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.

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Source: Kon Jai Baan, 2012

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Abstract

Cities have historically developed near water bodies. The increasing prevalence urban space has had a marked effect on the ecology of urban waterways. Many rapidly urbanizing areas experience a growth in informal housing often located on environmentally fragile land. These communities of urban poor are often unjustly blamed for the degradation of the environment, while carrying the largest burden of said degradation. Processes of urbanization in Chiang Mai, the second largest city in Thailand, have been accompanied by a decrease in air and water quality. This thesis researches *the human-environment interactions between the city and the urban canals in Chiang Mai, Thailand?* An environmental justice approach is applied to this study looking at how the environmental ills, recognition, and capability to participate in the management of the canal differ between different stakeholder groups. The research is based on water quality tests in 10 sites in July, September and November, and interviews with 52 stakeholders from the business, chuchom, governmental and not-for-profits sectors. Water quality tests indicated the canals to be severely degraded, with the lowest water quality measured in July. However, no significant differences were found in the water quality between sites. Notwithstanding, chumchon experienced more disamenities including flooding and health impacts. The tourist area benefited from water infrastructure, with lower levels of flooding. A top-down management of the canals is centered on the national government. This restricts the capabilities available to local stakeholder to affect the present situation. Any long term solution to the state of the canals would need to recognize both the root causes of environmental degradation and informal housing. While there are no easy solutions, a participatory approach including all stakeholders is likely to be an important part of it.

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Introduction

The Mae Kha and Ku Wai are canalized urban streams that flow through Muang Chiang Mai Municipality in Northern Thailand. The canals have been heavily polluted with increasing urbanization in the city, and continue to receive high concentrations of wastewater effluent. The disamenities of the canals, however, are not equally distributed. The purpose of this investigation is to describe the physical and social factors which characterize both the state of the canals and the distribution of their disamenities. A mixed methods approach informed by environmental justice was used to reach an understanding of these social-environmental interactions.

The world is an increasingly urban place; in 2012, 53% of the world's population lived in urban areas (World Bank, 2012). As such, the interrelation of urban populations with environmental systems is one of the central mechanisms of our time. Water, among the most valuable and essential of all resources, is central to this relationship. How is this resource managed? Who reaps its benefits? And who risks going without (Marcotullio, et al., 2003; De Jong, 2012; Srinivasan, 2012)? In 2009, about 33% (UN-Habitat, 2012) of the urban population of developing countries lived in slums or low income communities (un-stat, 2012), and (in 2007) 25% lacked adequate sanitation (UN-Habitat, 2012). UNEP estimated that improved sanitation alone could reduce hygiene-related deaths by up to 60%, and diarrheal episodes by up to 40% (UN-HABITAT, 2010). These risks are not equally shared among all members of society. Informal settlements, often located in fragile environmental areas, face the brunt of the natural risks associated with increased urbanization and destructive environment management practices but are often excluded from decision making processes (UN-HABITAT, 2010). An environmental justice study of the human-environmental relations is necessary for a better understanding of the impacts of urbanization on both people and the environment.

About 34% of Thailand's population lives in urban areas (CIA, 2013), of which 27% live in slums (UN-stat, 2012). These groups are at increased risk of experiencing the negative consequences of environmental pollution. One such consequence which urban areas are more likely to face is resulting from inadequate drainage and sewage systems to service the population, which leads to a number of negative impacts. Thailand is mostly serviced by mixed sewers that transport its wastewater and runoff to nearby rivers or other receiving waterbodies. The lack of permeable surfaces in urban areas combines with the discharge of untreated wastewater to extensively pollute the surrounding waterways (World Bank, 2008). In Chiang Mai, mixed sewers discharge the majority of the city's wastewater into the Mae Kha canal, which then takes it to the Ping River (Chiang Mai Municipality, 2010). During the dry season, the Mae Kha has a low flow of black odorous concentrated wastewater, while heavy storms in the rainy season cause the polluted water to overflow, contributing to the spreading of diseases and other negative impacts (Tjallingii, 2012, p.102). Low lying areas in the south of Chiang Mai, which house many chumchon, are most often affected by seasonal episodes rotating between flooding, mosquito plagues, and putrid smells.

In 2005, Chiang Mai city included a total of 60 registered low income communities (CODI, 2005). Today, the area around the urban canals alone houses at least 16 low income communities, of which 10 are located in the inner city (CODI, 2013). Urban poor informal communities are often located in open, inhabitable areas such as natural parks. The location of poor communities near available spaces along waterways has resulted in these communities being frequently blamed for the environmental degradation associated with development and increased urbanization (UN-Habitat, 2003). This is worsened by environmental policies, which are concerned with city beautification rather than environmental rehabilitation or protection (Ribeiro & Srisuwan, 2005; UN-HABITAT, 2010). In such circumstances, evictions of the poor and demolition of informal communities are commonly performed under the guise of environmental protection, but without housing solutions or a broader environmental policy (UN-HABITAT, 2010). In 2013, Thailand's central government approved a THB 300 billion (EUR 7.5 billion) budget towards the beautification of the Mae Kha canal in Chiang Mai. Relocation of the chumchon along the Mae Kha and Ku Wai is a central pillar of this plan (Wassan, 2013).

This plan ignores ample evidence that the urban poor are not nearly the most significant source of pollution to the canal (Kold et al., 2001). Moreover, the plans for relocation are being arranged without real participation of the urban poor. "The exclusion of urban slums from the mainstreamed urban socioeconomic environment reflects a more deep-seated phenomenon of structural poverty: they come as an emanation of social, political and institutional disparities and deprivations that are exacerbated by the pressures of sustained urban growth. Slums effectively segregate urban areas into the 'rich' and the 'poor' city – the 'urban divide' resulting from economic, social, political and cultural exclusion" (UN-HABITAT, 2010). Discussions on the role of the urban poor in polluting the canal distract from the main issues afflicting the canal, namely inadequate housing and wastewater treatment infrastructure. Further, such plans are unlikely to have long lasting effects, as previous evictions in 2000 and 2005 were both followed by the return of communities to the city and the rise of new urban poor, as peri-urban areas lack the necessary logistical services for communities to earn a living (POP, 2013).

This following section introduces the objective of the study and research questions. The second chapter introduces the context in which the research site is located. The third chapter introduces the issues facing urban stream. The fourth chapter introduces the applied theoretical framework of environmental justice and defines the central terms for this thesis. The fifth chapter looks at the applied methods used to design the study, including the stakeholder analysis and water quality analysis. Following this, the results are described in four parts: justice of distribution, procedural justice, recognitional justice, and proposed solutions. Lastly, the conclusions are presented with summarizing remarks.

Objective of the study

Bohemen (2012) has stated that the integration of biophysical and social sciences is necessary to generate a better understanding of social-ecological interactions. The objective of this thesis has been to look at the environmental justice of the Mae Kha in Chiang Mai. The expectation was that the risks of water pollution were greater among the chumchon (slum) populations. Access to a clear map of actors involved in the management of the canal, combined with an understanding of the levels of water pollution and local hydrology, will hopefully facilitate chumchon and not-for-profit organizations in their attempt to promote a more inclusive and environmentally responsible arrangement. Fiksel (2006) captures the essence, stating that, "Greater understanding of our surroundings is essential for effective decision making with regard to global sustainability, since industrial, social, and ecological systems are so closely intertwined".

Research question

What are the human-environment interactions between the city and the urban canals in Chiang Mai, Thailand?

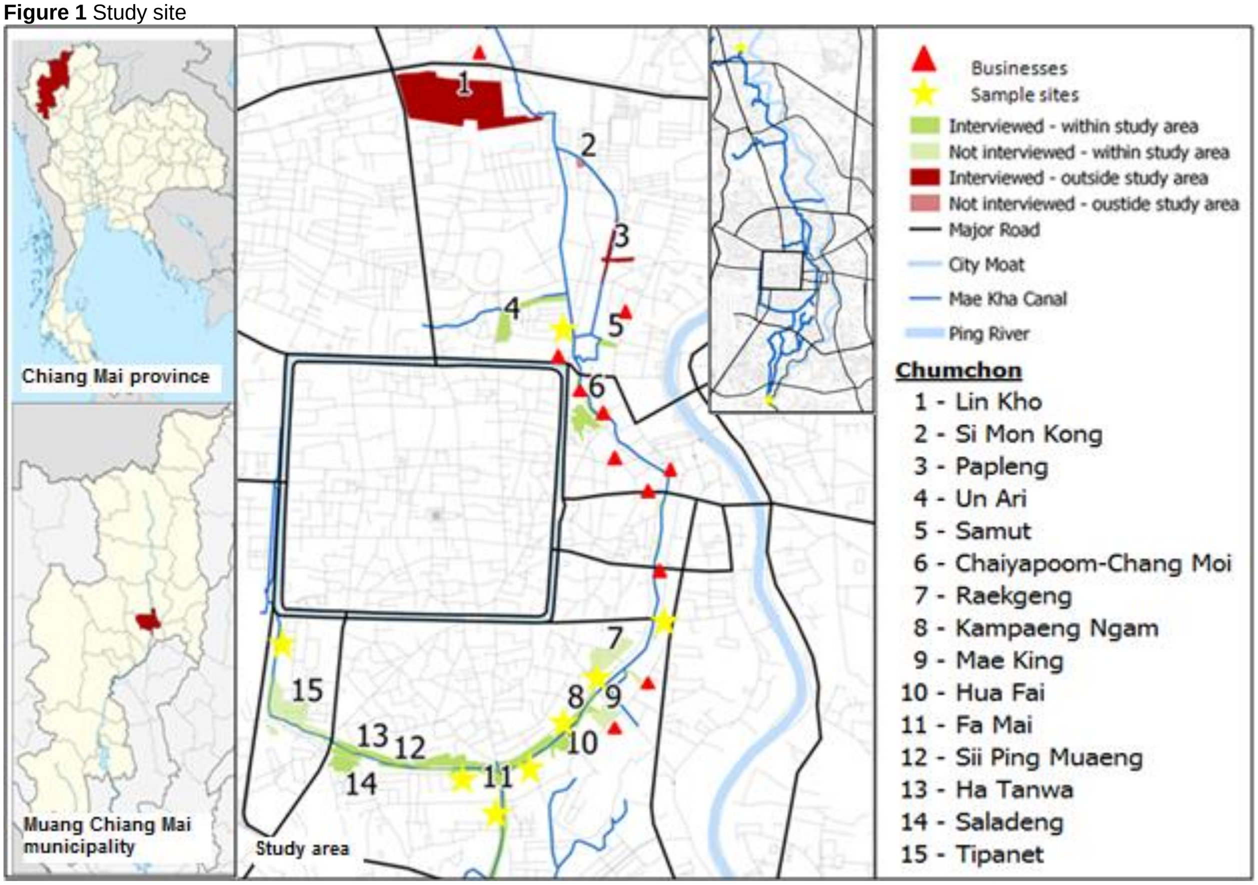
This question has been researched through five sub-questions formulated using the environmental justice framework**:**

- *What factors contribute to the wastewater flows in the inner city urban canals?*
- *How are environmental impacts distributed along the trajectory of the Mae Kha canal?*
- *How does the recognition of the canal and stakeholders differ across stakeholder groups?*
- *How do different stakeholder groups participate in the management of the canal?*
- *How do different stakeholder groups value the canals, and envision their improved management?*

Geographical Framework

The study site is situated on the Mae Kha, an urban canal in Chiang Mai City in Northern Thailand. The boundaries of the study site have been defined around the historical center of Chiang Mai (Figure 1). This chapter discusses the area in detail with a short review of Thailand, Chiang Mai and the Ping river catchment.

Figure 1 Study site



Source: Chumchon were delineated from Google Earth satellite photos, and verified against maps from CODI and Kon Jai Baan. Insets: location of Chiang Mai province in Thailand (top left; wikicommons, 2009), Chiang Mai municipality in Chiang Mai province (bottom left; wikicommons, 2005), the old city, locations for water sample collection, interviewed chumchon, and businesses (Open Street Maps, 2013).

The study site

The study site extends through approximately 6km of the urban trajectory of the Mae Kha canal (Figure 1). The site boundaries are set along the Kampaeng Din wall which represents the historical outer border of the old city. This area is considered the center of Muang Chiang Mai. This area was chosen for the study site due to its distinct historical-ecology, as it was canalized from an alluvial stream that was canalized to function as the city's drainage and protective moat when Chiang Mai was founded over 700 years ago (Chief of Maintenance, 2013). The part of the city located within the contours of the old wall has the highest density of population and surface imperviousness of the entire watershed. This area produces large volumes of wastewater effluent which are mostly discharged into the canal (Kold et al., 2001). Ad hoc growth has made the banks of the Mae Kha the main urban area for settlement of chumchon and rural migrants (Tan-Kim-Young, 1979). A combination of these factors has led to significant degradation of the stream's ecology over time (Guigno et al., 2005).

The urban canal can be divided into the eastern Mae Kha and the western Ku Wai streams. Both sides are fed by a combination of the Doi Suthep Mountain range, city waste water and urban runoff. 3 km of the 6 km of is lined with cement, facilitating urban drainage and flood prevention, but contributing to a degraded water quality and higher flood risks downstream (Walsh et al., 2005; unesco-ihe, n.d.).

Zoom-in

Most chumchon community leaders that were interviewed were asked about the general situation in each chumchon. However, in chumchon Kampaeng Ngam, 10% of the households were interviewed in addition to the community leader. This community was chosen to provide a close up perspective of the experience on the ground, due to its position in between the urban business area east of the city and the primarily chumchon populated area south of the city. Kampaeng Ngam is said to experience high levels of pollution (Srisuwan, 2005) and has been highly active in negotiating land rights and promoting canal cleaning activities.

Zoom-out

The larger area outside of the study site was mapped in slightly less detail in order to understand the broader trajectory of the canal. Additionally, some actors that were mentioned frequently during interviews were located outside the main study area, generally upstream, and so were interviewed in the interest of completing the picture (see Figure 1). These actors included chumchons Lin Kho, Papleng and Samut as well as a fish salesman in Muay Mai market and Lanna Hospital. Water quality tests were also done upstream and downstream of the city to compare results with those from the city centre.

Thailand

The Kingdom of Thailand is located in the center of Southeast Asia, bordered on land by Myanmar, Laos, Cambodia, and Malaysia, and at sea by Vietnam, Indonesia, and India. Adjacent water bodies include the Gulf of Thailand to the south, and the Andaman sea to the east of its southern peninsula (CIA, 2013).

Thailand's territory covers 513,120 km^2 with a total population of 67,741,401 (CIA, 2014). The capital city of Bangkok is the political, commercial, industrial and cultural heart of Thailand and its metropolitan area includes approximately 22% of the country's total population (NSO, 2012). Chiang Mai, the second largest city in Thailand, represents about 2.5% of Thailand's population (NSO, 2010). About 95.9% of Thailand's population is ethnically Thai, 2% is Burmese, and 2.1% others (CIA, 2013). The country's official language is Thai and Buddhism is the primary religion, practiced by around 93.6% of the population (CIA, 2013).

An upper middle income country, Thailand has sustained positive economic growth during recent decades. In 2012 it had a GDP (PPP) of USD 645.2 billion, at USD 9,500 per capita. With medium HDI and GINI scores of respectively 0.690 (UNDP,2013), and 53.6 (CIA, 2014), it is clear that recent development has benefited the quality of life of a large portion of the country. Historically an agricultural society, the industry now only represents 12.3% of the Thai economy, but 38.2% of employment. Currently, Thailand's economy is primarily service-based with services representing the largest economic (44.2%) and employment sectors (48.2%). The third leg of the Thai economy, industry, represents 43.1% of the economy and 13.6% of employment. The remarkably low unemployment rate of 0.7%[1] might obscure larger issues with underemployment, as 7.8% percent of the population lives below the poverty line (CIA, 2014).

Thailand's recent development has been fueled by the combined forces of rapid industrialization, urbanization, and intensified agricultural production and fishing. This growth has not been without cost as the degradation of land, water and air quality and extensive loss of natural habitats have become serious issues in Thailand. It is estimated that air and water pollution costs the country 1.6 - 2.6 % of GDP per year, and that roughly one third of Thailand's surface water bodies are considered to be of poor quality (World Bank, 2013).

[1] This is partially due to the inclusion of informal labor in unemployment statistics, and some argue that local culture could play a factor and cause over-reporting of employment due to personal pride (esri.go.jp)

Thailand is a constitutional monarchy and has been headed by King Bhumibol Adulyadej[2] since 1946 (CIA, 2013). The country is divided into 77 provinces (CIA, 2013), each of which is further subdivided first into municipalities[3], then districts, and finally sub-districts (UNEP, 2009). The provinces are often grouped into 4 regions: Northern, North-Eastern, Central and Southern, both for providing government services and for statistical information.

On the political side, Thailand has also experienced some political turbulence. "Since 2005, Thailand has been trapped in cycles of mass demonstrations, street violence, marshal laws, and unstable societal conditions" (Sinpeng, 2014, p.158). Most recently, starting in November 2013, protests have rallied against a governmental pardon for former prime minister Thaksin Shinawatra, which led to a forced resignation of his sister and current prime minister Yingluck Shinawatra in January 2014. Following her resignation, general elections were held in February but were declared invalid after mass disruptions coordinated by opposition leaders. The current stalemate has led to increasing tensions, violence and many deaths. This comes after nearly a century of hostility against the populist policies of Thaksin Shinawatra and the Thai Rak Thai party to which he is tied[4] (BBC, 2014).

The two opposed political groups are often associated with their yellow or red shirts. The yellow-shirt, anti-Thaksin, People's Alliance for Democracy (PAD) group have recently given up on the current democratic system and are demanding that their non-elected counsel be permitted to take control of Thailand. This group is generally of higher income or middle class with a stronghold centered in Bangkok. They have in the past had support from both the military and the monarchy, two strong powers in Thai society (Sinpeng, 2013).

On the other side the red-shirt, pro-Thaksin United Front for Democracy and against Dictatorship (UDD), are the voting base for Thaksin and associated political parties and politicians. They are often characterized as the poor rural-urban populations which have organized following the 2005 coup d'état. This UDD movement been described as "one of the most powerful social movements in recent Thai history" (Sinpeng, 2013, p.159), and are a defining element of Thailand's political landscape (Sinpeng.2014).

Chiang Mai City

Chiang Mai city, the capital of Chiang Mai Province is located in Thailand's Northern Region (Lekuthai, 2008) at 18° 47' 24.0" N, 98° 58' 37.2" E, and an altitude of 314 masl. The city of 40,216 km^2 is located in a valley it and surrounded by mountainous parks, including Doi Pui Suthep, Obkhan, and Doi Inthanon (the tallest mountain in the nation) National Park. The historic city is recognizable by the square moat that surrounds it (Figure 1). Founded in 1296 by King Mengrai as the capital of the Lanna Kingdom (Lekuthai, 2008), Chiang Mai's development, like many pre-industrial cities, has been historically dependent on the nearby Ping river. The city's position at the feet of the Doi Suthep mountain range on a vast floodplain provides it with both a natural flood buffer and fertile soils for food production (Gugino et al., 2006; Ribero & Srisuwan, 2005).

Chiang Mai has a total population of around 234,600 (NSO, 2010). The surrounding metropolitan area which covers 2900 km^2 has a population of 1,655,642 (NSO, 2010). 97,676 people, or about 7% of the population, live in *chumchon (*Annex 12*)* (Community Department, 2010). The city is subject to the Chiang Mai provincial government but has its own elected mayor and municipal council. The government of the city center is divided into 4 districts and 16 sub-districts or *tambons* (cmcity, 2013).

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[2] The ninth king of the House of Chakri also called Rama IX has reigned Thailand since,1946, making him the world's longest-serving current head of state and the longest-reigning monarch in Thai history. The functions of the Monarch include, Head of State, Head of the Armed Forces, Adherent of Buddhism, and Upholder of religions.

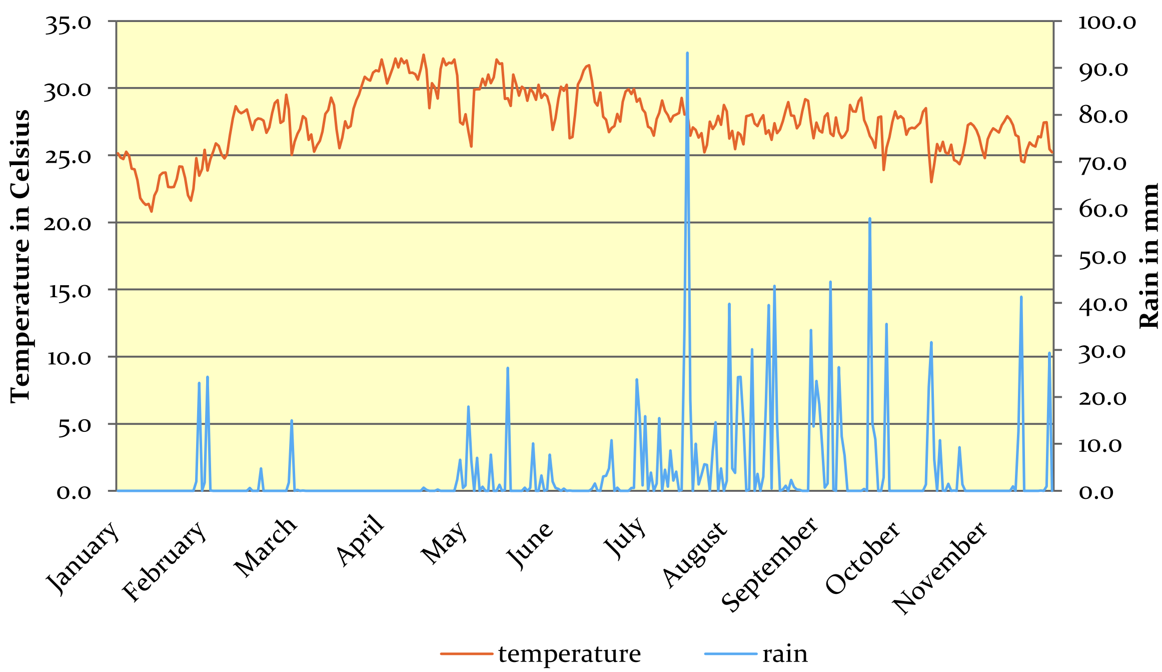
[3] 2 districts, Pattaya and Bangkok are specially governed districts of which Bangkok is generally counted as its own province.

[4] Palang Prachachon (PPP) and Peau Thai Party (PTP) (Sinpeng, 2013)

The economy of Chiang Mai city is heavily reliant on tourism while that of the province is largely agricultural. The city is also developing into an important academic center with six universities in and around the city, including Chiang Mai University, Chiangmai Rajabhat University, Rajamangala University of Technology Lanna, Payap University, Far Eastern University, and Maejo University, and with the ambition to be recognized as a UN creative city (Lekuthai, 2008).

The climate of Chiang Mai is classified as tropical wet and dry (Köppen *Aw*), as it is located near the outer edges of the tropical zone with high temperatures year-round and a prominent dry season (Köppen, 1936) (Figure 2). Chiang Mai receives an average annual rainfall of 1,183.5 mm, with seasonal intensity ranging from 4.6 mm in the driest month of February to 236 mm in the wettest month of August (TMD, n.d.). Low temperatures range from 13.7 - 23.7 °C (January - June), and highs range from 28.3 - 36.1 °C (December - April; *HKO, 2012*). Figure 2, shows the temperature and rain patterns for the study period. Chiang Mai generally has a high humidity averaging around 80% with a low point of around 58% in March (TMD, n.d.). Total annual sunshine averages 2684 hours, with daily averages ranging from 4.42 hours in August to 9.40 hours in February, and an annual daily average of 7.33 hours (HKO, 2012).

Figure 2 Daily rainfall and temperature values for 2013



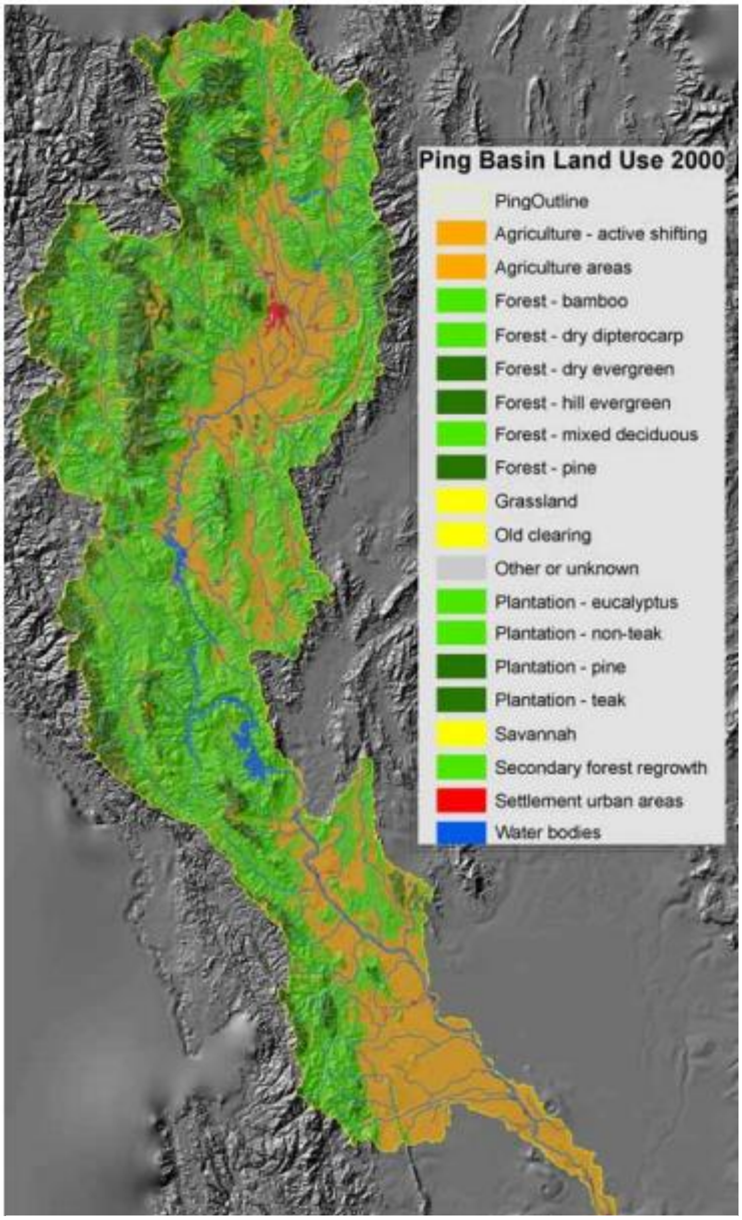
Source: Chiang Mai Meteorological Department

The Mae Kha

The Mae Kha defines the historical outer borders of Chiang Mai, and today still accompanies parts of the outer wall as historical monuments. The floodplains of the Ping river are located between the Ping and the Mae Kha, and were historically used as rice paddies to feed the city. The canal was long considered a valuable environmental asset, as a source of fish, rice and fresh water, flood prevention, transport and recreation. According to historical accounts, the Mae Kha canal was once a natural stream, a tributary of the Ping River. The stream was canalized to surround the city and function as the protection and drainage for the Lanna Kingdom. The canal is fed by the Mae Ta Chang and Mae Huak rivers, both of which flow down from the Suthep-Pui mountain. The canal is presently about 16 km long, its width fluctuates seasonally and locally between 1 and 10m and has an average depth of 2.5m, which also varies by season and location (Ribeiro & Srisuwan, 2005). The canal extends through 3 municipalities: Mae Rim, Muang Chiang Mai and Saraphi. It drains the urban runoff and houses hold grey water from more than half of Muang

Chiang Mai´s *tambons* into the Ping River (Sanitation department, 2013). In the west of the city, the Ku Wai canal flows down the Doi-suthep Mountains into the Mae Kha. While it is not clear exactly how much wastewater is discharged into the canal, it is known that this canal receives significant effluents from Chiang Mai University's campus wastewater treatment center, as well as some wastewaters from east of the city. The Ku Wai stream joins the Mae Kha, closing the moat around the city, at which point the canal streams down a further 4 km until it reaches the Ping River.

Figure 3 Land use of the Ping River Basin, 2000



Source: Thomas, 2006

Ping River Basin

The Ping river basin (Figure 3) spans portions of 5 provinces: Chiang Mai, Lam phun, Tak, Kamphaeng Phet and Nakhonsawan (gwp-sea, 2008). The Ping basin covers approximately 35,000 km² (Thomas, 2006) and has a long and narrow shape. Its boundaries to the north and west are with the Salawin and Kok river basins, to the South with the Maekhlong and Sakaekrang river basins, and to the East with the Yom and Wang river basins (gwp-sea, 2008). It covers 22% of the large Chao Phraya-Tachin river basin which covers a third of the country (Mapiam & Sriwongsitanon, 2009), and transports about 24% of the Chao Phraya river basin's total runoff (Thomas, 2006).

The hydrology of the Ping River is largely dictated by the natural seasonal patterns which consist of a dry and a rainy season. The Ping Basin is vulnerable to yearly flood events related to southwest monsoon which takes place between mid-May to mid-October. This brings air of high humidity originating from the Indian Ocean towards Thailand resulting in heavy rains that peak between August and October (Khedari, 2002). The short periods of heavy rain result in a large fraction of precipitation being lost to surface runoff, leading to low base-flow in the late dry season and frequent droughts in the basin (unesco-ihe, n.d.). The urbanization of the basin further increases surface run-off, exacerbating seasonal droughts and floods (Fletcher et. al., 2013; Thomas, 2006). However, the topography of the area makes such flooding events less common and less extreme in the central area of Chiang Mai City than they are east or downstream of the city (CENDRU, 2012).

Following the rainy season, the dry season occurs in two distinct phases. First, the northeast monsoon which follows the rainy season brings cool and dry air from the Siberian anti-cyclone between November and February, creating cool and dry weather. The second period is dry and warm and occurs between mid-February and mid-April (Khedari, 2002).

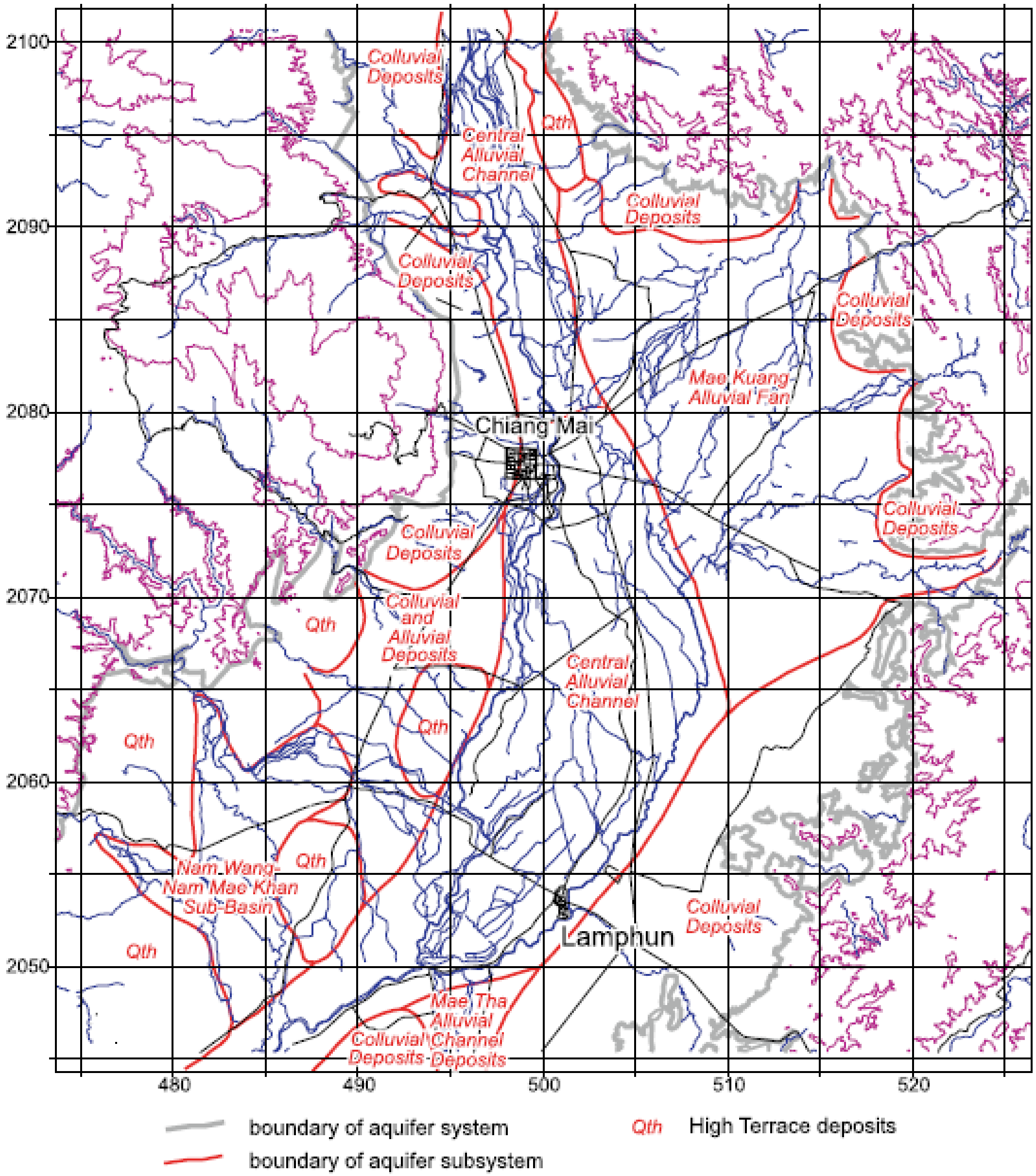
The topography of the Ping river basin is characterized by various mountains and low-land valleys. It can be divided into 2 parts: the upper Ping, which is located north of Bhumipol Dam, in Doi Tao district in Chiang Mai province, and the lower Ping to the south of the dam (Thomas, 2006). Chiang Mai is located in the upper Ping river basin. The upper Ping river basin has a catchment area of approximately 25,370 km^2 and covers the provinces of Lamphun and Chiang Mai. Annual runoff and rainfall are around 6,815 million m^3 and 1,174.1 mm, respectively (Mapiam & Sirongsitanon, 2009). The terrain of the basin is undulating and rolling, and divide the upper Ping river basin into 14 sub-catchments. Most of these catchments are ungauged, with the Mae Kha canal likely falling into an even smaller sub-catchment (Fletcher et al., 2013). The Mae Kha is located in one of the 15 sub-catchments which Mapiam & Sirongsitanon (2009) modeled in the Ping river section 2 catchment (18°40'28.84" N 98°59'31.58" E).

Geology of the area

Margane & Tatong (2009) discuss the main attributes of the Chiang Mai-Lampun (Figure 4) basin as follows: It is relatively flat with elevations of between 280m and 360m. The dominant tectonic features of this basin are N-S extensional faults, NW-SE dextral shear faults, and NE-SW sinistral shear faults. A sequence of Precambrian to Permian sedimentary rocks is exposed in the area around the basin. West of the basin these rocks were intruded by granites (Carboniferous and Triassic). Continuous down-faulting since the late Cretaceous has governed the sedimentation pattern. The basin fill reaches a thickness of about 2000m. In the areas with high subsidence rates, sand and gravel have been deposited with high accumulation rates during the Quaternary. The more stable blocks are dominated by the deposition of slope-wash sediments (colluviums) consisting mainly of clay and silt. In some areas almost no down-faulting or even uplift has occurred, as evidence by the preservation of the gravel beds at higher elevations (‘High Terrace’). Such interfingering units are observed throughout this area, providing evidence of the rapid change of the courses of the streams and rivers (Margane & Tatong, 1999).

For the area of Chiang Mai a few aspects of the geology of the area can be discussed: Sand and gravel beds can be traced mostly only over short distances. On the basis of lithological characteristics, the Chiang Mai-Lamphun basin down to a depth of around 200m can be subdivided into the following zones: ‘Central Alluvial Channel’, the ‘Mae Kuang Alluvial Fan’, the ‘Nam Wang-Nam Mae Khan Sub-basin’, the ‘Zones of Colluvial Deposits’ and the ‘High Terrace Deposits’, as indicated in Figure 4. The Central Alluvial Channel and Colluvial Deposit zones occur near Chiang Mai City. Clayey and silty colluvial deposits have also been mapped in several areas along the foot of the mountain ranges. The central part of the Chiang Mai-Lamphun basin is dominated by the deposition of sand and gravel transported under high energy conditions by the Mae Nam Ping, down-faulting occurs in this area. The geology of the area affects the hydrology of the area and water use for the people living in Chiang Mai. The central alluvial channel, where Chiang Mai is located, is the area of highest groundwater exploitation potential in the basin. However, this aquifer is highly vulnerable to groundwater pollution, due to the lack of a continuous cover of clayey/silty sediments (Margane & Tatong, 1999).

Figure 4 Geological map of Chiang Mai



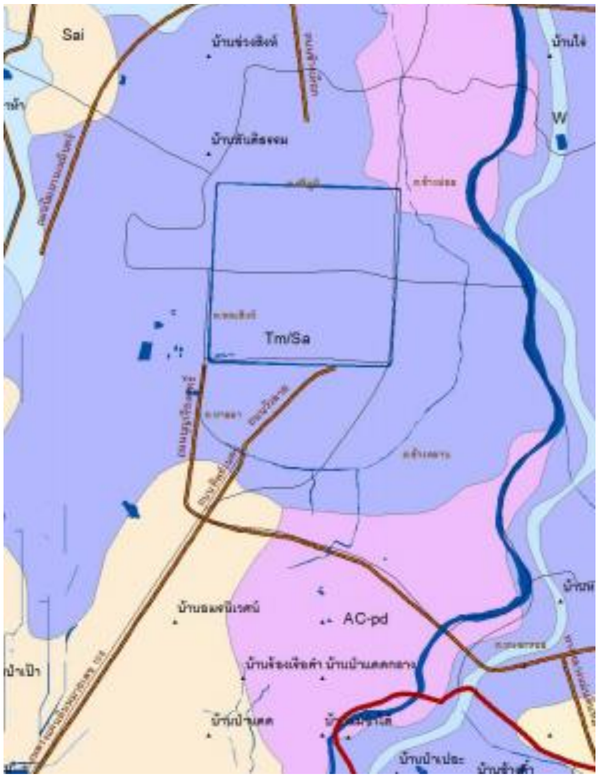
Source: Margane & Tatong, 1999

In 1999, water levels in the shallow part of the aquifer system in most areas were relatively uniform and variations generally stayed within the natural annual water level fluctuation of 1 - 3m (Margane & Tatong). The lowering of the water table in many areas didn't reach more than 2 m/a year especially in areas with low permeability such as colluvial deposits and high terrace deposits zones. Overexploitation is more probable to occur in places such as agricultural areas which rely heavily on groundwater, as well as in areas of low permeability such as the City. The area of the Chiang Mai basin around the Mae Kha was considered to have a medium level of groundwater vulnerability due to the effectiveness of the unsaturated zone. The area East of the city is considered to have high vulnerability (Margane & Tatong, 1999). However, no recent papers were found on the subject and Margane & Tatong comment on the lack of monitoring and availability of data at the time the paper was written in 1999.

Soil

Surface soil type also affects the permeability of the area. Soil maps of Chiang Mai (Figure 5) showed that the soil types *Tm/Sa* and *AC-pd* dominate the area. The areas Northeast and Southeast of the canal also include *Kt* and *Hd* soil types respectively. The soil classification used in Thailand describes the characteristics of these soils as follows:

Figure 5 soil map of Chiang Mai



Source: adapted from LLD, n.d., to fit the research area

Tm/Sa **– Tha Muang and Nat Sapphaya**

The soil types prevalent in and around Chiang Mai center is a mix of Tha Muang and Nat Sapphaya shown on the map in blue.

Tha Muang consists of coarse-loamy, mixed, active, calcareous, typic ustifluvents, with gently undulating terrain and 2% slope. This soil is well drained and has fast permeability with slow surface run off.

Nat Sapphaya consists of fine-loamy, mixed, active, nonacid, isohyperthermic aquic ustifluvents, with level to nearly level terrain, and 0-1% slope. This soil has passable drainage and is moderately permeable, providing a slow runoff for surface water.

Kt **– Korat**

Korat soil type is found west of the city and in the upstream areas of the Mae Kha , indicated in the map in light blue. It is characterized by fine-loamy, siliceous, isohyperthermic (oxyaquic) kandiustults, with gently undulating to undulating terrain, and 2-6% slope. The soil is of washed deposit from sandstone origin and has passable drainage and moderate permeability with fast surface run-off.

Sa **– Sai Ngam**

Sai Ngam soil is found northwest and southwest of the city, indicated in the map with cream color. It is characterized by coarse-loamy, mixed, semiactive, isohyperthermic utic haplustalfs. It is found on gently undulating terrain with a 2-3% slope. The soil is of alluvial origin, and offers good drainage, fast permeability and slow surface run-off.

Hd **– Hang**

Hang soil is found south of the city in the area where the local waste water treatment plant is located. It is characterized by fine, mixed, semiactive, isohyperthermic typic endoaqualfs., with nearly level terrain and 1% slope. The soil is of alluvium origin and has bad drainage, slow permeability and slow runoff.

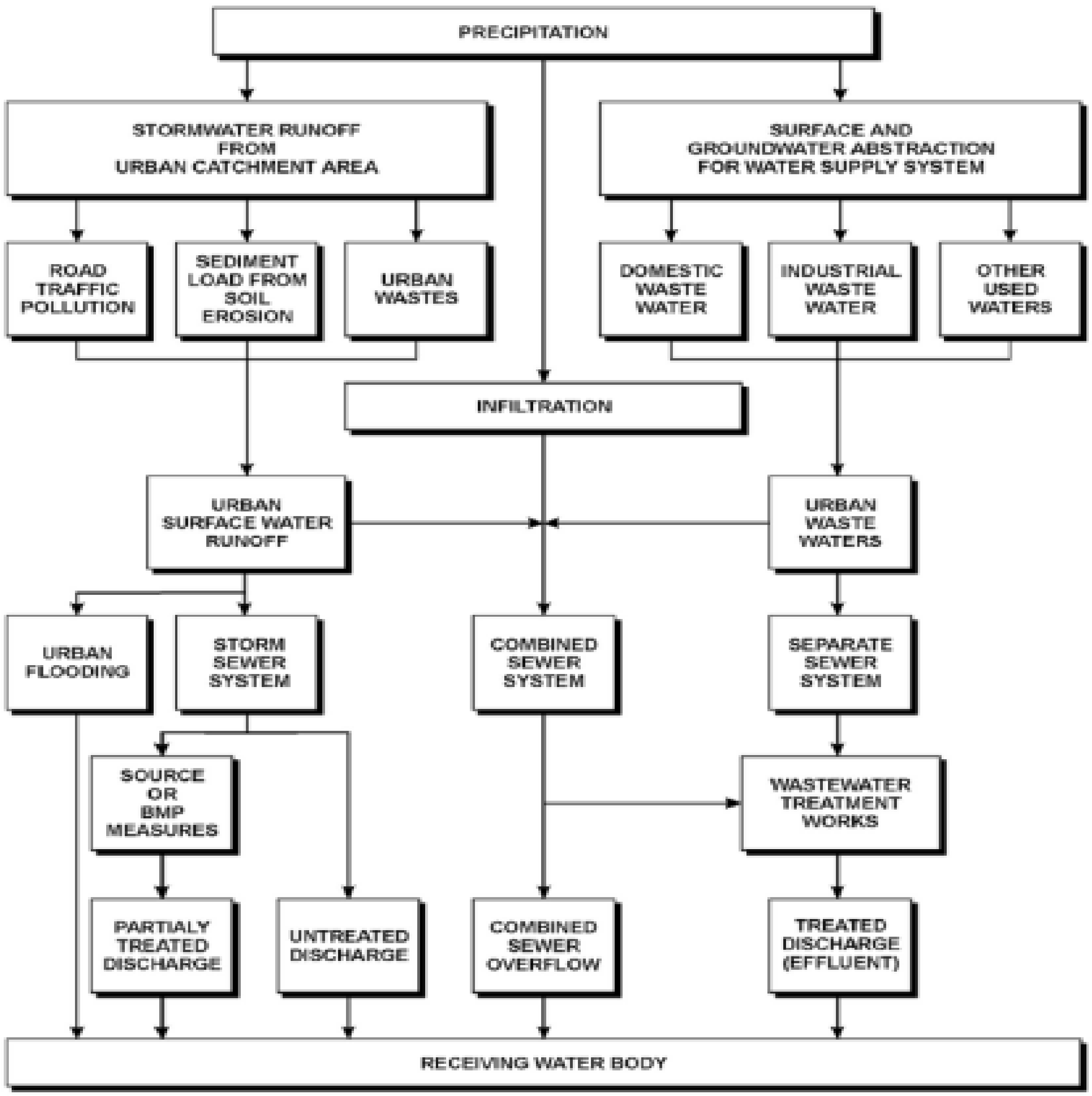
AC-pd **– unknown**

AC-pd is found near the North and South of Chiang Mai where the Mae Kha flows in and out of the city, indicated in the map in purple. Unfortunately this soil type could not be identified even after the land department was contacted.

Urban Streams

Urbanization can be defined as "the developments of habitats and associated infrastructure facilities required for economic and social activities necessary for livelihood of growing human population" (Hager, et al., 2013). This process results in many watershed alterations that influence the physical, chemical, and biological characteristics of a stream (Wenger et al., 2009). Urbanization is an increasingly important element in understanding hydrology, especially in relation to pollutant fluxes (Paul and Meyer, 2001). The generally negative impact that urbanization has had on water quality has earned it much attention from government policy and community organizations in pursuit of clean water (Hager, et al., 2013).

Figure 6 Movement of water in an urban environment



Source: Technical Documents in Hydrology, No. 50, UNESCO in UNESCO, 2004 in Walsh, 2005

Streams are valuable ecosystem elements that serve as habitats for a potentially diverse and productive biota. Streams transport and carry of water and processors of the materials in that water including primary productivity and leaf litter breakdown. As such, provides basal resources for lotic food webs, yielding fishable protein. This in turn leads to community respiration which transforms organic matter into CO_2 an essential service for streams receiving effluent from wastewater treatment plants. These processes, also contribute to the removal of water-column nutrients from point and non-point sources which can improve water quality in rivers, downstream reservoirs and estuaries. These services are essential for a human society that depends upon its rivers to provide water for municipal, industrial, and agricultural uses, to serve as waste-water disposal sites, and to provide aesthetic and recreational opportunities for its citizens (Meyer, 2005) As such, it comes as no surprise that streams have historically been important social and cultural foci for the human inhabitants of their catchments (Walsh, 2005). Processes of urbanization generally result in substantial alterations of surface and subsurface hydrology of local catchments by the introduction of vast impervious areas, efficient hydraulic conveyance systems, and the supply of large volumes of piped water (Figure 6).

Base flow is water that percolates into the groundwater supply before reaching the stream gradually, sustaining stream flow during rainless periods (Wenger et al., 2009). Runoff occurs when rainfall intensity exceeds the infiltration capacity of the soil. Runoff thus increases as permeability decreases. Runoff processes are affected by vegetation clearing, soil compaction, ditching and draining, and impervious surfaces such as roofs, roads and parking lots. Urban waterways have a low subsurface flow and are often only replenished by *storm runoff* or *direct runoff* (Wenger et al., 2009). Increased imperviousness also reduces the fraction of water that can be filtered through soil and plants. The effects of storm drains on base flow is sometimes counteracted by leakage of water supply or sewerage infrastructure, in cities importing water from outside the catchment or operating impoundments (Walsh, et al. 2005).

In another effect, an increase in the percentage of precipitation that leaves the watershed as runoff also decreases the amount of precipitation that evaporates locally. For example, in a forested watershed, 40% of annual precipitation might be exported as runoff, whereas 70% or 80% might be exported as runoff in a watershed where 70% of surfaces are impervious (Carey *et al*. 2010 in Hager, et al., 2013). The balance of these figures is returned to the local atmosphere through evaporation and vegetative transpiration.

Urban stream syndrome

The term *urban stream syndrome* describes the commonly observed ecological degradation of streams draining from urban land. In a review of existing literature on the subject, Walsh et al., (2005) listed a number of common symptoms consistently experienced by urban streams (Table 1), including: a flashier hydrograph, elevated concentrations of nutrients and contaminants, altered channel morphology and stability, and reduced biotic richness, with increased dominance of tolerant species (Paul and Meyer 2001, Meyer et al. 2005). Other symptoms which are also often (but not always) observed include a reduced base flow, increased suspended solids, longer duration of extreme flow magnitude, increases in the frequency with which sediment-transporting and habitat disturbing flows move down the channel network (Booth & Blesdoe, 2009), and two- or three-fold increases in peak-flow for moderate-sized floods in moderately urbanized watersheds.

Impervious cover is generally used as an indicator of urban intensity and, in the absence of deliberate management imperviousness is highly correlated with stream degradation (Booth and Jackson 1997). While the quality of streams with low total imperviousness can vary widely, from minimally altered to degraded, as the total imperviousness increases the best attainable condition declines until only degraded streams are observed (Wenger et al., 2009). This was observed to follow a stepped threshold relationship, where good stream ecological condition occurs up to a particular level of total imperviousness, often cited as 10% and beyond which degradation is highly likely (Walsh et al. 2005). However, the shape of the relationship between an ecological metric and a source of environmental stress may depend on the sensitivity of the response variable, the mode of action of a stressor, or possibly the number and interactions of stressors. Walsh et al. (2005) observed that this stepped-threshold relationship may be a function of how urban areas are developed, with widespread piped drainage networks only being universal beyond a certain level of development, and correlated a threshold level of drainage rather than total imperviousness.

Symptoms of the urban stream syndrome that appear to be globally applicable are predominantly driven by urban storm water runoff. This has been observable as flood control is managed in almost all urban areas through direct piped connections between impervious surfaces and streams. This is particularly true for *floodplains*, which are part of a stream's "high-flow channel" and are prone to seasonal inundations. Urbanization often expands into floodplain areas with modifications of the waterways to avoid local flooding. Such modifications almost always have significant downstream consequences, including flooding and erosion (Wenger et al., 2009). Gutters, drains, and storm sewers are installed in the urbanized area to convey runoff rapidly to stream channels. Natural channels are commonly straightened, deepened, or lined with concrete to make them hydraulically smoother. Each of these changes increases the hydraulic efficiency of the channel, so that it transmits the flood wave downstream more quickly and with less storage in the channel and its banks. Higher downstream flood peaks typically result with frequent overbank flooding. Frequent, small high-flow events in conventionally drained urban catchments may be more important causes of channel incision and resultant ecological impacts than infrequent, larger events (Walsh et al, 2005).

Upstream developments which decrease sediment yields and increase runoff such as land clearing, increased impervious surfaces or other soil disturbances can result in an increase in erosion and sediment delivery downstream (Booth & Blesdoe, 2009). This in turn makes canals susceptible to widening during storm events (Booth & Blesdoe, 2009). The effects of urbanization differ when it occurs on land previously used for agriculture (Wenger et al., 2005). In the US, where land use changed in stages from forest to agriculture to urban development, this resulted in increased sediment loads and channel narrowing or shallowing. Small natural streams which typically have relatively low levels of both dissolved and particulate constituents might be more vulnerable to such processes (Booth & Blesdoe, 2009).

Table 1 Symptoms of urban stream syndrome

Feature	Consistent response	Inconsistent response	Limited research
Hydrology	↑ Frequency of overland flow ↑ Frequency of erosive flow ↑ Magnitude of high flow ↓ Lag time to peak flow ↑ Rise and fall of storm hydrograph	Baseflow magnitude	
Water chemistry	↑ Nutrients (N, P) ↑ Toxicants ↑ Temperature	Suspended sediments	
Channel morphology	↑ Channel width ↑ Pool depth ↑ Scour ↓ Channel complexity	Sedimentation	
Organic matter	↓ Retention	Standing stock/inputs	
Fishes	↓ Sensitive fishes	Tolerant fishes Fish abundance/biomass	
Invertebrates	↑ Tolerant invertebrates ↓ Sensitive invertebrates		Secondary production
Algae	↑ Eutrophic diatoms ↓ Oligotrophic diatoms	Algal biomass	
Ecosystem processes	↓ Nutrient uptake	Leaf breakdown	Net ecosystem metabolism Nutrient retention P:R ratio

Source: Walsh et al., 2005

Solutions

The degradation of urban streams is often considered to decrease the quality of life in the surrounding area. Therefore, much of the research on the topic has been in the direction of ameliorating as well as understanding the issue. A short review on the performance of various restoration measures improving the quality of urban streams is shown in Table 2.

