Waterways to Greenways: A Case Study in Shangjie, Zhengzhou, Henan, China

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Abstract

This case study introduces how we used a water sensitive approach to plan a storm water and sponge city project, which expanded into a holistic green infrastructure project. The project is in the Shangjie district in city of Zhengzhou, Henan China. The whole site is 61.16 km² including several waterways. The city is expanding into areas that were previously agricultural. Developers and city both desire to improve the ecological value of the city to boost the economic growth of the Shangjie district.

The main goal for the client is to transform the existing industrial city into a more resilient and livable ecological region. Our approach is to holistically solve the region's increasing demand for flood control and storm water management, and to improve ecological and recreational values along these riparian corridors. We propose additional waterways and water bodies to act as green infrastructure, then link the greenways to existing or proposed parks to form a comprehensive greenway network.

Our multidisciplinary team conducted detailed investigations and collaborated extensively. The team consists of hydraulic engineers, civil engineers, environmental planners, landscape planners, urban planners, economic planners, and others. We used a variety of technologies, including GIS, Infoworks, remote sensing technology, MIKE model, and lab tests.

Keywords: Blue-green network; Green Infrastructure, Greenway, Ecological Planning, Sponge City

Introduction

Shangjie is a district of Zhengzhou, Henan province. It occupies an area of 61.1 square kilometers, with a population of 136,800 in 2017. West of Shangjie is its main water body, Sishui River, which is a tributary of China's second biggest river – the Yellow River. Shangjie has considerably rich change of elevations, and potentially good varieties of biological communities. Ku River Watershed on the north and Sou River Watershed on the east are two other watersheds included in Shangjie district. (Figure 1&3).

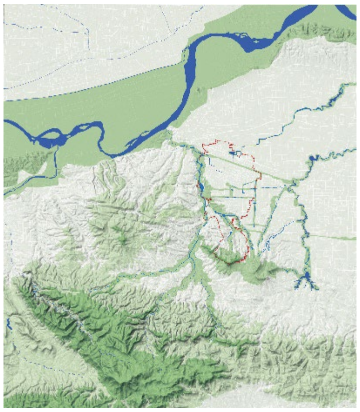


Figure 1: Shangjie Location and Sishui River a tributary to Yellow River.

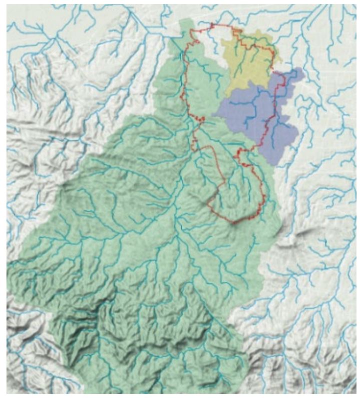


Figure 2: Shangjie natural Watershed

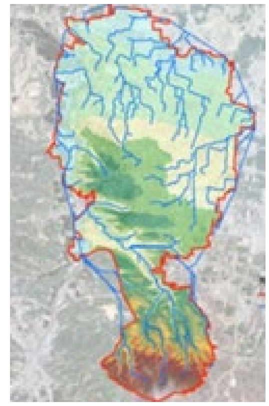


Figure 3: Shangjie rich landforms.

The district has been expanding in the past 24 years at the rate of 1 km^2 per year. With the expansion of the city, more agricultural land at the south has been changed into urban development (Figure 5). The northern part of the city was built a couple decades ago, and its storm water capacity can only accommodate a 1-year flood. The major problem the city faces is potential flooding in the summer and a drought. Our team actually encountered a flood during our site visit on July 26, 2018 (Figure 6:).

Existing Ecology (Figure 4):

The overall ecological planning is challenged by fragmented ecological land use. Large patches of habitat are gradually broken into small pieces due to new development in the woodland, and the ecological greenway connections need to be further established. The terrain in the southern and western portions of the district is dominated by mountains and waterways, and the green space has been carved by development. Currently 136.65 hectares of development land have conflicts with the green space planning. As more developers seek opportunities to develop in these areas, controlling the ecological corridor has become crucial in this overall planning.

Existing Hydrology (Figure 8a)

The Sishui River and Ku River are parts of the major flooding system for the region. Ku River is part of the major flooding system for Shangjie. Both rivers are designed to accommodate the 20-year storm only, not meeting China's 50 year flood standard for city like Shangjie. The Central Road drainage channel (light blue in Figure 7) is one of the major channels to divert the north mountain water to the river. However, the drainage capacity has been compromised by a lack of maintenance during recent years with silt in the channel, which creates a backlog of water in the drainage pipe during heavy rains.

