Transformations of Urbanising Delta Landscape

An Historic Examination of Dealing with the Impacts of Climate Change for the Kaoping River Delta in Taiwan

Chen Kun Chung

A+BE Architecture and the Built environment

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V.J. (Han) Meyer

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Rector Magnificus, Voorzitter
V.J. (Han) Meyer, Technische Universiteit Delft, promotor
Prof.em.ir. M. de Hoog, Technische Universiteit Delft
Prof. H.Y. Lee, Nat. Taiwan University
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To my parents, parents in law and three beloved babies: Wen, Ho and Lei.

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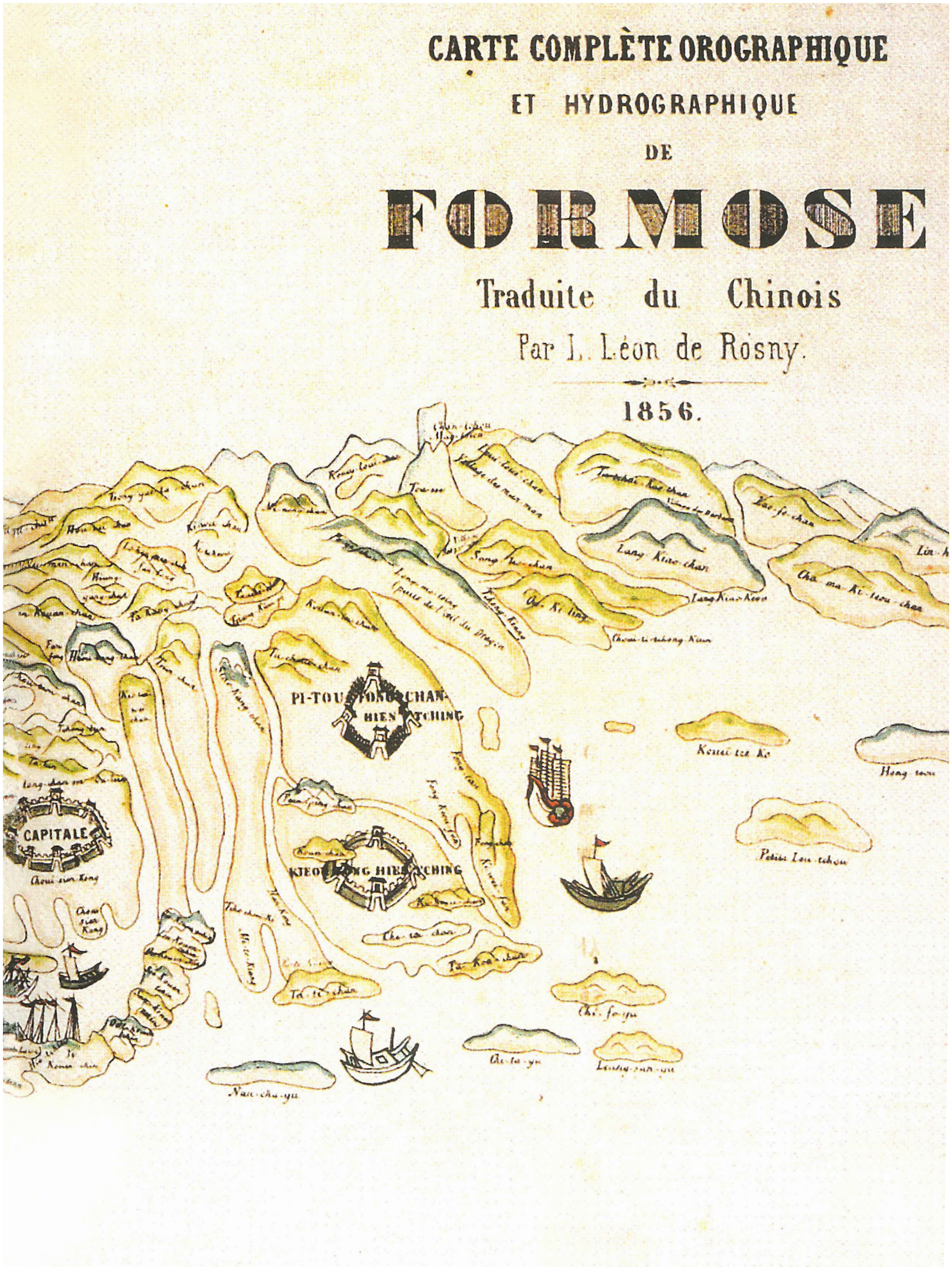

The map of Taiwan (Formose as an old name) by French in 1856. Source from LGR 2005, provided by Jun-Xiong Wang (王俊雄)

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I still remember the chilly but fresh wind and the tall steeple of the Nieuwe Kerk as if it were yesterday when I firstly arrived in Delft with my family, and with some vague ideas about water and urban design, at dawn. There was a hope that these ideas could be further clearly reframed and refined here as some useful and practical concepts for my country, Taiwan. I did not imagine what I learned and gained is far more than what I could expect at that moment. I would like to express my heartfelt gratitude to the following people who helped me during the seven-year of writing this thesis.

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Summary

This dissertation argues that the floods following extreme precipitation result not only from very heavy rainfall but also from the significant impact of human activities on natural water systems. While most literature emphasises that the increasing magnitude of storm rainfall extends beyond the original protection standards of hydrologic facilities in highly populated delta cities. Based on the knowledge of urban morphology, this study analyses how human systems have affected the transformation of natural water processes in the Kaoping River Delta. The relationship between human environments and natural landscape is illustrated via a 3-layer analytical framework which consists of a natural landscape layer, an infrastructure layer and an occupation layer. This layer-based approach views landscapes as a whole system in which each element interacts with the others. In order to transcend the limitations of traditional urban morphology and the overlay-mapping method, this research initiates an analysis framework with the delta scale from a deductive perspective. Furthermore, it argues that the significant progress of infrastructure technology is the crucial factor to dominate the transformation of modern urban pattern. This influence could be identified by the analytic process of the 3-layer approach from the perspective of the delta or regional scale. This new starting point of a theoretical framework for analysing urban forms has been proved in the Kaoping Delta case. Furthermore, it could be a new and valid theoretical background to extend the knowledge of urban morphology.

The formal transformation of the Kaoping Delta is divided into four main periods, which reveals human activities have affected the operation of natural systems since a century ago. From a delta scale perspective, those effects interacting between different layers can be identified in six different topographies (in italics) of the whole river catchment area.

A The dike system along the main stream in the plains protects delta cities against floods, which enables rapid urbanisation. Population growth in delta cities increases food demand, which causes the intensive agricultural cultivation of mountain areas.

B The dike system narrows the original riverbed in the river basin, which raises the water level of the river during storms. This situation blocks the drainage outlets of delta cities and induces higher frequencies of urban inundations.

C The dike system along the main stream in the plains has significantly changed the surface flowing path of river and dramatically decreased the recharge of groundwater in foothills. It causes serious land subsidence in coastal areas when the ground cannot obtain sufficient groundwater.

D The dike system and the bridges of transportation crossing river has resulted in the lag-sedimentation of the river in the river basin. When a significant amount of river sand deposits in the riverbed rather than being transited to the estuary to supply the demand for sand along the coast, it induces serious erosion in the coast.

Following this context, this study organised a five day workshop in Kaohsiung, 'Workshop on Water Environment Development in Kaohsiung' in 2012 to further examine the results derived from Chapters 3 and 4, and to demonstrate how a 3-layer approach can work between multiple disciplines as a platform for collaboration. This workshop followed the theoretical framework of the 3-layers to explore the entire Kaoping River catchment area and its two tributary basins as the chosen local-scale sites: the Meinong River and the Love River. This workshop gives the best demonstration of how to practically utilise the 3-layer approach to organise multiple-disciplinary work, and then to make an integrated plan. The results and process of this workshop are also generalised as a framework, which could be applied to other cases.

Samenvatting

In dit proefschrift wordt betoogd dat overstromingen na extreme neerslag niet alleen het gevolg zijn van zeer zware regenval, maar ook van de aanzienlijke invloed van menselijke activiteiten op natuurlijke watersystemen. In de meeste literatuur wordt echter benadrukt dat de oorspronkelijke beschermingsnormen van hydrologische voorzieningen in dichtbevolkte deltasteden worden overschreden door de toenemende hoeveelheid neerslag tijdens hevige buien. Op basis van kennis van stedelijke morfologie is in dit proefschrift onderzocht welke invloed menselijke systemen hebben gehad op de natuurlijke waterprocessen in de delta van de Kaoping (een rivier in Taiwan). De relatie tussen menselijke omgevingen en het natuurlijke landschap wordt geïllustreerd met een analytisch kader waarin drie lagen worden onderscheiden: het natuurlijke landschap, de infrastructuur en de gebruiksfunctie. Bij deze drielagenbenadering wordt een landschap beschouwd als één groot systeem, waarin elk element met de andere elementen interageert. Om de beperkingen van de traditionele stedelijke morfologie en de "overlay-mapping"-methode te overstijgen, is bij dit onderzoek een nieuw analytisch kader gebruikt waarin naar de schaal van de delta wordt gekeken vanuit een deductief perspectief. Daarnaast wordt betoogd dat de belangrijke vooruitgang op het gebied van infrastructuurtechnologie de cruciale factor is die de verandering van het moderne stedelijke patroon bepaalt. Deze invloed kan worden vastgesteld met de analytische methode van de drielagenbenadering vanuit het perspectief van de schaal van de delta of de regio. Dit nieuwe uitgangspunt van een theoretisch kader voor het analyseren van stedelijke vormen heeft in het geval van de Kaopingdelta zijn waarde bewezen. Daarnaast kan het een nieuwe en nuttige theoretische achtergrond vormen waarmee we onze kennis van de stedelijke morfologie kunnen vergroten.

In de verandering van de vorm van de Kaopingdelta zijn vier hoofdperiodes te onderscheiden. Hieruit blijkt dat menselijke activiteiten al een eeuw lang van invloed zijn op de dynamiek van natuurlijke systemen. Op de schaal van de delta kunnen effecten die tussen verschillende lagen interageren worden waargenomen in zes verschillende topografieën (cursief gedrukt) van het gehele stroomgebied van de rivier.

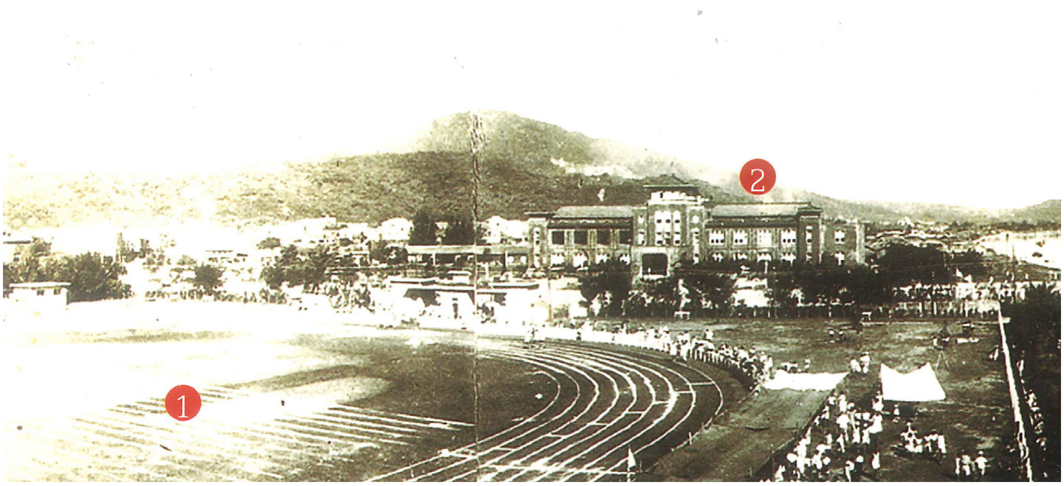
A De dijken langs de hoofdstroom in de vlaktes beschermen de deltasteden tegen overstromingen, waardoor snelle verstedelijking mogelijk wordt. Door bevolkingsgroei in de deltasteden stijgt de vraag naar voedsel, waardoor berggebieden intensiever worden gebruikt voor de landbouw.

B Door de dijken wordt de oorspronkelijke rivierbedding in het rivierbekken smaller, waardoor het waterniveau tijdens hevige buien stijgt. In deze situatie worden de afwateringskanalen van deltasteden geblokkeerd, waardoor er vaker overstromingen zijn in stedelijke gebieden.

C Door de dijken langs de hoofdstroom in de vlaktes is het gebied waar de rivier kan komen aanzienlijk gewijzigd en wordt het grondwater aan de voet van heuvels en bergen veel minder snel aangevuld. In kustgebieden zorgt dit voor ernstige bodemdalingen doordat de grond niet voldoende grondwater krijgt.

D Door de dijken en de bruggen over de rivier hopen sedimenten zich op in het rivierbekken. Wanneer een aanzienlijke hoeveelheid rivierzand bezinkt in de rivierbedding en niet naar de riviermond wordt getransporteerd, neemt de aanvoer van zand naar de kust af, met ernstige erosie van de kust als gevolg.

Verder werd voor dit onderzoek in 2012 een workshop georganiseerd: ‘Workshop on Water Environment Development in Kaohsiung’ (Workshop over de ontwikkeling van de wateromgeving in Kaohsiung). Het doel van deze vijfdaagse workshop in Kaohsiung was om de resultaten van hoofdstuk 3 en 4 verder te bestuderen en om te laten zien hoe een drielagenbenadering kan fungeren als platform voor samenwerking tussen meerdere disciplines. Bij deze workshop werd uitgegaan van het theoretische kader van de drielagenbenadering voor de bestudering van het gehele stroomgebied van de Kaoping en van de bekkens van de twee zijrivieren, de Meinong en de Love, die werden gekozen voor de lokale schaal. De workshop was een uitstekend voorbeeld van de manier waarop de drielagenbenadering in de praktijk kan worden gebruikt voor multidisciplinair onderzoek en het maken van een geïntegreerd plan. Daarnaast zijn het resultaat en de methode van de workshop veralgemeniseerd tot een theoretisch kader dat ook in andere gevallen kan worden toegepast.



The Love River in 1950: (1) The City Stadium; (2) The City Municipality. Source from LGR 2005 provided by Yu-Ru Lin (林育如)

1 Problem statement: The Problems of Delta Cities

Deltas, which traditionally had important roles in providing people with fresh water, fertile soil and vast plains in the past, play even more crucial roles today. With the arrival of globalisation, deltas now occupy crucial places for shipping networks throughout the world. As a result, numerous people are moving into deltas to pursue more opportunities. Currently, deltas are the areas with the most rapid urbanisation (World Bank, 2009). However, man-made development deeply affects the natural work of a delta, and this has caused some problems in water management. Furthermore, the effects of climate change: rising sea levels, extreme precipitation, etc., have also gradually emerged as serious threats to deltas. How a highly urbanised delta, with its limited flexibility, can develop in harmony with nature has become an urgent issue.

Figure 1

The flooding of the Kaoping River Delta in 2008, Source: Net Ease News, Retrieved 1st Oct. 2014 from http://news.163.com/photonew/00AN0001/11003_02.html

§ 1.1 Prologue: Threats to deltas

§ 1.1.1 The increasing frequency of extreme precipitation

According to statistics compiled by The OFDA/CRED International Disaster Database (EM-DAT) for world disasters from 1900 through 2009, the frequency of disasters, and their effects on population and resulting economic losses, have risen dramatically since 1970. Hydro-meteorological damages (including floods, tropical cyclones and droughts) have been the major factor to cause such disaster. Particularly in recent years, the occurrence of extreme catastrophes has increased significantly. Examples include Hurricane Katrina hitting New Orleans in 2005, the 5-year drought in Australia in 2007, Typhoon Nargis ripping through Myanmar in 2008, Taiwan' s Typhoon Morakot in 2009, Pakistan's floods in 2010, Australia's centennial floods in 2011, and three months of devastating rain in Thailand. These disasters have all exceeded past experience both in terms of their scale and type. The worsening disasters may be attributed to climate change, which has led to an increase in the frequency of climatic extremes. Furthermore, rapid urbanisation and economic development also play a role in causing natural disasters.

§ 1.1.2 The high disaster risk areas: highly urbanized areas and the magnitude of natural disasters

In estuarine deltas in the tropics, extreme disasters mainly result from heavy rains triggered by tropical cyclones (TC). In addition, according to the "2009 Global Assessment Report on Disaster Reduction, Risk and Poverty in a Changing Climate" (UNISDR 2009) released by the United Nations, more people are becoming exposed to high disaster risks. For middle and low income countries, due to such rapid economic development, the increase in their vulnerability to disasters is much larger than the enhancement of their ability to prevent disasters. This situation has brought about an even higher disaster risk levels. As estimated by the World Bank in 2010, coastal areas and estuarine deltas are places where populations are more likely to be exposed to high-risk disasters (Fig. 2).

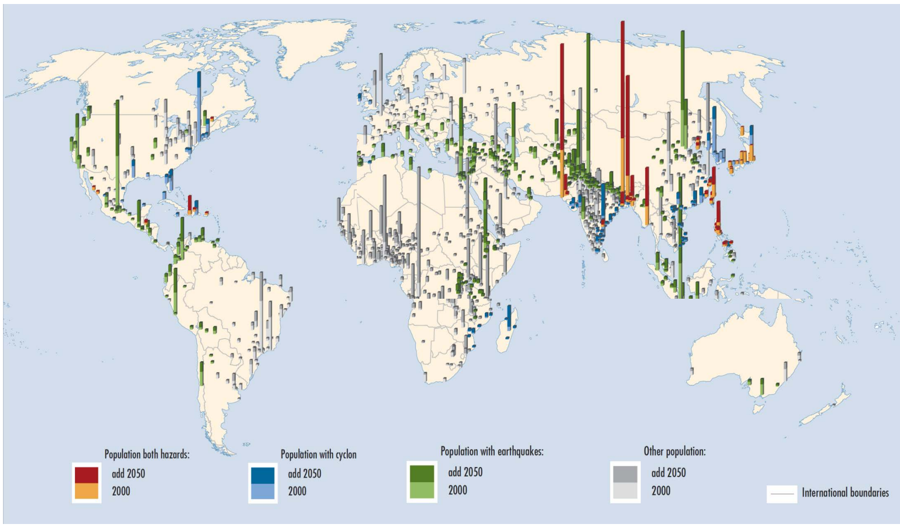


Figure 2
The estimated distribution of disastrous population in 2050 (Source: World Bank 2010)

§ 1.1.3 The new challenges of water knowledge

When the situation of dense urbanisation combines with the occurrence of extreme climate, it becomes more difficult to create a good and safe water environment. The flood patterns resulting from extreme rainfall are different from traditional patterns which could be managed by building dikes as a defence system. Because the congested rainwater resulting from changed runoff paths by human intervention might be one of the main reasons leading to a freshet which could not be controlled by simply building dikes, the major concern is how to increase the spatial capacity of water retention or drainage. Both of these require more space. The field of flood governance thus faces new challenges while man-made landscape has occupied most of the proper lands. The emerging question is how to diachronically analyse the interaction between cities and the environment from the perspective of human geography, and therefore expand the knowledge of relationships between people's daily lives and water space.

§ 1.1.4 From the perspective of a whole river basin: The Kaoping River basin in Taiwan as show case

Dense urbanisation and climate change have gradually emerged as two factors of causation in the case of serious floods. These factors are making flood governance in deltas more complicated. The traditional paradigm to deal with floods obviously could not solve these new challenges. Numerous inundations occurred inside dikes, due to the congestion caused by excess storm water. This kind of flooding which mainly resulted from human intervention in natural landscape has occurred on several occasions in different reaches of the same river. An overview exploration from the perspective of an entire river basin is necessary if we want to find their respective characteristics and see how they are related to the river and to each other. This study examines the Kaoping River basin (most is located in Kaohsiung City) as an example which has a very dense population around 20,000 people/ per km2 in the downtown area and where extreme rainfall, more than 500 mm/ per day, so often happens. These conditions will be a good showcase to analyse how to prevent a highly urbanised delta from flooding during times of extreme precipitation form the perspective of a whole river basin.

§ 1.1.5 The analysis of three map-layers

The most important basis of knowledge for this new trend is a more complete understanding of the transformation and interrelation between natural and artificial space. We can refer to the Dutch experience of flood governance, which has changed from the idea of water defence, i.e. the Delta Works, to the idea of Working Together With Water or Room for the River.

The analytical framework of a three map layer, including the layers of natural landscape, infrastructure, and occupation, will illustrate the process by which the natural water context has been interfered with or changed by human geography. This study will redefine the new role of the human landscape within the historical context of floods in the Kaoping Delta. By compiling knowledge of the history and human geography, we shall rethink the relationship between the city and nature, and propose new possibilities for them to exist side by side in the Kaoping River catchment. The results of this research will provide crucial knowledge about how to deal with the development of delta urbanism in the face of the impact of extreme rainfall, and will contribute to a more integrated knowledge base for flood governance in the future.

§ 1.2 Scope

The Kaoping River comprises the Laonong Creek (荖濃溪), the Ailiao Creek (隘寮溪) and the Qishan Creek (旗山溪) from its upper reaches and flows through two administrative zones, Kaohsiung City (高雄市) and Pingtong County (屏東縣). The main urbanised areas of the catchment are concentrated in the downtown areas of these two regions and in some major districts, e.g. Meinong (美濃) and Qishang (旗山). The population of downtown Kaohsiung is more than one and half million, and it is distributed around the Kaohsiung Port, Zuoing Navy Harbour (左營海軍軍港), and along railroads and highways (LGR, 2011). Downtown Pingtong, with a population of 200,000, has developed along major transportation networks (Fig. 3). Since the construction of the Kaohsiung Port during the period of Japanese colonisation, it has become an important agricultural distribution centre in the Kaoping Delta.

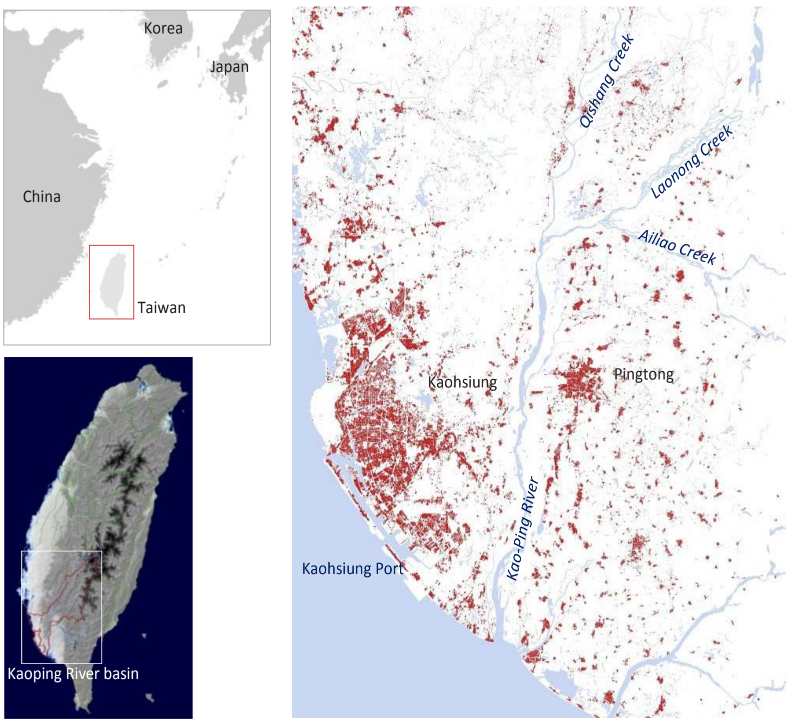


Figure 3
The location of the Kaoping River Delta and its delta cities (Map by author)

§ 1.2.1 Extreme characteristics

The average rainfall of The Kaoping River catchment is 3,046 mm per year, while the average annual runoff is 8,455 million cubic meters per year. The water mainly comes from summer rainfalls, especially the torrential rains brought by an average of 3-4 typhoons or tropical low pressures hitting the area annually. The average annual precipitation is approximately 2,502 mm, of which around 69% of the rainfall is concentrated between May and October. Furthermore, due to uneven distributions in the timing and location of the rainfall, its intensity varies greatly. There is an extremely marked difference in the river flow between the peak summer flood season and the dry winter season (TGR, 2011a). The river's annual average sediment-transport volume is 35.61 million tons, representing 10,934 tons of sediment-transport per square km of the drainage area, and it ranks 11th in the world (Table 1). As the river is short and its upstream riverbed is narrow and steep, large amounts of sand and gravel are carried by the torrential rains through the rushing currents to the downstream plain, forming a wide and shallow riverbed. As a result, severe overflows and flood disasters often occur (TGR, 2008).

	Rhine	Kao-Ping
Length	1,320 km	171 km
Depth-average	Arnhem: 8 m	
Discharge-average	2000(summer)m3/s	250 m3/s
Discharge-extreme	12,000m3/s	29,100 m3/s
Sediment transport	0.4 million ton/yr	35.6 million ton/yr
Sediment-average	0.0063 kg/m3	4.5 kg/m3

Table 1
Quantitative comparison of Rhine (Europe) and Kao-Ping River. (Sources: Meyer and Nijhuis 2013; TGR, 2008)

§ 1.2.2 New challenges under the impacts of climate change

Taiwan is located in the west of the Pacific Ocean where typhoons and tropical cyclones (TC) very frequently occur (Fig. 4). Although the abundant rainfall that typhoons bring in the summer is an important source of fresh water in Taiwan, typhoons often result in severe flooding. Dike systems were traditionally the main way of dealing with flooding. This method was obviously designed to keep the storm water outside the dike. A secondary effect is that a significant amount of land could also be reclaimed from the dike's narrowing of riverbed width.

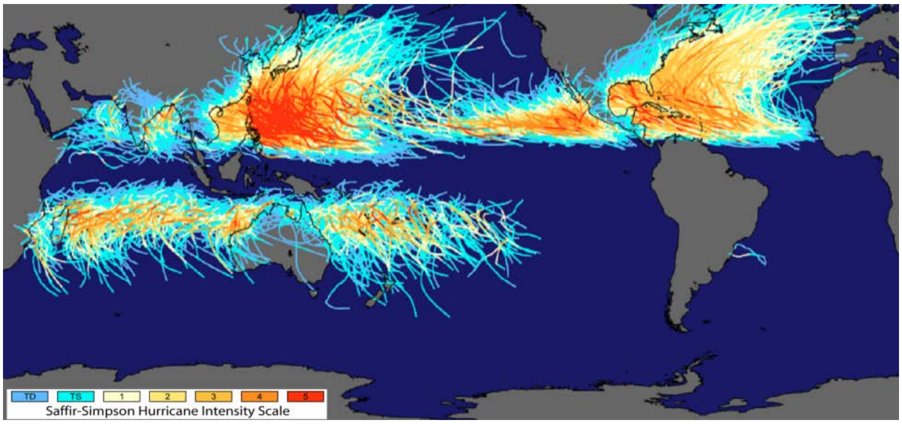


Figure 4
The tracks and intensity of all tropical storms in the world before 2006. (Source: NASA- Earth Observatory http://www.physicalgeography.net)

However, unpredictable extreme precipitation due to climate change has gradually become another significant issue. Extreme precipitation implies that storm water will not only come from outside, but also from inside the dike. In addition, the extreme rainfall resulting from a typhoon usually accompanies an astronomical tide, which frequently paralyses the drainage of low-lying land in an estuary delta. In the case of the Kaoping River basin, although the major dike system along the main stream is nearly complete, the areas inside the dike system have still been seriously inundated many times by extreme precipitation, and over the last decade, the condition has gradually been worsening year by year.

Ever since the 1990's, Taiwan has been forced to pay more attention to the effects of global climate change: sea levels rising, the increased frequency of storms and extreme precipitation. Highly urbanised estuarine deltas in Taiwan are especially vulnerable in this changing climate. In 2010, when Typhoon Fanapi caused severe flooding in Kaohsiung, more than 600mm of rainfall accumulated in just six hours. This type of extreme rainfall is becoming a common event in Taiwan. The accumulated rainfall of Typhoon Morokot amounted to almost 3,000 mm over the course of four days. In 2008, Typhoon Jangmi accumulated more than 1,000 mm in one and a half days; in 2007, Typhoon Krosa accumulated close to 1,000 mm, in one day. Typhoon Haitang (2005) accounted for more than 2,300 mm of rainfall; Typhoon Mindulle (2004), over 2,000 mm. In 2001, Typhoons Nari and Toraji each lasted for only a day, but accounted for about 500 mm of the rainfall apiece (425 mm and 574 mm, respectively). Taiwan has, in fact, seen nine typhoons in the past decade with a 100 or 200-year return period – that is to say, the rainfall of each of those typhoons would be expected to occur only once every 100 or 200 years and yet Taiwan has seen this almost once a year for the past decade. This data clearly suggests that Taiwan's climate is changing to the point where extreme precipitation is becoming a more normal phenomenon (TGR, 2011b) (Fig. 5).

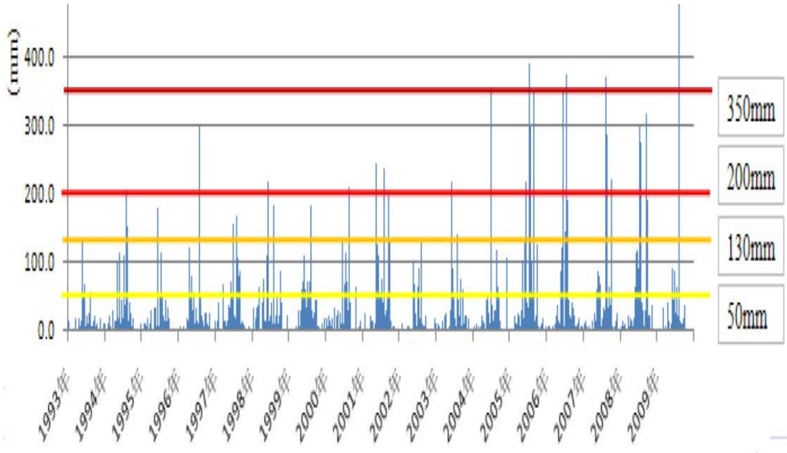


Figure 5
The magnitude of daily precipitation of the Kaoping River catchment from 1993 to 2009. (Source: TGR, 2011b)

The average annual rainfall in Taiwan is about 2,500 mm. The average monthly rainfall is between 110 mm and 340 mm, with the main rainy season lasting from June to September, and the main dry season extending from October to March. Since this mostly accompanies typhoons (tropical cyclones, or TCs), the heavy rainfall usually occurs over short periods. In general, if the average monthly rainfall is extremely high – greater than 380 mm – it is highly likely that flooding will have occurred during that month. Conversely, if the average monthly rainfall is extremely low – less than 100 mm – for several consecutive months, there is strong evidence that a drought will be occurring (Wan 2009). Applying this standard to the average monthly rainfall in the Kaoping River catchment reveals that the fluctuation of average monthly rainfall levels in the catchment during the period from 1993 to 2009 has become much more extreme than in the rest of the country. The extreme rainfalls in the Kaoping River catchment mainly occur between June and August, and the catchment sees much more rainfall in those months than the rest of the island sees. Moreover, the rainfall in the Kaoping River catchment during the October-March dry season is also far below the average for the rest of the island (TGR, 2011b) (Fig. 6). Thus, while climate change causes more extreme rainfall conditions all across Taiwan, fluctuations in precipitation for the Kaoping River catchment are especially extreme.

It remains extremely difficult to predict the distribution of extreme rainfall events such as tropical cyclones (TCs), largely because current technology and meteorological modeling is unable to accurately predict the movements of storm clouds. The distribution of rainfall can play a significant role in mitigating or exacerbating the effects of a TC on the human population in a catchment area. For example, Typhoon Morocot, which had an accumulated rainfall of 3000 mm, caused disastrous mudslides in the mid-and-upper reaches of the Kaoping River, but relatively few incidents in the lower reaches, which include the city of Kaohsiung. Typhoon Fanapi, on the other hand, it produced only 600 mm of rain, but caused severe flooding in Kaohsiung City. This reminds us that not every river basin is internally homogenous, but rather a complex system that incorporates elements of geographical and geological distinctiveness, as well as a continuous flow of water. Both of these characteristics influence our integrated and holistic strategies for watershed management in the Kaoping River Basin.

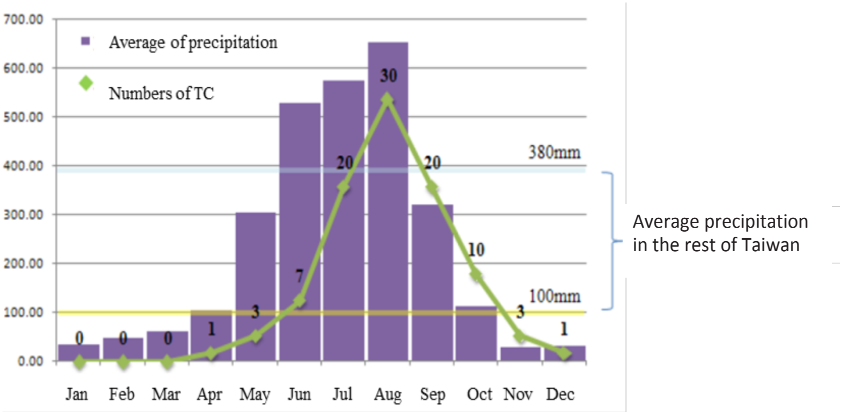


Figure 6
The monthly average precipitation of the Kaoping River catchment from 1993 to 2009. (Source: TGR, 2011b)

§ 1.2.3 A turning point in making an integrated policy for water management

In general, a river basin begins in mountainous areas in the upper reaches, flows into a flood plain in the midstream, and ends in an alluvial estuary in the lower reaches, which usually belongs to many different authorities or even countries. It is very difficult to create an integrated policy with a vision of a whole river basin. The Kaoping River basin is small, but almost fully contained within one administrative zone. Moreover, the original authority, Kaohsiung County, merged into Kaohsiung City, the highest level of local government, in 2010. A new vision for the new territory is needed at present. Thus this case is an appropriate example to illustrate how to deal with the effects of extreme rainfall from the point of view of the whole river basin (Fig. 7).

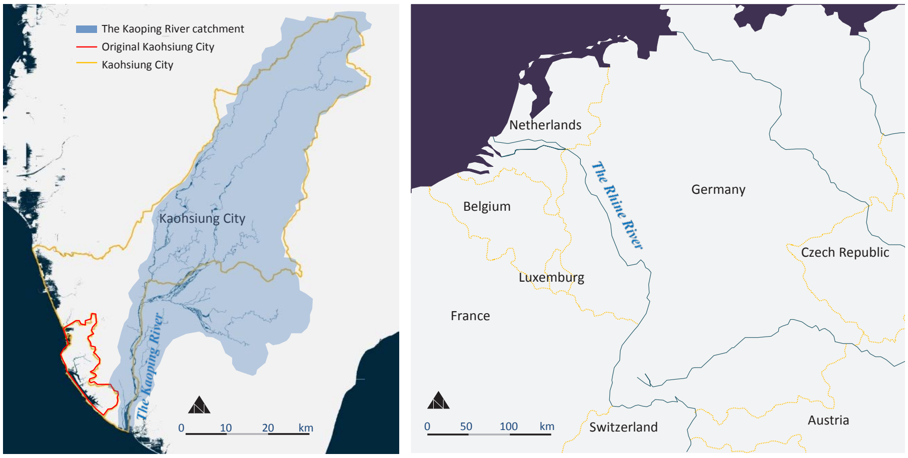


Figure 7
Comparing the situation of the Rhine River which flows through many countries, most of the Kaoping River catchment is under the authority of Kaohsiung City. (Source: TGR 2008; Google Map)

§ 1.2.4 A new vision for a post-industrial port metropolitan

Since the 1960s and '70s, many harbours in the world have been regenerating their port areas in order to adapt themselves to the new logistical trends of containerisation and post-industrialisation. For instance, one may think of London, New York, Boston, Baltimore, and Rotterdam. Many piers and factories around old harbour areas have been relocated. Therefore, vast obsolete harbour areas close to the city centres have become available, thus offering important sites and opportunities for the renewal of these port cities (Tilman 1994). Furthermore, these areas can also provide a good chance to adjust these highly urbanised areas to new challenges, both in terms of economic development and climate change, in the future.

Waterfront renovations always attract massive investment and many stakeholders. Thus, many studies are currently focusing on this topic, including changing planning culture in metropolitan and planning as a strategic approach (Olds 2001; Salet et al. eds. 2003; Herrschel and Newman 2002; Newman and Thornley 2005; Healey 2007; Majoor 2008); to the multifunctional development of urban land uses (Majoor 2006); emerging urban patterns of poly-nuclear geographic structure (Kloosterman and Musterd 2001); financial management (Flyvbjerg et al. 2003); network of intercity and global economic hierarchies (Sassen 1991; Castells 1996; Newman and Thornley 2005) and even from a critical perspective of the gentrification process (Harvey 1973).

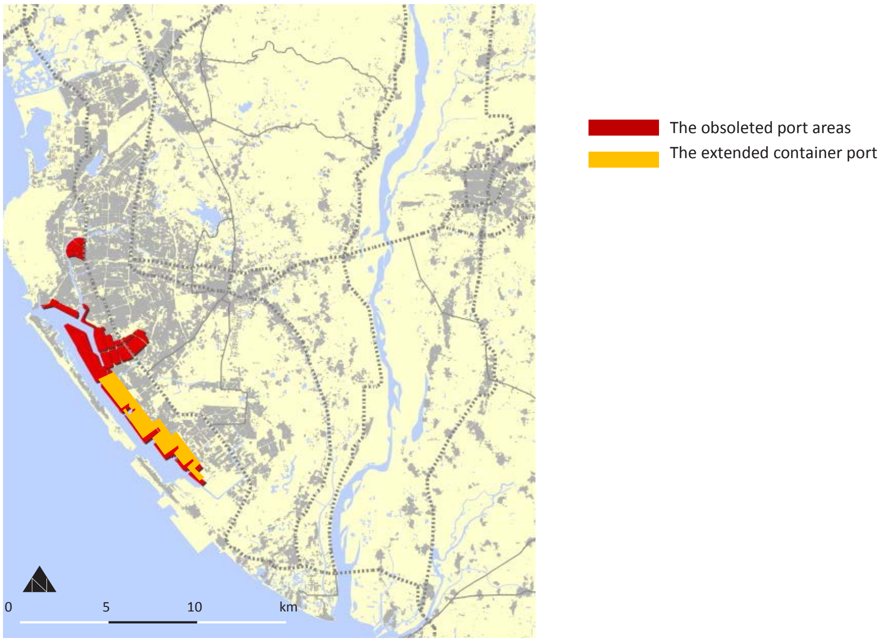


Figure 8
The areas of waterfront renovation (including potential industrial areas) (map by author)

However, there have been few studies that have focused on analyses of relationship between artificial port-cities and natural deltas and the possibility to adjust port-cities to the challenges of climate change through these mega-renewal projects. Even in the Netherlands, the most famous country in the area of water governance in the world, although several new policies have been established for delta development with the main approach of working together with water, such as the 'Ruimte voor de Rivier' (Room for the Rivers) of 'Planologische Kernbeslissing' (Fundamental Spatial Planning Decision), etc. (Deltacommissie 2008, http://www.deltacommissie.com/en/advies), it is doubtful whether these plans can also be adjusted to a highly and densely urbanised region, such as Rotterdam, while they have been developed mainly in rural areas. In large cities and the densely urbanised parts of the delta, these new approaches meet their limits (Meyer 2009).

A similar development seen in post-industrial port cities has occurred in the Kaohsiung Port areas. Vast obsolete harbour areas close to the downtown regions become available, because the main logistic function of the harbor has shifted from the north to the south of port due to containerization (Fig. 8). This case also wants to explore how an urban renewal strategy can be created from the perspective of water management in a post-industrial port metropolis.

§ 1.3 Research Questions

Based on the aforementioned problem statement, there are two main issues that emerge: highly dense delta urbanisation and the effects of climate change. The simultaneity of these two phenomena will expose delta cities to high disaster risks. Most literature emphasises that the massively increasing magnitude of storm rainfall extends beyond the original protection standards of hydrologic facilities, which pose high flooding risks to the rapid growth of population in delta cities. However, what they ignore is that the rapid development of the human landscape has a crucial influence on flooding. This research hypothesises that:

the floods following extreme precipitation result not only from the huge magnitude of rainfall but also from the huge intervention of human landscape, e.g. urban patterns, transportation, and even hydrologic instruments, on natural water system.

In order to prove this hypothesis, the main research question is derived from the perspective of a whole river basin as follows:

How does the role of the human landscape intervene in the natural mechanism of the water system to result in delta inundation under the impact of climate change?

This central question comprises five major parts, including:

1. **What theories would help to understand the interrelationship between water systems and spatial patterns? What is the present paradigm to conduct floods?**
2. **What is the transformation of the human landscape?**
3. **What is the transformation of natural water systems?**
4. **What is the inter-relationship between human landscapes and water systems?**
5. **How do the impacts of climate change, mainly focusing on extreme rainfall, influence the whole delta water system?**

Question (A) is the first step in constructing a proper analysis framework which could organize multi-disciplinary knowledge, including urbanism, civil engineering and hydrology; Question (B) ~ (D) represent the major content of this research which is designed to illustrate the formal transformation of the human and natural delta landscape; Question (E) attempts to explore the reasons for delta inundation based on the aforementioned knowledge base in order to prove the research hypothesis.

Finally, this research organizes a workshop to further test the practical application of this study. The concept of Research by Design is introduced to this workshop to build up a working framework for multidisciplinary collaboration. The previous conclusion will also be tested and modified by the results of this workshop as a final result of this research.

§ 1.4 Analysis Framework

§ 1.4.1 Theoretical background

A great challenge in launching this study lies in finding a substantial theoretical background to deal with multi-disciplinary issues, especially between hydrologic engineering, landscape architecture and urbanism. Basically, the main issues relating to water are different in these realms. This research will adopt the Three Layer Model as a major part of its theoretical background. This concept has been developed in the Netherlands in recent decades. Therefore, a clear examination of the Dutch experience is necessary.

The development of urban morphology in the Netherlands

Most of the Netherlands' territory is located on the Rhine River Delta which, according to Bradshaw and Weaver's delta classification (Bradshaw and Weaver 1995), is a wave-dominated delta. Sedimentation deposited around the estuary of a wave-dominated delta will be delivered and scattered along the coast by strong sea-waves. This constant process is what has formed the special landscape of the Dutch territory, i.e. sand dunes, marshes and flood plains, with a very soft and fully aquiferous substratum of peat on which the Dutch developed their traditional polder landscape. It was this unique polder landscape that inspired the Dutch to develop their spatial knowledge of urban morphology.

The research of urban morphology has been systematically developed at the Delft University of Technology, TU Delft in the Netherlands, since the 1970s in order to response the fierce environmental criticism on the Delta Works, for instance, Palmboom's research on the differences in dynamics between urbanized landscape layers, Steenbergen and Reh's studies on landscape compositions, and Tummer's work involving the designing of a new spatial relationship between city and landscape (Meyer 2005). However, this analytical approach faced a new challenge in 1993 and 1995 when there were two near-floods, which led to the evacuation of some 2,000,000 residents, in the Netherlands. Although some immediate emergency plans were proposed to reinforce the flood defenses, they met with some financing and technological problems (van de Ven ed. 2004). This event led the Dutch to develop a new policy approach known as Room for the River in order to overcome the limits of traditional hydrologic engineering (Warner and van Buuren 2011).

Dutch three layer model

The Room for the River concept is not just related to river space. In fact, it includes at least four major aspects. (1) Climate robustness and adaptiveness; (2) The maintaining of landscape, culture and history; (3) To restoring and strengthening of ecological values; (4) More space for urban development (Edelenbos et al. 2013). A crucial step in achieving these diverse aims is that of how to construct a comprehensive analysis framework. Therefore, based on McHarg's systematic layer analysis in his work 'Design with Nature', a triplex model which consists of three main layers including Occupation, Networks and Substratum was developed in the Netherlands. Through this framework, a complex polder and delta landscape could be further clearly illustrated.

However, most of the related research uses this layer concept without paying further attention to explaining the interrelationship between the different layers (Meyer and Nijhuis 2013). Based on the context of the Dutch layer approach, this research will set out to construct a 3-layer framework of deductive reasoning to fill this gap.

§ 1.4.2 Methodology

Based on the aforementioned theoretic background, this study proposes the main phases of the working process according to the following steps (Fig. 9):

- **Literature sources**
  This study mainly draws from three domains of knowledge: natural landscape, infrastructure, and spatial patterns over the past 100 years. The data is derived from three main sources. First, geographic information from 100 to 50 years ago is collected from the GIS system of the Taiwan Centennial Historical Maps created by Taiwan Academia Sinica, including The Taiwan District Map made by Japanese colonial authorities between 1898 and 1944. In addition, this method also draws on useful information from The Map for Economic Development made by the Council for Economic Planning and Development in 1985, 1992, 1999, and 2003. Secondly, data on water contexts over the past 50 years is collected from The Hydrological Year Book of Taiwan compiled by the Taiwan Water Resources Agency, and the planning reports for each river. Third, information on infrastructure and spatial patterns is obtained from government reports, plans, records, and local histories.

- Construction of the geographical layers system
  The collected geographical information from these three domains is digitally integrated into a basic map. Some maps, for instance The Taiwan District Map and The Map for Economic Development, were not digital files, so they are redrawn as digital data for the purposes of this study.

- A chronological portrait of the respective layers
  All of the information is arranged chronologically. Because the process of rapid urbanisation in Taiwan was triggered by Japanese colonisation, rapidly increased after World War II, and reached a peak in the 1980s, this study uses the Taiwan District Map of 1898 as its starting point. It represents the original conditions of the natural landscape before the huge and rapid changes that human intervention made on the landscape. The transformation of the respective layers in this phase is then illustrated.

- The analysis of deductive causality between layers
  This study further identifies the current problems at each layer and then lists the general factors that may cause these problems. These possible factors in the different layers are connected to form a complete mechanism via an analysis of deductive causality. This analysis is mainly based on qualitative analyses, due to the lack of historical statistics about the environment. Some quantitative analyses are carried out when these statistics are available.

- The comprehensive interpretation of all deductive causal relations
  This study will identify the crucial factors and how they affect other factors. Finally, the interrelationship of the natural and human landscapes regarding the transformation of the deltas is illustrated.

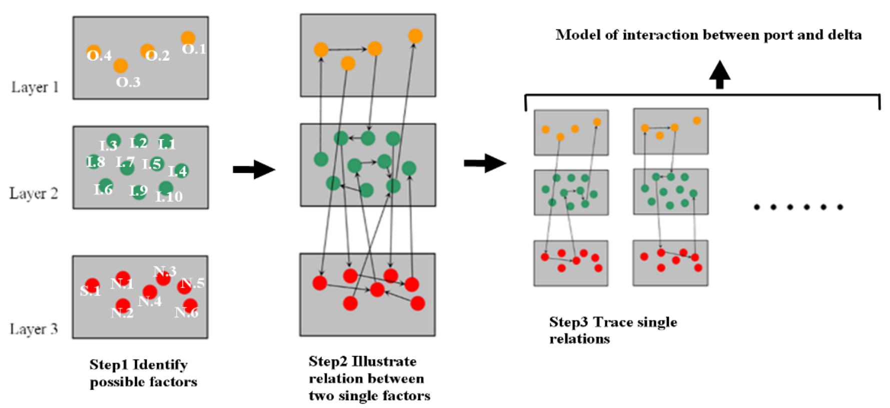
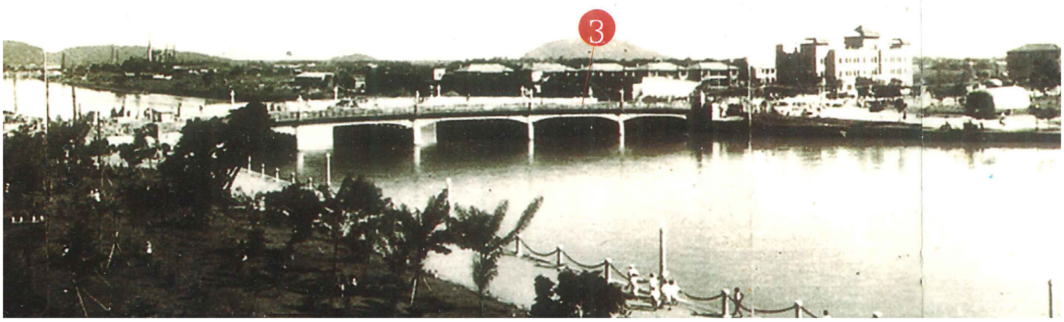


Figure 9
The process of a deductive 3-layer approach (Graphic by author)



The Love River in 1950: (3) The Chung Chen Bridge (中正橋). Source from LGR 2005 provided by Yu-Ru Lin (林育如)

2 Theoritical background: Concerning the Layer Approach

This study analyses how the human landscape has affected the transformation of natural water contexts in the Kaoping River Delta. The relationship between the human landscape and natural landscape can be examined via a 3-Layer analytical framework. This layer-based approach views landscapes as a whole system in which each element interacts with the others. The initial concept of layer analysis dates back to the 19th century in Germany. Ferdinand von Richthofen (1833-1905) classified the complex characteristics of a given site into three main domains. It was in the late 19th century when the concept of layers was introduced into Landscape at Pennsylvania State University. The overlay technique was adopted as a systematic method to compile and map information in their planning and design. McHarg refined the aforementioned approaches and aimed to provide a theoretical basis for overlaying information. His book Design with Nature (1969), focused on both natural and artificial attributes in a given area and photographing them as individual transparent maps. He then superimposed the maps over each other to construct the necessary suitability maps for each land use. This concept became an influential analytical structure of planning in the Netherlands beginning in the 1990s, when it was introduced into the Netherlands as a Framework Model (Casco Concept), and then was adopted on a national level to develop into a more comprehensive triplex-structure.

This study attempts to adapt this triplex structure to the analysis of water context in the Kaoping River Delta. The study then develops a 3-layer framework, which consists of a natural landscape layer, an infrastructure layer and an occupation layer. This framework draws on knowledge from three different domains: theories of form and urban form, theories of dealing with storm water, and the layer conceptual approach. The related literature is further examined in this chapter.

§ 2.1 Theories of Form and Urban Form

§ 2.1.1 The Development of Morphology

The word 'Morphology' consists of two Greek words, μορφή (morphé) and λόγος (logos). The former means 'form' and the latter means 'study'. Research from a morphological perspective has a long history in many different disciplines. The systematic works of morphology date back to the Age of Discovery in the early 15th century when huge numbers of new species of animals and plants were collected from abroad and returned to Europe. How to study these varied and fantastic species became a new field of biology. There are three main applications of morphology to study these species, including the comparative, functional, and experimental perspectives. Three main questions arose: (1) how can we know a complex nature by form? (2) What are the functions of these forms? (3) What is the mechanism of genesis and transformation? [1]Systema Naturae by Carl Linnaeus in 1737 and On the Origin of Species by Charles Darwin in 1845 are two classical studies from that time.

Carl Linnaeus (1707-1778) was a representative naturalist who tried to resolve the first issue. In his book Systema Naturae, Linnaeus systematically classified 4,400 species of animals and 7,700 species of plants by a method of taxonomy that became known as 'Linnaean taxonomy'. He constructed a hierarchy system, including kingdom, class, order, genus and species, to classify the enormous numbers of species that he recorded (Fig. 10). The concept of scientific classification has influenced many other disciplines to do similar morphologic research. [2]

Charles Robert Darwin (1809-1882) adopted a morphological analysis to construct the core of his famous theory of evolution by "Natural Selection." In his book On the Origin of Species, he illustrated how the different beaks of the finches are suited to each preferred food by studying both living species and fossils he collected during his voyage (Fig. 11).

1 http://en.wikipedia.org/wiki/Morphology_(biology), access 2013/02/25

2 http://en.wikipedia.org/wiki/Carl_Linnaeus#Systema_Naturae, access 2013/02/25

He demonstrated that the process of fitness is an important part to natural selection, which induces a branching pattern of evolution. [3] [3]This concept of evolution has greatly influenced subsequent studies about the transformation of forms in many disciplines (Fig. 11).

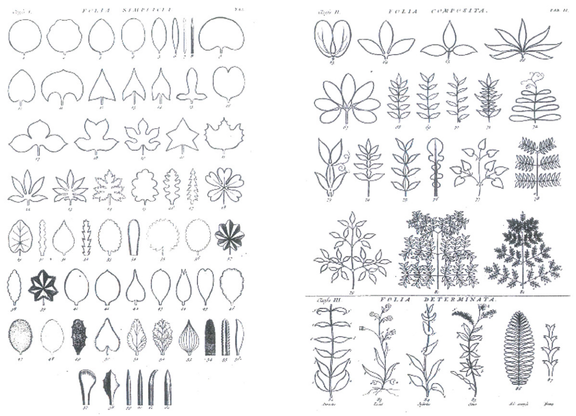


Figure 10
Classification of leafs (Source: Linnaeus 1737, http://en.wikipedia.org/wiki/Carl_Linnaeus)

Figure 11
Left: Comparative study of the beaks of finches, (Source: Darwin, C. 1845)
Right: Comparative study of the skeleton of the arm (Source: Leche 1909)

3 http://en.wikipedia.org/wiki/Charles_Darwin, access 2013/02/25

The approach of biological morphology has significantly affected many disciplines, including architecture. The concept of evolution has been adopted by architecture to study spatial forms since the 19th century. It was thought that research on biological morphology, a systematic classification technique of the plants and animals in the Enlightenment, could be a knowledge base for the development of spatial morphology (Moudon 2004). The historical transformation of space could be further classified in order to know how to fill up the gap between existing and new building types (Collins 1965). Some architectural theorists, for instance John Ruskin, Marc-Antoine (Abbe) Laugier, and Viollet-le-Duc, even called themselves Darwinian. They argued that the process of how space responds to social practice is quite similar to the process of natural evolution. Furthermore, they attempted to develop some architectural methods of drawings and classifications to distinguish different spatial forms in order to interpret the evolution of modern spatial form (Neuman 2013).

§ 2.1.2 The Development of Urban Morphology

Definition

It is not a precise definition to say that urban morphology is the study of urban forms, because there are two major approaches to study urban forms: formal and relational. However, the boundary between these two different realms is confused since the relational study of spatial forms, Network Cities, Flowing Space, or Telecommunication Space etc., seems prevalent in the academic literature. Moudon uses the term 'Urban Typomorphology' as a more precise definition, although Urban Morphology is still a common term to refer to research that uses this kind of approach.

"Typomorphological studies reveal the physical and spatial structure or cities. They are typological and morphological because they describe urban form (morphology) based on detailed classifications of buildings and open spaces by type (typology). Typomorphology is the study of urban form derived from studies of typical spaces and structure. " (Moudon 2004)

The analytical approach of urban morphology is quite similar to the approach of biological morphology, namely to explore the relationship, such as order, mechanism or evolution etc., between different spatial forms (species) by means of a graphical-comparison framework. The main analytical elements of urban morphology usually include the buildings and their surrounding environments, although they might be at different scales.

Moudon identified three main schools of urban typomorphology: Italian, British, and French. Among them, in Italy, Saverio Muratori (1910-1973) and his follower, Gianfranco Caniggia (1933-1987), analyzed the changing process of buildings and their related open spaces in traditional Italian towns by an extensive classification in order to realize how they mutate over time. In England, M.R.G. Conzen and his principal followers, the Urban Morphology Research Group at University of Birmingham, studied town plans, and considered streets, plots, and buildings as three major elements, in order to identify types of urban fabric. In France, Quatremere de Quincy, Abbe Laugier, and Durand etc. of the Versailes School explored how physical space transformed to respond to social change by establishing a comparison framework of typo-morphology (Moudon 1997). In fact, these three, what Moudon labeled "schools," are very similar in topic, analytical framework and methodology. They are more like one school in three different locations rather than three schools. However, some different and valuable points of view emerged in these three separate places.

Except the aforementioned three schools, what Moudon ignored is the development of urban morphology in the Netherlands. Based on the unique spatial development for dealing with the unique lowland-landscape, there are numerous studies dedicated to this subject, for instance the journal Ontwerp, Onderzoek, Onderwijs (Design, Research, Education), a series of lecture noted by Rein Geurtsen with the title as De Stad – Object van bewerking (the city – object of treatment) in the 1980s, and the studies contributed by Palmboom, Steenbergen, Reh and Tummers etc. (Meyer 2005). All of this generated fruitful results of urban morphologic research.

