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Creating Sustainable Future of a Degraded Urban Canal: Mae Kha, in Chiang Mai, Thailand

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CREATING SUSTAINABLE FUTURE OF A DEGRADED URBAN CANAL: MAE KNA, IN CHIANG MAI, THAILAND

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ABSTRACT

Chiang Mai is the largest and the most significant city in the Northern region of Thailand. It was established in 1296 as the capital of Lanna Kingdom. Since then, the city is famous for its exquisite authentic Northern culture, essential trading routes, an abundance of natural places, and agriculture derived along the Ping River as well as a functional canal system in the city. In the past few decade, uncontrolled and unplanned urban development, deforestation, and the lack of public awareness have caused landscape degradation in the city. Consequently, Chiang Mai has faced several serious environmental problems such as congestion, pollution, inadequate green spaces, and the haunting memory of the inundating catastrophe in 2010.

Mae Kha Canal is one of the most important features in Chiang Mai's water system that nourishes local agriculture, irrigation, and transportation. Fresh pure water originates from the mountain adjacent to the West of Chiang Mai city flowing through the city to the Ping River in the South. Unfortunately, since the unregulated growth of urbanization, the canal has suffered with massive amounts of pollution. As the result, the city has turned its back on the canal, making it a dumping site.

Moreover, the problem has existed for a long time, resulting in extensive sewerage and garbage piling up in the canal. About two thousand households nearby have added the severity. Some of them have taken over the canal banks, shrunken the canal and piled it up with sediment and garbage. Recently, after the significant flood in Chiang Mai, 2010, people had started to promote the essential role of Mae Kha Canal by establishing a campaign to bring back the precious abundance of the Ping River. However, the process takes time, budget, and well-distributed responsibilities from communities, and organizations to achieve the revitalization of Mae Kah Canal.

What will be the future of the canal? How do we bring Mae Kha Canal back to life? This thesis studied ecological and sustainable approaches to revitalize the water system using intensive site analysis and site planning for effective design strategies.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Mae Kha Canal has been suffering from deterioration for the past 30 years due to a rapid urbanized of Chiang Mai. Intensive researches and interviews demonstrate that water pollution, low water flow, uncoordinated organizations involvement, properties rights, and society's neglect are major factors that had transformed Mae Kha from functional and beautiful to unpleasant canal with an absence in ecological function. Moreover, people who live nearby did not know that Mae Kha Canal existed. As a result, Mae Kha was deserted in severe degradation and turning into an open sewage of the city. It is hardly to believe that once Mae Kha Canal was one of the significant water features since the foundation of Chiang Mai city. Ultimately, Water pollution is an urgent issues that need immediately attention.

The aim of this thesis is to apply sustainable and ecological approaches to mitigate pollution in Mae Kha Canal focusing in the congested urban area. The goal is to bring Mae Kha Canal back to life so that people can interact with nature and wildlife. In terms of ecological function, Mae Kha Canal will play an important role as green infrastructure to protect the city from floods and function as a stormwater drainage way. Furthermore, Mae Kha Canal will be promoted as a cultural green corridor to connect people back to water, and perform as a new city linear park. This proposal could stimulate economic and tourism in the city.

1.2 Hypothesis

The application of ecological and sustainable approaches together with using intensive site analysis and site planning, for effective design strategies will enhance and revitalize future of Mae Kha Canal.

1.3 Overview of Chiang Mai

Chiang Mai is the second largest city in Thailand after Bangkok. It is the significant center of Northern Thailand region in economic, education, cultural preservation, natural resources, and tourism. In the past few decades, the city expands in every direction, especially, in the East of Ping River.[1] The total

[1] Wanchai Boonsurat, *Wastewater problems in Chiang Mai municipal area* (Chiang Mai University, 1990), 5-6.

population in Chiang Mai province is 1.6 million, in the municipal area is 234,244 with 1,537 density (people/km) in 2015.[2] The major population is tourists which is estimated to reach eight millions in 2016.[3]

In today's scenario, Chiang Mai has developed rapidly with an absence of appropriate city planning, strong regulations and a legal framework. As a result, the city fail to articulate the future development in order to support an increasing population growth and city sprawl. Furthermore, Chiang Mai has faced with several environmental issues from lack of vision to inefficient environmental management. This thesis emphasis on one of the most urgent environmental issue of water pollution.

1.3.1 Chiang Mai Water System

Chiang Mai is located in the center of a prime location. Suthep Mountain lies along the West of the city with abundant natural resources, especially fresh water. Chiang Mai municipality has several significant water features. One of the fresh water resources comes from Huay Kaew watershed at Suthep Mountain. Huay Kaew creek's clean water feeds to the city moat, later combines with Mae Kha Canal and is released to Ping River in the East of the city.[4] One of the most historically significant water systems, the City Moat was excavated in 1296 together with a protected brick wall construction to secure the inner city.[5] Nowadays, it has become Chiang Mai's tourist attraction and the center of cultural events receiving great supports and excellent maintenance from the city.

Currently, the physical conditions of these water features are acceptable. They still maintain in good water quality, so that people can swim and use them for transportation. In contrast to these water features, Mae Kha Canal is in critical degradation and needs urgent help.

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[2] "2016 Statistic of population in Chiang Mai municipal area," *stat.bora.dopa.go.th*., accessed January 30,2016, http://stat.bora.dopa.go.th/stat/statnew/statTDD/views/showDistrictData.php?rcode=50&statType=1&year=57.

[3] "2016 Statistic of Chiangmai Tourists," *Department of Tourism,* accessed January 30, 2016, http://newdot2.samartmultimedia.com/home/details/11/0/24948.

[4] Civil Engineering Chiang Mai University Natural Disaster Research Unit, " Mae Kha Canal Sustainable Development," *CENDRU*, accessed February 14, 2016, http://cendru.eng.cmu.ac.th/maekha/canal-management-masterplan.

[5] Dhevhet Phongphattanavhud, Ritthiphon Wongpanngow, *The Directional Change and Waste Water Problem in Mae Kha River* (Civil of Engineering Project, Chiang Mai University, 2010), 5-8

1.4 Site Background and Context

1.4.1 Mae Kha : A Journey of Deserted Canal

720 years ago,the first king who established Chiang Mai selected Mae Kha Canal as one of the propitious features strategically located the city. It is believed that the essential of these water features were to serve as a city's guardian. In 1662, an outer city protection; 4-5 meter in width and 2 meter in depth, Mae Kha Canal and levee were constructed by using a ditch and dike technique. The purpose was to prevent the city from the overflow of Ping River and enemy invasion.[6] Before 1950's, Mae Kha Canal was an exuberant, beautiful, clean canal that could be used for drinking, fishing, and function of other daily life. Where most of land were used for rice paddy and forest, Mae Kha was a major water resource for agriculture, irrigation, and drinking. At that time, the villagers believed that there were spirits living inside the levee, so people took good care and respect.[7]

After 1950's, during the urbanization period, the government authorized urbanization of Chiang Mai by promoting urban infrastructures and facilities. Chiang Mai started to expand and land prices in the city were gradually increased. Unfortunately, most of the properties were possessed and traded without any vision of urban planning. Rice fields and forest opted to disappear from the city. While Chiang Mai was enthusiastic about being urbanized, the environment and natural resources were used or destroyed as a sacrifice to greed. For example, some parts of the protected levee was completely demolished in excuse for increasing the city's modernized image. Moreover, Nhong Yai, the largest natural swamp in Chiang Mai utilized as water retention to protect from austere inundation, was completely transformed to commercial and residential areas. Similarly, Mae Kha Canal's appearance was in poor condition and decadence from society's neglect.[8]

In the present, rural population have migrated to Chiang Mai city seeking for job opportunities. Most of them stayed in informal settlements occupied the properties along Mae Kha Canal which made canal narrower and more degraded. Mae Kha Canal was in critical conditions. It released unpleasant smell as garbages and wastewater were discharged directly in to the canal. With nearly nine millions population and tourists, more people with no restricted planning regulation, Mae Kha became an open

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[6] Idib.,3-4

[7] Khon.Jai.Baan, *Diary of Mae Kha* (Thailand: National Multimidia Group, 2011),18-19

[8] Idib., 20-21

sewage of the city and could no longer perform an ecological function anymore. Despite it has been well serviced as a great water system, neglecting from government and society has brought degradation to future of Mae Kha Canal.

1.4.2 Study Area

To understand the overall context of Mae Kha Canal, the study area covers a three-mile canal corridor that flows through different land use types in urban Chiang Mai City (See Figure 1). The goal of this study area is to investigate how land use and community have effected and influenced the existing condition of the canal. The studied site starts from a 12-lane super-highway, the area that indicates the edge of urban boundaries, pass through dense residential and vibrant tourist-business area and down to the south of city center where Mae Kha Canal merges with Lumkuwai Creek from the West in local community area.

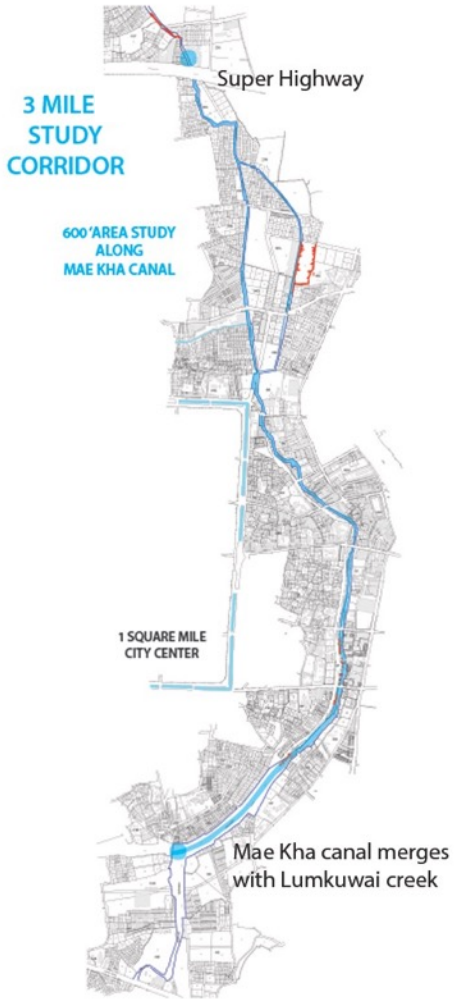

Figure 1: Site Study Area : 3 Mile Corridor

CHAPTER 2. LITERATURE REVIEW

This project addresses the chronic issue of Mae Kha Canal pollution that has been tormenting adjacent communities and depleting the beautiful image of Chiang Mai. In this Chapter, First of all, the study needs to know why waterways are mostly in severe degraded in urban area in general. After that, the investigation focuses on Mae Kha Canal in water pollution issues. The study includes what caused pollution problems in Mae Kha Canal, and how to mitigate this problem by using ecological and sustainable approach are addressed in this chapter as well.

2.1 Study of Degraded Urban Waterway

Why are rivers and canals in severely degraded in urban areas?

