SHAPING THE SUSTAINABLE CITY THROUGH WATER ORIENTED URBAN DESIGN

By

SIYU YU

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To my family

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Siyu Yu

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Chair: Bradley Walters
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There are many water issues in our lives, ranging from regional planning to local planning, from city scale to neighborhood scale, there is no denying that water has influenced every aspect of urban construction environment. So water serves as a kind of infrastructure to guide the urban design and construction, that is to say, the water issue should be taken into main consideration in decision making and urban design.

Water can serve as a kind of infrastructure to guide the planning of urban space. Water environments—such as waterways and coastal waters, and water supply catchments—are key areas where urban development can have significant impacts. Accordingly, different urban space will be formed in terms of the water infrastructure design. Water oriented urban design has 3 main goals: to improve the sustainability of urban recycle, to sustain the development of urban built environment and to provide the emotional experience of users. Firstly, the main point of water oriented urban design is sustainability, that is, water serves as a factor to guide the development, which not only enhances the quality of urban built environment, but also helps the circulation of culture and economy. Secondly, water as a way of life and also a kind of infrastructure; it is a retreatment of urban infrastructure system and people's behavior and awareness of

importance of green infrastructure. The Low Impact Development solutions can also be taken as function of the green infrastructure to reduce the volume of storm water run-off, which to some extent solves water resource issues. Thirdly, different regions have varied waterfront conditions, which can form the particular feature of a unique site.

CHAPTER 1
INTRODUCTION

The greatest global challenge is to balance the expanding human needs with shrinking resources and a changing world climate. Failure to find a balance threatens every aspect of the world's population, which is also the major impediment to achieving sustainable design and planning. We are all trying to address critical issues: study the methods to plan, design, and build healthy and smart cities as the burgeoning population overburdens the infrastructure system; find the solution to provide food, energy, and transportation in an ecological-friendly and resource-saving way.

> Today, even with conventional water supply strategies and technologies, water shortages commonly plague communities around the globe. The world Health Organization (WHO) reports that over two billion people—roughly one out every three people on the planet—live in a water-stressed area. (http://www.sherwoodinstitute.org/research)

Urban design is to give users different experiences and sense of placing while physically constructs the place to support the need of function and structure in general. The emotional demands of the sense of placing are the final goal of the designer. But what is sense of placing? The sense of placing is the emotional experience of users in a particular place, such feelings as excitement and delight, which contains the spirit of place and place attachment. Firstly, the spirit of place is the fundamental characteristic of the place, which endows the site with the specific emotion and feature, such as the image of the site. Secondly, the place attachment, for instance, our memory and image of the community can help us to build the relationship between the community and the residents.

As is known to all, different sites can bring us various senses of place which can give us varied experience. For instance, the urban area can give us feelings that may

be totally different from what we experience in rural zone. Moreover, different urban sectors can give us a variety of experiences: the central business district brings us the senses of high-speed development and modern atmosphere, while the natural reserve park takes us back into nature to enjoy peaceful life.

As there are water issues in our lives, ranging from regional planning to local planning, from city scale to neighborhood scale, there is no denying that water has influenced every aspect of urban construction environment. So water serves as a kind of infrastructure to guide the urban design and construction, that is to say, the water issue should be taken into main consideration in decision making and urban design.

The word “sustainable” means environmentally-friendly and eco-responsible. In terms of sustainable design, we mostly focus on how to reduce the reliance on fossil fuels, the use of renewable energy, the use of sustainable materials and so forth. Sustainable design is a three-dimension issue. What we have to do is to design the connection between community, economy, and environment. It is the human awareness, which is the core of community rather than the high-tech and economic support, that plays a vital role in sustainable design and material recycle.

The sustainable design for the building may take the weather data and other parameters into consideration. From the point of weather data, parameters such as the temperature, humidity, sunlight, and wind speed are the primary index for the sustainability of a building design.

In order to achieve sustainability, we should first take advantage of the local resources to meet the need of the community. And we must figure out what is the appropriate scale for the self-sufficient community. As what is usually done in the urban

regional planning, we settle the planning unit as the administrative region of the city area. As for the issue of sustainable community, I think it all depends on the local land resources, geographical environment and the urbanization level of the community.

Regarding to the urbanization level, the higher urbanized region may divide the community into narrower areas, such as blocks. However, for the less urbanized parts, the community maybe kept as the union of several provinces to help each other to meet the fundamental need of the resource supply.

In the meantime, water can serve as a kind of infrastructure to guide the planning of urban space. Water environments—such as waterways and coastal waters, and water supply catchments—are key areas where urban development can have significant impacts. Accordingly, different urban space will be formed in terms of the water infrastructure design. Water oriented urban design has 3 main goals: to improve the sustainability of urban recycle, to sustain the development of urban built environment and to provide the emotional experience of users. Firstly, the main point of water oriented urban design is sustainability, that is, water serves as a factor to guide the development, which not only enhances the quality of urban built environment, but also helps the circulation of culture and economy. Secondly, water as a way of life and also a kind of infrastructure; it is a retreatment of urban infrastructure system and people's behavior and awareness of importance of green infrastructure. The Low Impact Development solutions can also be functioning as the green infrastructure to reduce the volume of storm water run-off, which to some extent solves water resource issues. Thirdly, different regions have varied waterfront conditions, which can form the particular feature of unique site.

Study objectives. The main goal of this study is to develop guidelines for urban planners and policy makers to use when planning and designing infrastructure that promote sustainability of the water infrastructure and the urban environment. To achieve this goal, three objectives are developed. The first is to develop an understanding of the links between urban water infrastructure and the built environment, second, to examine and measure the impact of the water, using GIS, user surveys, and an inventory of the infrastructure' attributes, and finally to develop a set of design guidelines for each urban water system which can be used to locate and design new urban areas that promote the sustainability of itself and the urban living environment.

Take the WOD (Water oriented development) mode as the study mode, this thesis will study the water issue in urban design and urban space shaping from the 4 parts of "capture, filter, use, and habitat". Accordingly, storm water management, potable water supply, water for commerce and recreation are selected to be the outline frame of this paper to study the impact of water on the built environment. Water issues in Wuhan, storm water management in Seattle, and water using problems in Venice.

Wuhan, the capital city of Hubei Province in China, is known as "the nine provinces leading thoroughfare". It is the political, economic, cultural center of central China, connecting Nanchang, Changsha, Zhengzhou, and Hefei, which are important cities of central China. The chief water issue of Wuhan is the city flooding in terms with the urban infrastructure. When the rainy season comes, the city is paralyzed. Population growth, traffic congestion, urban contamination, resources shortage, the gap between the rich and the poor, all these metropolitan issues in Wuhan could have some relation with the ecosystem and the metropolitan issues that cause city flooding. Based on this

information along with environmental factors which will be identified in this research, methods will be chosen to guide Wuhan solving the water issues.

CHAPTER 2
LITERATURE REVIEW

Understanding Sustainable Design

> Sustainability as a part of the concept “sustainable development”, that of the Brundtland Commission of the United Nations on March 20, 1987: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (World Commission on Environment and Development.(1987). Our common future. Oxford: Oxford University Press, p. 43.)

Sustainability is the cooperation of the environment, economy and culture, which is not only about the food supply and energy crisis, but also the balance of every aspect of our life demands with the health of nature system. Sustainable development concerns about energy, materials, air and water issues, especially the water issue, which is considered to be the choke point of human demands.

The word “sustainable” means environmentally-friendly and eco-responsible. In terms of sustainable design, we mostly focus on how to reduce the reliance on fossil fuels, the use of renewable energies, the use of sustainable materials and so forth. Sustainable design is a three-dimension issue. What we have to do is to design the connection between the community, economy, and environment. It is the human awareness, which is the core of community, more than the high-tech and economical support, that plays a vital role in sustainable design and material recycle.

To achieve sustainability, we should first take advantage of the local resource to meet the need of the community. And we must figure out what is the appropriate scale for the self-sufficient community. As we usually do in the urban regional planning, we settle the planning unit as the administrative region of the city area. As for the issue of

sustainable community, it probably all depends on the local land resources, geographical environment and the urbanization level of the community.

Regarding to the urbanization level, the higher urbanized region may divide the community into narrower areas, such as the blocks. However, for the less urbanized parts, the community maybe kept as the union of several provinces to help with each other to meet the fundamental need of the resource supply. In terms with the sustainable design for the building may take the weather data and other parameters into consideration. From the point of weather data, such as the temperature, humidity, sunlight, and wind speed, which may be the primary index for the sustainability of a building design.