Due to jurisdiction boundary limits, the west part of Shangjie can only drain to the north through Ku River to release its flood waters, which conflicts with the fact that the west of Shangjie is in two watersheds. Jinhua Road to the east often functioned as an overland release channel at rainfall above 1 year storm to carry storm water from the Sou River to the Ku River watershed.

Figure 4: Existing land use within ecological corridor

Figure 5: Green space change into development

Figure6: Flood at Central Road

Figure7:existing Drainage System

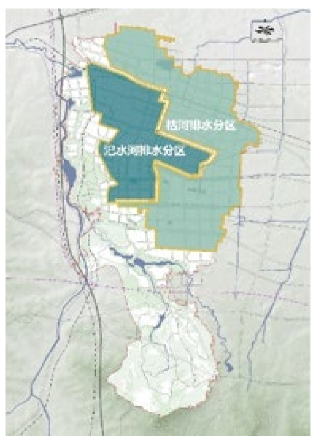


Figure 8a: existing waterways

Figure 8b: existing waterways

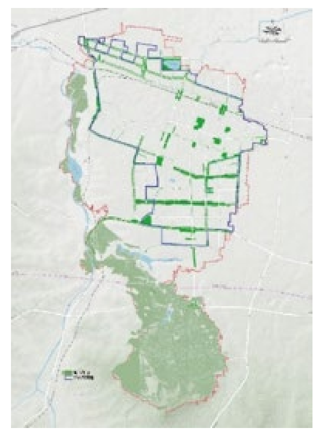


Figure 9:Existing greenspace system

<u>Existing Storm Water System (Figure 7)</u>

Shangjie has a fairly complete drainage systems with a total length of 110 km of drainage pipe. However, the overall minor system capacity is still very low, although it meets the minimum China's regulatory requirement. 69% of the pipes (75.9km) is designed to accommodate the 1 year storm, and 25% (27.3km) of the drainage system is designed to accommodate the 1 to 2 year storm. Only 6% of the drainage network (6.8km) is designed to accommodate the 2 year storm.

<u>Existing Green space: (Figure 9)</u>

The green space distribution is unbalanced and disconnected. The city has 10 segments of recreational greenway with total length of 22.5km, which needs planning readjustment. Currently the city only has small parks within the old district and the park facilities are not adequate for the recreational needs of the nearby residents. The new district also needs to plan more public parks. The new regulations require the city to provide "green space (min. 2000 m^2) within 300 meters, and parks (min.5000 m^2) within 500 meters" as part of the nation-wide city regeneration effort.

Background and literature review

Several government departments have engaged in different contracts within separate disciplines. The approved planning projects are: *Shangjie Water System Planning (2010-2020)*, *Shangjie Sponge City Planning (2017-2030)*, *Shangjie Storm Water Planning (2016-2030)*, and *Shangjie Green Space System planning (2005-2020)*.

The planning provided by different companies were not coordinated and cannot be implemented through urban planning. The Global Greenway Campaign has proven that green planning can bring ecological, cultural and recreational benefits in a comprehensive manner. Greenway and green space planning can successfully create multipurpose corridors (Fabos, 2004).

We adopted the multipurpose greenway approach and presented this to the city leaders. The city government is very pleased to find that our multidisciplinary approach provides a holistic planning result, which will help city leaders and different departments to jointly make urban planning decisions.

Although green infrastructure planning needs to be actively planned with multi-functionality as a goal, as many planners are uncertain about how to proceed. It is very important to foster multidisciplinary collaboration across authorities and departments (Rieke Hansen, Sussams et al. 2015), as well as providing a specific and thoughtful analysis of the site to determined multifunctional needs in GI projects.

Our hydrology engineers are following the water sensitive urban design approach to determine the waterway width and ecologists are using river continuum concept (RCC) (Vannote et Al, 1980) to determine the corridor functions and needs. Depending on the location of each river segment, the ecological value and corridor requirement should be different. A riparian corridor could be from 30 meters to a couple hundred meters wide. It will function as an erosion and sediment control buffer (Lowrance at al, 1985), and the filtration efficiency increases with corridor width (Karr and Schlosser, 1978). Riparian corridor plants should be woody trees and shrubs to stabilize the river bank, regulate stabilize ground water level, take up nitrogen from groundwater and retain phosphorus (Lowrance et al 1985, Yates and Sheridan 1983).

Goals and Objectives

Our agreed project goals and objectives with the city contain four thematic plans: 1) flood and hydrology planning; 2) water quality protection planning; 3) environmental and habitat protection planning; 4) urban planning improvement, including land use suggestions and green space system planning.