Analytical framework

The main issue for these three schools was to find clues in response to the dramatic transformation of modern architecture. The main purpose of their studies was to understand how to fill the gap between modern architecture and historical urban forms (Menghini 2002; Cataldi 2003; Moudon 2004). Muratori uses 'crises' to describe such gaps, but used the term in a more positive way, viewing crises as a process through which the traditional forms transform themselves to become broader and more comprehensive, to adapt to new conditions (Muratori 1963; translation by Maretto 2012). In Muratori's studies, he draws an analogy between cities and organisms, arguing that it is necessary to study spatial traces and fabrics with their surrounding environment. Furthermore, he uses type, fabric, organism and operative history as four fundamental concepts to understand the balanced relationship between human beings and their spaces over time (Cataldi et al. 2002), in order to reveal the ongoing process of spatial transformation (Marzot 2002). Following this concept, Gianfranco Caniggia (1933-1987) developed his analytical method of "procedural typology" including substratum type, leading type, synchronic variant, diachronic transformation and typological yield. He argued that built objects comprise four different layers of scale: the building, the group of buildings, the city and the region, and together they construct the human environment (Fig. 12) (Cataldi 2003).

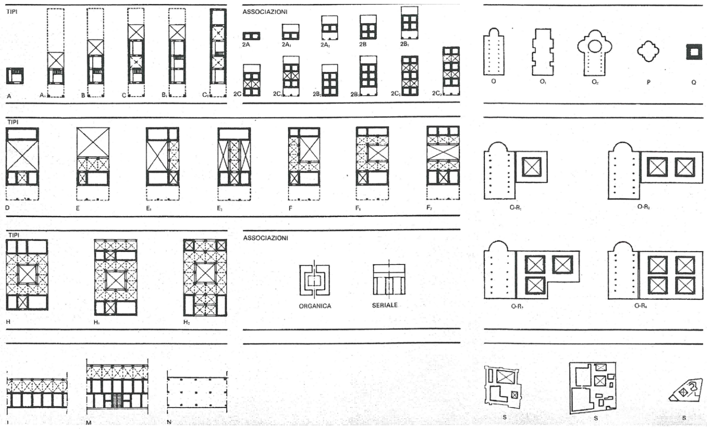


Figure 12
The diachronic mutation of house types in Florence, Rome, and Genoa (Source: Caniggia and Maffei 1979, cited by Moudon 2004)

M.R.G. Conzen developed his analytical method in his study with three main components, which present the plan in a two-dimensional layout: the building form and the pattern of land and building utilization. All these components were to be re-identified within their historical and cultural contexts in which they were transformed in their respective periods. For example, the ground plan has the longest transforming period among the periods of the building form and the pattern of land and building utilisation. These differences, with their distinctive periods, could be further historically stratified. This stratification varies from an urban fabric to another, and provides some clues to fill the gap between historic and modern architecture (Fig. 12) (Whitehand 2009).

The Versailles School in France sees modern systematic classification as dating from biological morphology and the classification of plants and animals. The Versailles School identified two main groups of building types: consecrated buildings and typical plans. J.N.L. Durand further succinctly illustrates the method behind his work. The first phase is to choose a proper scale. That might be the buildings or the parcels for an architectural design, or the city blocks or groups of blocks for an urban fabric analysis. The second step is classification of building types by the selected criteria, e.g. volume, function, and style. This procedure is mainly based on the analyses of comparisons and analogues. The third step is to refine the processes of comparisons and analogues as concepts, and finally, in the last phase, the relationship between different types could be identified (Fig. 13) (Moudon 2004).

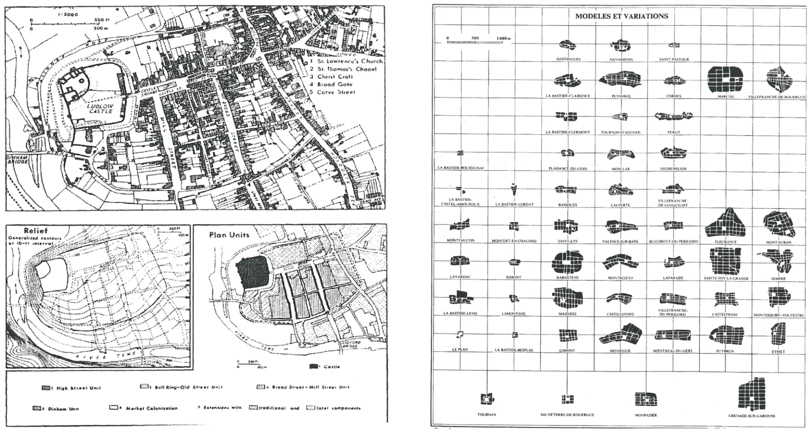


Figure 13
(Left) Conzen's plan units and the compositeness of the town plan; (Right) Type as group of specimens and exemplar (Source: Left - Dyos ed. 1968; Right –Panerai et al. 1980, cited by Moudon 2004)

In Holland, there is a strong tradition of typo-morphological research based on the age-old technology of reclamation and channel-system to deal with different soil layers. Inspired by both the Dutch tradition and the earlier works of urban morphology in France and Italy, Delft University of Technology (TU Delft) began to systematically develop their own knowledge of urban morphology. The previous approach had gradually shifted from built urban structure (stedelijk bouwwerk) to urbanised landscape (verstedelijkt landschap). Urban structures are treated as components of the urbanised landscape (Meyer 2005). Palmboom tried to analyse the dynamics between natural and urbanised landscape layers in order to understand the inevitable limits for future development. In his study "Rotterdam Verstedelijkt Landschap" (Rotterdam urbanised landscape) in 1987 (Fig. 14), he points out this dynamic has shaped Rotterdam as a city of separated islands which have their own internal logics. Furthermore, he argues urban designers should try to enhance the existing qualities rather than to fight against the fragmentation of the city. Tummers argues that every large urban region has its own typical city-land relationship. In his work "Het Land in de Stad" (the land in the city), he tried to explore this relation to lessen the contrast between the city and the open space by means of comparison analysis of several Dutch towns. In Reh and Steenbergen's study of polders in the Netherlands, they tried to explore the internal structure of polders. They claim that every single piece of lands is connected directly to the higher grid levels (Fig. 15) (van den Burg ed., 2004).

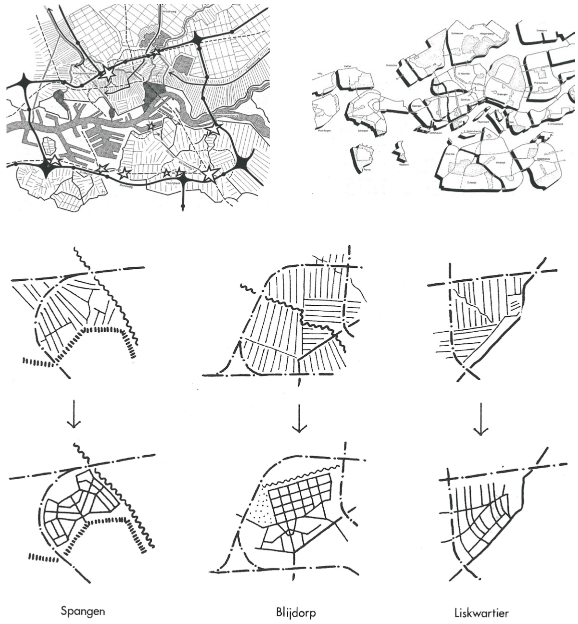


Figure 14

Human intervention on the landscape in Rotterdam case. Later human constructions, such as highway system, which do not respect the original landscape, have resulted in a city of separated islands. These islands all have their own internal logic and are poorly connected to a higher scale level. (Source: Palmboom 1987, cited from van de Burg ed. 2004)

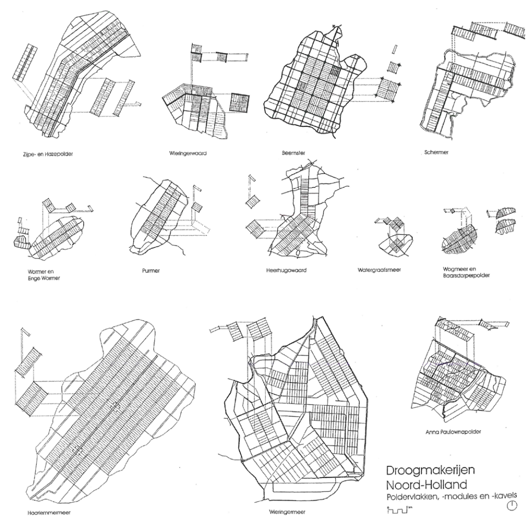


Figure 15

Polders and the basic units which are part of their grid (Source: Reh and Steenbergen 1999

Critiques and debates: a new approach of urban morphology

These traditional approaches to urban morphology seem to have been gradually losing their importance within the mainstream of spatial science. Moudon points out that a crucial reason is "most urban morphological research has focused on historic European cities (Moudon 1997)" which has weakened the capability of urban morphology to interpret contemporary urban forms worldwide. Based on the analysis of this study, we would say, on the contrary, what Moudon mentioned is a crucial result rather than a crucial reason. The crucial reason is that because the methodology which traditional morphology has adopted is not broad enough to give insight into the transformation of modern urban forms. It could merely be adopted to interpret those historic European cities. This study argues that the most important element of this broad vision is how to choose the proper scale of typological analysis.

Based on the work of biological morphology, most traditional urban morphological studies construct a nested hierarchy to classify complex spatial forms. For example, Conzen's three-tier hierarchy consists of town plan, building form and the pattern of land and building utilisation. The level of a town plan is the highest scale in this analytical framework. They presume that all of the possible factors that might affect the spatial transformation are limited to their framework and interact together internally. But what they ignore is that there is a higher-level factor that can affect the transformation of the entire system.

There is no doubt that the dramatic transformation of modern urban forms is dominated by tremendous change: cultural (religious, economic, political) and technological. The cultural factor indicates what a planner intends to do while the technological factor indicates what a planner can actually put into practice. The latter usually has a more dominant impact on the transformation of urban forms than the former. The great progress of building technology is the key element that supports the huge transformation of modern urban forms beyond the natural limits. Based on this context, we can find some new clues to help interpret, on a larger scale, the dramatic transformation of modern urban forms in an analytic framework. A good example of this is the city of Pingtung on the Kaoping River Delta in Taiwan. It was only possible to build a modern grid system in Pingtung City after the completion of the main dike system along the Kaoping River, to protect this area from flooding. This grid urban form was based on the functional demand of transportation (Fig. 16). It subsequently faced the new challenges of inundation resulting from the impact of global climate change. It reveals that a region higher than the level of the scale of a town, a level such as that of a delta scale, needs to be considered. This is a new approach compared to the traditional method of urban morphology. This approach developed at the end of the last century, into a 3-layer methodological approach, which will be discussed later.

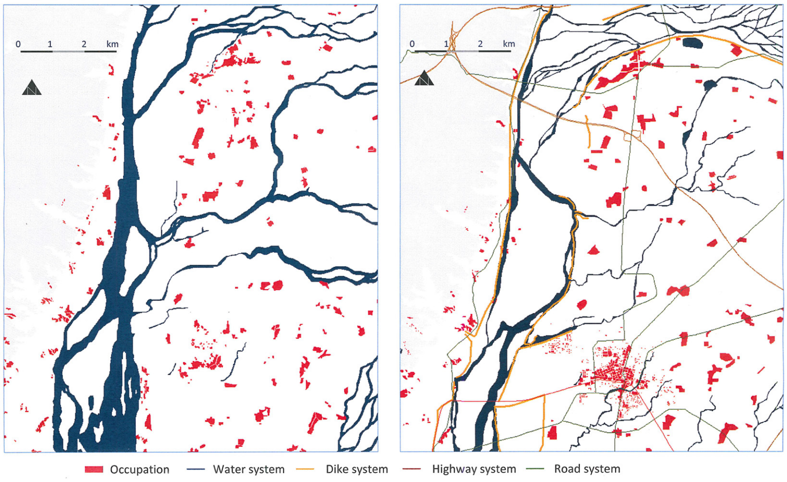


Figure 16
The transformation of Kaoping Delta: Urban forms could be develop by a relational concept after the completion of a dike along the river (Map by author)

§ 2.1.3 Theories of City Form – regarding Lynch's work 'Good City Form'

The study of urban forms has traditionally been an important area in the research of urban design theory. The theories of interpreting spatial forms are classified into three main approaches in Kevin Lynch's work Good City Form: planning theory, functional theory, and normative theory. Planning theory mainly focuses on the research on how public decisions about city development are or should be made. Institutions that are related to the development of urban forms are main concerns in this kind of theory, rather than urban form itself. It sometimes is named 'decision theory'. Functional theory attempts to explain the mechanism of urban forms from different perspectives, including historical, social, cultural, economic, and political. In this theory, the mechanism of urban forms, rather than urban form itself, is the main concern. Lynch concentrates his effort on clarifying normative theory, which deals with the relationship between human values and urban forms. This area also provides this study with some valuable points of reference.

Normative theories

Lynch divides the normative theory into three major groups (Lynch 1987): the cosmic theory, a machine model, and Organism. Of the three, the cosmic theory can be used to interpret some city forms which embody certain kinds of religious concepts that link human life and the order of the universe or the cosmos. The mechanism model explains some city forms which are formed in some specific functions or missions. Organism theory is usually used to describe some developments of city forms that are apparently autonomous with definite boundaries and size. It can recognise its form when its form has changed (Fig. 17).

Application

From these three normative theories, this study chooses to borrow the concept of a machine model to explain the spatial development of the urban grid system in the Kaoping River Delta. As described by Lynch, this model can explain a temporary settlement that was built for clear, limited, practical aims. Some good examples of these are the colonial cities where the typical goal is to allocate land and resources quickly and to provide well-distributed access to them. Following this concept, this study constructs a clearer image of spatial patterns during the period from Japanese colonisation to Taiwanese governance after World War II.

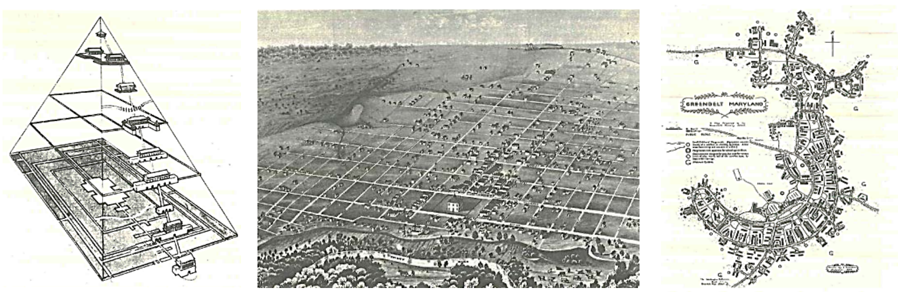


Figure 17

(Left) the cosmic theory of a Chinese wall city; (Middle) A mechanism model of a colonial city; (Right) A town plan of organism. (Source: Lynch 1987)

§ 2.1.4 The Theories of Urban Transformation

Based on the changes of economic production, the transformation of city forms could be roughly classified into three eras: marketplaces, industrial production centre, and service provision centre, consumption and knowledge centre (Carmona et al., 2010). Hargroves & Smith (2005) further identify six waves of innovation that have motivated urban transformation. The first wave produced walking cities with using water power. The second wave developed cities along railroad. The third wave saw linear development along electric tramway. The fourth wave enabled sprawl in all directions due to cheap petrol and autos. The fifth wave with powerful internet and digital technologies began the regeneration of the obsolete industrial cities. The sixth wave is the beginning of resource production related to renewables, water, energy and water system etc. (Fig. 18) (Hargroves and Smith 2005). Newman et al. (2005) argues the response to climate change and peak oil will be the impulse of the sixth wave.

In the case of the Kaoping River Delta, there are three clearly distinct waves of technological innovation that significantly changed the urban forms. The first dramatic change began in the Japanese colonial period when a twin-core intercity system was built by Japan, connecting the cores, Kaohsiung and Pingtung, with a railway. After World War II, Kaohsiung Port and its surrounding area were constructed as the heavy industrial centre of Taiwan. Many industrial parks were built in suburban areas, mainly along the highway system. Another significant change emerged in the 1970s when popularity of autos with convenient traffic networks led urban forms to transform as a 'tent-like' structure (Fig. 19) (Hall 1998). The areas in the urban periphery have developed to be a highly urbanised region.

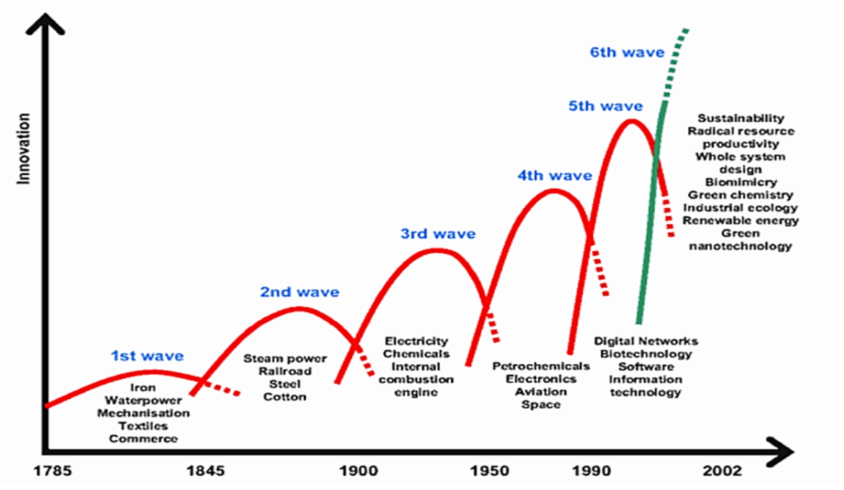


Figure 18
Six waves of innovation (Source: Hargroves and Smith 2005, adapted by Carmona et al. 2010)

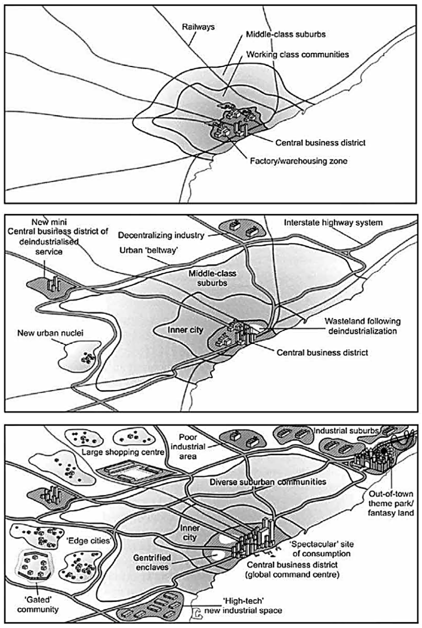


Figure 19

The transformation of city forms (Source: Knox and Pinch 2000)

§ 2.1.5 Theories of Port and City

Based on Kondratieff's 'long wave theory', Meyer (1999) further refines the spatial relationship between cities and their ports. He reorganises the transformation of port cities into four major phases (Fig. 20) (Meyer 1999): (1) Entrepot port – the port is just like an entrance for an enclosed city. All the import or export goods are stored along piers in a major public space. In this phase, a port is part of a city; (2) Transit port – the port is a regional entrance. Goods are delivered through the city. The port area begins to be separated from urban space and has its own distinctive function; (3) Industrial port – the port and city are completely separated into distinct functions. The imported goods may be processed in the port area and then exported again entirely without passing through the city; (4) Distribution port and network city – the linear character of the transit port gradually disappear when a transit port develops into a distribution port. There are several specialised distribution hubs which together form a network within a port city. Goods could continue be distributed for serving large continental areas.

These four phases provide a clear framework to illustrate the formal transformation between cities and their ports, if we say the relational transformation is a major concern in long wave theory. [4] Following the development of a port city, the laid out of a port has shifted from in the city, next to the city, farther away from the city, to being spread out over the city. The waterfront is reclaimed from the port area and reshapes the urban landscape while the port with its potentially central position leads the redevelopment of the urban space.

This transformation model of port cities accurately captures the historical change of the Kaohsiung Port from the colonial age to the post-industrial age. A new challenge for the city, being a post-industrial port city, is how to deal with a huge amount of obsolete port areas. This model is instructive in many ways.

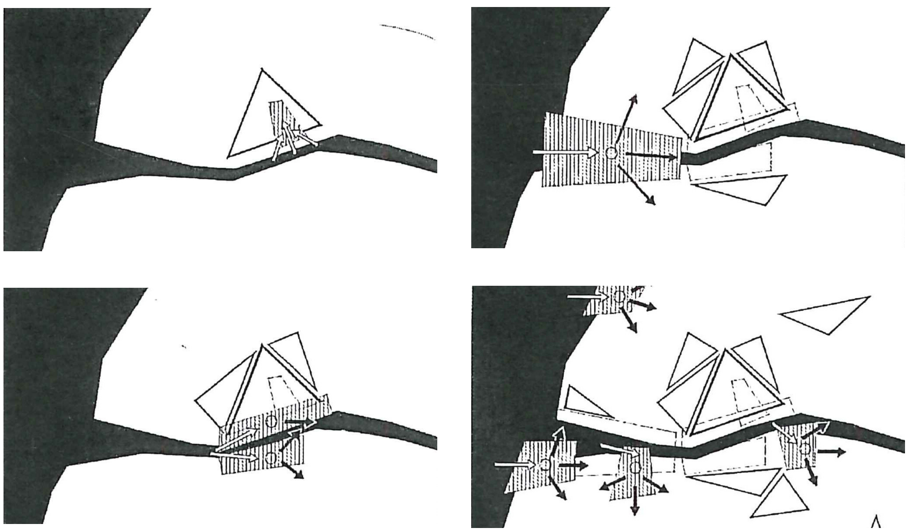


Figure 20
Transforming structure of a port city (Source: Meyer 1999)

4 he economist Kondratieff divides city development in nineteen and twenty centuries into five major phases:
- 1782-1845: the energy revolution; new cities arise and economic functions are liberated.
- 1846-1892: the infrastructural era; expanded and develop in g urban structure is absorbed into an evolving regional and national urban system.
- 1893-1948: increase in (auto) mobility; along with the reinforcement and concentration of economic activities, the basis is laid for the formation of metropolitan districts.
- 1949-1998: globalisation and internationalisation of industry arrive on the scene, accompanied by the 'office era.'
- 1999-2048: an increasingly interwoven quality; networks, whose structures are constantly changing, become more and more important in the Information Age.

§ 2.2 Theories of Dealing with Storm water

§ 2.2.1 Hydrologic Concepts

The traditional approach to management of urban storm water was to drain runoff from urban surfaces as quickly as possible through a pipe or channel system (Parkinson et al 2010). The primary goal is to prevent local inundation (de Barry and Paul 2004; Reese and Debo 2003). However, the traditional approach increases peak flows, which can induce inundation in the lower reaches of rivers and cause a more serious problem in river basins. Several additional management models have been developed to complement the traditional model. Currently, there are five major models to deal with storm water: conveyance, detention, extended detention, infiltration, and water harvesting (Ferguson 1998).

Conveyance

Conveyance aims to drain the surface runoff of storm water from the ground to the sea or rivers. Pipe and channel systems are the two major instruments for conveyance. This is the aforementioned traditional management model, which dates back to the ancient Roman cities where streets were built with gutters as a drainage system. The first drainage in modern industrial city dated to a new community in Illinois U.S.A. in 1869 (Ferguson 1998). Subsequently, drainage has been the most important way to deal with urban storm water. Misunderstandings of this concept encouraged the development of highly urbanised areas with carelessness to natural water context. Today, this concept is still an essential tool to resolve urban floods. However, more and more concepts have been developing to complement this concept (Fig. 21) (Parkinson et al 2010).

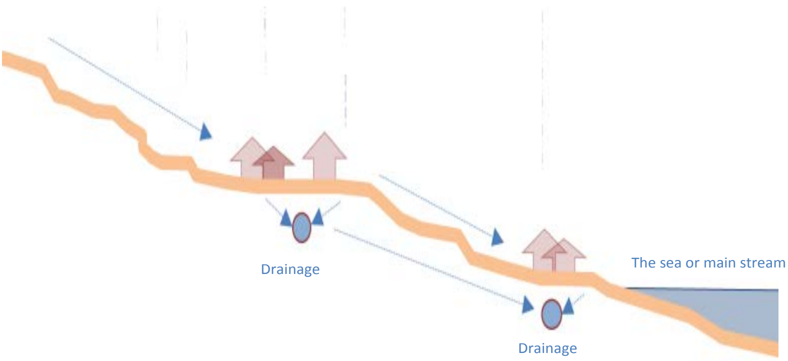


Figure 21
The concept of conveyance (Source: based on Ferguson 1998; Graphic by author)

Detention

The aim in detention is to slow down the surface flow of storm water. This concept complements the shortages of conveyance because it can reduce the peak flow level of the main stream and efficiently minimise downstream flooding (Reese 2001) when it could be applied at a proper watershed-wide basis (Ferguson 1998). The decreased rate of flow could also reduce the erosion of the waterfront. Detention has been a popular approach in metropolitan areas because when designed well, the spatial forms of detention can further improve urban landscapes. In addition, sometimes detention is the most practicable option when the capacity of conveyance systems cannot be enlarged due to a highly dense downtown area.

Extended detention

Extended detention refers to detention sites that have some extended function, besides detention, which can remove pollutants from the water. The main goal is to improve the quality of collected runoff water. Because it takes a long time for the treatment processes, generally speaking, an extended detention site needs a larger area than a detention site. Thus, it is difficult to put this concept into practice in a highly urbanised area, especially under the impact of extreme rainfall, because it is almost an impossible task to find enough suitable land that can contain a tremendous amount of rainfall, which can sometimes be more than 600 millimetres per day. Some other alternatives, therefore, need to be considered together to reduce the risk of inundation (Fig. 22).

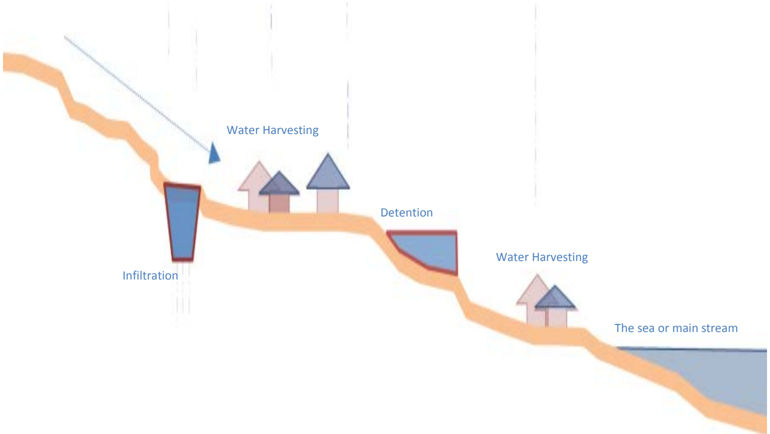


Figure 22
The concept of extended detention (Source: based on Ferguson, B.K. 1998; Graphic by author)

Infiltration

Infiltration refers to the condition when runoff water soaks into the ground and no longer flows on the ground surface. Storing excess storm water underground is an ideal concept, because not only can it directly reduce the peak flow level of the main stream, but also the ground is a good filter to remove the pollutants from water. However, this approach has to deal with two crucial problems. First, a porous soil structure is necessary for water infiltration. In general, this kind of soil structure can be found in the top fan of a river delta. But most of the delta cities are located in the bottom fan of a delta where the soil is almost all clay or peat. This model can only be implemented with some soil improvement schemes. Second, water infiltration also needs a long time to process. It is not a good option when flood prevention is the main concern.

Water Harvesting

Water harvesting refers to holding and using the runoff water on-site. There are many ways to implement this model, including a dam, a reservoir, irrigation, or water tanks on rooftops or in gardens. Although water harvesting is quite an ancient idea, it has only recently been adopted in the modern industrial cities. Interestingly, water harvesting has become quite a fashionable idea today. It is known by some fashionable words such as 'Sponge City', since the traditional flood management met its bottleneck in highly urbanised areas under the impact of extreme rainfall. Because water harvesting holds rainfall in places that are not included in a traditional hydrological scheme, it has provided a new way of looking at the current situation of delta cities. The popularity of water harvesting might imply that multidisciplinary collaboration will be necessary in the future.

§ 2.2.2 Paradigm Shift - from defending against water to working with water

The changing paradigm

A paradigm is a set of ideas and methods by which we believe we could deal with a certain subject properly. The change of paradigm often results from technological innovation. Thus, a change in the paradigm of storm water management can be viewed as the evolution of storm water practices. Novotny divides the evolution of storm water management into five paradigms (Novotny et al. 2010): (1) Basic water supply; (2) Engineered water supply and runoff conveyance; (3) Fast conveyance with no minimum treatment; (4) Fast conveyance with end of pipe treatment; and (5) integrated water resource management. In addition, based on the cases in the United States, Reese, A. and Debo, T. (2003) also divide this evolution into nine paradigms (Reese and Debo 2003): (1) Run it in ditches; (2) Run it in pipes; (3) Run it in storm water pipes; (4) Keep it from storm water pipes; (5) Well, just do not cause flooding; (6) Do not pollute; (7) It is the ecology; (8) Water is water is watershed; and (9) Green and bear it. What we should note is the aforementioned evolution does not have very sharp period boundaries. In fact, in this case, several paradigms might simultaneously co-exist.

We can see ‘pipe’ as a crucial element in these two similar classification structures. All of these paradigms can be roughly divided into a no-pipe age, a pipe age, and a pipe improvement age. The last paradigms of both these two structures could be viewed as a statement of what is a new concept for future development. T.N. Debo & A. J. Reese note the basic issue is the unliveable environment made by urban sprawl. They assert that it can be improved through some combination schemes. Some examples are low Impact Development (LID), Green Infrastructure, Better Site Design, Conservation Development, Zero Discharge, Sustainable Development, and Multi-objective Floodplain Management. One more interesting point is that, from their point of view, their last paradigm will return to a small-scale approach, because it is typically under the jurisdiction of local governments.

There is a striking difference of opinion between these two structures in the last paradigm. V. Novotny et al. introduce a trinity structure, consisting of society, economy, and environment, to illustrate their final ideal paradigm ‘Integrated (Water) Resource Management (IRM)’. From their point of view, this requires a more comprehensive approach and a higher level of political cooperation. Comparing the more technological perspective of T.N. Debo & A. J. Reese’s, they provide a broader vision for diverse participants, including governments, social movements (NGOs), and private sectors etc.

This study would like to express another perspective about the 'last paradigm'. That emphasises a multidisciplinary collaboration through a 3-layer analytical framework that has been in practice in the Netherlands.

Dutch experience: from the Zuiderzee Works and the Delta Works to Room for the River

The Zuiderzee Works and the Delta Works are series world-famous hydrologic engineering works which the Dutch are very proud of. The main concept of these works is to defend against storm surges through means of a huge dike system. To this day, these works have not only protected northern and southern the Netherlands from flooding, but has also attracted numbers of tourists from all over the world. However, criticism emerged in the 1960s in the Netherlands for concerning a more sustainable eco-system and the uncertainty of climate change in the future. The concept of 'Working Together With Water' and 'Room for the River' has developed since the end of the 20th century as a reconsideration of the Delta Works. These two different concepts have their own social and political background, both of which have profoundly affected the development of hydrology in the world.

The shortage of food was an important issue in the Netherlands at the end of the 19th century. The earlier small-scale farming agriculture gradually transformed after the Industrial Revolution. But because the original farmlands which were reclaimed by small dikes were too small and fragmented to be cultivated by modern machines, the countrywide goal was to reclaim large amounts of farm fields. The serious flood in the north part of Holland in 1916 drove the Dutch to consider a multifunctional plan to conduct the flooding and agricultural problems. The plan of the Afsluit Dike (Afsluitdijk) was the most representative of initiatives of that time. Except the function of flood defense, completion of that dike could reclaim 1650 square meter of new land area, about 4% of the territory of the Netherlands, from the Zuiderzee. In addition, the water area that was enclosed by the dike became a fresh water lake called the IJssel Lake (Ijsselmeer), after the river that drains into it. This lake could also provide the surrounding cities with fresh water (van der Wal 1998). This plan successfully integrated the concerns of agriculture, economy, and urban plan with hydrologic engineering and was the contemporary paragon of urban transformation in the world.

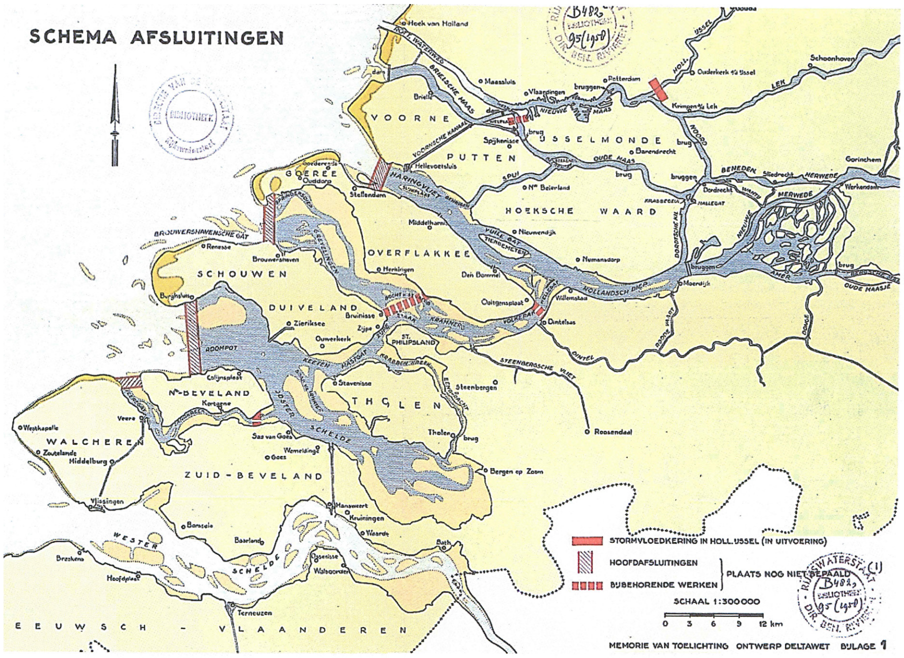


Figure 23
The Delta Works according to the act of 1958 (Source: van de Ven ed. 2004)

Based on the experience of the Afsluit Dike, the Dutch government decided to close the estuaries of the Rhine and Scheldt after the serious floods of 1953. This plan and its related projects are commonly known as the Delta Works. In addition to protection against floods, this plan not only improved the soil salinisation conditions in the downstream areas, but also reduced the tidal effects on the canal navigation between Rotterdam and Antwerp. Furthermore, a new road system that was constructed above the dike system greatly improved the transportation in this region. The southwest part of Holland which was originally a series of poor isolated islands has transformed into a wealthy and integrated region (van Veen 1950; Meyer 2009). This plan, again, integrated multifunctional demands with hydrologic engineering and attracted worldwide attention (Fig. 23).

Since the 1960s, the issue of environmental protection has emerged. The closing of the dikes had greatly changed the brackish estuary ecosystem, many species of fish, birds and plants disappeared. Water quality has deteriorated and the original tidal environment has been damaged. In addition, the barrier has caused the fishery industry to shrink in the upper reaches of the river, because the work has totally blocked the paths of fish migration. There had an intense debate about whether should they continue the rest of those large-scale hydrologic schemes. Under the strong ecological

Figure 24

The revised plan of 1986 for the Delta Works with the names of the completed and newly designed works (Source: van de Ven ed. 2004)

protest, the Markerwaard reclamation was been cancelled, although the surrounding dike of the Markerwaard was completed in 1975. At almost the same time, the new Delta Commission was set up and presented a new concept of the Oosterschelde barrier, a barrier with sliding gates, which could satisfy both the preservation of the brackish environment and the function for decreasing storm surge (Fig. 24, 25) (van der Wal 1998). These two cases are the landmark to represent a dramatic turning point of hydrologic approach in the Netherlands. But, two events of 'near flooding' in 1993 and 1995 reveal this new environmental approach still need to be further improved especially under the uncertain impact of climate change.

Figure 25
(Left): The Oosterschelde storm surge barrier (Source: van de Ven ed. 2004)(Right) and model (Source: Meyer 2009)

A new approach: Room for the River

After the near flooding in 1993 and 1995, the Netherlands government reconsidered a more ambitious program, Room for the River, to combine a flood defense program with the different concerns of environment, urban development and economic development. This plan actually boasts 39 implementations throughout the country, and will be completed in 2015. These sub-planes along the rivers Ijssel, Lek, Maas and Waal together make up the program Room for the River. The major goal is to enlarge the peak discharge from 15,000 cms (cube meter per second) to 16,000 cms. There are nine major methods to enlarge the cross-section area of the riverbed, including deepening the river, strengthening dikes, lowering groynes, water storage, high-water channel, depoldering, dike relocation, lowering of floodplains, and removing obstacles (Fig. 26, 27) (http://www.roomfortheriver.com/).

The most attractive part in this program is the integration of urban development with a hydrologic project. A good example of this is the plan 'Room for the Waal Nijmegen' (Fig. 28) (http://www.roomfortheriver.com/). The Waal River bends sharply near Nijmegen and narrows as a bottleneck. This induces a high flooding risk in this region, which was realized in 1993 and 1995. A proper plan was necessary for the city Nijmegen. Nijmegen is an ancient city located on southern bank of the Waal River with limitations on urban development in the east, south, and west areas. Developing toward the north crossing the Waal River is a better option going forward. From the perspective of hydrology, the plan is to move the Waal dike in Lent and construct an ancillary channel in the flood plain. The river will be widened from 300 meters to more than 700 meters. It becomes more difficult to develop this ancient city across the river. This program tries to fill the gap by creating an island in the Waal and a unique river park in the heart of Nijmegen with room for residences, recreational activities, cultural activities, water and nature. As a result, the Room for the River program creates a new city center that connects both sides of the river into a whole urban space. The river will no longer flow alongside the city, but rather through it.

Figure 26

The sub-plans of the plan of the Room for the River. http:// www.roomfortheriver.nl

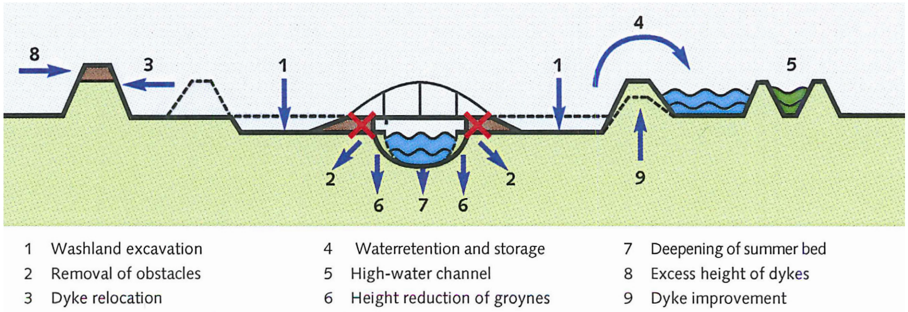


Figure 27

The ways how to make room for the river. (Source: the official website of room for the river. http:// www. roomfortheriver.nl)

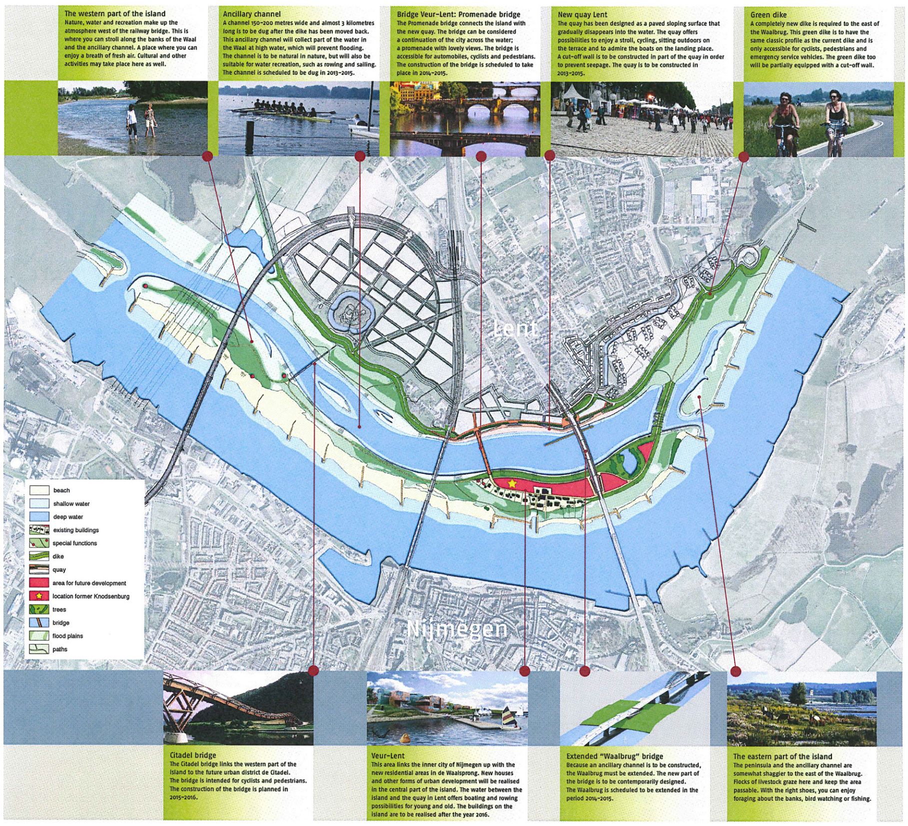


Figure 28

The integrated plans in Nijmegen for the concept of the Room for the River (Source: the official website of room for the river. http:// www.roomfortheriver.nl)

§ 2.3 The Concept of Layer Approach

§ 2.3.1 The conceptual development of 'Layer' in spatial science

Layer is a conceptual tool that is commonly used in many disciplines, including geography, landscaping, and urbanism. It can be viewed as an extended meaning of group, category, distribution or classification; that is, it is a way to classify complex phenomena in a certain area into several different groups for some specific purposes in order to reveal the genius loci of a place. This concept was first adopted in spatial science to explain landscape as a whole system. The method of map-layering has become one of the major tools of spatial planning today following the development of Geography Information Systems (GIS). However, most research applies this concept as a systematic tool to show all data. There are few studies that give attention to logically analysing the relationship between different layers.

The concept of landscape as a system dates back to the 19th century. Alexander von Humboldt (1769-1859), the founding pioneer of modern geography, viewed the earth as an inseparable organic whole. He tried to explore how the many phenomena of nature interact with each other at different places on the earth. He believed only by understanding the interconnections of phenomena could you evaluate any one of them (Meyer and Nijhuis 2011). Based on his observation of vegetation and agriculture, he inductively generalised the theory of altitudinal zonation and his most famous work The Kosmos (VU GeoMet 1996a).

In almost the same era, Carl Ritter (1779-1859) developed the idea of unity in diversity. He recognised, much more like von Humboldt, the great complexity of nature as a unity because of the interconnectedness of phenomena. When he examined the relationship between sets of phenomena in a given area and between separate areas, he began his work with a technique of "areal differentiation." He started work by defining a particular area as a unit of the physical environment, and then added the human element of that place; finally, he showed how man adapted to and used that habitat. In same manner as von Humboldt, he used induction as a major conceptual tool by which he constructed an effective way to organize geographical material and completed his famous work: Die Erdkunde (Geography) (VU GeoMet 1996a).

After von Humboldt and Ritter, the discipline of academic geography began to appear in Germany, France, and Great Britain in the 19th century. In Germany, Ferdinand von Richthofen (1833-1905) introduced a 2-level description of "chorography and chorology." "Chorography" was for the description of the many traits in a given area and “chorology” was for the explanation of the areal distribution of chorographic traits by examining the causes and the interrelations of phenomena (VU GeoMet 1996b). Based on their dynamics he distinguished three domains: land surface (abiotic milieu), flora and fauna, and human society (Meyer and Nijhuis 2011).

In France, Jean Brunhes further focused on the surface features of the earth that are produced by humans. In his opinion, these phenomena make up the essential facts of human geography. He divided them into 3 groups: nonagricultural human constructions (houses, roads, and villages), agricultural patterns (both plants and animals) and resource exploitation or nonagricultural land use (mining, lumbering, hunting, etc.). Brunhes combined these phenomena with those of physical geography to construct his analytical framework (VU GeoMet 1996b).

§ 2.3.2 Overlay mapping as a primary form

It was in the late 19th century when the concept of layers was introduced into landscaping. Landscape architects Olmsted, Lynn Miller and Charles Eliot at Pennsylvania State University, began using hand-drawn, sieve-mapping overlays through sun prints produced on windows. They adopted the overlay technique as a systematic method to compile and map information in their planning and design. For example, in the Manning’s Billerica Plan from 1912, the recommendations and changes in urban circulation routes and land use were displayed using four different maps, including soil, vegetation, topography, and land use. After that, overlay technique gradually was commonly adopted, notably for the city plan for Dusseldof Germany in 1912, the regional plan of New York in 1929, and the London County plan in 1943. However, a theoretical explanation of the rationale for synthetically using this technique was still lacking (McHarg et al. 1998).

An academic discussion of the overlay technique did not appear until Jacqueline Tyrwhitt’s work in 1950. She drew four maps: relief, hydrology, rock types and soil drainage, on transparent paper at the same scale, and made reference to common control features. These data maps were then combined into one land characteristics map which provided a synthesized interpretation of the first four maps (Tyrwhitt 1950; Steinitz et al. 1976; McHarg et al. 1998). George Angus Hills also introduced a well-documented data-overlay technique in the plan for Ontario Province in 1961. He divided regions into consecutively smaller units of physiographic similarity based on a gradient scale of climate and landform features. He regrouped these units through a process of comparing differences and ranking to determine their relative potential for land use (McHarg et al. 1998).

§ 2.3.3 Overlay mapping as an analysis of inductive reasoning

A systematic framework

McHarg refined these approaches and aimed to provide a theoretical basis for overlaying information. His approach focused on both natural and artificial attributes in a given area and photographing them as individual transparent maps. He then superimposed the maps over each other to construct the necessary suitability maps for each land use. This method was firstly developed by him in the Richmond Borough project in New York to propose criteria to select a highway route. He thought the plan should be considered in a larger context of social responsibility, not merely concerning savings in time and budget. He divided all the related factors into two major groups of maps. One group was the traditional physical criteria that engineers are normally concerned with, including slope, bedrock foundation, surface drainage, soil drainage, soil foundation, and susceptibility to erosion. All the factors in this group directly reflected the cost of highway construction. The other group consisted of the evaluations of natural and social processes, including historical value, values of water, forest, wildlife, scenic, recreation, residential, institutional, and land. Each factor was photographed at three grades of value in the gradation of color from dark to light. The mapped superimposition of the first group reveals the sum of physiographic factors influencing highway construction. The darkest tone represents the greatest obstruction of highway construction while the darkest tone in the map superimposition of the second group represents the sum of social values and physiographic obstructions. The lightest tone reveals the areas of least social value (Fig. 29) (McHarg 1969)

.This method was improved upon, and made more clear and explicit in his subsequent research. For example, in the study of the Philadelphia metropolitan area, the physiographic region was divided into three components: uplands, piedmont and coastal plain. This division revealed the principal roles in the water relationship. Following that, he selected eight phenomena: surface water, marshes, flood plains, aquifers, aquifer recharge areas, prime agricultural land, steep lands and forests and woodlands, for further examination. He constructed four phases to illustrate an urban suitability selection process (Fig. 30):

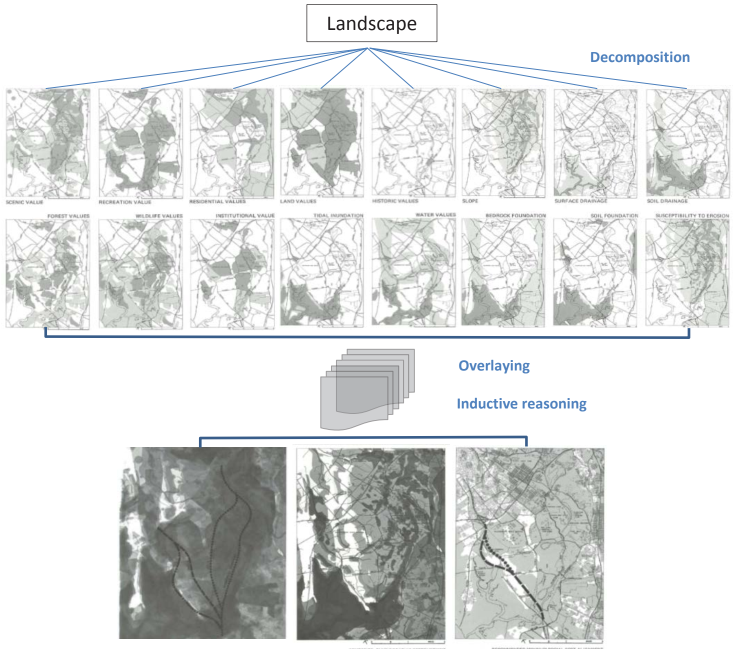


Figure 29
The concept of McHarg's analysis framework (Source: McHarg 1969)

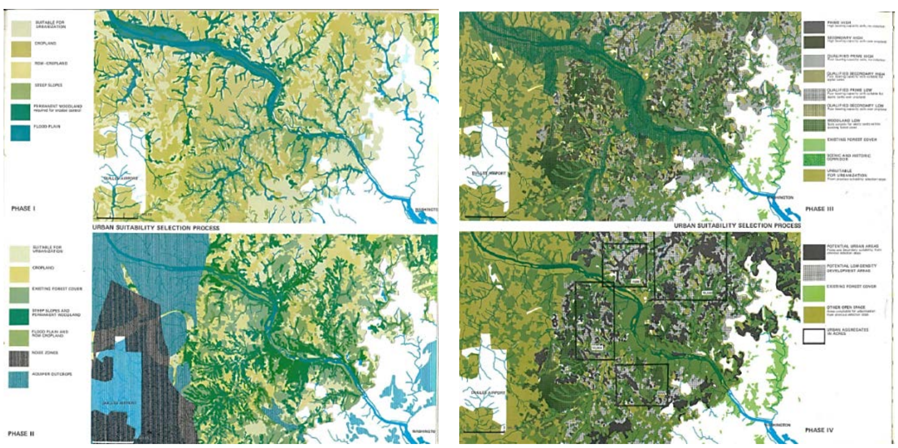


Figure 30
The concept of McHarg's analysis framework in the Philadelphia metropolitan area (Source: McHarg 1969)

Phase1: Exclusion of flood plains, woodlands for erosion control, steep slopes, row-cropland, cropland.

Phase2: Exclusion, in addition to Phase I, of aquifer outcrops, noise zones, existing forest cover.

Phase3: Exclusion, in addition to Phases I and II, of scenic and historic corridors. The ranking of urban suitability based upon bearing capacities of soils and suitability for septic tanks.

Phase4: Identification of aggregations of urban suitable land.

These X-ray-like maps displayed the proper land use: conservation, urbanisation or recreation, which then were combined with others as overlays to produce comprehensive suitability maps (McHarg 1969).

Layer approach via Inductive reasoning

Although the two aforementioned methods manifest in two different ways, they are similar in logical background of inductive reason. The premises of an inductive logical argument indicate some degree of support (inductive probability) for the conclusion but do not entail it; that is, they suggest truth but do not ensure it (http://en.wikipedia.org/wiki/Inductive_reasoning). In the Richmond case, the site map was divided into sixteen-factor maps. The darkest tone in the superimposition map of these sixteen factors indicates that most factor maps suggest the truth of being a natural or social obstruction in this area. The logic of this method is similar to that which was employed in the Philadelphia case, but in a contrary process. In the Philadelphia case, the factor maps of natural or social obstructions were gradually excluded from the site map by four phases. The suitable areas were what appeared on the final map.

However, the layer approach of inductive reasoning, which was employed by McHarg, only compiles the information that was already known. A new method of layer approach is needed to reveal that which we do not yet know.

§ 2.3.4 Layer approach in the Netherlands

Based on McHarg's concept, the layer approach has been developed in the Netherlands as the 'triplex model' since the 1970s. This modified model includes three main layers: a-biotic, biotic and anthropogenic factors (Kerkstra and Vrijlandt 1988; Meyer and Nijhuis 2013) to illustrate a complex landscape system. The concept of triplex model further embodied in the 'Framework Model' (Casco-concept) for conducting the complex interrelationship between nature and human landscape (de Bruin et al. 1987; Kerkstra and Vrijlandt 1988; Sijmons 1991; Nijhuis and Bobbink 2010).

These studies were integrated into a more comprehensive and stratified model as a three- layer approach (also known as the Dutch layer approach), including substratum, networks and occupation, by De Hoog, Sijmons and Verschuren in 1998 when they developed a theoretical structure to explain the logic of some fifty spatial plans and spatial ideas in the Netherlands in 1996 (RPD 2001; van Buuren 2003; van Schaick and Klaasen 2009). They suggest distinguishing three major layers, the substratum layer, the networks layer and the occupation layer (Table 2), as a strategic model which could provide a normative framework for strategic choices regarding Dutch spatial planning tasks (van Schaick and Klaasen 2009). This concept is included in the Dutch official planning policy, for instance the Fifth Memorandum on Spatial Planning (VROM 2001) and the Memorandum on Space (VROM 2006).

		Design and planning	Approach
Layer 3	Occupation	Accommodating spatial claims and shrinkage in relation to values and attractivity	'Ecology' approach (An ecology defined as a locally characteristic 'life-style-environment') Mold-Contramold approach (city vs. landscape)
Layer 2	Networks	Strengthening the position of the Netherlands in international networks Control and steer the growth of mobility	Complexes approach (developing nodes for exchange of information and knowledge) Corridor approach (developing main ports and hinterland connection)
Layer 1	Substratum	Dealing with the physical effects of climate change Modernising the water management system	Nature engineering Civil engineering
	Coherence	Creating synergy between inter-vention	Conditioning spatial planning Facilitating spatial planning

Table 2
Design tasks and noted approach in the analysis of 50 plus Dutch spatial plans for the Netherlands(Source: De Hoog, Sijmons & Verschuren 1998)

In their opinions, there is a time-relationship between these three layers. In general, the transformation of substratum is the slowest of the three layers, then networks, then occupation (Fig. 31,Left). These three layers could be re-arranged in order from bottom to top through this time-relationship (Fig. 31,Right), which will set priorities and conditions for spatial plans (De Hoog et al., 1998). After the serious floods in 1995 and 1997, the concept of water management in Holland has gradually shifted from "fighting against the water" to "working together with water". This model provided a cohesive framework of spatial planning to re-consider the relationship between artificial and natural landscapes in the future.

Although three-layer approach provides a broader vision to examine natural landscape, it still needs further improvement. First, the rationale of this triplex model is still vague. A finer methodology for exploring the interaction between different layers needs to be developed further regardless of whether it is for inductive or deductive approaches. Second, a crucial question is how to apply this model to real plans or designs. This triplex model implies a multi-disciplinary approach, which is quite different from the conventional way to deal with water issues. Thus it is very important to develop a theoretical framework that can serve as a comprehensive working platform to collaborate through different disciplines.

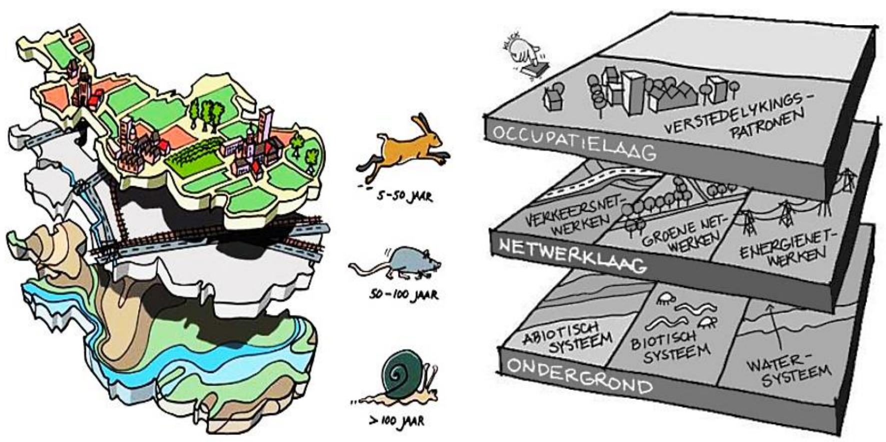


Figure 31
Left: Three-layer approach can be elaborated into detail. (Source: MIRUP 2003)
Right: Each layer has its own transforming period. (Source: MIRUP 2003)

§ 2.4 Commentary

We can very roughly classify the theories discussed in this chapter into three main groups: (1) Theories that try to deal with the gap between traditional and modern cities; (2) Theories developed under the impact of the relational concept of urban forms; and (3) The modification of theoretical approaches to deal with new challenges under the impacts of climate change.