Urban areas have high potential to pollute water in many ways. Most of the problems are directly related to human impacts. According to the Journal of Interamerican Studies and World Affairs, the urban rivers and canals are in critical deterioration under these principal developments: high population growth, rapid urbanization, and road system construction.[9] In developing cities, people in suburban areas tend to leave their hometown and move to a city seeking for job opportunities and better income. Some of them can not afford to live in proper residential areas, so they end up living in slums that are mostly illegal occupied along rivers and canals. Living in congested insanitary areas, they have no choice but to dispose of the sewage waste directly into the water source. As a result, they face health problems and increasing water pollution. Not only does residential developments reduce water quality but also industrial wastewater released illicitly from factories.

The increase in population goes along with an intensive construction of roads and highways. With rapid development, urbanization, and the expansion of the road system, some waterways are filled up which directly affects the functioning of the city drainage systems (See Figure 2). Road systems keep expanding to support the needs of people without any concern for the negative impact on the urban ecology. In addition, people's perception of water has also changed. They neglect and turn their backs on the canals, altering them into dumping sites and sewage drainage.

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[9] Stanley Heckadon Moreno, " Impact of Development on Panama Canal Environment," *The Journal of Interamerican Studies and World Affairs*,Volumn 35,Issue 3, Special Issue: The future of Panama and the Canal (Autumn, 1993), 129-149.

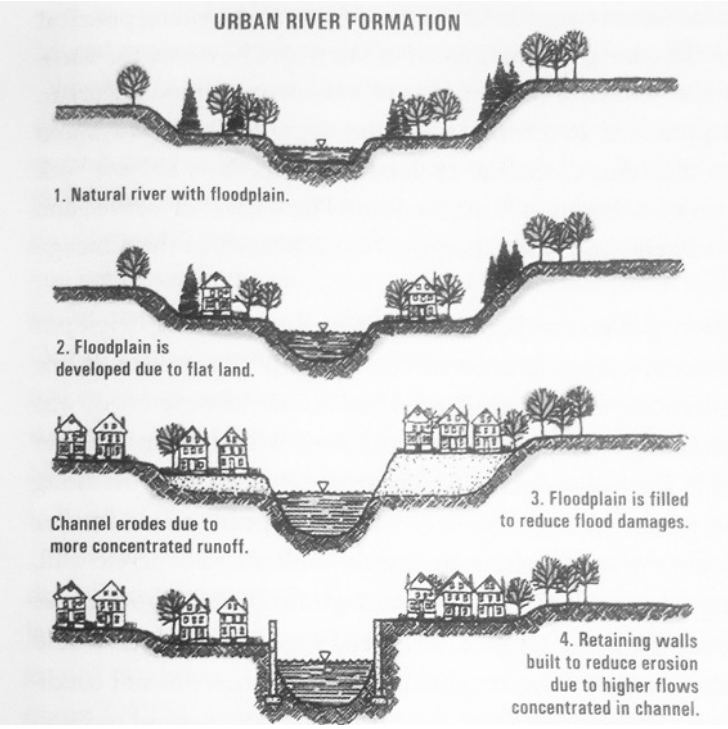

Figure 2: Urban River Formation
Originally Published in James Grant Mac Broom, The River Book (Hartford, Ct.:Natural Resources Center,1998),148.

In terms of ecological fact, according to the research of the California water and land use partnership, most of urbanized areas are covered by impervious surface. When impervious surfaces increase, less water can infiltrate which increases surface runoff. As a result, the increasing of surface runoff requires more infrastructure to mitigate the flooding issue.[10] Waterway such as rivers and canals are managed as drainage channels which are usually lined up with concrete to quickly divert water and prevent erosion. This has a significant negative impact to the environment and the ecological system, resulting in extensively reduced biodiversity, altered plant and animal communities, and destruction their natural habitats.[11] With a lack of nature in the city, we are in prone to disturb natural ecosystems which hinders the resilience of cities. Destroying the environment ultimately reduces the quality of our lives, and especially leads to water quality degradation. There is no easy way to solve these water problems. But

[10] Emily Ruby, "How urbanize affect water cycle," *California Urban Water and Partnership,* accessed October 28, 2015, http://www.coastal.ca.gov/nps/watercyclefacts.pdf.

[11] "Concrete Lined Channel," *floodengage.com,* accessed *October 28, 2015,* http:// www.floodengage.com/option.php?id=58.

the cooperation of the government sector, stakeholders and community will help in taking action in shaping a new approach to revitalization of urban rivers and canals.[12]

2.1.1 What Caused Pollution in Mae Kha Canal?

There are three major issues that cause pollution in Mae Kha: wastewater discharge, inadequate water treatment plants, and low public awareness. The impact of the city's unregulated growth has been causing natural waterway directional change and pollution. First, wastewater discharges directly into the canal from settlers who illegally occupied the land along the river banks. Commercial and industrial factories, along with urban run-off add to the problem.[13] Second, an inadequacy of water treatment plant in Chiang Mai where the drainage system is a combined system of wastewater and runoff. In rainy season, there is an overload of water in the treatment plant that directly affects a purifying process. With only one treatment plant available, the system to clean water for the entire city before releasing to the natural river is not sufficient.[14] Furthermore, the constructed wastewater pipe system does not yet cover the municipal area. The future plan of a complete drainage system was implemented in the city masterplan, however; the full effective system is waiting to be installed. Third, low public awareness of degradation in Mae Kha Canal. Since urbanization, people have turned their backs on the canal. Also the government and stakeholders have low attention to improve Mae Kha's condition.[15] As a consequence, pollution and environmental degradation in Mae Kha tends to increase and adversely affect the people who live and work with it.

2.1.2 Water Quality in Mae Kha Canal

According to the Thai Surface Water Quality Standard from Pollution Control Department in Ministry of Natural Resources and Environment, Mae Kha Canal is categorized as Class 5 (See Figure 3). The water quality in this class is heavily polluted, which is not suitable to use for any activity except navigation.[16] The canal's existing condition shows in Figure 4.On the other hand, the adjacent City Moat,

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[12] Bonnie Fisher, and Beth Benson, 2004, "Remaking the urban waterfront," n.p.: *Washington,D.C. : Urban Land Institute,* c2004., 2004. *Louisiana State University*, EBSCO*host* , October 28, 2015, 37

[13] Praweponn Sukutsathian,(Khon.Jai.Ban Community Architects) in discussion with the author. December,2015.

[14] Chiang Mai Municipal Government, *Chiang Mai Wastewater Drainage System map(*Chiang Mai, 2015)

[15] Khon.Jai.Baan, *Diary of Mae Kha* (Thailand: National Multimidia Group, 2011), 27-28

[16] "Water Quality Standard," *Pollution Control Department, Ministry of Natural Resources and Environment,* accessed March 03,2016, http://www.pcd.go.th/info_serv/en_reg_std_water05.html.

is classified as Class 2, and its water can be use for recreation such as fishing, swimming and is suitable for cultural events during Thailand's New Year. City Moat is treated very well as a tourist attraction.

Classification and Objectives	
Classification	**Objectives/Condition and Beneficial Usage**
Class 1	Extra clean fresh surface water resources used for : (1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction (2) ecosystem conservation where basic organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment process before use (2) aquatic organism of conservation (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption, but passing through an ordinary treatment process before using (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption, but requires special water treatment process before using (2) industry
Class 5	The sources which are not classification in class 1-4 and used for navigation.

Figure 3: Surface Water Classification and Objectives
"Water Quality Standard," *Pollution Control Department, Ministry of Natural Resources and Environment,* accessed March 03,2016, http://www.pcd.go.th/info_serv/en_reg_std_water05.html.

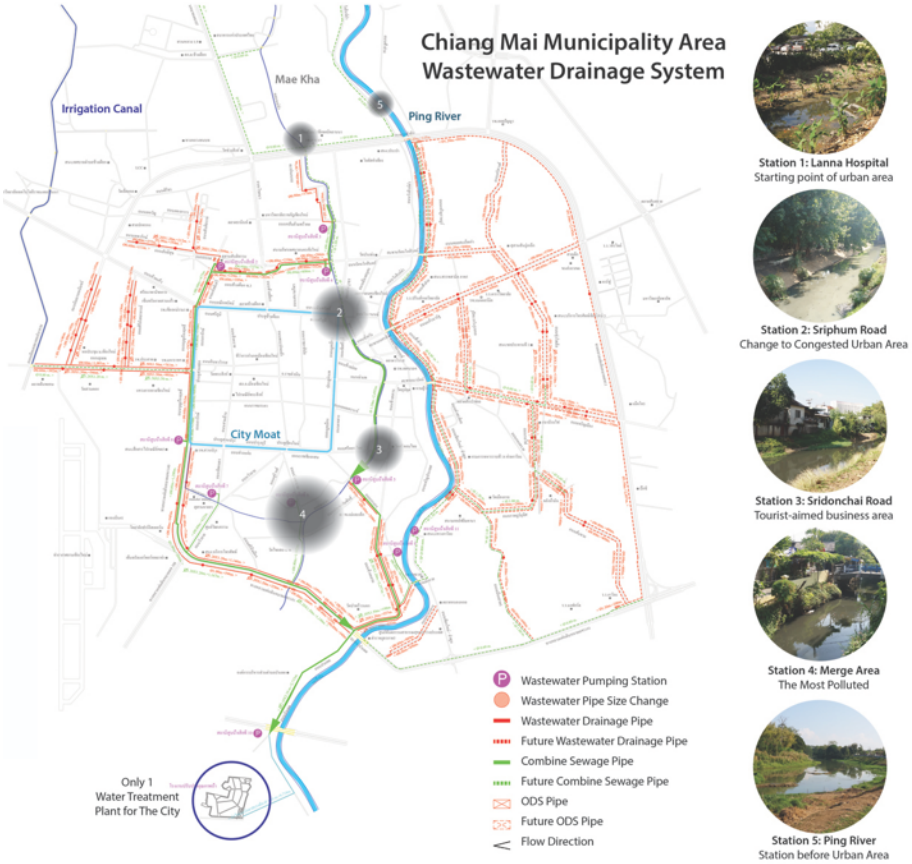

Figure 4: Chiang Mai Municipality Area Wastewater Drainage System
Chiang Mai Municipal Government, *Chiang Mai Wastewater Drainage System map (*Chiang Mai, 2015)

From the research, Impacts of the Urban Environment on Area Water Source: The Klong Mae Kha- Chiang Mai, Thailand, Mae Kha becomes more degraded when it flows through the urban area, starting at Station 2. As Figure 4 illustrates, better sewage drainage pipes were installed (the green line) between Stations 2 and 3, which are in very dense urban areas, making a pollution rate of the canal higher. Lastly, the heaviest pollution level is at Station 4 because of a lack of pipe system combined with more pollution from Lumkuwai Creek in the West.[17]

There are statistically significant differences of pollution substance rates in each of Mae Kha Canal water quality station investigated by researchers from Buffalo State University of New York co-operated with Chiang Mai University.[18] For example, the data demonstrates that D.O. (Dissolve Oxygen) rate is critically lower than the water quality standard (See Figure 5). Also, E.Coli rate is significantly higher than the standard, especially in congested urban areas.

