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## **Low Impact Development of City Wall-Canal System from Urban Segregator to Green Archival Linkage—“Sponge City” Rejuvenation Design of Historic Eastern Water Gate Area of Nanjing**

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**Abstract:** The city wall-canal system forms the structure of Nanjing’s landscape pattern. However modern development not only erodes the public space along it, pollutes the Qinhuai River, but also results in urban waterlogging. This article starts from the study of the area inside and around city wall of Nanjing and proposed the “Green Belts” strategy as the green infrastructure to stitch the broken city wall-canal system on urban level. On local level, it zooms in the eastern water gate district as the most contentious site based on a series of site analysis and proposes the “cut-remove-suture-grow” strategy. As to the detailed design, this article proposes the concept of nine water processing systems for storm water and flood management and rainwater harvesting integrated with the conservation of city wall under the low impact development mode. Then the concept is further developed through the detailed design of 4 subdivided sites.

**Keywords:** City Wall-Canal System, Nanjing, Eastern Water Gate Area, Low Impact Development, Storm Water and Flood Management, Green Infrastructure, Conservative Planning and Design.

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## 1. Introduction

Located in the lower Yangtze River drainage basin and Yangtze River Delta economic zone, Nanjing is recognized as one of the Four Ancient Capitals of China. It is the capital of today’s Jiangsu province in eastern China and has a prominent place in Chinese history, having been the capital of China in above ten dynasties and thus prestigious of cultural heritage since the Three Kingdom period including the existing city wall and canal system. Nanjing has gone through the vicissitudes of urban development in parallel to the construction of city wall-canal system. The city wall used to constitutes the protective border of Nanjing and the canal was entrenched as major part of the Qinhuai River in large region for waterways, livelihood and flood control in ancient ages. Qinhuai River is the blood of Nanjing and has nursed the resplendent civilization of the city.

But in modern times, Nanjing has spread far across the city wall for new development. And the city wall-canal system no longer functions as the traditional military defense, transportation channel and water facilities. Consequently, public space along it is eroded and it leads to many problems, such as culture recession, river pollution, flooding and overflow due to the malfunction of sewage infrastructure, community segregation on two sides of the city wall-canal system. This paper focus on the historic walled city area (Figure 1) of Nanjing to study the impact of modern development on environment of space along city wall-canal system and proposes “Low impact development” oriented solutions alternatively to restore the hydrological, ecological and social function of the city wall-canal system.

**Figure 1.** Area of historic walled city of Nanjing.



## 2. Methods

Figure 2 illustrates the process of the overall design technical methods based on “analysis-strategy-design” sequence from strategic design on urban level to strategic design on local level to concept design on local level and finally to detailed design.

Firstly, the analysis of the historic background and environmental features of the city wall-canal system constitutes the starting point for the design process. It examines the ecological, hydrological, historic, aesthetical, social and economic value of it. So on urban level, the city wall-canal system is

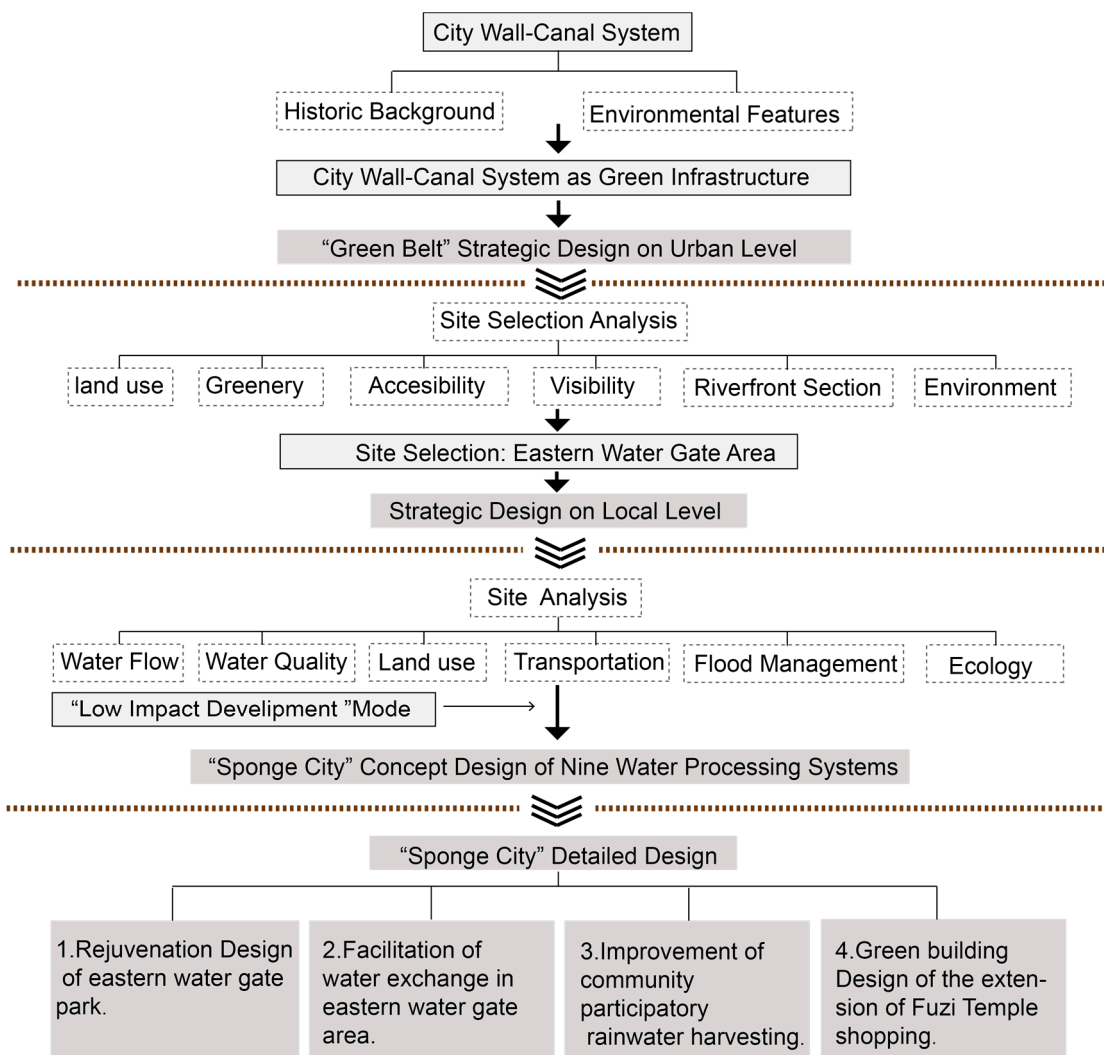
newly defined as the “green infrastructure” and five types of green belts are proposed in strategic design to re-stitch the green public space for retarding urban sprawl and restoring historic context.

Secondly, the analysis of land use, greenery, accessibility, visibility, riverfront section and environment of city wall-canal system in different area of Nanjing sets the base for site selection. Thus eastern water gate area is the most contentious and critical and is chosen for further strategic design on local level.

Thirdly, key issues and major problems are found according to the site analysis of eastern water gate area including water flow, water quality, land use, transportation, flood management and ecology. “Low Impact Development” mode is introduced as the technical guidance for the “Sponge City” concept design of this area to preserve and recreate natural landscape features of the canal integrated with the historic feature of city wall. There form nine water processing systems in this area in total for flood control, storm water and drainage management, grey water recycling.

Finally, the “Sponge City” concept design is dissected into 4 parts for the detailed design, namely rejuvenation of eastern water gate park, facilitation of water exchange in eastern water gate area, improvement of community participatory rainwater harvesting, green building Design of the extension of Fuzi Temple shopping center.

**Figure 2.** Overall design technical methods.



### 3. Analysis and strategic design on urban level

#### 3.1 Historic background of city wall-canal system in Nanjing

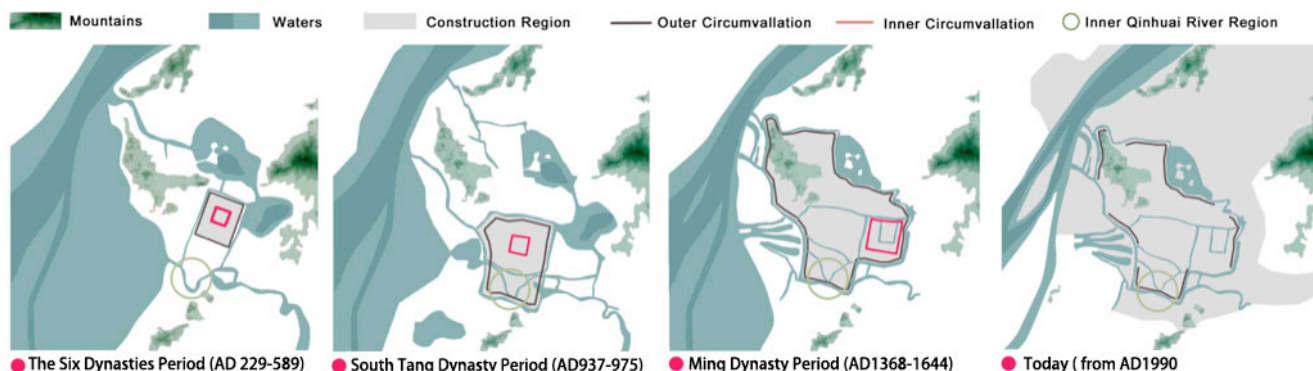
The city wall-canal system is composed of existing city wall from Ming dynasty and canal system including inner Qinhuai River and outer Qinhuai River (Figure 3). The emperor of Ming dynasty extended the city wall to 36KM as the military defense for inner city based on the construction work before. But only two thirds remain nowadays. Inner Qinhuai River used to be the stimulus and catalyst of Nanjing. The old city was shaped along it and gradually grew from this spine. Outer Qinhuai River is the moat and flows in parallel to the city wall. It connects eastern and western waters for flood control.

**Figure 3.** (a) City wall. (b) Inner Qinhuai River. (c) Outer Qinhuai River. (d) Panoramic view of city wall-canal system.



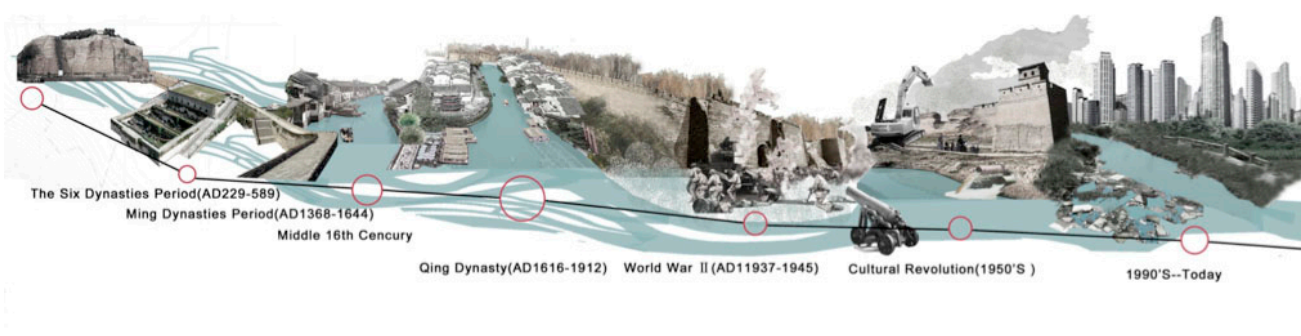
In retrospect to history of Nanjing urban sprawl, Figure 4 shows the territory expansion process with reference to city wall-canal system of Nanjing from the Six Dynasties period till today. During the Six Dynasties period (AD 229-AD589), the emperor relocated his city southwards in Nanjing and built 2 layers of city wall in proximity to the inner Qinhuai River. In the South Tang dynasty (AD 937-AD975), Nanjing was expanded to include the inner Qinhuai River and people began to gather along the inner Qinhuai River for commerce and transportation. In Ming dynasties (AD1368-AD1644), Nanjing grew southwards further and gradually blossomed from inner Qinhuai River with the population of 1 million and area of 42km<sup>2</sup>. The inner Qinhuai Riverside became the most prosperous place in Nanjing for business and livelihood. In twentieth century, however, one third of the city wall was dilapidated in 1940s and people dissipated from inner Qinhuai River to newly developed area with the trend of urbanization across the city wall.