The goal of sustainable design consists of 4 points, firstly, to learn the connection of the urban construction environment and the nature system; Secondly, to make full use of the nature to help the urban built environment development, and design architecture that are portion of nature system; Thirdly, to minimize the reliance of the fossil fuel; Finally, enhance the using efficiency of nature resource.

Sustainable development concerns about energy, materials, environment, community and water issues. Sustainable energy contains carbon footprint elimination, renewable energy, and clean transportation. The dwindling resources and climate changes are the two major challenges of our future; both of them are related to fossil fuels. There is no denying that fossil fuels not only do harm to our environment but also give some negative impacts on our daily lives. They may release greenhouse gases, and definitely can‘t meet the demands of transportation of the future. So we should seek out new energy to replace fossil fuels, such as bio-fuels, which can be used for the new

drive of the future transportation. Sustainable environment includes cycling, system and connection of ecosystem; Sustainable community consists of economy diversification &growth, place making aesthetic, steady employment, capital improvements and public health; Sustainable water system is waste-water treatment and reuse, rainwater reuse, aquifer recharge &quality, water balance, efficient systems and conservation.

Water issue is considered to be the choke point of human demands. The problem may come from any aspect: the source of the water, the quality of water, waste water distribution and the interaction between the water system and other infrastructure systems, such as energy supply system, and environment system.

Understanding Urban Design

Urban Spatial Form

Urban design is a process of urban space shaping while enhancing the experience and improving the function of it. The definition of space originates from the Latin “spatium”. Space is a set of element and spot in line with the specific geometry environment and location, distance between the two locations or virtual area between the specific boundaries. Urban space is the carrier of people’s living, work, recreation and transportation. The space studied in this paper is a combination of vertical plane, which includes buildings, structures, trees, outdoor dividing wall, etc., and horizontal plane, such as the ground and water. It consists of environmental sculptures, users and space elements, which is dominated and affected by the vertical plane in urban space. It is a limited area separated from the nature environment and a carrier of people’s living, work, recreation and transportation. The planning of urban transportation, organization of city buildings and urban landscape are always the first impressions of a city. Those impressions and understandings are named as the urban spatial forms.

Urban space may be divided into two parts: urban public space and urban private space. This paper focuses on the urban public space. It is the open space among construction entity in a city or agglomeration. It is designed to serve the public, which is an open area for urban residents' social activities and communications. Urban public space mainly consists of nature environment such as forests and water. Basically it is the place for people's social lives, and represents the essence of city's actual environment. It is a multicultural carrier, which shows the city's unique charm. The overall quality of urban public space construction has a direct influence on city's competitiveness as well as public's satisfaction. As a result, the city's decision makers, builders and residents all pay specific attention to its urban public space.

Urban Design Goal

Emotional experience and place making

Urban design is to give users different experiences and sense of placing while physically constructs the place to support the need of function and structure in general. The emotional demands of the place making are the final goal of the designer. But what is sense of placing? The sense of placing is the emotional experience of users in a particular place, such feelings as excitement and delight, which contains the spirit of place and place attachment. Firstly, the spirit of place is the fundamental characteristic of the place, which endows the site with the specific emotion and feature, such as the image of the site. Secondly, the place attachment, for instance, our memory and image of the community can help us to build the relationship between the community and the residents.

As is known to all, different sites can bring us various senses of place which can give us varied experience. For instance, the urban area can give us feelings that may

be totally different from what we experience in rural zone. Moreover, different urban sectors can give us a variety of experiences: the central business district brings us the senses of high-speed development and modern atmosphere, while the natural reserve park takes us back into nature to appreciate the peaceful life.

Organizing urban spatial structure

There are 3 main urban forms: Linear city, grid city and highly centralized city. Urban design is a physical planning, aiming at improving the environmental quality of urban space based on the comprehensive planning, people's behavior, civil life, and special art design. The urban ecosystem space interacts with the urban construction space to sustain a multiple urban spatial form. All elements in the urban system stay in harmony, such as moving water, wild life, air circulation, history, culture, politics and technology. The reason why the ecosystem space can play the role to balance the urban construction space is that the eco space interacting with the built space can produce the spatial mosaic relationship, which can help to define the scope and impact of the urban spatial structure. There are four types of urban eco-spatial structure in general: wrap-around, wedge-style, core type and connected ribbon style. (Figure 2-1)

Wrap-around style. The development of city is focused within certain range, and the ecological space wraps around the core city to limit the expansion of city. Satellite towns nearby are scattered in the "green ring" formed by the eco-space, in which they are kept certain distance to the core of the city. Settings the greenbelt to control central city spreadhas become the best practices of ecological space balance metropolis space structure. London, Paris, Milan, Melbourne have used this tactic.

From the point of landscape ecology, wrap-around relations meet the city's needs of gathering both urban construction space and urban ecological space

separately. And it can also bring lots of ecological benefits from green belt around without breaking the stability of the Green Belt around city.

Wedge style. The outskirts of the city construction space radiates outward from the central city and are interspersed with urban ecological background, which forms a mode with "green wedge" as the main structural element. Its main function is to introduce the ecological environment of the suburban urban space to city, and to increase the interface length between the urban ecological space and urban construction space. It also plays an important role for the urban ecological space to penetrate outside-in. Copenhagen, Moscow, Melbourne, have applied this tactic.

From the perspective of landscape ecology, the wedging-inlaid relationship does not destroy the continuity of the ecological background when the city construction space continuously extends. At the same time it allows the existence of large ecological area to form ecological sources and protects the landscape security pattern in the urban areas.

Core style. The different functional groups in the city develop around large areas of the ecological core, and each of them is separated by a green buffer zone. Randstad and Singapore follow this structure.

From the perspective of landscape ecology, the core type builds large-scale ecological source (green heart) in the center of urban construction space, while green buffer zone links green heart and peripheral ecological background, thereby enhancing the ecological stability and ecosystem service function of the green heart and forming an open-center ecological spatial pattern.

Connected ribbon style. Urban ecological space and urban construction space forma linear mosaic pattern. As a result, it maintains lateral open between the functional groups in the city, and the city's ecological space can play a greater performance and has a good accessibility. Munich, Milan and Paris are in use of this mosaic relationship.

With this the mosaic relationship it will form ecological corridors. Ecological corridor in this linear space organizational model can significantly increase the interface of urban construction space and urban ecological space, contributing to the generation of edge effects on the ecological space. Meanwhile, these ecological corridors are also the most important structural elements for increasing connectivity in the landscape patterns.

The urban structure in China also has typical characteristics, which mainly manifest in the following two forms: strong-core cluster-composed city and multinucleated cluster-composed city (Figure 2-2).

Strong-core cluster-composed city. The city has a dominant central region, which was relatively high-density urban area formed at the undeveloped period before the rapid urbanization and industrialization in 1980s, covering the urban region with the traditional urban boundary. Such cities generally have a long history, good industrial base and other advantages. In 1990s, along with the rapid development of urbanization, industrialization and the rapid extension of urban size, relying on the dominant central region and the support of urban transportation and communication technology, the discrete functional group was formed around the outskirts of the urban area. In the way of urban space expansion, the strong nuclear cluster city traffic arteries Development District tend to be relying on or connected to township space of the outskirts of the city

by transportation artery, the central district of the urban outskirts also has the growth trend of outward nuclear radiation. Lots of big cities in China are typical strong-core cluster-composed cities, such as Beijing, Shanghai, and Chengdu.

Multinucleated cluster-composed city. Compared with the strong-core cluster-composed city, the dominant feature of the central region is not that obvious. There is no obvious wrap- around feature of outskirt functional group and the central district. The whole urban region space characteristic is “axis& group” network-like and multi-core scatter ribbon.

After years, if the multinucleated cluster is formed as the dominant strong-core cluster, city may encounter with the same problems as the development of the strong-core city, the issue we should give highly concerned is the function of the ecosystem in this urban extension structure, which may affect the shape changing of the city. Ecosystem is the organic system of interacting and interdependent relationships in conjunction with the nonliving environment such as water, air. There are lots of processes composing the complexity of the system, including the energy circuits, food chains, natural cycles, species interactions, succession and so on.

As the Holocoenotic principle said, the interrelationship of the nature and humankind accounts inevitably for the most of the complexity of the ecosystem. The health of the human communities cannot be separated from the ecosystem service, such as the flooding control, storm protection, the alleviation of the climate change; also, the diversity of the ecosystem is in relation to the human activities. We should take responsibility to protect the biodiversity of nature since we are the part of the ecosystem, for instance, creating the greenway to build the ecological network, setting act to fulfill

the conservation of the species; Take more issues into consideration when doing urban planning and design, such as, air circulation, wild life habitat, moving water, water edge of the city, etc.