Our goal is that we provide a holistic solution and planning regulation recommendation for the city to achieve storm water management goals, as well as riparian corridor and upland habitat restoration goals. The way to achieve this plan is to legally change land use, as well as adding individual parcel's land use condition into the zoning plan (in China called controlled detailed planning).

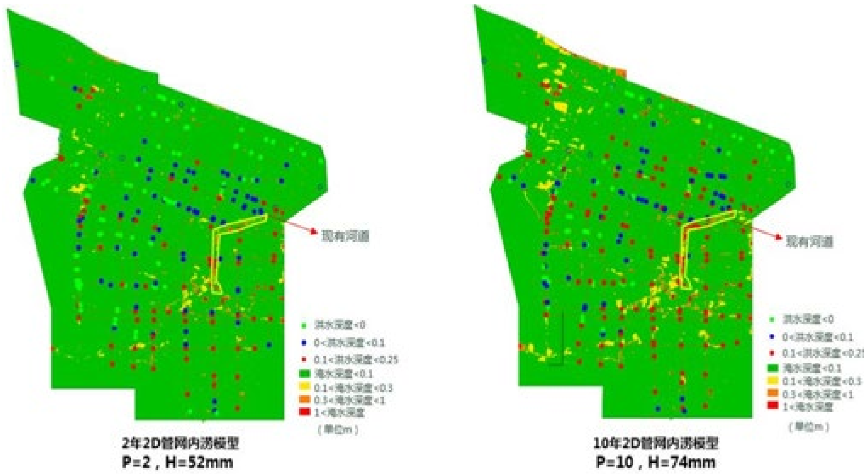


Figure 10 & 11: Infowork simulation of 2 year and 10 year storm overflow, Red spot is overflow more than 1 meter deep.

Methods

We took a water sensitive approach to plan the water system first, with the function of flood reduction, flood retention, water quality improvement, and wetland reconstruction. Our goal is to protecting and recovering the ecological function in the mountains and along the waterways by protecting or creating patches, corridors, and stepping stones for animals as well as wild plant communities. The recreational function should easily overlay with the water function and be enhanced by proper landscape design and join with other green spaces.

We used GIS data to simulate the region's watersheds first, then analyze the drainage system data to find out how the surface water is organized. Meanwhile, we also studied the existing city green space system, and determined the needs for green space, biodiversity management, bike routes, land use and urban planning constraints and opportunities, as well as the needs for tourism planning.

After taking all the data into the consideration, we decided on different water management criterion to come up varies solutions/facilities (such as waterways, lakes, wetland, pond, etc) and check the zoning availabilities of each facilities with government's planning and other departments. We need to modify the current green space network planning to provide the spaces for the water facilities. The revision is very likely to be adopted, since china is going through a stage of upgrading additional storm water facilities and green spaces for the city. We synergize the blue and green network, as well as combining other greenway goals such as "natural protection, biodiversity management, water resources, recreational, and cultural/historic protection" (Ahern, 2002).

Ecological integrity is one of the top priorities even when we are planning the waterways. The ecological objectives for waterway and greenway planning are to 1) design riparian greenways with increased edge dimensions to filter storm water contamination (Lowrance at al, 1985), and 2) plan parks and planting species to function as conduits and stepping stones for wildlife (Forman and Godron 1984, 1986) to build redundancy for storm water and human recreational uses.

Everyday landscape plays important role in people's life, this landscape are places people live and go about their daily activities. (Thompson, Catherine Ward, & Council of Europe, 2000) Scotland also has "good Places, Better Health' public initiative to develop an environmental model for environment and health. We expect green space closer to homes and higher green space distribution to reduce stress of the public (Thompson, C.W, 2012)

In terms of greens space system planning, both human beings and animals should be considered. For human beings, distance is a key factor of the green space distribution. For animals, we are considering to collect the storm water to fill the storm water retention, as well as using it to form ponds and waterways for wildlife needs and creating multi-functional biodiversity (Hu Huizhong, verbal communication).

Our civil engineer simulated 2-year flood with 52mm of storm water and 10-year flood with 74mm storm water. The simulation concluded both flood events can overwhelm the existing drainage system and it will create waterlog in many streets. ((Figure 10&11)

Results

By understanding the interaction of different landscape elements such as waterways, planting, humans, topography, etc,, we were able to address systemic ecological issues through a comprehensive ecological plan. The overall planning holistically solved flood hazards, recreational uses, and ecological needs by overlaying different systems in the same space as much as possible. These will provide multiple functions to save lands as well as create synergy for water, people and animals.