**Figure 4.** Urban sprawling process of Nanjing.



Similarly, the city wall-canal system has gone through vicissitudes for 1800 years. Figure 5 shows the rise and falls of it vividly and graphically. Nanjing was firstly the capital of Wu Kingdom in the Six Dynasties period and the city wall was built of just clay and stone. In Ming dynasty, the city wall was elongated to 35.26 km with 2 layers and 30 gates to enhance the military defense power. During the peak time of Ming dynasty in middle sixteenth century, the existing pattern of city wall-canal system was established where the outer Qinhuai River canal was excavated along the city wall as the moat while the inner Qinhuai River remained its organic form. In Qing dynasty (AD1616-AD1912), the inner Qinhuai River thrived of commerce, culture and transportation as the spine of the city. During the Second World War (AD1937-1945), 13 km of the city wall was damaged due to sabotage and road works. In Chinese Cultural Revolution in 1970s, the cynical activists tore down many parts of the city wall which was regarded as the symbol of feudalism. And in today's massive urbanization process, the inner Qinhuai River has been severely polluted, exacerbated by flooding and storm water overflow.

**Figure 5.** Vicissitudes of city wall-canal system.



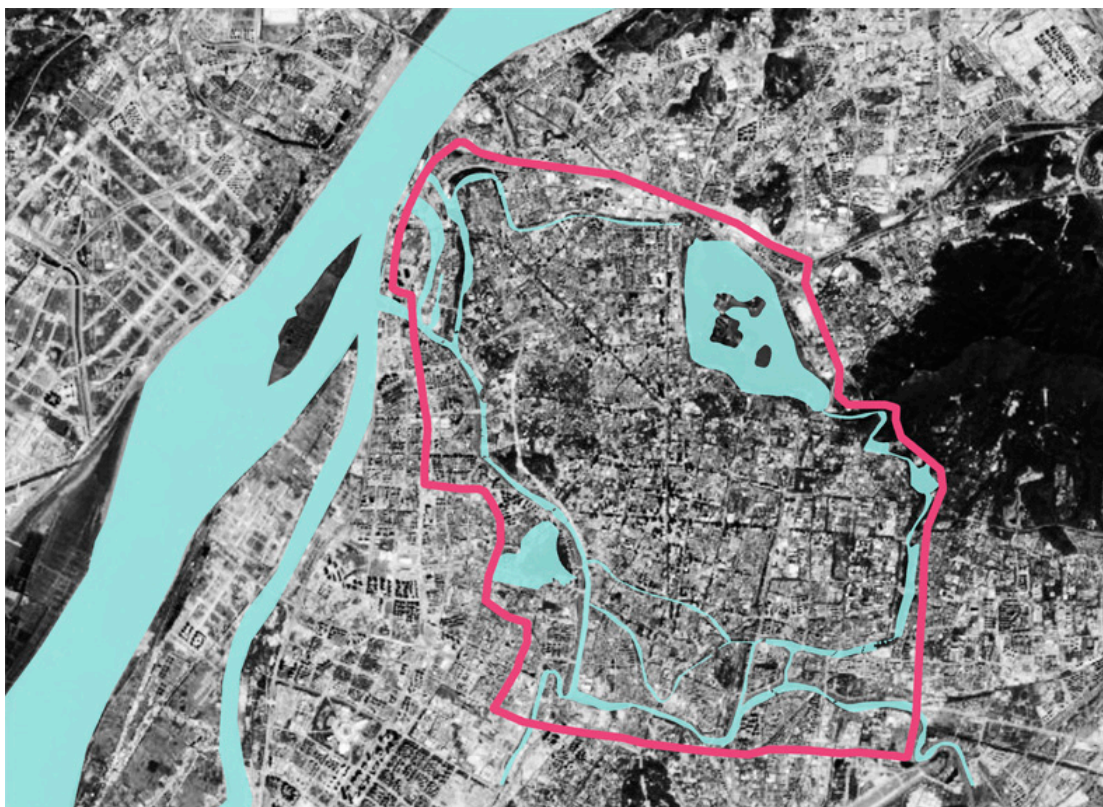
### 3.2 Environmental features of city wall-canal system in Nanjing

#### 3.2.1 The landscape pattern of Nanjing

Nanjing's urban form has been delicately designed for thousand of years in accordance with its natural landscape pattern. Figure 6 shows the current satellite map of the overall landscape pattern of the historic walled city of Nanjing which is situated in the plain surrounded by Zhong Mountain and Yuhuatai Mountain. The city wall-canal system forms the framework of the landscape pattern. The city wall demarcates the boundary of the historic capital city in Ming dynasty with the natural barrier of

surrounding mountains as military defense. The canal (also called Qinhuai River) flows eastwards and bifurcates into inner Qinhuai River which flows through the inner city and outer Qinhuai River which flows in line with the city wall and connects the waters of Xuanwu Lake and Mochou Lake. Then the outer Qinhuai River and the inner Qinhuai River confluence into the Yangtze River finally in large region. The framework of the landscape pattern is further consolidated by three urban axes in north-south direction which were the main arteries in different ancient dynasties. The site of historic palace of Ming dynasty sits in the south east part and most historic cultural communities and blocks are located near the riverside of inner Qinhuai River.

**Figure 6.** Satellite map of the landscape pattern of Nanjing historic walled city.



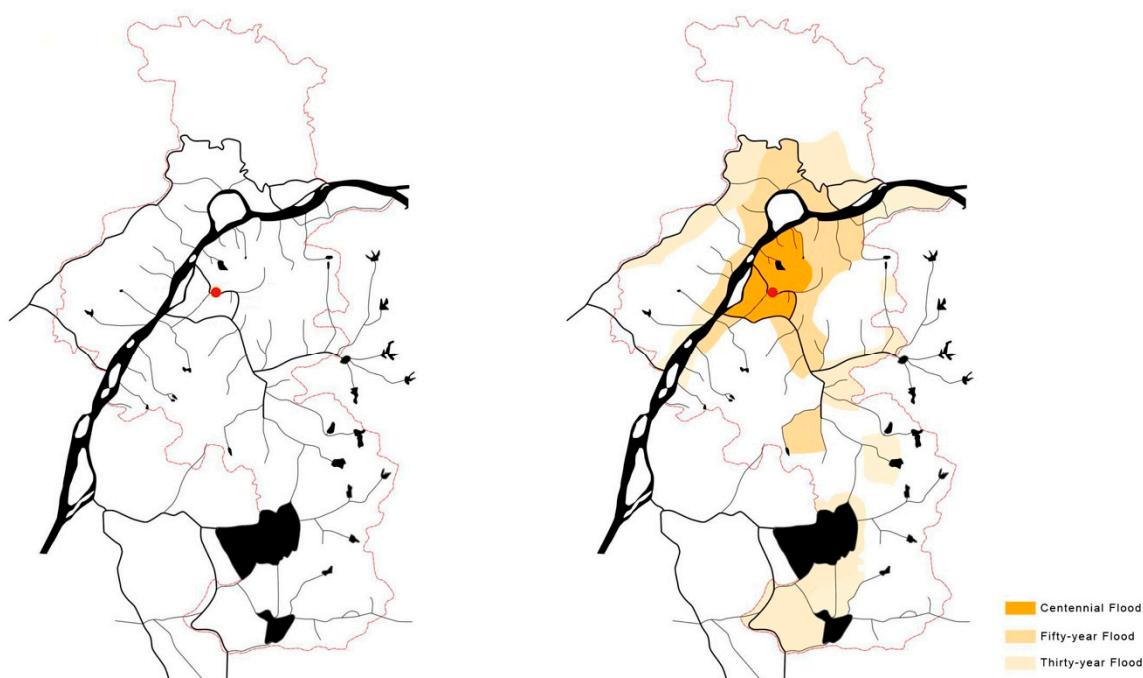
### 3.2.2 Hydrological adjusting function of Qinhuai River

Qinhuai River is an important branch of Yangtze River and relates it to many dispersed water bodies in the east part of metropolitan Nanjing (Figure 7a). Figure 7b shows the flood control level of metropolitan Nanjing. The historic walled city of Nanjing lies just 4km to Yangtze River, thus in the critical position for the resistance of the 100-years frequency flood.

Qinhuai River has a long history for water control management. In Ming dynasty, it was the important water channels for the grain transportation to the capital Nanjing from rest of the country. The governors constructed the water gate and dam, built the water networks, dredged the inner Qinhuai River. In Qing dynasty, to facilitate the residents' daily use of Qinhuai River, the water quality was significantly improved by diverting fresh water to flush out the pollutants. The first time for modern water improvement was during 1952-1980 after the establishment of new China. The canal channels were dredged again for flood resistance and discharging, waterlogging drainage, water diversion, water

transportation. The second time for modern water improvement was during 1980-2000. With the rise of tourism and the development of Qinhuai River Scenic Area, the river channel was periodically scavenged of sludge for better tourism environment. The third time for modern water improvement was during 2002-2005 when Qinhuai River was redefined as the civilization symbol of Nanjing. Comprehensive strategies were introduced for the creation of the city brand.

**Figure 7. (a)** Distribution of water bodies in metropolitan Nanjing. **(b)** Flood control level of metropolitan Nanjing.

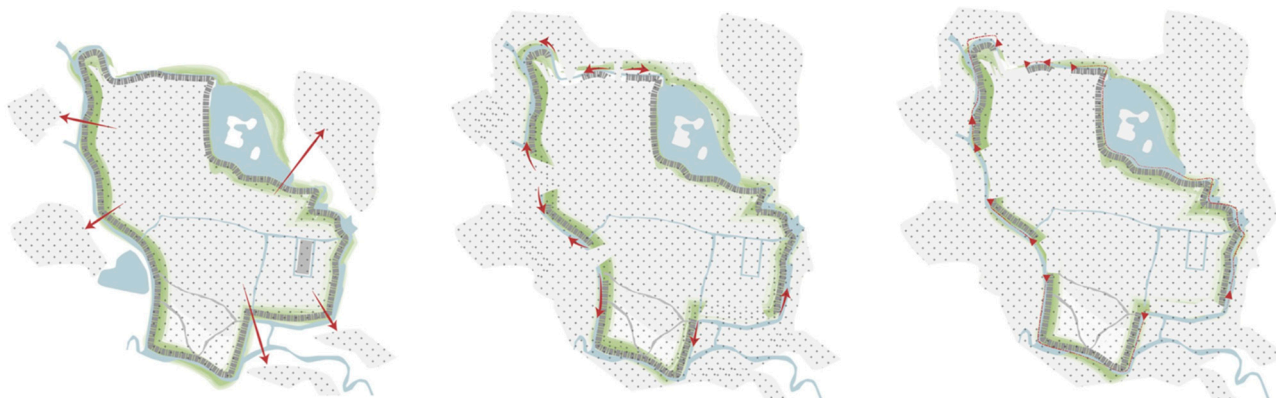


The strategies for water improvement vary from time to time, following the major function of Qinhuai River. Nowadays, its function should be reexamined for not only storm water and flood control, urban renewal, but also the enhancement of the ecological environment and social implications.

### 3.2.3 Encroachment of the green public space along the city wall-canal system

As to the traditional walled with complete city wall, new urban development usually occurs far away from the inner city and with main arteries connected (Figure 8a). However, in Nanjing, due to the rupture of the city wall, the inner city grew from the disconnected points outwards (Figure 8b). Consequently, the green open space of the city wall has been gradually eroded and encroached by new construction along it, which severely endangers the urban landscape pattern and form (Figure 8b).

