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Climate Change Adaptation: Designing Resilient Heritage Landscape in Taiwan

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ABSTRACT

Due to climate disasters caused by global warming, large-scale adversities are gradually brought in various regions. Manifestations of this are the issue of drought, heavy rainfall, forest fires caused by strong storms or heat waves in recent years. Besides, many climate disasters have appeared in the form of water-related catastrophes. For example, the rising sea-level and flooding may lead to danger to the lives of residents, loss of economic crops, and more importantly, irreversible destruction of cultural heritage in coastal urban areas. When these calamities occur, the local government needs to develop huge and expensive interventions for the aftermath and reconstruction, especially if the city does not have a climate adaptation strategy. Cultural heritage in particular can be irreversibly affected by disasters.

The main issue of this paper is thus how to deal with the water disaster caused by climate change to cultural heritage by improving urban resilience. However, many urban areas are now steadily developing resilience city planning. Moreover, referring to water management standards, both European and Asian regions have developed strategies that suit their spatial conditions. Under these principles, I am going to explain the impact of climate change on cultural heritage in Asia, Taiwan. In Lukang Town (central region of Taiwan) there is a street called Lukang Old Street which conforms with the Fujian-buildings style that was developed from 1784 to 1845. From 1683 to 1850, a total of about 170 years, the area experienced a large number of Han immigration and port commerce trade, but later the port was silted and could no longer be used. However, recent flooding has occurred almost every summer, causing local governments to expend a tremendous amount of capital to protect cultural heritage. Although climate change is included in the national strategic planning, it is lacking at the local level. Whence, we analyze the management concepts of sponge city and Low-Impact Development (LID) and, on the basis of these approaches, we then advise practical operational methods for the Lukang urban planning area. We divide the area according to the concept of sponge city and risk analysis, then configure LID measures according to spatial conditions. Finally, we conclude by demonstrating that the application of water management to urban areas can effectively reduce the chances of flooding and increase the resilience of heritage landscapes.

Keywords: Urban Heritage, Climate Adaptation, Water Management, Resilience

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INTRODUCTION

Industrial development affects the atmospheric emissions as well as the global climate so that the issue of climate warming is receiving attention from various countries. According to the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (IPCC AR4 , 2007), one hundred to the global average temperature rise of 0.74 ℃, and present a more rapid warming phenomenon in the past 50 years (about every ten years increased by 0.13 ℃). With climate change, whether it is a city, villages, forests, every corner of the earth is not immune. Human activities get especially affected by climate, once a climate disaster occurs, it will always cause many casualties, loss of economic crops, and damage to infrastructure, etc., which the destructions are not only in urban areas but especially cultural heritage areas. For example, Chennai in India in 2015 and Thailand in 2011. Heavy rains in Thailand caused the World Heritage Site of Ayutthaya to remain submerged in water, causing insurmountable loss to the foundations of historic built structures. Therefore, to reduce the number (severity) of cultural heritage affected by disasters, it is necessary to improve the resilience planning of this area.

The first chapter will discuss the theoretical framework of climate impact on cultural heritage and the issue of facing water challenges. According to the above theoretical discourse, the heritage of the area studied in this paper belongs to cultural resources; and the current situation of Lukang facing the water challenge is a specific (sub-system) resilience. Therefore, we have listed some examples of cities in cultural heritage sites. These cities apply planning methods at different levels, to solve flood issues and improve urban resilience. As the reason, we will focus on the level of urban planning to analyze water management and answer the topic.

In the second chapter, the main focus is on the Asian region, the sponge city, the urban planning method proposed by China in water management. The main concept of this water management method is based on the U.S. LID, and the content is to increase the permeable pavement, collect rainwater and reuse it, to reduce the amount of water discharged. After the analysis of the "Xiamen Sponge City Pilot", we understand that this water management operation is divided into regions from large to small, to control the overall drainage volume, and then achieve the goal of reducing the peak drainage.

In Chapter 3, we carried out the strategic analysis and environmental analysis of Lukang Town following the planning method mentioned in Chapter 2. We found that the strategic planning of this area also mentioned that due to this area has a high development density, it is recommended to apply LID measures in urban planning. In the environmental analysis, we will start from the historical perspective, since cultural heritage is the core value of the area. The analysis results indicate that the soil in this area is poorly permeable, and some blocks have fewer rainwater drainage pipelines, so flooding is more likely to occur.

The fourth chapter proposes the areas suitable for the use of sponge cities based on the three areas of the urban planning area. The first and second areas are cultural heritage protection areas and maintenance areas, so it is only recommended to increase the permeable pavement in the private parking lot or use Perforated Pipe Systems is under low-usage neighborhood roads. The third area is mainly a residential area with more large open spaces (parks, schools, etc.), so LID measures are configured according to space conditions.

Overall, we concluded that even in a high-density building environment, the concept of sponge city and LID changes on the block can still be used to reduce the chance of flooding.

CHAPTER 1 Climate change, cultural heritage, and urban resilience

1.1 Climate change and cultural heritage

1.1.1 Water challenges for cultural heritage

Thanks to the continuous progress of global industrial development, the overall carbon emission is likewise increasing, disrupting the earth's natural ecosystem and greenhouse gas cycle mechanism, leading to global warming and climate change problems. Accelerated anthropogenic climate change threatens the ability of the earth's ecosystem to maintain human well-being. The global ecosystem has limited the capacity to meet the needs of a growing population (Mathevet, et al., 2016; Nkoana, et al., 2017). According to the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (IPCC AR4 , 2007) the already observed impacts of climate change triggered an increase "in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level". Over the last 100 years the global average temperature rises of 0.74 ℃, whereas in the past 50 years a more rapid warming phenomenon has been detected (about every ten years increased by 0.13 ℃). The report also pointed out that since the 1950's the earth's warming phenomenon has a close relationship with human activities (90% probability (IPCC AR4 , 2007)). As the temperature rises, the glaciers of Greenland and Antarctic Ice are melting rapidly (Stocker, et al., 2013), leading to changes in ocean salinity and also affecting marine ecosystems. "Coastal risk is dynamic and increased by widely observed changes in coastal infrastructure, community livelihoods, agriculture and habitability" (Coninck, et al., 2018). Nevertheless, the melting of glaciers is the cause of the sea-level rise. Therefore, higher sea levels may cause more dangerous hurricanes and typhoons. Scientists show that between 1963 and 2012, almost half of all deaths from Atlantic hurricanes were caused by storm surges (Rappaport, 2014). Flooding in low-lying coastal areas has forced people to move to higher places, and millions more are more vulnerable to flood risks and other climate change impacts. The prospect of rising coastal water levels threatens basic services such as the Internet, as many basic communication infrastructures are located on the path of rising sea levels. New elevation data show that by 2100, areas now home to 200 million people could fall permanently below the high tide line. Climate Central mainly aimed at analyzing the altitude data of coastal areas to estimate the probability of flooding in the future. For example, in China in 2050, an area of land with a population of 93 million may suffer more floods than average every year, especially the most populated Shanghai and the low-lying Jiangsu province (Central, 2019). Sea level has always been a threat to the world and cultural heritage. Flooding is another problem for cultural sites. When a site is submerged by water, it undergoes many changes, including the degradation of physical characteristics. Now, as accelerated climate change is affecting the ecological framework, the situation is getting worse. Facts have proved that the earth's climate changes greatly. But human behavior has triggered some unusual accelerations (Perry, 2019).

"World Heritage properties and heritage sites in general are exposed to the impacts of natural and man-triggered catastrophic events, which threaten their integrity and may compromise their value which on local and national communities, both because of their cultural importance, and socio-economic value." (UNESCO, 2008)

Like all resources on public land, cultural resources are also affected by environmental factors such as climate change. As weather patterns become more extreme and unpredictable, they will bring new risks to the management of cultural resources. Urban heritage is becoming more and more vulnerable to disasters: rapid population growth, unplanned urbanization, and poverty, especially in developing countries. The fragility of cultural assets is related to their physical environmental characteristics, such as location and building form, materials, and protection quality. The types and potentials of disasters belong to local characteristics, and their adverse effects on cultural assets are also different. Floods, earthquakes, slope disasters, fires, long-term climate effects, and other natural disasters can all destroy cultural assets. "These factors can lead to the loss of the local ecology, which played an essential part in planning historic cities in harmony with their natural environment, thereafter often regulated through traditional beliefs and practices" (Jigyasu, 2019). In addition to the external environment, some damage comes from problems with internal building structures. For example, some cultural assets are directly repaired without considering appropriate strengthening or risk reduction; some are caused by the fragility caused by building materials or design forms, such as the low bearing capacity and stress of mud, and the lack of resilience of masonry structures in the face of earthquakes. Easily damaged, high-arch or large-span structures are difficult to cope with huge seismic forces. In addition to substantive characteristics, the vulnerability of cultural assets is also driven by the socio-economic environment. The degree of urbanization, excessive emphasis on economic development, changes in land use, or zoning may all expose cultural assets to more risks. For example, the agglomeration effects of urbanization and economic activities have caused historical and cultural assets to be surrounded by new high-rise buildings, road elevations have increased, and adjacent building bases have also been elevated, causing changes in the external environment to become a source of risk for cultural assets in the face of earthquakes or floods.

Since cultural heritage occupies such grand importance in human life, facing the IPCC Climate disasters are even more urgent. Scholar Perry proposed, according to UNESCO, 16 out of 252 natural world heritage sites (NWH) are threatened by climate change (Perry, 2019). There are more than 700 cultural monuments on the UNESCO World Heritage List. If the global average temperature rises by only one degree Celsius, more than 40 locations will be directly threatened by water in the next 2000 years. As the temperature rises by three degrees, in the long run, about one-fifth of the cultural world heritage will be affected (Marzeion & Levermann, 2014). Notably, there are many cultural sites of the UNESCO world cultural heritage are located in low-lying coastal regions (Reimann, et al., 2018). The water threat manifests itself as heavy rainfall, flooding, or storm surge. The increased rainfall can overload roofs and drains, penetrate traditional materials (such as thatch, corncobs, plastering, etc.), or bring pollutants to the surface of buildings, and floods can cause catastrophic losses. Changes in humidity affect the growth of microorganisms on stones and wood, and the formation of the salt in a more subtle but more general way. Salt degrades the surface and affects corrosion. Dry summers increase the salt and weathering of the stones and protect archaeology. The ruins and the soil supporting the foundation of the building are gradually drying out. According to these reports, the flood disaster caused by rising sea levels threatens cultural heritage in several different ways. If governments do not pay attention to this situation, it will have an irreversible and strong impact on cultural heritage.

Figure 1 A view during maintenance works. The floor has been raised 1 m and the lower part of the door has been bricked up and used to host sewage drainage pipes (photo D. Resini, courtesy INSULA, Venice)

Figure 2 Water shortage in the moat of De Wiersse Castle after summer (September, 2019)

BOX 1   Two opposite cases: cultural heritage affected by flooding and water shortage

Venice, Italy

Venice is a unique coastal city included in the UNESCO World List of Cultural Heritage, since ancient times has suffered from many climate hazards, such as sea-level rise, storm surges flooding the city, the Lagoon freezes over during most severe winters (Camuffo, et al., 2018). The water level of the lagoon is rising and is particularly vulnerable to seasonal effects, and it is predominantly prone to flooding from October to December each year. In 2018, Venice faced the biggest flood in more than 10 years. Three-quarters of historical monuments were attacked. The flood exceeded the normal water level, and the flooding was as high as 150 cm. The elevated sidewalks where residents and tourists walk on weekdays were flooded, this has been the highest water level since the end of 2008. From the threshold of many buildings, the floor has been raised and the lower part of the door has been bricked up and used to host sewage drainage pipes due to flooding prevention. However, the MOSE flood barrier system is a project designed to protect the city of Venice and the lagoon from flooding. Although it was delayed in construction, it successfully protected Venice for the first time during the storm on October 3, 2020 (Spears, 2020).

De Wiersse Castle, Netherlands

Irregular rainfall due to climate change not only led to flooding disasters but also can cause water shortages due to rainfall deficiencies. The cultural heritage of Achterhoek of the Province of Gelderland in the Netherlands, De Wiersse Castle, has also been indirectly damaged by climate change. The Dutch early urban planning of Gelderland was based on the land being below sea level, thus the river was planned to be located on the edge of De Wiersse Castle and become a fast drainage channel for floods. As the water level of the moat decreased, the foundations of the castle fall and collapse without the buoyancy of the water. Castle managers responded by pumping groundwater, but could not keep it away for the long term.

From these two examples, we can grasp the protection of cultural heritage under climate change is very difficult and complicated. In this case of how to solve climate disasters, the concept of resilient landscape heritage becomes an important operation method for this field.

BOX 2 Cultural heritage affected by water pollution

Shiga Prefecture, Japan

In recent years, due to the temperature increase produced by climate change, not only in Europe but also in Asia, abnormal climate phenomena took place. In Shiga Prefecture, Japan, there is a historic lake called Lake Biwa. It was formed about 4 million years ago. It is the largest lake in Japan, occupying one-sixth of the area of Shiga Prefecture, with a total area of 670.33 square kilometers and a shore of 241 kilometers. It also has a rich ecosystem. In 2015, "Lake Biwa and its waterside landscape heritage of prayer and life" were recognized as a "Japanese heritage" by the Agency for Cultural Affairs (Heritage, n.d.). A series of tangible and intangible cultural heritage has also developed around Lake Biwa. For example, since ancient times, people have used water as a way to treat diseases and remove impurities. Also because of respect for water, there are many temples and shrines built around Lake Biwa. The most famous temple is the Hieizan Enryakuji Temple, which has been designated as a World Cultural Heritage and National Important Cultural Property.

However, according to research, the warm winter phenomenon in 2006-2007 caused the lake water temperature to rise (Pacific Consultants Co., 2015). As a result, the natural hot-warm water convective cycle essential to have the right oxygen percentage distribution under lake level to guarantee life loss efficiency dramatically. Normally, the water cycle of Lake Biwa relies on low-temperature winter snow and summer temperature rise. The alternation of hot and cold water brings the long-term lack of oxygen at the bottom of the lake to the upper layer so that the oxygen content in the water can be effectively provided to the organisms at the bottom of the lake. But because of the warm winter, the temperature of the lake is not low enough, and the upper water could not effectively circulate with the bottom. Therefore, it has been pointed out that if the dissolved oxygen concentration is low, phosphorus tends to elute from the bottom of the lake, which causes eutrophication, which may lead to deterioration of water quality and adverse effects on the ecosystem in the lake.

At present, the local government of Japan is also studying related phenomena (agriculture, infectious diseases, aquaculture, etc.) that may trigger this issue (Pacific Consultants Co., 2015). If this situation persists, it will definitely affect the lives of surrounding residents, and the cultural beliefs that people have long believed in will also be destroyed.

Figure 3 A community living by Lake Biwa

Figure 4 Traditional dance to reward the god of water

Figure 5 The unique fishing mode and food culture of Lake Biwa - Oisade fishing (オイサデ漁)

Figure 6 Hieizan Enryakuji Temple

(Sources: The website of Shiga Japan Heritage)

1.1.2 The strategic role of cultural heritage

To discuss the impact of climate change on cultural heritage, we should start with:” why cultural heritage needs to be protected?”.

Because we need to understand the value of cultural heritage to know the importance of that being affecting everyday life. The cultural landscape can reveal itself in many different forms. It can be a monument, a historical building, or a place where wars have occurred. The Blue Shield network is a non-governmental, non-profit, international organization committed to the protection of heritage across the world. They announce that “cultural heritage – tangible and intangible – is important. It is a vital expression of the culture that makes up unique communities and its loss during conflict and disaster can be catastrophic.” However, this phenomenon not only gradually increases the vulnerability of culture, on the other hand, it also makes cultural heritage a vulnerable and sensitive element of the city (Gandini, et al., 2018).

Nowadays, cultural heritage has brought various benefits to our society, environment, and economy. It plays an important role in economic development and growth through tourism and leisure industries, including urban and rural revitalization (Alexandrakis, et al., 2019; Janssen, et al., 2017). “The protection and management of cultural heritage resources are a way of ensuring their maximum possible vitality, values and functions to the benefit of current and future generations, attributing them an important role in a sustainable social system (Szmelter, 2013).” The above discussion all stand for cultural heritage is not just a part of visual art, but an important role in the development of society, economy, etc. in the past and future of mankind. Just as the current ocean erosion is destroying coastal sites. These sites can tell us how the past society has adapted to the rise in sea level after glaciers, and sea-level rise has such a profound impact on human history (Erlandson, 2010). Some scientists and policymakers began to study the contribution of archaeology to current environmental problems (Diamond, 2005; Rick, Torben C.; Erlandson, Jon M., 2008). Ms. Thompson-Flores put it: “cultural heritage should be understood not only as a victim of climate change but also as a resource to reduce its impact and consequences”. Experts of the IPCC have indicated the utility of culture in adapting to climate change by enabling communities to be more resilient (Anon., 2020). Take the water shortage in the Kathmandu Valley of Nepal as an example (Shrestha, n.d.). The impact of climate change has further exacerbated the growing water shortage problem. Traditional water resources such as stone spouts and wells play an important role in meeting the increasing water demand in the Kathmandu Valley. However, the state and non-state authorities did not pay enough attention (Shrestha, n.d.).

In 2007, UNESCO formulated the Strategy for Reducing Risks from Disasters at World Heritage Properties. Mainly determine five disaster reduction goals. The purpose of the strategy is to assist the contracting states to incorporate heritage concerns into their national DRR policies and management plans for world heritage properties. This will strengthen the protection of world heritage and contribute to sustainable development. One of the researchers of the EUR-OPA Major Hazards Agreement mentions that the development of long-term strategies can prevent cultural heritage from climate damage (Sabbioni, et al., 2008). Nevertheless, the threat posed by climate change to cultural heritage is of secondary importance to many countries' policies. Most countries still put homeland security and economic issues first, ignoring that cultural heritage can also affect the development of a society and value.

Until 2018, the Work Plan for Culture 2019-2022 was adopted by the Council of the European Union. Member States define the main topics and working methods for policy collaboration on culture through Work Plans for Culture adopted by the Council of Ministers. The plan is considered a strategic tool that sets priorities and determines specific actions to cope with the increasing shift to digital technology in the field of cultural policy, globalization, and the growth of social diversity.

To help understand and plan for the impact of sea-level rise on modern coastal populations around the world, we should do more to document the successes and failures of societies that faced similar challenges in the past (Erlandson, 2010).

1.2 The urban resilience paradigm

1.2.1 What is urban resilience?

Cities, "after suffering wars, earthquakes, religious transitions, destructions with no reconstructions and the maintenance of the ruins, still remain nowadays a place of special significance" (Beinart 2005:181)

Cities all over the world are making plans, setting agendas, and clarifying goals for urban resilience. However, is urban resilience really possible? Resilience to what, for what, and for whom? Besides, in many cases, resilience has been used as a substitute for sustainability, but not so. Resilience and sustainability need to be linked, but be cautious and clear (McPhearson, 2014).

On the European Commission's website page on The Resilient City, it says, "A resilient city assesses, plans and acts to prepare for and respond to all hazards – sudden and slow onset, expected and unexpected," and also it can maintain the continuity of services and functions in the event of any shock or pressure violation while protecting and improving people's lives (Commission, n.d.). In recent years, there are only occupying 2 percent of the land, cities are responsible for 70 percent of global GDP, greenhouse gas emissions (GHG), and global waste, and over 60 percent of global energy consumption (UN-Habitat, 2016). Cities are hot spots responsible for threatened global ecological boundaries (Chelleri, et al., 2012). Italian planner Bernardo Secchi recognizes that the impact of climate change and increasing social inequality are key aspects of a new urban problem (Secchi, 2013). Around a decade ago, reference to resilience is made in adaptation planning, policy development, and implementation at different administrative levels, not only concerning urban climate policy (Davoudi, et al., 2012). Facing the real challenges of the increasing fragility of modern cities, this concept of resilience encompasses ecological, social, economic, and infrastructure systems (CURTIN & PARKER, 2014). And this concept is gradually being applied to the field of urban planning and design and risk management. Urban resilience has had particular uptake within the context of climate change, being used primarily as a conceptual framework for assessing system vulnerabilities regarding urban physical structures and functions and services (Gersonius, et al., 2008; Prasad , et al., 2009; Chen & Graham, 2011).

Not all hazards can lead to disasters. Disasters occur when the disaster causes destruction and the community cannot respond independently. Therefore, pre-emptive measures can help build better resilience and avoid infrastructure damage, which can lead to serious social and economic consequences.

However, many researchers have postulated that cities could become the hubs of change and transformation, turning the crisis into an opportunity (Seto & Satterthwaite, 2010; Lankao & Dodman, 2011; UN-Habita, 2011). Urban resilience is for the unknown and the unknowable (Kates & Clark, 1996; Peterson, et al., 2003a; Polasky, et al., 2011a), for having the capacity to deal with complexity, uncertainty, and surprise (Walker, et al., 2009a.; Biggs, et al., 2012a; Carpenter , et al., 2012a). Resilience provides sources of memory, flexibility, options, and innovations for transformation and can help turn a crisis into an opportunity (e.g., (Gunderson & Holling, 2002; Nykvist & Heland, 2014)).

Therefore, International Council for Local Environment Initiatives (ICLEI) opted for a broader, more integrated approach, defining urban resilience as the ability of cities to anticipate, prevent, absorb and recover from shocks and stresses, and to improve essential basic response structures and functions, while integrating the different aspects of urbanization, sustainability, development, and climate change (Bizzotto, et al., 2019). "Resilience can solve natural phenomena (floods, earthquakes, epidemics), man-made disasters (oil spills, radiation accidents, system failures), or socioeconomic crises in response to shocks and pressures caused by rapid changes in the environment, technology, society, and demographic structure (Political and social shocks, terrorist attacks, financial crises)" (Bizzotto, et al., 2019, pp. 4-6). These shocks and pressures will affect one or more urban systems such as food supply chains, energy grids, and mass transportation systems. They may also cause spillover effects in the city-region. However, the interaction and interdependence between urban systems can also be used wisely, taking advantage of their complementary and synergistic features to achieve broader sustainable development. The 2030 Agenda and its Goal 11 "make cities inclusive, safe, resilient and sustainable" has clearly emphasized the need to adopt and implement comprehensive policies and plans for inclusiveness, resource efficiency, climate change mitigation and adaptation, and resilience to disasters (UN, 2015). In the international community (United Nations), the Sendai Framework for Disaster Risk Reduction (2015-2030) (UN, 2015)has been formulated as an operational framework at the local level. Among them, ten basic requirements have been formulated to make cities resilient to speed up implementation at the local level. The ten basic elements are directly aimed at monitoring disaster risk reduction actions, and they are key and independent steps to establish and maintain resilience. The actions identified under each basic principle should become part of the overall disaster risk reduction planning process and influence the planning and design of urban development. The Resilient Cities program from the ICLEI covers issues surrounding climate change mitigation and adaptation, disaster risk reduction, and food security, while cities in the URBACT Resilient Europe Network work together to learn and share experiences to foster resilience and sustainability. The 100 Resilient Cities (100RC) initiative, launched by the Rockefeller Foundation aims to support cities around the world in formulating and implementing strategies that can improve urban resilience in the face of multiple shocks and pressures (including climate change). Especially engaged cities are expected to improve their performance in the face of a wide range of severe shocks, such as earthquakes, floods, or fires, and chronic stresses such as unemployment, migration, water, and food shortages. Instead of preventing or mitigating the loss of assets due to specific risks (The Rockefeller Foundation & Arup, 2015). The World Bank Group's Urban Resilience Program (CRP) was established in June 2017 to enable cities to make investments to increase their resilience to climate and disaster risks and obtain the necessary financing to ensure that these investments are realized. Incorporating resilience into socio-economic development planning and infrastructure will guarantee development investment. This means that if the cost of the city's investment in post-disaster reconstruction is to improve the city's ability to reduce disasters and increase resilient recovery, it will no longer need to spend a lot of money on "repair" after a future disaster, and it can also invest funds in sustainable development goals. This will become a positive cycle. Thus, understanding urban resilience and urban sustainability as two concepts that promote the diversification of solutions to social-ecological problems, which means that urban planning needs to adopt new metaphors and paradigms to further transform the city (Wilkinson, 2012).

On the other hand, Dr. Timon proposed that the urban resilience system does not exist alone. It also needs to be combined with the concept of sustainability, so that it will not bring a more serious ecological burden to the city in order to achieve the purpose of urban resilience. For example, after Superstorm Sandy hit New York City and the New Jersey coastline, there was much discussion about large technical infrastructure solutions for dealing with expected future storm surge and coastal flooding: for example, closeable sea gates at the narrow section of the entrance to New York harbor (McPhearson, 2014). The planning and management of urban resilience must seriously consider the comprehensive view of social ecology so that the results can contribute to the realization of equity, human well-being, and ecological integrity.

Sustainability and resilience both follow the precautionary principles regarding resource use and emerging risks, avoid fragility, and promote future ecological integrity. Sustainable development can be therefore defined as development that fosters adaptive capabilities and creates opportunities to maintain prosperous and desirable social, economic, and ecological systems (Holling, 2001; Folke, et al., 2002). How should the city's resilience system be defined? When we talk about the concept of resilience, we will inject the damage caused by meteorological disasters into the city and the ability to recover. Therefore, it is urgent to identify different types of obstacles in the process of adaptation in order to bridge the gap between climate change science and the planning and implementation of cultural heritage adaptation to climate change. Research on urban resilience and climate change also focuses on the development of new models for governance and policymaking, in which adaptive governance based on flexibility, learning, experimenting, and ultimately, transformation is key to building resilience (Leichenko, 2011; Davoudi, et al., 2012). Asprone et al. proposed, the concept of city resilience includes different and multidisciplinary meanings, what is intended for preservation of functionality after extreme events, and what is intended for a "resilient" response depending on the type of extreme event (Asprone & Manfredi, 2013).

However, the concept and framework of flexibility are not fully defined, it is that what resilience means is not clearly defined (McPhearson, 2014). In particular, the concept of sustainable development and resilient development are often confused. "However, the current, more ecological concept of resilience is not only about bouncing back and recovery (….), often discussed as adaptive capacity. In this context, resilience is the capacity of a system to experience shocks while retaining function, structure, feedbacks and, therefore, identity" (McPhearson, 2014; Folke, et al., 2010; Tuvendal & Elmqvist, 2012). In other words, resilience can be seen as a necessary way to meet the challenges of sustainable development. Climate adaptation aims to reduce the risks posed by climate change, including floods caused by extreme rainfall events. However, on the whole, climate adaptation can also generate synergy among many urban challenges by simultaneously addressing multiple areas of urban development.

Sustainability	Manage resources in a way that guarantees welfare and promotes equity of current and future generations
Resilience	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, i.e. capacity to change in order to maintain the same identity.
System resilience	The resilience of a system to all kinds of shocks, including novel ones.
Specified(sub-system) resilience	The resilience "of what, to what";resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks.
Transformation	The capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.

Table 1. Definition of sustainability and resilience concepts   Sources: Author, based on (McPhearson, 2014)

1.2.2 Policies, plans, and projects for urban resilience

For city managers and decision-makers, resilience is an increasingly important issue. Especially when faced with such a complex composed of public and private sectors, more policies and regulations are needed to cooperate. Under the premise of implementing resilient cities, different levels of strategic planning and risk assessment are required. While these plans are being applied, relevant planning tools or policies are also demanded to be carried out at the same time. Although the concept of urban resilience has been extensively explored and recently also explored, it remains an important issue in terms of its operation. Therefore, there is a great need to show how the concept of resilience can be transformed into best practices for planning operations. Here are different experiences addressing urban resilience focus on water challenges at different scales and through different tools (policies, plans, design actions) recently developed in Europe and Asia.

The National Climate Adaptation Strategy (NAS) of the Netherlands, 2016

The Netherlands is considered here as a typical case for countries that are adapting to climate change at different government levels (Fatorić & Biesbroek, 2020). Since 2005, the Dutch government has had a holistic perspective on spatial adaptation and has briefly mentioned the role of tourism and heritage sites in their first National Adaptation Strategy (NAS) (VROM, 2007). However, the national framework Delta Programme adopted in 2010, the focus shifted towards improving flood risk management, ensuring sufficient freshwater supply, and ensure the main economic sectors are climate-proof and water-resilient through the implemented Delta Plan on Spatial Adaptation (Delta Programme, 2018). Starting from the national strategy of the Netherlands. The National Climate Adaptation Strategy (NAS) (Meijs, et al., 2016). Since ancient times, the Netherlands has faced the rise of sea level and the decline of land caused by the quality of charcoal soil. Therefore, the Netherlands has long experience in climate planning. They divided the national adaptation strategic plan into proposals and implementation methods, and each department Due to long-term accumulated experience, there have been a series of cooperation methods with local governments. Usually, climate change is only reminiscent of disasters and shortcomings, but the strategic plan of the Netherlands also analyzes the advantages of climate change as an industry that can be improved or promoted in the future, i.e., Temperature changes increase the choice of more cash crops, and the warm winter can reduce energy consumption. On precipitation and drought, the possible impacts are clearly listed, and the countermeasures are clearly described.

In terms of how to define whether the area is in an urgent state of being processed, the Dutch government proposed that Timeliness, Affected Areas, and Uncertainty must be considered in order to analyze the relative adaptability and investment life. One of the important aims of this strategy is said that although the vulnerability of certain vital functions has prompted the revision of policy and the implementation of measures, it could be claimed that too little attention has been given to the likely impact of flooding. The urgency of effective measures is partly due to the long life-cycle of the infrastructure that supports vital functions such as energy provision and transport (Meijs, et al., 2016). Under the influence of climate change, more long-term planning and efficient infrastructure investment are needed to reduce more disasters.

