to map 'beauty'?, *Landscape Research* 19(3):112-119
Ataov, A., (1998), Environmental aesthetics, *Journal of Planning Literature* 13(2):239-257
Backhaus, A., Fryd, O., (2013), The aesthetic performance of urban landscape-based stormwater management systems: a review of twenty projects in Northern Europe, *Journal of Landscape Architecture* 8(2):52-63
Bai, F., (2000), Probe the Quality of Environment Greening in Inhabited District of Comfortably-off Families, *Chinese Landscape Architecture* 6(67):38-42.[In Chinese]
Bai, X., (2005), Probing the Demonstration Engineering of Collection Rain Water in Beijing, *Construction Science And Technology* 14.[In Chinese]
Barry, D. S. (2013), *Plato*, Available from: www.mycrandall.ca/courses/grphil/plato.htm, (accessed 9.10.2015)
Behrens, R. R., (1998), Art, design and gestalt theory, *Leonardo*:299-303
Benedict, M. A., McMahon, E. T., (2002), Green infrastructure: smart conservation for the 21st century, *Renewable Resources Journal* 20(3):12-17
Benedict, M. A., McMahon, E. T., (2006), *Green infrastructure: linking landscapes and communities*, Island Press
Beneke, G., (2003), *Regenwasser in Stadt und Landschaft: vom Stück-Werk zur Raumentwicklung; Plädoyer für eine Umorientierung*, Inst. für Freiraumentwicklung und Planungsbezogene Soziologie
Bickhard, M. H., (2001), Why children don't have to solve the frame problems: Cognitive representations are not encodings, *Developmental Review* 21(2):224-262
Bishop, I. D., (1997), Testing perceived landscape colour difference using the Internet, *Landscape and Urban Planning* 37(3):187-196
Borja, A., Franco, J., Valencia, V., Bald, J., Muxika, I., Jesús Belzunce, M., Solaun, O., (2004), Implementation of the European water framework directive from the Basque country (northern Spain): a methodological approach, *Marine pollution bulletin* 48(3):209-218

List of References

Bowden, M. J., (1984), Environmental perception in geography: a commentary, *Chicago: University of Chicago, in: TF Saarinen, D. Seamon, JL Sell (Eds.), Environmental Perception and Behavior: An Inventory and Prospect, Department of Geography Research Paper* (209):85-92

Bowman, T., Thompson, J., (2009), Barriers to implementation of low-impact and conservation subdivision design: Developer perceptions and resident demand, *Landscape and Urban Planning* 92(2):96-105

Brander, L. M., Koetse, M. J., (2011), The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results, *Journal of environmental management* 92(10):2763-2773

Brown, T., Keane, T., Kaplan, S., (1986), Aesthetics and management: bridging the gap, *Landscape and Urban Planning* 13:1-10

Brown, T. J., Itami, R. M., (1982), Landscape principles study: procedures for landscape assessment and management—Australia, *Landscape Journal* 1(2):113-121

Brunson, M. W., Effects of traditional and" New Forestry" practices on recreational and scenic quality of managed forests, 1991,

Harbin Statistics Bureau (2014), *Natural Geography*, Available from: www.harbin.gov.cn/zjhrb/sqgl/csgk/zrdl.htm, (accessed 9.10.2015).[In Chinese]

Burns, M. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., Hatt, B. E., (2012), Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform, *Landscape and Urban Planning* 105(3):230-240

Butler, D., Parkinson, J., (1997), Towards sustainable urban drainage, *Water Science and Technology* 35(9):53-63

Canter, D.V., Craik, K.H., (1981), Environmental psychology, *Journal of Environmental Psychology* 1(1):1-11

Carlson, A., (1993), On the theoretical vacuum in landscape assessment, *Landscape Journal* 12(1):51-56

Cary, H., Burges, G., (1859), *The Works of Plato*, Henry G. Bohn

Chang, N., (2010), Hydrological connections between low-impact development, watershed best management practices, and sustainable development, *Journal of Hydrologic Engineering* 15(6):384-385.[In Chinese]

Che, W., (2011), Some Important Problems of Chinese Urban Rainwater (In Chinese), *Water & Wastewater Engineering* 37(8).[In Chinese]

Che, W., Frank, T., Li, J., Zhang, Y., (2012), Introduction to Auckland modern stormwater management (I): relevant legislation and plans (In Chinese), *Water & Wastewater Engineering* 48(3).[In Chinese]

Che, W., Li, J., (2011), The Application Of The Low Impact And Green Rainwater Infrastructures In The Multiple-Dimension (In Chinese), *Water & Wastewater Engineering* 37(12).[In Chinese]

Che, W., Ma, Z., Wang, S., Zhang, Q., J., W., (2013), Specific Planning for Stormwater Management and Utilization in Chinese Urban Planning System, *China Water & Wastewater* 29(2).[In Chinese]

Che, W., Tang, N., Zhang, W., (2007), Analysis on the characteristics of rainfall in China for urban rainwater utilization, *33*.[In Chinese]

Chemero, A., (2003), An outline of a theory of affordances, *Ecological psychology* 15(2):181-195

Chen, L., Wei, W., Fu, B., Lü, Y., (2007), Soil and water conservation on the Loess Plateau in China: review and perspective, *Progress in Physical Geography* 31(4):389-403

Chen, S., (2010), The Urban Layout and Construction of Cheng Du in the Ming Dynasty (In Chinese), *Journal Of Chengdu University (Social Sciences)* 2.[In Chinese]

Cheng, H., Hu, Y., Zhao, J., (2009), Meeting China's water shortage crisis: current practices and challenges, *Environmental Science & Technology* 43(2):240-244.[In Chinese]

Cheng, J., Xu, Q., Yang, K., Liu, L., Fan, Q., (2007), Comparison of Foreign Urban Rainwater Resource Utilization Management Systems and Some Inspirations(In Chinese), *China Water & Wastewater* 23(12).[In Chinese]

Cho, S. H., Poudyal, N. C., Roberts, R. K., (2008), Spatial analysis of the amenity value of green open space, *Ecological Economics* 66(2):403-416.[In Chinese]

EEE Smart Cities (2009), *IEEE Smart Cities*, Available from: http://smartcities.ieee.org/about.html, (accessed 01. 17. 2016)

Clamp, P., Powell, M., (1982), Prospect - refuge theory under test, *Landscape Research* 7(3):7-8

Cohen, P. R., (1996), Empirical methods for artificial intelligence, *IEEE Intelligent Systems* (6):88

Council, W. F., (2010), *Open Space Strategy* (W. F. Council, ed.), Waltham.

Crawford, D., Timperio, A., Giles-Corti, B., Ball, K., Hume, C., Roberts, R., Andrianopoulos, N., Salmon, J., (2008), Do features of public open spaces vary according to neighbourhood socio-economic status?, *Health & Place* 14(4):889-893

Cross, R. C., Woozley , A. D., (1966), *Plato's Republic: A Philosophical Commentary* Macmillan

Dasgupta, S., Huq, M., Wheeler, D., Zhang, C., (2001), Water pollution abatement by Chinese industry: cost estimates and policy implications, *Applied Economics* 33(4):547-557 de la Fuente de Val, G., Atauri, J., de Lucio, J. V., (2006), Relationship between landscape visual attributes and spatial pattern indices: a test study in Mediterranean-climate landscapes, *Landscape and Urban Planning* 77(4):393-407

Deadman, P., Gimblett, R. H., (1994), A role for goal-oriented autonomous agents in modeling people-environment interactions in forest recreation, *Mathematical and Computer Modelling* 20(8):121-133

DeLucio, J., Múgica, M., (1994), Landscape preferences and behaviour of visitors to Spanish national parks, *Landscape and urban planning* 29(2):145-160

Ding, R., (2004), Experts Talk about Usage of Rain Water, *Construction Science And Technology* 16.[In Chinese]

Ding, Y. (2005), *The Perspective of Rainwater Recycle in Beijing Urban Area*, Available from: www.chinawater.net.cn/zt/20zrhg/CWSNews_View.asp?CWSNewsID=22570, (accessed 4.3.2015).[In Chinese]

Dong, L., Che, W., Hai, Y., (2007), Present Status and Problems of Rainwater Utilization Plan in Some Chinese Cities, *China Water & Wastewater* 23(22).[In Chinese]

Dreiseitl, H. (2008), *Zhangjiawo New Tow*, Available from: www.dreiseitl.com/index.php?id=55&lang=en, (accessed 06.11.2014)

Dreiseitl, H. (2012), *Tianjin Cultural Park*, Available from: www.dreiseitl.com/index.php?id=58&lang=en, (accessed 08.11.2014)

Dreiseitl, H., (2013), In conversation with Herbert Dreiseitl, *Journal of Landscape Architecture* 8(2):74-75

Dreiseitl, H. (2015), *Atelier Dreiseitl*, Available from: www.dreiseitl.com/data/ATELIER/PDF/AD_office_profile.pdf, (accessed 4.5.2015)

Dreiseitl, H., Grau, D., (2005), *New Waterscapes: Planning, Building and Designing with Water*,

Dreiseitl, H., Grau, D., (2009), *Recent Waterscapes: Planning, Building and Designing with Water*, Birkhäuser

Dreiseitl, H., Grau, D., Ludwig, K. H., (2001), *Waterscapes: Planen, Bauen und Gestalten mit Wasser*, Birkhauser Boston

Ebi, K. L., Burton, I., (2008), Identifying practical adaptation options: an approach to address climate change-related health risks, *Environmental Science & Policy* 11(4):359-369

Echols, S., Pennypacker, E., (2008), From stormwater management to artful rainwater design, *Landscape Journal* 27(2):268-290

Egan, D., (1990), Historic initiatives in ecological restoration, *Ecological Restoration* 8(2):83-90

Er, J., Tian, Y., (2007), *Bulletin of Flood and Drought Disasters in China in 2007 (In Chinese)*, in: *2007*, Beijing, The Minstry of Water Resources of the People's Republic of China pp. 8.

