STORMWATER PLANNING AND DESIGN, HANGZHOU, CHINA

by

CHAOZHONG WANG

Under the direction of Bruce K. Ferguson

ABSTRACT

Because of rapid development and poor stormwater management, problems of flooding, water scarcity, and water pollution are becoming more serious in China. Moreover, the drainage infrastructure is mostly buried, invisible, and thus, in a sense, they are invisible to most citizens. That is a modern tragedy. This thesis examined the good stormwater uses in the past of China and the environmentally sound and aesthetically beautiful stormwater management in the United States. After that, this thesis mainly explored the comparison between the Chinese & the United States experience and how the combination of aesthetic and functional stormwater design in the United States could be adjusted to apply in China. This was reflected in one design.

INDEX WORDS: Chinese Garden, Stormwater Management, Environmental Art, Ecological Art, Natural Process

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INTRODUCTION

Purpose of the Study

Because of rapid development and poor stormwater management, problems of flooding, water scarcity, and water pollution are becoming more serious in China. City planners and landscape architects now regard these as problems. Now in China, conveyance through storm and sanitary sewers is the main way to deal with the runoff, which has contributed to the problems described above. Moreover, the drainage infrastructure is mostly buried, invisible, and thus, in a sense, they are invisible to most citizens. That is a modern tragedy. There are two ways for the modern Chinese people to learn to be wiser in dealing with Stormwater Management. One is to learn from the ways of the past in China, the other is to learn from abroad. This thesis will examine the good stormwater uses in the past of China and the environmentally sound and aesthetically beautiful stormwater management in the United States. After that, this thesis will mainly explore the comparison between the Chinese & the United States experience and how the combination of aesthetic and functional stormwater design in the United States could be adjusted to apply in China. This will be reflected in one design.

CHAPTER 2

STORMWATER MANAGEMENT IN CHINA

Introduction

In Contemporary China, stormwater is dealt with unwisely and has caused a lot of problems. But in China's past, there were a lot of good techniques and thoughts to deal with stormwater. This is mainly reflected in Chinese classical garden design. Stormwater has much influence as an aesthetic and functional element in Chinese garden design. It is used as waterfalls, streams, and pools in the garden. Sometimes it catches the ephemeral character of stormwater such as waterfalls or using the sound of the water to create imagination in nature. In other situations it is used to reflect the landscape and then enlarge the feeling of the space in a small space. Finally, there is almost always a big pool and several streams in the Chinese classical garden design, which can act as a stormwater management system and resolve the on-site runoff and also clean the stormwater before it is released into the river.

Current Stormwater Technique and Its Problems

In today's China, conveyance through storm and sanitary sewers is still the main way to deal with the runoff. When a development project begins, people begin to clear the existing vegetation, bury the stream on-site to replace it with sanitary sewers, and pave the soil with all kinds of impervious pavements. By doing this, the ability of the soil to absorb and store rainfall and release it slowly back to natural streams is greatly changed. Accordingly, the frequency and magnitude of flooding increases in Southern China. In the past several years, much more serious floods have happened. In Northern China, it is another situation. The groundwater aquifer is reduced as withdrawal demands grow. The underground water level drops seriously at Beijing and sandstorms occur because of the lack of water. Although it can't be all owing to poor water management measures, it causes a number of these problems. Moreover, the drainage

infrastructure is mostly buried, and thus, in a sense, its presence is denied to most citizens. And this causes people's indifference to serious water problems.

Water in Traditional Chinese Garden Design

Origin of Chinese garden

There are two most important philosophical thoughts in China: *Taoism* and *Confucianism.* They affect the Chinese thinking very strongly. Both of them have strong opinions about nature. *Confucius* said "mountains and streams equal benevolence and wisdom" and "The wise enjoy the streams, the benevolent enjoy the mountains; the wise are active, the benevolent passive; and the wise are happy, the benevolent long-lived."[1] To *Confucius*, people can be inspired by natural phenomena and people should learn from nature to be good. For *Taoism*, it goes further. *Laozi*, the man who created the *Taoism,* said that the *Tao* (way) gave free rein to nature.[2] There are no other overriding elements, all things develop in their own way as their nature dictates. In all, Chinese think that humankind is merely a subordinate constituent of nature and should live in harmony with nature.

Because of this philosophy, the "mountain and water" poetry and painting began to flourish about 1500 years ago. People thought that the beauty of mountains and rivers was close to their own mind. So they went out to tour the country and enjoy the beauty of nature. At the same time, they also drew what they have seen or written about natural beauty. Accordingly, mountains, rivers, springs, and rocks became "favorites" of the literati and painter; mountain and river poetry and painting became the main avenues of artistic expression. Later, people wanted to recreate the image of nature seen and expressed in "mountain and water" poetry and painting; so emerged the Chinese garden.

From the points we talked about above, we can see that Chinese gardening art relates closely to the water and mountains found in nature. But the garden artists did not stop there, they went a step further. They did not simply imitate the types of scenery to be found in natural

settings; rather, they expressed the artistic ideas and conceptions which emerge from the profound understanding of and feeling for nature. People can't recreate the real hills and waters in their own garden, so they tried another way to reflect that. For example, *Zhang Nanyuan*, a late *Ming* dynasty rockery designer, advocated using flat terraces, mild slopes and small hills and winding streams to make the garden closely resemble the natural world.

Hill and water are the two basic elements in Chinese garden design, so the Chinese classical garden is also called "Hill and Water Garden". The famous landscape architecture professor Chen Congzhou wrote in his book: "Hills are valued for their veins and waters for their sources, and if these are properly set out, the whole garden will come to life."[3] When talking about the relationship between hills and waters, he said: "The waters follow the hills, and the hills are brought to life by the waters," and "streams meander because of the hills and paths follow the terrain." [4] Hills and waters not only create the skeleton of the Chinese garden, but provide a contrast to the other important element: architecture, which provides places for people to rest and appreciate the garden, as a contrast to naturalistic features. As both are essential components of the garden, they are often positioned as dui-jing, opposing vistas, providing refreshingly different views from one to the other. With the further application of plantings, one Chinese garden is created.

Hill (topography), water, plants, and architecture are the main four design factors in Chinese garden design. Water plays a very important role in Chinese garden design. Combined with man-made hills, trees, pavilions, and *Taihu* lake stone, many water scenery gardens rich in the beauty of nature are created. From the garden, people get spiritual enjoyment derived from natural beauty. A person's state of mind interacting with the mountains and rivers can achieve a state of harmony between object and self.

Geographic difference and water sources

From the above section, we can know that water plays a vital role in Chinese garden design. So one of the most important things the Chinese garden artists need to do is to find the water and design with water. Accompanied by Chinese *Feng-shui*, which prophesied wealth wherever water is found, sources of water became the essential site-selecting factor. For the Chinese garden, a generous expanse of placid water, combined with a varied composition of hills and other components, is a central feature that lends serenity, beauty, and even mind relaxation to gardens of different sizes.

Garden artists need to have different ways to deal with the completely different climates of North China and South China, The famous landscape architecture professor *Chen Congzhou* said: "in places where there is little water, ample attention should be given to its preservation; and in districts where water is more than abundant, its drainage becomes a must."[5] Most parts of southern China are rich in water resources and many cities are located on the banks of rivers. Among them, *Suzhou*, the city which has the most beautiful gardens in China, is a typical example. Located on the lower reaches of the *Yangtze* River and on the shores of *Taihu* Lake, *Suzhou* is situated in an area interlaced with rivers and canals. During the *Ming* and *Qing* dynasties, the city was crisscrossed by canals and alleys. Most houses were fronted by alleys and backed by canals that linked up with waterways outside the city. It was easy to divert water for use because of the high water table. Garden designers made great use of water in *Suzhou* gardens, a majority of which centered upon streams and pools. Combined with man-made hills, trees, pavilions, and *Taihu* Lake stones, many water scenery gardens rich in the beauties of nature are created at Suzhou and elsewhere in Southern China.

In the northern part of China, it is another situation. Arid northern China presented a great problem to garden designers. Therefore, many gardens are arid gardens, which, according to Chinese aesthetic, lose a lot of beauty. But garden artists there make a great use of stormwater to create beautiful gardens, such as the *Summer Palace* and the *Perfect Garden*. Actually, the

greenway system of Beijing is designed basing on resourceful stormwater use. The garden designers in Beijing collect runoff from a range of mountains to the northwest of Beijing and the spring water from *Yuquan (Jade Spring) Mountain* in the western suburbs to *Kunming Lake* of the *Summer Palace*, which is dredged and enlarged to become a water reservoir. Now it follows the terrain and man-made channels, flowing from the north of the city into the city proper where it forms a series of lakes.[6] The water enters the imperial gardens of the *Forbidden City* and the moat that surrounds it before flowing south. Based on this watercourse, all the famous gardens in Beijing are created and connected to become a green system of today (Figure 2.1).

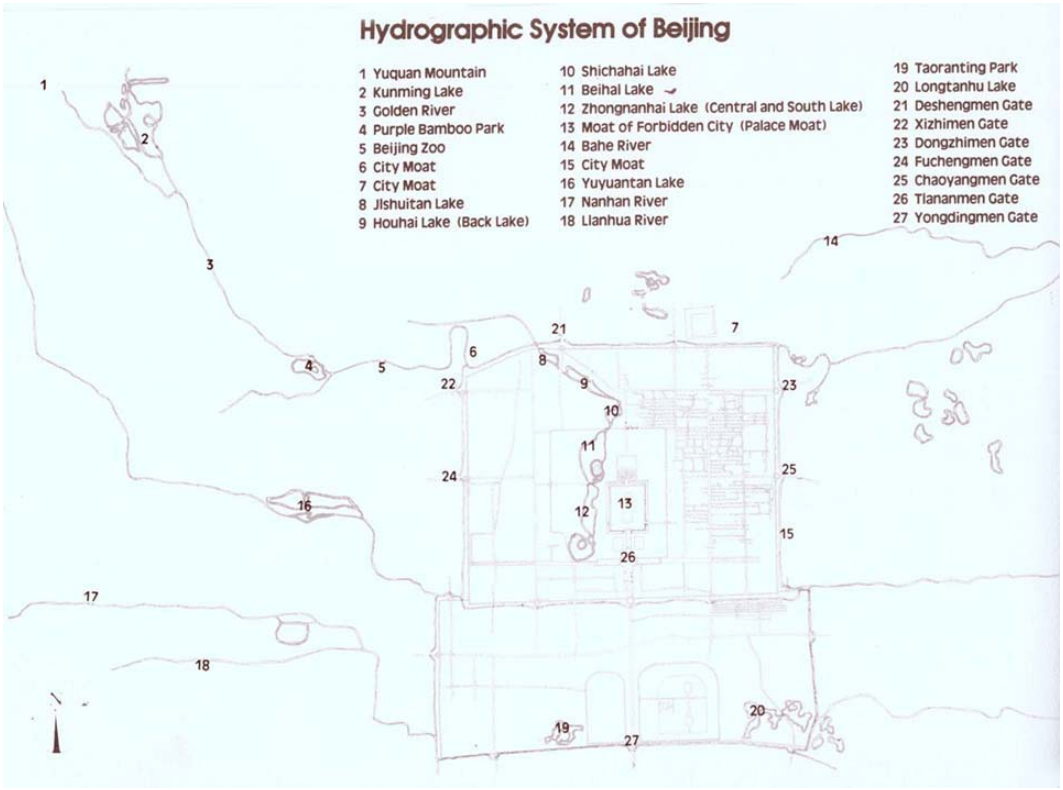

Figure 2.1 Hydrographic System of Beijing. Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 102.

Different water features

In Nature, water is found in a variety of forms, shapes and actions: rivers, lakes, creeks, ponds, waterfalls, springs, marshes, etc. Accordingly, in Chinese gardens, there are a lot of different water features. A pond of clear water can give people a feeling of brightness, openness, and serenity. The atmosphere it creates is just what the aesthetic concept of *Taoist* philosophy described. Besides, the tinkling streamlets, with their sound and movements, are often used as an effective enticement for visiting hidden garden scenes and added to the garden's natural charm. In all, garden landscapes were dotted with active and still water, reflecting the "spirit of poetry and the intention of painting." By ingenious designing with water, beautiful waterscapes can be achieved as required by local conditions and nature.

Basically, there are three kinds of water features in Chinese classical garden. First, point-shape water features, which include waterfalls and springs. Second, line-shape water features, which mainly means creeks and gullies. They wind through a garden and combine with stones and plants to create beautiful landscape. Finally, area-shape water feature, the pool, is the visual and physical focus of a garden and is often combined with a dam or bridge to create a beautiful, open, and serene landscape.

Point-shape water feature

This is where accessible, natural springs are used as water resources in Chinese gardens. Wells are dug deep enough to connect watercourses with an underground water source to assure a water supply during the dry seasons. The temperature of well water, cool during summer and warm during winter, is desirable for people's use. Often, it is connected to some historic story to make the garden more appealing and with more meaning. The *Hupao Spring Garden* in *Hangzhou* is a perfect example of this. The story said that one famous Buddhist monk dreamed that two tigers were digging in his courtyard to get water in one dry year. So when he awoke, he

ordered his people to dig in the place he dreamed and actually got a spring. After that, a beautiful garden was created in thanks for the guidance of the Buddhist God.

Waterfall is another point-shape water feature in Chinese gardens. Waterfalls offer the designer great chances to create a variety of water scenes that replicate the beauty of nature. The excitement of exuberant running water is a great contrast to the tranquility and serenity of the garden. Generally, waterfalls are molded into a remote recess of artificial hills and carefully constructed with rocks and plants to create fascinating sights. Differences in size, length, and section produce specific artistic visual and sound effects in the garden. According to *Chen Lifang*: "In Chinese gardening practice waterfalls are classified by shape and type as follows: Falling straight down, linear falls, falling from the left and right sides, and falls in layers."[7] The design is decided by the volume of water available from the water source. *Xiequ (Harmony and Interesting) Garden*'s waterfall in the *Summer Palace* of Beijing is a good example of the waterfall. Here, the water flows bubbling down into the lotus pond. A flat bridge crosses the gently flowing falls. This fascinating landscape reminds the visitor of a real valley found in nature.

Line-shape water feature

There are two basic line elements in Chinese classical garden design: *Xi* (creek) and *Jian* (gulley). Creek means a relatively slow moving water course carrying water down the side of a mild topography or hill, while gulley refers to sections of a creek marked by a swift, turbulent flow. The pleasant gurgling of the stream as it passes over its gravel bed is one of the most beautiful sounds in a Chinese garden. Generally terraces, pavilions and galleries are designed on the banks of the creek to view the creek and its bordering gardens and to enjoy the sound of the water.

Creeks and gullies should be designed with changes in both height and plan. The changing elevations will make the water flow change from one part to the next, intermittently rushing down

a steep gully and then slowing as the creek changes to a nearly level bed. Furthermore, creeks and gullies should meander through the garden to divert the viewer's line of vision and create the perceptual illusion of extensive space of the garden. A splendid example can be seen in the *Jichang Garden* of *Wuxi*. The garden designer channeled spring water from *Huishan Mountain* to the garden and created a stream called the *Baying Gully (Gully of Eight Musical Tones)* (Figure 2.2, Figure 2.3). It was a stream of water falling from different heights on stones of different

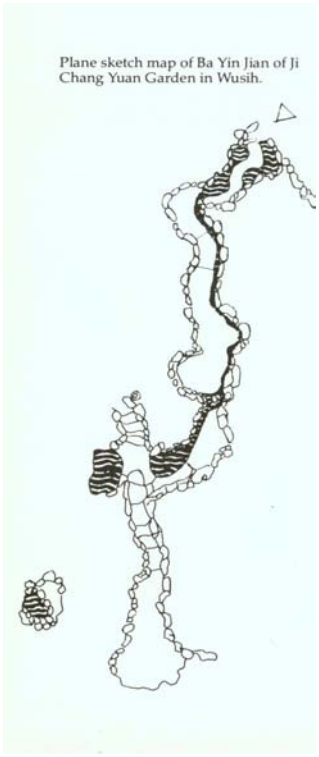

Figure 2.2 Left: Plan, sketch map of *Baying Gully of Jichang Garden*, Wuxi. Reproduced from Chen Lifang and Yu Sianglin, *The Garden Art of China* (Portland: Timber Press, 1986), 96.

Figure 2.3 Right: *Baying Gully of Jichang Garden*, Wuxi. Reproduced from Zhu Ya-xin, *Landscape Design in Chinese Gardens* (McGraw-Hill Book Company, 1988),184.

sizes, shapes, and densities. The gully gets its name because the water as it strikes differently shaped holes in the rocks, which produces sounds reminiscent of musical instruments playing eight tones. The gully is surrounded by a thick growth of trees and stone cliffs and is still and quiet within these woods. Here, the active and viable streams contrast with the secluded and serene woods and stone hills to create an even stronger effect. There is an ancient poem to describe the relationship well: "When a valley is quiet, springs are even louder to hear." Unfortunately, a blockage at the mouth of the spring has slowed the flow of water, and as a convenience to viewers, a winding path has been built in the ravine. As a result, the "*Gully of Eight Musical Tones*" has lost much of its previous charm. It needs restoration in order to manifest its original charm.

Area-shape water feature

Pool is the most important element in water scenery design in Chinese garden. It is the visual focus of a Chinese garden where it exists. A water pond reflecting the sun's rays can brighten up a courtyard garden and freshen up the landscape. It can also highlight all manner of scenery by mirroring blue sky and white clouds, sunrises and sunsets, and all the changes of the seasons. Although the pond is "empty", it becomes "filled" with all kinds of magnificent sceneries, a characteristic of gardens with ponds.