The National Plan for Adaptation to the Impacts of Climate Change of Japan, 2015

Nearly three-quarters of Japan's land is mountainous, which is the foundation of its steep and short rivers. For this reason, coupled with the limited period of precipitation in Japan (the rainy season from June to July and the typhoon season from August to September), the amount of rainfall that can be captured is limited. Therefore, the drought events in Japan are historically Frequent occurrence. The most recent example is a nationwide drought. It occurred in the spring of 1994. Due to long periods of low rainfall, the water quality of the main rivers began to deteriorate and forced the quantification of water supply until November of the same year. Besides, Japan's population is concentrated in areas with lower elevations (alluvial plains account for only 10% of the total area), and more than 50% of the population and 75% of total assets are on these plains. For Tokyo, there are 13,120 square kilometers of land whose elevation is equal to or lower than sea level. In September 2015, the Kanto and Tohoku regions caused large-scale flood damage (Castillon, 2020).

Therefore, the Japanese government issued the National Plan for Adaptation to the Impacts of Climate Change (Cabinet Decision, 2015), detailing how the country will respond to the challenge of climate change. First, the background and problems are given from the international climate trends and their local adaptation work, and their basic adaptation strategies (including mainstreaming adaptation into government policies). The report also discussed its adaptation methods, such as building resilience to improve adaptive capacity. Taking care of protecting, restoring, and creating the natural environment to ensure that the environment and adaptation measures are not burdened. As well as monitoring and observing the impact of climate change, it is vulnerable to climate change. Departments affected by changes (including water resources, natural ecosystems, coastal areas, and human health) guide adaptation. To this end, it is necessary to appropriately combine engineering and ecology, land use, social and institutional methods, and take measures based on factors such as Japan's socio-economic conditions, regional and sectoral characteristics, and the degree of impact of climate change.

Towards a more resilient Lisbon UrbaN Green Infrastructure as an adaptation to climate change (LIFE LUNG)

Another case of a resilient city in Europe, which is a large-scale urban strategy, Brisbane, Portugal. It faces threats related to climate change due to its geographic location and climate. Although the city receives more rainfall in winter, the average annual rainfall is decreasing. This means longer droughts and more seasonal floods, reducing soil water uptake and soil conservation. At the same time, the average temperature increases at a rate of 14 °C per year, and the maximum temperature increases up to 5 °C. Therefore, climate change will have a negative impact on the quality of life and health of Lisbon citizens and their urban green spaces. The development process of LIFE LUNG (Towards a more resilient Lisbon UrbaN Green InfraStructure as an adaptation to climate change) (LIFE LUNGS, n.d.) is from September 2019 to August 2024. The main goal is to implement the municipal climate adaptation strategy (EMAAC) by using urban green infrastructure as a tool to adapt to climate change. It will also promote and develop related ecosystem services. Its overall goal is to improve Lisbon's resilience and climate change. This project is a strategic plan for an urban area. It is subdivided into six actions, some of them are supported by planning tools. It will develop an urban green infrastructure with zero waste of rainwater and improve flood resistance while maintaining high quality. The flexible ecological basis to achieve water use goals. Then, by developing more green spaces, the temperature rise caused by the urban heat island is solved. Another important feature of the project is that it contributes to EU policies and strategies that promote active citizenship by involving people in planting activities. Although there is no specific policy on this issue, some policies and other instruments emphasize the importance of citizenship in the development of a more united and democratic Europe. Citizen participation in environmental issues, especially in urban areas, is essential for ensuring a better understanding of the threats and impacts of climate change and proving that cooperation and active participation can lead to better results.

Tianjin Culture Park

Water management occupies a great place in climate adjustment. Not only in Europe, but also in Tianjin, China in Asia. Due to its proximity to the sea and heavy rain, the Tianjin Cultural Park (Tianjin Cultural Park, 2012) was completed in 2012. Tianjin is one of China's top 5 cities, not just in size and population but also in terms of business investments. This park covers an area of 90 hectares and is located in a cultural recreation center in the city center. The main goal was to increase outdoor comfort and create dynamic social pedestrian routes. In addition, the 10-hectare lake is the center, and the water feature serves a dual purpose for the park. They are part of the water collection and filtration system and have different levels and can be used for various purposes. The lake is a stormwater feature, a balancing pond that can effortlessly handle a 1 in 10-year storm event and buffer a 1 in a 100-year storm event. Then in times of low rainfall or for events can be drained as additional plaza space or ice skating in the winter. It is also a water storage basin along the coast, which overlooks the city and prevents the rise of brackish water from the ocean. In addition, recycled rainwater is also used to irrigate the surrounding landscape planting. Generous tree plantings link subsurface, decentralized retention trenches that feed the lake via a cleansing biotope. Not only prevents flooding from heavy rains but also cools the city and Social Interaction has brought many positive effects.

Figure 7 Aerial views of Tianjin Cultural Park Sources: (Tianjin Cultural Park, 2012)

Figure 8 Tianjin Cultural Park Sources: (Tianjin Culture Park, 2012)

Bishan-Ang Mo Kio Park

The original name of Bishan-Ang Mo Kio Park in Bishan Park. It is one of the most popular parks in the center of Singapore. Bishan-Ang Mo Kio Park was rebuilt in 2006 due to the Active, Beautiful, Clean Waters (ABC Waters) Programme of the Public utility board in Singapore. The main design concept of this park is to transform the old “rapid rainwater drainage” system into natural drainage and increase infiltration for urban resilience and heavy rain brought by climate change. At the same time, it applies the application of a water-sensitive urban design approach (also known as ABC Waters design features in Singapore) to managing rainwater sustainably. The area of the park has expanded from the original 53 hectares to 62 hectares. In the middle of the park lies the Kallang River, which runs through it in the form of a flat riverbed. It was originally a straight concrete drainage channel with a length of 2.7 kilometers. Due to the project’s goal of increasing the river’s flow and coordinating with the natural ecological planning, it has been converted into a 3 kilometers natural drainage channel. River water. When the water level in the river is low, people can approach the river bank and enjoy recreational activities on the riverbank, and during heavy rain, the parkland by the river can also double as a transportation channel.

In particular, before the renovation project started, 10 soil biotechnologies and local plant species were tested at the drainage outlet on one side of the park. Then seven of them were selected for use along the banks of the main river to ensure plants and organisms Survival is undoubted.

Figure 9 Before and after completion of Bishan-Ang Mo Kio Park   Sources: Photo by Pagodashophouse

1.3 Resilient heritage landscapes

"While culture is essential both as an asset and a tool for city reconstruction and recovery, it is often left out or given limited consideration as part of these efforts," said Laura Tuck, Vice President for Sustainable Development, World Bank.

Cities are developed from cultural heritage. In the term "resilient city", "urban" plays a role in adapting to climate change to adjust management and design methods. It means that certain parts of the city need to be renewed and adjusted, but cultural heritage is usually in the state that under protection and maintenance, it may not be allowed as much change as a city. In addition, in the "cultural heritage affected by climate disasters" mentioned in the previous section, if there is no relevant protection plan, tangible cultural heritage may also become a sensitive and vulnerable part of the city. Then, leading to the financial burden of the city becomes a vicious circle. However, the cultural heritage in the city is often one of the highlights that attract tourists (Fatorić & Biesbroek, 2020). If the resilience of the city is improved so that floods or rainstorms do not occur so frequently, then cultural heritage will no longer be easily destroyed. Once the disaster in the city declines, cultural heritage can continue to play the role of attracting tourists, and it can also increase the financial income of the place. The relationship between cultural heritage and the city also forms a positive cycle because of the resilient raised.

Landscape resilience is defined as the ability of a landscape to sustain desired ecological functions, robust native biodiversity, and critical landscape processes over time, under changing conditions, and despite multiple stressors and uncertainties (Beller, et al., 2015). To reach the goal of making cities more inclusive, safe, resilient, and sustainable, the key to success is to integrate culture into reconstruction and recovery processes, including built and living heritage and creativity (World Bank Group, 2019).

The integration of the concept of Cultural Heritage into disaster resilience has been emphasized in the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030, particularly within Priority for Action 1 "Understanding disaster risk and Priority", and within Action 3 "Investing in disaster risk reduction for resilience" (UNISDR, 2015). However, "these disasters need not have happened as they did, had there been prior recognition of the loss of traditional knowledge systems due to unplanned development and resulting vulnerabilities of urban heritage (Jigyasu, 2019)." Traditional communities in historic cities often develop a variety of resilient features in the urban environment that – intentionally or unintentionally – contribute to prevention and mitigation, emergency response, and recovery. We should not treat urban heritage as merely a disaster We should realize that heritage can play an active role in reducing disaster risk, achieving sustainable recovery, and building resilience to disasters (Shrestha, n.d.). Restoring the role of traditional knowledge systems in urban planning and management and determining their potential role in disaster risk reduction is an important challenge for enhancing the security and resilience of historic urban areas (Jigyasu, 2019). To examine the relationship between sustainable development and cultural heritage, we must first recognize the important role of cultural heritage in society. Cultural heritage can reflect the long-term relationship between humans and the living environment, and people's attitudes towards other life forms, and the values of high quality of life (Europe, 2005). Cultural heritage is closely connected with human life and even integrated into the development process of society, economy, and environment (Nocca, 2017).

Cultural heritage is all the aspects of the environment resulting from the interaction between people and places through time Heritage Communities are defined as “people who value specific aspects of cultural heritage which they wish, within the framework of public action, to sustain and transmit to future generations” (Europe, 2005). In recent years, cultural heritage is not limited to monuments or representative landmarks, it also includes the coastal scenery such as the rural areas where people live, historical cities, and other coastal scenery. Even the areas where wars have occurred in the city, or religious ceremonies, etc., cover human emotional sustenance (UNESCO & Cultural, 2003). Therefore, we can say that the development of the city is the step of inheriting cultural heritage. If the cultural heritage is lost, it means that the landmarks in the city and the lifestyle passed down by ancestors will disappear, and the city residents will be unable to determine their sense of existence (Szmelter, 2013). It can be seen that the inherent value of cultural heritage to present and future generations, as well as the significant role and positive contribution it may play in all core areas of sustainable development.

Moreover, urban resilience is both a target and a process in which cultural heritage supports the building of a community able to prevent, cope with and recover from disturbances and/ or disasters (Fabbricatti, et al., 2020). As recognized by the 2030 Agenda for Sustainable Development and many countries around the world, culture is a tool for achieving a peaceful and sustainable future. It is no longer a dividend for development, but a prerequisite for achieving development. The new international policy for Disaster Risk Reduction 2015-2030 states that the value and dissemination of cultural heritage contribute to the establishment of safe, inclusive, resilient, and sustainable human settlements and cities (UNESCO, 2008).

The traditional growth model of urbanization is changing, economic growth is gradually slowing down, and it is experiencing a new practice period of urban transformation with new urbanization as the starting point (ZHANG , 2019). “However, most of the many small towns that have been or are being developed are driven by economic benefits and ignore the unique cultural temperament, ecological environment, and economic development structure of small towns (ZHANG , 2019).” “The specific characteristics of Heritage Community Resilience is defined as well as identify any critical actors and variables, strategies, and governance mechanisms, which influence both Heritage Community and Community Resilience. It predicts the challenges and highlights the potential that culture and heritage can develop for Community Resilience, towards further perspectives of the resilient circular city (Fabbricatti, et al., 2020).” Therefore, placing culture at the core of urban reconstruction and recovery strategies, help to restore the material and social structure of the city. Because culture will take into account human needs and characteristics, and these views will gradually enhance the sense of belonging in the community.

Especially in the rapid development of this city and the high frequency of natural disasters, it is seriously affecting the survival of human beings. Coupled with the climate change brought about by global warming, many areas are suffering from storms caused by storms, droughts, and freshness. Brought forest fires. These climatic disasters not only harm the natural ecology and animals but also cause a lot of damage to the city and cultural heritage.

If cultural heritage is the main core concept of urban reconstruction, then the impact of climate disasters on cultural heritage requires effective strategic countermeasures to reduce damage to the city. Therefore, the concept of resilient heritage landscape, is the main axis of urban development and resilient cities. Landscape heritage should no longer be the second priority in climate adaptation strategies, but a strategy to protect human culture must be put forward to maintain the vitality of urban infrastructure and consolidate the most basic of urban residents a sense of belonging. In addition, Cultural and creative industries are also important assets to improve the competitiveness and attractiveness of the regional economy, while cultural heritage is a key element of the image and identity of cities and regions, and is often the focus of urban tourism (URBACT, n.d.). If cultural heritage is the key to the economic benefits of a city, the two parties will become complementary roles. And "resilience" has become the key to link the city and the cultural heritage landscape. Because the city needs the value of cultural heritage, and cultural heritage needs resilience Cities to reduce climate disasters. Culture and creativity can help produce specific locations and high value-added products, thereby maximizing economic returns and benefiting citizen participation and community building (European Commission, 2017).

BOX 3 Prague, the Czech Republic

In 2002, the Czech Republic suffered severe flooding due to the Vltava River (the river passing -through the historic center of Prague). The total losses amounted to 24 billion CZK (1 billion Euros). For infrastructure, houses, and the environment has caused serious damage, and the local historical buildings and historical relics in the museum have been severely damaged (Bransten, 2002). At that time, the city of Prague did not have a strategy to deal with the impact of climate change. However, because of this flood event, the city began to develop a resilient flood risk management system to improve the ability to adapt to flood risks in climate change. Before the establishment of a protection system, the area of Prague threatened by floods was 57.5 square kilometers (accounting for 11.6% of the city). Now, the total area of 52.5 square kilometers of the previously threatened area has been protected. In order to solve this problem, Prague adopted a gray infrastructure as the mainstay and blue and green infrastructure as a supplement. Fixed obstacles built along the river to control the flooding of the Vltava River: dykes, embankments, mounds, solid concrete walls, which basically protect most of Prague from 500 years of flooding (Lorencová, et al., 2015). For example, the gate of Čertovka (Old Town) is a steel sliding door, 23.5 m long, 4.9 m high, and weighs 45 tons. The transportation and installation of mobile barriers to flood-affected areas are based on the "Prague City Flood Management Plan". In Dubeč, a training area was established for training in the installation of mobile barriers. Other measures in the channel network along the Vltava River, such as closures, pumping systems, and safety valves. The green and blue infrastructure can serve as some kind of additional support for flood barriers, and it is very useful in solving flash flood disasters caused by extreme rainfall. The costs and benefits of the implemented flood protection measures were calculated for particular events with different return periods: 20, 50, 100, and 500-year flood (CLIMATE-ADAPT, 2016).

In this example, the success and limiting factors mainly occurred in the installation of the flood control system, that is, the approval process. Because it is the center of the historical town, it requires the participation of investors, designers, and historical conservationists before the planning of the case begins. In order to maintain a panoramic view of urban history. Also, with the requirements of cultural and historical heritage preservation authorities, the line of the mobile flood control measures was required to be as invisible as possible.

Figure 10 Prague hit by floods in 2002   Sources: (Mikule, 2004; Vesela, 2004)

However, the process of response and strategic planning is very important, need to consider the return on investment. For example, for disasters caused by climate types, we need to consider defining the types of post-climates. In the strategic proposal, the importance of data analysis and structuring, we must clearly analyze the measures encountered in the pre-disaster stage Prioritization can effectively improve resilience and reduce risks. If you want to know the priorities of strategies based on an objective point of view, you need to use value analysis to overcome the obstacles of different stakeholders. Due to the different stakeholders have different cost considerations, it requires a balance between data collection and accuracy of results in order to be cost-effective (Gandini, et al., 2018).

1.4 Learning outcomes

In this chapter, we mentioned that cultural heritage is indeed affected by climate disasters, and many international organizations and foundations are also proposing the concept of sustainable development and resilient cities for the impact of climate disasters on cities. Although there is no standard detailed strategy and detailed rules for resilient cities at this moment, there are many planning tools and index that create by organizations can help the developing process of urban resilience.

However, in recent years, cultural heritage has been included as an important role in the sustainable development of cities and future urban development. According to international organizations, UNESCO and the World Bank, they have all put forward the fact that reducing disaster risks in historical areas can help cities grow. Not only urban areas need to have the function of "resilience", but also cultural heritage, especially those in urban areas, need to have the function of resilience. Thus, cultural heritage is no longer representative of fragility, it can be used to assist urban innovation (resistance of historical knowledge to natural disasters) and financial support (attracting tourism). Therefore, increasing the resilience of the city has become a part of the resilient heritage landscape.

From the above boxing examples, we can know that in order to achieve resilient cities adapted to different climatic conditions, a variety of strategic plans and planning tools are needed to assist. In terms of strategic planning, especially in the Netherlands According to the National Climate Adaptation Plan and the LIFE LUNG plan of Lisbon, the climate and geographical conditions of each region are different. Therefore, button-up (from private knowledge, local government to strategic plans) partnership is very important In Asian countries, Japan, the climate adaptation plan proposed by Japan focuses on long-term soil and water conservation based on natural construction methods. Many private organizations cooperate with the government to develop warnings before disasters (earthquakes, tsunamis, and floods) occur, so as to reduce the probability of human damage.

In the context of urban planning, the corresponding application tools are also extremely important. In the case of LIFE LUNG, the general direction of the future heat island reduction goal was first planned from the strategy, and then several planning tools have been used to achieve it. The Water Resources Management Action releases by the central government are used to plan to reduce rainwater waste and flood disasters. Besides, the design cases belonging to the urban and community scales: Arkadien Winnenden, Tianjin Culture Park, and Bishan-Ang Mo Kio Park are all based on water management, which achieves sustainable development tools such as water cycle, rainwater treatment, natural drainage, etc. Although gray infrastructure is mainly used in Prague to block a large amount of flooding, the green and blue natural drainage facilities have also been proven to be effective when heavy rains occur Reduce urban surface runoff. When implementing urban planning in historical areas, it is necessary to coordinate with historical researchers and plan within acceptable (not destructive) limits.

Overall, historical areas should be more resilient to climate change and other natural disasters, reduce their vulnerability and improve resilience to climate adaptation. Local authorities and communities can use new knowledge and new tools to improve the reconstruction and social recovery of historical areas. So that cultural heritage no longer exists in the city as a fragile role, but can enhance the economic opportunities of residents, and develop common interests from it.

In the urban environment, there are two different ways of cultural heritage. In some cities, cultural heritage is the role of risk assets. However, this paper discusses a specific water disaster under climate change. It consumes a huge amount of money to improve the resilience of the research area, so cultural heritage has become an important resource (to attract tourists' money), prompting the government to reinvest in the urban system again (the historical value will be explained in Chapter 3). Therefore, I think the appropriate concept of this case study is resilience heritage, and also in the type of urban resilience is a specific(sub-system) resilience. Besides, in Chapter 2, we will analyze in detail the characteristics of these planning tools and the problems that water resources management can solve. Especially in urban areas where cultural heritage is located, how to use these tools and existing landscape cases in water management.

CHAPTER 2 Water management for cultural heritage

Water is very important to our way of life. International water-related problems include water shortage and uneven distribution. How to use water in a way that is in harmony with nature and the water cycle, and how to reduce greenhouse gas emissions related to water treatment are also worthy of attention. Especially with the increase of the global population and the shift from rural areas to urban areas, the scale of urbanized areas is increasing the pressure on the natural environment and its supporting systems; what is important is the water cycle, increased risk due to sea-level rise and extreme weather events (causing flooding). Besides, more land is being paved or surfaced, and as a result, water can no longer drain into the soil and must be treated through the sewer system. In urban areas, the rain caused street surface flooding. The main reason for this is the insufficient capacity of the existing sewer system to transport water. Particularly in extreme weather events, it is necessary to adjust the spatial layout of infrastructure and built-up areas to reduce risks. Therefore, many organizations that study sustainable urban development recommend investing in the blue infrastructure of the city, so as to improve the climate adaptation resilience of the city.

The importance of the natural water cycle within urban environments is being recognized in many countries around the world. In Australia, the practice is combining the urban water cycle with urban development which is known as water sensitive urban design (WSUD). The system takes the water cycle as the core and considers the management of rainwater, water supply, and sewage (reclaimed water) as all aspects of the water cycle. Through the protection of the natural water system and the combination of landscape and stormwater management, it can relieve urban water pressure and reduce Significant results have been achieved in water pollution and maintaining urban water ecological balance (Bai & Ji, 2014; Morison & Rebekah, 2011). The low impact development (LID) in the US, emphasized the use of small-scale control measures with scattered sources (such as biological retention facilities, green roofs, grass ditch, permeable paving, etc.) to maintain the relative stability of the hydrological characteristics before and after the development of the site, and reduce the impact of human engineering development on the environment (USEPA, 2000; Wang, et al., 2012). In the UK, the sustainable drainage systems (SUDS) aim that under the premise of comprehensively considering water volume and water quality, methods such as increasing rainwater infiltration to replenish groundwater are used to reduce runoff and reduce runoff pollution from the source (Jones & Macdonald, 2007). In Asian countries, Singapore also has a related technology called Active, Beautiful, Clean (ABC) Waters design, which is natural systems consisting of plants and soil that detain and treat rainwater runoff (Yau, et al., 2017). In Japan, it is called the Japan Rainwater Storage and Infiltration Technology Association, “Rainwater Technical Data”. These management measures are not exactly the same, because in addition to the differences in technical standards, in some measures, they also assume part of the functions of the public policy. The differences in different regions need to consider not only the hydrological conditions, infrastructure conditions, etc., but also the cost tolerance, the organization of various departments and the distribution of power and benefits, legal binding, and execution paths. Here we will discuss the two concepts proposed by Asian countries and European regions, sponge cities and water sensitive cities, to compare the same and different approaches, and then find out which approach is more suitable for our study area Lukang which is located in Taiwan.

2.1 The Sponge City

China is a country with serious water problems, whether it is a water shortage or flooding, water quality. In the past 20 years, due to the rapid development of industrialization and urbanization, and the frequent occurrence of extreme weather events, the damage caused by floods has increased exponentially. These damages are mainly concentrated in cities and are largely the result of heavy rainfall in summer. Their frequency and intensity have increased significantly in the past few decades (Xiaotao, 2016). Since the 1980s, China has experienced unprecedented urban expansion and wealth growth. Since 1980, the urban population has increased six times to approximately 750 million people. In the process of urbanization, the design, implementation, and maintenance of underground infrastructure (such as drainage systems) in built-up areas cannot keep up with the pace of urban development on the ground. These urban drainage systems are often designed based on a single design storm, so flooding is not considered A series of possible ways in which risks may change in the future due to changes in land use.

For example, Beijing, the capital of China, has more than doubled its land coverage in the past 10 years, and there have been several devastating floods. The affected Beijing urban area was built in the past 20 years. Various studies have shown that one of the main reasons for the recent flood events in Beijing is the lack of residual capacity of the drainage system to deal with extreme weather (Duan, et al., 2015). In addition, these studies show that these urban areas do not have sufficient retention capacity to allow rainwater to infiltrate and stay during heavy rains. Another reason for the increase in urban flooding in China is that many cities fail to protect their original water conservancies infrastructure systems, such as urban lakes and ponds, canals, and wetlands around the cities. In most cases, urban sprawl caused severe losses in unpaved, green, or open areas, as well as the loss of water bodies in the surrounding areas of the city and the old city center. In response to the increasing impact of flooding, the Chinese central government called for widespread adoption of the sponge city method nationwide in 2013 which is called the Sponge City Construction Technical Guide-Low-impact development rainwater system construction; and launched a project to provide financial support to promote the implementation of this method in some pilot cities (Jia, et al., 2017; Li, et al., 2016). Currently, the sponge city model is gradually popularizing. However, in the selected pilot cities, the effective implementation of sponge city technology and the use of it as a guiding concept for urban planning in the remaining 600 cities (above 1 million) in China still face many challenges (Zevenbergen, et al., 2018).

2.1.1 Concepts

The Technical Guidelines for Sponge City Construction-Low-Impact Development Rainwater System Construction has been started since 2013. According to this manual, the concept of Sponge City is mainly based on LID facilities. For example, on the scale of strategic planning, the Sponge Manual has comprehensive recommendations to follow. In the detailed streetscape design, it is set up under the 10 facilities proposed by LID. There are six concepts of sponge city, which is permeation, storage, stagnation, purification, reuse, and drainage (SPCC, 2014). Each of those concepts related to several LID measures. The first one is permeation, which is necessary to strengthen the penetration of nature and put penetration first. And the LID measures are the Green roof, Permeable pavement. Secondly, the storage is to keep rainwater, we must respect the natural topography so that the rain can be scattered naturally, and accumulate rainfall to achieve regulation and peak shifting.; the LID measures are Soakaways, Trenches, Chambers, and Rainwater Harvesting. Third, stagnation is to delay the rainwater runoff formed in a short time; Bioretention (Rain Garden), Enhanced Grass Swales, Dry Swales. Fourth, purification means through soil penetration, vegetation, green space systems, water bodies, etc., water quality can be purified, and it can be divided into rainwater collection and purification into residential areas, rainwater collection, and purification in industrial areas, rainwater collection, and purification in municipal public areas. The related LID measure is Roof Downspout Disconnection and Vegetated Filter Strips. Fifth, reuse. The main emphasis is on conserving through “permeation”, keeping water in place through “storage”, and then “using” the water in place through purification, such as building construction, green irrigation, car washing, etc. Finally, drainage is related to the Perforated Pipe Systems, which has utilized the combination of urban vertical and engineering facilities, the combination of drainage and waterlogging prevention facilities with natural rivers, and the combination of surface drainage and underground rainwater pipes to achieve general discharge and discharge of excess rainwater.

However, the term “sponge city” is used in the context of urban water use and does not originate in China. In 2005 and 2008, this term was used to describe the rainwater runoff in Hyderabad, India (Rooijen, et al., 2005), which offsets the water demand of the city and the surrounding agricultural water. The potential for the impact of supply. And an urban design project in Vietnam, which is considered a sponge city. It is embedded in a system of alternating low-lying and high-lying areas, allowing seasonal flooding of the Lam and Vinh rivers to penetrate the territory, instead of damage the city. Develop the existing waterway into a completely open interconnected network to maintain its irrigation and drainage functions and become the local transportation system (Nguyen, 2015). However, the term sponge city in China began to be used at the end of 2014 with government support, and also the development of LID systems and facilities is an important pathway of the SPC construction program (Li, et al., 2016). The aim is to restore the city’s ability to absorb, infiltrate, store, purify, drain and manage rainwater, and at the same time regulate the water cycle to simulate the natural hydrological cycle. Secondly, to improve the function of the urban ecosystem and reduce the occurrence of urban floods (Chen, 2016). Third, maintaining 70-90% of the average annual rainwater on-site use of the concept of green infrastructure and use control measures. In strategic planning, it should have proper planning, legal framework, and tools to implement, maintain, and adjust infrastructure systems to collect, store, and purify (excess) rainwater. Besides, sponge cities can not only treat excess water but can also reuse rainwater to help mitigate the effects of drought. The expected benefits of sponge cities are reduction of economic losses (due to flooding); improvement of the livability of cities; establishment of an environment that creates and promotes investment opportunities in infrastructure upgrades, engineering products, and new technologies.

2.1.2 Challenges

The scope of application mentioned in “Technical Guidelines for Sponge City Construction-Low-Impact Development Rainwater System Construction (SPCC, 2014)” is mainly based on low-impact development (LID) regulations. However, the core of LID is to maintain the same hydrological characteristics before and after site development. It means that the total amount of runoff, peak flow, peak present time, etc. cannot change much after development. Therefore, from the perspective of the hydrological cycle, to maintain the total runoff constant, it is necessary to adopt methods such as infiltration and storage. That is to say, increase the permeable area and reduce the drainage.
In addition, there is no rigid annual rainfall limit in the application of sponge cities. However, it is necessary to calculate the total annual runoff control rate of the city and its corresponding design rainfall target based on the total annual runoff, so that the best volume control rate is 80%-85%.

Since 2014, the concept of sponge city has been officially implemented in cities in China. The main goal is to be defined as runoff-volume-focused of the low impact development (LID) to retain 60–90% runoff on sites. In 2015, 16 cities were first selected as pilots. In 2016, another 14 cities were added. Although the pilot cities covered regions with different climates, they hardly included cities in western China. The research report (Li, et al., 2017) pointed out that most of the pilots in these sponge cities are concentrated in the central and southeastern regions of China which are green-field developments; the annual rainfall ranges from 410-1830 mm and the annual average temperature ranges from 4.6-25.5 degrees. From these pilot cities, demonstration areas have been designated, and each area is not less than 15 square kilometers. In 2016, the concept of sponge city expanded to a series of urban sustainable development goals such as ecosystem restoration, improvement of deteriorating urban water bodies, reduction of urban heat island impact, and construction of smart urban water cycles. Scholars pointed out that such a scale includes water system management, ecosystem multi-functionality, urban hydrology, and runoff control framework, urbanization, and the impact of human activities on the natural environment, etc. However, the current sponge city foundation lacks a sound system to support it. Especially It is the drainage characteristics that must take into account complex factors such as soil structure, land salt simplification, and so on (Li, et al., 2017). Therefore, to apply this strategy, it is necessary to seriously evaluate local conditions, potential and local resources. Besides, the Chinese government’s vigorous promotion and funding will improve the data analysis of water resources, and a more precise and accurate flood encounter and warning system (Zevenbergen, et al., 2018).

2.2 The Low Impact Development (LID)

From the previous paragraph, we can see that the main implementation engineering design method of the sponge city is the development of low impact development in the United States and Canada. There are three main ways in the concept of the sponge city, the first is to maintain the original ecology of the city, and the second is to repair the damaged environment, and the third is to maintain a sufficient percentage of water-permeable in the city according to the construction concept of LID and promote the storage, infiltration, and purification of rainwater according to local needs. Compared with sponge cities, LID is a small module to achieve big goals, while Sponge City is a strategic framework for solving water resources management.