Understanding Water Oriented Urban Design (WOD)

Water issues nowadays. As there are water issues in our lives, ranging from regional planning to local planning, from city scales to neighborhood scale, there is no denying that water has influenced every aspect of urban construction environment. So water can serve as a kind of infrastructure to guide the urban design and construction, that is to say, water issue should be taken into main consideration in decision making and urban design.

> Today, even with conventional water supply strategies and technologies, water shortages commonly plague communities around the globe. The world Health Organization (WHO) reports that over two billion people—roughly one out every three people on the planet—live in a water-stressed area. (http://www.sherwoodinstitute.org/research)

In the meantime, water serves as a kind of infrastructure to guide the planning of urban space. Water environments—such as waterways and coastal waters, and water supply catchments—are key areas where urban development can have significant impacts. Accordingly, different urban space will be formed in terms of the water infrastructure design. Water oriented urban design has 3 main goals: to improve the sustainability of urban recycle, to sustain the development of urban built environment and to provide the emotional experience of users. Firstly, the main point of water oriented urban design is sustainability, that is, water can be served as a factor to guide the development, which not only enhances the quality of urban built environment, but also helps the cycle of culture and economic. Secondly, as a way of life and also a kind of infrastructure, water is a retreatment of urban infrastructure system and people's

behavior and awareness of importance of green infrastructure. The Low Impact Development solutions can also be functioning as the green infrastructure to reduce the volume of storm water run-off, which to some extent solves water resource issues. Thirdly, different regions have varied waterfront conditions, which can form the particular feature of unique site.

Urban Space Shaping in According to WOD

Water may organize the urban space in different scales:

Invisible controlling system

Water may be worked as an invisible system for urban system, either in a positive or negative way. Water system is considered to be the link of the urban construction space and green space to sustain the health of the human communities through ecosystem service, such as the flooding control, storm protection, the alleviation of the climate change.

Open space

Water is an irreplaceable element in our local ecosystem, which reminds us of using it in the open space realm to reconnect the community and natural water cycle. Integrating urban landscape design with sustainable urban water management may activate the landscape and protect the open space as well.

Individual building

As the individual building scale, the crucial issues are the water use and recycle in the building, such as storm water collection, waste water reusing and the water using capacity of the building. Lots of techniques are taken into use to help to reduce the building footprint in a sustainable way, such as the low impact development, rain garden, controlling stormwater quantity and quality of the site.

Water Issue Management through WOD

Sustainable water solutions are of reusing, cleaning, conserving and protecting. Sustainable water management contains three streams, potable water, waste water and storm water management from regional scale to individual building. Potable water means water that is safe to drink; Waste water management includes sewage treatment, waste management, industrial waste-water treatment, agricultural wastewater treatment and radioactive waste treatment; Storm water is captured from the region by the green roof and a subsurface infiltration system, and then via the used water recycles to the groundwater after being cleared pollutants. Storm water can help to control flood and sustain water supply.

Since reusing is the crucial part of sustainable design, water oriented design solutions for water crisis are reusing, reducing, cleaning and conserving, focusing on water supply, sewers, drainage, and waterway health. Firstly, reduce demand of water supply in every aspect of the urban construction and sanitation; Secondly, use water more efficiently, give full play to the grey water system and improve the black water system; Thirdly, maintain the water infrastructure and keep track of the urban water way, from the perspective of biological, hydrology, sediment quality, geomorphology, water quality and continuity of the waterway.

Relationship between the WOD and Sustainable Design

Ecologically sustainable development is the ultimate goal of the water oriented urban design, which includes built environment forming and water cycle management. at the same time, sustainable design criteria guide the rules of water oriented urban design.

Sustainable design takes the built environment as the design objective, concerns about economic, social and ecological sustainability. Sustainable design goes beyond the cost, schedule and quality, and it also calls for public health, safety and ecology when programming the design. Water oriented urban design focuses on water issue in urban built environment, concerning water function in urban space shaping and water management in the urban area, which is a sub-discipline of sustainable design.

Designing for sustainability is restorative, dynamic and flexible, which is the same as water oriented urban design that is flexible to solve urban issues according to water design and management to some extent. Water issue interacts with other elements when shaping the city, such as, history, culture, politics and technology. Accordingly, water design in the city should be changed with these factors, which is the flexibility of the WOD.

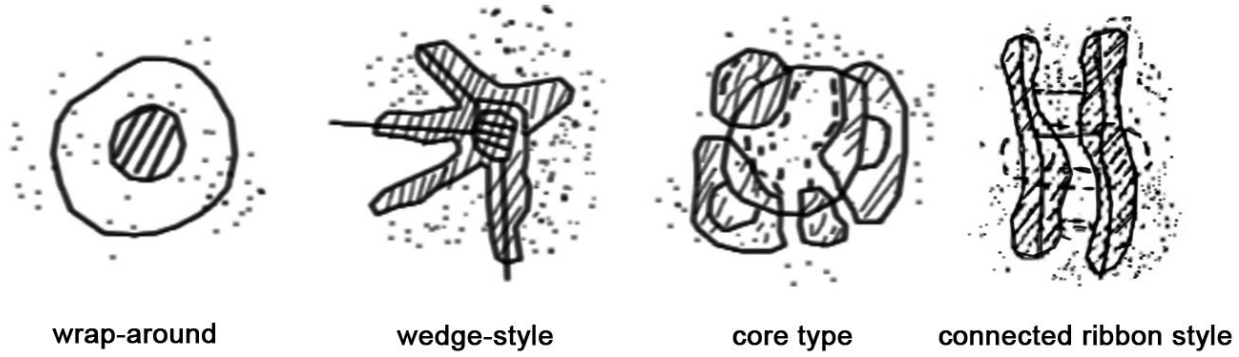

Figure 2-1. Four types of organizational model of urban eco-spatial structure. Source: Adapted from Du Qi.

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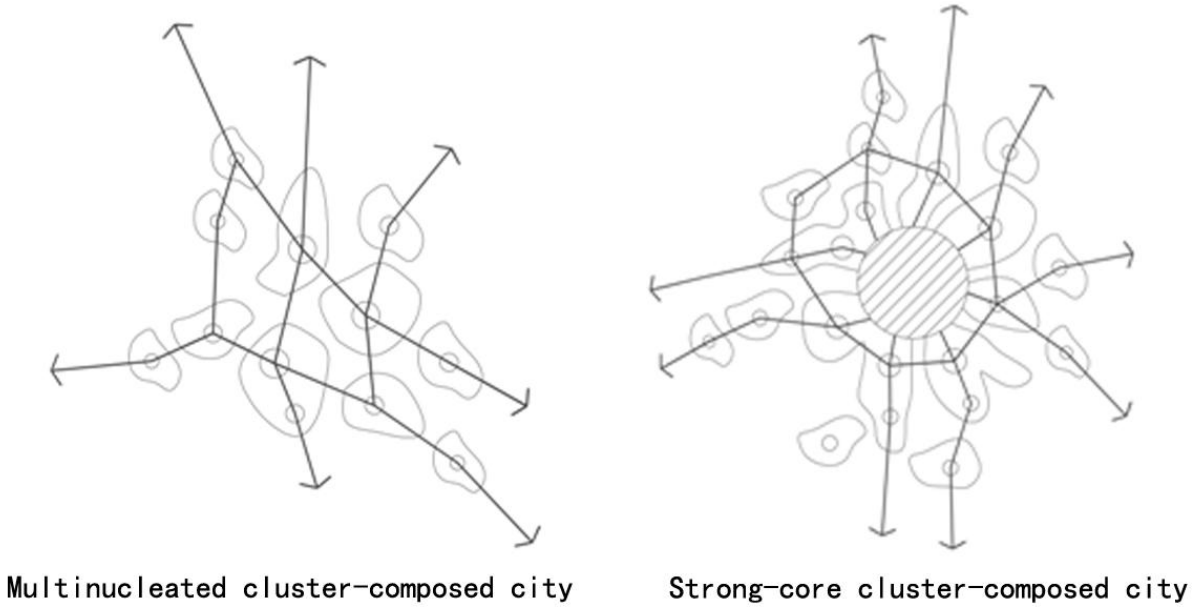

Figure 2-2. Urban structure forms in China. Source: Drawing by Siyu Yu.