The gap between traditional and modern cities

Urban morphologists have to allow for an apparent distinction between traditional and modern cities. They try to fill the gap based on the understanding of the traditional spatial patterns. They presume that a better way for developing urban forms in the future can be developed by classifying the knowledge of spatial forms in the past. Urban Morphology indeed has found some valuable clues to help them interpret the transformation of historic urban forms. However, their research still does not lead to a substantial theoretical basis to help us to realise the context of modern spatial transformation. Finally, as Mouton remarks, the research of Urban Morphology has been limited to the study of historic cities.

In fact, traditional Urban Morphology studies are doomed to be limited to the research of historic cities, because they did not develop a broader analytical framework in scale to explore the transformation of urban forms. Basically, a town or a city scale is usually the largest scale in the studies of Urban Morphology. What they ignore is that the context of the transformation of modern urban forms has always occurred within an intercity or even an international scale, such as the scale of a river delta, in the case of this study. Reconnecting the transformation between the traditional and modern to construct a broader structure is a new approach to Urban Morphology.

The relational concept of urban forms

To say that most of the current urban studies have shifted from a formal research to a relational research does not mean that we do not study urban physical forms. Rather, it means that most current studies about urban forms are based on the relationship of urban or global networks. Studies on developing an urban pattern to respond to the flows of capital, labour, and technique prevail all over the world. Consider, for example, theories of flow space, network city and global city, instead of studies dealing with the relationship between urban formal forms and natural landscape. The realm of knowledge about how to deal with natural issues has gradually shifted from urban planning to other disciplines, e.g. hydrology. The relational concept of urban forms has met this new challenge beginning with the emergence of climate change in the 1990s, when neither urbanism nor hydrology could individually resolve the serious flooding problems in highly urbanised areas. A new theoretical approach to developing physical urban forms should be considered under this context.

The modification of theoretical approach

A new analytical framework of urban forms can be constructed within multi-disciplinary collaborative approaches. As the aforementioned theories show, both overlay mapping and Dutch layer approach emphasise the interacting processes between different layers. The diverse data from different realms of knowledge can be rearranged into an integrated structure. However, how to explore the relationship between different layers will be a crucial issue in the future. In McHarge's work, he adopted the method of inductive reasoning to link maps of different factors. Although this method is appropriate for simplifying the complex phenomena that are already known, some problems, such as the issues of flooding and groundwater, are difficult to be resolved just by overlaying the existing information. The triplex model seems to be developing its main method within the context of deductive reasoning, but a more explicit methodology still needs to be constructed.

The analytical framework of this study

Based on the aforementioned theoretical background, this study constructs the 3-layer framework of deductive reasoning in order to find causal relationship between different layers. This causal relationship will answer three questions. First, which are the crucial elements to affect others within these three layers? This research will explore this part in two different scales: delta and city scales. The infrastructure including hydrologic instruments and transportation will be examined in delta scale. Then, urban pattern and drainage will be two important factors to be explored in city scale; Secondly, this study will further reveal how can these factors profoundly affect the natural landscape? The mechanism of water systems will be illustrated both in delta and city scale, including the original operation of water system and the affected operation system. Furthermore, this research will especially explore how the affected system works under the effects of climate change. And finally, how these crucial elements could be changed? This research will construct a collaboration framework of trans-disciplinary by the concept of research by design and try to find how to control these factors to adapt delta cities to storm rainfall. Based on this analytical framework, we begin this study.

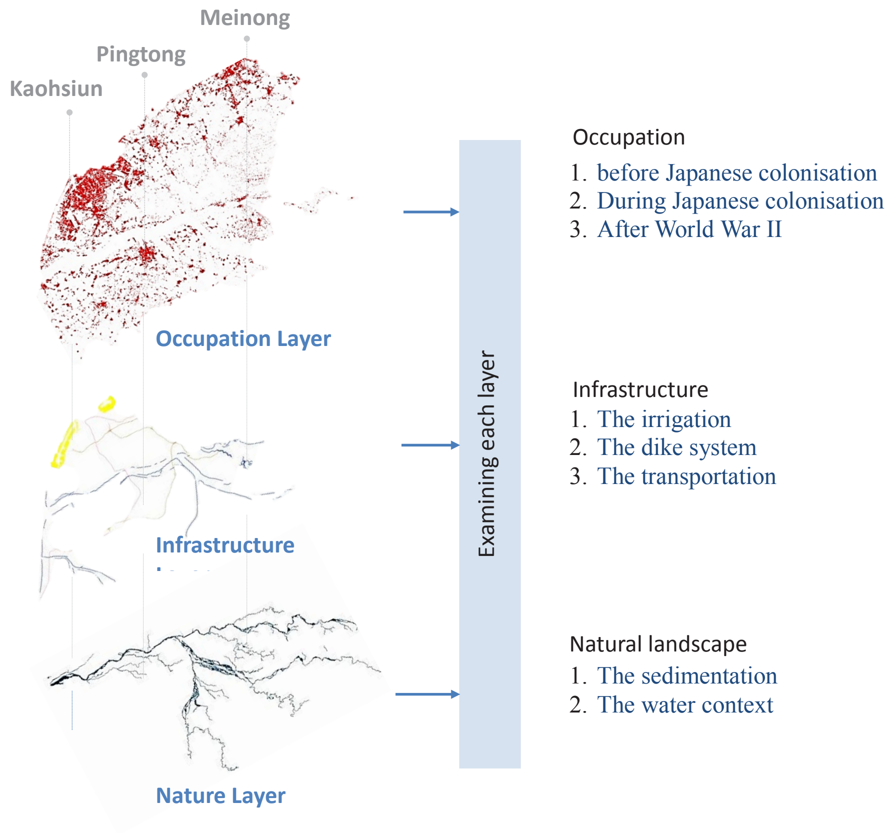


Figure 32

The analysis framework of 3-layer approach (Map by author)

3 The 3-layer Analysis at Delta Scale

This chapter analyses the transformation and mechanism of the Kaoping Delta using the layer approach methodology. This method comprises three major levels of analysis: the natural landscape, infrastructure and occupation layer. The analysis of the natural landscape focuses on the formation of the soil structure and the mechanism of the water environment before the considerable disturbance being created by artificial construction. The material mainly draws from data in the Taiwan District Map, Taiwan Baotu (台灣堡圖). This map is a precise record about the pre-colonial status of Taiwan's natural landscape, transportation and built environment. It was made by the Japanese as a basis point from which to make plans. The rapid spatial urbanisation began during Japanese colonisation. The Taiwan Baotu could be viewed as a description of the original status of the natural environment one hundred years ago. The analysis of the infrastructure layer mainly investigates the history of building hydrologic and traffic infrastructure constructions during the Japanese colonial period and Taiwanese development plans after World War II. Although these plans increased the development of regional modernisation, they significantly changed the natural landscape. The analysis of the occupation layer tries to reveal the historical context of urban blocks and public spaces. This can help us more precisely clarify the reasons floods occur, and to find the potential spatial capacity when a plans for extreme climate are made. Every single part of the analyses will be revealed on the monitor tablet in two ways: one is with one highlighted signal which identified the precise position of the present examining layer; the other is with two highlighted signals which illustrate the interrelationship between different layers and factors (Fig. 32). Finally, the study will construct a causal relationship between these three layers to illustrate the transformation and mechanism of the hydrological system of the Kaoping Delta, which will be the source of data from which to make a subsequent spatial plan (Fig. 33).

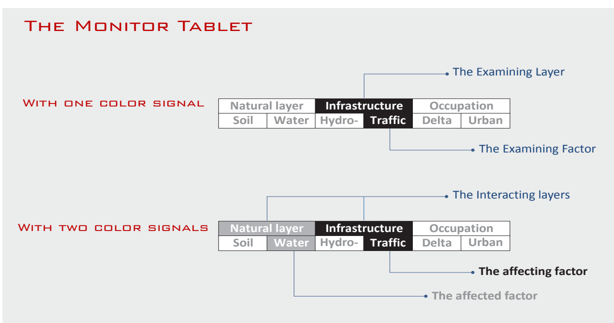


Figure 33
The illustration of the monitor table

§ 3.1 The Layer of Natural Landscape

§ 3.1.1 A wave-dominated delta

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The Kaoping River experiences extremely different discharge patterns between the summer and winter seasons. Enormous amounts of sediment is carried by summer storms and deposited at the river mouth (Fig. 34) (TGR, 2008). The strong sea currents from south to north remove and scatter these deposits along the coast. This forms the Kaoping plain and Dago Bay. This kind of delta is very similar to a wave-dominated delta (Fig. 35). Both sedimentation and erosion are prominent forces that can affect the transformation of a wave-dominated delta. If the amount of sediments is very large, sediments will be spread along the coast by strong tides. On the contrary, coastal erosion will be very serious. Besides accumulating along the coast, sand will also easily silt up or make the riverbed or estuary shallow. When that happens, the water overflowing the bank will find another route to flow into the sea. This produces a dendritic riverbed and huge area of wetland in the down reaches. Furthermore, the silt around the estuary will be transported to the coast by continuous tides. This forms a barrier island along the coast. Consequently, large amount of sediment has dual roles in this region. On the one hand, it is helpful to make a robust coast that protects the coast from floods originating in the sea. On the other hand, it silts the riverbed, and this enhances the risk of floods along the waterfront.

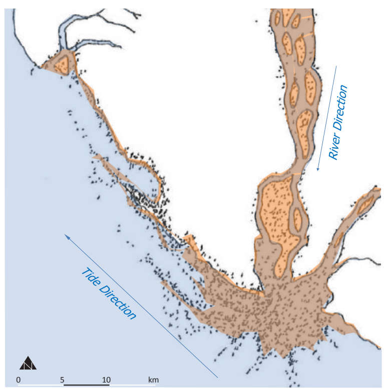


Figure 34
The operation of tide and fluvial sedimentation. Huge amounts of sediments had been transited to the estuary which was carried by tide from the south to north scattering along the coast and forming a natural sand dune. (Graphic by author)

In fact, floods in this area mainly come from the river rather than from the sea. It can partly explain why a dike system was built only along the river bank. On the map of Taiwan District Map of Qing Dynasty (LGR, 2005), about 300 years ago, we can see that the sand bar had already formed the original shape of the Kaohsiung Harbour (Fig. 36).

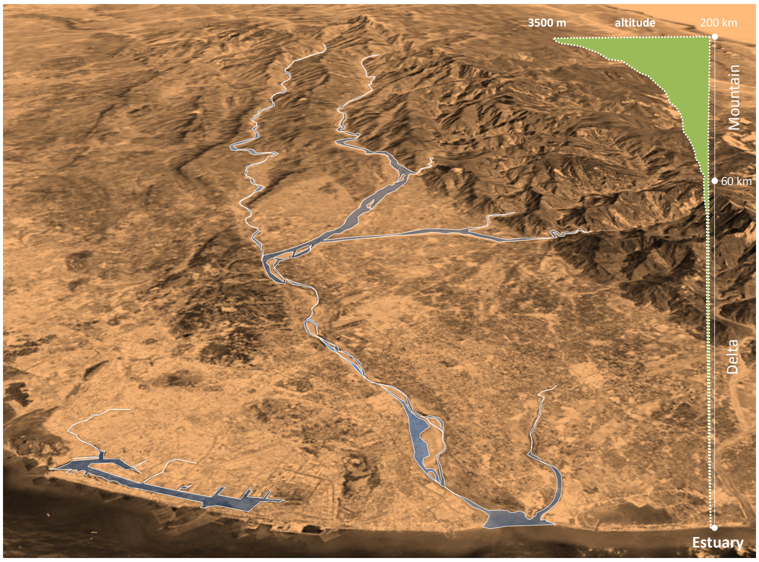


Figure 35
The river system in the Kaoping River Delta (Source: based on Google Map, Montage by author)

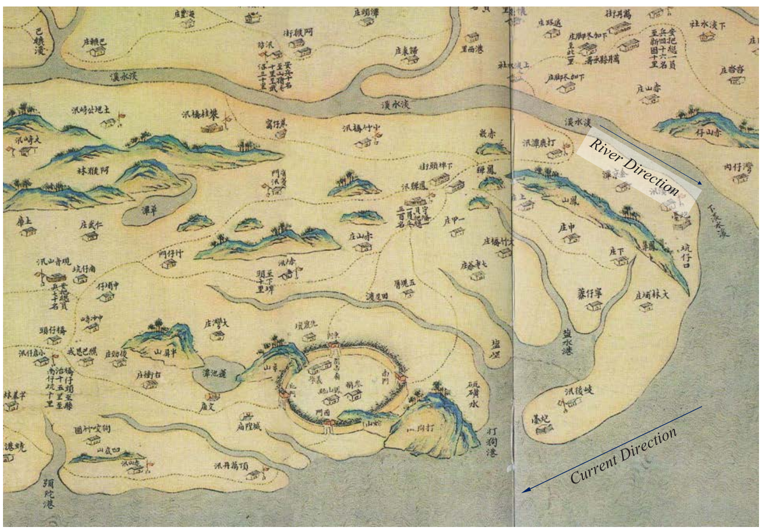


Figure 36
The historical map reveals the sand dune, had been robust enough to settle villages and military camp.(Source: LGR, 2005)

§ 3.1.2 Sedimentation in a wave-dominated delta

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The riverbed of the upper and middle reaches of the Kaoping River is very steep in the mountainous area. When the river flows through the mountains onto the plains, carrying large amounts of sand and stone, the speed of water flow will sharply reduce. The slow flowing water lets the sedimentation of the river begin. Due to the different weight of soil particles, gravel and sand will be deposited first, and then silt and clay (Fig. 37). This order of sedimentation forms the main soil texture of the Kaoping Delta. The geological profile of the Kaoping River Delta (TGR 2011a) reveals that the substratum in the middle reaches, the top alluvial fan of delta, is mainly comprised of gravel and sand. This is different from the lower reaches, which are mainly comprised of clay and silt. Gravel and sand, of which particles are larger than 0.05 mm (a particle of gravel is larger than 2mm), increase the soil porosity. Subsurface with coarse sediments allow surface water to infiltrate into the ground very quickly. Water flowing along pores between soil particles becomes several aquifers, namely F1- F3. These aquifers comprise the abundant ground water beneath the Kaoping River delta. According to historical records, the region located in the middle reaches of river had very poor keel soil that consists of big particles of gravel and sand (LGR, 1990).

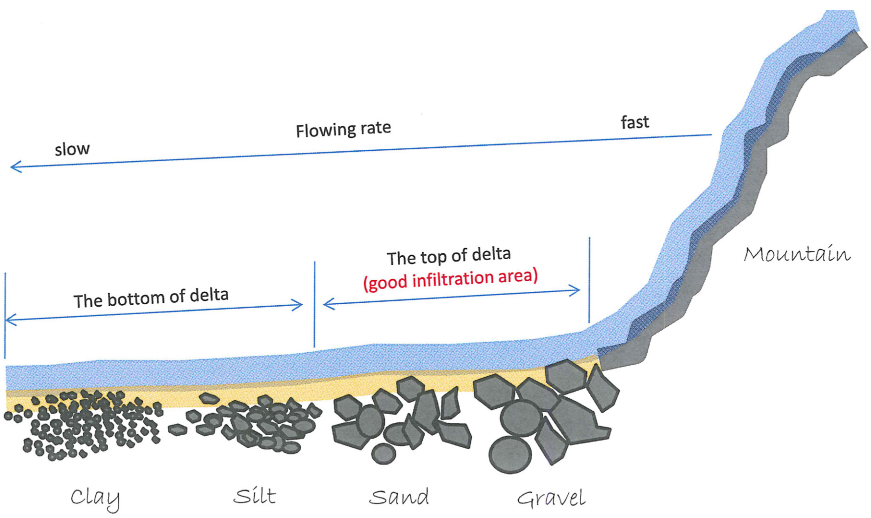


Figure 37
The process of sedimentation in the Kaoping River Delta (Graphic by author)

§ 3.1.3 Soil Structure

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Because the particles of clay are small and light, they can be transported for a long distance. Thus these clay-layers are mainly distributed around the estuary, the bottom of the alluvial delta. Furthermore, because a particle of clay is smaller than 0.002mm, there is almost no space inside a deposited clay-layer for groundwater to flow. This forms aquitards underground, namely T1 –T3 (TGR 2011a) (Fig. 38) which reduces water flow or infiltration. On the other side, the big-pore layers of soil, mainly located in the midstream, the top of the alluvial delta, become the major infiltration zone. When water infiltrates into ground, it will slowly flow along pores of soil particles from the top to the bottom of the delta. In some areas, when the ground water is too abundant to be contained in soil pores, especially when a heavy rainfall occurs in the infiltration zone or when aquifers are confined by aquitards, groundwater will copiously discharge as natural springs. The blue area illustrates the area which has many natural springs. The Kaoping Delta historically had very abundant ground water. The Japanese even considered using two artesian wells to supply the 50,000 residents of Kaohsiung Port City with potable water. Although they finally suspended this plan because the groundwater was very hard, it shows there was abundant groundwater in this region.

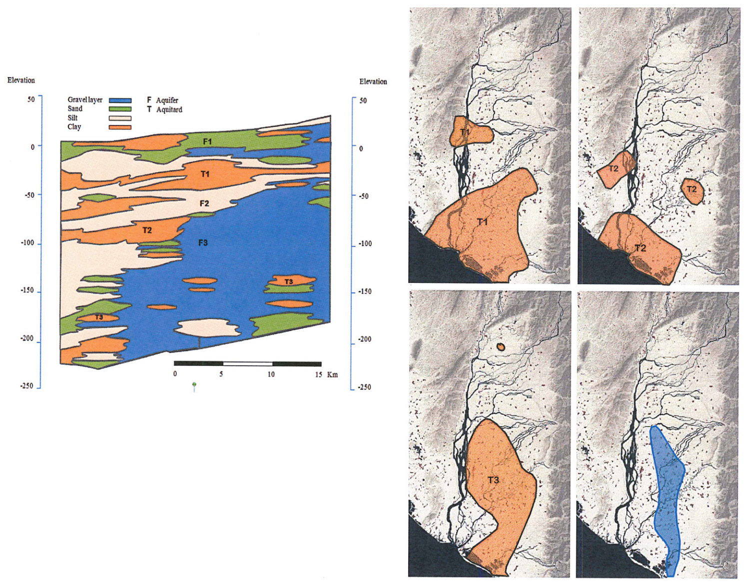


Figure 38

The substratum profile of the Kaoping Delta (Source: based on TGR 2011; Graphic by author)

§ 3.1.4 Water infiltration and local crops

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

This soil structure also influenced the choice of major local crops. Because gravel was deposited at the top of the alluvial fan right where the river emerged from the mountains, the soil was full of gravel and small stones. Historical records show that the soil in this region was very poor keel (LGR, 1990). It was suitable only for certain plants in the upstream area which needed both the conditions of abundant water and good soil drainage. Historically, the upstream districts, e.g. Meinong and Chishang, were famous for their bananas, tobacco and sugarcane. The cultivation of these plants is different from growing rice. One of the major differences is that the rice paddy needs soil with low permeability, called a plow pan or a traffic pan, beneath the surface soil to keep water within soil. On the contrary, for raising bananas, tobacco or sugarcanes, because too much soil moisture will decay the roots, it is necessary to improve the soil permeability The original soil structure on the top of delta was very suitable for these plants. Although the original soil structure of the delta can be illustrated by these traditional local crops, the original sand soil with good permeability has gradually formed a dense hard pan after years of cultivation, which kept water in the farms. Thus, it can now also be used for growing rice. In fact, rice has become the major crop in this region (Fig. 39).

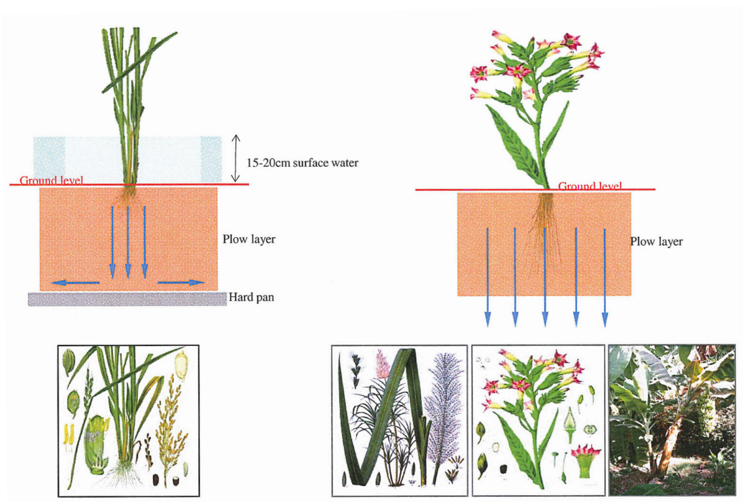


Figure 39

The infiltration and local crops, the traditional crops also illustrate this early substratum. There were three main crops, including sugar cane, tobacco and bananas (from left to right), in the upper Kaoping River in history. A good drainage soil is needed to raise them. (Source: background picture from Wikipedia http://en.wikipedia.org/wiki/Rice; Montage by author)

§ 3.1.5 Multi-bifurcate surface water system

Natural layer		Infrastructure		Occupation	
Soil	**Water**	Hydro-	Traffic	Delta	Urban

Because the river flow in the upper reaches of the Kaoping River was formed in the mountain regions, it has barely changed in the past 100 years. The riverbed was changeable in the middle and lower reaches where the water flowed through the mountainous zone into the delta plain. Due the terrain of the Kaoping delta being higher in the northeast than in the southwest, the major waterways on the Kaoping delta ran in roughly similar directions from the northeast to the southwest. Furthermore, because of huge sedimentation, the riverbed, which contained many sand dunes, was easily clogged. When the original riverbed silted up, partial water, on the one hand, would flush through the silts forming levee deposits along the waterfront. At the same time, part of the water flow would find new southern waterways in which to flow. This repeated process of silting up and changing of the channel resulted in a multi-bifurcate channel network on the delta (Fig. 40). According to The Japanese Taiwan District Map (Academia Sinica ed. 2010), the original water channels from 100 years ago reveals that no sooner had the river flowed into delta plain than it branched out. The map illustrates this channel network occupying most of the delta area, which meant that the whole river basin functioned as a flood plain. Because Fongshan Hill divides the Kaoping Delta into Kaohsiung Plain and Pingtung Plain, the natural water system in Kaohsiung Plain is independent of the Kaoping River system. These two surface water systems did not combine together until the construction of the Tsaogong-zwen irrigation channel.

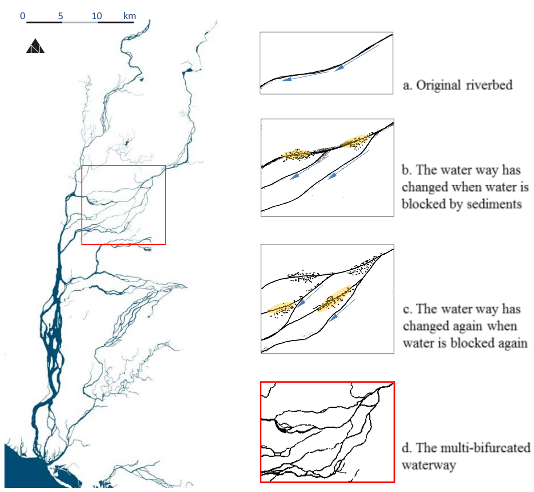
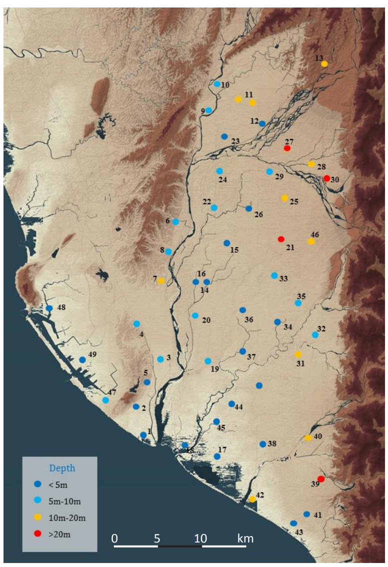


Figure 40
The form of surface water context of the Kaoping River; (Source: Based on Academia Sinica, 2010, Graphic by author)

§ 3.1.6 The ground water structure

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Owing to the aforementioned soil texture of the Kaoping delta, the surface water is easily infiltrated into the ground in the middle reaches, the top of alluvial fan, in where gravel and sand has formed a steady replenishment of groundwater. This means that there are two major destinations of river water when it flows through the flooding plain. One part of the water is surface water discharge into the sea, the rest part becomes groundwater. The groundwater flows slowly between the interstices of soil layers when water permeates into the ground. There is a system of abundant ground water beneath the Kaoping Delta, and a high groundwater level. In general, the average depth of the groundwater level is around 5m beneath the ground surface in the middle and bottom of the alluvial delta plain. The highest level of groundwater could even reach 1-2 m in depth. Groundwater will flow upwards to the surface as springs in these areas with high levels of groundwater when flowing of water is reduced by rock pan or dense layers of clay. Springs have been the most important water source for settlements on the Kaoping Delta. Additionally, because the soil layer in the piedmont area is a very permeable soil layer, it reveals that water will infiltrate deeply into ground. the level of groundwater would be deeper than 10m, even more than 30m (TGR,2011a) (Fig. 41).



Well No.	Ground level	Groundwater level	
		level	depth
01.Shihua (石化)	3.99	-0.45	4.45
02.Linyuan (林園)	5.01	2.11	2.9
03.Tsoliao (潮寮)	9.00	3.56	5.44
04.Jwufong (永芳)	18.56	10.32	8.24
05.Zhaoming (昭明)	8.91	5.68	3.23
06.Sipu (溪埔)	29.14	21.75	7.39
07.Jiuqu (九曲)	27.01	12.87	14.14
08.Dashu (大樹)	23.85	16.48	7.37
09.Chungczhou (中洲)	39.44	34.19	5.25
10.Qishang (旗山)	43.8	34.62	9.18
11.Jiyang (吉洋)	54.1	42.66	11.44
12.Meinong (美濃)	54.03	50.37	3.66
13.Zingcheng (新成)	151.18	140.33	10.85
14.qingsi (清溪)	19.65	14.94	4.8
15.Haifong (海豐)	33.34	28.93	4.41
16.Chenjing (前進)	18.25	16.43	1.82
17.Datan (大潭)	3.42	-1.03	4.45
18.TongGun (東港)	3.00	0.40	2.60
19.Zingzhuang (新庄)	10.67	5.61	5.06
20.Oneden (萬丹)	16.76	9.72	7.04
21.Fonhua (繁華)	44.22	21.23	22.99
22.JiuJu (九如)	34.62	24.91	9.71
23.Tokoo (土庫)	40.93	36.57	4.36
24.Ligun (里港)	38.41	32.25	6.16
25.Yanpu (塩埔)	58.10	43.30	14.8
26.Pontsao (彭厝)	35.61	31.65	3.96
27.Kaosu (高樹)	87.62	56.96	30.66
28Taishang (泰山)	67.25	50.64	16.61
29.Zinnan (新南)	52.69	44.74	7.95
30.Guanfu (關福)	75.06	51.09	23.97
31.Oneluan (萬巒)	29.32	18.85	10.47
32.Chishang (赤山)	27.03	22.00	5.03
33.Chanzing (建興)	36.98	29.04	7.94
34.Neipu (內埔)	22.92	20.66	2.26
35.Laupi (老埤)	35.15	28.11	7.04
36.Sishi (西勢)	17.97	14.04	3.93
37.Dahu (大湖)	11.09	6.72	4.37
38.Zinpi (新埤)	12.28	8.63	3.65
39.Daxiang (大嚮)	44.87	7.18	37.69
40.Xiangta (餉潭)	37.23	22.81	14.42
41.Shuidilioa (水底寮)	6.86	2.82	4.04
42.Dazhuang (大庄)	2.90	-7.71	10.61
43.Derzin (德興)	3.58	-0.14	3.72
44.Kending (崁頂)	9.26	6.85	2.41
45.Gundong (港東)	4.37	0.43	3.94
46.Majia (瑪家)	81.75	38.94	42.81
47.Fongming (鳳鳴)	10.56	2.44	8.12
48.Yanchen (鹽埕)	2.43	0.17	2.26
49. Gunho (港和)	5.40	1.39	4.01

Figure 41

The locations of monitoring wells and the average depth of ground water level (Source: based on TGR 2011a; Graphic by author)

§ 3.2 The Infrastructure Layer

§ 3.2.1 Hydrological engineering before Japanese colonization

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Hydrological systems were the most important infrastructure for settlements on the Kaoping Delta in the past. Because the surface water systems of the Kaohsiung Plain and the Pingtung Plain are separated by Fengshan Hill (鳳山丘陵), different hydrological engineering approaches were needed in the Kaohsiung and Pingtung Plain. The Pingtung Plain is located in the middle and down reaches of the Kaoping River, where the riverbed is wide, shallow and full of sandbanks. The river easily overflowed its banks during the rainy season and caused serious flooding. On the contrary, because the Fengshan Hill blocked the overflowing water, there was no serious flooding there. However, obtaining sufficient drinking water for sustainable development is a major problem. Thus the Chongi Dike in the Pingtung Plain and the Tsaogong-zwen irrigation channel in the Kaosiung Plain were two important hydrological facilities in the Kaoping Delta before the Japanese colonial period.

There was no irrigation in the Kaoping Delta before the Tsaogong-zwen irrigation channel. The main water source of farmland was rainfall. The farmland was also called "Kan-Tein-taim (看天田)" then, which means the water source relied on God (LGR 2005) (Fig. 42). The problem of irrigation was not resolved until the construction of Tsaogong-zwen irrigation channel (曹公圳) irrigation in 1839. The water resource problem was relatively minor in the Pingtung Plain, where local residents could easily find abundant groundwater. In contrast, the rough structure of the Chongi Dike was not constructed until 1920, because of a limited budget and technology, and it was still insufficient to prevent flooding.

Figure 42
Water system and agricultural land use in history (Source: LGR 2005)

§ 3.2.2 The twin-core inter-city structure on a delta

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Taiwan, a sub-tropical island, produces abundant agricultural products. According to a Japanese survey, about 1.5% of the world's sugar output was contributed by Taiwan in 1910 (TDELS). Thus, Japanese regarded Taiwan as an important logistic base to support their military in Asia. To achieve this goal, it was important to build an efficient export port. Kaohsiung, at the centre of the Jianan Plain (嘉南平原) and Kaoping Plain, was the best location to build a port. The blueprint in Japanese authorities' mind was to construct the Kaoping Delta as a twin-core inter-city structure (Fig. 43): in addition to Kaohsiung Port, Pingtung City was the other core which could distribute agricultural products of the Kaoping Delta. This plan would integrate the whole delta to be the hinterland of Kaohsiung Port. Before the Japanese occupation, most towns in the Kaoping Delta had populations of around 5,000 with the exception of Zaoin (左營) and Fengshan (鳳山) Cities. After the construction of the twin-core structure, significant labour was needed in the Kaohsiung and Pingdong cities. The populations of these two cities quickly increased to 40,000 in Pingdong (屏東), and 80,000 in Kaohsiung from 1920 to 1937 (TDELS).

There were three infrastructure priorities for this twin-core structure. The first was a potable water system for Kaohsiung Port with a planned population of 50,000 and irrigation for the remaining agricultural areas. The second was a dike system to protect the middle and down reaches of the Kaoping River from flooding. The third was a transportation network connecting the towns to extend the hinterland of the Kaohsiung Port.

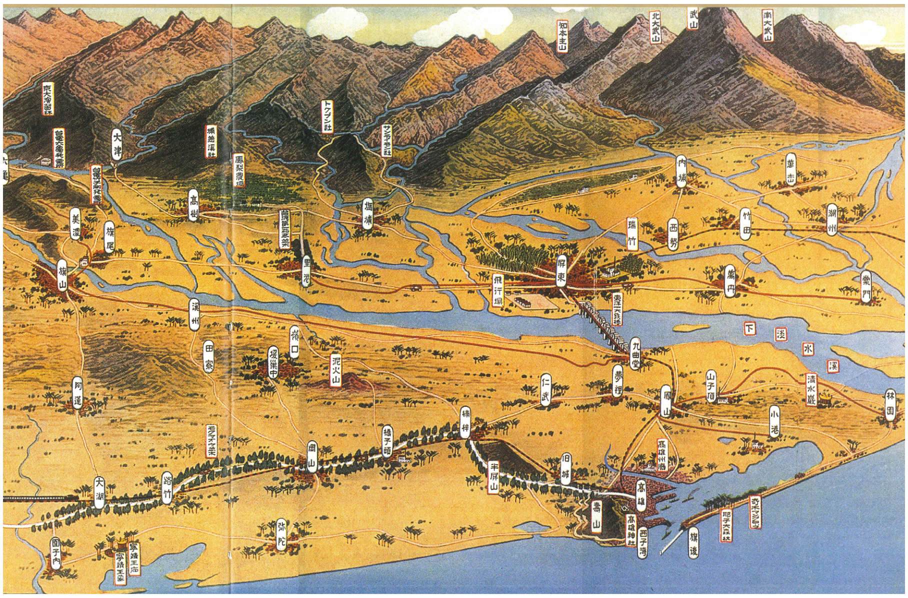


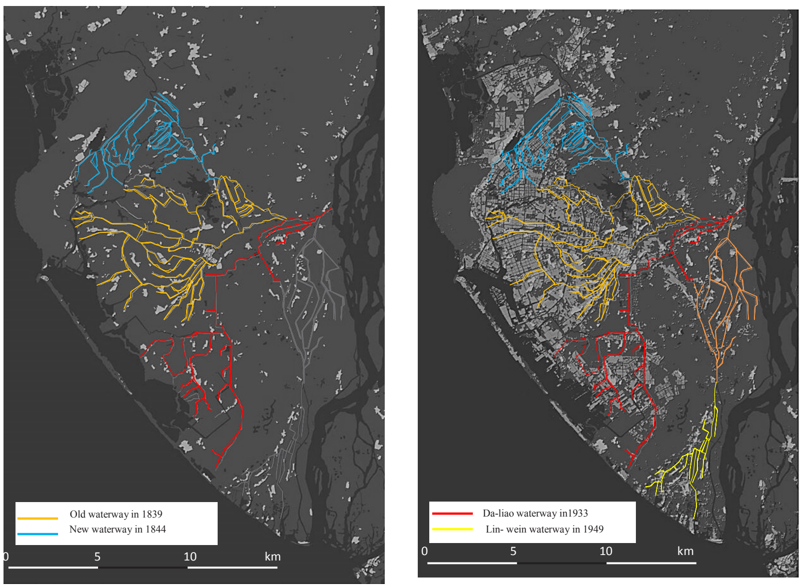
Figure 43
Japanese main concept about the development of the Kaoping River Delta as a 'twin-core structure'(Source: LGR 2005)

§ 3.2.3 Drinking water and irrigation water

Natural layer		Infrastructure		Occupation	
Soil	Water	**Hydro-**	Traffic	Delta	Urban

It was necessary to address the potable water issue first, while Japanese colonial authorities planned to develop a 50,000 person city around Kaohsiung Port after the port was built. Japanese colonial authorities originally planned to use abundant groundwater from two artesian wells in Gushan (鼓山) District. This idea was suspended because the groundwater in this area was too hard. Finally, Japanese colonial authorities copied the approach used for the Tsaogong-zwen irrigation channel, drawing directly from the Kaoping River. They built a dam in the lower reaches of the river to collect water. To this day, this potable water system still supports 80% of the drinking water of Kaohsiung's 1.5 million residents.

Following agricultural development in the delta, Japanese colonial authorities launched 5 main irrigation projects, including the Laonong River, the Yiliao River, the Qishan River, the Wulwo River and new part of the Tsaogong-zwen irrigation channel. These irrigation projects collectively supplied 1 billion tons of water annually to an area of around 39,000 ha. Among these projects, the Tsaogong-zwen irrigation channel was the largest which irrigated about 6,477 ha area; And Shizitoazhen irrigation channel, which reused the expelled water from Zouzhimen Power Plant, was the second largest irrigated area with 4380 ha.; and then the Ailiozhen and Jiuliozhen irrigation respectively irrigated 3,700 and 23,77 ha.; Onedan-zhen, Taishan-zhen, and Chishan-zhen irrigated an area of about 1,000 ha.; the remaining irrigated areas were all less than 1,000 ha. (TGR, 2008) (Fig. 44)



:e 3.12: The development of the irrigation system on Kaohsiung plain in1905 (left) and 2005 (right). The urban development around the port area pushes the agriculture to the margin of the plain.
:ce: Based on TGR 2007; Montage by author)

Figure 44

The development of the irrigation system on Kaohsiung plain in1905 (left) and 2005 (right). The urban development around the port area pushes the agriculture to the margin of the plain. (Source: Based on TGR 2007; Montage by author)

§ 3.2.4 Dike system along the main stream

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Besides irrigation plans, a flooding problem needed to be resolved in the Pingtung Plain. The area along the I-Lioa Creek, one branch of the Kaoping River, was the most flood-prone region in Pingtung Plain. Because large amounts of sediment frequently silted the riverbed when water flowed through mountains to the plain, river channels were very changeable, which formed a net-like waterway flowing through a large area in Pingtung Plain, through Chungzhin, Linlow, Neipoo, Zoutein and Onedan. Floods occurred frequently during the rainy season in this area (Chen, C. S. 1993; Xie, H. R. 2009). Local residents contributed money to build a dike before the Japanese colonial period, but the project was not very successful. Flood problems did not ease until 1902 when the Tson-Chi Dike (昌基堤防), 952m in length, was built (LGR 1973; Xie, H. R. 2009) .

Two serious inundations in 1920 further revealed the insufficiency of the Tson-Chi dike. A new dike plan started in 1929. The new dike system was built mainly along the downstream of the Kaoping River and the south bank of the I-Lioa Creek toward to the west. This new dike system had been completed in 1938 (Chen, C. S. 1993), which forced water to flow northwest through the north boundary of Ian-Pu (鹽埔), Li-Gun (里港) to the main branch of the Kaoping River. This not only protected the area from floods in the rainy season, but also reclaimed huge sections of land from the river. This reclaimed land was called 'He-ba-tein (河壩田)' which means lands gained from damming the river (Fig. 45).

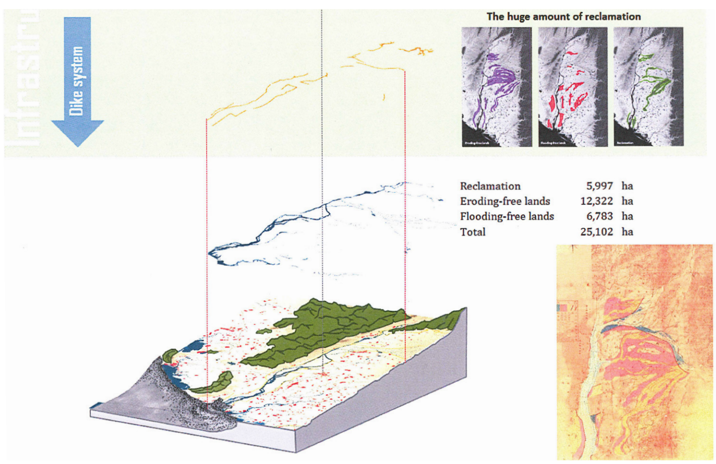


Figure 45
The effects of the dike system (Based on LGR 2005; Graphic, map and montage by author)

§ 3.2.5 Transportation during The Japanese colonial period

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	**Traffic**	Delta	Urban

A railroad was completed in 1908 that connected Kaohsiung City and Pingtung City. It further helped Kaohsiung to become an export port and Pingtung to become a distribution centre. Pingtung City was originally a small town of about 5,000 in the past. Its location is just at the point which has the shortest distance from Kaohsiung Port while the railroad extends through Fengshan Hill into Pingtung Plain. Thus this was a good location to establish a distribution centre which could greatly reduce logistics costs.

Besides railroads, the design of both the local and inter-city roads was based on the concept of a twin-core structure. Between them, the roads around Kaohsiung Port were laid out in a grid system, in which the direction of the main roads was toward the port area. The layout differed little in Pingtung. Although the design of roads was also based on grid system, there were five grid systems along five directions connecting downtown Pingtung with surrounding cities in order to collect agricultural products more efficiently (Fig. 46).

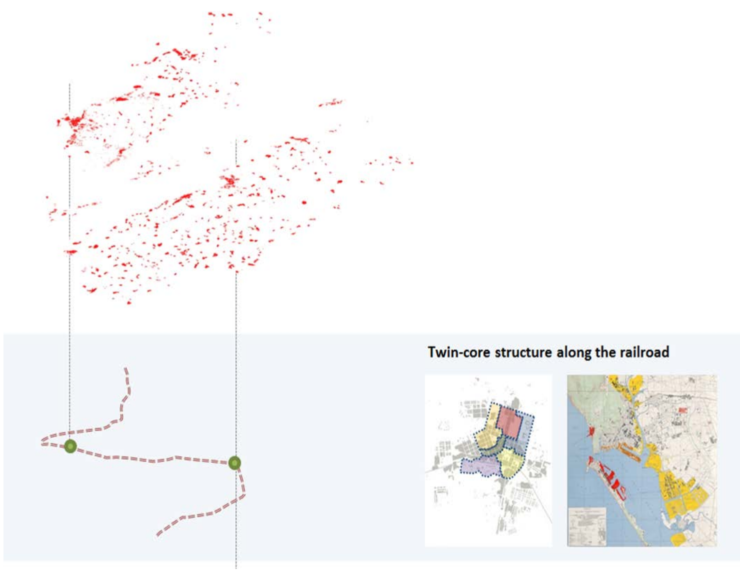


Figure 46

The impacts of transportation to spatial pattern, Two major delta cities, Kaohsiung and Pingtung, were linked by railroad. Their individual spatial pattern was mainly developed by following the grid street system. (Source: Based on LGR 1991; Map and Montage by author)

§ 3.2.6 Transportation after World War II

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

After World War II, the primary economic policy of the Taiwan government was to promote industry by developing agriculture. Rice, sugar, bananas and pineapple were still the main products being exported from Kaohsiung Port. Following its agricultural development, the irrigation area of Tsaogong-zwen (曹公圳) increased rapidly to its peak (CCAT, 2013). Because the foundation of the city's industry and transportation system was established by Japanese colonial authorities in the Kaohsiung Plain, the national policy, the first Four-year Economic Development Plan, planned to construct Kaohsiung as the heavy industrial centre of Taiwan. The major exporting products gradually shifted from farm produce to products from the Export Processing Industrial Park. These industrial parks were mainly situated along the highway that was completed in 1978. The industrial landscape became the dominant image of Kaohsiung City (Fig. 3.15). The rapid growth of the port accompanied dense urbanisation around the port area which pushed agriculture out to the east. Due to the shift of land uses, the old system of the Tsaogong-zwen irrigation channel gradually lost its irrigation function. The original system needed to be extended. The construction of Dalio-Zwin in 1933 and Liyuan-Zwin in 1949 revealed this trend of spatial change (Fig. 47).

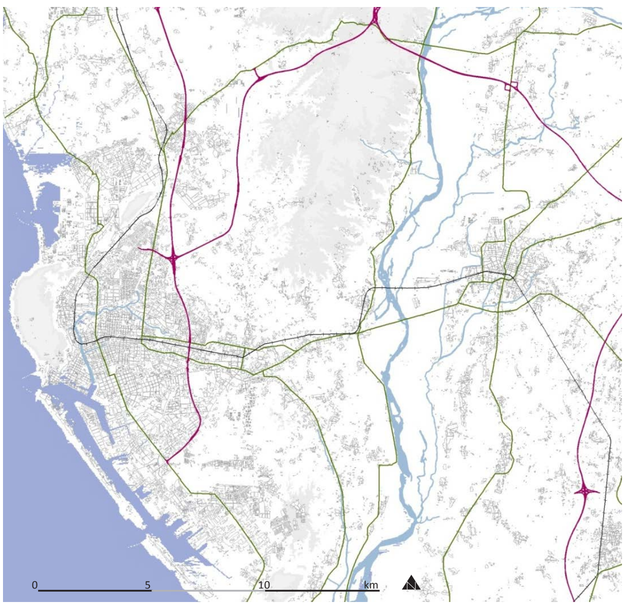


Figure 47

The transportation of Kaohsiung downtown after World War II (map by author)

§ 3.3 The Occupation Layer

§ 3.3.1 Walled cities and settlements (before 1895)

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The Takao Bay, the location of Kaohsiung Port now, was not in a very good condition for anchorage of ships in early history. Because it is small and shallow and also experiences strong tides, large seagoing vessels and clippers could not be anchored inside the bay. It was only used for sheltering a few junks or fishing boats from storms (Chang, S.Z., 2000). Thus there was little inshore fishing along the coast in Kaohsiung. According to the Kangsi District Map of 1719 (Figure 3.2), there were just Takao-Xun and Qihou-Xun with no village around Takao-bay. The major economic activity was small-scale farming before the Japanese colonial period throughout the delta plain. Because security and settlement were the main concerns to the authorities, towns usually developed beside 'Xun (a military unit then)'. Due to abundant groundwater, settlements could obtain water easily without having to be along the waterfront. As a result, settlements were evenly distributed on the delta plain except for the walled cities, Fengshan and Zaoing, which needed to be built beside the mountains and waterways for defence purposes, and the villages in the piedmont of the delta, which because of the low groundwater level, had to be situated beside the river to get water. Most towns developed along major streets (Fig. 48).

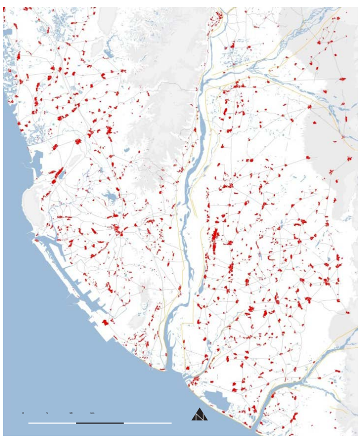


Figure 48
The scattered villages before 1895 (Source: Based on Academia Sinica ed.; Map by author)

§ 3.3.2 The spatial pattern around the port area (1895-1945)

Natural layer		Infrastructure		**Occupation**	
Soil	Water	Hydro-	Traffic	Delta	**Urban**

During the Japanese occupation, the townships of Zuoing and Fengshan gradually lost their original political and military functions. Kaohsiung and Pingtung had comprised a twin-core intercity structure. Among them, the construction plans of Kaohsiung Port had been carried out in 1908, 1912 and 1937 respectively (LGR 1984) in order to build Kaohsiung into an important export port. Furthermore, the Japanese colonial authorities also launched the "Takao Downtown Remediation Plan" in 1908, and three city expansion plans in 1912, 1921 and 1936 for the rapid urban development around the port area. These plans arranged the port related industries, for instance cement, metal and chemistry factories, around the port area. Moreover, they used a grid-street system for the major spatial pattern. The port related business was blended into this grid-system: transportation and customs businesses were located in Xinbing-ting (新濱町), Jiejiang-ting (堀江町), Shanxia-ting (山下町) and Shou-ting (壽町) near the port and stations; cold-storage businesses were located in Chihou-ting (旗後町), Xinbing-ting, Chou-ting (湊町), Ruchuan-ting (入船町) and Yanchan-ting (鹽埕町); rice, sugar and fertiliser businesses were located near transportation nodes. Some large steel factories were located in Xinbing-ting, Chou-ting and Ruchuan-ting with many small factories surrounding them (Fig.49) (Chen, W.S. et al. 2002). Following the rapid growth of ports, Hamasen (哈瑪星) and Yancheng (鹽埕) districts gradually became the new city centres.

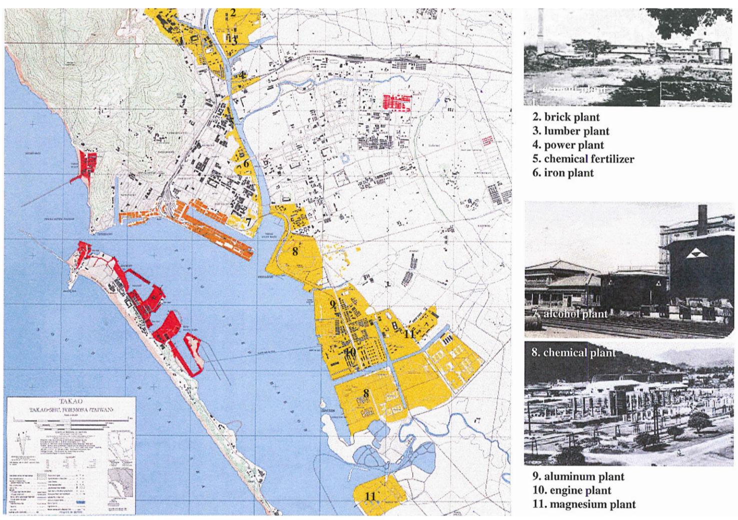


Figure 49
Spatial pattern of Kaohsiung Port during Japanese colony (Source: Based on LGR 1984; Map and montage by author)

§ 3.3.3 The spatial pattern of the distribution centre

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

At the same period of Kaohsiung Port development, the Taiwan Sugar Company established their headquarters in Pingtong in 1909 to accelerate agricultural development of the Kaoping Delta. Furthermore, the Japanese also enacted the Ahou (阿緱, the old name of Pingtung) City Plan in 1913 in order to increase the logistical efficiency of space and to make Pingtong as one of the twin cores of the inter-city structure. Although the basic urban pattern of Pingtong and Kaohsiung were both designed using the grid system, the grid pattern in Pingtong, which obviously developed along four main streets, was quite different from that used in Kaohsiung. Pingtong downtown comprises six districts, including Ben-ting (本町), Moguang-ting (末廣町), Xiaochuan-ting (小川町), Heijin-ting (黑金町), Rong-ting (榮町), and Ruosong-ting (若松町). Most of the financial institutions were located in Ben-ting and the western Moguang-ting and Xiaochuan-ting. Logistics-related businesses were concentrated in Heijin-ting along the railroad. Air Force related facilities were located in Rong-ting and Ruosong-ting (LGR 1991). The logistical efficiency was rapidly enhanced by this spatial pattern. Kaohsiung and Pingtung had taken the places of Zaoing and Fengshan as the two new centres (Fig. 50).

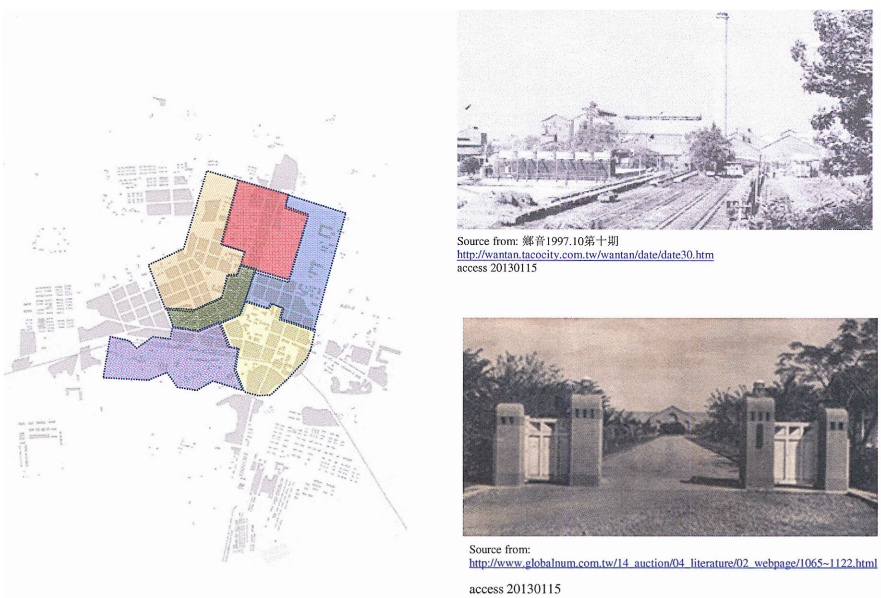


Figure 50

The spatial pattern of Pingtung City during the Japanese colonial era (Source: Based on LGR 1991; Map and montage by author)

§ 3.3.4 Around-the-clock factory (from the 1960s)

Taiwan's Government largely continued the approach of the Japanese colonial authorities to develop Kaohsiung. But the major policy goal was to promote industrial development via agriculture. The twin-core intercity structure still worked very well in its initial stages after World War II. The operation of the large factories located in Gushan, Xishijia and Qianzhen and the light industry in Yanchengpu's continued (Dai, B.T. 2004). Furthermore, the Taiwan Government also extended and upgraded the port functions of Kaohsiung through a four-year economic development plan begun in 1953 in order to build Kaohsiung into an industrial center of Taiwan for the coming age. In 1958, a 12-year expansion plan for Kaohsiung Port was implemented. Through this plan, a great amount of land was reclaimed by using the silt from dredging the port, which was developed for commercial piers and the largest industrial park in Taiwan, Linhai Industrial Park. In 1963, the Qianzhen Export Processing Zone was established in Kaohsiung. Later on, with the goal of enhancing economic growth, the Nanzi Export Processing Zone was built. The industrial parks along main transportation routes and around downtown had become the dominant spatial patterns. At the same period, the role of the distribution center in Pingtung was gradually neglected. Following the expansion of the Kaohsiung Port and the establishment of the export processing zones and the heavy industrial parks, including China Steel Corporation, China Shipbuilding Corporation and Chinese Patroleum Corporation, large numbers of workers were attracted to this area (Fig. 51). The population of Kaohsiung rapidly increased 5-fold during a 30-year period, from 200,000 in 1943 to one million in 1976.

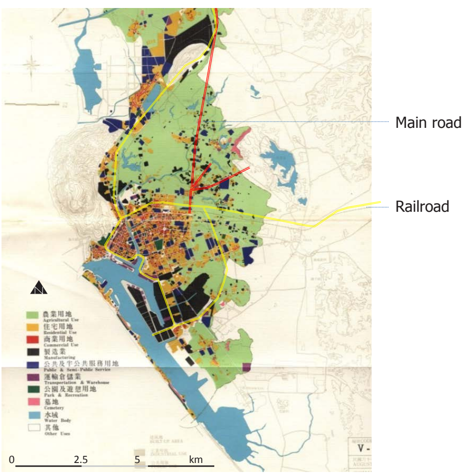


Figure 51
Land use after War II. Industrial Parks were developed along transportation. (Source: Based on LGR 1984; Map and montage by author)

§ 3.4 Mapping the centurial transformation

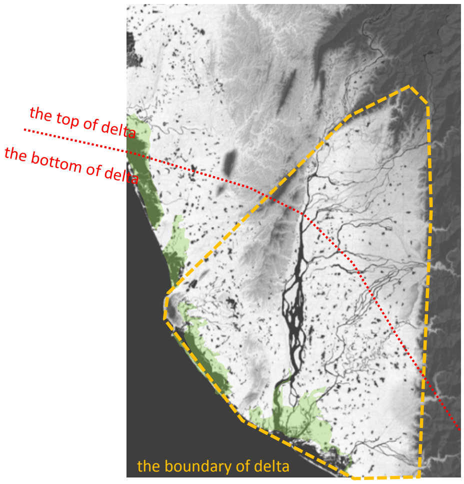
Based on the aforementioned analyses, the following three maps try to illustrate the centurial transformation of the Kaoping Delta by three timescales, e.g. 1895, 1945 and 2001. These maps consist of the data respectively from three layers, including the elevation and water system of the natural landscape, railroad and dike system of infrastructure, and building area of occupation. The elevation is viewed as a constant element to be a background for the all data in these three maps.

A The map with the timescale of 1895: This map is based on the Taiwan District Map (台灣堡圖) which was made by Japan through a detailed investigation on Taiwan from 1895 to 1905 in order to enhance the efficiency of colonial rule. Because the rapid urbanisation did not occur until the Japanese colonial era, the information on this map could be viewed as a stage in which natural landscape- especially the water system in this case- had not yet been disturbed by human interventions.