Table 2 Impacts of different restoration measures on selected parameters of stream quality

Restoration measure	Aesthetics/ amenity	Channel stability	Enhanced N processing	Improved ecological condition	
				Riparian	Instream
1. Riparian revegetation	S			S	
2. Instream habitat enhancement	S	S	S		
3. End of pipe stormwater treatment	*?		*		
4. Eliminate allied stressors	*?		*?		
5. Dispersed stormwater treatment		*	**		
3 + 4	*?		*		
5 + 4	*?	*	**		*
5 + 4 + 2	*	*	***		**
5 + 4 + 2 + 1	*	*	***	*	***

Source: Walsh et al., 2005; Allied stressors include sanitary sewer overflows or leaks and point source or long-lived pollutants from earlier land uses (e.g., Miltner et al. 2004). Dispersed storm water treatment is assumed to be extensive enough to reduce frequency of runoff from the catchment to near the pre-urban state (Walsh et al. 2005). The likelihood and magnitude of success are indicated by symbols: S - some improvement likely but long-term sustainability unlikely, *? - improvement likely in some cases, *, **, *** - likely improvement of increasing magnitude.

The complexity of interactions between multiple related urban stressors and various components of stream ecosystems results from relatively few common interrelated impacts that arise from the way urban areas are built and managed (Annex 2), and has significant consequences on the catchment scale (Walsh et al. 2005). While issues of sewage and industrial effluents also negatively impact water quality, especially when they are poorly managed, controlling such impairment without addressing storm water impacts is unlikely to ameliorate the problems (Walsh, et al. 2005), especially if the goal is to maintain or return biodiversity flows and habitat dynamics to within some range of their natural variability. In other words, manipulating individual in-stream elements is unlikely to be self-sustaining unless large-scale catchment processes are also addressed with at-source approaches to treatment (Booth & Blesdoe 2009; Walsh et al. 2005).

Attempting to cure the urban stream syndrome has been a process of hit and miss. Some treatment systems which have proven inefficient include: 1) in-channel mitigation and treatment without addressing the source of the problem, 2) one-size-fits-all practices based on “single-factor” ecology or extrapolation across all stream types, and 3) piecemeal, reactionary interventions which do not involve intensive stakeholder participation ad lack clearly defined goals.

On the contrary, interventions which are protective of stream health minimize changes in the magnitude, frequency, duration, and variability of stream-flows. This means to store, infiltrate, evaporate, or otherwise slowly release storm-water runoff at rates similar to that of the pre-development hydrologic regime. However, site-scale runoff management, natural geomorphic processes of sediment delivery and canal change are incompatible with most urban land uses. Therefore, rehabilitation expectations need to be realistic. Re-stabilized channels will typically be larger and less geomorphically complex than pre-urbanization channel forms, and altered habitat and flow patterns, water velocities, sediment flux, and organic inputs (Booth & Bledsoe, 2009), may carry an ecological legacy of extirpations that precludes the return of pre-disturbance biota (Booth & Blesdoe, 2009). Biological communities in rehabilitated urban streams may be diverse and complex, but they will depart significantly from pre-development conditions.

A multi-faceted approach is more likely to achieve positive results with various activities that can contribute to stream health. Adding coarse woody debris, constructing in-channel gravel beds, and widening vegetative buffer zones and tree cover can result in increased nutrient retention (Booth & Blesdoe, 2009). Vegetated landscapes designed to absorb water – such as green roofs, and rain gardens – can contribute to the reduction of both the amount of urban storm water runoff and its associated pollution load (Pataki, 2011). Green roofs may also delay the timing of peak runoff, alleviating stress on storm-sewer systems. Similarly, rain gardens and bio-retention filters can reduce the volume of surface runoff. However, it is difficult to demonstrate conclusively that these features lead to improvements in water quality (Pataki et al., 2011). Community-led local actions such as riparian fencing and planting, water-chemistry source control, fish-passage projects, and certain in-stream structures, can improve the condition of urban streams in the short term but are unlikely to produce permanent effects, as they do not incorporate the reestablishment of self-sustaining watershed processes.

Small-scale community-driven projects have also produced anecdotal evidence of critical links between ecological and socio-ecological revitalization. Efforts such as the conversion of vacant lots to parks, planting of street trees, stream cleanings, and community gardens appear to create social cohesion, increase access to municipal services, and create positive feedbacks for ecological, physical, social, and economic improvements. Understanding the mechanistic nature of these links could have important implications for urban management and sustainability (Hager, 2013). Research on urban stream ecology needs to integrate social, behavioral, and economic research (Pickett et al., 2009; Meyer et al. 2005). The success of any attempt to improve the ecological condition of urban streams will largely depend on human attitudes and behaviors within the catchments (Booth & Blesdoe 2000).

Many research gaps remain, such as analyzing the impacts various government policies, cultural norms, and biogeoclimatic conditions on the urban stream syndrome. Future success in stream rehabilitation must include a systematic monitoring system to assess the pre- and post-urban processes and conditions. Monitoring is essential for understanding the extent to which integrated management can maintain ecosystems that closely resemble pre-impact structure and function rather than creating new types of regional stream ecosystems (Downes, 2002). In the US, studies in environmental justice have gone a long way by producing a large data base of empirical data on systematic issues related to social and environmental injustice, and such endeavors can contribute to this goal from the bottom up.

Theoretical Framework of Environmental Justice

Environmental justice (EJ) emerged as a normative concept and a social movement in the United States during the 1970s. It was initially defined as the study of spatial distribution of environmental ills amongst different groups of people (differed by class, race or ethnicity) (Ernstson, 2013). More recently, the framework has expanded to include issues of power that are paramount to the interpretation of different forms of inequality, especially issues of recognition and participation (Cook & Swyngedouw, 2012). Schlosberg (2003; 2010; 2013), in particular, has pushed for a capability approach to studying issues of environmental justice.

EJ tackles issues of both environmental quality and social justice in an integrative manner. Its largest contributions have been in the US, where EJ studies have revealed national patterns where race and class were the most significant variables associated with the location of environmental hazards including commercial hazardous waste facilities, hazardous waste disposal sites, various types of incinerators, polluted water, toxic releases from industry, lead poisoning, and other types of environmental dangers (Schlosberg, 2003). In addition, studies have shown that government agencies such as the EPA enforce environmental laws in poor chumchon and chumchon of color less stringently than in wealthy white chumchon (Schlosberg, 2003). As Bullard observed: "[T]he unifying insight of environmental justice recognizes that neither the costs of pollution nor the benefits of environmental protection are evenly distributed throughout [the American] society" (1994 in Schlosberg, 2003). Recently, EJ has gained popularity outside of the US where similar situations abound (Walker, 2012; Ako, 2013).

Environmental Justice, like urban ecology, has contributed to a reassessment of the term "environment" to include urban areas, breaking the urban-nature boundary (Schlosberg, 2013; Bohemen, 2012). Similarly, EJ has also called for a reevaluation of the concept of justice. Political theory has generally treated justice as a question of equity in the distribution of social goods centered on socioeconomic factors, and rooted in the economic structure of society (Schlosberg, 2003). Schlosberg (2013) urges scholars and activists to move beyond equity of distribution and to consider justice in include a broader vision of capabilities, including recognition and participation, among others.

The capabilities approach

The basic argument for a capabilities approach to questions of environmental justice is the assumption that many human capabilities are dependent on the natural environment. It follows that certain environmental entitlements should be treated as a matter of basic justice (Holland, 2008). The capabilities approach and EJ share a normative perspective of development, which focuses on human functioning flourishing and finds injustice in the forces that limit this potential (Schlosberg and Carruthers, 2010).

With the capabilities approach, Amartya Sen and Martha Nussbaum introduced a "theory of justice that focuses on the capacities necessary for people to function fully in the lives they choose for themselves. Their central argument is that we should evaluate the justice of arrangements not simply in distributive terms, but more particularly in how those distributions affect the ultimate wellbeing and functioning of people's lives" (Schlosberg and Carruthers, 2010, p15). Nussbaum discusses capabilities as "the conditions or states of enablement that make it possible for people to achieve things; capabilities are people's real opportunities to achieve outcomes they value" (Holland, 2008). Environmental injustice diminishes these abilities to function fully, through poor health, destruction of economic and cultural livelihoods, general environmental threats and political exclusion (Schlosberg, 2013).

The specific approaches of Nussbaum and Sen differ from each other somewhat, in the extent to which these capabilities are considered as fixed and universal. Nussbaum has defined a list of fundamental capabilities, to which Holland (2008) argues environmental services should be added. On the other hand, Sen views capabilities as something that needs to be defined on the ground (Schlosberg and Carruthers 2010), an approach which is followed by Schlosberg and this thesis. However, both Nussbaum and Sen share a purely equity-based notion of justice, and remain squarely liberal, focusing on the freedom and functioning of individuals. Schlosberg (2010; 2013) deviates from these guidelines, arguing for a community-based application of the capability approach to issues of EJ. He argues that "In practice, environmental injustice is not simply an individual experience; it is embedded in community" (Schlosberg and Carruthers, 2010, p18). In his study on the application of this framework for indigenous chumchon in Arizona and Chile, "the collective experience of injustice – the impact on the abilities of chumchon to function and renew themselves – is absolutely crucial".

The capabilities approach thus urges us to begin by looking at how internal and external conditions shape the capabilities of different groups in order to assess what justice is and what it requires (Holland, 2008). This study applied EJ theory by looking at various elements of capabilities including the unequal distribution of impacts and responsibilities and the social and spatial dimensions that are implicated within these. Secondly, issues of recognition were addressed by answering the following questions: Who is identified as important to be included in the decision making process? Between which groups of stakeholders is there contact? Who is perceived to be *polluters* of the canal? Next, possibilities for participation in the decision making procedure were explored in terms of the roles assigned to various stakeholder groups. Lastly, capabilities were investigated including which were viewed as essential to having power to change the canal, and what opportunity there was to participate in the actions that are viewed as central to solving the pollution issues of the canal (Walker, 2010).

> *"[T]hese four dimensions of justice cannot be conceived of* or *actualized in isolation. The justice of capabilities necessitates a political focus on distributional justice: healthy chumchon require some form of redistribution of environmental bads and goods. In order to achieve distributional justice and the justice of capabilities, procedural justice and recognitional justice are necessary."* – Cook & Swyngedouw, 2012

Distributional Justice

"For the most part, the concept [of environmental justice] has been used to illustrate the fact that low income chumchon and chumchon of color face more environmental risks than more well-off or white chumchon; this is linked, of course, to the other injustices in economic and social conditions disempowered chumchon face" (Schlosberg, 2009). EJ has thus served to show how the distribution of environmental risks mirrors the inequity in socioeconomic and cultural status. However, the goal of EJ is not limited to merely showing this unequal distribution but also to explore why certain groups are exposed to these risks (Schlosberg, 2013). "[T]he ways in which environmental inequalities are understood, the nature of the socio-environmental relations that are at issue and the evidence that is used to give credence to claims of injustice gives importance to the spaces of different social and environmental categories and to different notions of space itself" (Walker, 2010).

Space is not a neutral term, it is itself constructed by and through social practices. A distinction can be made between geographical space and social space, which defines the different socio-ecological circumstances in which experiences take place, and where issues concerning race and class often fall. These forms of space affect the experiences of environmental risk as well as capabilities to deal with them (Walker, 2010). Questions of distributional justice are not limited to the distribution of the impact of pollution but also the distribution of responsibility for the pollution between different groups. Moreover, EJ aims to answer such questions as: Does pollution take place as the result of an informed decision? What were the factors involved in the choice made? Are the consequences of these actions experienced by the same people responsible for the decisions? Is there a dislocation between the allocation of benefits and disadvantages coming from these activities? Are the disadvantaged groups in a position to impact this distribution and is their suffering recognized by those making these decisions? (Walker, 2010)

Recognition

Recognition addresses the claim of chumchon to the right to be recognized as a legitimate part of the city. The recognition of chumchon as being unfairly affected by environmental degradation has been one of the main goals of many EJ movements. Acknowledgement by mainstream environmental groups and governments is essential to progress towards righting injustices (Schlosberg, 2003). "Where social group differences exist and some groups are privileged while others are oppressed, social justice requires explicitly acknowledging and attending to those group differences in order to undermine oppression" (Young 2011).

The basic thesis of the politics of recognition has been laid out by Honneth as a key link between recognition from others and personal human dignity. "The language of everyday life is still invested with a knowledge – which we take for granted – that we owe our integrity, in a subliminal way, to the receipt of approval or recognition from other persons" (Honneth, 1995 in Schlosberg, 2003). This can be discussed in the context of a *distributional sphere* in which the definition of pollution itself is the result of social meanings which are formed by procedures, and principles which are rooted in the local context, and thus differ between groups and areas and are susceptible to change over time (Schlosberg, 2003).

Mis- or mal-recognition is a cultural and institutional form of injustice, demonstrated by various forms of insults, degradation, and devaluation at both the individual and cultural level. Such actions "impair these [actors] in their positive understanding of self – an understanding acquired by inter-subjective means" (Taylor, 1994 in Schlosberg, 2013). Place stigmatization, it is argued, can result from the siting of stigmatized technologies, such that positive senses of place are threatened and replaced with associations of danger, threat and degradation (Walker, 2010). But devaluing of, for example, gender, ethnic or racial groups, are not always experienced in distinct spatial spheres, and as such there can be various experiences tied to a single location (Walker, 2010).

Participation

Honneth (1995) and Young (1990) indicate the importance of participation in decision-making processes, addressing justice both as distribution and as the recognition of difference. Young (1990) imagines "democratic decision-making procedures as an element and condition for social justice". Honneth (1995) elaborates that there is a direct link between a lack of respect and recognition and a decline in a person's membership and participation in the greater community, including their right to participate in the institutional order.

The lack of participation in environmental decision making comes, in large part, from limitations imposed on the basis of race, class and gender. The existing range in such structural obstacles includes limitations in access to political, legal, scientific, and other resources needed to fully participate in environmental decision making. These phenomena are products of an institutionalized pattern of disrespect and disesteem that frame everyday interaction.

Indeed, the theoretical importance of participation has been confirmed by the repeated demands from local EJ movements for structural changes in the processes behind environmental policy. The type of change sought goes beyond delegating powers to actors from the mainstream environmental groups or government agencies which recognize the issues and defend community interests. EJ chumchon desire to be consulted from the start, speak for themselves, work with a variety of other groups and agencies, and be offered a full partnership in the making of decisions and ongoing oversight of environmental risk (Schlosberg, 2013). Such forms of inclusion ensure that the level of recognition and procedural justice accomplished are not short-lived, or dependent on single actors.

"There is a sense in which a call or demand for more democracy, openness and inclusion processes of decision-making is about enabling access to spaces, and flows between spaces, that have previously been restricted. In this way a lack of procedural justice is intimately wrapped up with a closed geography of information, access and power and procedural fairness with a fluidity of movement of people, ideas, and perspectives across the boundaries of institutions and between differentiated elites and lay spaces, creating open rather than constrained networks of interaction and deliberation" (Walker, 2010).

Environment

The struggles for environmental justice are "embedded in the larger struggle against oppression and dehumanization that exists in the larger society" (Bullard, 1994 in Schlosberg, 2003). Beyond this, what is meant by the 'justice' in environmental justice encompasses not only equity, recognition, and participation, but more broadly, the basic needs and functioning of individuals and chumchon (Schlosberg, 2013). To the extent that identities are constructed in place, whenever the biophysical conditions of that place is threatened, undermined, or radically transformed, these changes will also affect the identity and personal integrity of the people who identify with it (Schlosberg, 2003). EJ highlights how people are immersed in the environment, in particular through the manipulation of nature. The sources of environmental injustices are connected to exploitative relations with the environment and through these a disregard and abuse of the people whose wellbeing and capabilities are dependent to this natural environment (Schlosberg, 2013).

Natural metabolisms and transformations become discursively, politically and economically mobilized and socially appropriated to produce environments that embody and reflect positions of social power (Swyngedouw and Heynen, 2003). This begs the recognition of the discourses that are being carried through nonhumans, and the ways in which these are already inserted in the decision making discourse (Holifield, 2010). Such recognition would require a bridging of the artificial divide between basic human needs and environmental protection.

Including the environment in the capabilities approach translates to an already inherent recognition of environmental services to EJ (Schlosberg, 2013). To be effective this would require attention to the functioning of environmental systems, in addition to the social systems which depend on these ecosystems. The interruption, corruption, or defiling of the potential functioning of ecological support systems is an injustice not only to human beings, but also to all non-humans that depend on the integrity of the system for their own functioning. The treatment or abuse of human and non-human individuals and systems is based on the same loss of the ability to function that is central to all studies applying a capability approach (Schlosberg, 2013).

Weakness

The most important criticism raised against environmental justice studies comes from the more critical branches of social sciences such as Marxist urban political ecology, which tends to take a more global perspective and in which contemporary environmental inequalities are described as the results of neoliberal forms of capitalist development and class hegemony (Holifield, 2010). These schools of thought have criticized the empiricist orientation of EJ for its lack of depth, especially in regard to the use of theory (Holifield, 2010). Swyngedouw and Heynen argue that EJ "has tended to operate in terms of a liberal and hence, [with a] distributional perspective on injustice, [avoids] radical critiques addressing hegemony of neoliberal capitalism in the organization of human-nature relationships" (Holifield, 2010). While the capabilities approach used adds a more theoretical depth to EJ, the study does indeed maintain a very local perspective and fails to tackle in depth many of the global or even national scale processes involved.

A second point of criticism has been the close relationship between research and activism that is often considered blind to power inequalities within these groups, and the possible negative impacts of the movement towards others (Cook & Swyngedouw, 2012). While a bias was introduced in this approach by initiating contact with local NGOs and by using the community perspective for the initial introduction to the issues, the perspectives of businesses and government officials are represented at a similar number within the study (Walker & Bulkeley, 2006).

In summary, the applied framework of environmental justice uses a capabilities approach to consider the relations between low income chumchon living along the Mae Kha canal and the pollution of the canal by looking at the conditions or states of enablement that make it possible for these chumchon to achieve an improvement of the environment in which they live. To do this, the research looks at the distribution of pollution and related disamenities, recognition of the issue and the chumchon themselves by different stakeholder groups involved in the management of the canal, access to participation in the decision making process for the management of the canal, and the perceived solutions to the issues and perceived opportunities to participate in these solutions.

Definitions

Before proceeding it is necessary to describe how key terms were operationalized in the research design. Such terms include, first, the names of stakeholder groups: *chumchon*, businesses, government institutions, and not-for-profit (NFP) organizations, and second, the main types of capabilities discussed within the environmental justice framework: distribution, recognition, and participation.

Chumchon

Chumchon is a Thai term that refers to a community or group of households, which often meet the definition of a slum. UN-HABITAT (2010) defines slums as household units consisting of one or a group of individuals living under the same roof in an urban area, deprived of one or more of the following amenities:

1. Durable housing: a permanent structure providing protection from extreme climatic conditions
2. Sufficient living area: no more than three people sharing a room[5]
3. Access to improved water: an amount of water that is sufficient, affordable and that can be obtained without extreme effort
4. Access to improved sanitation facilities: private or public toilet shared with a reasonable number of people
5. Secure tenure: *de facto* or *de jure* secure tenure status and protection against forced eviction

The definition of chumchon in this study was taken to include those considered as such by local NFPs and government institutes (GIs). Of these, only one (Sii Ping Muang) appears not to fit the UN-HABITAT definition of slums, as a result recent improvements in conditions due to local development projects over

[5] *It is possible that many inner city tenements defined as slums according to UN-HABITAT, due to the 'sufficient living area' criterion, would not be regarded as chumchon under Thailand's national definitions. (UN-Habitat, 2010)*

the last 20 years. We refrain from using the term "slum" in the paper as many households and some chumchon as a whole have gone to great strains to upgrade their facilities and do not themselves consider their living standards as inadequate, as the term slum implies. Thus, the term chumchon avoids the stigmatization that often comes with the title of "slum". In fact, in Thai these communities active in upgrading activities and satisfied with their living conditions are referred to as chumchon, while more degraded communities (such as those made out of waste material) are referred to as *eslam*.

Businesses

The group of businesses was defined broadly to include all scales of for-profit establishments, including small and informal businesses, market stalls, garages, laundries, restaurants, hotels of various sizes, hospitals, and universities, as well as the municipally run slaughter house.

Government Institutions

In general, government institutions (GIs) include all agencies under the organizational structure of the government, with the exception of CODI which is an autonomous GI. CODI was included at a NFP because it functions as such, and despite relying entirely on government funding it operates independently of government level politics.

Not-for-profits

Not-for-profits (NFPs) include a variety of organizations which represent the civil society organized around the canal. In general, two types of NFPs were identified: those organized around environmental issues and those organized around social issues related to chumchon. One exception was Hok Kan Ga, an organization representing business interests in the area.

Distribution

The justice of distribution is designed to include the presence and experience of environmental risk, with an allowance for these to be defined in each individual interview. Thus, interviewees were asked to define the problems they experienced with the canal. From these interviews, an initial list was compiled which included flooding, health risks and water pollution, among others. To this end, water quality was investigated in terms of list of important parameters (discussed below) to analyze the differences in water quality throughout the city.

Recognition

The assessment of recognition considered both the recognition of actors involved with the canal as having the right to participate in its management, and the recognition of the canal itself as a valuable element of the city. The first type was measured by asking which actors are involved in the management of the canal, and which actors *should be* involved in the management of the canal. Recognition of the canal was measured by asking what is good about the canal, and then specifically if the canal had economic, social, historical or cultural/spiritual value to the interviewee.

Participation

Participation was defined broadly to include both the process by which the canal is formally managed by through GIs, and also the way it is managed informally by different actors, including activities directed towards changing the state of the canal either by policy or direct action. To measure this, interviewees were asked to identify the actors related to the Mae Kha, and then to describe their role. Further, power sources that interviewees believed to affect their own participation level were measured by analyzing interviews and identifying which actors were mentioned as powerful and why, as well as by factors that defined the power relations between interviewees and other actors. A second level of participation was defined in terms of solutions, or activities that were mentioned as crucial to improving the canal as described by each interviewee. Access to this type of participation was then explored by asking interviewees who *should be* involved in achieving these solutions, how, and what their own role should be.

Methodology

This research applies a mixed methods approach to bridge the gap between the water quality and stakeholder analyses as the main aspects in the environmental justice framework. The methods applied will first deal with the stakeholder analysis, as this forms the foundation for the water quality study including the choice of sampling sites. Each section discusses methods for data gathering, processing and analysis.

Stakeholder Analysis

The term stakeholder is used to refer to actors that contribute to a policy problem, are needed to solve the problem, or are affected by either the problem or problem-solving activities (Bryson, 2004).

A stakeholder analysis aims to understand a dynamic social system and the changes it experiences (Grimble & Wellard, 1997). This process involves three steps: i) identifying stakeholders ii) differentiating between and categorizing stakeholders, and iii) investigating relationships between stakeholders (Reed, 2009). The strength of the stakeholder method lies in its sensitivity to different perspectives in different sectors of society

Figure 7 Mapping of the Mae Kha

Identifying stakeholders:

A field survey of the urban trajectory of the Mae Kha canal was used to identify relevant actors, land uses and point sources of pollution located directly along the canal (Desai & Potter, 2006). The survey of the area took place during April 2013. Initially, the Mae Kha canal was mapped using satellite images from Google Earth. These images were ground-truthed and elaborated by walking along the route and annotating printed satellite photos of the area (Figure 7). These annotated maps were digitalized using Google Earth's GIS functionality, and shared with various NFPs involved in environmental justice issues around the canal. The focus on actors directly along the canal is based on the assumption that they will be the most affected by the quality of the canal.

Differentiating and categorizing stakeholders

From the field surveys, businesses and chumchon were identified as two broad groups of stakeholders located along the canal. A non-random, convenience sampling method was applied to select interviewees. This consisted of contacting mapped communities that were in contact with the local NFP Kon Jai Baan, and interviewing any willing community leader, creating an inherent bias in the study, but possibly towards those most concerned with the canal. These interviews were used to snowball contacts with other community leaders, GI and NFPs (Reed, 2009). Unfortunately, most communities did not have contact with businesses, so in order to contact businesses the researchers approached businesses which had been identified as perceived sources of pollution during interviews. There was a higher degree of non-response when contacting businesses than there was with other stake holder groups. One reason for this might be that these interviews were often walk-ins and the researchers had not been referred by a known contact. In the end a total of 11 communities, 11 businesses, 8 GIs, 5 NFPs, and 13 households were interviewed. The total number of stakeholders mentioned includes a much larger group of about 150 different stakeholders (Annex 1).

Investigating the relationships between stakeholders

Semi-structured interviews were held with stakeholders who were asked to first define the problems of the Mae Kha and name the stakeholders involved in the management of the canal. Second, interviewees were asked to define all stakeholders who were involved with the Mae Kha in any way. It was attempted to complement the oral interview by using *rich pictures*, which are intended to stimulate the imagination

(Flood 2010). A *rich picture* is a pictorial representation of the significant components and linkages of a system of interest (Bell & Morse, 2010). Two types of rich picture exercises were developed on the basis of the ideas of action research I Floods (2010) and Bell & Morse (2010), the first of which was a mapping exercise to identify stakeholders and their relations to each other and the canal, following these steps:

1. Write down on post-it notes all stakeholders involved with the Mae Kha in any way
2. Add to each stakeholder their relation with the Mae Kha in one sentence
3. Draw lines to connect various stakeholders with each other and describe the relationship
4. Finally, categorize each stakeholder was by level of influence on what happens to the Mae Kha canal using colors: red for highly influential, orange for mildly influential, yellow for little influential and blue for not influential
5. After completing the rich picture, review the image and allow interviewees to tweak the drawing.
6. Ask Interviewees if there are still any actors affected by the Mae Kha or affecting the Mae Kha which are not included in the drawing. If so, add and categorize them to complete the picture.

This method was complicated by the language barrier, and the interviewees often exhibited difficulty in understanding the task. In many cases the researcher drew the lines as they were explained by the interviewee. Nonetheless, the review of the *rich picture* was a valuable aspect of the interview as it allowed all the linkages to be reviewed and confirmed with interviewees, and any elements that had been left out to be added in the final steps.

Household survey

Interviews with community leaders gave an image of activities taking place on a community scale. However, this left a question of how individual households viewed the Mae Kha. To get a better understanding, chumchon Kampaeng Ngam was selected for a zoom-in[6] view, and several individual households were interviewed. Households were chosen through a non-random sample of convenience while walking around the community in May 2013. A total of 14 interviews were done in this community representing 10% of the population, which is the generally accepted standard for a non-random sample to be considered as representative of the total (van belle, 2011).

Semi-structured interviews were held with community members following the same themes as previous interviews, but with the second type of rich picture. The manner in which the rich picture was created in these interviews follows these steps:

1. Draw a picture of the Mae Kha, as you see it
2. Add to this picture sources of pollution, and actors involved with the Mae Kha
3. Draw a second picture of how you would like the Mae Kha to look
4. Add to this drawing the activities that are required to achieve this goal, and the roles of different stakeholders in achieving this goal
5. Review the drawing and make changes if necessary

(Bell & Morse, 2010)

As was the case with the stakeholder mapping exercise, this was not easy to implement. Most households were not willing to make drawings, claiming that they could not draw. Most drawings were ultimately made by the researcher by following the descriptions and directions of the interviewees. As was true for the first rich picture exercise, significant added value came from reviewing the drawing. This was easier with the drawing than with stakeholder networks, because there was no language barrier. Moreover, seeing the drawings, visualizations of a clean and vibrant Mae Kha, were deeply moving for some of the interviewees.

[6] This is discussed in more detail in the geographical framework.

Complications

In total 13 communities were contacted out of these two interviews could not be completed. The community leader from Raekgeng did not show up for the interview, and would no longer answer phone calls, and the interviewer fell sick during a session with a women's community leader from Tipanet, which was not possible to reschedule.

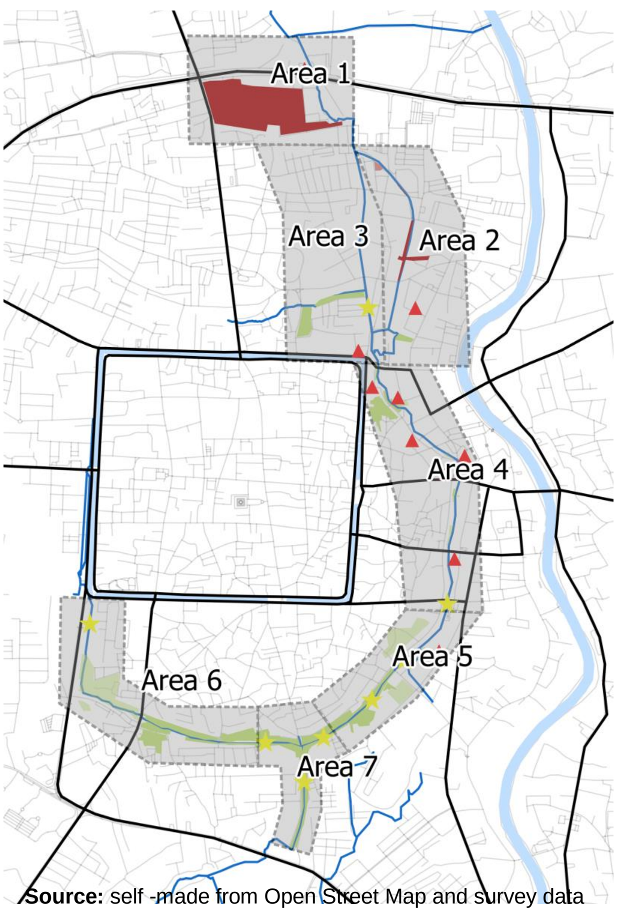
Some questions, including the 'use of the Mae Kha' were sensitive, and most stakeholders refused to mention using the canal. To get around this the question was rephrased to ask about the 'known uses of the Mae Kha', and interviewees were more willing to mention the canals uses in the context of past uses or other people's uses. These were included in the analysis as uses of the canal, under the assumption that past uses in particular could still add to the risks people experience due to their past contact with the canal.

Another problem faced was that many stakeholders were uncomfortable with implicating others of polluting the canal, especially those with whom they had a relationship. It was often necessary to mention specific actors and to ask if they thought they polluted or not, which unavoidably influenced the actors identified in response to this question.

A third issue encountered was that corruption and political power were often hinted at, but never openly discussed. Moreover, translators were not comfortable with asking further questions on this issue. Such mentions were often followed by a 'laughing it off', which made it hard to analyze these critical issues in the study.

Data Analysis

Figure 8 Study Area for Justice of Distribution



Source: self -made from Open Street Map and survey data

Most interviews were recorded and transcribed. Interviews which were not recorded were transcribed from detailed notes. Transcriptions were done using Mircrosoft Word or NVivo software and subsequently coded using Atlas-ti software. Coding followed the design indicated by Mckether et al. (2009) to use unstructured interviews for social network analysis. Interviews were coded for stakeholders and relations to facilitate the conversion to a network view using UCINET. Interviews were also coded for other themes, including: disadvantages, solutions, values of the canal, stakeholders important to the management of the canal, stakeholders responsible for polluting the canal and sources of power.

A list of values for each of these factors was formed from the answers given by stakeholders during the semi-structured interviews. For the distribution of environmental ills, areas and social groups were divided. Eight areas were delineated including: 1, up-stream, 2, side stream, 3water gate, 4, inner city, 5 Mae Kha chumchon area, 6, merge point and 7 Ku Wai stream (Figure 8). Some of these areas include only informal areas and some include only businesses. The Merge point, in particular represents only 1 interview with Fa Mai. These sections broadly correlate with those used for water sampling stations (2-9). Four social groups were identified: businesses, NFPs, GIs and chumchon.

Mentions of each response for each factor were totaled by group and normalized in order to compare the perspectives of different groups, and graphically represented using spider graphs.

Issues of distribution in particular required further substantiation for the environmental justice claims. The issues identified in interviews, including flooding, health risks and water pollution, were further investigated using a variety of methods. Flooding was investigated by consulting flood maps provided by the CENDRU research center at Chiang Mai University, as well as by mapping the distribution of water management infrastructure and assessing its influence on the distribution of flooding. Health issues could not be confirmed as the health departments claimed not to have any information on the issue. And water quality issues were researched in detail by performing water quality tests of various parameters in collaboration with the Chiang Mai University Environmental Sciences Department.

Water quality

The methods for the water quality analysis include the choice of sample sites, sampling dates, choice of parameters, collection techniques, testing methods and data analysis methods. These methods were used to assess the water quality of the Mae Kha canal, and to investigate the differences in water quality for different areas of the city.

Sample sites

10 sample sites where selected, 8 of which (sites 2 through 9) reflect the water quality in the Mae Kha canal in the urban center of Muang Chiang Mai, while sites 1 and 10 represent the water quality upstream and downstream of the urban area, respectively. Sites 7 and 8 are located within the Ku Wai urban stream which merges with the Mae Kha south of the city center. The Ku Wai stream receives a significant amount of its water from the Maharan wastewater treatment center which treats wastewater from the campus of Chiang Mai University. Sites 2 through 6 reflect the quality of the urban section of the Mae Kha canal itself. Site 9 measures the quality of the canal after the Mae Kha and Ku Wai streams have merged into one. The combined Mae Kha canal flows south and ultimately joins into the Ping River at site 10. A description of the land use around each of the sites is presented in Table 3.

Table 3 Characteristics of water sample sites

Site	Location	Stream	Land Use	Water sources
1	Upstream	Mae Kha	Agriculture	Agriculture and households
2	Un Ari	Mae Kha	Urban (Watergate) – Residential	Highway runoff, flushing station, chumchon, city drainage
3	Sri Don Chai road	Mae Kha	Urban - Tourism industry	Hotels, restaurants, other businesses, city drainage
4	Slaughter House	Mae Kha	Urban - Residential	Chumchon and slaughter house
5	Kampaeng Ngam	Mae Kha	Urban -Rresidential	Chumchon, downstream of slaughter house
6	Pre-merge Mae Kha	Mae Kha	Urban - Residential	City drainage, market drainage, chumchon
7	Ku Wai	Ku Wai	Urban - Residential	Chumchon, downstream of highway
8	Kanchanaphisek Park	Ku Wai	Urban - Green space	Moat discharge, CMU campus WWTP, road runoff
9	Fai Mai merge	Mae Kha	Urban - Residential	Chumchon
10	Downstream	Mae Kha	Suburban – Residential	Central WWTP, households, market

Sites 1, 9 and 10, are not located in the study site, they were included as reference on the water, prior to the city, as it exited the city, and at the entrance to the Ping River. These were not tested for TKN, Chloride and Oil and Grease levels as these parameters were chosen specifically for effluents tied to some of the land use in the urban area. The engineering department charged a fee for each of these tests, and as the research was entirely self-funded, the expenses were avoided.

Sample Dates

Water samples were collected during the different phases of the rainy season in Chiang Mai: at the start of the rainy season in July, mid-rainy season in September, and late rainy season in November (Table 4). This period represents what is expected to be the most drastic period of water quality change experienced in the urban area of Chiang Mai, ranging from almost pure wastewater at the end of the dry season, high levels of urban runoff during the intense rainy season. The start of the rainy season was expected to have the lowest quality of water with the lowest flows and wastewater accounting for a larger fraction of the total water in the canal. As indicated in Table 4, the samplings were planned to take place at regular 2 month intervals, however scheduling difficulties caused the dates to be adjusted. The second round of tests was postponed due to lack of equipment, and the third round of tests was postponed due to a combination of severe rain and the incidental flushing of the canal for the Loi Krathong lantern festival, which would severely affect the water quality and not accurately reflect the state of the canal during the late rainy season.

Table 4 Sampling dates

Early Rainy Season	Mid-Rainy Season	Late Rainy Season
4 July 2013	13 September 2013	27 November 2013

At each sampling date, varying temperatures and precipitation levels (Figure 2, p.10) were expected to have different impacts on the water quality as it was tested. The samples taken during the mid-rainy season were expected to have higher fractions of rain water and urban run-off. Despite the addition of relatively clean rainwater, the rainy season can also introduce other processes that degrade the overall water quality. The increased flow can result in more turbulence and soil erosion, releasing nutrients, heavy metals, microorganisms, and other constituents from the sediment and banks. Dredging of the canal to minimize flood risk may exacerbate these effects. Additionally, rain can lead to saturation of plants along the banks and in-stream, decreasing their efficiency in filtering water, and in some cases leading to plant death under conditions of flooding and high stream velocity. Lastly, rains contributing to urban runoff can carry a number of contaminants from urban surfaces into the canal, such as exhaust particulate depositions, food waste, discarded chemicals, and animal feces.

The Late rainy season is expected to have the best overall quality, as flows are decreased, base flow is replenished , and much of the previous contamination has been pushed downstream. This period can also benefit from more efficient ecological processes and such as wetland filtration services provided by plants in the canal banks. This period still experienced occasional rain, including cases of flash floods (Figure 2).

Parameter description and measurement

Parameters were selected on the basis of probable point-source water pollution sources, which were based on land use around the urban canal. A detailed mapping of the area around the Mae Kha indicated household effluent, markets, a variety of small shops including garages, restaurants, arts and craft shops and beauty salons, city drainage pipes, and a slaughter house. Wastewater presented the most serious issues, however solid waste was also observed.

Based on the observed pollution point-sources a list of 18 relevant parameters was compiled (Table 5) using the WHO water quality assessment guide (1995,
Annex 3) and the standards of the Thai pollution control department (2013) for surface water, and effluent from housing estates, pig farms, and industry (Annex 4,Annex 5,Annex 7,Annex 8). The final list of parameters includes: alkalinity, air temperature, water temperature, pH, total dissolved solids (TDS), chloride (Cl^-), nitrate (NO_3^-), ammonia (NH_3), total Kjeldahl nitrogen (TKN), phosphate (PO_4^{3-}), hardness, conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total coliform bacteria (TCB), total faecal coliforms (TFC), and oil and grease.

Table 5 Water quality parameter testing methods

	Parameter	Methods	Storage period	Storage method
1	**BOD**	5210 5-day BOD test	5 days	Cooled at 4°C
2	**COD**	5220 C. Closed Reflux, Titrimetric Method	0-11 days later	Cooled at 4°C
3	**DO**	iodometric method	On site	n.a.
4	**Phosphate**	Spectrophotometric method	0-2 days	Cooled at 4°C
5	**Nitrate**	Spectrophotometric method	0-2 days	Cooled at 4°C
6	**Ammonia**	Spectrophotometric method	0-2 days	Cooled at 4°C
7	**TKN**	4500-Norg B . Macro-Kjeldahl Method	Within 2 weeks	Following standard methods
8	**TDS**	Electrometric method (CONSORT C933)	On site	n.a.
9	**Air Temperature**	2550 B mercury-filled Celsius Thermometer	On site	n.a.
10	**Water temperature**	2550 B mercury-filled Celsius Thermometer	On site	n.a.
11	**pH**	4500-H^+B. Electrometric method (CONSORT C933)	On site	n.a.
12	**EC**	2520 B. Electrometric method (CONSORT C933)	On site	n.a.
13	**Alkalinity**	2320 B. Titration Method	0-1 day	n.a.
14	**Hardness**	2340 C. Titration Method	0-1 day	n.a.
15	**Oil and Grease**	1664 Hexane extraction	Within 2 weeks	Following standard methods
16	**TCB**	9221 B MPN 4 tube test	Same day	1 day cultivation 37°C
17	**TFC**	MPN 4 tube test	After TCB	2 day cultivation 37°C
18	**Chloride**	4500-Cl- C. Mercuric Nitrate Method	Within 2 weeks	Following standard methods
19	**Velocity**	tennis ball on a string - 2m string	On site	n.a.
20	**Depth**	Stick	On site	n.a.
21	**Width**		Remotely	n.a.
22	**Free CO2**	4500-CO_2 D. Carbon Dioxide and Forms of Alkalinity by Calculation	Remotely	n.a.

Heavy metals are noticeably absent from the list of parameters, as they would require analysis of soil samples which was not feasible with the available laboratory equipment. Sample collection and testing of the selected parameters are discussed shortly below.

Water Sample Collection

Water quality was assessed through chemical, physical, and biological water quality tests of grab samples taken during 3 phases of the rainy season. Grab samples are only representative for the water quality at a specific time on a specific day, and should only be considered as an indication of the water quality in these seasons. Table 6 summarizes the applied collection, storage and conservation methods used on water samples for each parameter.

Table 6 Water sample collection methods

Parameter	Collection	Storage container	Conservation
BOD	Bucket	BOD flask	Ice
PO_4^{3-}, NO_3^- and NH_3	Bucket	Plastic	Ice
Oil and grease	Bucket	Glass	Ice
TCB and TFC	Bucket	Glass	Ice
DO	Bucket		n.a.
COD, Hardness and Alkalinity	Bucket	Plastic	Ice
Cl^- and TKN	Bucket	Plastic	Ice

Water Quality Parameters

The methods applied to test each of the parameters are summarized in Table 3. Some supporting information on each of these methods is discussed shortly below, along with relevant interferences and uncertainties for each of the tests. The tests that were done on site as well as those for BOD, COD, hardness, alkalinity, total coliform bacteria and faecal coliform bacteria were performed by the author under the experienced supervision of M.S. ThoraNit MoungMoon and Chotiwut Techkaijvej at Chiang Mai University. The tests for nutrients were performed by Chotiwut Techakijvej, a master student from the faculty of environmental sciences, also researching water quality of the Mae Kha in a parallel study. TKN, Chloride and Oil and Grease tests were performed by the Chiang Mai Environmental Engineering Faculty by order.

pH

pH represents the activity of ionic hydrogen in a solution, and is defined by the following equation:

$$pH = -\log_{10}[H^+] \ ,$$

where $[H^+]$ is the concentration in moles of hydrogen ions per liter of solution. pH general falls within the standard 0 to 14 scale and represents the balance of hydrogen (H^+) and hydroxide (OH^-) ions, or the acid balance of a solution. Lower values represent more acidic solutions, and higher values represent more basic solutions, with a value of 7 indicating a neutral acidity, i.e. a balance between hydrogen and hydroxide ions. pH measurements indicate the intensity of the acidic or basic character of a solution at a specific temperature. This is controlled by the dissolved chemical compounds and biochemical processes in the solution (Chapman, 1996).

The electrometric method is a common and reliable technique for measuring the pH of aqueous wastes under moderate pH ranges. The pH of the sample is derived from a measurement of the difference in voltage potential between a glass hydrogen ion-selective electrode and a reference electrode. Before measurement, the device is calibrated by immersion in a series of solutions with known pH levels (APHA, 1992).

Alkalinity

Alkalinity is a measure of the capacity of a solution to neutralize acids. The alkalinity of a water sample is controlled by the total concentration of titratable bases, which, in aquatic systems usually consists mainly of carbonate, bicarbonate and hydroxide. Other basic compounds such as borate, phosphates, and silicates can also neutralize acidity and contribute to the alkalinity of a solution. Without this acid-neutralizing capacity, any acidic mixture added to a stream will cause an immediate change in pH, increasing the related effects that rainfall or wastewater influent will have on a stream (EPA, 2012).

Sample alkalinity was measured by titrating the sample with a strong acid, measuring the amount that can be added before an end-point pH level is attained (APHA, 1992).

Free Carbon Dioxide

Total CO_2 is the sum of concentrations of all inorganic forms of carbon dioxide, i.e: CO_2, H_2CO_3, HCO_3 and CO_3. Thus free CO_2 is the component of carbon dioxide that is in gaseous equilibrium with the atmosphere, corresponding to the sum of concentrations of CO_2 and H_2CO_3, both of which can be converted into organic carbon by autotrophic organisms. Significant concentrations of H_2CO_3 are usually only found in water samples with a pH above 9, and it is usually present in very low concentrations in surface waters (Chapman, 1996).

If total alkalinity is determined mainly by carbonate, bicarbonate, and hydroxide, and total dissolved solids are ≤ 500 mg/L, then free CO_2 can be calculated from the sample's pH and total alkalinity. These conditions were present in the samples collected in this study, and so calculations free CO_2 could be performed based on ionization constants (APHA, 1992).

Dissolved Oxygen

Dissolved Oxygen (DO) is the measure of oxygen concentrations in water. The iodometric method determines the dissolved oxygen concentration by performing a series of oxidation-reduction reactions. First Mn^{2+} (as MnSO4) and an alkali-iodide reagent (KI in an NaOH solution) are added to a 100mL sample. Under these conditions, the DO that is present oxidizes some of the Mn^{2+} to Mn^{4+}. After the MnO_2 precipitate settles, sulfuric acid is added to acidify the solution. MnO_2 then oxidizes the I^- to allow it to form free I_2. Subsequent titration with sodium thiosulfate ($Na_2S_2O_3$:$5H_2O$) reacts to convert the I_2 back to the ionic form, I^-. The amount of I_2 is directly related to the concentration of oxygen in the original sample, and the results of this titration are used to calculate the corresponding DO concentration. The endpoint is determined by using calorimetric indicators (APHA, 1992).

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) of a sample is an indication of the concentration of biochemically degradable organic matter. The measure is defined by the amount of oxygen necessary for aerobic organisms to oxidize the present organic matter to a stable inorganic form (Chapman, 1996).

5-Day BOD tests were performed by filling a 300ml airtight bottle to the point of overflow, and incubating it at $20^{\circ}C$ for 5 days. DO was measured before and after incubation, and BOD was calculated as the difference between the two measurements. Since the initial DO is determined when the sample was collected, any change is assumed to be due to biological activity and is included in the BOD (APHA, 1992).

Chemical Oxygen Demand

Chemical oxygen demand (COD) is defined as the oxygen equivalent of the amount of a strong chemical oxidant that is required to oxidize all of the organic and inorganic materials in a sample. It is often used to represent the susceptibility to oxidation of these materials in water bodies (Chapman, 1996).

The standard methods that were used consist of boiling the sample in a mixture of acids and an excess of a strong chemical oxidant (in this case potassium dichromate, $K_2Cr_2O_7$), after which the remaining (unreduced) oxidant was titrated using ferrous ammonium sulfate to determine the amount that was reduced. The corresponding quantity of matter that was oxidized in the initial redox reaction is then obtained and used to calculate the COD in terms of oxygen equivalence (APHA, 1992).

Chloride

Chlorine most commonly occurs in natural waters as ionic chloride (Cl^-), which enters surface waters through atmospheric deposition of oceanic aerosols, weathering of certain sedimentary rocks (mostly rock salt deposits), industrial or sewage effluents, and agricultural or urban runoff (Chapman, 1996).

The Mercuric Nitrate Method was used to titrate the sample with mercuric nitrate ($Hg(NO_3)_2$) to form mercuric chloride in a soluble, slightly dissociated form, which reacts with an indicator at an endpoint pH level whereupon the initial level of chloride can be calculated (APHA, 1992).

Hardness

The hardness of natural waters is usually defined by the levels of dissolved calcium and magnesium salts. Total hardness refers to the total content of these salts, and includes carbonate hardness (concentrations of calcium and magnesium hydrocarbonates), and non-carbonate hardness (calcium and magnesium salts of strong acids) (EPA, 2001).

Hardness was measured using the acid EDTA which combines through chelation with the calcium and magnesium present in the sample. The prior addition of an indicator causes a change in colour in the solution once all calcium and magnesium has been reacted, at which point the quantity of EDTA added was used to calculate the hardness (APHA, 1992).

Ammonia Nitrogen

Ammonia is often a component of municipal or community waste. It can enter waterways by natural means due to the breakdown of nitrogen-rich matter in soil and water, excretion by various organisms, reductive digestion of nitrogen gas in water and gas exchange with the atmosphere (Chapman, 1996).

In the spectrophotometric method a reagent is added to the sample that produces a color ranging from pale yellow to brown, depending on the level of ammonia present. A pale yellow color indicates a level of ammonia nitrogen of 400 – 1000 mg/L. The resulting color is analyzed using a spectrophotometer which gives a value that is used to calculate the concentration of ammonia in the sample (EPA, 2008).

Nitrate

Nitrate (NO_3^-) is the most common form of combined nitrogen found in natural waters, with natural sources including igneous rocks, land drainage and plant and animal debris (Chapman, 1996).

In the spectrophotometric cadmium reduction method nitrate is reduced to nitrite in the presence of an indicator. The oxidized cadmium reacts to form a red color proportional to the original concentration of nitrate. This is measured either by comparison to a color wheel with a scale in mg/L, or using a spectrophotometer which takes measurements of absorbed 543 nm light. The absorbance value is then converted to the equivalent concentration of nitrate by using a standard curve. Methods for making standard solutions and curves can be found in the standard methods literature (APHA, 1992 in EPA, 2012).

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen and ammonia and is measured in mg/L. High concentrations of TKN usually indicate contamination by sewage and manure discharges. Ammonia (NH_3) typically constitutes approximately 60% of TKN (Shifflett, n.d.).

In the Macro Kjeldahl Method, sulfuric acid (H_2SO_4), potassium sulfate (K_2SO_4), and cupric sulfate ($CuSO_4$) are added as catalysts to convert the amino nitrogen of organic materials to ammonium. In the reaction, free ammonia also is converted to ammonium. After the addition of a base, the ammonia is distilled from an alkaline medium and absorbed in boric or sulfuric acid. The ammonia is then determined either colorimetrically, using an ammonia-selective electrode, or by titration with a standard mineral acid (APHA, 1992).

Phosphorous

Phosphorus occurs widely in nature in plants, microorganisms, animal wastes and many other organic and synthetic materials. It is widely used as an agricultural fertilizer and as a major constituent of detergents, particularly those designed for domestic use (EPA, 2001, p88). In natural waters and in wastewaters, phosphorus occurs mostly as dissolved orthophosphates and polyphosphates, and many organically bound phosphates. Changes between these forms occur continuously due to decomposition and synthesis of organically bound forms and oxidized inorganic forms (CHAPMAN, 1996, p96). The significance of phosphorus is principally with regard to the phenomenon of eutrophication (over-enrichment); phosphorus in combination with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, drastic diurnal variations in dissolved oxygen levels, and related problems (EPA, 2001, p88). In most natural surface waters, phosphorus ranges from 0.005 to 0.020 mg/L PO_4-P. Concentrations as low as 0.001 mg/L PO4-P may be found in some pristine waters and as high as 200 mg/L PO_4-P in some enclosed saline waters (Chapman, 1996, p96).

Using a spectrophotometric method, ammonium molybdate and antimony potassium tartrate react in an acid medium with phosphorus-containing samples to form an antimony-phospho-molybdate complex. This complex is reduced to a blue-colored complex by ascorbic acid, the intensity of which is proportional to the concentration of phosphorus and can be accurately measured with a spectrophotometer (EPA, 1978).

Oil and Grease

Oil and grease or fat oil and grease are basically oils unfortunately these cannot be measured directly. Instead, its measured in combination with various compounds such as petroleum products, resins, asphaltenes, and many other materials which can be any material recovered as a substance soluble in the solvent. Oil and grease concentration is determined quantitatively by using an organic extracting solvent, wherein any material recoverable from the solute is counted as a constituent. Many groups of substances have physical characteristics similar to oil and grease, and are unavoidably included in the measurement. Compounds that can be similarly extracted from an acidified sample and which will not volatize during the process include: oxygen, nitrogen and sulfuric compounds, organic dyes, and chlorophyll (APHA, 1992; Chapman, 1996).