CHAPTER 3
CASE STUDIES

Seattle Waterfront-From Commerce to Recreation

Seattle waterfront experienced two reforms, before the first redevelopment in 2002; there was no public marina and facility equipment. Lots of area lacked renovation and unity. But with the changing function of the city, the waterfront was no longer just for shipping and transit, there are lots of other uses, such as recreation. Planners redesigned the waterfront area with some improvement and events to attract more tourists, adding some commercial activities and developing the boat tour, which substantially increases waterfront activities and greater tourism. At that time, the pedestrian connections, public moorage, Pier Park, aquarium redevelopment and the connection of the Washington street boating land have been high concerned by designers. The renovation of this reform is to regulate the function division of the waterfront area, but due to the condition and situation, the issues above have not been deeply solved.

As the second renovation came, the main idea of the James Corner operation was to build the connection between the waterfront and city to the maximum. The design team emphasized the idea of region sharing. The waterfront should be linked with other public space to integrate the point, line and aspect elements to build the circulation of the urban landscape of the marine city, which is a city of a riverfront development. On the other hand, water can serve as the link of the culture and art of urban area. Waterfront area can be the recreation center to bring about different experience and feelings for citizens to enjoy.

Methods. Although the second reform of Seattle Waterfront is still at the stage of concept design, water has already been considered to be a kind of infrastructure to guide and sustain the recreation design of the marine city:

- Building the connection between the water and land. Taking the waterfront area as a point, the network and pathway to the waterfront as a line, integrate the point, line and aspect elements to build the circulation of the waterfront and city layout. Designer creates different events and activities to attract people from different place and multiple levels.

- Take the waterfront as the place for Seattle community and civil life. Use the sculpture to build the identity of the water bay area. Building the connection of the waterfront with other parks is to set up the continuity of the waterfront.

- Design sustainable water infrastructure and create the opportunities to help the public participate in the working process of the infrastructure; the scale of water infrastructure is also controlled by the sustainable and green criteria. Use landscape design to settle plaza in harmony with waterfront.

- The James Corner operation did the survey about the favorite events and designed key points, such as trees, lawn, urban beach, pier walk, decking, paving, seating, elevation of the pier. The pier walk, river terrace, lawn, raise elevation, paving and seating were selected by public as the crucial renovating part（Figure 3-1）.Lots of sustainable visions have been settled into the waterfront design. The paving should be designed with solar energy;

Singapore-Potable Water Supply and Storm Water Management

In 1961, Singapore signed a one-hundred-year agreement with Malaysia through which water, a signify cant amount of Singapore's supply, would be sold to Singapore by Malaysia at $0.03 per 1000 gallons (Branca, 2009). This fixed price is locked in contractually for the full one-hundred-year term, and does not rise as inflation does. Naturally, this has caused a great deal of friction between Malaysia and Singapore, and when the contract expires in 2061 there is a good chance that Malaysia will be unwilling to renegotiate a new contract. To reduce its dependence on Malaysia, and in an effort to environmentally sustainable, Singapore has gone to great lengths to both conserve its current water resources, and to create more of a resource through a technology it has

created called NEWater. In addition to imported water, and NEWater, Singapore obtains some water from desalination, and a large portion from rain-water reservoirs (Branca, 2009).

In response to these challenges, Singapore has developed extensive cutting-edge technologies which have dubbed it a global leader in environmental sustainability. There are several strategies and technologies that Singapore has employed; most significant are those related to water usage and conservation, and waste management.

Potable water means water that is safe to drink. “Potable water is free from pollution, harmful organisms and impurities,” (water-technology.net, 2009). In Singapore, the potable water is named NEWater.

Currently, Singapore has three water reclamation plants that can hold a total capacity of 20 million gallons of water each day. About 6% of these 20 million gallons of water is used for indirect potable use. It is mixed with water imported from Malaysia, which can afford 1% of water requirement every day. However, the rest of the 20 million gallons that is used as industrial water (Public Utility Board, 2008).

Although NEWater is safe to consume, and technically potable, there is still a psychological stigma that the public has attached to consuming reclaimed water. This is why the small amount that is used for potable purposes is diluted with the traditionally-filtered potable water at the reservoir site. It is expected that over time, as the technology becomes more widely recognized and accepted, the general public will become more comfortable with consuming NEWater.

Water from any Tap in Singapore is Safe to Drink. The government takes the responsibility and ownership of providing safe drinking water to its citizens. So that it

takes guarantee of every drop. They are so confident that they are planning to ban bottled water in Singapore in order to avoid pollution because of the plastic.

Venice-Flooding Control and Transportation

Historical Development of Venice

Venice, “the city of water”, locates in the northeast Italy, which consists of over 100 small islands, canals and bridges. Water is considered to be the most important symbol of the world-famous city. The seaways along Venice region are more than 1,000 kilometers. For centuries, Lagoon and canals provides local people with living source, city defense, transportation, as well as attracts millions of tourists every year. The dynamic ecosystem remained harmonious over hundreds of years. It’s not until the recent years that the balance between local hydrological system and people has been broken down by intense human activities. Floods are the biggest threat to the historical city. On one hand, it has significant hit on the local tourist industry which is the major income of the city. On the other hand, frequent floods cause permanent damage to its historical sites and art works. With more and more severe floods in the last few decades, it becomes a major problem of public health. Big floods sometimes make thousands of people become homeless in Venice.

There are multiple factors leading to floods problem in Venice, such as subsidence, climate change, erosion, pollution, etc. Some area in the Venice region has already been below the sea levels, which becomes even more vulnerable. The average water level of Venice in 21st century is about 25 centimeters above the water level first measured by a mechanical instrument installed at Punta Della Salute in 1872. Local and global human activities, such as unreasonable land use, poor management of artificial canals, and chemical pollutions, have even increased the vulnerability of Lagoon region.

Sufficient Methods to Solve Water Issue

Water governance improvement

Since Venice is facing all kinds of water problems, such as floods, and poor water quality, the local government has taken some steps to improve water governance in the city region.

- The water quality standards are based on standards of Europe with some nationwide and regional regulations.
- Pollutants discharges and emissions are strictly monitored and controlled by the Venice government and environmental police department.
- Fresh water quality is monitored daily by the region.
- Municipalities authorize an inter-communal, publicly owned company to deal with Wastewater treatment and sewage discharges, since the sewage coverage in the historical city is only about 70%.
- The water quality of Venice Lagoon is monitored by the Venice Water Authority with its Anti-Pollution Service.
- Since Marghera industrial zone is the major pollution source in the Lagoon region, the Venice Port Authority is maintaining the canals particularly in this area.

Considering the essential cultural and economic role that water plays, it is important to improve the water governance in Venice. Some strategies can be applied:

- vertical and horizontal area that can fluctuate in coordination with the flooding;
- long-term planning;
- putting the water and other ecological factors into policy, from the municipal to the regional scale.

Water collection of Campo

Campo Santo Stefano is one of the most important urban public spaces in the city of Venice, since it stands for a specific urban value with continuous spatial

sequences, which taking the water collection issue in designing the public space from the municipal to the regional scale.

Along with a series of open space located in the San Marco Area, it is Campo Sant' Angelo that runs parallel to the Grand Canal and lies along the path between the Academia Bridge and the Rialto Bridge. It is a system of ground infrastructure connecting with other squares system to deal with all the water management issues in Venice. The pavement of the square is higher than the surrounding areas, which was used to collect the rainfalls during the old days into the two wells that symmetrically locate in the main path-way across the square. The structure of floors and steps built in the late 15th century is of great architectural value, since it connects different levels of the square and the wells(Figure 3-2).

Campos are the places for public gathering and water management, which helps to sustain the livings of residents around the squares. At the same time, the public and social aspects of the square should go with the residents' suggestions.

Best Practices of Case Studies

Firstly, rebuild the waterfront into public space with recreation elements. River side of Seattle is not only the commercial transportation hub, but also the green core of the city, which connects lots of other parks and green ways to build up the city eco-system. At the same time, waterfront can be adopted into urban public space system to serve as a recreation center for the citizens. Waterfront design may also add lots of recreation elements to create energetic public space to provide places for social and culture life of the city.

Secondly, specify storm water management system. In terms of Seattle and Singapore, the storm water management system is monitored by different water

controlling sectors from government to private water company. As for Seattle, the city is divided into 4 storm water management sectors, and all of them have different level water treatment criterions. Typically for the Seattle waterfront, the storm water management contains 4 steps: pre-treatment, primary treatment, second treatment and tertiary treatment. After the purification, water can be reused.

Thirdly, use tributaries, which are the transportation artery, to disperse the pressure of can also release urban flooding. The drainage system in the main city area, such as shopping center areas, should be highly technically improved. The method in Venice is that water runoff around the shopping center goes directly into the main outlet canal, where combined sewers are applied.