Er, J., Tian, Y., (2012), *Bulletin of Flood and Drought Disasters in China in 2007 (In Chinese)*, in: *2007*, Beijing, The Minstry of Water Resources of the People's Republic of China pp. 15.

Fan, Z., The Analysis of Precipitation Trend and Design of Storwmater Management, Tianjin University, 2011, http://d.wanfangdata.com.cn/Thesis_Y2242439.aspx.[In Chinese]

Farina, A., (2006), *Principles and methods in landscape ecology: towards a science of the landscape*, Springer

Father, S., Spirit, H., (2015), 2.15. 1 Numerical meaning, *The Esoteric Codex: Numerology*:84

Federer, C. A., Vörösmarty, C., Fekete, B., (1996), Intercomparison of methods for calculating potential evaporation in regional and global water balance models, *Water Resources Research* 32(7):2315-2321

Fine, G., (2003), Plato on knowledge and forms: selected essays.[In Chinese]

Fjørtoft, I., Sageie, J., (2000), The natural environment as a playground for children: Landscape description and analyses of a natural playscape, *Landscape and urban planning* 48(1):83-97

Frankfort, H., (1950), Town planning in ancient Mesopotamia, *Town planning review* 21(2):99

Frederiksen, H. D., (1996), Water crisis in developing world: misconceptions about solutions, *Journal of Water Resources Planning and Management* 122(2):79-87

Frontmedia. (2008), *Project in Detail: UF Soft R&D Center*, Available from: www.worldbuildingsdirectory.com/project.cfm?id=980, (accessed 11.14.2014)

Gao, X. (2014), *The Cooperation of Departments to Deal With Rainwater Issues* Available from: www.chinajsb.cn/bz/content/2014-10/23/content_143097.htm, (accessed 23.5.2015).[In Chinese]

Garbarini, F., Adenzato, M., (2004), At the root of embodied cognition: Cognitive science meets neurophysiology, *Brain and cognition* 56(1):100-106

Gärling, T., Golledge, R. G., (1989), Environmental perception and cognition*Advance in Environment, Behavior, and Design*, Springer, pp. 203-236

Geiger, W. F., Dreiseitl, H., (2001), *Neue Wege für das Regenwasser: Handbuch zum Rückhalt und zur Versickerung von Regenwasser in Baugebieten*, Oldenbourg

Geography, A. D. o., (2004), *Environmental perception*, Oxford University Press.

George, S. S., Nielsen, E., (2000), Signatures of high-magnitude 19th-century floods in Quercus macrocarpa tree rings along the Red River, Manitoba, Canada, *Geology* 28(10):899-902

Gibson, D. V., Kozmetsky, G., Smilor, R. W., (1992), The Technopolis Phenomenon: Smart Cities, Fast Systems, *Global Networks. Rowman & Littlefield, New York*

Gibson, J. J., (1977), The theory of affordances, *Hilldale, USA*

Gimblett, H. R., Itami, R. M., Fitzgibbon, J. E., (1985), Mystery in an information processing model of landscape preference, *Landscape Journal* 4(2):87-95

Giroud, J. P., (1983), Geotextile Drainage Layers For Soil Consolidation, *Civil Engineering for Practicing and Design Engineers* 2(3):275-295

Gleick, P. H., (1993), *Water in crisis: a guide to the world's fresh water resources*, Oxford University Press, Inc.

Gobster, P. H., (2001), Forests and landscapes: linking ecology, sustainability and aesthetics,

Goh, J. O., Park, D. C., (2009), Culture sculpts the perceptual brain, *Progress in brain research* 178:95-111

Goldstein, S., Goldstein, A., (1985), *Population Mobility in the People's Republic of China. Papers of the East-West Population Institute, No. 95*, ERIC

Grau, D., (2009), New Water Culture for Tianjin, *Topos* 68:46-52

Grinde, B., Patil, G. G., (2009), Biophilia: does visual contact with nature impact on health and well-being?, *International Journal of Environmental Research and Public Health* 6(9):2332-2343

Gullone, E., (2000), The biophilia hypothesis and life in the 21st century: Increasing mental health or increasing pathology?, *Journal of Happiness Studies* 1(3):293-322

Hai, D., (2009), Foresight from a hundred years ago, *Govepnment Legality* 2009, (15).[In Chinese]

Halpern, D. F., Voĭskunskiĭ, A., (1997), *States of mind: American and post-Soviet perspectives on contemporary issues in psychology*, Oxford University Press

Han, F., 'The Analysis of the Construction of "Fou Shou Gou" in Song Dynasty (In Chinese)', *Chinese social and science newspaper (In Chinese)*2011.[In Chinese]

Han, G., Huang, Y., (2013), Study on the Construction of Drainage System of Historical City in Perspective of Urban Safety: Case Study of Fushou Ditch, *Modern Urban Research* (12).[In Chinese]

Haney, W. G., Knowles, E. S., (1978), Perception of neighborhoods by city and suburban residents, *Human Ecology* 6(2):201-214

Hani, D. (2009), *Emperical research*, Available from: www.experiment-resources.com/empiricalresearch.html#ixzz1bppAMhOc, (accessed 10.1.2015)

Hartig, T., van den Berg, A. E., Hagerhall, C. M., Tomalak, M., Bauer, N., Hansmann, R., Ojala, A., Syngollitou, E., Carrus, G., van Herzele, A., (2011), Health benefits of nature experience: Psychological, social and cultural processes*Forests, trees and human health*, Springer, pp. 127-168

Hartson, R., (2003), Cognitive, physical, sensory, and functional affordances in interaction design, *Behaviour & Information Technology* 22(5):315-338

Havens, K. E., James, R. T., East, T. L., Smith, V. H., (2003), N: Pratios, light limitation, and cyanobacterial dominance in a subtropical lake impacted by non-point source nutrient pollution, *Environmental Pollution* 122(3):379-390

Hedfors, P., Berg, P. G., (2003), The sounds of two landscape settings: auditory concepts for physical planning and design, *Landscape Research* 28(3):245-263

Heft, H., (1988), Affordances of children's environments: A functional approach to environmental description, *Children's Environments Quarterly*:29-37

Heft, H., (2010), Affordances and the perception of landscape: An inquiry into environmental perception and aesthetics, *Innovative Approaches to Researching Landscape and Health. London: Routledge*

Hendriks, K., Stobbelaar, D. J., Van Mansvelt, J. D., (2000), The appearance of agriculture: An assessment of the quality of landscape of both organic and conventional horticultural farms in West Friesland, *Agriculture, ecosystems & environment* 77(1):157-175

Hengeveld, H., De Vocht, C., (1982), Role of water in urban ecology, *Urban Ecology* 6(1):5-347

Herbert, E. J., (1981), Visual resource analysis: Prediction and preference in Oakland County, Michigan, *Unpublished master's thesis. Ann Arbor, MI: University of Michigan*

Herzog, T. R., Bryce, A. G., (2007), Mystery and preference in within-forest settings, *Environment and Behavior* 39(6):779-796

Hillman, J., Whyte, W. H., Erickson, A., (1980), *The City as Dwelling: Walking, Sitting, Shaping*, Center for Civic Leadership, The University of Dallas

Holdren, J. P., Ehrlich, P. R., (1974), Human population and the global environment: Population growth, rising per capita material consumption, and disruptive technologies have made civilization a global ecological force, *American Scientist*:282-292

Hopkins, P., (2007), Oil and Gas Pipelines: Yesterday and Today, *Pipeline Systems Division (PSD), International Petroleum Technology Institute, American Society of Mechanical Engineers (ASME). Available online at http://www. engr. mun. ca/~ spkenny/Courses/Undergraduate/ENGI8673/Reading_List/2007_Hopkins. pdf*

Hou, Y., (2004), Formation of Chinese Ancient Civilization Based on the New Archaeological Discovery of Taosi Site (In Chinese), *CULTURAL RELICS OF CENTRAL CHINA* (5)