**Figure 8. (a)** Normal urban development mode. **(b)** Urban sprawling mode of Nanjing. **(c)** Encroachment of green public space along city wall in Nanjing.



This emergency of the city wall-canal system leads to many ensuing problems:

- (1) Fracture of cultural context, disappearance of traditional life and fabric and vandalism of traditional buildings (Figure 9a);
- (2) Inner city waterlogging and the exacerbation of the hydrological environment (Figure 9b);
- (3) Segregation of social groups inside and outside of the city wall-canal system (Figure 9c).

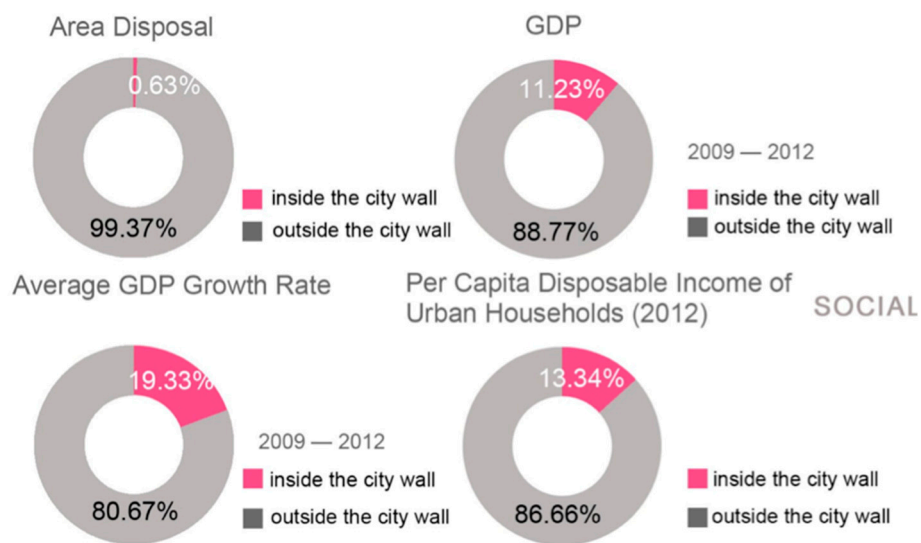
**Figure 9. (a)** Fracture of cultural context. **(b)** Waterlogging. **(c)** Segregation of social groups.



Figure 10 shows the comparative research findings of the economic and social conditions inside and outside the city wall. The urban area outside the city wall is much larger than the area inside the city wall and has more freedom for new development without the fixed constraint of city wall-canal system. Thus the economic condition outside the city wall is much better in terms of average GDP growth rate and per capita disposable income of urban households.



**Figure 10.** Comparative research of the economic and social conditions inside and outside the city wall.



### 3.3 “Green Belt” strategic design on urban level

According to the “Nanjing Green Space System Planning”, four green belts and six green wedges are proposed including Qinhuai River Scenic Green Belt, Ming City Wall Scenic Green Belt and six random green wedges cutting into the historic walled city. Additionally, more than 30 water courses are planned and interconnected for waterfront green belt system.

Considering above documents, on urban level, the city wall-canal system is newly defined as the “green infrastructure” in strategic design. Five types of green belts are proposed to re-stitch the green public space at the rupture of the city wall-canal system for retarding urban sprawl and restoring historic context. Figure 11 is the plan of the “Green Belt” strategic design. Belt A works as the connection for community on double sides to integrate more community amenities and space; belt B restores the historic context near Xuanwu lake scenic zone; belt C is around the eastern water gate area for the rehabilitation of ecological and hydrological function; belt D is at Mochou lake area to reconcile the privatization of the public space at waterfront; belt E functions as the public green space for cultural exchange near the cultural relics of Stone City in the Six Dynasties period.

## 4. Analysis and strategic design on local level

### 4.1 Site selection analysis for strategic design of critical area on local level

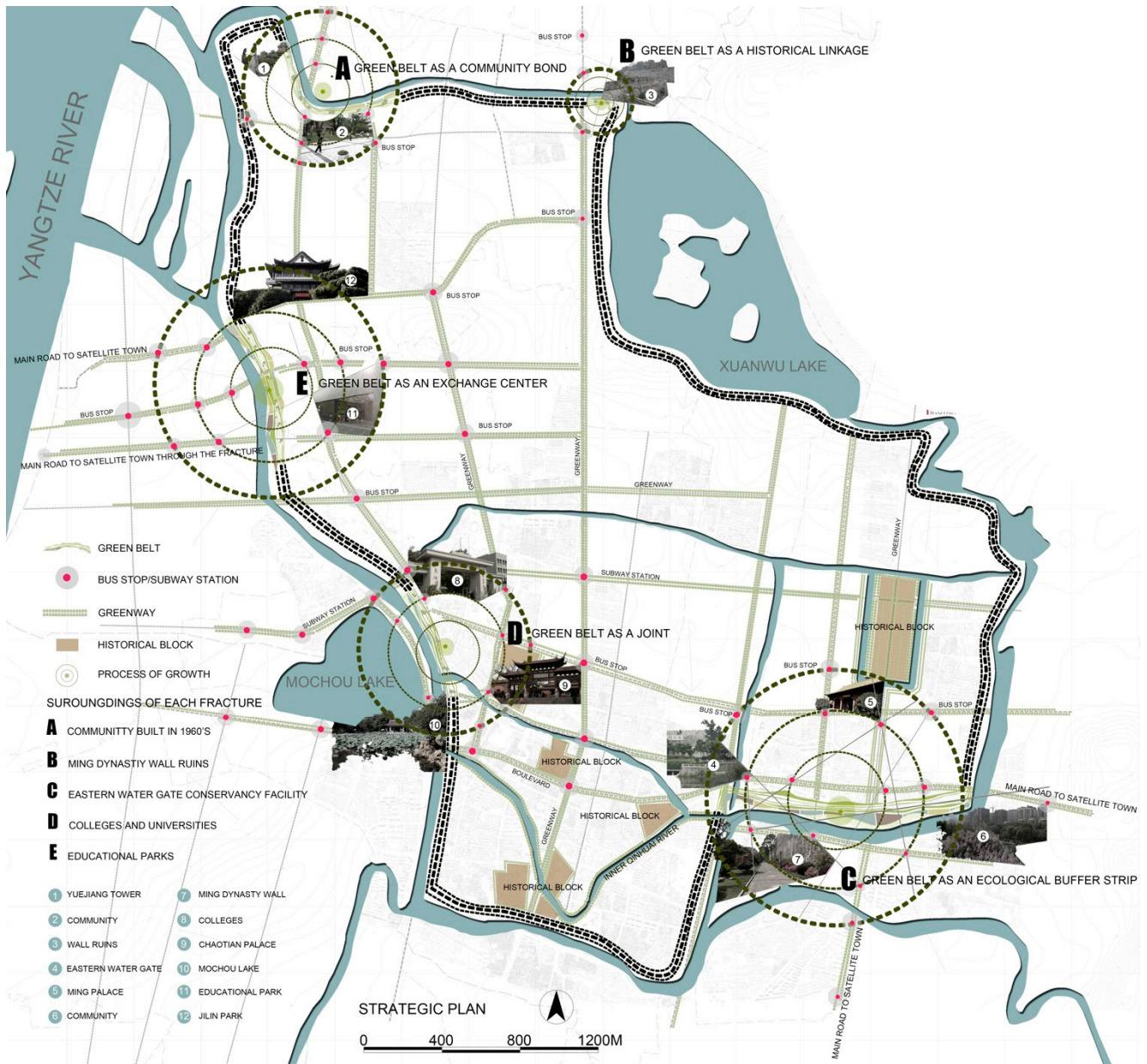
#### 4.1.1 Single factor analysis

##### (1) Land use

The land use along the City Wall-Canal System is proposed to be adjusted for enhancing the public access to it. And the most problematic parts are highlighted as follows (Figure 12a). The area between the river and the road needs to be converted into green space to allow the landscape continuation along the riverside. Factories with historic value can be converted into cultural or commercial buildings. The

large parking lots along the riverside are suggested to be removed. Public space needs to be released from the southern riverbank covered mostly by commercial use.

**Figure 11.** Plan of the “Green Belt” strategic design.



**(2) Greenery**

The encroachment of the green space of City Wall-Canal System mostly occurs at the broken surface of the city wall near the Mochou Lake and the eastern water gate (Figure 12b).

**(3) Waterfront accessibility**

The waterfront interface is classified into different levels in terms of accessibility (Figure 12c).

(4) Visibility

Eight spots are figured out as blocked of the sight view of City Wall-Canal System by high-rise buildings (Figure 12d).

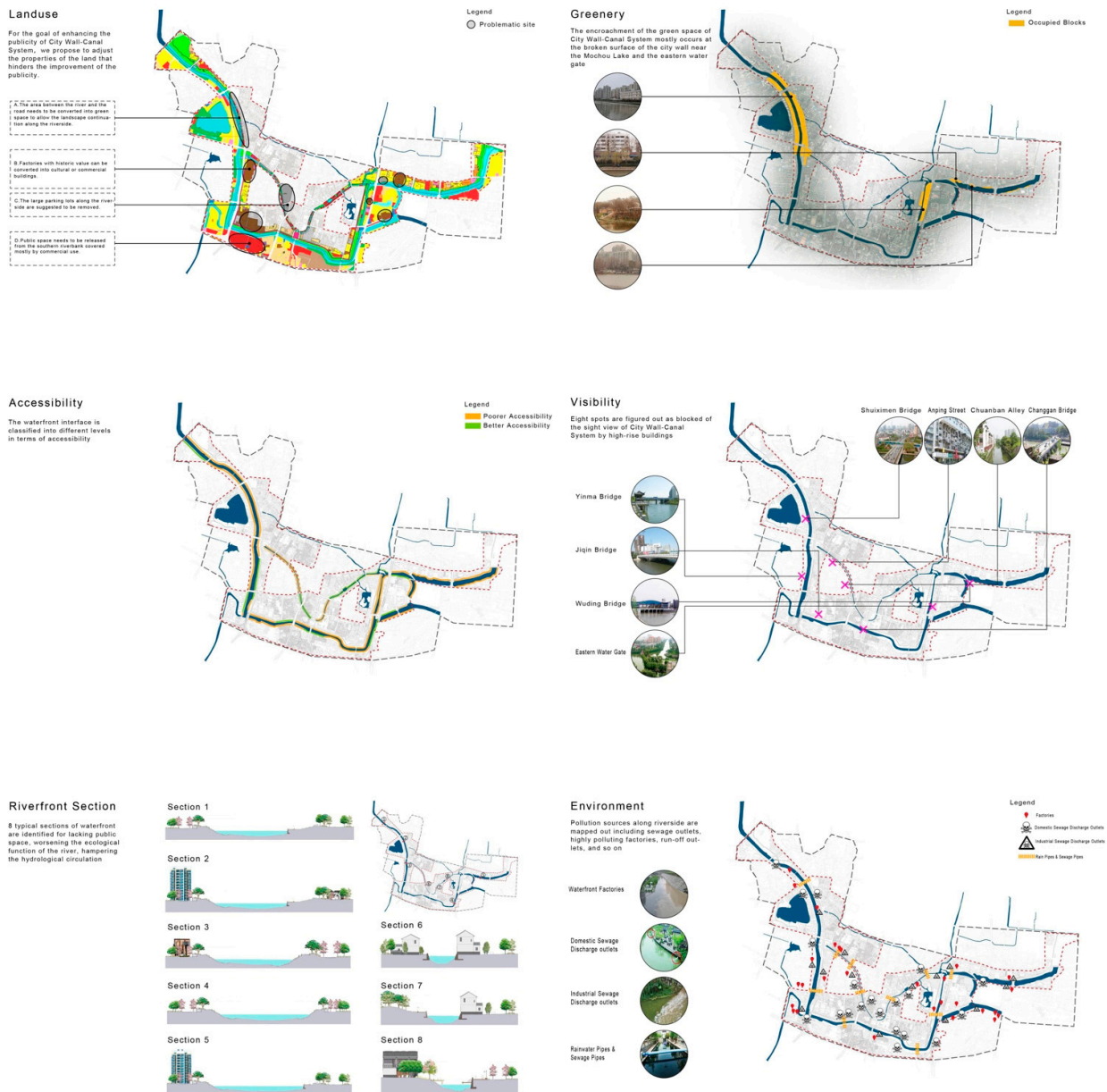
(5) Waterfront section

8 typical sections of waterfront are identified for lacking public space, worsening the ecological function of the river, hampering the hydrological circulation (Figure 12e).