However, the Ministry of the Interior construction agency in Taiwan and the National University of Taiwan also proposed in 2016 a "water environment low impact development facility operation manual" suitable for Taiwan's environment, as well as "water environment low impact development facility operation manual preparation and case assessment plan." The goal is to LID's planning concept and evaluation method, import Taiwan's urban planning development and public construction projects. The "Water Environment Low Impact Development Facility Operation Manual Development and Case Assessment Plan" is a compilation of responses from scholars, private construction companies, and local governments through several seminars. Then put forward suitable for Taiwan's current environment and engineering implementation of the "water environment low impact development facilities operating manual."

Therefore, in the second section, we will discuss the application and challenges of low-impact development in more detail and refer to the operation manual of low-impact development facility for the water environment.

2.2.1 Concepts

As we mentioned at the beginning of this chapter, low-impact development mainly uses small-scale measures and decentralized sources (Coffman, et al., 2012) to maintain the stability of the hydrological characteristics before and after the on-site development and to reduce the impact of human engineering development on the environment. Instead of using long-term retention wet ponds to control runoff from subdivisions. In recent years, investing in green infrastructure to increase multiple benefits and enhance urban resilience (CVC, 2015, p. 7)has gradually been incorporated into climate adaptation strategies. As a result of traditional rainwater management methods have gradually been unable to control storm surges or heavy rainfall caused by climate change (Guillette, 2016) Or in order to prevent local floods, a large number of water bodies are discharged to other places, which leads to imperfect utilization of rainwater. Such a vicious circle also brings greater financial burdens to municipal units (CVC, 2015). However, the design of the LID is based on the conditions of Natural Ground Cover and applied to urban areas. So, it is not only reduced the role of runoff, but also in filtering water quality, eliminating nutrients, pathogens, and metals has been confirmed.

The main principles of LID are as follows (DOD , 2004):

- Integrate stormwater management strategies in the early stages of site planning and design
- Try to manage rainwater as close to the water source as possible, divide it into parts, and distribute it to various places
- Microscale behavior
- Encourage and promote environmentally friendly design
- Promote natural hydrological characteristics and create hydrological multifunctional landscapes
- The main focus is on prevention, not mitigation and rehabilitation
- Reduce construction and maintenance costs
- Enhancing the environmental protection capabilities of communities and society through public activities
- Education and participation

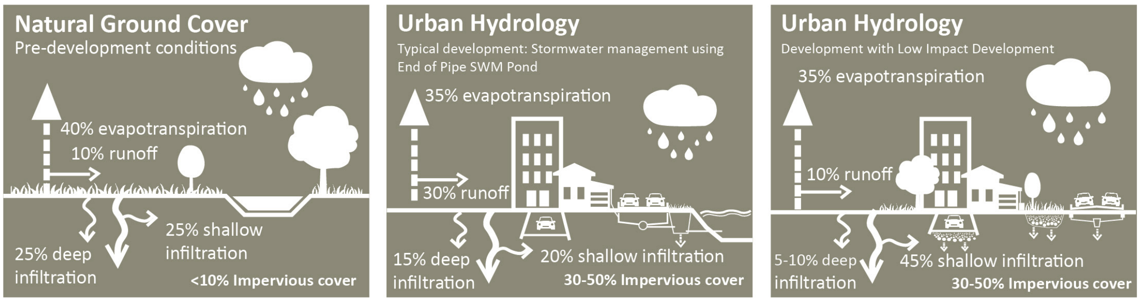


Figure 11 Natural Ground Cover method advocated by LID Sources: Author, based on (CVC, 2015)

In some cases, the cost of LID projects is higher than traditional rainwater management practices (CVC & TRCA, 2010). However, in most cases, we have achieved significant savings due to reduced costs for site grading and preparation, rainwater infrastructure, site paving, and landscaping. Plus, to quantify the environmental benefits and avoidable costs that can be achieved by using LID technology. Of course, examples of environmental benefits include reducing runoff and pollutant load into downstream waters and reducing the incidence of combined sewer overflows. Finally, more research is needed to improve environmental performance and reduce long-term operating and maintenance costs (United States Environmental Protection Agency, 2007).

Direct Benefits	Indirect Benefits
Decreases runoff volume and peak discharges	Increases green space, creating healthier living and work environments
Improves water quality through on-site natural filtration	Creates local green jobs
Reduces erosion	Contributes to wildlife habitats
Replenishes groundwater resources	Reduces urban heat through permeable surfaces
Improves climate change resilience	Decreases beach closures and increases fishing activities leading to greater revenues from tourism, supporting Ontario's economy
Reduces water-related infrastructure damages	Lowers road maintenance costs
Reduces spending on:	Enhances property values
• municipal infrastructure fixes and upgrades	Increases road safety with traffic calming measures
• land acquisition for stormwater management	Reduces road noise levels through vegetation buffers
• traditional stormwater infrastructure	Vegetation absorbs carbon dioxide
Maintains or enhances source water quality, improving wastewater treatment plant assimilation and reducing drinking water treatment needs	
Creates less strain on wastewater treatment plants and combined sewer outflow systems during wet conditions	

Figure 12 Direct and indirect benefits of using LID Sources: (CVC, 2015)

2.2.2 Application of LID

Cities are complex areas; they are composed of many complex structures. Therefore, it is necessary to have a complete strategic structure before implementing LID. According to the guide book, the main goal is interacting stormwater management into the planning process, then strategic planning should be required hierarchical processing. Landscape-based Stormwater Management Planning is the guideline of planning and design. The size of the plan is divided into 5 categories, and the analysis or design is carried out according to the size of the land. Landscape-based Stormwater Management Planning is the guideline of planning and design. The size of the plan is divided into 5 categories, and the analysis or design is carried out according to the size of the land. The ultimate goal is to maintain the ecological integrity of healthy sites, underground watersheds, and watersheds, or to strengthen the ecological integrity of places where conditions have degraded before development. To apply this method to stormwater management planning, it is necessary to fully understand the natural and hydrological characteristics and functions. For example, biophysical, hydrological, hydrogeological, and natural heritage features; the interrelated functions of these features; modifying factors (climate); and; temporal factors Of course, to complete a comprehensive risk assessment and analysis, a multidisciplinary team should determine the opportunity to integrate the facility into the landscape. Therefore, these issues can be further resolved in the later stages of the planning process.

According to the Operation Manual of the Low-Impact Development Facility for Water Environment (NTU, 2015) proposed by Taiwan, the low-impact development design process should first understand the current conditions of the development zone or base, and conduct a detailed site analysis to achieve the design goals. Therefore, the recommended steps will be 1. Determine the scope of site implementation 2. Basic material collection and site analysis 3. Determine design goals 4. Evaluation and selection of suitability for low-impact development facilities 5. Layout and planning of low-impact development facilities 6. Whether it meets the design objectives 7. Low-impact development facility design 8. Monitoring and maintenance management planning.

The second point (NTU, 2015)of the data collection mainly contains three categories, (1) geomorphological information: terrain, slope, soil conditions, water table, land use patterns before and after development, etc., for the analysis of the implementation site geomorphological conditions; (2) Hydro data are mainly rainfall data in neighboring areas, taking into account climate change and data integrity, and it is suggested that hydro-analysis should be carried out from nearly 30 years' data to understand the hydronic conditions of the site of implementation, and the results of past hydro-analysis can be collected for comparison to enhance the perfection of the results; (3) Rainwater sewer system information : to understand the distribution of the water collection area and the relevant location of future planned drainage The fourth point of facility suitability and choice points out that LIDs are suitable in highly developed urban areas , with recommended locations for parking lots , courtyards , parks , roads and utility spaces , but not on large or highway traffic . The fifth point of the development facility layout planning, the analysis of the results of the text and the site of the water collection area analysis, and then the water collection area and the design target required mass size in the appropriate position However, the selected location is the surface area of the permeable surface. For example, lower ground, easy to connect with sewers, lower water table, and lower sediment content around the surface.   In general, the ratio of LID's facility area to treatable surface runoff (impermeable area) is approximately 1:4 to 1:10 However, the sixth point is a rolling design, and to confirm the rainwater load. It needs to be simulate through the SWMM's water management. If the met target is not met, the fifth point will be returned to adjust the field layout.

If it focus on the content of the landscape, these five types of risk assessment are indispensable, namely Physiography and Landform, Ecological Context, Natural Heritage and Open Space Systems, Soils, and Hydrogeology. These five items will be about determining the location of the facility. Dimensions, etc. At the community scale (e.g., Secondary and Block Plan stages (CVC & TRCA, 2010, p. 36)), the exploration of rainwater management solutions should focus on a thorough understanding of the physical and ecological characteristics of the landscape. For example, the combination of local soil characteristics, groundwater depth and flow patterns, topography, and natural heritage features within and near the site provides a basic basis for exploring landscape-based rainwater management strategies (CVC & TRCA, 2010). But if it is the first step in the planning process, should identify opportunities to protect natural heritage features (i.e., green infrastructure) and incorporate features that contribute to the ecological integrity of the landscape into the overall development plan.

SCALE	PLANNING STAGE	DESCRIPTION
Watershed plans	Master Plans Growth Plan Official Plan	1. Major themes and objectives for the municipality's future growth 2. Challenges and opportunities for growth (municipal policy direction for innovative SWM approaches; climate change initiatives).
Community/ Sub-watershed	Secondary Plan	1. Major elements of the natural heritage system: terrestrial, aquatic and water resources (hydrology, hydrogeology, fluvial geomorphology. etc.). 2. Stormwater management objectives: surface and groundwater resources; future drainage boundaries; locations and watercourse realignments
	Block Plan	1. The location: roads, parks and open space blocks, natural heritage features and buffers, and stormwater management facilities 2. A full range of opportunities to achieve stormwater management objectives are identified 3. Establishing a template for the more detailed resolution subsequent stages in the planning and design process.
Neighbourhood	Draft Plan of Subdivision/ Functional Servicing Plan	1. Conceptual design for stormwater management facilities. 2. Consideration of stormwater management objectives achievement 3. Objectives influence the location and configuration of each of the components listed above
	Registered Plan	Detailed design for stormwater management facilities.
Site	Site Plan	1. Identified Site-specific opportunities into all of the components of a development (landscaped areas, parking lots, roof tops and subsurface infrastructure). 2. Solutions of context with strategy for the block or secondary plan area to ensure that functional requirements are achieved
Site	CA Permits and other approvals	Detailed design of SWM for the site

Table 2. Summary of stormwater management planning at key scales and land use planning stages

Sources: Author, based on (CVC & TRCA, 2010)

2.2.3 Detailed analysis of LID infrastructure

It is necessary to consider the choice and location of a suitable LID practice. From the perspective of traditional water management measures, it is easier to implement and re-developed areas, because there are more hardware infrastructures. If you want to renovate the developed building-intensive areas, it will destroy too much of the original infrastructure. However, in the concept of LID, the solution to flooding is to reduce the peak drainage and increase natural permeation. Besides, the construction method of LID is based on the modular green construction of small blocks, so even in areas with a small amount of space, it can be Realize this value (Shafique & Kim, 2017; Bradford, 2016). Such as (1) Roof catchment area, (2) Ground catchment area, (3) Artificial ground catchment area is more suitable for restricted space. Besides, other LID green constructions are suitable for different space conditions. Therefore, users should first understand the basic functions of each LID and use them in appropriate places to obtain multiple benefits. We divide water management into three important features, treatment, water cycle, and detention and infiltration. These features will be marked on each LID module to help identify areas suitable for later use. The following will list the various green constructions of LID and the corresponding opportunities and challenges.

1. Treatment

It has two functions, a beautiful environment (leisure place) and an increasing drainage area. The main purpose is to filter and temporarily store water before the rainwater is discharged.

Bioretention (Rain Garden)

Sources: Author

• Description: Biological retention system is also called a rain garden, which is a recessed landscape feature designed to process and store rainfall runoff from the site. Bioretention is a somewhat complicated system that can be designed to infiltrate the underground drainage system or be filtered into the groundwater. Improve the aesthetics of nearby areas by providing trees and plants (CVC & TRCA, 2010).

• Purposes: It has been proven to be an effective system for managing large amounts of rainwater runoff and improving water quality. Rain garden reduces runoff and peak flow

• Opportunities: temporary storage, infiltration, filtration, peak reduction

• Installation locations: Soft side roadside or open land in the low-density development zone, or roadside landscaping in a high-density area.

• Challenges: maintenance of vegetation, risk of groundwater pollution (due to rainwater directly entering the ground), stagnant water, and mosquito breeding

Vegetated Filter Strips

• Description: Also known as the buffer zone and grass filter zone, it is a gently sloping area with dense vegetation. The runoff is regarded as a single stream from an adjacent impervious area. The vegetation can be composed of various trees, shrubs, and native plants to increase Aesthetic value and water quality benefits.

• Purposes: To slow down the runoff speed, filter out suspended sediment and related pollutants, and provide some infiltration to the lower soil. It also can store snow and infiltration during snow melting.

• Opportunities: infiltration, filtration, peak reduction

• Installation locations: residential roads and between roads

• Challenges: risks of groundwater pollution, vegetation maintenance, private land property, standing water, and mosquito breeding

Roof Downspout Disconnection

• Description: The method of cutting the downpipe is to direct the water flow of the roof downpipe to the permeable area of the building, and the flow path length through the permeable area is required to be at least 5 meters.

• Purposes: To achieve water balance, although it also helps to improve water quality.

• Opportunities: infiltration, filtration, peak reduction

• Installation locations: roof drain

• Challenges: Many site restrictions, topographical restrictions, low land permeability, private property (need to develop long-term maintenance plans and incentive plans)

Enhanced Grass Swales

• Description: Enhanced grass slopes are open channels covered by vegetation (also called enhanced grass slopes). Check the dams and vegetation in the swamp to slow down the flow of water so that it can settle, filter by roots and soil matrix, and evapotranspiration. And penetrate into the bottom soil.

• Purpose: To transport, treat and weaken rainwater runoff, to transport rainwater, especially for roadway drainage

• Opportunities: temporary storage, infiltration, filtration, peak reduction

• Installation location: along the parking lot, curbs, gutters, and rainwater drains

• Challenges: Risk of groundwater pollution (due to rainwater directly entering the underground layer), high demand for plant maintenance, stagnant water, and mosquito breeding

Dry Swales

• Description: A dry swale can be thought of as an enhanced grass swale that incorporates an engineered soil. The dry swale can be thought of as an enhanced grass swale that incorporates an engineered soil.

• Purposes: Open channels, filter media or growth media that transport, treat and attenuate rainwater runoff, so that rainwater can be filtered, evapotranspired, and penetrated into the underlying native soil

• Opportunities: infiltration, filtration, peak reduction

• nstallation locations: along the parking lot, curb

• Challenges: Risk of groundwater pollution (due to rainwater directly entering the underground layer), high plant maintenance requirements

Sources: Author

2. Water cycle

This category is to collect rainwater and can be used in the original building. The collected rainwater can be used for non-absorption purposes, such as water for toilets and plants. To achieve the concept of water conservation and water circulation

Green Roofs

• Description: Known as “living roofs” or “rooftop gardens”, consist of a thin layer of vegetation and growing medium installed on top of a conventional flat or sloped roof. And create a green space for passive entertainment or aesthetic enjoyment.

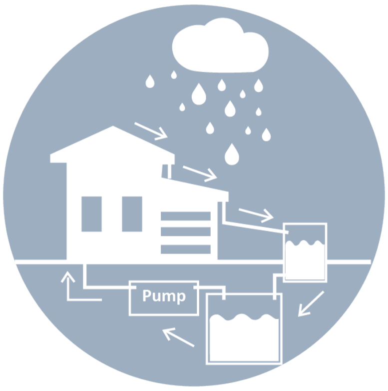
• Purposes: Improve energy efficiency, reduce urban heat island effect, improve air quality, and heat insulation of buildings.

• Opportunities: filtration, recycling (reuse), peak reduction

• Installation locations: roof (public and private)

• Challenges: High maintenance cost, private property (need to develop a long-term maintenance plan and incentive plan)

Rainwater Harvesting



• Description: Rainwater harvesting is the process of intercepting rainwater (especially during heavy rain events), transporting and storing it for future use. By reducing the demand for water resources, rainwater harvesting can significantly save costs.

• Purposes: Rainwater is reused and can be used for non-drinking water. For example irrigation, toilets in buildings, etc.

• Opportunities: storage, filtration, recycling (reuse), peak reduction

• Installation locations: roof (blue roof), storage tank above ground or underground (permeable sidewalk above the parking lot and grass above the basement), Catchment Area

• Challenges: mosquito breeding, freezing of storage tanks in winter, etc.

Sources: Author

3. Detention and infiltration

Infiltration or adding pipelines to increase the temporary storage of rainwater so as to reduce the peak of stormwater, and has the function of filtering water quality.

Soakaways, Trenches, Chambers

• Description: The site for underground rainwater infiltration operations is filled with granular stones. It receives runoff from the inlet of a porous pipe and makes it penetrate into the local soil. There are a variety of facility design options to consider, such as seepage channels, seepage ditches, and seepage chambers. A series of proprietary manufactured modular structures installed underground, usually located under a parking lot or landscape area, creates a huge space for the temporary storage of rainwater runoff and allows it to penetrate the native soil underground.

• Purposes: To collect rainwater and filter the water quality of runoff

• Opportunities: storage, infiltration, filtration, peak reduction

• Installation locations: Very suitable for water-permeable spaces confined to narrow areas between buildings or properties, or road passages, and high-density development contexts.

• Challenges: The risk of groundwater pollution (due to rainwater directly entering the underground layer), private property

Permeable Pavement

• Description: Permeable pavements are another alternative to traditional impervious pavements. It allows rainwater to pass through them into a stone reservoir, where rainwater seeps into the native soil below or stays there temporarily.

• Purposes: Permeable paving can filter, store, or permeate runoff. Compared with traditional impervious paving surfaces such as concrete and asphalt, it can reduce or eliminate surface rainwater flow

• Opportunities: infiltration, filtration, peak reduction

• Installation locations: low traffic roads, parking lots, driveways, pedestrian plazas, and sidewalks

• Challenges: Risk of groundwater pollution (due to rainwater directly entering the underground layer), unsuitable high-use traffic roads, winter deicing salt seepage into the underground layer

Perforated Pipe Systems

Sources: Author

• Description: It can be considered as a long seepage trench or linear seepage pipe designed to transport and penetrate rainwater runoff. Where the topography, groundwater level, and runoff quality conditions are suitable, the perforated pipe system can be used to replace traditional rainwater sewer pipes.

• Purposes: Underground rainwater transportation system, designed to reduce runoff and thereby reduce the pollutant load of receiving water

• Opportunities: temporary storage, infiltration, filtration, recycling (reuse), peak reduction

• Installation locations: runoff from roofs, sidewalks, parking lots, and low-to-medium traffic roads

• Challenges: The risk of groundwater pollution (due to rainwater directly entering the ground), stagnant water, and mosquito breeding

2.3 Case studies

For the case analysis of the sponge city, we will focus on the first batch of sponge city pilots in the coastal area of China, Xiamen. In 2015, two areas in Xiamen were selected as sponge city pilots, namely the Maluan Bay pilot area in the old city and the Xiang'an pilot area in the new city, with a total pilot area of 35.4 km2.

According to "Xiamen: Building a Sponge City Adapting to Climate Change" (Liu & Mei, 2020), Xiamen has a continental monsoon climate with an average annual rainfall of 1530 mm. The rainfall from March to September accounts for more than 80% of the annual rainfall, from October to September. The coming February will be the dry season with little rain in autumn and winter. Rainfall time distribution is extremely uneven, and it is often affected by typhoon weather; the intensity of short-duration rainstorms is high, due to climate change, urban waterlogging, typhoon rain and other extreme rainstorms increase, and mountainous flooding problems. In September 2016, the typhoon "Moranti" brought heavy rains and caused floods, resulting in 17,907 houses collapsed, 105,000 mu of crops were damaged, and a direct economic loss of 10.2 billion yuan. Sea level rise also brought a series of damages. The problem not only exacerbated the damage caused by storm surge disasters, but also caused problems such as seawater intrusion, soil salinization, and coastal erosion.

At the same time, it also reduces the discharge capacity of urban sewage, drainage pipe networks, and river channels, increases the threat of floods in coastal areas, and weakens the function of Xiamen's port. However, in 2015, Xiamen began to plan a sponge city, the main goal is "good water ecology, water safety guarantee, water environment improvement, beautiful water landscape, and rich water culture".

Figure 13 Location of pilot sponge cities Sources: Author, based on (Li, et al., 2017)

Figure 14 Maluan Bay Pilot Area and Xiang'an Pilot Area in Xiamen Sources: Author

2.3.1 Maluan Bay Old Town

The total pilot area of the Maluan Bay Old Town is about 20 square kilometers, of which the water area is 4.5 square kilometers, the urban built-up area is 6.4 square kilometers, and the rebuilt area is 9.1 square kilometers. The geographical structure of this area is a coastal low-lying terrain, so many bays are formed. The surface runoff flows through the bay area into the sea, and the confluence of seawater and freshwater forms an ecological wetland with good biodiversity. However, the water body of this bay area is located at the end of the tide. In the initial stage of the city, rainwater and part of the combined sewage enter the bay area along with the surface runoff and drainage system, thus causing water bank pollution. Besides, heavy rains and high tides often cause flooding disasters in cities. According to the "Technical Guidelines for Sponge City Construction", the total runoff control target in Maluan Bay is 70%, and the designed rainfall is 26.8 mm. In terms of drainage and flood control standards, the built-up area should deal with torrential rains not less than once in a 50-year; the standard for moisture prevention is once in a 100-year.

Since this place is an old town, referring to the Xiamen: Building a Sponge City Adapting to Climate Change, the old community should follow: "..., based on protecting the historical and cultural city as a whole and not destroying the original historical and cultural heritage, Gradually improve the related facilities adopted in the construction of sponge city,..., the permeable paving rate of the reconstructed and expanded buildings and the community should not be less than 40%; through the structural transformation of parking spaces with permeable pavement, the rainwater from the parking sides is introduced into the grass swales or an appropriate amount is underground introduced to regulate the peak of a rainstorm. " Furthermore, nine transformation methods for engineering construction(LID) are proposed: real estate in the building community (squares, parking lots, sidewalks, etc., with permeable pavement); enterprise transformation (permeable pavement, landscape water bodies, bioretention, etc.); urban village transformation (the village is suitable to adopt permeable ground, trenches, drainage facilities, etc. in the square and sidewalks); public facilities (permeable pavement, rain garden, etc.); road construction (about 47.17 kilometers of rain and sewage pipe network, permeable pavement, initial rainwater abandonment facilities, etc.); Sewage treatment and regeneration facilities (sewage and reclaimed water plants); drainage pipe network (102 kilometers of newly reconstructed drainage pipe network: rainwater pipes meet the standard of once in 2 to 3 years; key areas are once in 3 to 5 years); river water system (reconstruction of existing drainage canals, dredging, embankment reinforcement, shore greening, water quantity and quality assurance system; new water system main project, water system green belt construction, etc.); tide and sea facilities (bay dredging, ecological construction, comprehensive management of coastline environment (sewage and garbage), construction of tidal dikes, construction of coastal green spaces, etc.) (Wang & Wu, 2015).

In terms of target accessibility analysis (Wang & Wu, 2015), the total target of rainwater control for "seepage, retention and storage" projects in the pilot area is 344,000 cubic meters, of which the total target for rainwater control for "seepage and retention" projects is 108,000 cubic meters. The total control target is 236,000 cubic meters. According to calculations, the total amount of rainwater controlled by the "seepage, retention, and storage" project is 213,000 cubic meters, and 61.9% of the total rainwater control target (344,000 cubic meters) can be achieved in three years; the “clean “project will focus on river improvement in the near future. Significantly improve the water quality of the water function area; the recent scale of the “utilization” project is 20,000 cubic meters per day, which can replace 20% of the urban water supply; the three-year planning task of the “drainage” project is the dredging of flood drainage ditches, rain, and sewage pipes. The transformation of the network can effectively improve urban flood control and drainage capacity.

In order to achieve the above flood reduction goals, apart from the division of large areas, LID measures are mainly arranged in each area unit. Therefore, in the old city, it is divided into community reconstruction, enterprise factories, public and new projects, road networks, drainage systems, sewage and reclaimed water plants, river systems, and anti-flooding facilities. The LID measures are implemented in different conditions and areas. For example, in areas 09 and 10 of the demonstration spaces, there is the old city center (9.69 hectares) and the factory of the enterprise (one of the areas is 24.97 hectares). In order to reduce construction damage in the old city center, only rainwater storage tanks are installed next to the old buildings. The enterprise factory covers a wide area, so it can incorporate facilities with different functions, but mainly transform the existing garden into the rain garden, ecological pond. Besides, the above-ground rainwater collection tanks can be connected to the roof, which increases the water circulation

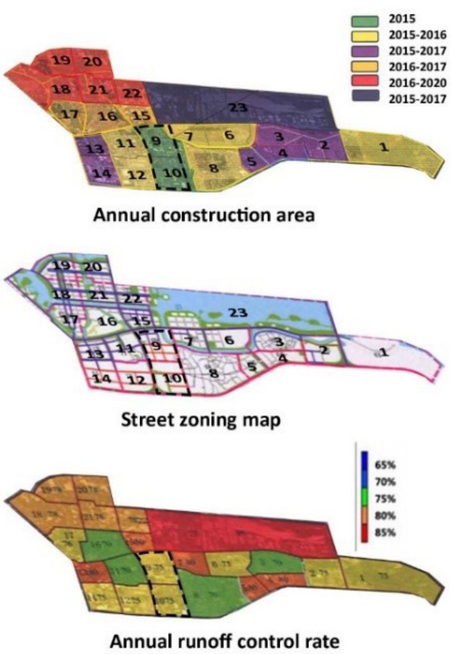


Figure 15 Zoning map of Maluan Bay Old Town

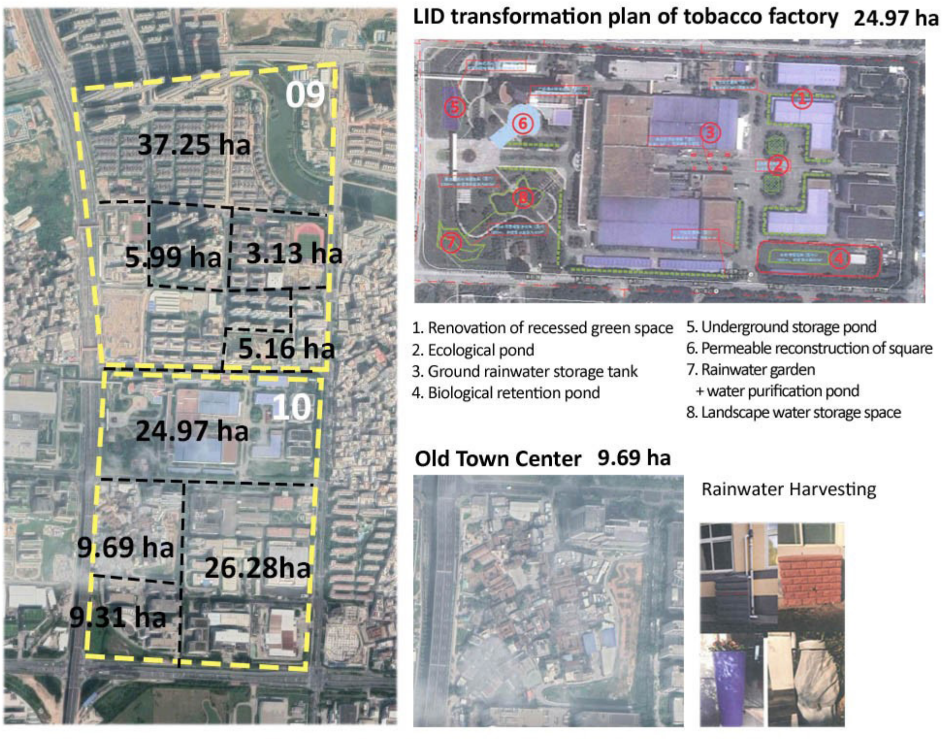


Figure 16 Configuration map of LID measures for areas 9 and 10

Source: Author, based on (China Urban Planning Institute, 2015)

2.3.2 Xiang'an New City

Xiang'an New City is a key development area of Xiamen City, with major infrastructure projects and industrial layout. However, Xiang'an New City has the characteristics of large height difference between north and south, small watershed area, fragile ecological environment, low groundwater level, and prominent seasonal water shortage problems. Therefore, the corresponding solution goals are oriented to the compliance of various assessments such as flood prevention and drainage, water quality compliance, runoff pollution control, river surface rate, and ecological shoreline restoration (Xiamen City Planning Society, 2018). The area will be divided into three phases from 2015 to 2030. The plan divides the area into seven control units, with three systems (building community system, road system, and green space system) to control the indicators of total annual runoff flow. Sponge construction in new communities.