Hou, Y., 'Terrible Smell of Recycled Water in Guyue Community', *Beijing Youth*2006, http://house.focus.cn/msgview/1032/19580554.html.[In Chinese]

Hough, M., (1995), *Cites and natural processa basis for sustainability*, Routledge New York: Taylor and Francis Group

Hoyer, J., Dickhaut, W., Kronawitter, L., Weber, B., (2011), *Water sensitive urban design: principles and inspiration for sustainable stormwater management in the city of the future*, Jovis

Hu, L., Huang, F., Li, H., Li, G., Chen, L., White, E., (2005), Spatial variability of shallow groundwater level, electrical conductivity and nitrate concentration, and risk assessment of nitrate contamination in North China Plain, *Environment International* 31(6):896-903.[In Chinese]

Hubler, A. W., (2007), Understanding complex systems, *Urbana* 51:61801

Hudson, B., (1993), The view from the verandah: prospect, refuge and leisure, *Australian Geographical Studies* 31(1):70-78

Hughes, C., (2006), Qualitative and quantitative approaches to social research, *Coventry: Department of Sociology, Warwick University*

Hulth, S., Aller, R. C., Canfield, D. E., Dalsgaard, T., Engström, P., Gilbert, F., Sundbäck, K., Thamdrup, B., (2005), Nitrogen removal in marine environments: recent findings and future research challenges, *Marine Chemistry* 94(1):125-145

Hünefeldt, T., Brunetti, R., (2004), Artificial intelligence as “theoretical psychology”: Christopher Longuet-Higgins’ contribution to cognitive science, *Cognitive Processing* 5(3):137-139

Ittelson, W., 'Environmental psychology and architectural planning', *American Hospital Association Conference on Hospital Planning in New York*, 1964,

Jacks, B., (2004), Reimagining walking: Four practices, *Journal of Architectural Education* 57(3):5-9.[English]

Jazairy, E. H., (2011), *Scales of the Earth*, Harvard University Press

Jensen, M. B., 'Stormwater management in the urban landscape', *11th International Conference on Urban Drainage, Edinburgh, Scotland, August*, 2008, Vol. 31,

Jiabao, W., 'Let the Science and Technology Lead China’s Sustainable Development', *Speech in the Conference of Capital Science and Technology [H]. the Central People's Government Website of PRC: http://www. gov. cn/ldhd/2009-11/23/content_1471208. htm. November*, 2009, Vol. 3,

Jiahua, P., Houkai, W., (2010), Annual Report on Urban Development of China, *China Social Sciences Press, Beijing*

Jiang, L., (2003), On the Original Model of China's Early Civilization and Its Evolution, *Academic Research* 2003, (7) [In Chinese]

Jiang, Y., (2009), China's water scarcity, *Journal of Environmental Management* 90(11):3185-3196.[In Chinese]

Kamvasinou, K., (2006), Reclaiming the obsolete in transitional landscapes: perception, motion, engagement, *Journal of Landscape Architecture* 1(2):16-27

Kang, X., Zhai, L., (2014), Example Analysis of Stormwater Managmeent Projects in Beijing, *Water & Wastewater Engineering* 40(9):81-86.[In Chinese]

Kaplan, D. R., (2010), The Geography of Chinese Power: How Far Can Beijing Reach on Land and at Sea?, *Foreign Affairs* 89(3):23

Kaplan, R., Kaplan, S., (1989), *The experience of nature: A psychological perspective*, CUP Archive

Kaplan, R., Kaplan, S., Brown, T., (1989), Environmental preference a comparison of four domains of predictors, *Environment and behavior* 21(5):509-530

Kaplan, R., Kaplan, S., Ryan, R., (1998), *With people in mind: Design and management of everyday nature*, Island Press

Kaplan, S., (1975), An informal model for the prediction of preference,

Kaplan, S., (1988), Perception and landscape: conceptions and misconceptions, *Environmental aesthetics: Theory, research, and application*:45-55

Kathrin, B. (2006), *Hannover Kronsberg - The Rainwater Management Concept*, Available from: www.unil.ch/files/live//sites/ouvdd/files/shared/Colloque%202006/Communications/Eau/Bonnes%20pratiques/K.%20Brandt.pdf, (accessed 9.11.2015)

Kaymaz, I. C., (2012), Landscape perception, *Landscape Planning, In ech, Croatia*:251-276

Kellert, S. R., (1995), *The biophilia hypothesis*, Island Press

Kelso, F., (2004), *Steam, Stone and Wood: 19th Century Commerce in Port Deposit, Maryland*, Fred Kelso

Kessler, R., (2011), Stormwater strategies: cities prepare aging infrastructure for climate change, *Environ Health Perspect* 119(12):A514-A519

King, D. B., Wertheimer, M., (2005), *Max Wertheimer and Gestalt Theory*, Transaction Publishers

Konečni, V. J., (1978), Daniel E. Berlyne: 1924-1976, *The American Journal of Psychology*:133-137

Kozlowski, T. T., Davies, W. J., (1975), Control of water balance in transplanting trees, *Journal of Arboriculture* 1(1)

Kronvang, B., Grant, R., Larsen, S. E., Svendsen, L. M., Kristensen, P., (1995), Non-point-source nutrient losses to the aquatic environment in Denmark: Impact of agriculture, *Marine and Freshwater Research* 46(1):167-177

Langdon, F. J., (1966), *The social and physical environment: a social scientist's view*, Building Research Station

Lapka, M., Cudlinova, E., Kindlmann, P., Dobiasova, B., (2008), Perception of contemporary rural landscape by its future managers: Czech and Japanese students of landscape planning, *ECOLOGY-BRATISLAVA-* 27(2):196

Large, A. R. G., Petts, G. E., (1996), Historical channel-floodplain dynamics along the River Trent: implications for river rehabilitation, *Applied Geography* 16(3):191-209

Li, C., (2015), Journal of Chemical and Pharmaceutical Research, 2015, 7 (1): 262-265, *Journal of Chemical and Pharmaceutical Research* 7(1):262-265.[In Chinese]

Li, G., Zhou, J., Yang, H., Chen, J., (2005), Phosphorus fractions in sediment profiles and their potential contributions to eutrophication in Dianchi Lake, *Environmental geology* 48(7):835-844.[In Chinese]

Li, H., (2005), The Analysis of the Influences and Contribution of the Water Conservancy Project for Arise of Qin Dynasty, *Water Resources Development Research* 5((4)).[In Chinese]

Li, H., Gu, D., Ku, T., Stott, L., Chen, W., (1998), Applications of interannual-resolution stable isotope records of speleothem: Climatic changes in Beijing and Tianjin, China during the past 500 years—the δ 18O record, *Science in China Series D: Earth Sciences* 41(4):362-368.[In Chinese]

Li, H. T., (2000a), From the Agricultural Civilization to the Industrial Civilization: On Histroical Experiences Taken From the Social Transformation of Western Countries in Modern Times and their Enlightment, *Exploration and Free Views* 1.[In Chinese]

Li, L., (2002), *The urban water management of Xian city in Xihan dynasty*, in: *The Study of Chinese Ancient Capital-The Chinese Ancient society about the origin of urban civilizatio at upper stream of the Yangtze River Academic Proseminar Treatise Collection(In Chinese)*, Si Chuan, The Association of China Ancient City. [In Chinese]

Li, L., (2005a), On Warping Irrigation Being the First Important Stage in the History of China's Farmland Water Conservancy, *AGRICULTURAL HISTORY OF CHINA* 25((2)) [In Chinese]

Li, L., (2005b), On Warping Irrigation Being the First Important Stage in the History of China's Farmland Water Conservancy, *Agricultural history of china* 25(2).[In Chinese]

Li, L., Yin, C., He, Q., Kong, L., (2007), First flush of storm runoff pollution from an urban catchment in China, *Journal of Environmental Sciences* 19(3):295-299.[In Chinese]

Li, Q., Lin, S., (2011), *Sixth National Population Census of the People's Republic of China in 2010* (H. d. b. o. statistics, ed.). [In Chinese]

Li, Q., Zhao, D., Bezard, E., (2006), Traditional Chinese medicine for Parkinson's disease: a review of Chinese literature, *Behavioural pharmacology* 17(5-6):403-410.[In Chinese]

Li, S., Xing, G., Zhou, J., Tang, Z., Ji, M., 'Analysis of Rainwater Utilization System of Tianjin Based on Low Impact Development', *Remote Sensing, Environment and Transportation Engineering (RSETE), 2012 2nd International Conference on*, IEEE, 2012, pp. 1-4.[In Chinese]

Li, W., (2000b), Beijing starting of rainwater management project, *China Water & Wastewater* 5:025.[In Chinese]

Li, W., (2012), Analysis On The Development Of Urban Planning Construction From Tang Dynasty To Song Dynasty, *Shanxi Architecture* 36(14).[In Chinese]

Li, X., Jelen, M., Smith, B., Upchurch, M., Saari, S., 'Implement Permeable Pavements to Improve Infrastructure Sustainability–A Case Study', *Transportation Research Board 93rd Annual Meeting*, 2014,