The pond design should vary with the size of the pond to achieve the best results. In a small garden, medium and small-sized ponds make a compact courtyard appear more spacious. They are usually square shaped with limited plants to retain a mirroring water surface for full reflection of the blue sky. Large central ponds are often shaded by tall deciduous trees with dark foliage to create a refreshing, cool atmosphere in the summer. Visitors can experience great peacefulness from the reflections of blue sky, white clouds, light-gray rockery, and green trees. During the winter, the bright sunshine filtered through bare twigs brings warmth and cheerfulness in the

garden. In larger gardens, evergreen trees are planted to cast dark shadows on part of the central pond, contrasting with the bright reflections of the pond's exposed portion.

Another important element to decide the water pond's beauty is its shape. *Chen Congzhou* said: "Water by itself is formless; it assumes forms only when it is flanked by banks. Consequently, water inlets, dams and banks are the important means of lending form to the water surface whether they are in a straight-line pattern or in snaky twists."[8] Inlets are one important way to create beautiful shape of ponds. The inlets are used to divide the water surface into distinct areas in order to relieve the monotonous appearance of the water pool. For a big island, architecture, and ornamental trees and shrubs are set to provide both a landscape to be seen and a place to appreciate the landscape outside. (Figure 2.4)

Figure 2.4 *Fu Zhuang, (Wild Ducks Village) Yangzhou, Jiangsu Province*. Reproduced from Zhu Ya-xin, *Landscape Design in Chinese Gardens* (McGraw-Hill Book Company, 1988), 75.

The bank is another important element to the formation of a pond. Therefore, despite the seemingly extravagant utilization of rocks in Chinese gardens, the embankments of pools were treated with high aesthetic thought. The garden designer spends a lot of time and money to choose rocks to make banks and the rocks evoke different emotions. Delicate rocks miraculously lend a feminine touch to water, and rugged ones, a masculine vigor. Seemingly ugly stones are valued for their uniqueness and originality.

The water level is also an important element in Chinese classical garden design, for it is crucial that the size of the reflected object be proportionate to the reflection pond and be placed as close to the water surface as possible to obtain a complete reflection. The Chinese garden designers took great efforts to ensure that the water level was maintained up to the edge of the embankment in order to obtain the garden scenes along the pond and a full reflection of the sky. Besides, it gives the exquisitely designed architecture a fascinating floating effect and opportunity to appreciate water from different water experience.

Layout

According to Professor *Peng Yigang*: "The layout of the water used in Chinese gardens can be divided into two basic ways: concentrated use of water, and scattered use of waters." [9]

The first means the use of large bodies of water. Generally, the garden is created around a main pool. Architecture, terraces, and decorative rockeries are arranged to encircle the water feature, which creates a kind of centripetal, peaceful, and open feeling. Because of the mirroring effect of the water surface, it can make a garden appear larger and more spatial than it actually is. As for the form of the pond, most of them are irregularly shaped except for those at some royal gardens where rectangular or square pools may be used to meet the overall composition. In the latter case, the water pool will occupy the whole garden space and will leave no room for plants and rockeries. Although serene and peaceful, it will appear a little monotonous. While in the

former case, the relation of pool, architecture, plants, and terraces are arranged meticulously to achieve a kind of natural feeling.

One of the excellent examples of the concentration of water use is *Fishing Net Garden (Wangshi Garden)*. (Figure 2.5) This garden was built in the twelfth century during the *Song* Dynasty and rebuilt at about *Qianlong* (1736-1796) times of the *Qing* dynasty. The garden is built around a pool. There are lots of buildings, plants, and rockeries, which are arranged around the pool to provide beautiful landscapes.

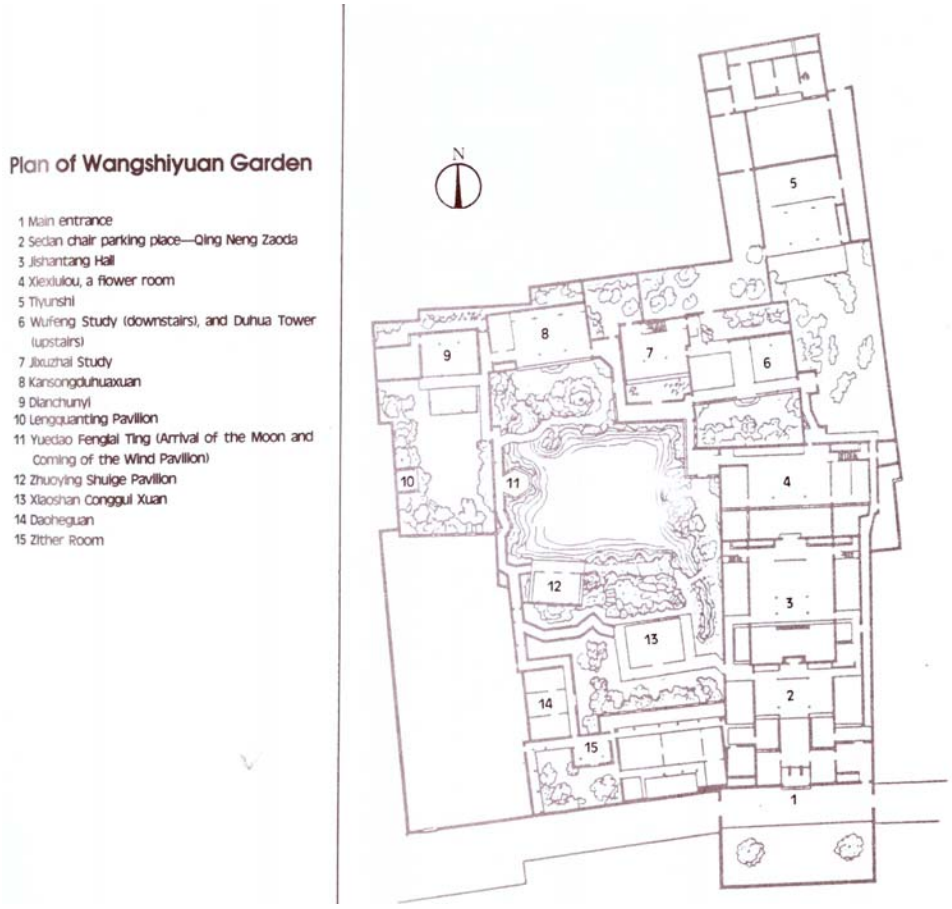

Figure 2.5 Plan of *Fishing Net Garden*. Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 51.

To make the garden appear spatial and open, the garden designer placed small pavilions near the pond and set the large halls and the study room well back from it. Another technique the garden designer used was to arrange scenery at opposite corners of the pond to provide opposite views, which make the garden look bigger than it actually is. For example, a tall pavilion called *Yuedaofenglai Pavilion* is set on the southwest side of the pool with a low terrace; (Figure 2.6)

Figure 2.6 *Yuedaofenglai Pavilion* view from the *ZhuoYingShuige Pavilion*, *Fishing Net Garden*. Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 53.

On the northeast side corner a water pavilion and connecting walkway stand against a library-study in the background. (Figure 2.7) The result is a magnificent image of the two leaning out across the pond towards each other. Finally, to relieve the monotony of the square shape of the

pond and create a feeling of a source of water, two streams are extended outside of the pool and disappear under a bridge or rockery.

In contrast to the concentrated use of water, the scattered use of water creates a kind of mysterious, endless, and deep-view landscape. The water is divided into several connecting parts to make the water landscape appear mysterious and endless. By scattering the water, many landscape centers can be created. The broad part of water can be combined with buildings, terraces, and plants to create a center, while the shallow stream can act as connecting space. By this, all the spaces can keep their individual characters and also are connected together to create a kind of complex and interesting water/land relationship.

Figure 2.7 *The Jishuzhai Study* and *Zhuwaiyizhixuan Pavilion* view from *Yuedaofenglai Pavilion*. Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 52.

The typical example of scattered water is the *Humble Administrator Garden (Zhuozheng Garden)* (Figure 2.8). This garden was built in the sixteenth century during *Ming* Dynasty. Originally the site was marsh land. After dredging, a lake was formed and divided by several islands into several different kinds of landscapes.

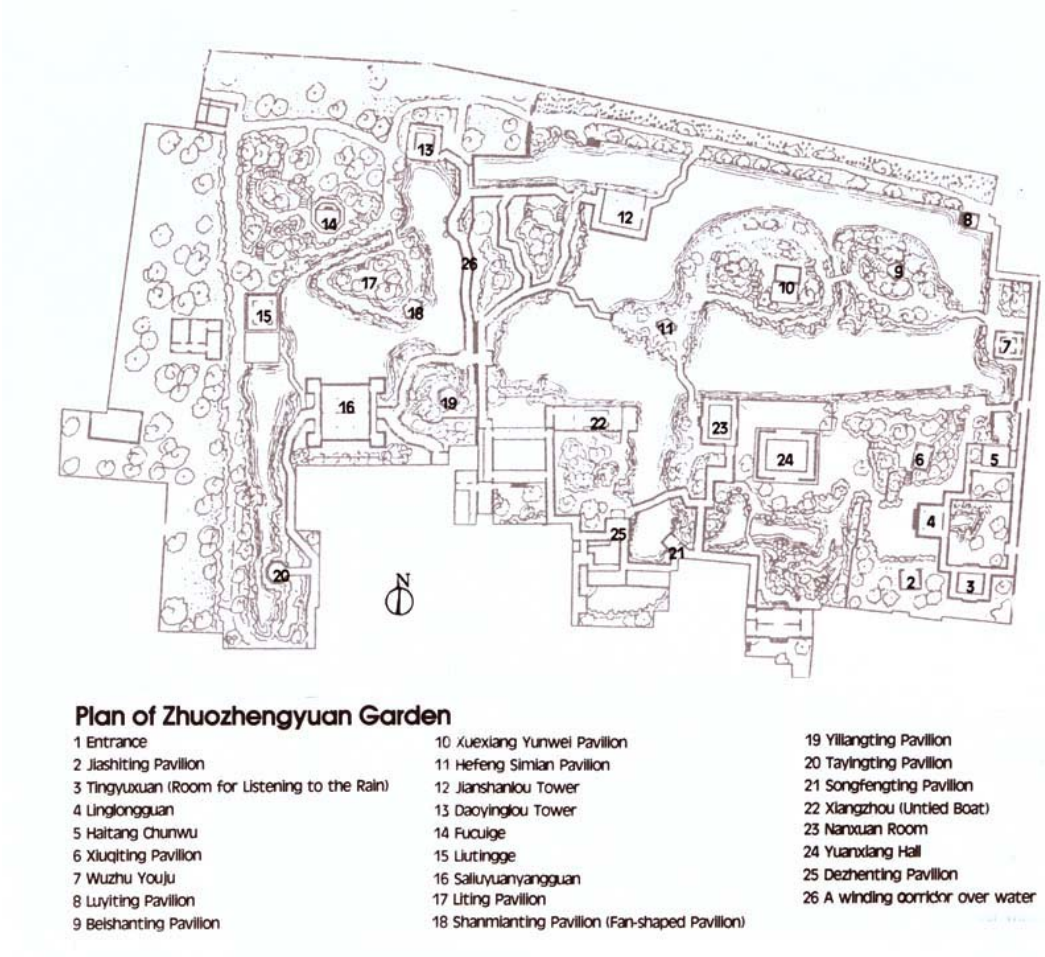

Figure 2.8 Plan of *Humble Administrator Garden*. Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 72.

At the central part of the garden, a large pool is set in front of the main building, *Yuanxiang Hall*. (Figure 2.9) Combining with the background hill, they create the main hill-water skeleton of the garden. At the west of this district, there is a small water-courtyard which is surrounded by corridors, a covered bridge and a pavilion on all sides and connected to the other water parts by the winding covered bridge (Figure 2.10). This creates an intimate feeling of a water courtyard

Figure 2.9 Lotuses in the pond north of *Yuanxiang Hall, Humble Administrator Garden*, Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 74.

Figure 2.10 *The Little Flying Rainbow Corridor*, *Humble Administrator Garden*, Reproduced from Zhu Ya-xin, *Landscape Design in Chinese Gardens* (McGraw-Hill Book Company,1988), 75.

which contrasts with and complements the main part. The third part of the waterscape is the one after the main hill. Here the water is long and shallow, which directs people's viewpoint into the farther landscape. At the east corner of the garden, one little pond creates another kind of feeling about water (Figure 2.11). Because the pool is so small, it needs another way to remind people of the water's existence. Here, clusters of bajiao (banana plants) are planted by the banks to give the garden owner a chance to listen to the sound of rain falling on the banana plant leaves.

Figure 2.11 The bajiao (banana plants) and rocks behind *Tingyuxuan*. *Humble Administrator Garden*, Reproduced from Dongchu Hu, *The Way of the Virtuous* (New World Press, 1991), 74.

The two kinds of water layout also have direct relationship with the overall garden layout. In his book *On Chinese Gardens*, Professor Chen divided Chinese gardens into two kinds: "those for "in-position viewing" i.e. lingering observation from fixed angles, and those for "in-motion viewing" i.e. moving observation from changing angles. The former means that there are more visual points of interest appreciate from fixed angles, while the latter demands a longer "touring" vista." [10] These two kinds of garden correspond to the two water layouts. Generally, the "in-position viewing" connects to the concentrated use of water, while "in-motion viewing" has more relationship with the scattered use of water. Using the examples that we have discussed above, in Fishing Net Garden, there are many buildings in which you would love to sit and linger a while. You can stand by the balustrade and count the swimming fish or watch the opposite landscape, or you can seat yourself in the Yuedaofenglai Pavilion to wait for the moon to rise and greet the breeze. Outside the veranda the shadows of flowers move along the walls, and looking out through a window there are rock ridges and peaks like those in a painting. While in Humble Administrator Garden, paths connect to all parts of different waters landscapes, and different buildings are built to and from the water and visitors can get all kinds of different feelings about water. The view changes with every step.

Animal use in water garden

Fish and geese are common creatures in existing Chinese gardens. Gold carps are loved and widely bred in small and large ponds. Water pavilions and bridges over the water are ideal for the appreciation of fish. A scenic spot called the Fish-Watching Flower Harbor (Hua Gang Gua Yu), along the West Lake in Hangzhou, is famous for its thousands of goldfish. Mandarin geese swimming in couples embellish the watercourses with their white feathers and graceful movements, and are favored as a blessing for devoted marriage. The rings of ripples caused by the geese or the gold carp are perceived as great beauty to be enjoyed in a pond of still water. They enhanced the serenity of a Chinese garden. Moreover, it is only in such a background of

extreme peace and serenity that the garden's exquisiteness could be appreciated. Relativity is ingeniously practiced in the art of Chinese gardens. The delicate movements are essential to enjoy the tranquility and peace of a Chinese garden.

Conclusion

The Chinese garden creates beautiful landscape and artistic thought. It also absorbs the heat in summer and keeps the garden warm in winter by adjusting the microclimate. And, it provides some good techniques to deal with stormwater. But it is limited in its function to solve stormwater issues and also did not do much about ecological function. By keeping the water in a fixed level in most of the gardens, it did not do much to show the process of stormwater.

[1] Dongchu Hu, *The Way of the Virtuous: The influence of Art and Philosophy on Chinese Garden Design* (New World press), 11.

[2] Hu, *The Way of the Virtuous: The influence of Art and Philosophy on Chinese Garden Design,* 10.

[3] Congzhou Chen, *On Chinese Gardens* (Tongji University Press), 2.

[4] Chen, *On Chinese Gardens*, 2.

[5] Chen, *On Chinese Gardens*, 38.

[6] Hu, *The Way of the Virtuous: The influence of Art and Philosophy on Chinese Garden Design,* 101.

[7] Chen Lifang and Yu Sianglin, *The Garden Art of China,*(Timber press, Portland, Oregon), 85.

[8] Chen, *On Chinese Gardens*, 52.

[9] Peng Yigang, *On the Composition of Chinese Classical Gardens*. China Architectural and Industrial Press, 1993, P45

[10] Chen, *On Chinese Gardens*, 1.

CHAPTER 3

ENVIRONMENTALLY SOUND STORMWATER MANAGEMENT IN THE UNITED STATES

Introduction

In contemporary America and other Western countries, based on the diverse and interrelated fields of urban ecology, the environmental art movement, and environmentally sound stormwater management, a new aesthetic for stormwater management in the city is being explored by many landscape architects, city planners, and environmental artists. It is composed mainly of two parts: The first is environmentally friendly stormwater planning, which solves the functional part of stormwater management and provides a scientific base for stormwater planning. By combining the use of conveyance, extended detention, infiltration, and stormwater harvesting, it provides a scientific way to resolve the stormwater issue. The second of the new aesthetics in America is the environmental art movement and ecological art, which provides a lot of inspiration and good examples on how stormwater can be used as a design element. The second part will be discussed in the fourth chapter.

Environmental advantages of the stormwater management in the United States

Historic context

For most of the 20th century, stormwater management was under the charge of engineers throughout the United States. They thought stormwater was a nuisance, instead of a resource. They followed a standard model of conveyance technology by using an efficient drainage system to bury the stormwater underground and convey it to the nearest streams or other water bodies.

This system solved early sanitary problems and safety issues. But at the same time, it caused downstream flooding and channel erosion, and the deterioration of environmental quality.

However, great landscape architects have provided ingenious ways to solve the problem. Rather than a nuisance, these landscape architects have viewed stormwater as a resource. They have sought to work with the hydrologic cycle and try to mimic predevelopment hydrology to the greatest extent possible. By doing this, they not only solve the stormwater problem, but also create aesthetically beautiful and ecologically healthy landscapes.

The earliest and one of the most famous landscape architects who adopted this strategy was Frederick Law Olmsted. His Emerald Necklace in Boston's Back Bay Fens area might be the world's most famous urban water treatment project. As a collection of sewage and swamp water, the Fens created both a distinct health problem and a flood control problem. Olmsted's plan transformed the Fens into a public park system and also solved the drainage problem. (Figure 3.1)

Figure 3.1 Frederick Law Olmsted, *The Riverway, Boston, 1900,* Reproduced from Julius Gy. Fabos, Gordon T. Milde, & V. Michael Weinmayr, *Frederick Law Olmsted, Sr. Founder as Landscape Architecture in America* (The University of Massachusetts Press 1968), 63.