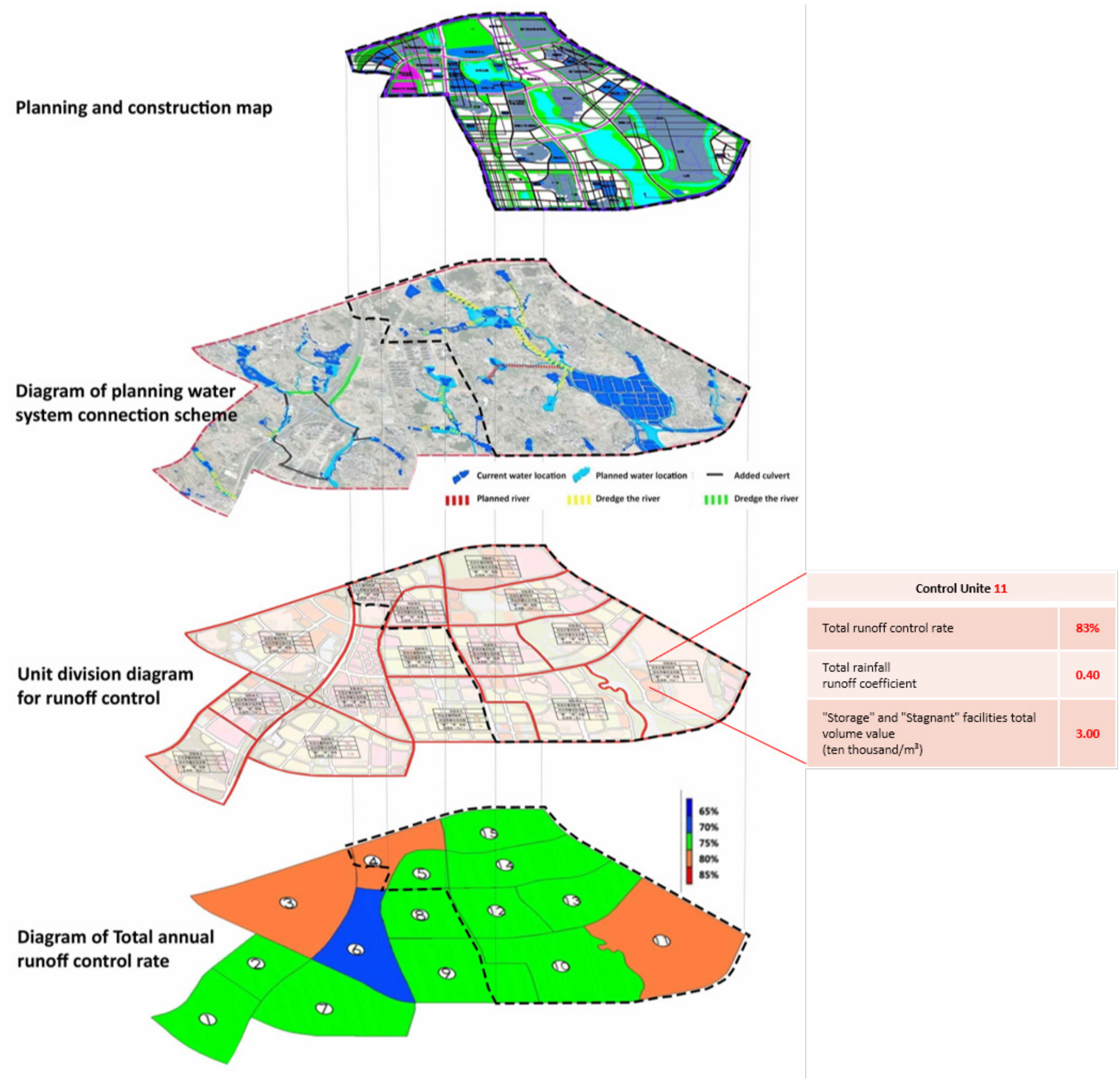


Figure 17 Conceptual layout of Xiang'an New City

Sources: Author, based on the Sponge City Construction Implementation Plan for the Pilot Area of the Southern New City of Xiang'an City

According to the requirements of sponge city construction, all roads and squares in newly-built communities in Xiamen need to be pavement permeable, and the permeable paving rate is not less than 70%. For projects with a hardened area of more than 2000m2, storage tanks, landscape water bodies, etc. will be built. And propose the corresponding construction from the four water management categories (water ecology, water environment, water resources, water safety) of the sponge city construction indicators. First, the goal of the ecological construction of the water system is to reduce the total amount of regional runoff, and construct artificial wetlands at the end to intercept and treat the initial rainwater, so as to achieve a total annual runoff control rate of 75%, corresponding to a design rainfall of 32mm. Second, the water environment plan will reduce runoff pollution through the construction of low-impact development facilities at the source, and rainwater pipes will be constructed to intercept and purify the initial runoff pollution. And combined with the construction of ecological floating beds and constructed wetlands at the end for systematic control to achieve regional non-point source pollution control. From model calculation, under the 75% total runoff control rate of the overall pollutants in the pilot area, the reduction rates of SS and COD reached 67.07% and 66.59% respectively (Wang, 2020). According to the calculation of rainwater runoff zoning, 15 artificial wetlands need to be arranged in this area, with a total area of about 20,600 square meters and an adjustment volume of about 5730 cubic meters. Finally, improve water safety, build low-impact development facilities to reduce runoff peaks, delay the formation of rain peaks, optimize rainwater pipelines and road elevation designs, and strengthen rainwater drainage capabilities. And build the end storage green space and river and lake water systems for system control to ensure Regional drainage and flood prevention safety (once in 50 years). In terms of risk assessment, 8 recessed regulated storage green spaces (parks) will be built in the depressions of other internal areas, with a total regulated storage area of 48350m2 and a regulated storage volume of 35100m3 (Wang, 2020).

According to official Chinese news sources (Chen, 2019; Wu, et al., 2019), in March 2019, an expert team composed of the Ministry of Housing and Urban-Rural Development, the Ministry of Finance, and the Ministry of Water Resources came to Xiamen for a performance review. The main flood drainage channel of Haicang Xinyang in the old city has eliminated water pollution and is gradually restoring the water ecology and surrounding natural ecology, and the seven waterlogging points have been treated. Xiang'an New City has formed a relatively complete contiguous sponge effect through the construction of "sponge skeleton" and source sponge construction. However, due to the short construction year, there are fewer relevant results analysis reports.

2.4 Learning outcomes

The second chapter mainly discusses the use of water resources management and challenges restrictions. It is found that there are many different word usages in the water management model between countries, but the main concept is to replace the traditional gray construction with green construction, that tries to achieve the effect of water balance in a natural way as possible. Therefore, we especially analyzed the sponge city concept proposed by Asian countries, China. The term sponge city was formally proposed by China as a national development goal in 2014. The concept behind the sponge city is mainly supported by the LID proposed by the United States and Canada, so we consider the strategic framework of the sponge city for the development of urban construction in China. In the LID manual, the design and planning details from strategic use to small size are explained. Besides, the planning space at different scales is suggested to correspond to the risk analysis. The main analysis content is Physiography and Landform, Ecological Context, Natural Heritage and Open Space Systems, Soils, Hydrogeology. If the planned area is community-scale or block-scale, it is necessary to focus on the soil structure, water permeability index, and the distribution of groundwater catchment areas.

According to the “Technical Guidelines for Sponge City Construction”, seven major factors including annual total rainfall capture rate, peak runoff coefficient, total suspended solids (TSS) reduction rate, permeable road surface rate, greening rate reduction rate, roof greening rate, and rainwater utilization rate have been determined. index. Rainwater utilization is a recommended standard, not a mandatory standard. This standard is for blocks and roads. In the “Technical Specifications for the Construction of Sponge City in Xiamen”, there is no regulation on the block scale, which can be defined on the block scale, block scale, or even city scale. The two pilot cities in Xiamen have divided the blocks on the neighborhood scale. Each block has its specific land-use type and goals to be achieved.

In the case of reference, we observe that the current sponge city pilots are mainly concentrated in the central and southeastern regions of China. And the climatic conditions are between 4.6-25.5 degrees and the annual rainfall is between 410-1380 mm. Next, we analyzed the first batch of sponge city pilots proposed by China, Xiamen City. Because sponge cities have been created in fewer years, Chinese officials have also used pilot projects with different spatial conditions to improve case references. In the case of the pilot in Xiamen, the pilot is located in the coastal area, and the pilot area has selected the new city and the old city. It mainly shows that under different time and space conditions, the application methods of sponge cities are different.

In the old city, due to flooding and water quality problems, drainage and dredging work were first planned. First, the drainage and flood control of indicators is according to the total annual runoff of the area unit. Then, it is distributed the location, type, and quantity of LID following by the control amount of the area unit. In the old city, it is divided into community reconstruction, enterprise factory, public and new projects, road networks, drainage systems, sewage and reclaimed water plants, river systems, and high tide prevention facilities. So that the rainwater storage tanks were installed next to the old buildings; and the factory mainly converts the existing landscape garden into a rainwater garden, an ecological pond; the factory roof is connected to an above-ground rainwater collection tank, etc. The area that mainly uses LID is to maintain the original facility functions as much as possible and increase the water management function. On another hand, the new city is an area under development, and the geographical conditions are water shortage but flooding in summer. Therefore, it focuses on the role of water storage and seepage. These green constructions are focused on improving penetration, reducing peaks during heavy rains, etc. And these small blocks of modules are also more suitable for use in dense urban areas, road construction, or private gardens.

Based on the above, the third chapter will analyze this study area, Taiwan, Lukang Old Street. Therefore, we will first analyze the basic historical introduction and current strategic framework, and then analyze the environmental content suggested by LID. We will try to analyze the scope of the sponge city and the area where LID facilities can be applied without destroying the historical reserve. However, because SWMM simulation belongs to the category of environmental engineering, more detailed rainfall and drainage simulation analysis is required. Therefore, this paper will propose from the first point to the fifth point according to the planning steps of the “Water Environment Low Impact Development Facility Operation Manual” Point site layout recommendations. Therefore, in Chapter 3, we will focus on the analysis of the geography and regional historical background during site selection. Rainfall and climatic phenomena will only be briefly described. For the SWMM water from points 6 to 8 Models and supervision planning, etc., will submit suggestions to a more professional team for analysis.

CHAPTER 3 Lukang town: values and risks

In chapter three, we will analyze the town of Lukang, located in the central region of Taiwan, as a research area. The town of Lukang is located in the coastal area of central Taiwan. Around the 17th century, Deer Harbor was one of Taiwan's main official ports, once attracting a large number of "Han" Chinese from China to do business and settle here. Due to the development of commerce and the prosperity of mission, about two hundred temples were built here, and a commercial street arranged by Yi-style buildings has been developed, which is now the old street of Deer Harbor. So today, two temples built in the 16th and 17th centuries are designated as national monuments, 13 buildings are designated as county monuments, and several streets are designated as monument preservation areas (including Deer Harbor Old Street). At present, most of the buildings in the Deer Harbor Heritage Preservation Area are used for commercial use by residents (a small number are still private residences), and Deer Harbor Old Street has attracted many tourists.

Deer Harbor, however, is located in the coastal area and is vulnerable to typhoons in summer. And many times, due to heavy rains and storm surges brought flooding problems, the above-mentioned national monuments, Deer Harbor monuments preservation area and many residents' homes are not immune. The county government put forward three possible causes of flooding in Deer Harbor. First, Deer Harbor was an early port, with most of the land area as all-made plains, so the terrain was low; Second, the drainage lines in the old street area are old and cannot be affected by the current climatic conditions; Finally, the original design of the drainage channel, Deer Harbor Creek, because of the high tide of the sea cannot discharge the river into the sea. And in 2018, Changhua County Water Resources Department has proposed that Deer Harbor should be set up in the flood pool. But so far, there is no real plan for this. As such flooding occurs more and more frequently, not only residents but also many cultural reserves in Deer Harbor are affected. The disadvantages of affecting cultural heritage mentioned in chapter I will place a significant financial burden on municipalities and will also result in the loss of cultural heritage. Therefore, in this case, we chose Deer Harbor Town as the area of this study. We will analyze Taiwan's existing climate strategic plan, Deer Harbor's current urban plan, to see whether Deer Harbor has a strategic plan for climate adaptation; As well as environmental risk analysis, proposed to sponge city and LID concept of water management regional planning. We will try the concept of water management, a way of planning that enhances urban resilience in the event of a climate disaster on cultural heritage.

3.1 Cultural heritage

In the early Lukang, around the end of the Ming Dynasty, the Han people began to emigrate and cultivate, engage in farming and fishing. In 1731, Lukang was opened as a trading port on the island of Taiwan, with almost 100 sailing ships entering and leaving every day. Since the recording of 1785, the coastline has gradually moved outwards, extending more than 2 kilometers. During that period, the sediment was deposited, the ship could not enter the port, so the port has no longer existed(Figure 18). From 1785 to 1956, Taiwan was colonized by different regimes. First, First, the Qing Dynasty, the Japanese rule, to the postwar period after the Second World War in 1945 and the U.S. military stationed in Taiwan, until now the Republic of China rule. The decline of Lukang was from the Japanese rule. The ships could not enter the port because of sedimentation. In addition, the railway plan did not pass through Lukang, so commercial activities in Lukang Old Street no longer prosper as before. From Figure 19, we can see that the previous river course was located on the border of Lukang Old Street. Due to the prevalence of early trade, Lukang became the largest port in the central region of Taiwan, also the shopping streets was developed, which is the Lukang Old Street.

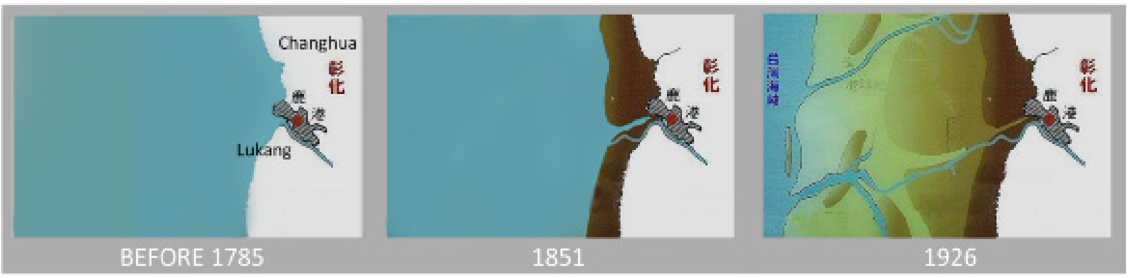


Figure 18 Lukang Channel Siltation Map   Sources: (Tony, n.d.)

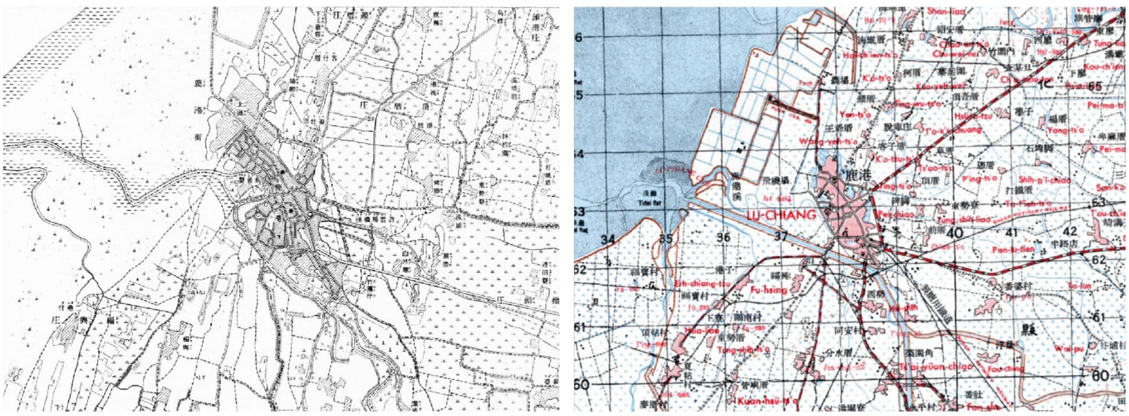
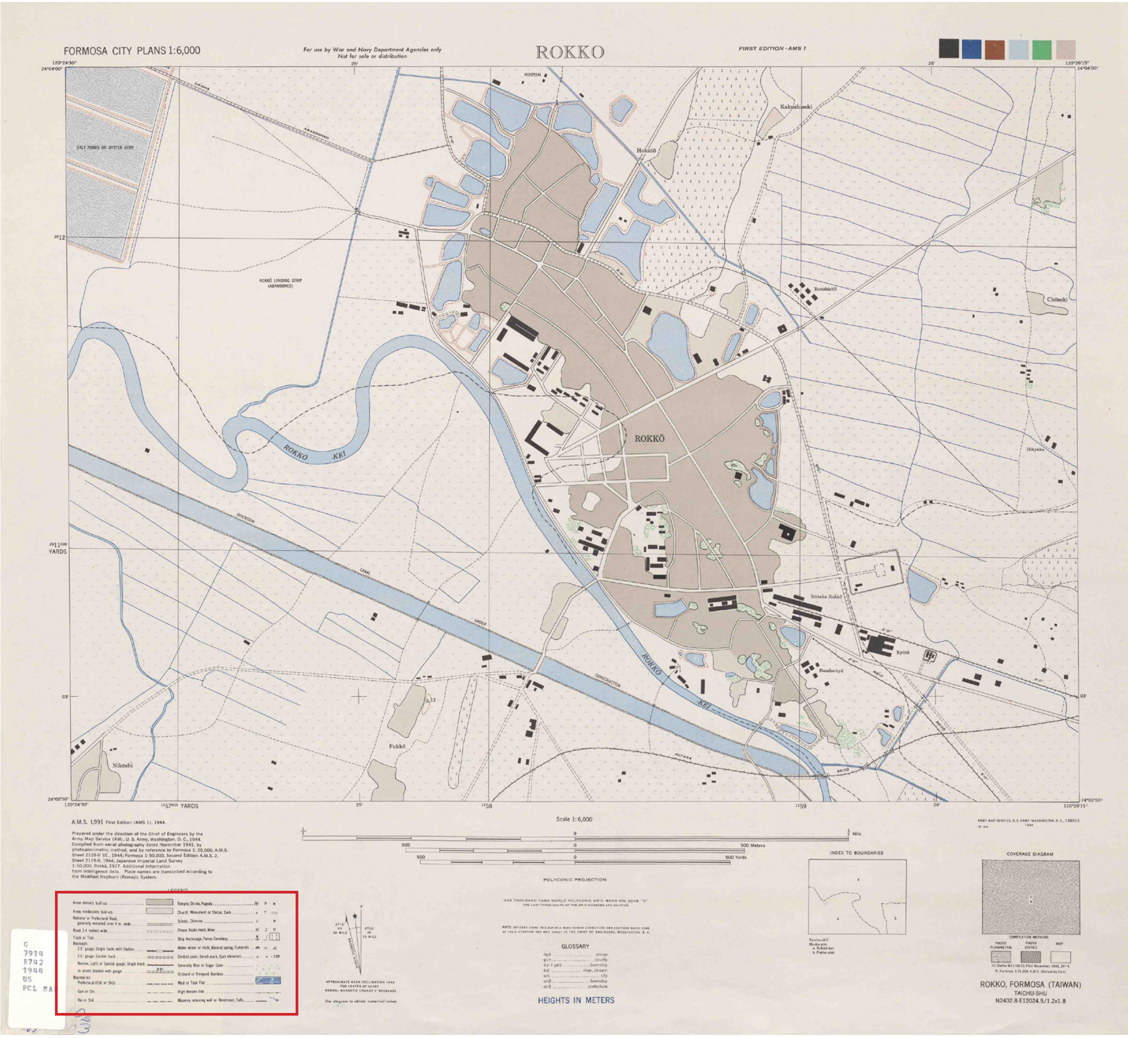


Figure 19 During the Japanese Occupation in 1898 and the Republic of China in 1956. Sources: (Academia Sinica, 2021)



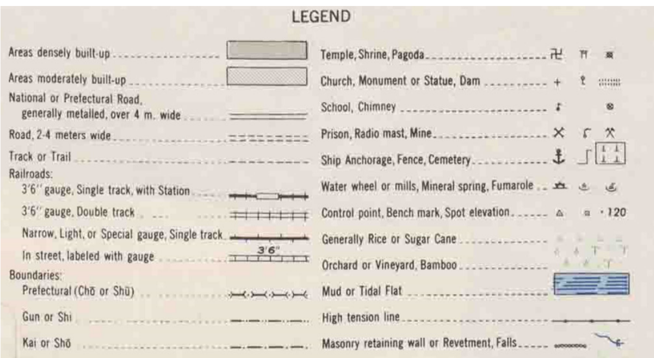


Figure 20 A map of Lukang drawn by the U.S. military in 1944 Sources: (Academia Sinica, 2021)

After the trade developed, it also brought a wave of immigrants. Most of the population was from Quanzhou(China), and then the beliefs and temples were brought to Taiwan. As can be seen from Figure 21, the current cultural preservation area is composed of these monuments. The Lukang Historic Preservation Area is about 10.57 hectares which are about 500 meters in length including Old Street, Lukang Mazu Temple, etc. The buildings were built in the early Qing Dynasty, the architectural style is in the Min-style(Fujian style), it is also the oldest street in Taiwan. In the Lukang Historic Preservation Area, in addition to the ancient Min-style buildings, it also includes the National monument, Longshan Temple, which is protected by the Cultural Heritage Preservation Act. Also, there is the county-level historic site, Lukang Mazu Temple.

Figure 21 Scenery of Lukang Old Street Sources: Changhua Tourism Bureau

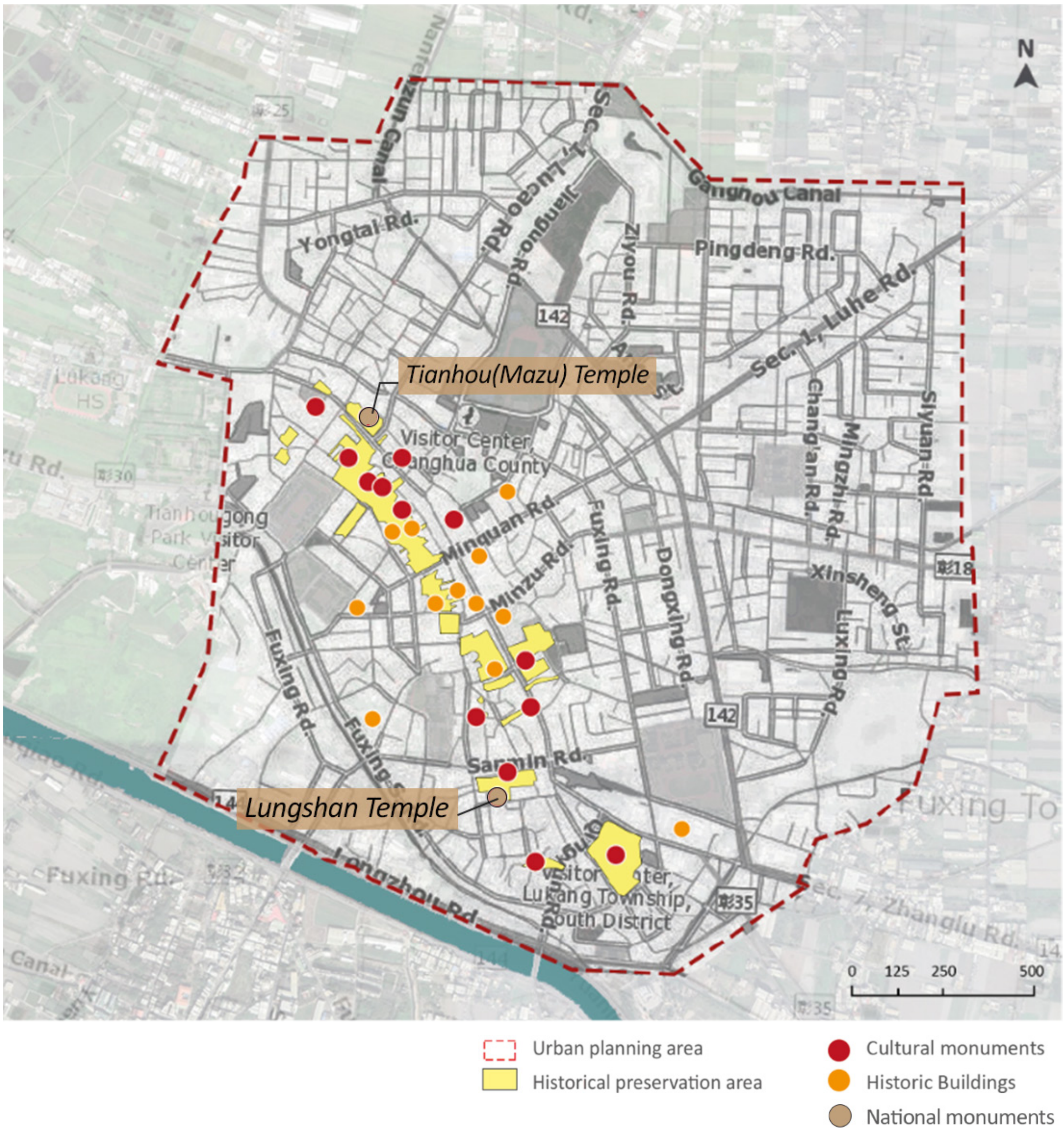


Figure 22 Location of Lukang Historic Sites. Sources: Author

Fujian(Min)-style architecture in Lukang Old Street

The cultural context of Fujian(Min)-style architecture is Minnan culture. Minnan culture is mainly distributed in mainland China, Taiwan, Singapore, and Malaysia. Historically, it has integrated Fujian-Vietnamese culture, Chinese culture, Islamic culture, Nanyang culture, Western culture, and Japanese culture (Zheng, 2010; Su & Wang, 2008). Beginning in the seventeenth century, Minnan culture began to develop with overseas immigrants in southern Fujian and became a highly influential culture in East Asia. It has been the main culture of Taiwan and Singapore.

The concept of “five elements” is included in the Min-style building and has been recorded in the ‘Ancient Chinese Book’. The book, specifically describes the nature of the five elements, listing the order of water, fire, wood, gold, and soil. This concept is also deeply integrated into the building that is most closely related to daily life.

In addition to the orientation of the house, the scenery and the sculptures of the paintings can also be found in traditional architecture to pursue the harmony of the five elements of harmony.

The main function of the ridge is to fix the tiles and increase the weight of the roof to prevent strong winds. At the junction of the ridge and the ridge, the South-style building has two types: “horseback” and “swallowtail”. Temples, official homes, and well-known mansions use the flying “Swallowtail Ridge”, while ordinary houses use “horseback”. “Horseback” has five kinds of shapes, such as water, fire, wood, gold, and earth. There are many types of traditional Chinese architecture. Most of the existing buildings in China and Taiwan are the buildings left over from the Ming and Qing Dynasties.

Figure 23 The architectural form of Lukang Old Street Sources: Changhua

Figure 24 The typology of Min-style architecture roof Sources: (Wang & Yang, 2010)

The Lukang Tianhou Temple

The Lukang Tianhou Temple (Chinese: 鹿港天后宮; pinyin: Lùgǎng Tiānhòu Gōng, alternatively "Tienhou"), also known as the Lukang Mazu Temple. It is a Chinese temple dedicated to the Chinese sea goddess Mazu, and it is one of Taiwan's most famous and popular Mazu temples. The Chinese sea goddess Mazu is the deified form of the Fujianese, Lin Moniang, traditionally dated AD 960–987 (wikipedia, n.d.). In 1591, the trade between Lukang and coastal towns in mainland China had been quite frequent. The local people raised funds for construction in order to ensure the safety of merchant ships going back and forth at sea. From 1683 to 1974, due to disrepair, prosperity, and other reasons, there have been many constructions. Until now, this temple has a history of more than 400 years.

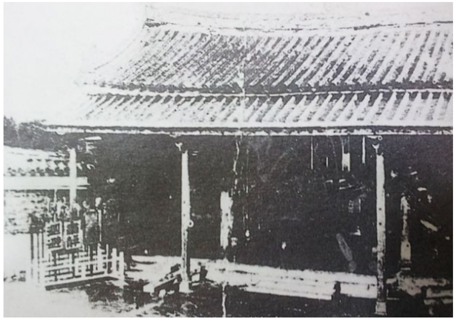


Figure 25 Lukang Tianhou Temple became a temple for worshippers Sources: Lukang Tianhou Temple, the photo was taken in 1633

The reason that the Lukang Tianhou Temple is selected as a national monument is that this temple was located at the entrance of the Lukang River in the old days. Residents believe that it controls the maritime transportation hub of Quanzhou, and has marine cultural characteristics and regional development significance. Its location at the estuary and settlements illustrates the close relationship between Mazu Temple and settlement development and also witnesses the close relationship between Lukang Town's early trade prosperity, cultural gathering, and settlement history (Ministry of Culture, 2019).

Figure 26 Lukang Tianhou Temple Sources: Lukang Township Office

Most of the murals or sculptures in the temple are rich in meaning. For example, there are three pairs of dragon pillar stone sculptures in Tianhou Temple, which are located in Sanchuan Hall, Main Hall, and Apse Hall. The dragon column was carved by craftsmen (Jiang Wenhua, Jiang Wenshui) in 1936. Its shape is a single dragon plate column with multiple hollow carvings and four-claw holding beads. The column is decorated with shrimps, crabs, fish, fish, and gods, etc. Especially the stone pillars in the apse hall are speculated to be carved in the 19th century. And also, this space is dedicated to the Jade Emperor, so dragons are used to symbolize the status of respect. The magpies and peony flowers on the other stone pillars symbolize wealth (Ministry of Culture, 2019).

Figure 27 Stone pillars with dragons carved in Tianhou Temple. Sources: Lukang Tianhou Temple

On the top of the plaque, there is a pair of "toad seats". The toad seat has a chrysanthemum in its mouth, which is a metaphor for longevity and auspiciousness; the other has a camellia in its mouth. The camellia is a periwinkle, which means the four seasons of spring. The "Bohai Mengxu"(薄海蒙庥) plaque was written by Wang Lanpei, a famous person in Lukang in 1830. "Bohai"(薄海) refers to the Taiwan Strait. In the early years, the ancestors crossed the sea from the mainland(China) to Taiwan and had to pass through the dangerous Taiwan Strait. All the ancestors came to Taiwan safely under the protection of Mazu, and they became more devout in the faith of Mazu. In addition, there are several plaques dedicated to Lukang Tianhou Temple by the Qing Dynasty officials (Ministry of Culture, 2019).