Li, Y., (1995), The relics of the ancient cities in the modern cities-the analysis of the streets and water well of the Qin Dynasity (In Chinese), *Archaeology and Cultural Relics* 1

Li, Y., (2013), Evaluation of Flood Regulation and Storage Capacity in Harbin Qunli National Urban Wetland Park, *Modern Landscape Architecture* 2013(10).[In Chinese]
Li, Z., (2010), The Inspiration of Urban Drainage from "Fou Shou Gou" of Ganzhou City in the Song Dynasty (In Chinese), *Resourles Inhabitant And Envivanment* (19).[In Chinese]
Liang, Z., Wu, K., He, J. (2012), *Haidian Geographic Condition*, Available from: http://hd.bjgtj.gov.cn/publish/portal41/tab4033/, (accessed 14. 11.2012)
Liao, Q., Zhang, S., Chen, J., (2013), Risk Assessment and Prediction of Water Shortages in Beijing, *Resources Science* 35(1):140-147
Lin, M., Yu, K., (2012), Structure the Urban Green Sponge: Study on Planning an Ecological Stormwater Regulation System [J], *Urban Studies* 19(5):4-8.[In Chinese]
Litton, R. B., (1968), Forest landscape description and inventories,
Liu, C., Yang, X. S., (2012), Application Study of Landscape Design Based on Visual Authenticity and Intellectual Authenticity, *Advanced Materials Research* 594:2936-2938
Liu, H., (2013), Green Building Exploration and Practice in Qingdao (In Chinese), *Chemical Materials for Construction* 2013((6))
Liu, J., (2012), *Yearbook of Tianjin*.[In Chinese]
Liu, J., Diamond, J., (2005), China's environment in a globalizing world, *Nature* 435(7046):1179-1186
Liu, L. (2007a), *How can Beijing welcome Olimpic Game Olympic Games*, Available from: http://guoqing.china.com.cn/zhuanti/2007-04/27/content_8179711_2.htm, (accessed 5.19.2015).[In Chinese]
Liu, X., (2007b), On the Origin of the Well and Canal Constructing Technique (In Chinese), *HUAXIA ARCHAEOLOGY* (1)
Liu, Z., Research on River System of Haidian District in Beijing China Agricultural University, 2007c, http://wenku.baidu.com/view/13c9ba275901020207409c15.html.[In Chinese]
Long, D. A., (1982), Kant's Pragmatic Horizon, *American Philosophical Quarterly* 19(4):299-313
Longuet-Higgins, C., (1987), *Mental processes: Studies in cognitive science*, The MIT Press
Loucks, D. P., van Beek, E., (2005), Water Resources Systems Planning and Management-Facts about Water,
Lowenthal, D., (1967), *Environmental perception and behavior*, University of Chicago, Department of Geography
Lowenthal, D., (1972), Research in Environmental Perception and Behavior: Perspectives on Current Problems, *Environment and Behavior* 4(3):333-342
Luymes, D. T., Tamminga, K., (1995), Integrating public safety and use into planning urban greenways, *Landscape and urban planning* 33(1):391-400
Lynch, J. A., Gimblett, R. H., (1992), Perceptual values in the cultural landscape: a computer model for assessing and mapping perceived mystery in rural environments, *Computers, environment and urban systems* 16(5):453-471
Lynch, K., (1960), *The image of the city*, MIT press
Magill, A. W., Litton, R. B., (1986), A color measuring system for landscape assessment, *Landscape Journal* 5(1):45-54
Maier, J. R. A., Fadel, G. M., 'Affordance-based methods for design', *ASME 2003 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, American Society of Mechanical Engineers, 2003, pp. 785-794,
Major, J. S., Queen, S., Meyer, A., Roth, H., Medhurst, W. H., Mote, F. F., (2015), 16.5. EXTERNAL LINKS 63, *The Esoteric Codex: Esoteric Cosmology*:62
Maller, C., Townsend, M., Henderson, W. C., Pryor, A., Prosser, L., Moore, M., Leger, L. S., Victoria, P., (2008), *Healthy parks healthy people: The health benefits of contact with nature in a park context*, Deakin University and Parks Victoria
Marcus, C. C., Francis, C., (1997), *People places: Design guidlines for urban open space*, John Wiley & Sons
Maruani, T., Amit, C. I., (2007), Open space planning models: A review of approaches and methods, *Landscape and Urban Planning* 81(1-2):1-13
Massoud, M. A., Tarhini, A., Nasr, J. A., (2009), Decentralized approaches to wastewater treatment and management: Applicability in developing countries, *Journal of environmental management* 90(1):652-659
Maulan, S., Shariff, M., Kamal, M., Miller, P. A., (2006), Landscape Preference and Human Well-Being, *ALAM CIPTA, International Journal on Sustainable Tropical Design Research & Practice* 1(1):25-30
McBroom, M. W., Zhang, Y., (2011), Best Management Practices (BMPs),
McSpadden, L. M., (1999), Environmental litigation, *Encyclopedia of Environmental Sciences* 20:213

Miller, T. T. B., The greening of community development: an analysis of ecological restoration and neighborhood planning in the fenway, Massachusetts Institute of Technology, 2001,
Min, Q., Li, Y., Cheng, S., LIU, S.-d., YU, W.-d., (2005), Ecological footprint-based comparison of living consumption of meso-scale cities' residents in China—Taking Taizhou, Shangqiu, Tongchuan and Xilin Gol as examples, *Journal of Natural Resources* 20(2):287-292
Mintz, Y., Serafini, Y., (1992), A global monthly climatology of soil moisture and water balance, *Climate Dynamics* 8(1):13-27
Mitchell, G., (2005), Mapping hazard from urban non-point pollution: a screening model to support sustainable urban drainage planning, *Journal of Environmental Management* 74(1):1-9
Modrak, D. K., (1981), Perception and Judgment in the" Theaetetus", *Phronesis*:35-54
Mohammed, K., (2006), *Blackburn with Darwen Open Space Strategy* (B. w. D. Council, ed.), Blackburn.
Mok, J. H., Landphair, H. C., Naderi, J. R., (2006), Landscape improvement impacts on roadside safety in Texas, *Landscape and Urban Planning* 78(3):263-274
Mokyr, J., (1999), Editor's Introduction: The New Economic History And The Industrial Revolution, *The British Industrial Revolution: An Economic Perspective* 2:1-127
Moore, G. T., Lackney, J. A., (1993), School design: crisis, educational performance and design applications, *Children's Environments*:99-112
Mostafavi, M., Doherty, G., (2010), *Ecological urbanism*, Lars Müller Publishers Baden
Múgica, M., De Lucio, V., (1996), The role of on-site experience on landscape preferences. A case study at Doñana National Park (Spain), *Journal of Environmental Management* 47(3):229-239
Mulder, A., (2003), The quest for sustainable nitrogen removal technologies, *Water science & technology* 48(1):67-75
Museum, H., (2010), Report Of The Large-Sized Drain System In Xiang City Of The Warring States Period To The Han Dynasty (In Chinese), *Cultural Relics of Central China* 2
Muxika, I., Borja, A., Bald, J., (2007), Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive, *Marine Pollution Bulletin* 55(1):16-29
Nasar, J. L., (1987a), The effect of sign complexity and coherence on the perceived quality of retail scenes, *Journal of the American Planning Association* 53(4):499-509
Nasar, J. L., (1987b), Environmental correlates of evaluative appraisals of central business district scenes, *Landscape and Urban Planning* 14:117-130
Nasar, J. L., (1992), *Environmental aesthetics: Theory, research, and application*, Cambridge University Press
Nasar, J. L., (1994), Urban design aesthetics the evaluative qualities of building exteriors, *Environment and behavior* 26(3):377-401
Nassauer, J., (1980), A non - linear model of visual quality, *Landscape Research* 5(3):29-30
Nassauer, J. I., (1995), Culture and changing landscape structure, *Landscape ecology* 10(4):229-237
Nicholls, A., Liebscher, M., (2010), *Thinking the unconscious: nineteenth-century German thought*, Cambridge University Press
Novotny, V., (1995), *Non Point Pollution and Urban Stormwater Management*, CRC Press
Novotny, V., (2003), Water quality: Diffuse pollution and watershed management*Water quality: diffuse pollution and watershed management*, John Wiley & Sons
Novotny, V., (2009), *Sustainable urban water management*, in: *Water and Urban Development Paradigms* (J. S. K. N. M. Feyen, ed.), pp. 19-31
Novotny, V., Ahern, J., Brown, P., (2010), *Water centric sustainable communities: planning, retrofitting and building the next urban environment*, Wiley. com
Tianjin Shi Zhi Office (2007), *Soil Resource*, Available from: http://www.tjdfz.org.cn/tjtz/tdgl/tdzy/, (accessed 01.10.2014).[In Chinese]
Ongley, E. D., Zhang, X., Tao, Y., (2010), Current status of agricultural and rural non-point source pollution assessment in China, *Environmental Pollution* 158(5):1159-1168
Oxford, (2014), *Oxford Dictionaries*, Oxford University Press.
Palmisano, S. J. (2008), *A smarter planet: the next leadership agenda*, Available from: http://www.ibm.com/ibm/cioleadershipexchange/us/en/pdfs/SJP_Smarter_Planet.pdf, (accessed 11.1.2016)
Pandey, D. N., Gupta, A. K., Anderson, D. M., (2003), Rainwater harvesting as an adaptation to climate change, *Current science* 85(1):46-59
Parsons, R., (1991), The potential influences of environmental perception on human health, *Journal of environmental psychology* 11(1):1-23