He used tidal gates to control the amount of water in the Fens and then buried a huge sewage interceptor in the Boston side of the Fens basin to reduce health hazards. At the same time, the Fens parkland was designed to be a temporary storage basin for runoff and provided lots of space for recreation. Fabos, Julius Gy. acclaimed "the purpose of Olmsted and later Eliot plans was threefold: to make an engineering solution the occasion for creating a needed municipal open space; to link newly annexed communities to the historic municipal center; and to provide, as in Central Park, a variety of forms of recreation – pleasure driving, picnicking, and education at the Arboretum." [1] The Emerald Necklace project proved that landscape architects could use inspired engineering to solve the problem of stormwater and transform it into a valuable resource to be appreciated by people who use the park system.

The next genius landscape architect was Ian McHarg. In his groundbreaking work, *Design with Nature,* he posited that "place is a sum of natural processes and that these processes constitute social values, inferences can be drawn regarding utilization to ensure optimum use and enhancement of social values. This is its intrinsic suitability."[2] By analyzing natural processes such as water, vegetation, soil, and slope, different land uses are recommended. As part of natural processes, water management is one of the most important factors in McHarg's ecological planning. For example, in McHarg's water feature analysis map of the Philadelphia metropolitan area, five kinds of water phenomena are analyzed: surface water and riparian lands, marshes, 50-year floodplains, aquifers, and aquifer recharge areas. Accordingly, recommended land uses are suggested for every inventory. (Figure 3.2) The ecological planning McHarg created was revolutionary. "In that book the whole idea of water management and land-use planning came to bear," states France, "and computer-map overlays were laid out," spurring the development of geographic information systems. [3]

Solutions and ideas about stormwater issues keep on going. It has gone through a lot of change and improvement. Recently, it has caught people's attention again in a two-day international symposium in February 2000, entitled "Water Sensitive Ecological Planning &

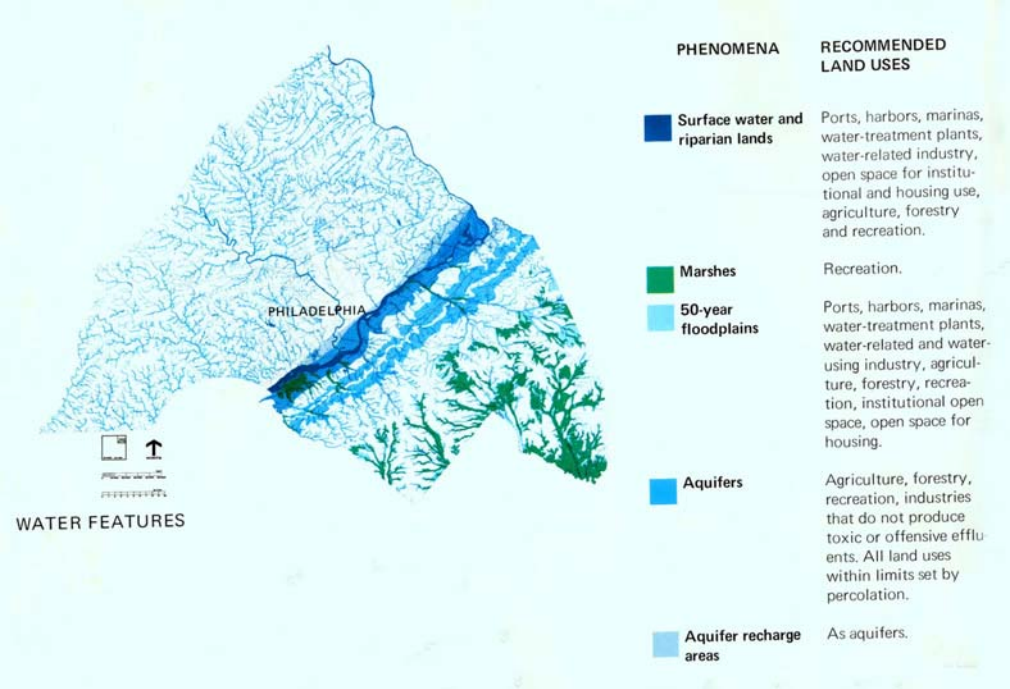

Figure 3.2 Ian McHarg, *Summary Map of Water for Part of the Metropolitan Area ,* Reproduced from Ian L. McHarg , *Design With Nature* (Eugene Feldman, The Falcon Press, Philadelphia), 62.

Design." This symposium was held by Robert France to celebrate the centennial anniversary of Harvard's Department of Landscape Architecture. There were a lot of experts in stormwater planning who expressed their ideas and presented their effort to better utilize stormwater in this conference.

In that symposium, Bruce Ferguson posited a landscape is an open, dynamic system with inflows and outflows of rainwater. In a healthy, predevelopment natural system, precipitation represents the inflow. It infiltrates into soil, recharges ground water, keeps a continual, moderate base flow, and benefits plants and soils. (Figure 3.3) In contrast, in developed areas, dense

impervious surface characterizes the land. Because rain cannot infiltrate the ground where it falls, it turns into runoff. Excessive runoff causes flooding and erosion problems and water pollution as well. A hope of a real cure in solving this problem is restoring infiltration as close to the source of inflow as possible. “Urban infiltration constitutes the restoration of a site’s hydrologic process. It

Figure 3.3 Jen Uncapher, *Runoff is worse on impervious surfaces than vegetated soil.* Reproduced from Bruce Ferguson, *Re-evaluation stormwater: the nine mile run model for restorative redevelopment* (Rocky Mountain Institute, Snowmass, Colorado), 4.

restores groundwater to the earth and balanced flow regimes to streams. In addition to addressing flooding and erosion, which are targeted by conveyance and detention systems, infiltration supports groundwater recharge, stream base flows, water quality, aquatic life, and water supplies. Because it turns the hazard of storm flows into the resource of base flows, it is environmentally the most complete solution to the problem of urban stormwater.”[4] Restoring infiltration as close to the source of inflow as possible is a key to success. Because the further runoff travels, the faster it moves, and the more it accumulates to move together in a large flow. Faster speed and

bigger volume give water erosive force and cause flood and water pollution. As a result, controlling water quality and runoff damage is most easily and economically achieved if stormwater management starts at the point where rainwater contacts the earth.

Another interesting approach to stormwater design in the "Water Sensitive Ecological Planning & Design" symposium is called *Low Impact Development* (LID), which advocates managing stormwater in a micro scale. According to Larry Coffman: "the LID could develop a site or retrofit existing urban areas and…maintain or restore the predevelopment hydrological regime…dramatically reduce nonpoint pollutant loads and water quality problems…preserve the ecological / biological integrity of receiving streams and waters…effectively engage property owners in pollution prevention…reduce stormwater infrastructure construction and maintenance costs…and reduce site development and urban retrofit costs" [5]The techniques LID use include reducing imperviousness, conserving natural resources and ecosystems, maintaining natural drainage courses, reducing use of pipes, minimizing clearing and grading, and using open swales, rain gardens, etc to recreate detention and retention storage. It also tries to get the cooperation of property owners to use stormwater management measures by providing effective public education and socioeconomic incentives. From above description, we can see that the basic theory of LID is the same as Ferguson's: restore predevelopment hydrologic functions on site.

Concept

According to the above review of the history of stormwater planning and design, the best way of dealing with stormwater is to restore the predevelopment hydrologic functions on the site. How can it happen? First we need to understand fundamental concepts of stormwater hydrology and their implications for urban planning and design. Other than conveyance, detention, extended detention, infiltration, and water harvesting are the four main methods for managing stormwater. They all can capture and keep water on site, but they differ in the time they hold on and how they

transport water. The following part will discuss how these techniques work and what kinds of environmental benefits can be obtained by using these techniques.

Detention and Its Environmental Benefits

Detention modifies conveyance to slow down the rate of flow of surface runoff. [6] By holding the rainwater for a while and slowly releasing it to a nearby water body, detention can reduce flood peaks.

Detention is accomplished by using detention ponds that temporarily store storm runoff. Generally a detention pond consists of three parts: a basin to store the stormwater, an inlet system that bring runoff into the basin and an outlet that conveys the runoff out. (Figure 3.4)

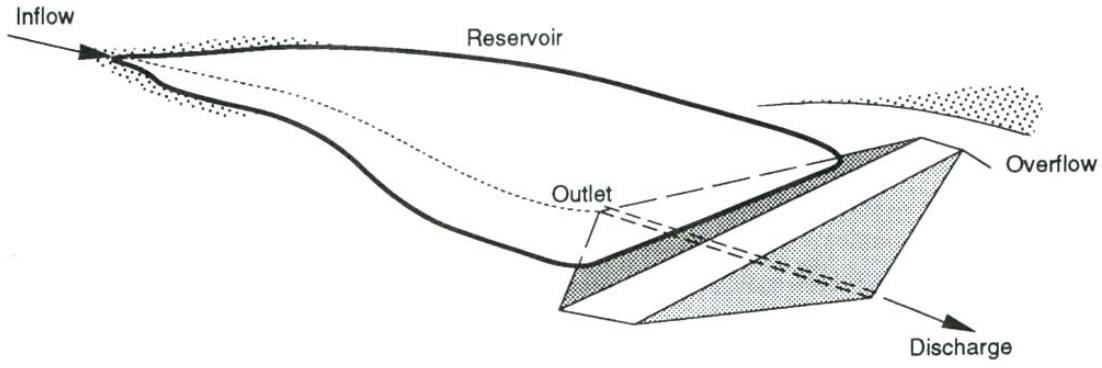

Figure 3.4 Bruce Ferguson, *A detention basin*. Reproduced from Bruce Ferguson, *Introduction to Stormwater* (John Wiley & Sons, Inc),150.

The volume of the reservoir above the outlet's invert elevation is the storage space. The basin collects runoff during storm events and then lets it out gradually through the constricted outlet. In the early stage of a storm, the basin's outflow is less than the inflow because of the constriction of the outlet. So the water in the basin grows until the time the inflow become less than outflow.

(Figure 3.5) At this point the detention basin gets maximum storage, which is the required storage for the pond. This is the way that detention works: reducing the peak flow.

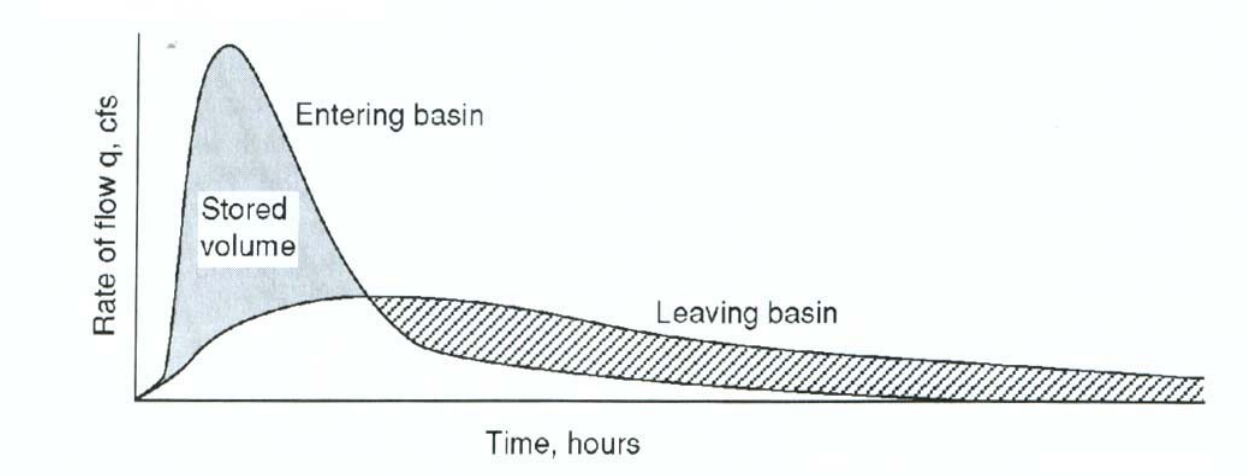

Figure 3.5 Bruce Ferguson, *Detention storage volume determined by rates of flow entering and leaving the basin.* Reproduced from Bruce Ferguson, *Introduction to Stormwater* (John Wiley & Sons, Inc),154.

There are two kinds of detention facilities: dry ponds and wet ponds. The former store water only when stormwater is being detained, while the latter have a permanent pool of water and store stormwater above the water surface of the permanent pond. Dry detention ponds completely become dry sometimes after the storm. People need to consider how to design them so that it can benefit the community instead of presenting an eyesore. While wet ponds can be designed beautifully and combined with community activities such as hiking trails, parks, fishing areas and wildlife habitat. (Figure 3.6) They even can increase property value of the lots around the wet detention ponds. So when we design detention ponds, in addition to detention needs, social, environmental, and recreational needs also need to be considered for their success.

But it needs to be noted that detention ponds do not reduce the total flow volume. The entire volume eventually is released to flow downstream. So after a storm, the flow from several

Figure 3.6 *Meadowbrook Pond and Wildlife Habitat project*, Reproduced from Willam Macelroy and Daniel Winterbottom, *Stormwater Ponds,* Landscape Architecture, 4/2000, 48.

detention ponds in a watershed may cause another high peak rate. For this reason, detention needs to be used very carefully. Dry detention ponds almost do no good to improve stormwater quality because of their short detaining time, while wet detention ponds can make some quality improvement by trapping pollutants in runoff such as nutrients, metals, and sediments. The water quality improvement can't be assured, because it depends on a lot of factors. Finally, detention ponds used alone as a stormwater management tool can't deal adequately with the issues of groundwater replenishment, base-flow contribution or channel erosion.[7]

Extended Detention and Its Environmental Benefits

Extended detention means holding the water on site for extended periods after rain. During this time period, solid sediment particles and the pollutants settle out and sunlight and microorganisms may begin to break down greases and oils. Extended detention mainly aims at improving water quality, although it likely reduces peak storm flow as well. A holding time from fourteen to twenty-one days is recommended to achieve maximum water quality benefits.[8]

Extended detention is achieved by using extended detention basins. There are two kinds of extended detention basins: dry extended detention basins and wet extended detention basins. Dry detention ponds are designed to be dry after about 72 hours following a rain event or a series of rain events if they occur frequently. By controlling the size of the outlet, a temporary pond can be created and the time of its existence can also be decided by design. During the time, pollutants settle out and are trapped on the pond's bottom. When the pond is dry, exposure to sun and oxygen helps break down the greases and oils of the settled pollutant elements. By acting like this, a dry extended detention basin helps improve water's quality. Because the runoff will be held for sometime, it also reduces the flood peak.

In wet detention, there is a permanent pool that stores water all the time. When raining, the volume is added into the existing water and replaces some of it. Thus, the runoff stays in the pool longer and has more time for silt and pollutant-laden sediments to settle out. It is very important because the first flush gets treatment, improving the water's quality. To achieve the best result, the area of the "live zone", which is the part "old" where water is replaced by the "new water", needs to be designed carefully. It means a pond's length: width needs to be 2:1 or more. This can be achieved by placing inlet and outlets, and creating peninsulas or islands to lengthen the water flow path. [9]Another consideration in the design of wet ponds is to increase volume by increasing the surface area rather than the depth.[10] Some part of the pond should be designed to be less than 18 inches for wetland plants to grow to improve the water quality. Wetland plants help to remove

the fine suspended particles and contribute to microbiotic activities that degrade soluble pollutants. A combination of deep pond/shallow marsh wetland has effective functions in improving water quality. A deep pond can slow velocity of incoming runoff, promote settling of coarse sediments and aid in even distribution of water across the wetland marsh part. The wetland marsh can provide different water depths and a complex substrate surface, which can increase contact of the runoff with microbes colonizing sediment surfaces and create the shallow flows and meandering flow paths critical to pollutant removal. Their configurations can be designed as the following diagram to achieve the desired effect. (Figure 3.7)

In addition to improving water quality, wet extended detention ponds provide a great chance for multiple benefits: creation of greenspace, wildlife habitat creation, and even educational and recreational opportunities. They can be designed to provide a lot of low-energy

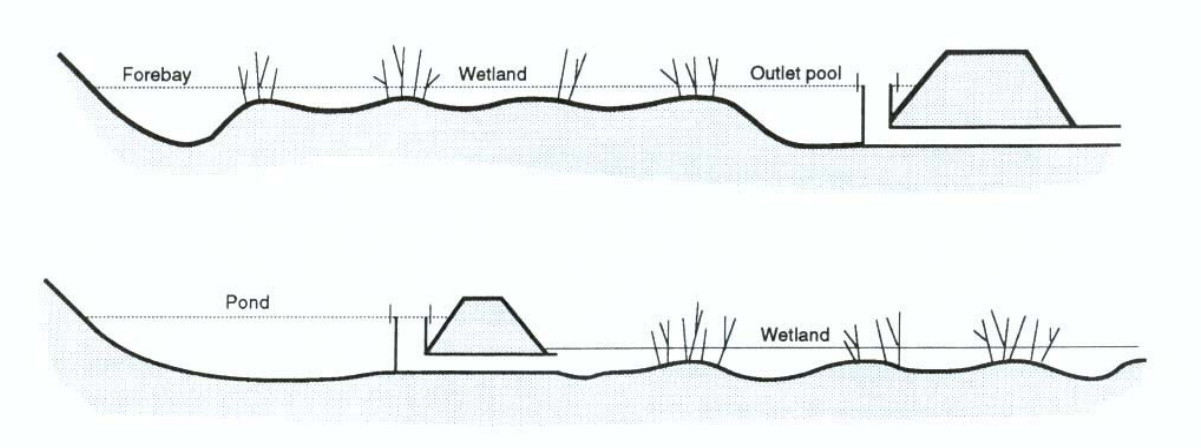

Figure 3.7 Bruce Ferguson, *Schematic configurations of extended-detention basins in profile*: *extended-detention wetland (top) and pond-wetland (bottom).*
Reproduced from Bruce Ferguson, *Introduction to Stormwater* (John Wiley & Sons, Inc),184.

outdoor activities such as hiking, bird watching, or sightseeing. They can also increase property value of the lots around the ponds. So when we design extended detention ponds, multiple functions need to be considered for their success.