(6) Pollution source

Pollution sources along riverside are mapped out including sewage outlets, highly polluting factories, run-off outlets, and so on (Figure 12f).

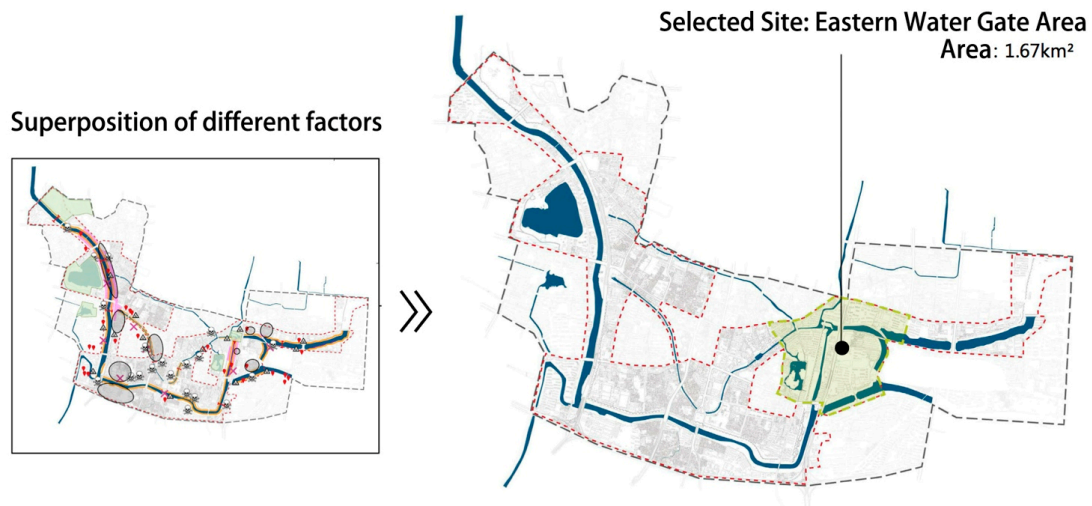
**Figure 12.** (a) Land use. (b) Greenery. (c) Waterfront accessibility. (d) Visibility. (e) Waterfront section. (f) Pollution source.



#### 4.1.2 Superposition of different factors

The six factors mentioned above are superposed to specify the eastern water gate area which covers all the problems. This typical key area of 1.67 km<sup>2</sup> is selected for further strategic design on local level (Figure 14).

**Figure 13.** Superposition of factors and site selection for design on local level.



#### 4.2 Strategic design on local level

An analogy of “urban surgery” is drawn to illustrate strategies of eastern water gate area, which includes 4 Phases: cutting, removing, suturing and growing. In phase 1, green space cuts into waterfront to stop the expansion of uncontrollable development. In phase 2, the constructions encroaching the public space would be removed for further renovation of waterfront and public facility development. In phase 3, scattered green space would be interconnected as the green belts and archival linkage to stitch the broken surface of city wall. In phase 4, more green public space is to grow from the green belt and permeate through the historic blocks and communities on both sides of the City Wall-Canal System to form the whole green network.

### 5. Site analysis and “Sponge City” concept design of eastern water gate area

#### 5.1 Site analysis of eastern water gate area

Eastern water gate area of the city wall-canal system is an important waterway transportation junction and the facility center for water exchange and flood control. It used to be the entrance of waterway to the inner city and the surrounding area was farmland and wetland 50 year ago. Figure 15 shows the existing context of eastern water gate area which has been fully developed for real estate.

It's worth mentioning that the eastern water gate itself has the significant function in history. It was firstly built in South Tang dynasty as the only waterway entrance of the militarily defended walled city. In the Six Dynasties period, it became the exchange junction of transportation and the market formed here for commerce. In Ming dynasty, the initial water gate was reconstructed of 3 layers with the first layer as water sluice gate and the second and third layer for food storage and garrison. It was the largest

center for water exchange of inner Qinhuai River and outer Qinhuai River to keep the water level of the inner Qinhuai River higher than that of outer Qinhuai River. However, nowadays, the eastern water gate is dilapidated and loses its traditional function for water management and flood control. It is wrapped by high rises along the canal with poor access to public waterfront (Figure 16).

Figure 14. 4 phases of strategic design on local level.



**Figure 15. (a)** City wall-canal system in eastern water gate area **(b)** Existing urban fabrics of eastern water gate area.



**Figure 16. (a)** Satellite map of eastern water gate. **(b)** View of eastern water gate.



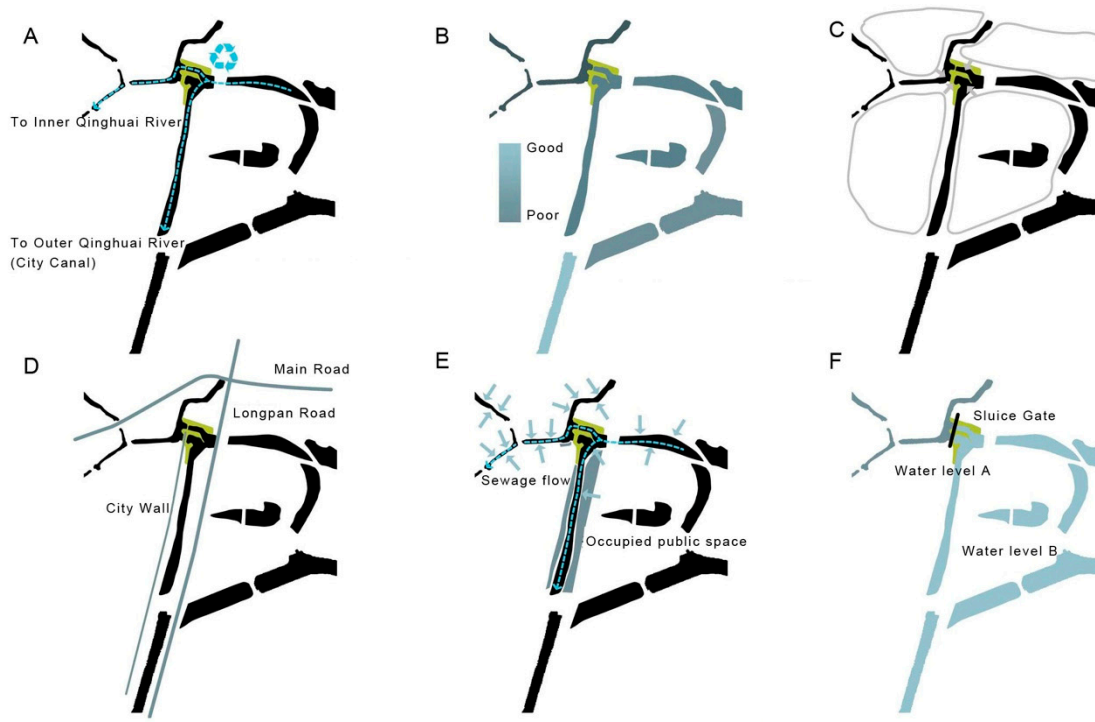
Figure 17 illustrates the site analysis of eastern water gate area. The Qinhuai River flows westwards and bifurcates into 2 branches (inner Qinhuai River and outer Qinhuai River) at eastern water gate. But the water quality of inner Qinhuai River is much worse than outer Qinhuai River since it’s somewhat dissected from natural water bodies. Even though the eastern water gate area has been partly redesigned as community park, it is of poor accessibility due to the limited area and artificially designed landscape. The city wall coupled with express way along it further isolates nearby communities. The real estate development erodes the public space of the city wall-canal system in this area and the domestic sewage is discharged directly into the canal resulting in pollution of inner Qinhuai River. Now, new water facilities have partly replaced the historic eastern water gate for flood control.

### 5.2 Low impact development mode

“Low impact development” mode is an approach to land development or redevelopment which integrates nature to manage urban hydrology to minimize the impact on site. It involves principles such as treating storm water close to its source, minimizing imperviousness to create functional and promoting site drainage to treat storm water as a resource instead of a waste product. There are many techniques and green infrastructures integrated into the process of water permeation, retention, storage, recycling

and drainage such as bio-retention facilities, water purification pipes, rain gardens, and permeable pavements. By applying “low impact development” mode, urban hydrology is managed in a way that prevents urban waterlogging, reduces runoff pollution, promotes water recycling and restores a watershed's hydrologic and ecological functions which could be further integrated with aesthetic and historic features.

**Figure 17.** (a) Water flow. (b) Water quality. (c) Accessibility. (d) Transportation. (e) Pollution. (f) Flood control.



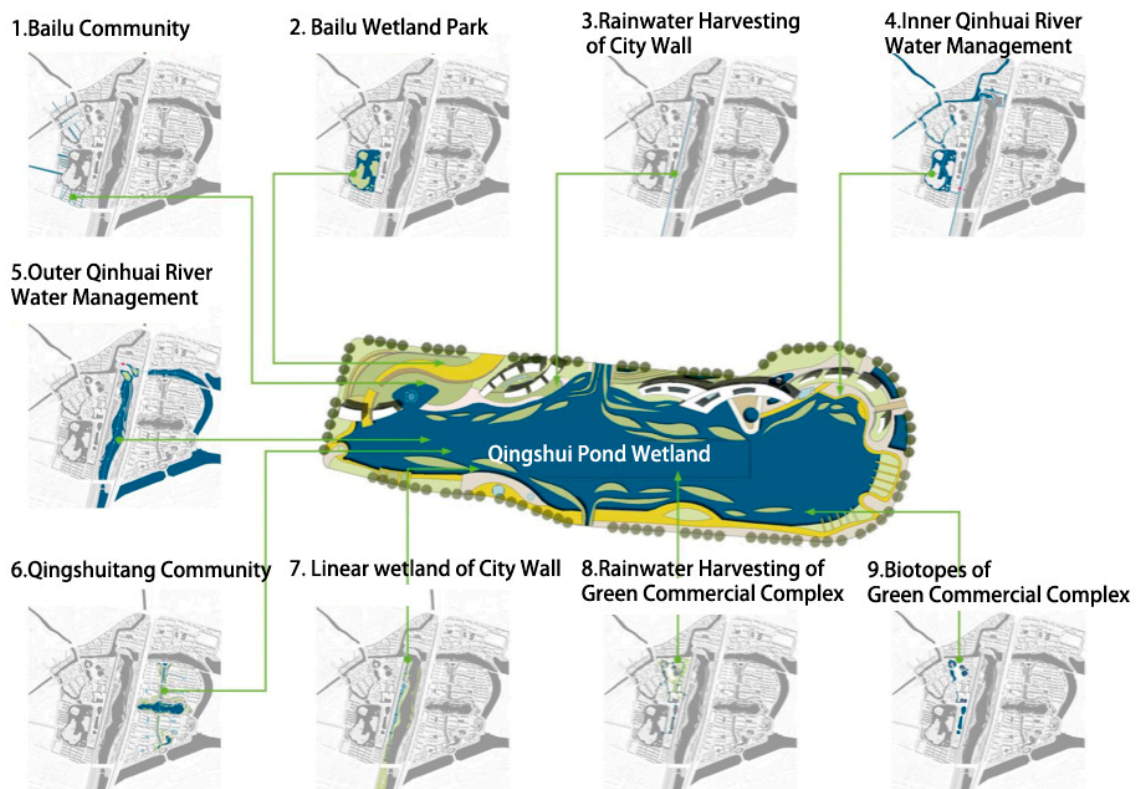
### 5.3 “Sponge City” concept design of nine water-processing systems

Based on the “low impact development” principles, there form nine water processing systems in this area (Figure 18):

- (1) The flood control and water level adjustment function of eastern water gate is rehabilitated by constructing 3 new water sluice valves for flood control and storm water management in 4 different phases.
- (2) The shopping street in Fuzi temple historic area is extended to the eastern water gate integrated with the water processing and harvesting facilities through vertical greenery and complex design of landscape and amenities.
- (3) Three biotopes are distributed in the green shopping street to purify, recycle the rainwater in sequence.
- (4) The storm water is recycled and reused within the buildings of Bailu community, cleaned of sedimentation when channeled to Bailu park for further purification.
- (5) The rainwater is collected and pumped away to prevent the corrosion of the city wall.
- (6) The water collected from city wall and purified in Bailu park infiltrates through linear wetlands and partly diverted into outer Qinhuai River.