B The map with the timescale of 1945: The main information of this map is based on the modification of Taiwan District Map in 1945. This is the year when Japan retreated from Taiwan. Thus this map represents the data which records the transformation of the natural and human landscapes during Japanese colony. Except that, another important source is from maps made by the US Army for military use. These maps are very precise and detailed, focusing especially on buildings and blocks in downtown areas, which reveal a clearer stage of the first urbanization phase in Taiwan.

C The map with the timescale of 2005: The main source of this map is from The Map for Economic Development (經濟建設發展計畫地圖) made by Council for Economic Planning and Development (經濟建設委員會) in 1985, 1992, 1999, and 2003. After War II, Taiwan had experienced very rapid urbanisation from the 1970s to 1990s. Kaohsiung City, originally a small port city with a population of 200,000, has become a highly urbanised metropolis with a population around 1.5 million through this process.

These three diachronic maps represent that a massive transformation had occurred during the past century not only in human landscape but also in water system. There is obviously a strong relation between these changes. The following maps just reveal a rough overview of these changes. A more delicate relationship will be illustrated in the next section.

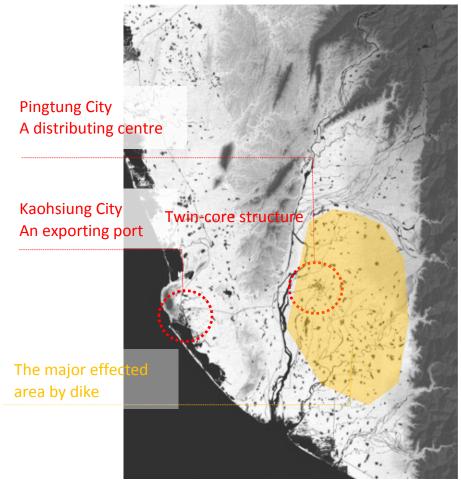


The Kaohsiung River Delta in 1895

(Source: Based on Academia Sinica ed. 2010; Map by author)

The water system of the Kaohsiung River Delta before Japanese colony could be viewed as an original situation without too much intervention by human landscape. The main stream flows from north to south along the mountain foothills of Phonshan Hill. Numbers of tributaries flow from North-east to south-west into the main stream. Light green areas were once swamps.

There was no prominent infrastructure at this stage. Most towns evenly scattered in the bottom area of the delta. The spatial pattern is quite different from upper area of the delta where residents usually built their house beside tributaries.

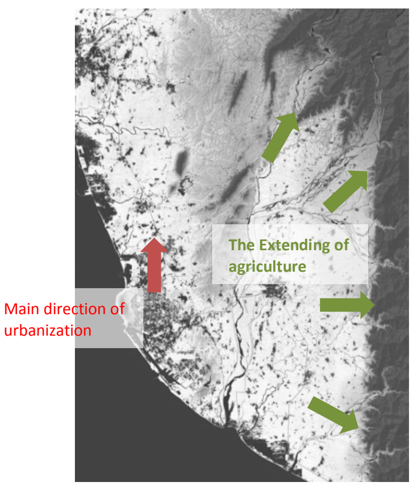


The Kaohsiung River Delta in 1945

(Source: Based on Academia Sinica ed. 2010; Map by author)

This is the first phase of urbanisation in the Kaoping Delta. Several prominent infrastructures, including harbour, railroad and dike system, were constructed in this stage by Japan in order to build this region as an international logistic base. Kaohsiung City as an exporting port and Pingtung City as a distribution centre were linked by railroad as a twin-core intercity structure.

At the same time, a new dike system had been completed along the main stream of the Kaoping River, which has massively changed the flow of surface water system of the Kaoping River. A significant amount of new farmland was reclaimed from the river due to the change in the riverbed.

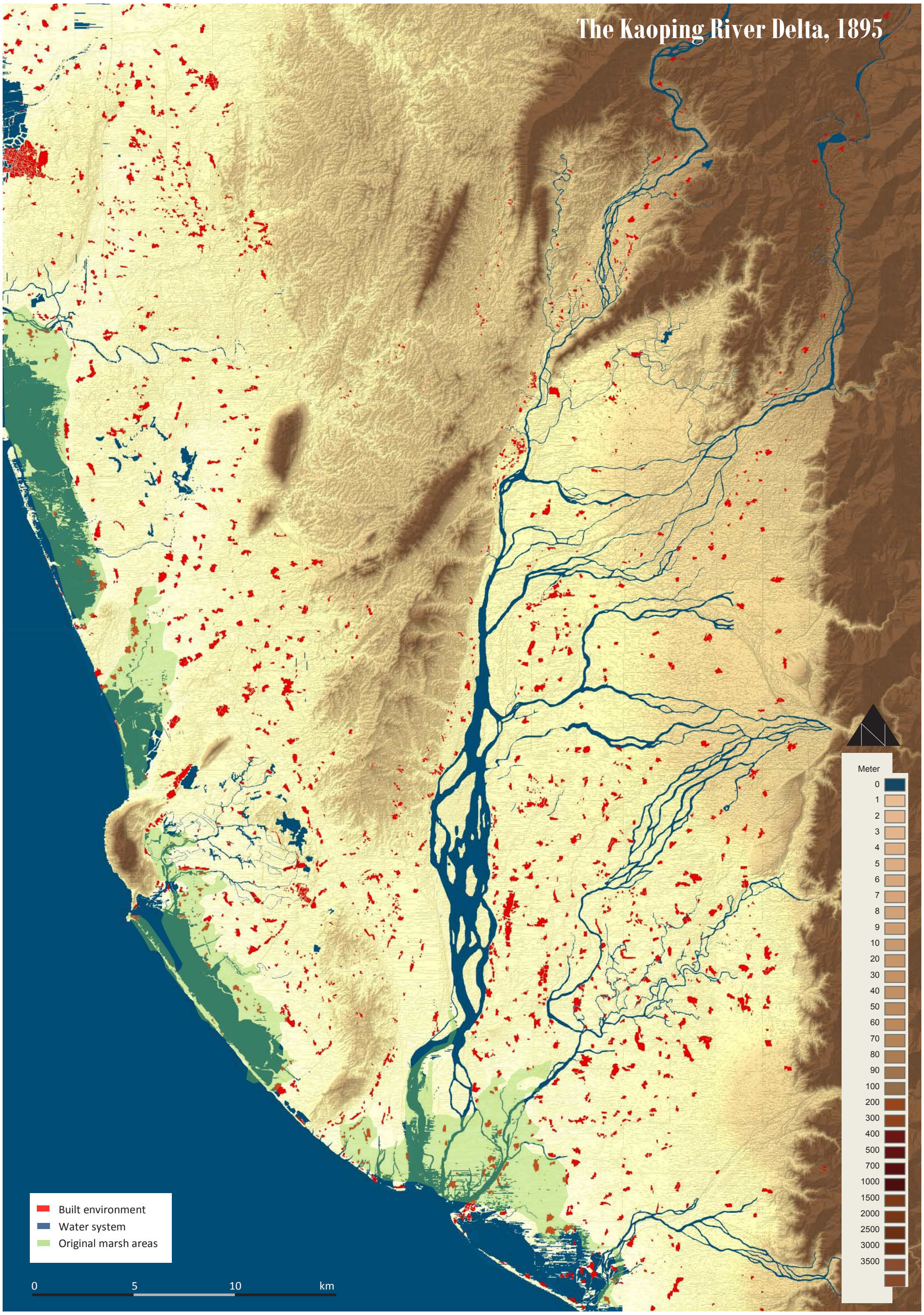


The Kaohsiung River Delta in 2005

(Source: Based on Academia Sinica ed. 2010; Map by author)

After War II, the Kaoping Delta experienced its second urbanisation phase which was more rapid than in the previous stage. Following the rapid urban sprawl of Kaohsiung City along transportation, the original twin-core structure had gradually eclipsed and was replaced by a single metropolis. The major direction of urban development was toward the north rather than the east in order to make a stronger linkage with other metropolises in the west of Taiwan.

The extension of the dike system further limited the boundary of the riverbed. Numerous tributaries, marshes and wetlands had disappeared due to rapid urbanisation.



The Kaoping River Delta, 1895
Meter
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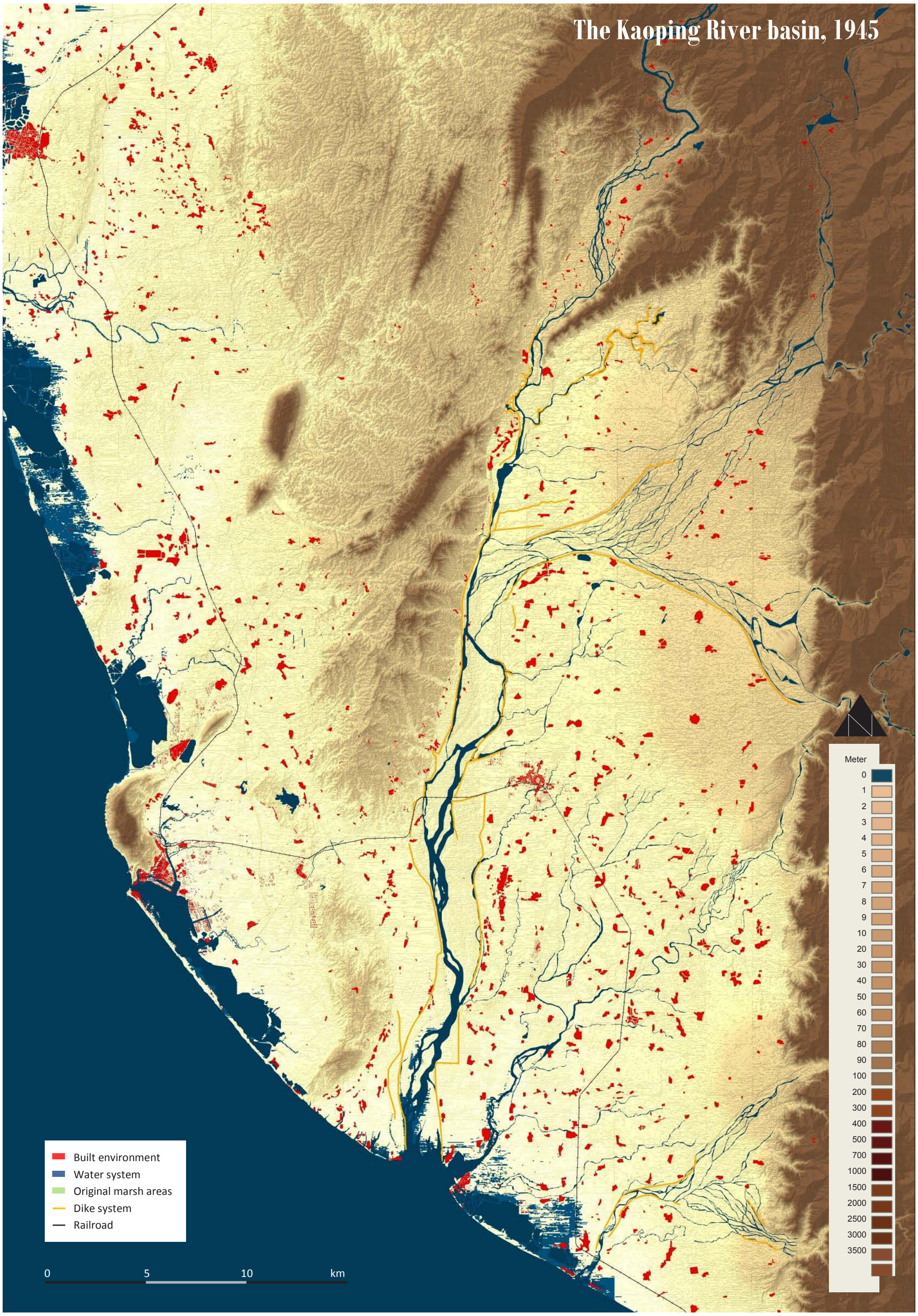
2500
3000
3500
Built environment
Water system
Original marsh areas
0
5
10
km



The Kaoping River basin, 1945
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3000
3500
Built environment
Water system
Original marsh areas
Dike system
Railroad
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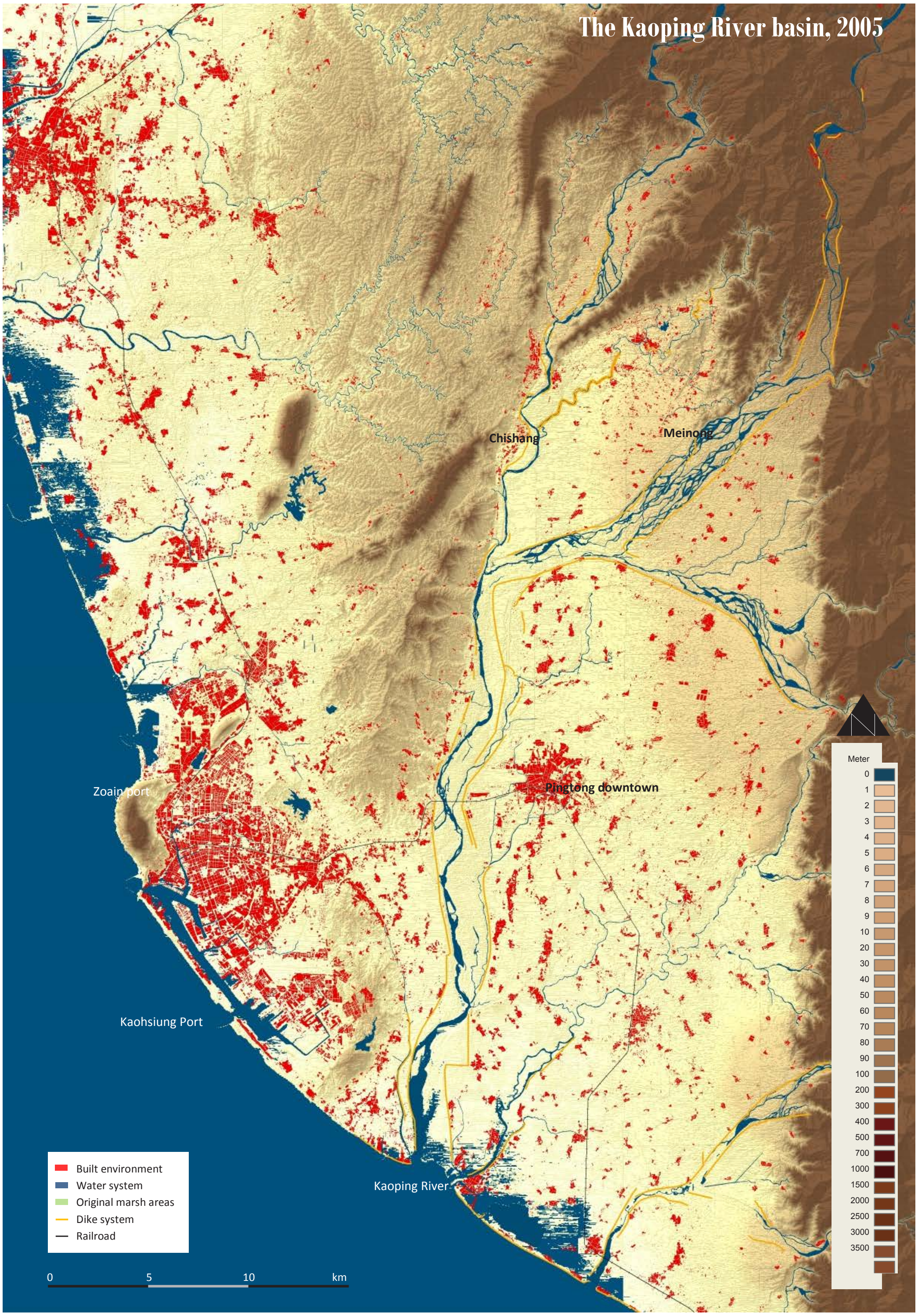
km


The Kaoping River basin, 2005
Chishang
Meinong
Pingtong downtown
Zoain port
Kaohsiung Port
Kaoping River
Built environment
Water system
Original marsh areas
Dike system
Railroad
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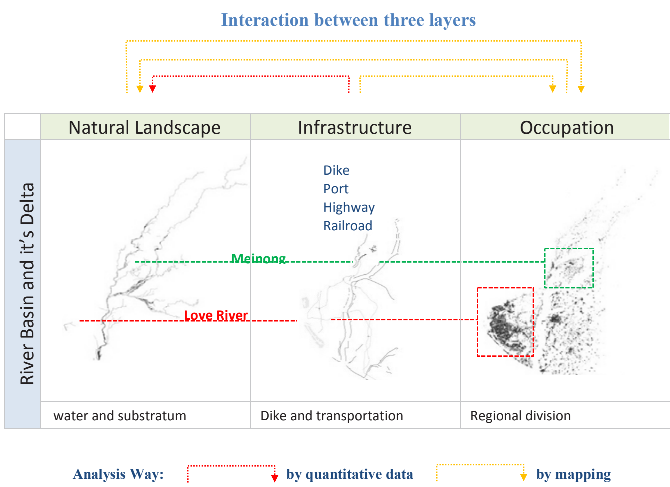
§ 3.5 The Interaction Analyses between 3 Layers

The diachronic portrait of three layers: natural landscape, infrastructure and occupation, reveals that although the infrastructure, such as hydrologic engineering and transportation networks, laid the foundation for the regional division and rapid urban development of Kaoping Delta since the construction of Kaohsiung Port 100 years ago, it also largely changed the original water context. The Kaoping Delta was rich with natural wetlands and marshes before it was developed and transformed into a dense urbanised area due to the great demand for development during the past century. There are two main areas of impact areas from this change. First, the new dike system narrowed and changed the original river channel, which reduced the capacity to channel water, raised water levels, decreased capacity to recharge groundwater, and increased river discharge. Second, because rapid urbanisation results in a large and increasing amount of urban pavement, more and more rain runoff drains directly into urban drainage, which largely increases river discharge. In Taiwan, the flooding risk of rapidly increasing discharge resulting from spatial development has been dealt with via hydrological engineering technology, namely, by the control over the infrastructure layer. This type of solution faces a new challenge under the effects of global climate change. The question is: what are the alternative options? A further research into the inter-relationship between different layers is necessary to illustrate crucial effects and mechanisms of delta transformation which can help to inform the creation of an integrated policy.



§ 3.5.1 Hydrology (Dike system) + Water (Surface) Changes in surface water and reclamation

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The completed dike system along the main Kaoping River bank not only eased damage to freshets but also pushed urban development without the limitations of environmental conditions. Both the Japanese twin-core structures, which connected Kaohsiung (an export port) and Pingtung (a distribution centre) by railroad, and Taiwanese industrial centres, which connected the export processing zones by highway, were based on the construction of dikes. For this reason, planners can develop delta cities by totally following a transit orientation, without environmental limits. However, the construction of dikes has obviously affected the flow of the natural water system (Fig. 52). Because the channel has been changed, the original riverbed has become farm land, which was called Ho-Ba-Tian, which means the land reclaimed from damming the river. The path change of natural water did not cause any problems at that time. On the contrary, the reclaimed lands were viewed as a fruitful reward from flooding. In fact, the more serious problems happened several decades later from a combination of other issues.

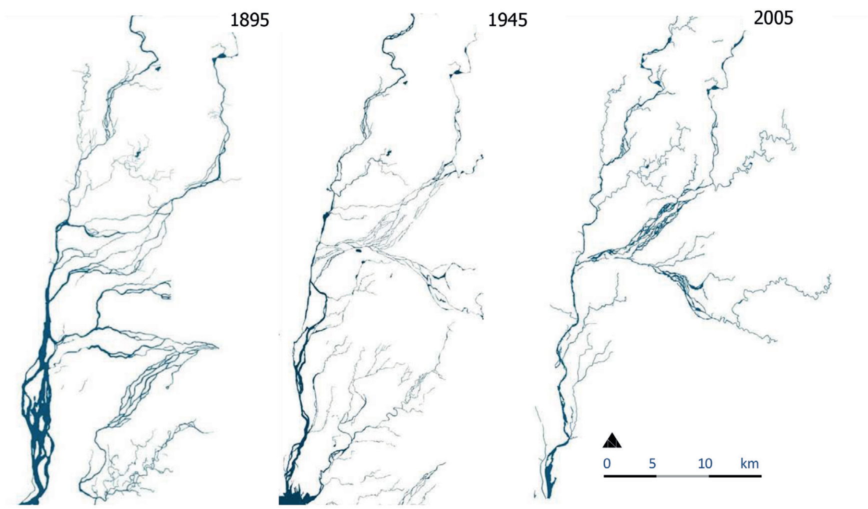


Figure 52
The transformation of riverbed of the Kaoping River (Source: Based on Academia Sinica ed. 2010; Map by author)

According to the Japanese records, the construction costs for flood management in the Kaoping River was about 7.32 million dollars. River-reclamation of 5,997 ha, erosion-free lands of 12,322 ha and flooding-free lands of 6,783 ha were regained after the construction. The total amount reclaimed was 25,102 ha. Among them, river reclamation occurred on land which was originally riverbed. Erosion-free lands are the areas which flowed through and were eroded by river water during heavy rainfalls. Flood-free lands are the lands which were often flooded in the rainy season. All of these lands were either the original riverbed or the floodplain, most of which had been used to farm sugarcane (Fig. 53).

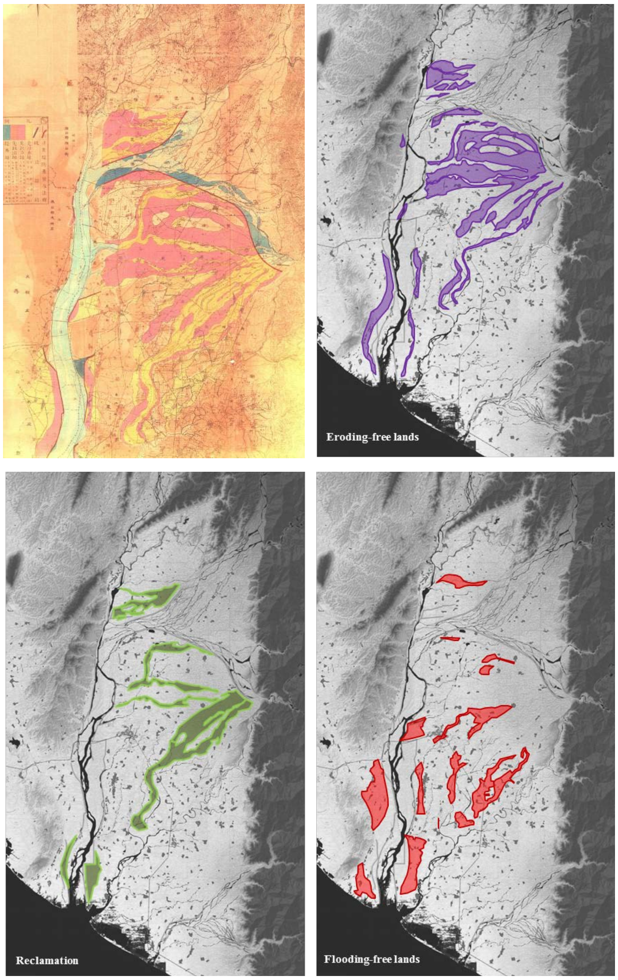


Figure 53
The reclaimed lands after the completion of the dike (Source: Based on LGR 2005; Map by author)

§ 3.5.2 The narrowed channel and rising river levels

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The new dike system not only changed the path of the surface water but also raised the original river level. This increases the risk of overflow and the burden on the dike. Furthermore, rising river levels also increase the rate of river flow, which increases the risk of dikes damage/erosion. The rising river levels mainly result from the reshaping of water and the decrease of infiltration and evaporation by dikes. Because the width of the channel was narrowed, the water originally outside the dike will be added to the water inside the dike under the same conditions of river depth and discharge. In addition, because the narrowed channel also reduces the interface area between water and air or land, a decreasing amount of water will infiltrate into the ground and evaporate into the air. The water which originally should be groundwater or vapour continues to flow on surface. The added discharge raises the river level as well. Because the elevation of the waterfront along the Kaoping River is lower and the discharge is greater than the downstream area than in the midstream area, there is a strong effect of river level rising in the lower reaches (Fig. 54).

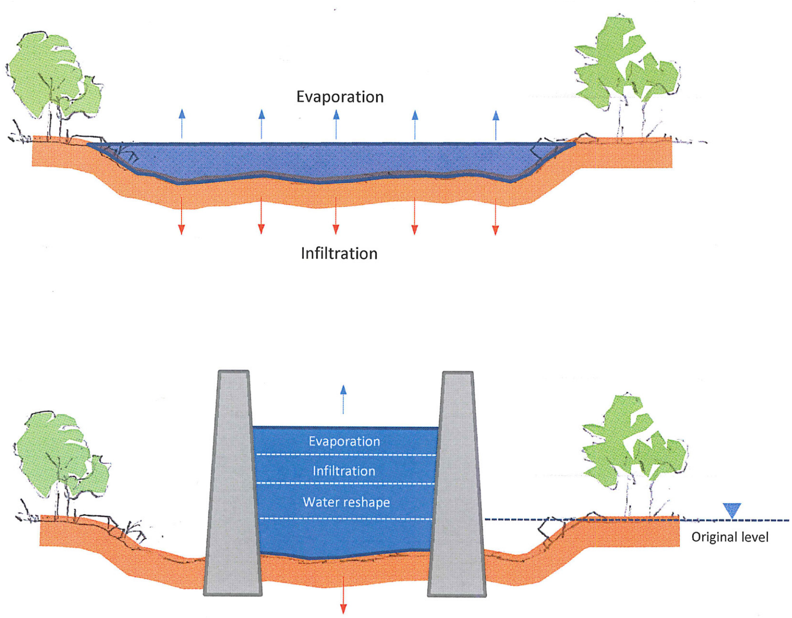


Figure 54
The change mechanism of river after the completion of the dike (Graphic by author)

§ 3.5.3 The backwater effect of tributaries

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Because of the change of the river's path after the construction of the dike, most water flows directly into the main stream along the dike system. This increases river discharge and water levels. In addition, the reshaping of water and the decrease of infiltration and evaporation raises the river level as well. The increasing discharge and river level puts pressure on tributaries to flow into the main stream, which results in the backwater effect to tributaries. It means water will be congested at the confluence of the tributary and main stream to form a water plug which will push water back upstream. This backward force extends along the dikes of branches toward to the upper reaches and causes an overflow at the end of dike. One example is the Meinong Creek, one branch of the Kaoping River. Although the dike in the lower reaches was built to connect to the dike along the main stream of the Kaoping River, it is difficult to build dikes or widen the channel in Downtown Meinong around the midstream, because the people had built houses right alongside the river. Thus, although the dike protected the lower reaches from floods, the backwater directly affects the Downtown Meinong around the midstream and causes serious floods. The report of the "Potential Flooding Areas in Pingtung County," compiled by the Taiwan Water Resource Agency, reveals most of the inundation areas are located around the confluences of branches and main stream or at the end of a dike, which illustrates the relationship between the backwater effect and flooding (Fig. 55).

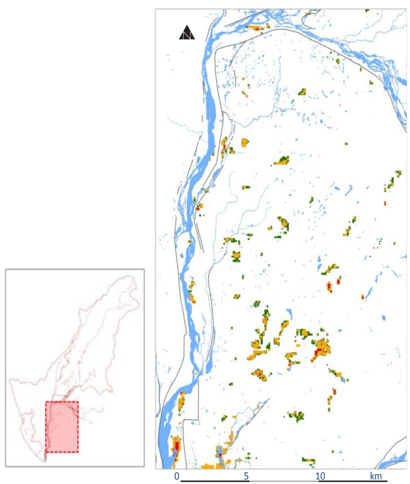


Figure 55

The potential flood areas of 24hr-precipitation of 600mm in the lower reaches plain of the Kaoping River (Source: Based on TGR 2011; Map and montage by author)

§ 3.5.4 Hydrology (Dike system) + Water (Groundwater)
The unbalance between groundwater use and infiltration

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

Although the new dike system’s changing of the original water path has greatly reclaimed a large amount of new lands which had suffered serious flooding or soil erosion in the past, it has also greatly reduced the recharging area of groundwater. Because most of those lands are located on the top of the delta, where the river just flows through the mountains onto the plains and begins to deposit sediment, the soil structure in these areas, mainly containing gravel and sand, is permeable. Water can infiltrate the ground very quickly. They are very important areas for the recharge of groundwater. The river water, which originally should infiltrate into the ground in these areas, is forced by the dike to keep flowing on the ground. This induces not only the increasing of river discharge but also the decreasing of groundwater recharge. Furthermore, because the dike protects the delta from flooding and helped reclaim a great amount of fertile lands, it promoted the rapid expansion of the human landscape in the delta. The residents living in these new expanding town areas still continue using the traditional way to obtain water from the groundwater. This stimulated the total consumption of groundwater. For example, the new immigrant population of 14,000 after World War II in Fengshan town relied only on three wells for their drinking water. Both water consumption and infiltration are two important factors to keep a stable groundwater system. The new dike system induced not only increased consumption, but also the decreased infiltration of groundwater. This resulted in a shortage of groundwater. The Hydrological Yearbook of Taiwan reveals this unbalanced groundwater system: the amount of groundwater infiltration was 1,664 million tonnes, while the amount of groundwater consumption was 3,797 million tonnes in 1936. The situation did not improve until 2000 when the Taiwan government forbade the use of groundwater due to serious land subsidence. The recharge amount of groundwater increased to 2,822 million tonnes and the consumption decreased to 1,630 million tonnes in 2000 (Fig. 56).

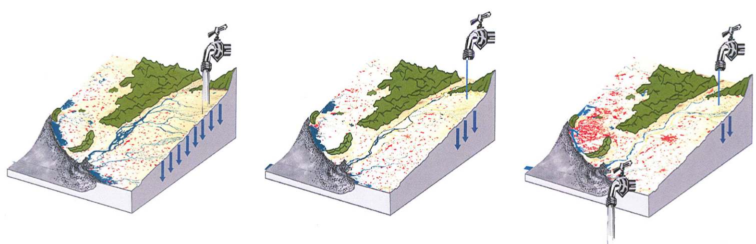


Figure 56
The image of the changing of groundwater utility in the Kaoping River Delta (Graphic by author)

§ 3.5.5 Hydrology (Dike system) and Soil Structure Land Subsidence

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The imbalance of the groundwater system will lead to a decrease in groundwater that originally existed within pores of soil, which will induce the drainage of deep and shallow surface clay layers. The soil will be compacted by its own weight and buildings, which will lead to serious land subsidence. Taiwanese ignored the imbalance of the groundwater system for a long time. In fact, the Taiwanese did not renew the related data of the Hydrological Year Book in 1936, when the data about the infiltration and consumption of groundwater could last be found, until 2000, when the Kaoping Delta faced the most serious problem of land subsidence. The soil structure gradually changed after the construction of dikes due to the continuing imbalance in the groundwater system, but the severe problem of subsidence did not emerge until the 1970's. Tiger Shrimp were the straw that broke the camel's back.

In the 1970's, Taiwanese invented a new technique to breed tiger shrimp which caused shrimp farms to become a high profit business. The largest shrimp farming area once reached to 1945 ha. along the coast of the delta. Although breeding tiger shrimp is marine aquaculture, a huge amount of fresh water is still needed when the water salinity of fish ponds increases due to evaporation during the procedure. The abundant groundwater in the Kaoping Delta was the best option. Although this shrimp business was suspended in 1988 due to an unknown shrimp disease, the abuse of groundwater caused an irrecoverable land subsidence damage (Fig. 57).

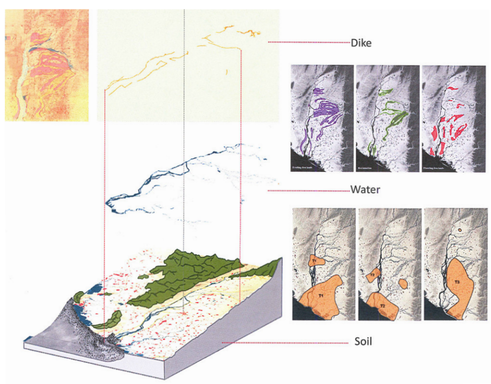


Figure 57
The impact of decreasing groundwater recharge on the soil structure (Based on LGR 2005; Graphic, map and montage by author)

§ 3.5.6 Traffic System and Water (Surface) - Bridge piers and sedimentation

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The first bridge on the Kaoping River was built for the railroad by Japanese colonial authorities in 1913. After World War II, the dramatically increasing amount of automobiles promoted the demand of for roads. Besides the railroad, at present there are seventeen bridges across this river: six roads across the main stream and eleven roads across the tributaries of the Kaoping River. Because the riverbed of the Kaoping River is wide, most of the bridge piers have to be built on the riverbed itself. This greatly reduces the effective cross section area of the river. For example, the first bridge was built by Japanese for trains and is 1,526m in length, supported by 23 piers. Each pier comprises three elliptic pillars, whose width are 2.8m, 3.3m, and 4.45m, respectively (Lin, C. et al. 2008). Stacked together, the effective cross section area of the river decreases 703 m2 which is equal to 1.7 times the area of a basketball court. Bridge piers disturb water flow. Many eddies are formed when water flows through piers, inducing the beginning of sedimentation. This is one of the major causes of serious riverbed silting (Fig. 58).

§ 3.5.7 Traffic System + Soil Structure - The lag sedimentation in estuaries

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The Kaoping Delta is a wave-dominated delta. The sediments in estuaries are transited to the coast line by currents, which is the main source of coastal sand. That is to say there are two contrary effects which impact the transformation of the coast. On the one hand, sea currents extend the delta coast if the sediments around an estuary are abundant enough to be carried by currents to the coast line. On the other hand, sea currents erode the coastline. Thus, when sedimentation occurs in the middle stream due to the disturbance of water flow by bridge piers, the lag sedimentation in the estuary of the Kaoping River will result in severe erosion along the coast of the Kaohsiung Port. A plan that was prioritised for silt-dredging after Typhoon Morocot in 2008 shows that the severely silted reaches of the river are highly related to the locations of bridges (TGR 2009). In addition, because the dikes changed the path of the river flow, water congested at the confluence of the Lounong Creek and the Qishang Creek, another severely silted reach. The total amount of dredging silt in this plan is more than 8 million tonnes, which would require 2,200 truckloads per day for an entire year. A coastal investigation from 2002 to 2010 revealed that the coast line had retreated 50m to 100m inland; in some areas had the retreat even reached 200m (Fig. 59).

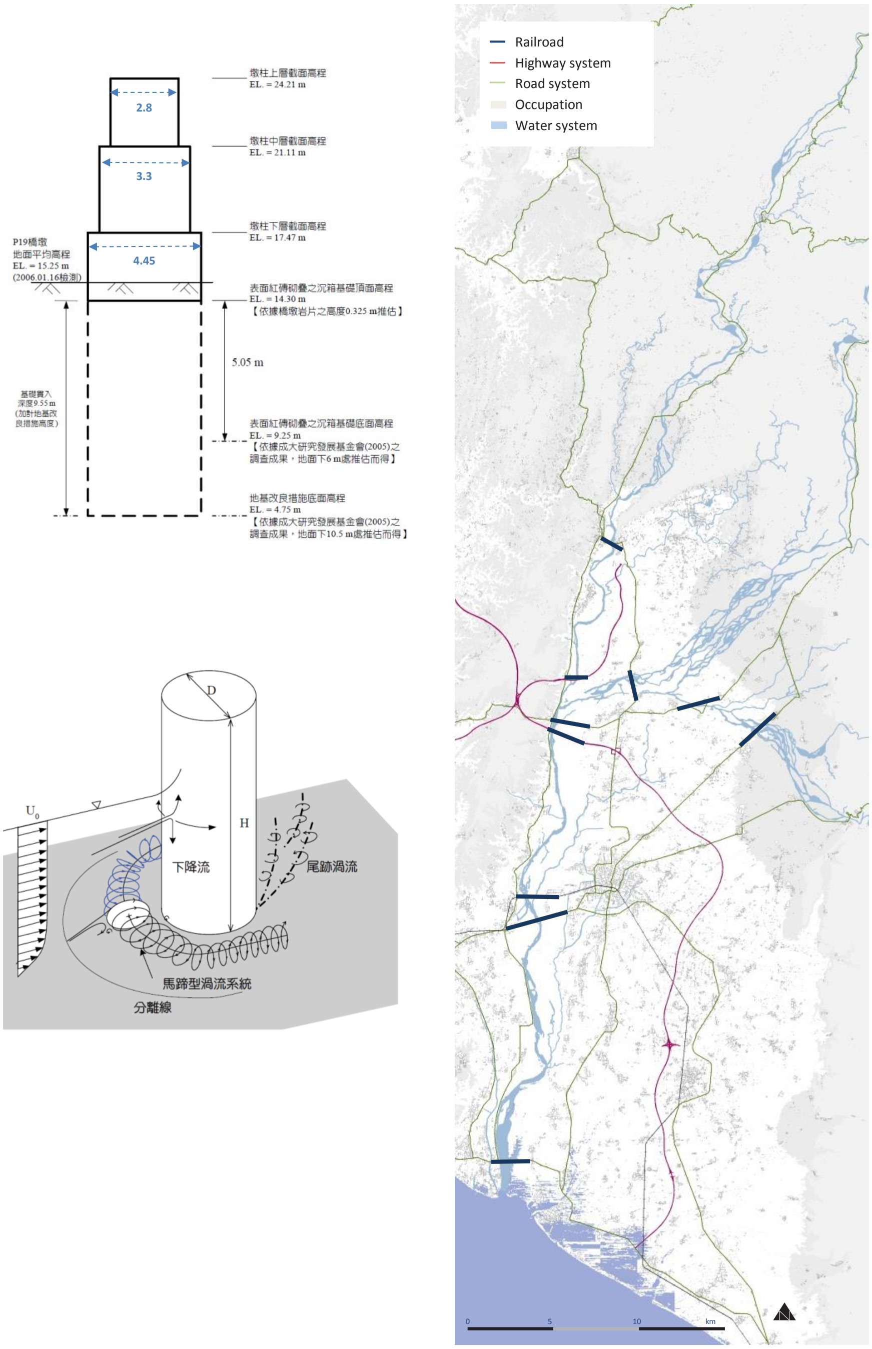
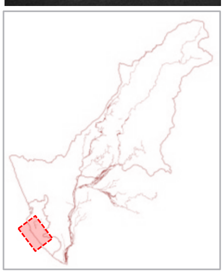
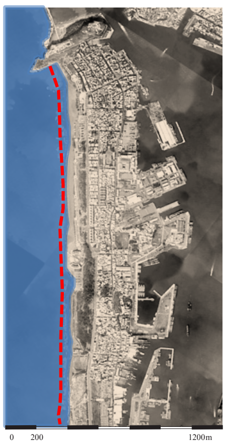


Figure 58

The impact of bridge piers on the lag sedimentation of the river (Right): The locations of bridges on the Kaoping River (Map by author); (Up-Left): The pier section of Kaoping Iron Bridge, Source: (Source: Lin, C. et al. 2008) (Dow-Left): The beginning of sedimentation behind a pier, (Source: Lin, C. et al. 2008)

No	Location
1	Between Bowlay No. 1 and 2 bridges
2	Between Lioqai and Zingfa bridges
3	Between Zinwei and Tsoumio
4	Upper Ligun Bridge
5	Between Lilin and Ligun Bridge
6	Upper Nanzisien bridge
7	Sechali
8	Between old and new Chiwei Bridge 01
9	Between old and new Chiwei Bridge 02
10	Shennon Bridge
11	Around Ailio bridge
12	Chenzin
13	Between Cose and Gwafu Bridge
14	Between Siechun and Kaoping bridge
15	Between Kaoping bridge and Tsokonzwu
16	Wandan Bridge
17	Moalin area
18	Dashu
19	Nanhwa Bridge
20	Zinwei Bridge
21	Between Dazin and Zinlio
22	Between Gwanzin and Nanhwa
(yellow dot)	100,000 m^3
(red dot)	500,000 m^3





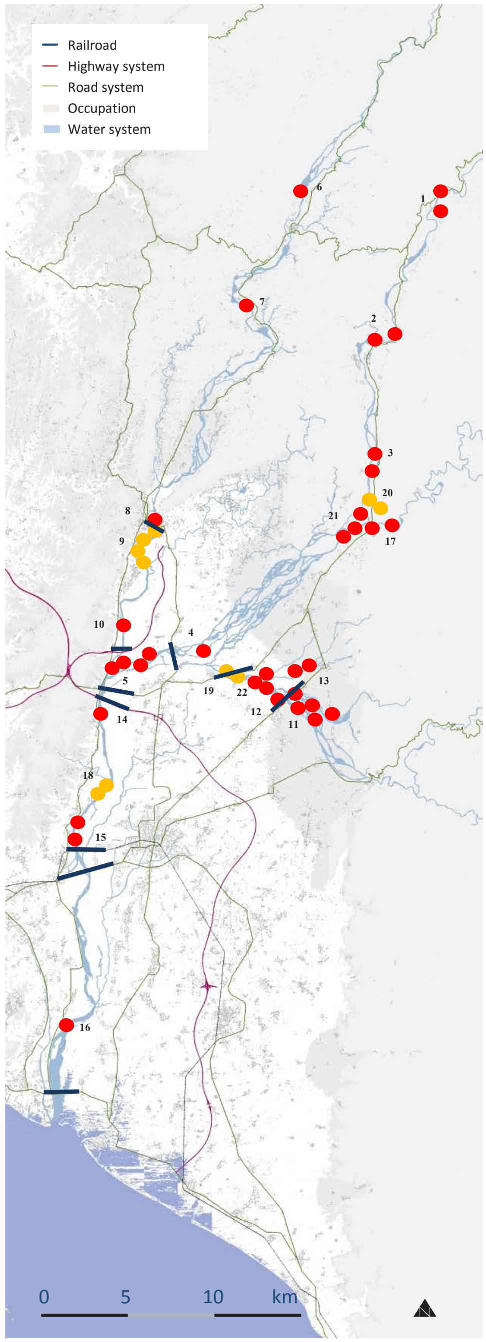


Figure 59

The impact of lag sedimentation on coastal erosion. (Right): The plan of riverbed dredging after Typhoon Moracot (Source: Based on Huang, Y.P. 2010; Map by this research) (Up- Left): Dredging work on the riverbed of the Kaoping River after Typhoon Moracot, (Source: Young, W.F. 2009)(Down-Left): The coastal erosion of Kaohsiung from 2002 to 2010; the red dashed-line is the coast line in 2002 (Source: LGR 2011b)

§ 3.5.8 Traffic System and Land Use - The expansion of agriculture

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

From the time of the construction of the Kaohsiung Port to 1937, the population of Kaohsiung and Pingtung increased to 40,000 and 80,000 respectively. This triggered the beginning of urbanisation in the Kaoping Delta. After World War II, Kaohsiung was designated to have the role of the heavy industrial centre in Taiwan. An enormous number of workers immigrated to Kaohsiung City following the rapid development of the harbour, export processing parks, and heavy industrial factories. The population of Kaohsiung increased to one million from 1945 to 1976, and reached its peak of 1.6 million in the 1990's. The rapid development of spatial urbanisation pushed the agricultural activities toward the margin of the city. Most of them moved to the upper and middle reaches of the river within the mountain areas due to a convenient transportation system (Fig. 60).

The rapid increase of population stimulated demands for agricultural products for the populace's daily lives. Cultivation in the mountain areas was a good investment with high profits and low costs given the reduction of farming fields in the delta plain. Thus the primary vegetation type in the mountain area shifted from protophytes to fruit trees and vegetables. Among them, the betel palms are popularly because their nuts are strong stimulants usually used by manual workers to sustain themselves during their long working day.

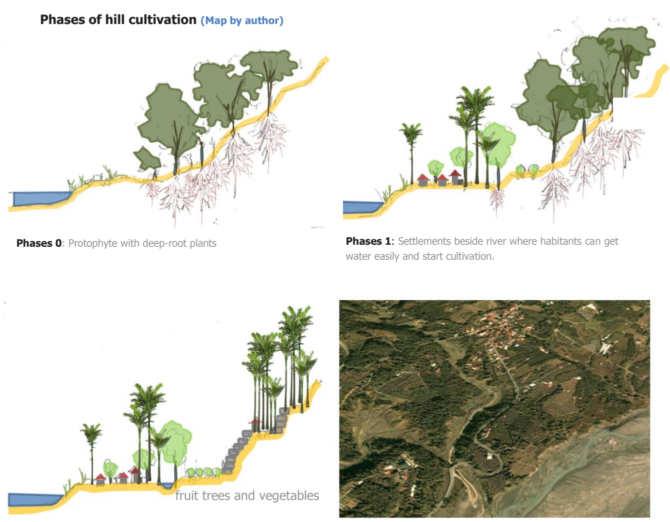


Figure 60
The effect of urban sprawl on the surrounding hills (Source: Google map)

§ 3.5.9 Traffic System and Land Use - The cultivation of hills and mudflows

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

In general, people build houses in valleys as a base for hill cultivation where they can draw water easily from the river and then gradually reclaim their farming fields near remote mountains. The first step of hill cultivation is to remove the existing vegetation and then to improve soil fertility. Thus, the surface soil structure to a certain depth has been totally changed. Most of these high-profit high-reward plants have fine shallow roots which cannot effectively grab soil on the ground when a huge amount of storm water flows through. Under these conditions, serious landslides can occur. In addition, farmers always eliminate other plants in order to give their plants the best environment to grow. This practice also exposes soil directly to the erosion of storm water, and accelerates the erosion of the surface soil.

These cash crops have growth cycles that range from several months to several years. Farmers have to soften the soil and improve the soil fertility, which transforms the soil structure from hard to soft. The softened soil can be eroded very easily by rainfall and become mudflows. The mudflows flow down to the valley and into the river, causing a serious threat not only to the safety of the villages in the valleys, but also to the burden of the dikes in the middle and lower reaches. For example, a very serious mudflow which resulted from Typhoon Morocot in 2008 buried a whole village and claimed 398 lives (Fig. 61).

Figure 61
Abusive of cultivation on hillside (Source: Google map)

§ 3.5.10 Traffic System and Spatial Pattern - Two structures of grid system

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The grid street system was an enduring Japanese concept in the development of cities in Taiwan. The grid system satisfied the goals of the colonial government to construct a spatial pattern with highly efficient logistics, reduced costs and time, and the most flexible pattern for future expansion. The urban plans of Kaohsiung City and Pingtung City fully embody this concept. Furthermore, based on the grid system, two different grid systems were designed in order to suit the different functions of Kaohsiung as an export port and Pingtung as a distribution centre. The grid roads for the export port were pointed directly toward piers to maximise efficiency of delivering goods. The grid system for the distribution centre comprised four grid systems as a radial-grid pattern along main traffic roads for maximum efficiency of collecting goods (Fig. 62). This traffic orientation design simultaneously dominated the following plans of land use and public facilities, including the entire urban pipe system. This meant that all drainage had to be arranged as a grid as well. The grid drainage increased the risk of water congestion during a storm. In addition, the grid urban block system changed the way water flowed on the surface ground. The risk of flooding significantly increases when the runoff from storm water flows along the grid street and accumulates in low-lying areas.

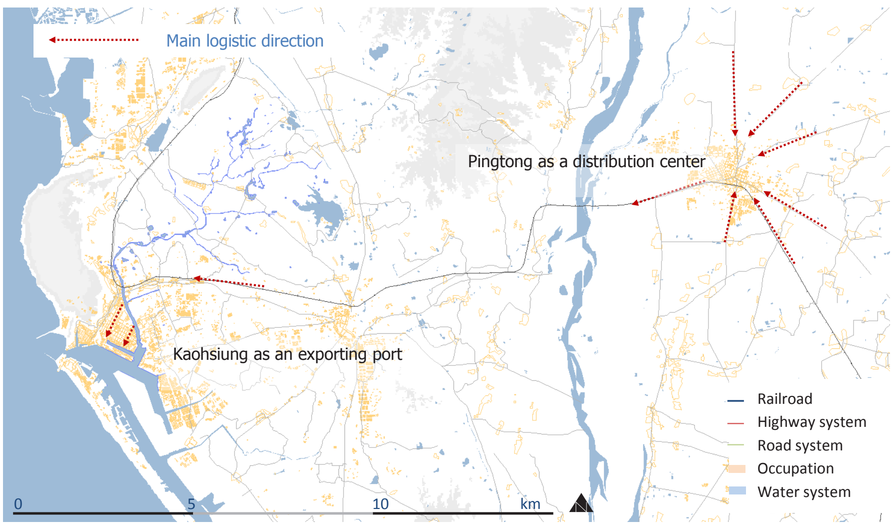


Figure 62
The major transportation pattern of the Kaoping Delta during the Japanese colonial era (Map by author)

§ 3.5.11 Spatial Pattern and Local Hydrology - The change of storm water flow

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Delta	Urban

The floods in Pingtung City are good examples to illustrate the impact of the grid street on urban inundation. The Chong-Lan-Zwin Canal (崇蘭圳), the One-Nein Creek (萬年溪) and the Sa-Sir Creek (殺蛇溪) are three main waterways that collect most storm water from drainage and surface runoff in Pingtong City (Fig.63). The main direction of water flow in this area is from northeast to southwest. The aforementioned radial-grid structure is directly on the path of storm water flow. Because the drainage and the road system were built mainly along the radial-grid pattern rather than natural water contexts, the storm water which flows through downtown is rerouted and can easily become congested at some points. This leads to flooding problems mainly in two areas.

First, a large amount of storm water coming from the northeast outside downtown will be blocked and then clogged in the northeast part of the radial-grid structure. The blocked storm runoff then changes its path and flows directly to the One-Nein Creek or the Sa-Sir Creek. Floods occur in this area when an enormous amount of storm water exceeds the designed capacity of these two creeks, e.g. the floods in 2005, 2007, and 2010 (LGR 2007; Dawa News 2010). Second, when the runoff of storm water has flowed along the radial-grid structure into downtown, it will easily become congested at the intersections of four grid systems. Floods occur in the downtown area due to an overloaded drainage, e.g. the flooding in 2006 (LGR 2007) (Fig. 64).

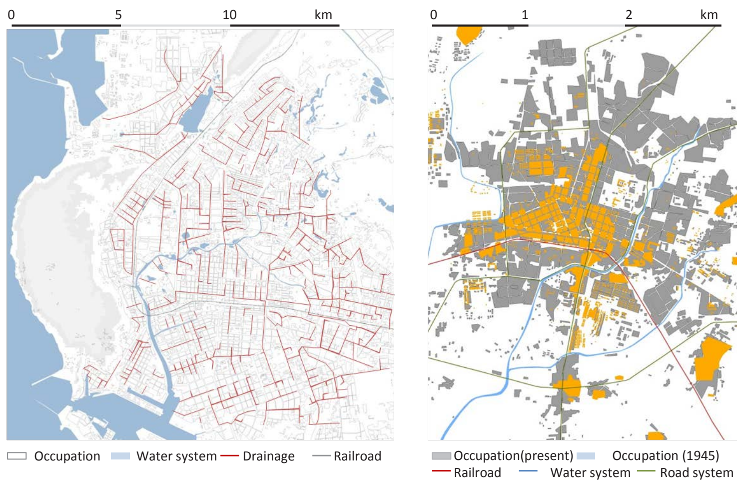
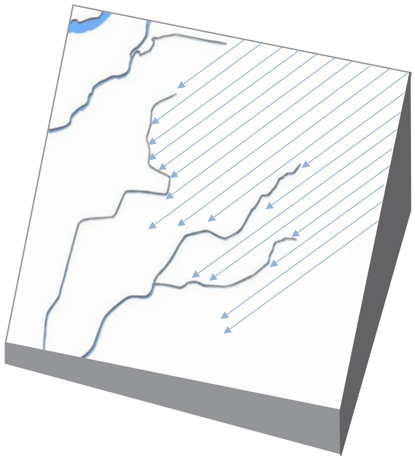
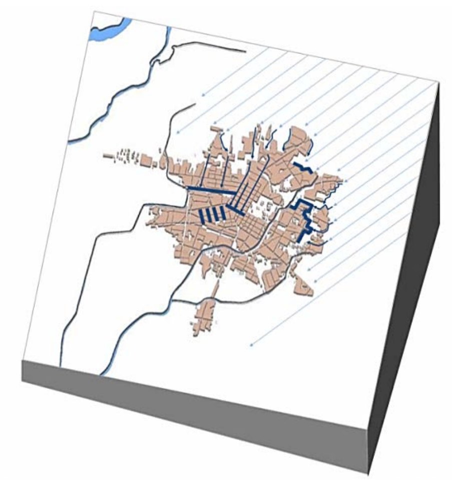


Figure 63

The storm water drainage in the Love River basin; (Right): The radial-grid urban pattern in Pingtong City; the yellow part is the spatial pattern in 1945 (Map by author)



Original water flow way



Flow way has changed
when urban constructions
block the ways

The historical flooding areas in Pingtong City; Dark pink part is the present occupation; Light pink part is occupation in 1945; Blue line is the water system; Dark blue part is the flooding area in 2007; Light blue part is flooding area in 2010.

Original data: 2010-10-12, Dawa News (大華晚報); Pingdong City vol.299 (屏東市政299期，2007/09)

Figure 64

The changed over-land flow path of stormwater (Map by author)

§ 3.6 Conclusion: The Transformation Model of the Kaoping Delta

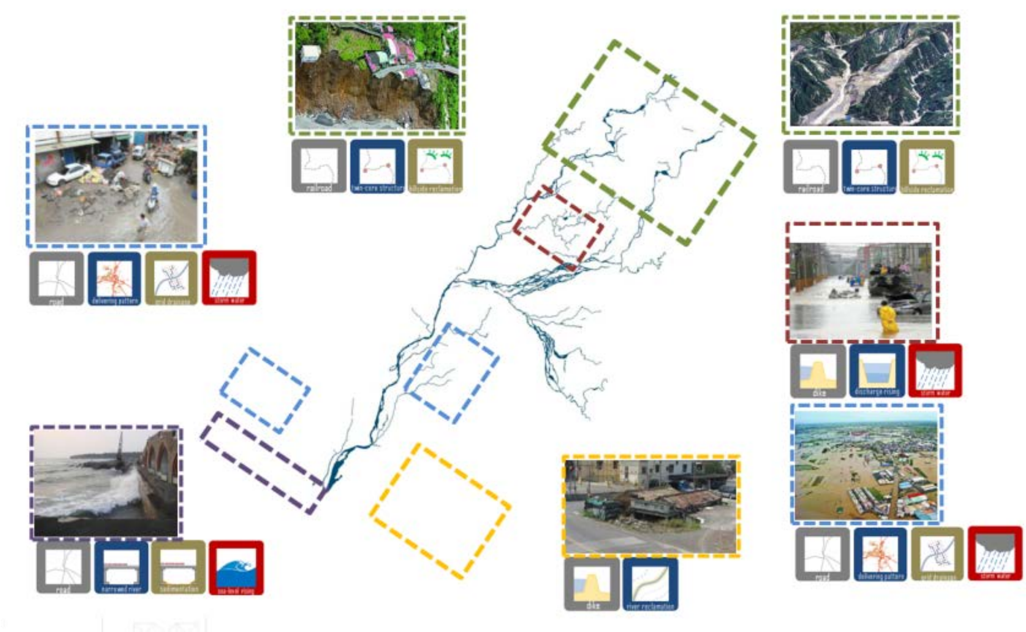
The natural landscape of the Kaoping Delta has been greatly transformed in the past century since the Japanese colonial authorities developed the delta urbanism as a twin-core structure. This study classifies the physical factors which might affect the transformation of water contexts into three main layers of natural landscape, infrastructure, and occupation in order to explore the inter-relationship between these factors. Some crucial causal relationships between the different layers can be found in this study (Fig. 65).

First, although the construction of dikes has protected the settlements in the delta from inundations and provided the Kaoping Delta with a significant amount of fertile land for agricultural development, it canalises the original river channel and greatly decreases the width of river. This change to the riverbed not only increases the discharge and the water level of the river but also reduced the infiltration of ground water. The increase in water discharge and water level blocks distributaries from flowing into the main stream and then leads water congestion at confluences.