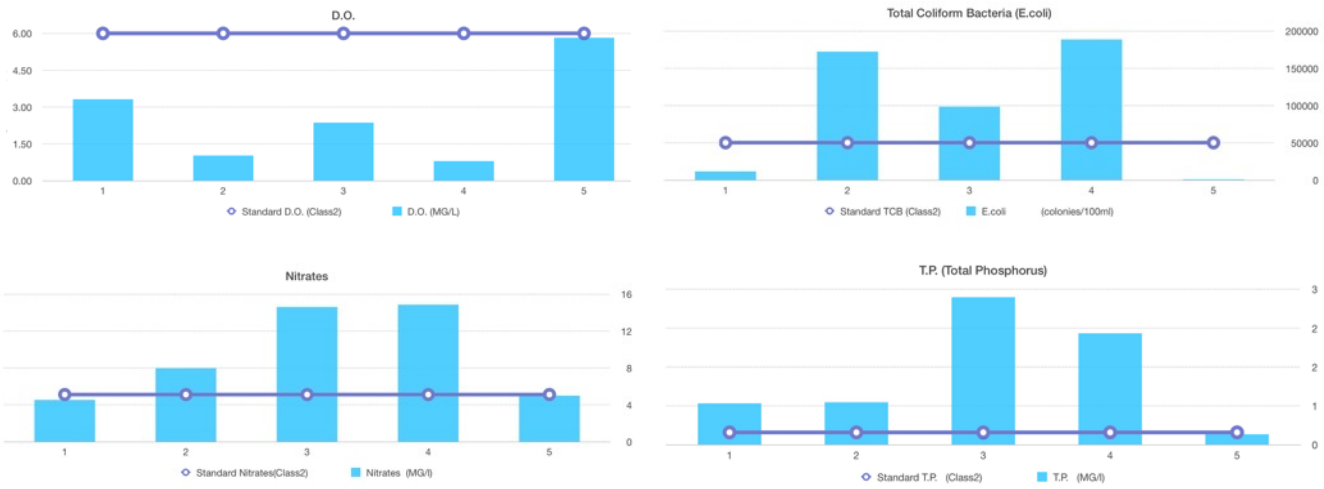

Figure 5: Polluted Substances in Mae Kha Canal : D.O., Total Coliform Bacteria (E.coli), Nitrates and Total Phosphorus (TP).
Harmony Gugino, Kim Irvine, Radchadawan Ngern-klun, Kom Sukontason, Kabkaew Sukontason, Chira Prangkio and Pattarin Thunyapar, *Impacts of the Urban Environment on Area Water Source: The Klong Mae Kha- Chiang Mai, Thailand*, Poster Presentation Proceedings, The 4th International Symposium On Southeast Asian Water Environment, 2006, Asian Institute of Technology, Bangkok, Thailand, pp. 85-88, 2006.

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[17]Harmony Gugino, Kim Irvine, Radchadawan Ngern-klun, Kom Sukontason, Kabkaew Sukontason, Chira Prangkio and Pattarin Thunyapar, *Impacts of the Urban Environment on Area Water Source: The Klong Mae Kha- Chiang Mai, Thailand*, Poster Presentation Proceedings, The 4th International Symposium On Southeast Asian Water Environment, 2006, Asian Institute of Technology, Bangkok, Thailand, pp. 85-88, 2006.

[18] Idib., 85-88

Seasonal differences also impact pollution rate in Mae Kha Canal. The research of water quality examination from Utrecht University reveals that the pollution rate in dry season is higher than those in rainy season, due to low water input. In contrast, during rainy season, more water flushes pollution substances down the drain. In the late rainy season, pollution rate tends to raise back again.[19]

2.1.3 Mae Kha Canal Initiative Restoration Projects

In the past 50 years, various municipality projects with more than $15 millions spent were established to restore Mae Kha. Dredging canal and wastewater pipe installation in parallel to the canal were addressed to enhance water quality. In 1990's, with support from OECF, Overseas Economic Cooperation Fund organization, Mae Kha was constructed with concrete lining in the urban area, expanded the canal to 2-2.5 meter in depth and 4-5 meter in width in order to improve water flow and reduce erosion. Also, there was a canal beautification project that provide 2 sides of walkway with fence and light poles with intention to attract people to use the canal, however; this project was not quite successful in long-term management and maintenance program.[20] From site observation, the walkway is neglected with no maintenance with some parts covered up with vegetation. Moreover, there are nobody uses this walkway, since it is occupied by informal settlements and too narrow for pedestrian.

Communities also involved in Mae Kha Restoration programs. According to the documentary of Khon.Jai.Ban, the community architecture group who works closely with local communities, it is mentions that the community pays good attention to maintain Mae Kha Canal and the erosion of historical levee. They grow vegetations along the canal's banks and take care of big shading trees. Although there are many supports from external organization, it is hard to resolve the problems without understanding the real situation in the communities. For example, the government provided trash trap machines for the canal with no service to take the trashes out of community. As a result, this project is not successful because the community alone could not fix the problems.[21]

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[19] Christie Mettes, *From the muddy banks of the Mae Kha : An Environmental justice perspective on the human-environment interactions along the urban streams of Chiang Mai,Thailand (*University of Utrecht, Master Sustainable Development International Development Track, 2014), 29, 66-67.

[20] Dhevhet Phongphattanavhud, Ritthiphon Wongpanngow, *The Directional Change and Waste Water Problem in Mae Kha River* (Civil of Engineering Project, Chiang Mai University, 2010), 5-8

[21] Khon.Jai.Baan, *Diary of Mae Kha* (Thailand: National Multimidia Group, 2011),37

Ultimately, Mae Kha Canal is in need of community and public involvement, administrated stewardship program with co-operate from government and private sectors that would establish an ethic that empower the responsibility to protect, preserve, and create sense of awareness to the canal.

2.2 Ecological Water Treatment System

2.2.1 Treatment Wetland

According to water quality analysis (see Figure 5), Mae Kha Canal contains extremely high rate of total coliform bacteria (E.coli), Nitrates and Phosphorus from communities and industries discharge. In addition,Urban runoff is one of the factors that causes pollution in Mae Kha Canal. The US Environmental Protection Agency data describes the polluted runoff in congested urban areas. This is, mostly covered by an impervious surface impacted by stormwater runoff with pollutants from sediment, total suspended solids (TSS), oil and grease from vehicles, heavy metals from roofs and vehicles, pesticides and nutrients from lawn and gardens and thermal pollution.[22] These polluting substances are directly released to Mae Kha Canal, which increase the pollution rate and destroy the natural ecosystem.

Why choose wetland treatment ? Wetland plants have the ability to adapt and survive in abundant supply of water. In addition, wetland ecosystems create natural environments as home to wildlife, fish , amphibia, birds and native vegetations. According to Dr. Kadlec and Mr. Wallace, Treatment Wetland Research, mentions that ;

> Wetlands have a higher rate of biological activity than most ecosystems, they can transform many of the common pollutants that occur in conventional wastewaters into harmless byproducts or essential nutrients that can be used for additional biological productivity. These transformations are accomplished by virtue of the wetland's land area, with its inherent natural environmental energies of sun, wind, soil, plants and animals. These pollutant transformations can be obtained for the relatively low cost of earthwork, piping, pumping and a few structures. Wetlands are one of the least expensive treatment systems to operate and maintain.[23]

From the information of Land&ScapeSeries: Waterscapes describes the treatment of water process categorized into five stages. First, pre-treatment performs as a screening to remove large elements such as residual wastes, oil and grease traps. Second, primary treatment separates suspended

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[22] "Nonpoint source: Urban Areas," *EPA United States Environmental Protection Agency*, accessed March 03,2016, https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-urban-areas.

[23] Robert H. Kadlec, Scott Wallace, *Treatment wetlands*. n.p.: Boca Raton, FL : CRC Press, c2009., 2009. Louisiana State University, EBSCOhost (accessed March 26, 2016), 4

solids, filtering sediment in plant beds or pond. Third, secondary treatment takes out carbon pollution by adding oxygen from wetland plants or conventional techniques used in activated sludge plants. Fourth, tertiary treatment eliminates nitrogen and phosphorus. Finally, the finished products polish treated water in natural wetland ponds before release to natural environment. The advantage of wetland, is that planted filters have ability to alter sludges into water, carbon dioxide, and nutrients. On the other hand, conventional wastewater treatment plants produce huge amounts of sludges that can cause disposal problem.[24]

2.2.1.1 Type of Constructed Treatment Wetland

The definition of Constructed Treatment Wetland by Dr. Kadlec and Mr. Wallace is:

> Modern treatment wetlands are man-made systems that have been designed to emphasize specific characteristics of wetland ecosystems for improved treatment capacity. Treatment wetlands can be constructed in a variety of hydrologic modes.[25]

In the current development, there are three types of wetland:

First, Free Water Surface (FWS) wetlands contain areas of open water with similar environments that mimic to natural wetland with floating, emerged and submerged natural vegetations that attract various wildlife. FWS wetland is suitable for stormwater treatment because it has ability to sustain unpredictable flow rates and changing water levels. Not only do they perform as water purification, but FWS wetlands also provide the benefit of water retention areas that can store water to use during the dry season. These wetlands are not expensive compared to other alternatives, however; they require a considerable amount of flat land to perform ecological function.[26]

Second, Horizontal Subsurface Flow (HSSF) wetland process composes of filtering gravel base planted with wetland vegetation. Wastewater flow horizontally under surface from inlet to outlet. These treatment plants are used for the secondary and tertiary treatment process for small scale project or for

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[24] Hélène Izembart, and Bertrand Le Boudec. *Waterscapes : el tratamiento de aguas residuales mediante sistemas vegetales = using plant systems to treat wastewater.* n.p.: Barcelona : Gustavo Gili, c2003., 2003. Louisiana State University, EBSCOhost (accessed March 26, 2016), 20-23.

[25] Robert H. Kadlec, and Scott Wallace. *Treatment wetlands*. n.p.: Boca Raton, FL : CRC Press, c2009., 2009. Louisiana State University, EBSCOhost (accessed March 26, 2016), 5.