Extended detention is designed to improve water quality; however, quantitative certainty of downstream water quality results can't be assured. The degree of effectiveness is influenced by numerous site-specific factors.[11] Furthermore, although extended detention can lessen the peak flood problem, it does not affect storm flow volume. The entire volume running downstream is the same as before. Finally, extended detention, alone, does not significantly address groundwater replenishment or base-flow contribution.

Infiltration and Its Environmental Benefits

Infiltration systems capture water on site and soak water directly into the ground. Unlike detention and extended detention, infiltration discharges water to its natural path in the subsurface, trying to restore a site's hydrological process. It supports groundwater recharge and base flows and improves water quality, aquatic life, and water supplies. By turning the hazard of storm flows into the resource of base flows, it is environmentally the most complete solution to the problem of urban stormwater.[12]

Infiltration begins with porous pavements. Pavements are major surface covers in developed areas. Crushed stone, porous asphalt and porous concrete can be used for parking lots or residential driveways to provide the first step for rain to connect to soil.

Infiltration basins are designed to keep runoff on site for some time and infiltrate it. The time is decided by the basin's depth. Underground basins can be constructed for use where there is no room for open infiltration. Then, the surface of the basin can still be used for parking or recreation. The storage capacity of underground basins is achieved by using open-graded aggregate. The basin can be under porous pavement. According to Thompson and Sorvig, the size of the rubble should be graded, large at the bottom to small near the top. Over the smallest gravel,

several inches of soil are placed to match the original grade.[13] Sometimes the basin's capacity can be supplemented by using perforated pipes or underground chambers.

Another important infiltration facility is vegetated swale. It is used to convey stormwater, however, it moves stormwater runoff as slowly as possible to keep the rain on the site as long as possible and allow it to soak into the ground.[14] Generally swales are wider than they are deep, the water is spread over a broader area and stays longer, which will slow the water and allow the runoff to soak into soil. The vegetation also helps filter the runoff and removes sediments and pollutants. Designed by Murase Associates, OMSI"s bioswales exhibit the functions described above. (Figure 3.8) The gentle sloped swales retain and soak water instead of hurrying it out of

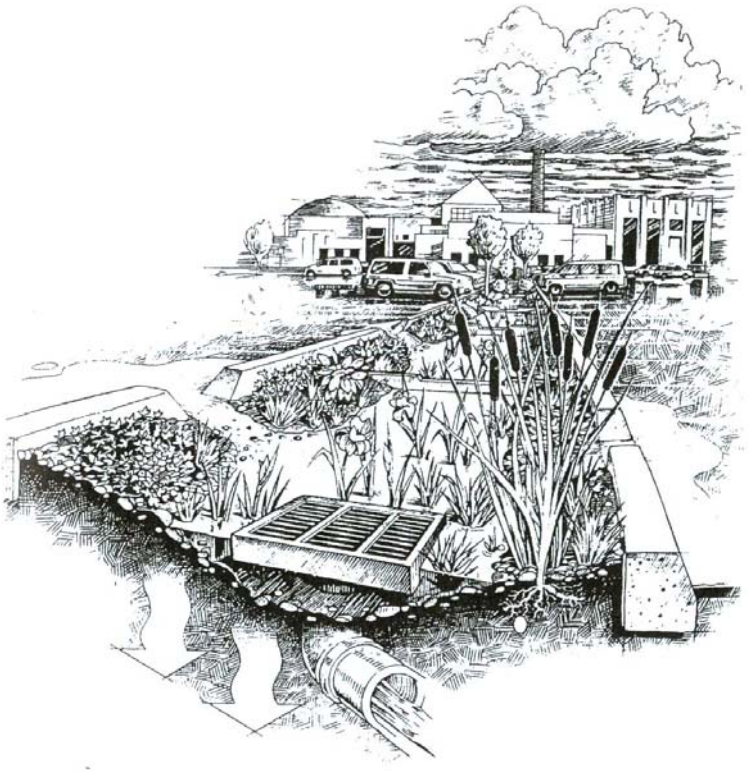

Figure 3.8 Jeff Foster, *Bioswale at OMSI* filters, slows, and infiltrates runoff from parking. Reproduced from J. William Thompson and Kim Sorvig, *Sustainable Landscape Construction* (Island Press), 183.

sight. Check dams slow the speed of water and give it time to infiltrate. Wetland plants such as cattails and yellow iris filter and biologically break down pollutants. These swales improve water quality and look attractive.

When considering infiltration, two things needed to be paid special attention: soil infiltration ability and ground water contamination. To be suitable for infiltration, underlying soils need to have the suitable infiltration ability. So Ferguson suggested design infiltration according to the soil profile. Plan the site of infiltration basin to take advantage of the most favorable horizons in the profile.[15] As for ground water contamination, King County, Washington, requires that one of the following conditions needs to be met: Either runoff must be treated to remove pollutants of concern before infiltration or it can be demonstrated that the basin's soil has the ability to reduce the risk of contamination.[16]

Water harvesting and Its Environmental Benefits

Water Harvesting means collecting runoff from roofs, paved surfaces, and the landscape for direct use. It is a great example of solving the rainwater problem at the source.

Harvested water can be used for irrigation or visual display. The simplest way for irrigation is grading the site to direct water into planted beds or swales. In other situations, it may need more complex systems such as cisterns or tanks to store water for future use. Water harvesting is especially important in those states with dry climates. A great example is found at the Lady Bird Johnson Wildflower Center near Austin, Texas. The water harvesting systems contain four cisterns and two 25,000-galloon fiberglass storage tanks, which collected water from 17,000 square feet of roof area. It can collect about 300,000 gallons of water for site irrigation and aesthetic display.[17]

Harvested rainwater can also be used for drinking water. The water quality needs to be paid special attention. Only water coming from the roof can be used, because water from pavements contains a lot of contaminants such as oils and salts. The water collected from roofs also needs to

be processed by filtration systems before it can be used for drinking water. The systems can be very simple using just gravel, sand, and charcoal to achieve potable quality standards, or more complex ones such as UV sterilization and ozonation.[18] The water cistern or tank also should be made of nontoxic materials such as stainless steel and tile.

Water harvesting is a good example of treating stormwater as a resource instead of a nuisance. The water collected can help maintain and extend urban water supplies and reduce the need for imported water from distant places. It also helps moderate both peak flows and floods by reducing the overall stormwater volume.

How to make it happen

Four kinds of alternative stormwater planning methods have been discussed above. When we deal with realistic problems, these four techniques need to be used wisely to achieve the best results after considering a specific site situation. One technique may be used as the main method, with others used as supplement measures. The main goal is to solve the stormwater runoff at the source by imitating the natural hydrology system. Two examples are provided here to illustrate this: one is Village Homes, the other is Hunter Park.

Village Homes is a great example of how site-sensitive open drainage can be successful. It was designed by Robert Thayer and colleagues for developer Michael Corbett in Davis, CA, USA in 1975. The natural drainage system was one of the most difficult innovations to get approved.[19] The city's Planning Building and Public Works Department were strongly against it, and the FHA even refused to approve it despite of its obvious environmental advantages. But the success of the open drainage system of Village Homes demonstrates its validity. At village Homes, the lots are graded towards attractive and meandering vegetated swales instead of the street, so that rainwater from roofs and lawns can be directed into the creeks. (Figure 3.9) These creeks are landscaped elements with rocks, bushes, and trees. The water flows slowly in these vegetated swales and

Figure 3.9 *Cross Section of a common area and drainage swale in Village Homes*, Reproduced from Judy Corbett and Michael Corbett, *Designing sustainable communities: learning from village homes* (Island Press, 2000), 44.

some of it infiltrates in the stream. Check dams made of wood help to slow the flow of the water and prevent surges downstream. Some wet detention ponds detain water on-site and lessen the flow volume and provide beautiful landscapes to the residents of Village Homes. (Figure 3.10)

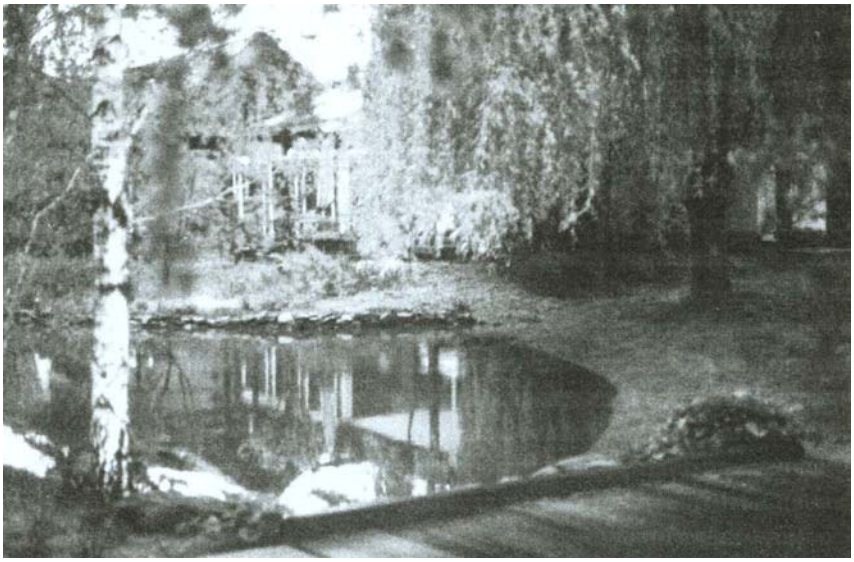

Figure 3.10 *Ponds in Village Homes allow Rainwater to be absorbed*, Reproduced from Judy Corbett and Michael Corbett, *Designing sustainable communities: learning from village homes* (Island Press, 2000), 47.

This open drainage system can absorb the runoff from a 10-year storm on-site and contribute a lot to solve downstream floods. The vegetated swales and the wet detention ponds also help to improve the water's quality by removing pollutants and soil particles. Allowing the soil to infiltrate water significantly reduces the irrigation need for plants. This open drainage system provides beautiful landscape and great experience of water to residents when it rains. It even helped the developer save about $800 per lot by avoiding construction of a storm sewer system.[20]

The drainage system at Hunter Park in Pittsburgh provides another ideal example although it is only hypothetical. In October of 1998, the STUDIO for Creative Inquiry and Rocky Mountain Institute hosted an interdisciplinary design charrette to envision and illustrate measures to redevelop streetscapes, parks, and properties in the watershed of Nine Mile Run in Pittsburgh, USA by using stormwater techniques. Hunter Park is a neighborhood park which lies near the headwaters of the watershed. The surrounding blocks are mostly covered by impervious streets, sidewalks, and roofs. Most of the runoff from the impervious surfaces is connected directly into the urban sewers and causes problems of sewer overflows, water pollution, and reduced base flow.[21] Solving runoff at Hunter Park would contribute to cleaner water and less flood downstream in the Nine Mile Run watershed.

The proposed drainage system uses almost all alternative stormwater strategies to filter, detain and infiltrate runoff to solve the flood problems and improve water quality. (Figure 3.11) The first step is to reduce impervious cover and allow infiltration by narrowing street pavements and using permeable edges. (Figure 3.12) The rainwater from roof leaders, street gutters, and drainage inlets is disconnected from stormwater sewers and diverted into vegetated swales in and around the park. At the upper part of the park, a woodland biorentention area, consisting of sand and soil mixtures and native plants, dissipates the energy of runoff and collect coarse sediments. After that, the rainwater flows into a constructed wetland, where the water pollutants get filtered and some water will be detained. Overflow drainage from the wetland will flow into a vegetated

Figure 3.11 The Nine Mile Run Ecosystems and Infrastructure Charrette, *Plan for Hunter Park*, Reproduced from Bruce Ferguson, Richard Pinkham, and Timothy Collins *Restorative Redevelopment: The Nine Mile Run Model* (Rocky Mountain Institute), 9.

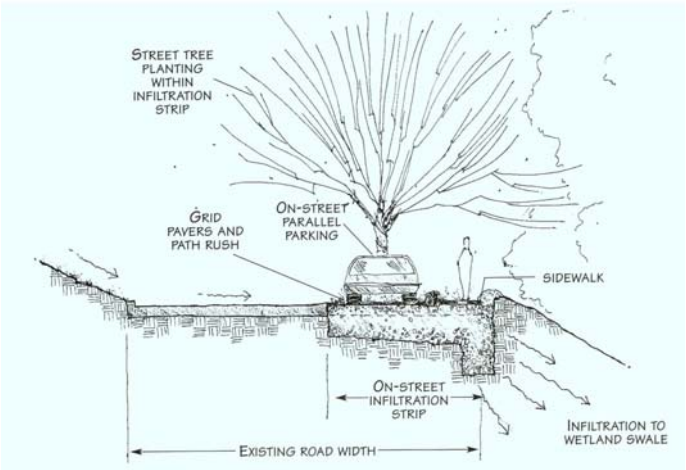

Figure 3.12 The Nine Mile Run Ecosystems and Infrastructure Charrette Team, *Proposed Pervious Parking Strip* , Reproduced from Bruce Ferguson, Richard Pinkham, and Timothy Collins *Restorative Redevelopment: The Nine Mile Run Model* (Rocky Mountain Institute), 11.

swale, which will filtrate the pollutants with its vegetation and further infiltrate the runoff by using specially constructed stream beds. (Figure 3.13) At the bottom of the park, a public square will be constructed in the area where shanty houses once stood. As a community center, the plaza borders on a daylighted (reopened) stream, which will provide aesthetic beauty and educational opportunity to the public. In all, the design for Hunter Park detains, treats and infiltrates stormwater from the park and adjacent communities. It solves problems such as floods and groundwater recharge, improves water quality, and provides aesthetic beauty and educational opportunity to the public.

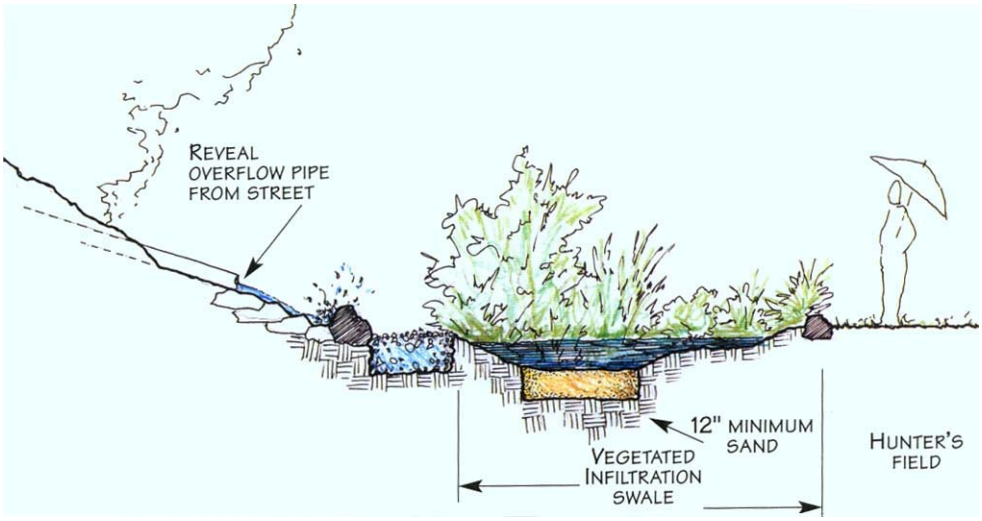

Figure 3.13 The Nine Mile Run Ecosystems and Infrastructure Charrette Team, *Construction of Hunter Park's swales for stormwater infiltration, storage, and water-quality improvement,* Reproduced from Bruce Ferguson, Richard Pinkham, and Timothy Collins *Restorative Redevelopment: The Nine Mile Run Model* (Rocky Mountain Institute),10.

The above two examples demonstrate some principles which make a successful open drainage system dealing with stormwater. First, minimize development impacts to stormwater by wise planning, which includes reducing imperviousness, conserving natural resources and

ecosystems, and reducing use of pipes. Secondly, mimic natural hydrology systems by using detention, extended detention, infiltration, and water harvesting. This will reduce flood problems, improve water quality, groundwater recharge, and create biological habitat. Finally, runoff should be dealt with at the source, which means on-site. Because the further stormwater travels, the faster it moves, and the more it accumulates, the worse effect it causes. So it is most easily and economically achieved at the place where runoff begins.

[1] Julius Gy. Fabos, Gordon T. Milde, & V. Michael Weinmayr, *Frederick Law Olmsted, Sr. Founder as Landscape Architecture in America* (The University of Massachusetts Press, 1968), 59.

[2] Ian L. McHarg, *Design With Nature* (Eugene Feldman, The Falcon Press, Philadelphia),104.

[3] Kathleen Webb Tunney, "Innovative Stormwater Design: The Role of the Landscape Architect*", Stormwater Magazine*, Volume 2 Number 1, (January/February 2001).

[4] Bruce Ferguson, *Introduction to Stormwater,* (John Wiley & Sons, Inc.),191.

[5] Larry Coffman, Low Impact Development: A New Stormwater Management Paradigm Micro-Scale Source Management, *http://www.gsd.harvard.edu/news/conferences/watersymp/*

[6] Ferguson, *Introduction to Stormwater,* 149.

[7] Ferguson, *Introduction to Stormwater*, 165.

[8] William Macelroy and Daniel Winterbottom, "Stormwater Ponds*", Landscape Architecture, 4/2000*, 54.

[9] Ferguson, *Introduction to Stormwater*, 179.

[10] Macelroy and Winterbottom, "Stormwater Ponds*",* 54.

[11] Ferguson, *Introduction to Stormwater,* 187.

[12] Ferguson, *Introduction to Stormwater,* 191.

[13] J. William Thompson and Kim Sorvig , *Sustainable Landscape Construction*, (Island Press), 157.