- (7) The purified water of Bailu park is discharged into outer Qinhuai River to be diverted into Qingshui pond.
- (8) Qinshuitang community is reformed gradually for community participatory rainwater harvesting. The green public space is used as play grounds in dry seasons and water cistern in rain seasons and the water from the cistern is further transported into Qingshui pond for bio-purification and sedimentation.
- (9) The water of outer Qinhuai River is exchanged through eastern water gate facilities and flows into inner Qinhuai River before purification through linear wetland along the city wall. The nine water processing systems in this area confluence into the flood detention area in the Qingshui pond and wetland park for further sedimentation, bio-purification and supplement to underground water storage.

**Figure 18.** Nine water processing systems.



## 6. “Sponge City” detailed design of eastern water gate area

### 6.1 Design strategies

“Sponge city” is an analogy of a city with highly effective hydrology adjusting capability. It absorbs rainwater and runoff during rainy season with high resilience but releases water and replenishes wetlands or underground water in dry seasons for the goal of maintaining the relatively stable level of rivers and preventing urban waterlogging.

According to the above nine water processing systems, the eastern water gate area is divided into 4 parts for “Sponge City” detailed design: Rejuvenation Design of eastern water gate park; facilitation of water exchange in eastern water gate area (Figure 19a); improvement of community participatory



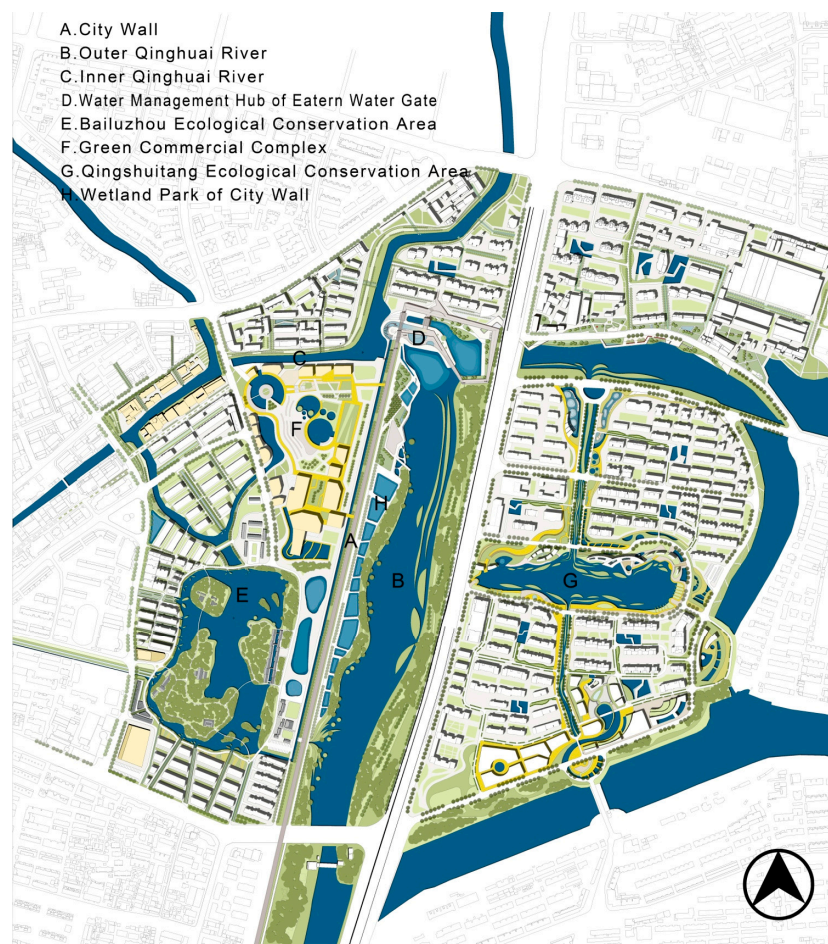
rainwater harvesting (Figure 19b); green building Design of the extension of Fuzi Temple shopping center (Figure 19c).

**Figure 19.** (a) Rejuvenation Design of eastern water gate park. (b) Improvement of community participatory rainwater harvesting. (c) Green building Design of the extension of Fuzi Temple shopping center.



Figure 20 shows the overall plan of the “Sponge City” detailed design of eastern water gate area.

**Figure 20.** Plan of the “Sponge City” detailed design of eastern water gate area.



6.2 Rejuvenation Design of eastern water gate park

The key of above strategies lies in the regenerative design of eastern water gate park which constitutes the monitor and adjustor of Qinhuai River in 4 different phases: low water period, high water period, potential flood period, potential heavy rainfall period. Accordingly, five sluice gates are proposed to regulate water level on urban scale. And in eastern water gate area, the city wall is redesigned to integrate walkways on top and water processing facilities inside which as a whole constitutes the green infrastructure complex. The water of inner and outer Qinhuai River is pumped up to water processing pipes inside city wall and the rain water is also collected and channeled into it. Then the water goes through purification channels, oxygen basin, silt sieve, sedimentation pond, infiltration wetlands and biotopes for water exchange and purification. The Figure 21 and Figure 22 show the water processing lines and plan in details respectively.

Figure 21. Water processing line of eastern water gate .

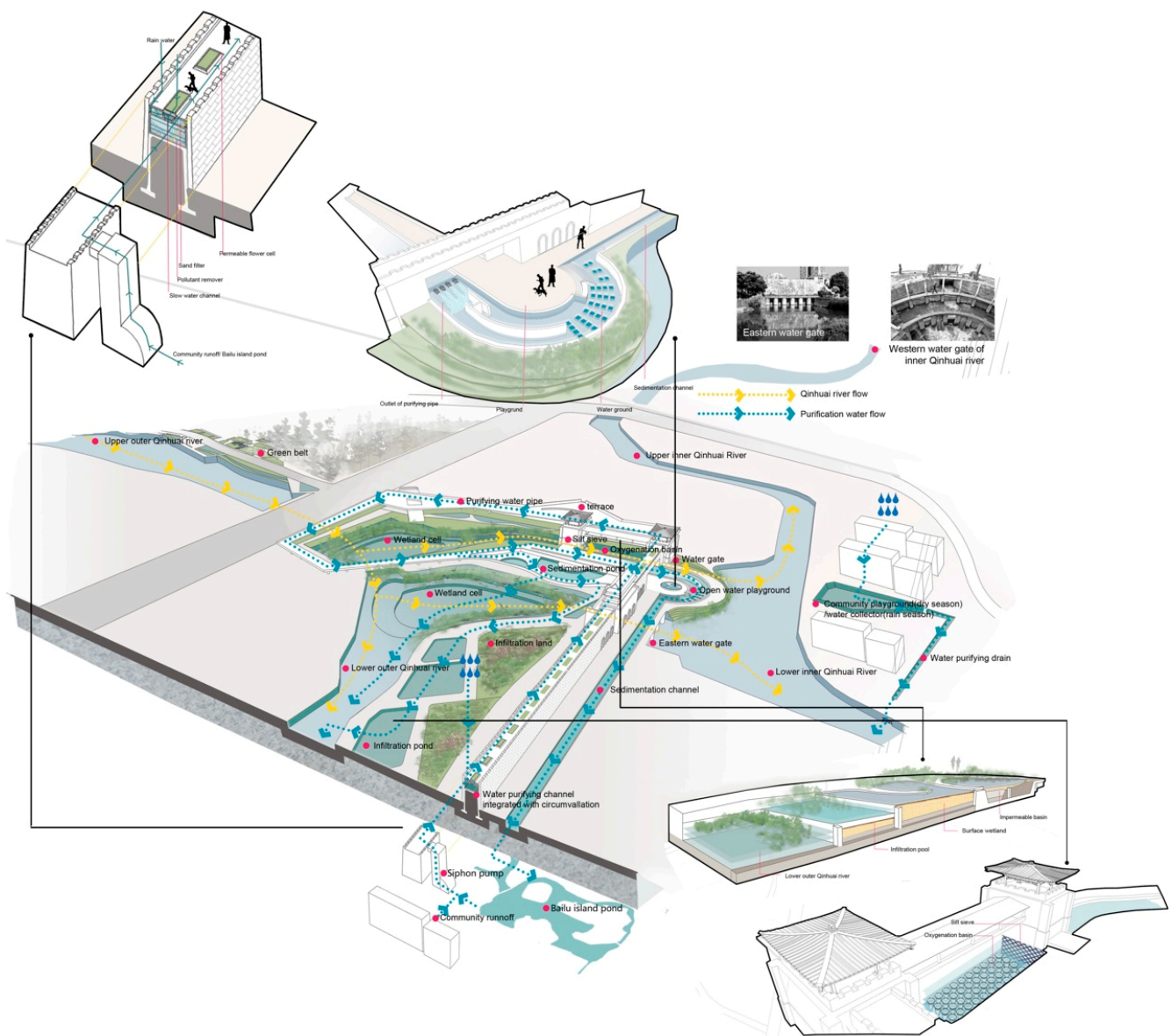
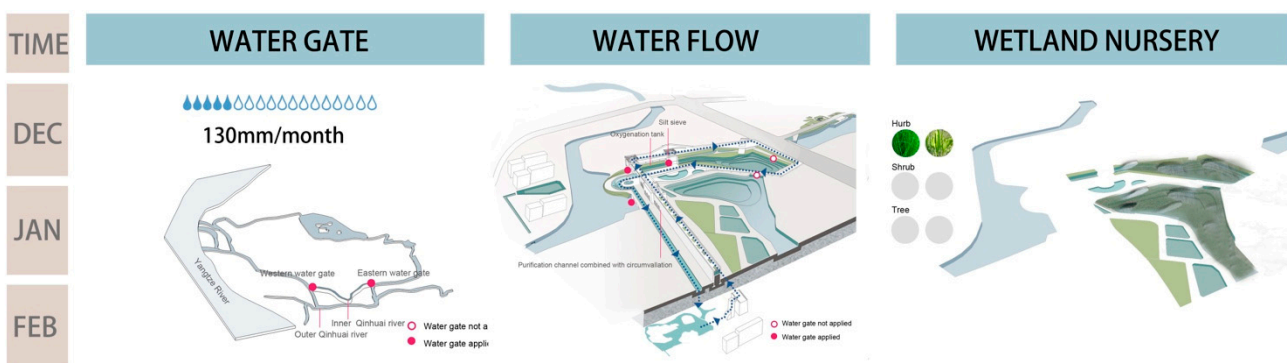


Figure 22. Plan of the eastern water gate park.