Water management system can be served as a symbol of the public space, which gathers public; Wells of Campos in Venice used to collect water in history, and are kept as a symbol of public space now. Infrastructures that collecting water in waterfront area of Seattle have been designed to be a symbol of the waterfront square, and also the water recycle process is open to public.

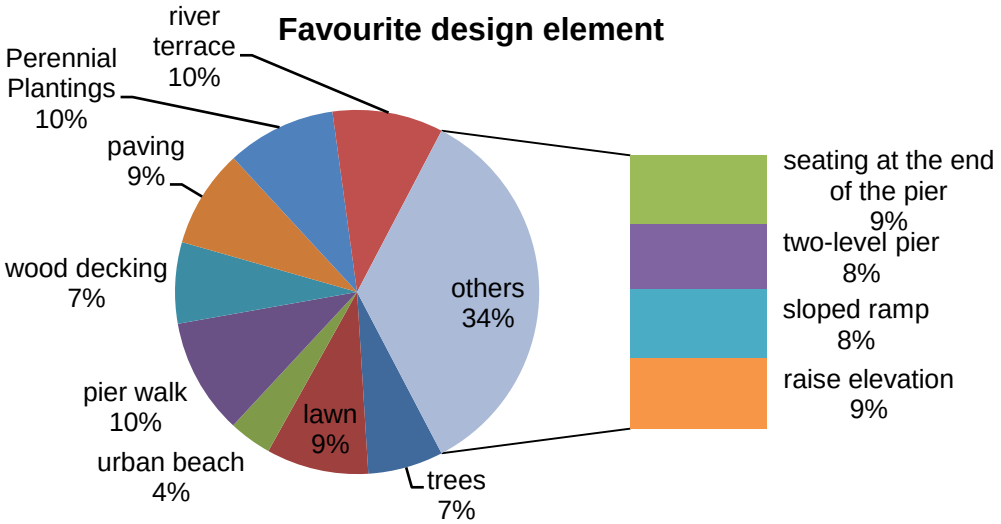

Figure 3-1. Survey of design points of Seattle Waterfront. Source: Adapted from James Corner Field Operations.

Figure 3-2. Water use in Venice. A) Public space shaping. B) Water collection of Campo in Venice. Source: Photos courtesy of Siyu Yu.

CHAPTER 4
METHODOLOGY

The thesis first analyzes urban design and urban spatial form, and compares eco-spatial forms of typical cities around the world. Then it analyzes the relationship between urban eco-spatial form and urban spatial form, and what the function of urban ecosystem plays on the urban spatial form. Finally, the thesis focuses on water function in shaping cities and figures out what is water oriented design.

In this thesis, there are three case studies: Seattle waterfront design, potable water and storm water management in Singapore and flooding control and water transportation in Venice. Seattle waterfront analyzes the relationship between the water front design and the public space shaping; Singapore potable water and storm water management studies on the urban invisible system that functions in the urban space shaping and maintains the recycle of the urban system; Venice's transportation is mainly based on water, which suffers the crisis of urban flooding and sea level rise. It is a typical case to find out the effective methods to deal with urban flooding issues. Comparing water issues in each of the cities with those in Wuhan, it summarizes the best practices of these three cities.

Finally, it analyzes the context of Wuhan and the main cause of urban flooding in Wuhan, then compares water issues of each cities in case studies with those problems in Wuhan to find the suitable design solutions of water issues in Wuhan.

CHAPTER 5
RESULTS

Water Oriented Management of Wuhan

Description of Wuhan

The context of Wuhan

The region that has been chosen to analyze for the next two parts is located in Wuhan, which is the capital city of Hubei Province in China (Figure5-1). Wuhan is known as "the nine provinces leading thoroughfare"; because of its key role in domestic transportation, Wuhan was once addressed as the “Chicago of China”. It is the political, economic, cultural center of central China, connecting Nanchang, Changsha, Zhengzhou, Hefei, which are the important cities of central China. The area of Wuhan is 8549.09 kM^2. In 2008, the population of Wuhan was 8.97 million, accounting for the 15.7% of Hubei Province (Census 2011).

Serving as a major transportation hub, the transportation of Wuhan city contains bridge, railways, public transit and highway. Two bridges, called the Wuhan Yangtze Great Bridge connect the main metropolitan areas, Wuchang, Hankou and Hanyang, which are the three towns of Wuhan. With dozens of railways, roads and expressways passing through the city, traffic jams are a feature of Wuhan city, which may be not the origins of urban sprawl, but sort of urban low efficiency. Population growth, traffic congestion, urban contamination, resources shortage, the gap between the rich and the poor, all these metropolitan issues in Wuhan can be solved by the strategies of smart growth.

The red parts in figure 5-2(A) are represented as the suitable construction land. Figure 5-2(B) shows the layout of the three towns of Wuhan, each of them is separated

by the Yangtze and Han Rivers. Wuhan can be kept as the political and education center of Wuhan(Figure 5-2). Lots of hi-tech districts are developed there to support the technological innovation of the Hubei Province, while Hankou and Hanyang serve as the financial and industrial center. Each town has infrastructure and public services to support citizens' daily lives. Green spaces are scattered into 3 towns following the nature context, parts of mountains are redeveloped for tourists, and most mountains are protected for nature conservation. The historical districts are strictly protected to link the past and present.

The context of the nature environment

Wuhan City is located in the center of China, eastern Hubei Province, the interchange spot of Yangtze River and Hanjiang River, its geographical longitude is 113 ° 41 ' to 115 ° 05', north latitude is 29 ° 58 ' to 31 ° 22', Administrative Region (SAR) area of the municipal area is 8494 square kilometers.

The annual average temperature is 16.9°C, extreme high temperature can reach 42.2°C, and extreme low temperature can be -18.1°C. The average annual rainfall is 1280.9 mm, the annual maximum rainfall is 2105.3 mm, heavy rain is mostly concentrated in May to October, during which rainfall accounted for 73.78% of the year.

Wuhan City has a total of 166 lakes, the waters area consists of 779.56 square kilometers, and regular lake water level is generally 18.6 meters to 20.0 meters with a regulation and storage depth that is generally 0.5 m to 1.0 m.

East Lake, which is the largest of the "lakes in city", divides into five scenic areas, more than 100 spots, and has about 33 sq km the vast waters, 12 large and small lakes, more than 120 harbors, 111.5 km shoreline. The landscape of East Lake has long coastline and a number of landscape types. On the other hand, the department

connected with the city was hardened, and set up walking trails for visitors to rest and entertainment. Moreover, the boardwalk corridor is set in a natural ecological region to maintain the ecological authenticity, and important nodes are also set for larger crowds to gather in public squares.

Metropolitan Design

Urban growth boundary

The perspective of smart growth emerges in the comprehensive plan of Wuhan, which has seven wedge-shaped green spaces, ten leisure ecological zones, all connected by the outer ring road. The outer ring road can be used as the urban growth boundary of Wuhan City to control the urban sprawl (Figure 5-3). The core of the urban growth boundary is to delimit the nature resources areas and economically sensitive areas to limit the urban development area. The basis of the smart growth is to take the green infrastructure as the open space to protect the land use.

Mix land use

The entire Wuhan city is divided into eight parts in the comprehensive plan of Wuhan in 1971, each part contains 1 million inhabitants, green ribbon or wedge-shaped split areas are connected by Rapid Transit Route. While in the new 2020 comprehensive plan, there are lots of mix-use space (the orange polygon in the figure 5-4) intersected with the urban transportation, which fully takes the Transit Oriented Development into practice (Figure 5-4). The plan provides a variety of transportation choices for us to use public transportation instead of private cars, which is the cause of the low density development leading to urban sprawl.

Preserve open space and critical environmental areas

The city is building a leisure park and an urban landscape park on both sides of the linear ecological corridor along the river of the city. This creates the axis-wedge urban space for residents, workers, visitors, children, families, single people, and older adults to get around and interact with the people around them in order to protect the environment while stimulating economic growth.

The comprehensive plan of Wuhan (2009-2020) won the Global Planning Outstanding Contribution Award. The success of the plan is to build the city into the nature environment and find a suitable structure of its own—“the city of 100 lakes”. With the development of urban construction, the nature resources are also protected. A city should pursue development rather than growth, the best and most efficient development is the pursuit of quality, rather than the pursuit of speed. To pursue the development of quality, we should not only value the economic indicators of growth as present but in the future. While the pursuit of speed makes us concern about the GDP, give up the environmental protection and also neglect the quality of urban nature.