Second, the rapid development of transportation not only promoted the development of hillside agriculture but also increased the demand for building bridges. The cultivation on hills induced the liquefaction of soil during storm rainfall and then led to serious mudflows which is a deadly threat to the middle and lower reaches of the river. In addition, a great number of bridge piers caused the sedimentation lag around the estuary which caused a huge amount of sediment to be deposited in the river channel rather than in river mouth. Serious erosion of the coast occurs when the sand supply from the river mouth has been disrupted.

Finally, the construction of dikes provides favourable circumstances to develop a traffic-orientation space without any limitations from the river. Thus the grid street system has been adopted as a main concept to develop the delta cities since the Japanese colonial period. The grid street system greatly changed the natural path of water flows. Urban inundations will likely occur in places where storm runoff is very easily clogged.

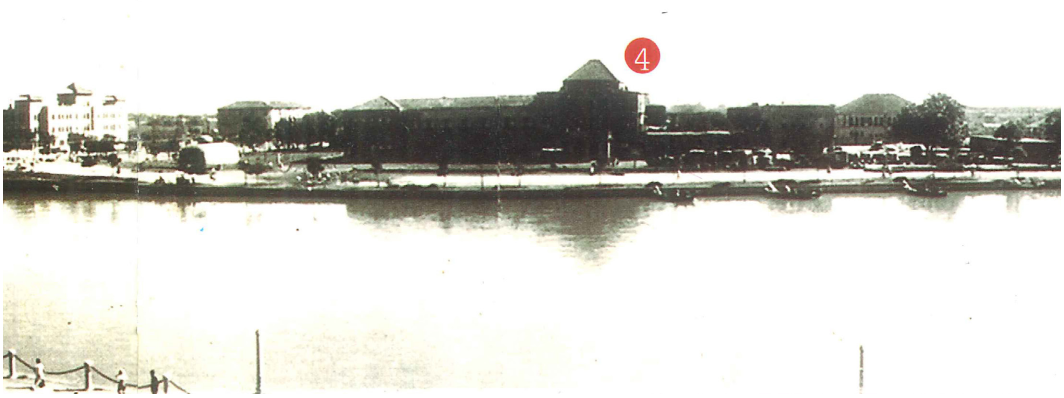
Problem analysis on the aspect of river basin



Key Intervention	Direct Effects	Indirect Effects	Natural Pressure	Problems
dike	river reclamation **Reclamation** The waterfront has been fixed by dike for reclamation. The disappearance of flooding plain has dramatically decreased water infiltration.		storm water **Typhoon Fanapi, 2010** 600mm, 6hr **Typhoon Morakot, 2009** 3,000mm, 4days **Typhoon Jangmi, 2008** 1,000mm, 12hr **Typhoon Krosa, 2007** 1,000mm, 1day **Typhoon Haitang, 2005** 2,300mm sea-level rising **The tide range of the Kaohsiung Port is around +/-75cm. The rise of sea level is about 0.37cm per year in last decade**	Landslide Urban flood Floods inside the dikes Land subsidence Coastal erosion
	discharge rising **Discharge rising** The disappearance of flooding plain let the water flow into main stream, which raises discharge and water level.			
railroad	twin-core structure **Twin-core structure** The railroad connected Kaohsiung Port and Pingdong City which had been two most urbanised areas on the Kaoping Delta.	hillside reclamation **The over-use of hillside** The rapid urbanization had promoted the development of agriculture in rural areas. Since most of the available farm had been occupied in plain, hillside became a good option.		
road	narrowed river **Bridges as obstacles** There are 7 bridges crossing the lower reaches of the Kaoping River which is about 38 kilometers in length.	sedimentation **Obstacles and Sedimentation** The columns of bridges block sediments delivering to the estuary.		
	delivering pattern **Delivering orientation** The spatial pattern which was based on grid system had mainly developed along major traffic lines.	grid drainage **Grid drainage** The grid spatial pattern has dominated the form of urban drainage. Water flowing in urban area has to flow along the direction of the roads.		

Figure 65

A comprehensive analysis framework about all factors and their locations (Montage by author)

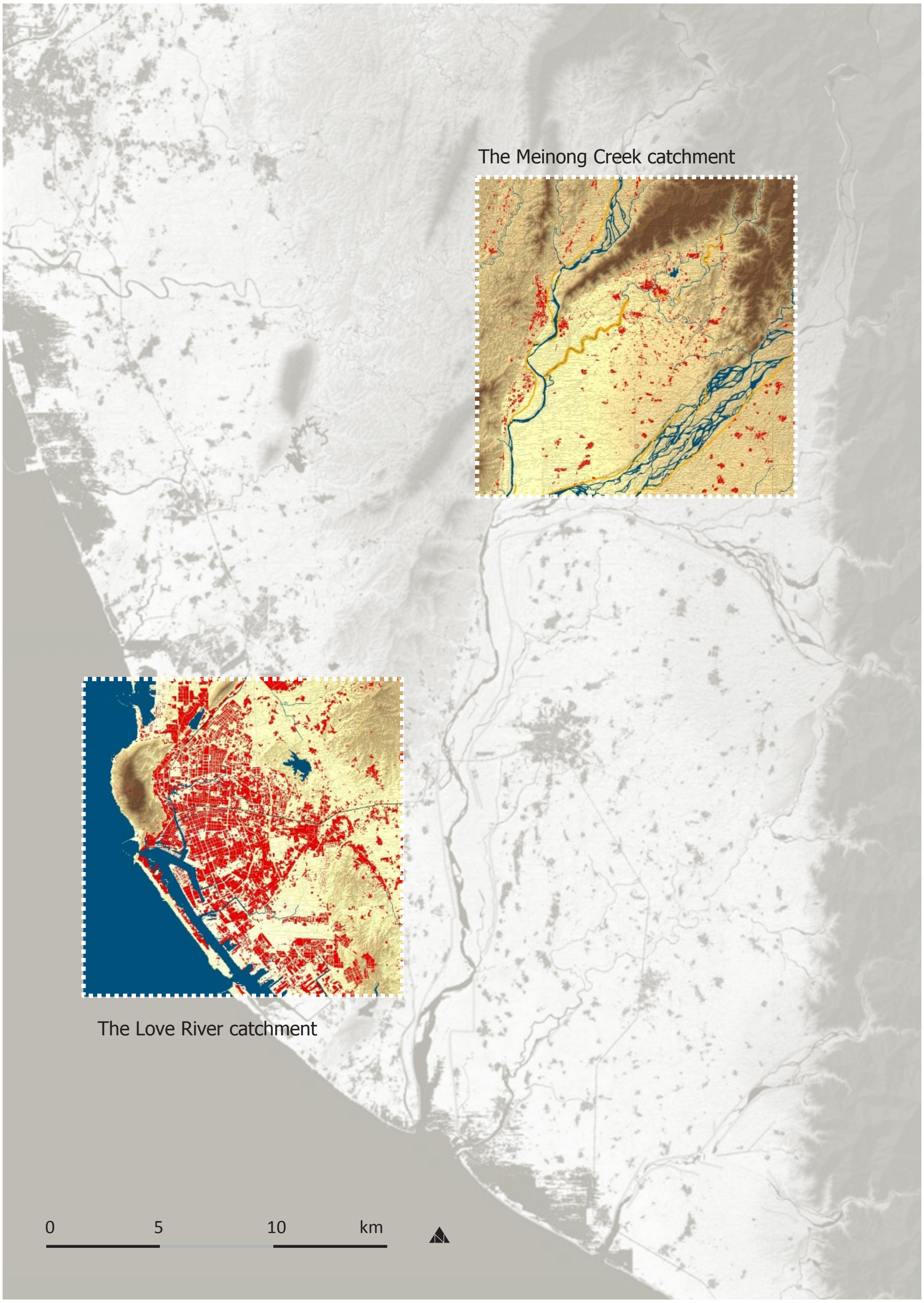


The Love River in 1950: (4) Kaohsiung local Court. Source from LGR 2005 provided by Yu-Ru Lin (林育如)

4 A Down-Scale Portrait of the 3-layer Case studies of the Meinong River and the Love River

Based on the aforementioned inter-relationship between the different layers of the Kaoping Delta, this section will further explore how the transformation in a delta scale can affect the inter-relationship between spatial urbanisation and natural water contexts at the city scale. Two tributary catchments, the Meinong Creek and the Love River, are chosen as examples. These two areas have a higher risk of flooding on the Kaoping Delta, and are respectively located at the upper and the lower reaches of the alluvial fan on the delta. The Meinong Creek is located on the upper fan of the delta, the location of the most important infiltration groundwater area in the delta. Because the soil is mainly comprised of sand and gravel, the soil texture in this area is porous. The runoff water on the ground easily permeates into the ground, resulting in a low level of ground water. Residents of this area in the past typically built their houses beside the river in order to obtain water more easily. On the contrary, the Love River catchment is located on the lower portion of the alluvial fan where Japanese built a gridded road system to support the working of Kaohsiung Port. The natural landscape, the water context, and the spatial pattern in the Love River catchment area are quite different from that in the Meinong Creek catchment area. This section will use a down-scale analysis of 3-layers to explore how these three layers interact together in delta cities.

The Love River in 1950: (5) The Rose Catholic Church. Source from LGR 2005 provided by Yu-Ru Lin (林育如)



The Meinong Creek catchment
The Love River catchment
0
5
10
km

§ 4.1 The 3-layer Portrait of the Meinong River Catchment Area

§ 4.1.1 The Natural Landscape Layer

MEINONG

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The Meinong Creek catchment area is located on the upper reaches of the Kaoping Delta's alluvial fan with hills surrounding the west, north, and east sides. This is the region where the Kaoping River flows directly through the Central Taiwan Mountain Range, into plains, and starts its sedimentation process. Because gravel and sand are deposited first and comprise a porous soil structure, it is an important recharge area for ground water in the delta. The urbanised area is at the central plains area with an elevation of about 45m through which the Meinong Creek flows from the northeast to the southwest and into the Kaoping River (Fig. 66).

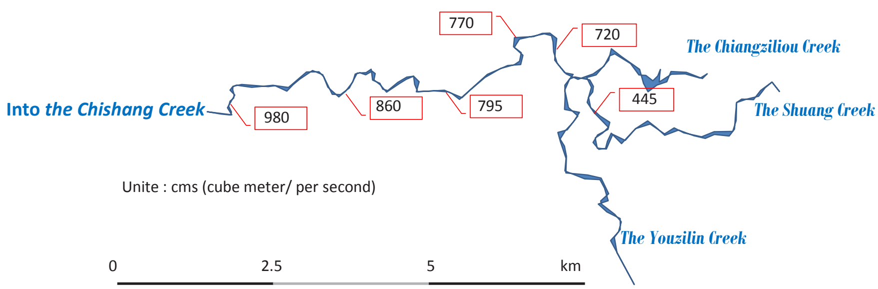


Figure 66
The maximum designed discharge of the Meinong Creek catchment area. (Source: Based on TGR 2005; Graphic by author)

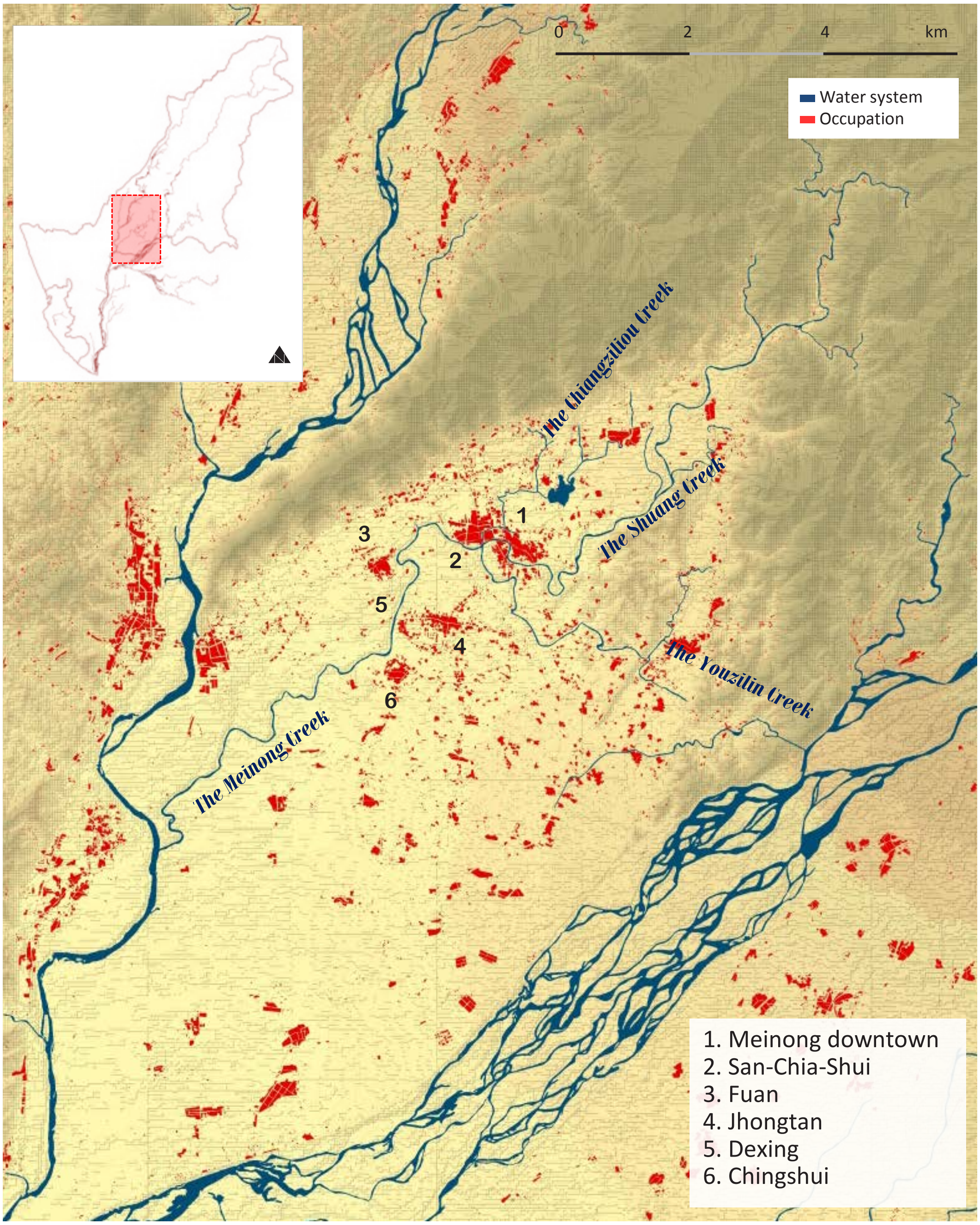


Figure 67
The Meinong Creek catchment area and the location of villages. (Source: Based on Academia Sinica ed. 2010; Map by author)

The Meinong Creek flowing through Meinong district is a tributary of the Kaoping River and is also a local drainage basin. It has been under the authority of the central government since 2000. The designed capacity of the riverbed is a 50-year return period; the largest designed discharge is 770 cms at the San-Chia-Shui area and 980 cms at the confluence with the Chishan Creek (TGR 2005). The current dike system ends at about Fuan village, because the downtown of Meinong is too dense to build a dike. In addition, because the slope of the terrain around the confluence of the Chishan Creek (旗山溪) and Meinong Creek is quite gradual, water easily congests and flows back if the Chishan Creek is simultaneously in a high water level. The San-Chia-Shui area is a flood-prone area when the congestion of water elevates the water level.

Water system: A triangular location gathering the over-land flow from hills

The terrain of the Meinong Creek catchment area gently slopes down to the Kaoping River from the northeast to the southwest. The main creek consists of three major tributaries: the Shuang Creek (雙溪), the Chiangziliou Creek, also named the Jhongjheng Lake Drainage (羌子寮溪/中正湖排水) and the Youzilin Creek, also named the Jhuzimen Drainage (柚子林溪/竹子門排水). These tributaries gather the over-land flow from the hills on the three sides and converge at Sanjiashui (三洽水). The creek makes a U-turn to bypass some higher ground and then directly flows through Fuan village (福安里), Jhongtan (中壇), Dexing (德興) and Chingshui (清水) villages after flowing through the downtown area (Fig. 67). Because most of the river water comes from rainfall, the difference of water level between summer (rainy) and winter seasons is significant. The maximum designed discharge is based on the standard of 100-year frequency peak (TGR 2005).

The shape of the Meinong plain is like a gentle sloping triangle with two upper sides surrounded by hills (Fig. 68). The runoff of storm water from the hills gathers into three main tributaries and flows into the center of this triangle at the San-Chia-Shui area, around the downtown area. Because the creek water can quickly permeate deeply into the ground and slowly flow through the porous soil toward the southwest part of the upper triangle where the ground mainly comprises gravel and sand, the level of groundwater depth is usually lower than 10m in this area (Fig.68). The remaining water continuously flows into the main stream of the Kaoping River through the bottom part of the triangle, where the larger space functions as a floodplain. This catchment triangle illustrates an original mechanism of water system: a huge amount of storm water is collected in the upper area of the triangle and then either flows together into the Kaoping River or floods into the bottom of the triangle. This system provides the midstream of the Meinong Creek with a more livable and safer waterfront than the downstream area.

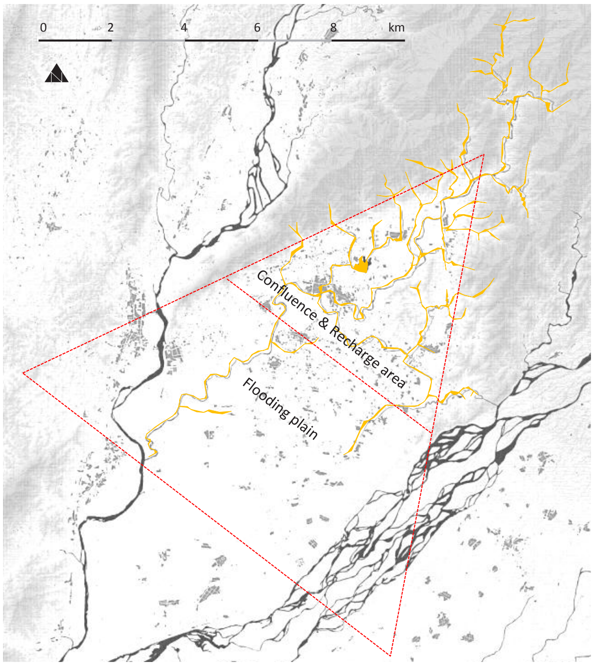


Figure 68
The water texture of the Meinong Creek catchment. (Source: Based on TGR 2005; Academia Sinica ed. 2010; Map by author)

Elevation: the irregular levee deposits surrounding downtown Meinong

MEINONG

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The gentle sloping terrain slightly undulates around the place where three creeks converge (Fig. 69), because the sediment due to the flooding of the Youzilin Creek has accumulated to form an irregular sand dune along its southern bank. The elevation of this sand belt is around 47-48m in height, which is higher than the elevation of the northern bank. Thus the Meinong Creek makes a U-turn here to bypass it. Compared to the height of this sand dune, several areas are relatively low lands, at around 43-46m in height, including the downtown area, the San-Chia-Shui area, and the areas between the Chiangziliou Creek and the Youzilin Creek from the Meinong Junior High School to the Kao-Mei Medicine College. Historical maps show that the riverbed in the upper reaches of the Meinong Creek has not changed too much since 1904. On the contrary, the lower reaches formed a more meandering riverbed because of the erosion of water.

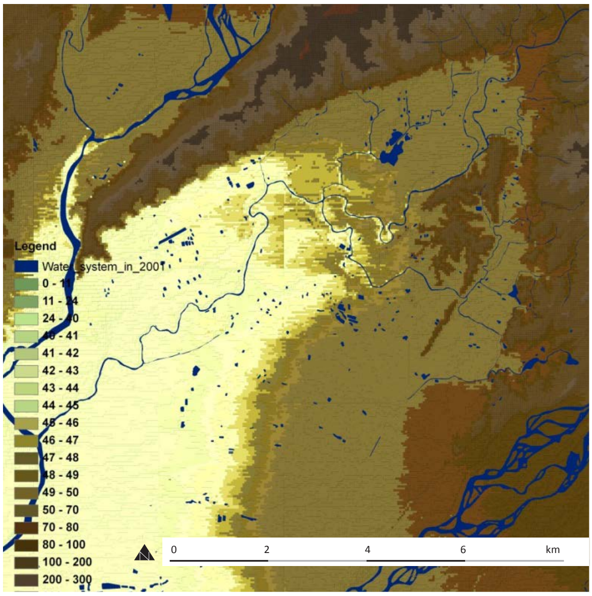


Figure 69
The elevation analysis of the Meinong Creek catchment area (Source: Based on Academia Sinica ed. 2010; Map by author)

§ 4.1.2 The Infrastructure Layer

Hydrological infrastructure

Meinong

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

Irrigation: The authority of irrigation in Meinong is the Farm Irrigation Association of Kaohsiung Taiwan. Because the ground level in the east is a little higher than in the west, the main water source for irrigation is the Laonong Creek in the east, through central Meinong, and finally into the Meinong Creek. The total irrigated area, including Jhongtan (中壇), Jiyang (吉洋) and Jhuzimen (竹子門) three main areas, is 4858 ha, which consists of the Sanjianshi-zhen (三尖石圳), the Xianren-zhen (仙人圳), the Shizitoa-zhen (獅子頭圳) and the Guishang-zhen (龜山圳) canal systems. Rice paddy fields are the main lands to be irrigated. The largest canal system is the Shizitoa-zhen canal system which has been extended many times. Its water source mainly comes from the discharged water of the Jhuzimen Hydroelectric Power Plant (TGR 2005) (Fig. 70).

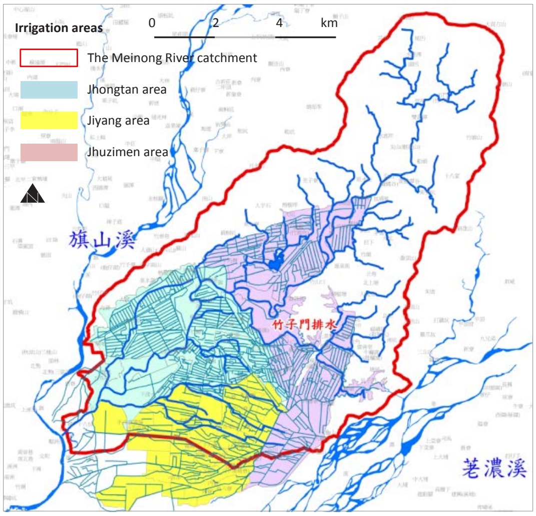


Figure 70
The irrigation network of Meinong (Source: TGR 2005)

Irrigation drainage

Surplus water from irrigation flows into the Meinong Creek via seven major drainages. Three of them are located on the right bank of the Meinong Creek. The slopes of all these three drainage beds exceed 1/100, because the relatively low land in the west is closer to the hill. On the contrary, the drainages located on the left bank have a drainage bed slope lower than 1/100, except for the Youzilin Creek. The Chiangziliou Creek and the Youzilin Creek are two major drainages areas in the upper reaches of the Meinong Creek. The average slope of the Chiangziliou Creek and the Youzilin Creek bed are 1/36 and 1/78 respectively. Due to the steep slope, the swift current can easily cause a backwater effect during a storm when they flow together into the Meinong Creek at the San-Chia-Shui area (TGR 2010) (Fig. 70).

Storm drainage

Storm drainage is mainly installed in downtown Meinong. There are five storm drainages labeled A through E. Storm drainages A and C have an outfall height of 43.6m and 45.1m, respectively, and flow into the Meinong Creek directly. Storm drainages B, D and E have outfall heights of 44.6m, 45.5m and 45.5, respectively, and flow into the Chiangziliou Creek. The catchment area of storm drainage is limited to the downtown area, and the main outfalls are all located at the San-Chia-Shui area. The system is therefore easily paralysed due to water backflow when the water level increases rapidly (TGR 2010) (Fig.71).

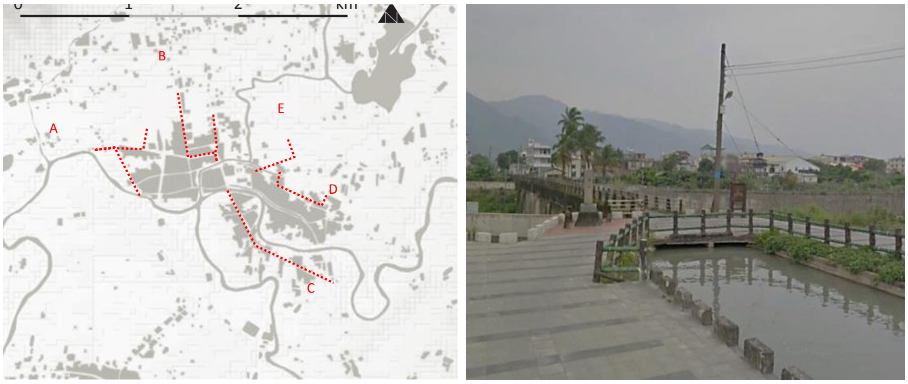


Figure 71
The rain drainage in the Meinong downtown area(Source: Based on TGR, 2010; Map by author)
The Meinong water bridge was built by the Japanese in 1927. (Map by author)

The intersection of creek and irrigation

The Meinong creek is separate from the irrigation system. Although there are two isolated water systems, the two still intersect due to the very dense fabric of irrigation on Meinong district. In order to solve the problem of this intersection, the Japanese colonial authorities built the Meinong Water Bridge to draw water to the Xiazhuangshui Irrigation (Fig.71 , Right). The width of this water bridge is 1.8m. A bike-lane was built on the channel in 1927 to cross the Meinong Creek. The Japanese colonial authorities also built a water pipe beneath the creek bed to cross the Meinong Creek for another intersection of irrigation.

The confluences of creek and main drainage

There are seven major drainages basins flowing into the Meinong Creek. The confluences of the creek and these main drainages basins appear as gaps in the dike system along the main stream. Furthermore, the backwater effect also paralyses the function of these major drainage basins due to the congestion of the main stream during storms. There are two ways to connect the creek and drainage basins within in the Meinong Creek. One is to extend the main stream's dike from the convergence points along the drainage bank to higher level ground, e.g. the Chiangziliou Creek and the Youzilin Creek. The other is for the main stream's dike system to directly cross the drainage system. A water gate controls the backwater effect of the main stream during storms. A ditch inside the dike is needed to drain storm water while the gate is closed. This method has been adopted for the remaining drainages basins which have a more gentle sloping drainage bed.

§ 4.1.3 The Occupation Layer - To derive water and to avoid flood

MEINONG

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The Meinong village dates back to the 18th century. The earliest settlers built houses on the northern bank of the Minong Creek (瀰濃河) and developed the first villages there. There were two main streets in the early village. One was the present Yong-an Street (永安街) along the northern bank of the Minong Creek and Meising Street (美興街) which runs from the confluence of three creeks directly to the northern mountain (LGR 1997) (Fig. 72). The elevation map of Meinong District further illustrates that there is a sand dune extending along the Youzilin Creek. We can roughly deduce that this sand dune results from the sedimentation of flooding surrounding the downtown area in earlier times. Mapping the settlement and water system maps in 1904 reveals that there were two main reasons to explain why the earliest settlers chose the northern bank of the Meinong Creek as their main settlement. One is that they could easily obtain water in this area, and the other is that they avoided living along southern bank of the Youzilin creek because it frequently flooded.

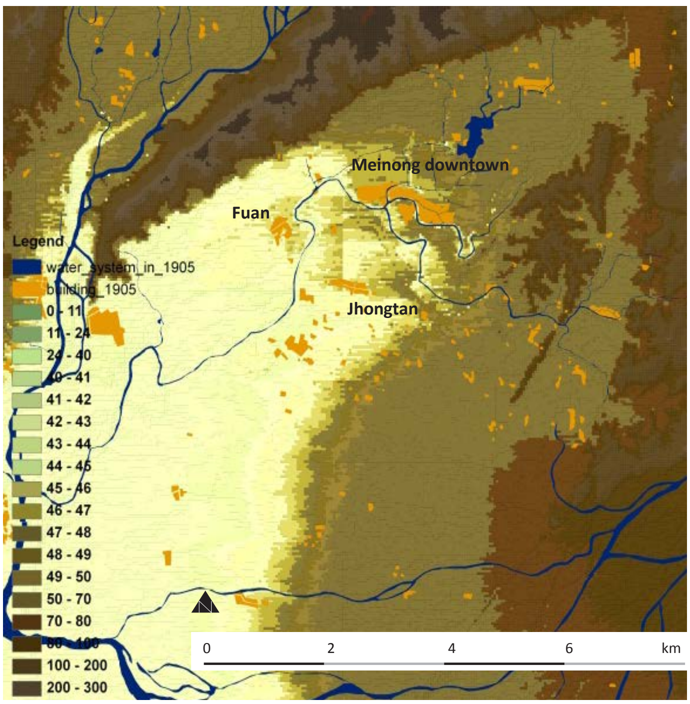


Figure 72
The relationship between human occupation and elevation

After World War II, agriculture was still the major local economy in Meinong. Instead of expanding the original downtown area, many small villages developed evenly along the alluvial plain between the Cishan River (旗山溪) and Laonong River (荖濃溪). These villages mainly settled not only on the positions where they can easily get water but also on higher ground. Besides the downtown location around the San-Chia-Shui area where three creeks converge, some villages developed along the feet of mountains to obtain water from mountain springs. Others developed beside irrigation channels. The context of the creek and irrigation system was the crucial factor that to affected the settlement patterns in Meinong. Besides the downtown area, the main villages, e.g. Fuan and Jhongtan village, were built on locations at higher elevations (Fig.73). Outside the early downtown area, a large amount of land in Meinong district consists of paddy fields. Because the soil with high percolation rates is suitable for planting tobacco, there were more than 4000 ha of tobacco fields in the past (150 ha still remain at the present) (TGR 2005). Because the long-period of agricultural cultivation has formed a layer of plow pan at the bottom of the soil which can keep water in surface soil, the soil in this area is also fit for growing rice. Nowadays, most of the agricultural lands in Meinong district are paddy fields.

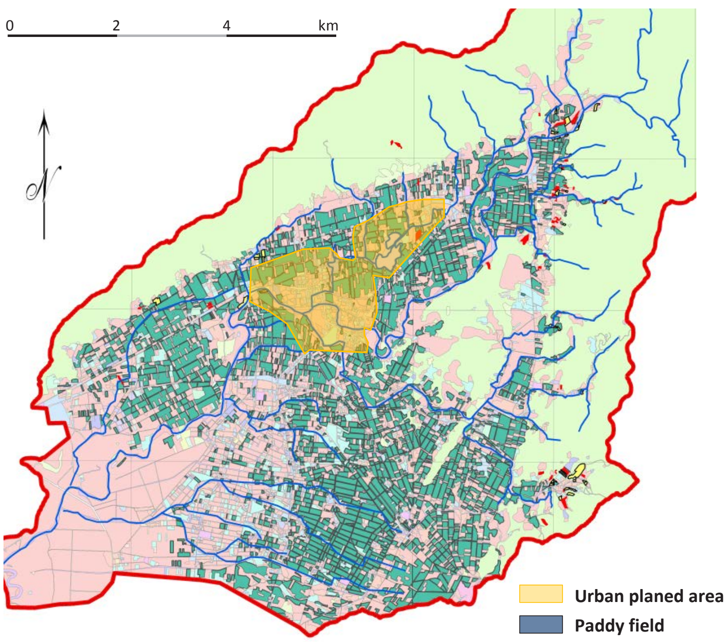


Figure 73
The land use of Meinong district (Source: TGR, 2005)

§ 4.2 The Interrelationship between Different Layers of the Meinong River Catchment Area

§ 4.2.1 Hydrology (Dike system) + Water (Surface)

MEINONG

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

Storm water

Meinong district floods almost every year after Typhoon Mindulle in 2004 due to the increased frequency of extreme rainfall (Fig. 74). The precipitation of Typhoon Mindulle flooded an area of 108 ha and the deepest flood depth at 1.5m; the storm in 2005 caused almost half of the Downtown Meinong flooded; Typhoon Wutip in 2007 had caused serious flooding in downtown Meinong. More than 4200 residents were in danger. Typhoon Kalmaegi in 2008 flooded an area of 250 ha. Typhoon Moracot in 2009 resulted in the flooding area of 150 ha; Typhoon Fanapi in 2010 had flooded an area of 120 ha.

Event	Precipitation (mm)					
	1 hr	3 hr	6hr	12hr	24hr	48hr
2004, Mindulle	39	71	128	181	357	442
2005, A storm	57	148	204	273	392	414
2007, Wutip	89	194	278	408	517	651
2008, Kalmaegi	121	220	290	365	540	647
2009, Moracot	54	117	213	348	634	879
2010, Fanapi	75	205	292	356	461	478

Figure 74 *The precipitation of historical typhoons , (Source: Based on TGR 2013; Table by author)*

The maps of historical flooding areas (TGR 2010) illustrate that the main locations of floods are concentrated on the plain at the mountain bases (Fig. 75), the San-jia-shui area downtown, around the end of main dike system, and at the confluence with the Chishan Creek (旗山溪). All of these sites are located at the positions where the flow rate reduces sharply. The flow rate slows down in the plains, which results in water congestion and flooding. The San-jia-shui area is relatively low-lying land where storm water will easily accumulate. Water will also easily congest around the ends of main dike systems, due to the riverbed being narrowed by dikes. Furthermore, the congestion of storm water at the lower reaches pushes water back to the dike-less areas and then overflows the river banks.

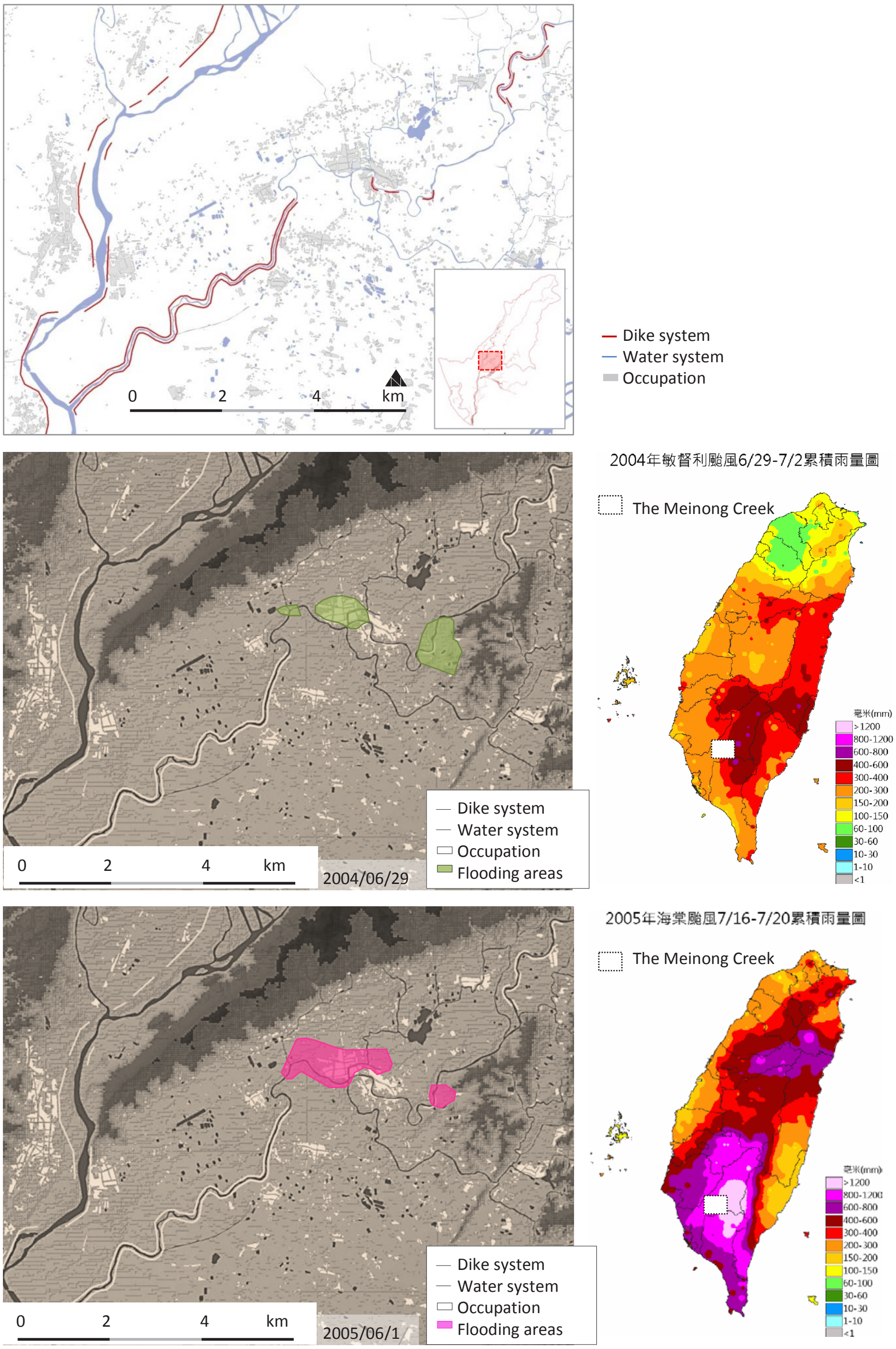
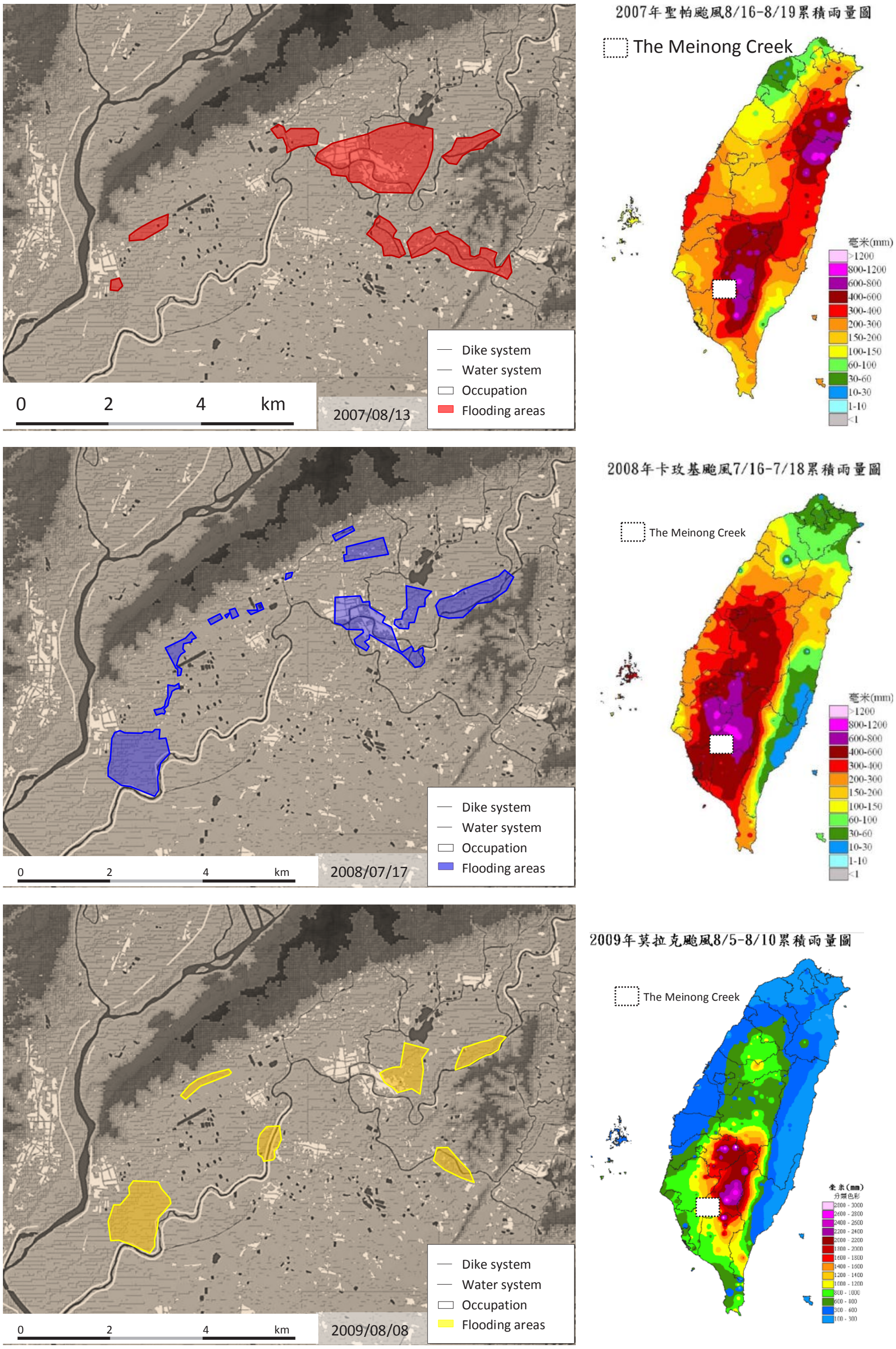


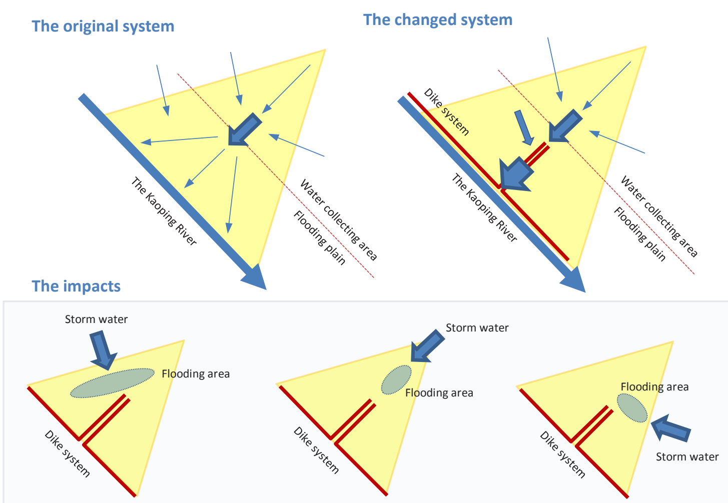
Figure 75

The distribution of flooding area of historical typhoons in Meinong(Source::Based on TGR, 2013; Map by author)


0
2
4
km
2007/08/13
Dike system
Water system
Occupation
Flooding areas
2007年聖帕颱風8/16-8/19累積雨量圖
The Meinong Creek
毫米(mm)
>1200
800-1200
600-800
400-600
300-400
200-300
150-200
100-150
60-100
30-60
10-30
1-10
<1
0
2
4
km
2008/07/17
Dike system
Water system
Occupation
Flooding areas
2008年卡玫基颱風7/16-7/18累積雨量圖
The Meinong Creek
毫米(mm)
>1200
800-1200
600-800
400-600
300-400
200-300
150-200
100-150
60-100
30-60
10-30
1-10
<1
0
2
4
km
2009/08/08
Dike system
Water system
Occupation
Flooding areas
2009年莫拉克颱風8/5-8/10累積雨量圖
The Meinong Creek

The runoff path of storm water

The aforementioned water context of the Meinong plain is a triangular system where storm water that collects at the top of the triangle can flood or be absorbed at the lower area. The construction of the main dike system of the Kaoping River which was extended to the midstream of the Meinong Creek has greatly affected the runoff path of storm water. First of all, the dike has totally changed the role of the bottom triangle as a flood plain. An enormous amount of storm water being collected in the top triangle is forced to flow into the narrowed and canalised Meinong Creek. Second, the dike system also blocks the runoff path of storm water from the surrounding hills. Finally, the dike system forces the storm water from the entire Meinong Plain to flow into the Kaoping River at just one confluence point. The result of the changed runoff path clearly causes floods and influences the distribution of flooding areas. We can further find there is a strong relationship between the inundation areas and the distribution of storm rainfall. First, if the runoff of storm water mainly comes from the northern hills, the flooding area is mainly located on the northern bank of the Meinnong Creek, as happened in the flood in 2008. Secondly, if the runoff of storm water mainly comes from the eastern hills, e.g. the flood in 2007, the floods will occur along the Youzilin Creek. Thirdly, if the storm water runoff mainly comes from north-eastern hills, e.g. the floods in 2004, 2007, 2008, and 2009, then the flooding area is mainly located along the Shuang Creek and the Chiangziliou Creek. Finally, no matter what the situation, the downtown area is always flooded because it is located exactly at the end of the dike system and at the centre point of storm water collection.



(Graphic by author)

§ 4.2.2 Hydrology and Occupation

MEINONG

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

Problems of the dikes and present strategies

Based on the analysis above, although the dike system along the Kaoping River and the lower reaches of the Meinong Creek has protected the lower area of the Meinong triangle plain from flooding, it creates freshets in the northern bank of the Meinong Creek and the downtown areas. How to deal with a huge amount of storm water outside the dikes is an urgent issue here. There are two main hydrological ways of thinking to resolve this problem. One is to extend the protection of the dike system to the upper reaches of the Meinong Creek. The other is to increase the area's water retention capacity. Both of these methods create unsolvable predicaments, however.

The Taiwan Water Resource Agency (WRA) has drawn up several strategies to deal with the inundations of the Meinong Creek catchment area. The first is to dredge the riverbed, to strengthen the bank within downtown Meinong, and to widen and heighten the dike. The second is to remove the constructions which impede river flow. The third is a proposal to enhance the storage capacity of the Chung Chen Lake in the upper reaches. The fourth is to create a buffer area to concentrate water around the San-jia-shui area. Finally, they propose seven detention ponds along the upper and lower reaches of the Meinong Creek. The three in the upper reaches can directly reduce the peak storm water levels and the rest can avoid the flow back of congested storm water to the downtown area (TGR 2005; TGR 2010). All of these strategies face strong challenges due to historic occupation patterns.

The predicament of flood management under the impacts of human occupation

The Downtown Meinong area is located at the top of the aforementioned Meinong triangle. This was the area with a porous soil structure where the surface runoff infiltrates deep into the ground. It was very difficult to obtain ground water here due to a low ground water level. Early settlers in Meinong had to build their houses beside the river in order to get fresh water. The location of Downtown Meinong was a good option where three small tributaries collected abundant runoff from surrounding hills and converged together. This was also the area which had a relatively dry ground, because the significant amount of storm water congestion here could be absorbed by the floodplain on the bottom of the Meinong triangle before the construction of the dike along the Kaoping River and the lower reaches of the Meinong Creek. Thus building houses right beside the river did not incur a high flooding risk at that time.

Because the lower reaches of the Meinong Creek were a flood-prone area in the past, early settlers reclaimed their farm fields mainly along the river bank toward the upper reaches of the creek from the waterfront. Some settlers even reclaimed their lands from the riverbed, because these lands still could be used during dry seasons. All of these reclamation were allowed by authorities, which are also permitted by the present government. The land-ownership map reveals this complicated situation from the middle reaches to the upper reaches of the Meinong Creek. Because most of the farmland in the lower reaches was reclaimed after the construction of dikes, there is a clearer boundary between the private lands and riverbed in the lower reaches than in the middle and upper reaches (TGR 2010) (Fig.76).

While the river bank is no longer safe from flooding after the construction of the dike, the mass privatisation of the waterfront and riverbed along the Meinong Creek poses the predicament of flood management, because it is very difficult and expensive to find land to build hydrologic instruments that is both available and suitable. Furthermore, a very special social circumstance has occurred throughout Meinong District now since the local residents have protested against the Meinong Reservoir (美濃水庫) and Geyoung Artificial Lake (吉洋人工湖). The locals generally have doubts about most of the plans which are proposed by the government. The eminent domain of private lands will incur another tremendous conflict between the government and local residents (Li, C.C. 2000).

The historical flooding data of the Meinong Creek reveal that setting hydrological instruments within a river basin should be considered as an integrated system. In the case of Meinong, although the dike system has prevented the lower reaches of the Meinong Creek from flooding, it has also decreased the flood plain area's size. The storm water which originally should have been absorbed in the lower reaches now congests at the end of the dike or at the confluences of tributaries. The congestion of storm water in the riverbed raises the water level of the upper reaches, which aggravates the upstream flood damage. This situation has become worse as the magnitudes of extreme storms steadily increase.

Furthermore, plans for flood management in this region are very difficult to be carried out due to the mass privatisation of the waterfront and riverbed in the Meinong Creek. It is almost impossible to obtain suitable land for the design of hydrological instrument using eminent domain because of the special social circumstances. The Meinong experience reveals it is important to manage extreme storm water by means of not only hydrological technology but also an integrated urban plan including land uses and the spatial patterns.

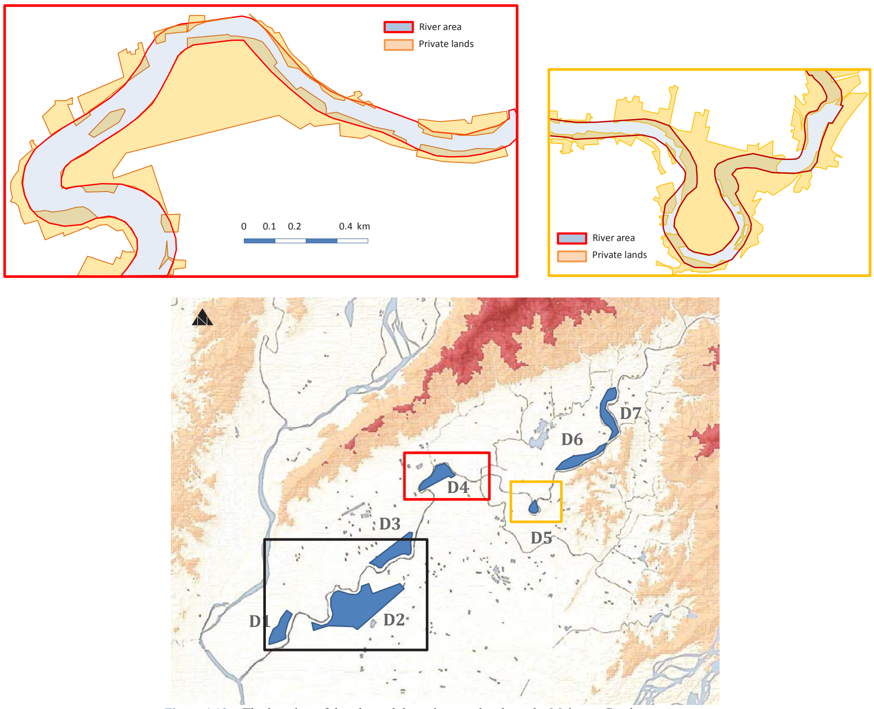


Figure 4.12a: The location of the planned detention ponds along the Meinong Creek
(Source:: Based on TGR 2010; Map and graphic by author)

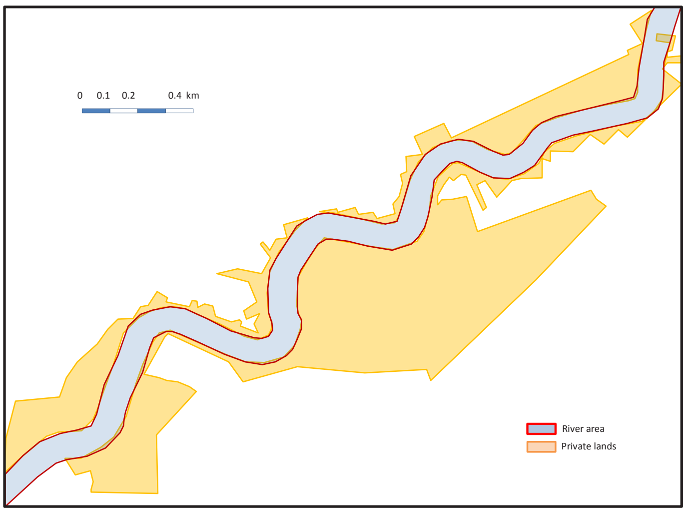


Figure 76

The location of the planned detention ponds along the Meinong Creek(Source:: Based on TGR 2010; Map and graphic by author); Some private lands are located in the riverbed in the upper reaches of the Meinong River, because the reclamation was warranted by authorities in early historical period. This situation is different from that of the lower reaches. Source:: TGR 2010

§ 4.3 The 3-layer Portrait of the Love River Catchment Area

§ 4.3.1 The Natural Landscape Layer

The Love River catchment area is located in the lower reaches of the Kaoping River and is surrounded by Dagu Mountain (打鼓山), Banping Mountain (半屏山) and Fengshan Hill (鳳山丘陵). The catchment is an alluvial plain with an area of about 62 km2. Most of the catchment area is formed by the sediment which is transited by sea currents from the mouth of the Kaoping River. The main stream flows through the downtown of Kaohsiung which has a population of about 700,000. The strong sea current from the south to the north carries the sediment which has silted up the estuary of the Kaoping River and its northern coast. The historical map, Qian-Long District Map (乾隆輿圖) from about 300 years ago, fully illustrates that the huge amount of sediment formed the rough shape of Kaohsiung Bay (Fig. 4.13). The sand dune, the present-day Chijin peninsula (旗津半島), surrounding the Kaohsiung Bay, was robust enough for village settlements and military camps, but the land surrounding the bay, the present downtown area, was still not livable. Since the completion of Kaohsiung Port 100 years ago, the surface water system has been changed by rapid urbanisation. This low-lying area surrounding the bay was full of marshes and wetlands in the past but has been filled in for urban development now.

Water system

THE LOVE RIVER

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The Love River catchment area used to be large lagoon. The oldest riverbed with a few metres in depth was formed around 400 years ago from the natural sedimentation of the Kaoping River extending the alluvial plain. Japanese colonial authorities deepened and widened the original riverbed to deliver logs while they were building the Kaohsiung Port, and this formed the present riverbed of the Love River. Two water supply the Love River. One is the salt water from tides. Because the Love River is a tidal river, seawater flows into the lower and even the middle reaches of the river; the other comes from the upper reaches, including rainwater, irrigation, and industrial and household sewage. Its headstream is quite short without a stationary water source (http://pwbgis.kcg.gov.tw/Love/). There are nine short branches, the Jiufenpi Drainage (九番埤支線), the Linzipi Draianage (林仔埤支線), the Benquen Drainage (本館支線), the Powzou Drainage (寶珠支線), the Neiweipi Drainage (內惟埤排水), the Jiurue Drainage

(九如支線), the Gushang Draianage (鼓山支線), The No. 2 Canal, and the Mingsan-Road Drainage (民生路排水) (Figure 77). Among them, the Benquen Drainage and part of the Mingsan-Road Drainage are covered by roads.

The surface runoff of storm water in the downtown area is collected by these branches. The duration of water flowing from the upper reaches to the estuary of the Love River is about 6 hours. The peak discharge of a 5-year frequency storm is about 410 cms (cube meter per second) at the river mouth (TGR 2003). The three largest branches, the Benquen Drainage, the Powzou Drainage and the Neiweipi Drainage, contribute more than a half of the total discharge.

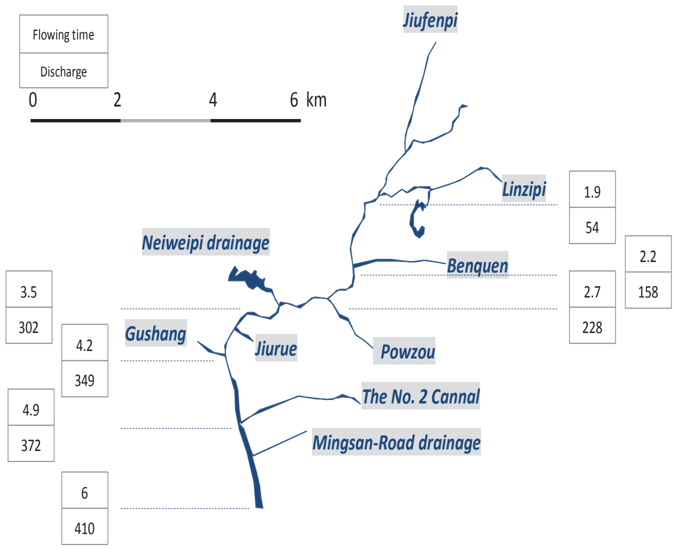


Figure 77
The duration of storm runoff peaks in the Love River(Source: Based on TGR, 2003; Graphic by author)

Soil structure

THE LOVE RIVER

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

Because The Love River catchment area is located on the bottom fan area of the Kaoping Delta, beyond the surrounding mountain areas, the ground here mainly consists of silt and clay. Most of the ground in this region is covered by a layer of clay (aquitard) as surface soil. Thus only a small amount of the rainwater actually infiltrates into the soil. Furthermore, because the groundwater level is quite high, about 1 to 5 metres in depth beneath the ground surface, water would flow upwards the leaks between layers of aquitards. In some areas, especially at the interface areas between plain and mountain, ground water will pour out of the ground as an spring in places where the water pressure rapidly increases when the flow is blocked by hard ground layer, such as a mountain rock layer (Fig.78). A great amount of ground water can come out of an spring. For instance, Japanese colonial authorities originally planned to use it to supply fresh water to the Kaohsiung port area designed for a population of 50,000 (LGR 1984).