A. Hydrological Master Plan:

To solve the overall flood problem, we propose to change the existing catchments (Figure 13) from two to three, this will respond more to the natural topography as illustrated by our GIS study (Figure 2 and Figure 14). After that, we add Jinjing Rd green corridor and Danjiang Rd green space as part of the major storm system to release the storm directly into the nearby Heng River (Figure 15). This is reduce the flood pressure to Jinhua road, and eventually reduce the flood pressure of Ku River.

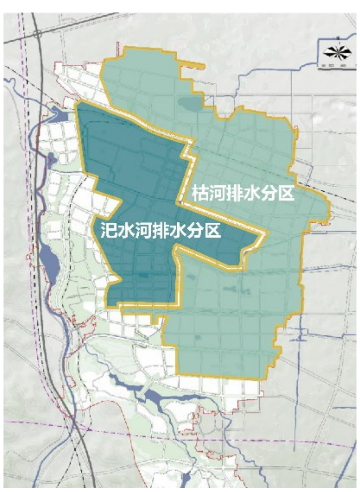


Figure 13: Boundaries of current drainage areas

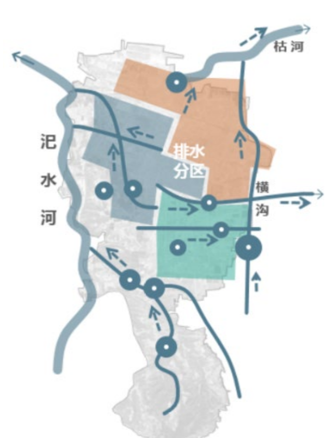


Figure 14: Proposed drainage areas

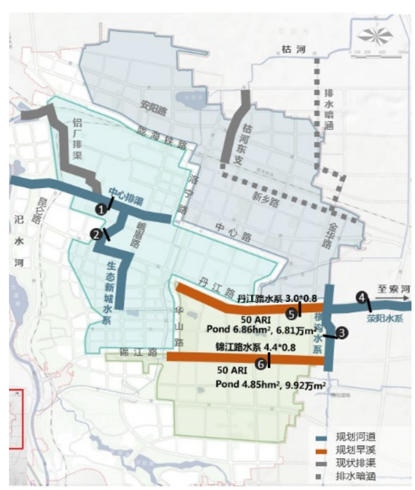
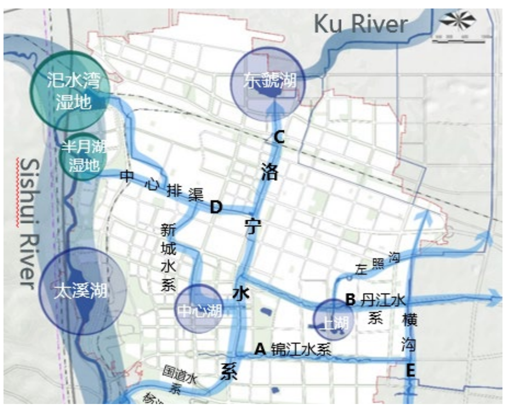


Figure15: Proposed Drainage Channel

Then we created a water master plan (Figure 16-18) to convey the overall flood through both storm pipe and open water channel system, i,e, green infrastructure, this system include retention and detention pond, landscaped sunken creek system at the same time. The newly added open water channel system serve as Green Infrastructure with the combined function of flood reduction, flood retention, water quality improvement, recreation opportunities, as well as ecological corridors.

The newly planned water channels include (Figure 16) A. Jinjiang waterway, B. Danjiang waterway, C. Luoning waterway, D). New City waterway. We also proposed changes be made to, E) Central flood channel and F) Heng River to allow flood release.

The storm water from the south part of Jinjiang Road will be collected by storm water pipes and then released from the pipe into Jinjiang's green space waterways. The purpose of Jinjiang green belt will treat and retain the water for irrigation or creational uses. The Storm water from Jinjiang Road to Danjiang Road will be collected by Danjiang's storm water pipes and then released to Danjiang Green Space. Then the Danjiang green belt could treat the water and retain the storm water for irrigation or creational uses. Excess water will be drained into Heng River directly.