Partridge, D., Rowe, J., (1994), *Computers and creativity*, Intellect Books
Pathak, N., (2002), Water Treatment and Rainwater Harvesting*Sustainable Water and Soil Management*, Springer, pp. 57-90
Pauly, B., (2010), Direct observation as evidence, *Encyclopedia of Case Study Research. Thousand Oaks: SAGE Publications, Inc*
Pei, H., Ma, J., (2002), Study on the algal dynamic model for West Lake, Hangzhou, *Ecological Modelling* 148(1):67-77.[In Chinese]
Perls, F., Hefferline, G., Goodman, P., (1951), Gestalt therapy, *New York*
Pickett, S. T. A., Cadenasso, M. L., McGrath, B., (2013), *Resilience in ecology and urban design: Linking theory and practice for sustainable cities*, Netherlands, Springer Science & Business Media
PingSong , Z., Xiaohong Liao , Xichun Li (2013), Primary conception on flood control system of Four-inlets river system after the operation of Three Gorges Project, *Water Resources and Hydropower Engineering* 2013,(44):(2)
Pocock, D. C. D., (1972), City of the mind: A review of mental maps of urban areas, *The Scottish Geographical Magazine* 88(2):115-124
Poleto, C., Tassi, R., (2012), Sustainable Urban Drainage Systems, *Drainage Systems*:55-72
Prowse, T., L., Schwarcz, H., P., Garnsey, P., Knyf, M., Macchiarelli, R., Bondioli, L., (2007), Isotopic evidence for age - related immigration to imperial Rome, *American Journal of Physical Anthropology* 132(4):510-519
Puckett, J., (1995), Identifying the major sources of nutrient water pollution, *Environmental Science & Technology* 29(9):408A-414A
Qian, P. D. Y., (1999), Drainage in Chinese Ancient Cities, *STUDIES IN THE HISTORY OF NATURAL SCIENCES* (2)
Qiang, Z., Kong-Jian, Y., Di-Hua, L., (2005), The width of ecological corridor in landscape planning [J], *Acta Ecologica Sinica* 9:036
Qiu, J., (2010), China faces up to groundwater crisis, *Nature* 466(7304):308-308.[In Chinese]
Quitzau, M. B., (2007), Water-flushing toilets: Systemic development and path-dependent characteristics and their bearing on technological alternatives, *Technology in Society* 29(3):351-360
Reed, E. S., (1986), James J. Gibson's revolution in perceptual psychology: A case study of the transformation of scientific ideas, *Studies in History and Philosophy of Science Part A* 17(1):65-98
Reed, E. S., Jones, R. K., (1978), Gibson's theory of perception: A case of hasty epistemologizing?, *Philosophy of Science*:519-530
Ren, Y., Wang, X., Ouyang, Z., Zheng, H., Duan, X., Miao, H., (2008), Stormwater runoff quality from different surfaces in an urban catchment in Beijing, China, *Water Environment Research* 80(8):719-724
Rishbeth, C., (2001), Ethnic minority groups and the design of public open space: an inclusive landscape?, *Landscape Research* 26(4):351-366
Roberts, C., Cox, M., (2007), The Impact Of Economic Intensification And Social Complexity On Human Health In Britain From 4000 Bc (Neolithic) And The Introduction Of Farming To The Mid 19 Th Century Ad And Industrialisation (Post-Medieval Period),
Roth, M., (2006), Validating the use of Internet survey techniques in visual landscape assessment—An empirical study from Germany, *Landscape and Urban Planning* 78(3):179-192
Ruddell, E. J., Hammitt, W. E., (1987), Prospect refuge theory: a psychological orientation for edge effects in recreation environment, *Journal of Leisure Research* 19(4):249-260
Rumming, K., (2004), Hannover Kronsberg handbook, *Jütte-Messedruck GmbH, Leipsig*
Salt, B., (2004), the big shift in Australian values, *Geodate* 15(4):6-8
Saunders, W. S., Condon, P. M., Hilderbrand, G. R., Meyer, E. K., (1998), *Richard Haag: Bloedel Reserve and Gas Works Park*, Princeton Architectural Press
Sayadi, S., González-Roa, M. C., Calatrava-Requena, J., (2009), Public preferences for landscape features: the case of agricultural landscape in mountainous Mediterranean areas, *Land Use Policy* 26(2):334-344
Schabel, H. G., Dwyer, J. F., (1985), Institutional aspects of forest recreation resource management in West Germany, *Landscape Journal* 4(1):1-6
Schauman, S., (1988), Scenic value of countryside landscapes to local residents: a Whatcom County, Washington case study, *Landscape Journal* 7(1):40-46
Scott, A., Carter, C., Brown, K., White, V., (2009), 'Seeing is Not Everything': Exploring the landscape experiences of different publics, *Landscape Research* 34(4):397-424
Scott, A., Shannon, P., (2007), Local landscape designations in Scotland: Opportunity or barrier to effective landscape management?, *Landscape and Urban Planning* 81(3):257-269

Scott, C. A., Drechsel, P., Raschid, S. L., Bahri, A., Mara, D., Redwood, M., Jiménez, B., (2010), Wastewater irrigation and health: challenges and outlook for mitigating risks in low-income countries, *astewater Irrigation*:381

Seeland, K., Nicolè, S., (2006), Public green space and disabled users, *Urban Forestry & Urban Greening* 5(1):29-34

Shannon, K., De Meulder, B., D' Auria, V., Gosseye, J., (2008), *Water Urbanisms*, in: *null*,

Shannon, K., Meulder, d. B., (2013), *Water Urbanisms 2 - East*, in: *Park Books - UFO: Explorations of Urbanism* Zurich, Switzerland, Park Books

Shao, M., Tang, X., Zhang, Y., Li, W., (2006), City clusters in China: air and surface water pollution, *Frontiers in Ecology and the Environment* 4(7):353-361.[In Chinese]

Shaw, R. E., Bransford, J., (1977), *Perceiving, acting, and knowing*, Lawrence Erlbaum Associates

Shuqiu, D., Zhigang, H., (2011), The Planning Study of Rainwater Recycling Basing on "Eco-Sponge Cities" *Urban Studies* 12:37-41.[In Chinese]

Silverman, H. J., (1977), Thinking and Being, *Philosophy Today* 21(3):241-249

Simon, B., (2003), Water Sensitive Urban Design,

Sleegers, F., Brabec, E., (2014), Linear infiltration systems along urban streets: evaluating aesthetic values, *Journal of Landscape Architecture* 9(1):48-59

Slovic, P., (1987), Perception of risk, *Science* 236(4799):280-285

Soini, K., (2001), Exploring human dimensions of multifunctional landscapes through mapping and map-making, *Landscape and Urban planning* 57(3):225-239

Song, L. Z. J., 'The accessment of the "Shui Bu Shi" of The Dang Dynasity ', *National Ecological Resources Legal Seminar*, 2008, http://www.cnki.net/KCMS/detail/detail.aspx?QueryID=12&CurRec=11&recid=&filename=FXHJ200810001097&dbname=CPFD9908&dbcode=CPFD&pr=&urlid=&yx=&v=MjY0MjNtVUw3TElWOFFJelhEWkxHNEh0bk5yNDlGWmVzR0N4Tkt1aGRobmo5OFRuanFxeGRFZU1PVUtyaWZadUp2RXlu,

Song, Q., Zhao, Z., Gong, Z., Ma, C., Dong, S., Yao, Y., Yan, C., (2012), CO2 emission law of dry farmland soil in black soil region of Northeast China, *Transactions of the Chinese Society of Agricultural Engineering* 28(23):200-207.[In Chinese]

Song, S. (2014), *Walking to Wold, Yantai*, Available from: http://blog.sina.com.cn/s/blog_beded5230101h66r.html, (accessed 9.10.2015).[In Chinese]

Song, Z., (2012), The Combination of Function and Landscape in the Design of Residential Zone *ChengShi Jianshe LiLun Yan Jiu* 13.[In Chinese]

Stamps III, A. E., (2004), Mystery, complexity, legibility and coherence: A meta-analysis, *Journal of Environmental Psychology* 24(1):1-16

Beijing Statistical Bureau (2008), *Beijing statistical yearbook 2013* (B. M. B. o. Statistics, ed.), China statistical Publishing House.