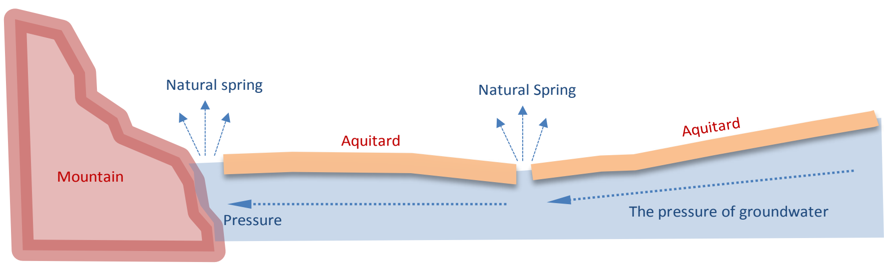


Figure 78
The flow of groundwater in Kaoping Delta (Graphic by author)

Elevation

The elevation in the Love River catchment is nearly all under 10 metres in height except in the areas of the Chengcing Lake (澄清湖), the Banping Mountain (半屏山) and the Shou Mountain (壽山). In some areas, e.g. Yancheng (鹽埕), Cianjin (前金), Jhongdou and Neiweipi (中都及內惟埤), the elevations are even lower than 1 metre. At some particular areas, e.g. Benguan (本館), Baojhugou (寶珠溝), Sinjhuangzih (新庄子), and around the Wenzao College of Languages (文藻學院), although the elevations of these areas are about 5 metres, they are surrounded by lands with an elevation of 6-9 metres, which have formed these areas as a closed and relatively lower basin. The historical map from 1905 reveals these basins were once the original riverbed or wetlands where water was easily retained when it flowed into these areas (Fig.79).

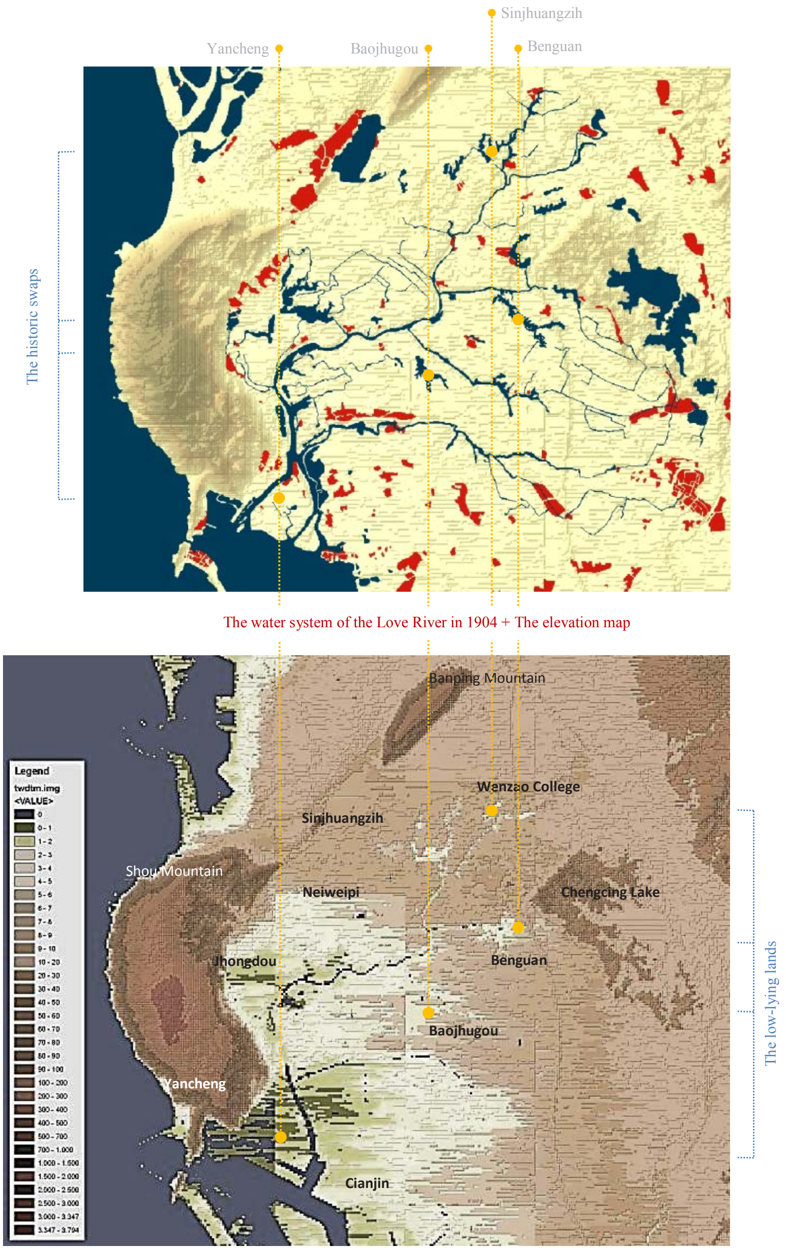


Figure 79

The present flood-prone areas in the Love River basin (Source: Based on Academia Sinica ed. 2010; Map by author)

The tide system

The daily tide flows into the Kaohsiung Port and then is divided into two directions: one is toward the Love River and the other is toward the main port channel and the export processing zone. The Love River is a tidal river. The tide affects the water level in the lower and the middle reaches of the river. The farthest place where tidal effects can be detected is around the Wenzao Ursuline University of Languages (文藻外語大學). Because there is no loop in this water system, water flows along the same aforementioned water track out of the port on the ebb. Pollutants brought in by the tides usually accumulate at the ends of the water tracks in the upper- and mid- reaches. The tide range is 0. 67 metres in average and 2.19 metres during storm surges (TGR 2010b) (Fig.80, 81, 82).

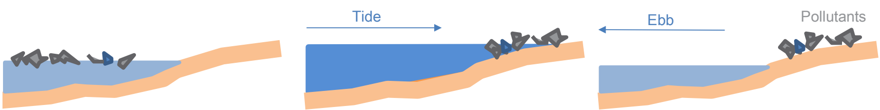


Figure 80
The pollution by tide (Graphic by author)

Figure 81
The path of tides and ebb flow in the Love River (Map by author)

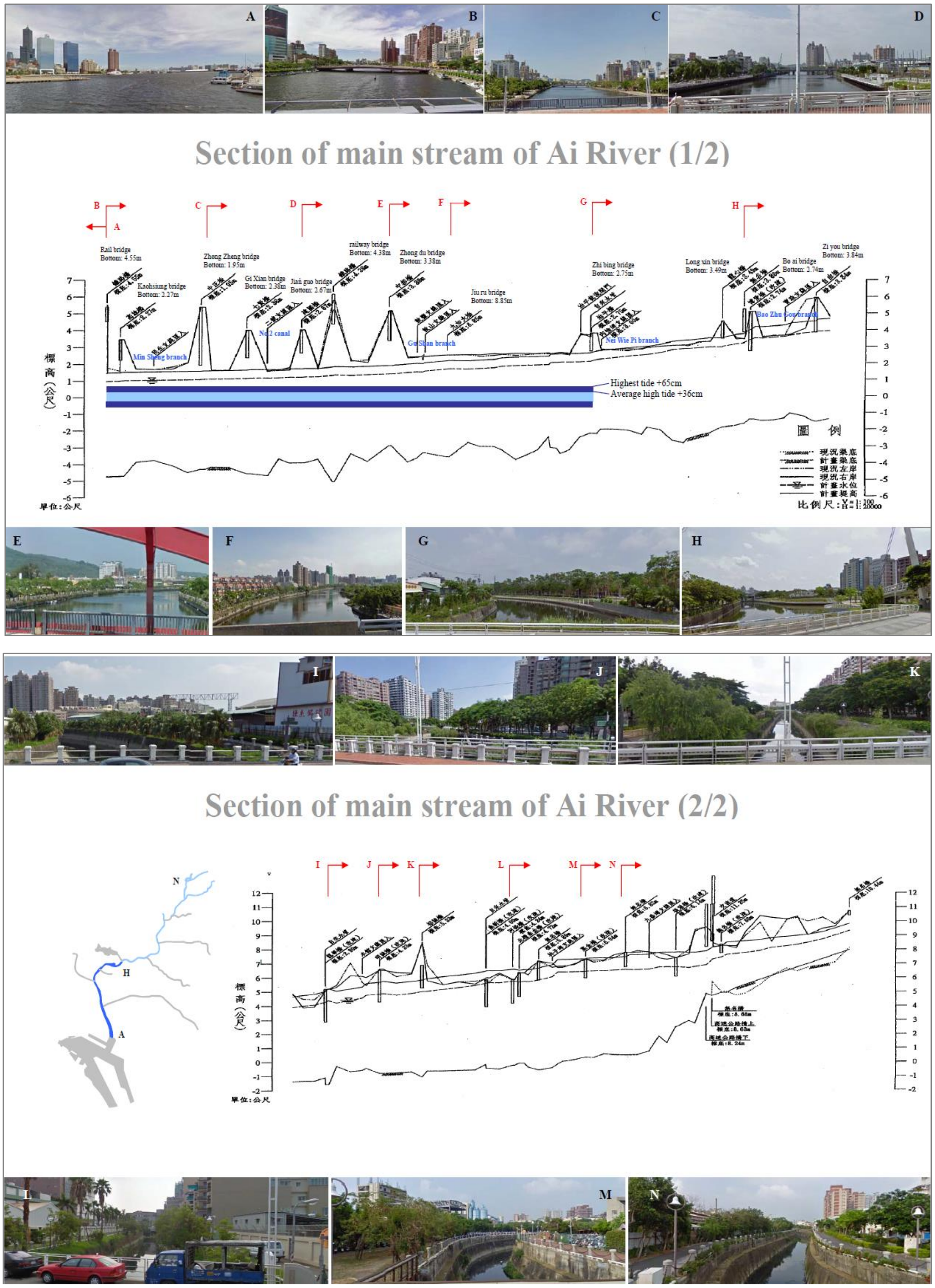


Figure 82

The section of the Love River (Source: Based on TGR, 2003, Montage by author)

§ 4.3.2 The Infrastructure Layer

The grid road system

THE LOVE RIVER

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The completion of the Kaohsiung Port triggered the rapid urbanisation of the Love River Basin. The grid street network became the major urban pattern to transform the agricultural landscape for industrial development. The major infrastructure network shifted away from the previous irrigation system to a dense traffic system with the main direction following the railroad and highway. The original waterways or wetlands were filled up or abandoned. The city space developed along the highway and the Love River as an extension of the street network grid. In the early colonial periods, Japanese authorities designed two different widths of streets, 5 Jian (間) and 10 Jian (1 Jian is around 1.818m), in the Urban Correcting Plan of Dakao (打狗市區改正計畫) of 1908 (Dai, B.T. 2004). The annual value of export businesses rapidly increased to 100 million dollars. More than 66% of the total exports were sugar. The rapid development of the export business further promoted urban growth. The diverse widths of streets, 10m, 15m, 20m, 25m, 30m, 40m, 50m and 60m boulevards, were designed in the urban extension plan of 1936 (Chen, W.S. 2004). The grid road network accelerated the delivery of goods and enhanced the efficiency of the port.

The road-dominated drainage

THE LOVE RIVER

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The transportation layer with an orientation towards freight shipping dominated arrangements for local drainage. Storm and waste water drainage systems are separated in the Love River catchment area. Storm water drainage has been designed for a rainfall standard of 5-year frequency. Storm water is collected by ditches on both sides of roads and flows into the Love River. In general, drainage pipe were set in low-lying areas, because the elevation of the lower reaches of the river is less than 3 metres. According to the data compiled by Taiwan WBA in 2003, almost all of the drainage pipes will be affected by the high tide water levels in the lower reaches of the river (TGR 2003) (Fig.83).

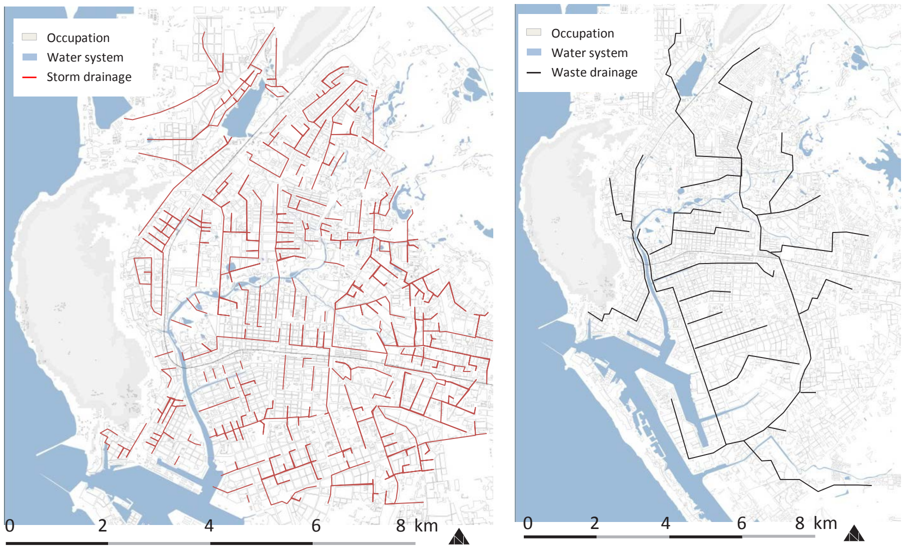


Figure 83

The storm water drainage network; (Right): The waste water drainage network in the Love River basin(Source: Based on TGR 2003; LGR 2009; Map and Montage by author)

Japanese did not build a sewage system when they developed the port and the surrounding areas. Most urban waste water was discharged into the rainfall drainage ditches and then flowed into the Love River. The lack of a sewage system resulted in a serious river pollution. Setting up a sewage system to improve water quality is a difficult task in a highly urbanised area, because there is barely available space for constructing a sewage system. The space beneath roads is already filled with electrical wiring, information cables, drinking water pipes, etc. Therefore, current strategies mainly focus on how to intercept the wastewater flowing into the main stream of the Love River. Large sewage pipes are placed mainly along both sides of the downstream banks and several major roads to collect wastewater which originally would flow into the river. Furthermore, ten intercepting gates have been installed in the middle and upper reaches to intercept waste water from the major branches. The intercepted waste water will be delivered to the treatment plant, and then discharged into the ocean (LGR 2009) (Fig.84).

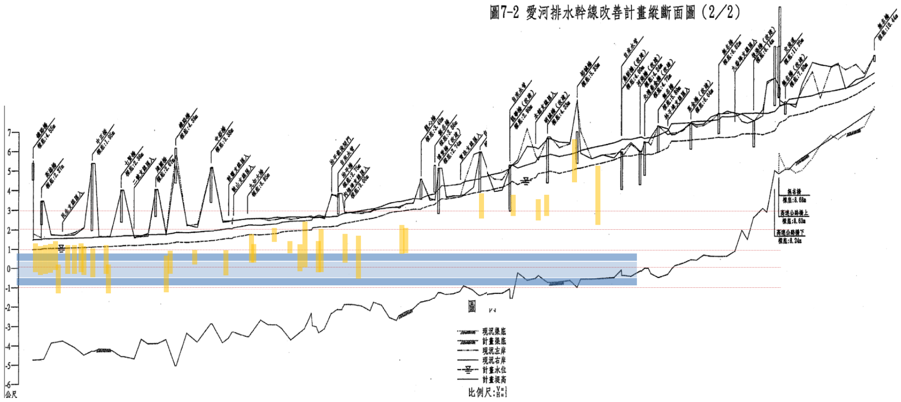


Figure 84

The height relationship between the positions of all drainage outlets and the water level of tides (Source: Based on TGR 2003; LGR 2009; Map and montage by author)

§ 4.3.3 The Occupation Layer

THE LOVE RIVER

Natural layer		Infrastructure		**Occupation**	
Soil	Water	Hydro-	Traffic	**Block**	Land use

The patterns of urban blocks

Japanese colonial authorities designed three different sizes of urban blocks: 72m*109m, 72m*136m and 72m*163m, in the Urban Correcting Plan of Dakao (打狗市區改正計畫). The present Yancheng (鹽埕) District was the target area in this plan. The sizes of these blocks were smaller than the later plans in order to suit the accessibility for walking. The major land-use of these blocks was for port related businesses. The urban blocks in later plans were enlarged to three different sizes: 300m*500m, 400m*600m, and 70m*100m, because of the popularisation of automobiles. The long side of these blocks was all facing toward piers of the port to increase logistical efficiency (Chen, W.S. 2004).

Urbanization and water contexts

The water texture of the city was ignored in the design of traffic orientated grid street. Creeks and wetlands, which were filled up or abandoned, were replaced by drainage and pipe systems. In general, these urban water systems were set along the streets which provided enough public space for a dense urban area. The major drainage ditches were built alongside the roads. Besides storm water, these open ditches also collected wastewater from some open markets, restaurants or small family factories. To this day, local residents who live along roads are still used to pouring their wastewater into these ditches. This has caused the water quality of the Love River to worsen even further. Although these kinds of wastewater could be intercepted by the intercepting gates, it will still flow into the river during a storm when all gates need to open in order to discharge excess storm water. This is another difficult problem to resolve (Fig.85).

Figure 85

The image of a section of a historic street(Source: Based on (background picture) LGR 2005; Graphic by author)

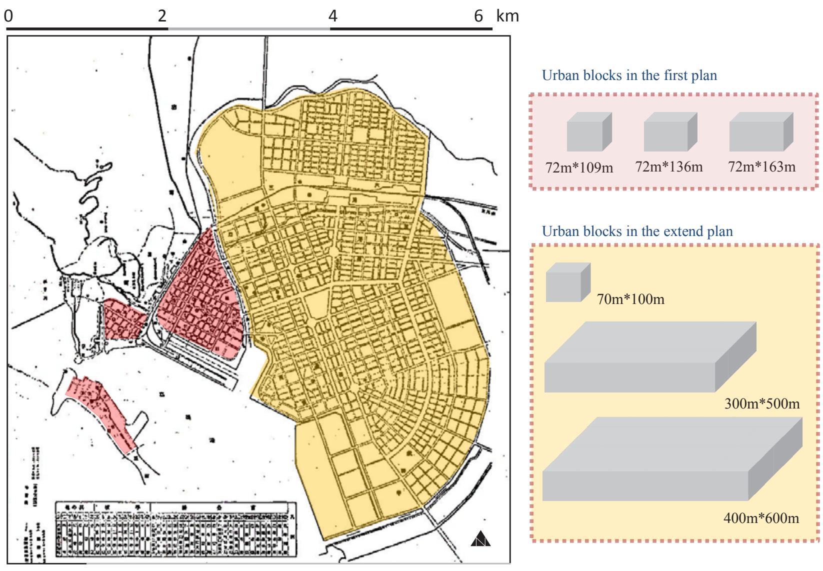


Figure 86

The urban block system in downtown Kaohsiung(Source: Based on (background picture) LGR 2005; Graphic and montage by author)

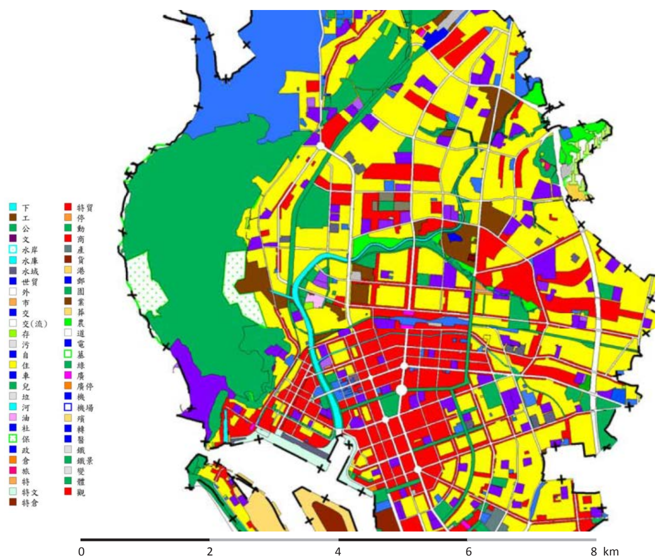


Figure 87

The current land use situation in the Love River basin. Red: business zone; Yellow: resident zone; Brown: public use (Resource: LGR 2009)

§ 4.4 The Interrelationship between Different Layers of the Love River Catchment Area

§ 4.4.1 Hydrology (Drainage) and Water System

THE LOVE RIVER

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The historic solution to drainage

In the past, most of the Love River catchment area consisted of wetlands inside the Kaohsiung Bay. The lands in the present Ianchen (鹽埕) district where the Love River flows into the bay were mainly salt fields then. Because this area is quite low-lying, the priority when settling here was to resolve the drainage problem. The existing natural condition was first improved upon by the plan for Kaohsiung Port and the surrounding area. Japanese colonial authorities used the silt of the Kaohsiung Bay to raise the ground elevation when they deepened the bay area for building the harbour. After World War II, the Taiwan government continued to use the same method to extend urban spaces in this region. Thus the natural feature of this low-lying land transformed from a flood-prone area to a flood-proof area.

The present predicament of drainage

This situation did not change until the 1990s, when the impact of climate change gradually emerged. Extreme rainfall became a serious challenge to the Love River catchment area. First, this region is a natural centre for the collection of surface runoff from the surrounding hills. The gradually increasing magnitude of storm rainfalls raised the flood risk of this region. In addition, because the elevation of this region is low, the tidal effect on the water level of the Love River reaches into the midstream region. This region is a high-risk area for flooding when an extreme rainfall comes with a high tide (Liou, C.M. 2004). The high tide will block the outlets of drainage in the lower reaches. For example, Typhoon Trami in 2001 resulted in the serious flood in the Zuoying(左營), Sanming (三民), Linia(苓雅), Chianzun(前鎮), Goshan(鼓山), Chianjin (前金), and Ianchen(鹽埕) district; Typhoon Fanapi in 2010 caused a serious flooding in the middle and upper reaches of the Love River.

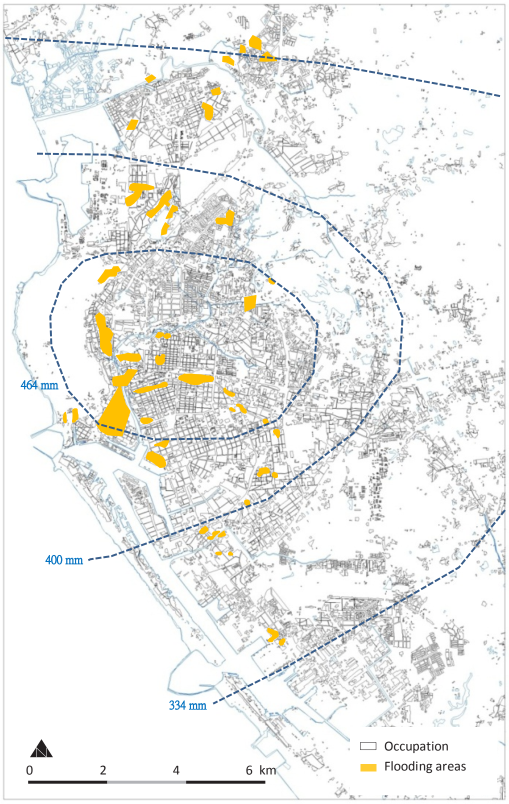
The present strategies

The primary flood-defense strategy in this area is to build drainage and pumping stations. Although a rain drainage system has almost been completed, there is just a standard for 5-year storm frequency (Liou, C.M. 2004), which is woefully insufficient for the current situation. Building detention ponds is another option to enlarge the capacity of water storage in the Love River catchment. However, finding enough funding for eminent domain for local governments to acquire land is a tough task in a highly urbanised area. The major flooding pattern in this region is a heavy rainfall that then subsides in a short time period. The most pressing issue for local governments is dealing with the huge amount of rainfall per hour. If the precipitation level is over 70 mm per hour and simultaneously meets the arrival of a high tide, the storm water would not only exceed the capacity of city drainage system but also be blocked by the high tide at outlets of drainage and then might cause a severe freshet, which is what happened with the floods in 2001 and 2010.

Typhoon Trami (潭美颱風)

Typhoon Trami brought a 24-hour rainfall amount of 579mm to Kaohsiung in 2001. The heaviest rainfall at that time was 126.5mm per hour, which is very close to the 1 in 100-year-storm rainfall intensity of 130mm. The three-hour rainfall of 329mm from 18:00 to 21:00 exceeded a 1 in 200-year-storm rainfall intensity of 300mm. Discharge from the Love River increased rapidly to a peak of 982cms which exceeded the 100-year-flood standard (TGR 2013).

Flooding was mainly located in the low-lying and the relatively low-lying areas, both banks of Canal No.2 in Pautzugo (寶珠溝), Ianchen (塩埕) districts, and No.2 and No.4 Docks (第二、四船渠) . The deepest flood water accumulated at Benho village (本和里) with a depth of 210 cm. The rest of serious flooding places were at around Lanchio and Sousin villages (藍橋里、壽星里) , and No.2 Canal with 100 cm, at Benquan village (本館里) with 145 cm, and along Pautzugo (寶珠溝) with a depth of 165 cm (TGR 2003) (Fig.88).



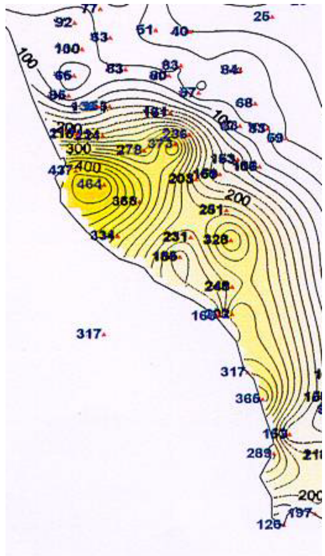


Figure 4.24 (Left): The distribution of the flooding area of TC Trami in the Love River; (Right): The distribution of precipitation by TC Trami (Source: Based on TGR 2003; TGR 2013; Map and graphic by author)

Figure 88
(Left): The distribution of the flooding area of TC Trami in the Love River; (Right): The distribution of precipitation by TC Trami (Source: Based on TGR 2003; TGR 2013; Map and graphic by author)

Typhoon Fanapi (凡那比颱風)

Typhoon Fanapi brought extreme rainfall and devastated a large part of southern Taiwan in 2010. More than 16,000 residents were evacuated. The map of rainfall distribution illustrates how the precipitation mainly concentrated in the Kaoping River basin. The heaviest rainfall occurred in Nanzi District (楠梓區). The precipitation of 618 millimetres during 20 hours is close to a 1 in 200-year-storm rainfall intensity of 300 millimetres (TGR 2013).

Flooding was mainly situated in northern downtown Kaohsiung downtown, including Nanzi (楠梓), Zoin (左營), Gushan (鼓山), Samming (三民) Districts, and the middle and upper reaches of the Love River. The highest level of flooding water had reached up to 3 metres and lasted almost 3 days in some areas. The Ianchen (塩埕) District, which suffered severely from the previous flooding, did not flood this time, although the amount of rainfall there was almost equal to the rainfall intensity of Typhoon Trami in 2001(LGR 2010) (Fig.89).

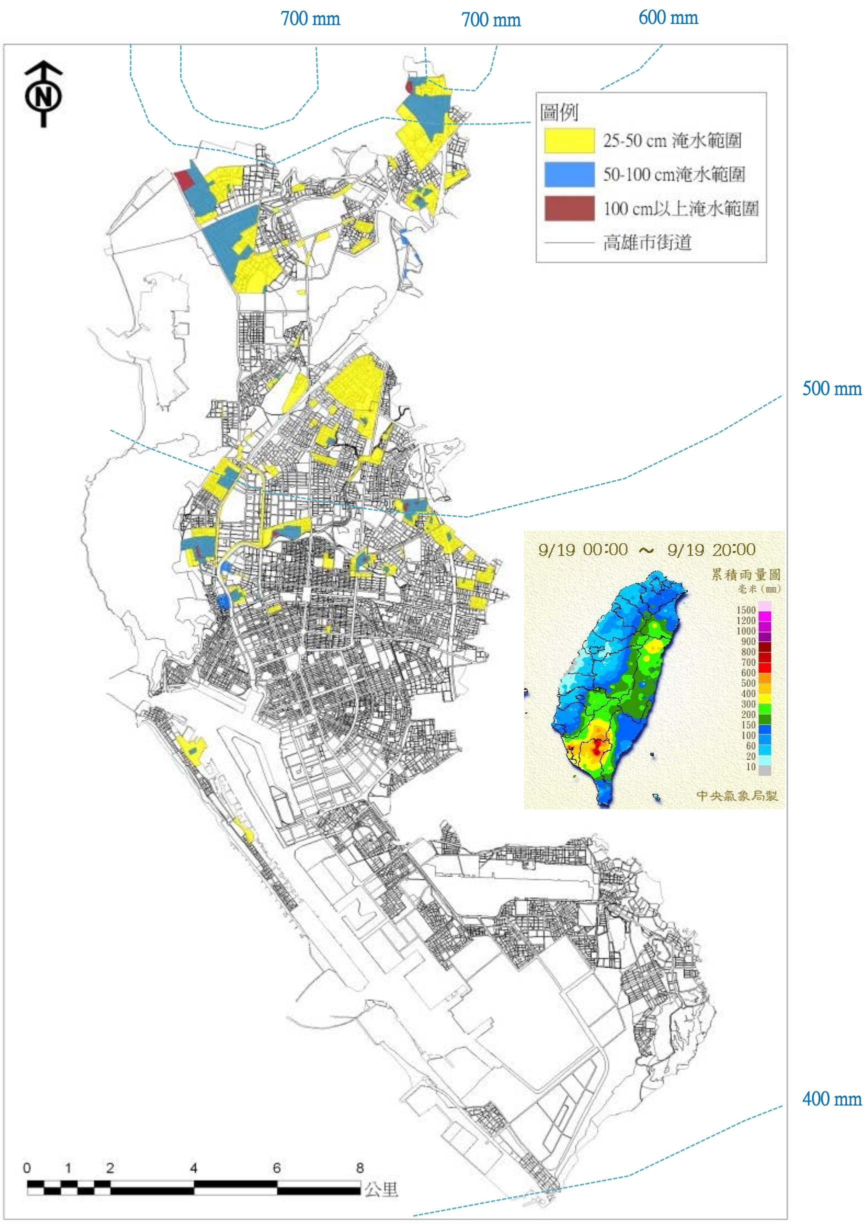


Figure 89

(Left): The distribution of flooding area of FanapiTC in the Love River; (Right): The distribution of precipitation of Trami TC, (Source: Based on WRA, 2003; CWB 2001, LGR 2010; Map and graphic by author)

§ 4.4.2 Hydrology (Drainage) and Occupation (land Use)

THE LOVE RIVER

Natural layer		Infrastructure		Occupation	
Soil	Water	Hydro-	Traffic	Block	Land use

The analysis: (Water path and Drainage) and Land use

The peak discharge at the estuary of the Love River occurred just at the time when the high tide was coming in at about one meter in height. The high tide level blocked most of the drainage in the lower and middle reaches of the Love River, including the drainages area of Canal No.2 (二號運河), Gushan Canal (鼓山運河), and Pautzugo (寶珠溝). Enormous amounts of storm water gushed from the drains and caused serious floods in these lower-lying areas along the river. These areas were once the riverbeds or wetlands and had been filled in for urban development. These low-lying lands were also located in the confluence area of many drains, including the drainages of Fudingjin (覆鼎金), Janshiho (金獅湖), and little K and K Major Pipe (小K幹線和K幹線). These are the areas where the surface run-off of storm water from the surrounding hills would naturally congest.

According to the investigation of the flooding caused by Typhoon Trami by the Kaohsiung Government, which examined this flood from different aspects of river and drainage discharge, design criterion for flooding, and drainage analysis in surrounding areas, the crucial cause of this flood was extreme rainfall which came at the same time as a high tide level. The following several conclusions were drawn (LGR 2001):

- Tidal effect: Storm water was congested with the high tide in the middle and lower reaches of the Love River. The high tide level reached 1m in height, which at that time was even higher than some drainage outlets. Enormous amounts of water congested at the estuary, elevating the water level of the middle and lower reaches. The high water level blocked most of the drainage areas. It caused water to gush from seep holes.

- **Insufficiently designed criteria for drainage: The designed criterion for drainage in the Love River is a 20-year return period. The precipitation of Typhoon Trami exceeded the standard of a 100-year flood, even a 200-year flood, which was beyond the existing drainage capacity.**

- Huge amounts of water coming from surrounding hills converged together in the relatively low-lying areas, which exceeded the designed drainage standard.

- The other possibilities including silted pipes, construction barriers on the riverbed, and the improper angle of confluence pipes, caused this flood.

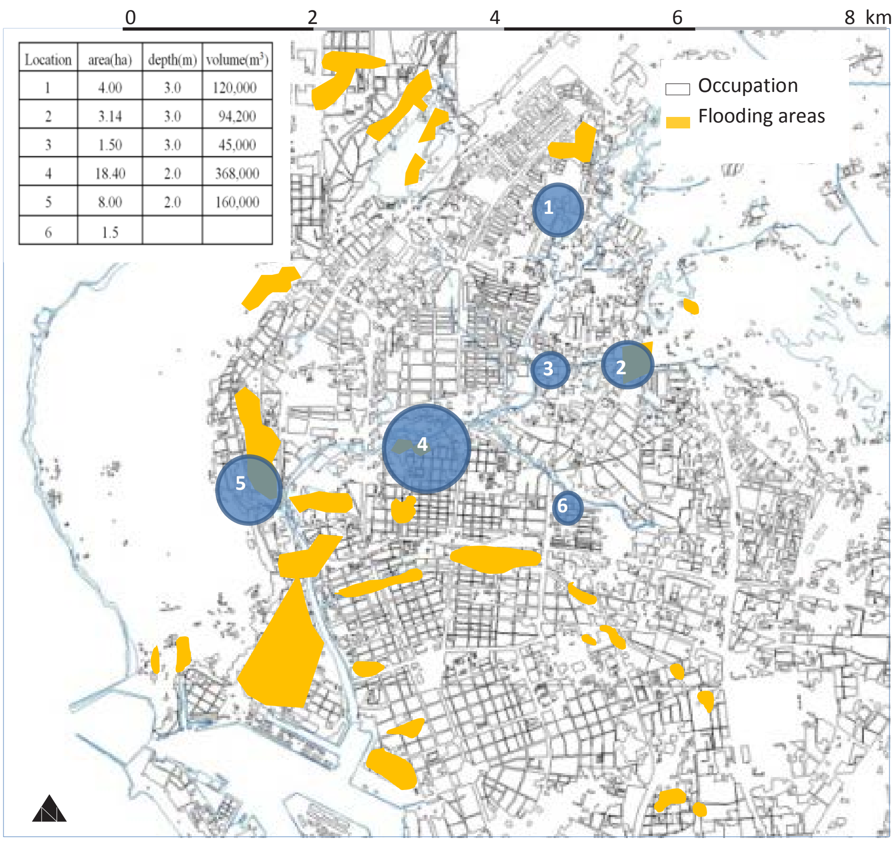
The analysis above reveals that the crucial reasons for this flood were extreme rainfall and high tide. The extreme storm water came together with the high tide from 18:00 to 24:00 (TGR 2010b). It induced the congestion of storm water at the outlets of drainages. That the flood waters subsided following the ebb and abating of the storm shows that the drainage had not been silted. It meant the original hydrological instruments were unable to prevent the Love River catchment area from flooding, rather than the problem of clean pipes. It was necessary to re-examine the whole system.

After this flood, the Kaohsiung Government proposed short, middle, and long term strategies to combat floods in the future. The short term strategy mainly focused on cleaning silt and widening parts of the riverbed to increase the capacity for extreme run-off. In addition, some gates were planned to intercept excess storm water flowing to the low-lying areas, e.g. Benho village (本和里) and Benquan village (本館里); The middle and long term strategies planned to rebuild some bridges which decreased the drain capacity of riverbed and to build pumping stations in Ianchen (塩埕) district. Furthermore, six detention ponds were planned to be set up along the river bank, because the total flooding of about 3 million cube metres had far exceeded the original designed capacity of the whole river system. A flood of such huge magnitude could not be resolved just by simply technically increasing the capacity of the riverbed itself. The entire space was around 35 ha which can contain 0.44 million cubic metres of water. Although this plan was still insufficient to combat a flood of similar magnitude, it was expected to achieve the standard of a 20-year flood when the sea level exceeded the average high tide by 20cm (LGR 2001) (Fig.90).

This plan shows that improving the current situation by rebuildin a safe and robust waterfront in this region is a difficult task. Typhoon Trami was a storm with a rainfall intensity of a 100-year-flood. The following plan, with a designed standard of about a 20-year-flood, does not even accommodate the rainfall intensity of Typhoon Trami. Maybe the case of Typhoon Trami could be viewed as an occasional disaster for Kaohsiung from the aspect of scientific statistics. What we should not ignore is that the storms with similar rainfall intensity have occurred almost every year in the past decade in Taiwan. The Love River catchment area did not suffer such serious flooding until 2010 when Typhoon Fanapi again devastated this area.

Typhoon Fanapi mainly damaged the districts in the middle and upper reaches of the Love River: Zuoying (左營), Sanming (三民), Goshan (鼓山), and Nanzi (楠梓) district, because its heaviest rainfall was concentrated in the north of downtown Kaohsiung. The heavy rainfall began in the afternoon of November 19th when the high tide was coming in. The peak of the high tide level arrived in Kaohsiung at 18:43 and ebbed to the lowest level at 22:53. According to the investigation of the Fanapi flood compiled by the Kaohsiung Government (LGR 2010), the flood first began in some very low-lying areas at 15:00 and then gradually emerged in other relatively low-lying areas at about 17:00 when the tide had almost reached its high tide level. The flood had entirely subsided in the most flooding areas at about 22:00. It shows that the tide circle had profoundly affected the flood.

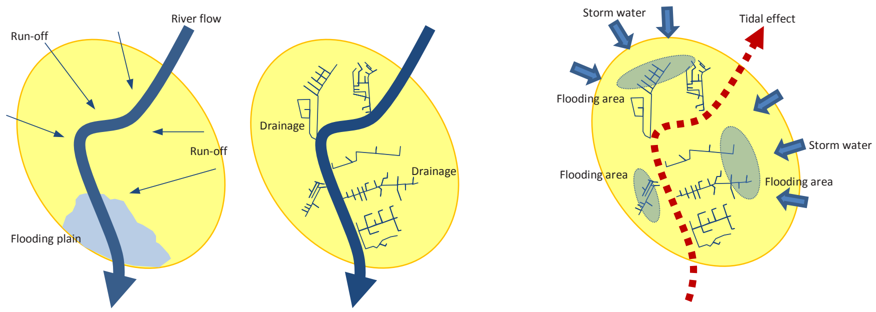
This flood reveals, again, the rain drainage in the Love River catchment is quite insufficient due to the very low elevation and the tidal effect. Although the rainfall during Typhoon Fanapi was larger than during Typhoon Trami, the heaviest rainfall occurred in northern downtown of Kaohsiung rather than in the Ianchen (塩埕) district. It caused a serious flood in Benho village (本和里) and Pautzugo (寶珠溝). The former plan to build detention ponds along the Love River was reconsidered in local discussions, although the completion of this plan is based on a low standard of a 20-year flood (LGR 2001).



Location	area(ha)	depth(m)	volume(m^3)
1	4.00	3.0	120,000
2	3.14	3.0	94,200
3	1.50	3.0	45,000
4	18.40	2.0	368,000
5	8.00	2.0	160,000
6	1.5		

Figure 90
The location of the planned detention ponds after TC Trami along the Love River (Source: Based on LGR 2001; Map by author)

In fact, even such an insufficient plan of detention ponds had just partly been completed after the flooding from Typhoon Trami. The detention pond in Benho village (本和里) and the heart of the Love River (愛河之心) are two complete cases. The heart of the Love River is the alternative plan for the Sanming No.1 Park detention pond (三民一號公園滯洪池) in the original plan. The total storage volume of storm water of these two cases is less than 30% of the original plan. The rest of the plan was suspended, because it is very difficult to carry out the eminent domain of the suitable lands. The current population of the Love River catchment is around 800,000. The average density of population is more than 13,000 per square-kilometer. Finding large and available pieces of land in such a highly urbanised area is an enormous political challenge.



The original system The changed system The impacts

§ 4.5 Conclusion

In this chapter, we make a downscale analysis of the three layers on the cases of the Meinong River and the Love River catchment. The analysis reveals that the completion of infrastructure, including dikes, drainage and transportation, has changed the natural path of surface runoff of storm water. This dramatic transformation did not cause a serious flooding problem until the 1990s, when the impact of extreme rainfall was emerging as a new threat. Even though the main reason for inundation in the Meinong River is similar to that in the Love River catchment area, a serious congestion at confluences of rivers, tributaries or drainages, this analysis nevertheless further distinguishes some differences in the effects of dikes, drainage and tides.

Rethinking the relationship between dikes and extreme rainfall

The water level of the main stream has risen since most of the river water is forced by the dike system to directly flow into the main stream of rivers. The raised water level will further block the water from tributaries flowing into the main stream. This situation will become more severe following the growing impact of extreme rainfall, which will cause enormous amounts of surface runoff to congest at the confluences. The congestion of storm water at confluences will further induce the backwater effect which will push water back to the middle or upper stream and then flood those areas without dikes.

A good example of this is the case of the Meinong River. The downtown Meinong area is situated in the middle reaches where the earlier settlers built houses right on the river bank. These rural houses entirely occupied the proper space to build dikes. Thus it is almost impossible to extend the dike system from the mid and lower reaches of the Meinong River to downtown Meinong. Hence, although a dike may reduce the threat of floods at the mid and lower reaches of the river, the backwater effect would push water back to inundate the dike-less areas, i.e. downtown Meinong, when a high river level blocks tributaries from flowing into the main stream.

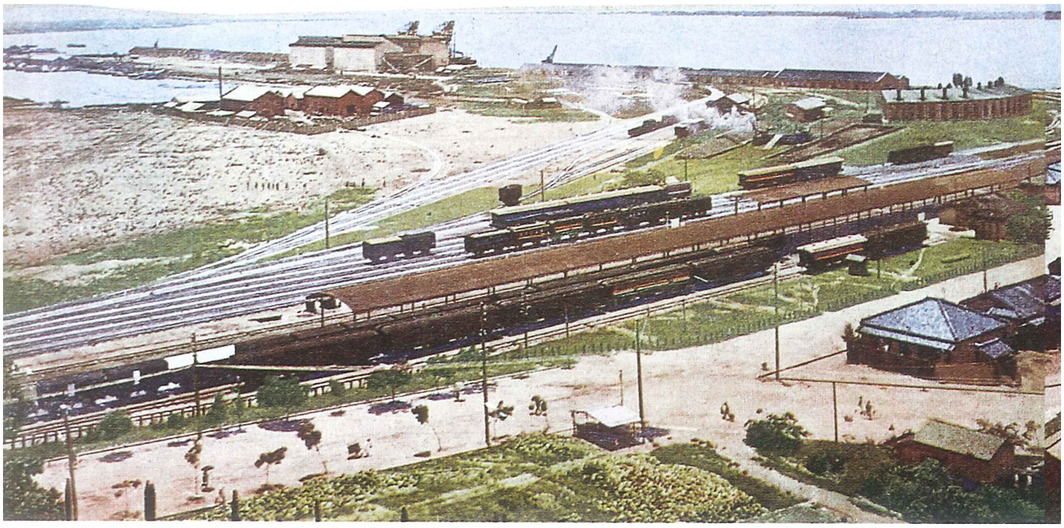
Rethinking the relationship between drainages and extreme rainfall

The construction of drainage in a delta city usually has to follow the arrangement of traffic system. This kind of arrangement has changed the natural path of runoff flow and will cause some urban inundations. Furthermore, the lower elevation and the tidal effect will make the situation worse because a high tide level can easily block all outlets of drainages in a low-lying area. For example, in the case of the Love River, because the urban water context has to be arranged as a grid system, that arrangement results in at least two serious problems. First, the grid system will force water to flow unnaturally in a right angle path which will cause some serious bottlenecks when significant amounts of storm water flow together to some confluence points. Second, the rapid urbanisation will also increase the spatial demands of other piped systems, including gas, electricity, and cable lines. It will be very difficult to extend the capacity of the drainage system beneath the streets. This is why the rainfall drainage of the Love River catchment area is just based on the standard of a 5-year flood, and is almost impossible to be upgraded.

An unreasonable standard

The major concept of flooding governance in Taiwan is based on controlling the flood risk of rivers. The central government's Taiwan Water Resources Agency (TWRA) has the authority to manage large rivers while the remaining smaller rivers are managed by local governments. The safety standard of flood risk for large rivers, which is based on the standard of a 100-year or 50-year flood, is always higher than for the smaller ones, which is based on the standard of a 20-year flood. But in the case of Taiwan, delta cities are usually located on the catchment areas of smaller rivers. It means a huge number of residents are exposed to a relatively low level of flood protection. For example, the population density in the Meinong River catchment area is 350 persons per square-kilometres, and 40,000 people live in an area of 120 square kilometres. This number is much smaller than the 14,400 persons per square kilometres in the Love River catchment: 1 million people live in an area of 67 square kilometers. The flood protection structures of the Meinong River are designed to protect its waterfront against a 50-year flood at maximum, while the safety standard of the Love River is designed to prevent its waterfront from a maximum of 20-year flood. Not to mention the drainage system in the Love River catchment area is only based on the standard of a 5-year flood. This unreasonable standard should be reconsidered.

The crucial hydrological issue for these problems is how to retrieve the available and suitable lands in a highly urbanised delta region. This is an almost impossible mission, especially in the current political climate of Taiwan. This predicament has compounded the growing impact of extreme rainfall as a new challenge. An alternative concept to answer this new challenge is to rethink flood management in a more comprehensive way, including urbanism and infrastructure, in addition to the hydrological techniques. It means the collaboration of multiple disciplines is crucial to propose an integrated strategy.



The newly development of Kaohsiung Port area in 1908. Source from LGR 2005 provided by Bo-Zheng Yan (顏博政)

5 The Challenge of Urban Transformation: Other Urgent Issues except Flood

Since the Open Reforms in the 1990s, China has been experiencing rapid industrialisation and urbanisation in its coastal region. Kaohsiung, as the biggest industrial port and city of Taiwan, faces great challenges of urban transformation under the competition of China's new rising cities. Many industrial factories had been moved from Kaohsiung to China. The shrinking of industrial development profoundly affected the development of urban economy and human landscape. The impacts embody in several issues: (1) the stagnation of port business; (2) remaining infrastructure; (3) obsolete industrial lands. Furthermore, after a long term industrial development, Kaohsiung is suffering from serious environmental pollution. Thus, how to catalyse a major transformation of the spatial structure is a tough task. In 2010, Kaohsiung City combined with Kaohsiung County to form Kaohsiung Metropolis City. Based on the new and larger territory, the aforementioned issues have to be re-considered from a more integrated and broader perspective.

The newly development of Kaohsiung Port area in 1908. Source from LGR 2005 provided by Bo-Zheng Yan (顏博政)

§ 5.1 The shrinking of industrial development

§ 5.1.1 The change in industry structure

After war, Taiwan government took the advantage of its port industry which Japanese left to build Kaohsiung as the heavy-industrial centre of Taiwan. The role of the twin-core intercity structure had gradually faded. The major spatial development was based on the port area as the main core toward to the north and south. This change of spatial cores could also be recognised in the changing population of delta cities during the period from 1951 to 2000. The population of Kaohsiung increased rapidly to 1.5 million in 2000 while the population of Pingtong was still around 200,000 (TDELS, LGR 2011) (Figure 91). The extending of urban space raised the demand of transportation infrastructure. The completion of port railroads and an airport further integrated the new extension areas and old city centre.

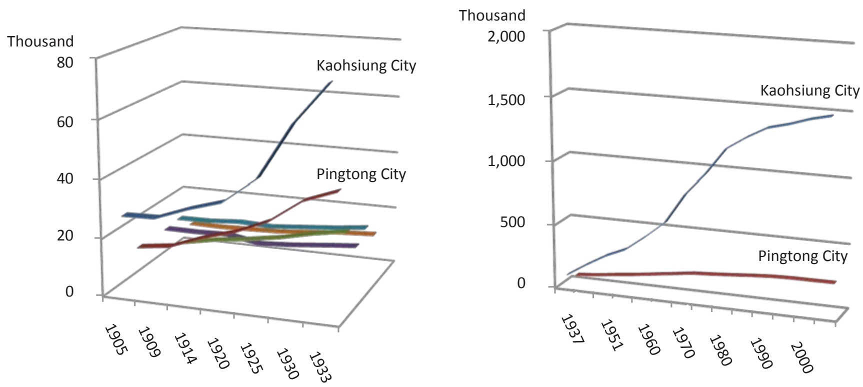


Figure 91
The population of Kaohsiung City and Pingtung City from 1905 to 1933 (left) and from 1937 to 2000 (right). Original source: TDELS, LGR 2011; Redrawing by author

This rapid industrial development had reached its peak in around 2000. Since the 1990s, the Open Reform policy of China had resulted in the tremendous industrialisation and urbanisation in those cities along the coast. Comparing to cities in Taiwan, these cities can provide manufacture investors with a more attractive investment environment, including cheap labour and land. Thus, most companies in Taiwan relocated their factories to China. The industrial structure in Kaohsiung has been changing since then. The changing percentage of industrial employment from 1986 to 2005 had illustrated that primary industries had decreased from 11.49% to 0.78%; Secondary industries had increased to the peak of 43.1% in 1986 and then decreased to 31.94% in 2005; Tertiary industries had increased from 56.66% to 67.29% (Figure 92) (LGR, 2007a). The output percentage of secondary industries had decreased from about 80% in 1986 to 52.74% in 2001 (Figure 93) (LGR, 2006).

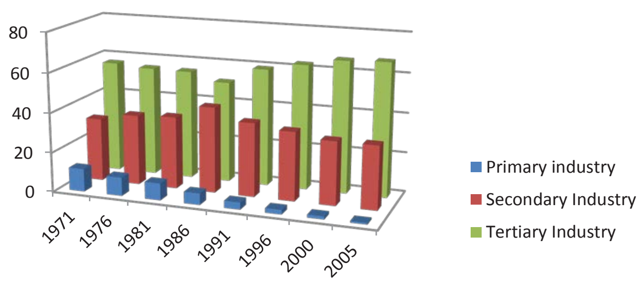


Figure 92
The development of three industrial sectors in Kaohsiung City from 1971 to 2005Original source: LGR 2007a; Redrawing by author

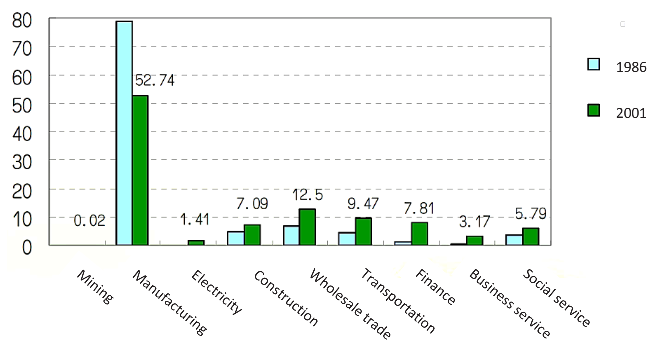


Figure 93
The development of manufacturing in Kaohsiung City in 1986 and 2001Original source: LGR 2006; Redrawing by author

§ 5.1.2 The impact of shrinking industry structure upon urban space

The situation of shrinking industry had become clearly visible in the early developed port areas, including Ian-Chen (鹽埕), Chan-Ching (前金), Sing-Sin (新興) and Lin-Ya (苓雅) Districts. In fact, the chart of changing population density shows that the rapid decreasing of population density had already occurred in these districts since the 1960s, when the impact of Fordism occurred (LGR, 2006) (Figure 94). The sales volume of cars had increased rapidly from 10,000 in 1967 to 130,000 in 1979, and then kept the level on about a half million annually after 1986 (TGR, 2014) (Figure 95). Massive production of cars stimulated the development of suburban areas. Furthermore, because of a highly dens population and expansive land prices in the old downtown area, most companies had been relocated from downtown to suburban areas which could still be connected by highways or railroads. The spatial pattern of this new trend was similar to a tent-like structure mentioned by Hall when he analysed how urban forms were transformed by popularity of cars and convenient road systems (Fig. 19) (Hall 1998). After the Open Reform Policy of China, most manufactories were moved to China, which was the last straw that further accelerated the shrinking of the downtown area.

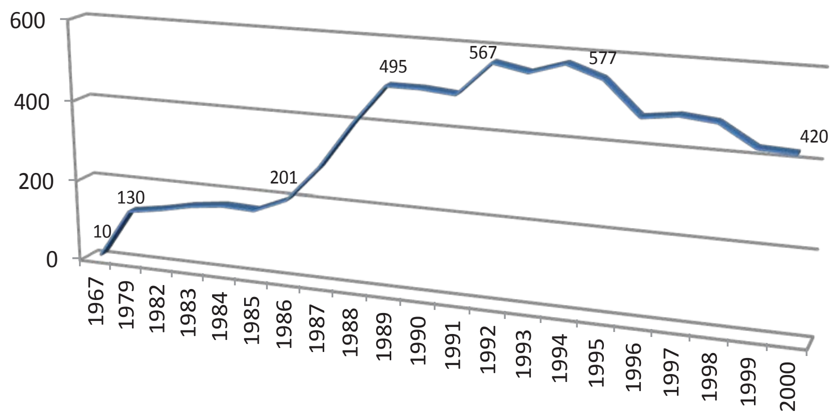


Figure 94

The sales volume of car in TaiwanOriginal source: TGR 2014; Redrawing by author

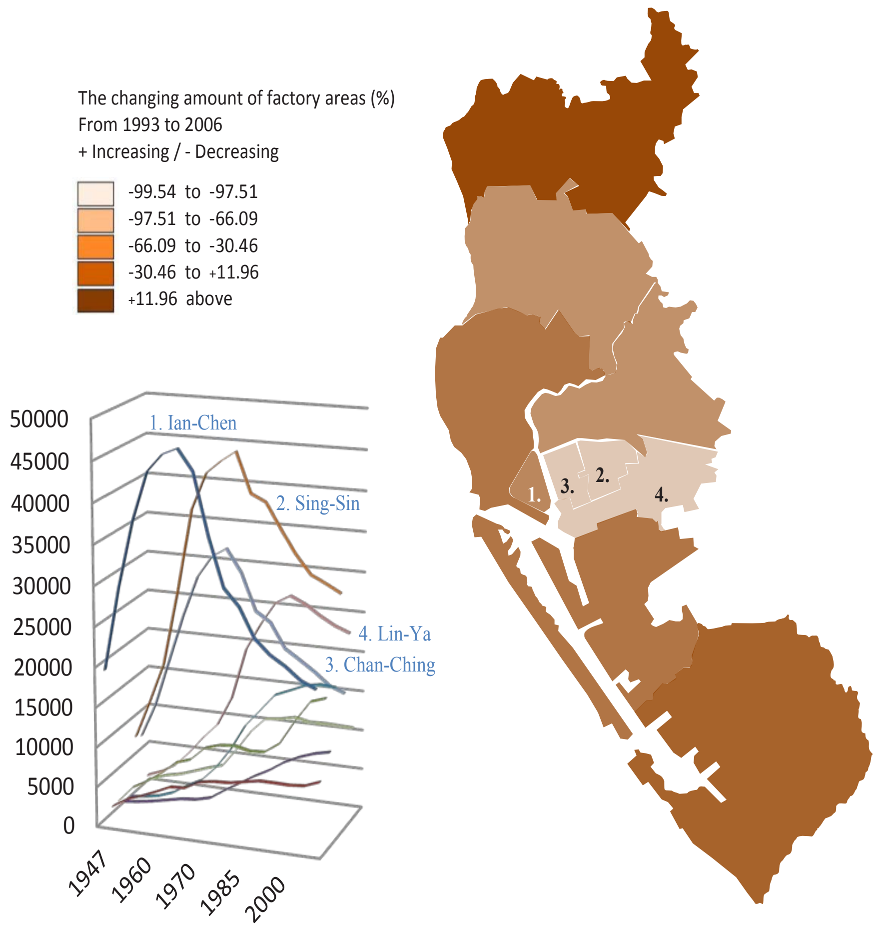


Figure 95

The relationship between the changing amount of factory areas and the changing population densities.Original source: LGR 2006, 2011; Redrawing by author

§ 5.2 The impact of shrinking manufacturing sector on port city

§ 5.2.1 The stagnation of port business

The direct impact of shrinking industry on Kaohsiung Port is the stagnation of its port business. According to the world ranking of container ports, Kaohsiung Harbour had rapidly fallen from the 4th in 2002 to the 13th in 2013. In fact, the volume of containers in Kaohsiung did not decrease, on the contrary, it increase slightly from 8.5 million in 2002 to the level of 9.6 million in 2011. The main reason which caused such a quick drop in its ranking is the rapid development of coastal cities in China. Compared with these new developing cities, Kaohsiung is lagging far behind (TGR, 2014a) (Figure 96).