The hexane extraction method uses a 1L sample which is acidified to pH < 2 and processed with n-hexane three times in series through a separatory funnel. The resulting extract is then dried using sodium sulfate, where the solvent is distilled from the extract and it HEM (hexane extracted material) is desiccated and weighed (APHA, 1992).

Total Dissolved Solids

Total dissolved solids refer to the portion of solids in a water sample that are dissociated into their constituent ions, i.e. not suspended. These are the fraction of solids that would pass through a filter, whereas the captured portion would constitute the suspended fraction. Specifically, dissolved solids are defined as the portion of solids that pass through a filter of 2.0 mm (or smaller) pore size (APHA, 1992).
In the electrometric measurement of TDS, measurements are obtained by a calculation consisting of conductivity (µS/cm) measurements multiplied by an empirical factor, which can vary between 0.55 to 0.9, depending on the expected soluble components and temperature of the sample (Ramteke and Moghe, 1988 in IIS, 2006).

Conductivity

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This depends on the presence of ions, their concentration, mobility and valence, and on the temperature of measurement. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds do not often dissociate in solution and are generally poor conductors (APHA, 1992).

The method of measuring a solution's conductance involves the submergence a probe containing two spatially fixed and chemically inert electrodes. An alternating current is used in order to avoid polarization at the electrode surfaces. The conductance is directly proportional to the surface area of the electrode, and inversely proportional to the distance between the electrodes, which are used to convert the measurement of resistance to a value for conductivity (APHA, 1992).

Microbiological Indicators

Many microorganisms in surface waters originate from water polluted with human excrement. Fresh waters also contains local microorganisms of all types – bacteria, fungi, protozoa and algae – some of which can also produce toxins and transmit, or cause, diseases. Coliforms are used as indicators of fecal contamination in order to provide a high margin of safety. While the exact safety factor depends on the ratio of coliforms to pathogens, this is never quantified in practice. Experience has shown that this approach is sufficiently effective (EPA, 2001, p.46)

Total Coliform Bacteria and Fecal Coliform

Coliform bacteria are commonly used as indicators of sewage contamination, as they are found in human and animal feces. Species that fall into this category are generally not harmful, but they are indicative of the possible presence of pathogenic bacteria, viruses, and protozoa that also live in human and animal digestive systems. Total coliform tests include a group of bacteria which are aerobic and facultative anaerobic, gram-negative, non-spore-forming, and rod-shaped which ferment lactose with gas formation within 48 hours at 35°C. This definition includes the following species of interest: E. coli, E. aurescens, E. freundii, E. Intermedia, Aerobacter spp., Aerogenes spp., A. Cloacae (EPA, 2001).

The Most Probable Number (MPN) method applies a serial dilution of samples into media, with the aim that some dilution will introduce a single bacteria into the media to ferment for a 24 hour incubation period at 37°C. By observing gas production (or the lack thereof), it is possible to determine the most probable number (MPN) of the organisms that were originally present in the sample. Four tubes of media (Lauryl tryptose broth)with decimal dilutions of 1:1, 1:10, 1:100, 1:1000 mL were inoculated. Those samples where bacteria thrived were inoculated and incubated with 5ml of fecal coliform specific media (EC broth) for 48 hours at 37°C. Counting of tubes with gas production was used to determine the MPN for each group of coliforms (EPA 2003; EPA n.d.).

Interferences

Hardness: Some metal ions interfere by causing fading or indistinct endpoints or by stoichiometric consumption of EDTA. Suspended or colloidal organic matter also may interfere with the end point (APHA, 1992).

COD: Chloride reacts with silver ions to precipitate as silver chloride, therefore inhibiting the catalytic activity of silver. Bromide, iodide, and any other reagent that precipitates with silver ions can interfere similarly. Such interferences are negative in that they tend to restrict the oxidizing action of the dichromate oxidant itself. However, under the rigorous digestion procedures for COD analyses, chloride, bromide, and iodide can react with dichromate to produce the elemental form of the halogen and the chromic ion. Results then are in error of overestimation (APHA, 1992).

DO: Nitrite interferes by converting iodide (I^-) to iodine (I_2), thus leading to overestimation of dissolved oxygen in the sample (APHA, 1992).

Oil and Grease: Organic solvents have the ability to dissolve not only oil and grease, but also other organic substances. In the measurement, any filterable soluble substances (e.g., elemental sulfur, complex aromatic compounds, hydrocarbon derivatives of chlorine, sulfur, and nitrogen, and certain organic dyes) that are extracted and recovered are included in the measurement of oil and grease (APHA, 1992).

Total Kjeldahl Nitrogen: Nitrate in excess of 10 mg/L can oxidize a portion of the ammonia released from digested organic nitrogen, producing N_2O and causing a negative interference. When sufficient organic matter in a low oxidation state is present, nitrate can be reduced to ammonia and cause a positive interference. Large quantities of salt or inorganic solids that dissolve during digestion may raise the temperature above 400°C, at which point pyrolytic loss of nitrogen begins to occur. The presence of large amounts of organic matter will allow a large amount of acid to be consumed leading to the same effect (APHA, 1992).

Phosphorus: Positive interference can be caused by silica and arsenate only if the sample is heated. Negative interferences can also be caused by the presence of fluoride, thorium, bismuth, sulfide, thiosulfate, thiocyanate, or excess molybdate. The blue color is caused by ferrous iron which does not affect results at concentrations less than 100 mg/L. Sulfide interference may be eliminated by oxidation with bromine water. Ions that do not interfere in concentrations up to 1000 mg/L are Al^{3+}, Fe^{3+},Mg^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Li^+, Na^+, K^+, $NH4^+$, Cd^{2+}, Mn^{2+}, Pb^{2+}, Hg^+, Hg^{2+}, Sn^{2+}, Cu^{2+}, Ni^{2+}, Ag^+, U^{4+}, Zr^{4+}, AsO_3^-,Br^-, CO_3^{2-}, ClO_4^-, CN^-, IO_3^-, SiO_4^{4-},

NO_3^-, NO_2^-, SO_4^{2-},SO_3^{2-}, pyrophosphate, molybdate, tetraborate, selenate, benzoate, citrate, oxalate, lactate, tartrate, formate, and salicylate. If HNO_3 is used in the test, Cl^- interferes at 75 mg/L (APHA, 1992).

Uncertainties

Collection: The samples were obtained using a bucket dropped into the water from a bridge. It would have been more suitable to take the samples below the surface since the surface often has a higher degree of compounds such as oil and pollen, as well as higher levels of gas exchange (APHA, 1992). This was, however, impossible due to the infrastructure of the canal. COD samples were collected in plastic bottles rather than glass bottles as advised by the standard methods.

Sampling location and time: There are significant gaps in the period of sample collection for the first round of collection in comparison to the second and third rounds, which might affect the diel differences in discharge patterns and hydrological processes. Sample sites 4 and 5 were meant to measure the quality upstream and downstream of the slaughter house to measure its impact of its discharge on downstream water quality as a point-source of pollution. The discharge time for the slaughter house is between 8pm and 4am, thus significantly different from the collection period. A second issue is related to the location of the sample collection. The first sample was collected off the bank of the canal upstream of slaughter house outflow. This point was unreachable during subsequent collections due to the increase in water level. Therefore the second and third samples were collected from a bridge a few meters downstream of the outflow point. This collection point was deemed acceptable following the theory on water flow and mixing, and observations which suggest that the effluent flow would continue along the side of the canal and only blend downstream, following the first bend. However, the low and sometimes stagnant flow and soil pollution increases the possibility that both sample sites 4 and 5 were affected by the effluent.

Conservation: The standard methods suggest the preservation of samples for BOD and COD analysis by acidification to pH ≤ 2 using concentrated H_2SO_4. The COD samples were never analyzed immediately: the first round was analyzed one day after collection, the second round 11 days after collection, and the third round 2 days after collection. BOD samples were preserved before analysis by freezing the bottles but not by decreasing the pH.

Measurements in the field: Field flow measurements are affected by numerous uncertainties. Depth is measured with a stick, and it is difficult to determine exactly when it first touches the soft bottom of the canal. Several assumptions are made for the calculation of the constant that is used to estimate the flow. Often, it was impossible to measure the velocity, and during the dry season the water was stagnant in some locations.

Tests in the laboratory: Firstly, the analysis of BOD, phosphorus, nitrate, ammonia nitrogen, oil and grease, chloride, TFC, TCB, DO, TDS, conductivity and pH were each replicated three times to detect errors in the analysis and to achieve reliable results. However, the same was not done for Alkalinity, Hardness or COD, due to insufficient chemicals to perform the tests. Secondly, the literature on MPN Total Coliform Bacteria and Fecal Coliform Bacteria tests recommends that the analysis be performed on a minimum of 5 tubes each of at least 3 decimal dilutions (EPA 2003; EPA n.d.). In this case 3 tubes were used with 3 decimal dilutions during the first round of test and 3 tubes with 4 decimals dilutions in subsequent rounds. The increase in dilutions was applied to achieve a higher possible MPN in order to compare the results with Thai standards. The usefulness of total coliforms as an indicator of sewage contamination is questioned as total coliform can also result from animal manure, soil, submerged wood, and other sources. Even fecal coliform tests include a genus, *Klebsiella*, which can originate from textile, pulp and paper mill waste. *E. coli* and enterococci are considered as better indicators of health risk from water contact. Total and fecal coliform tests were used in this study because they are used in the local standard for surface water quality, and the area lacks the industry that can complicate results.

Thirdly, the BOD method is subject to various complicating factors including the oxygen demand resulting from the respiration of algae in the sample, and the possible oxidation of ammonia which can occur in the presence of nitrifying bacteria. The presence of toxic substances in a sample may also affect microbial activity leading to a reduction in the measured BOD. The conditions in a BOD sample bottle usually differ from those in a river or lake, and therefore, the interpretation of BOD results and their implications must be done with great care and by experienced personnel. In this study, the tests were done in cooperation with experienced students, however it is still important to note the sensitivities of the test and interpretations of the BOD results. Lastly, most samples indicated levels of Alkalinity below 20 mg $CaCO_3$/L, as the low alkalinity method (APHA, 1992) was not subsequently applied these are therefore presented as < 20mg $CaCO_3$/L.

Analyzing the results

The results of the water quality tests were analyzed using the SPSS 17.0 statistics data software package. First, normality of the sample was tested to choose what type of statistical analysis to perform, because normal data is an underlying assumption in parametric testing. The non-normal distribution of most of the samples limited the tests to non-parametric tests. Friedman, Wilcoxon and Mann-Whitney U tests with mean ranks, as well as a comparison of medians and standard deviation were used to compare the results between seasons, canals and sites.

The Friedman test was used to compare the results between sites and seasons for each parameter; it is the non-parametric alternative to the one-way ANOVA with repeated measures. It can be used to test for differences between groups if the dependent variable being measured is continuous but violates the assumptions necessary to run the one-way ANOVA with repeated measures (i.e. in this case it was not normally distributed). The test was used to analyze the differences between group means and their associated procedures, such as variation among and between groups (De Vocht, 2007; laerd statistics, 2013). Where the Friedman test indicated that there were differences between sites or seasons, a post-hoc Wilcoxon signed-rank test was used to analyze where these differences occurred. The Wilcoxon signed-rank test is the nonparametric test equivalent to the dependent t-test, and can be used without the normality assumption. The test is used to compare two sets of measurements that come from the same sources (De Vocht, 2007; leard statistics, 2013). It was used to investigate the differences in parameter measurements between seasons.

The Mann-Whitney U test is a non-parametric test used to compare differences between two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed, and was used to compare differences in water quality for the various parameters between the Ku Wai stream (sites 7 & 8) and Mae Kha stream (sites 2-6) (De Vocht, 2007; laerd statistics, 2013).

Results Distribution

The results follow the four components of environmental justice: 1) distribution of environmental ills, 2) participation roles assigned to stakeholders in managing the canal, 3) recognition of stakeholder groups by others, and 4) capabilities of stakeholder groups to effect change in the state of the canal.

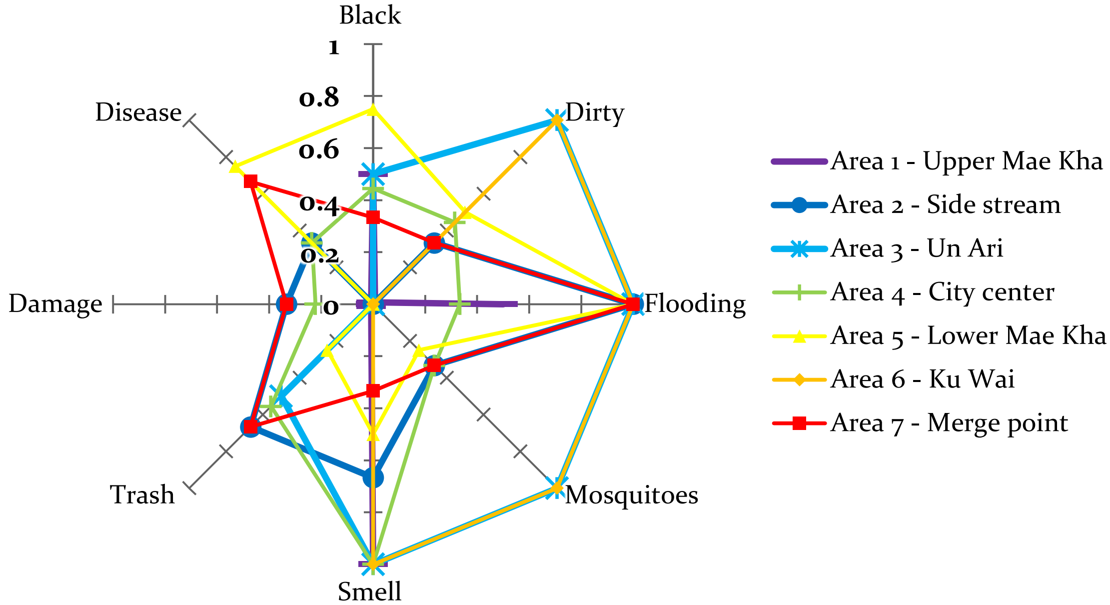
Distribution of environmental Ills

"Generally, one of the key directions of environmental justice research in the past few years has been based on an acknowledgement of the plurality of environmental (in)justice experiences" (Schlosberg, 2013). These injustices are not always defined in physical space but often in social space, be it class, race or gender. In this section we first analyze the different experiences between areas (Figure 8, p.27), and then between stakeholder groups. The environmental ills that were identified during interviews were further researched to shed light on the injustices which give rise to these differences in exposure to environmental risks. This includes discussions on use of the canal, flooding, water quality and land and water management practices, which affect the hydrology of the city and underlie many of these issues.

Physical Distribution of Environmental Ills

Figure 9 Summarizes the degree of each identified environmental ill that was experienced by chumchon and businesses in different areas (for area boundaries see Figure 8, p.27). As the spider graph indicates, flooding and odorous water (smell) represent the most common concerns, shared by stakeholders in all areas. However, we can see that the degree of concern for each varies depending on the area. The city center in particular had a low incidence of flooding, while the chumchon downstream along the Mae Kha (5), the side stream of the Mae Kha (2), the merge area where Fa Mai community is located (7) and Ku Wai stream (6) all indicated significant experience with floods.

Figure 9 Spatial distribution of environmental ills. Values indicate the fraction of interviewees per area who mentioned each ill.



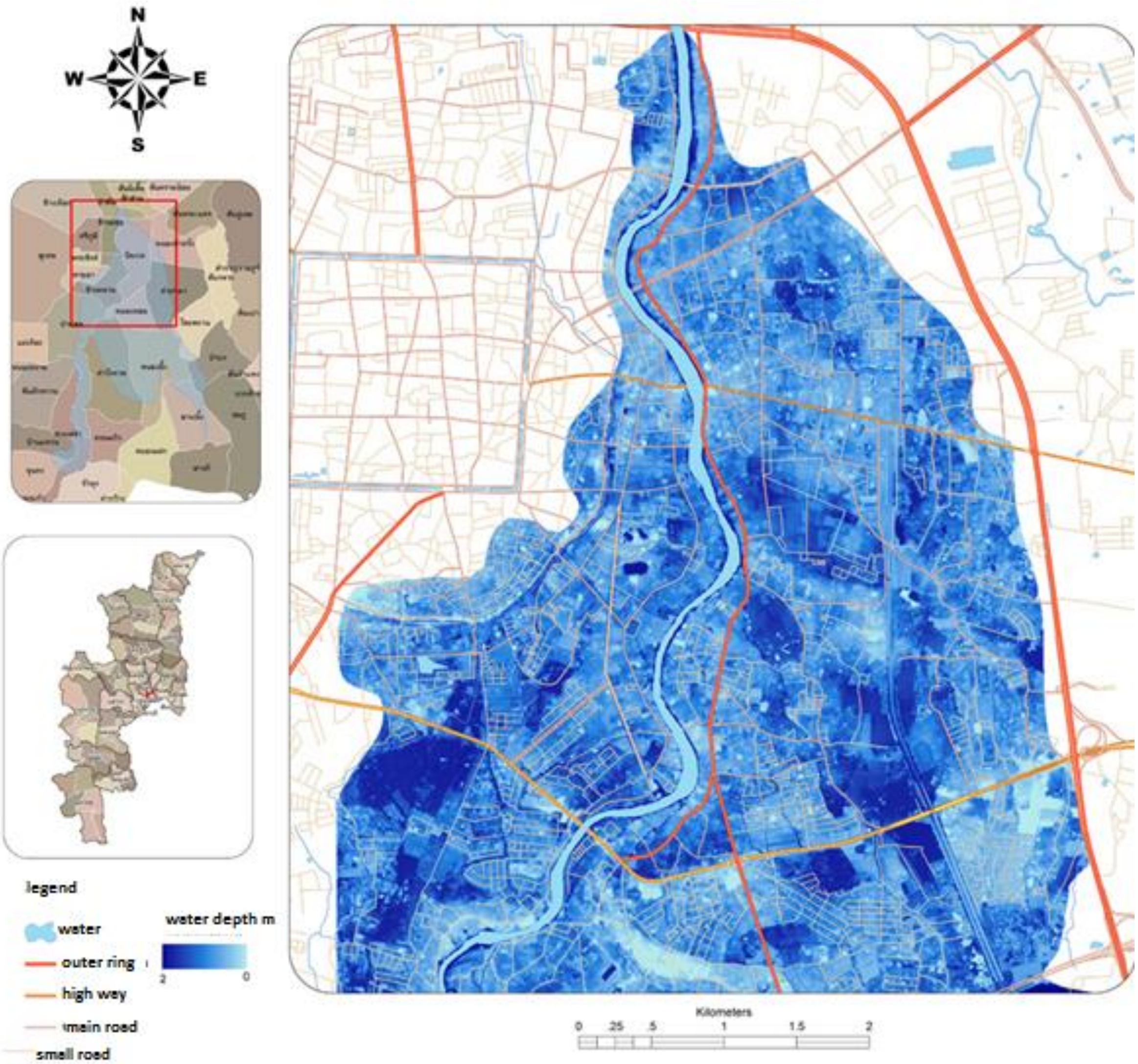
Source: based on rich picture exercises during interviews held in 2013

The smell of the canal was a bigger concern for areas 1, 3, 4 and 6, the first three of which are located more upstream in the city. Disease was most often mentioned by interviewees in areas 5 (lower Mae Kha) and 7 (merge point), but was also mentioned by some in areas 2 (side stream) and 4 (city center). Mosquitoes, which can facilitate the spread of some diseases, were mentioned as a concern in all areas. The frequent mention of mosquitoes in areas 3 (Un Ari) and 6 (Ku Wai) in association with the canal was unexpected as these areas experience a healthier flow regime (Table 9, p51). Mentions of other issues vary, with some voicing concerns of the water's black color, the canal being dirty or filled with trash, but these concerns were generally shared across the board. Some areas, both upstream and downstream, also mentioned physical damage to their communities due to flooding events of the Mae Kha.

Following the interviews, the reported issues of flooding and health risks were investigated using other sources. When contacted, the Health Department claimed to have no information on health issues related to the Mae Kha, such as occurrences of dengue fever, diarrhea or other issues, for any of the areas or for specific communities. Flood maps were obtained from the department of Civil Engineering at Chiang Mai University (CENDRU, 2012), and indicate the distribution of flooding events around the city. A map showing interpolated results of modeling of the flood area (Figure 10) shows indeed that areas downstream and east of the Mae Kha are most vulnerable to flooding. The flooding is more extensive when the Ping River experiences over bank flooding, which has occurred with increasing frequency (Sriwongsitanon, 2010). The most recent heavy flooding events occurred in 2005 and 2011 (Marine Department, 2013).

Some areas indicated by the map to be at high risk of flood, such as the area parallel to the city square near Tha Pae road, did not exhibit a corresponding level of concern during interviews. On the other hand, some areas indicated as low risk on the map, such as the side stream in the north of the city, mentioned frequent flooding during interviews. It is likely that these deviations are the result of factors not considered in the model, such as human intervention through the use of storm water drainage or management of canal water flows. In fact, stream management for urban areas is generally an issue of flood management (Booth & Blesdoes, 2009). This issue of urban infrastructure is discussed in more detail in the section.

Figure 10 Chiang Mai flood risk map

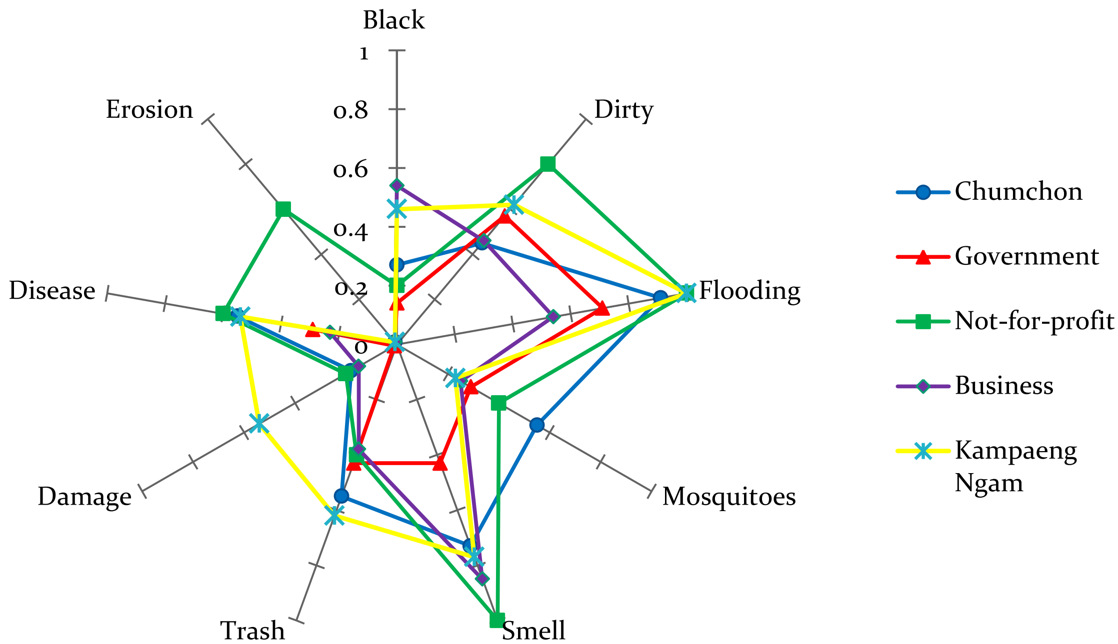


Source: CENDRU (2012)

Social distribution of environmental ills

"Flooding clearly demonstrates the need to go beyond the socio-spatial patterning of risk in order to understand inequality. ...[flood risks] has to be seen in interaction with socio-spatial patterns in who is most vulnerable to flood impacts and how this vulnerability is being produced and reproduced for different people and communities" (Walker, 2010). From the distribution of environmental ills around the Mae Kha, it is clear that some issues, especially those of flooding and disease, were more prevalent in areas downstream of the city where more chumchon are located, than in areas upstream and the city center where more businesses are located. To take a closer look at the differences between stakeholder groups, the same data was organized to analyze the distribution of environmental ills between stakeholder groups (Figure 11). Chumchon and businesses included in the sample are located directly along the canal, and their issues represent direct experiences. Governmental Institutions and NFPs are not located directly along the canal, and the problems the indicated represent their recognition of issues facing the canal and the people living along it.

Figure 11 Distribution of environmental ills among stakeholder groups. Values indicate the fraction of interviewees per group who mentioned each ill.



Source: based on rich picture exercises during interviews held in 2013

Figure 11 confirms that chumchon more frequently reported issues with flooding, while businesses and chumchon both often reported issues with the bad smell of the canal. Businesses, especially hotels, found the smell of the canal to directly impact their business. The worst smell is experienced during the warm dry period when the canal level is low. This period coincides with the Songkran festival, which is the busiest season for tourism in Chiang Mai. The smell of the canal has been described as a mix of rotting fish and composting vegetation (Condotel, 2013), and in certain areas during the height of the dry season the anaerobic condition produces a smell of sulfur (Gum Hak Doi Suthep, 2013; observations in March and April 2013). Many hotels reported having received complaints (Cendara, 2013) and even walk-outs due to the stench of the canal (Panda Hotel, 2013; Tha Pae Inn, 2013; Guest House, 2013; Condotel, 2013).

Despite most businesses along the canal attempting to block the view of it, with the exception of The Red Brick Hostel who reported no windows in their rooms facing the canal (2013), most businesses received complaints or comments on the poor state of the water. It is thus understandable that so many businesses would bring up the appearance of the canal as a prominent issue. On the other hand, chumchon were more concerned with the trash floating in the canal. It is unclear if this accumulation of solid waste downstream is simply the result of the water flow, a difference in maintenance of the canal or a combination of both.

Hotels that indicated flooding occurrences were located downstream of the city (Condotel, 2013; Red Brick Hostel, 2013). Flooding was felt by most chumchon located downstream, although some upstream and side stream chumchon also reported flooding, and ascribed it to human rather than natural forces. Chumchon

Papleng and Samut both suggested that flooding in their communities was the effect of water gates remaining closed during the rainy season to protect the city center. Chaiyapoom Chang Moi, just inside of the inner city, reported that they had experienced floods from blocked drainage systems, while community Saladeng, downstream, reported floods originating from Tipanet and Hai Ya roads. Thus, both natural from heavy rains and its topography as a floodplain, and human factors related to infrastructure, are likely to contribute to flooding.

Floods affect communities in many ways; residents in Kampaeng Ngam reported significant damage to their households due to the seasonal flooding of the canal. In chumchon Kampaeng Ngam and Samut, many households indicated having to evacuate the area during past floods, sleeping on the streets or with friends and relatives (Kampaeng Ngam, 2013; Samut, 2013). Moreover, many communities reported negative health effects during floods, especially skin rashes and diarrhea among children. However, flooding could also have more serious health effects due to the sewage effluents in the canal. Some health risks were also identified in the hot dry season, some related to mosquitoes, but also respiratory illness, skin rashes, and headaches. During visits to the site during the dry season, the researchers even had personal experiences with health issues including headaches and skin rashes.

Recognition

The effects of environmental ills are amplified by the lack of recognition for those who experience them. Lack of recognition from GIs and NFPs makes it harder to tackle the issue, and indicates a void between stakeholders. When NFPs and GIs were asked to list the issues relating to the Mae Kha, it was apparent that in general NFPs had a broader vision of the issues affecting the Mae Kha than did GIs, and the recognition of issues by GIs was scattered, with each department only knowing about those issues falling under its official responsibility.

NFPs also showed a broad concern for the canal, which included recognition of many of the issues afflicting communities, such as health risks, flooding, bad smell and mosquitoes. NFPs also recognized the increased erosion affecting the canal, which as discussed before can increase flooding and damage in the downstream area, and affect the stream's ecology and riparian area. The issue of damage resulting from flooding was not broadly recognized by either NFPs or GIs. This was surprising as residents of Kampaeng Ngam indicated that emergency provisions from the government and Buddhist temples both during and after large floods were satisfactory. The limited recognition of issues related to the Mae Kha might be related to the fact that large over bank floods coincide with the flooding of the Ping, and thus might not be conceived as an issue of the Mae Kha. The next section will offer additional insight into the recognition of distributed effects, by looking at the influence of local water infrastructure and land use plans in allocating environmental ills.

Urban hydrology of the Mae Kha

People have intended and un-intended impacts on the natural hydrological cycle. Urban societies in particular are dependent on their capacity to consciously manage the local hydrology in order to provide sufficient water for drinking, food production and sanitation and simultaneously prevent flooding. Water is commonly collected through dams and reservoirs, directed with pipes and canals, water gates and drainage systems, and cleaned through wastewater treatment systems. The implementation of all these types of water infrastructure have significant effects on every aspect of the local hydrology.

Water use

Thailand has the highest volume of per capita water use in Asia (Chokewinyoo, 2013). In 2003, the average volume of household water use was 8.6 cubic m^3 per week. In Chiang Mai, the most important source of drinking water is surface water from the Ping River (Otaki, 2008; Margane & Tatong, 1999). The management of water use for Chiang Mai is poorly organized, as no clear estimates of local water use for Chiang Mai could be found; only data for the province as a whole which includes a wide range of land uses from national parks to rural agriculture to urban areas. Despite most of Chiang Mai having access to piped water, many areas still rely on groundwater. Various businesses and households in Chiang Mai have indicated using groundwater to save costs (Condotel, 2013; Ha Tanwa, 2013; Fa Mai, 2013, households in

Kampaeng Ngam, 2013). Groundwater use is more prevalent in rural areas outside Chiang Mai, but the lack of monitoring of its extraction rate and quality present risks to both health and the environment as groundwater levels decline (Srinivasan et. al., 2013). Urbanization and provision of piped water and drainage infrastructure lead to decreased infiltration in urban areas. Water loss through leakage can partly offset the impact, but it also leads to increases in water use. Water loss is more likely if there is insufficient system maintenance resulting from budget constraints, lower quality pipes, and equipment that exceed their lifespan, as is the case in Chiang Mai. The total rate of water loss or leakage in Thailand reached 37.30% for Bangkok Metropolitan Area and 26.69% in the Provinces.

Wastewater treatment

In Thailand, private establishments are responsible for their own wastewater but the treatment of household wastewater is the responsibility of the state, through public wastewater treatment facilities (Wolrd Bank, 2008). The industrial sector in Thailand produces about 6.8 million m^3 of waste water per day (Chokewinyoo et al., 2013) and households approximately 14 million m^3 (Worldbank, 2008; Chokewinyoo et al, 2013). For the past two decades, the Thai government has invested approximately 83 billion THB to construct 101 community wastewater treatment plants around the country. The combined capacity of all these treatment plants is 3.2 million m^3 per day, and is discharged into local waterways after treatment (Chokewinyoo et al., 2013). In 2006, when there were 95 central wastewater treatment plants with a capacity of over 2 million m^3 per day, the utilization rate of the total capacity stood at 60%. This represented only 14% treatment of the total wastewater generated by households. Most of the household wastewater was instead discharged untreated into public waterways, while existing facilities were operating significantly under capacity and with insufficient network coverage of wastewater drainage pipelines (World Bank, 2008), with services that over only 34% of urban areas (Chokewinyoo, et al., 2013). The major constraints to wastewater treatment in Thailand are thus the high cost of investment, incomplete infrastructure (treatment centers without the connecting sewage network) and lack of continuous operation and maintenance (Chokewinyoo et al., 2013).

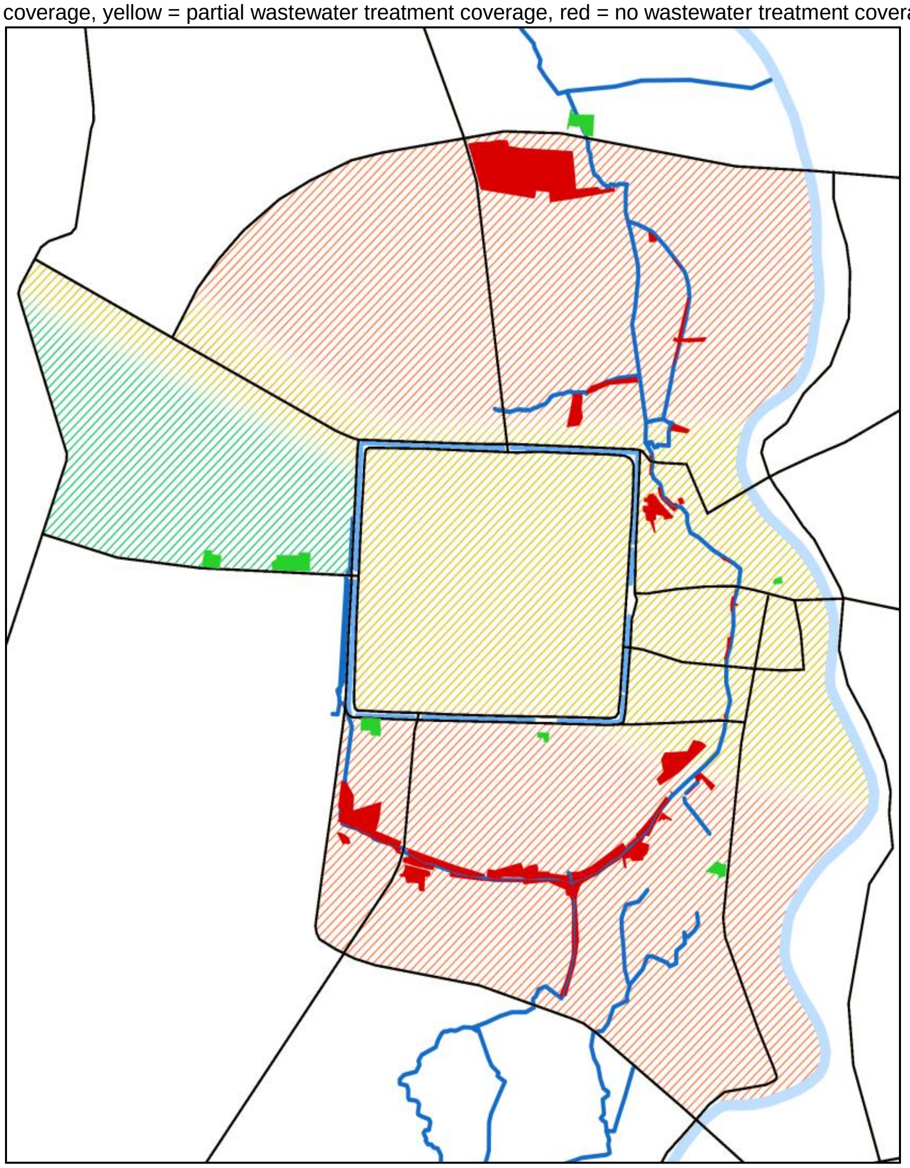
Drainage in Chiang Mai

Most of the wastewater in Chiang Mai is discharged into nearby waterways. For households in the urban center of Chiang Mai, west of the Ping, this is the Mae Kha and Ku Wai canals (sanitation department, 2013). There is a local waste water treatment plant (WWTP) which treats a fraction of the city's local household grey water. Black water is by and large treated on site in septic tanks for both households connected to the system and unconnected. Figure 12 gives an overview of which parts of the city are covered by a wastewater treatment system. The only major area that is completely covered is the independently operated WWTP of Chiang Mai University. Part of this area which is not part of the University campus is also connected to the public WWTP. The public WWTP treats a portion of the wastewater from the area in yellow, while many areas remain completely untreated. Any untreated wastewater from these areas is discharged into the local Mae Kha ad Ku Wai waterways. The sanitation department itself was not able to confirm in detail which parts of the city were covered by the wastewater treatment plant and which were not. Most of the areas where chumchon are located are not connected to any waste water treatment system. The areas that are partially serviced are the main touristic areas, inside the square moat, and east of the city center.

There are three different networks of pipes which comprise the drainage system of Chiang Mai. The first are the old mixed drains which accompany nearly every street and lead directly to the Mae Kha. These are neither mapped nor regularly maintained. This system transports the wastewater from the parts of the city indicated in Figure 12. The parts of the city east of the Ping lack any waste water treatment, and discharge all of their water to the nearby canal. Secondly, there is a 1.2m diameter collection pipe running 3m beneath the Mae Kha, which collects water from around the city and transports it 10km south of the city to the Pen Para WWTP, in San Pak Wan district in Hang Dong. This pipe was built by the central government in combination with the WWTP. A third set of pipes consists of a growing network of 27km of pipes which carry water from the city to the collection pipe. The drainage system maintenance office takes care of the second and third sets of pipes (Sanitation Department, 2013). Several major streets, Tha Pae, Sii Pun, Sri

Don Chai and Loi Khro are connected to the collection pipe through a mixed rain and sewage drain. There is no monitoring system in place to measure how much water is transported through each of the local drainage systems, however, the chief of drainage maintenance indicated that the total capacity of the drainage system is about 20.000m^3/day, and is estimated to transport at about 50% of capacity, or 10.000m^3/day.

Figure 12 Areas of the city around the Mae Kha serviced by waste water treatment plants. Green = full wastewater treatment coverage, yellow = partial wastewater treatment coverage, red = no wastewater treatment coverage.



While the chief of drainage maintenance could not give an estimate of the total water use for the city, Chiang Mai University Campus WWTP treats approximately 100.000m^3/day (Tsuzuki, 2009). The rest of the municipality is at least 4 times the size of the campus. This wastewater is comprised of mostly grey water and rain water, as black water is primarily treated using household septic tank systems. Small houses have simple septic tanks, and bigger buildings have an added aeration component (Chief of Maintenance, 2013). Septic sludge is regularly collected from households in most of the interviewed chumchon, but the sanitation department (2013) could not provide information about either how or where the sludge is disposed.

Wastewater treatment in Chiang Mai

Pen Para WWTP is an aeration lagoon with a 3 step system: The first tank has 12, 40 horsepower aeration pumps, and flows naturally as the water level increases into the second tank, which has 8, 20 horse power aerators and flows similarly into the third tank, which is a collection tank from which clean water flows into a nearby stream that transports it to the Ping river (Tsuzuki et al., 2009; WWTP, 2013). There are no systems in place to monitor the quantity of water being treated at the plant, nor the amount of water lost due to leakage in the now 20 year old distribution system. The waste water treatment capacity is 55,000 m^3 (Tsuzuki et al., 2009; WWTP, 2013) but due to budget restrictions it runs at only $20{,}000m^3$, operating every other day (WWTP, 2013). The water is treated every other day and discharged into the nearby waterway that flows into the Ping in Hang Dong. The discharged water is only measured for DO levels, and the water quality pre-treatment is not measured, so the efficiency of the treatment cannot be assessed. The system produces $50m^3$ of sludge per year which is dredged and dumped without any monitoring of its quality, and as with the household septic tanks the government official who was interviewed did not know where or how it was disposed. Interviews with the sanitation department and water treatment plant indicated that there is little communication between the two departments. Engineers at the water plant were under the impression that the plant treated the entirety of waste water from the city.

According to the law, businesses including hotels and hospitals are responsible for their own waste water treatment. However, the fines for discharging wastewater into the water bodies are low (5000 THB). As such, many businesses may find it preferable to pay the eventual fine rather than investing in water treatment. Moreover, while the secretary mayor (2013) and water quality analyst (Water Quality Analysis, 2013) both indicate that many businesses including hotels have been observed discharging untreated wastewater, few are ever fined (Secretary Mayor, 2013). Recently introduced monitoring systems for water treatment rely on self-monitoring in combination with scheduled tests by local authorities (Water Quality Analysis, 2013), such a system is more susceptible to fraud. Additionally, businesses might be checked if the government receives reports of suspicious water being discharged into the canal. According to state officials this happens quite often and complaints usually originate from chumchon (Water Quality Analysis, 2013; Sanitation Department, 2013; Secretary Mayor, 2013). This type of control primarily effects bigger establishments, as the wastewater they produce is in larger quantity and more noticeable. During the research various hotels were interviewed but none were willing to show their wastewater treatment system. Many businesses also claimed that they were not even aware of any regulations for wastewater treatment.

Figure 13 Study Area for Justice of Distribution

Parameters	Standards
pH	5-9
SV_{30}[7]	0.1-200 mg/L
Temperature	25-35°C
DO	1-8 mg/L
BOD	<20 mg/L
SS	<30 mg/L
TCB	<5,000 MPN/100 ml
Oil and grease	<20 mg/L
TKN	<35 mg/L
COD	<120 mg/L
Settleable solids	<0.5 mg/L
Sulfide	<0.1 mg/L
TDS	<500 mg/L
TFB	<1000 MPN/100ml

Source: Lanna Hospital interview, 2013

Two private WWTPs are known to discharge water into the Mae Kha, including the Chiang Mai University (CMU) WWTP and Lanna Hospital WWTP (Figure 12 north and west of the city square). The CMU WWTP is the largest WWTP in the city and is responsible for the waste water from CMU campus, including University Hospital dorms, canteens and laboratories of the science faculties. The water treatment consists of screens, sedimentation tanks, aeration tanks, clarifier tanks, chlorination tanks, sludge thickener, an anaerobic sludge digester and sludge drying beds (Tsuzuki, 2009). The plant treats 100,000 m^3 per day and releases the treated water to the Ku Wai stream west of the city. Before the water discharged from science laboratories reaches the WWTP, departments apply some level of pre-treatment.

[7] Active sludge volume : Active Sludge is good sludge, It lives in the reactor chamber of the SBR and contains all the bacteria needed to treat the sewage that comes in contact with it.

Table 7 Standards for hospital effluents

The Lanna Hospital WWTP includes a settling tank, filtering system and aeration tank, and is discharged into the upper Mae Kha. It treats and discharges 220m^3 per day (Lanna Hospital, 2013). The water is drained separately from the hospital wards, the canteen, and the laboratories, but they are all treated together. The water discharged by hospitals is required to meet the standards indicated in Table 7. This list falls short of the recommendations from the WHO (n.d.) for health care establishments, which also include:

- Microbiological pathogens
- Hazardous chemicals
- Pharmaceuticals
- Radioactive isotopes
- Local hazards (of contagious disease, e.g., cholera)

An Interview with the chief of the hospital laboratories indicated that while the content of hazardous chemicals in wastewater discharged from the laboratory facilities were not monitored, they should be low, as the staff follows standard procedures for dilution of materials containing hazardous chemicals (Lanna laboratories, 2013).

Other sources of water

The most visible sources of wastewater effluent to the Mae Kha canal are the various chumchon located near the banks of the city which have pipes sticking out directly from the houses to the canal. It is therefore not surprising that these chumchon are often singled out as responsible for the water quality of the city. In fact, various restaurants and hotels also had pipes flowing directly into the canal, most notably Gekko restaurant and President Hotel, but also garages, laundries and other small businesses. Information on Thai quality standards for each of these effluents are contained in Annex 6, Annex 7 and Annex 8.

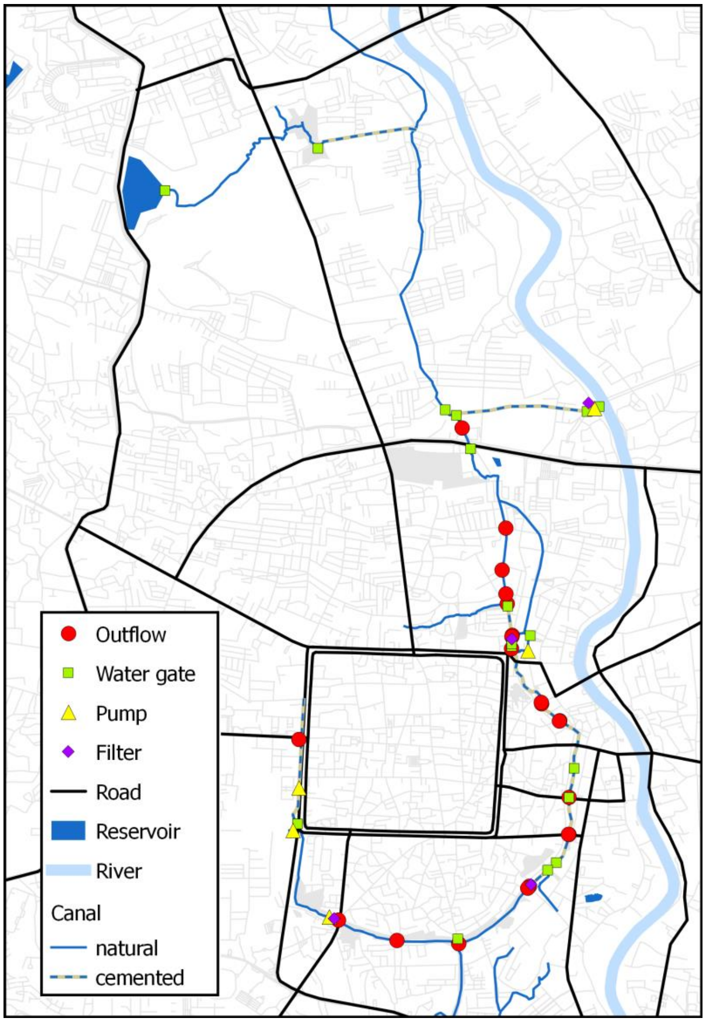
The biggest source of wastewater by volume, however, includes the majority of the rest of the city (Sanitation Department, 2013, Kold et. al., 2001), which drains into the Mae Kha. 15 outflow pipes for the city's mixed drainage were mapped along the Mae Kha, 2 – 4 at each bridge crossing the Mae Kha (red dots, Figure 14). The impact of storm drains on urban streams has been well documented (unesco-ihe, n.d.; Walsh et. al., 2005) as discussed in the previous chapter. Additionally, the central moat discharges water into the Mae Kha in at least two locations, in the northeast and southwest corners of the canal.

Another less visible but significant source of wastewater is a pig slaughter house, owned and operated by the municipality, which discharges untreated wastewater directly into the Mae Kha. This slaughter house is located out of view, behind Hua Fai community, and discharges its waste into a small channel that first runs through the community before reaching the Mae Kha. This open drainage channel constitutes a serious health risk to the Hua Fai community. The FAO (Verheijen et al., 1996) lists the main waste products of a slaughter house to be:

1. Manure, contents of stomach and intestines
2. Edible products such as blood and liver
3. Inedible products such as hair and bones
4. Fat (recovered from the wastewater by means of fat-separation)
5. Wastewater (average values BOD: 5, COD: 10, TKN: 0.68, SS: 5.6, P: 0.05)

Interviews with government officials (water quality analysis, 2013) and an employee of the slaughter house (2013) indicate that the wastewater is not monitored at this site, but manure and the contents of pig stomachs and intestines are washed out with the wastewater and discharged daily to the canal. Other interviews suggested that leftover inedible parts are sometimes also discharged into the canal (Ha Tanwa, 2013; Samut, 2013). This was denied by employees of the slaughter house, however pig skin and hair were both found during water sample collections in the immediate area.

Figure 14 Water infrastructure for the Mae Kha



Source: Self-made map of the study area using survey data, Google Earth, Open Street Maps, QGIS

Various markets located along the canal including Tipanet Market, Muay Mai Market and Kom Market are also known to discharge their untreated wastewater to the canal (Sanitation Department, 2014). However, surveys of the areas by the researchers were only able to locate the discharge point for the Kom market, located south of the City near where the Ku Wai and Mae Kha canals merge. At this discharge point, it is likely that the market effluent combines with wastewater from a larger portion of the city before it enters the canal, as the flow is fairly high. Water leaking from septic tanks of households and businesses located along the canal are likely to be an additional source of water pollution, but are not monitored. There is also no data to assess leakage of the wastewater pipes that are buried beneath the Mae Kha, considering the age of the pipes and the lack of maintenance this is another likely contributor.

Water Infrastructure

Besides the drainage systems, other infrastructure build around the Mae Kha were also mapped. Major components included the cement lining of parts of the canal, water gates, water pumps, and filtration stations (Figure 14). Infrastructure related to the Mae Kha has two main goals: securing water for the agricultural area (upstream), and preventing floods in the urban area (downstream). The construction of roads around the city, forming two large circles around it, has cut the urban trajectory of the Mae Kha into three parts: the upper Mae Kha, the middle Mae Kha, and the lower Mae Kha. These three parts are separated by large closeable water gates that coincide with the outer rings of the city. The study focuses on the middle section of the Mae Kha.

The natural flow of water from the Suthep mountain range in the Northwest into the Mae Kha has been disrupted by a large irrigation canal which captures the majority of this water, as well as several small dams in the Suthep foothills area. One of these, a small dammed lake called “green lake” flows into the Mae Kha (start of the Mae Kha in the north in Figure 14). This dam is surrounded by Chiang Mai Lanna golf course, which is also a significant source of water demand in the area, especially in the dry season, as well as a potential source of fertilizer and pesticide pollution (Salenave, 2011). This upstream area has a lower density of housing and a generally natural riparian zone.

Proceeding downstream, the stream is diverted at two locations before it reaches the outer ring of Chiang Mai, through cement lined canals and water gates (Figure 14). The first diversion of the canal is used to streamline two different streams into a straight line to the urban area, which increases the water flow and hydraulic efficiency towards the second canal diversion, which discharges water into the Ping River to protect the city from flooding during the rainy season (Sanitation Department, 2013; Marine Department, 2013). This happens just before the Lanna Hospital, making their WWTP the main water source for areas downstream of the hospital during certain parts of the year (Kold et al., 2001). The area downstream from this area also has a higher density of households.

The water gates to the Ping also include pumps which make it possible for water to be pumped from the Ping into the Mae Kha during the dry season. A similar pump is located at a water gate at the start of the study area, just before chumchon Un Ari. This pump brings water in through a pipe from the Ping river to flush the inner city trajectory of the Mae Kha during the Songkran and Loi Krathong festivals (Un Ari, 2013; Sanitation Department, 2013). Upstream of this water gate, the canal is divided into two streams. When the gate is closed, the upstream water levels rise leading to an increase in flow through the side stream, which passes by the Muay Mai market before returning to the main course.

The stream which carries the wastewater from the Muay Mai Market maintains a fairly steady flow (Sanitation department, 2014). This area is surrounded by undeveloped lands, and is not very accessible or visible. However, communities in this side stream, including chumchon Samut, located downstream, and chumchon Papleng (2013), located midstream, both report yearly flooding events. There are numerous infrastructural interventions at the outflow point of the side stream into the Mae Kha, including a water gate, and two filters to strain debris out of the canal, though neither of the filters are functional (Sanitation Department, 2013). Much of this infrastructure was built by the national government, while the local government lacked the budget and skilled personnel to utilize it (Wassan, 2013).

In the main course of the canal, stretching from the initial water gate in chumchon Un Ari up to chumchon Hua Fai, is a 3km section lined in cement (Figure 14). The lining of the canal increases the hydraulic efficiency of the water flow through the city center. Two small water gates located at the end of the cement lined canal control the inflow of nearby side streams and maintain a higher water level in the city during the dry season. Another filter unit is located at the end of the cement-lined section of the canal, and like the two upstream, it is not operational.

Downstream from the cemented section, the canal continues into a natural riparian zone. This area is primarily occupied by chumchon, with many parts unreachable by large vehicles and with a high density of households. The narrower cement-lined canal, combined with low lying bridges, increases peak flow in this area during the rainy season. This causes stream bed erosion and widening of the stream in the downstream natural riparian zone, increasing pollutants and suspended matter in the water and threatening the habitat and biodiversity of aquatic life (unesco-ihe, n.d.). The location of households along the canal banks also narrows the canal and limits the riparian area, further exacerbating these risks.

The government's solution is to dredge the canals to avoid the flooding, but the concentration of households around the canal and low bridges obstruct these activities. Some households are removed in order for dredging machinery to gain access to the canal, and the recovered sludge is then dumped onto the banks of the canal. Many pollutants are stored in the soil, and dredging can release these into the water, decreasing the quality (Pitt, 1995). Dumping the sludge in residential areas carries serious health risks if the sediments have high levels of heavy metals (Stephens et al., 2001). Previous research on heavy metals content in the Mae kha show an increasing trend (Kold et al., 2001; Gugino, 2006; Yang, 1997)

The Ku Wai stream, which flows to the west of the city, is fed by the adjacent CMU WWTP and Pimanship golf course. The flow is controlled by a water gate located near the southwest corner of the city's outer moat. Suan Karnhanapisek Park is located just downstream of the water gate, to the south of the moat's southwest corner. Within the park, canal water is aerated by an installed cascading waterfall. After the park it continues through chumchon Tipanet, down to Tipanet road where a pump and filter facilitate the flow of water under the road, and downstream to join the Mae Kha.