Steup, M., (2008), Epistemology,

Stewart, A. L., (1986), Urban farmsteads: Household responsibilities in the city, *Historical Archaeology* 20(2):5-15

Steyer, J. P., Bernard, O., Batstone, D. J., Angelidaki, I., (2006), Lessons learnt from 15 years of ICA in anaerobic digesters, *Instrumentation, Control and Automation for Water and Wastewater Treatment and Transport Systems IX* 53(4):25-33

Stirling, C. o., (2008), *Public Open Space Strategy Better-parks for all* City of Stirling.

Stokman, A., 'Water purificative landscapes–constructed ecologies and contemporary urbanism', *Transforming with water. Proceedings of the 45th World Congress of the International Federation of Landscape Architects IFLA*, 2008a, pp. 51-61,

Stokman, A., 'Water purificative landscapes–constructed ecologies and contemporary urbanism', 2008b, pp. 51-61,

Su, C. (2013), *Natural Environment of Tianjin*, Available from: www.tjdfz.org.cn/tjgl/zrhj/index.shtml.[In Chinese]

Su, Y., Wang, S., Che, W., (2014), Optimization Design of Sunken Greenbelt Based on the Concept of “Sponge City”, *South Architecture* 3:007.[In Chinese]

Sun, S., (2013), The analysis of Spatial Distribution and Outline of Drought in Liao Ning, *Disaster Reduction in China,* 6.[In Chinese]

Sun, W. (2012), *Address from District Mayor*, Available from: english.bjhd.gov.cn/home/201105/t20110527_260270.htm, (accessed 3.19.2015).[In Chinese]

Sun, Y., (2011), The Urban Drainage of the Song Dynasty (In Chinese), *Disaster Reduction in China,* (20) Suresh, M., Smith, D. J., Franz, J. M., (2006), Person environment relationships to health and wellbeing: An integrated approach, *IDEA Journal* 2006:87-102

Swaffield, S. R., Foster, R. J., (2000), *Community perceptions of landscape values in the South Island high country: a literature review of current knowledge and evaluation of survey methods*, New Zealand Department of Conservation

Szreter, S., (1999), Rapid economic growth and ‘the four Ds’ of disruption, deprivation, disease and death: public health lessons from nineteenth‐century Britain for twenty‐first‐century China?, *Tropical Medicine & International Health* 4(2):146-152

Thornthwaite, C. W., Mather, J. R., (1957), Instructions and tables for computing potential evapotranspiration and the water balance,

Tian, F., Ni, G., (2013), *Real-Time Flood Forecasting and Efficient Use for Sound Water Cycle in Densely Populated Urban Area* in: *2013.6.16* 7th UN-CECAR International Conference on Leadership in Sustainability, 7th UN-CECAR International Conference on Leadership in Sustainability.

Tony, W., (2006), An overview of water sensitive urban design practices in Australia, *Water Pract. Technol* 1(1)

Townsend, A. M., (2013), *Smart cities: Big data, civic hackers, and the quest for a new utopia*, WW Norton & Company

Turenscape. (2009a), *landezine：Qunli National Urban Wetland by Turenscape*, Available from: http://www.turenscape.com/project/project.php?id=435.[In Chinese]

Turenscape, (2009b), *Landscape Design of Harbin National Wetland Park*.

Turenscape. (2011), *The First Stormwater Management Park in Harbin-Qunli National Wetland Park*, Available from: http://www.turenscape.com/news/msg.php/1292.html, (accessed 19.5.2015).[In Chinese]

Turenscape. (2015), Available from: http://www.turenscape.com/english/, (accessed 3.5.2015).[In Chinese]

Turk, A., (1972), Ecology, Pollution, Environment,

Tveit, M., Ode, Å., Fry, G., (2006), Key concepts in a framework for analysing visual landscape character, *Landscape research* 31(3):229-255

Tveit, M. S., (2009), Indicators of visual scale as predictors of landscape preference; a comparison between groups, *Journal of Environmental Management* 90(9):2882-2888

Ulrich, R. S., (1979), Visual landscapes and psychological well‐being, *Landscape research* 4(1):17-23

Ulrich, R. S., (1983), Aesthetic and affective response to natural environment*Behavior and the natural environment*, Springer, pp. 85-125

Urbonas, B., Stahre, P., (1993), *Stormwater: Best Management Practices And Detention For Water Quality, Drainage, And Cso Management*,

Vachaud, G., Passerat de Silans, A., Balabanis, P., Vauclin, M., (1985), Temporal stability of spatially measured soil water probability density function, *Soil Science Society of America Journal* 49(4):822-828

Valderrama, A., Levine, L., Bloomgarden, E., Bayon, R., Wachowicz, K., Kaiser, C., Holland, C., Ranney, N., Scott, J., Kerr, O., (2013), Creating Clean Water Cash Flows Developing Private Markets for Green Stormwater Infrastructure in Philadelphia,

Van, d. P. I., (2008), The Bugs Eat the Waste: What Else is There to Know? Changing Professional Hegemony in the Design of Sewage Treatment Plants, *Social studies of science* 38(4):605-634

Van Drecht, G., Bouwman, A. F., Knoop, J. M., Beusen, A. H. W., Meinardi, C. R., (2003), Global modeling of the fate of nitrogen from point and nonpoint sources in soils, groundwater, and surface water, *Global Biogeochemical Cycles* 17(4)

Van Rooijen, D. J., Turral, H., T., W. B., (2005), Sponge City: Water Balance Of Mega‐City Water Use And Wastewater Use In Hyderabad, India, *Irrigation and Drainage* 54(S1):81-91

Verderber, S., (2009), Preventing chronic disease among the aged: A call for evidence-based design research, *HERD: Health Environments Research & Design Journal* 2(3):71-83

W., Y., H., Q., Z., S., L., K., (2009), Study on rain&flood resources utilization assessment and utilization model, *China Water Resources* 15:13-16.[In Chinese]

Waldheim, C., (2006), *The landscape urbanism reader*, Princeton Architectural Press

Wang, D. (2006), *The Drainage Pipes of Qin Dynasty in Epang Palace*, Available from: http://culture.people.com.cn/GB/22219/4008839.html, (accessed 27.4.2015).[In Chinese]

Wang, G., Guo, Y., (2013), Development of New Media in Smart City *China-Today Forum* 11:50.[In Chinese]

Wang, J., (2008), Study' the Conceals One's Abilities Strategy 'from the book' the Chinese Modern history' written by Jiang Tingfu (In Chinese), *Journal Of Jinggangshan University* 29(6).[In Chinese]

Wang, J. X., Zhang, L. M., Hou, R., Zhang, C. C., (2013a), Analysis and Comparison between Digital and Smart Water Conservancy*Geo-Informatics in Resource Management and Sustainable Ecosystem*, Springer, pp. 424-434.[In Chinese]

Wang, K., (2010), Landscape design in residential district, *Shanxi Architecture* 3:034.[In Chinese]

Wang, L., Liu, J., Xiong, W., (2013b), *China Statistical Yearbook 2013*, in: *China Statistical Yearbook*, Beijing.[In Chinese]

Wang, M., (2011), The Flood Prevention Of The The Forbidden City (In Chinese), *Beijing Archives* 11.[In Chinese]

Wang, M., Webber, M., Finlayson, B., Barnett, J., (2008), Rural industries and water pollution in China, *Journal of Environmental Management* 86(4):648-659.[In Chinese]

Wang, X., The Effect Evaluation of Rainwater Retention in Different Underlying Surface China Agricultural University, 2015, http://www.bjdky.com/cn/index.html.[In Chinese]

Wang, X., He, Y., (2001), *The Three Strategies of the Public Health in the Palace of Qin Dynasty (In Chinese)*, in: *The research of the Culture and Xianyang of Qin Dynasity Conferennce Prceeding-The seminar of the research and study of the Qin Culture* Xian, Y.