Figure 28 The plaque in the temple is pronounced "Bohai Mengxu" (薄海蒙庥). Sources: Lukang Tianhou Temple

3.2 Building uses and open spaces

The land analysis data in this section is from Taiwan, National Land Surveying and Mapping Center of the Ministry of the Interior. We divide the main analysis items into three items, satellite maps, building land use maps, and open space maps. From the satellite picture, we can see that the building density in this area is very dense, and there is not much green space or open space. In the west of the picture, there is a street composed of red roofs that can be clearly seen, which is Lukang Old Street. Figure 30 shows the zoning map of the building. The land types in this map are divided into 5 types, commercial land, residential land, industrial land, cultural heritage land, and government agency land. The five types of land are selected, and the main purpose is to understand the conditions of space composition. For example, each facility of LID is suitable for different spaces. If you want to consider installing green roofs, you need to understand the distribution of private residences and public residences (land used by government agencies) before planning the effective distribution method.

Therefore, according to building land uses, we can see that there are dense commercial and residential areas in the Lukang Old Street area. However, the northwest and northeast in the picture are mainly residential areas, and they are less dense. Most government office buildings are located in the northwest or near the old streets.

Then, the open area map is mainly divided into green space (including school playgrounds and parks, etc.), parking lots, and sidewalks. It can be clearly seen that the area of Lukang Old Street hardly has any open space. There are many parking lots in the surrounding area, followed by surrounding schools and parks. Therefore, when the LID is applied to improve the flooding situation, the surrounding parking spaces and green spaces can be well-planned, and also it is not recommended to set the LID in the cultural preservation area.

Figure 29 Satellite image of the urban planning area Sources: Author, based on Google Map

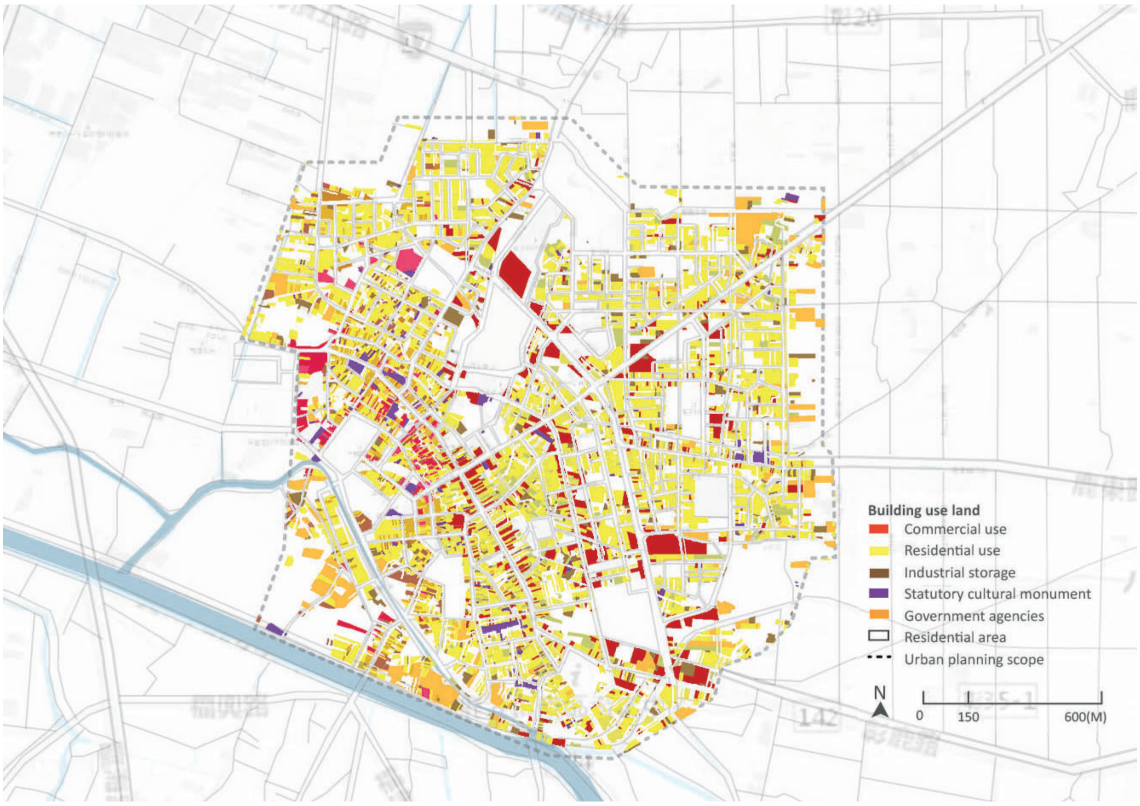


Figure 30 Building's land use map of the urban planning area   Sources: Author, based on National Land Surveying and Mapping Center of the Ministry of the Interior

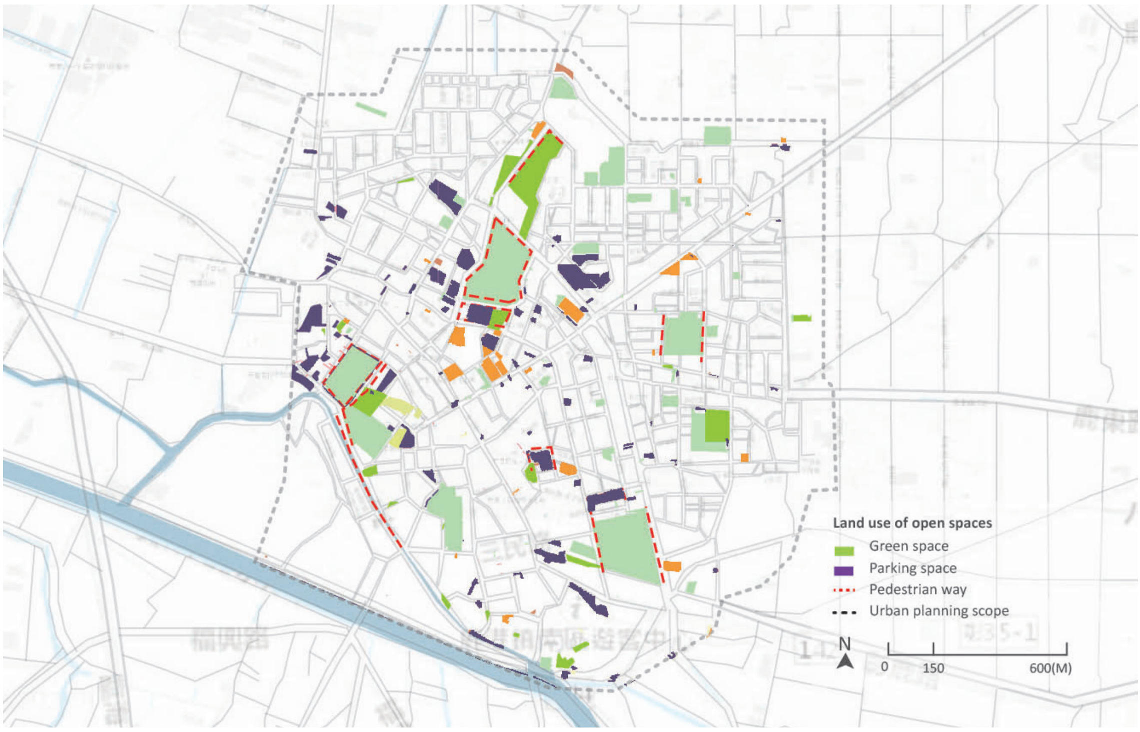


Figure 31 Open space map of the urban planning area. Sources: Author, based on National Land Surveying and Mapping Center of the Ministry of the Interior

3.3 Road infrastructures

In the analysis of the road system, we divide the level of roads into four categories, namely cultural heritage preservation road, main road, secondary road, and neighborhood street. The main purpose of road analysis is that there are many road-related designs in LID facilities, such as permeable pavements and perforated pipe system that should be installed on low-usage roads. Therefore, if the low-usage roads are screened out, and other spatial conditions, it will be possible to plan a more suitable local way.

Lukang Old Street is mainly distributed in the cultural heritage preservation area, so it will not be considered to place LID measures. Therefore, low-use roads near the old street and in the non-protected area will become an important role because of the water in the old street. The roads that can be planned and arranged to the surrounding area will reduce the chance of surface runoff. Secondly, other roads will be graded by width. The main road is greater than or equal to 20 meters to greater than or equal to 10 meters. Because most of the roads in this size interval are two-way, the usage of traffic is also the largest road in this area. Therefore, it is not suitable to install high-permeability paving and perforated pipe systems on the main road. The secondary road is less than 10 meters wide to greater than or equal to a 6-meter road. From the figure, we can see that the network of secondary roads is composed of many small blocks, and there are neighborhood roads in these blocks. In the northwest and northeast of the picture, these neighborhood roads form many blocks that are mostly residential land. However, if we want to adopt LID in these residential areas, we will need to consider the design of permeable pavement. Because the residential is private land, it is more difficult to install LID instead of public property; so, the road will become the focus of installing LID in this area.

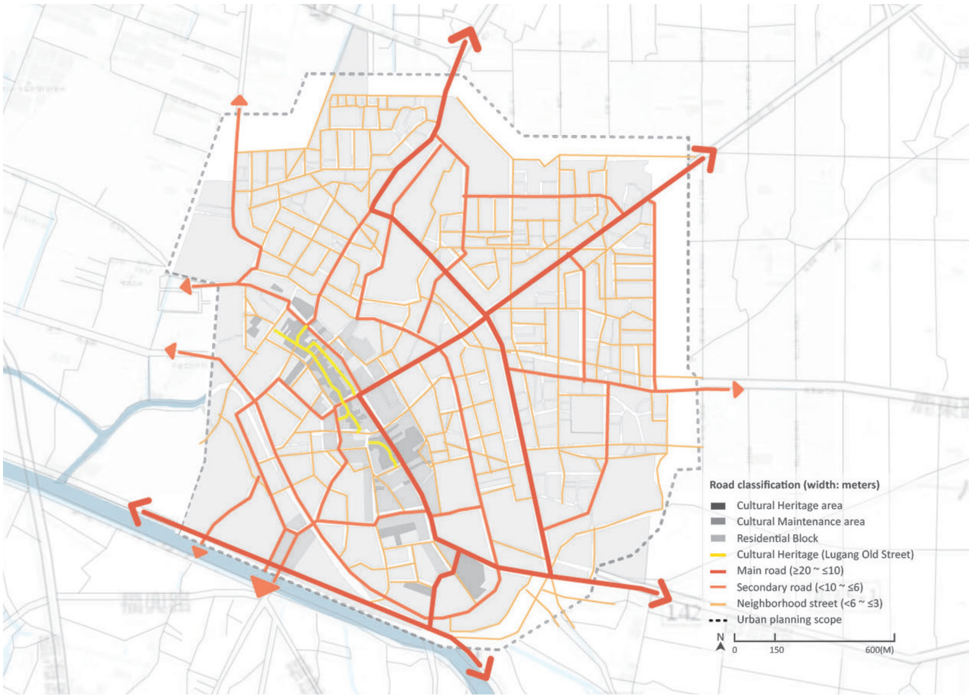


Figure 32 Road system analysis diagram Sources: Author

3.4 Climate conditions

In terms of meteorology, climate change characteristics of Taiwan in the past analyzed the long-term variation of hourly rainfall from 1961 to 2005. In the study, they found that over the past 40 years, the duration of rainfall decreased gradually, but the intensity of average hourly rainfall increased gradually. That is, it has been less rainy in recent years, but when it does, it will be more than usual. In terms of both the hourly and daily accumulated rainfall, although Taiwan is divided by the Central Mountain range, the extreme rainfall intensity in the west is strong in recent years, while that in the east is not obvious or even weak. (Chao-yi, et al., 2010)

The climate of Lukang Town is characterized by hot summers, not cold winters, small annual temperature differences, the concentration of two quantities, and obvious dry seasons. The average annual temperature is 22.1◦C, the average monthly temperature of 28.3◦C in July is the hottest month; the average monthly temperature of 14.2◦C in January is the coldest month. Although the average annual decrease of two amounts is more than 1,000 mm, the phenomenon of dryness in summer and winter is very obvious. The average decrease of two amounts in the four months from May to August accounts for more than two-thirds of the year, and from October to December Three months account for only one-third of the annual rainfall. Since the rainy season is usually from late May to early June, June has the highest monthly average rainfall. The monthly averages of June and November are two, and the difference was even 31 times as much as once. The main reason for the summer concentration is the abundant moisture brought by the summer monsoon and gambling wind. During the winter drought, when the northeast monsoon prevails, the town is located in the two shadows zone and lacks moisture.

Since Lukang Town does not have a relevant annual average rainfall analysis, refer to the nearby area, Taichung Weather Station. This information refers to the monthly average rainfall for 30 years from 1991 to 2020 in the Central Meteorological Bureau of Taiwan. We can see that the rainfall gap between summer and winter is very large, the highest in summer is almost 350 mm, but in November there is only 25 mm of rainfall. The average annual total rainfall in these 30 years is 1762.8 mm.

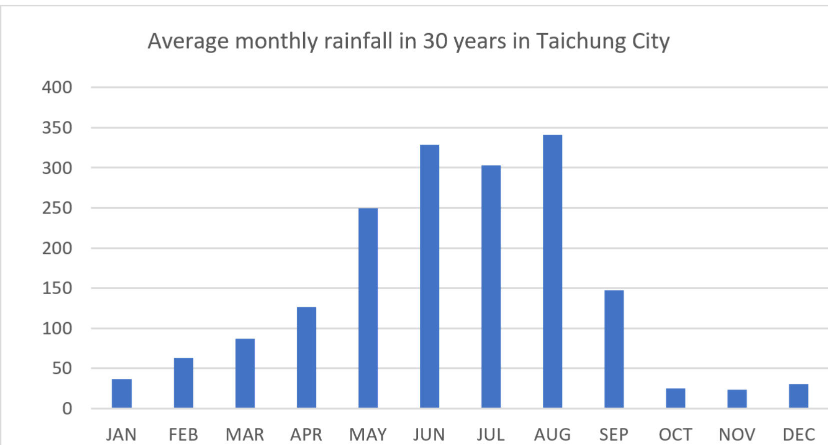


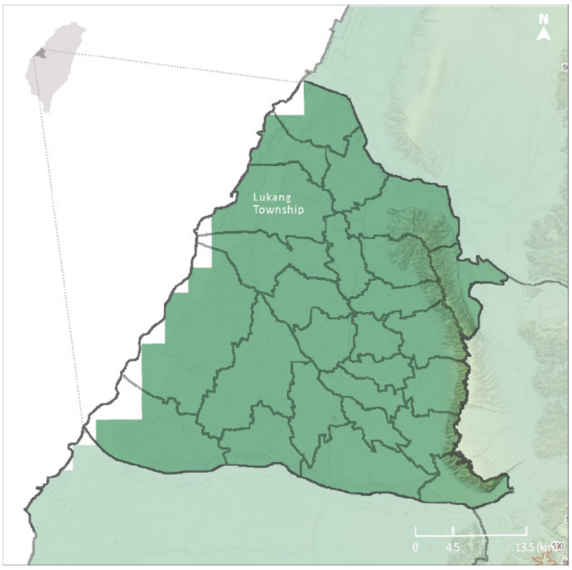
Figure 33 Analysis on a 30-year monthly average rainfall of nearby weather stations in Lukang Town
Sources: Author, based on (Central Weather Bureau, 2021)

3.5 Orography and soil

Lukang Town belongs to Changhua County and is located on the north bank of Lukang River in the northwest of Changhua Plain. It is 24 degrees to 24 degrees 10 minutes north and 120 degrees 22 minutes 30 seconds to 120 degrees 30 minutes east longitude. The total area is 71.8 km², which is a long and narrow urban area. According to the data in 2018, the population here is 86,818, and the density is about 2.2 thousand/km². According to the data, the average elevation of this area is about 3 meters. In order to understand the spatial conditions of the large environment, we divide the topography into two sizes. Figure 34 is the largest-scale, which is the rendering of the topography of Changhua County. We can see that the east on the map is the mountainous terrain, but in Figure 35, it zooms to the area of Lukang Township. The elevation and slope of this area have not changed significantly, so it belongs to flat land. The whole area can be divided into three parts: alluvial plain, coastal lowland, and tidal flat new land). Figure 35 shows the slope analysis of Lukang Town. This area has the first level slope, which means that the slope percentage is less than or equal to 5%. Especially in the urban planning area, the terrain is flat and there is no obvious slope change. The percentage of the slope may affect the drainage design. In LID, the drainage slope required by different facilities and the slope for calculating water retention is different. For example, if the vegetation ditch is in an area with a slope of 0.5%, it can achieve average water retention of 6%; the average value of 1% higher than the slope is 3.4%; the average value of the slope of 3% is 3.0%. Overall, LID recommends that the slope of the facility is about 0.5% to 1.0% as the best value (National Taiwan University Recommendation).

The composition of the soil is also highly related to the location of the LID facility. Because LID mainly produces three benefits: Retention, Detention, and Infiltration. These three effects require the cooperation of soil and surface materials to take effect. For example, Retention uses surface bumps and pores in the sand to retain water; Infiltration is to infiltrate through the bottom layer to subsidize the underground aquifer.

This soil analysis data comes from the open data of the Agricultural Laboratory of the Executive Yuan in Taiwan. According to the analysis, the soil types in Lukang Town are mainly new and old alluvial soils, namely Clay slate and Sandy shale. According to the soil geology and infiltration parameter table, compared with sandy soil and loamy soil, the maximum infiltration rate of clay soil is the lowest, 25.4 mm/h; for sandy soil, the maximum infiltration rate is 127.0 mm/hr. Therefore, we can know that the water permeability of the geological types of Lukang Town is relatively low. Then we analyze the soil water permeability in the urban planning area, and it is obvious that most of the areas have incomplete drainage. However, in the upper-middle and lower right corner of the map, there are areas with good drainage. Therefore, in this well-drained area, LID facilities with high infiltration rates can be arranged. Since the soil surface conditions in Lukang are mostly unfavorable for drainage, soil improvement can be implemented (*The detailed method is complete in the Operation Manual of The Low-Impact Development Facility for Water Environment, and it is suitable for soil improvement experiments in Taiwan). In terms of planning and design, a water-retaining layer can be set from the surface of the LID facility to a depth of 15 to 30 cm, thereby increasing the flood storage space of the surface water storage area and improving the flood reduction efficiency. Especially in the construction phase, the layered configuration and compaction of the soil will affect the efficiency of infiltration and drainage. In order to maintain the effect of LID, if the soil infiltration is really too low, LID concealed pipe facilities should be used. Therefore, the rainfall-runoff before the flood peak will be discharged to maintain the water retention space of the LID facility. From the explanation of LID facilities in Chapter 2, most of the measures have the effect of infiltration. Therefore, if it is in an urban area (for example gas stations, high traffic roads, or industry), soil improvement cannot be carried out, to avoid excessive infiltration of polluted water to the groundwater source.



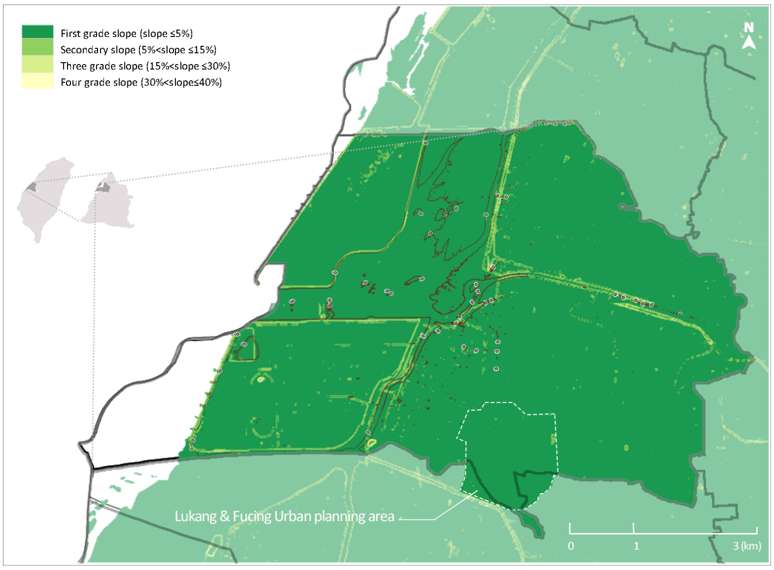
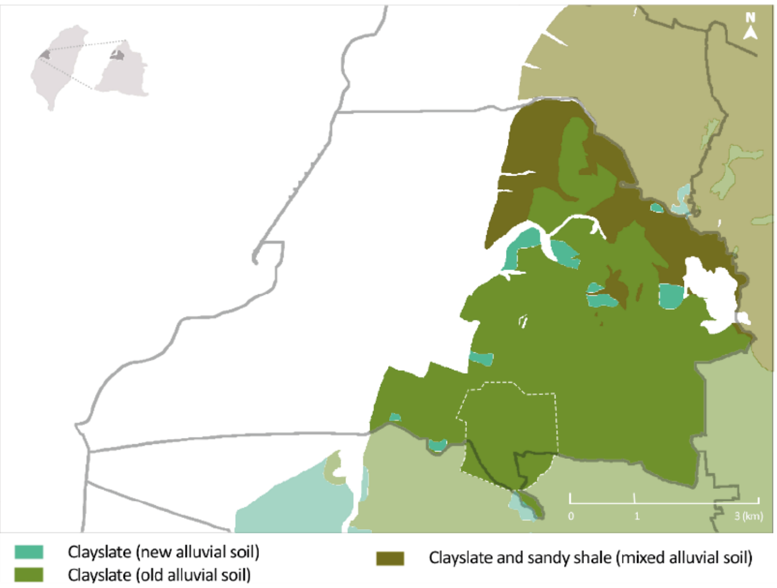


Figure 34 Rendering of contour lines in Changhua County

Figure 35 Slope analysis chart of Lukang Town

Sources: Author, based on Open information from the Lands Department of the Ministry of the Interior



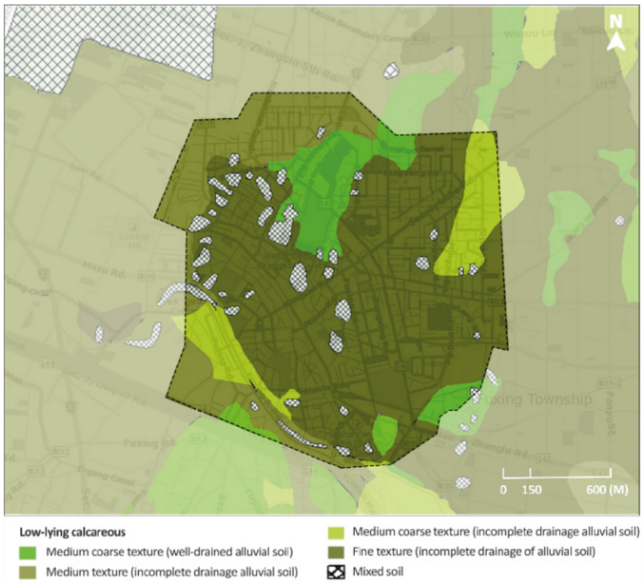


Figure 36 Analysis of Soil Types in Lukang Town

Figure 37 Analysis of Soil Water Permeability in Urban Planning Area

Sources: Author, based on Open data of Taiwan Agricultural Experiment Institute

3.6 Hydrology

3.6.1 Natural and artificial watercourse network

The main terrain of Taiwan's main island is with towering mountains in the middle, and the surrounding areas are mainly plains or basins. The water resources in the central area are the Wu River, which mainly flows from the high mountains of the eastside to the coastal areas in the west. However, it the main natural streams that flows through Lukang Town are the Qiug'an Canal, the Yuanlin Main Canal, and the Jiuzhuoshui River.

Figure 39 is the artificial drainage system around the Lukang Urban Planning Area. In this area, there is an old Lukang Canal flowing through, however, this river is currently abandoned, and a new river improvement plan is underway. The direction of the drainage channel is divided into upper and lower areas, the upper part is drained through Ji'an Canal, and the lower part is entered to the Yuanlin Main Canal.

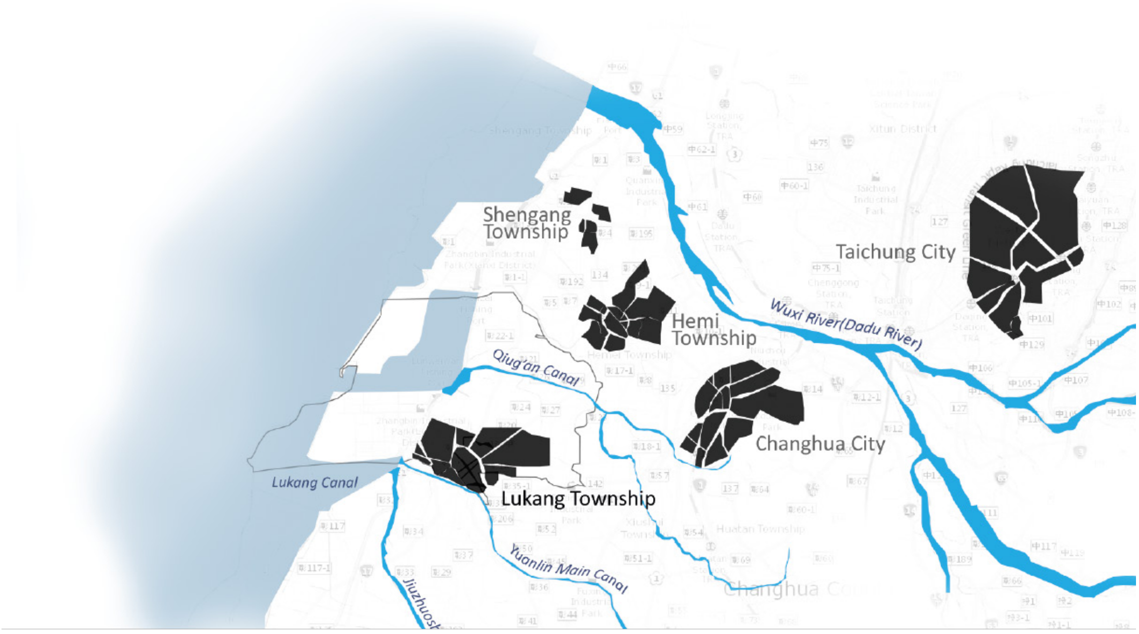


Figure 38 Hydrological distribution analysis   Sources: Author

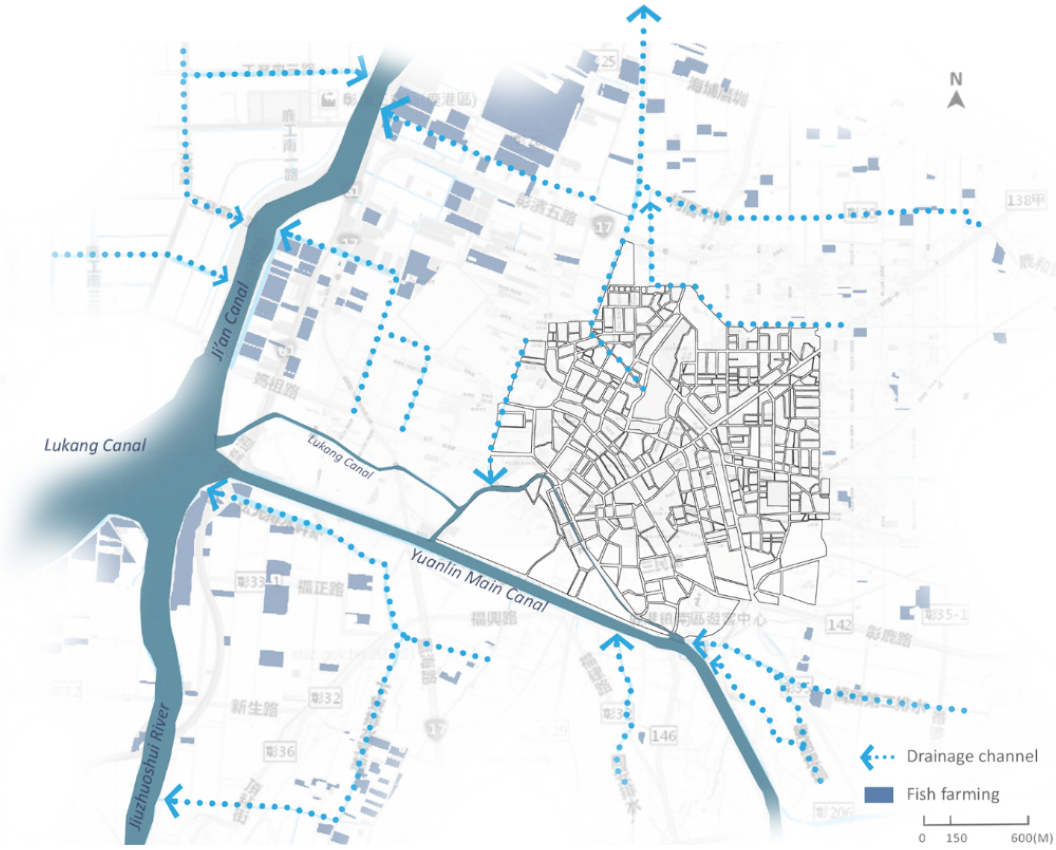


Figure 39 Drainage system in the surrounding area of Lukang Urban Planning Sources: Author

3.6.2 Groundwater and catchment

Groundwater reflow area refers to the surface water infiltration underground formation, and it is a regional groundwater flow source area, which has one of the following circumstances, and by the central competent authority designated for groundwater reflow geological sensitive area: First, for the multi-layer groundwater layer of the common reflow area. Second, the re-injection of groundwater can be used as an important source of regional water supply. The average annual water uses in Taiwan from 88 to 97 was about 17.95 billion cubic meters, of which 8.03 billion cubic meters (45%) were supplied by rivers, 5.59 billion cubic meters (31%) were pumped from groundwater and 4.33 billion cubic meters (24%) were supplied from reservoirs. The importance of groundwater resources is well important (Water Resources Department of the Ministry of Economy, 2010).