The two streams merge into one which flows downstream to the Ping River. On the way, there is third fork at Mahidol road, where the water can be rerouted through an alternate waterway that also leads to the Ping. The final portion of the canal's trajectory is lined with cement and optionally dammed with a water gate. At this point, large amounts of surface foam are visible, indicating probable pollution, commonly a result of household wastewater with significant levels of laundry and soap residues. An accompanying strong smell of sulfur persists, indicating eutrophic conditions (Chapman, 1996).

Summary of findings

A survey of water infrastructure in the city indicates that many services are designed to cater to a limited area. Facilities for wastewater treatment in the city are severely lacking, and the areas which have partial coverage are concentrated along the touristic area in the city center. The majority of the wastewater from the city is discharged into the canal. The water routing infrastructure tells a similar story. The systems in place protect the city center from flooding, not only neglecting other parts of the city, but increasing the risk and severity of flooding in such areas. However, the largest obstacle is the lack of information on these systems, which makes monitoring and enforcement of regulations a difficult task.

Urbanization is accompanied by increases in impervious surfaces, and the expansion of efficient hydraulic conveyance systems. This decreases the amount of the total rainfall which is available for infiltration, and thereby decreases groundwater recharge and subsurface flow. This in turn affects stream health by lowering base flows. Thus, in the long dry season, stream flow contributors mainly consist of wastewater collected by the city drainage system or discharged directly by households and businesses (unesco-ihe, n.d.).

Results of water quality measurements

This chapter looks in detail at the water quality of the Mae Kha using 19 parameters: water temperature, air temperature, pH, alkalinity, conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), free carbon dioxide, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates, ammonia nitrogen, TKN, phosphate, chloride, hardness, oil and grease, total coliform bacteria and fecal coliform bacteria.

Table 8 Classification and uses of surface waters in Thailand

Classification and Objectives	
Classification	**Objectives/Condition and Beneficial Usage**
Class 1	Extra clean fresh surface water resources used for : (1) consumption which does not require complete water treatment processing, only ordinary processing 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 processing before use (2) conservation of aquatic organisms (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment processing before use (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption which requires special water treatment processing before use (2) industry
Class 5	The sources which are not suitable for classification in classes 1-4 and used for navigation

Source: PCD, 2013

The measured results are compared against Thai standards for surface water and effluents as well as international standards used by the WHO (Chapman, 1996), FAO (Ayer & Westcot, 1985) and EPA (2001).

The data were analyzed using SPSS non-parametric statistical instruments to answer questions relating to the spatial and seasonal differences in water quality.

Thai classification of surface waters (Annex 4) uses 18 parameters to define the class to which a water sample belongs (Table 8). The water in the Mae Kha canal generally falls into class 5. EPA (2001) standards apply a similar categorization of surface waters, with 3 classes (A1, A2 and A3), depending on the (increasing) degree of treatment which should be applied, thus waters not falling within these standards are comparable to the class 5 waters of Thailand. The EPA uses 39 parameters to define the quality of surface waters (2001, p15).

Site Observations

Sites 1 and 10 change which represents the water quality upstream and downstream from the study site, change after the first round of tests. This was done after the initial chosen sites seemed unreachable.

During the tests in November the canal looked best. This period was relatively cool in Chiang Mai and the test followed a few heavy rain events and the flushing on the canal for the Loi Krathong festival. The riparian area was green and lush and the water, having a green color flowing through the city, made it fresh and agreeable. However, it should be mentioned that the area was surveyed during the rain event a few days earlier and much of the area downstream of the city was flooded, with chumchon residents trying to unclog bridges which were plugged with trash and water hyacinths that had been carried down the canal from the city.

Table 9 Canal depth, velocity, width and riparian zone at sample sites

Site	Depth (m) Sept	Depth (m) Nov	Velocity (m/s) Sept	Velocity (m/s) Nov	Width (m)	Riparian zone
1 Upstream	60	15	0.91	0.28	4.66	Earthen banks vegetated, with water plants
2 Un Ari	55	47.5	0.20	0.15	8.41	Cement
3 Sri Don Chai road	>100	>100	0.38	0.17	8.55	Cement with water plants on either side
4 Slaughter house	120	n.a.	0.54	0.30	11.65	Earthen banks bare with some fruit plants planted and chickens
5 Kampaeng Ngam	120	n.a.	0.76	0.45	9.23	Earthen banks with fruit plants planted
6 Pre-merge Mae Kha	150	50	0.44	0.25	6.95	Earthen banks with fruit plants planted
7 Ku Wai	150	32	0.40	0.36	4.74	Earthen banks with fruit plants planted
8 Kanchanaphisek Park	190	n.a.	0.30	0.13	10.38	Stepped hollow brick with plants and a park[8] around the area
9 Merge	150	65	0.68	0.46	4.74	Earthen banks with fruit plants planted
10 Downstream	50	19	2.08	2.11	9.45	Cement tunnel

Source: observations in 2013

July was surely the worst quality measured, however during the initial mapping of the canal in April it had appeared to be in an even worse state. Between April and July the first rain events of the season occurred and the canal was flushed in late April for the Songkran festival. Nonetheless both dates had very low water

[8]In the third occasion most of the smaller shrubs, grass and weeds had been pulled, so the soil was bare with the exception of larger trees

levels, with almost no measurable flow in the urban area. The canal smelled like sulfur, especially downstream and upstream of the city center. The water running near site 2, in Un Ari, and downstream of this site where the side stream that comes from the Muay Mai Market enters the city had a black and oily complexion. Sandbanks dumped into the canal during previous flood events were often observed, as well as algae growing on the bottom and sides of the canal. Gas bubbles rising from the sediment indicated the anaerobic decomposition of sewage sludge and produced a notably ripe stench. Downstream of the city, accumulations of surface foam were seen covering the canal. Along the Ku Wai stream, which flows faster and has a grayish color in the dry season, thick slabs of white/grayish algae were seen along the sides of the canal, and large pieces of black algae were floating in the canal. Many parts of the canal both inside and outside of the city were covered by water hyacinths.

During the tests in September, it had not rained heavily right before the samples were collected, though it had been cloudy and rained a little almost every day. The night after collection it rained heavily and the next day the canal was green, however, on the day of collection the canal had been dark and covered by water hyacinths in most of the area.

The depth and velocity could not be measured in the first round of tests, as the appropriate tools to measure the depth were not available, and flow was insufficient. For the rounds where depth was measured a decrease was observed between September and November (Table 9). The velocity of the stream also decreased between September and November (Table 9), which follows expectations with less rain and runoff to feed the canal directly and a reduced base flow. The width of the canal was stable as the housing around the canal and cemented lining ensure a limited capacity for change. The riparian zone can be broadly divided between a cement lined urban area and earthen banks with tree shading and planting of the surrounding areas.

Weather

The weather was warm and sunny for the first round tests in July, during the entire collection period except for a the last site when the sun was already setting, around 6pm. The second and third rounds of tests were faster and ended earlier, around 3pm. For the second round of tests it was sunny in the morning, became cloudy around 12pm, rained a little around 1pm and remained cloudy. For the third round of tests in November it was cool and cloudy, with some light rain around mid-day before the sky cleared.

Air and Water temperature

Table 10 Air and water temperature for each water sample collection.

Site	Temperature (°C)					
	July 4th		September 13th		November 27th	
	Air	Water	Air	Water	Air	Water
01. Upstream	27*	27	28	27	24	25
02. Un Ari	31	29	28	28	26	27
03. Sri Don Chai road	30	29	29	26	25	26
04. Slaughter House	29	29	29	28	26	26
05. Kampaeng Ngam	29	29	30	29	27	27
06. Pre-merge Mae Kha	32	30	29	28	30	27
07. Ku Wai	35	30	29	28	30	28
08. Kanchanaphisek Park	32	30	28	28	27	27
09. Merged	34	31	30	28	30	28
10. Downstream	34*	30	30	28	31	26
Average	**31**	**29**	**29**	**28**	**28**	**27**

Thai standards for appropriate water temperature for aquatic life is 23–32°C (PCD, 2013). Orange highlights indicate when water temperature is equal or higher than air temperature.

Air temperature was measured in the range of 24 – 34°C (Table 10). The lowest air temperature was measured upstream (site 1) in November, and the highest was measured in the Ku Wai stream (site 7) in July. Water temperature was measured within the range of 25 – 31°C (Table 10), the lowest water temperature was measured upstream (site 1) in November, and the highest was measured at the point where the Mae Kha and Ku Wai streams merge (site 9) during July. On average, measured temperatures were higher in July and cooler in November. As expected, measured water temperatures are generally lower than air temperatures. However, cases were recorded with water temperature equal or warmer than the air temperature (Table 10).

Higher water temperature is often an indication of water pollution. However the sites where higher temperatures were measured were not consistent, and not even the warmest of the samples. Moreover, it can be seen that such instances were more common in November, which could be explained by the relatively cool weather in November increasing the appeal of a warm water shower. Also it is of course possible that it is due to human error.

Research by Kold et al. (2001) measured no significant changes in water quality during a 24-hour survey, nonetheless discharges are prone to be concentrated in certain parts of the day. The fact that the first round of tests in the present study took several hours longer than the second and third round of tests is sure to have had an effect on the temperatures measured, and potentially also on other parameters. Discharges from the ice factory (Kold et al., 2001) and slaughter house (2014) are also concentrated in evening and nighttime hours which can produce diel variations in these areas.

Temperature also affects many other water quality parameters. The effects of increased water temperature include: an increase in the rate of chemical reactions; increased evaporation and volatilization of substances from water; decreases in the solubility of gases such as O_2, CO_2, N_2, and CH_4; impacts on the metabolic rate of aquatic organisms increasing respiration rates leading to more oxygen consumption and decomposition of organic matter; increased growth rates of bacteria and phytoplankton leading to increased water turbidity, macrophyte growth and algal blooms, when nutrient conditions are suitable (Chapman, 1996).

Alkalinity and pH

Table 11 Alkalinity and pH measurements for each water sample.

	Alkalinity as $CaCO_3$ (mg/L)			pH		
	July 4th	Sep. 13th	Nov. 27th	July 4th	Sep. 13th	Nov. 27th
Site	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**
01. Upstream	<20*	54	72	6.9	5.7	6.7
02. Un Ari	<20	106	155	4.6	6.7	6.8
03. Sri Don Chai road	<20	132	143	4.3	6.7	6.7
04. Slaughter House	<20	102	138	4.7	6.7	6.8
05. Kampaeng Ngam	<20	114	138	4.2	6.7	6.7
06. Pre-merge Mae Kha	<20	120	159	4.0	6.9	7.0
07. Ku Wai	<20	118	138	5.5	6.8	6.9
08. Kanchanaphisek Park	<20	98	95	6	6.9	6.9
09. Merge	<20	118	139	4.7	6.8	7.0
10. Downstream	<20*	110	99	4	7.0	7.2
Average	**6**	**107**	**127**	**4.9**	**6.7**	**6.9**

Thai standards for surface water quality require 5-9 (PCD, 2013). Red indicates pH below these standards.

There is a close relationship between alkalinity and pH levels with higher alkalinity contributing to a stable, basic pH. Levels of alkalinity are largely defined by the concentration of carbonates. The highest average alkalinity and pH levels were measured in November and the lowest in July (Table 11). Alkalinity was measured in the range of 3 – 155 mg/L as $CaCO_3$. The lowest alkalinity was measured at the downstream site (site 10) in July, and the highest level at the pre-merge Mae Kha site (site 6) in November. pH measurements ranged from 4 – 7.2, with the lowest level at the downstream site (site 10) in July and the highest were at the park (site 8) and pre-merge Mae Kha (site 6) sites in November. Natural waters have a pH of 6 – 8.5, such as were measured in September and November. Lower values (< 6) are known to occur in dilute waters with high organic content (Chapman, 1996, p84). pH levels below 4 are highly acidic and can affect fish reproductive systems. Waters with low alkalinity (< 24 mg/L as $CaCO_3$) have a low buffering capacity and can, therefore, be susceptible to fluctuations in pH, for example from atmospheric acidic deposition (Chapman, 1996, p85).

There is no statistically significant difference in the pH or alkalinity between different sites: H(2) = 4.644, p = 0.864 > 0.05 for pH[9] and H(2) = 4.631, p = 0.866 > 0.05 for alkalinity[10]. Moreover, a Mann-Whitney U test indicated no statistically significant difference in pH and Alkalinity values between the Ku Wai and Mae Kha canals: U = 25, P = 0.132 > 0.05 for pH and U = 29.000, P = 0.212 > 0.05 for alkalinity.

Increasing average levels of alkalinity and pH were observed between July and November. Statistical tests were done to confirm these relationships. A Friedman test showed no statistically significant difference in alkalinity between seasons ($\chi^2(2) = 14.877$, p = 0.094 > 0.05). However, a statistically significant difference was found in pH between seasons ($\chi^2(2) = 12.800$, p = 0.002 < 0.05). Post hoc analysis with Wilcoxen signed-rank tests applying a Bonferroni correction resulted in a significance level set at p < 0.017. Median measured pH levels for July, September and November were: 4.64, 6.77 and 6.85, respectively. There were significant differences between July and September (Z = -2.599, p = 0.009 < 0.017), July and November (Z = -2.701, p = 0.007 < 0.017) and September and November (Z = -2.601, p = 0.009 < 0.017).

Free Carbon Dioxide

Table 12 Free carbon dioxide measurements for each water sample.

Site	Free CO_2 (mg/L)			
	July 4th	September 13th	November 27th	
	Early	Mid	Late	Average
01. Upstream	2.2*	241.8	28.7	90.9
02. Un Ari	263	47.4	49.1	119.83
03. Sri Don Chai road	822.8	59.1	57	312.97
04. Slaughter House	8	25.8	23.9	19.23
05. Kampaeng Ngam	245	36.5	27.8	103.1
06. Pre-Merge Mae Kha	803.2	42.4	55	300.2
07. Ku Wai	27.7	35.7	34.7	32.7
08. Kanchanaphisek Park	279.3	38.9	43.7	120.63
09. Merge	1119.9	31.6	63.4	404.97
10. Downstream	600*	23.6	12.5	212.03
Average	**417.11**	**58.2**	**39.58**	**171.63**

There are no Thai standards for free CO_2 levels (PCD, 2013).

[9]With mean ranks for pH at site 1 of 15.00, site 2 of 11.67, site 3 of 9.83, site 4 of 13.83, site 5 of 11.33, site 6 of 18.00, site 7 of 18.17, site 8 of 19.67, site 9 of 18.17 and site 10 of 19.33

[10]With mean ranks for alkalinity at site 1 of 10.67, site 2 of 16.67, site 3 of 20.33, site 4 of 16.17, site 5 of 17.17, site 6 of 19.17, site 7 of 16.00, site 8 of 9.83, site 9 of 17.67 and site 10 of 11.33

High levels of free CO_2 were measured at several locations close to the city especially during the dry season, indicating low levels of plant productivity. The free CO_2 levels ranged from 2.2 – 1119.9 mg/L, with the highest level measured at the merge point of the Ku Wai and Mae Kha streams (site 9) in July and the lowest level at the upstream site (site 1) also in July (Table 12). The levels of free CO_2 varied wildly, with the lowest average levels measured at near the slaughter house (site 4), and the highest average levels measured at the merge point (site 9). However, the Kruskal-Wallis H test showed no statistically significant difference between free CO_2 levels at different sites ($H(2) = 13.077$, $p = 0.159$)[11]. The Mann-Whitney U test indicates that the free CO_2 levels in the Ku Wai canal were significantly lower than those in the Mae Kha canal ($U = 2.000$, $P = 0.001 < 0.05$).

As with the pH and alkalinity measurements, average levels of free CO_2 improved (decreased) between July and November. However, a Friedman test showed that the difference in free CO_2 levels between seasons was not statistically significant ($\chi^2 (2) = 15.218$, $p = 0.085 > 0.05$).

Carbon dioxide is highly soluble in water, and atmospheric CO_2 is readily dissolved at the air-water interface. In addition, CO_2 is produced within water bodies by the respiration of aquatic biota during aerobic and anaerobic heterotrophic decomposition of suspended and sedimented organic matter. CO_2 dissolved in natural water is part of an equilibrium involving bicarbonate and carbonate ions, whose concentrations are dependent to some extent on the pH, and affect acidity and alkalinity. At high concentrations of free carbonic acid (pH 4.5 or lower), water becomes corrosive to metals and concrete as a result of the formation of soluble bicarbonates (Chapman, 1996, p88). High levels of free carbon dioxide may also enhance the effects of de-oxygenation and of high ammonia concentrations and excessive levels of carbon dioxide that may have adverse effects on aquatic life (EPA, 2001, p37).[12]

Hardness

Table 13 Hardness measurements for each water sample.

	Hardness (mg/L EDTA)			
	July 4th	September 13th	November 27th	
Site	Early	Mid	Late	Average
01. Upstream	124*	53.3	25	67.43
02. Un Ari	116	110	50	92
03. Sri Don Chai	114	110	49	91
04. Slaughter House	164	106.7	52	107.56
05. Kampaeng Ngam	122	116.7	49	95.9
06. Pre-merge Mae Kha	114	120	52	95.33
07. Ku wai	96	110	47	84.33
08. Kanchanaphisek Park	90	86.7	42	72.9
09. Merge	114	116.7	32	87.57
10. Downstream	120*	123.3	24	89.1
Average	**117.4**	**105.3**	**42.2**	**88.3**

Red = hard water, yellow = soft water. No highlight = water that is within a normal range

[11] With mean ranks at site 1 of 11.00, site 2 of 23.33, site 3 of 18.67, site 4 of 20.67, site 5 of 20.67, site 6 of 10.00, site 7 of 4.33, site 8 of 4.33, site 9 of 15.00 and site 10 of 11.33.

[12] Water with a pH level below 7 may dissolve metals to an extent which, if not causing deterioration of storage tanks or distribution mains, may still give rise to undesirable metal concentrations. Such waters are also unlikely to deposit calcium carbonate as a protective scale in pipes. The interrelationship between pH, hardness and alkalinity was studied by Langelier who in 1936 proposed a means of calculating the corrosivity or scale-forming tendencies of a water.

Hardness indicates aggregate levels of minerals, primarily calcium and magnesium, that move through the earth (Chapman, 1996). High levels of minerals (hardness) can influence the total alkalinity of water. Hardness measurements in the study area ranged from 24 – 164 mg/L EDTA (Table 13). The lowest levels were measured at the downstream site (site 10) in November and the highest at the slaughter house (site 4) in July. The most desirable range of hardness is between 80 and 100 mg/L EDTA[13], however there is no definite categorization (EPA, 2001). Total hardness of less than 80 mg/L may result in corrosive water, while hardness above 100 mg/L is considered excessive and may lead to scale deposits in pipes, heaters, and boilers.

The average hardness was measured to decrease between July and November. During July and September most of the samples indicated hard water, while most of the samples collected in November showed soft water. One possible reason for this change in water hardness in November is the fact that the canal was flushed two weeks earlier for the Loi Krathong festival on November 17th. However, "seasonal variations of river water hardness often occur, reaching the highest values during low flow conditions and the lowest values during flood" (Chapman, 1996, p88). The Friedman test showed no statistically significant difference in hardness between seasons ($\chi^2(2) = 7.060$, $p = 0.631 > 0.05$.

The lowest average hardness was measured upstream (site 1) at 64.73 mg/L EDTA, and the highest at the slaughter house (site 4) at 107.56 mg/L. The Kruskal-Wallis H test, however, yielded no statistically significant difference in hardness between the different sites ($H(2) = 2.952$, $p = 0.966 > 0.05$)[14]. The Mann-Whitney U test also indicated no statistically significant difference in hardness values between the Ku Wai and Mae Kha canals ($U = 28.000$, $P = 0.185 > 0.05$).

Dissolved Oxygen

Table 14 Dissolved oxygen measurements for each water sample.

Site	Dissolved Oxygen (mg/L)			
	July 4th	September 13th	November 27th	
	Early	Mid	Late	Average
01. Upstream	0.4*	6.4	4.5	3.76
02. Un Ari	0.0	2.9	0.4	1.1
03. Sri Don Chai road	0.0	1.8	1.2	1
04. Slaughter House	0.0	1.1	0.2	0.43
05. Kampaeng Ngam	0.0	2.2	0.0	0.73
06. Pre-merge Mae Kha	0.0	1.5	0.0	0.5
07. Ku Wai	1.9	1.0	0.8	1.23
08. Kanchanaphisek Park	1.3	4.4	2.7	2.8
09. Merge	0.0	1.7	0.8	1.97
10. Downstream	0.0*	3.7	6.6	3.43
Average	**0.4**	**2.7**	**1.7**	**1.6**

Thai standards: Red= class 5, <2 mg/l. (Class 3: 2-5 mg/L, Class 2: 4-6 mg/L) (PCD, 2013)

Dissolved Oxygen (DO) measurements showed complete absence of oxygen in the water for many sites; such waters cannot sustain life for most species. Surprisingly, fish were observed in both the Mae Kha and

[13] http://www.capitalhealth.ca/nr/rdonlyres/e46h42vuy3uqkmaapv6voufgmf2sccz7gwvvhz7ge57vqmgmstxfz6dans32ukzj40cv2j62jsbuqeu3dwhsvwqzt2b/interpretationofchemicalanalysisofdrinkingwater.pdf

[14] With mean ranks at site 1 of 14.67, site 2 of 16.33, site 3 of 15.33, site 4 of 18.83, site 5 of 19.33, site 6 of 12.33, site 7 of 13.00, site 8 of 10.67, site 9 of 16.00 and site 10 of 18.50.

Ku Wai on various occasions. The average DO level for July was 0.4mg/L, at which time all sample in the inner city Mae Kha had 0 mg/L (Table 14). The Ku Wai stream (sites 7 and 8) fared better with DO levels of 1.3 – 1.9 mg/L, while upstream (site 1) had a DO level of only 0.4 mg/L. The observed differences were confirmed by a Mann-Whitney U test that indicated that average DO levels in the Ku Wai Canal were significantly higher than those of the Mae Kha canal ($U = 13.5$, $P = 0.012 < 0.05$).

Generally, the sites upstream and downstream of the Mae Kha (sites 1 and 10, respectively) had the highest levels of DO, and the park (site 8) had the highest level within in the city. Average levels at these sites all put them into Thai surface water standards class 4 (PCD, 2013). However, a Kruskal-Wallis H test showed no a statistically significant difference between the DO for different sites ($H(2) = 10.341$, $p = 0.324 > 0.05$)[15]. The highest average DO levels were measured in September (2.7 mg/L). In July (average 0.4 mg/L) measurements at all sites indicated DO levels below Thai standards for surface water (2 mg/L). The highest DO level was measured downstream (site 10) at the outflow of the Mae Kha to the Ping, which was 6.6 mg/L in November. A Friedman test showed a statistically significant difference in DO levels between seasons ($\chi^2(2) = 18.908$, $p = 0.026 < 0.05$). Post hoc analysis with Wilcoxen signed-rank tests using a Bonferroni correction resulted in a significance level set at $p < 0.017$. Median measured DO levels for the July, September and November were 0.00, 2.20 and 0.80, respectively. There were significant differences between July and September ($Z = -2.803$, $p = 0.005 < 0.017$), but no significant differences between July and November ($Z = -1.960$, $p = 0.050 > 0.017$) or September and November ($Z = -1.784$, $p = 0.074 > 0.017$).

Waste discharges that are high in organic matter and nutrients can lead to decreases in DO concentrations as a result of increased microbial respiration, that occur during the degradation of the organic matter. Water with D.O. levels of 0 mg/L present anaerobic conditions (Chapman, 1996, p86). DO levels are also limited by temperatures; under the conditions present during testing, with temperatures ranging from 27 – 29°C, DO can reach a maximum of 7.67 – 7.95 mg/L.

Biochemical Oxygen Demand

Table 15 Biological oxygen demand measurements for each water sample.

Site	BOD_5 (mg/L)			
	July 4th	**September 13th**	**November 27th**	
	Early	Mid	Late	**Average**
01. Upstream	7*	4.72	3.2	4.97
02. Un Ari	32	22.2	9.2	21.13
03. Sri Don Chai road	35	11	22	22.67
04. Slaughter House	31	7.65	8.12	15.59
05. Kampaeng Ngam	20	9	26	18.33
06. Pre-merge Mae Kha	33	7	6.97	15.66
07. Ku Wai	18	9	15.6	14.2
08. Kanchanaphisek Park	32	14	4.97	16.99
09. Merge	15	8	26	16.33
10. Downstream	12*	8	1.2	7.07
Average	**23.5**	**11.4**	**10.1**	**15**

Thai standards for surface water quality: Red = class 5 >4 mg/L. (Class 4: 2-4 mg/L, class 3: 1.5-2 mg/L, class 2: <1.5 mg/L.) (PCD, 2013)

One factor that can cause low levels of DO are high levels of microbial life in the water, which are indicated by the measure of BOD and which can also cause increases in Free CO_2 (Chapman, 1996). High levels of

[15]With mean ranks at site 1 of 22.50, site 2 of 13.83, site 3 of 14.00, site 4 of 10.33, site 5 of 10.83, site 6 of 8.33, site 7 of 19.00, site 8 of 23.33, site 9 of 12.50 and site 10 of 20.33

BOD were measured throughout all sites (> 4mg/L), which indicates that under Thai standards the water should only be used for navigation (Class 5, Annex 4, PCD, 2013). While EPA standards are laxer at 5 – 7 mg/L, most of the samples exceed this standard as well (EPA, 2001, p75). The measurements at the upstream (site 1) and downstream (site 10) sites showed lower levels of BOD during November, satisfying the standards for Thai surface water class 4 and class 2, respectively. Unpolluted waters typically have BOD values of 2 mg/L or less, whereas those receiving wastewaters may have values of > 10 mg/L (Chapman, 1996, p99); many sites had values much higher than this.

On average, the highest levels of BOD were measured at Sri Don Chai road (site 3) at 22.67 mg/L (Table 15). A Kruskal-Wallis H test indicated no significant difference in BOD between sites ($H(2) = 11.191$, $p = 0.263 > 0.05$)[16]. There were also no statistically significant differences in BOD values between the Mae Kha and Ku-Wai canals ($U=38$, $P = 0.586 > 0.05$).

With a range of 1.2 – 33 mg/L, there was an apparent decreasing trend in average BOD from July to November. A Friedman test showed a statistically significant difference in BOD between seasons ($\chi^2(2) = 9.800$, $p = 0.007 < 0.05$). Post hoc analysis with Wilcoxen signed-rank tests with a Bonferroni correction ($p < 0.017$) showed that median BOD levels for July, September and November were 25.5, 8.50 and 8.66 mg/L, respectively. There was significant difference between July and September ($Z = -2.803$, $p = 0.005 < 0.017$), but none between July and November ($Z = -1.988$, $p = 0.047 > 0.017$) or September and November ($Z = -0.459$, $p = 0.646 > 0.017$).

Chemical Oxygen Demand

Table 16 Chemical oxygen demand measurements for each water sample.

Site	COD (mg/L) July 4th Early
01. Upstream	120
02. Un Ari	160
03. Sri don chai road	138
04. Slaughter House	128
05. Kampaeng Ngam	120
06. Pre-merge Mae Kha	114
07. Ku Wai	138
08. Kanchanaphisek Park	138
09. Merge	114
10. Downstream	96
Average	**132.6**

Thai industrial effluent standards require < 120 mg/L, and large pig farm effluent standards require < 400 mg/L for standards

COD is another measurement of oxygen consumption, and is correlated to BOD levels which are usually somewhat lower. Unfortunately, due to difficulties during the testing phase, only the COD measurements from the first round of tests in July are presented here (Table 16). COD is not included in the Thai surface water quality standards, but is included in the effluent standards for industrial water use and pig farm effluent. It stands to reason that water quality for surface water should be lower than that of industrial effluents. EPA standards require BOD < 40 mg/L (EPA, 2001, p79).

[16]With mean ranks at site 1 of 3.83, site 2 of 21.50, site 3 of 22.33, site 4 of 15, site 5 of 19.30, site 6 of 13.50, site 7 of 17.17, site 8 of 16.17, site 9 of 17.33 and site 10 of 8.83.

Generally, concentrations of COD observed in surface waters range from < 20 mg/L in unpolluted waters to > 200 mg/L in waters receiving significant effluent (Chapman, 1996, p98). COD tests are best applied to heavily polluted waters and to wastewaters. This is because the sensitivity of the normal test procedure is not adequate for waters with an oxygen demand of < 25 mg/L (EPA, 2001, p78). During the tests performed in July, COD levels ranged from 96 – 160 mg/L. Average COD levels were 132.6 mg/L, which is above the Thai standard for industrial effluent of 120 mg/L. The pre-merge Mae Kha, merge, and downstream sites (sites 6, 9 and 10, respectively) were the only sites not in violation of the 120 mg/L industrial effluent standard. The highest level of COD was measured at Un Ari (site 2) at 160 mg/L. It appears that the level of COD is somewhat diminished by the downstream site (site 10) as the stream leaves the city, but is still quite high.

Total Dissolved Solids

Table 17 Total dissolved solids measurements for each water sample.

Site	TDS (mg/L solids)			
	July 4th	September 13th	November 27th	
	Early	Mid	Late	Average
01. Upstream*	415*	80	126	207
02. Un Ari	343	188	300	277
03. Sri don chai road	321	193	308	274
04. Slaughter House	346	203	306	285
05. Kampaeng Ngam	346	198	278	274
06. Pre-merge Mae Kha	331	218	327	292
07. Ku Wai	286	218	285	263
08. Kanchanaphisek Park	245	187	273	235
09. Merge	333	224	333	296.67
10. Downstream*	325*	174	190	229.67
Average	**329**	**188**	**273**	**263.33**

Thai standards require < 5000 mg/L industrial effluent, < 500 mg/L for building effluent and, < 1300 mg/L for irrigation use.

Concentrations of total dissolved solids upstream between July and November ranged from 80 – 415 mg/L(Table 17). These measurements represent two different upstream locations, with the location used in July differing from that of September and November. The lowest measurement in the inner city area was 187 mg/L at the park (site 4) in September. The highest measurement was 346 mg/L at both Kampaeng Ngam and the adjacent slaughter house (sites 9 and 8, respectively) in July (Table 17). A Kruskal-Wallis H test found no statistically significant difference in TDS levels between different sites ($H(2) = 5.184$, $p = 0.818 > 0.05$)[17]. The Mann-Whitney U test also indicated no statistically significant difference in TDS values between the Ku Wai and Mae Kha canals ($U = 26.500$, $P = 0.150 > 0.05$). While there are Thai standards for TDS in surface water, the measured values did not violate any of the effluent standards which did include TDS (industrial effluent, building effluent and irrigation use). The FAO indicates that water used for irrigation usually has levels of TDS in the range of 0 – 2000 mg/L, with levels below 450 mg/L being preferable. The measured TDS levels all fall within these ranges.

The lowest average levels of TDS were measured in September, at 188 mg/L, and the highest in July, at 329 mg/L. The site with the lowest average TDS levels was the upstream site (site 1), while the site with the highest average TDS levels was the merge point between the Mae Kha and Ku Wai canals (site 9), with

[17]With a mean ranks for site 1 of 11.00, site 2 of 16.67, site 3 of 16.00, site 4 of 18.83, site 5 of 17.17, site 6 of 19.17, site 7 of 14.50, site 8 of 10.33, site 9 of 21.00 and site 10 of 10.33

296.67 mg/L. A Friedman test showed a statistically significant difference in TDS between seasons (χ^2 (2) = 16.667, p = 0.000 < 0.05). Post hoc analysis with Wilcoxen signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at p < 0.017. Median TDS levels for the early, mid and late rainy season were 332, 195.50 and 292.50, respectively. There were significant differences in average TDS levels between July and September (Z = -2.803, p = 0.005 < 0.017) as well between September and November (Z = -2.805, p = 0.005 < 0.017), however the difference in TDS levels between July and November was not significant (Z = -1.125, p = 0.260 > 0.017).

These results are not surprising as the canal has lower water levels in July and consists of wastewater in greater proportion. Storm events, which are most common in the period around September, often stir up the sediments, resuspending contaminants that had been buried in the soil (EPA, 2012). In the late season these particles get a chance to settle. Waters with low levels of TDS generally have a low buffering capacity, i.e. low internal resistance to pH change (EPA, 2001, p84) and waters with high levels of TDS may qualify as "saline" (EPA, 2001, p100). TDS levels are also often correlated with conductivity levels (Chapman, 1996, p83), as TDS includes both ionized and non-ionized matter, the first of which is reflected in the conductivity (Ayers & Westcot, 1985).

Conductivity

Table 18 Conductivity measurements for each water sample.

	EC (µS/cm)			
	July 4th	September 13th	November 27th	
Site	Early	Mid	Late	Average
01. Upstream*	779*	151	236	388.67
02. Un Ari	641	353	537	510.33
03. Sri don chai road	610	363	545	506
04. Slaughter House	649	381	548	526
05. Kampaeng Ngam	649	372	540	520.33
06. Pre-merge Mae Kha	634	410	604	549.33
07. Ku Wai	537	409	540	495.33
08. Kanchanaphisek Park	461	351	515	442.33
09. Merge	625	421	620	555.33
10. Downstream*	616*	327	352	431.67
Average	**621**	**354**	**504**	**493**

Measurements of conductivity ranged between 151 – 779 µS/cm. Like the TDS, the lowest level measured was at the upstream site (site 1) in September, and the highest was upstream in July, when another site was used (Table 18). In the inner city, the highest measured conductivity was 649 µS/cm at the slaughter house and Kampaeng Nam (sites 4 and 5) in July, and the lowest was 351 µS/cm at the park (site 8) in November. The site with the lowest average conductivity was upstream (site 1) with 388.67 µS/cm, and the site with the highest average level was at the merge point for the Mae Kha and Ku Wai canals (site 9) with 555.33 µS/cm. However, a Kruskal-Walis H test indicated no statistically significant difference in conductivity between the different sites (H(2) = 5.169, p = 0.819 > 0.05)[18]. Also, a Mann-Whitney U-test indicated that there was no statistically significant difference (U = 26.000, P = 0.139 > 0.05) in conductivity between the Ku Wai and Mae Kha canals.

[18]With mean ranks at site 1 of 11.00, site 2 of 16.17, site 3 of 16.00, site 4 of 19.17, site 5 of 18.00, site 6 of 19.33, site 7 of 14.33, site 8 of 10.33, site 9 of 20.33 and site 10 of 10.33.

The conductivity of most fresh waters range from 10 – 1,000 μS/cm, but can exceed 1,000 μS/cm in polluted waters (Chapman, 1996, p84). The conductivity levels as measured in the study area fall within a healthy range, useable for irrigation under Thai (PCD, 2013) standards (< 2000 uS/cm) as well as FAO (Ayers, 1985) (< 700 uS/cm) and EPA (2001) (< 1000 uS/cm) guidelines.

Seasonally, the highest levels of average conductivity were measured in July (621 μS/cm) and the lowest in September (354 μS/cm). A Friedman test showed that there was statistically significant difference in conductivity between seasons ($\chi^2(2) = 16.800$, $p = 0.000 < 0.05$). Post hoc analysis using a Wilcoxen signed-rank test with a Bonferroni correction ($p < 0.017$) of the median conductivity levels for July, September and November at 629.5, 367.5 and 540 uS/cm, respectively, showed significant differences between July and September ($Z = -2.803$, $p = 0.005 < 0.017$) and between September and November ($Z = -2.803$, $p = 0.005 < 0.017$) but no significant difference between July and November ($Z = -2.293$, $p = 0.022 > 0.017$).

Conductivity is sensitive to variations in dissolved solids – mostly mineral salts – and the degree to which these dissociate into ions, the amount of electrical charge on each ion, ion mobility and the temperature of the solution all have an influence on conductivity (Chapman, 1996, p83). It is important to note that there is an interrelationship between conductivity and temperature, the former increasing with temperature at a rate of about 2% per degree Celsius rise (EPA, 2001, p49).

Nitrates

Table 19 Nitrate measurements for each water sample.

Site	Nitrate (mg/L)			
	July 4th	September 13th	November 27th	
	Early	Mid	Late	Average
01. Upstream	6*	5.7	1.9	4.53
02. Un Ari	14	0.1	9.8	7.97
03. Sri don chai road	36	0.4	7.4	14.6
04. Slaughter House	26	0.7	7.8	11.5
05. Kampaeng Ngam	18	0.4	8.3	8.9
06. Pre-merge Mae Kha	26	0.1	7.5	11.2
07. Ku Wai	32	0.1	8.2	13.43
08. Kanchanaphisek Park	30	0.8	6.7	12.5
09. Merge	36	0.8	7.8	14.87
10. Downstream	24*	0.1	5.2	9.77
Average	**24.8**	**0.9**	**7.1**	**10.93**

Thai standards for surface waters require < 5.0 mg/L (22.13 NO_3^- mg/L), Red = in excess of standards.

The range of Nitrate concentrations varies significantly from 0.1 – 36 mg/L, with the lowest occurring at the Un Ari, pre-merge Mae Kha, and Ku Wai, and downstream sites (sites 2, 6, 7, and 10, respectively) in September, and the highest at Sri Don Chai road and the merge point for the Mae Kha and Ku Wai canals (sites 3 and 6, respectively) in July(Table 19). On average, the site with the lowest levels of nitrate was the upstream site (site 1) with 4.53 mg/L, and the highest averages were at the merge point between the Mae Kha and Ku Wai (site 7), at 14.87 mg/L. Performed Kruskal-Wallis H-tests did found no statistically significant difference in nitrate levels between different sites ($H(2) = 1.502$, $p = 0.997 < 0.05$)[19]. The Mann-Whitney U test indicates that there is no statistically significant difference in nitrate levels between the Ku Wai and Mae Kha canals ($U = 44.000$, $P = 0.938 > 0.05$).

[19]With mean ranks at site 1 of 11.67, site 2 of 15.17, site 3 of 16.67, site 4 of 16.50, site 5 of 14.67, site 6 of 18.50, site 7 of 16.50, site 8 of 16.67, site 9 of 16.17 and site 10 of 12.50.

Average nitrate levels decrease from July to September and then increase again from September to November. July had the highest average nitrate concentrations with 24.8 mg/L and September was the lowest, with only 0.9 mg/L. A Friedman test showed a statistically significant difference in nitrate levels between seasons ($\chi^2(2) = 18.200$, $p = 0.000 < 0.05$). Post hoc analysis was applied using Wilcoxen signed-rank tests corrected by Bonferroni ($p < 0.017$). Median nitrate levels for the July, September and November were 26.00, 0.40 and 7.65, respectively. There were significant differences between July and September ($Z = -2.803$, $p = 0.005 < 0.017$), July and November ($Z = -2.803$, $p = 0.005 < 0.017$) and September and November ($Z = -2.703$, $p = 0.007 < 0.017$).

In September, most sites except site 1, 2 and 5, had levels of nitrate within the acceptable range for Thai water quality standards. In July and November none of the sites had nitrate levels in excess of Thai water quality standards for surface water (> 22.13 mg/L). The FAO suggest levels below 44.26 mg/L to be used for irrigation, but also mentions that levels greater than 22.13 mg/L might have moderate negative effects (Ayers & Westcot, 1985). EPA standards for nitrates in surface waters are set at 50 mg/L (EPA, 2001, p69), which is higher than all values measured in the Mae Kha.

Nitrate may be biochemically reduced to nitrite (NO_2^-) by de-nitrification processes, usually under anaerobic conditions. The nitrite ion is rapidly oxidized to nitrate. Natural concentrations seldom exceed 0.1 mg/L NO_3-N (0.44 NO_3^- mg/L), and can reach higher levels of up to 5 mg/L (22.13 NO_3^- mg/L) due to the discharge of municipal and industrial wastewaters, as well as inorganic nitrate-based fertilizers. Concentrations in excess of 5 mg/L NO_3-N (22.13 NO_3^- mg/L) usually indicate pollution by human or animal waste, or fertilizer runoff (Chapman, 1996, p92).

Ammonia Nitrogen

Table 20 Ammonia nitrogen measurements for each water sample.

Site	Ammonia Nitrogen (mg/L)			
	July 4th	September 13th	November 27th	
	Early	Mid	Late	Average
01. Upstream	30.2*	0.9	4.9	11.99
02. Un Ari	18.2	0.1	10.0	9.44
03. Sri don chai road	15	0.1	7.6	7.55
04. Slaughter House	12.4	0.3	12.0	8.22
05. Kampaeng Ngam	19.4	0.2	8.0	9.21
06. Pre-merge Mae Kha	22.6	0.3	8.2	10.37
07. Ku Wai	13.2	0.1	6.6	6.65
08. Kanchanaphisek Park	14.8	0.1	9.4	8.1
09. Merge	15.8	0.2	11.0	8.99
10. Downstream	16.8*	0.1	7.6	8.16
Average	**17.8**	**0.2**	**8.5**	**8.83**

Thai Standards: Blue = in excess of standards. Thai standards for surface water require < 0.5 mg/L NH_3-N (0,607945, NH_3.).

The levels of ammonia nitrogen measured range from 0.05 – 22.6 mg/L, the lowest level 0.1 mg/L was measured on various sites in September (Un Ari, Sri Don Chai road, Ku Wai, Kanchanaphisek park and downstream), and the highest at the upstream during July followed by pre-merge Mae Kha (site 6) in July (Table 20). On average, the site with the lowest levels of ammonia nitrogen was the Ku Wai (site 7), while the site with the highest average levels was the upstream site (site 1), this was influenced by the high levels during the first round of tests at a different site. The pre-merge Mae Kha site (site 6) showed the highest average level of ammonia nitrogen in the city. Kruskal-Wallis H tests found no statistically significant difference in ammonia nitrogen levels between different sites (H (2) = 1.166, p = 0.999 > 0.05)[20]. The Mann-Whitney U test also found no statistically significant difference in ammonia nitrogen levels between the Ku Wai and Mae Kha canals (U = 42.000, P = 0.815 > 0.05).

The lowest average ammonia nitrogen levels were measured in September at 0.2 mg/L, and the highest in July at 17.8 mg/L. All of the sites had levels of ammonia nitrogen higher than those stipulated by the Thai standard for surface water quality (0.5 mg/L) in July and November, but in September all sites except the upstream site (site 1) complied with Thai surface water standards. A statistically significant difference in ammonia nitrogen levels between seasons was found using a Friedman test ($\chi^2(2) = 20.000$, $p = 0.000 < 0.05$). Post hoc analysis was applied using Wilcoxen signed-rank tests using a Bonferroni correction ($p < 0.017$). Median NH_3^- levels for July, September and November indicated 16.30, 0.155 and 8.10 mg/L, respectively. There were significant differences between July and September ($Z = -2.803$, $p = 0.005 < 0.017$), July and November ($Z = -2.803$, $p = 0.005 < 0.017$) and September and November ($Z = -2.803$, $p = 0.005 < 0.017$). The high level of ammonia nitrogen at the upstream site (site 1) in September can be attributed to agricultural runoff it is still much lower than levels at that site in other seasons. The overall low levels measured in September are most likely due to dilution from the heavy rain during this period.

Unpolluted waters contain small amounts of ammonia and ammonia nitrogen compounds, usually < 0.12 mg/L. Concentrations beyond 2.43 – 3.65 mg/L could be an indication of organic pollution such as from domestic sewage, industrial waste or fertilizer runoff (Chapman, 1996, p91). Ammonia is often used as an indication of sewage contamination. Free ammonia can change into saline ammonia with changes in pH and temperature. High levels of ammonia can decrease the effectiveness of chlorine in disinfecting water (EPA, 2001, p28). The FAO (Ayers & Westcot, 1985) considers levels between 0 – 6.08 mg/L to be common in irrigation.

Total Kjedahl Nitrogen

Table 21 Total Kjeldahl nitrogen measurements for each water sample. TKN is not included in Thai standards for surface water**.**

Site	Total Kjeldahl Nitrogen (mg/L)			
	July 4th	**September 13th**	**November 27th**	
	Early	**Mid**	**Late**	**Average**
02. Un Ari	18	2.8	12	10.93
03. Sri Don Chai road	14	2.7	9	8.57
04. Slaughter House	13	3.5	8.1	8.2
05. Kampaeng Ngam	7.1	3.4	8.6	6.37
06. Pre-merge Mae Kha	16	4.1	7.8	9.3
07. Ku Wai	15	3	7.3	8.43
08. Kanchanaphisek Park	10	2.6	7.4	6.67
Average	**13.3**	**3.2**	**8.6**	**8.37**

The level of TKN were measured at 7 sites in the inner city, ranging from 2.6 – 18 mg/L, with the lowest levels being measured at the park (site 8) in September, and the highest at Un Ari (site 2) in July. The highest average levels were measured at 10.93 mg/L at Un Ari (site 2), and the lowest were 6.37 mg/L at Kampaeng Ngam (site 9)(Table 21). Kruskal-Wallis H tests found no statistically significant difference in TKN levels between different sites (H(2) = 1.541, p = 0.957 > 0.05)[21]. The Mann-Whitney U test indicates that

[20]With mean ranks at site 1 of 17.00, site 2 of 16.33, site 3 of 12.83, site 4 of 14.33, site 5 of 18.00, site 6 of 16.67, site 7 of 13.00, site 8 of 16.33, site 9 of 16.67 and site 10 of 13.83.

[21] With mean ranks at site 2 of 13.33, site 3 of 11.33, site 4 of 11.67, site 5 of 8.67, site 6 of 12.67, site 7 of 10.67 and site 8 of 8.67.

there is no statistically significant difference in TKN values between the Ku Wai and Mae Kha canals (U = 37.000, P = 0.533 > 0.05).

Average levels of TKN were highest in July and lowest in September. These average TKN levels were observed to decrease from July to September and then to increase from September to November. A Friedman test showed a statistically significant difference in TKN between seasons ($\chi^2(2) = 12.286$, p = 0.002). Post hoc Wilcoxen signed-rank tests found TKN median values for July, September and November at 14.00, 5.00 and 8.10 mg/L, respectively, and indicated no significant differences between July and September (Z = -2.366, p = 0.018 > 0.017), July and November (Z = -2.197, P = 0.028 > 0.017) or September and November (Z = -2.366, p = 0.018 > 0.017) when applying the Bonferroni correction (p < 0.017).

TKN is not among the parameters in the Thai standards for surface water quality, but it is considered in the effluent standards for industrial effluent, building effluents and pig farms, and it stands to reason that surface waters should be below these standards. In the water samples measured, all levels of TKN are below these effluent standards, which are 100 mg/L for industrial effluent , 35 – 40 mg/L for building effluent, and 120 – 200 mg/L for pig farm effluent. However, EPA standards are set at 1 – 3 mg/L (EPA, 2001, p71) for surface waters, which are exceeded in most of the samples.

Phosphates

Table 22 Phosphate measurements for each water sample.

	Phosphates (mg/L)			
	July 4th	September 13th	November 27th	
Site	Early	Mid	Late	Average
01. Upstream*	10	0.3	0.3	3.5
02. Un Ari	6.2	0.1	2.8	3.0
03. Sri don chai road	6.4	0.1	2.4	3.0
04. Slaughter House	5.0	0.3	2.9	2.7
05. Kampaeng Ngam	5.8	0.3	3.2	3.1
06. Pre-merge Mae Kha	7.2	0.2	3.1	3.5
07. Ku Wai	5.2	0.3	3.5	3.0
08. Kanchanaphisek Park	6.8	0.2	2.6	3.2
09. Merge	6.0	0.3	3.0	3.1
10. Downstream*	6.0	0.2	1.2	2.5
Average	**6.5**	**0.2**	**2.5**	**3.1**

TKN is not included in Thai standards for surface water.

Phosphates were observed in a range from 0.12 – 10 mg/L. The lowest level was measured at Un Ari (site 2) in September, and the highest at the upstream site (site 1) in July, followed by site 5 in the pre-merge part of the Mae Kha (Table 22). The upstream site also had the highest average phosphate levels, most likely due to agricultural runoff as the upstream sites, especially at the first location used in July. The downstream site (site 10) had the lowest average levels of phosphates, followed by the site 4, at the slaughter house. Kruskal-Wallis H tests showed no statistically significant difference in phosphate levels between different sites (H(2) = 0.774, p = 1.000 > 0.05)[22]. The Mann-Whitney U test indicates that there is no statistically significant difference in phosphate levels between the Ku Wai and Mae Kha canals (U = 43.000, P = 0.876 > 0.05).

[22] With mean ranks at site 1 of 15.00, site 2 of 14.00, site 3 of 14.00, site 4 of 15.33, site 5 of 17.33, site 6 of 16.50, site 7 of 16.33, site 8 of 15.67, site 9 of 17.67 and site 10 of 13.17.

Average phosphate levels show an apparent decrease between July and September and an increase between September and November. The highest average levels of phosphates were observed in July (6.5 mg/L) and the lowest in September (0.2 mg/L). A Friedman test showed a statistically significant difference in phosphate levels between seasons ($\chi^2(2) = 20.000$, $p = 0.000$). Post hoc analysis with Wilcoxen signed-rank tests was conducted with a Bonferroni correction applied of $p < 0.017$. Median phosphate levels for July, September and November were 6.10, 0.245 and 2.85 mg/L, respectively. There were significant differences between July and September ($Z = -2.803$, $p = 0.005 < 0.017$), July and November ($Z = -2.803$, $p = 0.005 < 0.017$) and September and November ($Z = -2.803$, $p = 0.005 < 0.017$).

While phosphates are common pollutants found in wastewaters, they are not considered in the Thai effluent standards. The EPA (2001) recommends limits of phosphates in surface waters of 0.5 – 0.7 mg/L. Looking at these standards, it is clear that the levels of phosphates measured in July are very high, in September are within standards, and in November again exceed standards.

Oil and Grease

Table 23 Oil and grease measurements for each water sample.

Site	Oil and Grease (mg/L)			
	July 4th	September 13th	November 27th	
	Early	Mid	Late	Average
02. Un Ari	0.28	0.99	1.2	0.82
03. Sri Don Chai road	1.2	0.28	1.1	0.86
04. Slaughter House	1.8	0.83	0.98	1.20
05. Kampaeng Ngam	0.28	1.3	1.7	1.09
06. Pre-merge Mae Kha	1.8	0.84	1.1	1.25
07. Ku Wai	0.56	0.68	0.83	0.69
08. Park	0.28	1.5	0.7	0.83
Average	**0.9**	**0.9**	**1.1**	**0.97**

Thai standards require < 5.0 mg/L for industrial effluent, 50 – 100 mg/L for building effluent, < 15 mg/L for gas stations, and < 5.0 mg/L for irrigation use.

Oil and grease was measured at levels ranging from 0.28 – 1.8 mg/L. The lowest measurements belong to samples taken at Un Ari (site 2), the park (site 4), and Kampaeng Ngam (site 9) in July, and Sri Don Chai road (sites 2, 4, 9, and 3, respectively) in September, and the highest measurements belonged to sampled taken at the downstream Mae Kha site and the Slaughter House (sites 5 and 8, respectively) in July. The Ku Wai (site 7) had the lowest average levels of oil and grease at 0.69 mg/L, and the downstream Mae Kha site (site 5) had highest average levels of oil and grease at 1.25 mg/L. Areas near the Kampaeng Ngam community, just downstream from the city, exhibited the highest apparent levels of oil and grease (Table 23). Kruskal-Wallis H tests did not find any statistically significant difference in oil and grease levels between different sites ($H(2) = 3.705$, $p = 0.717 > 0.05$)[23]. The Mann-Whitney U test indicated no statistically significant difference in oil and grease values between the Ku Wai and Mae Kha canals ($U = 26.000$, $P = 0.37 > 0.05$).