[14] Thompson and Sorvig , *Sustainable Landscape Construction*, 182.

[15] Ferguson, *Introduction to Stormwater*, 199.

[16] Macelroy and Winterbottom, "Stormwater Ponds*",* 54.

[17] Daniel Winterbottom, "Rainwater Harvesting*", Landscape Architecture 4/2000*, 40.

[18] Winterbottom, "Rainwater Harvesting*",* 46.

[19] Judy Corbett and Michael Corbett, *Designing sustainable communities: learning from village homes* (Island Press, 2000), 45.

[20] Corbett, *Designing sustainable communities: learning from village homes,* 47.

[21] Bruce Ferguson, Richard Pinkham, and Timothy Collins, "*Restorative Redevelopment: The Nine Mile Run Model* " Volume 2,Number 5 (July/August 2001).

CHAPTER 4

INSPIRATION FOR STORMWATER MANAGEMENT DESIGN IN THE UNITED STATES

Introduction

As discussed in the second chapter, the second part of the new aesthetic in America is the environmental art movement and ecological design, which provides a lot of inspiration and good examples on how stormwater can be used as a design element. The environmental art movement which originated in the seventies has provided a lot of works, which, although for the most part symbolic, express provocative themes of control of and/or interaction with natural systems. Later, the ecological artists have emphasized not only the connection of nature and culture, but also the engagement of natural process and culture's capacity to heal stressed ecosystems. Four examples which demonstrate how to combine art with stormwater design will be discussed.

Environmental Art

Historic context

Environmental art is an art movement which started in the late 1960s. As a rebellion against traditional art which expressed the relationship between people and nature through painting or sculpture, this group of artists began to seek inspiration from nature and try to interpret its life-generating forces to create radically new kinds of art. "Rather than representing it in paint on canvas, a handful of artists chose to enter the landscape itself, to use its materials and work with its salient features. They were not depicting the landscape, but engaging it," John Beardsley observes, "Their art was not simply of the landscape, but in it as well."[1] The main explorers are represented by Michael Heizer, Robert Smithson, Nancy Holt, and Robert Morris. Many of them

began to work in the desert of the American West, because it gave those artists freedom and space to work. They try to "articulate, even to shape, the contemporary relationship to nature."[2] Their works often try to interpret specific environmental problems, as well as the forces and phenomena of nature. By visualizing the forces, processes, and phenomena of nature: organic growth, light, water, crystals, and other elements, nature was interpreted "as alive and constantly changing through an art that mirror its cycles and rhythms."[3] Environmental art not only provides a new way of creating art, but also calls attention to nature itself. This is a great innovation in the history of art.

One thing that needs to be said is that environmental art is a broad and vague classification. It may be called "earthworks, earth art, or even ecological design",[4] which might be applied at different times to specific groups within the larger class. Here, the earthworks of environmental art will be discussed mainly. It included both permanent sculptures like the *Spiral Jetty* and the temporary site-specific sculptures such as *The Running Fence*. These works will be discussed in the following parts.

Double Negative

Michael Heizer is an important figure in the environment art movement. He thought that the art world was afflicted with a too grand preciosity, that artworks were valued only as commodities for the elite.[5] Trying to change this phenomenon, he began to walk into the desert to begin his exploration. One of the important artworks he created is *Double Negative*: 50 feet deep, 1500 long two cuts in the mesa surface facing each other across a deep indentation in the escarpment at Nevada, USA. (Figure 4.1) It didn't occupy space; actually it composed space itself. The two sunken spaces correspond to each other, providing a different experience from the old sculptures which occupy and intrude on the space. At the same time, the sculpture also echoes with the distant river, which is surrounded by greenery and contrasts powerfully with the desert. (Figure 4.2) When people get into the space, they experience different perceptions of changing

light and shifting space, and the power of nature. The light crashes down and transfigures the art piece and creates an ancient scared experience, and brings to mind Heizer's almost religious vision of art.

Figure 4.1 Michael Heizer, *Double Negative,* Reproduced from Gilles A. Tiberghien, *Land Art* (Princeton Architectural Press), 93, fig.4.

Figure 4.2 Michael Heizer, View from *Double Negative,* Reproduced from Gilles A. Tiberghien, *Land Art* (Princeton Architectural Press), 93, fig.3.

Spiral Jetty

Robert Smithson began his career as minimalist. Environmental art is a logical extension for him. *Spiral Jetty* is one of his main environmental artworks. *The Spiral Jetty* was constructed in the waters of the Great Salt Lake, Utah, USA. Smithson was drawn to the site by the knowledge that it contained a micro-organism that colored the water pink. Using black basalt rocks and earth from the site, the artist created a spiral of 1500 feet long and 15 feet wide that stretches out into the translucent red water. The artistic contrast between the pink water, white salt crystals, and black basalt boulders achieves a strong effect, which is really site-specific. (Figure 4.3) The spiral shape is also one of nature's most fundamental forms. The *Spiral Jetty* shows nature's effect from the crystallization of salt on the layers of rock, which indicates the dimension of time. Catherine Howett thought that the *Spiral Jetty* "was meant to serve as a crucible of human engagement with both natural and cultural processes at work in that place over long eons of time."[6] Beardsley also thinks *Spiral Jetty* "provides a particularly lucid example of this correspondence between art work and site."[7] The water level of the Great Salt Lake has risen and submerged the piece. It surfaced several times after 1970. The artist indicated his desire to rebuild the work and make it taller before his death.

Figure 4.3 Robert Smithson, *Spiral Jetty,* Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 15.

Running Fence

Compared to *Spiral Jetty*, Christo's *Running Fence* is more temporary and public. However, they are both monumental and reflect their sites' character. *Running Fence* is an 18-foot-high nylon fabric which extends across 24.5 miles of farmland in Sonoma and Marin counties in California, USA. By changing its forms, colors, and texture, which is in response to the site's atmospheric conditions, *Running Fence* successfully defines the California landscape. It also reveals the regional contour by winding its way through the landscape. (Figure 4.4) *Running Fence* connects the landscape to its borders: to the sea "by extending like a fold in the flow of a wave", and to the sky "by making the horizon mobile".[8] (Figure 4.5) In this sense, it unites the landscape, and ignores all boundaries which are created by humans.

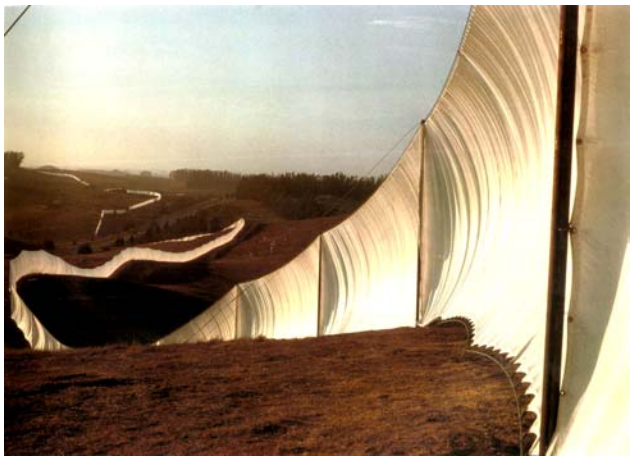

Figure 4.4 Right: Christo, *Running Fence,* Reproduced from Gilles A. Tiberghien, *Land Art* (Princeton Architectural Press), 207.

Figure 4.5 Left: Christo, *Running Fence,* Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 32.

Running Fence achieved great exposure through a lot of pubic participation. "Eighteen public hearings were held; three sessions in the Superior Courts of California were devoted to the project; and 450 pages of environmental impact statements were prepared."[9] Just as paying attention to its relationship to nature, Christo showed equal interest in the complex negotiation process involved in implementing his work. These pubic participation processes are "the cultural structures that help determine the visible form of human interventions in the landscape".[10] This kind of publicity helps to make the artwork known to a large number of people and provides them a great chance to experience the grandeur of nature and art.

Sun Tunnels

Nancy Holt's *Sun Tunnels* demonstrated another way to connect people to nature. By framing such phenomena as the summer solstice sunrise and sunset, she successfully awakes our relationship to the source of life – the sun.

This artwork is constructed in the desert landscape near Lucin, Utah, USA. Consisting of four concrete cylinder pipes, *Sun Tunnels* is aligned to the rising and setting of the sun on the summer and winter solstices. At sunrise and sunset on the summer and winter solstices and for about ten days before and after, the sun can be seen through these pipes. (Figure 4.6) In addition to this connection to nature, holes are cut through the pipes according to four constellations: Draco, Perseus, Columba, and Capricorn. During the day, the sun's rays penetrate the pattern of holes, and create beautiful configurations of the constellations on the bottom of the tunnel, as spots of starlight. (Figure 4.7) Holt thought, in *Sun Tunnels*, "Day is turned into night, and an inversion of the sky takes place: Stars are cast down to earth, spots of warmth in cool tunnels." [11] It poetically strengthens the experience of time and the perception of nature.

Sun Tunnels also provides a comfortable shelter from the wind or sun of the hot desert. In addition to that, it provides visitors a "locator" in the desert. [12]The landscapes are organized

around these four pipes. Beardsley thought that "*Sun Tunnels* are a dignified yet humanly scaled setting in which to experience the grand awfulness of the natural surroundings."[13]

Figure 4.6 Nancy Holt, Sunset, summer solstice, *Sun Tunnels,* Reproduced from Gilles A. Tiberghien, *Land Art* (Princeton Architectural Press), 149.

Figure 4.7 Nancy Holt, Viewed from the darkened interior of one of the tunnels, *Sun Tunnels,* Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 35, fig.27.

Characteristics of Environmental Art and Criticism

The environment art movement encouraged people to take a fresh look at the relationship between art and nature. For example, *Sun Tunnels* strengthened people's perception about sun by providing an art piece for people to experience directly and feel strongly, and *Running Fence* reveals regional topography and climate by providing a spectacle of landscape. By working directly with nature, these artists awakened and strengthened people's sense of nature. Nature was no longer thought as a static landscape which is expressed only in static painting. These environmental artists interpreted nature as alive and visualize nature's forces and processes to depict specific landscapes. Accordingly, they create a lot of site-specific landscapes.

The environment artists also gain freedom by going outside the gallery and achieve greater visual exposure to the general public instead of only to the elite. Most of the environmental artworks can't be purchased, so the public have a better chance to see them. Some environmental artists even thought public participation was an important aspect of their works. For example, *Running Fence* mobilized hundreds of workers, engineers, and advisers to work on its installation and achieved great visual publicity.

However, a lot of environmental artworks are not really environmentally sound. Heizer's *Double Negative* and Smithson's *Spiral Jetty* required extreme manipulations of nature by bulldozing and disturbing the earth. These works are also criticized for their ignoring of life-support systems and natural processes at the site.[14] Some of environment artworks didn't respect nature; their aesthetic is expressed by showing their control of nature. This can be seen from artists' preference to create works in highly disturbed sites such as mining pits. Deserts have also been selected by artists who may not understand the ecology of the environments.

Positive Change

Although most of the environmental artists can be criticized for their ignorance of and insensitivity to the ecological complexity of a site and the natural processes, some are an

exception. Among them are Richard Long, Hamish Fulton, and Andy Goldsworthy. Their works displace a sensibility to environment and barely intrude into the landscape. Beardsley thought that "Fulton made no mark other than footprints and took nothing but photographs."[15] Long organized landscape elements such as rocks and sticks in very sensitive ways. (Figure 4.8) Goldsworthy created beautiful and temporary landscape which shows people's respecting of nature instead of controlling it. (Figure 4.9) Together, their work represents the beginning of a more sensitive and ecologically responsible art movement, which might be called ecological art.

Ecological Art

Historic context

The development of ecology has provided a unique and useful perspective for people to understand nature better. Some artists began to explore "art that functions for environment awareness, improvement, or reclamation by transforming wastelands, focusing on natural history,

Figure 4.8 Richard Long, *A Line in Scotland, CulMór,* Reproduced from John Beardsley, *Earthwork and Beyond* (Abbeville Press), 43, fig.36.

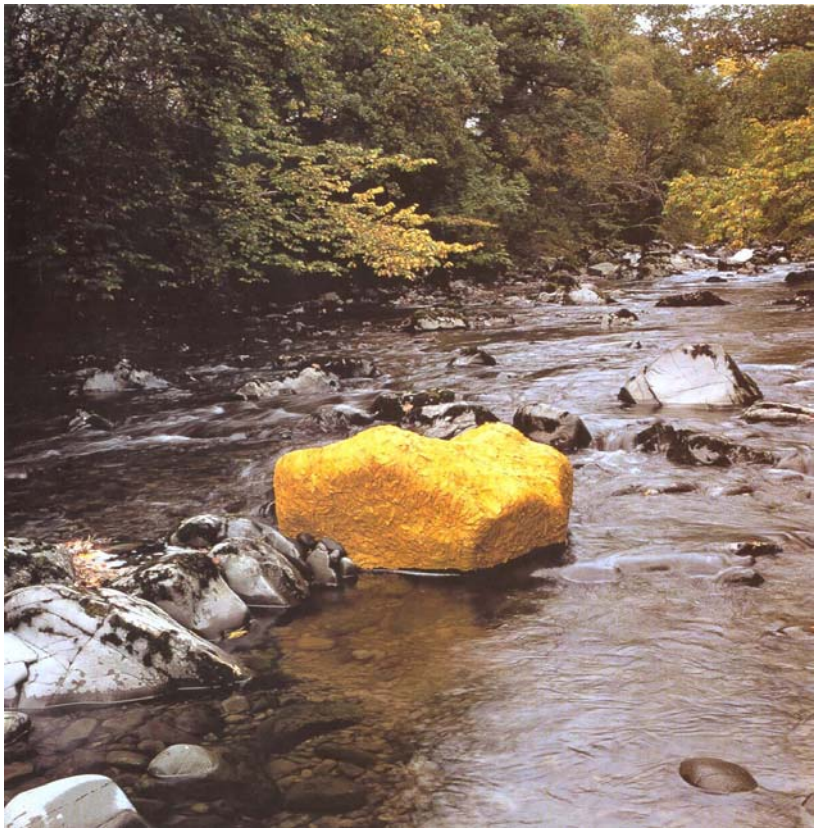

Figure 4.9 Andy Goldsworthy, *Yellow Elm Leaves Laid Over a Rock, Low Water,* October 15, 1991. Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 53.

operating utilitarian sites, making parks, and cleaning up pollution."[16] In 1992, Barbara Matilsky curated an exhibition called *Fragile Ecologies,* which took a retrospective look at a number of major artists such as Alan Sonfist and Mel Chin who focus on this direction. Matilsky named this art ecological art. This exhibition traveled to many regions of this country after its initial exhibition at Queens Museum of Art in New York City and reached a large audience. Matilsky thought that the artists "propose or create ecological artworks that provide solutions to the problems facing natural and urban ecosystems."[17] These diverse artworks emphasized not only the connection of nature and culture, but also the engagement of natural process and culture's capacity to heal stressed ecosystems.

Rhinewater Purification Plant

Hans Haacke began working with natural materials and processes in the mid-1960s. His artworks include making ice sculptures or using water to create mist and erosion. At the beginning of the seventies, however, Haacke began to concentrate on "revealing the detrimental impact of human actions on the natural systems".[18] Two years later he made an artwork called *Rhinewater Purification Plant* at the Museum Haus Lange, Germany to display the Krefeld sewage plant's discharge, which is officially treated enough to return to the Rhine River. By showing the murky water from the plant in large glass bottles, Haccke brought people's attention to the plant's role in degrading the river. The water was then treated, filtered, and released into a rectangular tank containing goldfish. The surplus water is used to water the museum's garden.

Matilsky observes "the presence of a large fish bowl and the picture-window view into the wooded landscape served as a point of contrast between a life-supporting ecosystem and one on the verge of collapse."[19] (Figure 4.10) This work is "a political and ecological statement" and Haacke was though of as "one of the first artists to focus on nature's processes and systems."[20]

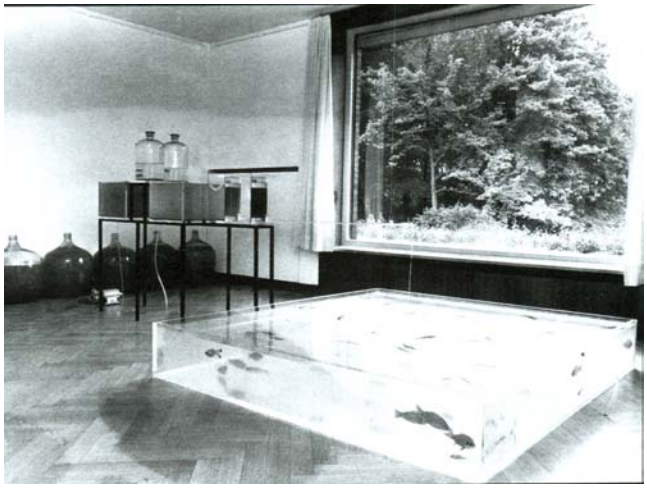

Figure 4.10 Hans Haacke, *Rhinewater Purification Plant,* Reproduced from Barbara Matilsky, *Fragile Ecologies* (Rizzoli International Publications, Inc.), 41.