[26] Idib.,5-6

small communities. HSSF requires smaller surface areas than FWS, but construction cost is more expensive.[27]

Third, Vertical Flow (VF) technology was developed by Dr. Seidel in Germany in the 1950s. The system allows water to flow vertically through permeable layers of filtration or slide slope. On top, the sand bed was planted by emerged wetland vegetation and controlled in 20-cm. in depth of water. The system is designed to reduce space, plant roots generate good oxidation and excellent nitrification capacity during the secondary and tertiary treatment.[28]

Another efficient process is a combination of HSSF and VF wetland called “Hybrid Constructed Wetland”. There are various type of combination for specific treatment use. The concept of primary using VF filter to remove total suspended solids (TSS) follows by HSSF wetland for better polishing is suitable for Mae Kha’s situation. This hybrid system will strengthen the capacity of wetlands to effectively purify water.[29]

2.2.2 Plants in Treatment Wetlands

Floating Aquatic Vegetation (FAV) can be used in municipal wastewater treatment. Suspended solids are removed by bacteria metabolism and physical sedimentation. Also, the plants uptake can remove Nitrogen and Phosphorus. The common species used in aquatic treatment system are water hyacinth (Eichhornia crassipes), pennywort (Hydrocotyle spp.), duckweed (Lemna spp.), water lettuce (Pistia stratiotes) and mosquito ferns (Azolla spp.). These plants may appear in FWS wetland. Water hyacinth and duckweed both are frequently used for removing algae from oxidation pond effluents. Also, plants’ roots are excellent support for Nitrogen and Phosphorus removal following secondary treatment. To use these type of floating plants, it is necessary to consider their unintended development which could cover water surface and block the sunlight from accessing under water.[30] Makkasan Treatment Wetland Project in Bangkok, Thailand, reports that water hyacinth performs well to absorb nutrients and heavy

[27] Idib.,6

[28] Idib.,7

[29] Idib.,203

[30] Idib., 85-88

metals with ability to treat water 30,000-100,000 cubic meters/day. Together with a water turbine adding aeration, the water treatment efficiency can increase in double.[31]

Emergent Soft Plants are used in the largest number for treatment wetland. In the book, Treatment Wetland, it describes how emergent plants outlive in flooded conditions. They transport oxygen from their leaves to root systems in respiration process. The result helps increase oxygen rates in water.[32] According to Nonghan,Treatment Wetland Project in Sakonnakorn, Thailand, it reports the use of plants in marsh and pond. In marsh with 0.1-0.2 meter in depth, Cattail (Typha angustifolia L.), Umbrella plant (Cyperus alternifolius L.), Papyrus (Cyperus papyrus), Ground chesnut (Eleocharis dulcis), and watergrass (Echinochloa crusgalli), are used to reduce BOD and perform suspended solids and fecal coliform bacteria removal and also reduced Nitrogen and Phosphorus rates. In 1-meter deep pond, submerged plants are used to treat water such as Hydrilla (Hydrilla verticillata (L.f.) Royle), pondweed (Potamogeton malaianus Miq), and Water lilly (Nymphaea lotus).[33]

2.3 Water in Northern Thai Culture

Thai culture has a strong bond with water since the establishment of the Nation. According to NAGA: cultural origins in Siam and West Pacific, aquatic symbolism can be found in Thai rituals, literature, folk art, painting, architecture, city planning, and numerous activities in daily life. Living in water based civilization, Thai capitals were located in close proximity to the rivers and canals in order to maximize the use of navigation, transportation, agriculture, and daily consumption. In Chiang Mai, water was impacted in ancient settlements and urban forms where city moats surrounded the square center city and were constructed to prevent flood and protect the city from enemy similar to Mae Kha Canal.[34]

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[31] "Makkasan Treatment Wetlands Project, Bangkok," *Rdpbproject.Com.,* accessed March 27, 2016 ,http://www.rdpbproject.com/press56/index.php?option=com_content&view=article&id=270&Itemid=155.

[32] Robert H. Kadlec, and Scott Wallace. *Treatment wetlands*. n.p.: Boca Raton, FL : CRC Press, c2009., 2009. Louisiana State University, EBSCOhost (accessed March 26, 2016), 100.

[33] "Royal Project of Treatment Wetland System,"*web.ku.ac.th*, accessed March 27, 2016, https://web.ku.ac.th/king72/2542-06/active02.htm.

[34] Sumet Jamsai, *Naga: Cultural Origins in Siam and the West Pacific(* OUP Australia and New Zealand January 4, 1990), 46-60.

Northern culture demonstrates the relationship between people and water through unique traditions. During the wet season (May-November), there are numerous events that occur in the water resources in Ping river, City's moat and canals. One of the most famous event is Lanna Yi-Peng or known as Loi-Krathong (floating flower) Festival. On the full-moon night in November, temples and houses are decorated with beautiful illuminated lanterns which are displayed or launched into the sky. In water, Krathong - traditionally made of banana trunk and decorated with flowers, candles, and some money are floated on rivers. People believe that floating Krathong carries away their bad luck and misfortune. Also, this culture is a great opportunity to demonstrate respect to the goddess of water, Phar Mae Kongka.[35]

In dry season, the most famous celebration festival is Thai New year called "Songkran" hold on April 13th-15th. It is traditionally a religious festival that people congregate for Buddha Sculpture parade and pour water with flowers on the Buddha for the belief of prosperity and happiness. Chiang Mai has a unique Songkron celebration when people gather around City Moat and Ping River to enjoy water-fights and swim in the water to cool down from the heat in April. At the temple, people dressed in traditional Northern costumes make a merit and pray for good luck in New Year. This festival attracts a lot of tourists to Chiang Mai.[36]

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[35] Graduate school Chiang Mai University. 2016. "Loy Kratong Festival". *Grad.Cmu.Ac.Th*. http://www.grad.cmu.ac.th/eng/index.php/loy-kratong-festival. accessed March 26, 2016

[36] "Songkran - Water Festival in Thailand," *Chiangmaibest.com*, accessed March 26, 2016, http://chiangmaibest.com/songkran/.

CHAPTER 3. METHODS

3.1 Vision

The future of Mae Kha Canal was developed and enhanced by using ecological and sustainable approaches to transform the severely polluted canal back to a pristine and functional canal. A principal of sustainable development that focuses in three aspects: social, economics, and environments were addressed as a design philosophy. The cultural green corridor that stretches three miles, was designed to represent the new linear park in the heart of the city of Chiang Mai. This would connect people to different nodes such as green areas, commercial and cultural nodes. The green corridor creates a pathway for pedestrian and bicycle routes providing accessibility to communities along the canal which promotes interaction between man and nature in an urban city. Not only it performs as a green linkage, but also preserves natural habitats and home to wildlife and native vegetations. Eco-tourism will stimulate the economy for local community and attract more visitors to Chiang Mai. Moreover, Mae Kha will bring back nostalgia in the past when it was a significant protector of the city. The ultimate goal is to see people cherish, respect and dedicate the preservation of Mae Kha Canal as it is a valuable resource of the city.

3.2 Goals

3.2.1 Mitigate Pollution in Mae Kha Canal

- To promote ecological and sustainable approach in improving water quality in Mae Kha Canal.
- To educate people how to purify water by using ecological methods and the benefits of long-term maintenance and development.
- To create a pilot project of an urban wetland park in the North of Thailand that integrates ecological processes and recreation spaces.

3.2.2 Promote Green Linkage

- To propose new linkage of the city by promoting green corridors where people can interact with nature and enjoy recreation spaces.
- To promote a stewardship program that encourages participation of communities, government, organizations, stakeholders and private sectors in coordination to Mae Kha Canal development.

3.2.3 Enrich Northern Culture

- To promote Chiang Mai’s wealth of unique northern culture.
- To articulate people with Mae Kha Canal’s significant history and encourage a sense of preservation and respect.

- To make a future generation proud and strongly devote to protect precious natural and historical resources of Chiang Mai

3.3 Study Method: Case Study Analysis

The case studies for Mae Kha Canal projects separate into two sections of urban planning and site scales. The first section is urban planning scale focus on the improvement of a canal that affects urban development. The second section investigates the function of an urban treatment wetland park in water purification process and recreation program.

3.3.1 Urban Development Project

3.3.1.1 San Antonio Riverwalk

Basic statistics about the San Antonio Riverwalk are:

Location: San Antonio River, Texas, U.S.A.

Area: 13 miles

Completion date: 2013

Project Cost: $384.1 million

The San Antonio River Walk is an important urban fabric and a tourist destination of downtown San Antonio along San Antonio River banks. In 1921, a flood catastrophe destroyed lives and the city. To prevent disastrous inundate, part of the plan was addressed to pave over the bend and create a storm sewer and plan to develop flood control of the city. Fortunately, in 1926, San Antonio Conservation Society successfully protested against burying the river plan. Later, Architect Robert Hugman submitted his plan for the 2.5 mile riverwalk corridor with inspiration of rich New Orleans' culture. His proposal solved flood problems and stimulated commercial development in downtown.[37]

According to San Antonio River Improvement Fact Sheet, the data shows an information of construction technique;

> The improvements along the Mission Reach focused on ecosystem restoration using a technique known as fluvial geomorphology. This technique transformed the straightened river to replicate the original flow of the river while maintaining flood control, reducing erosion, re-introducing native vegetation and creating an environment more suitable for recreation and wildlife".[38]

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[37] "History Of The River Walk - The Official Website Of The San Antonio River Walk," *Thesanantonioriverwalk.Com*, access March 25,2016, https://www.thesanantonioriverwalk.com/history/history-of-the-river-walk.

[38] "San Antonio River Improvements Project," *Sanantonioriver.Org.*, accessed March 25,2016, http://www.sanantonioriver.org/proj_facts/facts.php.

The project also addressed an ecological approach to create natural pool restoration, restored natural habitats with native riparian along the banks, including planting over 20,000 trees.

Over 15 miles of river corridor provides green walks and bike trails, shading structures, picnic tables and seating areas. The riverwalk is lined with shops, restaurants, and entertainment spaces for recreation. Moreover, the featuring of cultural events attracts more people such as the Fiesta San Antonio festival in spring. The River Parade features flowery floats that float down the river and the Mud Festival is an annual cleaning of the canal's muddy bottom.[39]

This project is a great case study for urban canal development that revitalized downtown, stimulated eco-tourism and provided green infrastructure that integrates the uses of recreation. Compare this precedent to the thesis project, this project is similar to Mae Kha's condition in that the canal flows through congested urban area. If all the buildings and communities along Mae Kha could pay attention to the importance of the canal and be the crucial part of canal beautification, together with vision plan from the government, Mae Kha canal project could be successful as San Antonio Riverwalk.

3.3.1.2 Yanagawa Canal Restoration

Basic statistics about the Yanagawa Canal Restoration are:

Location: Yanagawa, Fukuoka, Japan

Area: 470 Kilometers

Completion date: 1987

Project Cost: $4 million

Yanakawa city is located in Southern of Fukuoka Prefecture, Japan. In the past, this city had been a seaside area before it became an agricultural city. It became a living water city, people dredged canals around the city to protect flood and sea water intrusion. After World War II, Yanakawa turned into an industrial city. As a result, the canal was in devastation. The water was polluted by industrial wastes and neglect on the value of natural water in the city.[40]

Until 1997, the government planned to enhance the streams to resolve the water pollution problem with a cost estimated around 20 million dollars. The citizens participated in the movement to improve the environment in the meeting with government. The community agreed to bring back

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[39] Idib.

[40] FY 2003: Support project for the publication of study activity result on water environments, *Canals and journey of water -- to restore historical water town(* Society of Water, 2004.1.24.), 1-2

"life with the canals," the days people enjoyed fishing and playing in the water.[41] With their great effort, the restoration plan was divided into three parts; renovating the water by making it flow naturally, controlling waste disposal from household and industry, and lastly improving the canal maintained system. This plan required costs of only about 1 of 5 of the first proposed budget.

Indeed, there are specialists to help approve the water quality before people release it into the mainstream. Some people establish a group to create organic washing detergent to reduce chemical substances, which dissolve in water. Furthermore, they brought back some traditional festivals. For instance, Mitsuoji is a water festival when the government pump water out to support fishing before helping each other cleaning the waterside. Consequently, Shubuta, a local fish, return to the canal because of clean water. Today, the canal becomes a tourist attraction that provides jobs and stimulates local economies to the communities.[42]

It is very fascinating to see the cooperation of local community, government and stakeholders to envision the future of Yanagawa Canal in this project. With an assistantship from the local community, they proud to be a part of the canal stewardship program to help preserve and maintain the pristine nature that will be inherited to the next generation. In contrary, Mae Kha Canal project would take time and effort to strengthen and enhance the relationship of people with water which will be the driving force to restore Mae Kha Canal.