Oil and grease is the only measured parameter that exhibited low levels in July. The average level of grease and oil did not vary heavily between seasons (0.9 – 1.1 mg/L). Friedman test showed no statistically significant difference in oil and grease levels between seasons ($\chi^2 (2) = 2.000$, $p = 0.368 > 0.05$). Thai standards for surface water quality do not include oil and grease. However it is a common water pollutant that is discharged by households and other actors, and included in Thailand's effluent standards for

[23] With mean ranks at site 2 of 10.00, site 3 of 10.50, site 4 of 13.33, site 5 of 12.83, site 6 of 14.67, site 7 of 6.50, and site 8 of 9.17.

industry, buildings, gas stations as well as for irrigational use. It stands to reason that these standards are laxer than those for surface waters. The measured levels of oil and grease do not surpass any of these effluent standards for oil and grease. However, all sites have exceeded the standards for oil and grease, 0 – 0.1 mg/L, defined by the EPA (2001, p60). The average values measured at Un Ari, Sri Don Chai road, and the park (sites 2, 3, and 8, respectively) exceed these levels.

Oil and grease measurements include petroleum, oil, grease and related materials. Problems caused by these substances include interference with such vital processes as the mass transfer of oxygen from air to water (essential in river recreation, for example), blockage of pipes, fouling of plant and animal life, odor and taste problems, and numerous biological processes.

Chloride

Table 24 Chloride measurements for each water sample.

	Chloride (mg/L)			
	July 4th	September 13th	November 27th	
Site	Early	Mid	Late	Average
02. Un Ari	61	17	32	36.67
03. Sri Don Chai road	53	19	32	34.67
04. Slaughter House	57	20	29	35.33
05. Kampaeng Ngam	34	22	29	28.33
06. Pre-merge Mae Kha	49	19	33	33.67
07. Ku Wai	54	22	26	34
08. Park	54	20	23	32.33
Average	**51,7**	**19,9**	**29,14**	**30.5**

Chloride is not included in Thai standards for surface water.

The levels of chloride measured range from 17 – 61 mg/L. At Un ari (site 2) both the highest and lowest levels of chloride were recorded, in July and September, respectively. Kampaeng Ngam (site 9) had the lowest average levels of chloride, and Un Ari (site 2) had the highest. Kruskal-Wallis H tests did found no statistically significant difference in chloride levels between different sites ($H(2) = 0.117$, $p = 1.000 > 0.05$)[24]. The Mann-Whitney U test found no statistically significant difference in chloride values between the Ku-Wai and Mae Kha canals ($U = 44.000$, $P = 0.938 > 0.05$).

The average level of chloride was highest in July (51.7 mg/L) and lowest in September (19.9 mg/L). There is an apparent decrease in average chloride levels between July and September, and an increase between September and November (Table 24). A Friedman test showed no statistically significant difference in chloride between seasons ($\chi^2(2) = 14.000$, $p = 0.001$). However, post hoc analysis with Wilcoxen signed-rank tests conducted with a Bonferroni correction ($p < 0.017$) showed no significant difference between any two seasons. Median chloride levels for July, September and November were 54.00, 20.00 and 30.50 mg/L, respectively. There were no significant differences between July and September ($Z = -2.371$, $p = 0.018 > 0.017$), July and November ($Z = -2371$, $P = 0.018 > 0.017$) or September and November ($Z = -2.366$, $P = 0.018 > 0.017$).

Sewage and some industrial effluents are known to contain large amounts of chloride. As such it is a common indicator of black water contamination (EPA, 2001, p37). However, chloride is not considered in the Thai water quality standards. Pristine freshwater chloride concentrations are usually < 10 mg/L, where higher concentrations can occur near sewage and other waste outlets (Chapman, 1996, p103). The FAO

[24] With mean ranks at site 2 of 11.50, site 3 of 10.67, site 4 of 11.67, site 5 of 10.67, site 6 of 10.83, site 7 of 11.33 and site 8 of 10.33.

considers levels below 1063.45 mg/L to be suitable for irrigational use (Ayers & Westcot, 1985), while the EPA (2001) maintains a standard of < 250 mg/L for surface water (the same standard they maintain for drinking water)(EPA, 2001, p38). Considering these standards, the levels of chloride measured in the study area are very low. No previous studies have assessed local chloride concentrations but the low levels are surprising considering the high levels for other indicators of waste water, including nutrients and microbial indicators (see next section).

Total Coliform Bacteria and Total Fecal Coliform Bacteria

Table 25 Total coliform bacteria and total fecal coliform most probable numbers as measured for each water sample.

Site	Total Coliform Bacteria and Total Fecal Coliforms (MPN/100ml)					
	July 4th*		September 13th		November 27th	
	Early		Mid		Late	
	TCB	TFC	TCB	TFC	TCB	TFC
01. Upstream*	> 2400	>2400	>24000	2100	>24000	>24000
02. Un Ari	1100	1100	11000	4600	>24000	>24000
03. Sri don chai road	240	240	>24000	2100	>24000	>24000
04. Slaughter House	>2400	>2400	>24000	300	>24000	11000-24000
05. Kampaeng Ngam	240	240	11000	11000	>24000	>24000
06. Pre-merge Mae Kha	240	240	11000	750	>24000	>24000
07. Ku Wai	240	240	11000	11000	>24000	2100
08. Kanchanaphisek Park	240	240	11000	2100	>24000	>24000
09. Merge	240	93	>24000	2100	>24000	11000-24000
10. Downstream*	>2400	>2400	11000	>24000	>24000	>24000

***The first round of tests was done with a 3 tube test which has a lower maximum. Thai standards for surface water quality set water with TCB levels of > 20000 and TFC >4000 as class 5, heavily polluted waters.**

As mentioned in the methods, different accuracy levels were used for tests conducted in July, and so only the results from September and November are directly comparable. Even so, it is worth noting that levels of total coliform bacteria and total fecal coliforms water samples reached maximum measurable levels (>2400) in many cases in July, and that, in general, the water quality measured in July was worse than that measured in September and November. All things considered, one possible explanation for the apparently lower levels of TCB and TFC in July involves rain leading to sewage and drainage overflow, which in the rainy season can lead to an increase in base-flow that includes septic water, seeping into the ground near the banks of the canal. We can see that on average, the levels of TCB and TFC are much higher in November than September, and more often reach the maximum level of sensitivity of the test (Table 25). Wilcoxen signed-rank tests were conducted and showed a significant difference in TCB and TFC MPN's between September and November ($Z = -2.213$, $p = 0.027 < 0.05$ (TCB); $Z = -2.570$, $p = 0.010 < 0.05$ (TFC)).

In general, TFC and TCB levels seem to be higher upstream and downstream, outside of the city, which might be due to lower use of septic tank systems outside of the city. The sampling site at the Slaughter House (site 8) also exhibited high levels of TCB and TFC, except for the TFC measured in September. It is not clear why this level was so low, especially considering the high level of TCB measured from the same sample. Kruskal-Wallis H tests did not find any statistically significant difference for TFC or TCB values between different sites ($H(2) = 1.549$, $p = 0.997 > 0.05$)[25]. A Mann-Whitney U test indicated no statistically

[25] With mean ranks of TFC at site 1 of 18.17, site 2 of 14.83, site 3 of 16.50, site 4 of 16.50, site 5 of 13.17, site 6 of 16.50, site 7 of 13.17, site 8 of 18.17, site 9 of 13.17 and site 10 of 14.83, and mean ranks of TCB at site 1 of 17.83,

significant difference in TFC and TCB between the Ku Wai and Mae Kha canals ($U = 44.500$, $P = 0.966 > 0.05$ (TFC); $U = 44.500$, $P = 0.968 > 0.05$ (TCB)).

TFC and TCB are often used as indicators for the presence of pathogenic microorganisms, where the absence of TFC indicates a strong probability that pathogens are absent (EPA, 2001, p44). Maximum EPA standards for surface water quality for fecal coliform bacteria (TFC) are 40,000 no/100 ml, that of total coliform bacteria (TCB) is 100,000 no/100 ml. These standards are much higher than those used in Thailand.

Summary of results for water quality

General patterns in water quality show seasonal improvement in the measured parameters following the initial tests in July, indicating as suspected that this had the worse quality. One exception has been TFC and TCB counts, which rose (i.e. quality declined) between July and November. Most parameters show the highest levels in July, with Cl^-, PO_4^{3-} , TKN, NH_3, NO_3^-, EC, TDS, BOD and DO showing improvement in September and subsequent decline in November. Oil and grease levels remained steady between July and September and increased in November. Hardness, free CO_2, alkalinity and pH show a continued improvement between July and November. In general, the water quality seemed to be better for sites outside of the city and in the Ku Wai stream.

On the basis of the measured parameters compared against Thai standards for surface water, the Mae Kha (and Ku Wai) can be classified as heavily polluted, falling into Class 5 of the standards. Parameters including nutrients (phosphates and nitrogen) and biological pollutants (BOD, TFC, TCB), exceed the standards in most locations, especially in July and November. Parameters tied to salinity (TDS, chloride, conductivity), on the other hand seem to show lower, more acceptable levels, suitable for irrigation. General levels of free CO_2, pH and alkalinity were very poor during the dry season, but improved markedly thereafter. DO improved somewhat in September, but was consistently below standards. Other parameters including BOD, nitrates, TFC and TCB were also consistently below the national standards. Levels of oil and grease, TKN and phosphates also exceed the EPA standards on various occasions.

Statistical tests show that there are important seasonal differences in the water quality, with the lowest water quality generally being measured in the dry season. On the other hand, no significant differences were found in the water quality between chosen sites, and only the level of DO and free CO_2 showed significant difference between the Ku Wai and Mae Kha streams. This was surprising as the Mae Kha seemed to receive more untreated waste water than the Ku Wai, and the Ku Wai showed a healthier flow.

Seasonal Differences

There were statistically significant differences in levels of NO_3^-, hardness, TKN, Cl^-, NH_3, TCB, TFC, EC, TDS, BOD, alkalinity, DO and pH in the water between seasons ($p < 0.05$). No such statistically significant differences were found for levels of oil and grease between seasons. Post hoc analysis using Wilcoxon signed-rank test was conducted with a Bonferroni correction applied resulting in a significance level set at $p<0.017$. Statistical tests indicated that for pH, alkalinity, NH_3^- and PO_4^{3-}, measurements were significantly different between each seasonal pair. TDS and EC showed significant differences between values measured in July and September as well as September and November, but not between July and November. Differences in NO_3^- levels were tested to be statistically significant between July and September and between July and November, but not between September and November. Hardness exhibited significant differences between July and November and between September and November but not between July and September. TFC and TCB could only be compared between September and November, and both showed statistically significant differences between these two samples. TKN and chloride levels had no statistically significant difference between any two seasons when using the Wilcoxon signed-rank test with Bonferroni

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site 2 of 17.50, site 3 of 13.83, site 4 of 13.83, site 5 of 12.50, site 6 of 12.83, site 7 of 11.83, site 8 of 16.17, site 9 of 16.33 and site 10 of 22.33.

correction, where the significance of difference between each two seasons was $p = 0.018 > 0.017$. What can be concluded is that while, there is a general improvement of the water quality after the dry season (as indicated by samples in July), the rate at which improvement occurs in the rainy season and at which the water quality degrades after the rainy season varies for different parameters.

Canals and Sites

There were no statistically significant differences ($p < 0.05$) between the values of pH, alkalinity, TDS, EC,TFC, TCB, NO_3^-, NH_3^-, PO_4^{3-}, Cl^-, TKN, hardness and oil and grease between the Mae Kha and Ku Wai canals. There were, however, significant differences in the levels of DO and free CO_2 in water samples taken from the Mae Kha and Ku Wai. Statistical tests on free CO_2 measurements showed the Mae Kha having a significantly higher mean rank of 13.97 compared to 3.83 for the Ku Wai stream, indicating higher levels of free carbon dioxide in the Ku Wai than in the Mae Kha ($U = 2.000$, $P = 0.001 < 0.05$). Similar tests on DO data showed a significantly higher mean rank of 16.25 in the Ku Wai streams, compared to 8.90 in the Mae Kha, indicating that dissolved oxygen levels in the Ku Wai canal were also higher than those in the Mae Kha ($U = 13.5$, $P = 0.012 < 0.05$). There is a close interaction between DO and free CO_2 levels and other parameters, which makes it noteworthy that these differences are not seen for alkalinity, pH or BOD which are correlated with DO and Free CO_2 levels.

Overall, water quality is poor, achieving the lowest possible class 5 for a water body under Thai standards. However, indicators of salinity consistently showed acceptable levels, which suggests that the water could still be used for irrigation. More research is needed to assess the levels of heavy metals and pesticides in the soil and sediments, as well as more specific indicators of pathogens such as *E. coli*, considering the high levels of TFC and TCB found in the water, and the high levels of COD measured in July. These tests will show whether the use of canal water for irrigation is likely to have significant health risks.

Environmental Services of the Mae Kha

Despite the canal being similarly degraded across different sections of its urban trajectory, exposure to the pollution of the canal is not distributed equally among all sectors of society. Walker mentions “Injustice in terms of distributional outcomes, cannot be reduced simply and solely to tests of unequal spatial patterning and disproportionate proximity.” There are various contributing factors which frame the ultimate distribution of the environmental ills. As discussed by the capabilities approach, a large difference lies in the opportunities available to different individuals or communities to change the situation (Schlosberg, 2003).

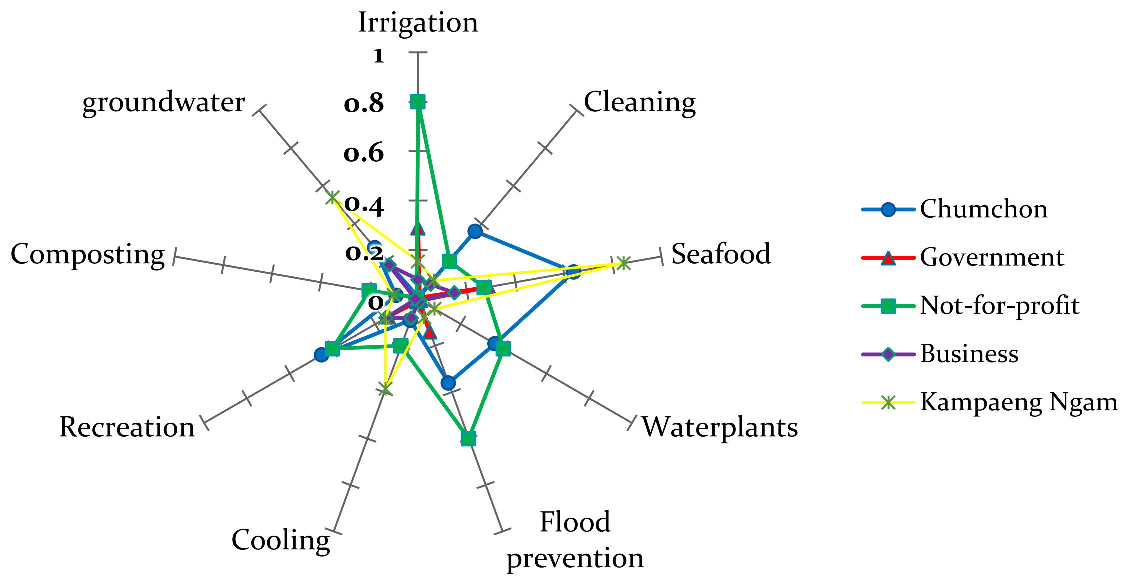
One clear sign of the differences in capabilities available to various stakeholder groups is their uses of the Mae Kha´s environmental services. To analyze this we look first at the environmental services which include the use of the Mae Kha for sustenance and non-sustenance purposes. As previously mentioned, the Mae Kha is heavily polluted and as such, most people who have another option would rather not use it. This was indicated various times during interviews in which people stated clearly that they would prefer not to live along the Mae Kha, but do not have a choice. While businesses can build walls that lock out the Mae kha, many of the chumchon and the urban poor who live there do not have this privilege, and are forced to deal with the flooding, smell and health risks associated with the canal. The chart shown in Figure 15 represents the recognition by various groups of the services provided by the canal, but not necessarily the rate of use per group.

The distribution of the use of the canal defines the risks experienced due to the pollution of its waters. When looking at the uses recognized by each group, it is clear that chumchon are more likely to mention uses such as consumption of seafood and water plants, and as cleaning water, which would increase exposure to levels of pollution in the water, especially pathogens and toxins. Some chumchon even reported using groundwater from wells adjacent to the Mae kha for non-drinking purposes. Surprisingly the chumchon did not mention irrigation as a use, even though many communities were seen to plant fruits and vegetables on the banks of the canal. In Kampaeng Ngam, the majority of households indicated the

Mae Kha as a source of fish for consumption, and the majority of the interviewed households indicated using groundwater.

Few businesses indicated using the canal, but a few mentioned their use of groundwater sources next to it. Similarly, very few GIs indicated the canal having any use. Those that did, mentioned its use for agricultural irrigation upstream, and as a source of fish for consumption for the urban poor. In general, NFPs recognized a much broader set of uses, including irrigational use of canal water for plants in the chumchon, and the collection of water plants and fishing for consumption.

Figure 15 Distribution of water advantages among stakeholder groups



Source: based on rich picture exercises during interviews held in 2013

A second group of environmental services provided by the canal are of a more indirect nature, and include less risk, but similarly add to the quality of life. Some chumchon and Kampaeng Ngam residents indicated the canal having a cooling effect, because of the water and the shading offered by the trees around the Mae Kha. In Kampaeng Ngam, many older residents were observed taking mid-day naps on bamboo sheds (salas) built along the canal, and indicated that it was cooler there. Businesses which are secluded from the canal, and have access to air-conditioning might not perceive these services.

Recreational uses of the canal, including swimming and boating, were mentioned in the past tense by both NFPs and chumchon; this was generally with an air of nostalgia and regret for the lost resource. Lastly, the canal has historically served Chiang Mai as a measure of flood prevention against the Ping river. This service was mentioned by most NFPs and a few chumchon. Moreover, in Kampaeng Ngam and Hua Fai, children were viewed playing in the canal and open sewage streams. Such risks are hard to minimize if people live along the canal.

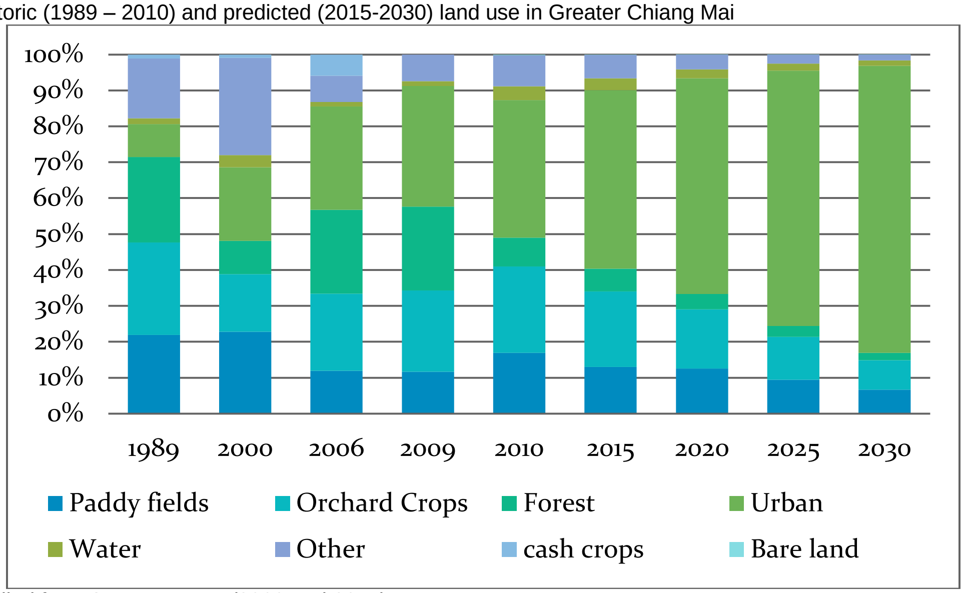
It is noteworthy that the service of the canal as drainage for the city was hardly mentioned when asked how the canal was used, however it was mentioned when we asked about the value of the canal (Figure 24, p 114). It seems that this service in particular is taken for granted and not seen as something which is personally used. The ways in which different stakeholder groups viewed the Mae Kha water as a source of substance and a valuable resource varies. Sustenance use, in particular, increases the associated health risks due to the deterioration of the canal, particularly with the high levels of microbial activity measured. “Pollution is socially contextualized, intersecting with life course, class and poverty, so that impacts of ‘equal doses’ are not equally experienced or coped with – an observation that extends to the unevenness of the pshyco-social as well as the physiological impacts of living with sources of risks” (Walker, 2010).

Urban Development

As discussed previously, the processes of urbanization are likely to have a negative impact on stream ecology, and negative environmental impacts that affect those who live near the canal (Urban Streams, p 17). Major contributing factors include the expansion of impermeable surfaces in the local catchment and drainage of the area, which negatively impacts the infiltration of water to the ground. Other factors related to urbanization including riparian deforestation, and increased waste effluent, contribute to the further degradation of the canal (Walsh et aal., 2005; Meyer, 2005; Fletcher et. al, 2013) .

The land use of the Ping River Basin is mostly used for agricultural purposes (Figure 3, p13)m with Chiang Mai City and Lamphun as exceptional growing urban areas (Thomas, 2006; Sangawongse et al., 2005; Romanos & Auffrey, 2002). As indicated in Figure 18, the urban cover of greater Chiang Mai has increased from 9% in 1989 to 38% in 2010 (Sangawongse 2006; Sangawongse 2012), and is predicted to increase to more than 80% by 2030. Such shifts in land use can have devastating effects on the catchment scale (Walsh et al., 2005). Recent land conversions have seen primarily rice paddy fields turned into urban land, including the flood plains around the Mae Kha, In the future, land currently used for orchard crops and forests are predicted to follow the same path (Sangawongse, 2012). “Land use and transportation plans directed urban expansion into fertile land areas suitable for rice growing. As a consequence from inappropriate and ineffective land use planning policies and practices, Chiang Mai city has experienced severe floods, traffic congestion, and air and water pollution” (Sangawongse, 2012, p. 23).

Figure 16. Historic (1989 – 2010) and predicted (2015-2030) land use in Greater Chiang Mai

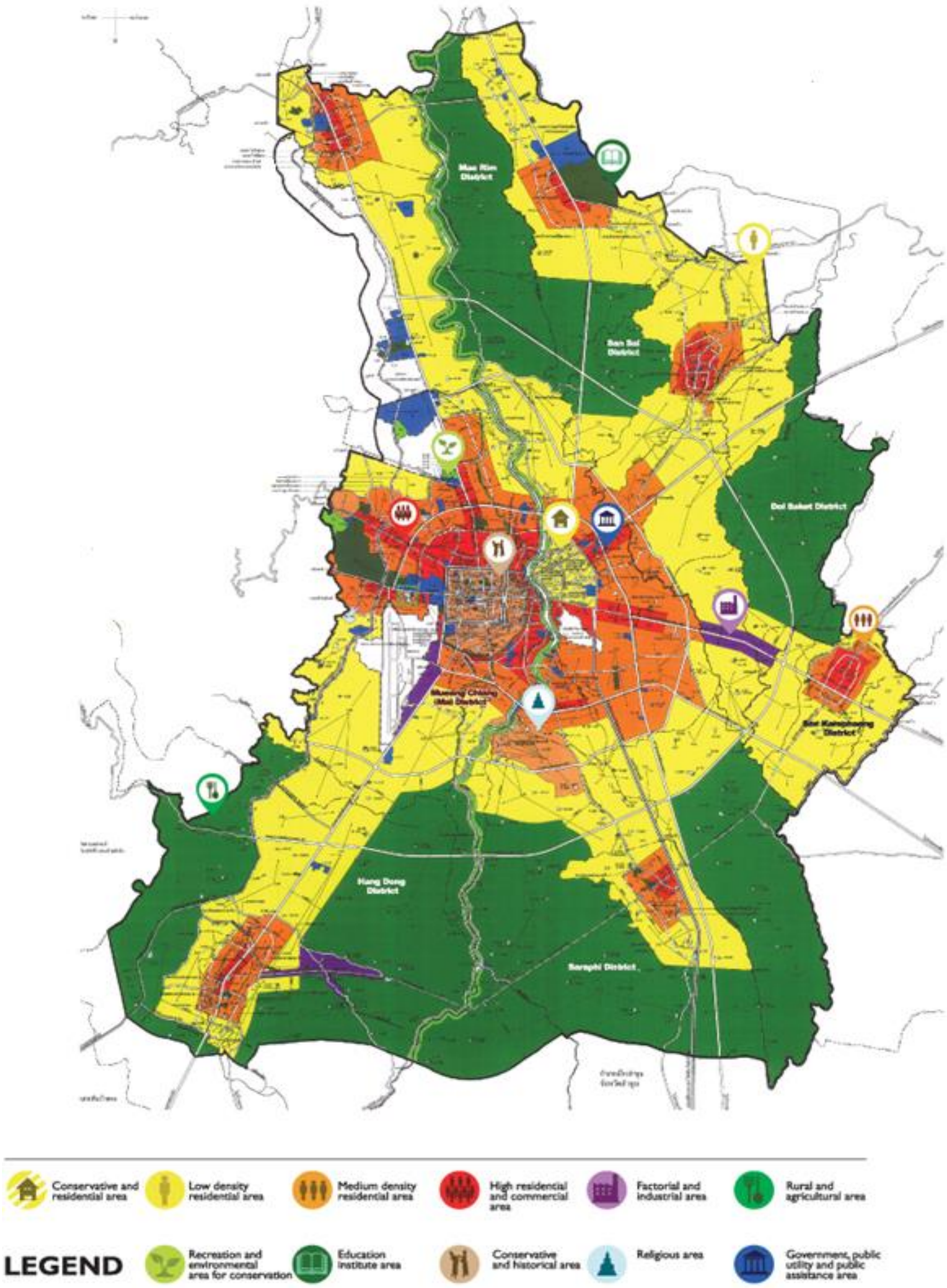


Source: Compiled from Sangawongse (2009 and 2011)

Urbanization often increases the discharge of domestic, commercial and industrial wastewater to water bodies, which can cause environmental and health problems for local inhabitants. As previously mentioned, urbanization can lead to increased flood events and droughts, and can even change local climatic patterns through urban heat build-up, leading to heavier rainfall (unesco-ihe, n.d). The ultimate effects of urbanization depends on its specific form.

Land development for greater Chiang Mai is directed by 5 year plans (Lekutai, 1998). It is one such national scale plans that is attributed as having designated Chiang Mai as the development hub of the North, leading to its recent rapid urbanization (Sangawongse et al, 2012). Land zoning provides a visual representation of the recognition and participation of various stakeholder groups and their interests, including the canal, in the development of Chiang Mai.

Figure 17 Chiang Mai zoning 2012



Source: G. Robinson & W. Moolkam, 2012

“Processes of land use planning that concentrate industrial activities, waste handling and energy generation together in ‘marked’ places, and that protect the environmental quality and land values of conservation and heritage areas, provide a less knowing and more institutionalized account of how recognition plays into the social-spatial patterning of urban industrial geography" (Walker, 2010).

The most recent 5 year land use plan for Chiang Mai, 2012-2017, allocated six principal land use zones (Figure 17):

1. Yellow: low density residential area, buildings not to exceed 12m
2. Orange: medium density residential area, buildings not to exceed 12m
3. Red: high density commercial and residential area, building height limited to 15 m or no limit
4. Brown: historical city center, buildings not to exceed 12m
5. Purple: industrial land use area, no height limit
6. Green: agricultural land use area, buildings not to exceed 12m

The land use map zoning system indicates that it is likely that for the city to continue to expand both vertically and horizontally. Low density residential areas have the same building height limit as the medium density residential and commercial areas, suggesting a potential for the density of these areas to even out. High density residential and commercial areas are located on the immediate outskirts of historical city center. These include the areas on the outer border of the Mae Kha, and the section to the east of the city square which is a touristic section of city. Parts south of the city square that are designated as high density (red) are currently used mainly for housing, including many chumchon (Annex 9) such as Mae-King, Hua Fai, Raekgeng, Saladeng and Sii Ping Muang. Many of these communities have already seen an increase in vertical growth.

The historic city center extends to the borders of the Mae Kha, and is qualified for preservation as an historical monument. In practice, these policies are mostly focused on the area inside of the square moat rather than the areas between the moat and the Mae Kha.

The current city development plans do not include the much needed increase in drainage and wastewater treatment capacity for the corresponding increases in population density which they permit. Considering that a significant portion of population increase will be located around the Mae Kha, it is likely this will lead to further the degradation of the canal. As Walker (2010) explains: "once places, as well as people and communities, become associated with trash they can then become the strategic or 'natural destination' for further unwanted land use."

Moreover, there is no expansion of green space planned for the city, and there is even an exclusion of current green space including Kanchanaphisek Park. This area is designated as a public utility area rather than a conservation or recreational environmental area. On the other hand, the banks of the Ping river are zoned as green space. Designing of an area as green space does not necessitate the eviction of chumchon, as aerial photos of the city confirm that the banks of the Mae Kha represent a green corridor through the city.

There have been some issues which have received special attention in the development plan for Chiang Mai, with some resistance to its continued unchecked expansion. Areas within 200m of a monastery are limited to a height of 9m. Moreover, residents living east of the Ping river opposed the zoning of this area for high density residential and commercial use, and succeeded in lobbying to re-zone the area for conservation and residential uses with a height limit of 9m (Fig 19, yellow stripes)(Sangawongse, 2012).

Hamilton (1994, p69), notes that land-use decisions "because they reflect the distribution of power in society, they cannot be expected to produce an equitable distribution of goods." The simple point is that there is a crucial link between lack of recognition and the inequitable distribution of environmental bads; it is a general lack of value of the poor [...] that leads to this distribution of inequity (Schlosberg, 2003). The current land use plans are evidence of a disregard during the planning procedure for the Mae Kha and therefore also for the chumchon living around it. Sangawongse (2012) describes Thai cities as "self-organizing systems" resulting from a mismatch between various local, provincial and national governance levels, which fail to tackle issues including suburbanization, urban sprawl and public transport. In the absence of clear housing policies for the urban poor and the provision of infrastructure necessary for the city and its people, continued urbanization will inevitably lead to increased environmental deterioration of the city landscape, which will likely affect the urban poor the most.

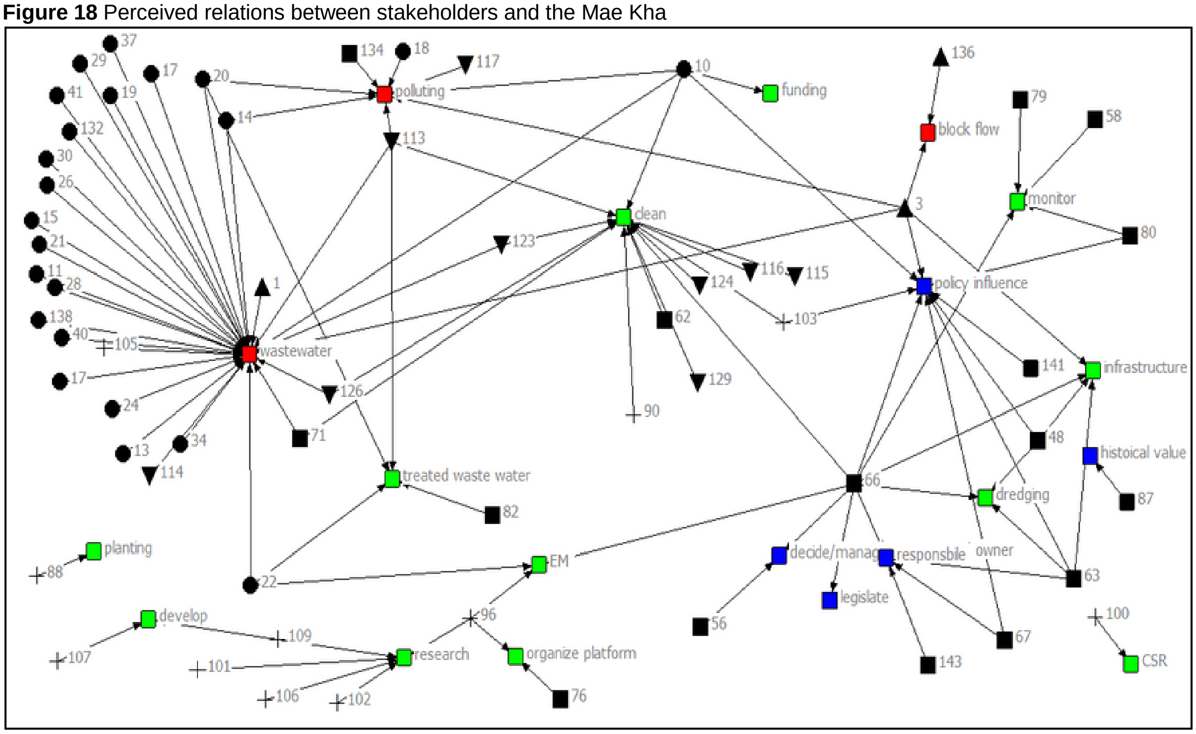
Results Justice of Participation

To understand the management of the Mae Kha a mapping of stakeholders was performed to identify the relevant actors and their relationships. This was done using literature research and interviews with stakeholders. The pollution of the Mae Kha canal is not only an environmental issue but also impacts issues of housing rights for low income chumchon living along the canal and monumental protection for the historic old wall that accompanies it. The first section of this chapter introduces each of the actors and their roles.

Participation with the Mae Kha

To define the roles of each stakeholder and stakeholder group, respondents were asked to draw rich pictures (Methodology, p28) of the connections between actors and with the Mae Kha. A non-weighted compilation network of the described relations of different stakeholder groups with the Mae Kha is presented in Figure 18. This graph does not represent a comprehensive network picture but rather how the relations are imagined by the interviewees. Despite interviewing actors from all stakeholder groups, a relatively homogenous image was created, with hubs of interaction centered around particular stakeholder groups.

Figure 18 Perceived relations between stakeholders and the Mae Kha



Legend: +: NFPs, ■: GIs, ▲: general population groups, ▼: chumchon, ●: businesses. ■: positive impact on the Mae Kha, ■: negative impact on the Mae Kha, ■: indirect impact on the Mae Kha.
Source: based on interviews with stakeholders during 2013, using UCINET 6.

The main issue discussed here is the appearance of a general pattern of relations between each stakeholder group and the Mae Kha. When asked for the role of various stakeholders in the management of the Mae Kha, the chumchon as a group (113) were most often implicated as sources of wastewater entering the canal. However, when individual chumchon were mentioned it was often related to cleaning events.

In the case of businesses, the opposite trend was apparent, with many individual businesses implicated in discharging wastewater directly into the canal. Businesses as a group (10) were perceived to have policy influence and to participate in cleaning activities, but no individual business was credited with taking part in cleanings. One particular business, 100 Pipers, has participated in funding projects to improve the Mae Kha, which are proposed by chumchon. Moreover they also fund the government cleaning activities such as dredging.

GIs were seen to have far-reaching indirect involvement with the Mae Kha, through monitoring of water quality, providing infrastructure, protecting the historical value of the canal and surrounding wall, legislating interactions with the Mae Kha, influencing related policies, deciding what happens with the canal, and holding responsibility for its state. Moreover, GIs were attributed with direct impacts including dredging of the canal, treating wastewater, creating a platform for dialogue, and government officials were mentioned as having helped to both clean and pollute the canal.

NFPs had the broadest of roles with various independent, standalone activities such as bank planting, organizing Corporate Social Responsibility (CSR) activities, performing research on the Mae Kha, applying EM to the water, organizing a platform for dialogue, cleaning the canal and having policy influence.
When mentioned, the general population (1) were seen as one of the sources of wastewater in the canal, and rich members of the population (3) were also mentioned to block the flow of the canal, by building their own Watergates. To take a closer look at the roles of each of these stakeholder groups, a detailed description of various stakeholders within each group involved with the canal follows.

Table 26 Stakeholders in the Management of the Mae kha and Ku Wai canals

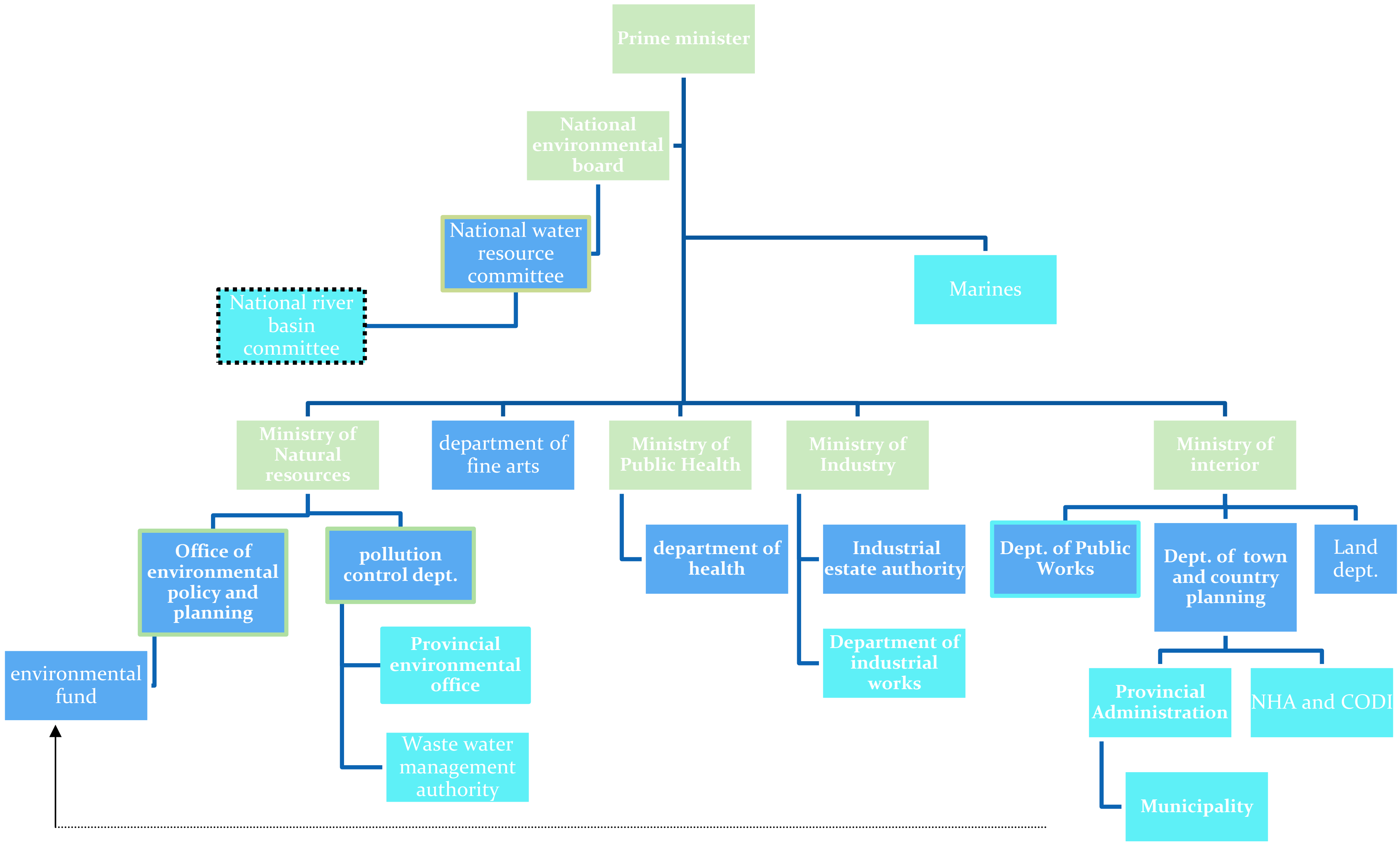
National	Provincial	Municipal	Chumchon	NFPs	Businesses
National environmental board	Provincial administrative organization	*Mayor*	*Fa Mai*	*4 regions*	*100 pipers-Whiskey*
Ministry of natural resources and environment	Chief administrative office (*governor*)	Advisory Mayor	*Ha Tanwa*	*Chumchon Thai*	*Arts and Crafts sales*
Pollution control department	Administrative department	Secretary Mayor	*Hua Fai*	*community network*	*Beauty Salons*
Office of natural resources and environmental policy and planning	PAO affair department	Deputy Mayors	*Klong Nung*	*Danset*	Belgian Hotel
Ministry of public health	*PAO planning and budget dept*	Municipal Clerks	*Lin Ko*	*Fun Baan*	*Centara Hotel*
Ministry of industries	Financial dept	Deputy municipal clerks	*Mae-King*	*Gum Hak Doi Suthep*	Condotel Hotel
Department of Industrial Works	*Engineering dept*	Municipal Council	*Muang Samut*	*Green Fragrance*	*Dormitories*
Industrial Estate Authority of Thailand	City council	*Districts*	*Papleng*	*kon jai baan*	*dying factories*
Ministry of interior	*Provincial water agency*	Social welfare-community development	*Raekgeng*	*Kun Ma Puthet*	*Factories*
National water resource committee	*Provincial environmental office*	Social welfare- clerical works	*Saladeng*	*Lanna Network*	*fish markets*
Royal irrigation department	*Hang Dong Department*	Technical services and planning- city development and promotion	*Sii Ping Muang*	*Mia Sawa*	*Garages*
Department of mineral resources	*Mae Rim Department*	Technical services and planning- planning and	*Si mon Kho*	*Nak Mae Kha*	*kom market*

	budgeting			
Department of rural development	Public health and environmental services –community health promotion	*Tipanet*	*People's Organization for Participation*	Lanna Hospital
Land development department	Public health and environmental services –community environmental sanitation	*Un Ari*	*Patana Mae Kha*	*Lasa Pasadu Grom land owner*
Department of public works	Bureau of Public Works- Design and construction	*Chayapoom Chang Moi*	*Supapanini*	*Laundries*
Town and country planning	Bureau of Public Works-public utilities	*Kampaeng Ngam*	*UN*	*Man New Life Insurance*
Waste water management authority	Bureau of Public Works-sanitary mechanics: *water quality management*		*Ho Kan ga*	*Muay Mai market*
Community organization development institute	Bureau of Public Works-sanitary mechanics: *water quality analysis*		*Dr. Chichol-CMU*	*Night Bazaar*
National housing authority	Bureau of Public Works-sanitary *mechanics: drainage system maintenance*		*Maejo University*	Panda Hotel
Government savings bank	Bureau of Public Works-sanitary mechanics: environmental promotion		*CMU WWTP*	*Pratu Chiang Mai Market*
Government housing bank	Office of the municipal clerk: local administration- ID issuing		*Rachapat University*	*Imperial Ping Hotel*
Department of Fine Arts	Office of the municipal clerk: local administration- disaster prevention and mitigation		*Rajamangala University*	*President Hotel*
ASEAN	Tambon Pa tan		*Dr. Wassan-CMU*	Red Brick Hostel
Marine Department	Tambon phra sing		Dr. Pasakorn-CMU	*Restaurants*
	Tambon sii phun		UCEA	*Son Poo Hospital*
	Tambon Haiya			*Suan Klong Hospital*
	Tambon Chang moi			Tae-Pae Inn
	Tambon Chang Klan			*slaughter house*
	Tambon chiang Pueak			*Villas*
	Tambon Suthep			*UBA*
	Tambon Mae Hia			
	Tambon Pa Daet			
	Community organizations			

Italic = mentioned in interviews, underlined = interviewed

Hereby the various stakeholder groups are discussed starting with the National government , which is often involved in an indirect manner, followed by the provincial and municipal governments, chumchon, NFPs and Businesses. Table 26 gives a comprehensive list of the actors included in each of the different stakeholder groups.

Figure 19 national level governmental actors in the management of the Mae kha



Adapted from UNEP, 2009 light blue: implementation, dark blue: monitoring and regulation, green: policy (outlined mix), doted outline: public consultation.

Governmental actors

There is a plethora of government actors involved in the large scale management of natural resources in Thailand. 24 institutions on this scale were identified to influence the Mae Kha, which will be discussed shortly. Generally the national level government sets the framework within which decisions at lower scales must be taken (Figure 19).

National Environmental Board

Most environment law in Thailand is based on the 1997 constitution that required every person to conserve natural resources and the environment (UNEP, 2009). The highest authority on environmental issues, including water issues, is the National Environmental Board (NEB), which was established by the national environmental protection plan (2008, World Bank). In general, the task of the NEB is to *"oversee the management of the country's natural resources and environmental quality"* (UN, 2009). The NEB[26] consists of ministers and experts (public and private sector):

. The responsibilities assigned to the NEB are as follows:

- specify measures for the strengthening and fostering of cooperation and coordination among government agencies, state enterprises and the private sector in matters concerning the enhancement and conservation of environmental quality
- supervise the Environmental Fund management and administration
- submit reports on the status of national environmental quality to the cabinet at least once a year

(UN, 2009)

The broad legislative power assigned to the NEB makes it the prime actor responsible for environmental policy. The composition of this board highlights one of the central problems in environmental management for Thailand, with such a high degree of centralization in policy making.

The Pollution Control Committee

This is a sub-committee working under the NEB, with a focus specifically on pollution issues. It is responsible for formulating policies for pollution-related areas including wastewater treatment (2008, World Bank).

Ministry of Natural Resources and Environment (MONRE)

This ministry, set up in 2002, is in charge of the management of Thailand's environmental resources in the broadest sense. This includes water, oceans, minerals, forests and jungles, managing the protection and managing of these resources. It includes various agencies: the Pollution Control Department (PCD), the office of Natural resources and environmental policy and planning (ONEP) and the Department of Environmental Quality Promotion (DEQP) (UNEP, 2009).

Pollution Control Department (PCD)

The PCD is responsible for the regulation, monitoring and policy formation related to activities in the monitoring and regulation of water and wastewater quality (World Bank, 2008). With respect to the Mae Kha, the PCD sets the standards for effluent and surface water quality against which the Mae Kha is monitored, and which defines its uses (water quality analysis, 2009).

[26] Comprising the Prime Minister as the Chairman, Deputy Prime Minister designated by the Prime Minister as the first Vice Chairman, Minister of Science, Technology and Environment as the second Vice Chairman, Minister of Defense, Minister of Finance, Minister of Agriculture and Cooperatives, Minister of Transport and Communications, Minister of Interior, Minister of Education, Minister of Public Health, Minister of Industry, Secretary-General of the National Economic and Social Development Board, Secretary-General of the Board of Investment, Director of the Bureau of the Budget, Experts in environmental matters not more than eight persons of which no less than half shall be representatives from the private sector, Permanent Secretary of the Ministry of Science, Technology and Environment as member and secretary.

Office of Natural Resources and Environmental Policy and Planning (ONEP)

This office is involved in policy formation for wastewater treatment (UNEP, 2009).

Department of Environmental Quality Promotion (DEQP)

The DEPQ focuses on increasing public awareness for environmental issues through public relation campaigns, spreading information on environmental quality, and facilitating research and development and action networks to promote environmental improvement (DEQP, 2014).

Ministry of Public Health

The Ministry of Public Health is responsible for the protection of public health and the prevention and control of disease. They are involved in the management of environmental resources through the Department of Health (DOH) (UNEP, 2009).

Department of Health (DOH)

The DOH is responsible for health care waste and infectious waste management, which includes regulating and monitoring hospital wastewater effluent. The DOH is responsible for fresh water quality monitoring as it relates to public health. Additionally, the office of the Permanent Secretary of the Ministry of Public Health is responsible for Hospital waste management (UNEP, 2009).

Ministry of Industry

This ministry, with is responsible for all hazardous waste generated from industries, these tasks are implemented by the Department of Industrial Works (DIW) and the Industrial estate authority of Thailand (IEAT) (World Bank, 2008; UNEP, 2009).

Department of Industrial Works (DIW)

The DIW is in charge of the supervision, promotion and support of industrial business operations, including coordination and monitoring of business compliance with national guidelines for environmental preservation, safety, hygiene and energy economization (World Bank, 2008; UNEP, 2009).

Industrial Estate Authority of Thailand (IEAT)

The IEAT is responsible for the development and establishment of industrial estates, where factories and industries are clustered. It is involved in regulating and monitoring industrial activities by providing an environmental management system to businesses in relation with a broader industrial accident prevention and relief system, including the regulation of wastewater treatment for industrial plants (World Bank, 2008; UNEP, 2009).

National Water Resource Committee

The NWRC was set up in 1996, and is responsible for the coordination, management and development of water resources at the national level. Its main functions consist of:

- preparing and submitting for cabinet approval objectives and policies for water resource development at all scales
- providing guidelines, support, and coordination to other agencies in preparing development plans and projects
- creating water management organizations both at national and river-basin levels
- approving and overseeing plans
- prioritizing and controlling the allocation of water resources between competing interests
- monitoring and maintaining water quality
- improving laws and regulations related to the development, control and maintenance of water resources and their quality
- promoting and supporting participation and transparency of procedures and the rights and responsibility of the public, NFPs and government organizations for efficient water management
- accelerating of preparation and plans for flood and drought protection, including warning systems

(Letcher, et.al., 2005)

River Basin Committees
The NWRC's water resource management plans are coordinated by River Basin Committees (RBC's) for 25 river basins across Thailand. A sub-committee was established for the Chao Phraya basin as a pilot project, which includes the Ping River. The RBC's responsibilities include managing the following activities within their river basin: addressing priorities in water resource issues, promoting public education, sustainable water resource management and facilitating local public consultations with stakeholders and beneficiaries (Letcher, et al., 2005).

Royal Irrigation Department (RID)
The RID is responsible for the development of water resources and management of irrigation and drainage systems nationwide (Letcher, et al., 2005).

Department of Mineral Resources (DMR)
The DMR manages groundwater resources nationwide (Letcher, et al., 2005).

Department of Rural Development (DRD)
The DRD is responsible for rural development, including domestic water development, nationwide (Letcher, et al., 2005).

Wastewater Management Authority (WMA)
The WMA state enterprise is part of MONRE and is responsible for implementing of waste water treatment projects including project design, operation and maintenance of the system (World Bank, 2008).

Environment Fund
With the passing of the Environmental Quality Promotion Act in 1992 a substantial Environment Fund was created (Atkinson, 1996; PCD, 2004). This fund is controlled jointly by the Office of Environmental Policy and Planning of the Ministry of Science, Technology and Environment, and the Environment and Resources Office of the Ministry of the Interior. Prior to this, the Department of Public Works was responsible for delivering environmental infrastructure as finished projects: urban roads, sewage treatment plants, solid waste landfill sites and so on (Atkinson, 1996). The EQP Act allows local authorities to formulate their own solutions to water pollution and solid waste management problems and to apply for money from the Environment Fund to implement their own solutions involving hardware acquisition. institution-building and public involvement (Atkinson, 1996; PCD, 2004). There have been difficulties in implementing this strategy, in large part due to a lack of local capacity to formulate proposals and generally plan and manage these processes (Atkinson, 1996).

Land Development Department (LDD)
A lot of the problems with water management in Thailand are considered by locals to result from highland land use (Walker 2003). Thus, water management policies are intertwined with land use policies, primarily directed at the highlands. The LDD's Office of Highland Development, in cooperation with the Watershed Management Division of the Royal Forest Department, coordinates and facilitates the implementation of policies and programs for the management of highland areas including: preparation of land-use plans that clearly identify watersheds, identification of land-development activities suitable for highland areas, participation in the preparation of management plans for the management of river basins impacting highlands and preparation of highland area management plans for each province, district and sub-district (Letcher, et al., 2005). For Chiang Mai and the Mae Kha in particular, the LDD has another role: as the owner of the public land (Annex 11), which includes most of the land surrounding the Mae Kha canal, are in charge of regulating and monitoring its use (POP, 2013).

Department of Town and Country Planning (DTP)

Previously the Department of Public Works, the DTP is responsible for controlling the construction standards of wastewater treatment systems for Local Administrative Organizations (LAOs) (2008, World Bank, 2008). DTP is responsible for the regulations, monitoring and implementation of wastewater treatment facilities. In Chiang Mai, the DTP constructed a wastewater treatment plant, cemented the Mae Kha in the inner city and constructed various urban water gates. These plans were designed at the national level without local governmental or public participation (Ribeiro & Srisuwan, 2005; World Bank, 2008). The DTP is also in charge of monitoring and regulating access to basic services including wastewater disposal and treatment, for low income chumchon, many of which are located along the Mae Kha canal in Chiang Mai.