Wang, X., Ongley, E. D., (2004), Transjurisdictional water pollution disputes and measures of resolution: examples from the Yellow River Basin, China, *Water international* 29(3):282-289.[In Chinese]

Wang, X., Zong, X., 'Research of the Development of Simulation Model of Urban Storm Water', in C. H. E. S. (CHES) (ed.), *Academic Annual Conference of Chinese Hydraulic Engineering Society* Beijing, Academic Annual Conference of Chinese Hydraulic Engineering Society 2008.[In Chinese]

Wanielista, M. P., Yousef, Y. A., (1993), *Stormwater management*, John Wiley & Sons

Water, M., (2005), Water sensitive urban design engineering procedures: stormwater, *Ecological Engineering, WBM Oceanics, Parsons Brinkerhoff, Melbourne, Australia*

Waterfield, R., (2005), *Athens: a history: from ancient ideal to modern city*, Basic books

Wei, S. (2013), *Saving and Renovating water Resource for Breaking Through the Difficult situation-the investigation of the usage of water resource in Tianjin*, Available from: http://www.gov.cn/jrzg/2013-06/15/content_2426715.htm.[In Chinese]

Wei, S., Zhu, F., Wu, P., C., L., Zhang, S., Zhou, J., Zhang, R., (2010), Distributions of typical contaminant species in urban short-term storm runoff and their fates during rain events: A case of Xiamen City, *Journal of Environmental Sciences* 22(4):533-539.[In Chinese]

Wertheimer, M., (1938), *Gestalt theory*, Hayes Barton Press

Wheater, H., Evans, E., (2009), Land use, water management and future flood risk, *Land Use Policy* 26:S251-S264

Whelans, C., Maunsell, H. G., Thompson, P., (1994), Planning and management guidelines for water sensitive urban (residential) design, *Water Authority of Western Australia*

Wiki. (2014), *Tainjin City*, Available from: http://zh.wikipedia.org/wiki/%E5%A4%A9%E6%B4%A5%E5%B8%82#.E5.BB.89.E6.94.BF.E4.B8.8E.E8.85.90.E8.B4.A5.E9.97.AE.E9.A2.98, (accessed 06.11.2014).[Chinese]

Wilderer, P., Schreff, D., (2000), Decentralized and centralized wastewater management: a challenge for technology developers, *Water Science and Technology* 41(1):1-8

William, S., (2012), *Designed Ecologies. The Landscape Architecture of Kongjian Yu*,

Wilson, E. O., (2007), Biophilia and the conservation ethic, *Evolutionary perspectives on environmental problems*:249-257

Wirth, L., (1938), Urbanism as a Way of Life, *American journal of sociology*:1-24

Wittfogel, K. A., (1981), *Oriental despotism: A comparative study of total power*, Vintage books New York

Wladawsky-Berger, I. (2013), *Are Smart Cities Empty Hype?*, Available from: http://blog.irvingwb.com/blog/2013/12/are-smart-cities-empty-hype.html, (accessed 21.2.2015)

Wohlwill, J. F., (1976), Environmental aesthetics: The environment as a source of affect*Human behavior and environment*, Springer, pp. 37-86

Wong, T. H., (2006), Water sensitive urban design-the journey thus far, *Australian Journal of Water Resources* 10(3):213

Woolley, H., (2003), *Urban open spaces*, Taylor & Francis

Wright, J. D., Itami, R. M., Fitzgibbon, J. E., (1984), An investigation of the variables effecting the perception of mystery in rural landscape scenery, *Unpublished Research Report. University of Guelph. Guelph, Ontario, Canada*

Wu, C., Tang, N., Wei, Z., (2007), Analysis on the characteristics of rainfall in China for urban rainwater utilization, *Water & wastewater engineering* 33(6):45-48.[In Chinese]

Wu, H., Maurer, C., Wang, Y., Xue, Z., Davis, L., (1999), Water pollution and human health in China, *Environmental Health Perspectives* 107(4):251.[In Chinese]

Wu, N., (2003), Building and Administrating of Suzhou during the Ming Dynasty (In Chinese), *JOURNAL OF YANGZHOU UNIVERSITY(HUMANITIES AND SOCIAL SCIENCES EDITION)* 7(4)

Wu, Q., Yang, Y., (2014), *Concentration on "Network of Blue and Green", and Construction together Livable Cities*, www.landscapecn.com.

Wu, W., Ge, Q., (2005), The possibility of occurring of the extraordinary floods on the eve of establishment of the xia dynasty and the historical truth of Dayu's successful regulating of floodwaters (In Chinese), *Quaternary Sciences* 25((6)).[In Chinese]

Xia, J., (2012), The health and epidemic prevention system of Qingdao in the German occupation period (In Chinese), *Chinese Journal of Medical History* 42((4))

Xia, X., (2013), *Beijing Statistical Yearbook*, Chinese Statistical Publishing House: Beijing.

Xie, H., Kung, C., Zhang, Y., Li, X., (2012), Simulation of regionally ecological land based on a cellular automation model: A case study of Beijing, China, *International journal of environmental research and public health* 9(8):2986-3001.[In Chinese]

Xie, Z., Wang, G., 'The Changes of Temperature and Precipitation in Beijing During Last 100 Years', *Chinese Science Abstracts Series B*, Elsevier Science, 1995, Vol. 14, pp. 67-68.[In Chinese]

Xu, C., Singh, V. P., (1998), A review on monthly water balance models for water resources investigations, *Water Resources Management* 12(1):20-50

Xu, H., Paerl, H. W., Qin, B., Zhu, G., Gao, G., (2010), Nitrogen and phosphorus inputs control phytoplankton growth in eutrophic Lake Taihu, China, *Limnology and Oceanography* 55(1):420.[In Chinese]

Xu, P., Che, W., Li, J., (2004), Analysis on improvement of urban environment made by green roof, *Environmental Protection* 7:41-44.[In Chinese]

Xu, X., (1991), The Analysis of the technology and influences of the "Long Shou" water channel in Xihan Dynasity *Agricultural Archaeology* 03

Xu, X., (2011), *Daoli Chorography*, Daoli District Chronicles Compilation Committee in Harbin.

Yan, P., Che, W., Zhao, Y., Li, J., Wang, S., (2013), Establish a Healthy Hydrological Cycle in Urban Area by Green Stormwater Infrastructure (In Chinese), *GREEN INFRASTRUCTURE* 02

Yang, B., Brown, T., (1992), A Cross-Cultural Comparison of Preferences for Landscape Styles and Landscape Elements, *Environment and Behavior* 24(4):471-507

Yang, Y., Guangsi, L., (2015), A Review on Sponge City *South Architects* 3:59-64.[In Chinese]

Yildirim, K., Akalin, B. A., Celebi, M., (2007), The effects of window proximity, partition height, and gender on perceptions of open-plan offices, *Journal of Environmental Psychology* 27(2):154-165

Yingqiao, Z., (2005), Archaeological Evidence of the Prehistoric Human Managing Water in China (In Chinese), *Cultural Relics Of Central China* 2005((3))

Yongyou, (2013), *World-class Sofetware Industrial Base-Yongyou Sofeware Park*, in: *Yonyou Software Co., Ltd.* , Wang, W. J.

Yu, C., Xie, Z., Xu, M., (2006a), Research the water quality of rainwater control projectin old urban areas of Beijing, *City Geology* 02.[In Chinese]

Yu, C. T., (2010a), *Qiong Tong Bao Jian*, Shan Xi, Shananxi Normal Univeristy Press.[In Chinese]

Yu, J., (2011), The First Stormwater Management Park in Harbin-Qunli National Wetland Park, *Chinese Habitat* 9.[In Chinese]

Yu, J., (2013), Intergrowth between Architecture and Rainwater-Qunli National Wetland Park in Harbin *Beijing City Planning & Construction Review* 01.[In Chinese]

Yu, J., Song, B., (2009), *Landcape Design of Qunli National Wetland Park in Harbin*

Yu, K., (1990), Chinese Ideal Model and Ecological Perspective, *Journal of Beijing Forestry University* 12(1):10-17.[In Chinese]

Yu, K., (1995), Cultural variations in landscape preference: comparisons among Chinese sub-groups and Western design experts, *Landscape and Urban Planning* 32(2):107-126.[In Chinese]

Yu, K., (1996), Security patterns and surface model in landscape ecological planning, *Landscape and urban planning* 36(1):1-17

Yu, K., (2001), The Culture that Has Been Ignored, The Beauty of Weeds--Qijiang Park in Zhongshan City [J], *New Architecture* 5:005.[In Chinese]

Yu, K., (2010b), China's Water Crisis,K. Shannon, B. De Meulder in: *Water Urbanisms 2 - East* (K. Shannon, B. De Meulder, eds.), pp. 256.[In Chinese]

Yu, K., (2012), The Big Feet Aesthetic and the Art of Survival, *Architectural Design* 82(6):72-77