Water Issue Management

Population growth, traffic congestion, urban contamination, resources shortage, the gap between the rich and the poor, all these metropolitan issues in Wuhan could be some relation with the ecosystem and the metropolitan issues to cause city water-logging. Last year, Wuhan was hit by a heavy rainstorm, and also Beijing, the capital city of China has been caught in a heavy rainstorm these days. These entire rainstorms cause the urban flooding problems of both cities. What really matters is that we should take measures to face with the problems rather than saying that these urban flooding

issues have something to do with the old urban water infrastructure, the increasing population as well as the unbalance of the nature environment and urban development.

As for the situation of the infrastructure now, we cannot replace the whole system of the water infrastructure of Wuhan. And the infrastructure issue may not be the only cause for the urban flooding of the city. The weakness of storm water system may be another reason for the flooding. The balance of nature environment and urban development is not just to protect the environment but we should take advantage of conserving the nature to help build a bright future, such as to reduce the runoff of storm water.

The city is an important carrier of human production and life. Meanwhile city has always been a vulnerable place where all kinds of disasters, accidents and risks happen. China is one of the countries that most affected by disasters, especially urban flooding. In China over 70% of the major cities, 50% of the population and 75% of the industrial and agricultural output are in the coastlands, eastern plains and hilly areas where they are severe flooding problems. Facing the increase of urban flooding, despite the government in China has increased investment in urban drainage, radical treatment of flooding cannot always achieve. Instead, the cities' economic loss caused by urban floods increase, with the continuous economic and social development of China. This prompts us to rethink about how to deal with flooding problem and how to keep a long-term coexistence with urban flooding. In recent years the idea of disaster mitigation is to adjust the relationship between human and water. Through switching from "flooding defense mode" to "flooding management mode", it attempts to coordinate relationship between human and water under the precondition for sustainable development.

Dialectically, the urban flooding itself also has two sides: it is not only a disaster caused by natural phenomena, but also an ecological process that is indispensable to maintain the natural ecological balance. Therefore, the complete elimination of water disasters is impossible and unwise. What we should do is to minimize the disaster loss caused by flooding when we are seeking for social and economic development, and try to keep as much beneficial functions that flooding plays in the natural ecological environment, such as groundwater purification and recharge, lakes maintenance, and soil improvement. Therefore, we should abandon the confrontational relationship between people and flooding in the past, and establish a new relationship, namely: under the precondition for sustainable development, we should learn to coexist with flooding. Instead of simple, brutal control of flooding, we should both control the flooding in an appropriate way, and take the initiative to adapt to and coexist with flooding.

Water oriented development have three meanings: first, the original meaning of the water drainage; second, management and utilization of flooding; third, to maintain ecological processes of flooding. The urban drainage planning strategy based on the new human-water relationship is to purse comprehensive benefits of the urban economy, society, environment, ecology, while protects the safety of the lives and property of the people at the same time.

Permeable storm water system

The rigid pavement cannot stop the rainwater, that is to say, rainwater runs more quickly into drainage often without filtering through the ground unless under natural pavement and green infrastructure. The running rainwater without filtering and cleaning by the soil may cause sewer blockage. Concentrated runoff can lead to high peak flows

causing flooding, erosion and city water-logging. Wuhan should change permeable construction materials for roofs, roadways and parking lots.

As for the community, the most efficient measurement is to reduce parking requirements and narrower road widths, which helps to create more walkable and interactive neighborhoods. Green infrastructure can be widely adopted into communities to build the bridge of smart growth and smart conservation to enhance the permeability of the green roof and help protect the storm water from run-off.

Green strategies for watershed

Wuhan East Lake is the biggest natural lake of National Scenic Area in the city. The scope of protection for the scenic spot is 88.2 sq. km and the water area is 33 sq. km, which is more than six times the West Lake in Hangzhou, Zhejiang Province of China. The length of the shoreline is 111.5km. East Lake is an important part of the “Hundred Lake City” in Wuhan, and the area of displaying image of Wuhan city. “Before in scenic spot, you can see the lake”, so construct lakefront landscape is focus and difficulty of East Lake scenic spot image creation. On the other hand, because of the wide water surface and long coastline, lakefront landscape design also becomes a significant issue of the East Lake scenic landscape planning and design.

The water strategy, in terms with the comprehensive plan of Wuhan, divides the water resource region into 4 sectors, which are water protect region, wetland protect region, water recreation region and harbor water area (Figure 5-5).

As shown in figure 5-5, the yellow polygons represent the parks that I propose to build along the watershed, which play the same role as the Campos in Venice. These parks can be public spaces that connect the waterfront space with the urban construction sector, and they also release the flooding crisis for urban space.

There are lots of lakes in Wuhan. Rebuilding the conjunctions of river to lake and river to river to release the flooding crisis of the river, this is similar to the relationship between artery and canals in Venice.

Relying on the construction of water recreation belt of Wuhan, it builds an interwoven urban ecological environment of the “Water Network” and “green network”.

Governance decision and actors for protection

The measures governors take to confront with the urban flooding issue, rainwater and waste-water should be divided. Pay more attention to use green infrastructure and enhance the awareness of the public to protect the natural environment. Education can be used as a way to inform the public of how to reduce waste-water and why it is important to recycle water, to teach children the importance of storm water management at an early age.

Water Oriented Design of East Lake

Overview of Lakefront Landscape of East Lake

Because of East lake is vast and adjacent to many around the city, it is not only a scenic spot on function, but also serves the surrounding community. So the waterfront coastline is a corridor by which people could apperceive and admire the landscape of East Lake, and the landscape design directly affects landscape character and atmosphere of East Lake Scenic Area. Researching and analyzing landscape situation there, it is easy to find the following problems on landscape of East Lake.

Single view of lakefront landscape

The lakefront landscape passageway of East Lake is mostly straight. It is close to the lake, but is straight. Some Lake Parkway even changed twists and turns coastline to become straight. Monotonous direction of straight passageway of lakefront landscape

makes the view of the landscape single. This lakefront landscape is simple and plain, and can only be called “channel”. Therefore, no landscape of lakefront in East Lake can be admired, and the lake is vast, but only has a monotonous way to see.

Flat shoreline design of lakefront

Only when the lakefront landscape has rich and varied plan, the richness of the lakefront landscape can be shown. The shoreline plan of East Lake is a single and uninteresting, such as single flat space composition of shoreline, landscape sketches, pavement, roads, etc. From a height overlooking the lakefront landscape, the first reaction is that there is no wave in shorelines as in lake surface. A vast expanse of lake needs to be supplemented landscape of lakefront shoreline. Only in this way can improve the overall Lakefront landscape image of East Lake. However, the existing landscape design on Lake Shoreline failed to enrich East Lake's lakefront landscape.

The plain lakefront facade landscape

Most of the shoreline use hardening revetment — with the wall perpendicular to the surface, rigidly set apart the natural water and artificial distinction shore district. It is not only anesthetic, but also affects the continuity and fluidity of the eco-system. The revetment facade lacks fluctuations as well as volatility, and the trees are neat and uniform. Its unchanged lakeside skyline is three “one” arranged in the distance.

Summary of Lakefront Problem in East Lake

East Lake, which is the largest “lakes in city,” divided into five scenic areas, more than 100 spots, and has about 33 sq. km the vast waters, 12 large and small lakes, more than 120 harbors, 111.5 km shoreline. Landscape of East Lake has long coastline and a number of landscape types. On the other hand, the department connected with the city was hardened, and set up walking trails for visitors to rest and entertain.

Moreover, set boardwalk corridor in natural ecological regions to maintain the ecological authenticity, and important nodes.

The East Lake is the largest “city lake”, whose shoreline is long. This characteristic attributes to the defect of the lake since the view node cannot fully cover the landscape. Walking in the lakeshore, one feels that it is endless; for the lake, visitors will naturally be discouraged. At the same time, the overall style of East Lake lacks change — a straight road with hard surface and artificial walls, which may deeply strengthen its largest features.

Water Oriented Design of East Lake

The perception of the lakefront area is far more than the area of attractions, and most of the East Lakeside view can be watched along the shoreline. Meanwhile, East Lake is the “City Lake”, whose visitors are mostly local residents; therefore, it should offer a variety of lakeside view sites. Unfortunately, such places are rare.

The green strategies to keep balance of the nature watershed with the urban construction is to restore the nature form of the urban lake and river, maintain the integrity of watershed vegetation, hydrological systems and water quality to protect the nature resource. At the same time, improving rainwater management and flooding protection can be crucial for East Lake. We should regularly clean up the lake bed and protect the natural reservoir.