From the groundwater sensitive area analysis chart, it can be seen that Lukang Town is not located in the groundwater gushing area. However, most of the Lukang urban project area is groundwater free aquifer replenishment area. Analysis of groundwater replenishment area It is also important for this paper because, in the concept of sponge city and LID, the ability to replenish groundwater is a very important sustainable concept. Although LID facilities already have many functions to recycle water, if they can also replenish groundwater, it can be maintaining the sustainable development of the environment. It is especially important for many coastal areas in Taiwan because the central area has a phenomenon that a large amount of groundwater is extracted for aquaculture fishery. For example, in the coastal area of Yuanlin County (below Changhua County), Many areas where the stratum has subsided are now completely submerged by seawater.

However, the distribution of the underground catchment area can also be adjusted to match the groundwater replenishment area. According to the concept of LID, the rainwater drainage pipe can be used as a perforated pipe system, so it can increase the amount of rainwater infiltration into the ground. Besides, the distribution position of the catchment area is also related to the drainage speed. If there is only one drainage pipe in a large area, it is obvious that flooding will occur when the rainfall is heavy. The drainage area in the urban planning area is divided into the New Lukang Drainage Area and the Old Lukang Drainage Area. In the new area, a large area with no drainage system is clearly vacated in the southeast. Therefore, we should pay attention to the high possibility of flooding in this area, requiring more permeable pavements, and natural seepage instead of pipeline drainage.

In the historical preservation area in the old area, the drainage pipelines are not densely distributed, so we will be able to use the surrounding drainage system and green space to plan biological retention ponds or rain gardens that can reduce peaks and temporarily store water, instead of relying on the established drainage system.

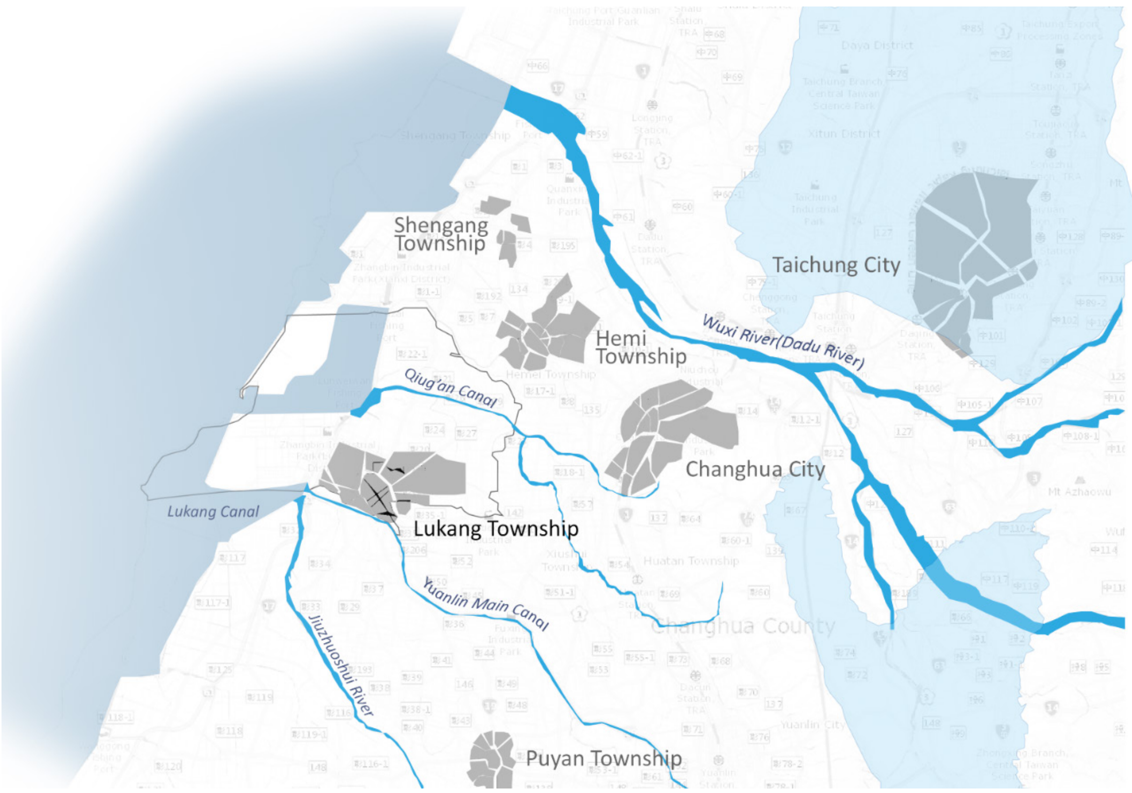


Figure 40 Groundwater sensitive area (water gushing area) analysis Sources: AuthorAuthor

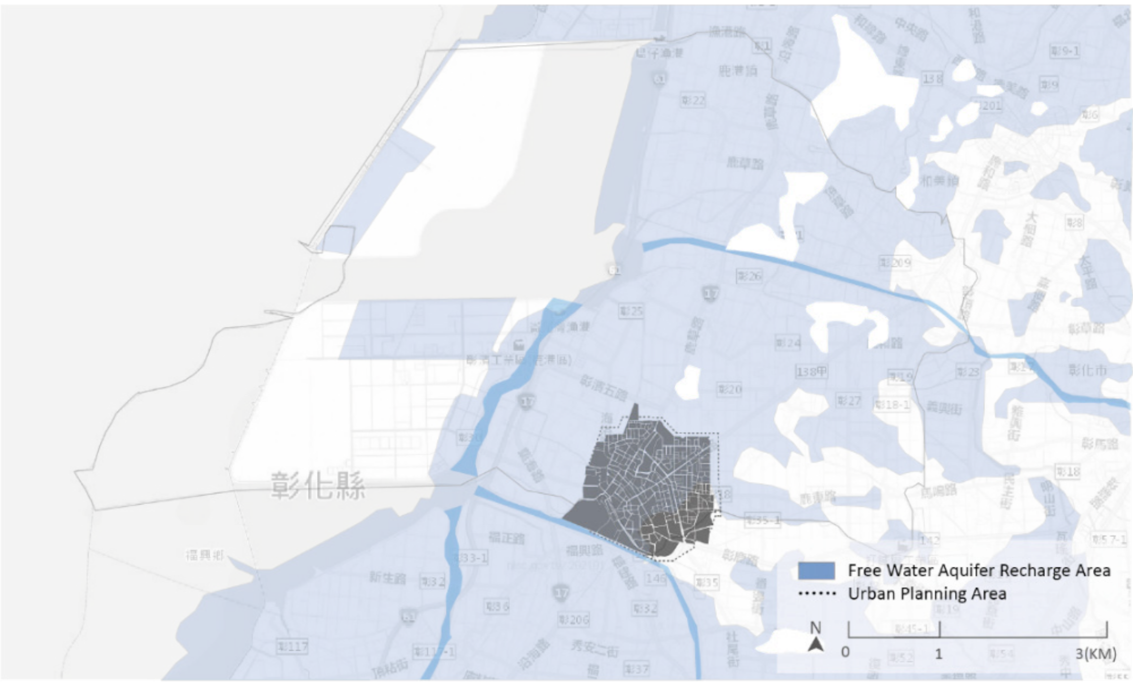


Figure 41 Groundwater free aquifer replenishment area in Lukang Township   Sources: Author

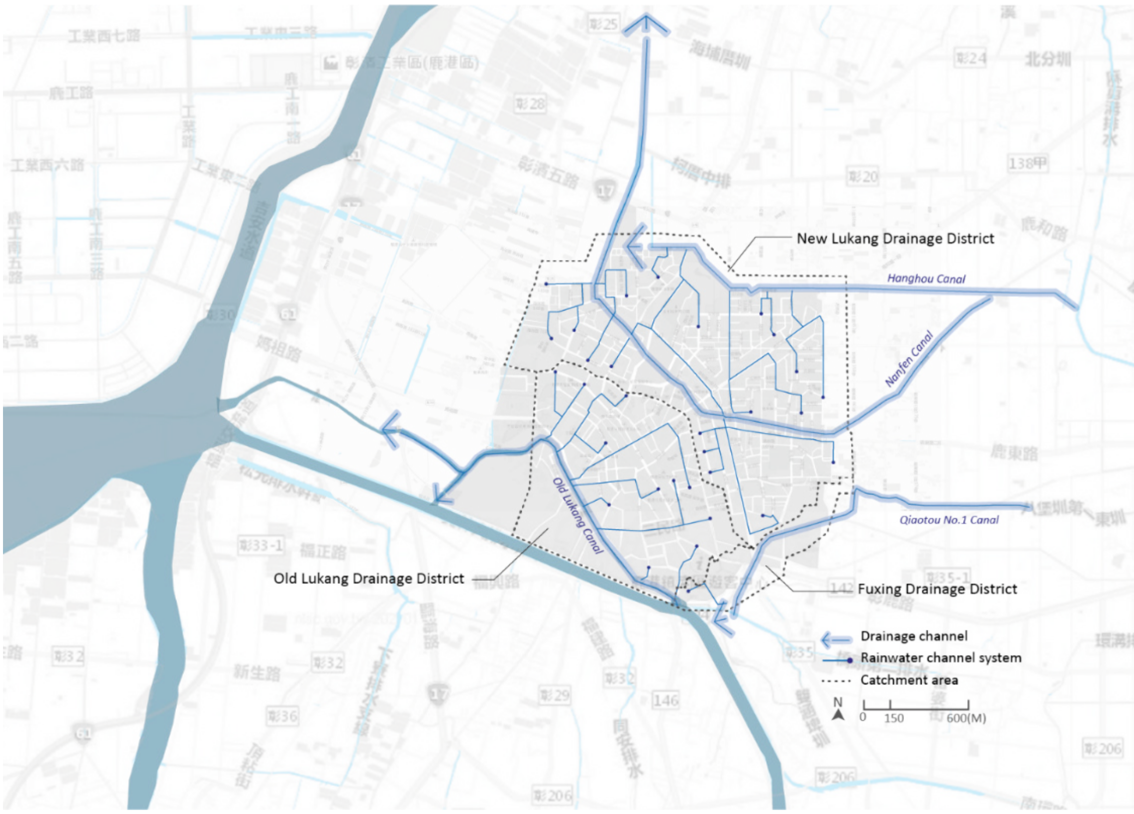


Figure 42 Rainwater drainage system in urban planning area   Sources: Author

3.6.3 Flooding risks

Future disasters

Taiwan is an island country. In terms of area, the plain area covers 9,489.90 square kilometers, accounting for 26.36% of the total area, while the rests are high mountains and sloping lands, accounting for 16,823.28 square kilometers, accounting for 46.73%. In other words, Taiwan is surrounded by the sea, and these cities of different sizes are almost all distributed on the plain surrounded by the sea. According to a new study released by Greenpeace's East Asia Institute in August 2020, sea levels in the waters around Taiwan have risen by 3.4 millimeters per year over the past 20 years, twice the world average. Without active carbon reduction in the next 30 years, Taiwan will be threatened by both sea-level rise and storm surge, which will hit an area of about 1,398 square kilometers of Taiwan, affecting about 1.2 million people. In the event of a storm surge, the flooded area would be up to about 2,120.60 square kilometers, accounting for about 6% of the total area of Taiwan. The number of people affected would be about 2.93 million, or 12% of the total population. (Yung-Jen & Jiao, 2020)

Besides, most of Taiwan's historical and cultural areas were located in ports along the west coast due to the early trade of seaports. For example, Tainan is the city with the richest history and culture among the six capital cities in Taiwan. The cultural heritage near the coastal area (Anping Castle), as well as other economic (Tainan Science and Technology Industrial Park) and ecological (Sicao Ecological tunnel) in Tainan are all likely to be impacted by the storm surge caused in 2050. Even Changhua County, which is located in the central region, will also be threatened. This area is not only offshore industrial areas, wind power generation, and even historical conservation areas will suffer serious and irreversible disasters.

Figure 43 A map of the impact range of Taiwan's sea level and storm tides under the scenario of inactive carbon reduction in 2050 Sources: (Chen & Wang, 2020)

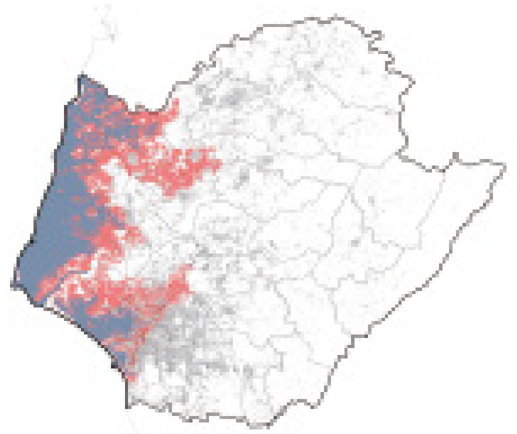


Figure 44 Areas affected by the storm surge in Tainan City in 2050 Sources: (Chen & Wang, 2020)

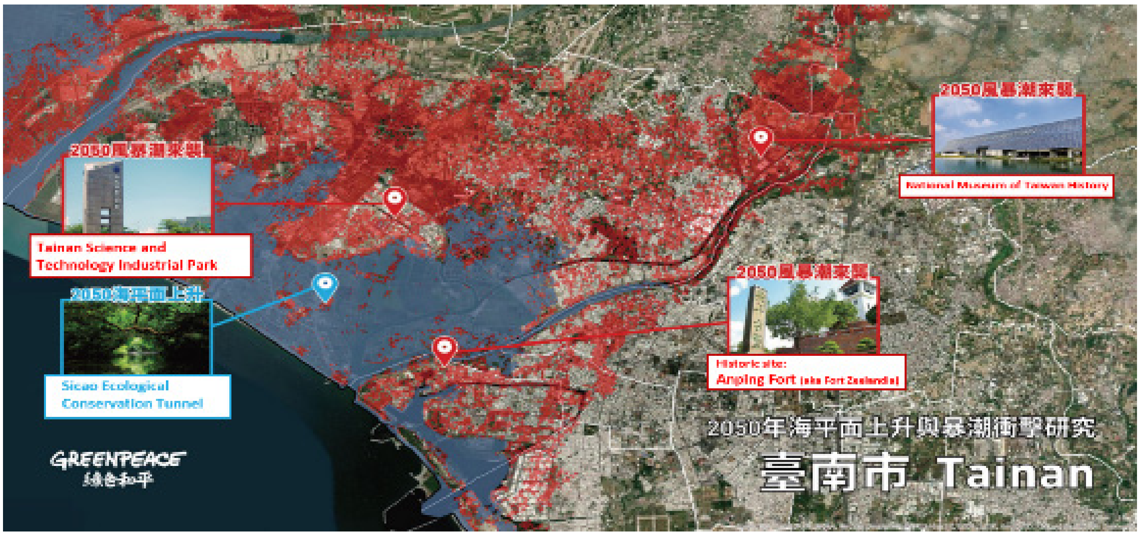


Figure 45 A simulated map of the area affected by the storm surge in Tainan City in 2050   Sources: (Chen & Wang, 2020)

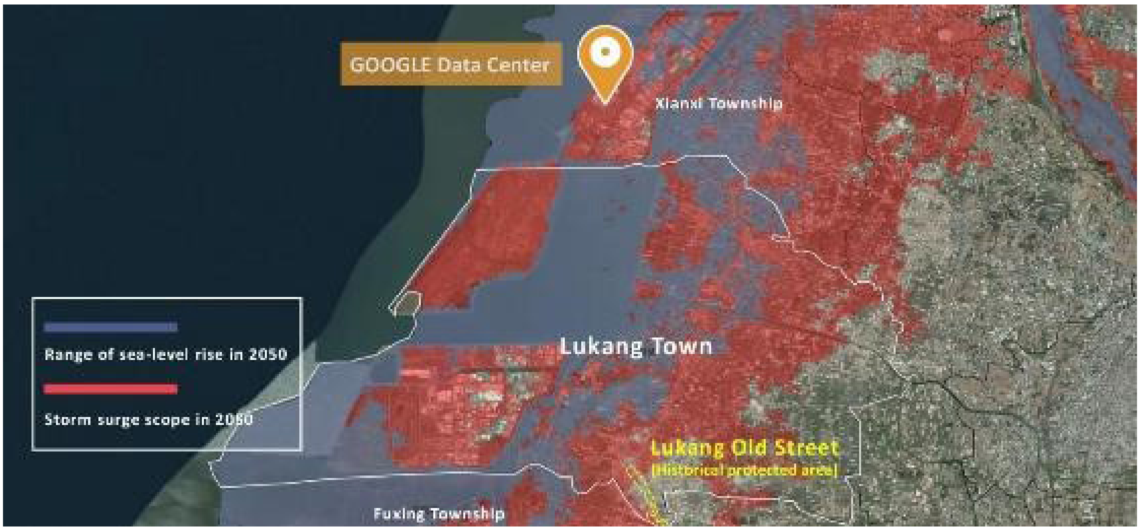


Figure 46 A simulated map of the area affected by the storm surge in Lukang in 2050. Sources: (Chen & Wang, 2020)

Current situation of flooding

Flooding events in the Old Street area of Deer Harbor, Deer Harbor, occur almost every summer and during typhoons. According to available data, flooding caused by typhoons in recent years occurred in 2004, 2005, 2007, 2014, 2017, 2018, 2019. Especially in July 2018, typhoon Maria's peripheral circular effects, the Taipei mountains accumulated more than 300 mm of rain. The town of Lukang also experienced 12 consecutive hours of heavy rain, with a cumulative rainfall of 261 mm and a daily accumulation of about 380 mm. According to the climate rainfall analysis (first 3.4 sections), the average monthly rainfall in July in the last three decades is about 325 mm. However, the typhoon's rainfall alone exceeded 380 mm, resulting in flooding.

Based on the Ministry of Economy Water Resources Department disaster prevention and flooding potential map open data, analysis of three consecutive days of rain may cause flooding areas. It is divided into rainfall accumulation of 6 hours 150 mm, 12 hours 300 mm, and 24 hours 500 mm. This situation to see the flooded area and the height of the flooding. According to the simulation, 6 hours and 150 mm of rain, outside the urban planning area (the map is near the top left), there will be a small portion of 1 to 2 meters of flooding, as well as a little 0.3 to 0.5 flood water. Most of this area is fishing land, so prone to water accumulation. Then there are the planned areas, where there are only two flooded areas in the cultural heritage area and the cultural maintenance area. At points A. and B. respectively, the road paving in the Point A area is almost impermeable. The road was completely paved, and the drain holes were almost covered with no visible holes. Even the holes in the road trees were covered to areas where only the trunks were exposed. The road paving in the Point B area is also covered with asphalt and cement drainage ditch covers. Where rainwater can be removed, only small holes in the drainage cover remain, and if covered by leaves or garbage, there is little rain infiltration.

In residential areas outside the cultural reserve, the maximum flood area is point C, the flood depth is about 50 cm to 1 m. In practical terms, point C is a vast area of crop arable land, because the terrain is relatively low-lying (lower than the road), so it is possible to form a rainwater pool area. If the rainfall accumulates to 12 hours and 300 millimeters (similar to the rainfall brought by the typhoon in 2018), the area of the cultural heritage that was originally flooded will be expanded and the depth could increase from about 50 centimeters to about 1 meter. Besides, flooding at point D will be expanded to two to three times, and more than half will be 50 cm to 1 meter deep. The site is the main road of a two - way road, surrounded by house buildings and impermeable parking spaces. The area at Point F is a complex of buildings within the lane, and the road is a one-way road. Most of the land surface is full of buildings, the permeable area is almost only cement built rainwater drainage pipes. Finally, for 24 hours 500 mm, more than 30 years of average monthly rainfall (not more than 350 mm) rainfall. Under such circumstances, nearly half of the urban planning area will be damaged by flooding. Especially in the lower right position of the area, for the most serious range of flooding. The depth of flooding reaches 1 to 2 meters of orange grade, which is nearly one floor high. Most residential areas will be flooded by about 50 centimeters to 1 meter. Even most cultural heritage and cultural maintenance areas will be flooded. As can be seen from these three flood maps of accumulated rainfall over time, most of the flooding has spread from the west side of Deer Harbor town to the east. Since the area is a coastal area (the Taiwan Strait is on the west side of Deer Harbor, about 2 km from the edge of the urban planning area), the sea level will be higher than the height of the passing area on days when the rainfall is in high tide, so the existing pumps can no longer play a supporting role in drainage. The main solution is still the need to reduce flood peaks, increase surface runoff permeable water, in order to reduce the short-term need to drain a lot of rain. And these water-prone areas will be soil permeable layer and rainwater drainage area analysis map to do overlap analysis, and then find suitable for this area of LID facilities.

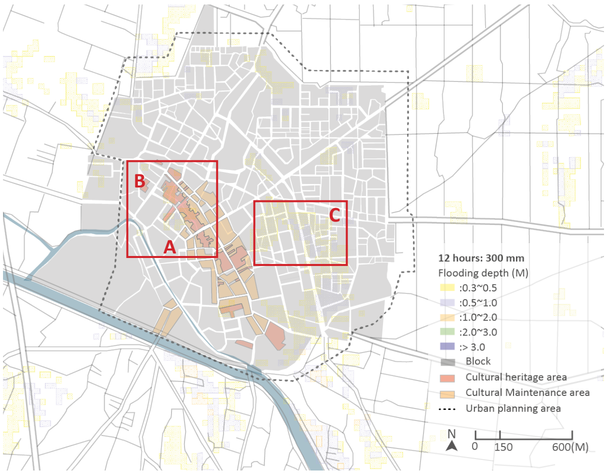


Figure 47 The first level of flooding potential map
Source: Author, based on Ministry of Economic Affairs and Water Resources

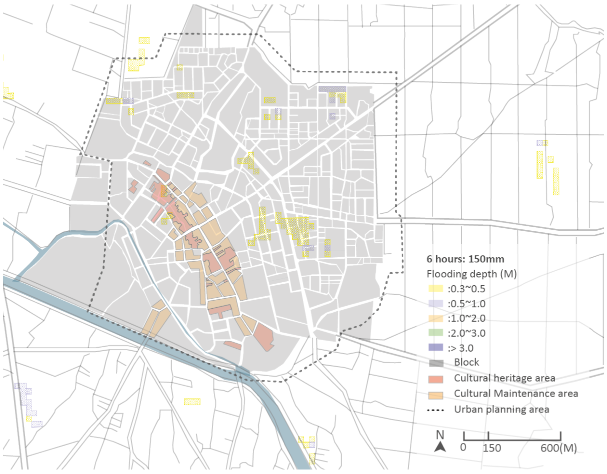


Figure 48 Figure 3-31 The Second level of flooding potential map
Source: Author, based on Ministry of Economic Affairs and Water Resources

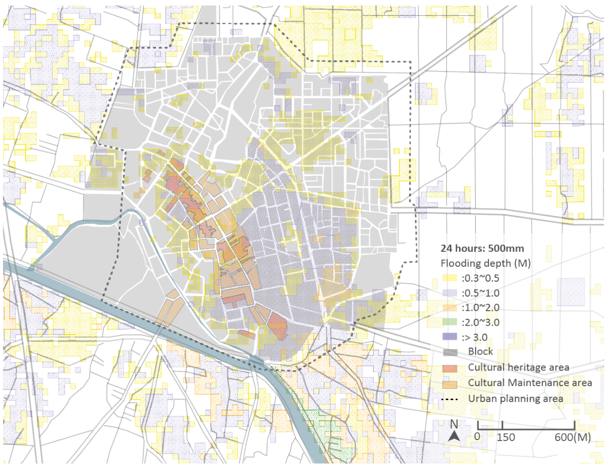


Figure 49 The last level of flooding potential map Source: Author, based on Ministry of Economic Affairs and Water Resources

3.7 Strategic and planning policies

3.7.1 The national level

Since Taiwan is an island country, the rise in sea level, temperature changes, extreme precipitation intensity and typhoon intensity brought about by climate change will directly affect the country's social, economic, ecological, cultural, and other development. In the early days, Taiwan actively promotes greenhouse gas reduction, energy conservation, and investment in related green industry research and development, so relatively speaking, there was a lack of integrated plans to promote climate change adjustment. After that, the National Development Commission established a task force in 2010, and successively released the Adaptation Strategy to Climate Change in Taiwan and the National Climate Change Adaptation Action Plan (2013-2017). In 2013-2015, the Environmental Protection Agency completed The Greenhouse Gas Reduction and Management Act., including The Greenhouse Gas Reduction Action Plan (Action Plan,2015) and The National Climate Change Action Guidelines (Action Guidelines, 2017). Besides that, The Coastal Zone Management Act., The Wetland Conservation Act, The Wetland Conservation Act., the Spatial Planning Act, and the Water Law have been published as the policy basis for Taiwan to promote climate change adjustment and mitigation. Finally, in 2018, the National Development Commission undertook to promote the results and convened 16 ministries and committees including the National Development Council to jointly study and draft The National Climate Change Adaptation Action Proposal (2018-2022).

The National Climate Change Adaptation Action Proposal (2016-2022)

This plan is issued by the Environmental Protection Agency of the Executive Yuan. It will be combined with 16 ministries and committees including the National Development Commission. According to the Greenhouse Gas Reduction and Management Act., the previous action plan will be continued and the implementation results of the plan will be counted as a reference for subsequent amendments.

• Objective:

Faced with the impact of climate change and time uncertainty, we need to consider its uniqueness. We will regularly publish adjustment results risk assessment reports and continue rolling corrections to ensure the country's sustainable development

• Principle:

1. Estimate the climate change trend of Taiwan's localization in the next century

2. Analyze Taiwan's adjustments to international climate disasters

3. Update based on the Greenhouse Gas Reduction and Management Act., the Three Land Laws (Coastal Zone Management Act., Wetland Conservation Act., and Spatial Planning Act) and revise the Water Conservancy Law

4. Drafting the "Manual of Adjustment Plan for High-Risk Areas"

3.7.2 The local level

Taiwan's urban planning is managed by the Construction Agency of the Ministry of Interior established by the central government and managed together with the Urban Development Bureau of the local government. The regional hierarchical unit is divided into four regions, North, East, South, and Central. The four regions are divided into 6 Special municipalities, 13 Counties, and 3 Cities. According to these three categories, they will be further divided into 6 categories, namely Mountain indigenous township, Rural township, Urban township, County-administered city, Mountain indigenous district, District. Then there is a Rural village, an Urban village following by, and Neighborhood is the lowest strata. Therefore, our research area is at the Urban township level, called Lukang Township. However, in the urban planning report, due to location of Lukang Old Street is located at the border of Lukang Township and Fuxing Township, so this area is divided into one of the Urban Planning Areas in Changhua County, called Lukang & Fuxing Urban Detailed Planning Book. The planning of this area also combines different planning tools (below Narrative).

flood maps of accumulated rainfall over time, most of the flooding has spread from the west side of Deer Harbor town to the east. Since the area is a coastal area (the Taiwan Strait is on the west side of Deer Harbor, about 2 km from the edge of the urban planning area), the sea level will be higher than the height of the passing area on days when the rainfall is in high tide, so the existing pumps can no longer play a supporting role in drainage. The main solution is still the need to reduce flood peaks, increase surface runoff permeable water, in order to reduce the short-term need to drain a lot of rain. And these water-prone areas will be soil permeable layer and rainwater drainage area analysis map to do overlap analysis, and then find suitable for this area of LID facilities.

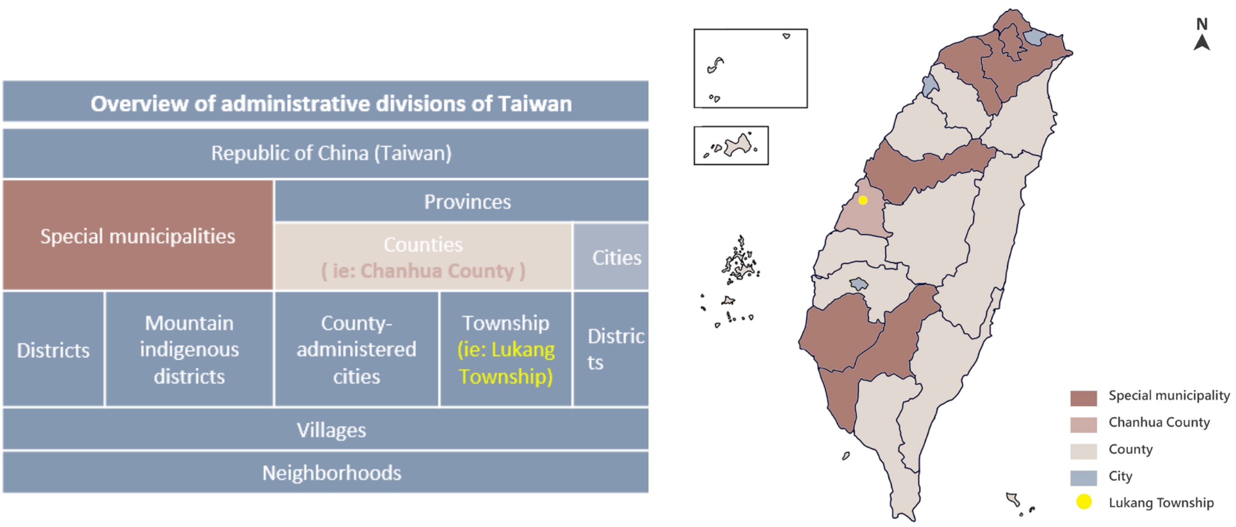


Figure 50 Overview of administrative divisions of Taiwan Sources: Author, based on (Anon., 2014)

The Changhua County Spatial Planning (2019-2036)

According to Changhua County Spatial Planning (2019), municipal, county (city), governments should do and cooperate with matters. Including the formulation of municipalities directly under the Central Government, county (city) land plan, urban plan review, strengthen coastal area protection, protection and utilization management, the formulation of local industrial development strategy, the production of the land functional zoning map, and the preparation of appropriate use of land, strengthen the handling of illegal use of land. The fourth of them, point 4.6, of the urban planning review, mentioned that the development case should carry out total net flow control, regulate the area of permeable water and retain flood control and flood storage buffer space, and strengthen the recycling of water resources, And environmental sustainability and other principles. As mentioned in the fourth item in strengthening the management of land and housing disaster reduction, municipalities directly under the Central Government, county (city) governments should incorporate the concept of sponge cities, low-impact development into the audit norms of urban design, strengthen the construction base and public facilities urban absorption design standards, increase urban flood prevention and mitigation capacity.