Yu, K., Lei, Z., Li, D., (2008a), Living with Water: Flood Adaptive Landscapes in the Yellow River Basin of China, *Journal of Landscape Architecture* 3(2):6-17.[In Chinese]
Yu, K., Li, D., (2003), *The Road Of Urban Landscape-Communicating With Mayors*, Beijing, Chinese Architecture & Building Press.[In Chinese]
Yu, K., Li, D., Li, N., (2006b), The evolution of greenways in China, *Landscape and Urban Planning* 76(1):223-239
Yu, K., Li, D., Liu, H., (2005), Growth Pattern Of Taizhou City Based On Ecological Infrastructure: A Negative Approach Physical Urban Planning [J], *City planning review* 9:76-80.[In Chinese]
Yu, K., Li, H., Li, D., (2008b), The Negative Approach And Ecological Infrastructure: The Smart Preservation Of Natural Systems In The Process Of Urbanization, *Journal of Natural Resources* 23(6):937-958.[In Chinese]
Yu, K., Wang, S., Li, D., Qiao, Q., (2010), Ecological Baseline for Beijing's Urban Sprawl: Basic Ecosystem Services and Their Security Patterns, *City Planning Review* 2:7.[In Chinese]
Yu, K., Xi, X., Xi, X., (2009), On The Construction Of The National Linear Culture Heritage Network In China [J], *Human Geography* 3:008.[In Chinese]
Yu, W., Li, S., Jing, Q., (2007), Ivestigations of Ancient Drainage System in China (In Chinese), *China Water Resources* 4.[In Chinese]
Zhan, X., (2011), Studies on scenic resources development of rivers in urban areas, *China Water Resources* (16)
Zhang, G., (2006), Passive Urbanization In Rapid Urbaniza-Tion [J], *City Planning Review* 5:009.[In Chinese]
Zhang, G., Based on Pattern Optimization of Land Use the Research of the Model in the Stormwater Management Zhe Jiang University, 2013.[In Chinese]
Zhang, H. S., Ding, Y. Y., (2003), *Demonstration and research of application technology and stormwater control of Beijing City*, pp. 6.
Zhang, J., Mauzerall, D., Zhu, T., Liang, S., Ezzati, M., Remais, J. V., (2010), Environmental health in China: progress towards clean air and safe water, *The Lancet* 375(9720):1110-1119.[In Chinese]
Zhang, K., Aguiar, L., Randelovic, A., McCarthy, D., Deletic, A., 'Determination of operational and challenge conditions for validation of stormwater biofilters and wetlands', *8th International Water Senitive Urban Design Conference 2013*, 2013, p. 87,
Zhang, L., Wu, X., Ji, J., Kolbe, H., (2004), Estimation of agricultural non-point source pollution in China and the alleviating strategies. I. Estimation of agricultural non-point source pollution in China in early 21 century, *Scientia agricultura sinica* 37(7):1008-1017.[In Chinese]
Zhang, Q., Zhang, J., (2002), Discussion on Urban Ecological Park, *Chinese Journal of Ecology* 3:014.[In Chinese]
Zhang, S., Ding, Y., 'The Study and Domstration of Application and Control of Rainwater Flood in Beijing Urban Area', *Collected Papers of Youth Technoloy Forum of Chinese Hydraulic Engineering Society*, 2005.[In Chinese]
Zhang , Y., (2005), Archaeological Evidence of the Prehistoric Human Managing Water in China (In Chinese), *Cultural Relics Of Central China* 2005(3)
Zhang, Y., Che, W., Liu, Y., Li, J., (2003a), Interrelation of pollutants in road runoff of Beijing urban area, *Urban Environment & Urban Ecology* 16(6):182-184.[In Chinese]
Zhang, Y., Wu, C., Yan, L., Jun, Q., (2003b), Interrelation of Pollutants in Road Runoff of Beijing Urban Area [J], *Urban Environment & Urban Ecology* 6:073.[In Chinese]
Zhao, J., The Characteristics of Waterlogging and Landscape Flood Storage in Beijing's Urban Aear (In Chinese), Bejing Universtiy, 2012.[In Chinese]
Zhao, L., (1980), *Xiao Ting Za Lu* (Z. B. Company, ed.), Zhonghua Book Company
Zhao, Y., Sheng, Y., Chen, Y., (2006), Study on city water shortage of China, *ADVANCES IN WATER SCIENCE* 17(3):389-394.[In Chinese]
Zhao, Y. Z. (2009), *Bejing Soil Types*, Available from: www.bjtf.org/images/content/2012-05/20120503214246651983.bmp, (accessed 8.3.2014).[In Chinese]
Zhen, M., The Usage Planning of Stormwater Management in China, Beijing University of Civil Engineering and Architcture, 2010.[In Chinese]
Zheng, X., (2003), Henan Provincial Institute of Cultural Relics and Archaeology,Large-Scale Pottery Workshop Site of the Warring State Period Discovered in the City Site of Zheng and Han States (In Chinese), *CULTURAL RELICS OF CENTRAL CHINA* (1)
Zheng, Y., Wang, X., (2002), Advances and prospects for non-point source studies (In Chinese), *Advances in Water Science* 13(1):105.[In Chinese]
Zhou, Q., Li, J., Zhao, J., (2003), Study on index system of assessment of public disaster perception in the western China, *Chinese Geographical Science* 13(3):284-288.[In Chinese]

Zhou, R., (2008), The Poetic Computer Program-UF Soft R&D Center No 1, *Architectural Journal* (7):52-57.[In Chinese]

Zhou, Y., The research of Rainwater Low-Impact Development in Residential Zones, Beijing University of Civil Engineering and Architecture, 2011.[In Chinese]

Zhu, G., (2008), Eutrophic status and causing factors for a large, shallow and subtropical Lake Taihu, China, *Journal of Lake Sciences* 1:005.[In Chinese]

Zhu, Q., Yu, K., Li, D., (2005), The Width of Ecological Corridor in Landscape Planning, *Acta Ecologica Sinica* 9:36.[In Chinese]

Zou, H., Zhang, Y., Huang, Y., Sun, Z., Yu, N., Zuo, S., Li, C., (2008), Effect of Plastic Film Mulching for Preserving Soil Moisture on the Growth and Yield of Maize in Semiarid Regionof Western Liaoning Province, *Chinese Journal of Soil Science* 4:035.[In Chinese]

Zube, E., Pitt, D., (1981), Cross-Cultural Perceptions Of Scenic And Heritage Landscapes, *Landscape planning* 8(1):69-87

Zube, E. H., Moore, G. T., (2013), *Advances in Environment, Behavior and Design*, Springer Science & Business Media

Zube, E. H., Sell, J. L., Taylor, J. G., (1982), Landscape Perception - Research, Application and Theory, *Landscape Planning* 9(1):1-33.

Appendix A: Content of questionnaire

雨水基础设施认知调查

（Survey of Landscape Perception about Stormwater Managmenet System）

性别 (**Gender**): ☐ 男(Male) ☐ 女(Female)

年龄（Age）: ☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ >60

教育背景 (Education Background)： ☐ 初中（Secondary school and below）☐ 高中 (Higher education) ☐ 大学 (Bachelor degree) ☐ 硕士以上 (Master Degree or above)

Closed-end Questions:

1. 您每周在群力公园内休闲活动的时间为多少小时？ (How long do you spend outdoors in this community per week?)
   ☐ 小于 1 个小时(Less than 1 hour) ☐ 1-2 个小时(1-2 hours) ☐ 2-3 个小时(2-3 hours)
   ☐ 3-4 个小时(3-4 hours) ☐ >4 个小时(Longer than 4 hours)

2. 如果您知道雨水收集和管理的相关知识，您是通过什么渠道来了解的？（多选）(Where did you learn the meaning of stormwater management?) (Multiple selection)

   ☐ 媒体 (Media) ☐ 通过观察附近的景色 (Surrounding environment) ☐ 友邻交谈 (Neighbourhood)
   ☐ 其他 (Others) ☐ 没有得到任何渠道 (Not at all)

3. 您在这个场地里，最喜欢的活动方式是什么？(What is your favourite kind of activity in this site?)

   ☐ 散步(Walking) ☐ 坐着休息(Sitting) ☐ 高眺远望 (Overlooking) ☐ 无所谓 (Don't Care)

4. 您知道这我们所在的地点是怎样收集和利用雨水的？(Did you gain knowledge from the surrounding environment about how stormwater management works?")
   ☐ 知道 (Yes) ☐ 不知道 (No)

5. 自从您住在这个公园附近，您是否越来越开始关心城市的雨水问题？(Have you become more concerned with the urban rainwater issues since you have been living here?)

   ☐ 是的 (Yes) ☐ 不，没变化 (No)

6. 您最喜欢公园里的绿色基础设施的哪部分?（多选）
   (Which landscape element would be your be your favourite?) (Multiple selection)

   ☐ 多样的植物(Plant borders) ☐ 收集雨水的水池 (Peaceful rainwater pond)
   ☐ 草坪 (Broad lawn) ☐ 雨水广场(Rainwater square) ☐ 林荫小路 (Shady path)

7. 从群力公园优美程度而言，您认为哪些部分需要改进？（多选）(Which landscape components should be improved?) (Multiple selection)

   ☐ 水体 (Water body) ☐ 植物 (Plant system) ☐ 道路 (Road) ☐ 草坪 (Lawn)

8. 如果您给公园的景观的优美程度从 5 到 1 打分，您会打多少分？ (Please you evaluate the aesthetic value of the stormwater management system with a score from 1-5., which scores will you give?)

   ☐ 5 分，极好 (5 Points, Very high) ☐ 4 分，优秀 (4 Points, Quite high) ☐ 3 分,一般 (3 Points, Moderate) ☐ 2 分,很差 (2 Points , Quite low) ☐ 1 分，极差 (1 Point, Very low)

9. 其他的公园相比，您相信这个公园会成为成功的通过用景观治理雨水的经典例子吗？
   (Do you think the project is going to be a classical, comparing with other similar projects in China)
   ☐ 相信(Yes) ☐ 不相信 (No) ☐ 不确定 (No Sure)