Multi-view shoreline landscape design of East Lake

Landscape design should be close to nature. The design techniques of a single line sight cannot create a rich landscape space while in the space of a rich landscape, people's attention will shuttle from the vertical and horizontal directions; people’s attention is always motive.

East Lake landscape design should use the multi-perspective and multi-line as the design method guide to open up a variety of viewpoints and visions to separate lake landscape and shuttle various sight channel. People's view of space shuttle among the various landscapes aiming at providing a different perspective for people to watch the landscape space. This creates a rich and various landscape corridor and landscape.

Geometry graphic reconstruction of the East Lake landscape design

The East Lake landscape graphic design should select more split view, and reconstruct the geometry. Waterfront landscape design creates different patterns of small spaces through the split and reconstruction of the geometry, which display a lively sense of rhythm and pace, and constant change between the space and place.

At the same time, combined with the lake landscape graphic design, lakeside landscape boundary is expressed by geometry after being separated. According to landscape design in East Lake, we may as well use triangular patterns to form multidirectional space and a variety of spatial effects such as retaining walls, pavement, pieces, and squares.

Fluctuating elevation designs for East Lake

To solve the problem that the landscape of East lake elevations are too flat, we should add arbitrary altitude variation to the elevation according to their reconstruction performance. For example, we can apply triangular bulkhead to the conjunction of the landscape channel and water surface, which can produce not only transitional space from path to water level, but also altitude variation through triangles in different shapes.

Bright colorway for landscape of East Lake

The design can adopt fresh pavement on its solid landscape, which make landscape space vivid and interesting. To find more feasible suggestion for the

innovation of waterfront landscape of East Lake, we should start from the influence of cubism on modern sight design, turn to the multi-viewport and abundant forms of cubism in composition, explore the style and image of the simplified landscape carefully, and try to figure out various design methods and forms on planar, vertical and color design.

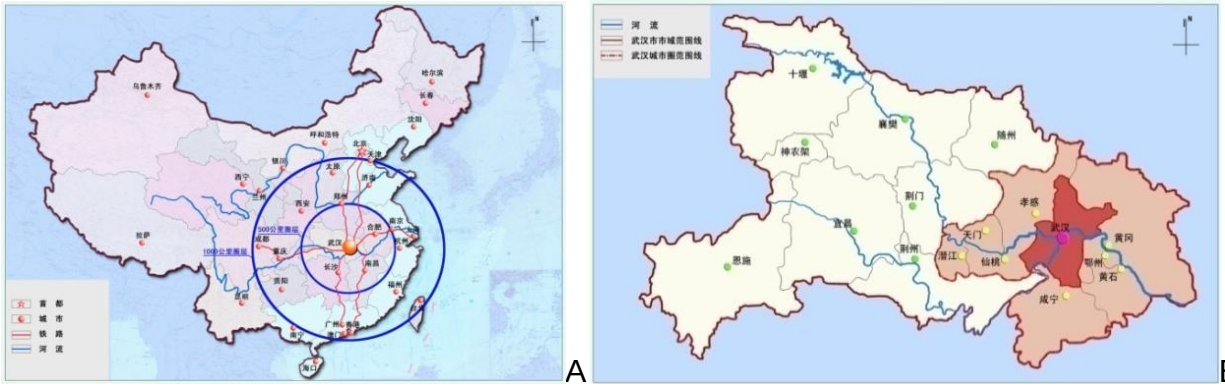

Figure 5-1. The geographic location of Wuhan. A) The geographic location of Wuhan in China. B) The geographic location of Wuhan in Hubei Province. Source: Wuhan City Planning Bureau, the comprehensive planning of Wuhan (2009-2020).

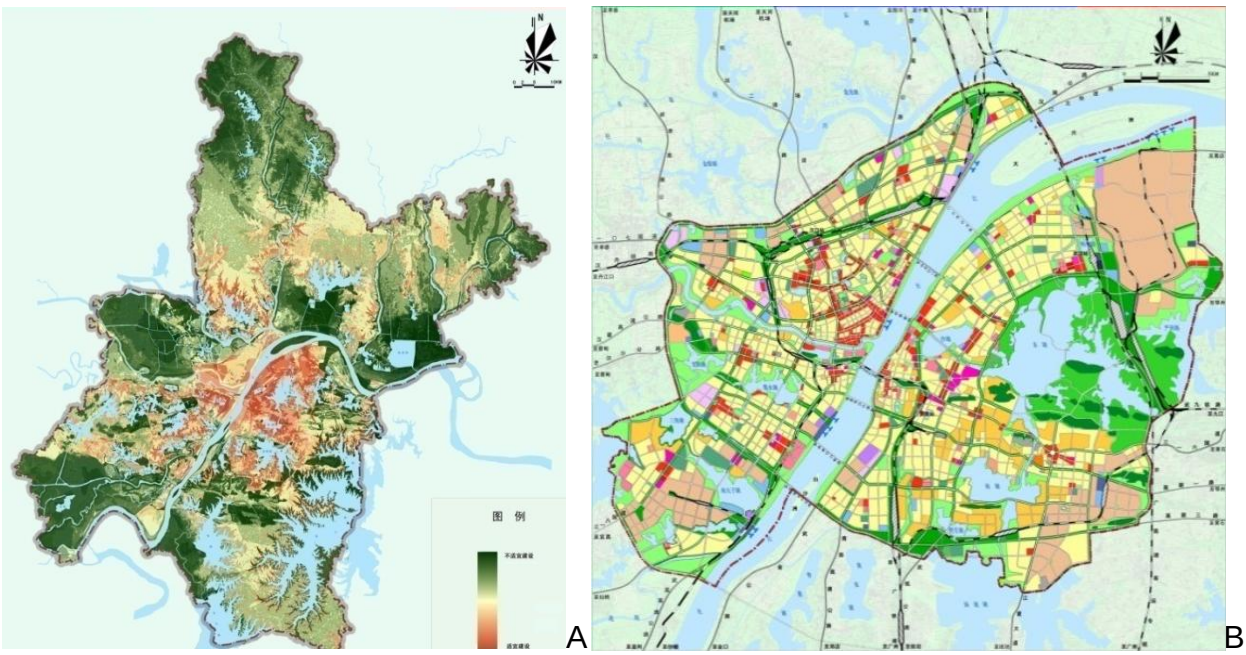

Figure 5-2. The land use context of Wuhan. A) The sustainability of Wuhan. B) The land use of Wuhan. Source: Wuhan City Planning Bureau, the comprehensive planning of Wuhan (2009-2020).

Figure 5-3. The outer ring road and the urban growth boundary of comprehensive plan of Wuhan (2009-2020). Source: Wuhan City Planning Bureau, the comprehensive planning of Wuhan (2009-2020).

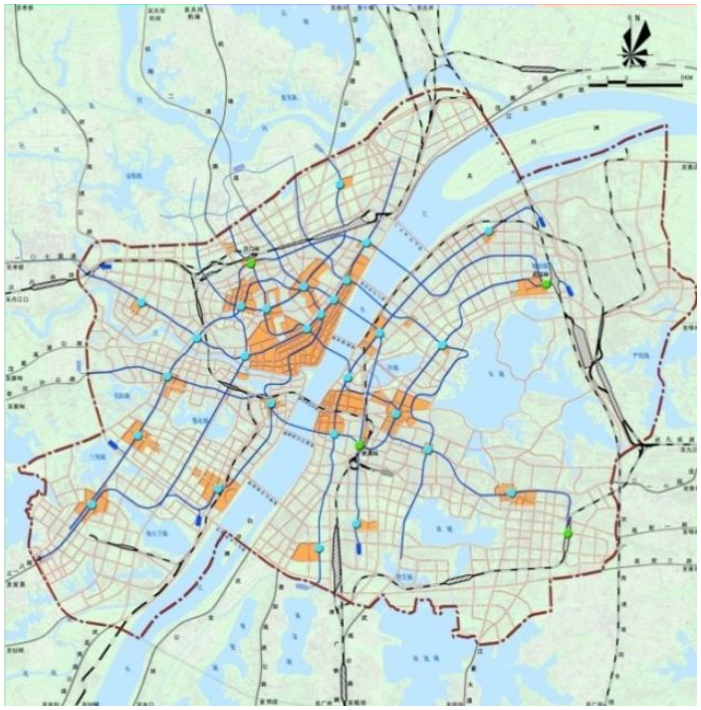

Figure 5-4. Mix land use layout of comprehensive plan of Wuhan (2009-2020). Source: Wuhan City Planning Bureau, the comprehensive planning of Wuhan (2009-2020).

Figure 5-5. Water protection sector of Wuhan City. Source: Adapted from Wuhan City Planning Bureau.