Time landscape

Since the mid-sixties, Alan Sonfist has been concerned with achieving public awareness of ecological issues in his works. He tried to use his work as a dialogue with society to make the experience of aesthetics accessible to common people. While still in his teens, he tried to work out a plan called *Time Landscapes*. The purpose of this artwork is to return some metropolitan areas to their natural conditions prior to settlement by planting native trees and vegetation. But Sonfist does not want to simply create a beautiful park or forest; he creates a living artwork, a monument to nature's process. This work emphasizes nature's ability to rebuild itself. The artist believes that "nature deserves to be resurrected and commemorated in much the same way as the heroes and events that have shaped both human and natural history."[21]

Sonfist's first *Time Landscape* is realized in Greenwich Village, New York, USA. (Figure 4.11) Sonfist reclaimed an urban wasteland and planted a tangle of pre-Colonial plants to create a

Figure 4.11 Alan Sonfist, *Time:Greenwich Village, New York,* Reproduced from Barbara Matilsky, *Fragile Ecologies* (Rizzoli International Publications, Inc.), 82.

glimpse of Manhattan as image before Europeans arrived on the continent. Now the *Time Landscape*: *Greenwich Village, New York* has grown and kept on changing itself. Art and nature become indistinguishable from each other and the artist's identity disappears. Using very simple measures, Sonfist successfully makes the public aware of nature's existence. The artist expresses "a message that the survival of civilization depends on its coexistence with natural systems." [22]

Revival Field

Compared to the above two examples, Mel Chin's *Revival Field* in 1991 "made a significant contribution to both ecology and the evolution of ecological art" by showing how certain plants help to extract toxic heavy metals from contaminated soil. [23] Catherine Howett thought *Revival Field* did "attempt to offer real solutions, practical or theoretical, to problems facing a particular ecosystem."[24]

After researching the work of Rufus Chaney, Senior Research Scientist at the Department of Agriculture, Chin began to conceive a plan to demonstrate Chaney's theory at a Landfill in St. Paul, MN, USA. With the cooperation of Chaney, Chin chose six hyperaccumulators—plants that selectively absorb heavy metals from toxic soils as they grow—to plant at a 3600 square feet section of landfill. The landfill is contaminated by such heavy metals as cadmium that have seeped out of used batteries. The selected plants are planted in a circle field, which is fenced in with chain link and subdivided by two walkways. (Figure 4.12) Beardsley thought the composition did "evoke the crosshairs on a rifle scope and suggesting that the earth was targeted for restoration."[25] At the end of growing seasons, Chin and his assistants harvested the plants and then analyzed them for the presence of heavy metals. (Figure 4.13) The result demonstrated the plant's ability to remove contaminants from soil, although its effect is not as strong as Chin thought before. [26] In this work, "art and nature become inseparable" and a unique approach is used to reflect "the processes, life forms, and physical configurations of the planet".[27]

Figure 4.12 Mel Chin, *Revival Field ,* Reproduced from Barbara Matilsky, *Fragile Ecologies* (Rizzoli International Publications, Inc.), 110, fig.98.

Figure 4.13 Mel Chin, View during first harvest, *Revival Field ,* Reproduced from Barbara Matilsky, *Fragile Ecologies* (Rizzoli International Publications, Inc.), 111.

Characteristics of Ecological Art

The ecological artists have shown three strong characteristics in their design. The first one is their choosing of sites. Because ecological artists try to mitigate environmental problems and educate people about the relationship between human and nature, they have generally chosen sites located in or near large metropolitan areas. Sonfist's *Time Landscape*: *Greenwich Village, New York* is a good example. Because of the easy access to the public, how damaged habitats or sterile urban sites are transformed into life-generating places is exhibited vividly to the public. Their goal to "propose or create ecological artworks that provide solutions to the problems facing natural and urban ecosystems" can be achieved for the best result. This is an improvement to environmental artists, who located their artworks in remote places such as deserts.

The second characteristic shown in ecological art is its interdisciplinary problem-solving. Because ecological artists need to resolve a total network of relationships rather than isolate and interpret one aspect of nature, they need collaboration with other disciplines. For example, in his *Revival Field*, Chin cooperated with Chaney, an agronomist at the U.S. Department of Agriculture, to create the artwork for testing the plant's ability to remove contaminants from soil. The ecological art gets more community involvement than environmental art because their sites and subjects are close to the public. Matilsky observes "ecological art has become a catalyst for a heightened awareness of nature as well as a model of interdisciplinary problem-solving."[28]

The third, and the most important characteristic of ecological art, is its effort to connect culture and nature. Trying to address the processes of organic growth and other natural phenomena in urban situations, the ecological artists successfully celebrated nature process and ability to the public. Their work concentrated more on nature's ability than the artist's character. Sonfist's *Time Landscape* let native shrubs and trees grow by themselves, while Chin's *Revival Field* used plant's ability to remove contaminants from soil. This emphasis on nature process and change is reflected in Tamara Graham Calabria's observation that "the ecological artwork is open to the change and flux introduced by a particular environment, whether it is in the form of the

accommodation of natural process or the response of viewers."[29] Matilsky thought ecological art "consummately expresses the process of creation by enhancing the foundations of life."[30]

The Art of Stormwater Design

Art + stormwater design

Tamara Graham Calabria thinks that there are three levels of stormwater design. In the highest level : "physically, the feature may cleanse the waters of impurities, encourage its infiltration into the ground to replenish groundwater supplies, or direct its flow to vegetation which returns it to the atmosphere through evapotranspiration; symbolically, the feature reveals the interconnection between nature and culture by engaging the site, and by so doing it hermeneutically reveals to visitors aspects of this complex relationship, ideally giving them a stronger sense of continuity with nature." [31] Robert Thayer also wanted to change "the obfuscation of ecological clarity by technology". He thought "in the ordinary landscape, the instances in which intentional land design aims at a higher, symbolic meaning and embodies that meaning in some decipherable form are few when compared with the countless millions of 'ordinary' landscapes structured by the dominant, operative, contemporary technological paradigms." [32]How to make landscape design, which can express the idea of natural process, be aesthetically beautiful, and meet the social function, is a very meaningful exploration in stormwater planning and design. The following four examples illustrated aspects of potential answers.

Mill Creek Canyon Earthworks

Designed by Herbert Bayer, *Mill Creek Canyon Earthworks* is located in the downstream canyon of the rapidly developing East Hill area of Kent, Washington, USA. It is conceived as part of a statewide project *Land Reclamation as sculpture*: where eight different artists contributed

designs in different areas for the reclamation of environmentally damaged sites. Occupying a 2.5-acre portion of a 96-acre city park, this artwork is supposed to control flooding, restore fish runs, and create a beautiful place for the public.

One main goal of designing *Mill Creek Canyon Earthworks* was to solve the flood problem. The slopes and shapes of the landforms are designed to hold the water on site for some time. Consisting of a ring pond; a ring mound bisected by the creek, two concave and convex mounds, and a cone, the system of stormwater management is created in a beautiful art form. (Figure 4.14) The image of the environmental artwork changes with different depths of water. The storms create a dynamic relationship "between positive and negative form, water and land, solid and void."[33] The whole site is designed to hold 652,000 cubic feet of stormwater, which is equal to one foot deep water in a 15 acre area. The landforms are designed to be experienced for the enjoyment of the visitors, providing different kinds of spatial enclosure and lots of activities such as families picnicking, sunning, children playing, and walking. (Figure 4.15) A vegetated swale is devised to collect and move runoff from the lawn, which makes the natural process of stomwater flow visible to the public. C. Timothy Baird thought by showing "the natural process of stream flow, surface runoff, and the rise and fall of flood waters", Bayer successfully connected nature and culture. [34] The success of this project offers a solution to create both aesthetically beautiful and functionally workable landscape. It is a great design which combines stormwater management, public art, and human use.

Surely, there are still some things that the artists can do to make his work more environmentally sensitive, such as using permeable pavements, native plant species, or infiltration basins and swales that encourage infiltration.

Figure 4.14 Herbert Bayer, *Mill Creek Canyon Earthworks,* Reproduced from Barbara Matilsky, *Fragile Ecologies* (Rizzoli International Publications, Inc.), 46.

Figure 4.15 Herbert Bayer, *Mill Creek Canyon Earthworks,* Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 93, fig.91.

Renton Waterworks Gardens

Designed by Lorna Jordan, an artist, *the Renton Waterworks Gardens* is located on the property of the East Division Water Reclamation Plant in Renton, Washington, USA. Much of the property and surrounding areas were historically part of the Black River floodplain. Collected stormwater from 50 acres of roads and parking lots is purified and filtered in a series of beautiful gardens. Beardsley appraised the project in these terms: it "turned the stormwater problem into an attractive public environment enriched with a subtle narrative."[35]

The *Renton waterworks Gardens* is composed of five garden rooms: The Knoll, The Funnel, The Grotto, The Passage, and The Release. The five gardens created a flowering plant shape in plan, which "conveys a story about the filtering power of plants to cleanse water." [36] (Figure 4.16) Beginning with the Knoll, the polluted stormwater is collected and pumped to the top of the Knoll, where it enters the site to begin its purification journey. After that, the stormwater is transported into the Funnel, where the stormwater's sediment is deposited in six leaf-shapes ponds. A fantastic mosaic-tiled garden room called the Grotto provides more interest to the journey. (Figure 4.17) The grotto is historically linked to sacred springs in Renaissance gardens; here, it symbolizes the rebirth of degraded water. [37] The Passage gives the stormwater another chance to deposit itself. Finally, after the coarse particles of stormwater are settled down, they are drained into the last garden room-the Release, where a braided wetland system makes the last step to purify the water and also prevents flooding during storms. The purified stormwater is discharged into Spring-brook Creek gradually.

By solving both water purification and peak storm flows, the waterworks gardens exhibit the stormwater purification process in an aesthetically beautiful manner. Using a lot of symbolic meaning and classical themes, the artist gave the artwork a strong meaning. Michael Leccese thought that Jordan "created a modern ecological experience" and "a place where industry and nature have to meet". [38]

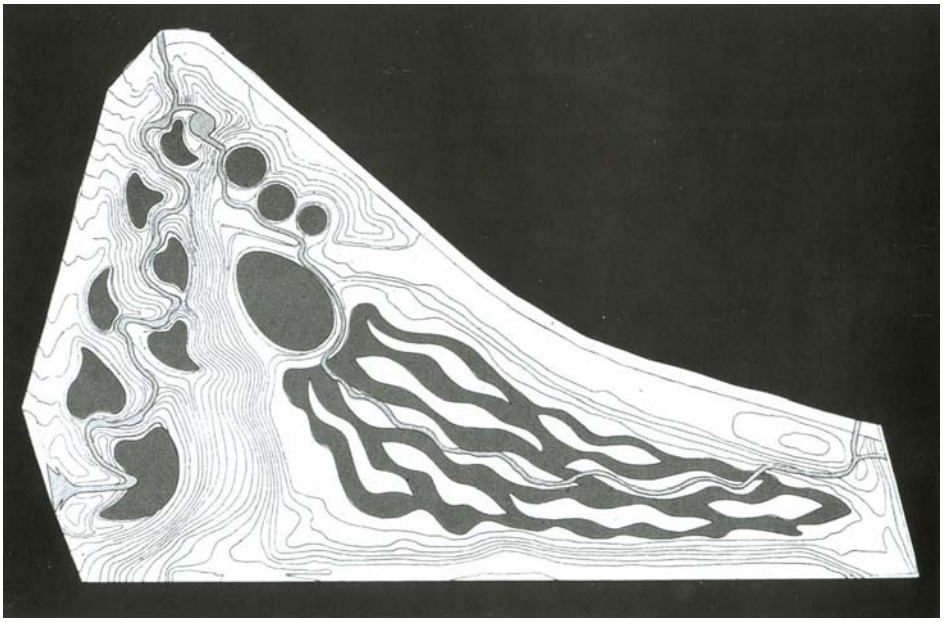

Figure 4.16 Lorna Jordan, Plan for *Renton waterworks Gardens,* Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 176.

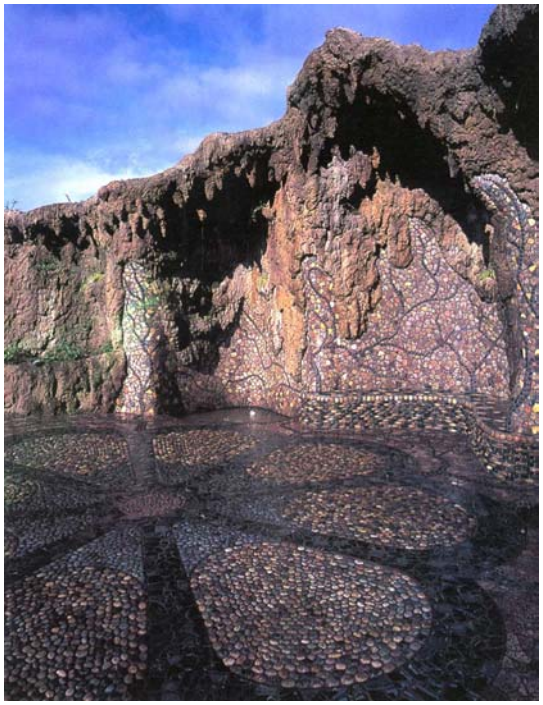

Figure 4.17 Lorna Jordan, *Renton waterworks Gardens:The Grotto,* Reproduced from John Beardsley, *Earthworks and Beyond* (Abbeville Press), 175.

There are two minor drawbacks of the design. One is that stormwater is pumped into the site instead of flowing into the site naturally; the other is infiltration can be used to solve the flood control better.

Kelsey-Seybold Clinic Landscape

Scott Slaney, a landscape architect of The SWA Group, designed the *Kelsey-Seybold Clinic landscape* in Houston, Texas, USA. This project created both functional and meaningful landscape. Functionally, the designed landscape would "allow for the interaction of patients, family and friends, doctors and caregivers within the natural environment" and solve the stormwater flood problem on site. Symbolically, the landscape would "recall native Texas landscapes and evoke the natural healing associate with water."[39] (Figure 4.18)

The Kelsey-Seybold Clinic has a 250,000-square-foot central facility, which required a public open space to provide identity, easy access, clear wayfinding, and more than 1,200 parking spaces. Because of the region's annual 40 inches of rain, most of which is stormwater, the landscape needs to resolve the stormwater floods on site. A previous proposal was to build an underground 12 x 12 x 1,000 foot box culvert to detain water underground. The cost for the system would be one million dollars, nearly half of the site development budget. By combining the landscape with a surface basin, the design functions the same and cuts the budget in half.

The main landscape is composed of a large lawn dominated by a single live oak, a detention basin, a circular pool with jetted fountain, and a stream connecting them. (Figure 4.19) In dry weather, the city water recirculates from the fountain to the basin via the stream. In wet weather, the detention basin holds stormwater on site. The landscape not only solves the flooding problem, but also has important meaning behind it. "The fountain was suggested by a rock dome considered sacred and healing by the region's Indians. The oak-lawn evokes The Texas hill country savanna. Human geometry suggests order."[40] The landscape provides a great public space for the interaction of doctors, patients, and family and friends. People may wonder why Slaney

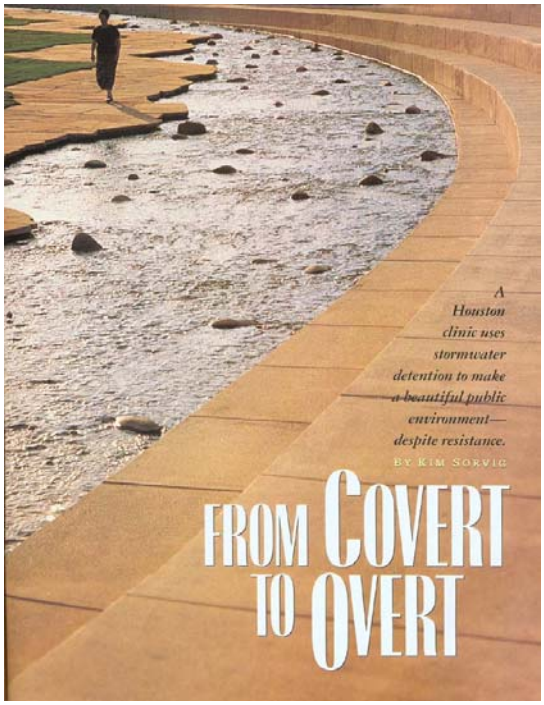

Figure 4.18 Scott Slaney, *Kelsey-Seybold Clinic landscape,* Reproduced from Kim Sorvig, *From Covert to Overt,* Landscape Architecture, 5/2000, P67

Figure 4.19 Scott Slaney, *Kelsey-Seybold Clinic landscape,* Reproduced from Kim Sorvig, *From Covert to Overt,* Landscape Architecture, 5/2000, P69

used detention, instead of infiltration, as the main stromwater management method in this design. The answer is Houston's clay soil, of which Ferguson said "infiltration of large amounts of water into this types of soil for flood control is out of the question." [41]

Water Pollution Control Laboratory

Designed by Murase Associates, the landscape of the *Water Pollution Control Laboratory* at Portland, Oregon has provided another great example of how to combine stormwater with an art solution. The laboratory was established to monitor the quality of Portland's water, and to educate the public on the use of natural systems to mitigate pollutants from stormwater runoff. The research concept was applied to the six-acre site's outdoor design which shows how stormwater may be treated to improve its quality. It educated the public how the landscape functions to filter polluted water, and provided them with beautiful landscape. According to Richard Hansen, a Colorado based landscape sculptor and landscape architect, these aspects of the landscape design "are starting to deal with how the water comes in and goes out. It seems like a better interweave—a sculptural presence integrated with an ecological process."[42]

The stormwater enters the site from a stone-lined, curving concrete flume. The stones in the flume dissipate the water's energy and allow pollutants and sediments to settle out. (Figure 4.20) The water then enters into the stormwater pond from the flume's weep holes. In the pond, the polluted water settles and is cleansed by the wetland plants in the pond. A semicircular wall symbolically encircles the water and marks the depth of the pond. (Figure 4.21) The exposed height of the wall varies from two to eight feet. An overlook structure provides people a chance to view the landscape, notice the changing height of the water, and see the natural process. Most of the stormwater is infiltrated on site. During heavy rains, the excess purified water is released into the Willameter River.

The bioswales at the parking lot are planted with wetland plants such as cattails, slough sedge, and soft rush to purify the water. Small weirs slow runoff and allow it to infiltrate on site.