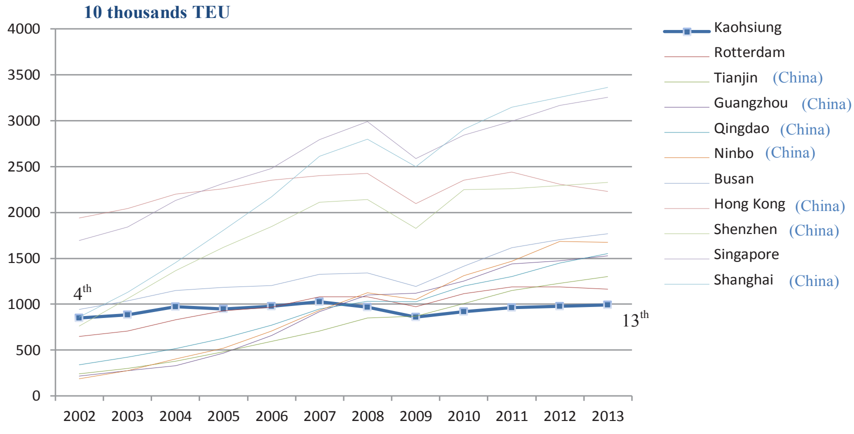


Figure 96
International ranking of container port and their container volumesOriginal source: TGR 2014a; Redrawing by author

The development of port toward to the south

Since the 1960s, containerisation has become an important shipping technology. Deep-water Ports have been necessary foraccommodating huge inter-continental ships, which forces the extension of original harbour areas toward the sea. The traditional port areas for bulk cargo terminals have gradually lost their function and been the obsolete urban spaces in downtown areas. Following the stagnation of the port business, the impact of containerisation has also massively affected the spatial fabric of Kaohsiung Harbour.

The Kaohsiung Inter-continental Container Centre (KICC) plan

This KICC plan was launched in 2011 which aims to reclaim about 422.5 hectares of new land from the sea. The whole project consists of 19 deep-water piers with water depth of 16 to 18 metres, 10 industrial chemical piers and 4 bulk cargo terminals. Among them, 5 deep-water piers will be equipped for shipping huge inter-continental container ships. The site is located on the outside of the Kaohsiung Second Port area. The first phase which is the construction of a dike with the length of 6,515 metres along the boundary of plan site in the sea will be completed in 2017. It is estimated that the whole project will be completed in 2019 (LGR 2007b) (Figure 97).

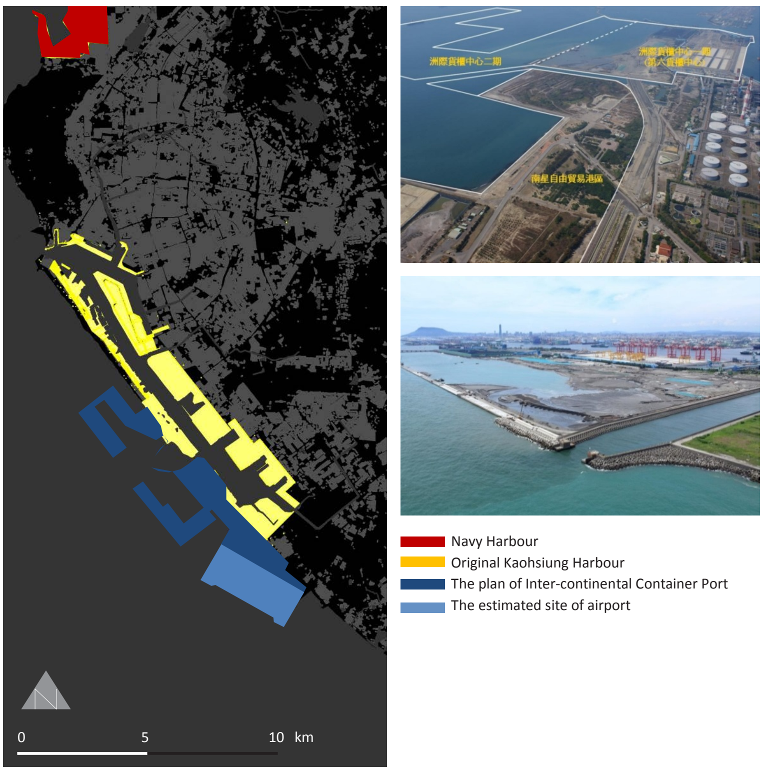


Figure 97
The location and development of Kaohsiung Harbour Source: LGR 2007b

From the perspective of Kaohsiung Municipality, the completion of KICC will eventually replace the old port areas, including Wharf 1-22. Because these piers are located in downtown Kaohsiung, the renewal of these waterfront areas is expected to promote local economic development.

The renewal of obsolete port areas
- Kaohsiung Waterfront Renovation Project at Wharf 1-22

The authorities of port areas and urban areas respectively belong to Kaohsiung Harbour and Kaohsiung Municipality. Until today, most port areas have been restricted except for port staff. Kaohsiung is a port city without any leisure activities for the waterfront. Due to containerisation and the shrinking of the manufacturing sector, the obsolete bulk cargo terminals, Wharf 1-22, have become the available lands for urban renewal (Figure 98). This is the first time that municipality can re- considers an integrated plan to connect the development of the water/ waterfront and urban spaces. Kaohsiung Municipality hope that this renewal project will consist of some crucial functions for urban development in the future as follows (LGR 2007b):

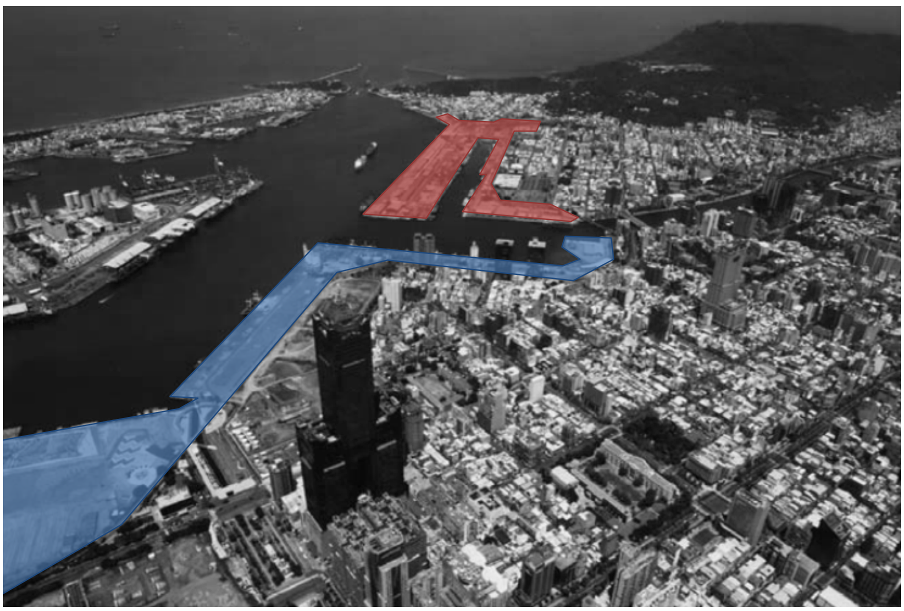


Figure 98
The location of Wharf 1-22: (Red) Wharf 1-12, (Blue) Wharf 13-22 (Source: LGR 2007b, montage by author)

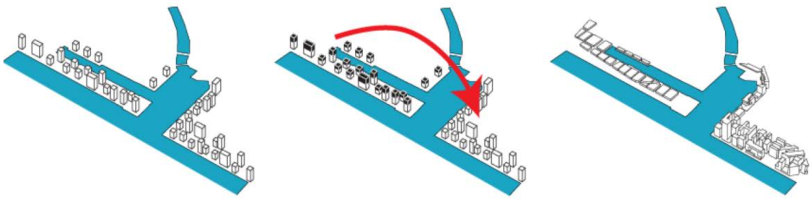
- the entrance of both the waterfront leisure area and international port city
- An unique landscape combining tourism and cultural industry
- A focus on sustainability including ecological protection and waterfront recreation
- Multi-functional design to combine and promote the development of surrounding areas
- An integrated consideration to improve the spatial quality of neighbouring communities

Finally, the municipality invited Team-KWF form the Netherlands to make a plan for these issues through an international competition in 2007.

Team-KWF constructed their design based on three major concepts, including the diversity of urban atmosphere, connections with the original urban fabric and eco-sustainable structures. First of all, a plan of how to arrange the building volumes was made. A low-density structure was arranged at Wharf 1-12 and Wharf 13-22 was designed as a high-density structure. This diversity in structural volumes could be defined with different spatial characters by which a divers urban atmosphere could be created. Secondly, several different transportations networks were re-organised to implement the idea of connectivity, including the connections between mountains and water, new and old urban fabrics, and different density structures. The third, the green system and public space system should combine the original park system with mountains as an integrated eco-system (Figure 99) (LGR 2007b).

The scheme by Team-KWF

The design about diversity



The design about connection

The design about eco-structure

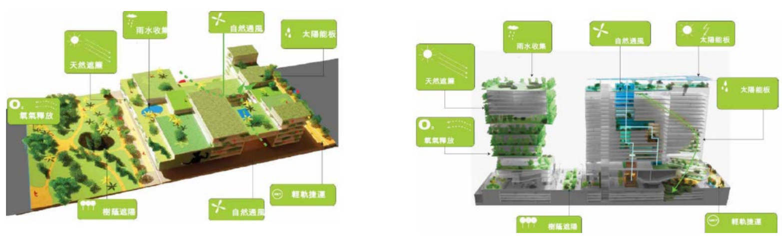


Figure 99

The scheme of Wharf 1-22 by Team-KWF with three main concepts and design strategies (Source: LGR 2007b)

§ 5.2.2 The obsolete infrastructure

The Construction and obsolescence of the harbor railroad

The Kaohsiung Harbour Railroad consists of two main parts, Port No.1 Rail and No.2 Rail. Parts of No.1 Rail had already been constructed by the Japanese since 1941. The other part had not been worked on until 1967 when the amount of cargo transition of Kaohsiung Harbor had been increasing rapidly. Due to the same reason, the second port of Kaohsiung Harbor had been completed in 1965. Following the extending of the harbour, the extension of the port rail was necessary, which promoted the completion of No.2 Rail in 1977. No. 1 Rail with a length of 13.5km was built as a ring system by circling the old downtown area. No.2 Rail with a length of 8.7km was built for supporting the demand for cargo handling between the old and newly extended No.2 Port (Figure 100) (LGR 2008a).

The shrinking of the manufacturing sector also caused a decrease in logistical demand. Furthermore, the relocation of major port businesses toward the south resulted in a decrease in cargo handling between No.1 and No.2 Port. Kaohsiung Harbour Railroad had gradually lost its logistical importance. The No.1 Harbour Railroad had ceased to function in 2008, because it caused serious traffic congestion in the downtown area. Following its rapid shrinking, No.2 Harbour Railroad had also ceased operations in 2011.

The renewal of the obsolete railway and rail station

There are two main concerns consist in the renewal plan of the obsolete harbour railway and rail station proposed by the Kaohsiung municipal government. The first concern, keeping the transportation function of railway is still the major consideration. Most railways on the No. 1 Harbour Line will be consisted in the plan of city ring tram and the rest will be restored as automobile roads or redesigned as boulevards. This city ring tram system will connect both the red line and the orange line metro systems, which is expected to promote the usage of the public metrosystem.

The other is the renewal plan for obsolete railroad stations. Among them, the municipality put most attention on the of Kaohsiung Harbour Station renewal plan which is 12.2 hectares within the downtown area. The goals of the station renewal plan include (Figure 101) (LGR 2008a).:

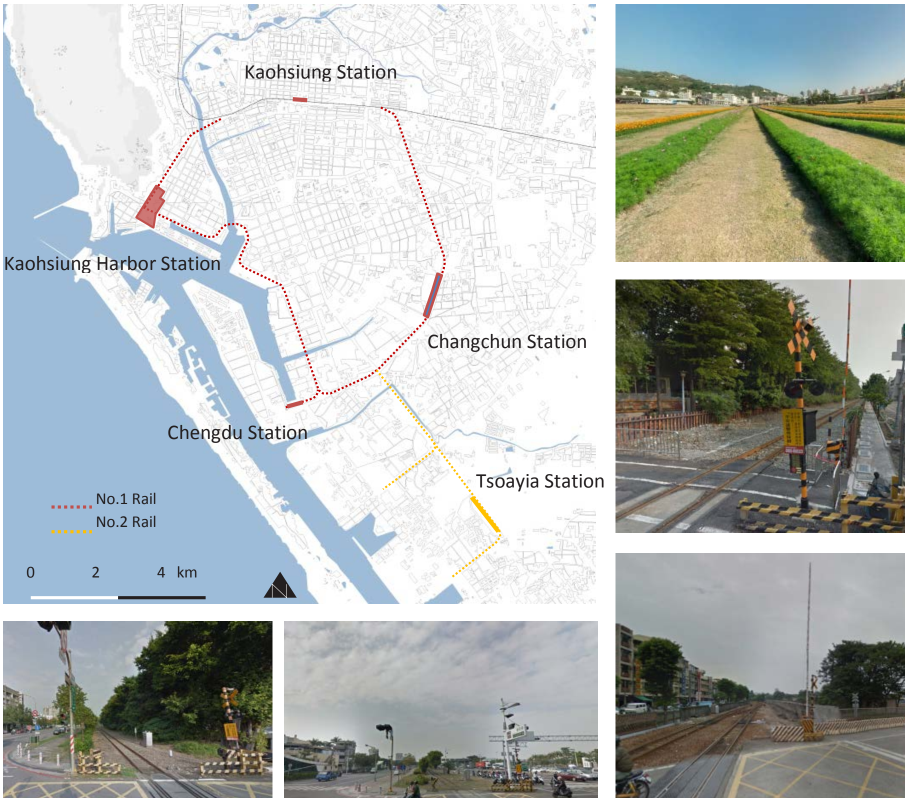


Figure 100

The location of Port No.1 Rail and No.2 Rail   Source: LGR 2008a

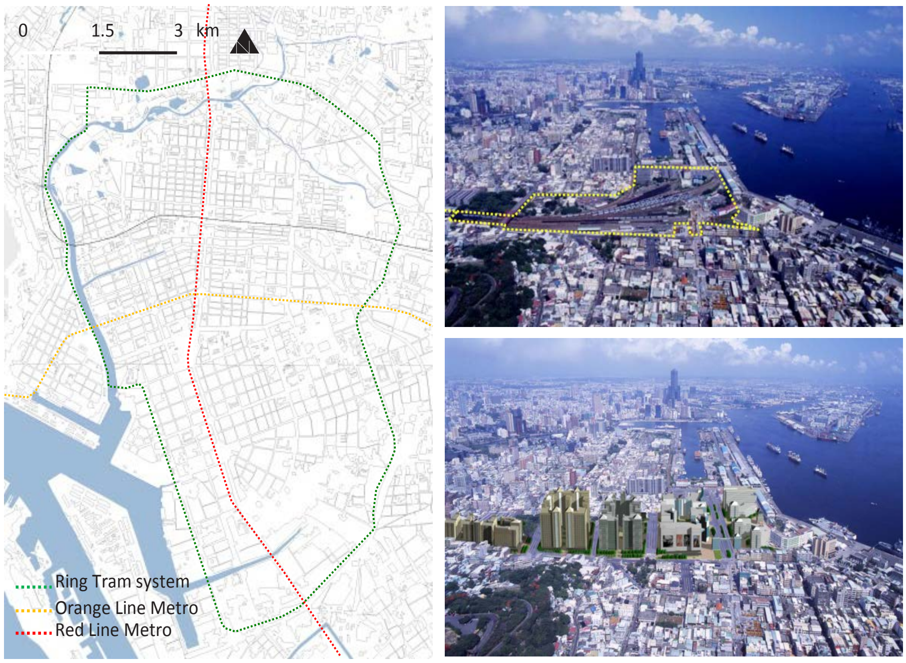


Figure 101

The location of Ring Tram system and City Metro system (Left); the location and design of regenerating Kaohsiung Harbour Station (Right)   Source: LGR 2008a

- Combining the metro and ring tram system to support a new urban tourism centre
- Making a new city image by connecting the mountains and the sea
- A important starting point for the waterfront regeneration plans
- Promoting local economic development

However, the final plan shows that making the biggest real estate profit is the major aim of municipality. A rather high floor area ratio (more than 400%) is allowed, which will make an image of a building wall between the mountains and water.

§ 5.2.3 The obsolete industrial lands

The increasing of obsolete industrial spaces

The Japanese located most heavy-industrial factories along the Kaohsiung Harbour because of its convenient location for shipping raw or industrial materials and products, from the chemical industry, aluminium companies, magnesium plants and iron mill etc. After World War II, Taiwan government took over these plants and continually operated them. Following the rapid growth of manufacturing in the 1960s and 70s, this region had developed as a dense industrial park. These factories had gradually ceased production since the 1990s due to strong competition from Chinese cities. This huge amount of obsolete industrial spaces has become an important problem which has deteriorated the quality of the urban environment (Figure 102) (LGR 2010a).

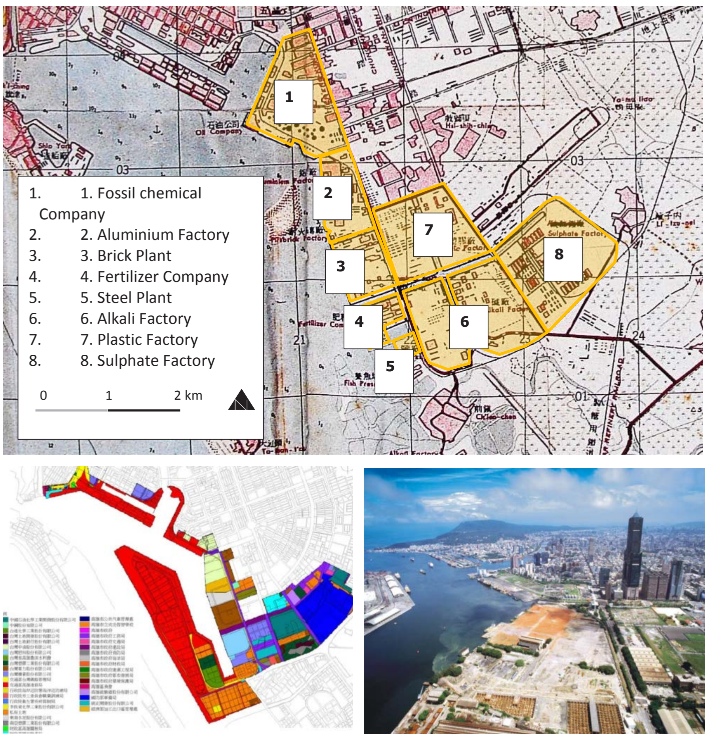


Figure 102

The location of heavy industrial plants after war (up); the location of the recent plants (down left) ; obsolete industrial areas (down right). Source: LGR 2010a

The renewal project for obsolete industrial areas

Kaohsiung Government proposed the plan of Kaohsiung Multifunctional Commerce and Trade Park, KMCTP for the regeneration of the obsolete industrial areas in 1999. Although the title of the plan was related to commerce and trade, i.e. the tertiary industry sector, the municipality showed its ambition for this plan by trying to develop both secondary and tertiary industries, including: manufacturing, shipping business, logistics, commerce and trade, and recreation. Both the renewal plans of Wharf No.1-22 and Kaohsiung Harbour Station were part of the original plan. The total planned area was 588.63 hectares (Figure 5.13) (LGR 2010a).

Several concepts were studied by the municipality in an international competition. These ideas finally were developed into three main schemes including Eco-City made by EDAW, Global City made by Charpentier, and Aquantainment City made by OMA. The case of Eco-City mainly focused on extending and connecting the existing environmental system by creating a long artificial peninsula system. The case of Global City emphasises creating a strong city image by arranging a spatial axis directly towards the port. The case of Aquantainment City emphasises how to create waterfront areas suitable for water tourism and activities (Figure 103).

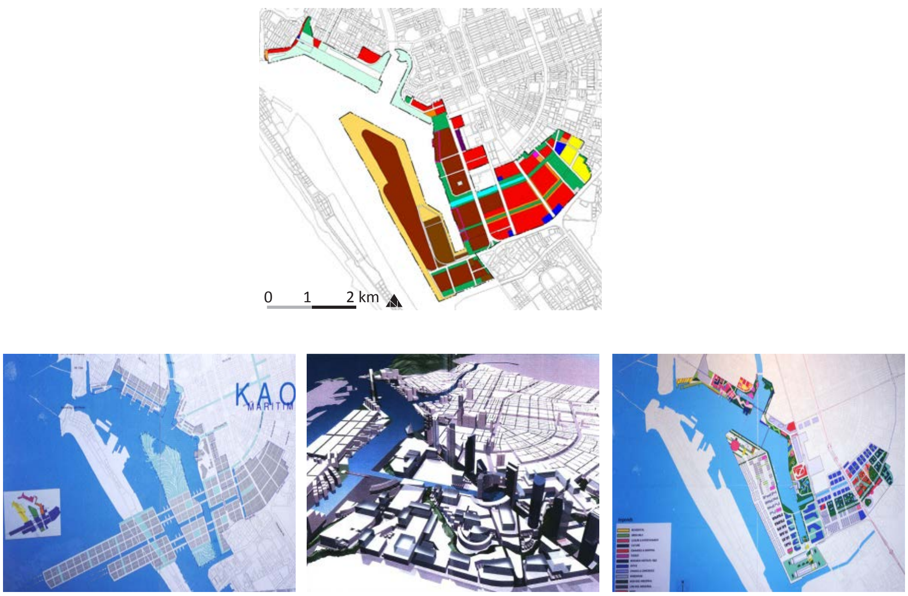


Figure 103

The land use plan of Kaohsiung Multifunctional Commerce and Trade Park, KMCTP (up); and the concepts from the international competition Source: LGR 2010a

§ 5.3 The environmental effects of manufacturing

The side-effects of heavy-industry have been very serious environmental problems in Kaohsiung, including air and water pollution, which did not disappear with the shrinking of manufacturing. The pollution problems have profoundly affected local habitants, which have been reflected in local lifestyles. For example, because the potable water of Kaohsiung comes from the Kaoping-Dam installed in the lower reaches of river, it is very difficult to control the water quality for the entire Kaoping

Figure 104
Water station for filling drinking water ; Buying drinking water has been a special tradition in Kaohsiung
Source: Kaohsiung Environmental Protection Bureau, 2002, http://61.218.233.198/journal/13/ok/content/ch1-03.htm; 優福公司宣傳照，*2013, https://plus.google.com/photos/100790057453125159418?banner=pwa*

River catchment area. Thus, extensive water treatment is needed to keep water drinkable, which results in a noticeable chemical odour remaining in the water. As a result, local residents use tap water mainly for sanitation. People also used to buy drinking water from private water stations (Figure 104).

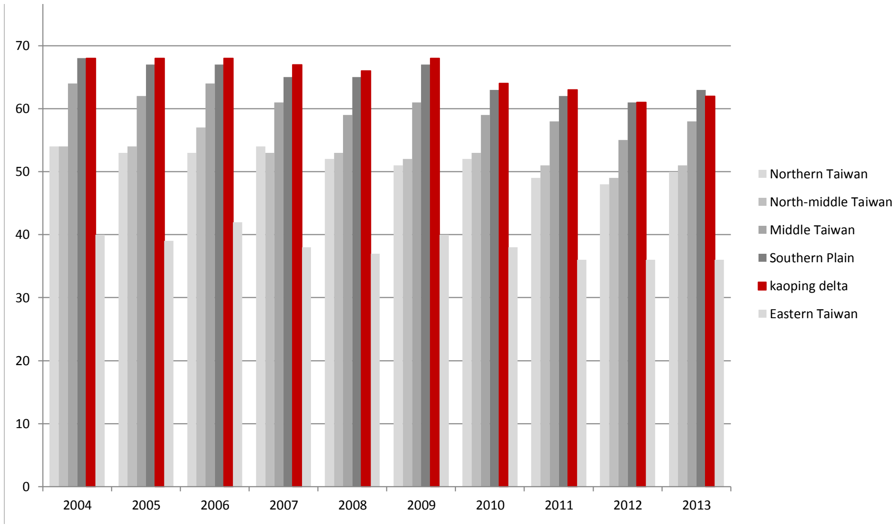


Figure 105

The distribution rate of PSI in Taiwan from 2004 to 2013. Source: TGR 2013a

Figure 106

*The emission of air pollution from fossil chemical plants; the huge amount of motorbike-commuters Source: China Time 2014/01/15, http://roll.sohu.com/20140115/n393527230.shtml;Apple Daily, 2014/02/24, http://www.appledaily.com.tw/appledaily/article/headline/20140224/35661230/ ;[*犇報·第*22*期*]* 五都選舉之角落觀察, *http://chaiwanbenpost.blogspot.nl/2011_01_01_archive.html , 2011/01/13*

§ 5.3.1 Air pollution

Heavy industry in Kaohsiung has caused serious air pollution mainly through two ways. First, the emission from production processes and burning of waste; Second, a significant amount of motor commute between industrial parks and their surrounding houses. According to the data from 76 air monitoring stations in Taiwan, the Kaoping Delta is still the region with the worst air pollution. This assessment monitors different airborne pollutants, including particulate matter (PM10), sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone (O3), non-methane hydrocarbons (NMHC), and total hydrocarbons (THC). All these data are further transformed into a more comprehensive indicator, the Pollutant Standards Index (PSI), by weighing their harms to human beings. The rate of PSI represents the level of air pollution. The air will cause health problems if the rate is higher than 100. The data shows the Kaoping Delta has 36 days with harmful air in 2005 (TGR 2013a) (Figure 105, 106).

§ 5.3.2 Water pollution

The development of heavy industry and rapid urbanisation also caused serious water pollution, especially in the Love River which flows through downtown Kaohsiung. After World War II, the Taiwan government adopted Japanese methods to drain all rainfall and wastewater into the Love River by the ditch system along the roads. The pollution of the Love River came to a peak in the 1970s. The Love River resembled a dirty and smelly sewer. The improvement plan started in 1979 (Yuein 2004). The original drainage system was separated into rain and wastewater systems. But due to the prohibitive costs of building a sewer system in the old downtown, local government tried to apply a new concept of collecting most waste water at some key locations. There were eleven gates built along the river for collecting waste water in the 1980s (Yuein 2004). The completion of a treatment plant and main sewer pipe further improved the water quality of river in 1987. Presently, there are still four main gates remained working, including Gu-Shan Gate (鼓山截流站), Zhi-Ping Gate (治平橋), Pou-Zu Gate (寶珠站), and No.2 Gate (二號運河站) (TGR 2003) (Figure 107). The concept of collecting waste water has its shortcomings. Because the Love River is still the only waterway that drains rainfall discharge during storms, all its gates have to open for draining peak discharge. Thus, waste water will flow in to the river again. This situation results in a unfavourable outcome where the water quality of the Love River is worse in the summer (storm season) and better in the winter.

Figure 107

The location of waste water pipe and the main gates for collecting waste Source: TGR 2003

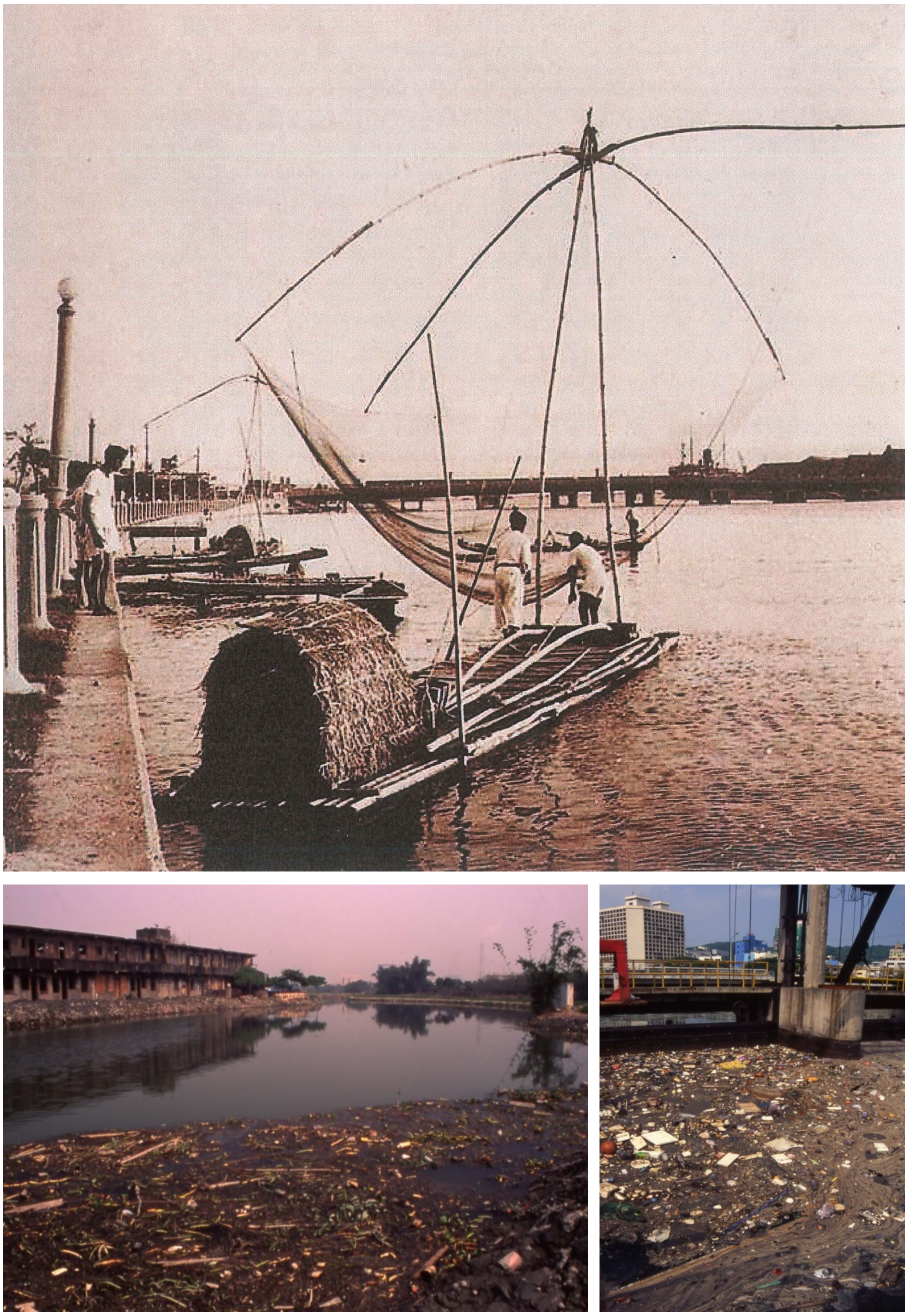


Figure 108
the transformation of the Love River water quality after the World War II
*Source: Association for Culture and Ecology L. L. Hsu (*高雄文化愛河協會, 許玲齡*)*

§ 5.4 The vision of local government for transformation

§ 5.4.1 A contradiction with the central government

The plan of KMCTP actually was one branch project of the Asia-Pacific Regional Operations Centre (APROC) plan of Taiwan, first officially advocated in 1993. It was an attempt by Taiwan's central government to improve its shrinking industries under the strong competition of other Asian cities. This plan, on a national level, designed Taiwan as six centres including: manufacturing centre, shipping centre, aviation business centre, financial centre, telecommunication centre and media centre. From the perspective of the central government, Kaohsiung fit into its plans for manufacturing and shipping centres. The APROC was in the late 1990s because such a broad project was too complicated to achieve a consensus among Taiwanese cities. For example, Kaohsiung could not be satisfied by this plan, so they proposed a multifunctional one in order to include all their own priorities.

§ 5.4.2 Local vision

Kaohsiung residents have been quite familiar with the side-effects of manufacturing since the national policy made Kaohsiung the heavy-industry centre of Taiwan. Presently, the problems of environmental pollution, traffic congestion and public safety are still nightmares for local inhabitants. In order to satisfy both state policies and local expectations, the local government tried to make a plan including two main goals: First, they dealt with the national policy as a concept of the global city, an major ambition for politicians; second, from the local perspective, they hope to develop this area as a centre of culture, tourism, commerce, trade and manufacturing, becoming a new urban centre connecting three cores in the future, called One Centre with Three Cores, as follows (Figure 108) (LGR 2010a).

- Northern Kaohsiung: Focusing on obsolete manufacturing areas, the local government hopes these old heavy and processing industry parks can be upgraded into high-tech industry parks. Furthermore, after the successful hosting of the World Game event in 2009, the municipality also hopes that this area could be developed as a public park combined with its nearby historical heritage areas left from the Wall City period.

- Middle Kaohsiung: Because most tertiary industrial buildings are still concentrated in the old downtown area, it will be developed as a commerce and trade core.

- Southern Kaohsiung: Following the launch of the Kaohsiung Inter-continental Container Centre, municipality hope this area could be developed as a logistics core. Furthermore, they hope to extend this idea to integrate the future development of airport as a Free Trade Zone.

- Old port areas are expected to be developed as a new centre of a marine city which has is in a crucial position to (1) connect three main cores; (2) combine urban green and blue corridors; (3) link the old and new urban fabrics; (4) shape the new image of the marine city.

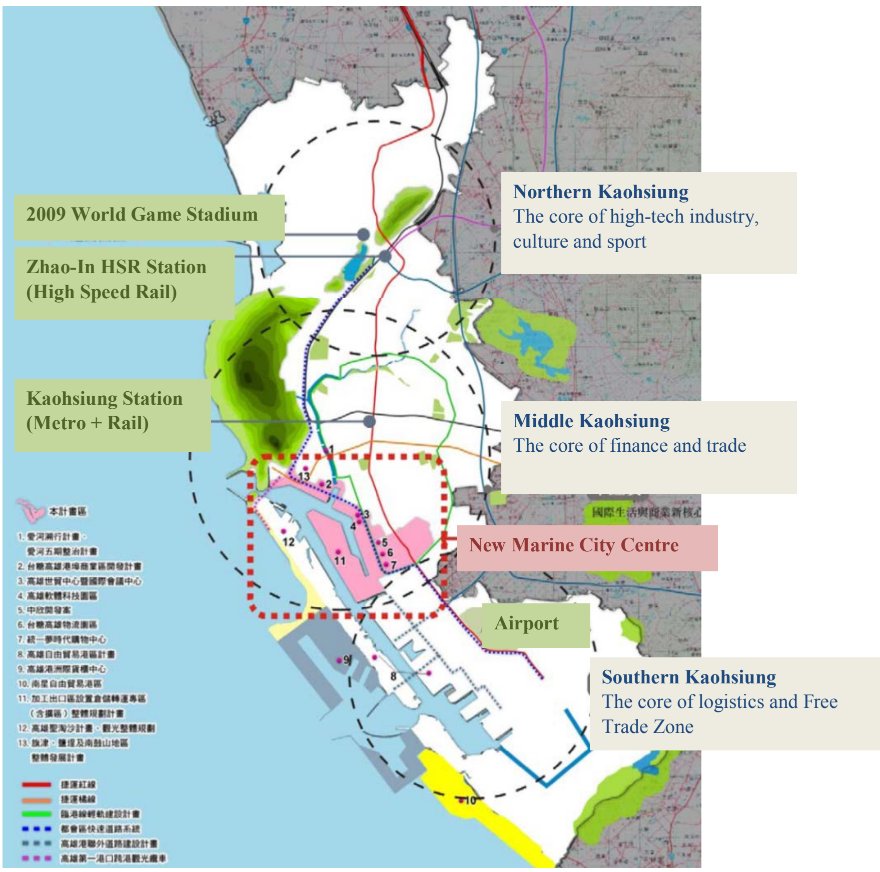


Figure 109

The new development vision of Kaohsiung (Source: LGR 2010a)

§ 5.4.3 The difficulties

There are still a lot of difficulties that have to be overcome for Kaohsiung Municipality to transform this port city according to their ideal paradigm. According an investigation made by the Taiwan Control Yuan in 2011 (監察院, 100財調0041), the Kaohsiung Multifunctional Commerce and Trade Park plan had only been completed in the rate of 29.2% since 1999. This report pointed out that: because the authorities of the lands in the plan belong to many national organizations respectively, it is very difficult to organise them through local governments. In addition, the local government also met a bottleneck to in terms of attracting investments. Basically, the municipality tries to resolve this problem by putting huge public investments or increasing the floor area ratio of lands to attract private developers. This method obviously did not work well. This research tries to ask this question in another way: why these stakeholders or investors hesitant about investing in this area?

§ 5.5 Commentary - Another way to reconsider

Based on the master plan of Kaohsiung Municipality, the southern part of the city will be designed to support port development and the manufacturing industry in the northern part of the city should be upgraded to high-tech and physic industries. The obsolete port areas will be a catalyst for this transformation. The aforementioned question should divide into two aspects: one is about the development of the port itself; the other is related to waterfront development, from which we can further clarify the crucial problem of waterfront regeneration in this port city.

Port development and impacts on the city

According to the report compiled by OECD (2010), a well-functioning port could bring benefits to the city at least by four ways, including facilitating trade business through international supply chains, provide value added through economic activities, port-related employment, and being spatial clusters for innovation, research and development. Among them, there is a more special inter-relationship between ports and innovation. Comparing the top ten cities with the largest number of shipping patents, Zurich is the only one does not have a port. Not only will the existence of ports stimulate port-related innovation but also port-cities are very dominant in these continuous innovations, for instance, shipping, storage or logistical technology, to support a sustainable development. These port-related patents and researches are mainly created in universities located in port cities (OECD 2010). Thus, the establishment of these knowledge institutions will further backbone the sustainable development of ports by fostering innovations, doing research and offering maritime education or training programs. A practical problem is, while these knowledge workers usually show more concern for their surrounding environment, how to provide a friendly and livable environment to attract them to live in? It will be a crucial issue for Kaohsiung.

Waterfront regeneration

Due to containerisation, waterfront regeneration has become a worldwide trend. Several different aspects could be applied to examine this phenomenon. From the historical perspective of transformation, Meyer (1999) framed a four phase structure to explain the formal transformation of port cities (Fig. 20) (Meyer 1999). This structure emphasises that several specialised hubs within a city will develop and further connect together as a network when a transit port transforms into a distribution port. Old harbour areas should act as a strategic place to create a new association between residential and traffic functions for the development of a new image, an attractive city for new types of businesses and employees. From the perspective of port logistics trends, Notteboom (2007) has a similar argument as Meyer. In his opinion, there is a new approach toward logistics networks. The traditional chain between order and delivery has shifted into networks, which implies there are many options to route cargo via a main or regional distribution centre to various solutions. Furthermore, for this new trend, Notteboom advises port authorities to demonstrate a high level of environmental performance in order not only to ensure community support but also to attract trading partners and potential investors (Notteboom 2007).

From the aspect of waterfront renewal itself, several types of waterfront renewals could be classified, including market orientation (encouraging urban tourism or business activities), spatial orientation (creating public spaces or preserving historical spaces), and financial orientation (adding capital value by intensive land use). Although most local governments usually expect a 'multi-functional' (better including all) plan, the right-mix of functions is necessary to combine the distinctive properties of each port-city. An allocation rate of land use, i.e. public space, residential, office, commerce, port and other, could clearly illustrate the different spatial patterns of these types (Fig 109) (OECD 2010).

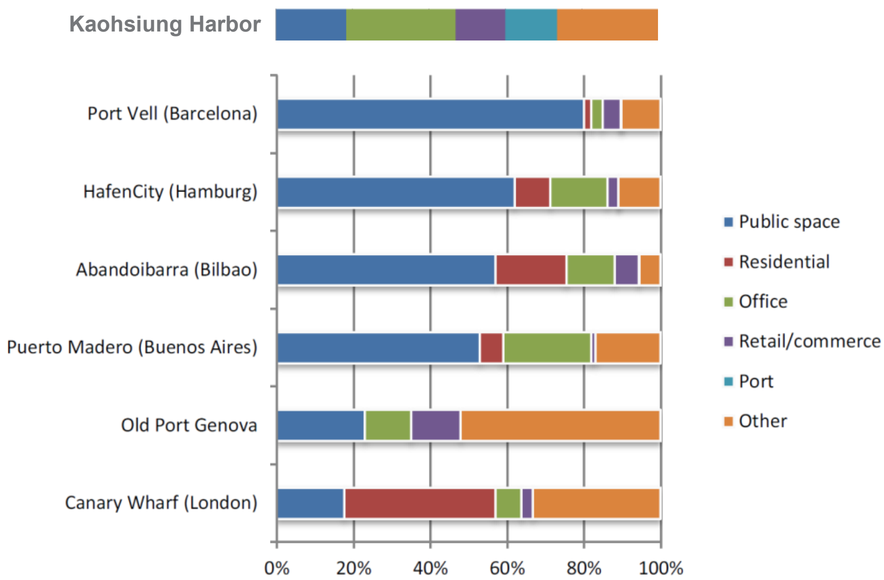


Figure 110
The allocation rate of land use of different water renewal schemes Source: OECD 2010

Two very different spatial patterns are revealed in the cases of Port Vell in Barcelona and Canary Wharf in London, which represent two different contexts of waterfront development. The project of Port Vell in Barcelona was designed following the Barcelona Olympics in 1992. The clear main goal was to create a highly attractive urban space for tourism. This plan is very successful attracting more than 16 million visitors per year. In contrast, Canary Wharf project in London was a plan with rather high intensification of land uses in order to respond to the pressure of a house shortage (OECD 2010).

Compared with these cases, the case of waterfront renewal in Kaohsiung shows an even higher intensification of land use than Canary Wharf in London. This quite unusual allocation rate of land uses has raised another important issue. The highly intensive land use implies it will cost a significant amount of investment which is far beyond what the local government can offer. In the case of Canary Wharf, its good environmental qualities and abundant historical heritage sites in London are substantial assets which attract huge amount of investments. The crucial question is could Kaohsiung provide such kind of urban qualities to attract investment? Here, the Port Vell case is perhaps a good example for Kaohsiung. With a budget of just 51.54 million euros by the Port of Barcelona could provide wonderful urban qualities to facilitate local tourism.

A background of knowledge for a trans-disciplinary working frame

The aforementioned theoretical background provides this research with another way to reconsider the difficulties when those renewal plans are implemented in Kaohsiung. The question should be extended to consider as what factors have been provided by Kaohsiung to attract various investors when low labour and land costs are no longer available in Taiwan? Likewise, flooding and pollution definitely create negative impacts. The city's economic decline and environmental pollution together with a flooding problem have already been three urgent issues in Kaohsiung. Unfortunately, a large budget is needed for every issue. Due to limited local financial capacities, how can priorities be set? This chapter reveals that the local government had met a serious bottleneck when they put in significant public investments for the improvement of the economic shrinking before the further improvement of floods and environmental pollution. This research rethinks this priority question in another way. Is it possible to make a plan for flood management, which is also helpful for the other two issues? A workshop as a design test was organised as a part of this research. This is explained in the next chapter in order to further answer this question.

An amphibious tank supported by military during the flood of the Kaoping River Delta in 2008, Source: Net Ease News, Retrieved 1st Oct. 2014 from http://news.163.com/photonew/00AN0001/11003_02.html

The flooding of the Kaoping River Delta in 2008, Source: Net Ease News, Retrieved 1st Oct. 2014 from http://news.163.com/photonew/00AN0001/11003_02.html

6 Towards a long term multidisciplinary strategy - The Kaohsiung Workshop as an Example

The aforementioned analysis of a 3-layer approach reveals that the natural landscape of the Kaoping River Delta has been greatly altered by man-made infrastructural systems, including dike systems and drainages, since the beginning of the 20th century. Serious water problems did not occur until the emergence of climate change impacts in the 1990s. Additional questions include: can the practical foundations of these results be carried out? Could this 3-layer framework be a substantial base to organise a workable platform for multi-disciplinary collaboration?

The method of research by design is adopted by this research. This concept has been developed in the past several decades as one of the major methodologies at TU Delft. According to different factors, i.e. object, context, actor, time, and way of testing, there five main types of research by design, including prototype design, experimental design, design re-construction, scenario design, and leaving out pre-suppositions. Referring to the method of design reconstruction, this research will construct a framework for multi-disciplinary collaboration.

Following this context, this study organised a five-day workshop in Kaohsiung: 'Workshop on Water Environment Development in Kaohsiung' in 2012 to further examine the results derived from Chapters 3 and 4. This workshop followed the theoretical framework of the 3-layer approach to examine the entire Kaoping River catchment area and its two tributary basins as the local-scale sites: the Meinong River and the Love River. The participants mainly consisted of urban planners and hydrologists coming from the government, universities, and local non-profit organisations, including Kaohsiung Municipality, the Taiwan Water Resources Agency, the Taiwan National Science and the Technology Center for Disaster Reduction, Delft University of Technology, Deltares, Taiwan National Pingtung Technology University, and Taiwan National Cheng Kong University. The goals were both to develop a strategic plan for research by design and to construct a multidisciplinary collaboration platform based on the 3-layer approach.

§ 6.1 Framing a multidisciplinary platform

§ 6.1.1 The Concept of Research by Design

The concept of 'study by design' is defined by De Jong as "the development of knowledge by designing, studying the effects of this design, changing the design itself or its context, and studying the effects of the transformations (de Jong, T.M. et al., 2002). " That means that design is viewed as 'means-oriented designing' rather than 'goal-oriented designing'. The main goal is to understand which requirements should be met by a test procedure during a pre-design study. According to different factors, such as: object, context, actor, time, and ways of testing, De Jong furthermore classifies different ways of study by design into five different types (de Jong, T.M. et al., 2002).

- Prototype design could be constructed to find optimal solutions through a cyclical process of designing – testing – re-designing. In such a process, context is a constant that can provide fixed circumstances as a foundation for designers to improve their design. This essay also emphasises that a prototype design could not be reproduced at another location regardless of whether the context is new and different. Some ex / post evaluations are suggested for design improvement.

- Experimental design is conducted to analyse the effects of a test object in various contexts. In general, it is a typical scientific method in which various contexts are controlled as control variables and just one or a few contexts are manipulated as independent variable in order to find the precise effects of a test object.

- Design re-construction could be applied to the complicated condition between multi- contexts and actors. In fact, this design is somewhat like a process of continuous communication between different plans or maps from different stakeholders. The new integrated vision of the legend will be created through a cyclical process of interpretation, adjustment, re-interpretation and re-adjustment.

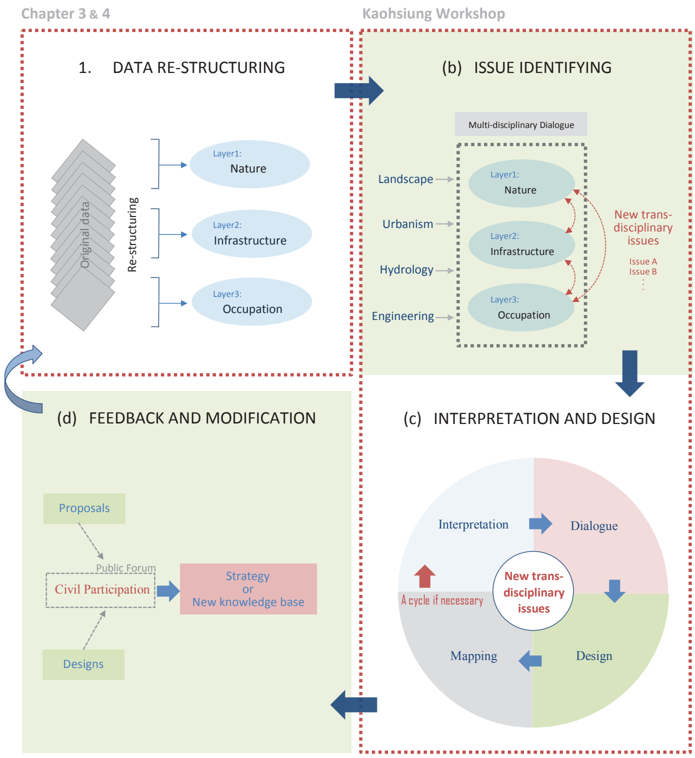
- Scenario design is usually arranged to gain a better insight into an uncertain future. Thus, not only the extension of the predicted future but also unexpected interventions will be included in the design when different scenarios are set out. This kind of design is especially helpful for a more flexible procedure for decision-making processes.

- Leaving out pre-suppositions is the last type of design this essay mentioned. The logic of this design is quite different from the aforementioned types of designs. A special context which is very different from what common sense might dictate will be set out to develop a brand new idea. Although these new ideas maybe extend beyond reality, they provide a good chance to re-think the new possibilities following pre-suppositions.

Based on the structure of design re-construction, this research will construct a working platform for multi-disciplinary collaboration which is expected to consider the interrelationship between different actors and contexts.

§ 6.1.2 The Framework

Based on the concept of design re-construction, there are four main phases will be arranged as a cyclical process to form the working framework in this chapter, including (a) data preparation and re-structuring; (b) issue identification; (c) interpretation and design; (d) feedback and modification. Among them, phase a will construct the related data as a 3-layer structure based on the analysis results in chapter three and four; Phase b and c comprise the Kaohsiung Workshop which was organised in 2012 for further developing the practical strategies of the 3-layer analysis; Phase d is the final results of the workshop which will provide a new standing point to launch another further process (if necessary). This process is illustrated as the following figure.



§ 6.2 The Kaohsiung Workshop as a Multi-disciplinary Platform

§ 6.2.1 The workshop brief

Aims

- Test the concept of the 3-layer approach
- Explore a long-term strategy for climate adaptation both in policy making and practice.
- Build up a collaborative platform for multi-disciplinary work.

Main issues

There are two main water issues in the Kaoping River, which are explored in this workshop:

- Extreme rainfall and space for water: The frequency of extreme rainfall has been rapidly increasing since the 1990s. For instance, Typhoon Moraket in 2009 caused about 3000mm of heavy rainfall within four days. In 2010, Typhoon Fanapi caused over 600mm of rain in Kaohsiung within six hours. It seems that extreme rainfall is no longer a fluke event, but almost annual events in Taiwan. Based on this new climate trend, how much flood prevention (water detentions, pumping facilities, dikes etc.) is enough? Where do hydraulic infrastructures fit into the picture? To what extent can spatial strategies fit into the current urban context? All of these questions need to be addressed properly in the city of Kaohsiung.

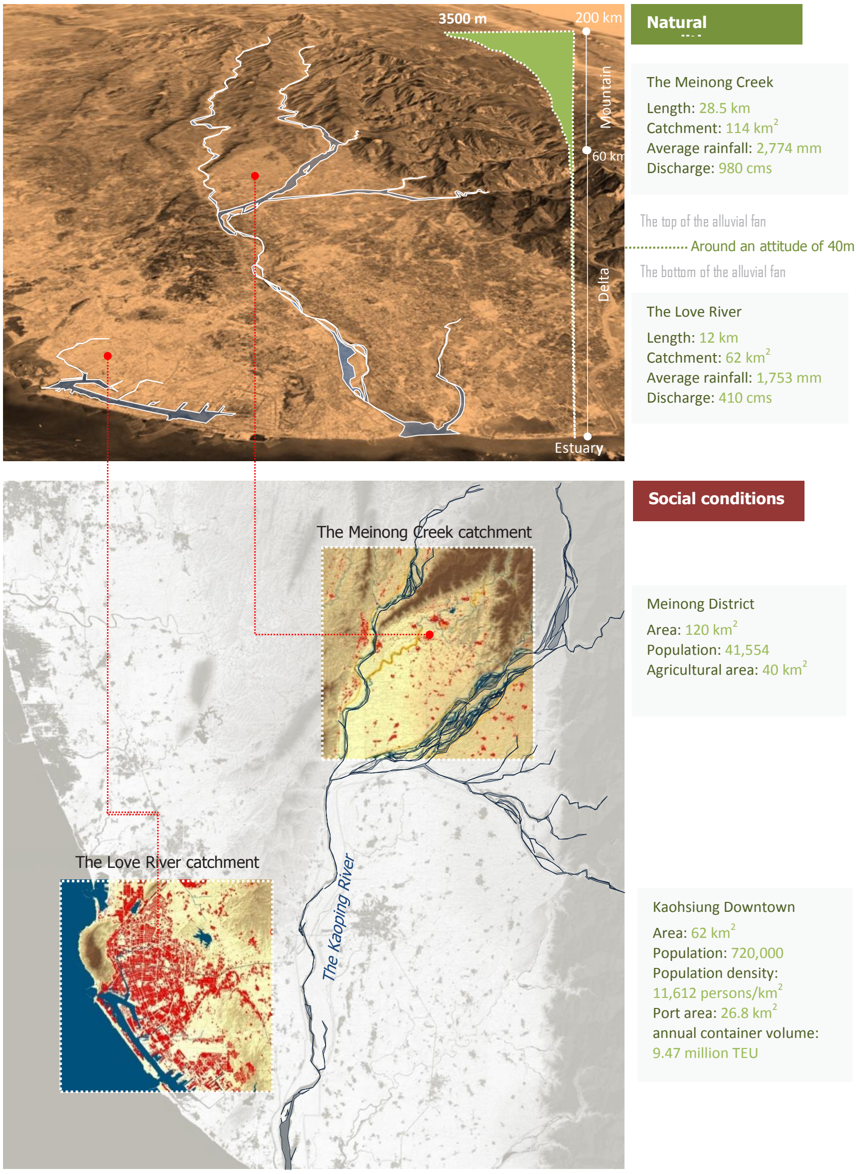
- Water usage and sustainable development: Besides the flood risks, rivers in Taiwan are normally very short and steep (e.g., the Kaoping river is a 170km-length river with an average slope about 1:150). The natural conditions make it difficult to keep fresh water on the island. In addition, the extremely uneven distribution of precipitation (the precipitation in dry seasons is only one-ninth of the total amount) exacerbates the shortage of fresh water both for domestic and industrial usage. Comprehensive strategies for water resource management are also a crucial task in Kaohsiung.

Agenda and participants

Schedule	Programme	Participants
Day 1	Knowledge exchange and sharing experiences Field survey ✓ Site 1: The Love River and urban wetland ✓ Site 2: The Meinong River catchment area	Dutch experts, Taiwan scholars, NGOs, and government sectors
Day 2	Workshop I: The Meinong River catchment area ✓ Clarification of problems ✓ Comprehensive analysis	Dutch experts, Taiwan scholars, NGOs, and government sectors
Day 3	Workshop I: The Love River catchment area ✓ Clarification of problems ✓ Comprehensive analysis	Dutch experts, Taiwan scholars, NGOs, and government sectors
Day 4	Strategy development Final integration	Dutch experts
Day 5	Presentation and further discussions Closing ceremony	Dutch experts, Open participation to citizens

Sites and their features

There are two focused sites in this workshop: one is the Meinong Creek catchment area on the upper reaches of the alluvial fan and the other is the Love River catchment area in the lower reaches of the alluvial fan.