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CHAPTER 6
CONCLUSION

Best Practice to Guide Wuhan

Planning Principles and Strategies of Urban Flooding Control through WOD. The water oriented urban drainage planning should follow the principles of sustainability, the principle of comprehensive benefits, systematic principle and dynamic principle, and based on watershed drainage principle.

The principle of sustainability. From the spatial scale of development, sustainable development advocates that the specific region does not harm the ability of other regions to meet their needs. Sustainable principle requires harmony between man and nature according to the relationship between them. In terms of urban drainage planning terms, the principles of sustainability reflects: urban construction should coexist with floods and water, the construction of the urban drainage system should control the risk of flood water in the affordable limits target rather than eliminating urban flood water. In short, the sustainable principle emphasizes promoting the development of the urban flood control model.

The principle of comprehensive benefits. With the development of urban economy, socialization and the improvement of the living standard, the requirement of water environment has also changed. Urban drainage system should be modified from the original single drainage project into the multi-objective comprehensive management for the purpose of protecting water environment, combining the engineering measures with water environment, social environment and ecological environment. That means grasping the relationship between “drainage” and “prevention”, “drainage” and “protection” in the drainage process; considering the present urban development status

of our country as well as demands on the environment for the urban long-term social development; integrating the drainage with the long-term ecological environmental protection. Like Germany, Holland and other countries adopt such initiatives as restoring floodplain natural storage conditions, keeping appropriate living conditions for aquatic plants and animals, and creating a good environment. It represents their significant switch on the concept of urban drainage, reflecting the new relationship between human and flood.

The systematic principle. We should establish a system concept for the urban drainage planning, which is based on the new relationship between human and flood. Change the traditional ideas of simple flood control. Combine with the urban drainage planning and coordinate it well.

The dynamic principle. In the background of rapid urbanization, urban society increases the requirements on water disaster prevention and control. As far as the national condition is concerned, our city still does not have the power to overcome the difficulties of flood control in the process of urbanization with a high investment in a short period. Therefore, we should realize that urban drainage is a long-term, dynamic process. Urban drainage planning should be carried out on the basis of sufficient argumentation on urban reasonable development stage, the overall layout, water environment capacity, according to the urban development stage, so that the city drainage planning will be flexible. Each stage drainage planning content embody the rationality, integrity, continuity, and dynamic, thus keeping the urban drainage project construction dynamically sustainable. At the same time, firmly establish the long-term water control thought, set up relatively stable dynamic investment mechanism according

to the proportion of urban economic development, and rationally arrange the construction content of each stage, adapting to the construction process variability.

Based on watershed drainage principle. Urban drainage and watershed drainage are inseparable, and the watershed drainage planning is formulated on the basis of a comprehensive study of the whole watershed. Therefore, the water oriented drainage planning should carefully handle the relationship between urban drainage and watershed drainage. In principle, urban drainage planning further refines the watershed drainage planning. The correct way is to promote the urban drainage planning under the guidance of the watershed drainage planning. The related up and downstream drainage planning should be in accordance with the watershed drainage. So is the watershed drainage project planning in the city.

Characteristics of Urban Flooding

- With growing urban population and assets density, the losses of city will be increased even though in the same submerged case.
- The new expanded urban area used to be agricultural land with low standards of drainage. Therefore, the flooding risk increases after urbanization.
- With urban spatial development, once flood occurs, not only the various underground facilities are vulnerable to disasters, but also transportation, water supply, gas supply, power supply system of high-rise buildings are easy to fail. So the loss is inevitable.
- Due to the complexity of urban asset types, even when flood water has receded, damage loss caused by flooding such as computer network is immeasurable, and the recovery becomes more difficult.
- City and its economic activity are strongly dependent on its lifeline system, once it is subjected to flooding, the loss range would be far beyond the inundated range, and its indirect losses are even more than the direct loss.
- Due to the urban high temperature and plenty of dust in the air, it forms the so-called “Rain Island Effect "-- a phenomenon that the frequency and intensity of urban rainstorms are higher than the surrounding areas.

- The large-scale urban expansion leads to soil erosion, local water system disorders, and blockage of river and drainage network, resulting in a reduced ability to urban drainage.
- The security requirements of the urban drainage are greatly improved, and design, construction, and management of urban drainage engineering are more difficult.

Counter measures of urban drainage planning based on WOD. Usually, urban drainage is to discharge redundant, useless and harmful flood water in time to avoid the city being flooded. Based on the new relationship between human and flood, the urban drainage cannot be simply known as "disaster" to be treated. From another point of view, it is also a kind of resource; we cannot neglect its value when making efforts to reduce the "disaster". It should be combined with the urban water demand, taking the environment, ecology, resources and other aspects into consideration, adopt the way of integrating storage with discharge to control urban drainage.

Make the best use of soil for storage. Study the ground water infiltration capacity, and make the best use of soil for storage. For example, increasing the green area in the city, with the beneficial rain water interception of vertical design, not only beautifies the urban environment, but reduces the rainwater runoff; Improve bicycle lane, sidewalk pavement structure design (such as paved permeable cushion, permeable surface brick); by adding rainwater infiltration, storage into the soil; Use the infiltration pipe, and build infiltration wells on both sides of higher ground at a regular distance; construct artificial seepage ground, concave down greenbelt, retain or install a storage capacity of water, wetland, utilization of rainwater infiltration to supply groundwater; develop ecological rainwater collection system combining grassed swales and detention pond, etc. In part, the effect may not be great, but in terms of the whole city, the underground soil for storage rain water will be very considerable. It is reported that the

urban perched water situation will get effectively alleviated, when the urban water storage, and the perched water table rate reaches over 15%.

Recharge groundwater using urban drainage. Many cities in China, especially northern cities over-exploit groundwater, causing the urban ground subsidence, a hidden peril to the urban security. Such as recharge groundwater using urban drainage, this will alleviate groundwater overdraft to some extent. If the 100mm rainfall infiltrate through green (grass), or infiltration wells, that can significantly reduce the burden of urban drainage, and relieve the influence on groundwater supply by urbanization.

Wetland protection and reducing urban flooding risk. On February 2, 1971 in Ramsauer, Iran signed "the Convention on Wetlands" , in which the definition of wetland is as follows: Wetlands are areas of marsh, fen or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters, consisting of beaches, estuaries, rivers, lakes, reservoirs, swamp forests, salt marshes and saline lakes, coast coral beach area; It's narrowly defined as the transition zone between the land and water. The hydrological function of wetland behaves in: serving as the recharge source or discharge area of groundwater; flood storage; slowing down the erosion of water waves. The latter two functions are also called the urban flooding drainage function of wetland. All wetlands connected with rivers have storage water-logging effect, which is related to the wetland attribute: the bigger the wetland is, the greater its water-logging storage capacity is. Based on the new relationship between human and flood, the urban drainage planning should strengthen the water project management of wetland.

We should take corresponding measures to restore wetland and reduce water-logging risk:

Firstly, wetland water supplements. Demolition of wetland water engineering, increasing the inlet channels by taking foreign water and storage of surface runoff, while the wetland perennial accumulating more water.

Secondly, do a good job in "retreat cultivated land and restore wetland." "Retreat cultivated land and restore wetland" is the most direct and effective way to restore wetland. We have been reclaiming land from lakes and wetland for a long time. Such activities make the wetland area continue to decline and the drainage function degrades. Therefore, we should promote soil and water conservation work like "Retreat cultivated land and restore wetland" to increase the water storage area and ensure the flood water storage function of wetland.

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BIOGRAPHICAL SKETCH

Siyu Yu was born in Nanchang, Jiangxi Province of China. She received her bachelor's degree in urban planning from Jiangxi Agricultural University. She then enrolled the Graduate School of College of Architecture and Urban Planning at Huazhong University of Science and Technology, Wuhan, China. During this time, she decided to get further education at University of Florida. She will graduate in December 2012 from the University of Florida with a Master of Science in Architectural Studies degree with a concentration in sustainable design. And she will graduate from Huazhong University of Science and Technology in March 2013 to get a graduate degree in urban planning.

Siyu Yu participated in the project of the comprehensive plan of North Bole in Xinjiang from July 2010 to September 2011. In the project, she worked on renovating the historical district of Bole, planning for the land use of different types, urban growth boundary, and ecosystem adaptation network and stormwater management. During May 2012 to August 2012, Siyu Yu joined in project of Green Corridor in Singapore. She mainly worked on water management, corridor design adaptation, and coordination of land use. After finishing her study at University of Florida, Siyu Yu wants to work in urban planning with concentration in Sustainable design.