In risk management, Changhua County Spatial Planning refers to the regional analysis of land conservation. According to environmentally sensitive areas and considering land use, the areas are divided into disaster sensitivity, ecological sensitivity, cultural landscape sensitivity, and resource use sensitivity, and others. The subdivision contents of disaster-sensitive areas are hillside areas, groundwater control areas, seawall areas, flood potential areas, river areas, and regional drainage facilities. The location of the map close to the middle red dot gathering place in Deer Harbor Old Street, which is a cultural landscape sensitive area, but does not overlap with other disaster sensitive areas. For the future (this plan is scheduled for 2036) for natural disaster cultural landscape and natural ecological space concept, the vision of cultural landscape is to preserve cultural assets at the same time, combined with the surrounding environment landscape planning, increase the development of tourism industry. From the picture, you can see that the Deer Harbor area is one of the three cultural landscapes of Changhua County. Therefore, the Changhua County government in this plan under the planning, and thus promote the national historical scenic area (described below).

According to Chapter 4 of Changhua County Spatial Planning, climate change adjustment plans are specifically divided into planning. As the risk analysis of Lilu Port is located in the flood-prone potential area (according to the planned disaster risk analysis, The Deer Port area is located in the coastal area is also low-lying terrain, a sea-level rise leads to difficult to drain p64), so sewer construction will be carried out.

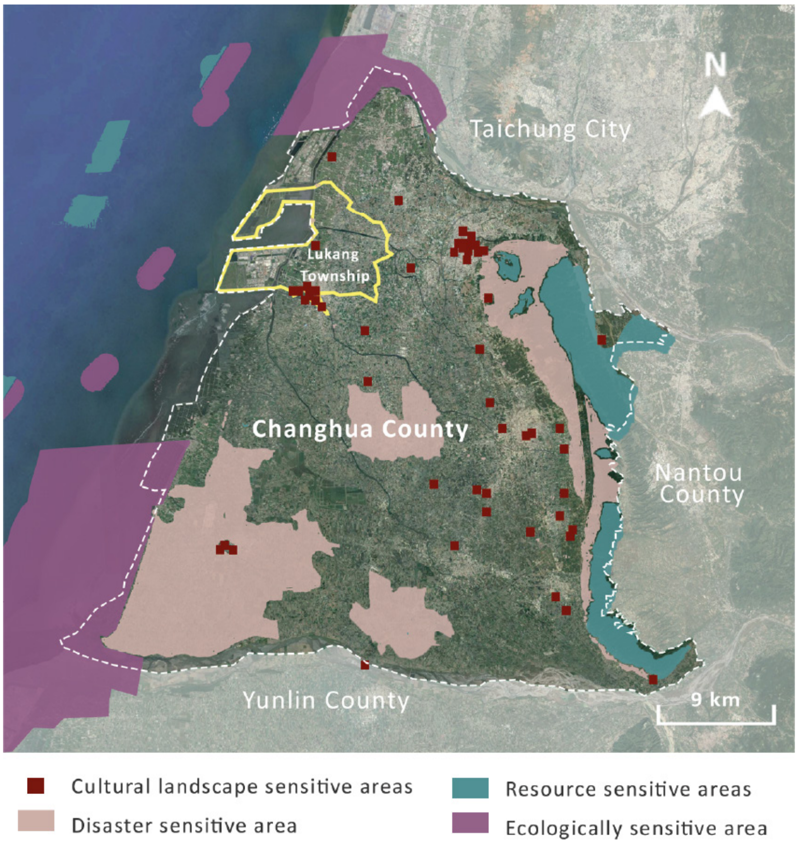


Figure 51 Zoning map of sensitive areas for land conservation

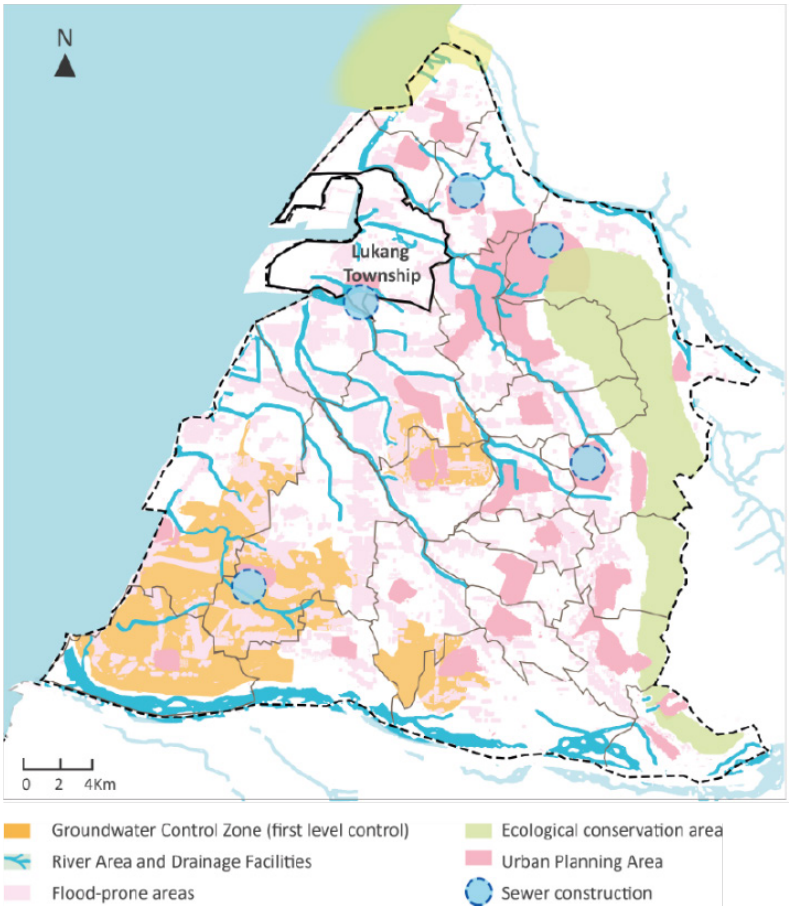


Figure 52 Spatial strategy map of climate change adaptation in Changhua County Sources: Author, based on (Changhua County Government, 2019)

3.7.3 The township level

The Lukang & Fuxing Urban Detailed Planning Book (2017)

This project area is located on the southeast side of Lukang Town and the northwestern end of Fuxing Township, across the townships of Lukang Town and Fuxing Township. It includes parts of the 19 miles of Lukang Town, including the Lukang Historical Settlement Preservation Area. The area is 375.45 hectares, and part of the 3 villages in Fuxing Township is 77.12 hectares, with a total area of 452.58 hectares. The total area is divided into three parts, high-quality residential area, old city living area, cultural heritage area (old street). Among them, the deserted Old Lukang Channel is contained in the old city living area.

The content of this plan is to effectively maintain the historical features and cultural assets of Lukang District. This plan strengthens relevant regulations on land use control in the preservation area. The original four types of preservation areas are simplified into two types of preservation areas, and the announced monuments and historical buildings are included in the first type of preservation area, which must be used following the relevant provisions of the "Cultural Asset Preservation Law"; It also regulates that the construction, reconstruction, addition, and new construction in the second type of preservation area should be approved by the Changhua County Urban Design Review Committee before construction. Besides, before the issuance of a demolition license for public and private buildings in the district, the Bureau of Culture must first conduct an on-site survey and provide opinions. If necessary, the demolition license must be issued after the Changhua County Urban Design Review Committee. However, the Lukang National Historic Scenic Area project mentioned above is a branch plan of the Lukang & Fuxing Urban Detailed Planning Book. In order to plan the National Historic Scenic Area, the county government also proposed three sub-projects; the Reserve of Lukang Historic Site Plan, the Lukang Channel Renewal Plan, and the Green Transportation Plan. The main goals of the Lukang Channel Renewal Plan are water purification and improvement, drainage and bank protection and waterfront environment construction, lane landscaping (historical lane), Lukang Fuxing sewage sewer, and other auxiliary planning tools.

From the above information, we can know that climate adaptation plans are lacking at the local level. In the national climate adaptation strategy, it is clearly mentioned that management units at various local levels should focus on urban planning to reduce the impact of disasters. Mainly. However, this concept only extends to urban-level planning and does not reach the local level. In the Changhua County Spatial Planning, it is pointed out that specific areas (mountains or coastal areas, etc.) should pay attention to the impact of climate change, and it is recommended that urban planning should refer to the Sponge City and LID. But in Lukang Town, an area that has a rich cultural heritage does no exact climate adaptation plan. Although it is mentioned that the sewage will be modified, in the Lukang and Fuxing Urban Detailed Planning Book and related urban plans, there was not implemented according to the national strategic plan. Therefore, the lack of connection between the national level and the local government in the urban plan is our main concern.

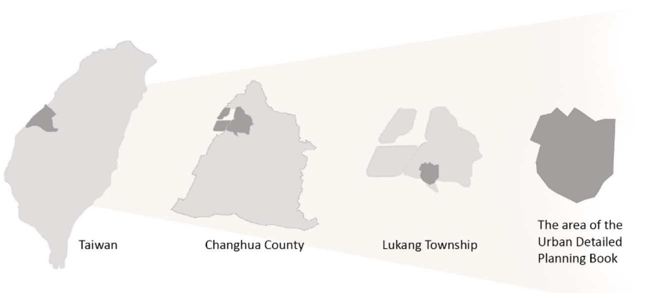


Figure 53 Lukang Fuxing detailed planning location Sources: Author

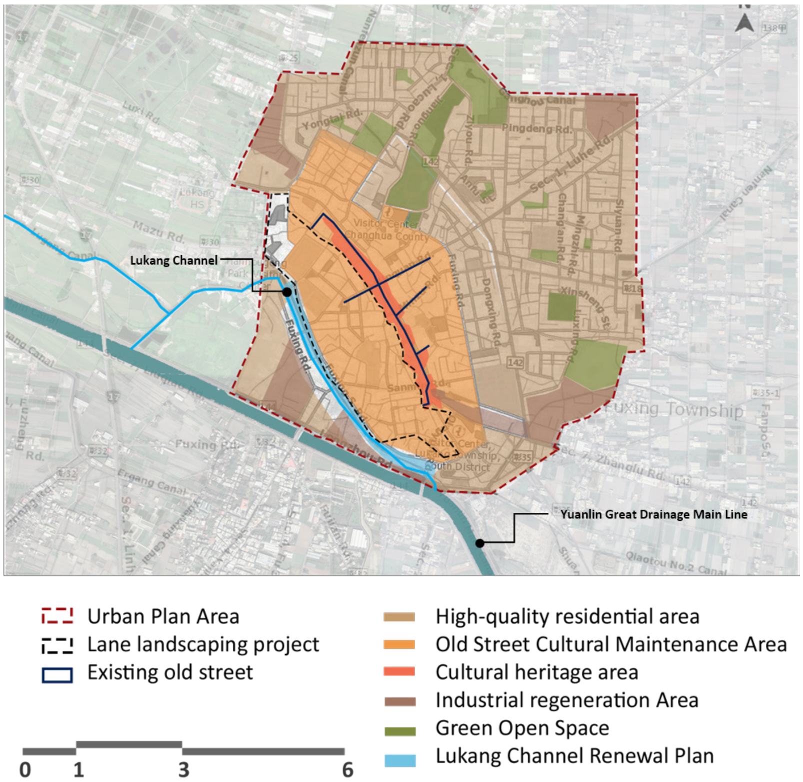


Figure 54 Schematic diagram of the overall spatial development of Lukang Fuxing's detailed plan- Sources: Author, based on (Changhua County Government, 2017)

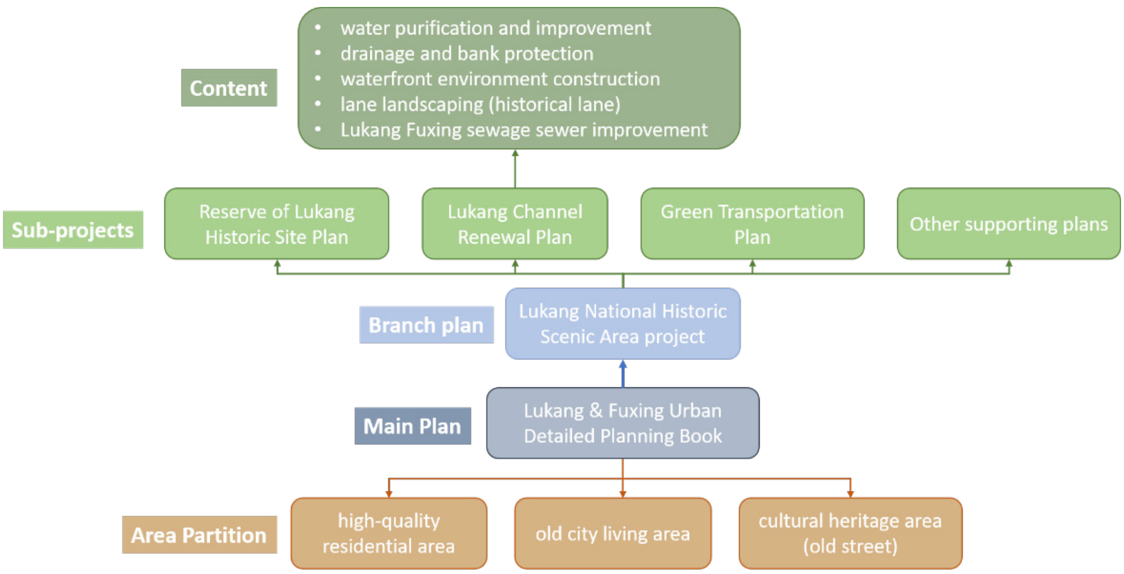


Figure 55 Diagram of Lukang & Fuxing Urban Detailed Planning Book Sources: Author

CHAPTER 4 Proposal for a resilient heritage landscape in Lukang

4.1 Risk assessment and proposed strategies

In order to understand how to improve the resilience of Lukang cultural heritage, we will analyze the results of the risk assessment to understand the climate disasters suffered by Lukang Old Street. Since this paper focuses on the definition of the location of disaster adaptation measures, the spatial conditions of the environment are the main consideration and risk assessment is based on a qualitative, more than quantitative, evaluation. According to such factors, we divide the environmental risk assessment into four types, namely: environmental issues, natural disaster issues, cultural heritage issues, and regional development issues. The pros and cons of environmental issues can be understood from geographic analysis and soil analysis. The contour distribution in the geographic analysis falls at 0 meters, which is almost the same as sea level. Therefore, it is prone to seawater intrusion on days of high tide. In terms of slope analysis, the terrain of this area is flat with an average slope of no more than 5%, which is conducive to the construction of LID facilities. However, in soil analysis, we can see that in the urban planning area, most of the area is impervious alluvial soil. Therefore, it may affect the index of rainwater infiltration. Nevertheless, this area is located in the free groundwater replenishment area, which is suitable for increasing infiltration rate and replenishing groundwater. Then, on the issue of natural disasters, it faces the impact of climate change. Greenpeace predicts that in the next 30 to 50 years, the coastal areas of Taiwan (including this research area) will face the problem of rising sea levels. Not only that, but climate change will also cause typhoons to increase rainfall and the risk of storm surges. Besides, this area is almost as high as the sea level, and flooding problems will continue to appear. Like the typhoon in 2018, the single-day rainfall (380mm) has been higher than the average monthly rainfall (almost 350mm) for 30 years (average highest rainfall month). This situation has resulted in the cultural heritage of this area in summer for many years. Soaking in water is very serious damage. Even the water pumps installed in and around the cultural heritage area cannot solve the problem of insufficient rainwater drainage, but in winter, there is a shortage of water.

The cultural heritage of Lukang Town is the richest area in central Taiwan. The most representative one is Lukang Old Street, where dozens of temples are located in this area. The architectural style is also the Han Min-style style that has gradually developed since the 17th century. The cultural heritage represented here is not only tangible buildings but also includes early cultural beliefs and business models. Because it is so special, this area has attracted a large number of tourists to visit here, and it has also promoted the development of the local tourism industry. The last thing I mentioned in the regional issues. According to the analysis of land use and roads, the population and building density in this area is very high. According to the detailed plan of Lukang Fuxing Urban Planning, the planned population is 65,000, and the living density is about 310 per hectare. The current total population of Lukang Town is 86,700, with a density of about 2.2 thousand/km², which is the fourth highest population density in Taiwan's township level. However, the high population density will lead to increased building density. In response to building needs, open space will gradually decrease, and the permeable area will decrease (including impermeable road materials), which will result in a highly developed area. Especially Taiwan's traditional landscape planning method is built for a large number of gray structures. As a result, rainwater cannot penetrate the soil, and under heavy rainfall, the peak of the drainage channel will be accelerated, causing flooding problems. However, the Changhua County Government issued a new urban planning proposal in 2019. Among them, it will be mentioned that in response to climate change, it will propose the future urban planning direction that can be incorporated into the concept of LID. Thus, it will be planned that the urban planning area of Lukang will undergo a sewer renovation project.

	Values	Risks	Strategies
Environmental issues	1. The area is located in the groundwater free holding layer 2. Flat slope terrain, suitable for LID measures	Poor permeability of most soil components	Soil improvement according to the Operation Manual of the Low-Impact Development Facility for Water Environment
Natural disaster issues	-	Flooding caused by sea level rise and storm surges	Climate adaptation: adopt the concept of sponge city (increase the permeable area, reduce the peak drainage)
		Water shortage in winter	Adopt LID measures: increase rainwater storage space
Cultural heritage issues	1. Rich cultural heritage 2. Cultural heritage increases tourism industry development	Maintaining heritage buildings increases municipal financial expenditure	1. Enhancing the concept of disaster prevention 2. Improve urban resilience through water management
Regional development issues	The municipality proposes climate adaptation recommendations: 1. Recommended to adopt LID planning method 2. Underground waterway reconstruction	The high population density results in a high degree of regional development, resulting in high building density, and therefore a lack of open space and permeable area.	1. The sponge city divides the area, and then configures the functions of infiltration, storage, stagnation, purification, use, and drainage according to the appropriate space type. 2. After zoning according to the sponge city, follow the measures of LID to achieve water management goals.

Table 3. Values, risks and strategies   Source: Author

4.2 Planning approach

It is mentioned in the above risk assessment that this area is a high development, high building density area. And in urban planning, there are not only commercial and residential areas but also cultural heritage protection areas. However, the concept of sponge city must consider the six concepts of the functions of infiltration, storage, stagnation, purification, use, and drainage. Taking into account the above reasons, the planning method will refer to the case of "Xiamen Sponge City Old Town Pilot" (in Chapter 2).

The main flood control elements of the sponge city are the calculation of the total runoff control target and the designed rainfall, which is then distributed to each area for water management models. However, the simulation of the water catchment area belongs to the category of environmental engineering. Therefore, the flood control standards of this paper will refer to the LID report, the Operation Manual of the Low-Impact Development Facility for Water Environment. The recommended setting of LID facilities is that if the ratio of the area of the facility to the overall area is 1:4~1:10, the effect of the facility may be achieved (The situation depends on the spatial rainfall and other factors, the exact configuration method must be calculated by the simulation of the catchment area). The perspective of this paper proposes regional planning for urban planners and provides a reference for the next stage of environmental engineering. Therefore, the proposal in the next section will calculate the area ratio of the implementation range and whether it meets the requirements in the range of 1:4~1:10.

Next, after the case content of Xiamen Sponge City is consolidated, the planning steps will be divided into three major steps here. The first step is regional zoning, according to the existing conditions of the space to do a large-scale regional division. Therefore, the Xiamen case separates the old blocks from the development zones in recent years, because the spatial composition of the old blocks is different from the development zones in recent years. For example, the drainage system in old blocks is relatively old and can no longer withstand the heavy rainfall caused by modern climate change. In recent years, the development zone will use more gray facilities to plan the composition of the block. The second step is to perform more detailed functional zoning (the six concepts of sponge city: infiltration, storage, stagnation, purification, use, and drainage) based on the environmental assessment (soil properties, etc.) after the zoning. Finally, the third step is to implement the layout of LID measures in blocks and streets according to function partitions and to integrate the area of LID facilities in the three areas. The location of the facilities in the block will be allocated according to the space conditions and needs. For example, if the spatial composition of this area is more large open spaces; mostly hard pavement that is impermeable; the soil composition is suitable for rainwater infiltration; located in the catchment area of rainwater drainage, it is recommended to adopt a larger bioretention to help flood storage and filter water quality.

According to this planning method, we decided to divide the urban planning area into three major districts to make recommendations based on the current spatial conditions and the regional analysis in the Lukang Fuxing Urban Planning Regulations. They are the cultural heritage protection areas where the cultural heritage is concentrated; and the mixed residential and commercial areas around the cultural heritage are divided into the second area, the cultural maintenance area; finally, this area is classified as the largest, and the development year is less than the cultural maintenance area. After the regions are divided into three categories, the planning concept of sponge city and the smaller-scale LID measures are allocated according to the spatial conditions.

Figure 56   Zoning map of the study area   Sources: Author

4.3 Urban planning proposal

The research area of this paper refers to the location of the Lukang Fuxing Urban Planning. There are many characteristic buildings rich in historical years in this area, but they may suffer more disasters in the future due to climate change. Therefore, the main purpose of this paper is to use water management practices to try to solve the cultural heritage in the urban environment, due to storm tides, or short-term heavy rainfall.

Therefore, in the first section of this chapter, the risk assessment issues and solutions in the third chapter are classified. Different regional environments require a rigorous risk assessment to support the planning concept. In this chapter, the three major districts have been evaluated and the corresponding solutions have been proposed. The following is a consolidated table for us and the target area ratio requirements. The total area of this urban planning area is 452.58 hectares. The total planning area of the cultural heritage area is 6,163 square meters; the total planning area of the cultural maintenance area is 11,891 square meters; the total planning area of the residential area is 648,443 square meters, so the total planned area of LID is 666,497 square meters (66.65 hectares). According to the Operation Manual of the Low-Impact Development Facility for Water Environment proposed by Taiwan, if the ratio of the area of the facility to the overall area is 1:4~1:10, the effect of the facility may be achieved. Based on the calculation results, the area ratio of the planning area proposed in this paper is approximately between 1:6 and 1:7, so it is possible to reduce the possibility of flooding. However, the main research goal of this paper is to use the concept of sponge city and the coordination of LID facilities; to propose an area suitable for implementing this planning method. Therefore, the exact SWMM water management simulation still needs to be calculated by environmental engineering and combined with regional planning to make rolling corrections.

4.3.1 Residential area

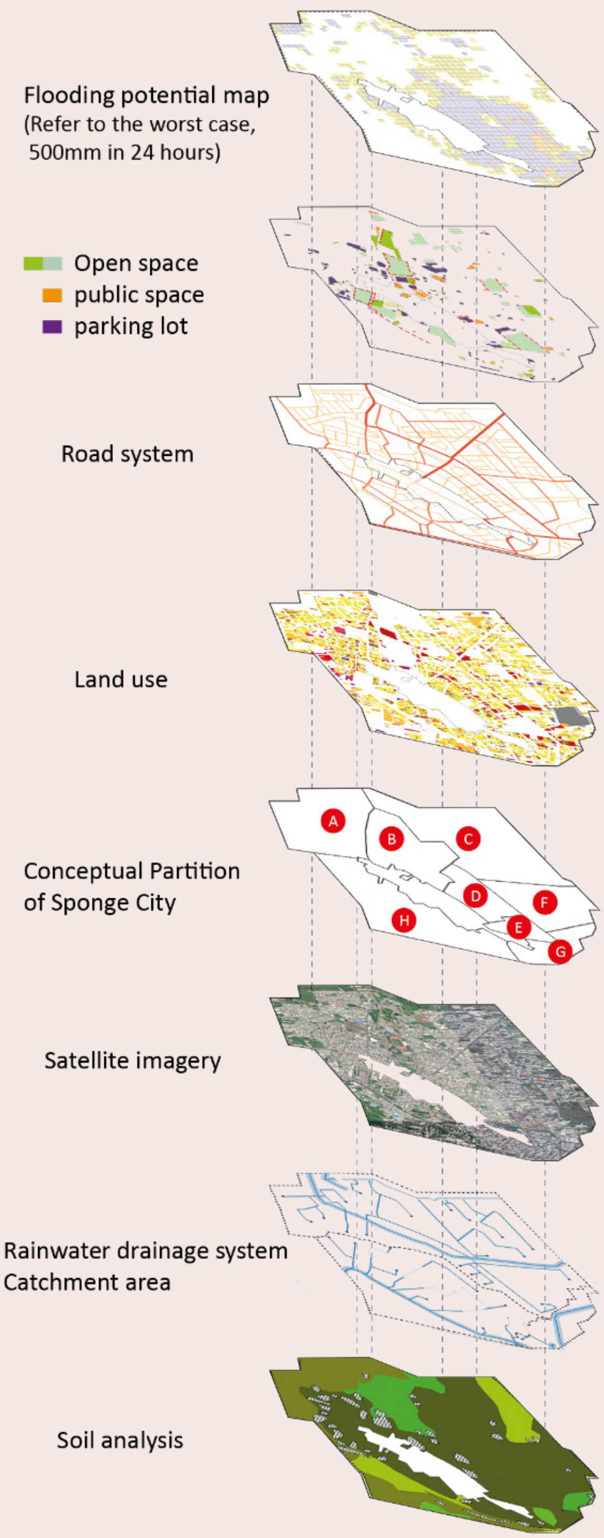


Figure 57 Analysis diagram of residential area Sources: Author

The residential area occupies the largest area of this research area, so the space conditions that need to be considered are more complicated. Therefore, we divide the area into 8 major areas according to the various spatial conditions of risk management. Then partition according to the functional concept of sponge city, and estimate the area after setting up LID facilities.

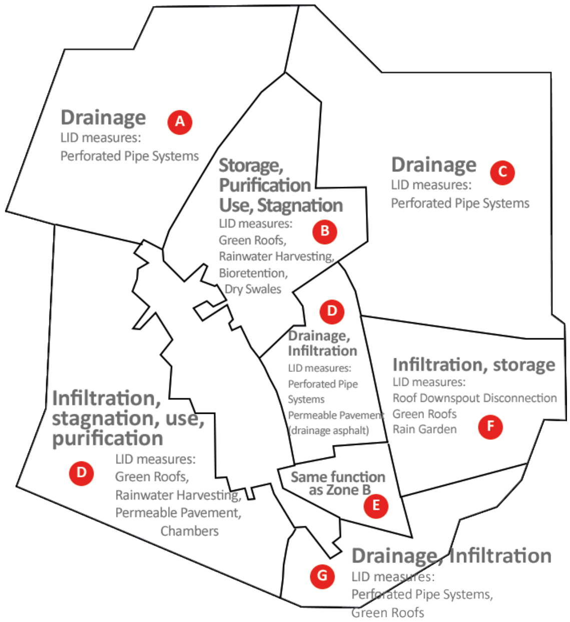


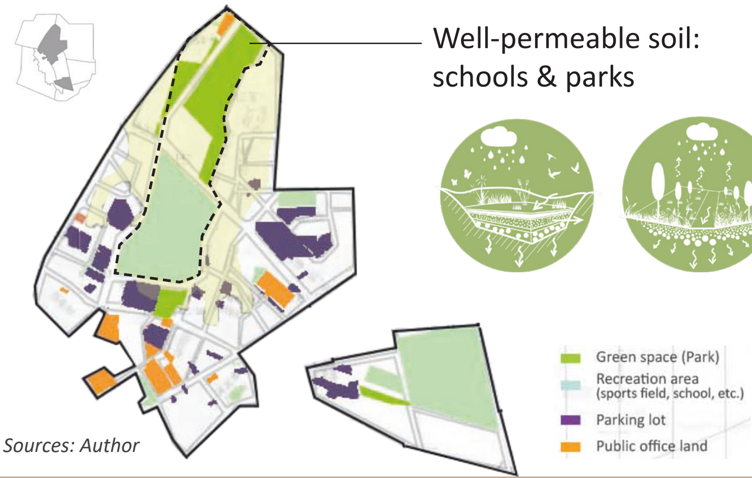
Figure 58 Proposal to partition the residential area according to the concept of sponge city. Sources: Author

Areas A & C | Draninge | LID :

Sources: Author

First of all, the spatial conditions of areas A and C are similar, and both have developed drainage systems, so the occurrence of flooding is expected to be less. However, the space in this area is densely populated with residential housing, so dense alley blocks have been developed. Therefore, in this case, we will put forward the concept of "drainage" based on the concept of sponge city. The green line in the picture is where the neighboring road and drainage channel overlap, so, it is recommended that these roads and their branches can be installed with the Perforated Pipe Systems.Thus, the developed rainwater drainage channel not only has the function of drainage but also reduces surface runoff to reduce the peak quality caused by heavy rain.