Figure 4.20 Robert Murase, Ariel view, *Portland Water Pollution Control Laboratory,* Reproduced from Contemporary Landscape Inquiry Project, http://www.clr.utoronto.ca/cgi-bin/clrdb/VIRTUALLIB/CLIP

Figure 4.20 Robert Murase, Flume, Semicircular Stone Wall, *Portland Water Pollution Control Laboratory,* Reproduced from Contemporary Landscape Inquiry Project, http://www.clr.utoronto.ca/cgi-bin/clrdb/VIRTUALLIB/CLIP

Traditional gutters are replaced by specially designed beautiful scuppers, which shoot stormwater to bioswales when it rains, providing people more experience of the beauty of stormwater.

All these elements help to create a great project which solves the stormwater problem in a poetic manner. Mike Faha, a Portland based landscape architect, extols "the project's stormwater management has been elevated to an art form and is the central organizing principle for the site plan."[43]

There are some minor problems with this design. One is caused from the hydrology of the Portland region, which has dry summers from July to August. Consequently the fish in the pond die and the water in the ponds tends to become anaerobic and can start to smell bad.[44] Another is a maintenance problem caused from the pollutants in the flume. They can clog the flume, and it needs to be cleaned out periodically.

Conclusion

The projects discussed above are all beautiful and functional. The *Mill Creek Canyon Park* holds the water on site, provides interesting art forms which change with the depth of water, and provides lots of activities to the public. The *Renton waterworks Gardens* improves the water quality with a flowering plant shape in plan, which "conveys a story about the filtering power of plants to cleanse water."[45] The *Water Pollution Control Laboratory* solves both the flood and the water quality problems while providing lot of beautiful landscape with rich meaning. In all the examples, natural processes are used to manage stormwater in a poetic way. These landscapes also successfully bridge the gap of "pragmatic and the poetic", weave together "a sculptural presence and an ecological process", and "hold a strong portent for the future." [46] These examples provide great inspiration for my proposed design in the next chapter.

[1] John Beardsley, *Earthworks and Beyond: Contemporary Art in the Landscape* (New York: Abbeville Press), 7.

[2] Beardsley, *Earthworks and Beyond*, 7.

[3] Barbara Matilsky, *Fragile Ecologies* (Rizzoli International Publications, Inc.), 38.

[4] Catherine Howett, "Ecological Values in Twentieth-Century Landscape Design: A History and Hermeneutics," *Landscape Journal Special Issue 1998*, 92.

[5] Beardsley, *Earthworks and Beyond*, 13.

[6] Howett, "Ecological Values in Twentieth-Century Landscape Design: A History and Hermeneutics", 94

[7] Beardsley, *Earthworks and Beyond*, 20.

[8] Gilles A. Tiberghien, *Land Art* (Princeton Architectural Press), 204.

[9] Beardsley, *Earthworks and Beyond*, 34.

[10] Beardsley, *Earthworks and Beyond*, 34.

[11] Quoted from Tiberghien, *Land Art*, 146.

[12] Tiberghien, *Land Art*, 200.

[13] Beardsley, *Earthworks and Beyond*, 34.

[14] Matilsky, *Fragile Ecologies*, 42.

[15] Beardsley, *Earthworks and Beyond*, 41.

[16] Quoted from Howett, "Ecological Values in Twentieth-Century Landscape Design: A History and Hermeneutics," 95.

[17] Matilsky, *Fragile Ecologies*, 56.

[18] Beardsley, *Earthworks and Beyond*, 41.

[19] Matilsky, *Fragile Ecologies*, 40.

[20] Matilsky, *Fragile Ecologies*, 42.

[21] Matilsky, *Fragile Ecologies*, 80.

[22] Matilsky, *Fragile Ecologies*, 82.

[23] Matilsky, *Fragile Ecologies*, 108.

[24] Howett, "Ecological Values in Twentieth-Century Landscape Design: A History and Hermeneutics," 95.

[25] Beardsley, *Earthworks and Beyond*, 172.

[26] Beardsley, *Earthworks and Beyond*, 172.

[27] Matilsky, *Fragile Ecologies*, 108.

[28] Matilsky, *Fragile Ecologies*, 57.

[29] Tamara Graham Calabria, "The Representation of Stormwater Management In design : Toward an Ecological Aesthetic," MLA thesis, University of Georgia, 91.

[30] Matilsky, *Fragile Ecologies*, 114.

[31] Calabria, "The Representation of Stormwater Management In design : Toward an Ecological Aesthetic," 101.

[32] Robert Jr. Thayer, "Landscape as an Ecologically Revealing Language," *Landscape Journal Special Issue 1998*, 119.

[33] C. Timothy Baird, "A composed Ecology," *Landscape Architecture, March 2003*, 71.

[34] Baird, "A composed Ecology," 73.

[35] Beardsley, *Earthworks and Beyond*, 175.

[36] Michael Leccese, "Cleansing Art," *Landscape Architecture, Jan 1997,* 70.

[37] Beardsley, *Earthworks and Beyond*, 175.

[38] Leccese, "Cleansing Art," 130.

[39] Quoted from Kim Sorvig, "From covert to overt," *Landscape Architecture, May 2002,* 69.

[40] Sorvig, "From covert to overt," 71.

[41] Quoted from Sorvig, "From covert to overt," 71.

[42] William J. Thompson, "The poetics of stormwater," *Landscape Architecture January 1999,*87.

[43] Thompson, "The poetics of stormwater," 63.

[44] Thompson, "The poetics of stormwater," 63.

[45] Leccese, "Cleansing Art," 70.

[46] Thompson, "The poetics of stormwater," 88.

CHAPTER 5

DESIGN APPLICATION: ENVIRONMENTAL DESIGN OF RUIYUAN RESIDENTIAL DISTRICT

Ruiyuan residential district —site description

Availability of the data is restricted to the materials from internet and the information collected from the author's participation in a previous design. Other types of site data are not compiled in China to the same degree as they are by agencies in the United States. The *Ruiyuan* residential district is a commercial and multi-family residential development in Hangzhou, China. It is adjacent to the newly constructed *Baidanghai* residential district at the east, *Yutang River* at the north, *Wenyi Road* at the south, and government agencies at the west.[1] Occupying an area of 10.2 acres, the *Ruiyuan* residential district is mostly a flat area, with a gentle slope from south to north of the site. A proposed development of the site includes architecture mostly of more than ten stories, with a strip of one-story commercial building at the east side. The soil is mostly clay, with ability to infiltrate rain water slowly. [2]

Geography and climate

Hangzhou is a beautiful city with long history and rich culture. Hangzhou is located at 30° north latitude, and 119° east longitude, on the southeastern coastline of China, bounded to the northwest and southwest by hills; to the northeast and southeast by Zhebei Plain. Lying in the north fringe of the subtropical zone, Hangzhou is about 200 kilometers from the East China Sea. It is a major city on China's Grand Canal. Hangzhou is of subtropical monsoon climate, with four distinctive seasons and mild atmosphere. The average monthly temperature ranges from 38.5 degrees F in January to 83.5 degrees F in July, with an annual average of 61.2 degrees F. [3]

Water resources

The annual average of rainfall of Hangzhou is 58 inches. Rainy seasons lasting from April to June and from July to September.[4](Figure 5.1) The water resource is abundant and can meet the requirement in normal years. But in some dry years, there are some water scarcities related to water supply or water pollution. It is predicted that the water requirement in Hangzhou will increase by 6.2% in the next fifteen years, which is caused by the development of the city. So water scarcity will emerge as a serious issue.[5] Water protection and efficient water use need to be paid special attention. Water pollution has been obvious in the Grand Canal, and in some of the rivers in the Hangzhou city. This has made water scarcity more serious in dry years and will continue to do so in the future. It seriously affects the people's lives and the tourism of Hangzhou.[6] The government has planned to solve the water pollution problem in the next five years. The goal is make the Grand Canal and the rivers in the city clean and to recreate the past beautiful relationship between water and city. [7]

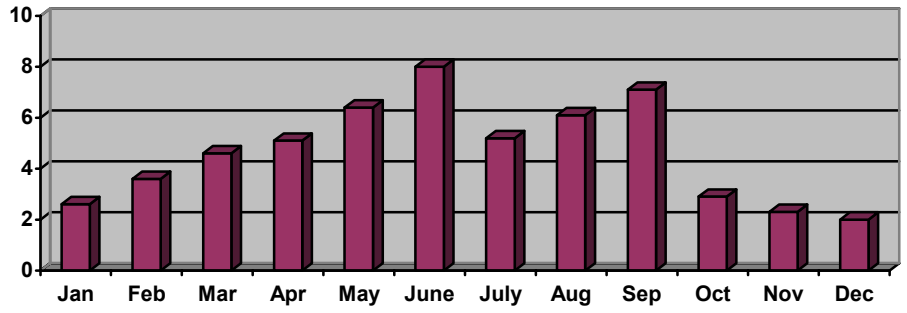

Figure 5.1 The rain chart of Hangzhou, unit: inch, Drawn according to the data from www.travelchinaguide.com/package/hangzhou.htm

Culture and history of the city

As one of the seven most famous ancient capitals in China, Hangzhou is China's key tourist city and a nationally famous historical and cultural city. Hangzhou enjoys a history of 2,200 years. It was the capital of Wuyue Kingdom (907-978 A.D) and Southern Song Dynasty (1127-1279 A.D.). The city first made a name for itself in the sixth century and grew rapidly, when the Grand Canal opened up and linked the area to other trade centers such as Beijing and Suzhou. The Song dynasty helped to make Hangzhou famous when they moved the capital there in the 12th Century. At that time, Hangzhou's arts and commerce received unprecedented impetus, transforming it, in Marco Polo's words into, *"a city of heaven...the finest and most splendid city in the world."*[8] Hangzhou is also famous for its agricultural products, such as cocoon silk and tea, fruits and other agricultural products. It is described as "*Land of fish and rice, Town of silk and tea, field of fruits and flowers*".[9] The China Silk Museum and China Tea Museum are located in Hangzhou, reflecting the culture of Hangzhou. Hangzhou is also one of the cradles of the Chinese culture with a lot of historic sites of Liangzhu culture, Wuyue culture, and Southern Song culture. A culture had prospered in this city as long as 4700 years ago, which is called "Liangzhu culture" and is as famous as the Great Wall. [10]

Famous landscapes of the city

Hangzhou is a major destination of tourism. Famous for its scenic beauty, Hangzhou is regarded as "Paradise on Earth". There are three main landscapes in Hangzhou: the West Lake, the Qiantang Tidal Bore, and the Grand Canal. The West Lake is the most famous (Figure 5.2).

Lying on the west edge of Hangzhou city, the West Lake is the symbol of Hangzhou as well as one of the most beautiful sights in China. Early in the Song dynasty, the famous poet Su Shi compared the lake to Xizi, one of the four most beautiful women in the history of China:

"Rippling water shimmering on sunny day; Misty mountains wonder in the rain; Plain or gaily decked out like Xizi; the West Lake is always alluring". [11]So the Lake is also known as Xizi

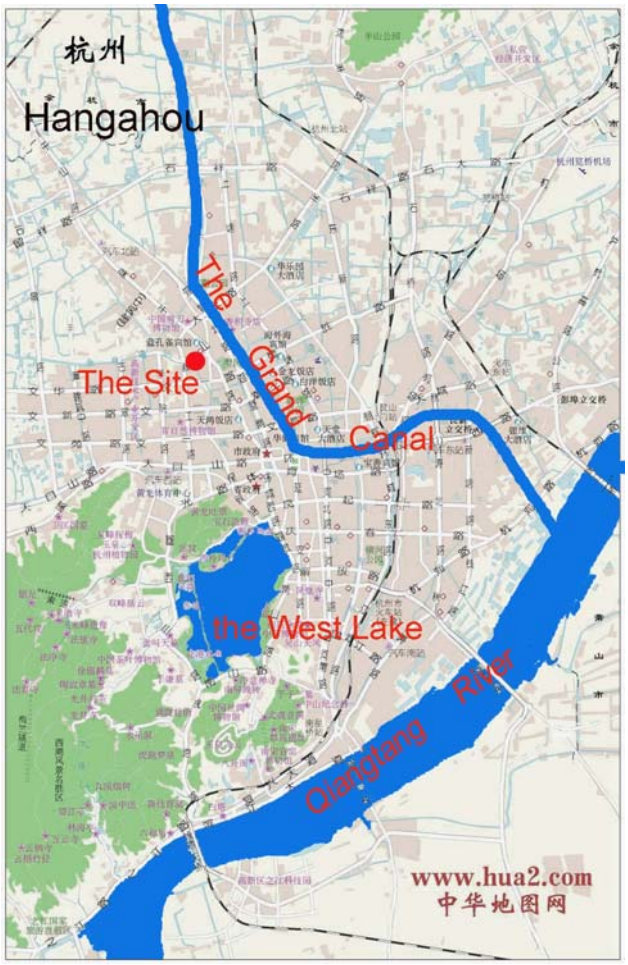

Figure 5.2 Map of Hangzhou city. Drawn according to the data from www.hua2.com

Lake. With an area of 1500 acres and a circumference of 9 miles, the West Lake, surrounded on three sides by rolling wooded hills, has attracted countless visitors for centuries. It consists of 5 sections, namely the Outer Lake, North Inner Lake, Yuehu Lake, West Inner Lake and Lesser South Lake. The beauty of the West Lake lies in a lingering charm that survives the change of seasons in a year, of hours in a day, and of different weathers. In order to display the best beautiful aspect of West Lake, 10 sights were named by people as the most beautiful, which

include Melting Snow at Broken Bridge, Spring Dawn at Sudi Causeway (Figure 5.3), Sunset Glow over Leifeng Hill, Lotus in the Breeze at Crooked Courtyard, Autumn Moon on Calm Lake, Listening to Orioles Singing in the Willows, Viewing Fish at Flowers Harbour, Evening Bell at Nanping Hill, Three Pools Mirroring the Moon, Twin Peaks Piercing the Clouds.

Figure 5.3 Spring Dawn at Sudi Causeway. Reproduced from http://gongwei.myrice.com

The Qiantang Tidal Bore is one of the most unusual natural wonders in the world. It is caused by the gravitation of celestial bodies and the peculiar shape of Hangzhou Bay. On the 18th day of August in the Chinese lunar calendar, thousands of tourists from both China and abroad would come here to watch Qiantang Tide. A scholar wrote: "The Tide comes in a little drum voice just like a silk thread across the River at far-viewing while it reaches nearby in thunder just like mountains." [12] People have been keeping the tradition of watching the Qiantang Bore since the Tang dynasty. With the lapse of time, the tradition of tide-watching becomes a grand occasion. And the local people organize various kinds of festivals to celebrate it.

The Grand Canal is also very famous. Canalized in the Sui dynasty (581-618), Beijing-Hangzhou Grand Canal is one of the greatest projects constructed in ancient China as well as the longest man-made waterway in world.[13] With a total length of 1764 kilometers, the canal, communicating Yangtze River, Yellow River, Huaihe River, Haihe River and Qiantang River, flows through Beijing, Tianjing, Hebei, Shandong, Jiangsu and Zhejiang with Hangzhou at its southernmost end. Since most of China's major rivers flow from west to east, the Grand Canal running north and south provides an important connector between several minor river systems. It has played an important role in strengthening economic and cultural intercourse between north and south and promoting the development of the country's economy.

Proposal from the previous plan

A design for the development of the Ruiyuan residential district was proposed by my former office─ Zhejiang Jiajing Architecture and Planning Design Institute(Figure 5.4, Figure 5.5). The design was awarded the First Place in a design competition. I participated in part of the environmental design. The green space is divided into three entrance plazas, the North and South parts, with a stream to connect the two parts. The main purpose is to reflect the "water village image" that is very popular in Southern China. [14] The landscape is organized around the stream, with bridges, plazas, and small pavilions surrounding the stream, creating an organic interaction between the two. Combining with architecture, "a beautiful water village is created in a modern sense." [15] Three kinds of water experiences are created in the design: "enjoying the water visually, setting upon the water, and playing in the water." [16]In the "enjoying the water visually" district, plaza, pergola, and bridges are set around the water to provide people different views of the water. In the "setting upon the water" district, the entrance of the architecture is built upon the water, and corridors are designed for people to create a kind of feeling of setting upon the water. The "playing in the water" district is designed at the end of stream with some playing furniture for the children. The average depth of the water is 14 inches, with some places of 28 inches.

Figure 5.4 Plan of Hangzhou Ruiyuan residential district. Reproduced from *The conceptual plan of Hangzhou Ruiyuan residential district*, Zhejiang Jiajing Architecture and Planning Design Institute, 2000.

The central entrance is the main entrance, and is designed to reflect the modern and traditional “water village” image. By overlapping of water and pavements, two views are created to connect the two parts of the green space. The other two secondary entrances are designed mainly to direct the car’s movement. The entrances of two underground parking garages are in these two entrances. A limited number of surface parking spaces are provided for visiting guests.

The design provided a beautiful image and met the main function of green space. Also by referring to the regional landscape ─ water village, it successfully brought meaning to the design. However, it did not consider any environmentally sound stormwater management methods such as detention or infiltration. Consequently, it did not solve flood problems, recharge underground water or improve water quality. By treating water as a static landscape, it made people unaware of problems such as water scarcity and water pollution and the natural processes of water. It disconnected people from nature.

Figure 5.5 The birdview of Ruiyuan residential district. Reproduced from the conceptual plan of Hangzhou Ruiyuan residential district, Zhejiang Jiajing Architecture and Planning Design Institute, 2000

An overview of the Design Method

Alternative designs for Ruiyuan residential landscape will be proposed. The design method will explore all the three kinds of inspirations that have been discussed in the previous chapters: Chinese Garden, Stormwater Planning, and environmental and ecological art. One design will be proposed for each of the inspirations. After that, aspects of all three designs will be combined to create a fourth design, which will utilize all the good aspects of the previous three designs: culturally meaningful, aesthetically beautiful and environmentally sound. A conclusion will be drawn to discuss the design method.