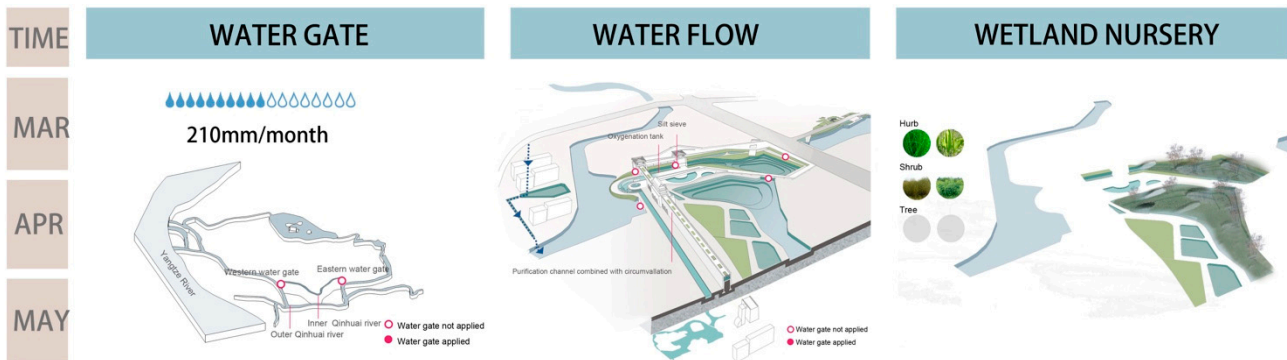
During the low water period from December to February, the precipitation is relatively low. Due to the decrease of the water level in low period, both the western and eastern water sluice gate are applied to maintain the certain depth of inner Qinhuai River. The inner Qinhuai River recycles and replenishes itself by being pumped from the bailu island pond through the siphon pump to the water purification channel integrated with city wall, and finally back to the bailu island pond. Meanwhile, the flora nursed in the wetlands begins to flourish (Figure 23).

Figure 23. Hydrology management in low water period.



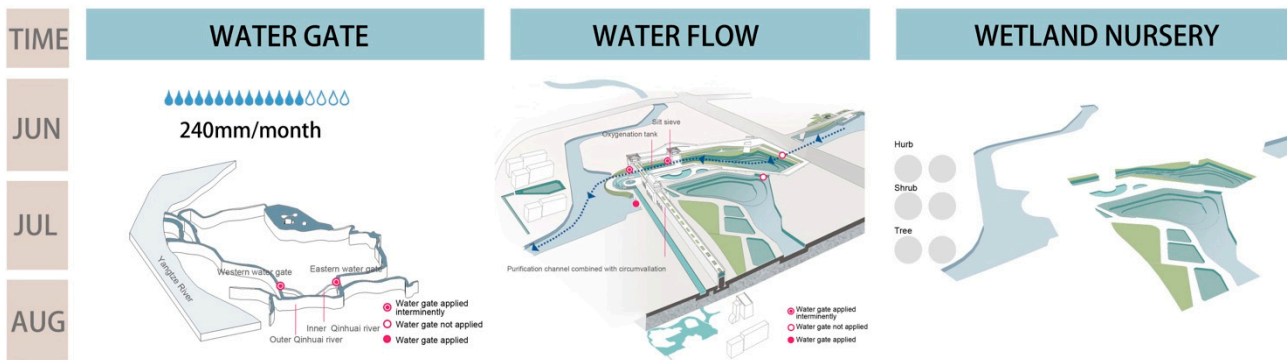
During the high flow period from March to May, it usually lasts for half a year with the stable water level and neither the western nor the eastern water sluice gate is applied. The main principle in this period is to recycle and purify the runoff of communities before discharged into the inner Qinhuai River. The open space within the community functions as the playground in dry seasons but water catchment in rainy seasons. The runoff is filtered and purified when channeled to inner Qinhuai River (Figure 24).

**Figure 24.** Hydrology management in high flow period.



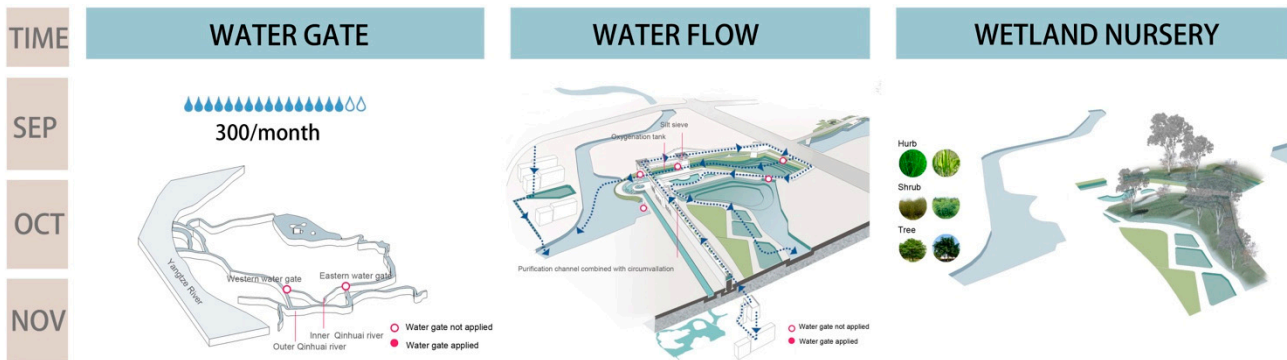
During potential flood period from June to August, Nanjing is required to withstand the centennial flood. Thus both the eastern and western water sluice gates are applied to resist the overflow of the upper outer Qinhuai River. In order to facilitate the water exchange in inner Qinhuai River, the water flows in from the eastern water gate intermittently to inner Qinhuai River. Then the water is pumped out through the western water gate. Consequently, the flood brings the silt with the water and the sieve collects silt for wetland nursery (Figure 25).

**Figure 25.** Hydrology management in potential flood period.



During the potential heavy rainfall period from September to November, the volume of urban runoff increases sharply during the heavy rainfall period, thus brings much pollutants to Qinhuai River. Additionally, to maintain the cleaning and vitality of Qinhuai River, the community runoff is not only collected and purified through the water channel before discharged to river, but also pumped to the purification pipes combined with city wall further before channeled to the wetlands for infiltration to a aquifer for replenishment of the underground water (Figure 26).

**Figure 26.** Hydrology management in potential heavy rainfall period.



On the one hand, the city wall walkways are integrated with water processing facilities including purification pipes, silt sieves, sedimentation ponds, wetland cells, infiltration ponds, oxygen basins, siphon pumps which as a whole control and manage flood and storm water. On the other hand, the archaic beauty and the historic scenes are presented just like the outdoor museum as people are walking down the walkways on top of the city walls. This green archival linkage further connects the communities on double sides to each other in every sense (Figure 27).

**Figure 27.** Perspective view of eastern water gate park.



**Figure 28.** (a) Water network. (b) Division of subzones. (c) Open interface. (d) Waterfront walkways. (e) Visual corridor. (f) Entrance to Bailu park.



**Figure 29.** Plan of water network of Bailu community in eastern water gate area.



### 6.3 Facilitation of water exchange of Bailu community in eastern water gate area

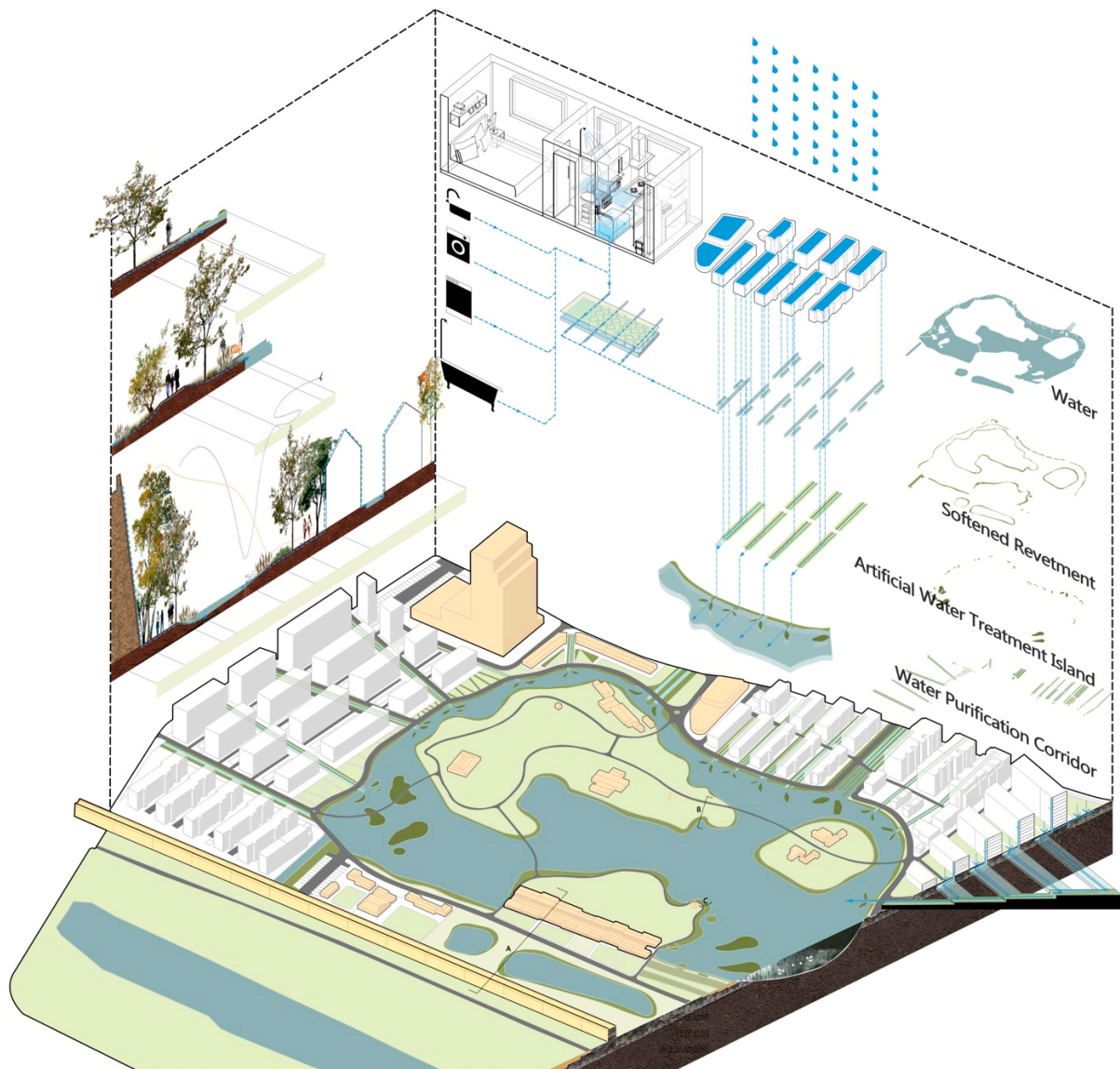
As to the reconstruction of water network in Bailu community, Firstly, it is proposed to rebuild the water network by introducing more water treatment corridor into the community to improve the water quality of the park. So it redefines the relationship between the park and the community around it (Figure 28a). Secondly, the water network corridor further divides the community into 8 sub-zones of the appropriate scale for renewal in sequence (Figure 28b). Accordingly, the waterfront interface to community would be more friendly to enhance the interaction between different people (Figure 28c). Thirdly, the continuous waterfront walkways connects the green space of the sub-zones and permeates into neighbourhoods (Figure 28d). Fourthly, more visual corridor to eastern water gate park would cut into the community fabrics to create more experience of leisure street (Figure 28e). Finally, Bailu park would be open to the public by increasing more active interface to the communities (Figure 28f). Figure 29 shows the overall plan of water network of Bailu community in eastern water gate area.