3.3.2 Urban Stormwater Treatment Wetland Park

3.3.2.1 Sydney Park

Basic statistics about the Sydney Park are:

Location: Portland, Oregon, U.S.A.

Area: 44 hectares

Completion date: Mid 2015

Project Cost: $10.5 Million

The objective of this park is to incorporate human, environmental, and engineering design through sustainable development philosophy which demonstrates the integration of social, environmental,

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[41] Khon.Jai.Baan, *Diary of Mae Kha* (Thailand: National Multimidia Group, 2011),22-23

[42] Idib., 23

and economic functions.[43] Sydney Park is the city's stormwater harvesting project that allows wetlands to improve water quality of urban run-off, a sustainable water supply for the park, and flood mitigation during heavy storms. On a 44-hectare site, showcase models for sustainable living in the inner city, stormwater is captured and cleaned 850 million liters per annum, bringing the target for 10% of water requirements of the city to be harvested and reused by 2030.[44]

According to Sydney Park's water treatment process, the parks consists of a series of swales, ponds and lakes that all function as water collectors from adjacent streets. Stormwater is collected through underground pipes and flows to pre-treatment, oil, and pollutant traps. Later, it flows through series of purified bioretention systems from which water filters by wetland plants and soil. After that, the water settles in retention ponds. Large wetland bank areas are treated by native riparian plant materials. Gabion walls use to help protecting erosion and providing habitats for local wildlife. Using local materials , sandstone and permeable paths make the park landscape become natural. This design creates an urban ecosystem to provide home to wildlife; especially waterbirds and native wetland vegetation along with beautiful landscape for public recreation.[45]

3.3.2.2 The South Los Angeles Wetland Park

Basic statistics about the South Los Angeles Wetland Park are:

Location: Los Angeles, California, U.S.A.

Area: 9 acres

Completion date: 2011

Project Cost: $25 Million

According to the City of Los Angeles Stormwater Program, a former MTA bus terminal covered with life-less concrete pavement was transformed into the nine acre South Los Angeles Wetland Park. This park is an integrated program of stormwater treatment combined with recreation spaces for

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[43] "Sydney Park Stormwater Harvest - Europe - AECOM - A Global Provider Of Architecture, Design, Engineering, And Construction Services,"*Aecom.Ca,* accessed March 25,2016, http://www.aecom.ca/vgn-ext-templating/v/indexjspvgnextoid=0680478a403bd310VgnVCM100000089e1bacRCRD &vgnextchannel=031493f020f8a210VgnVCM100000089e1bacRCRD&vgnextfmt=default.

[44] "Water Brings Fresh Heart To Sydney Park - The City Of Sydney Media Centre,"*Sydneymedia.Com.Au*., accessed March 25,2016, http://www.sydneymedia.com.au/water-brings-fresh-heart-to-sydney-park/.

[45] "Sydney Park - City Of Sydney,"*Cityofsydney.Nsw.Gov.Au*., accessed March 25,2016, http://www.cityofsydney.nsw.gov.au/vision/better-infrastructure/parks-and-playgrounds/current-works/sydney-park#page-element-dloadMaterials:.

beneficial use to the community. Urban runoff is collected, trash removed and polluted substances are purified in constructed wetland process which can clean up to 680,000 gallons of polluted urban runoff per day.[46]

In terms of stormwater treatment processes, the design team proposed a series of stormwater best management practices (BMPs) to enhance the quality of runoff water before discharge into the city stormwater system. As described,

> These BMPs include: a pre-treatment hydrodynamic separator structure designed to remove sediment, trash, and oil & grease; a three-cell treatment wetland containing wetland habitats and vegetation; and a parking lot with a vegetated swale to direct runoff from the parking lot to the wetland. Runoff from precipitation and irrigation on the 9-acre project site will be designed to flow into the treatment wetland.[47]

The wetland park helps mitigate the polluted substances such as bacteria, oil and grease, gasoline, and heavy metals that contain in runoff water. Moreover, native plant materials help purifying water and protecting bank erosion.[48]

> Seasonal differences impact is assigned in consideration of wet and dry season. During a storm event, runoff will be pumped into the wetland until the water reaches its maximum treatment volume control. The system can hold water in the level that treatment processes work effectively. Water will be collected in dry season prior to low flow water input. The water will be used for site irrigation to maintain the quality of wetland plants and to sustain wildlife habitats.[49]

Not only an innovative water treatment wetland park, but also the South Los Angeles Wetlands park includes a variety of recreational activities. These include jogging trails, cycling, picnic area, bird watching deck and walkway with educational signages describing the function of the wetland treatment. The visitors can learn about wetland ecosystem, native plants and wildlife habitats that blend sustainably in this urban area.[50]

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[46] "South Los Angeles Wetlands Park « City Of Los Angeles Stormwater Program," *City Of Los Angeles Stormwater Program*, accessed March 13,2016, http://www.lastormwater.org/green-la/proposition-o/south-los-angeles-wetlands-park/.

[47] "Preliminary Design Report Final Preposition O South Los Angeles Wetland Park," accessed March 13,2016, http://www.lapropo.org/sitefiles/lariver.htm.

[48] Tyler Silvestro,"LA Parking Lot Becomes Urban Oasis," *A/N Blog.,* accessed March 13,2016, http://blog.archpaper.com/2012/02/la-parking-lot-becomes-urban-oasis/#.VuWqwZMrJE4.

[49] "Preliminary Design Report Final Preposition O South Los Angeles Wetland Park," accessed March 13,2016, http://www.lapropo.org/sitefiles/lariver.htm.

[50] Tyler Silvestro,"LA Parking Lot Becomes Urban Oasis," *A/N Blog.,* accessed March 13,2016, http://blog.archpaper.com/2012/02/la-parking-lot-becomes-urban-oasis/#.VuWqwZMrJE4.

CHAPTER 4. FINDINGS AND DISCUSSION

4.1 Design Concept

- Proposed new green corridor along Mae Kha Canal.
- Introduce treatment wetland park to help mitigate pollution in Mae Kha Canal and storing water to use in dry season.
- Increase social interaction, stimulate economic and preserve nature in the city.

4.2 Design Diagram

Chiang Mai is the most significant city in the north of Thailand. Chiang Mai sits in close proximity to Ping River, the main river of the North. Having this advantage places Chiang Mai in the center of the North. In the last few decades, the city has suffered from environmental degradation as a result of unplanned and unregulated urbanization. One of the most urgent issue in Chiang Mai and Thailand which needs to be addressed is water pollution.

From this regional map (See Figure 6), it can be understood that Ping River watershed is the major resource of Chao Phraya River, the main river of Thailand. Ping and Chao Phraya Watershed occupies about 40 percent of the country. This valuable water resource is in a state of critical deterioration as a result of human activities such as agriculture, industrial, and wastewater from the cities. It is hard to imagine how much of wastewater will be released to the Gulf of Thailand and the world.

To help mitigate the issue of water pollution, this project focuses on Mae Kha Canal, the most degraded urban canal in the North, with the aim of creating a sustainable future for the degraded urban canal: Mae Kha in Chiang Mai, Thailand.

Looking into the City of Chiang Mai (See Figure 7), the City Center is located in the square City Moat. Chiang Mai was established in a great location. Fresh water originates from Doi Suthep National Park and the major water source of Mae Kha Canal is from Huay Kaew watershed. Water flows from the West down to Ping River in the East. All Chiang Mai water systems are in good condition, except for Mae Kha Canal, especially when it flows through urban areas. The water is extremely bad, smelly, dark color with garbage, and wastewater discharge, which makes Mae Kha an open sewage for the city. It is also interesting to know that people living in the surrounding areas have been unaware of Mae kha Canal’s existence.

The proposed vision of the project is to improve the water quality, and develop Mae Kha Canal to be new green corridor in the heart of the city to enrich the unique culture of Chiang Mai.