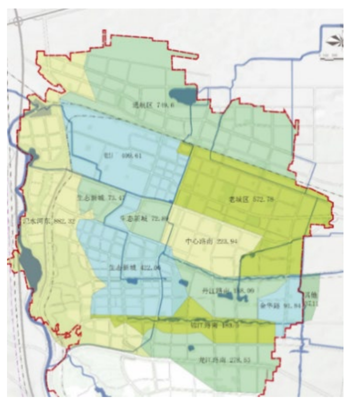
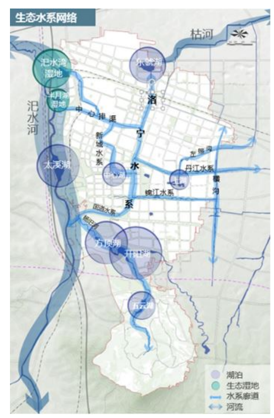
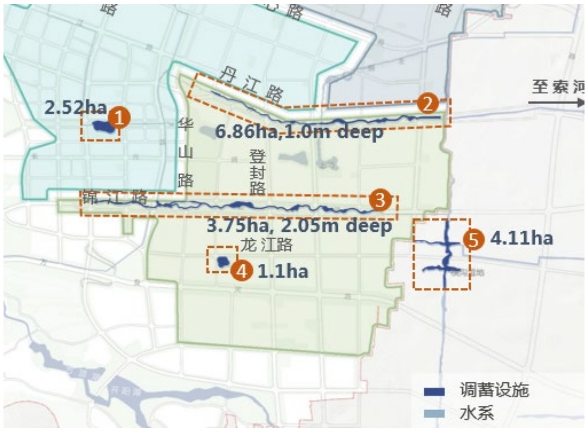



Figure 16 &17&18: Water Masterplan, Newly planned waterway including; A. Jinjiang waterway, B. Danjiang waterway, C. luening waterway, new city waterway, and improvement need to be made to: D. Central flood channel and E. Heng River to allow flood release.

These plans must coordinating with other district's leaders, since Heng River is not all within the jurisdiction of Shangjie District. Over the years the Heng River is not well maintained, and part of the river channel is filled with eroded soil. The district leaders need to coordinate with neighobor district leaders to allow Shangjie the possibility to use this green infrastructure solution.

The west side of Shangjie is Sishui River, and the riparian corridor has more open spaces. So we suggest to expand the flood channel of Sishui River to accommodate the 50 year storm to meet the regulation. Detailed design of Sishui River is coordinated with Sishui River Riparian Corridor Planning, see later chapter for more details.



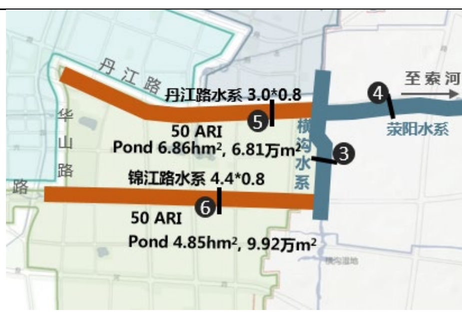
Water body	Detention Volume （1000m^3)	Detention Depth （m)	Water Area （ha)	Note
1	12.6	0.5	2.52	Retention
2	68.1	1.0	6.86	Detention
3	76.9	2.05	3.75	Detention
4	22.7	2.05	1.1	Detention
5	61.7	1.5	4.11	Retention
Total	**242**		**18.34**	

Figure 19 A &B Retention and detention ponds.

We planned retention and detention ponds to regulate the flood and storm water. The two retaining ponds are a total of 6.63ha and could reduce 74300m^3 of storm water during heavy storms. The three detention ponds are a total of 11.71ha and could adjust 167700m^3 storm water. (Figure 19).

<u>Danjiang Road Green Space Improvement (Figure 20-23)</u>

Danjiang Road green space total is 34ha. The green space is a power line corridor filled with shrubs and a small trees. Danjiang Road is the alternative route when the runoff exceeds the designed 1year storm capacity, and the surface flow continued east to Jinhua Road then then drain north on the street. So the proposed solution is to use the Danjiang Road's green space as retention pond, as well as the open channel to drain the excessive water into the Henggou River, which is the seasonal river on east of Shangjie district.(HengGou).



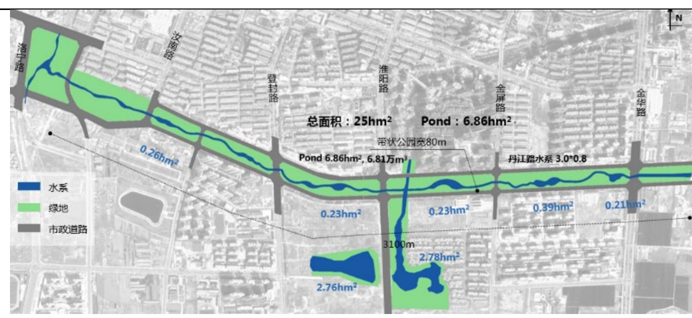


Figure 20&21 :Danjiang Rd green corridor retention requirement and key map

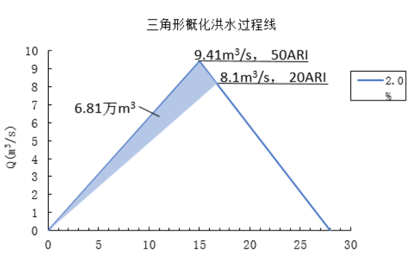


Figure22: Danjiang Road green space flood reduction graph.