The Community Organization Development Institute (CODI)

Low Income housing is intertwined with water management for Chiang Mai, as the banks of the Mae Kha canal are largely occupied by low income settlers. There is no government agency directly responsible to set policies for low income housing rather, they are set on an ad hoc basis by the national council of ministers (World Bank, 2008). The LDD and DTP regulate the housing sector in general while the National Housing Agency (NHA) and CODI are implementing agencies, responsible for providing housing services, upgrading slum chumchon, and assisting low income groups to achieve land tenure. In addition, two state-owned banks (Government Savings Bank and Government Housing Bank) play an important role providing credit to low income groups for house upgrading projects (World Bank, 2008). In Chiang Mai these projects are mostly organized through CODI under baan mankong programs.

CODI is a public organization under the NHA, which has consistently implemented community development programs that adopt a bottom-up approach. Their programs are aimed at improving living conditions for the poor and strengthening their organizational capacity. CODI supports community upgrading and achieving land tenure (CODI, 2013).

Which between 2003 and 2008 the Baan Mankong projected "supported 512 upgrading initiatives involving 1,010 [chumchon]. Community organizations [to] form their own savings groups and draw on soft loans, and find solutions that work best for them in terms of location, price and tenure, and negotiate with the landowners" (Boonyabancha, 2009, p309). This project facilitated infrastructure subsidies to support upgrading, and building or improving housing on-sit. These projects aim for collective land ownership which strengthens cooperative community processes and helps households transition from informal to formal. Moreover, communal land agreements secure longer term land security, as the land cannot be sold or repossessed when households face economic strains (Boonyabancha, 2009).

The Department of Fine Arts (DFA)

The DFA is in charge of the protection and restoration of historic monuments. It aims to conserve Chiang Mai's historical heritage sites including Buddhist temples, the Kampaeng Din wall and the Mae Kha canal. It has commissioned studies for the rehabilitation of the city of Chiang Mai, which include a proposal for the restoration of the fortification system that consists of the inner and outer city walls with the accompanying moat and canals (Mae Kha and Ku Wai canals). Towards this goal its policy is to preserve Kampaeng Din (the outer wall) as an historical monument and to evict the informal chumchon located in the area to a site ten kilometers out of Chiang Mai city center. Community participation in these plans is limited to voices/objections at public hearings, which are not necessarily addressed. CODI, local NFPs and chumchon negotiated with the DFA in 2005 towards an agreement where chumchon would be relocated from the Kampaeng Din wall in return for the right to rent the land next to it in Kampaeng Ngam, Ha Tanwa and Fa Mai (Srisuwan, 2005).

Military

"Following the 1932 revolution, Thai politics had been dominated for a half century by military and bureaucratic elite. Changes of government were effected primarily by means of a long series of mostly bloodless coups. [Today] the military continues to have a pronounced presence in all ranks of

Thai governance" (Lektuhai, 2008). Many mention the military as an important stakeholder for the management of the Mae Kha with the responsibility to evict chumchon, either for dredging the canal or taking the land.

Marine Department

The Marine Department is in charge of the all the waterways in Thailand, including the Mae Kha canal. Prior to 2004 the Marine Department, located in Bangkok, was also responsible for the day-to-day management of the Mae Kha. Following decentralization programs, in 2004 a regional department was set up in the North, and small streams including the Mae Kha were turned over to local authorities. The decentralization has not been successful in part because it was a top-down process, and many of the necessary skills and powers were not available to the local authorities. The decentralization took place with a one day workshop on the process to apply for funding from the central government (Interview with Marine Department, 2013). Despite the implementation of the decentralization of the Marine Departments responsibilities, most actors on the municipal level insist that the management of the canal continues to be the responsibility of the marine department and provincial government. This has undoubtedly resulted in no one taking responsibility for the canal.

Ministry of the Interior

The Ministry of the Interior is responsible for the Royal Thai Police, local administrations, internal security, citizenship, disaster management, land management, issuing national identity cards and public works. They are also responsible for appointing the 74 Governors of the Provinces of Thailand and are the main contact between the National and Provincial governments (UNEP, 2009).

Chiang Mai Provincial Government

The Chiang Mai provincial government also known as the *Local Organizing Agency*, the Chiang Mai provincial government sector is situated in between the local municipal and national level agencies; and the provincial governor is appointed by the central government (UNEP, 2009). The Mae Kha is seen by many as a responsibility of the provincial government, as it passes through 3 different municipalities**: Mae-rim** to the North, Chiang Mai City in the center and **Hang Dong** to the South. The roles within the Chiang Mai Province are discussed shortly.

Chief administrative office (Provincial Governor)

The Governor's Office is in charge of the management of provincial natural resources (UNEP, 2009).

Chiang Mai Provincial Administrative organization (PAO)

Since November 1997 the wording of the PAO act changed provincial administration to local administration to represent the process of decentralization. The president of the PAO is the Chief of Administrative Office (previously Provincial Governor), the Vice President of PAO is an Assistant, and Deputy of PAO is a Supervisor. The Royal Decree on PAO Office in 1998 describes the divisions of the PAO as follows:

1. Office of the PAO
2. Division of PAO City Council Affair Department
3. Division of Planning and Budget Department
4. Division of Finance
5. Division of Public Works (Engineering Department)
6. Others

(UNEP, 2009)

City Council

The City Council of the PAO consists of members elected by voters on a four year term. The number of members in each province depends on the population of the province. The City Council is responsible for the administration of the following public services within the province:

1. Provide local development plans assigned by the Interior Minister
2. Support the development of local administrative organizations

3. Cooperate with other local administrative organizations
4. Allocate budget to local administrative organizations
5. Protect, take care of, and preserve forest, land, natural resources, and the environment
6. Support the educational system
7. Uphold democracy, equality, and liberty and rights of people
8. Support each community to participate in local development
9. Support the development of technology
10. Set up wastewater treatment systems
11. Clean up waste and garbage
12. Reduce pollution and environmental problems
13. Administrate land and water transportations
14. Promote tourism
15. Support investment in the area
16. Set up and preserve land and water transportation for other local organizations
17. Establish a middle market
18. Uphold sports, customs, and culture in the community
19. Provide a Provincial Hospital, treatment, and contagious disease prevention and control
20. Establish and preserve museums and archives
21. Uphold mass communications and traffic engineering
22. Prevent and decrease public hazards
23. Set up security systems
24. Promote and create activities to cooperate with other local administrative organizations and to launch projects for local organizations to work on independently
25. Support and assist government sectors and other local administrations
26. Service government sectors, private sectors, state enterprises, and other local administrative organizations
27. Uphold public welfare for children, women, elderly, and handicapped citizens
28. Promote and provide projects in criteria of PAO law
29. Uphold and support other projects which can enhance for the lives of people in the community

(UNEP, 2009).

Local Administration Offices

Local administrative organizations are responsible for the implementation of wastewater treatment policy, and the management of resources and the environment within their jurisdiction. The Local Administration of Chiang Mai province is divided into 24 Districts, 204 Sub-districts and 1,915 villages. Local government offices are classified into 5 categories, with a number of office of each in the province:

1.	Provincial Administrative Office	1
2.	City Municipal Office	1
3.	Sub-district Municipal office	28
4.	Sub-district administrative office	184
5.	Sub-district council	7

(UNEP, 2009)

Provincial Environmental Office

The provincial environmental office is under the National PCD, and reports to them on the monitoring and implementation of national environmental policies at the provincial level. The office is also responsible for supporting the municipalities in its jurisdiction in implementing environmental policies. These municipalities report back to this provincial level (UNEP, 2009).

Provincial water agency (PWA)

The PWA is in charge of provincial drinking water provision and water treatment. But the capacity for the PWA to raise prices is constrained by a price control policy which limits private investment, forcing them to rely on government funds. More than 60% of the PWA's budget is subsidized by the national government, making its performance largely dependent on funds allocated by the central government each year. In the absence of a regulatory body, pricing decisions are politically motivated and not reflective of actual economic costs (World Bank, 2008).

PAO Planning and Budget Department

This department facilitates the implementation of National policies. For example, the WMA plans to invest at the provincial level to better utilize the capacity of existing waste water treatment facilities (World Bank, 2008), but due to the relatively large size of the city of Chiang Mai, a lot of activities are administered directly by the Municipal government rather than the Province.

Chiang Mai City Municipal Government

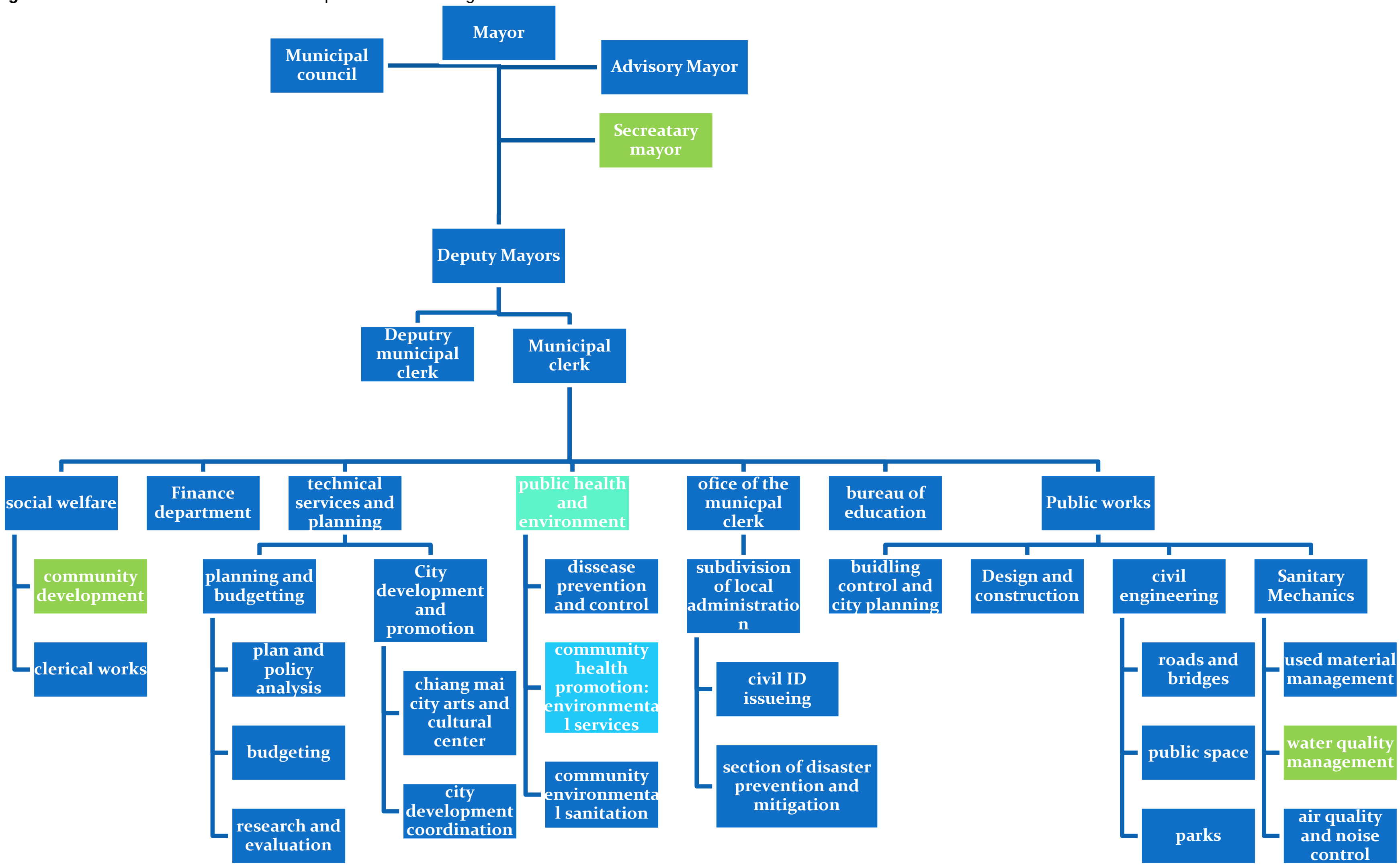
Chiang Mai City Municipality is divided into 4 districts: Nakornping, north east of the city square, contains 18 villages; Kawila, east of the Ping river, contains 26 villages; Sriwichai, west of the city square, is dominated by Chiang Mai University campus and contains 17 villages; and Mengrai, south of the city square, contains 20 villages. In total, Chiang Mai City Municipality is responsible for 81 villages in the most urbanized areas of the main Muang Municipality of Chiang Mai Province (Lekuthai, 2008). Within Chiang Mai City Municipality, the districts of Nakornping, Sriwichai and Mengrai each contain a section of the Mae Kha canal. The organization of the Municipal government is presented in Figure 20.

According to the Thai Constitution, local governments are allocated more power and budget for "education, morality and vision". During recent years, the government has implemented the Decentralization Action Plan in order to transfer functions, budgets, and personnel from the central government to nearly 8,000 local governments. These decentralization policies in Chiang Mai have generally transferred power from the national to the municipal scale. Among other things, Provincial administrative organizations (PAOs), Municipalities and Tambon (Sub-district) Administrative Organizations (TAOs) are now primarily responsible for waste collection, transport, treatment, and disposal. These local governments are able to contract the private sector to undertake some of the services.

The main responsibilities of Chiang Mai City Municipality (cmcity, 2013) are to:

1. Maintain law and order
2. *Provide and maintain land and water*
3. *Present clean streets, pathways, and public places, and manage waste and sewage disposal*
4. *Prevent and control communicable disease*
5. Provide fire extinguishers and fire fighting materials
6. Provide public training and education
7. Provide and maintain social welfare programs for mothers, children, youth, the elderly, and handicapped citizens
8. *Maintain local arts, tradition wisdom and culture*
9. Provide clean water supply
10. *Provide slaughter houses*
11. *Provide and maintain public hospitals*
12. *Provide and maintain a public drainage system*
13. Provide and maintain public restrooms
14. Provide and maintain electricity and public lighting
15. Provide local means for financial access, including pawn shops
16. Provide support for mothers and children
17. Provide public health services
18. *Control order and oversee safety and sanitation in public areas.*
19. *Improve slum settlements and housing management*
20. *Provide public markets, ferries, and parking*
21. *Oversee city planning and building control*
22. Follow other duties specified by law
23. *Promote tourism*

Figure 20 Institutional Framework of municipal Mae kha management



Source: Adapted from UNEP, 2009 and Cmcity, 2013, the blocks in green were interviewed and those in purple contacted but not interviewed.

The secretary mayor indicated that the main tasks of the municipality with respect to the Mae Kha are to "look after the canal by cleaning it and monitoring water and soil quality" (Secretary Mayor, 2013). These responsibilities are taken up by a variety of municipal departments and divisions. Those that affect the management of the Mae Kha canal are indicated in figure 2, and will be discussed shortly below.

The mayor
This is the highest executive position on the municipal level. The mayor of Chiang Mai is directly elected by Chiang Mai residents for a four year term. He is assisted by 4 deputy mayors representing each of the 4 municipal districts, who are appointed by the mayor himself. The mayor is further assisted by 2 advisors and 3 secretaries, who he also appoints (UNEP, 2009).

Deputy Mayors
The deputy mayors are empowered to administer over municipal matters which the mayor assigns to each, and are held accountable to the Mayor for these decisions (UNEP, 2009)

Advisor and Secretary to the Mayor
The advisors and secretaries to the mayor complement the Mayors activities as needed (UNEP, 2009). One of the two current secretaries to the Mayor has shown considerable interest in the Mae Kha and has been involved in promoting a plan for the improvement of the canal together with Dr. Wassan of Chiang Mai University's Faculty of Engineering (Secretary Mayor, 2013).

Municipal council
The Municipal Council has the power to issue ordinances of bylaw. The council is the main legislative body of the municipality and consists of twenty four members, six elected for each of the four districts. One member is elected as a council chairperson and another as vice-chairperson. Each council member serves a four year term (UNEP, 2009).

Municipal clerk
The municipal office is headed by the Municipal clerk and deputy clerks and includes 7 departments: the finance department, the bureau of education, the technical services and planning department, the social welfare department, the public health and environment department, the office of the municipal clerk and the public works department. Each one of these departments includes various sub-departments. These departments are responsible for the day-to-day activities in each of the 4 districts. The finance department and the bureau of education were not mentioned in interviews as departments directly involved in the management of the canal, though they certainly play a role (UNEP, 2009).

Technical services and planning department
Through two sub-departments of 1) planning and budgeting and 2) city development and promotion, the technical services and planning department is in charge of Chiang Mai's future development plans. These have in the past and present often included development plans for the Mae Kha (Ribeiro & Srisuwan, 2005; Kold et al., 2001). Many plans have been focused on the touristic value of the historical area, and with that the restoration of the old wall. Generally, these plans are devised without proper consultation and participation of the local chumchon inhabiting this area (Kampaeng Ngam, 2013; POP, 2013).

Public health and environment
This department is responsible for disease prevention and control, health promotion related to environmental services, and community environmental sanitation. The public health and environment department have been indicated as responsible for monitoring environmental water quality for pathogens, as well as differences in health for different areas (World Bank, 2008). Interviews with local organizations CODI and Kon Jai Baan have indicated that the national Thai health organization is also involved with community health around the Mae Kha (CODI, 2013; Kon Jai Baan, 2013). However, when this department was contacted they claimed not to have any function with chumchon or the Mae Kha canal.

Civil ID issuing

Part of the office of the municipal clerk is responsible for issuing civil IDs. Ownership of a civil ID in many ways defines the access to citizens' rights, including the right to vote and the right to receive services such as healthcare and social welfare. For a long time this ID was not available to slum dwellers, and hill tribe populations still find it difficult to acquire a civil ID. People without a civil ID are essentially locked out of Thai society, and limited in their capabilities and rights as citizens of Chiang Mai (Walker, 2003).

Section of disaster prevention and mitigation

This sub-department of the office of the municipal clerk is involved in the management of the Mae Kha and of the people around it during and preceding flood events (cmcity, 2013).

Public Works

The Public Works department is responsible for building control, city planning, design and construction, civil engineering and Sanitary Mechanics and has sub-departments dedicated to each of these subjects. Many of the responsibilities of the Marine department in managing the Mae Kha, including dredging, were transferred to the Public Works department in 2004. This department works closely with the Mae Kha for the implementation of infrastructure and monitoring of the canal (World Bank, 2008).

The Civil Engineering Department

This department is responsible for the building and maintenance of roads, bridges, public spaces and parks (cmcity, 2013). These activities directly influence both infiltration and water drainage. At least one chumchon, Saladeng (2013), reported flooding from the roads in recent years, and blockages from the bridges. The development of the parks and walkways along the canal also falls under the Civil Engineering Department. These developments have in the past taken place largely without input from the people living along the canal who have even been evicted or relocated. Current plans to develop the Mae Kha follow the same non-participatory decision making process (Marine Department, 2013; Secretary Mayor, 2013).

The department of sanitary mechanics

This department is involved with the management of used material, water quality, air quality and noise control. All of these activities influence the Mae Kha (cmcity, 2013).

The department of used materials

This department has recently had a positive impact on the canal by expanding garbage collection services to include low income chumchon (Ribeiro & Srisuwan, 2005). It was mentioned in interviews that the levels of solid waste in the canal have decreased markedly in recent years with this service.

The department of air and noise pollution

Air pollution is known to be an important non-point source for water pollution. Thus any improvements in air quality in Chiang Mai are expected to contribute to improvements of the Mae Kha as well (cmcity, 2013).

Water quality management

This subdivision of the sanitary mechanics division of the Public Works Department is responsible for three offices that handle 1) water quality control and treatment, 2) water quality analysis and 3) drainage system maintenance. All three of these offices were interviewed. "Under Section 18 of the Public Health Act of 1992, the disposal of sewage and solid waste in the area of any local government shall be the power and duty of such local government. With reasonable cause, the local government may entrust any person with the solid waste management tasks on its behalf under the control and supervision of the local government or may permit any person to operate the disposal of sewage or solid waste" (UNEP, 2009).

Waste water control and management

Most of Thailand's wastewater treatment plants (WWTP), including the one servicing Chiang Mai (Pen Para), were built by the DTP under instruction of the central government, with technical and financial support by MONRE between 1995-1997. The completed plant was then transferred to Chiang Mai's wastewater control and treatment office (UNEP, 2009). The WWTP is located in San Pak Wan district of Hang Dong Municipality, South of Chiang Mai city, where they report the quality of their effluent.

Budgets allocated to the Chiang Mai municipal government are insufficient to cover operational and maintenance costs for the Pen Para plant. One problem is that the municipal government has not been able to collect tariffs to fund wastewater treatment (World Bank, 2008; sanitation department, 2013). There is no popular support for such tariffs, and according to the drainage department, the municipality lacks the authority to levy its own taxes. Moreover, the Pen Para plant suffers from insufficient staffing. The WWTP was transferred to the municipal level without accompanying documentation such as blueprints; the head engineer, Anuson, lacks basic information about the plant including the size of the tanks, depths and flow rates of influent water, and seasonal and yearly changes in water inflow and outflow (WWTP, 2013). There is also no contact between the drainage management department and the Pen Para WWTP (WWTP, 2013; Sanitation department, 2013). Further, the plant has numerous technical problems including missing parts, wiring and instruments being stolen, a flow meter burned by lighting, aerators breaking down, and a lack of budget to replace or fix parts in the system.

Water Quality Analysis

The water quality analysis office was founded in 1995 in conjunction with the establishment of the Pen Para WWTP. It monitors water quality for the Ping River, the city moat, the Mae Kha, Ku Wai and Pe ja kan canals (east of the Ping river). This office is also in charge of ensuring that the water is safe to use during annual Songkran water festivals (Water Quality Analysis, 2013). Tests are performed in a laboratory facility located within the Pen Para WWTP. Before 1995, tests were performed sporadically by the CMU scientific department (Chief of Drainage Maintenance, 2013). The Mae Kha is measured monthly at 13 points for temperature, pH, DO and BOD (Water Quality Analysis, 2013). According to the Chief of Drainage Maintenance if the BOD levels are high, further tests should be done to measure COD, nitrogen and phosphorous levels however the data received from the Water Quality Analysis office did not show evidence of any of these tests (Chief of Drainage Maintenance, 2013). The water quality analysis office also tests the water being discharged from the treatment plant once a week, as well as the water quality at various locations where citizens report businesses discharging untreated waste water into the canal. The office is short on staff, with only a single employee, and is considered to be insufficient with only monthly and weekly monitoring (Water Quality Analysis, 2013).

Drainage system maintenance

This office takes care of the drainage system of Chiang Mai municipality including the Mae Kha, by monitoring waste water effluents from surrounding buildings, flushing the canal during water holidays, managing the water gates, discharging water into the Ping river during the rainy season, dredging the canal, removing water plants from the canal, building water gates and garbage collection systems, and adding EM or chlorine to the Mae Kha (WWTP, 2013), in order to get rid of the bad smell. Establishments caught discharging untreated waste water into the Mae Kha are given a warning followed by a fine (Chief of maintenance, 2013).

The office claims to organize meetings with NFPs (including Kon Jai baan, Rak Mae Kha and Patana Mae Kha) and community leaders to inform and arrange dredging and larger projects (Chief Maintenance, 2013). However, stakeholders indicated that little of this information is actually provided during the meetings.

The drainage system maintenance office is also underfunded, struggling to run at even its current limited capacity. The lack of monitoring does not allow any clear data on total water volume, peak flow seasonal changes, or other important parameters, and officers at the municipality indicate that businesses and households often bypass the drainage system, discharging untreated wastewater directly into old drains which go into the canal (Secretary of the Mayor 2013; Chief of Maintenance, 2013; Water Quality Analysis, 2013). Even though businesses are obligated to monitor and report their wastewater, these reports are often considered untrustworthy due to widespread corruption. Indeed, various hotels have been caught discharging untreated wastewater and none have ever been closed or fined (Secretary Mayor, 2013).

Section of Religious Affairs

Part of the bureau of education, the Buddhist authorities own much of the land around the Mae Kha canal. As indicated by CODI (n.d.), Buddhist land represents one of the largest homes to squatter chumchon, second only to the State owned land (Treasury Department, Fine Art Department, State Railway Authority, and Port Authority). This is associated with a Buddhist philosophy of "openness," where "Anyone can stay at the temple" (CODI, n.d.). Historically, temples defined community boundaries, and today many chumchon are still centered around and named after temples. Un Ari for example has a higher percentage of Burmese villagers due to its location near the Burmese Buddhist temple Wat Papao.

Community development

This sub-department is part of the Social Welfare Department and is the principle department in contact with the 94 low income chumchon in the city, including the 16 located along the Mae Kha canal. This department supports chumchon to organize community committees, and helps chumchon find land for relocation or to arrange rental agreements with other departments. The community development department is not legally allowed to directly invest in chumchon, only to facilitate community development through information and lobbying. They also work with CODI and Kon Jai Baan in these activities (Community Department, 2013).

Sub-district Administration Offices

Tambons are sub-districts that form the fourth level of administrative subdivision, after district, municipality, and province. 10 of the 16 tambons in Chiang Mai municipality have either the Mae Kha or Ku Wai canal flowing through them. These include: 1) Tambon Pa Daet, 2) Tambon Mae Hia, 3) Tambon Suthep, 4) Tambon Chiang Pueak, 5) Tambon Chang Klan, 6) Tambon Chang Moi, 7) Tambon Haiya, 8) Tambon sii phun, 9) Tambon phra sing and 10) Tambon Pa tan.

In 1997, tambons were integrated into the local government units with an elected Council. Depending on size and tax income, a tambon may either be administrated by a Tambon/Subdistrict Administrative Organization (TAO), or a Tambon Council (TC) consisting of two representatives from each village within that tambon. The tambon area belongs to a municipality and is administrated by the city council. The sub-district should in theory have the management of resources and the environment within their jurisdiction (Letcher et al., 2005), however, in practice tambons in Chiang Mai have little power beyond submitting reports and requesting municipal services such as canal dredging.

Community committee

Chumchon form part of sub-districts but also have their own committees. These committees are formed by 9 community members, which include a leader, a secretary, a treasurer, and volunteer groups for youths, seniors and women (Community Department, 2013). Chumchon see these committees as more influential than tambon administrations (Saladeng, 2013; Kampaeng Ngam, 2013; Fa Mai, 2013). The committee leader in particular is in direct contact with the municipal government through either the community development department or CODI, rather than sub-district administrative officers (Kampaeng Ngam, 2013; Ha Tanwa, 2013; Chaiyapoom and Chang Moi, 2013). These are often also in contact with NFPs and certain academics such as Dr. Wassan (2012) and take part in monthly municipal meetings (community department, 2013).

While some committees are said to have empowered their chumchon, others are said to function as a branch for local politicians to secure votes in return for small favors (POP, 2013). However, there seems to be little interaction between different community committees.

Chumchon

There are 16 chumchon surrounding the Mae Kha of which 9 are in the research area. A total of 10 chumchon were interviewed, 3 of which lay outside of the research area. This section will briefly introduce each of the chumchon located along the trajectory of the Mae Kha. Chumchon are discussed in terms of their size, their infrastructure, and their involvement in the management of the Mae Kha canal.

Lin Kho

The community of Lin Kho is located upstream of the Mae Kha near the Lanna hospital on the outer ring of the city. It has a total population of 920 people living in 290 households, for an average household size of 3. This community is one of the wealthiest chumchon, and its leader owns one of the largest bakeries in Chiang Mai. Most of the houses in this community are made of cement or brick and have septic tanks. In an interview the community claimed to be connected to the wastewater treatment center, however, the drainage maps provided by the drainage system maintenance department indicates otherwise. Lin Kho (2012) has tried to call upon the old spiritual values tied to water in Buddhism, in order to convince people of the value of the canal and the need to take care of it. To indicate this spiritual value of the canal they have organized *Loi Krathong* festival at the canal. This community is well connected with Dr. Wassan, the Patana Mae Kha NFP and the Secretary of the Mayor all present during our interview with the community leader. They indicated that many other chumchon lack the social position to have a voice in the management of the canal (Lin Kho, 2013).

Si Mon Kho

Si Mon Kho, located north of the city between Lin Kho and Muang Samut, is a community which was mentioned in interviews for having a large hill tribe population and many buildings constructed inside the canal (Un Ari, 2013). Si Mon Kho was not interviewed in this study. The community has a total population of 500 with 200 households, and an average household size of about 3. The majority of households in this community are built out of a mix of wood and cement. Si Mon Kho has full access to electricity and running water but has no wastewater treatment and discharges its wastewater directly into the canal (Si Mon Kho, 2013).

Papleng

Papleng was previously a two-part community formerly known as Klong Nung I and II. This community is located at the split of the Mae Kha canal in the vicinity of Muay Mai market north east of the city, stretching over to the Ping River. It is one of the oldest and largest chumchon in Chiang Mai, though large parts of it were dissolved and evicted in 2005 (POP, 2013). After moving many of the households to a suburb of Chiang Mai 10km outside of the city, many of the previous settlers returned. Papleng has a total population of 3200 people in 900 households, with an average of about 4 people per household[27]. This community is known for large numbers of apartment buildings housed by seasonal migrants from Burma and rural Chiang Mai (including hill tribes). The community leader indicated that there are about 40 hill tribe households located within the canal (Papleng, 2013).

The majority of houses in Papleng community are built out of brick and cement, though a large number are also built out of wood, and some of bamboo. Most of the community has access to water and electricity (many households share electricity), and many (but not all) households have septic tanks in place. The community is built mostly on public land and partly on private land where people lack land rights. The community leader (Pra Jun) mentioned that the municipality has planned and budgeted to clean the canal, and that these plans include evictions. She explained how community activities related to the Mae Kha are politically charged: "[the community takes part in] cleaning activities twice a year, … collect the garbage that is in the water and they intend not to litter. They plant some plants and vegetables to make the landscape prettier. They [keep] the Mae Kha clean, firstly for themselves, because they are living here, but also because otherwise they could face an eviction. They are afraid that otherwise it looks like they do not take care of the Mae Kha and might

[27] Population 3074, households 898 registered at the municipality.

face an eviction (Papleng, 2013)." The community is in contact with POP and CODI to assist in the relocation attempt by finding a land for them outside of the city.

Samut
This small unregistered community is located nearby the Muay Mai market with a small population of around 200 people. It was the only interviewed community which did not have an elected committee. When we visited this community the majority of the houses were made out of wood in traditional Thai style. The community uses septic tanks in at least some of the houses and has access to electricity and running water. The community members are disenfranchised with the local government, meaning that they have tried to register and organize but have not yet succeeded. They also feel cast out from local NFP networks. The Samut community is located on private land which the community members rent or own property. Most community members work at Muay Mai market (Samut, 2013).

Un Ari
Un Ari community is located north of the city built on land which was reclaimed filled in a lake (Annex 14). Un Ari has a total population of 582 with 127 households, and an average household size of about 5[28]. Most households are built out of cement and brick, though a significant part of the community is built out of bamboo. This community is located south of the ice factory and next to the water gate at the beginning of the city, behind Wat Papao. There is a side stream that runs through the community and ends in the Mae Kha through which a lot of wastewater is discharged. Approximately half of the population of the community is Burmese. Most households in the community have installed an oil trap for their kitchen water, as a result of the Chiang Mai EM project by POP. Some households have septic tanks but many do not. The community committee goes to sub-district meetings monthly and reports problems with the Mae Kha to the sub-district. They do not feel that they have a voice in the municipality or are even informed of the municipality's plans or activities. Un Ari takes part in canal cleaning activities during King's and Queen's days and gives weekly announcements to promote anti-littering behavior in the community (Un Ari, 2013).

Chaiyapoom and Chang Moi
These chumchon are located in the centre of Chiang Mai next to Wat Chai Sii Pum , Chang Moi houses 685 people in 118 households[29] with an average household size of about 6 Chaiyapoom (a neighboring community which is not directly along the canal) has a population of 1031, with 309 households and an average household size of 3. The chumchon got organized and formed a committee in 2003. Most houses are built from a mix of cement and wood, and the community has almost full access to piped water, electricity and septic tanks. The majority of the land is privately owned by the households, but a large part is located on public land and externally-owned private land (Lasapasadu Grompernarak)(Chaiyapoom and Chang Moi, 2013).

Chaiyapoom-Chang Moi have a volunteer group dedicated to environmental quality and are part of a national community network. As such they organize monthly canal cleanings and participate in city wide cleanings for the King's and Queen's days. The committee is also active in awareness campaigns to reduce littering, which include public announcements and storytelling about the historical value of the canal for Chiang Mai. The community cooperates with students to survey the canal, and 38 households have installed oil filters introduced by the POP Chiang Mai EM project, financed by Manu Life insurance (in cooperation with the municipality). There is no significant cooperation between chumchon and the government, and the community complains about the government's lack of transparency and partnership towards chumchon. This has demotivated the people and a decreased number of people are actively involved with the Mae Kha (Chaiyapoom and Chang Moi, 2013).

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[28] Total registered population of 500, and 127 households.
[29] A population of 613 and 91 households registered at the municipality.

Mae King

Mae King was indicated by CODI to be one community that was certain to face eviction under the municipality's current plans. The small community is located on a side stream, east of the Mae Kha, and experiences heavy flooding and health risks during the rainy season (Saladeng, 2013). Mae King has a total population of 500 with 70 households and an average household size of about 7. About half of the households in Mae King are built out of brick and cement and the other half out of wood. The majority of households have piped water though a small percentage use groundwater wells. The entire community has access to electricity, and most households have septic tanks. The community is under serious threat of eviction due to its location which is inaccessible without trespassing on private land. CODI is looking for suitable land for the relocation of this community (CODI, 2013).

Raekgeng

This community is one of the biggest in Chiang Mai and is located south of the Night market, north of Hua Fai. Raekgeng is surrounded by hotels and shopping areas, and includes 898 people with 239 households at an average household size of about 4 (Community Department, 2010). The community is located around a Buddhist crematorium. Many houses were recently moved for the construction of a public path which is now abandoned. A dying factory which was often indicated as an important polluter to the canal, used to be located in this area.

A small tributary stream flows through Raekgeng, into which many households discharge their wastewater which subsequently discharges directly into the Mae Kha. Raekgeng is also active in community cleaning activities for Queen's and King's days and participates in community meetings organized by the local municipality (Hua Fai, 2013).

Kampaeng Ngam

Kampaeng Ngam is located south of the city, and borders Raekgeng and Fa Mai. It has a total population of 564 with 140 households and an average size of 4(Annex 18). Approximately half of the households are ethnic hill tribe (mostly Akha) while the other half is ethnic 'Thai'. Kampaeng Ngam is one of the few chumchon in Chiang Mai where there is a good relation between the community organization and hill tribe population (Kon Jai Baan, 2013). In this community, 14 different households, including the community leader, were interviewed about their relationship with the Mae Kha.

Approximately 50% of households in this community are built out of cement and brick and the other 50% is built out of wood and bamboo in traditional Thai style. The community is located between the Mae Kha canal and the historic wall. In 2005 several households in Kampaeng Ngam were removed from on top of the wall and resettled on the banks of the canal. This was the result of an agreement between the arts department and Kampaeng Ngam in cooperation with CODI and POP to gain land rights for this area. As part of the arrangement, all households lost some of the area they lived on in order to make space for the households coming down from the wall, and to satisfy a rental agreement with the arts department. All of the households in this community have access to running water, electricity and septic tanks, however some households still use groundwater to save money (Kampaeng Ngam, 2013).

The community leader expects that the new government plan towards the Mae Kha will include evictions. They are accordingly preparing to organize a protest and negotiate these evictions, with goals of land re-organization and household upgrading. The community leader claims that the government wants to expel the 'Thai' population and keep the 'hill tribe' population turning it into a tourism attraction, as an 'ethnic' village. The community leaders of Kampaeng Ngam attend monthly meetings with the sub-district, but do not feel that they have the access to communicate with the municipality and to rely on CODI to voice their concerns. They also participate in canal cleaning events for King's and Queen's days (Kampaeng Ngam, 2013).

Hua Fai

Hua Fai is located south-east of the city, near Wat Hua Fai and the municipal slaughter house, south of Raekgeng and east of Fa Mai, it is across the canal from Kampaeng Ngam. Hua Fai has a total population of 1580 with 451[30] households, and an average of about 4 people per house. The majority of households are built out of cement and brick but many are also built out of wood. The majority of the community is located on land to which they have titles, though a small part is located on public land and new households try to move into the canal, but are quickly evicted. The community is faced with the stress of a growing population. The community is primarily Thai but has a growing "Hill tribe" presence. Hua Fai has full access to running water, electricity and septic tanks (Hua Fai, 2013).

The community committee has not yet been allowed to participate in planning and management activities related to the canal and community, as the newly elected officials have not been recognized by the municipality yet. After hearing of the 300 million THB budget allocated for the improvement of the Mae Kha, the community feels insecure for their future land security. Together with other community leaders they arranged a meeting with the Tambon leader and municipality officials, but were not given any useful information. During past years the community has had to remove households located in the canal, and to find ways to resettle them into the limited land available, increasing the density in the community (Hua Fai, 2013).

Hua Fai has been actively involved with the Mae Kha with canal cleaning activities on Queen's, King's and world environment days, as well as awareness programs with weekly announcements against littering, with threats of fines. The community has also been active planting the banks of the river to decrease erosion. NFP's have supported these activities Action Aid, donated a boat to facilitate in canal cleaning activities. However, local people have lost interest in the project due to a lack of cooperation from government actors (Hua Fai, 2013).

Fa Mai

Fa Mai is one of the biggest chumchon in Chiang Mai and is divided into 4 sub-sections, separated by the Mae Kha and Ku Wai canals with a total population of 1200 people and 315 households [31], with an average household population of about 4. The community was founded 30 years ago, and first formed a community committee, 26 years ago. Located in the south of the city, it is the southernmost community on the banks of the Mae Kha. The Northern parts of Fa Mai are located along the Kampaeng Din wall, and have arranged to rent the land from the National Arts Department for periods of one year at a time. These parts of the community seem more developed, and generally have septic tanks and running water. On the other hands the parts of the community downstream seem poorer, and lack land rights, as well as running water and septic tanks (Fa Mai, 2013).

An estimated 80% of the households in Fa Mai are constructed out of cement and bricks and 20% are constructed out of wood. The entire community has access to electricity but large parts of the community in the south are dependent on rain water harvesting and groundwater wells for water. This is a point of concern as the community is located directly on the banks of the canal and has no water treatment in place. There are plans to construct septic tanks but the community says they lack the funding for such a project (Fa Mai, 2013).

The community committee includes a community savings bank which, in cooperation with CODI's Baan Mankong program, facilitates household upgrading. In relation to the Mae Kha, Fa Mai feels threatened with eviction, is often blamed for canal pollution, and is excluded from relevant decision making processes. The community leader mentioned that, "We have to move out, but they don't ask us, while we have been living here for such a long time. We were not consulted in making up this plan. The pollution in the water comes from the city, from the hotels. But we have to move out because we would make the canal dirty. But we don't make it dirty. The reason it is dirty comes from the business part too. The people in the community start to take care of the water, before the municipality was caring about this. They were already cleaning it and after this the municipality came to complain about the water". In the past Fa Mai has participated in cleaning the canal on King's and Queen's days, but stopped due to the retreat of the NFP Suppanni which used to financially support these

[30] Population 1227, households 451, registered at the municipality.
[31] 1061 with 235 households registered by the community development department.

activities. They also resent the government for taking the credit for their labor, without giving any recognition (Fa Mai, 2013).

Ha Tanwa

Ha Tanwa is located on public land between the Kampaeng Din wall and Ku Wai canal. It borders Fa Mai to the east, Tipanet to the west, and Sii Ping Mueang across the canal. The community has a total population of 345[32] people with 110 households (Annex 18), at an average household density of about 3 (Ha Tanwa, 2013). These figures exclude the recent development of many dormitories (Kon Jai Baan, 2013; Ha Tanwa, 2013). The community women's leader considers that most of the people renting dormitories are of Burmese or Hill tribe ethnicity, which live in higher densities and are not considered as part of the community. Most houses are built out of brick and cement, and have access to electricity and running water. Running water was set up by the community itself and was funded by UNICEF (Ha Tanwa, 2013). However, many houses still use groundwater to save money and lack any type of water treatment system.

Like Fa Mai, Ha Tanwa has a savings bank which cooperates with CODI, and NFPs including POP, Kon Jai Baan and DANCED and have been involved in many household upgrading projects. The savings bank also functions as a security net to help community members in case of emergency (2013). Because only citizens with valid IDs are allowed to register in the savings bank, many hill tribe families are excluded from this service.

Ha Tanwa, together with Tipanet, Saladeng, Sii Ping Muang, Chaiyapoom-Chang Moi, organized the project "Khun Nam dii Ku Wai" in 1999 in order to clean the canal. Initially they did not get support from the municipality or the province but eventually did get support from CODI. After the chumchon experienced success in cleaning the canals, the municipality tried to take over the cleaning activities without including or recognizing the achievements of the chumchon, which angered chumchon who then stopped participating in the cleanings (Ha Tanwa, 2013). Ha Tanwa is also active in cultural activities and state that, "sometimes it can be difficult to talk about housing. Then it's easier to talk about culture instead". Like environmental activities, cultural activities can enhance the standing of the community in the city. Together with CODI and Kon Jai Baan, Ha Tanwa has organized a project to protect the old wall and have constructed a community park on top of the old wall.

Sii Ping Muang

This community is located along south of the Ku Wai stream in between Saladeng and Fa Mai chumchon and across the canal from Ha Tanwa. It has a total population of 1299 with 417[33] households and an average household size of about 3. The houses in this community are primarily built out of cement and brick, sometimes in combination with wood. The community reports full access to electricity, running water and claims connection to the national wastewater treatment plant, while households also have septic tanks. However, when consulting drainage maps, Sii Ping Mueang does not appear to be within an area covered by the drainage system, and thus their wastewater likely streams to the Mae Kha canal. This community is fairly developed and does not have the aesthetics of a community, but claims to have full land rights. Sii Ping Mueang has the highest rate of large dormitories observed in the area and have reported more than 20 such establishments which are primarily occupied by Burmese migrants. The community leader does not consider these residents or buildings as part of the community, and the community does not participate in any activities concerning the Mae Kha canal (Sii Ping Muang, 2013).

Saladeng

Saladeng was founded in 1986 and is located south of the Ku Wai canal. It borders Mahidol road to the south and Sii Ping Muang community to the west. The total population for this community is 875 with 276 households at an average size of about 3. The community committee includes a savings group and are involved in upgrading programs with CODI. This has provided access to electricity and

[32] 379 people and 109 households registered at the municipality.
[33] Total registered population 1257, and 417 households.

running water and has enabled household rebuilding with brick and cement. They have also organized a neighborhood watch program, increasing local security. Recently (2012), the community negotiated an agreement with the municipality to rent the land for a 5 year term (at 15 THB per m^2)(Saladeng, 2013).

Saladeng, which still lacks drainage and waste water treatment, attempts to decrease their environmental impact by collecting and selling waste oil. They are also in the process of applying for a Baan Mankong loan from CODI, to construct a drainage system that directs water that comes into the community from the roads into the Ku Wai stream. They participate in canal cleaning on King's and Queen's days and unclog bridges in the rainy season to prevent or relieve flooding (Saladeng, 2013).

Tipanet

Tipanet is one of the largest and oldest chumchon in the city, and is the furthest upstream community along the Ku Wai canal. This community has a total population of 1019, with 313 households and an average household size of about 3 (Annex 17). Tipanet also participates in community cleaning activities on King's and Queen's day (Saladeng, 2013; Ha Tanwa, 2013).

Hill tribes

The term *hill tribe* is used to describe indigenous ethnic communities from a number of tribes including the Karen, Hmong, Lahu, Akha, Yao, Lu-mien, Lisu, Kachin, Dara-ang, Lwua and Lawa. In Thailand, hill tribes represent 1.4 – 2% of the population, with around 1million people living primarily in the northern area. In this area some of these groups predate ethnic Thai, though all have inhabited it for hundreds of years (Heering, 2013). Hill tribes, with their separate languages and cultures, are often considered as non-Thai. The majority of Akha are Christian, which further excludes them from the national Buddhist culture (Residents of Kampaeng Ngam, 2013). Some hill tribe groups living in the rural areas of Chiang Mai Province have converted their villages to become tourist attractions (Tan-Kim-Young, 1979). Many have also migrated to urban areas to sell arts and crafts to tourists. Most hill tribe people in Chiang Mai live within chumchon, but are commonly excluded from the community. Their political access to the decision-making sphere is extremely limited, as they are not considered "Thai", and are often singled out as the source of pollution to the canal, due to their "rural life style". One Akha arts and crafts sales woman and a few Akha households were interviewed during the present research, though the results are not separated.

NFPs

The government's Decentralization Action Plan and the 1997 Constitution both mandate greater public participation in environmental planning and implementation of environ-mental services. Effective waste management relies on active community involvement in activities such as reporting open dumping of industrial waste and disposal site planning, as well as reducing of overall waste produced via reuse, recycling and composting initiatives. NFPs play a key role in bringing about this involvement, by building awareness and encouraging grass roots initiatives. In the following section the roles of relevant NFPs are discussed.

POP and community network organization

People's organization for participation (POP) focuses on community empowerment and environmental issues. Founded in 1996, POP describes their activities as community-led, whereby they assist chumchon to define their own problems and find solutions. Under its community network program, POP organizes meetings and workshops with and between chumchon, offers chumchon funding for activities, and helps chumchon in negotiations with the various levels of government. POP is tied to UCEA and Vompot a Christian organization from Bangkok and founded in 1978. Vompot NFP was supported by CCA-URM (Christian Conference of Asian Urban Rural Mission) it focused on working with "slum" chumchon (POP, 2013). The UCEA is another organization which initiated many of the activities that POP now heads, including the community network organization, and where it gets its focus on environmental activities from (Ribeiro & Srisuwan, 2005).

Gum Hak Doi Suthep

Gum Hak Doi Suthep (GHDS) is a small environmental organization led by Ricky Ward, a retired Australian. This NFP focuses on planting trees in Chiang Mai and conserving the local biodiversity of the area. Together with Dr. Wassan, GHDS has started planting the banks of the Mae Kha, especially in the areas that have been converted into parks, including, Kanchanaphisek Park and the walkway between Sri Don Chai road and Raekgeng community (GHDS, 2013).

Kon Jai Baan

Kon Jai Baan (KJB) is a local community architect group who design and build in cooperation with chumchon from the city. They raise awareness for community issues in the city through flyers, workshops and exhibitions. They want the chumchon to be recognized as legitimate elements of the city in order to facilitate negotiations for land rights and basic services, with the government. KJB maps chumchon and gives them access to this information during negotiations, which allows them to make better city plans. Their projects have generally focused on the cultural and social value of chumchon, including the restoration of the old wall, creation of a park and other public spaces in chumchon, and house upgrading (Kon Jai Baan, 2013).

Dr. Wassan and River Care

Dr. Wassan Jompakdee is a professor of mechanical engineering at Chiang Mai University and the head of River Care, an organization which aims to improve the waterways of Thailand. He has been active in designing local and national plans for the management of waterways. This includes the Master Plan for the Mae Kha canal which resulted in Chiang Mai being awarded a budget of 300 million THB to restore the canal and its surroundings (Chief maintenance, 2013). Dr. Wassan also organizes conferences and other activities between various stakeholders, including businesses, government, chumchon and NFPs to share information about the canal. He has been able to generate interest in the canal from government and industry by organizing symbolic activities such as Loi Krathong, bank planting, boat rides and other activities around the canal. He has also involved the university in the Mae Kha by getting first year students to participate in cleaning and researching the canal. These activities are often organized in cooperation with chumchon Lin Kho or Un Ari (Wassan, 2013)

Other mentioned NFPs

Many other NFPs were mentioned who have smaller roles or are no longer active in the area.

UCEA

UCEA (or Urban Community Environmental Activities) is no longer active in Chiang Mai. In the past they organized environmental activities around the principle of a participatory process where the goal was not environmental improvement per se, but rather a subject around which processes of social change could be organized (Ribero & Srisuwan, 2005). These participatory environmental projects aimed, "to create ownership of interventions (sidewalks, bridges, etc.) by the community involved. By actively contributing to a project, whether through decision making, design or implementation, the community will be in a better position to appropriate the project as its own and to look after its maintenance" (Ribeiro & Srisuwan, 2005, p189). With the implementation of UCEA, a network of squatter communities along the Mae Kha canal was formed. These activities are now organized with POP.

UN Life

UN Life invested in Chiang Mai chumchon to improve infrastructure for basic services, including water pipes and roads. Ha Tanwa (2013) and POP (2013) both described working with the UN Life foundation in the past.

Rak Mae Kha

This was a student group which organized to raise awareness around the issues of the Mae Kha canal and the chumchon that surround it. Their activities included mapping chumchon with Kon Jai Baan and organizing community workshops to identify problems. They have used this information to negotiate with the government for a more natural and social management of the canal (Kon Jai Baan, 2013).

Ki-o-suay-hom
ki-o-suay-hom is a local environmental organization that works together with Kon Jai Baan to map the local wealth of the city, including locations of local trees and monuments, some of which are located in and around chumchon. They cooperate with community volunteer groups for environmental and historical conservation of the city landscape (Kon Jai Baan, 2013).

4 region slum network
This national scale NFP cooperated with POP on policy issues related to relocation and land rights for chumchon (POP, 2013).

DANCED
Danish Cooperation for Environment Development (DANCED) is a Danish bilateral aid program which was active in Chiang Mai in the past. DANCED was one of the first organizations to offer direct funding to chumchon for household upgrading and landscape and environmental management. They attempted to install bottom-up development processes in Thailand. Many of their activities have now been taken over by CODI (POP, 2013). Besides DANSED, the German Technical Cooperation Institute (GTZ) was also active in similar projects in the past.

ChumChon Thai
Chum Chon Thai is a national organization working with "slum" chumchon to improve living conditions and local infrastructure. They also make funds available to local chumchon for activities (CODI, 2013).

Supanini
Supanini is an NFP which worked with Fa Mai to improve education and housing in the community, and has supported Mae Kha cleaning activities in the past (Fa Mai, 2013).

Lanna Womens Network
This network organizes workshops and other activities to empower women from the community, including assisting with activities involving the canal (Ha Tanwa, 2013).

Kum Map Puthet
This organization has done a variety of work in the past including a survey of chumchon, building a bike path along the canal, and organizing tours along the path (Chaiyapoom and Chang Moi, 2013).

Hok kan ga
Hok kan ga is a business association which organizes around business interests and communicates them to the government. It is not clear which businesses are represented by Hok kan ga. Many chumchon and NFPs distrust this organization, except Dr. Wassan who is said to be in contact with this organization. Hok kan ga has been said to influence governmental policy towards the Mae Kha. They are also involved in CSR activities which sometimes include investments in community or environmental issues (Kon Jai Baan, 2013; Wassan, 2013).

Businesses
There are various businesses located around the Mae Kha which have been reported to be important actors in influencing the policy for land management in the area. Many interviewees also make allegations that there are cases of corruption between the government and these businesses. Officially, the policy in Thailand is based on the principle that private sector should be responsible for providing necessary treatment of their emissions (World Bank, 2008). While many businesses might be represented by Hok kan ga, we will discuss some which were mentioned separately and are considered important.

Markets
There are various markets located around the Mae Kha; Muay Mai market and Kom Market are often indicated as important sources of wastewater to the canal (Papleng, 2013; Kon Jai Baan, 2013). These

large markets are connected to the canal through the city drainage system however, actors interviewed at the market did not know where their wastewater went. Many community members also work at these markets (Samut, 2013; Fish stand, 2013; Kampaeng Ngam residents, 2013).

100 pipers whiskey

This whiskey brand started a fund in Chiang Mai to improve the Mae Kha canal. They worked together with Dr. Wassan to implement a project which annually donates 500,000 THB to the municipal level and 100,000 THB to 5 different chumchon towards activities to improve the canal. The government has used these funds to perform dredging activities and plant on some of the banks of the canal (Secretary Mayor, 2013; Wassan, 2013).