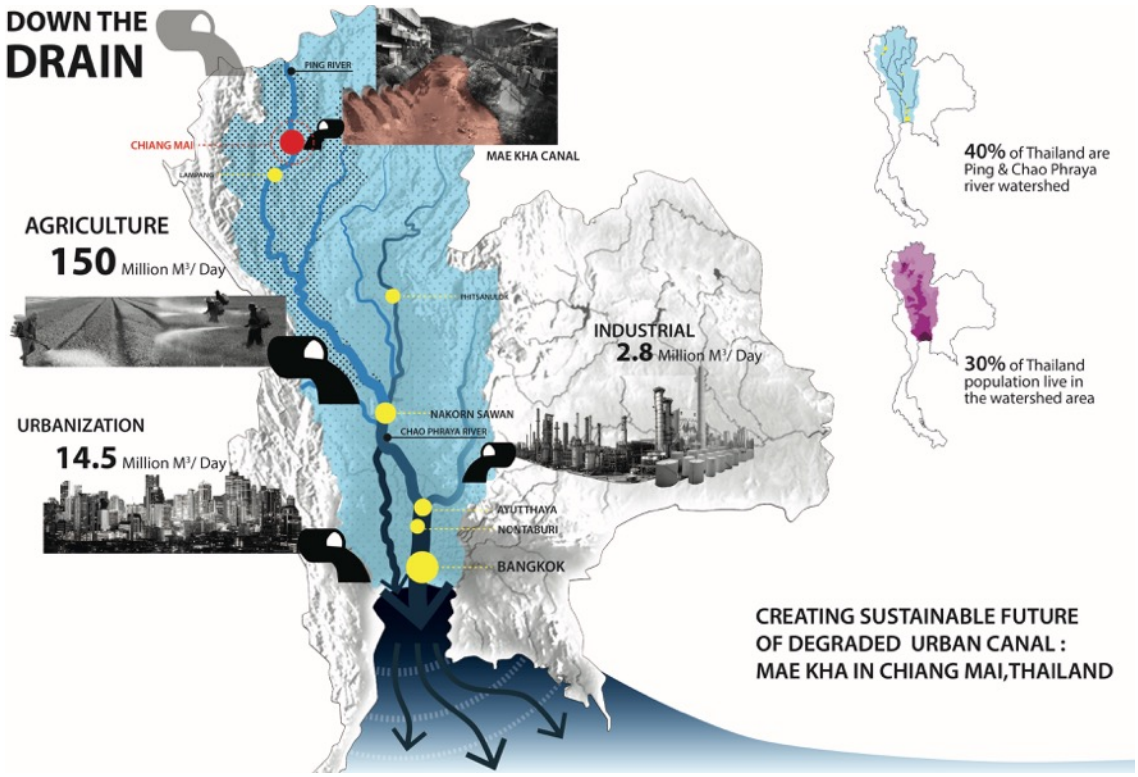

Figure 6: Down the Drain

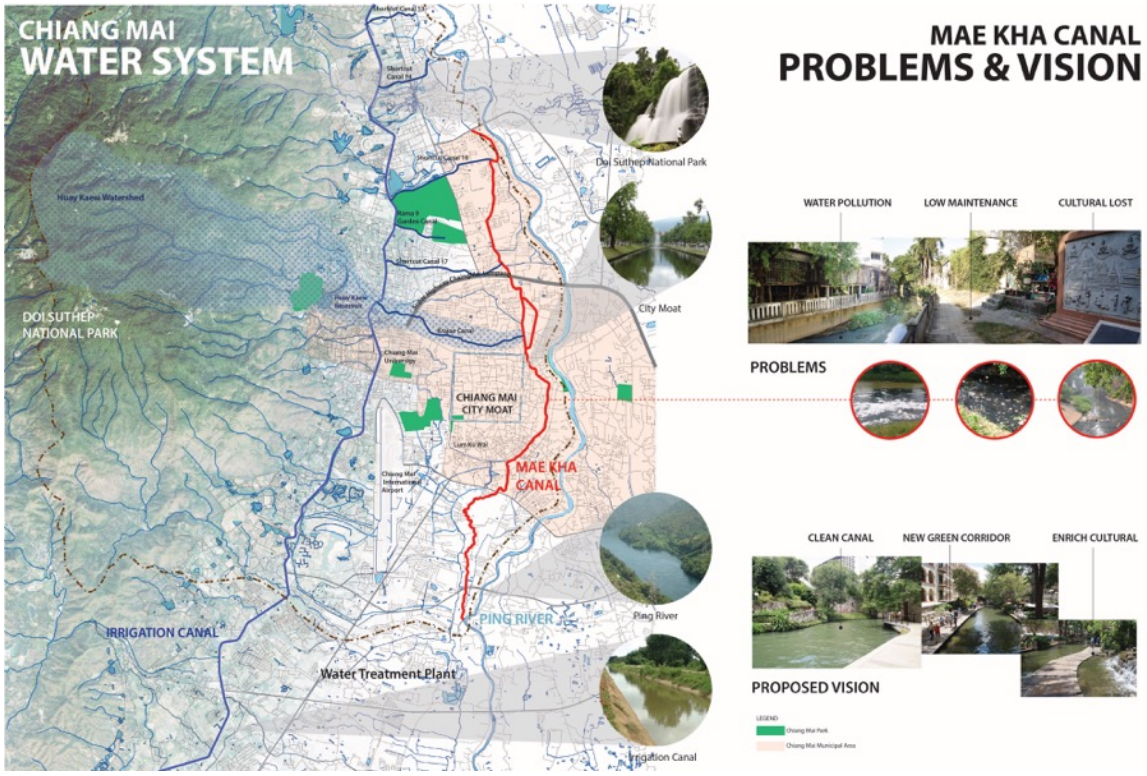

Figure 7: Chiang Mai Water System and Mae Kha Canal Problems.

Chiang Mai was founded in 1296, 720 years ago, together with the creation of City Wall and Moat to protect the city from potential enemies and floods. Mae Kha Canal was excavated as a second layer protection from Ping River overflow. In addition, the canal provided transportation, irrigation and clean water for daily use. As time went by, Chiang Mai became the center of the Northern region attracting business and tourists. People started migrated to the city seeking for jobs. Since then, communities have grown and occupied areas along the canal and rice fields at the same time forests have gradually disappeared from the city. In the present, Mae Kha has become narrower, more degraded, and is unable to perform ecological function anymore (See Figure 8).

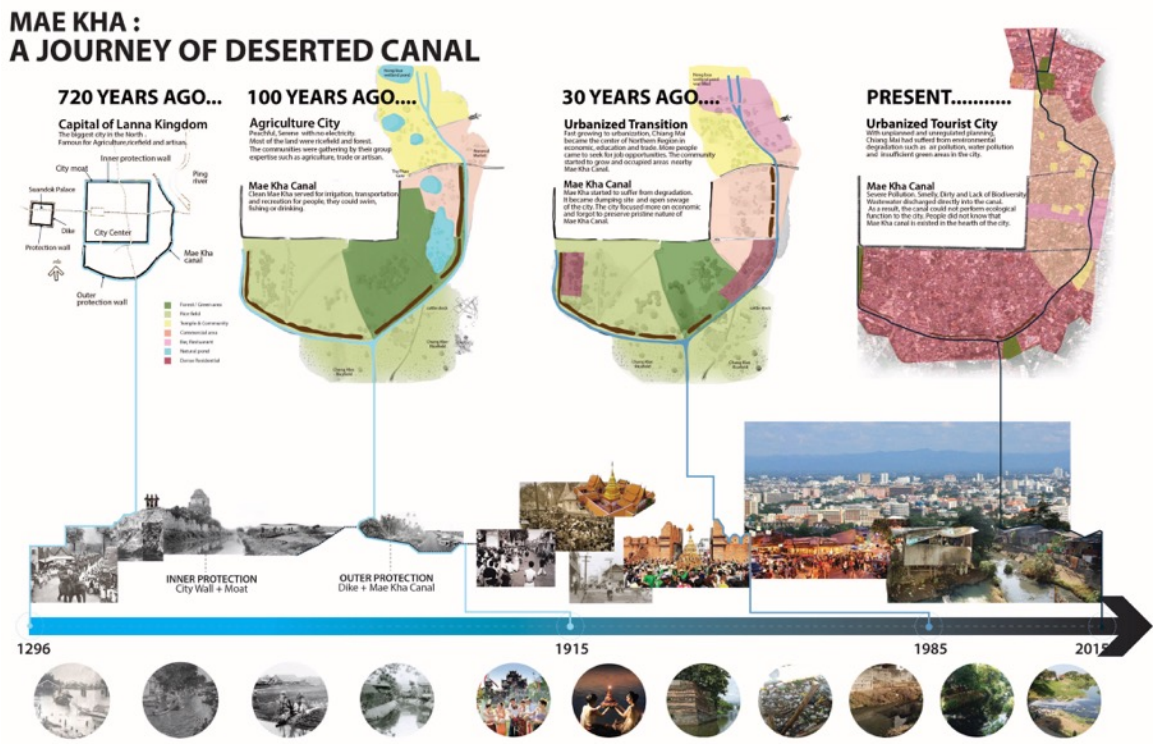

Figure 8: Mae Kha : A Journey of Deserted Canal

The maps demonstrate site analysis of the 3 mile studied corridor of Mae Kha Canal (See Figure 9). In the land use map, from the highway to the North of City Moat, land use transform can be seen from medium density residential to high density commercial mixed-use. Form on-site observation, it can be understood that the canal has a peculiar smell and wastewater discharge problems. Moreover, it is facing erosion and holds garbage. However; it is important to note that certain parts of the canal are beautiful, with rich native vegetation. The eastern areas, adjacent to the City Moat are highly urbanized with dense touristy businesses. The canal is covered with concrete banks and the water color is extremely dark.

Some parts of the canal are very narrow, hidden behind the buildings and lack diversity of ecosystem. Down from the South corner of the City Moat, mostly consists of dense residential areas. Mae Kha Canal appears to be in an extremely polluted condition with overgrown vegetation along the banks, which adds up to be a potential threat to people's health and welfare in a near future.

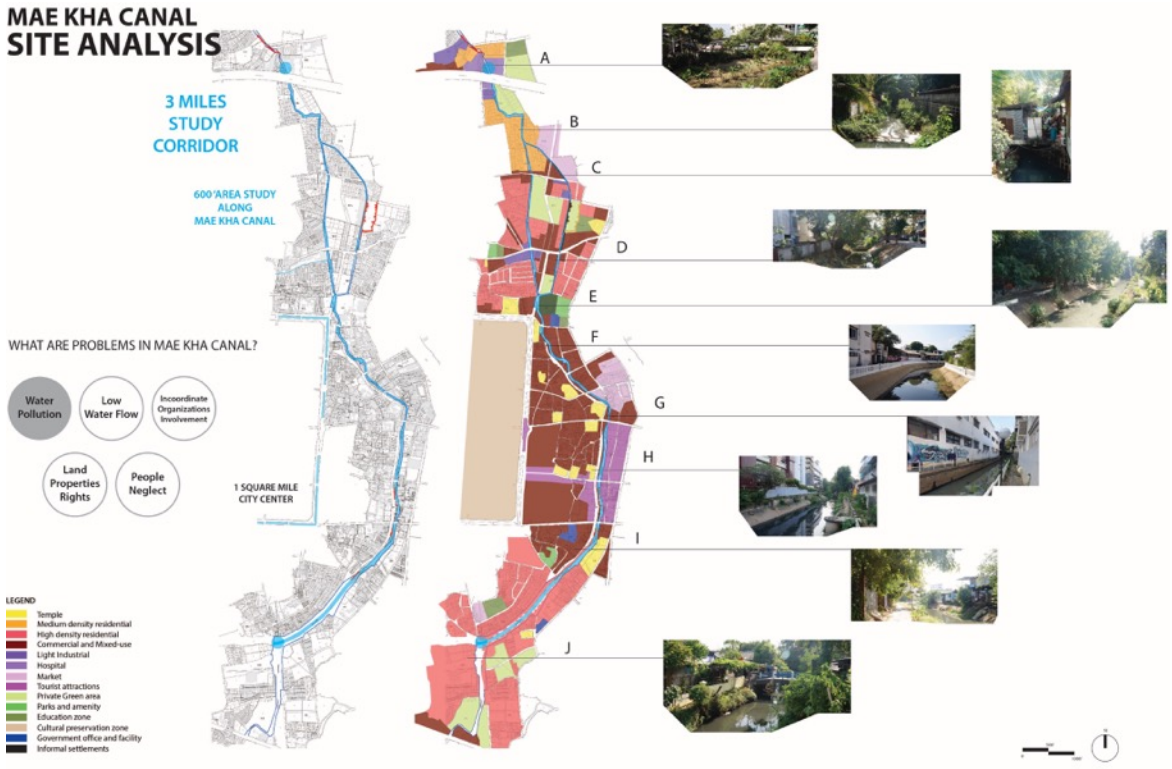

Figure 9: Mae Kha Canal Site Analysis

From extensive analysis and site observation, the study corridor has been divided into three phases according to an order of land use characteristics and water quality analysis; Phase 1 is local commercial mixed-use in transition to urban area; Phase 2 is tourist-aimed businesses in congested urban areas; and Phase 3 is dense community areas (See Figure 10).

In the overall site concept, to create a new linear park in the heart of the city, the proposal is analyzed into three significant types of nodes. First, commercial nodes, that are marked as attraction for people to rest, shop and eat at market, mall and restaurant along the corridor. Second, park nodes, that are implemented the potentials area close to the canal. For instance, park node 1, vacant private property has potential for development. This land is proposed to be sustainable community prototype for those who illegally live along Mae kha canal. Although this could be interesting pilot project, it will need time to convince the government to buy this land. Next, park node 2, this is the most feasible site because this

land is government's property that can take action as soon as possible. Also, the confluence of City Moat, Mae Kha Canal and Ping River are represented on this site as it can tide the close proximity from each other. This is a great opportunity to address green connections between these three important water features in Chiang Mai. Lastly, park node 3 is in a cemetery area. This site will need time to negotiate with the local community, because Thai people respect the land of the dead. Third, cultural nodes are emphasized temples and historical buildings for attraction spots along the corridor (See Figure 10).