Figure 23: Danjiang Road green space proposed layout

Danjiang Road green space will meet the 50 year flood requirement. The maximum depth of the pond will be 2 meters, and total retention area 25ha. Some of the locations will have low elevation to retain storm water for recreational use, ecological use, with a designed draining capacity of 9.4m^3/s. Biking and walking paths are also implement within the green space after the power lines are relocated underground.

Jinjiang Road Green Space (Figure 24-25)

We use the same approach to renovate Jinjiang Road's greenbelt. The solutions include: flood control, storm water management, landscape improvement, bike and hiking trail planning. The goal is to create a 35ha retention pond within Jinjiang Road's green space by alter the grading within the green space. The waterway also serve as a surface drainage channel with design speed of 6.5m^3/s.

Figure 24:Jinjiang Road green space location

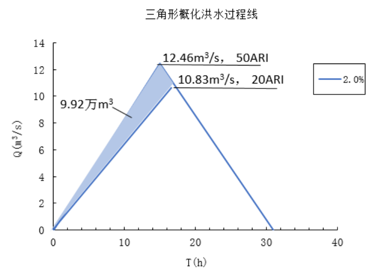


Figure 25: Flood reduction of Jinjiang Green corridor

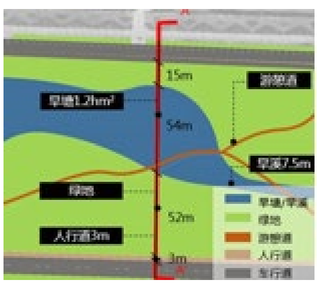


Figure 26: Jinjiang Road green space improvement plan

Figure 27: Jinjiang Road green space proposed section

Figure 28: Jinjiang Rd green space layout

B. Sishui River Corridor Ecological Planning

West of Shangjie district is Sishui river corridor, which drains directly into the Yellow River in north of Shangjie. Thus Sishui river water quality and biodiversity can have a substantial impact on the Yellow River. South of Shangjie is Wuyun Mountain, which could link to the upland Ecology Protection Zone-Wanshan Ecogilical Forest Park.

The whole Shangjie District is within both Sishui and Yellow River Riparian Corridors (Figure 29-31). As illustrated in case studies, some river corridors should range from 50 to 100 meters (Tossone 1981, Ranney et al, 1981) to be effective for biodiversity. Riparian corridors should also be linked with upland habitats (Forman 1983), we thus plan to link Sihui river riparian corridor to Wuyun mountain habitat through the underpass of the Sihui Park (Figure 30 &31). Beyond the underpass beneath Kunlun road (

Figure 37 &39), the corridor should continue on the east of Kunlun road at least 100 meters to provide enough forest interior for its biodiversity (Figure 34).

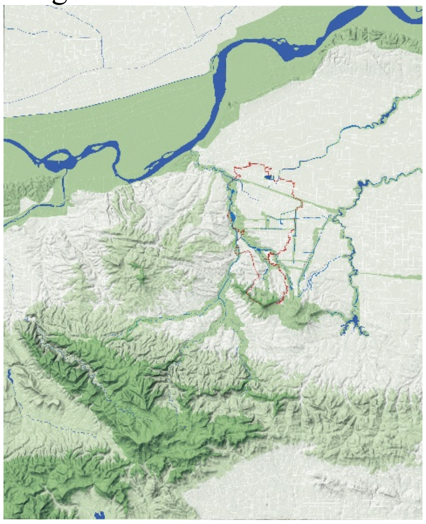


Figure 29: Sishui River Rapirian Corridor and surround habitat patches

Figure 30: Potential Habitat patches

Figure 31: Sishui Park Planned as connection corridors from upland to riparian corridor.

Sishui River's geomorphic floodplain is defined by earth cliffs (Figure 32).Within the geomorphic floodplain, most of lands is agricultural land on the west, and urban development is approaching from Shangjie district on the east. For interval based flood control, our engineers suggested to expand the river channel width and increase the embankment elevation. River channel is planned to be widened 50 meters to reach from 100.62 to 117.04 meter wide. The west embankment will increase from 0.26m to 1.72m, and the east embankment will elevate from 0.08 to 2.38 meter. This will improve the flood standard from 20-year to 50-year. (Figure 35&36).