Manu Life Insurance

This insurance company worked together with POP in funding a project to introduce kitchen oil traps at low prices for local chumchon (POP, 2013).

Mia Sawa

Community organizers from Chaiyapoom-Chang Moi (2013) indicated that Mia Sawa was a Japanese organization which installed the cement lining in sections of the Mae Kha in the city centre.

Land owners

This is an undefined group which generally used to refer to a rich and politically connected population. It is known that this *'Lasapasadu Gromperanarak organization'* owns a significant portion of land near the Mae Kha. One can observe various areas of open land around the Mae Kha. Chumchon and NFPs claim that there is a land-grab taking place around the canal, with increasing land values that have followed the urbanization of the area, and that this is one of the major forces which push for community evictions (Kon Jai Baan, 2013; Lin Ko, 2013; GRDS, 2013).

Hospitals

There are many hospitals located along the Mae Kha and Ku Wai canals, including Lanna, Son Poo, Suan Dok and Suan Klong Hospitals. These establishments, like other businesses, are required to treat their own water before discharging it into the canal. Chumchon around some of the hospitals have reported untreated water being discharged. Lanna hospital mentioned that they have on occasion failed water quality standards. The water quality standards to which they have to conform are set by the Health Department but do not consider pathogens or contain any standards for pharmaceutical or chemical micro pollutants (Lanna Hospital, 2013).

Hotels

Of the three major hotels located around the Mae Kha (Centara, Imperial Mae-ping and Le Meridien), only Centara was open to being interviewed on the environmental quality of the canal. Of the three, Centara hotel is located closest to the canal. There are also many smaller hotels around the canal, with 14 hotels identified in total, 6 of which were interviewed: Cendara (820 rooms), Tha Pae Inn (30 rooms), Condotel (110 rooms), Red Brick Hostel (42 rooms), Guest House (14 rooms) and Panda Hotels (20 rooms). Most hotels are located in the area of the Mae Kha parallel to and east of the city square, and are which has very few chumchon (Figure 1). Hotels increase the total density of population around the canal and many chumchon blame the abundance of hotels for the pollution of the canal. Indeed, many hotels have been said to discharge untreated waste water directly into the canal (Secretary Mayor, 2013; Fa Mai, 2013; Kampaeng Ngam, 2013). Moreover, hotels and tourists that stay in them do not feel responsible or connected to the canal. The importance of the tourism industry for the economy of Chiang Mai makes these actors and their interests important for the management of the canal. The water quality agency (2013) and secretary mayor (2013) both indicate that most of the hotels in this area have been caught discharging untreated waste water into the canal in the past. However, interviewed hotels, with the exception of Centara, one of the 3 enormous high rise luxury hotels in the area, showed little knowledge about the water treatment laws with which they were expected to comply. Centara (2013) reported that it and other hotels in the area attend monthly meetings organized by the municipality on the state of the Mae Kha with many of the chumchon.

Small businesses
Massage parlors, garages, beauty salons, Laundromats, arts and crafts workers (including fabric dying) and small restaurants are some of the types of small businesses located along the Mae Kha. Formal and informal businesses form an important source of employment for lower income groups in Chiang Mai. Many of these actors discharge their effluent directly into the canal or storm drains. 8 different small businesses were interviewed, a laundry services, a beauty salon, a fruit sales man, a fish sales man, an arts and crafts sales woman, a garage, and 2 small restaurants. Most reported that their water effluent was never inspected. These actors did not see themselves as sources of pollution, indicating that their water went either into the drainage system or was treated through the soil, but not thrown directly into the canal. They did not feel like they were a part of the decision making process but did lodge official complaints regarding the management of the canal to their sub-district representatives.

Slaughter house
The slaughter house is a municipally run business near Hua Fai community in the southeast of the city. This is the only slaughter house in the city, and it functions without much infrastructure, lacking any kind of cooling area or wastewater treatment. The effluent is discharged directly into the Mae Kha canal through an open drain that runs through Hua Fai. This effluent includes blood, excrement, the contents of the pig stomachs, and small pieces of flesh (slaughter house and secretary mayor, 2013). The slaughter house processes 200 pigs per day, operates during late night hours from 9pm to 5am, and is invisible to most of the city (slaughter house, 2013). Ha than was community leader (2013) has reported pig pieces being dumped into the canal, and during water sample collection we found pieces of pig skin in the area.

Fabric dying factory
Many chumchon indicated that the recently closed fabric dying factory in the vicinity of Raekgeng community was an important source of pollution to the canal, periodically discharging streams of different colors into the canal (Kampaeng Ngam, 2013; Hua Fai, 2013; Saladeng, 2013). While this factory is now closed there are still various households and small stores which dye textiles in the area, and streams of bright colors are sometimes visible in the canal.

Ice factory
There is an ice factory located north of the city, which was reported by Kold et al. (2001) to discharge cloudy white effluent water into the canal in the early mornings.

UBA
Utility Business Alliance is a Thai private water treatment company which is planned to take over the water treatment responsibilities from the local government in Chiang Mai (WWTP, 2013). This is part of the National Water Management Agency's plan to privatize in order to improve water management. The private sector participates in water supply mainly as operators, while construction of facilities are fully government financed (World Bank, 2008).

Contractors
The municipality has to hire contractors to dredge the canal, because it lacks the internal capacity to do this (Marine department, 2013).

Villas and Condos
Besides chumchon, there are also many villas and condominiums around the canal, many of which also lack water treatment and construct walls along the edge of the canal, narrowing it and taking over the riparian zone (Kampaeng Ngam, 2013).

Deciding on the Mae Kha
The decision-making process on the urban management of the Mae Kha canal is embedded within a Kafkaesque system. It is constructed out of a long list of GIs at various levels of governance, whose decision-

making process and responsibilities are entangled in a net of political self-interest and tokenist cooperation. Various governmental levels, businesses, chumchon and NFPs have both the interest and potential to influence the management of the canal, but these abilities are confounded by complex and muddled political power relations (Atkinson, 1996). The most influential actor in the management of the Mae Kha continues to be the national government, as it sets the policy, implements most of the infrastructure, and defines the funding. In general, the idea is that ministries set the national environmental policy and the departments and agencies under the ministries are responsible for the tasks of regulating and monitoring the activities tied to these policies, while local departments are in charge of the implementation. In practice most of the actions related to the Mae Kha are undertaken by instructions formed purely by the national government, without local government or public participation. As a result, much of the built infrastructure ends up being badly managed and underused (Ribeiro & Srisuwan, 2005; World Bank, 2008).

The 1997 Thai Constitution opened the door for political and administrative decentralization (Ribeiro & Srisuwan, 2005). However, "Legally, and according to tradition, local government in Thailand, although wishing to appear as a local, even 'popular' institution is, in fact, little more than an arm of central government and therefore basically uninterested in gaining greater local autonomy" (Ribeiro & Srisuwan, 2005). While, in theory, decentralization processes have reallocated responsibilities to municipalities, in reality, the municipality lacks the capacity to take them over. Without the decentralization of the power to collect taxes, change or make land rental agreements for public land, provide urban housing to the poor, set up projects which cross municipal borders, implement infrastructural projects, or even clean the canal, the municipality is unable to take the lead of the management of the Mae Kha. As the Chief of Maintenance (2013) explained: "The municipality doesn't have enough power to do things. If they get some budget from the province they can do some small things, but they do not have the power to order the military and the police to come and help them. So, sometimes even though they want to pave the road, or protect the old wall, if the people complain about it they have to stop, because they don't really have that much power." Moreover, the municipality hardly has the resources of skilled staff and capital on hand to carry out current functions, including the drainage system, WWTP, and regular dredging and flushing of the canal.

This multi-level construction of non-participatory decision-making weakens the trust between various levels of government. In 2013, the central government budgeted 3,000,000,000 THB to improve the Mae Kha canal. However, this budget was not tied to any specific projects or even governmental level. As a result, the municipal and provincial levels quarreled about who would be held responsible. The perception existed that any such major program would need to involve large scale evictions of chumchon. However, as the Chief of Maintenance put it in an interview, "[government institutions] don't know how to manage [such a program] because it can affect a lot of the people [....] Thailand has laws in place [to evict squatters] but to use the laws strictly is not the Thai way to do it. You can't just go there like evict people, it's about party [politics], no one wants to hurt people [and fall out of favor]" (Chief of Maintenance, 2013). The development of this plan did not only exclude local stakeholders, like chumchon, businesses, and NPFs with vested interests, but also excluded many local GIs currently involved with management of the canal, including the Marine Department, CODI, the Community Department, the Sanitation Department and the Pen Para WWTP. Instead, these stakeholders were limited to passing along rumors and discussing possibilities, and the project's impending implementation and details have gained a life of their own.

The failure of the process of decentralization is most visible in the plans to re-centralize the operation of the WWTP, putting it back under the national WMA. The re-centralization process was itself a centralized decision, taken without input from the engineers currently running the plant. The future of the plant is unclear to them. One option appears to be that the operation of the plant could be transferred to a private company: Utility Business Alliance (UBA). Chiang Mai Public Works hopes that the re-centralization will facilitate the management of the water infrastructure of the city, because the WMA has the power to implement tariffs for water treatment while the Chiang Mai municipality does not. Meanwhile, Mr. Anuson and Mr. Manupant at the WWTP seemed skeptical of this new development, hinting that corruption might be behind the change in direction.

Nonetheless, the municipality plays an important role in the management of the canal, not least because it is through them that local stakeholders such as chumchon, businesses and NFPs have access to the government. Moreover, the municipality has many responsibilities towards the canal including taking care of public health, and treating and monitoring wastewater. In fact, the 3,000,000,000 THB project to improve the Mae Kha was the result of a municipal proposal for a much smaller project, which was appropriated and blown up by the national government (Chief of Maintenance, 2013). Now the project has been taken over by the provincial government and the governor, who are exploring the possibilities available for the relocation of communities living along the canal (Chief of Maintenance, 2013).

Of course, these plans for relocation have not been discussed or even openly presented to concerned community leaders (Kampaeng Ngam, 2013; Hua Fai, 2013). Despite the mayor and council being democratically elected positions, they have often been described as weak institutions, functioning through clientalist relations (Ribeiro, 2005; Atkinson, 1996). The functioning of democracy is fairly new to Chiang Mai; directly elected municipal representatives have only been in place since 1999. Prior to this, positions in the mayor's office and council were directly appointed by the Ministry of Interior. In fact, the un-elected provincial government still has the power to appoint key municipal officials, such as the municipal clerk and section chiefs, and even to dissolve municipal assemblies and executive councils, and supervise the fiscal affairs of the municipalities (Atkinson, 1996; UNEP, 2009). As the Chief of Maintenance (2013) stated, "The municipality cannot talk to the land department, they cannot talk to the central government departments, so finally the municipality is just the supporter of the provincial government."

Participation becomes even more opaque for actors outside of the government. There is no clear process through which civil society and businesses can get involved in the management of the canal in any meaningful way. Moreover, local NFPs and chumchon know the relatively powerless position the municipality holds, and that it uses this foothold for personal gain. "This creates a hostility which both confirms local government in its detachment from local commitment and reduces the possibilities for real community benefits arising from local government programs" (Ribeiro & Srisuwan, 2005). Atkinson mentions that, "[h]owever well a poor community gets together to manage local environmental problems, without active cooperation from other urban groups and, in particular, the local authority, net benefits may be questionable and disillusionment is likely to ensue" (Atkinson, 1996). In fact, many communities have taken the initiative to organize themselves and implement various household and community upgrading projects. Moreover, they have taken it upon themselves to negotiate land rights in certain areas, set up savings banks which offer community members a certain degree of social security, and even organize activities to clean the canal. However, the continued exclusion of communities from the planning and implementation process, combined with the political instability, has dulled chumchon into inactivity. There is a feeling of uncertainty about their future and even the advances they have already gained, in particular due to fear of eviction. This fear has immobilized chumchon who are unwilling to either invest in the area or risk stirring up political unrest. The community leader of Kampaeng Ngam (2013) mentions that "the governor doesn't want to mess around with [these rumors of evictions], because he fears that he will lose votes[34]," explaining the non-responsiveness of government officials to his inquiries regarding the possibility of eviction.

What is at risk is an unwritten agreement between communities and politicians where the municipality turns a blind eye to squatters in exchange for votes during local elections (Ha Tanwa, 2013; Marine department, 2013; Chief of maintenance, 2013). This process maintains the *status quo* in which communities lack land security, and are thus vulnerable to such agreements. This is also part of the reason why, in the past, hill tribes and Burmese migrants, many of which lack civil ID cards, have been more likely to face evictions. These evictions fit within a discourse that appears to de-legitimize squatters, yet does not weaken the electorate. On the other hand, it reinforces discord between chumchon, and chumchon subsections. In addition, the political instability also limits institutes like NHA and CODI, which support chumchon in

[34] While the governor is not elected he is a representative of the same political party as the municipal government.

their undertakings. Because there is no clear housing policy, the activities by these institutes is susceptible to the political winds. In the past, the budget of NHA has been cut drastically with a change of government (World Bank, 2008).

The landscape of NFPs involved with the Mae Kha and surrounding chumchon has changed over time. However, the majority of NFPs are involved primarily with the chumchon and consider the Mae Kha only as an instrumental actor towards the goal of improving the quality of life of the chumchon, on the physical or institutional level. NGOs have played an irreplaceable role in calling attention to the plight of chumchon in Chiang Mai, assisting them in getting a seat at the table to negotiate for and obtain land rights, as well as demanding and obtaining finance for the provision of basic services such as water, electricity and garbage collection. In addition they have organized activities to improve the surrounding environment, including the Mae Kha, through technologies, activities and public relations. These activities have gone a long way towards not only empowering chumchon, but also changing the perception of chumchon in Chiang Mai.
There are a variety of businesses located along the Mae Kha which apparently contribute to the pollution load of the canal. There is very little interaction between chumchon and these actors, but there also appears to be little interaction between these actors and the government. While they are often accused of paying bribes to avoid following water standards, many showed little knowledge about the water quality standards in the city, and their water infrastructure in general.

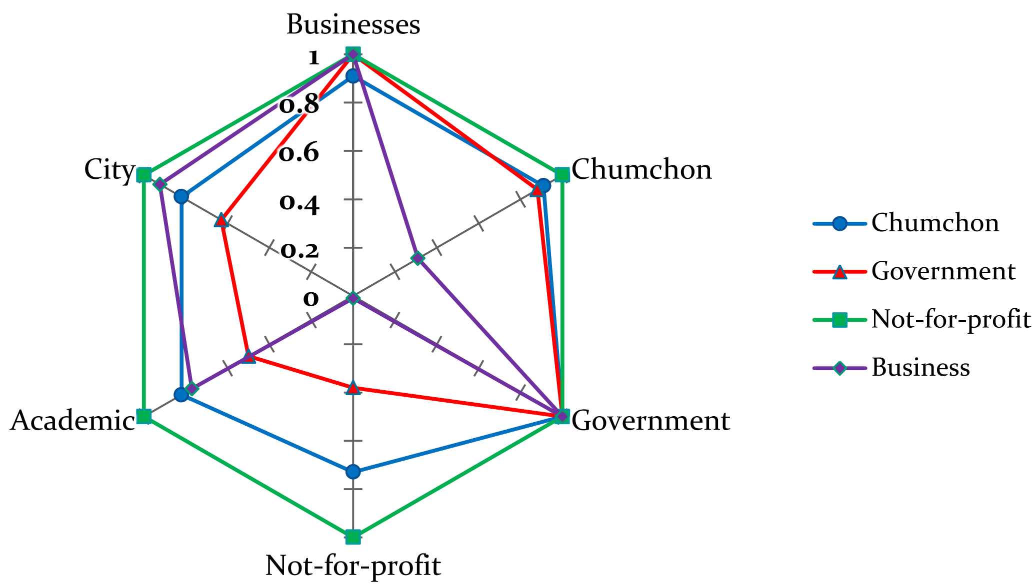
In summary, by mapping the stakeholders in the management of the canal it becomes clear that there are many GIs on many layers, and that those further from the canal often have most influence. The UNEP (2009), the World Bank (2008), as well several academics (Lebel, 2009; Ribeiro & Srisuwan, 2005) have pointed out that having so many GIs involved in water resources issues, combined with poor coordination between these GIs, is a major hurdle for the Thai Government in its effort to reach its water-management objectives. The various ministries each have different priorities and programs, and are often overlapping or in conflict, which has facilitated the shifting of responsibility observed in all sections of government. In the end, there is no office which takes the responsibility of maintaining the canal (secretary mayor, 2013). The National Water Resources Committee lacks the authority or operating mechanism to oversee and coordinate activities on the local scale. Decentralization is needed, but it has been implemented as a top-down *policy,* initiated without accountability or adequate participation of the local authorities, chumchon, NFPs or businesses. Moreover, the decentralization was thwarted by a failure to combine it with an increase in capabilities and resources including skilled staff, adequate funds, legislative power or even training to fulfill the task.

The variety of chumchon and businesses around the canal are faced with uncertainty about the laws they need to comply with and future they face. The organization of meetings on the subjects at the sub-district level has not yielded effective participation in the decision-making process, implementation or regulating capacity. In fact, the power continues to be highly centralized in Bangkok. Tokenist participation has disenfranchised actors at the local governmental scale, increasing clientalist tendencies to stay in power. The first hurdle for improved management of the canal is to greatly improve the inclination and capacity of local authorities and for communities to work together to create a “united front” (Ribeiro & Srisuwan, 2005).

Results Justice of Recognition

The politics of recognition can helps to explain the existing divergences in power that are available to different stakeholder groups. The central issue is often the recognition that certain stakeholder groups within the city have valuable knowledge, perspectives, and input which would be valuable additions to the decision-making process. The results of the rich picture (Method p28) indicate the recognition of stakeholders who currently are, or should be involved in the management of the canal (Figure 21).

Figure 21 Recognition of stakeholder groups involved in the management of the Mae Kha



Source: based on rich picture exercises during interviews held in 2013

The first notable aspect of the figure is the convergence of the curves in recognizing the universal recognition of the government as an important stakeholder group in the management of the Mae Kha canal (Figure 21). The second note is that NFPs recognize all other stakeholder groups as important to the management of the canal. However, NFPs were the least frequently recognized by every other stakeholder group. They were most often identified by chumchon, the group at the core of their activities. Nonetheless, even among chumchon they were the least often mentioned group.

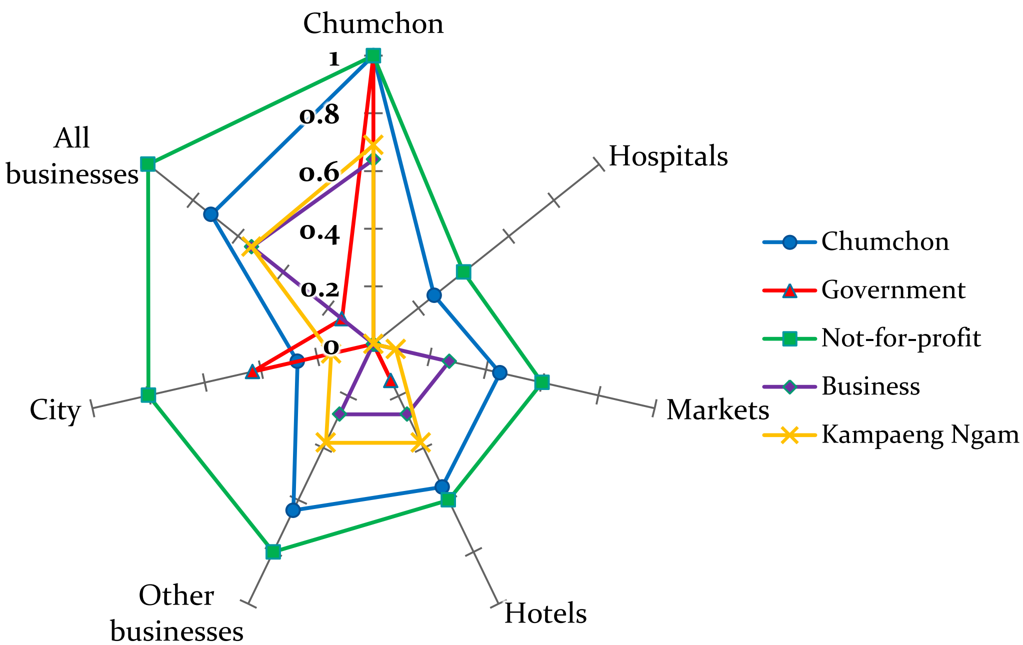
While chumchon were identified as important managing stakeholders by more than 80% of NFPs, GIs and chumchon, only about 30% of the businesses interviewed demonstrated the same recognition. Moreover, none of the interviewed businesses mentioned any NFPs. The group titled 'city,' representing the majority of the city, and through the drainage system comprising the biggest source of wastewater to the canal, was mentioned as important to its management by disproportionately few stakeholders. Shockingly, they were only recognized as important by just over 60% of interviewed government officials. Comparatively, over 80% of communities and 90% of businesses recognized the general population to be important for the management of the canal.

A mere 50% of the interviewed GI recognized academics as an important element in the management of the canal, despite the fact that faculty of Chiang Mai University have continued to play advisory roles in canal development plans. In contrast, businesses and chumchon acknowledged the importance of the academic community at a rate of around 80%. These frequencies could be partly the result of a social desirability bias, due to the presentation of the interviewer as academic researcher.

Every stakeholder group, at rates of 90 – 100%, recognized businesses as important actors which are or should be involved in the management of the Mae Kha. This is particularly interesting if we take into account the unclear role that businesses currently have in the management of the canal.

In the network mapping of relations of different actors to the canal, many businesses were indicted as polluters. A look at which stakeholder groups are perceived to pollute the canal shows a different picture.

Figure 22 Stakeholder groups perceived to pollute the Mae Kha



Source: based on rich picture exercises during interviews held in 2013

Interviewees were asked what the sources of pollution were to the canal. The identified sources can be divided into 3 main stakeholder groups: chumchon, the city and businesses. Businesses can be subdivided again into a further 4 subgroups: hotels, markets, hospitals and others (Figure 22). 'Other businesses' include: factories, slaughter house, dying factory, restaurants, laundries, garages, as well as businesses mentioned nonspecifically. Hotels, markets, and hospitals were each mentioned in a general sense, and constitute fairly well-defined categories.

It is interesting that while most chumchon were not recognized as important to the canal's management, they are singled out as the most commonly recognized source of pollution. Even chumchon themselves have indicated that they discharge wastewater into the canal and are thus part of the source of pollution to the canal, however they generally resent being singled out as the main source of pollution to the canal. As such, many chumchon feel misrecognized and excluded from the decision-making process. Such feelings are expressed by the community leader of Fa Mai:

"We disagree with the municipality to move people from the canal. We have lived here for a long time. We are the work force of the city. We have to move out, but they don't ask us, while we have been living here for such a long time. We were not consulted in making up this plan. The pollution in the water comes from the city, from the hotels. But we have to move out because we would make the canal dirty. But we don't make it dirty. The reason it is dirty comes from the business part too. The people in the community start to take care of the water, before the municipality was caring about this. We were already cleaning it and after this the municipality came to complain about the water" (2013).

Many chumchon and residents of Kampaeng Ngam, who have been living along the canal for longer periods, attribute the canal's increased pollution to the growth of the city, and particularly the tourism sector. Businesses in general are the second most mentioned contributor to the pollution of the canal, and are mentioned by all stakeholder groups. Of the specific businesses, hotels are the only one mentioned by GIs, but they were mentioned within all stakeholder groups and by more than half of the chumchon and NFPs. However, 'other businesses' were mentioned the most of any business subsection by both chumchon and NFPs, indicating that a wide variety of businesses are perceived to contribute to the pollution of the canal.

The city in general is known to be a large contributor to the pollution of the canal, and was recognized as such by the majority of NFPs, some GIs, few chumchon, and no businesses. Most chumchon and businesses indicated being under the impression that the majority of the wastewater from the city not located directly along the canal was treated at a centralized wastewater treatment facility, and had no idea that it was discharged into the Mae Kha.

Most stakeholders seemed to only be aware of the wastewater being overtly discharged directly into the canal, which was surprising especially from the GIs in charge of managing these flows. The issue of recognition was previously touched upon in the mapping of perceived problems and uses for the Mae Kha. This showed that GIs in particular had a limited knowledge of the use of canal products for consumption, and that many had a limited view of the problems experienced with the canal. The results for the recognition of actors which contribute to the pollution of the Mae Kha further illuminated the lack of understanding of the issues on the ground. The lack of recognition of communities, academics and NFPs as valuable stakeholders in the decision-making process is exemplary in these processes.

Businesses and the development of tourism which have led to increased urbanization and economic growth as well as the depletion of the environment of Chiang Mai, are not recognized as an important source of pollution. The focus of policy is on the chumchon, which have been misrecognized as the source of pollution. What is seen is that "Marked people in marked places become expected to live with incivilities (lack of services, pollution) and blamed for not looking after their own environment, with such institutionalized assumptions shaping where efforts by the state to address problems is and is not deployed" (Walker, 2010). Current policies in place aim for the beautification of the Mae Kha. Hotels and businesses which are seen as emblems of progress are part of this future landscape, while chumchon are viewed as the problem. The discourse presented assumes that removing chumchon is a solution to the state of the canal, and the development of the area. This in fact when as was shown in research on air pollution in England (walker 2010) the poor who live in the most heavily polluted wards do in general contribute to the worsening of the environmental quality, but contributed the least to emissions (Walker, 2010). In such circumstances it is unlikely that interventions focused on these areas would significantly improve the environmental quality if other areas and stakeholder groups are not recognized as part of the problem and the solution.

The root of power

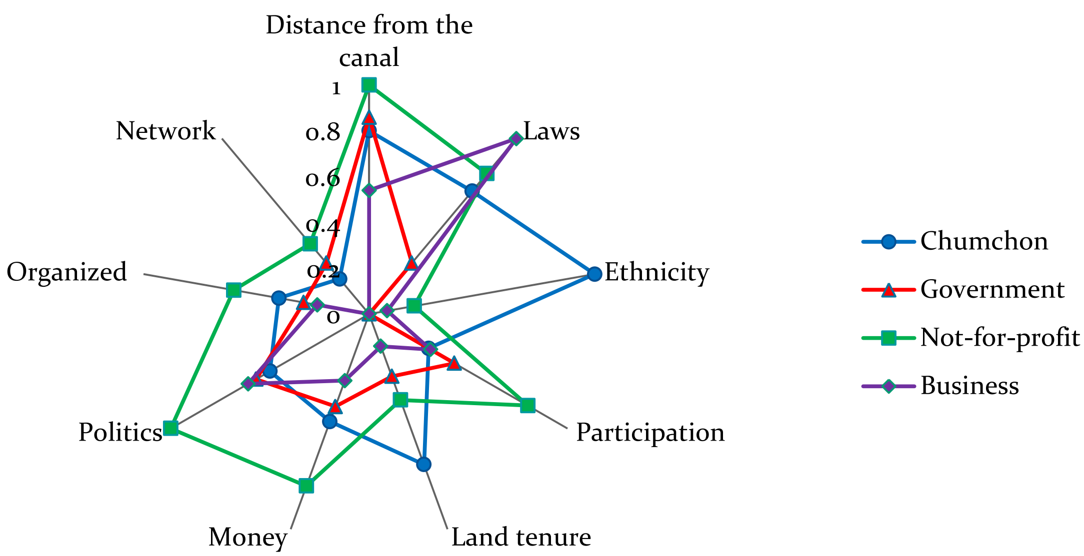
The misrecognition of certain stakeholder groups seems to be at the root of their exclusion in the management of the canal. In the interest of understanding what allows some voices to be heard and others suppressed, the discourses of interviews were scoured for factors presented as explanatory of the current power structure. In the end, 9 different factors were identified and organized, including: distance from the canal, laws, ethnicity, money, politics, network, being organized, having land tenure and participating in the management of the Mae Kha. These will be described shortly below.

Distance from the canal, as previously indicated those located directly along the canal were most likely to been seen as polluters. The position of a household within the canal seemed to cross a common line and was viewed as unacceptable among most stakeholder groups. Households in the canal had to be removed and were in fact not in a position to negotiate. **Ethnicity** was used as a source of power for chumchon, which would often deflect the accusations leveled against chumchon for being the source of pollution by indicating that it was the Burmese or hill tribes, who were 'not Thai, did not hold similar values, did not value the canal, were dirty and lived in the canal'. This thus related back to the question of what is the acceptable distance from the canal. Ethnicity was also mentioned by businesses and NFPs. GIs created structural barriers for these communities by making it harder for ethnic communities to get ID cards and have their rights recognized in general. In the past, evictions were directed primarily at chumchon which had high populations of hill tribe and Burmese residents. Indeed, these communities are often excluded from local chumchon organizations and movements to gain land rights and recognition.

Network of communities and **communities being organized** refer to chumchon being organized and actively participating in pursuit of their rights. The larger the network of active chumchon supporting each other, the harder it becomes for GIs to single out or evict any one group. These activities are primarily directed towards gaining land tenure, as legal land tenure gives communities security and legitimizes their position as members of the state, thus increasing their capacity to participate in the decision-making process. The main goal for chumchon organizations has been to earn land tenure. The lack of **land tenure**, designates chumchon as illegal squatters, this is the basis of the risks they face for eviction. This significantly decreases the power of chumchon in demanding services. Having land tenure increases the capacity of chumchon to participate in the management of the Mae Kha. It speaks for itself that those who have capability to participate in the decision making process, have more power, the possibilities to participate in the decision making process was discussed before.

Money and **local politics** were often used to explain issues relating to corruption, including issues of buying votes by passing regulations and implementing projects. **Laws**, while most people did not know what the laws were, the image was often called upon that stricter laws were necessary to improve the canal, and that it was a lack of laws that lay at the root of the problem.

Figure 23 The sources of power in the participation



Source: based on interviews held in 2013

The location along the canal was the most commonly mentioned disempowering factor limiting the participation of chumchon in the management of the canal. Local politics were also mentioned by a majority of all stakeholder groups to influence who has power in the decision-making, and was often related to issues of corruption. Ao from POP (2013)explains how these factors are interpreted in chumchon: "The woman you talked with [in Papleng], she feels that she has already moved from in the canal, to the outside… so that's why she feels she is ok and that she has done some activity to save the Mae Kha canal. That is why she feels that she has done good things, so she has the right to live there. But in reality, when the government wants to improve the area, they want to remove all of [the chumchon] and make it into some nice area. So that is why when they want to remove it, they will move all of them".

Chumchon in particular saw issues of land tenure and ethnicity to be paramount to their capacity to participate fully in the management of the canal. The law, surprisingly, was seen as a source of power by most stakeholder groups except the GIs, which might be explained by their awareness of the weak monitoring and implementing capacity to support even existing laws. The leader of chumchon Papleng mentions that, "some 40 Kamuk hill tribe households from Laos settled themselves inside the canal, thereby obstructing the water flow [...] that it is not the Thai way to build the houses in the water. This is what the immigrants do" (Papleng, 2013). The leader of chumchon Hua Fai mentioned that these migrations have turned their community into a slum (Hua Fai, 2013).

The influence of local politics and the limits to the capacity achieved through by chumchon organizing were addressed by Lung Win (Kampaeng Ngam, 2013), when we asked him why Kampaeng Ngam has not confronted businesses that they view as responsible for the polluting the water: "never, everyone knows, but never there's a [confrontation]. And if they have an argument, they have no power to fight them. So there's no point. The effects, the consequences are for the ones living along the canal". Kon Jai Baan (2013) states that there is a conflict of interests. While communities are interested in housing rights – the right to stay, the right to develop, human rights – the municipality's prime interest is in tourism, which represents the main income source for the city. This limits the organization of environmental and social issues to those which do not disrupt or conflict with the tourism industry. The relation between the chumchon and the municipality has an informal nature: "The team of local Politicians [go into] the neighborhood. They have a kind of negotiation [with the chumchon] that they will do anything they can [to] slow the process [of evictions], with statements like 'we know this prime minister we can negotiate'. It's a kind of [negotiation], but not properly or holistic way of this kind of housing and water quality and development project to be in the same place on the table" (Kon Jai Baan, 2013).

As implied by Kon Jai Baan, the party politics go beyond the local scene. POP explains how political ties reach all the way to the national government: "The budget [allocated] to improve Mae Kha canal. They got this budget easily, because it's Chiang Mai city, to improve the environment of Chiang Mai city, this kind of project gets approved easily, because our government now is Chiang Mai local people. The prime-minister comes from Chiang Mai. That's why. Because the people who voted for them, the main group is a north people group, Chiang Mai people group. And that is why they have to do something for Chiang Mai" (POP, 2013).

It becomes clear that the Mae Kha is a strong symbol for development, which many stakeholder groups with various interests try to utilize. For example, the community leader of Papleng explains why chumchon need to take care of the canal: "People in Chiang Mai think that slums are dirty and that they pollute the water. But since we live here, we are the ones who clean up and take care of the water and pick up the garbage. Those who have their own land take less care of the canal, because they are sure of their living situation, because they own their land. Businesses, restaurants, hotels and offices pollute the canal as well" (Papleng, 2013). Riberio & Srisuwan (2005) discuss the environmental activities organized by UCEA. Their descriptions can also be assigned to the activities by POP and Kon Jai Baan, which are "[aimed] at changing interactions and power relationships between organizations, networks, groups and individual stakeholders in a complex setting through a focus on environmental management". The approach describes a bottom-up approach which positions chumchon "[as] the main actors in the processes of problem identification, project design, decision-making, budget management and implementation. This public participation in environmental projects aims, among other things, to create ownership of interventions (sidewalks, bridges, etc.) by the community involved" (Ribeiro & Srisuwan, 2005, p. 179-180).

The different powers at play do not only influence the development of the Mae Kha, but are embodied to a certain extent in its use as it represents the city of Chiang Mai, its history and its development. These discourses are embedded within a longer history of class relations in the city.

Social classes and the Mae Kha

Historically, Chiang Mai (from 1296 – 1874[35]) was characterized by a social estate system which can be simplified into three principal social classes: the ruling class (cao-nai), the free peasantry (phrai), and slave labor (khaa) (Tan-Kim-Yong, 1979). After the abolition of slavery in Thailand in 1912 (Baker, 2006) the freed *khaa* people were to become the first 'slum' inhabitants of Chiang Mai, thus maintaining their position at the bottom of the social hierarchy. The new system of ranking compromised the extremely rich (Khon ruai), those who have (khon mii) and the poor (khon con). Many of these 'khon con' went to work at markets, living in make-shift chumchon on nearby land (Tan-Kim-Yong, 1979). Small chumchon appeared near the Warorot, Thon Lamyai, Nawarat, San Pa Koi markets, the swamp land in the North, and along the Kampaeng Din historic wall (Tan-Kim-Yong, 1979) (Annex 10), areas which still hold the majority of informal chumchon of Chiang Mai. New patterns of scattered small settlements have more recently emerged along the old city wall sites and the vacant private lands.

Historically, Chiang Mai segregated people of different cultures and nations by a zoning method. A lack of affordable housing combined with population growth has since turned this into an economic segregation. Low income chumchon were later joined by seasonal migrants from the rural areas, which tended towards more permanent migration after the 1970s (Tan-Kim-Yong, 1979). This period framed by the spread of neo-liberalism, experienced a decline in poppy trade[36] and the launch of Chiang Mai as Northern pole of development in 1977 (Srisuwan, 2005), which accelerated rural-urban migration in this region (Crooker, 1988). Among the migrants are various ethnic hill tribes, who are stigmatized by their previous involvement in the poppy trade (Crooker, 1998) and treated as non-Thai in Chiang Mai (Walker, 2003).

Initially, rural migrants lived under the patronage of wealthier people from their former village either at estates or factories. This patronage system was accompanied by a relationship of indebtedness and gratitude. Urbanization beyond the capacity of this system saw the raise of make-shift villages as a solution for housing the new urban poor. The choice of location for squatter settlements along the Mae Kha canal was dictated by the availability of publicly owned land, officially classified as unsuitable for housing (Fa Mai, 2013; Papleng, 2013). Many of the second generation of slum dwellers had limited access to education and were employed as non-specialized labor, with limited earning capacity and little opportunity to own land (Ribeiro & Srisuwan, 2005). Nowadays, a wide variety of occupations are held in this area including low positions in the state bureaucracy, small business owners and employees in the tourism sector (households in Kampaeng Ngam, 2013).

Tan-Kim-Yong's 1979 description of informal chumchon in Chiang Mai, introduces Kampaeng Din and Tipanet as the settlements located along the canal. These chumchon ranged in size from 34 – 243 households in size. Kampaeng Din includes what is now: Kampaeng Ngam, Raekgeng and parts of Chaiyapoom and Chang Moi, though in 1979, the eastern banks of the canal were not yet occupied (Tan-Kim-Yong, 1979). Kampaeng Din, was described as the largest and most squalor of the chumchon. Located in a swampy area 3 to 5 feet below street level, the community is described as facing unsanitary conditions. The environment is described as degraded, littered with solid waste, and with many water plants in the canal. Prior to 1979, the area primarily housed sick people who were excluded from society. In 1979 Tan-Kim-Yong described it as an area known for prostitution, gambling and drunkenness. With the lowest paid municipal workers from the sanitation department living there, as it was close to the junkyard. A slaughter

[35] Slavery was first abolished in Chiang Mai by the Anglo-Siam treaty over Chiang Mai edict abolishing slavery. The act of selling a person in slavery was abolished nationwide in 1897, while slavery itself was not abolished until 1912 (Baker, 2009).

[36] Thailand was never one of the large opium produces, but has had what is often called one of the most successful opium substitution campaigns led by King Rama IX starting from the 1960s (Crooker, 1988).

house was established in this area in 1965, workers at this establishment also moved to this area (Srisuwan, 2005; Ribeiro, 2005).

Similarly in 1979 chumchon Tipanet covered much of the same area north of the canal that it covers now, it has now expanded its territory south of the canal. Tipanet also formerly included much of the area that is now occupied by the Kanchanaphisek Park, as well as scattered settlements in what is now Ha Tanwa. The establishment of Tipanet community was spurred by the construction of the Tipanet shopping center around 1969, when construction workers and market vendors built the community on the outskirts of the market. After the land was defined as the property of the Municipality of Chiang Mai and the Crown, more houses upgraded in order to be allowed to rent the land. Tan-Kim-Young mentions 3 hill tribe households in the community that were used as a tourist attraction for the city.

The description of these chumchon as they were in 1979 exposes some of the social stigmas and class-relations as they are rooted in the development of chumchon along the Mae Kha canal in Chiang Mai. This period had already seen various plans from the government to remove chumchon and develop the land, a struggle which continues today. In 1979, the city's environment did not yet seem severely damaged (Tam-King-Yong), and the eventual degradation of the canal environment would contribute to these negative attributes being tied to the area and thus the people living in that area (Srisuwan, 2005).

In summary, a history of an underclass of slaves, which made way for low-income communities to establish themselves along the canal and around markets, is likely to have facilitated the continuation of a historical suppression of these communities in Thai society. Moreover, the recognition and othering of these groups as foreign 'migrants' and 'hill-tribes' who are not eligible for the same rights and benefits as the rest of the Thai population is deep seated. Together with a political class based on weak democratic traditions, which has historically ignored the interests of the poor and recently embraced the interests of economic development through tourism, the inequalities have only been exacerbated.

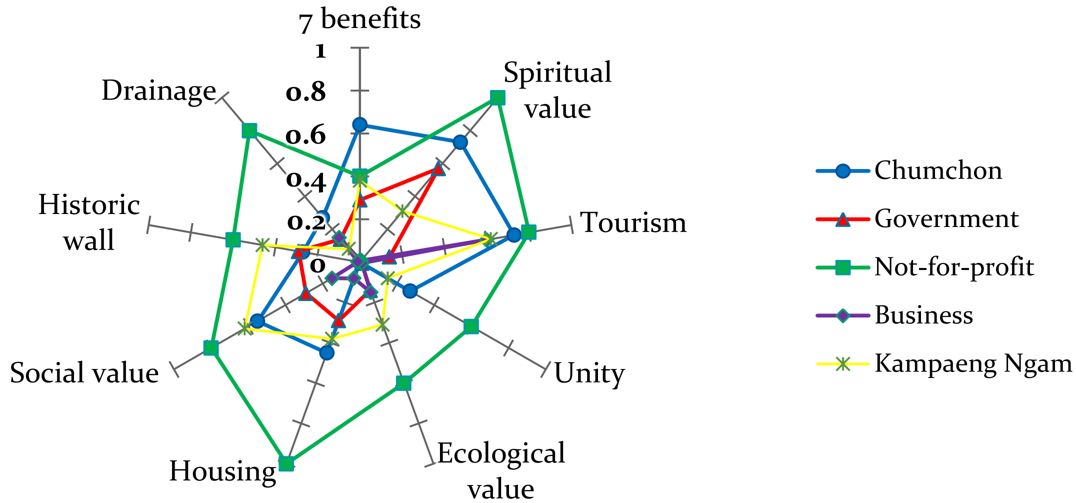
The way forward

The issue of recognition of stakeholders has been discussed in detail, but the recognition of the value of the canal itself is essential in paving a way forward. If the Mae Kha itself is not valued, it is unlikely that different stakeholders can be organized around the canal in any significant way. As mentioned before, activities around the Mae Kha seem to be embedded in a deeper discourse in which the Mae Kha is used as a symbol in various forms depending on the goal it can represent Chiang Mai itself or 'chumchon pollution'.

The most frequently mentioned value of the canal is its spiritual value, which came in many forms including rituals performed with the canal, its role in the Songkran and Loi Krathong festivals, and identifying it as tied to the local tradition (Figure 24). Communities including Lin Kho and Un Ari use these values to garner interest in protecting the canal among their residents. During water sampling in November, the researchers observed a household in Kampaeng Ngam sending off a floating arrangement on the Mae Kha for Loi Krathong, which exemplified the spiritual value associated with the canal. In general, many people indicate that environmental degradation has also defaced the spiritual values tied to the canal. Water in general has a high value within Thai Buddhist culture, something which is connected to the high concentration of temples along the canal. Indeed, much of the land along the canal is also owned by the Buddhist Department (CODI, n.d.).

Related to this is the historical value of the canal which is often indicated by two factors. The first is in the legend of Chiang Mai's founding, that features the Mae Kha as one of the 7 blessings of the surrounding landscape for which it was chosen as the location for the Lanna Kingdom. This factor was mostly mentioned frequently as a valuable factor of the Mae kha by chumchons. Some communities even mentioned using the story as a way to increase local pride for the canal, and with that decrease littering (Un Ari, 2013). The second historical factor is the historic wall, Kampaeng Din, which was originally built to follow along the canal. This wall has almost completely collapsed, with the sections that are still standing located within communities, especially chumchon Kampaeng Din, Ha Tanwa and Tipanet. The wall is owned by the Department of Fine Arts, which until a few years ago would periodically evict many households from on top of the wall, in order to protect the monument. The wall was the most frequently mentioned historical value associated with the canal by NFPs.

Figure 24 Value of the Mae kha



Source: based on interviews held in 2013

The city has used the Mae kha as a drainage way since its foundation more than 700 years ago, and it continues to be the main drainage way for the city. This environmental service of the urban waterway, on which both formal and informal households and businesses all rely was mentioned in 80% of interviews with NFPs, but much less frequently by other stakeholder groups. Additionally, ecological values associated with the canal, including the suport of green space around the canal, and its contribution to biodiversity were similarly recognized primarily by NFPs and few others.

The value of the canal as a feature of the tourism area and a potential tourist attraction was a much more popular sentiment. It was recognized as an important value of the canal by 60 – 80% of chumchon, NFPs, Kampaeng Ngam residents and Businesses, although, surprisingly only one (14%) of the interviewed GIs. Besides being a tourist attraction, the canal is of course also home for many people. As the community leader of Fa mai (2013) put it, "if a tourist like you would ask me [what the value of the Mae Kha is], I would say, it's just dirty water, it's polluted. If my daughter would ask me I would say, this is your house, your home." While most people live there out of need, some families have been there for generations, and have never known any other place to call home. Many of these, especially older people who have grown up along the canal, have memories of swimming in it, and have a strong emotional tie to this location. One older lady from Kampaeng Ngam (Ulai, 2013), who has already had to move her house out of the canal, and now lives with her husband and son in a single room, explains in a hopeless voice:

> Interviewer: what does she think about the threats for eviction?
> Ula (through translator): she says she knows about it but she doesn't know why it is that they want to evict them. She said that it used to be, the water used to be very clear.

> Interviewer: so does she think it is because the water is now dirty [that they want to evict communities]?
> Ulai (through translator): she said maybe, I think, or maybe they want the land, they want to build something else on the land, she says she doesn't know where to live if they have to move off the land she says she is poor she don't know where else she could go to live.

So while many people live in the chumchom because of poverty, it also has a social value, as most families live in multigenerational homes. Many Akha (hill tribe) also live in a community format with shared language and culture, maintaining a life style which is closer to that of a rural village. Indeed, these social values were indicated by the majority of chumchon, as well as the residents of Kampaeng Ngam. It was also recognized by most NFPs, though only a few of GIs and Businesses. Particularly through the organization of chumchon in environmental and other campaigns, NFPs hope to build unity between different chumchon who face similar problems to cooperate towards an improved situation of social and environmental rights. It is in this regard that NFPs identify the canal as a unifying factor, a vision that is also shared among some of the active chumchon. No businesses or GIs at all mentioned unity as a value, which reinforces the view that these are excluded from local action and organization around the Mae kha.

Solutions

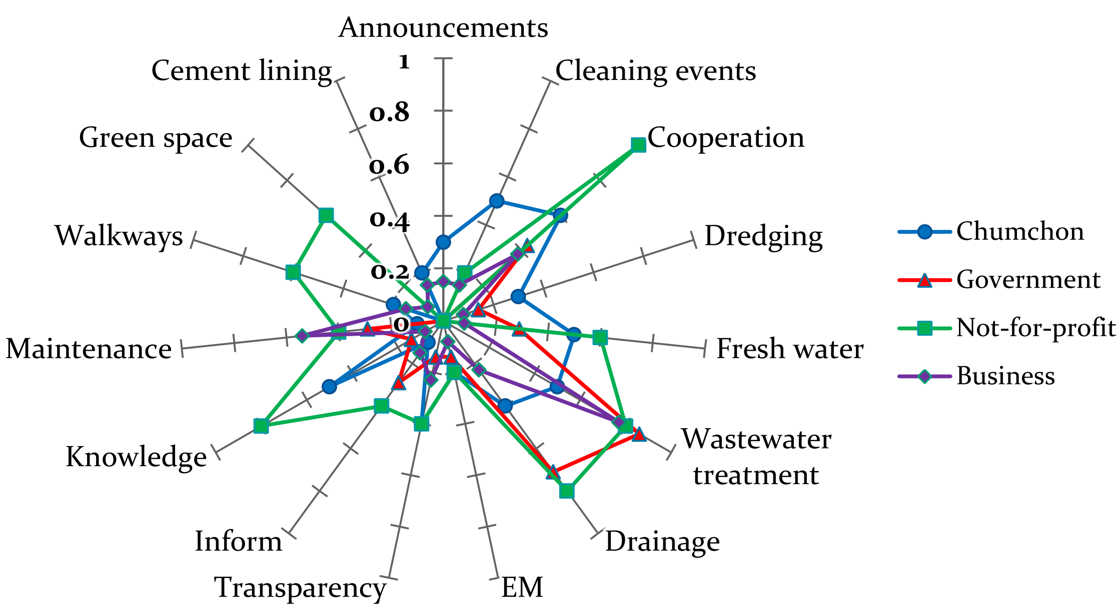
Having thoroughly discussed the problems of the Mae Kha, naturally the exploration of some solutions to the issues is in order. "Environmental Justice movements focus both on the nature of the injustice and the creative and crucial networked responses on the part of movements" (Schlosberg, 2013). Of course, different stakeholders have different images of what the problems are, and it should be unsurprising that different stakeholders also have different solutions in mind, as they tackle these different problems. It is most likely that there won't be one single solution, but rather a range of actions (Walsh et al., 2005). In general, three types of solutions were suggested in interviews: technical-infrastructural solutions, managerial changes and behavior changes. The first group represents mostly top-down large scale solutions, while the last two include bottom-up changes requiring a concerted effort.

Technical-infrastructural solutions include: diverting **fresh water** into the canal, **dredging** the canal, **treating wastewater,** expanding and improving city **drainage systems**, **cementing** the un-cemented sections of the canal trajectory, all activities which are expensive and large scale, and would most likely require government leadership. In fact, these are the solutions which are already being undertaken, but interviewees suggested that they need to be implemented more consistently or on an expanded scale in order to have the desired impact. A second set of solutions have a more social character, and need large scale public participation in order to be successful as they are organized from the bottom-up. These include: organizing **cleaning events**, stronger **cooperation** between stakeholders, putting **EM** in the water and increasing **green space** and **walkways** around the canal. Many of these aspects have also been implemented with limited success. A third set of solutions take place in the managerial sphere, and include: public **announcements** to promote public awareness and participation to improve the canal, increasing access to **knowledge** on levels of pollution, and the options available to minimize or reverse the negative impacts of this pollution, to be **informed** by the government on its plans and activities for the Mae kha, which relates to a broader desire for **transparency** in the decision-making process in the management of the Mae Kha.

The most frequently mentioned solutions fell into the technical-infrastructural sphere, especially with drainage and wastewater treatment systems. In the second group of solutions there was strong interest for better cooperation between stakeholders. There did not seem to be much indication of solutions in the form of managerial changes, even though most interviewees were unhappy with the current management.

The central government has attempted to take the infrastructural approach, building a wastewater treatment plant and drainage system which serve part of the city. They have also installed a pump which can flush the canal with fresh water from the Ping. These solutions have failed to make large scale impacts, due to a shortage in capital and qualified staff, and in the case of flushing due to the temporary nature of the solution. In the summer of 2013, fish farmers in the Ping river at the outflow of the Mae Kha experienced widespread fish die-offs from oxygen depleted water that came from the Mae Kha and some fraction outlet from the pen para WWTP (Thairath, 2013). Currently, businesses are responsible for their own wastewater treatment, and expansion and improvement of this decentralized system might be a better option (Chief of Maintenance, 2013). Solid waste filtering infrastructure to improve in-stream processes have been placed near Sri Don Chai road and Wichayanon road, but have never really worked. The government has experimented with putting EM in the water in the past, for short periods of time and with corresponding limited success. Chumchon have been evicted to construct walkways and parks, however they are not maintained and not often used. All of these projects were implemented through top-down initiatives without significant cooperation from local actors, and are now either completely abandoned or vastly insufficient.

Figure 25 Solutions for the Mae kha



Source: based on interviews held in 2013

Several projects with more local participation have fared better, including bank planting north of the city in cooperation with Dr. Wassan and Gum Hak Doi Suthep with chumchon Lin Kho, and planting activities in Ha Tanwa and Hua Fai have achieved moderate success, being maintained by local chumchon. Lanna hospital has had recent success with decreasing the smell of the canal on their premises during the low flow period by applying EM every two weeks. Chumchon have organized and participated in government led monthly meetings but do not feel like this has increased their participation in the management of the canal. On the contrary, these activities are often experienced as tokenist in nature. Chumchon feel not only a lack of participation and influence on future government plans, but even a lack of access to information on what they may be. This sentiment is shared by businesses of all sizes and even governmental actors like CODI and NFPs. Most actors are thus diminished to reacting to plans once they have already been introduced.

There seems to be very little communication between the aforementioned projects, which constitutes a divergence between political agendas and economic interests concerning the physical and cultural environment of Chiang Mai. The combination of the search for a quick fix to solve environmental problems without taking into account environmental processes, and the lack of public participation and coordination between different stakeholders, makes the coordination and implementation of a robust solution to the upgrading of the Mae Kha canal difficult. “Notions of social justice often rely on government intervention to implement or design a more just society. Most often, demands for distributional equity are made to government, which is where the remedy of such injustice is sown. But the environmental justice movement calls for government intervention only in part; to establish just laws on the distribution of environmental risk” (Schlosberg, 2013). This is a strong stumbling block as many chumchon which have already tried to become active have been blocked by the political establishment. At a political level, there is a struggle between central and local governments and civic representation. This distrust stands in the way of the needed participatory framework for large scale changes which can have a lasting impact on the Mae Kha.