Design inspired by Chinese garden

Figure 5.6 shows the design inspired by Chinese garden. The green space is divided into two parts: the northern part and the southern part. At the southern part of the green space, the water is scattered to create mysterious, endless and deep-view landscape. This scattered use of water builds "in-motion" viewing that Chen referred to, and people get different experiences of water when they walk in the green space---the view changes with every step. Different feelings are evoked by different shapes of water. A broad water surface is combined with terraces, plants and rockeries, providing a good space to appreciate water, while a winding, narrow stream develops changing relationships between water and path. One small, shallow pool creates a place for children playing with water.

A different image of water is provided at the northern part of the green space. Here, a kind of centripetal, open and peaceful feeling is created by setting a large pond with terraces and decorative rockeries. This concentrated use of water builds “in-position” viewing that Chen referred to, and people get different views of landscapes from fixed points. The terraces, pergolas and plants are arranged to and from water to provide interesting experiences. People can sit, rest or look to the landscape on the opposite bank. Two parts of the green space create different but interesting experiences with water. People can either walk to feel the different relationship

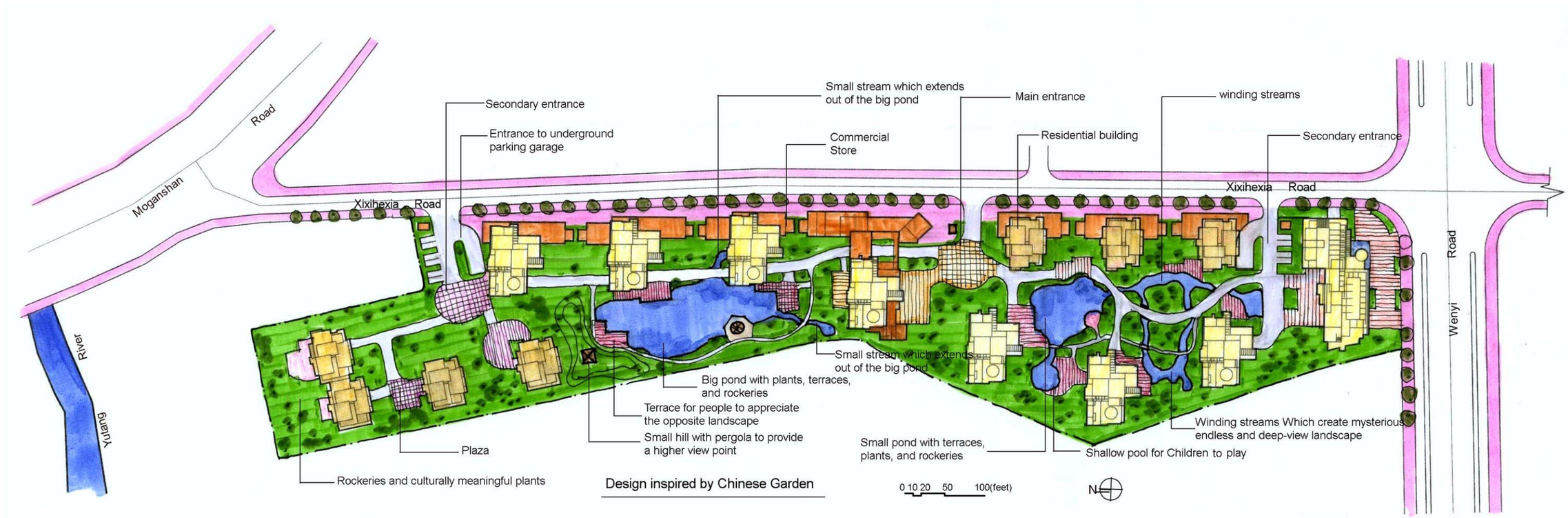

Figure 5.6 Design inspired by Chinese Garden

between water, land, and path; or sit in a shaded pergola to watch the opposite landscape. By referring to Chinese garden, the landscape is given deep cultural meaning. However, by treating water as a static landscape, the design does no good to solve flood problems, recharge underground water or improve water quality. At dry seasons, it even needs water supply from the city water network.

Design inspired by stormwater control

In a design for stormwater control, the green open space is divided into two parts: the northern part and the southern part (Figure 5.7). The buildings are designed with water cisterns to collect rainwater for irrigation in dry seasons. In the east and south streets, pervious pavement is used to infiltrate the rain into the soil with trees planted to intercept part of the rain. At the southern part of the green space, a small wet detention pond is designed with several plazas to take advantage of the waterscape. The pond is connected to several vegetated swales. These swales can detain and infiltrate some of the runoff and the overflow is directed into the pond. Woodland bioretention areas are designed in the west side of the site, which will detain some water as well as improve water quality.

A big wet detention pond is set at the southern part of landscape for people to better enjoy the waterscape. The plazas around it provide comfortable spaces to connect to water. The northwestern part of the detention pond is designed as a wetland area where wetland plants absorb pollutant particles to improve water quality. In heavy rains, overflow will be directed into the northern end of the district where it has a woodland bioretention area with an underground infiltration basin. It stores the water on site and infiltrates it. This solves the flood problem, and recharges the underground water. In some really big storms, overflow will be directed into the nearby city stormwater pipes. The system of water features creates a beautiful landscape, improves water quality, recharges the underground water and solves the flood problem at the

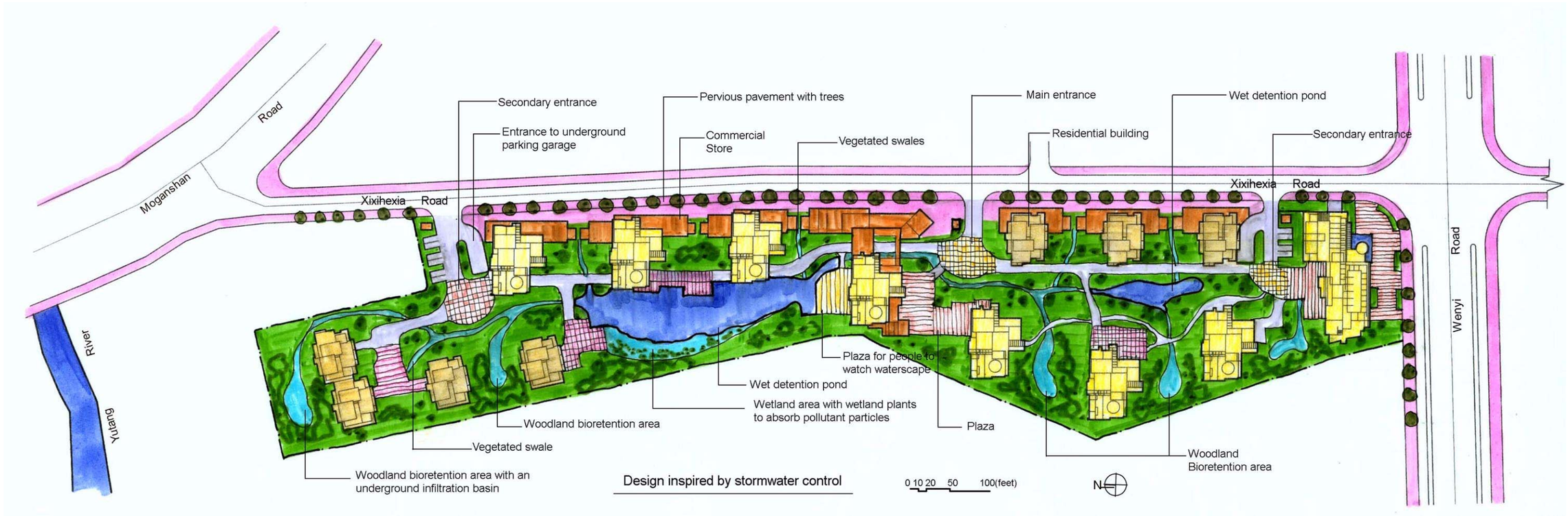

Figure 5.7 Design inspired by stormwater control

same time. However, this design did not refer to regional and cultural context. It is designed in a scientific or functional way; the "poetic" aspect of the stormwater has not been reflected.

Design inspired by environmental art and ecological art

Like the previous designs, in the design inspired by environmental art and ecological art, the green space is divided into two parts: the northern part and southern part (Figure 5.8). At the southern end of the site, a water pool with jets imaginatively reflects the source of water. A stream connects the whole site from the south to the north, symbolizing the Grand Canal that extends from Beijing to Hangzhou. Many vegetated swales, which represent the tributaries, connect to the main stream— the Great Canal. At the southern part of the green space, the stream is surrounded by changing topography with different types of floods tolerant grasses. Here, the natural process of stormwater is shown to the public: the water can submerge all the grasses in heavy rains and be infiltrated gradually after the rain. The change of water depth makes people understand the stormwater process better, creating a beautiful, dynamic relationship of land and water, mass and space. At the same time, this landscape reflects one of the most beautiful scenes in Hangzhou: the Qiantang Tidal Bore. The ebb and flow of the water symbolizes the water level change of the Qiantang Tide. At the north part of the green space, a big lake with several islands, causeways, and plazas are created to provide beautiful water landscapes while providing a great place for people to experience the water. The big lake symbolizes the West Lake, the most famous landscape in Hangzhou. This design detains water on site, recharges underground water, and improves water quality. By referring to the Grand Canal, the Qiantang Tidal Bore, and the West Lake, it brings context and meaning to the landscape. However, it can be improved by paying more attention to people's experiences with water.

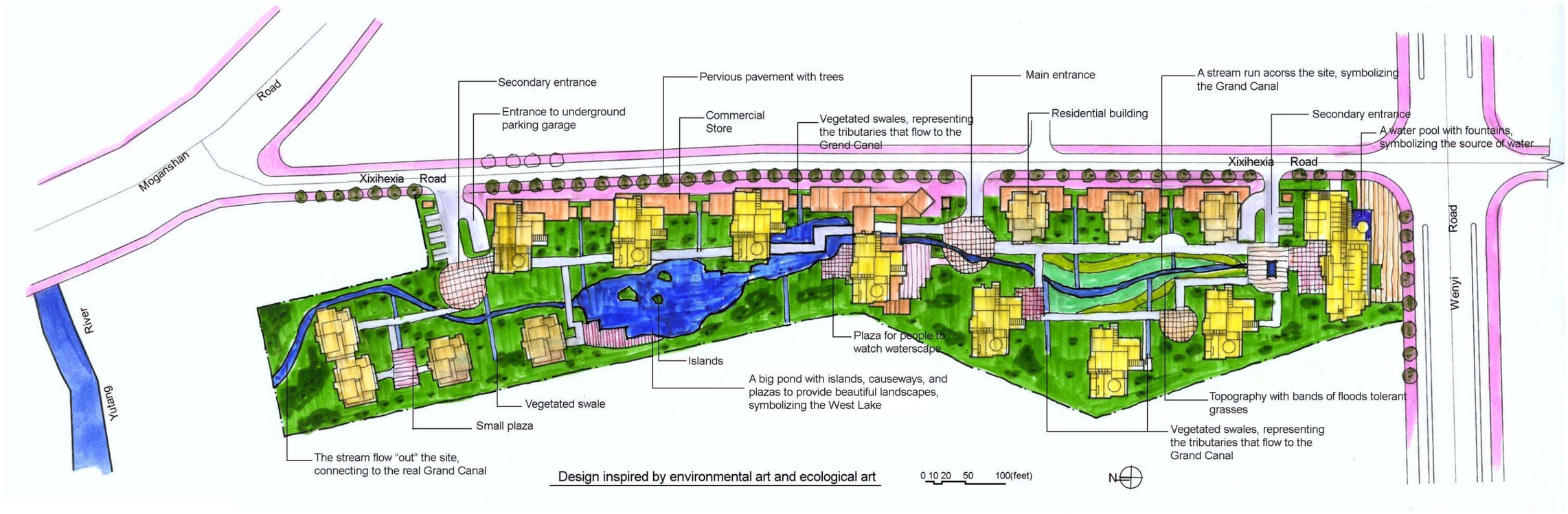

Figure 5.8 Design inspired by environmental art and ecological art

Design inspired by all three sources

This design will utilize all the good aspects of the previous three designs to create a final one which is culturally meaningful, aesthetically beautiful and environmentally sound (Figure 5.9).

In this design, cisterns harvest roof runoff water. At the east and south streets, pervious pavement is used to infiltrate the rain into the soil with trees to intercept part of the rain. The green space is divided into two parts: the southern part and the northern part. A stream connects the whole site from the south to the north, symbolizing the Grand Canal that extends from Beijing to Hangzhou, connecting the southern and northern China. At the southern part of the green space, the stream is surrounded by changing topography with different types of floods tolerant grasses. The stream is scattered in two directions to create mysterious, endless and deep-view landscape. It makes people get different experiences of water when they walk in the green space. The natural process of stormwater is shown to the public by depths of water which change according to the storm. The ebb and flow of the water symbolize one of the most beautiful natural landscapes in Hangzhou: the Qiantang Tidal Bore. The stream is linked to several vegetated swales which detain and infiltrate some stormwater. Overflow is conveyed to the stream. These vegetated swales symbolize the tributaries of the Grand Canal. At the west side of the site, woodland biorentention areas are designed to detain some water and improve the water quality.

At the northern part of the green space, a detention pond with wetland area at the northwestern side of the pond provides a centripetal and open feeling about water. By arranging different plants, terraces, islands and water causeways, it provides different views of landscapes from fixed points to residents. The pond symbolizes another famous landscape in Hangzhou: the West Lake. The pond and wetland combine to detain water and improve the water quality. In heavy rains, overflow will be directed into the northern end of the site where a woodland bioretention area is designed with an underground infiltration basin. In really big storms, the overflow will be directed into the nearby city stormwater pipes.

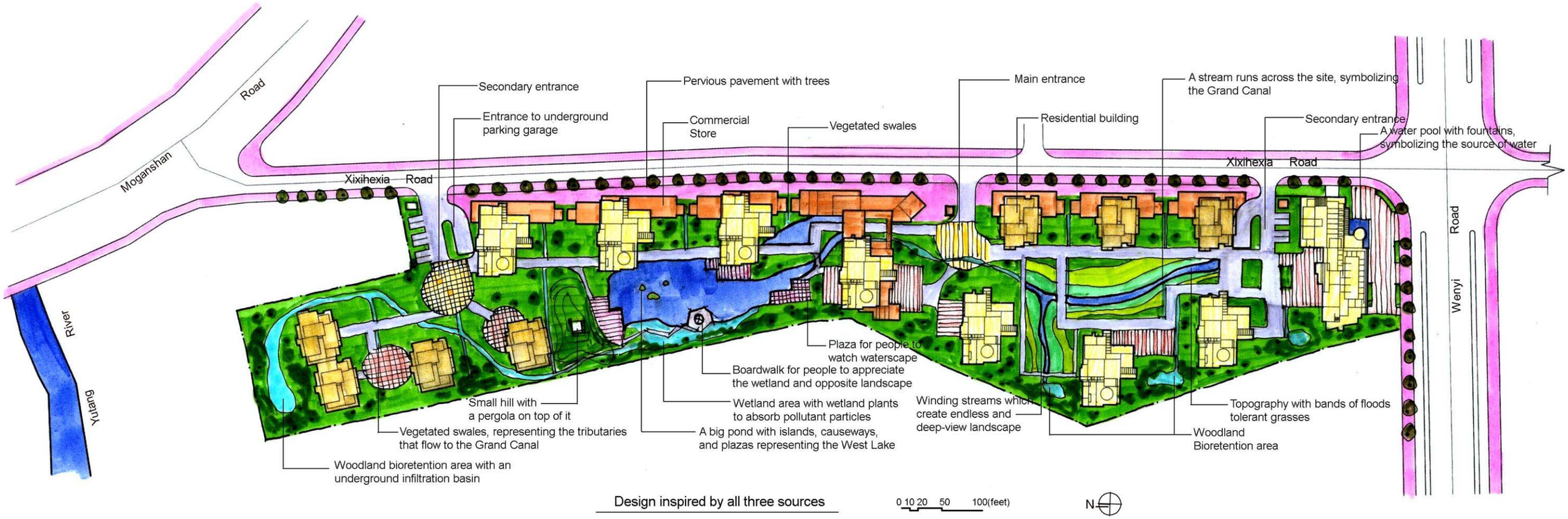

Figure 5.9 Design inspired by all three source

The landscape solves flood problems, recharges underground water, and improves water quality. Ecological and environmental values are paid attention. The landscape provides "in-motion" viewing and “in-position” viewing to residents. People can get different experiences with water. By showing natural process and regional cultural landscape, it brings context and meaning to the landscape.

Conclusion

From the design experience described above, some important ideas can be drawn. The design inspired from the Chinese Garden emphasizes people’s different experiences with water. Attention is paid to use water to create beautiful landscape and provide interesting spaces. The design inspired from stormwater control solves flooding, underground water recharge, and water quality. It provides environmentally friendly techniques to deal with stormwater, and create natural landscape. The design inspired from environment art and ecological art provides education to the public by showing the natural process of stormwater. It also provides culturally meaningful landscape by referring to its regional context. They all have advantages. By combining advantages from all the three resources China can create the aesthetic and functional stormwater design. This is shown in the fourth design, which combined advantages to create a culturally meaningful, aesthetically beautifully and environmentally sound landscape. The design method provides an innovative and useful way to address China’s future stormwater planning and design.

[1] *The conceptual plan of Hangzhou Ruiyuan residential district*, Written by Zhejiang Jiajing Architecture and Planning Design Institute, 2000

[2] http://www.hzland.com/

[3] http://www.travelchinaguide/cityguide/hangzou.htm

[4] http://www.hzland.com/

[5] http://www.hzland.com/

[6] http://www.hzland.com/

[7] http://www.hzland.com/

[8]Quoted from http://www.hangzhou.gov.cn

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[15] *The conceptual plan of Hangzhou Ruiyuan residential district*, Written by Zhejiang Jiajing Architecture and Planning Design Institute, 2000

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