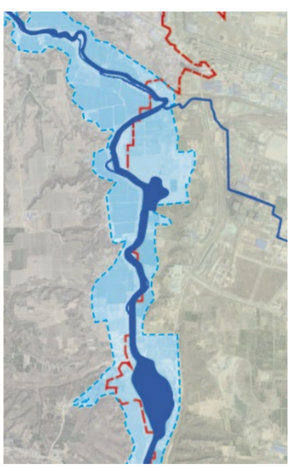


Figure 32: Geomorphic floodplain of Sishui River

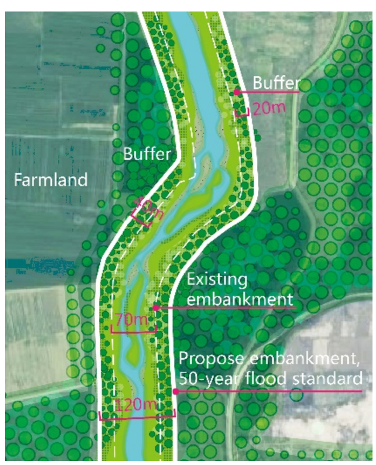


Figure 33: Sishui River Corridor Riparian Corridor Planning, Width increase from 70 m to 120m.

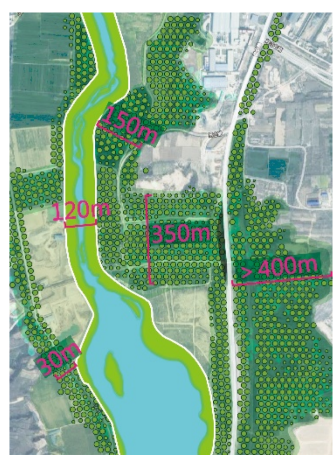


Figure 34: Wildlife corridor along east of Kunlun Road

We also made the suggestion to the government to keep the existing geomorphic floodplain（Figure 32）underdeveloped in the future, to keep Sishui's flood capacity to at least 100-year. This means the geomorphic flood plan either remain as agricultural land, or preferably planted as woody forest.
(Figure 35 &36).

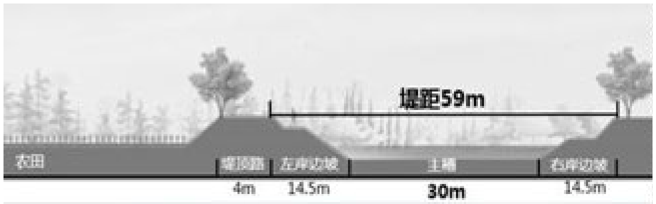


Figure35: existing Sishui River Cross-section of 20-year interval capacity.

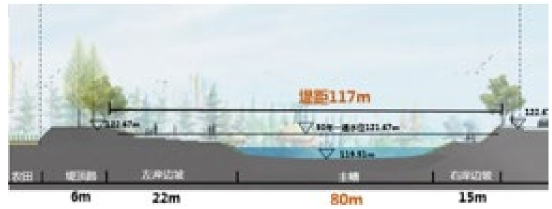


Figure 36: Proposed Sishui River Cross-section of 50-year interval

Besides removing the development within the mountain, more enhancements are needed to the ecological value, including: increasing the planting varieties, restoring riparian corridors, eco-engineering for the river bank, restoring wetland within the flood plain, improving planting at the key nodes.

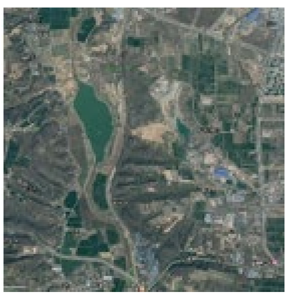


Figure 37: Sishui River Rapirian Corridor and

Figure 38: Taixi lake in Sihui River and Kunlun Road

Figure 39: Potential Wildlife Underpass beneath Kunlun Road.

We also recommended to use Danjing Road's green corridor, Jingjiang Road's green corridor, Luo Ning Road, Longhair Road, Heng Gou river corridor to form major greenway network to connect to the Sihui riparian corridor and Five Cloud Mountain ecological corridors. (Figure 38)

C. Planning improvement and Green space system

Every Chinese municipal government has two departments regulating development permits: land use and urban planning. Our planners found that in Shangjie's land use and urban planning permit have quite significant discrepancies, with only about 9.54 km²of land considered as developable land by one of the planning departments. We took this as an opportunities to re-adjust land use plan and urban plan together to protect more green patches and to maintain ecological corridor width.