Figure 30 shows the steps of water network project:



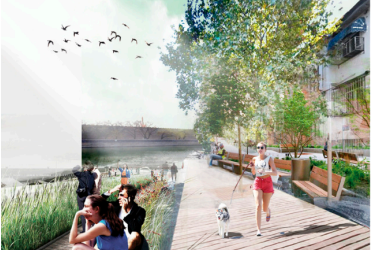






- (1) Soften the revetment of the park and build some artificial purification islands and corridors.
- (2) Convert the lakeside roads into permeable pavement to link the wetland and artificial purification islands.
- (3) Rainwater collected by the city wall is guided into the water pond of the park to prevent the erosion of the city wall. The recycled daily use water of the community is discharged into the park after several layers of purification.
- (4) The humanity and cultural environment is improved through community activities, cultural experience, and ecological education to make the community more colorful.

The comparison of the images before and after project could be seen in Figure 31.

**Figure 30.** Steps of water network project.



**Figure 31.** Comparison of images before and after the project.

Location index	Before	After
		
		
		

#### 6.4 Improvement of community participatory rainwater harvesting

In order to achieve the goal of “sponge city”, communities could also participate in and contribute to rainwater harvesting by integrating small interventions. In the east water gate area, Qingshuitang Community is chosen as the pilot area in community participatory rainwater harvesting (Figure 32).

As shown in Figure 33, the alternations structure of Qingshuitang Community consists of three parts:

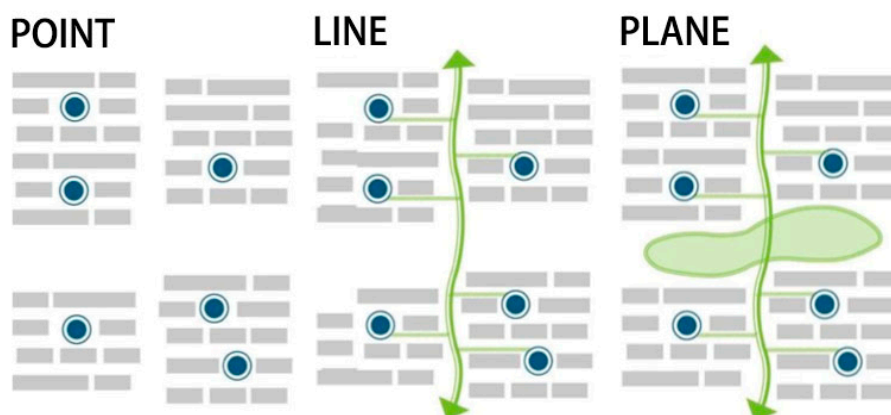
- 1) Point ---- Sort out the existing fabric and integrate “pointed” central water plaza into groups of living apartments. The water plaza not only takes the task of rainwater infiltration and storage, but is also a focal spot for daily activities of people living around.
- 2) Line ---- Fully utilize the current “vacant” land to create “linear” landscape and ecological corridor that connects all the “pointed” water plazas as a whole.
- 3) Plane ---- Transform Qingshuitang into a “plane” area of water storage and infiltration that links with outer Qinhuai River. Combined with the linear corridor, an ecological recreational zone at the community level in Qingshuitang community is created.



Figure 32. Plan of the Qingshuitang community.



Figure 33. The structure of interventions: point, line and plane.



Based on the three parts stated above, the following content will illustrate in detail how each part is integrated into the design and in which way each one of them contributes to the improvement of community participatory rainwater harvesting.

(1) Point – central water plaza of apartment groups

The pointed central water plaza of apartment groups is multi-functional in different period of time (Figure 34). It is the “playground” for residents living around when the weather is nice. During rainy days, the plaza could store water temporarily and the water stored could be re-used afterwards.

**Figure 34.** Multi-functional central water plaza

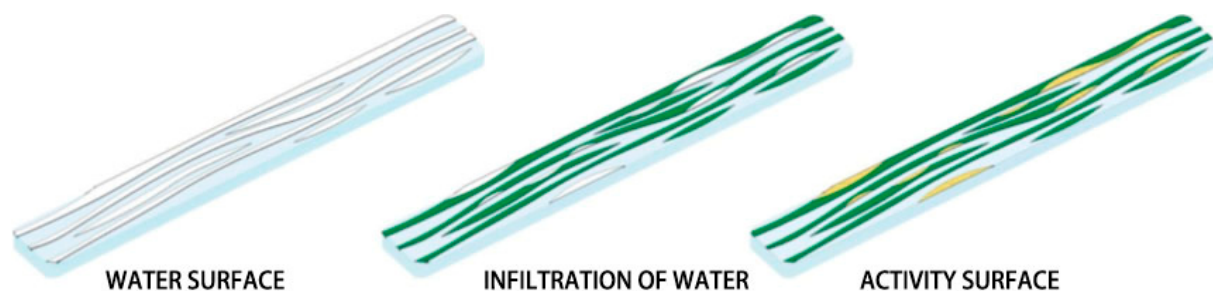


The plazas are also equipped with facilities that combine recreational activities and water together. Water balloon, sponge, sunken plaza, etc. are all small interventions that treat water to some extent and at the same time, provide conditions for people to play with.

(2) Line – ecological water infiltration corridor

The linear ecological water infiltration corridor collects all the water from the pointed water plaza and transports the water to Qingshuitang for concentrated water treatment. This corridor consists of three layers (Figure 35): water layer, ecological water infiltration layer, and paved activity layer. By laying all three layers together, the corridor combines water and recreation as a whole.

**Figure 35.** Three layers in water infiltration corridor



(3) Plane – qingshuitang community recreational center

The qingshuitang community recreational center is the area where everything comes together. In terms of function, here is the place where public functions of the community concentrates: community activity center, ecological education center and community fitness center.

In terms of ecology, lots of ecological green islands are implemented here. The islands consist of layers with different particles that could infiltrate water gradually. Through the natural process of infiltration by vegetation and soil, sediments begin to accumulate and islands are formed then. Rain water and water collected from the linear ecological corridor are infiltrated by the islands. Furthermore, the variety of species is increased in this way. Figure 36 shows the perspective view of Qinshuitang.

**Figure 36.** Perspective of Qingshuitang.



In terms of community activities, we also create various bank types that could satisfy different requirements of groups of people: hard bank, soft bank, laddered bank and waterfront platforms (Figure 37).

**Figure 37.** Different bank types around Qingshuitang

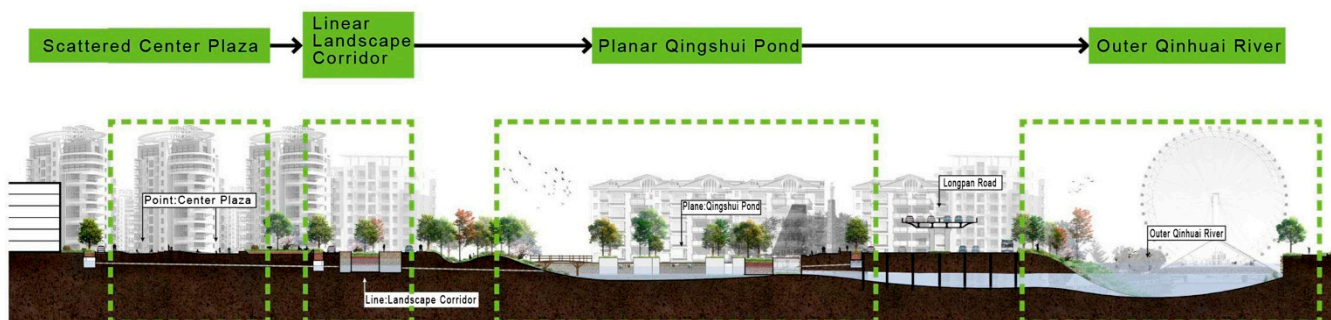


**(4) Water treatment circulation**

By intervening pointed, linear and planar structure, Qingshuitang community forms a water treatment circulation. Water collected in the pointed water plaza is infiltrated through the linear ecological corridor and transported to the central qingshuitang, where water is further treated and finally disposed into outer Qinhuai River (Figure 38).

Combined with spatial design for community activities, people living in Qingshuitang community are able to live and play with water. Simultaneously, being part of east water gate area and a significant node of the green belt, the community as a whole contributes to improving participatory rainwater harvesting.

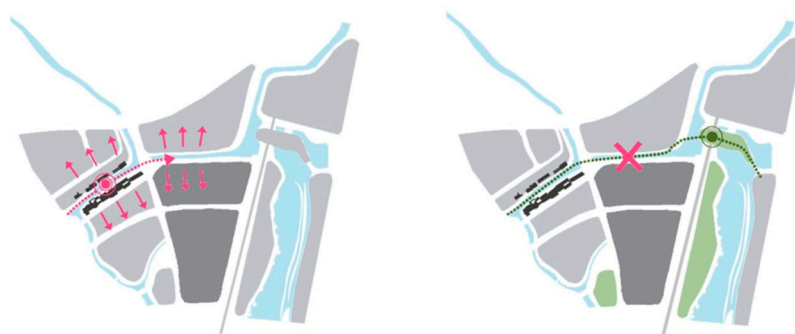
**Figure 38.** Water treatment circulation section.



*6.5 Green building Design of the extension of Fuzi Temple shopping center*

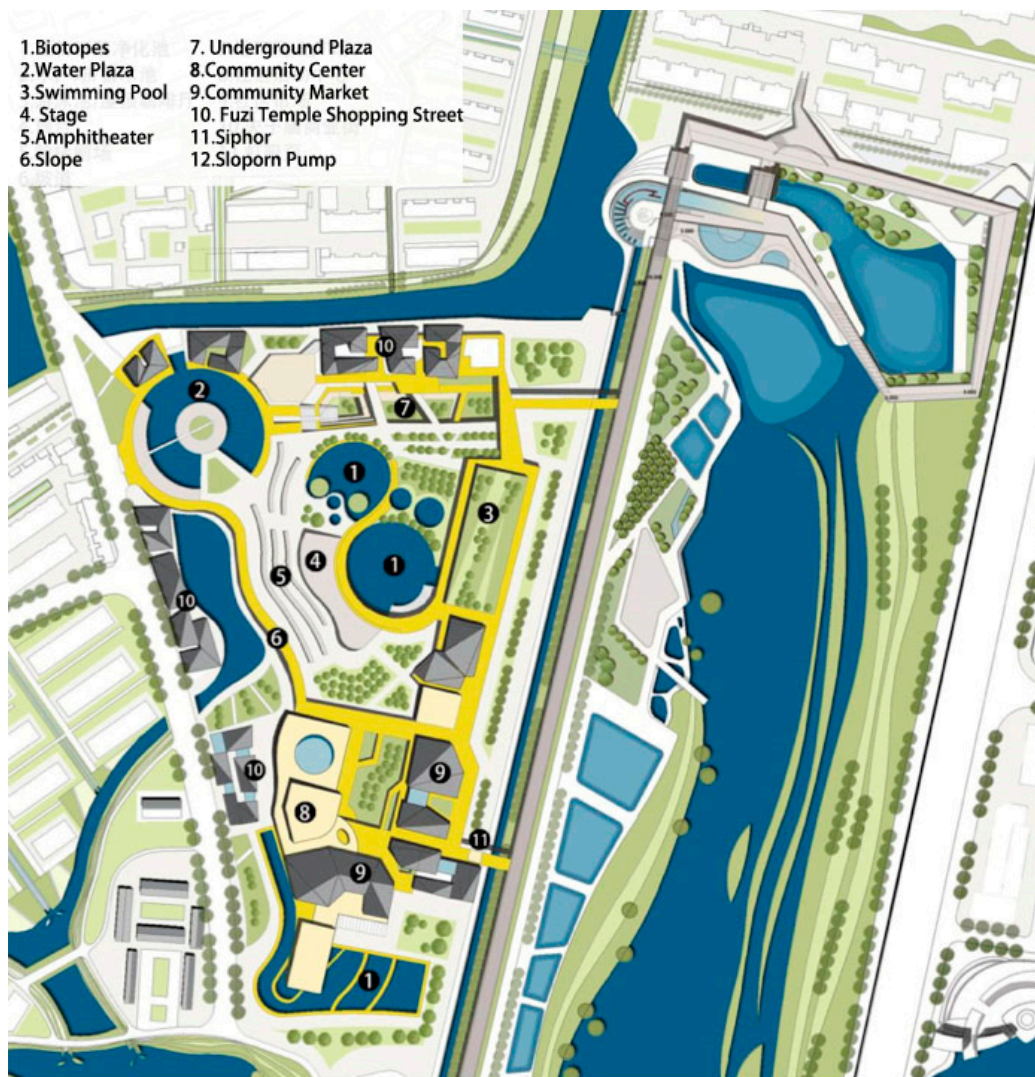
Fuzi temple was constructed in AD1034 in Song dynasty as a place to worship and consecrate Confucius on the north side of Qinhuai waterfront. Now, Fuzi temple area has been converted as tourism attraction, cultural and shopping center which is only 500 meters away from eastern water gate. And the surrounding area is fully developed for housing. Bailu community locates in between the Fuzi temple and eastern water gate. However, as the site analysis shows, not only the Fuzi shopping center causes much disturbance to nearby communities, but also these communities lack commercial amenities (Figure 39a). Besides, people have little public access to eastern water gate and city wall since it's wrapped mostly by residential communities (Figure 39b).