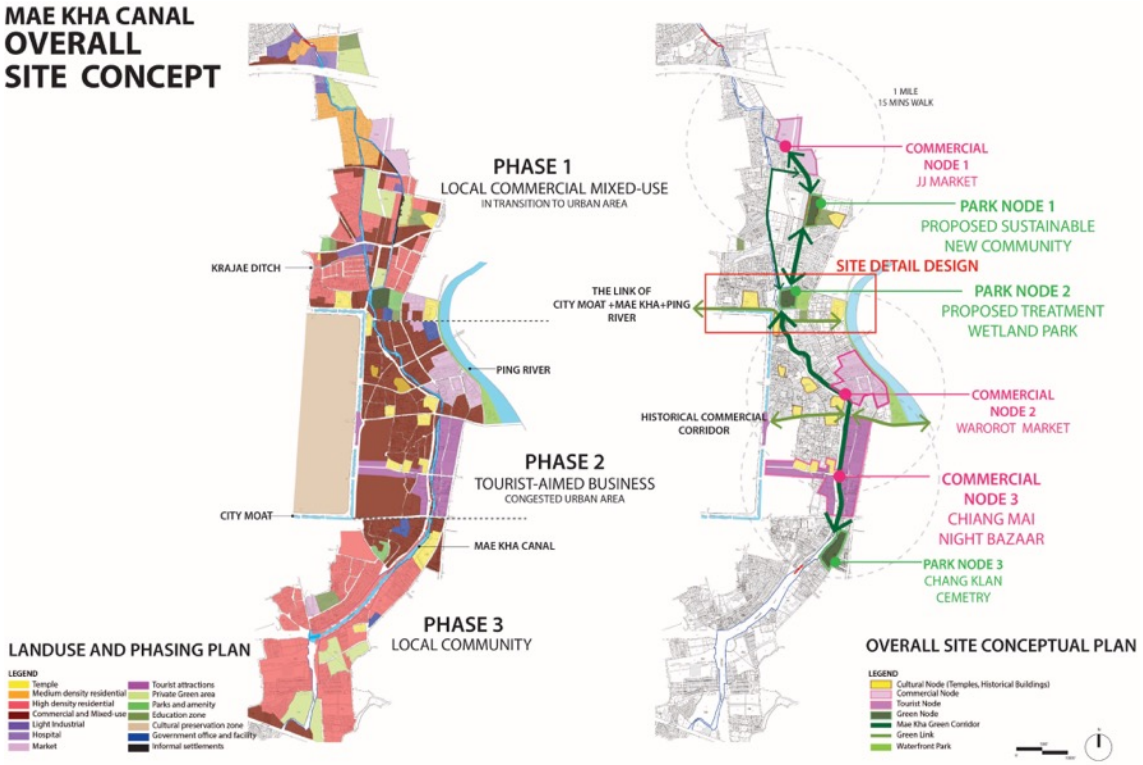

Figure 10: Mae Kha Canal Overall Site Concept

This new proposal of Mae Kha Canal corridor represents water treatment infrastructure of the city (See Figure 11). The potential properties adjacent to the canal are proposed to function as park and play an important role to purify water. Conventional water treatment system is recommended for pre-treatment stage in treatment node 1 and 2. This advance treatment effectively reduce unpleasant odor and heavy polluted substances before entering to ecological treatment wetland at treatment node 3. The aim of this treatment system is to reduce Mae Kha Canal pollution rate which is ranked in Class 5 down to Class 2, where the water is suitable for recreation, fisheries and aquatic conservation. Some areas of concrete canal transform to gabion lining that allows vegetation to grow and increase biodiversity to the canal.

Floating plant rafts are installed along the canal to help purify water. The ultimate goal is to remain Class 2 water quality throughout entire Mae Kha Canal corridor.

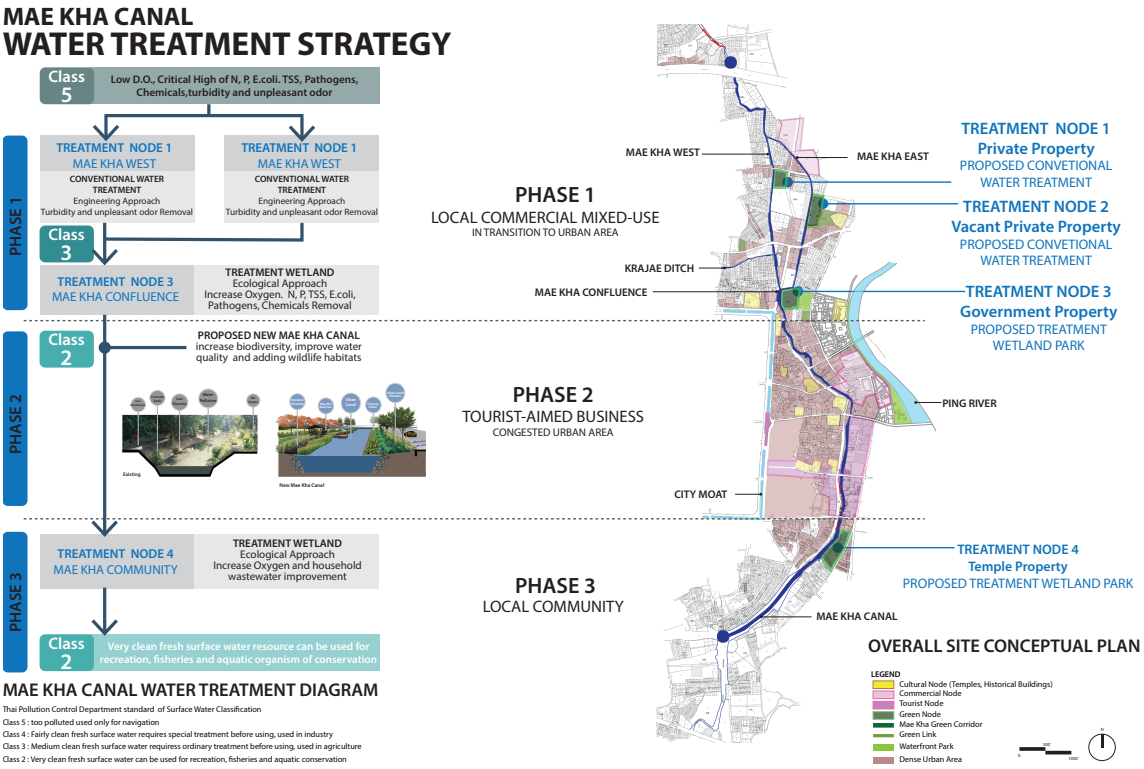

Figure 11: Water Treatment Strategy

From the analysis, Park node 2, in Phase 1, has been selected to continue towards site detail design (See Figure 12). This 4.75 acres area is very vibrant with temple, market and government offices. With a close proximity of 250 feet to City Moat and 1,600 feet to Ping River, the site is a great location to promote the connection of the three important water systems and emphasize the preciousness of water. The proposal aims to create pilot urban stormwater treatment wetland park to help mitigate pollution in Mae Kha Canal and also provide recreation for people and home to wildlife and native vegetation, a place where people can interact with nature.

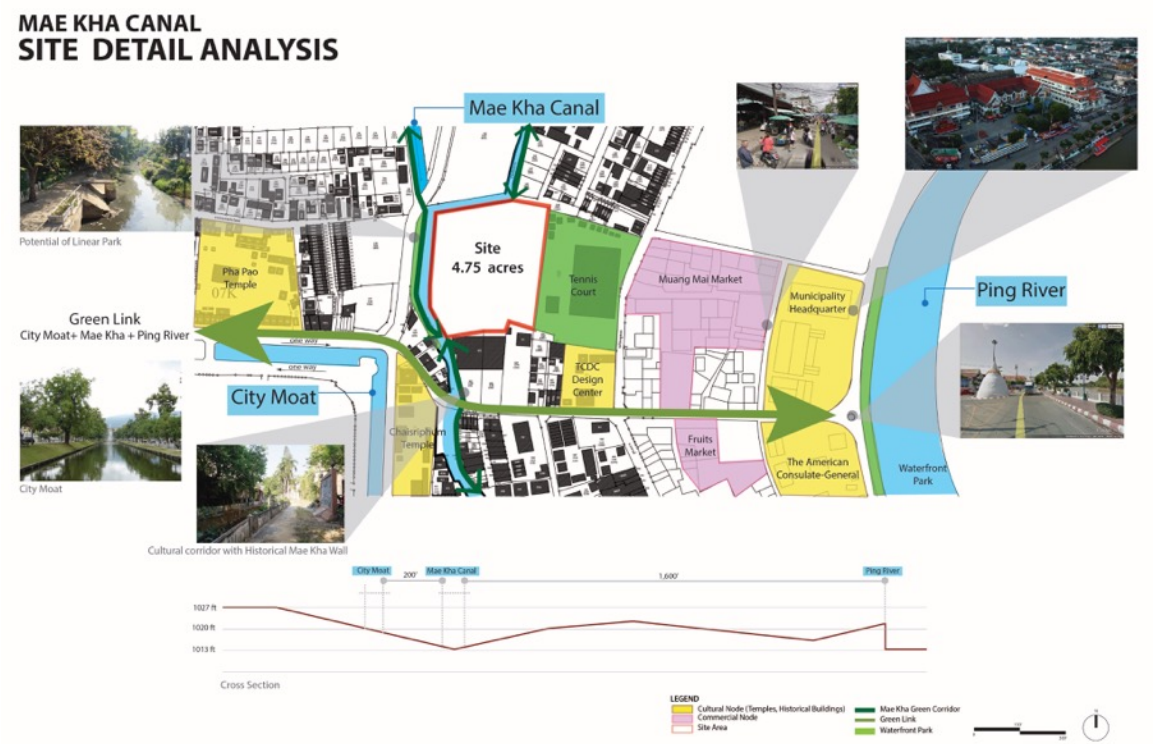

Figure 12: Site Detail Analysis

According to Sustainable Development Philosophy, the program cores divide into three important parts to create a sustainability approach; Social, Economics, and Nature. The programs are indicated by water level on site and local cultural events in Chiang Mai. They can roughly separate into two seasons: wet and dry. In Chiang Mai, rainy season starts from May to late of November. In these months indicate the programs that relate to high amount of water. During rain, the areas preserve for ecological function to purify urban runoff and protect fisheries as their breeding season. In the mean time, wetland education program tour provide to gain knowledge of the wetland park. In the late of rainy season, there is Loi Krathong festival to release flower float into the water to show respect to goddess of water at night. During the day, fishing season with cultural equipment promote an interesting events. In dry season, the highlight program is local boat tour along Mae Kha Canal that help stimulate tourism and provide jobs for the community. Also, on Songkran day, people get together to celebrate water festival in this park.

Two-thirds of site area design for treatment wetland park by using ecological approach to indicate treatment wetland programs. According to Figure 13, the series of treatment wetlands are installed. There are seven treatment steps include pre-treatment, primary treatment, secondary treatment, tertiary treatment, filter treatment, oxidation treatment and polishing with natural wetland. The goal is to reduce

polluted substances in the Mae Kha Canal and promote ecological education through wetlands. People can learn native wetland plants and see their function to improve water quality.