§ 6.2.2 Workshop Day 0 - Preparation - Commission introduction

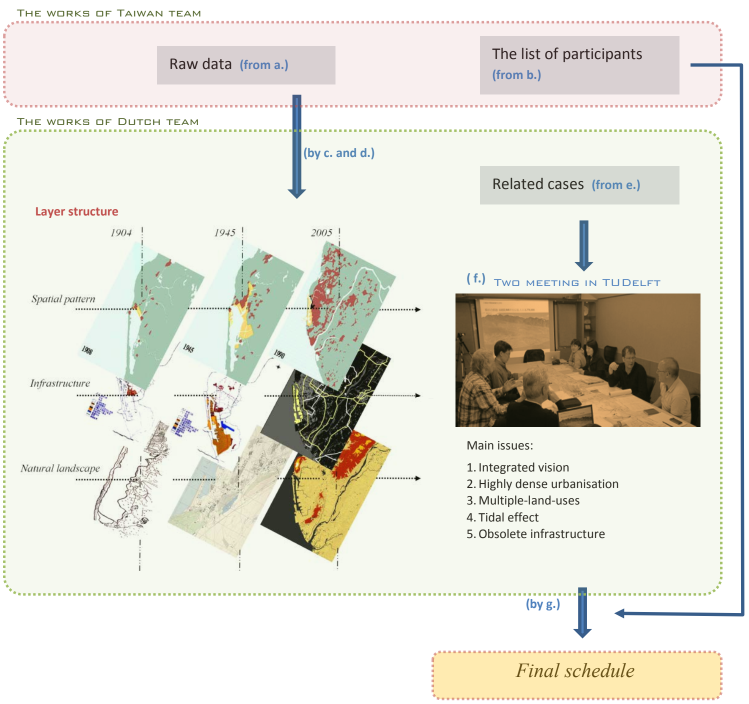
To Taiwan team:

- a. Data collection
- b. To organise trans-disciplinary participants, including experts, residents and governments.

To Dutch team

- c. A historical survey of two sites
- d. The clarifying of information
- e. The studying of related Dutch cases
- f. The identification of issues related to hydrology, urbanism and landscape architecture
- g. The arrangement of the workshop process

Working process



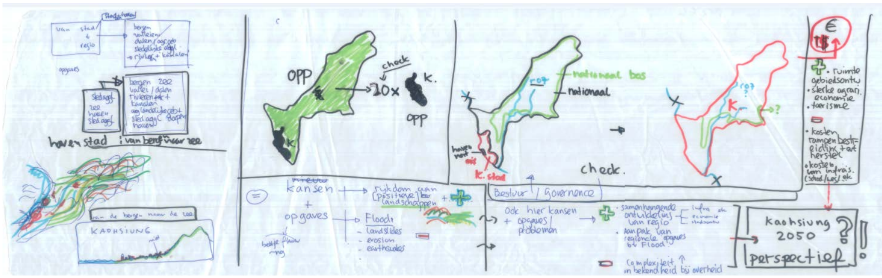
Commission introduction

The main goal of field surveys is to construct an integrated understanding of the Kaoping River catchment area. Besides that, the Meinong River catchment area and the Love River catchment area are two focused areas which are further introduced by local government about hydrologic instruments, current plans, and flooding history etc.

Data preparation

Based on the 3-layer framework, all data are classified into three groups. Furthermore, flood records are very important as input data to the 3-layer system.

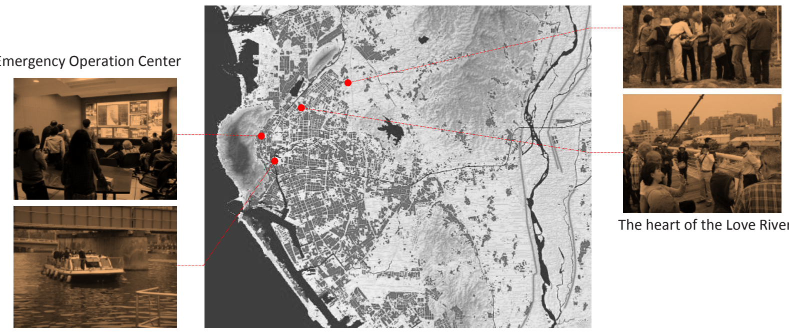
Information	Description	Source
Natural Landscape		
Soil structure	Distribution and section maps	Public Work Bureau
River discharge	The average and storm peak discharge of the Kaoping River and all its tributaries	Hydraulic Bureau
Ground water data	The depth of groundwater level	Hydraulic Bureau
Local precipitation data	The average of rainfall, and the distribution and duration of storm rainfall	Hydraulic Bureau
Tidal information	The timing, duration, and water levels	Fire Bureau
Infrastructure		
Hydrologic instruments	The capacity and location of drainage, including dike system, pipe, pumping station, and dam	Public Work Bureau
Transportation	Its history and current plans	Public Work Bureau
Occupation		
Human landscape	Land use, elevation, building area, infrastructure etc.	Urban Development Bureau
Flood records		
Historical flood data	Flooded areas, the depth of flooding water, duration of floods during Typhoon Moraket and Fanapi	Hydraulic Bureau
The scenarios of storm	The prediction of flooding areas and risk	Hydraulic Bureau



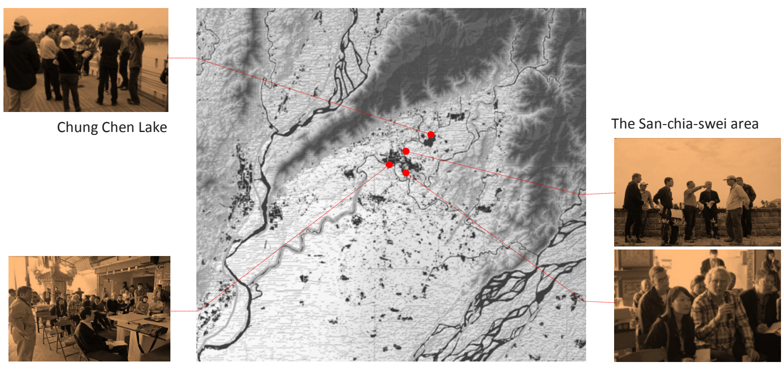
Script of summarizing the field observation (Graphic by Dirk van Peijpe)

The field survey process

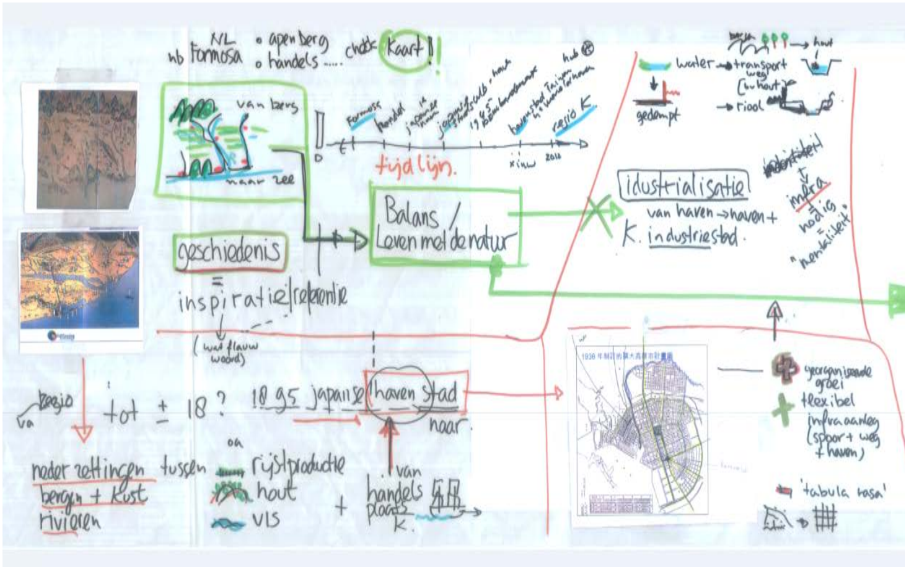
- Site 1: The Love River and urban wetlands



- Site 2: The Meinong River Catchment Area



Summary sequence of the field observations (Graphic by Dirk van Peijpe)



§ 6.2.3 Workshop Day 2 – Strategy development for the Meinong River catchment

Supervisor: Roelof Stuurman (Deltares), Prof. Han Meyer (TUDelft)

Commission introduction

The Meinong River catchment area is the most serious flood region in the Kaoping River Delta. Based on the analysis of the 3-layer framework, the main reasons for floods are: (1) natural topography induces storm water to flow into the downtown area; (2) there is no dike protection for the downtown area. The main issue is: how to find proper lands to build hydrologic instruments, including dike, detention ponds etc., when the acquisition of private lands via eminent domain is almost impossible.

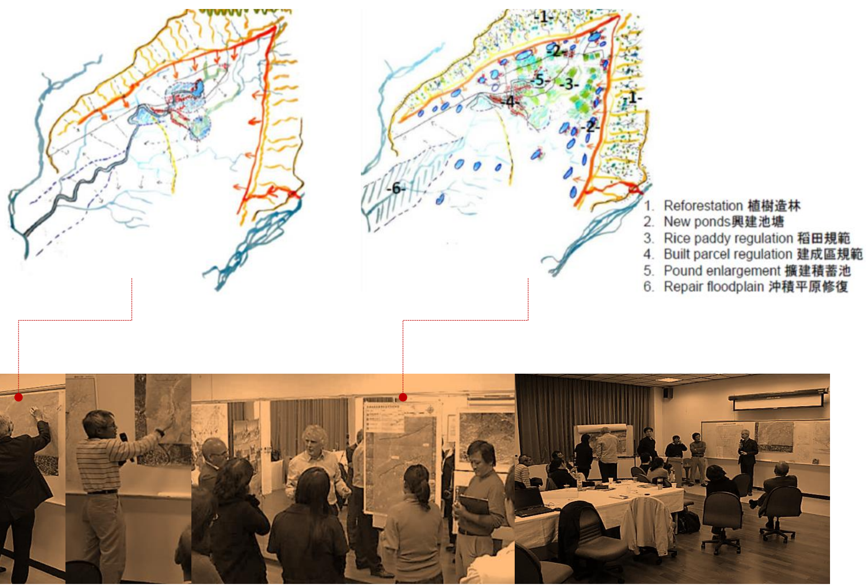
Working process

Because it is very difficult to find adequate land to build dikes and detention ponds, alternatives should be developed. This workshop uses the following steps to find other options:

- Re-identifying different topographies: Based on the discussion with the local government and NGOs, several topographies are pointed out which might possibly be related to the flow of storm water, including mountain areas, summer creeks, the foot of mountain areas, farm fields, building areas and flood plains in the lower reaches.

- Clarifying the present roles in the context of human landscape: Local participants provide a clear idea of how the locals work with these topographies in the present.

- Brainstorming: All the possible alternatives will be written and discussed with the locals about the possibilities and problems.



Final recommendation

In the end, the possible alternatives are identified. The main economic activity in the Meinong District is agriculture. There are a significant number of farm fields in this region. Most of them are rice fields with an area of about 4000 hectares. There are two rice-planting periods every year. Only in the second period, from July to October, might the growing rice encounter flooding from storms. An interesting fact is that rice will not die when it is flooded, if the flood does not last longer than one or two days (TGR 2010). This fact could make a paddy field into a good detention pond just through raising its field bank about 30 centimetres in height. Under this model, just 40% of the paddy field areas is enough to store an amount of floodwater that is almost equal to that which was produced by the last inundation. The government could encourage the farmers whose fields are at the path of storm water to heighten their field banks with some subsidies. It will be an efficient and cheap solution, compared to the significant costs of hydrologic engineering.

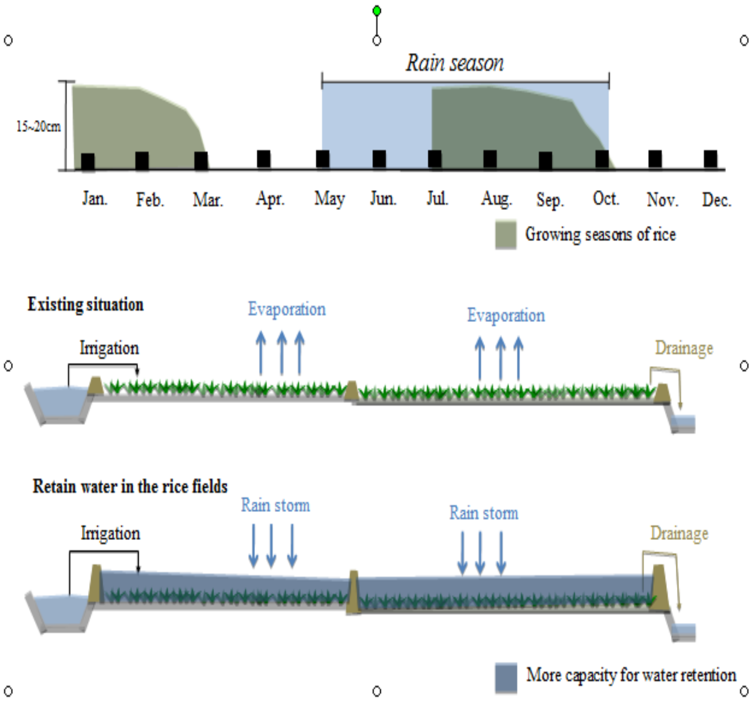


Figure 111
A rice-field as a detention pond, (Original idea: Roelof Stuurman; Graphic by P.W. Lu)

§ 6.2.4 Workshop Day 3 – Strategy development on the Love River catchment

Supervisor: Prof. Maurits de Hooge (TUDelft), Prof. Han Meyer (TUDelft)

Commission introduction

The Kaohsiung Port is located in the Love River catchment where the highest urbanized area in the Kaoping River Delta is found. The population density there is more than 25,000 persons per square kilometre. Thus, this is the most vulnerable region in the whole delta when a flood occurs. Based on the analysis of a 3-layer framework, the main causes of floods are: (1) the low-lying areas; (2) the wetlands were filled up for urban development; (3) drainage in a grid spatial pattern; (4) tidal effect. The major issue in this region is how to deal with tidal effects during a storm while considering that this region is too dense to find the available land for hydrological engineering projects.

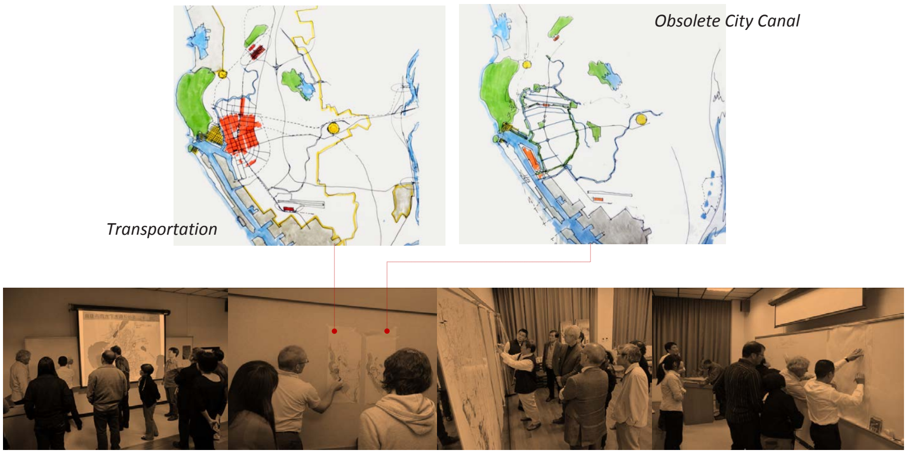
Working process

The case of the Love River catchment area has a more complex urban context than in the Meinong River catchment area, because this area has not only to face the flooding threat, but must also confront the problem of a shrinking port area. Therefore, this workshop follows the following steps to re-examine all of the infrastructure networks located within urban spatial patterns in order to develop an integrated proposal.

- The railroad system: There were three railroads in downtown Kaohsiung. One is the major central railroad. The others are branches mainly surrounding port area. Besides the central railroad, the remaining railroads are no longer being used.

- City canal system: The several city canals have been filled in or covered by roads. Most of them flow toward the port.

- The road system: The road system in Kaohsiung downtown is a very regular grid system. The major direction is toward to the Kaohsiung port.



Designing possibilities

Based on the aforementioned analysis, several possible designs are proposed. First, a flexible barrier on the river mouth or on the entrance of port could be an option. Second, because the direction of the downtown street grid is towards the port, road system could also be redesigned as a roadway drainage system. Last, a city blue belt is proposed as 'the Ring Canal System'. The local government can utilise the obsolete infrastructure network, including street grid system, railroad and canal systems, to reconsider their potential multi-functional uses and avoid the difficulty of declaring eminent domain on private properties. These designs should also consider their potential values for improving urban environments. For example, the Ring Canal System is also designed with multi-functionality in order to resolve the following current issues:

- Creating a beautiful city Blue Belt: This ring canal could create more than 40 kilometers of waterfront in downtown Kaohsiung. A beautiful waterfront will greatly improve the urban landscape. A beautiful urban landscape is usually the crucial element that helps the evolution of a post-industrial city.

- The utilisation of tidal effect to improve water quality: The ring canal system will create a flowing loop. The river flow could be controlled by a system of several water gates on this flowing loop. Sea water can be led into the downtown areas during high tides and flow back into the sea. In other words, the tidal effect can be utilised to flush out the Love River two times per day. It will greatly improve the water quality of the river.

- The function of a detention pond: The water gate system could divide the ring canal into several small sections. These small sections could function as several detention ponds.

The proposal for city ring canal system (Proposal and graphic by Prof. Maurits de Hoog)

§ 6.2.5 Workshop Days 4 and 5 – Development of an integrated strategy for the Kaoping River basin

Supervisor: Prof. Han Meyer (TUDelft), Prof. Maurits de Hoog (TUDelft), Roelof Stuurman (Deltares), Dirk van Peijpe (De Urbanisten)

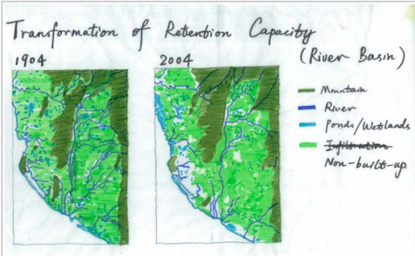
Commission introduction

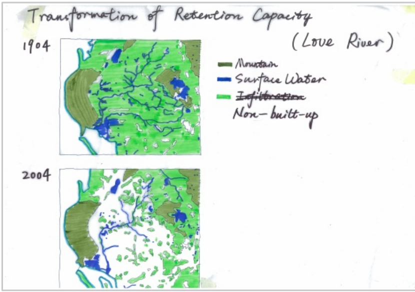
This workshop began to organise all data together into an integrated vision of the entire river basin after developing the aforementioned down-scale cases. The main aims were: (1) find the crucial elements within the inter-relationship between three layers, (2) clarify the key mechanisms for how these elements affect other layers, and (3) provide some strategies.

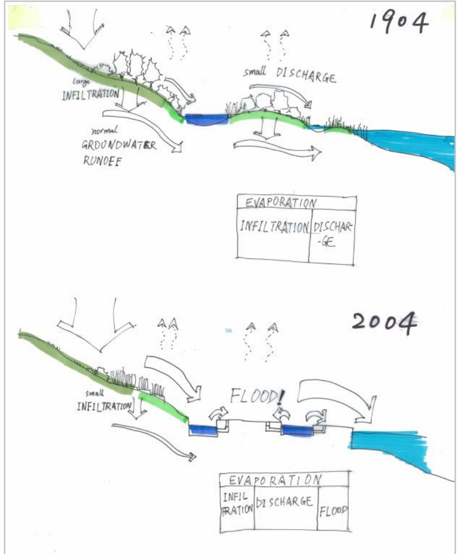
Working process

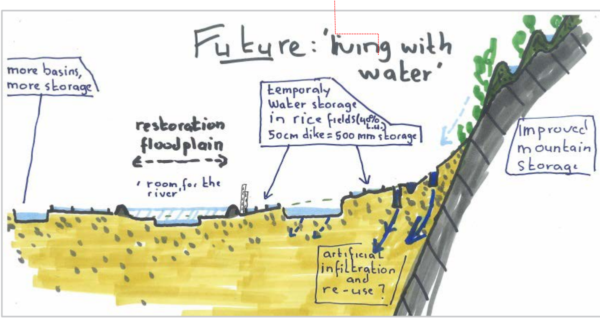
A solid framework of classification is necessary to explore a complex delta system. This workshop used the following phases to re-clarify these complicated factors.

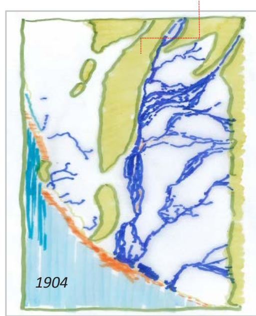
- Clarify all of the current water related problems on a map with a delta scale: This problem map will be linked to the original 3-layer map to find the most closely related factors. In this case, there are three main water related problems that can be identified on a delta map, including floods, land subsidence and coastal erosion.
- A topographical classification: The complex topography of the Kaoping Delta is divided into six areas with different topographical features, including mountains, foot hills, plain, river basin, delta city, and coast. This classification helps to systematically illustrate all of the water related problems from the perspective of a whole river basin.
- Clarify all different expectations from different stakeholders, including local residents, NGOs, central and local governments. Due to a long period of protests against the Meinong Reservoir Plan made by the central government, local residents do not trust the plans from the government. They have crucial but informal power within a special political context.
- Strategy development: Based on this topographical classification, this workshop will develop long-term strategies for these six individual topographies.

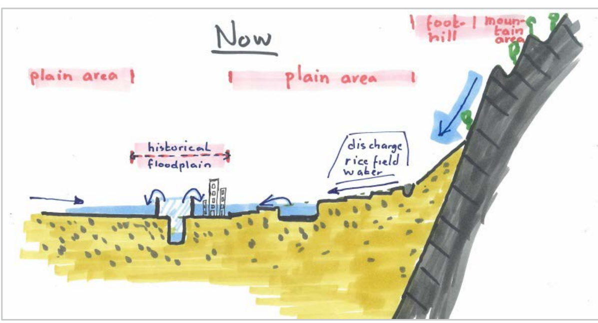

Transformation of Retention Capacity
(River Basin)
1904
2004
Mountain
River
Ponds/Wetlands
Non-built-up

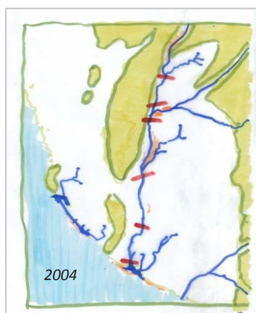

Transformation of Retention Capacity
(Love River)
1904
2004
Mountain
Surface Water
Non-built-up


1904
INFILTRATION
DISCHARGE
GROUNDWATER
RUNOFF
EVAPORATION
INFILTRATION
DISCHARGE
2004
INFILTRATION
FLOOD!
EVAPORATION
DISCHARGE
FLOOD


Future: 'living with water'
more basins, more storage
restoration floodplain
'room for the river'
temporaly water storage in rice fields
50cm dike = 500 mm storage
improved mountain storage
artificial infiltration and re-use?


1904


Now
plain area
plain area
foot-hill
mountain area
historical floodplain
discharge rice field water


2004

§ 6.2.6 Final recommendation

Based on the classification of six different topographies, this workshop finally developed six different guiding principles for each one.

- Mountain: Because of intensive agricultural cultivation, the native vegetation is now rapidly shrinking. Most of the native plants have a deep-root system to tightly grasp soil. When these native plants are replaced by cash crops which usually have a shallow-root system, heavy storm rainfall easily erodes the ground. This is a cause of serious disasters. Agricultural activities should therefore be forbidden in this area.

- Foothill: There were many natural wetlands in this area that have disappeared now due to rapid urbanisation. These wetlands or lakes could be very good detention ponds to store the excessive storm water. Furthermore, this area is also a good groundwater recharging area. Encouraging locals to rebuild these lakes would help both groundwater infiltration and the detention of storm water.

- Plain: This is the most highly flood-prone area now because of the shrinking of wetlands and rapid development of human occupation. Most of the lands in this area have been developed as paddy fields. Because it is very difficult for the government to acquire these private lands, re-thinking how to extend the detention function of these paddy fields is a good option.

- River basin: There has been a tremendous transformation of the Kaoping River basin in the past century. The area of riverbed has greatly decreased due to the completion of the dike system. Although it is impossible to restore the original environment, more space should be allocated for the river in the future.

- Delta cities: This is the area with a high risk of economic and social damage due to the high population density. Although it could hardly get sufficient land for building hydrologic instruments, re-thinking how to utilise the obsolete infrastructure is a good option.

- Coast: There are two main challenges for coastal area in the delta. First, the canalisation of the Kaoping River has caused a sharp decrease of sediments in the estuary. This induces serious coastal erosion. Second, a huge amount of obsolete waterfront area will be available in the future due to economic transformations. A more user-friendly waterfront should be developed. It is the only way to upgrade the current situation from 'a heavy industrialised city', where the basis of a friendly waterfront is a robust coastal area. Some strategies, e.g. sand engine in the Netherlands, should be considered.

Finally, based on this individual strategies, this workshop proposes a long term vision for the entire Kaoping River basin "KAOHSIUNG 2050 – living with water between the mountains and ocean."

KAOHSIUNG 2050 (Graphic by Dirk van Peijpe)

§ 6.3 Section Conclusion

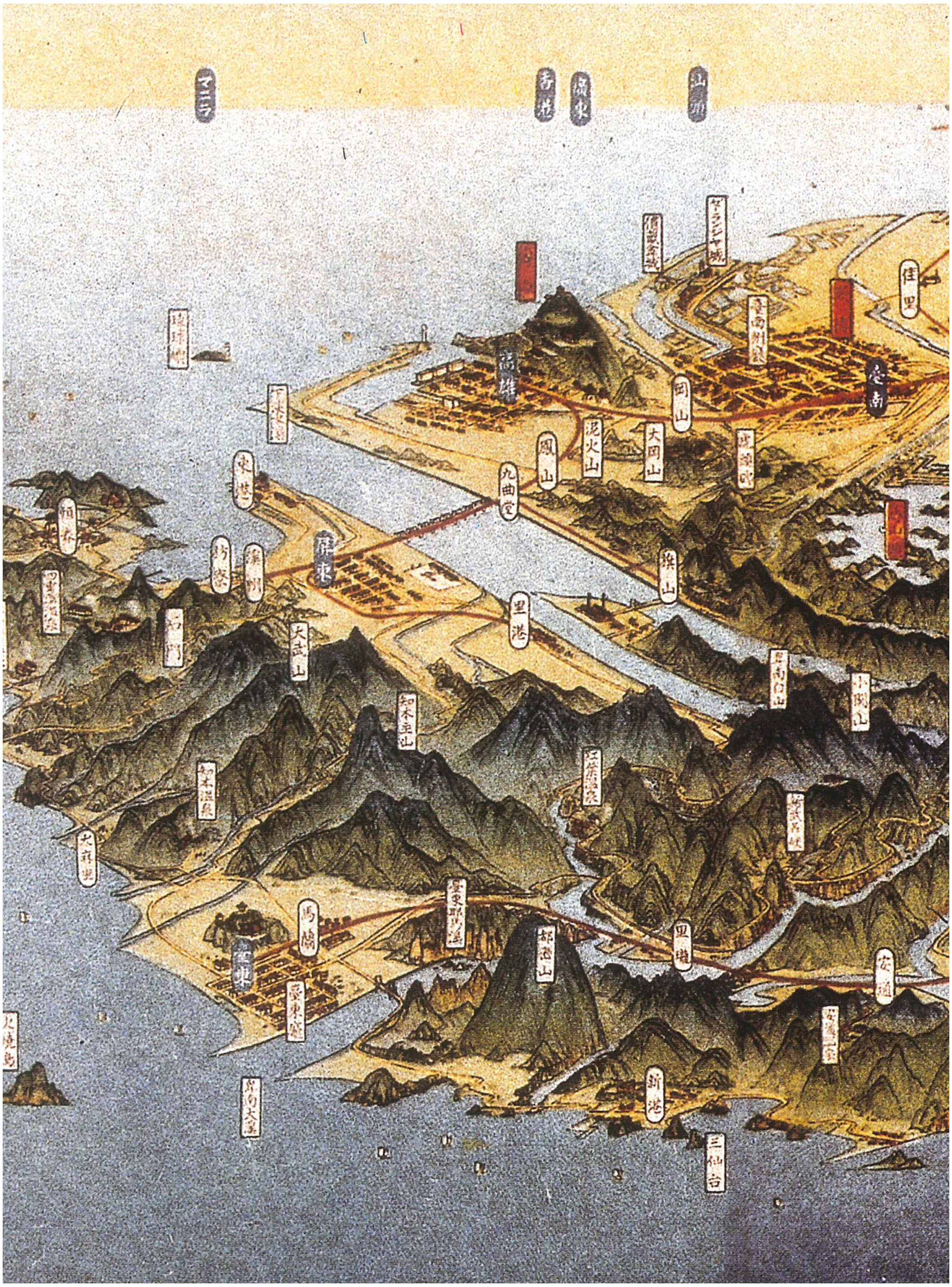
There were fruitful results after this five-day workshop based on the collaboration of multiple disciplines and organisations. The final report has exceeded beyond the reach of a single discipline. Key examples of trans-disciplinary issues include: encouraging farmers to heighten their field banks to keep some storm water in Meinong, or constructing the ring canal in Downtown Kaohsiung. To achieve the aforementioned proposals will be a tough task if there is no help from multi-disciplinary collaborations. The working framework of the 3-layer approach shows its powerful capability to conduct this issue at least in two ways. First, because the 3-layer structure provides a clear list of wide variety data, sources of these data will be the basic components in trans-disciplinary collaboration efforts. Second, the previous analyses of interrelationship between different layers create a communication platform for different stakeholders/ disciplines to promote the further debates and dialogues. The crucial factors which profoundly affect this interrelationship are usually the priority issues shared between different disciplines.

However, the final report should not be viewed as a completed proposal, because some new issues which need to be further clarified came up after the workshop. In fact, recommendations on three main perspectives had been suggested by the final report as another new knowledge base to be in explored in the future.

First, a comprehensive strategy for urban renewal should be developed under the approach concerning flooding, the economy and spatial quality, including: (a) what advantages could be provided by flood control instruments to stimulate the shrinking port business? (b) What kinds of new port-related or knowledge industries or businesses could be attracted by this new proposal? (c) How can the spatial quality of Kaohsiung City be further improved by new water management constructions? These approaches imply that the paradigm of 'Living with Water' should be incorporated as a crucial part of Kaohsiung City's identity.

Second, a project team should be organised to achieve the aforementioned approach. The main tasks of this team should comprise: (a) Defining the new standards concerning flood-risk; (b) Calculating the new demands of hydrologic instruments; (c) Starting some pilot projects to monitor the effects of new proposals on flood-prevention carefully in reality; (d) Constructing a civil forum to extend public participation.

Last, extending civic participation is a crucial phase to obtain public support. Therefore all different and related stakeholders have to be included in the project team. Thus, the participants of the project-team should consist of, at least, the related local and central governments, e.g. the local Hydrologic Bureau, Environmental Protection Bureau, and Urban Development Bureau, central Water Agency, NGOs, and academic and knowledge institutions.



The Taiwan Map in 1937. Source from LGR 2005 provided by Yu-Ru Lin (林育如)

7 Conclusion

This study can be divided into two major parts: One explores a delta through a 3-layer approach. The other constructs a workable 3-layer framework for multidisciplinary collaboration. The beginning of this study employs the concept of a 3-layer approach to explore the centurial transformation of the Kaoping River Delta in Taiwan. Then, based on the same concept, a workshop was organised in 2012 to demonstrate how a 3-layer approach can be applied in practice between multiple disciplines as a collaborative platform.

In the former part of the work, the formal transformation of the Kaoping River Delta can be divided into four major periods, including the early period, the colonial period with a twin-core intercity system, the period after war with rapid industrial development and the period under multiple challenges including the shrinking of industry, environmental pollution and the impact of climate change. The 3-layer framework illustrates that the infrastructure layer, especially the hydrological network, dominated the transformation of the other two layers and provided circumstances under which the concept of twin-core spatial pattern could be developed. After World War II, the dramatic progress in building technologies catalysed modern cities to pursue high levels of economic development without paying attention to the environment. The relational studies of urban space prevailed throughout the 20th century due to the globalisation of labour and capital. This situation did not change until the emergence of environmental issues and climate change in the 1980s and 90s. Delta cities, which are mainly developed by relational forms, suffer from serious environmental problems and inundations of their formal forms all over the world. Following this context, urban morphology should adopt another new approach, which was developed in the Netherlands beginning in the 1990s. Based on this context, this study starts initiates the examination of the Kaoping Delta. In the last part of the work, this study organised a workshop at Kaohsiung City based on the concept of research by design. The results and process of this workshop are also generalised as a practical framework, which could be applied to other cases.

Thus, the main contribution of this research could be divided into three major parts, including (1) the comprehensive analysis about the inter-relationship between the three layers of the Kaoping Delta; (2) The construction of a practical working framework for trans-disciplinary collaboration; (3) The contribution to theory and methodology.

§ 7.1 The comprehensive analysis about the inter-relationship between the three layers of the Kaoping Delta

We can interpret the formal transformation of the Kaoping Delta in four main periods:

- The early period

This is the period before Japanese colonisation. Because there was insufficient technology to protect the Kaoping Delta from flooding and provide this region with drinking water, the development of human settlements had to respond to the natural environment. Obtaining water was a crucial factor that dominated the development of spatial forms. There were two major ways to obtain fresh water in the Kaoping River Delta: one is directly from the river, the other is from the groundwater. The former way was more difficult than the latter one because most of the river bank along the main stream was located in areas that were then prone to flooding (except some waterfront areas along tributaries in the mid and upper reaches). On the contrary, there were abundant groundwater resources at the lower fan area of the Kaoping Delta (except in the upper fan area where the groundwater level is more than 20 metres in depth).

Historical map reveal that settlements were built right beside the riverbank in the middle and upper reaches, while others were evenly located on the delta plain in the lower reaches. This spatial pattern illustrates that the development of spatial forms had to fully respond to their environments. This is also the realm on which traditional Urban Morphology has focused.

- The colony period with twin-core intercity system

Natural and human interactions with the Kaoping River Delta were fundamentally transformed beginning with Japanese colonisation. The 3-layer analysis illustrates that the infrastructure layer dominated the changing of the other two layers. The aim of the Japanese colonial authorities was to construct the Kaoping River Delta as a logistics base to support their country and military in Southeast Asia, that is, to be a part of the Japanese international network of cities. Japanese authorities constructed hydrological instruments to create liveable conditions, for example the dike system along the main stream of the Kaoping River and the potable water system for Kaohsiung Port. Furthermore, transportation with the concept of grid road system was built at the same time to construct the Kaoping Delta as a ‘twin-core intercity network’, one part being Kaohsiung Port as an export centre; the other part being Pingtung as a distribution centre.

- The period after war with rapid industrial development

After World War II, the Taiwan government basically followed these main Japanese concepts to develop the Kaoping Delta as a heavy industrial centre of Taiwan, a part of Taiwanese international network cities. Based on the completion of the main dike system, Taiwanese developed delta cities fully following the relational logic of globalisation without any concern for their surrounding environment. The rapid industrial development had caused serious environmental problems. The Kaoping Delta became the most polluted region of Taiwan. In addition, the rapid industrial development had also brought rapid urbanisation. Relying on the protection of building technologies, an extensive amount of urban land was occupied for economic development including areas with potential value regarding flood management, for instance wetlands, which significantly raised the risk of damage.

- The period under multi-challenges

The situation where urban forms are dominated by relational concepts did not change until the 1980s, when the impact of environment pollution and climate change emerged as a serious threat. Those delta cities, which mainly developed from relational forms, suffer from serious pollution problems and inundations of their spatial structures. Redeveloping a delta city to adapt to its surrounding environment and climate change is the main concern of this study. Furthermore, the gradual shrinking of industry and the stagnation of port and logistics sectors has brought strong pressure on the local government to push for urban regeneration and upgrading industrial areas. Both of these aims would be very tough tasks within a polluted and flood-prone environment.

The results of the problematic analyses are revealed as follows:

- Due to the different properties of variety landscape, a classification of different topography is necessary to further explore the detail of the problems, including mountain, foothill, plain, river basin, delta cities and coast.

- The main dike system along the main stream of the Kaoping River has greatly changed and narrowed the original river path. There are almost 6000 ha of reclaimed land being created by this change. This land whose soil mainly consists of gravel and sand was the main groundwater recharge area in the delta. It reduces infiltration of groundwater. The rapid development of aquaculture along the coast was a major cause of the worsening land subsidence in 1970-1990. The subsiding rate was 10 – 15 cm per year.

- The dike system limits not only the flow of river water, but also huge sediments. Since the completion of the dike system, a substantial amount of sediment, which originally would have been delivered to the sea, was directly deposited within the riverbed. Because the sediment from river is the main source of sand to support a robust coast, the shortage of sand in an estuary will cause serious coastal erosion. It becomes a serious problem when port areas confront the threat of rising sea levels.

- Although the existing dike system is still a good way to prevent floods, ironically, it has caused serious floods in some cases, e.g. the Meinong River catchment area. The crucial problem is that due to rapid urbanisation, there is no space for hydrological instruments. The alternatives might be to find or create some new functions within the occupation layer.

- Neither urban forms nor urban drainage are built totally without considering the natural water contexts. This has caused serious floods in some cases, e.g. the Love River catchment area. The crucial issue is not only that urban drainage infrastructure might be congested, but also that the tidal effect might paralyse urban drainage systems. The key question is, again, there is no space for hydrological instruments due to rapid urbanisation. Alternatives might be to find some new functions within the infrastructure layer.

- The last, the improvement of the urban environment should be included to make a practicable scheme for flood management, while the local government's current priority is economic development rather than environment.

Comprehensive interpretation

The aforementioned analysis reveals that human occupation has affected the operation of natural systems, including water and soil, since a century ago. From the perspective of the delta scale, those effects interacting between different layers can be identified in six different topographies (in italics) of the entire river catchment area.

1 The dike system along the main stream in plains protects delta cities against floods, which causes rapid urbanisation. Population growth in delta cities increases food demand, which causes the abusive agricultural cultivation of mountain areas.

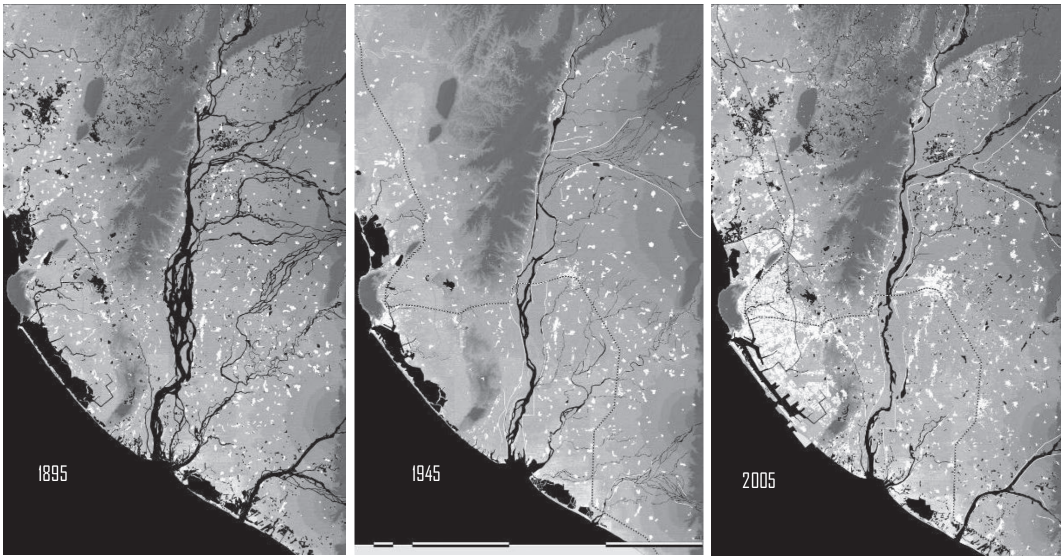
2 The dike system narrows the original riverbed in the river basin, which raises the water level of the river during storms. This situation blocks the drainage outlets of delta cities and induces frequency urban inundations.

3 The dike system along the main stream in the plains has significantly changed the surface flowing path of river and dramatically decreased the recharge of groundwater in foothill. It causes serious land subsidence in coastal areas when the ground could not obtain sufficient groundwater.

4 The dike system and the bridges of transportation crossing river has resulted in the lag-sedimentation of river in river basin. When a significant amount of river sand deposits in the riverbed rather than being transited to the estuary to supply the demand for sand along the coast, it induces serious erosion in coast.

From the perspective of the city scale, urban spatial patterns have fully changed the flow path of surface runoff from storm water. This intervention is one of the crucial factors to affect the occurrence of inundations in delta cities under the effects of rainfall when storm water is led to and accumulated together at some places by the spatial pattern. Rapid urbanisation is another important issue which massively limits the possibility to upgrade the original hydrological system.

The results of this analysis imply that a trans-disciplinary collaboration is necessary to simultaneously consider the different demands from three different layers together. Thus, based on the concept of Research by Design, this study initiated and organises a workshop to deal with the aforementioned issues.



The centurial transformation of the Kaoping River Delta

Recommendations for the Kaohsiung metropolis

Based on the aforementioned analysis, this research reveals a complicated context concerning inundations in the Kaoping River Delta which is related to an interrelationship between nature and human systems under the impacts of climate change. This situation results in an urgent need to re-examine how human systems/ environments, including hydrologic instruments, transportation and urban space, can be designed in the future. Like many delta cities in the world, flooding is just one of the important problems of Kaohsiung. Some problems, for instance, the bad quality of the urban environment and the shrinking of the port economy and industry, are even more important than inundations. This is a good turning point to develop a comprehensive strategy for combining urban renewal with a hydrologic approach. Recommendations as the followings might be the good options to Kaohsiung:

- A comprehensive water policy for Kaohsiung metropolis: Since the merging of Kaohsiung City and County, Kaohsiung Metropolis has had authority over most of the Kaoping River catchment area. How to make a harmonic development between urban and rural areas, port and city economy, or industry and agriculture is a tough task for the local government. All of these are related to water issues. Thus, some new standard referring to urban should be reconsideration rather than the old river-orientation one. For example in Kaohsiung's case, the new standard should consider the level of urbanisation, the situation of industrialisation, and combining the original hydrologic aspects as part of a comprehensive vision.

- Trans-disciplinary and Multi-stakeholder Collaboration: It is necessary to make an integrated policy for flood management. The major current schemes for flood management in Taiwan still focus on controlling riverbed, dike and water itself. There is very little attention given to spaces outside dikes. A similar situation exists in present urban planning schemes which seldom consider water issues. This fact causes serious problems for dealing with an excess of stormwater inside cities, especially in a highly dense urbanised metropolis like Kaohsiung. In addition to adapting the Water and Urban Planning Acts in the future, organising some formal working or communication platforms, for instance, a project team, as the aforementioned one in Chapter V, including various participants is important.

- The establishment of a 3-layer knowledge base: An effective multi-disciplinary collaboration is based on a substantial knowledge base whose content should include not only collecting water related data but also further framing these raw data. The concept of a 3-layer structure, including nature, infrastructure and occupation layers, might be a simple and practical method to frame these data. In fact, these three layers respectively represent three major related disciplines including ecology, hydrology and landscape architecture. Thus, a fine-grain analysis of inter-relationships between these three layers could further clarify the work of each discipline in a collaborative process.

§ 7.2 The construction of a framework for multidisciplinary collaboration

Understanding a delta system work is one thing, how this knowledge could be applied to a real case is another important aim in this research. Based on the aforementioned analysis of the 3-layer model, a framework is constructed to deal with the complexity of multi-disciplinary collaboration. Through the concept of 'design re-construction', this research proposes this framework with four main phases to achieve this goal, including:

- Data re-structuring: All data are classified according to the concept of 3-layers.
- Issue identifying: This is a preliminary communication process for multiple disciplines. Participants from different realms should provide their own related problems which maybe similar or contradictory to those from other realms. Those contradictory problems will be refined into new issues.
- Interpretation and design: This is a crucial step to find proper strategies through a process including brainstorm, dialogue, design, mapping and interpretation.
- Feedback and modification: It is an extended communication process with all stakeholders in order to find ignored issues or problems.

This four-phase procedure is a cycle process, that is to say, the result of a previous round maybe the foundation of decision making or a new standing point for the next round. Guided by this framework, a five-day workshop in Kaohsiung "Workshop of Water Environment Development in Kaohsiung" in 2012 was organised by this study to further examine the results derived from chapters 3 and 4. The workshop followed the theoretical framework of a 3-layer model to explore the entire Kaoping River catchment area and its two tributary basins as the down-scale sites: the Meinong River and the Love River. The participants mainly consisted of urban planners and hydrologists coming from the government, universities, and local non-profit organizations. The outcomes of this workshop were the following:

- From the perspective of the whole river catchment area, this workshop proposes a long term vision for the entire Kaoping River basin "KAOHSIUNG 2050 – living with water between the mountains and ocean."
- Regarding the case of the Meinong River, this workshop recommended building some small hydrological instruments in different areas. In addition, the government could use subsidies to encourage farmers whose fields are at the path of storm water to heighten their field banks. It would be an efficient and cheap way compared to the significant costs of hydrological engineering.

- Regarding the case of the Love River, this workshop recommended building a ring canal system, which has many functions, including: (a) creating a beautiful urban Blue Belt; (b) the utilisation of tidal effects to improve water quality, and (c) the function of a detention pond.

This workshop gives the best demonstration of how to practically utilise the 3-layer approach to organise multi-disciplinary work, and then to make an integrated plan.

§ 7.3 The contribution to theory and methodology and recommendations for further research

This research adopts and further refines the 3-layer approach as the major theoretical background to explore the centurial transformation of the Kaoping Delta. It not only provides a broader vision to illustrate the inter-relationships between natural and human landscape but also improves the capability of current theories and methodologies to analyse urban physical forms. There are two major contributions to theory and methodology respectively.

The theoretical improvement to analyse urban forms

The analytic process shows that to choosing a proper scale is crucial to explore the inter-relationship between nature and human spaces/infrastructure whose related knowledge is the foundation to resolve the physical problems between urban space and environment. There are two different scale levels, including the delta and city scale, in this analytic framework. In the case of the Kaoping Delta, the maps in delta scale reveal that spatial forms had been mainly guided by the relational concepts of globalisation rather than formal concerns. The artificial grid urban block system did not dominate the development of delta cities until the completion of the main dike system. The development of spatial forms did not have to respond to environmental limitations since the dike system could provide adequate protection for delta areas against flooding. That is to say, recent major theoretical approaches have dramatically shifted to theories based on relational logic.

This is the realm where the relational studies of urban space had prevailed over the 20th century, for example the theories of 'Network City', 'Space of Flows', 'Global City', 'Tele-community', etc. Unfortunately, traditional Urban Morphology has returned back to its original research of historical towns, because they are familiar with doing city/ town-scale studies. In general, the city scale is the largest scale to analyse urban physical forms, for instance, the town plan as the highest tier in Conzen's famous three-tier hierarchy. What they ignored is that another factor on a larger scale level has affected the change of urban forms, in this case, the dike system on a delta scale. When urban forms have been greatly transformed without the limitations of their surrounding environment, the urban form is beyond what traditional urban morphology can conceptualise. As a result, most urban morphological research either has only focused on historic cities, like Moudon's commentary, or has been called a potpourri of images or buildings randomly selected by architects, like Bandini's critique.

This research argues that the massive progress of infrastructure technology is the crucial factor to dominate the transformation of modern urban patterns. This influence could be identified by the analytic process of the 3-layer approach from the perspective of the delta or regional scale. This new standing point of theoretical framework for analysing urban form has been proved in the Kaoping Delta case. Furthermore, it could be a new and valid theoretical background to extend the knowledge of urban morphology.

The concept of deductive causality as a new methodology

Although 3-layer approach provides a broader vision to explore the transformation of delta landscape, the rationale of this approach by which a reasonable inter-relationship between layers could be found is still vague. McHarg's work is the first attempt to develop a systematic method for the layer approach. Based on the logic of inductive reasoning, he superimposed all layer maps together to re-mapping the new demand of land use. Unfortunately, this method was not adopted extensively by subsequent research. One of the main reasons is this method only compiles the data which were already known. It is difficult to truly realise the operation of the whole system. After McHarg, recent research has revealed that the layer approach is one of the major tools of spatial planning due to the development of Geography Information System, GIS. However, most of the research applies this concept as "a systematic tool to show all data". There is little research giving attention to logically analyse the relationship between different layers.

The Dutch layer approach argues there is a time-based relationship between the three layers. Thus, these three layers could be rearranged in order from bottom to top through this time relationship. The substratum with more than 100-year transformation period is at the bottom layer, then the networks layer with about a 50-year period in the middle layer and then the occupation layer with 30-year-period at the top layer. This logic is embodied in the images of almost all related documents. Although this concept provides a very useful point of view to consider the priorities and conditions for making decisions for spatial plans, it is still too rough to profoundly explore the delicate mechanisms of a layer model.

This research sets out a new methodology based on the concept of deductive causality to explore the inter-relation between layers. In fact, the method of deductive causality is an old methodology in history, which more or less has been used by most studies mentioned in this research. What this research did is to systematically re-organise the multi-disciplinary literature materials through this concept. The analytic method could be refined by four main phases as following:

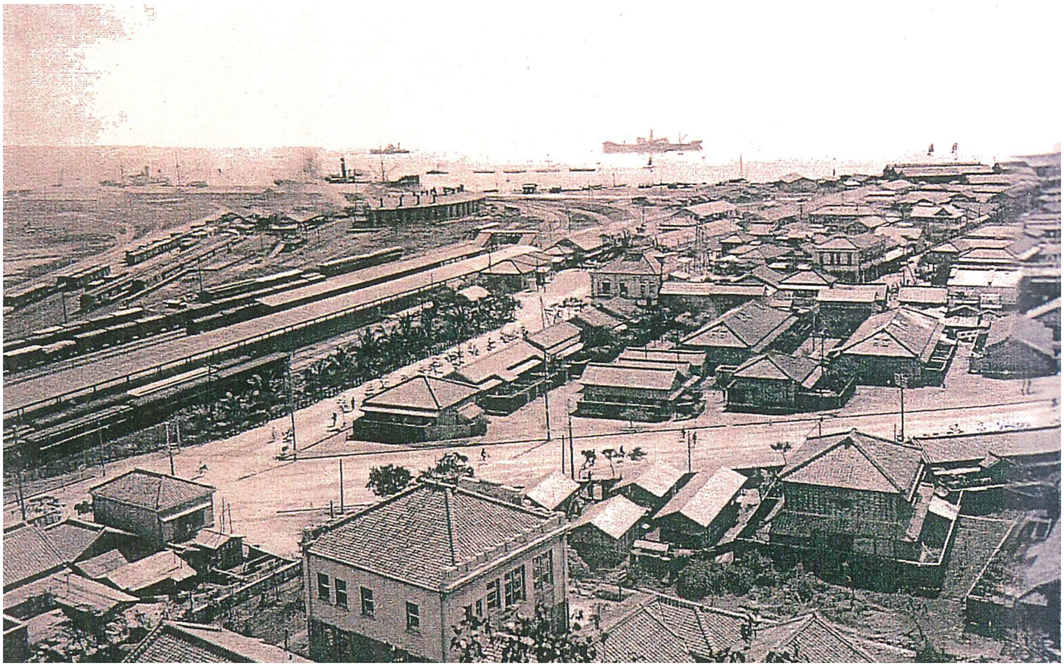
- Re-mapping all related literature and information into different geographic layers;
- A chronological portrait of respective layers to identify crucial events, policies and transformations;
- The analysis of deductive causality to clarify single causal relationships between layers;
- The comprehensive interpretation of all deductive causal relations.

Through this procedure, the crucial role of hydrologic engineering, which dominates the development of urban patterns in modern delta cities and then significant changes the operation of delta nature system, could be recognised. Furthermore, some important factors and their effects could be identified as well through this process, for instance the urban grid system, tidal effect and dike systems in this case, which are very useful elements to create subsequent strategies.

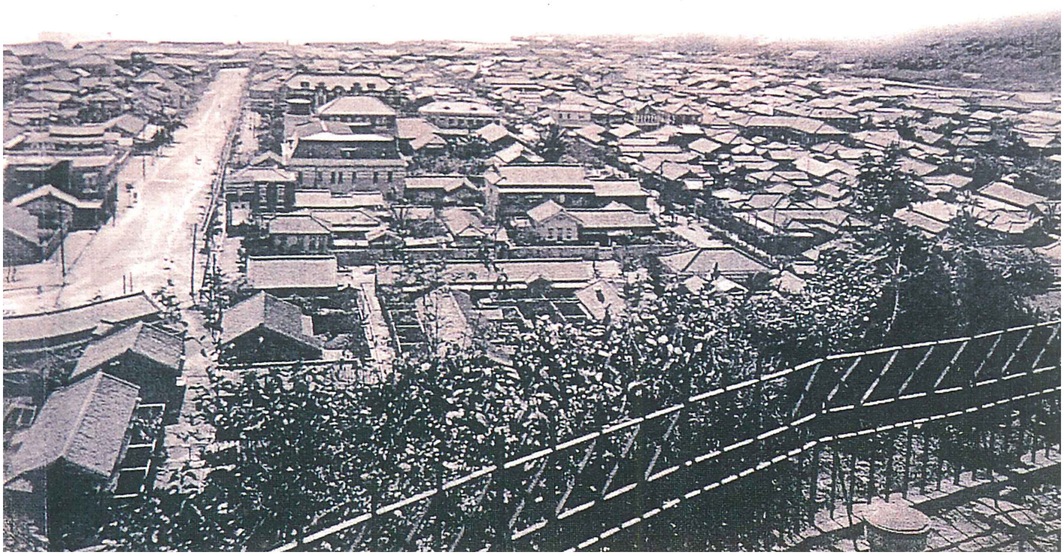
Recommendations for further research

Based on the aforementioned results of this research, several research aspects should be further encouraged in the future.

- Relational studies of urban space have prevailed for a long time, which have met problems under the impacts of environmental issues and climate change. A proper academic debate incorporating these kinds of researches will be necessary. Following this context, the urban morphological research with a broader vision, for instance 3-layer approach, should be encouraged.
- In Kaohsiung case, this research reveals the importance of a trans-disciplinary working framework and receives a fruitful result. However, the framework this research provided is just a beginning. Several crucial components including mapping skills, modelling, communication etc. should be further explored.



The newly development of Kaohsiung Port area in 1920. Source from LGR 2005



The newly development of Kaohsiung Port area in 1920. Source from LGR 2005

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Curriculum Vitae

Chen-Kun Chung was born on 18th May 1969 in Taiwan. He studied Architecture in Feng Chia University in Taiwan for the Bachelor degree and, in 2000, obtained his Master of Science in Graduate institute of Building and Planning of National Taiwan University. Being trained both in architecture and urban planning, he acquired skills in small scale design as well as to deal with urban issues in larger scales. The interests in understanding life in multilevel scales leaded him to work as the executive secretary of Green Travel Foundation from 1998 to 2007. During this period of time, he conducted many researches related to regional development and its relationships with industry, labour culture, nature and the meaning of space. Alongside academic reports, he also edited children's books within corresponding topics, which were awarded and recommended to children by the government, to inspire more thinking from the young generation.

The experiences of working with the local communities at that time made him aware of that only more advance knowledge could expend his ability to harmonize development with the nature. He then came to pursue his PhD at the Urban Composition Chair of the Urbanism Department, Delft University of Technology in 2008. His study was supported by 2010 DELTA/NTIO Joint Environmental Scholarship from the Delta Electronics Foundation. Also during the years in TU Delft, he worked with Kaohsiung government with research and workshop projects, as a co-principal investigator. During these works, not only the research data was collected and built, also the theory was tested and developed through the cooperation among the international teams of experts, the academic, the various governmental departments, the NGO workers and local communities.

Learning from the PhD research and the practice at the same time has increased his capability for clarifying the environmental and developmental urban issues. And, basing on theories, he is skilled in looking for solutions in reality with the dialogue among disciplines and approaches. He believes that the more sound ground of theory he helped to build would broaden the concept of urban development. And from this standpoint, he wishes more workable ideas and solutions would be produced to tackle urban issues with his contribution in the coming future.