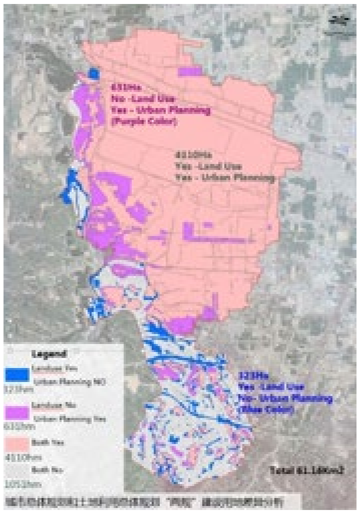


Figure 40: land use and urban planning discrepancy

Figure 41: Proposed removal of the small developable land within Five Cloud Mountain.

Figure 42: Sishui Park as Sishui River Riparian upland habitat Corridor

The most changes are within Five Cloud Mt. area, which has carved development in the only potential habitat (Figure 40). We worked with the city and offered two solutions to the conflict. Step one is to make the development more compact, and to bring small parcels closer to large one to share road and infrastructures (Figure 41). Step two is allowing ecological recovery by removing some developments out of the ecological sensitive areas. In Five Cloud Mt. area, about 1km² development must to move out. We also suggested to include more existing woodland and agriculture land into Sishui park upland corridor (Figure 42).

Within major green spaces and many other cultural spots, we recommended that the recreational greenway for Shangjie (Figure 39) link the historial elements, ecological elements, parks, service functions all to the nature through walking or biking. (Figure 40).

We used 5 tier park system plus urban greenways to plan the green spaces system. In these park system, walking distance is a key factor of the green space planning. From small to big, the parks are Pocket Park, Neighborhood Park, Community Park, Urban Ecological Park, and Ecological Park. Then we link all the major parks to an urban greenway network. We specified ecological functions such as storm water pond for birds to drink, and dense forest for birds to nest at different park level. We also emphasize more specific recreational use such as kid plan area, varies size of sports field, and jogging trails for active sports(Figure 43-45) .We expect green space closer to homes and higher green space distribution to improve the well-being of the public (Thompson, C.W, 2012).

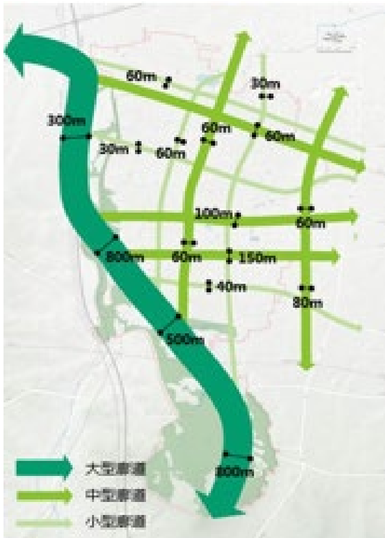


Figure 43: Greenway connections

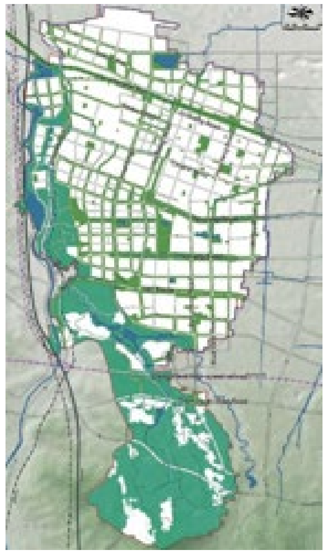


Figure 44: green space system planning

Figure45: Greenway destination points.

Conclusion

This project is still undergoing revisions, according to feedback from different government departments, and will be subject to expert panel and planning commission review. We received very positive feedbacks from the waterway planning result. We have done quite a few water master plans and hopefully can create more retention pond for storm water management as well as water resource for irrigation and recreation. However, the retention pond we proposed was reduced significantly due to the lack of land. The city is still pro-development and ecology is still not the highest priority at this moment. However, we found that the holistic planning is very beneficial, it is saving land for development due to multiple functions (flood control, water quality, and recreation). This project demonstrates the benefit of planning greenways comprehensively. Holistic master planning approach needs the collaboration of the following:

4. Strong leadership and collaboration from different city government departments, which depends on the vision of the highest leader in the region. In our case, the Shangjie district leader who was an urban planner before working for the government, and it can be this project's key support.
5. Technical collaboration within consulting service is the future trend in China, since client side (most government leaders) do not have enough experience to manage such projects.
6. Systemic ecological planning saves land and money, it also creates more interactions between different ecological elements.

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