Areas B & E | Storage, Purigication, Use, Stagnation| LID :



Sources: Author

Well-permeable soil:
schools & parks

Other areas with poor water permeability:
School, public institution building

In areas B and E, it can be clearly seen in the land use analysis graph that this area is mainly for parks, schools, and office buildings for public institutions. Therefore, the feasibility of implementing the plan is much higher than that of private land. The soil conditions are also the best location for water permeability in this area. Therefore, we will propose “storage, stagnation, purification, use” these four kinds of sponge city planning concept. Therefore, the concept of planning LID facilities is divided into two types. Schools and other public institutions in this area, if they are located in well-infiltrated soil locations, the concepts of storage and stagnation will be adopted. The outdoor open space that can be used in the area will be equipped with large bioretention and dry swales with low maintenance costs for plants (note the phenomenon of soil blocking drainage holes). If it is located in soil with poor infiltration and filtration, it is more suitable to plan for the concept of stagnation, purification, and use. Among them, the LID measures will be set up on buildings and underground to store rainwater; they are green roofs, rainwater harvesting, and chambers. The green roofs can not only collect rainwater for non-drinking water use but also reduce the heat of the building in summer. This can reduce the number of times the building uses air-conditioning.

Areas D | Draninge, Infiltration | LID :

Green lines:

Orange lines:

The spatial condition of area D is a mixture of residential and commercial areas, but the residential proportion is relatively high. Moreover, the building density is high; the open space is small, and the excess permeable area cannot be released; the form of the block is narrow and dense, but the use of cars is low. Therefore, we propose the concepts of drainage and infiltration. To reduce the chance of flooding, it is necessary to increase the permeable area and the planning of the drainage system. The green line is the overlap position of the road and the drainage pipe, so it is suitable for setting up Perforated pipe systems. The other orange roads can be set permeable asphalt pavement.

Areas F & G | Infiltration, Storage, Drainage| LID :

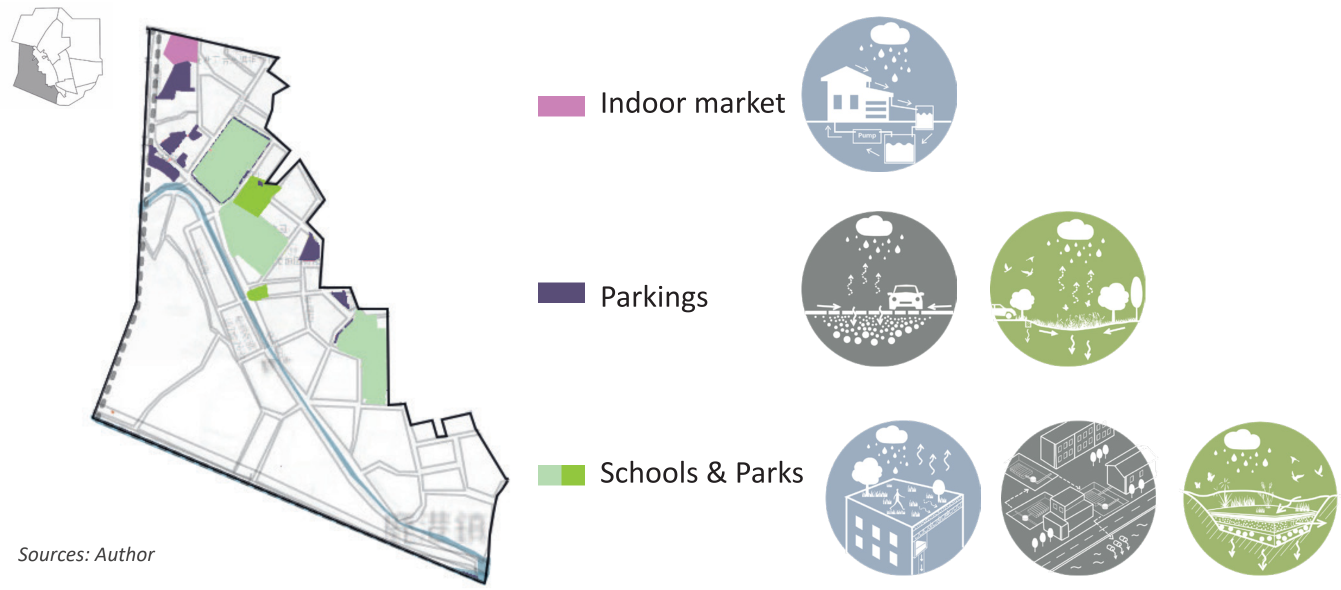
Sources: Author

Private residence
(concept suggestion, not mandatory):

Road system:

In the above-mentioned areas, planning suggestions are made in public spaces or public institutions. However, in the F and G areas, most of the soil is poorly permeable; there are few open spaces and mostly private residential houses; and the rainwater drainage system has poor drainage, resulting in the most serious flooding potential in this area. The flooded area. Therefore, it is necessary to propose Infiltration, storage, and drainage that can reduce the drainage strength under the limited drainage capacity. However, due to space constraints, the LID facilities in this area will be recommended to be installed in the private space of residents. It will propose green roofs, roof downspout disconnection to increase the permeable area and water circulation and to transform the garden of the private house into a permeable rain garden. In addition, perforated pipe systems will be installed in line with the location of existing drainage pipes. The important thing is that the required location is private property, and the local government will need to propose relative supporting measures and organize related knowledge activities to increase the citizen participation of residents.

Areas H | Infiltration, Purigication, Use, Stagnation| LID :



Sources: Author

Finally, it is area H. The space condition of this area is that most of the land is used for industry. Therefore, the focus of the planning will be on the upper left near area A. Because the space condition of this location is the closest to Lukang Old Street, and there may be flooding conditions (there is not enough space for water management in the cultural heritage area and the cultural maintenance area). Besides, this area contains two schools, two large parking lots, and a market managed by the local government. Therefore, the concept of sponge city in this area will be infiltration, stagnation, purification, use. If this area is to have a significant flood detention effect, the two playgrounds in the school can be developed into chambers. And also like the planning method of areas B and E, the school can install a green roof to reuse water. The existing conditions of large parking lots are asphalt pavement, and it is recommended to increase the permeable area and plan vegetable filter strips to reduce the possibility of water pollution. The market area is also very large, about 5,195 square meters. If the existing roof is transformed into rainwater harvesting, it will reduce surface runoff, and the recycling of water resources can be used by vendors in the market.

4.3.2 Cultural maintenance area

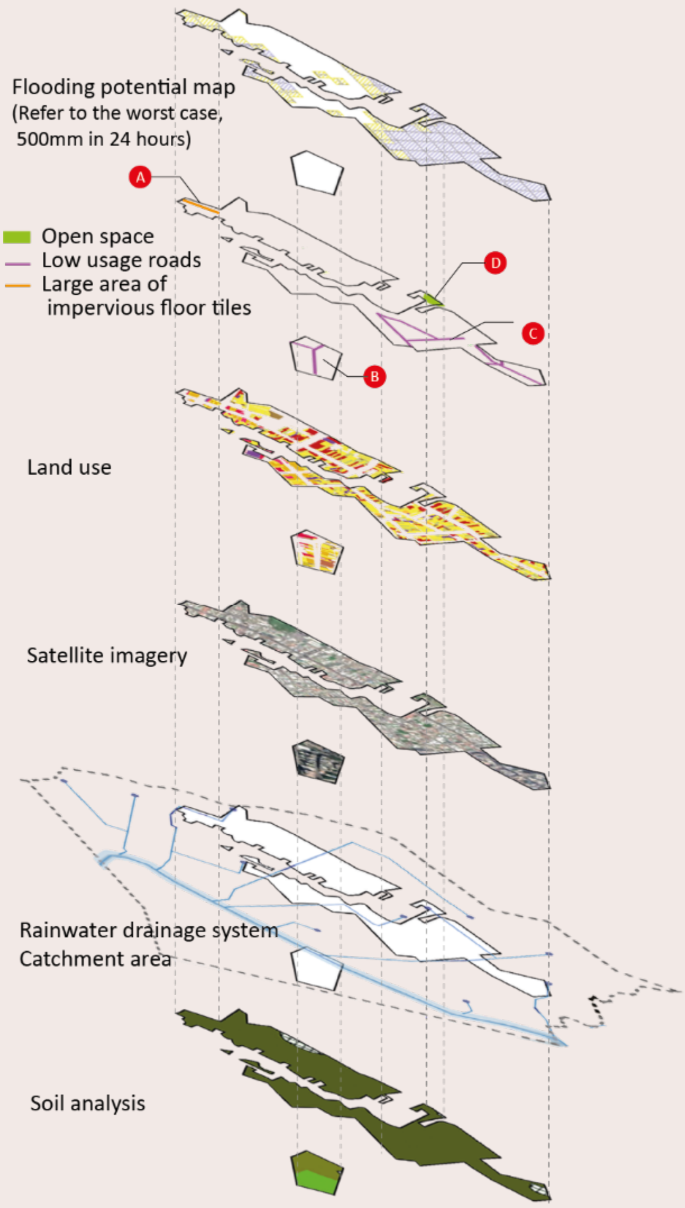


Figure 59 Analysis diagram of cultural maintenance area Sources: Author

On the periphery of the cultural heritage area, it is composed of a one-story residential and commercial area. The spatial conditions in this area are high-density building distribution, and it is necessary to propose effective opportunities to reduce flooding in this area. Therefore, we set the planning goal as infiltration, drainage; reducing rainwater runoff, increasing the permeable area, and controlling the flow of rainwater drainage.

The Sponge City Concept: Infiltration, Drainage

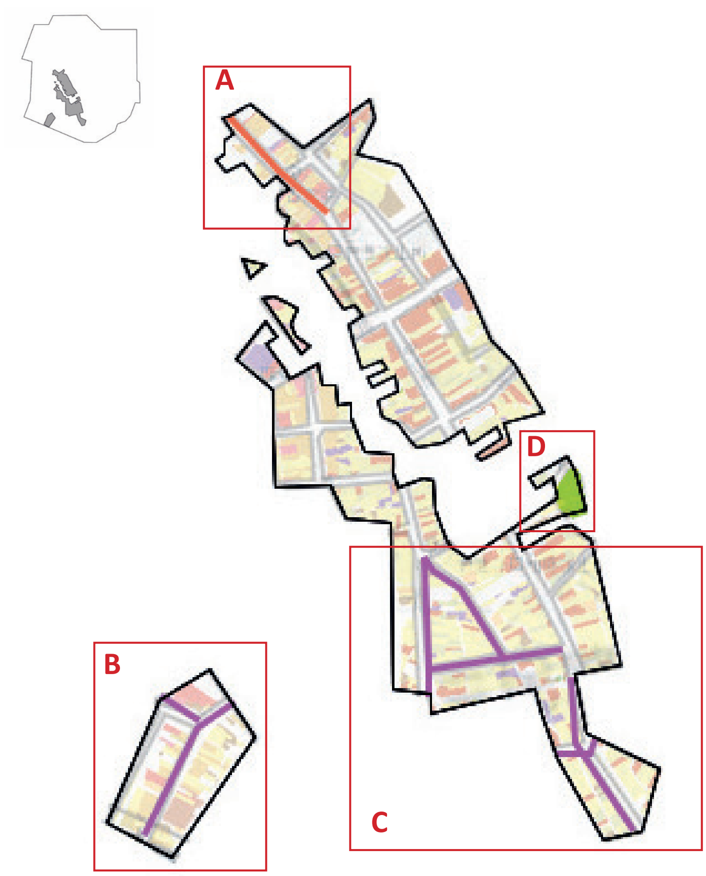


Figure 60 Location map of LID facilities Sources: Author

Area A | Road area is about 637 square meters

In Area A, this area is around the cultural heritage old street. Although this area is no longer protected by the Cultural Assets Protection Law, the sense of the history of the architectural space is still very strong. The current state of the streets along the orange lines may have been

re-planned in recent years. Therefore, the paving on the road is very neat, and the location of the tree hole where the arbor is located is also very neat. Nonetheless, the pavement on this road is made of impervious floor tiles filled with the cement material. Although the usage rate of this road is very high, the use of permeable paving will likely increase the frequency of road maintenance.

Therefore, we recommend that in a limited space, at least increase the permeable area around the tree hole, and you can set up enhanced grass swales of the LID facility. This facility is suitable to be installed on the roadside, drainage ditch, or small rainwater temporary storage tank, and will reduce the rainwater runoff.

Figure 61 The tree hole of the street tree in area A is covered with cement Sources: Google Street View

Area B & C | Low utilization road meters | Total area is about 9,688 square meters

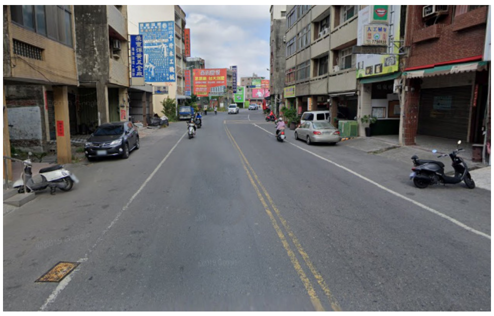


Figure 62 Photos of the current situation in areas B and C   Sources: Google Street

In the planning areas, B and C are both low-utilization roads, although the space conditions are not very similar, they are suitable for the same LID facilities. Half of the area of point B is located on well-permeable soil, but there is no rainwater drainage pipe, which cannot play an effective drainage function. If perforated pipe systems are installed here, the drainage function will be improved and the rainwater seepage to supplement groundwater.

Point C is located in a dense residential area in the city center, but it lacks rainwater channels (It may be the cause of the flooding potential map showing the flooding). The surrounding streets have a high usage rate, but the location of this area is a neighborhood street within an alley. Therefore, under a low utilization rate but high drainage demand, it is also suitable to set up perforated pipe systems to improve rainwater management efficiency.

Area D| Landscape green area is about 1,566 square meters

Figure 63 Current status of open green spaces in Area D Sources: Google Street View

Finally, Area D, an open green space for this area, which is located in a green garden of about 1,566 square meters in the building complex. According to this space condition, the most urgent problem to face is the flooding situation. Therefore, it is recommended that this area can be planned as a small and concave bioretention. The main function of Bioretention here is to collect the excess surface runoff from the surrounding impervious area and to achieve the effect of purifying the pool with planting configuration. Although the space is not large enough, effective use of each piece of land in the space can have different effects.

Overall, the street area of District A using LID facilities is approximately 637.14 square meters. The planned street area of Area B is approximately 3,166 square meters. Area C is also a street plan, with an area of approximately 6,522 square meters. The green area of District D is 1,566 square meters. Therefore, the area of the LID facility set up in the cultural reserve is 11,891 square meters.

4.3.3 Cultural heritage area

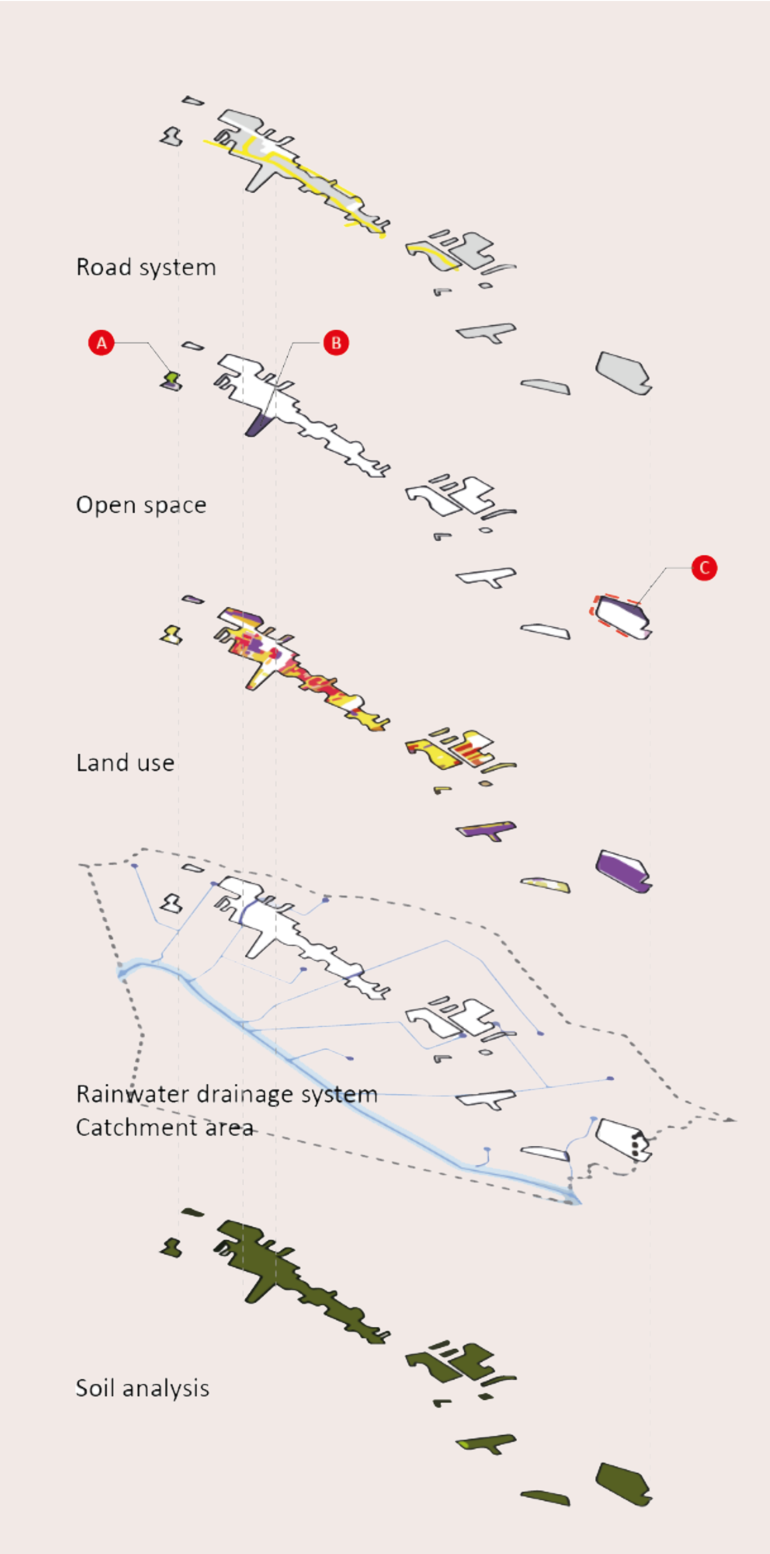


Figure 64 Analysis map of cultural heritage area Sources: Author

This area is a cultural heritage area, where Lugang Old Street (the yellow line in Figure 64) is located.Therefore, this area cannot be changed too much because it is restricted by cultural heritage regulations. If a restoration plan is required for the historical site itself, the necessary facilities must be added as needed without changing the original appearance of the historical site (Chapter 2 of the Cultural Assets Preservation Law, Article 24). If it is not in the main body of cultural heritage or historical site, and there is a need to change the urban plan, an application and review must be made to the competent authority (Article 35 of the same law).

However, under these conditions, the best practice is to make plans for the open areas around the monuments or to give private land suggestions in the limited area without affecting the original appearance of the monuments as much as possible. From this, we will select three planning areas from the open space map. It is important to note that this area is located on a soil composition with poor water permeability, so soil improvement technology must be used when applying LID measures.

Figure 65 Location map of LID facilities in the cultural heritage area Sources: Author

Area A | Private Area | Infiltration, Storage

Figure 66 Private space in front of cultural heritage (Lukang Rimao Commercial Bank) Sources: Google Street

The current situation in the first area (point A in the figure) is private land in front of the historic site, with small space conditions. According to the flooding analysis chart, there is no serious flooded area. Therefore, according to the main flooding problem in the cultural heritage area, this area is planned as “infiltration” and “storage” to reduce the peak according to the concept of sponge city. This area will be planned as a small garden (about 54.87 square meters) and a privately managed toll parking lot (about 59.3 square meters). Although this area is privately owned, there is very little open space in the cultural heritage area. Therefore, the government can give residents suggestions to assist residents in adopting LID measures without harming the rights of the other party.

In this garden area, the surrounding roads are not highly used car lanes. Therefore, if LID measures are installed, it will not affect the changes in the underlying water quality. Considering that this area is small in size and adjacent to rainwater drainage pipes. Therefore, according to the “storage” in the concept of sponge city, this area is recommended to be planned as a rain garden connected to the drainage function of sewers. The rainwater garden can mainly alleviate the peak drainage of rainfall, purify the water quality, and maintain the current state of beauty. If the rainwater collection pipe is added, it will be able to store water for reuse or drainage.

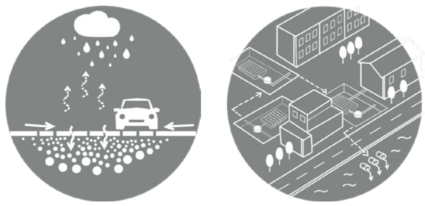
The other space is a privately managed toll parking lot, and it is an impervious area covered by cement. Therefore, corresponding to the “infiltration” function of the sponge city, the pavement of the parking space can be transformed into the form of permeable bricks. This approach will not change the function of the parking lot, but also increase the rainwater infiltration rate, purify the water quality, and supplement the function of the groundwater layer.

Area B | Large area of impervious parking lot | Stagnation, Purification, Use

Figure 67 Area B, satellite image of parking lot. Sources: Google Map

Figure 68 The parking space is asphalt pavement Sources: Google Street View

Figure 69 Art workshops next to the parking lot Sources: Google Street View



The second and third areas are purple, parking lots. In the second area (point B in the figure), this parking lot (approximately 2,144 square meters in total) is owned by the local government. Next to this area is a re-planned commercial area. This area is an official dormitory built during the Japanese Occupation. After the renovation of the Lukang Town Office, it has become a commercial artwork visit, providing various types of artists to create here. Since these two areas are owned by the local government, the planning will be able to work in a unified manner. And considering the problem of water shortage in winter, the area needs a large water storage tank to reuse rainwater. Therefore, this area is based on the concept of sponge city "Stagnation", "purification", and "use".

Due to the above conditions, we plan that the LID facilities here can be installed in the parking lot; permeable bricks can be installed on the surface so that the rainwater can be purified through the soil layer and collected in the Chambers under the ground. Through the use of these two measures, rainwater collected through permeable bricks will be used for landscape irrigation or non-drinking water in the neighboring art workshops. Therefore, the problems of reducing peaks and water shortage in winter can be solved.

Area C | Parking lot | Purification

Figure 71 The Parking lot located beside the monument(Lukang Wenwu Temple)

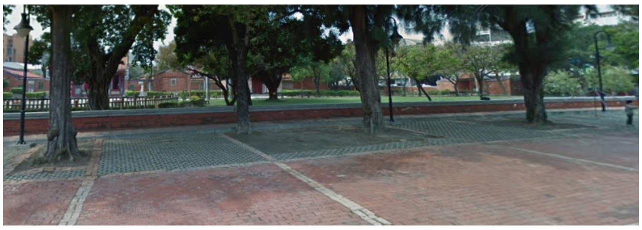


Figure 70 The growth surface of the trees are covered by permeable bricks.

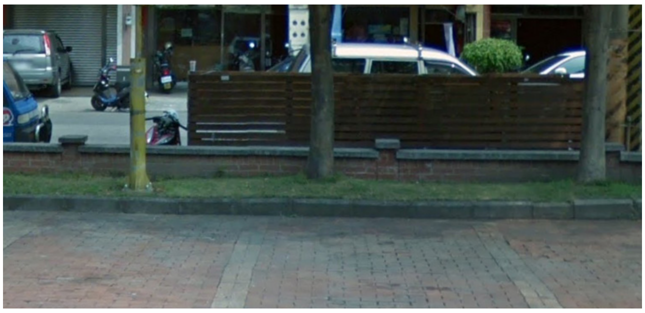


Figure 72 The grass ditch higher than the parking surface may reduce the effect of rainwater infiltration. Sources: Google Street View

The current location of the third area (point C in the figure) is the parking lot (approximately 3,905 square meters) next to the cultural heritage building. From the current photos, it seems that this area has been renovated, and the covered area of the parking grid is all permeable bricks. However, the surrounding trees are covered with permeable bricks or planting troughs that are higher than permeable bricks. Besides, the vehicle emissions in the parking space of a shift will likely affect the rainwater runoff and the vehicle emissions, causing water pollution. Therefore, if the issue of water pollution infiltrating the soil is not taken into consideration, the soil and groundwater quality may be destroyed.

According to the spatial conditions of this area, we will introduce the function of “purification” based on the concept of sponge city. To achieve water purification in the parking lot space, the space configuration can be done with the Vegetated Filter Strips of the LID facility. The vegetated filter strip is based on different planting configurations (grass plants, shrubs, trees) to intercept the pollutants before the rainwater penetrates, and then achieve the role of rainwater purification.

In summary, the planned area of this area is 6,163 square meters.

CHAPTER 5 Concluding remarks

The impact of climate change has been intensified year by year in every environmental space. However, many specialists around the globe are studying how significant climate change will be on human life. The day-to-day environment is the most relevant to people's existence. Therefore, many countries came out with climate adaptation plans to analyze the situations of regional space and face more severe climatic conditions in the future. As mentioned in the first chapter, the impact of climate disasters on urban space may also cause heavy casualties and property losses. Therefore, when planning climate adaptation plans, risk assessment is vital. There are usually planning deadlines and periodical analysis for major disasters due to the climate's persistent changes. In fact, the main objective of these climate adaptation plans is to increase resilience of cities. The concept of urban resilience is in a nutshell to set the city's spatial planning in such a way that the city is able to withstand the damage caused by the disaster long before it strikes and restore its original functionality in a short period of time.

However, climate disasters not only affect urban areas but are also affecting the cultural heritage placing what represents growth of the human species at risk. Should cultural heritage spots have the technology and adaptations to fight climate change? Some schools of thought pointed out that cultural heritage needs to have resilience to face as not to be severely destroyed during climate calamities especially those coming from water. Also, because water resources account for a very important role in human physiological needs. Few examples of water disasters could be the rising sea levels, the regional flooding caused by storm surges; or the impacts of crop fallow caused by lack of water. Therefore, improving cities water response could be a tool to improve urban resilience. Moreover, since most of a city's cultural heritage is located in the center, and cultural heritage is at the roots of urban development, improving a cities resilience will also benefit its heritage.

Water resources management is based on the laws of each countries with their own governance methods. For example, comparing Western countries with Asian countries, it is clear that different levels of rainfall and temperature changes will affect immensely the planning context. Therefore, if the area of interest is Taiwan, we should apply methods proposed by Asian countries. The Sponge City concept was born in 2013 from the Chinese government's water management needs. The hope for the future is that the construction of sponge cities will help the countries to effectively use water resources and reduce rainwater discharge by at least 70%. The United States of America's LID planning strategy is a basic form of Sponge City strategy. LID's goal is to carry out the urban planning with the lowest spatial impact possible for the environment. Especially in a high degree of regional development and high-density building areas, this planning method is more than suitable. The Sponge City concept has rapidly become a conceptual zoning plan for large areas. In fact, starting from the needs of a particular space condition the six functional zonings (infiltration, storage, stagnation, purification, use, and drainage) are tailored for each individual area. After functional zoning, the corresponding LID facilities will be subject to a more in-depth spatial analysis child of considerations regarding the computer assisted water simulations. Finally, the complete spatial configurations and analysis will be proposed.

Nonetheless, after understanding practically the operational strategy of the sponge city and LID concepts, it is now necessary to comprehend the environmental risk assessment of the research area of this paper in order to know how to configure suitable water management facilities under design conditions. In the environmental sub-risk assessment of Chapter 3, the current situation in Taiwan's response to climate disasters were analyzed. In particular the analysis of strategic planning, mentioned the urban planning report of the Changhua County Government in response to climate change. It is not surprising that the urban planning and development board of Changhua have suggested to apply the Sponge City and LID planning methods. Taiwan's government has also cooperated with the scientific academic community to produce the "Operation Manual of the Low-Impact Development Facility for the Water Environment". The essence of this manual the proposal of LID methodologies for the existing environmental space in Taiwan.

Linked to this, in the proposal in Chapter 4, we proposed some planning steps. However, the principal planning method of this dissertation is the "Sponge City Technical Manual". The planning steps referred into the "Operation Manual of the Low-Impact Development Facility for Water Environment" range from site selection to space configuration. As for the subsequent calculations regarding the SWMM watershed model, it involves the work of environmental engineers, so in this paper, we limited ourselves in the calculation of the areas referred to LID facilities dedicated to water management (last subsection of Chapter 4). The obtained areas were conforming to the proportions recommended by the standard. Therefore, this planning method meets the goal of reducing flooding opportunities.

In conclusion, through this research and analysis, we can understand how climate change is very harmful to life and especially cultural history. However, under certain circumstances, through by planning using the sponge city water management, we theoretically proofed that it is indeed possible to improve the urban resilience of the region. On the other hand, it can be demonstrated that large-scale changes cannot be done on an area rich of cultural heritage with the scope of adapting to climate asperities. However, we thought that if the surrounding small-scale areas are properly acted upon, the values of cultural heritage can be maintained, and urban resilience can improve. On the other hand, one of the biggest issues of highly developed urban areas is the most certainly the unused space on the roof of a private houses that is contrast with its need of more open spaces. In short, the government should plan educate the citizens more on water management throughout activities that allow citizens to actively participate enhancing the cohesion between communities and promoting the concept of resilient cities. On this note it is recommended that the government starts long-term risk management investment plan. In conclusion to achieve large-scale water management planning, adapting for climate change will be a problem and a necessity for every future generation.

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