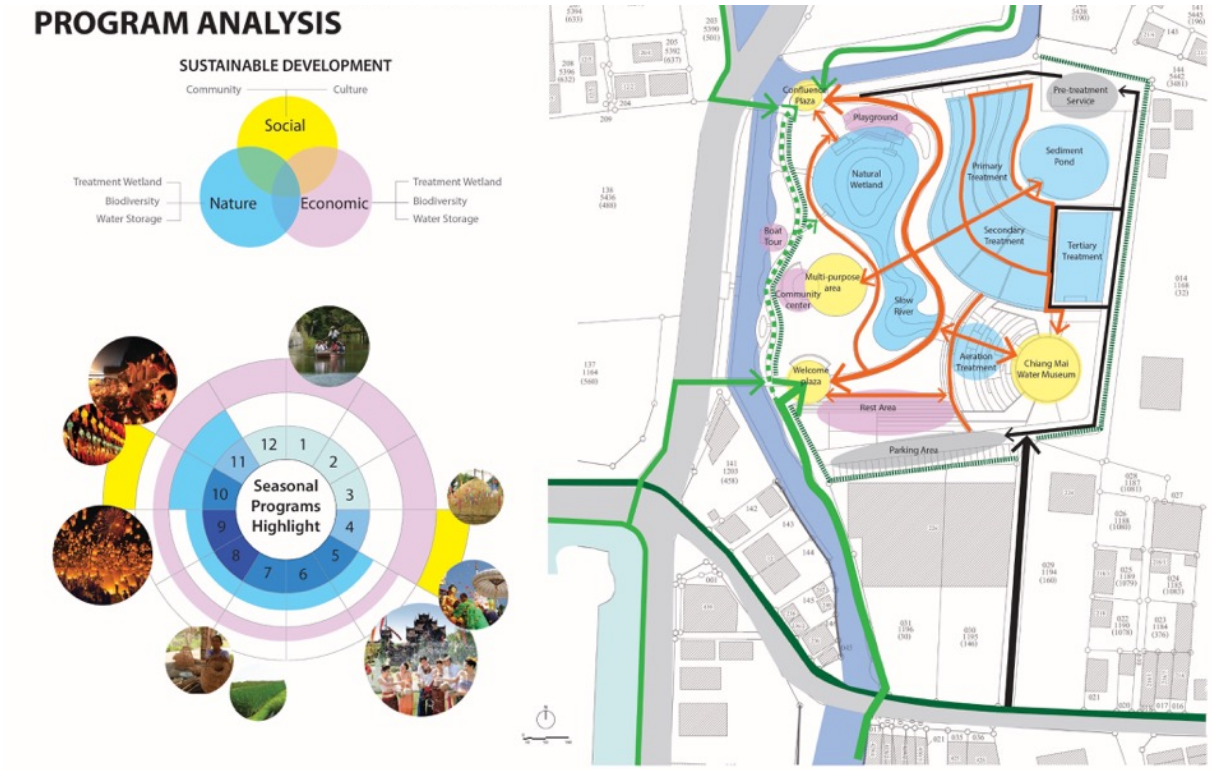

Figure 13: Program Analysis

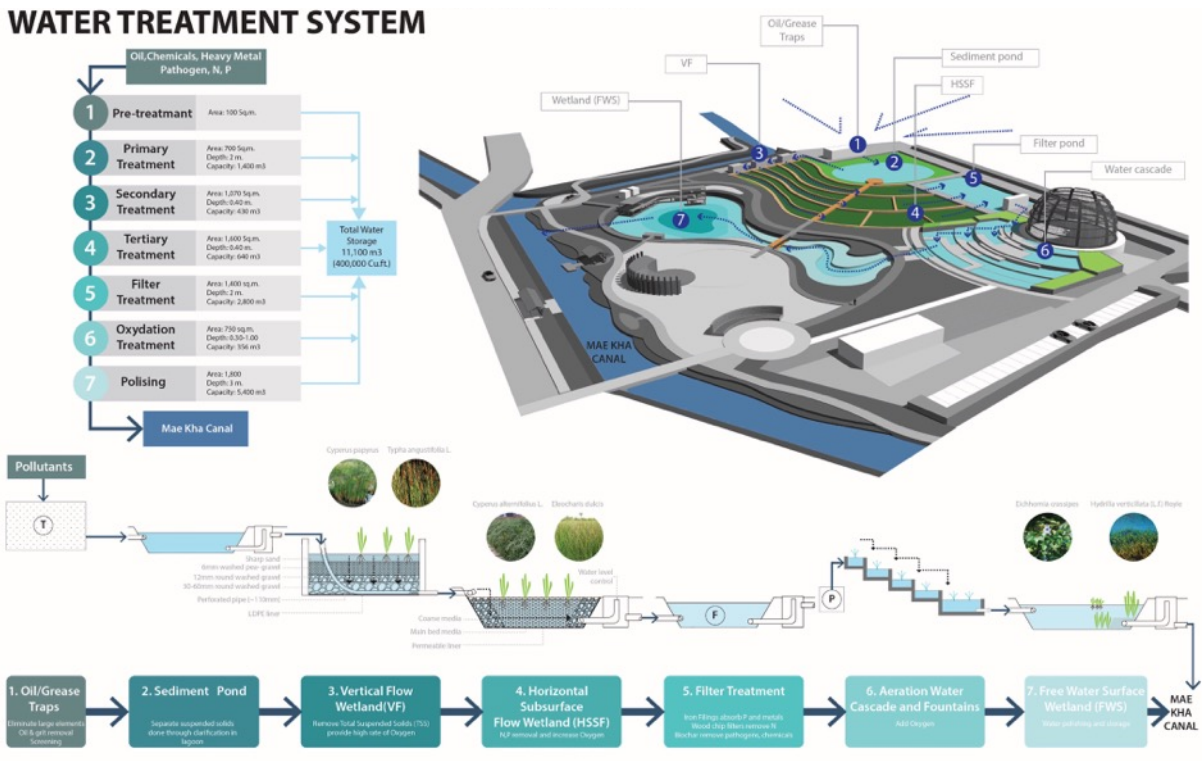

Figure 14: Mae Kha Water Treatment System

Figure 15: Master Plan of Mae Kha Stormwater Treatment Wetland Park and New Proposal of Mae Kha Canal.

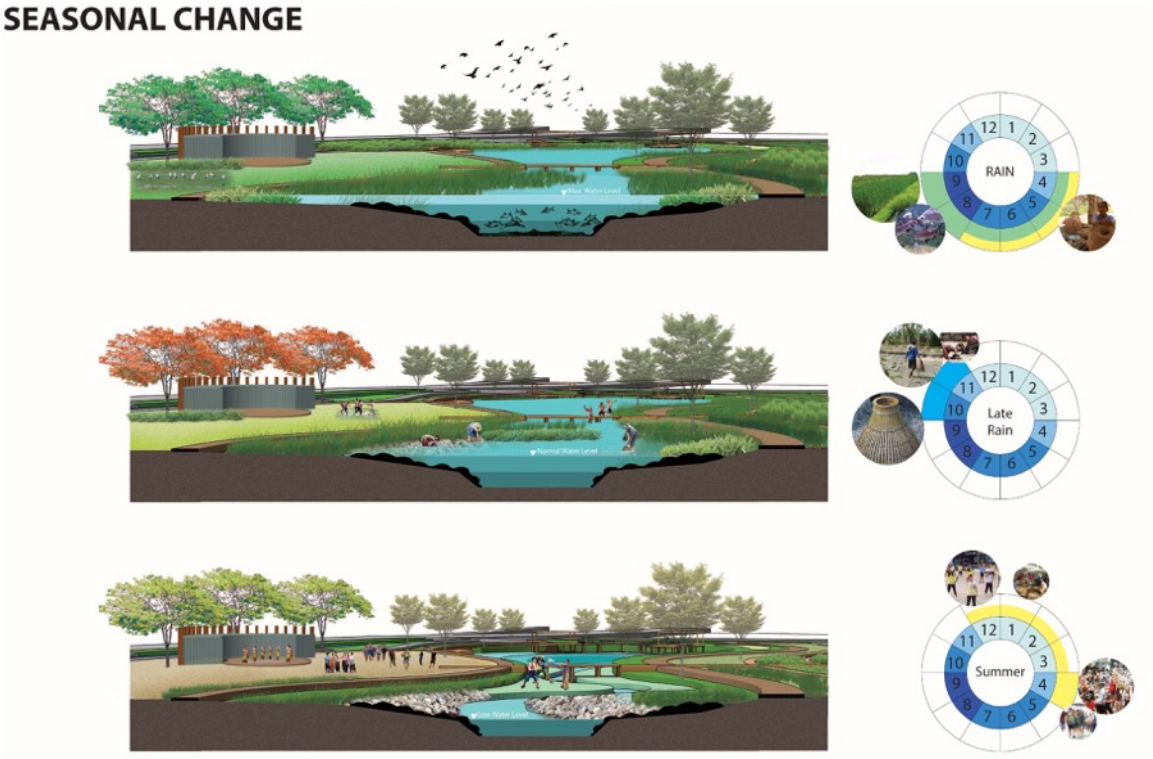

Figure 16: Seasonal Change Sections

Figure 17: Site Attractions

CHAPTER 5. CONCLUSIONS

Like many other developing cities, Chiang Mai has developed so fast, and has not protected its pristine natural resources that maintain the nostalgia for the city. The witness of this circumstance is Mae Kha Canal. Also, Mae Kha Canal is not widely recognized. Two blocks away, this canal is suffering from pollution, unpleasant smell and is known as an open sewage of the city.

In conclusion, it can be said that the transformation of urban water development plays a significant role in the restoration of cities in regard to socio-economic status, health and ecology. At the onset of the 20th century, we started paying attention to the negative impacts of industrialization and urbanization on the degradation of urban water bodies. This phenomenon has changed people's perception about this infrastructure as part of the city, and as an important aspect of their lives. Mae Kha Canal restoration project in dense urban settings has increased people's capability to appreciate landscape and the significance of protecting natural resources. Moreover, the improvement will stimulate property values, attract new businesses, and strengthen a new sense of community identity and pride.

It can be understood from the case studies that developed countries are able to effectively clean their rivers since they have adequate resources, a strong public sector capacity, and public institutions. Whereas, developing countries, like Thailand, struggle to rehabilitate their natural resources in the context of limited capacity and resources, as well as absence of appropriate public institutions, legal framework, and strong regulation. After all, one of the greater challenges being faced regarding urban canals is how to bring some kind of compatibility in balancing the needs of economic development as well as the need to protect this vital ecosystem.

From intensive research, site analysis and site observation, the Mae Kha Canal has a strong potential for developing to a new green corridor in the City of Chiang Mai. Three mile corridor stretches in the heart of the city provide accessibility and connection for the city and also recreation space for people. In addition, this site will be a new tourist attraction for the city, encouraging local economic improvement. Along its flow through different part of the city, this will provide great experience for visitors. They can perceive the story of the city, enjoy with nature while strolling or jogging along the canal.

The development of Mae Kha will provide great benefit to the city, however; the canal existing condition needs immediate action for improvement. From site visits, it is obvious that Mae Kha's extremely bad odor and condition take people's attention away. Also, a lack of proper pathway maintenance hinders the pathway usage. Therefore, the first steps of the Mae Kha development are to

eliminate the odor problems, improve water quality, clear and maintain walkways and canal condition, together with announcing water treatment policies and laws to control wastewater discharge. Furthermore, the cooperation of the community, government, stakeholders and non-profit institutions is encourage to implement the sustainable future of the Mae Kha Canal.

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VITA

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