**Figure 39.** (a) Disturbance to nearby communities by Fuzi temple shopping center. (b) Lack of public access to eastern water gate and city wall.



Accordingly, it is proposed that a green commercial complex combined with water processing facilities is constructed both as the extension of Fuzi temple shopping center and the linkage to the fragmented city wall and isolated eastern water gate park to provide more public space for communities. Low impact development mode principals are implemented through the green building design, rain water recycling which are integrated with commercial function and culture landscapes. Figure 40 shows the plan of the green commercial complex.

Figure 40. Plan of the green commercial complex.

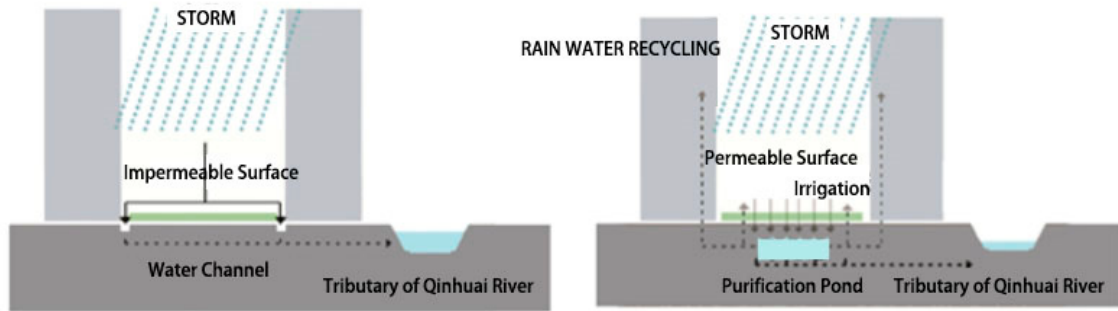


In traditional ways, the community runoff is directly discharged into Qinhuai River and exacerbates urban waterlogging in heavy rainfall seasons. Alternatively, the sustainable water management is proposed that the run off goes through the infiltration pond and purification basin, then channeled partly back to buildings for recycling and partly to Qinhuai River (Figure 41). The flora in biotopes for water purification varies from season to season. The playground also functions as the cistern in rainy season.

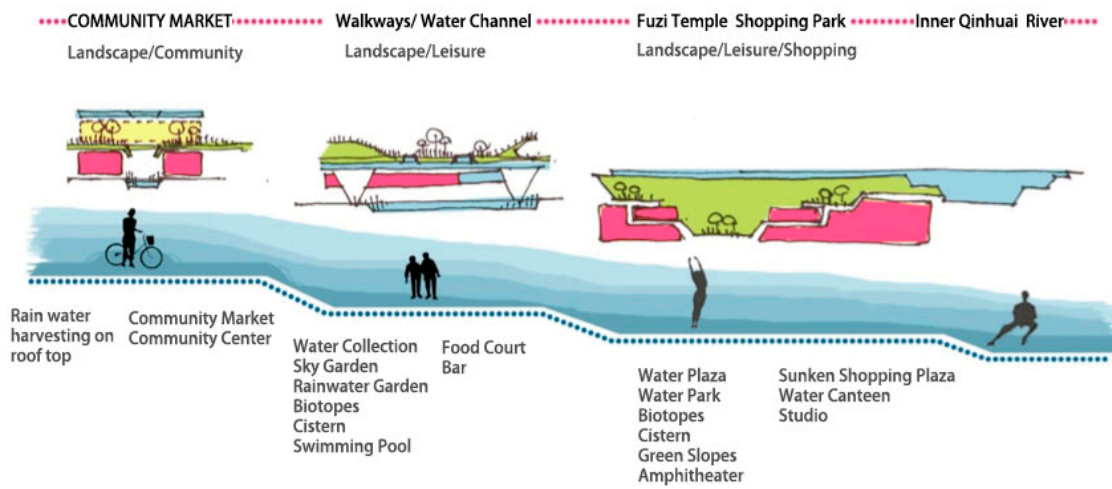
To achieve multi-space integration and sustainable water management, the linear public activity platform combined with water processing facilities is proposed to connect community markets, walkways, sky park and waterfront space, thus forming a multi-system of shopping, community activity, historic park and cultural landscape (Figure 42).

Based on the above strategies, Figure 43 and 44 shows the detailed water processing line. The city wall constitutes the green infrastructure to collect and transport rain water. The collected rainwater firstly confluent into catchment for recycling, and then flows through the vertical corridor to the biotopes, and finally flows into the water plaza and water stage for sedimentation before discharged into inner Qinhuai River. Meanwhile, the rain water collected by the water bar and restaurant could also be reused for swimming pool and other uses.

**Figure 41.** (a) Traditional way for water management. (b) Sustainable water management.



**Figure 42.** Linear public activity platform combined with water processing facilities.



**Figure 43.** Water processing line.

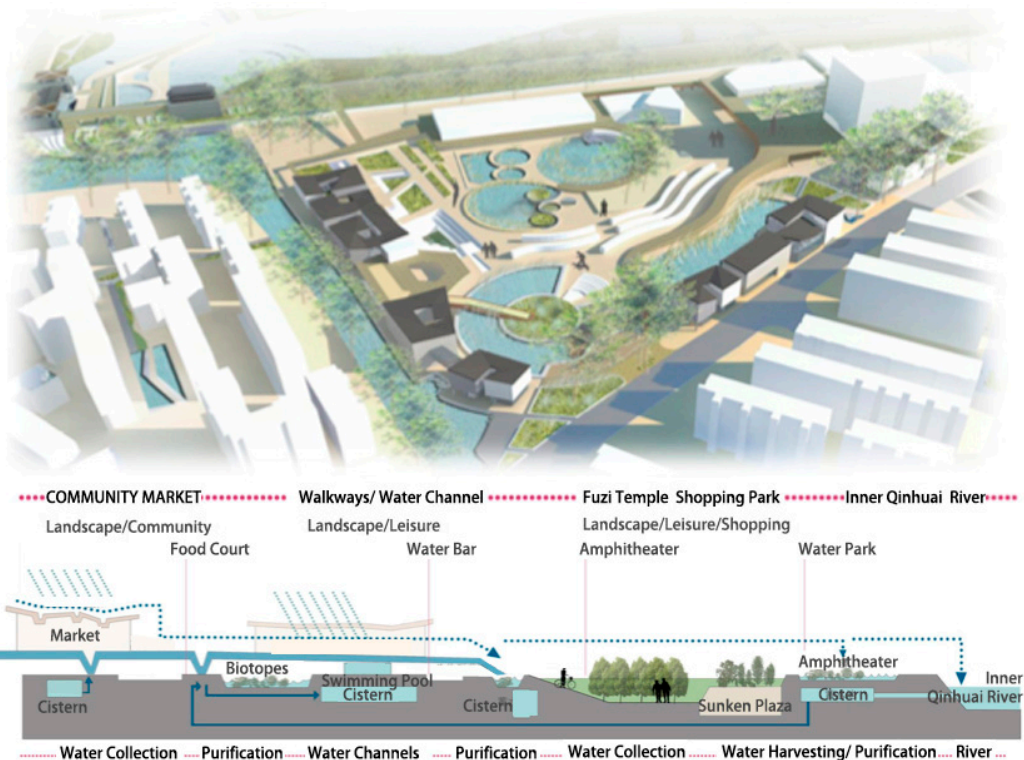
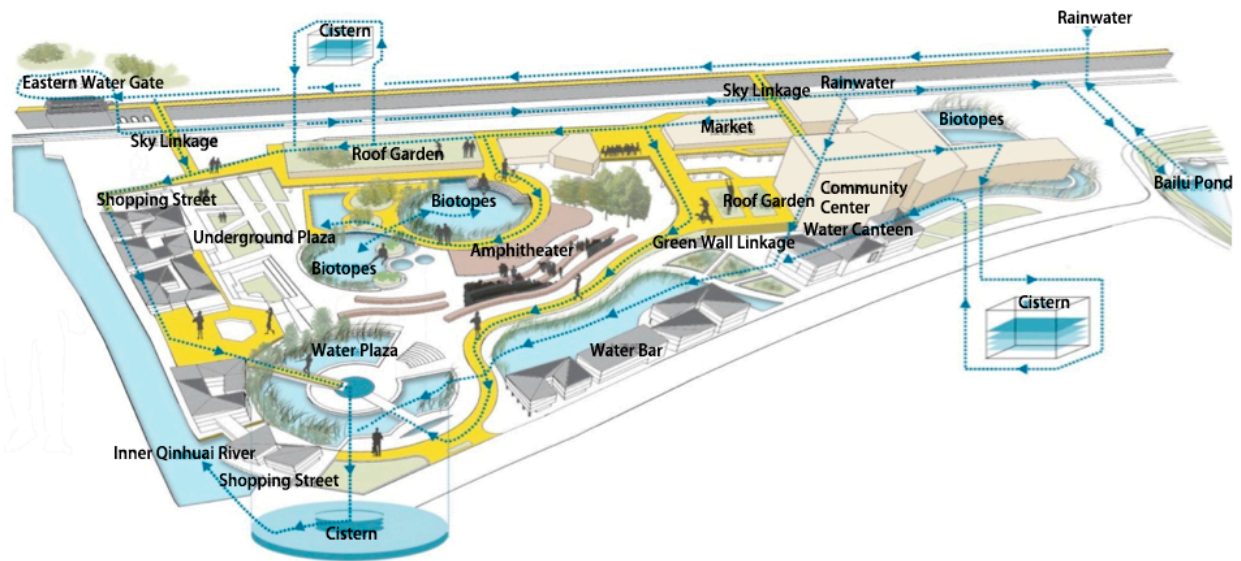


Figure 44. 3D water processing line.



### 7. Conclusions

Applying the “low impact development” mode, eastern water gate area would be the water exchange junction of inner and outer Qinhuai River for future urban hydrology management. Qinhuai River also extends into surrounding communities to form the water network for community participatory water management. Communitygreen commercial complex further links the city wall as the transition to Fuzi temple shopping center to enhance community activity with water experience. As is shown in Figure 45, eastern water gate area would become an sustainable commercial and residential area on waterfront with hydrology-management function of historic and cultural beauty.

Figure 45. Bird view of eastern water gate area.



## Acknowledgments

We are grateful to Mr. Zhang he, the tutor of our thesis, for his dedicated assistance and acute criticism. His thought-provoking guidance has led to great improvement of our analysis of the site and design concept. Gratitude is also due to many friends who joined us for fieldtrip and read through the paper through in its entirety and helped to polish it. We are solely responsible for any flaw and shortcomings to be improved.

## Conflict of Interest

The authors declare no conflict of interest.

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