Conclusion

What factors contribute to the wastewater flows in the inner city urban canals?

Urbanization leads to the expansion of impervious surfaces and efficient hydraulic conveyance systems, both of which decrease infiltration, groundwater recharge and subsurface flow (unesco-ihe, n.d.). Because the sub-catchment of the Mae Kha is ungauged, imperviousness is difficult to accurately measure. Extremely low streamflow during the dry season suggests a low base flow, and consists mainly of wastewater from the city drainage system, households and businesses along the canal. The land use of the Ping River Basin is mostly agricultural with the exception of urban areas in Chiang Mai City and Lamphun (Thomas, 2006; Sangawongse et al., 2005; Romanos & Auffrey, 2002). The urban cover of greater Chiang Mai has increased from 9% in 1989 to 38% in 2010 (Sangawongse 2006; Sangawongse 2012), and is predicted to increase to more than 80% by 2030. Recent land conversions have seen primarily rice paddy fields turned into urban land, including the flood plains around the Mae Kha. In the future, land currently used for orchard crops and forests are predicted to follow the same path (Sangawongse, 2012). Land use plans suggest the city is likely to continue expanding both vertically and horizontally, with high density residential and commercial zones on the immediate outskirts of the historical city center, along most of the Mae Kha and the tourist areas.

Wastewater treatment facilities in the city are severely lacking, with many areas completely without. A municipal WWTP treats a small fraction of the city’s wastewater (20,000 m3 per day), servicing limited areas in the square and to its east and west in the biggest tourist hotspots. The Chiang Mai University campus is the only area which is completely serviced by wastewater treatment, through a dedicated private WWTP. The treated effluent from this WWTP is discharged into the Ku Wai stream (100,000m3 per day). The majority of the wastewater and urban runoff from the city is discharged into the canals, including that from chumchon and businesses along the canal, though black water is mostly treated in decentralized septic tanks. Lanna Hospital discharges a fairly large volume of treated wastewater effluent (220 m3 per day) at the start of the canal, which they do not appear to monitor for healthcare specific standards. Moreover, various large markets and a municipal slaughter house, which rely on the municipality for wastewater treatment, discharge their wastewater directly into the canal.

Research is limited by available data and monitoring activities for the canal in the city. Further research and data collection is needed to contribute towards improved management of the canal. Topics with a significant need for more research include catchment scale problems, groundwater levels, surface imperviousness, volume and flow of the canal, leakage of the drainage system, the impact of the use of septic tanks on groundwater, interactions between the Ping river and the Mae Kha, and the impact of the roads on the hydrology of the area. Investigation of these topics will contribute to a more complete hydrological understanding of Chiang Mai, and provide information that will help determine steps to be taken to improving conditions in the urban canals.

How are environmental impacts distributed along the trajectory of the Mae Kha canal?

The existing drainage system limits flooding events in tourist areas, but increases the flooding risk in downstream chumchon areas. Moreover, water gates used to control this water flow contribute to flooding both upstream and downstream of the inner city. Infrastructure designed to improve water quality such as solid waste filters, and pumps to flush the canal are also concentrated on serving the tourist area.

Overall, water quality is poor throughout the canal, achieving the lowest possible class 5 for a water body under Thai surface water standards. The water quality exhibited improvement in the seasons tested following the early rainy season when conditions were still fairly dry. Statistical tests confirmed seasonal differences, with the lowest water quality measured in the early rainy (dry) season. In general, measured parameters indicated better water quality at sites outside of the city, as well as in the Ku Wai stream. These sites also had higher flow, even during the dry season. However, no statistically significant differences were found in the water quality between the selected sites, and only the levels of DO and free CO_2 were statistically significantly different between the Ku Wai and Mae Kha canals.

Flooding and odorous water were the most frequent ills to be related to the Mae Kha by stakeholders, and were shared by all areas. Interviewed businesses in the inner city tourism area had a low incidence of flooding, while the areas downstream and upstream of this area more frequently reported flooding as a problem. Downstream areas south of the square and the upstream area around Muay Mai market on the side stream all experienced significant problems with flooding, including damage to their communities. The smell of the canal was a bigger concern in areas located more upstream in the city, whereas health impacts were more often reported downstream of the Mae Kha. Mosquitoes, which can also spread some diseases, were mentioned as a concern in all areas. The frequent mention of mosquitoes in the areas of Un Ari and the Ku Wai in association with the canal was unexpected as these areas experience a healthier flow regime.

A look at the distribution between stakeholder groups showed that chumchon more frequently reported issues with flooding and health risks, while businesses and chumchon both often reported issues with the odor. The worst smells are experienced during the warm dry period when the water level is low. Chumchon were more likely to mention uses of the canal as a source of seafood and water plants, and as cleaning water. These uses increase exposure to the levels of pollution in the water, especially pathogens and toxins. Some chumchon and businesses also reported using groundwater from wells adjacent to the Mae Kha for non-drinking purposes.

Considering that there is no significant difference in the water quality for different parameters between different sites, it is likely that the differences experienced in the risks are related to the focus of management on the benefits the tourism area. Moreover, the lack of differences in water quality of even upstream and downstream sites, indicates that the issues afflicting the canal are not limited to the urban area, but extend to the catchment scale. More tests should be done to assess the levels of heavy metals and pesticides in the soil and sediments, as well as more specific indicators of pathogens such as E. coli, considering the high levels of TFC and TCB and the high levels of COD measured in the early rainy season. These tests will also show whether the use of canal water for irrigation is likely to have significant health risks.

How does the recognition of the canal and stakeholders differ across stakeholder groups?

Interviews identified 3 main stakeholder groups as contributing to the pollution of the canal: chumchon, the city and businesses. Businesses could be subdivided into 4 subgroups: hotels, markets, hospitals and others. 'Other businesses' includes: factories, slaughter house, dying factory, restaurants, laundries, garages, as well as businesses mentioned nonspecifically.

Chumchon were singled out as the most commonly recognized source of pollution to the canal, while businesses in general were the second most mentioned contributors. Both of these groups were mentioned by all stakeholder groups. Of the specific businesses, hotels were mentioned by all stakeholder groups and the only one mentioned by GIs. However, the subgroup 'other businesses' were mentioned the most, indicating that a wide variety of businesses are perceived to contribute to the pollution of the canal. The city was recognized as a contributor to the pollution of the canal by the majority of NFPs, some GIs, and a few chumchon, but not by businesses. Most stakeholders seemed to only be aware of the wastewater being overtly discharged directly into the canal, which was surprising especially from the GIs in charge of managing these flows. Other wastewater was generally imagined to be treated at a centralized facility.

When it came to identifying which stakeholder groups were either involved or should be involved in the management of the canal, the government was mentioned by all actors. After the government, businesses were the next most often mentioned, even though businesses are not directly involved in the current management of the canal. Involvement of the Chumchon was recognized by more than 80% of NFPs, GIs and chumchon, but only about 30% of the businesses. Moreover, businesses did not mention any NFPs at all. NFPs were in fact the least mentioned stakeholder group. On the other hand NFPs recognized all stakeholder groups as important to the management of the canal. The 'city,' itself, representing the majority of the city, and through the drainage system comprising the biggest source of wastewater to the canal, was mentioned as important to its management by disproportionately few stakeholders, especially among the government sector. Academics were also recognized by relatively few GIs. Businesses and GIs did not see large parts of civil society, particularly chumchon and NFPs, as stakeholder groups which are absolutely vital to include in the management of the canal.

The location along the canal was the most commonly mentioned disempowering factor limiting the participation of chumchon in the management of the canal. Local politics were also mentioned by a majority of all stakeholder groups to influence who has power in the decision-making. Local politics were often related to issues of corruption or clientalist relations. Chumchon in particular saw issues of land tenure and ethnicity to be paramount to their capacity to participate fully in the management of the canal. The law was seen as a source of power by most stakeholder groups except the GIs, which might be explained by their awareness of the weak monitoring and implementing capacity to support existing policies. Historically, slaves become the urban underclass after the abolition, and these free urban-poor communities form the foundation of the current chumchon. This may be part of the legacy of oppression experienced by these communities in Thai society today. Moreover, the recognition and othering of chumchon populations as foreign 'migrants' and 'hill tribes' who are not eligible for the same rights and benefits as the rest of the Thai population is deep seated. A political class based on weak democratic traditions and neo-liberal economics has maintained these inequalities.

There is limited recognition on the part of the GIs for both the stakeholder groups which should be involved in the management of the canal, as well as the impact the canal has on households in various communities. The level of recognition of actors which contribute to the pollution of the Mae Kha further illustrates the GIs lack of understanding of the issues on the ground. Overall, there is a lack of interaction between stakeholder groups. Even in the case of the NFPs, who have a clear overview of the situation on the ground, are limited in their recognition by others This is indicative of the weak bonds between various stakeholder groups.

How do different stakeholder groups participate in the management of the canal?

A variety of businesses, GIs, chumchon, and NFPs were identified as important to the management of the canal. There are many GIs on the national, provincial and local scales. The general idea is that ministries set the national environmental policy, departments and agencies under the ministries are responsible for regulating and monitoring, while local departments are in charge of the implementation. In practice most of the actions related to the Mae Kha are undertaken by instructions formed purely by the national government, without local government or public participation. The national government sets the policy, implements most of the infrastructure, and defines the funding. As a result, much of the built infrastructure ends up being badly managed and underused (Ribeiro & Srisuwan, 2005; World Bank, 2008). The decentralization of responsibilities to municipalities has happened without a decentralization of power. The municipality often lacks capacity to influence the management of the canal or even maintain its current duties towards the canal.

A lack of housing policy (World Bank, 2008), underlies both the relatively large number of chumchon and the current threat they face with eviction. At the local level, an unwritten agreement allows communities to squat in return for political support (Ha Tanwa, 2013; Marine department, 2013; Chief of maintenance, 2013). Hill tribes and Burmese migrants, who lack civil ID cards, are excluded from these arrangements. There is no clear process by which civil society and businesses can get involved in the management of the canal. Chumchon often take it upon themselves to get organized and lead development action, however, their continued exclusion from the planning and implementation process, combined with the political instability, has dulled many into inactivity.

Chumchon and businesses around the canal are faced with uncertainty about the laws they need to comply with and future they face. The organization of meetings on the subjects at the sub-district level has not yielded effective participation in the decision-making process, implementation or regulating capacity. Businesses in particular seem disconnected to processes on the ground. Except for allegedly paying bribes to avoid have to meet water standards, no clear roles were given to businesses in the management of the canal. Businesses showed little knowledge about the water quality standards in the city, and their water infrastructure in general. NFPs are involved primarily with the chumchon and with the canal only as an instrument towards the goal of improving the quality of life of the chumchon, on the physical or institutional level.

More work is required to investigate development plans and policies at the national level, however it may be difficult, as provincial level actors were quick to defer responsibility to the local or municipal levels. It appears that there is no clear policy on the management of the canal, but rather that national level GIs act in a reactionary fashion, whenever something is brought to their attention.

How do different stakeholder groups value the canals and envision their improved management?

The canal seems to acquire values outside of itself as a symbol which can be set in for various issues. The most popular values overall have to do with tourism. The canal is seen as a potential tourist attraction as well as simply a prominent element in the touristic landscape. In the way forward, it will be important to include these values in the framing of a solution, rather than relying on ecological values which are not widely shared. NFPs recognize a variety of values tied to the canals and were the only stakeholder group to attach significant ecological value to the Mae Kha.

The spiritual and historical values in particular have been utilized by chumchon including Un Ari and Lin Kho towards the goal of promoting behavioral change to reduce littering in the canal. Dr. Wassan has also made symbolic gestures to the canal in Loi Krathong, to gain attention for the state of the canal from the general population. Most notably, chumchon have organized canal cleaning days on King's and Queen's days, thus associating the cleaning activities with the highest and most beloved and unifying emblem in Thailand, its royalty. This embeds their activity of cleaning the canal in a discourse of nationalism and Thai identity, and has won them populist support for these activities.

The most frequently mentioned solutions to the problems experienced with the canal were sought in the technical-infrastructural sphere, especially with drainage and wastewater treatment systems. A second group of solutions focused on furthering cooperation between stakeholders. There did not seem to be much indication of solutions in the form of managerial changes, even though most interviewees were unhappy with the current management. Stakeholders in general did not have a clear idea of how the situation could be different or what the solutions would be. However, most stakeholders indicated an interest for a more participatory approach which could contribute to reaching the needed solutions. As indicated in the literature there is no one solution, and a lot of experimentation is still needed. In the end a variety of interventions, technical, behavioral and managerial, would have to be made to come to a sustainable solution. However, the indicated values should be integrated into the formation of any plan for the improvement of the canal.

The touristic and spiritual values tied to the canal could contribute to creating a broader platform of interest and participation on the subject. Tourism as the main economic force in Chiang Mai is responsible for attracting much of the chumchon population to the area, as well as the increasing population density of the area surrounding the canal. Hotels indicated that the stench results in a loss of business, and many agree that if the canal were clean it would be an asset to the tourism industry. The polluted canal stands in stark contrast with the 'imaginary' Chiang Mai which tourists flock to see, represented by its strong Buddhist culture and lush tropical mountains. Hotels have long remained aloof from the concerns for the Mae Kha, but since its condition has directly affected them, many have shown interest in playing a more active role in its management, even demonstrating interest in participating financially.

What are the human-environment interactions between the city and the urban canals in Chiang Mai, Thailand?

Finally, to answer the research question, the degradation of the canal has followed the urbanization of the city of Chiang Mai. The water quality is of the lowest class of standards, and is unfit for most uses. More research should be done on the presence of parasites, heavy metals and other toxins in the water and sediments of the canal. Processes outside of the canal and urban area, including agricultural runoff, and smog production, are also likely to have some impact on the canal. Nonetheless, land change in the urban area, particularly the increase in urban cover of Chiang Mai, certainly has a negative impact on the water quality of the Mae kha and Ku Wai canals. The increase in impermeable surface is also likely to affect the sub-catchment as a whole.

The management of the canal through infrastructural interventions such as cement lining of the banks, implementation of a city drainage, wastewater collection and treatment and positioning of water gates and water pumps, has mostly been planned and implemented by the national government. Local GIs feel little ownership of these projects. While these systems have been turned over to local GIs to run, they lack the necessary capacity to fulfill the tasks. As a result, much of the infrastructure remains un- or underused. The majority of the wastewater and urban run-off of the city is discharged directly into the canal, while black water is mostly treated through septic tanks. Businesses are officially responsible for their own water treatment, but a lack of monitoring capabilities and enforcement facilitates the circumvention restrictions.

Thailand as a whole has been experiencing heavier and more frequent flood events; this is also true for Chiang Mai. Flooding is one of the major disadvantages to people living near the canal. Much of the infrastructure and policies in place are directed at flood prevention, or to minimize the impacts of flooding. However, these interventions tend to benefit some more than others. Under the current management, the urban area which is used for tourism seems to experience most of the benefits, while areas directly upstream or downstream from this area seem to experience most of the disadvantages.

The banks of the canals downstream of the Mae Kha are heavily populated by chumchon. These populations face the brunt of the disadvantages of the Mae Kha, including flooding, health impacts, and land insecurity. The lack of housing policy to secure housing for low income urban dwellers, leaves the banks of the canal as one of the few areas available for them to live. As chumchon are most affected by the canal, they also have the most to gain from its rehabilitation, and most have a close relationship with the canal. As such, communities have also called upon the Mae Kha to gain land rights, by indicating their positive impact on the canal through cleaning events and publicity events.

However, chumchon are not the only ones who call upon the symbolic value of the canal. The canal has been part of Chiang Mai since its foundation more than 700 years ago, and is the target of many governmental plans. Most of these beautification plans include the eviction of the chumchon without any suitable housing option. Considering the relatively small impact of chumchon on the canal it is unlikely that such evictions will be sufficient to improve the water quality or aesthetic value of the canal.

The degradation of the canal is a symptom of a society that has failed to address or even recognize its social and environmental problems. Unless the interests of the urban poor and natural environment are put on the table and approached in a participatory way, in which all stakeholders are included and empowered in the planning, implementing and monitoring phases, it is unlikely that the issue of water pollution can be significantly improved in the long term.

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Annexes

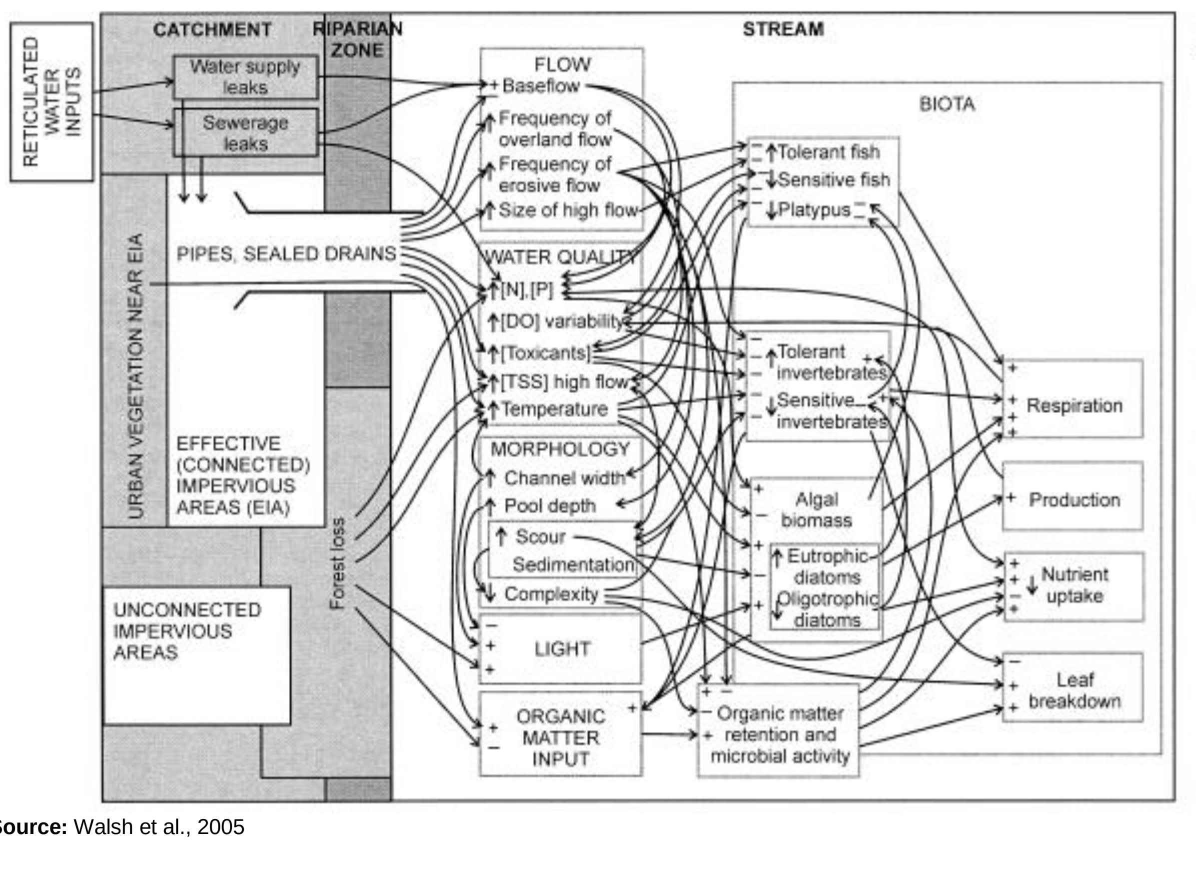
Annex 1 Interviews held

	Interview	Date	Stakeholder group
1	Un Ari	May 5, 2013	Chumchon
2	Chaiyapoom and Chang Moi	May 3, 2013	Chumchon
3	Kampaeng Ngam	May 20, 2013	Chumchon
4	Hua Fai	July 08, 2013	Chumchon
5	Saladeng	July 25, 2013	Chumchon
6	Papleng	May 1 and 3, 2013	Chumchon
7	Ha Tanwa	May 2 and 9, 2013	Chumchon
8	Fa Mai	May 22, 2013	Chumchon
9	Lin Kho	May 24, 2013	Chumchon
10	Sii Ping Muang	July 28, 2013	Chumchon
11	Samut	May 16, 2013	Chumchon
12	Lanna Hospital	June 17, 2013	Hospital
13	Maharon water treatment	June20, 2013	Hospital
14	Kon Jai Baan	February 20, March, 25 & 27, April 2, July 20, December 5	NGO
15	CODI	May 23, 2013	NGO
16	Dr. Virat CODI Bangkok	February 8, 2013	
17	POP	May 10 and 14 2013	NGO
18	Gum Rak Doi Suthep	July 7, 2013	NGO
19	Dr. Wassan	May 6, 2013	academic
20	Dr. Chichol	Talks June 27- November 27, 2013	academic
21	Community department	July 25, 2013	government
22	Sanitation department	June 13, 2013	government
23	Secretary Mayor	May 21, 2013	government
24	Marine Department	May 27, 2013	government
25	WWTP	July 29, 2013	government
26	Chief of Maintenance	May 29, 2013	government
27	Water quality control	May 27, 2013	government
28	red brick hostel	July 18, 2013	Hotel
29	centara hotel	July 2, 2013	Hotel
30	condotel	July 15, 2013	Hotel
31	panda hotel	July 15, 2013	Hotel
32	Tae Pai Inn	July 15, 2013	Hotel
33	Belgian hotel	May 20, 2013	Hotel
34	Kampaeng Ngam 1	May 17, 2013	Household
35	Kampaeng Ngam 2	May 17, 2013	Household
36	Kampaeng Ngam 3	May 17, 2013	Household
37	Kampaeng Ngam4	May 17, 2013	Household
38	Kampaeng Ngam 5	May 18, 2013	Household

39	Kampeang Ngam 6	May 18, 2013	Household
40	Kampeang Ngam7	May 18, 2013	Household
41	Kampaeng Ngam 8	May 18, 2013	Household
42	Kampaeng Ngam 9	May 19, 2013	Household
43	Kampaeng Ngam 10: Household & restaurant	May 19, 2013	Household
44	Kampaeng Ngam 11	May 19, 2013	Household
45	Kampaeng Ngam 12	May 19, 2013	Household
46	Kampaeng Ngam 13 : Household & Laundry	May 19, 2013	Household
47	hair dresser	May 20, 2013	small business
48	restaurant	May 20, 2013	small business
49	Restaurant (Kampaeng Ngam 10)	June 19, 2013	Small business
50	Laundry (Kampaeng Ngam 13)	June 19, 2013	small business
51	Garage	May 20, 2013	small business
52	Muay Mai market fish salesman	May 17, 2013	small business
53	slaughter house	July 27, 2013	small business
54	hill tribe market	May 20, 2013	small business
55	Bang Bua community leaders in Bangkok	26 February 2013	Chumchon

Note: Up to May, all interviews were done together with Merel Deelder. Most interviews were done with a translator, except the ones with Kon Jai Baan, Gum Rak Doi Suthep, the Belgian Hostel, Virat at CODI, Dr. Wassan and Dr. Chichol.

Annex 2 Urban Stream Syndrome



Source: Walsh et al., 2005

Annex 3 WHO suggested parameters for surface water

	sewage and wastewater	urban run-off	solid waste
temperature	1	1	
colour	1	1	1
odour	1	1	
residues	1	1	3
Suspended solids	3	2	3
conductivity	2	2	3
alkalinity			2
pH	1	1	2
Eh	1	1	
Dissolved Oxygen	3	3	3
Hardness	1	1	
Nutrients			
Ammonia	3	2	2
Nitrate/nitrite	3	2	2
organic nitrogen	3	2	2
phosphorus compounds	3	2	1
TOC	1	1	
COD	2	2	3
BOD	3	2	3
Sodium	2	2	
Potassium	1	1	
Calcium	1	1	
Magnesium	1	1	
Chloride	2	2	2
Sulphate	1	1	
Sulphide	2	2	
Silica	1	1	
Flouride	1	1	
Boron			
Aluminium			
Cadmium		1	3
Chromium		1	3
Copper	1	1	3
Iron	2	2	3

Lead	2	3	3
Mercury	1	2	3
Zinc			3
Arsenic		1	2
Selenium		1	1
Fats	1	1	
Oil and Hydrocarbons	2	3	2
organic solvents	1	1	3
methane			3
phenols	1		2
pesticides		1	2
surfactants	2		
feacal coliform	3	2	3
other pathogenes	3		3

Source: Chapman, 1996; Parameters suggested by the WHO for surface water receiving sewage and wastewater, urban runoff, or high quantities of solid waste (ranked from 1 to 3: low to high importance for measuring the parameter under site conditions.

Annex 4 Thai Surface Water Quality Standards

Parameter[1/]	Units	Statistics	Standard Value for Class[2/]					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
1. Colour,Odour and Taste	-	-	n	n'	n'	n'	-	-
2. Temperature	C°	-	n	n'	n'	n'	-	Thermometer
3. pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH Meter
4. Dissolved Oxygen (DO)[2/]	mg/l	P20	n	6.0	4.0	2.0	-	Azide Modification
5. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-	Azide Modification at 20°C , 5 days
6. Total Coliform Bacteria	MPN/100 ml	P80	n	5,000	20,000	-	-	Multiple Tube Fermentation Technique
7. Fecal Coliform Bateria	MPN/100 ml	P80	n	1,000	4,000	-	-	Multiple Tube Fermentation Technique
8. NO_3 -N	mg/l	-	n		5.0		-	Cadmium Reduction
9. NH_3 -N	mg/l	-	n		0.5		-	Distillation Nesslerization
10.Phenols	mg/l	-	n		0.005		-	Distillation,4-Amino antipyrene
11.Copper (Cu)	mg/l	-	n		0.1		-	Atomic Absorption -Direct Aspiration
12.Nickle (Ni)	mg/l	-	n		0.1		-	Atomic Absorption -Direct Aspiration
13.Manganese (Mn)	mg/l	-	n		1.0		-	Atomic Absorption -Direct Aspiration
14.Zinc (Zn)	mg/l	-	n		1.0		-	Atomic Absorption -Direct Aspiration
15.Cadmium (Cd)	mg/l	-	n		0.005* 0.05**		-	Atomic Absorption -Direct Aspiration
16.Chromium Hexavalent	mg/l	-	n		0.05		-	Atomic Absorption -Direct Aspiration
17.Lead (Pb)	mg/l	-	n		0.05		-	Atomic Absorption -Direct Aspiration
18.Total Mercury (Total Hg)	mg/l	-	n		0.002		-	Atomic Absorption-Cold Vapour Technique
19.Arsenic (As)	mg/l	-	n		0.01		-	Atomic Absorption -Direct Aspiration
20.Cyanide (Cyanide)	mg/l	-	n		0.005		-	Pyridine-Barbituric Acid
21.Radioactivity - Alpha - Beta	Becquerel/l	-	n		0.1 1.0		-	Gas-Chromatography
22.Total Organochlorine	mg/l	-	n		0.05		-	Gas-Chromatography

Pesticides						
23.DDT	µg/l	-	n	1.0	-	Gas-Chromatography
24.Alpha-BHC	µg/l	-	n	0.02	-	Gas-Chromatography
25.Dieldrin	µg/l	-	n	0.1	-	Gas-Chromatography
26.Aldrin	µg/l	-	n	0.1	-	Gas-Chromatography
27.Heptachlor & Heptachlorepoxide	µg/l	-	n	0.2	-	Gas-Chromatography
28.Endrin	µg/l	-	n	None	-	Gas-Chromatography

Source: Notification of the National Environmental Board, No. 8, B.E. 2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

Annex 5 Thai standards of effluent for pig farms

Parameter	Unit	Range or Maximum Permitted Values for These Categories	
		100 to 500 units	more than 500 units
1. pH	-	5.5-9.0	5.5-9.0
2. BOD	mg/l	30	20
3. Solids			
• Suspended Solids	mg/l	40	30
• Settleable Solids	mg/l	0.5	0.5
• Total Dissolved Solids*	mg/l	500	500
4. Sulfide	mg/l	1.0	1.0
5. TKN	mg/l	35	35
6. Fat , Oil and Grease	mg/l	20	20

Source: PCD, 2013

Annex 6 Thai categorization by type and size of buildings subject to effluent control

Building Type	Size				
	A	B	C	D	E
1. Condominium	500 units or more	From 100 to not greater than 500 units	Less than 100 units	-	-
2. Hotels	200 rooms or more	From 60 to not greater than 200 rooms	Less than 60 rooms	-	-
3. Dormitories	-	250 rooms or more	From 50 to not greater than 250 rooms	From 10 to not greater than 50 rooms	-
4. Massage parlors (or equivalent)	-	5,000 m^2 or more	From 1,000 to not greater than 5,000 m^2	-	-
5. Hospitals	30 beds or more	From 10 to not greater than 30 beds	-	-	-
6. Schools, Colleges, Universities, or Institutes	25,000 m^2 or more	From 5,000 to not greater than 25,000 m^2	-	-	-
7. Government offices, State enterprises, International agencies, Banks, and Office Buildings	55,000 m^2 or more	From 10,000 to not greater than 55,000 m^2	From 5,000 to not greater than 10,000 m^2	-	-
8. Department stores	25,000 m^2 or more	From 5,000 to not greater than 25,000 m^2	-	-	-
9. Fresh food markets	2,500 m^2 or more	From 1,500 to not greater than 2,500 m^2	From 1,000 to not greater than 1,500 m^2	From 500 to not greater than 1,000 m^2	-
10. Restaurants and food shops or food centers	2,500 m^2 or more	From 500 to not greater than 2,500 m^2	From 250 to not more than 500 m^2	From 100 to not more than 250 m^2	Less than 100 m^2

Source: PCD, 2013

Annex 7 Thai housing estate effluent standards

Parameter	Unit	Range or Maximum Permitted Values for These Categories		Method for Examination
		(A) 100 units but not more than 500	(B) more than 500 units	
1. pH	-	5.5-9.0	5.5-9.0	- pH Meter
2. BOD	mg/l	30	20	- Azide Modification at 20 oC , 5 days
3. Solids				
• Suspended Solids	mg/l	40	30	- Glass Fiber Filter Disc
• Settleable Solids	mg/l	0.5	0.5	- Imhoff Cone 1,000 cm3 1hour
• Total Dissolved Solids*	mg/l	500	500	- Dry Evaporation 103-105 °C, 1 hour
4. Sulfide	mg/l	1.0	1.0	- Titration
5. TKN	mg/l	35	35	- Kjeldahl
6. Fat , Oil and Grease	mg/l	20	20	- Sovent Extraction by Weight

Source: PCD, 2013

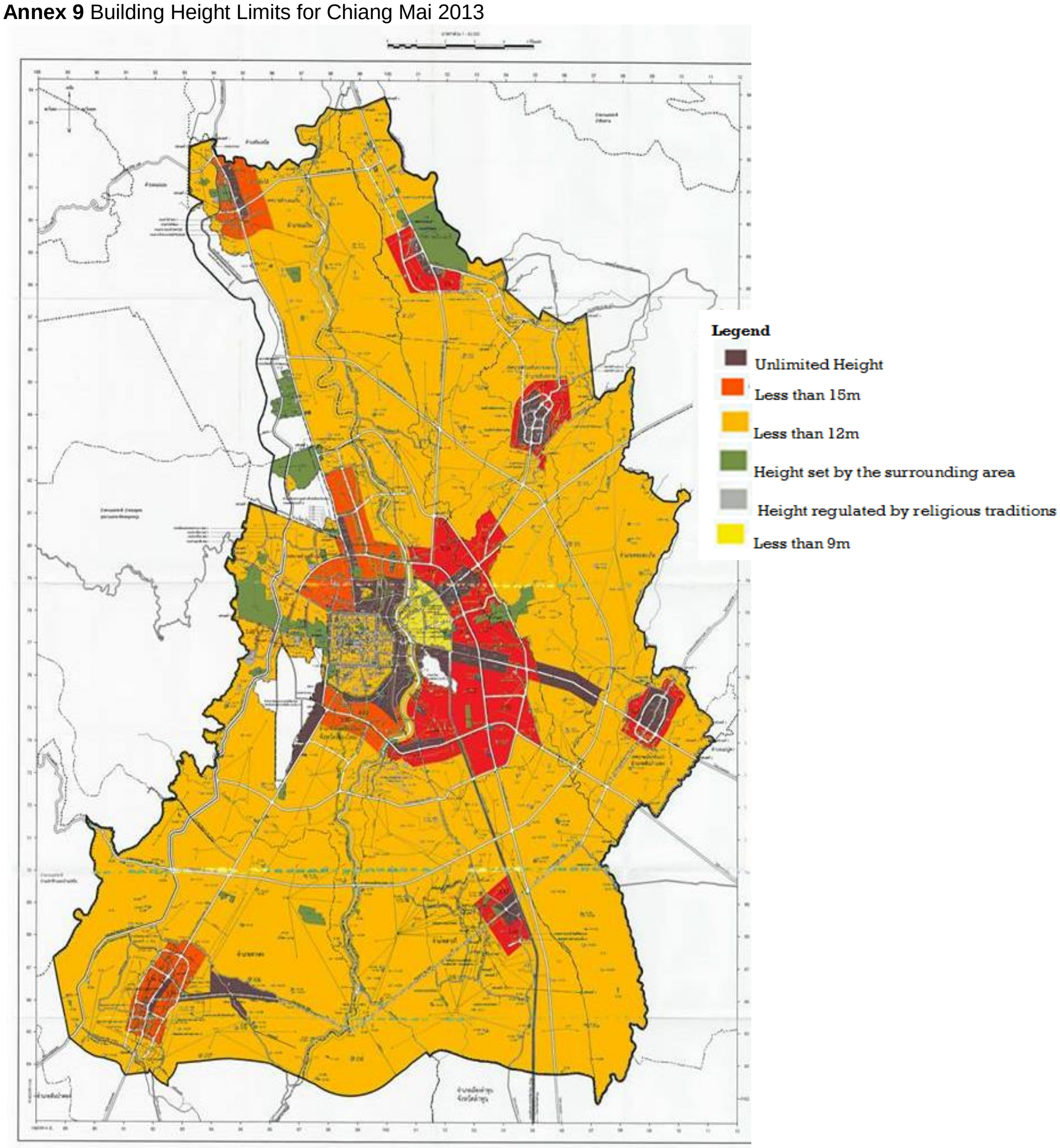
Annex 8 Thai industrial effluent standards

Industrial Effluent Standards		
Parameters	**Standard Values**	**Method for Examination**
1. pH value	5.5-9.0	pH Meter
2. Total Dissolved Solids (TDS)	• not more than 3,000 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 5,000 mg/l • not more than 5,000 mg/l exceed TDS of receiving water having salinity of more than 2,000 mg/l or TDS of sea if discharge to sea	Dry Evaporation 103-105 °C, 1 hour
3. Suspended solids (SS)	not more than 50 mg/l depending on receiving water or type of industry or wastewater treatment system under consideration of PCC but not exceed 150 mg/l	Glass Fiber Filter Disc
4. Temperature	not more than 40°C	Termometer during the sampling
5. Color and Odor	not objectionable	Not specified
6. Sulphide as H_2S	not more than 1.0 mg/l	Titrate
7. Cyanide as HCN	not more than 0.2 mg/l	Distillation and Pyridine Barbituric Acid Method
8. Fat, Oil & Grease (FOG)	not more than 5.0 mg/l depending of receiving water or type of industry under consideration of PCC but not exceed 15.0 mg/l	Sovent Extraction by Weight
9. Formaldehyde	not more than 1.0 mg/l	Spectrophotometry
10.Phenols	not more than 1.0 mg/l	Distillation and 4-Aminoantipyrine Method
11.Free Chlorine	not more than 1.0 mg/l	Iodometric Method
12.Pesticides	not detectable	Gas-Chromatography
13.Biochemical Oxygen Demand (BOD)	not more than 20 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 60 mg/l	-Azide Modification at 20 °C , 5 days
14.Total Kjedahl Nitrogen (TKN)	not more than 100 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 200 mg/l	Kjeldahl
15.Chemical Oxygen Demand (COD)	not more than 120 mg/l depending on receiving water of type of industry under consideration of PCC but not exceed 400 mg/l	Potassium Dichromate Digestion
16.Heavy metals		
1. Zinc (Zn)	not more than 5.0 mg/l	Atomic Absorption Spectro Photometry; Direct Aspiration or Plasma

2. Chromium (Hexavalent)	not more than 0.25 mg/l	Emission Spectroscopy ; Inductively Coupled Plama : ICP
3. Chromium (Trivalent)	not more than 0.75 mg/l	
4. Copper (Cu)	not more than 2.0 mg/l	
5. Cadmium (Cd)	not more than 0.03 mg/l	
6. Barium (Ba)	not more than 1.0 mg/l	
7. Lead (Pb)	not more than 0.2 mg/l	
8. Nickel (Ni)	not more than 1.0 mg/l	
9. Manganese (Mn)	not more than 5.0 mg/l	
10. Arsenic (As)	not more than 0.25 mg/l	Atomic Absorption Spectrophotometry; Hydride Generation, or Plasma Emission Spectroscopy; Inductively Coupled Plasma : ICP
11. Selenium (Se)	not more than 0.02 mg/l	
12. Mercury (Hg)	not more than 0.005 mg/l	Atomic Absorption Cold Vapour Techique

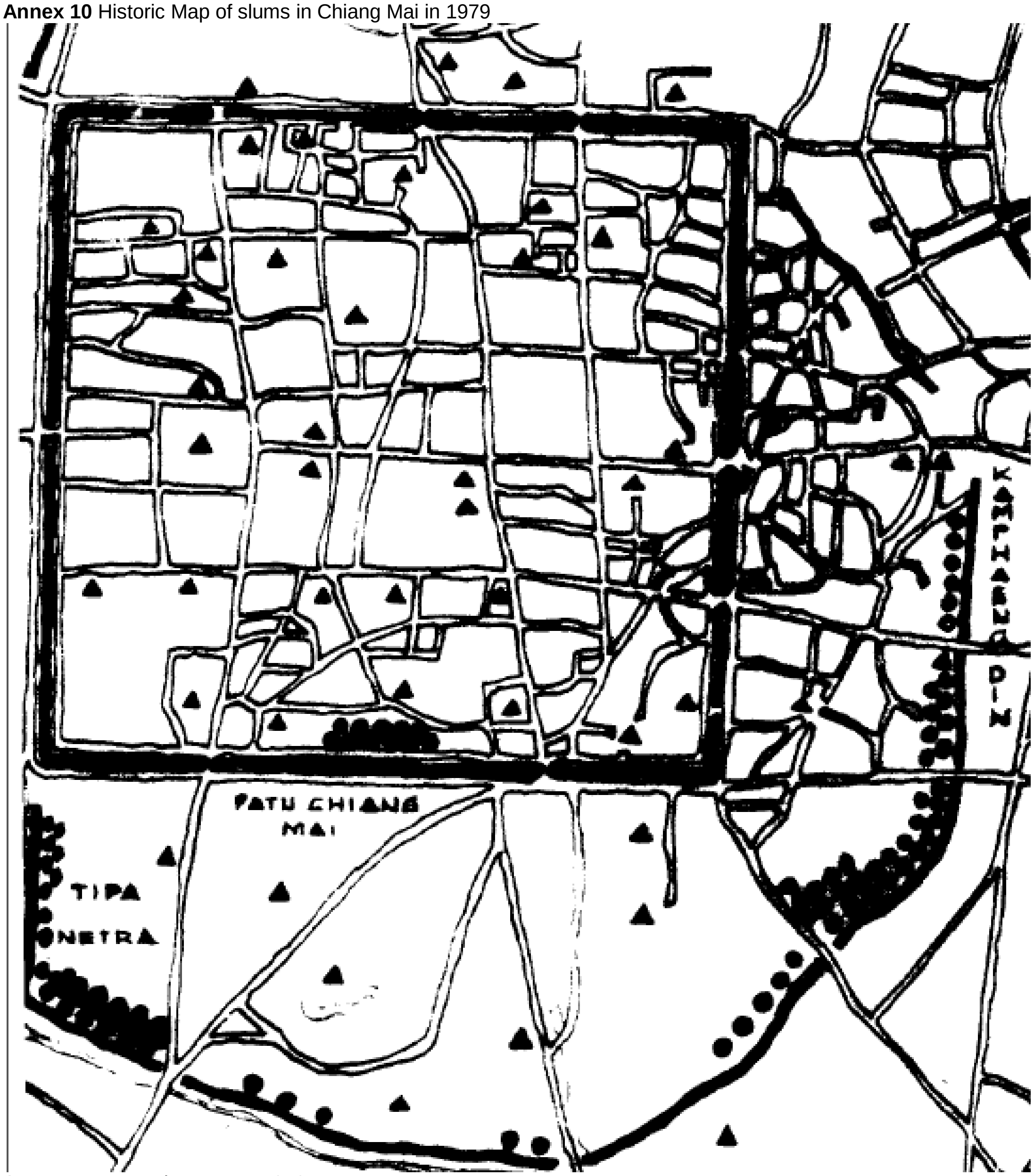
Source: PCD, 2013

Annex 9 Building Height Limits for Chiang Mai 2013



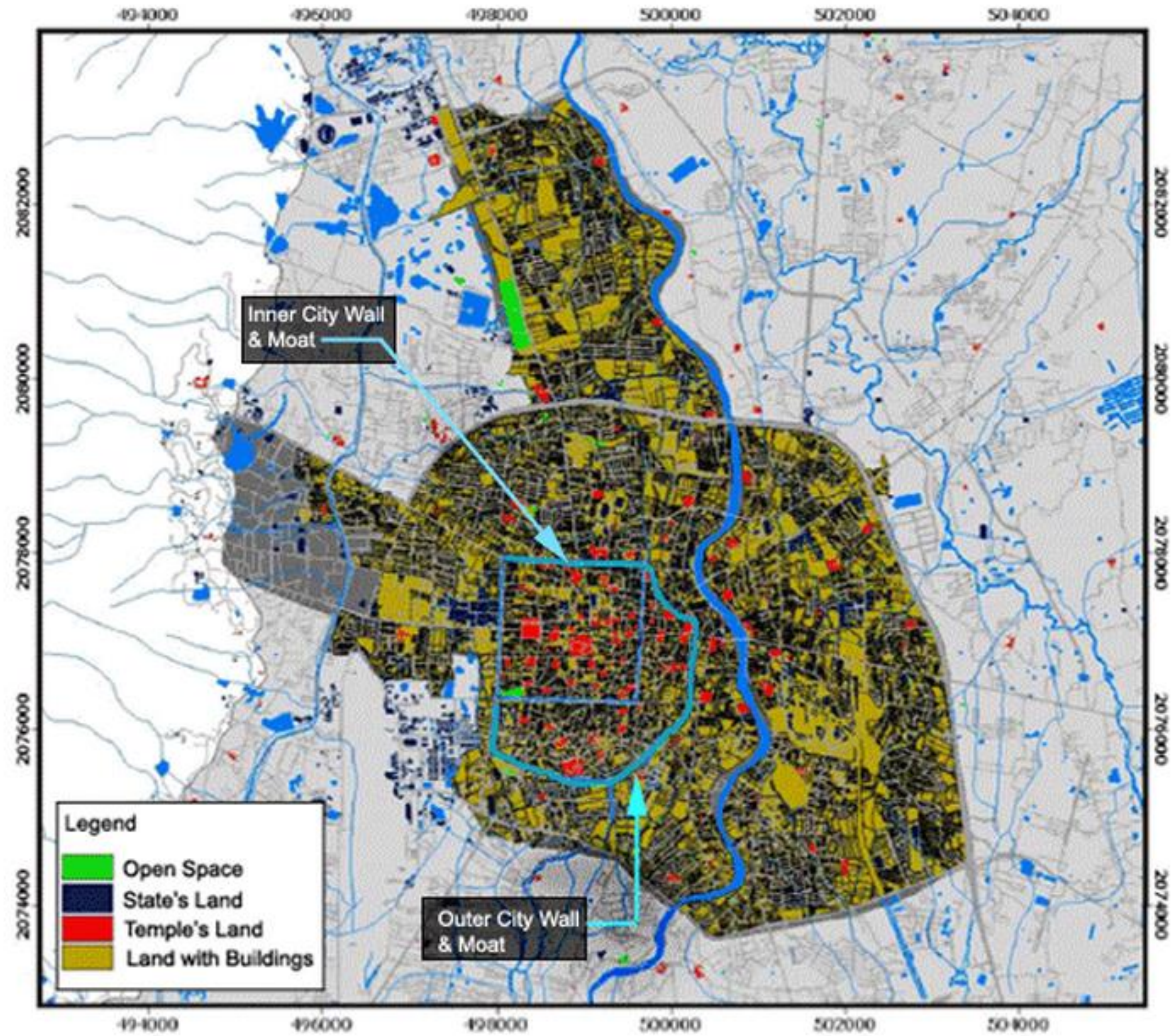
Source: Chiang Mai Municipal plan, 2012

Annex 10 Historic Map of slums in Chiang Mai in 1979



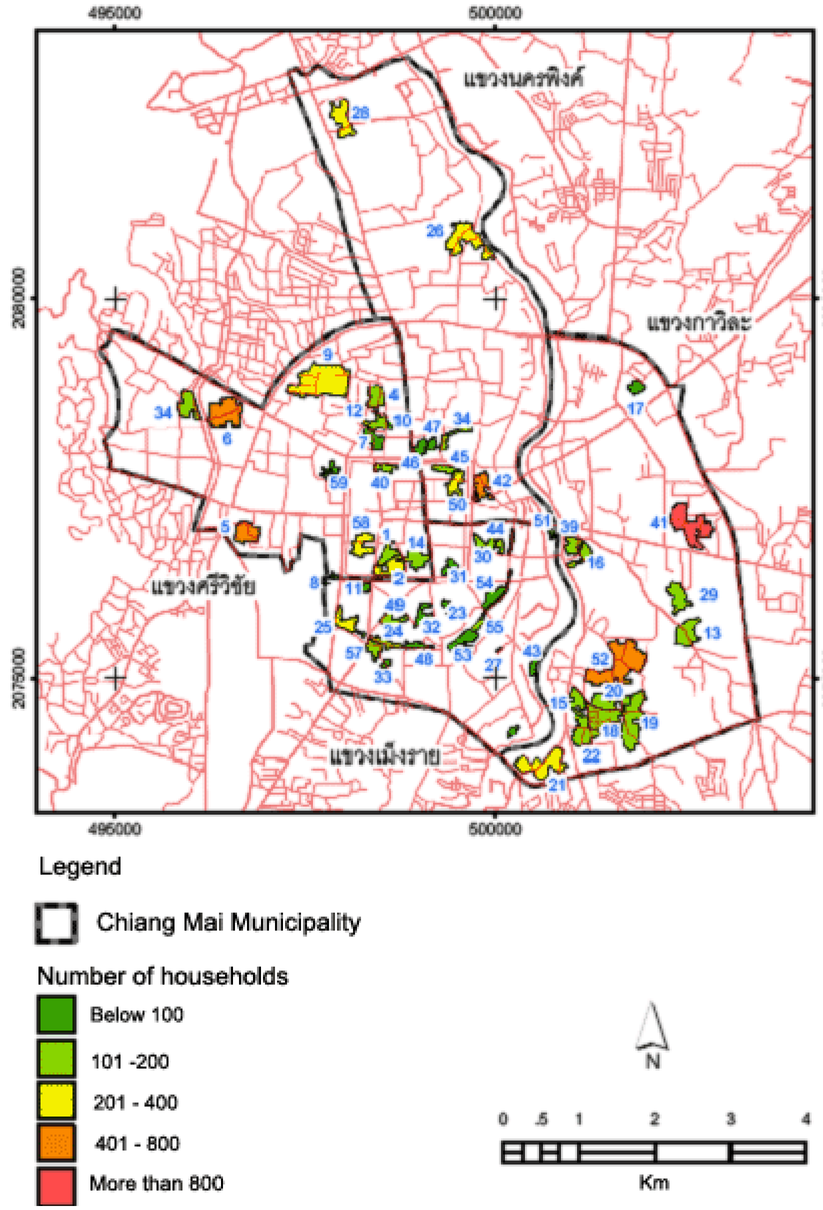
Source: U. Tan-Kim-Young, 1979

Annex 11 Map of land ownership for Chiang Mai



Source: CODI, n.d.

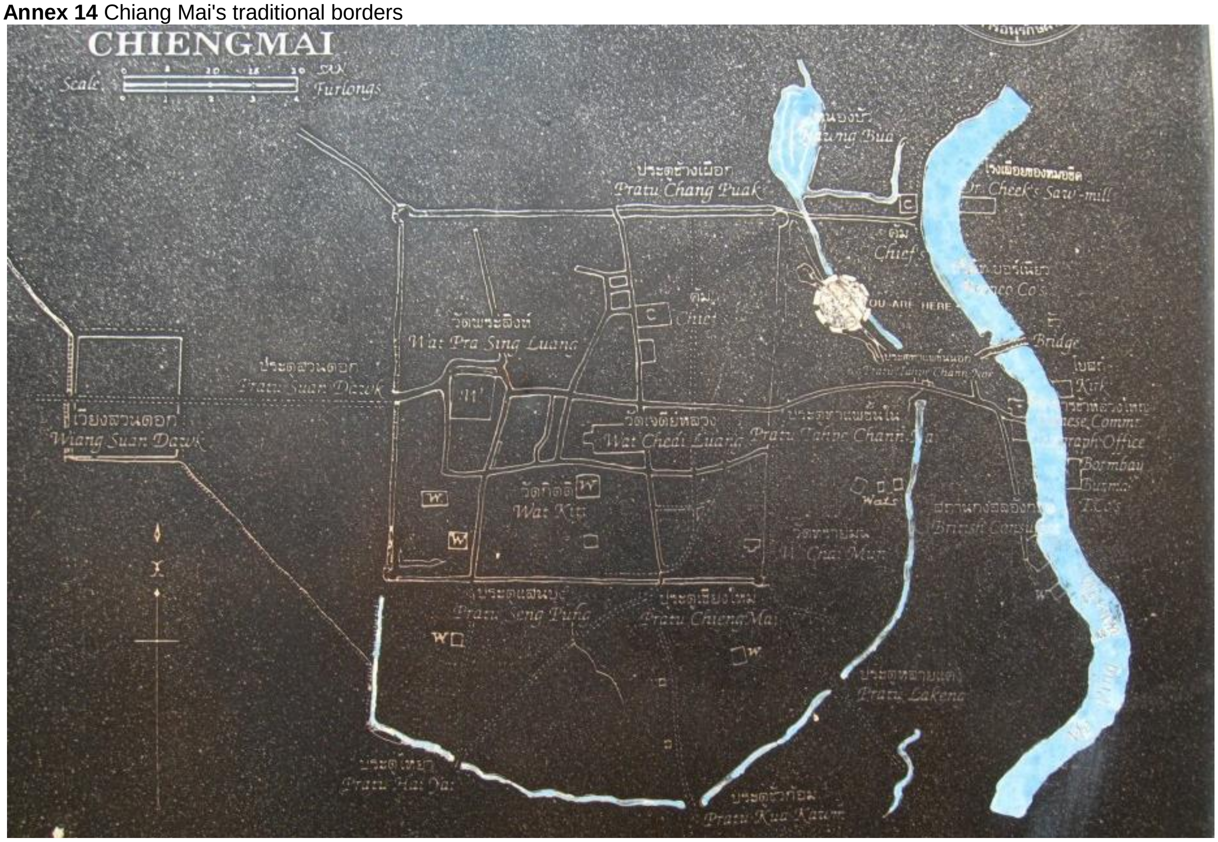
Annex 12 Map of squatter communities in Chiang Mai and their sizes



Source: CODI, n.d.

Annex 13 localized maps of different slums in Chiang Mai

Annex 14 Chiang Mai's traditional borders



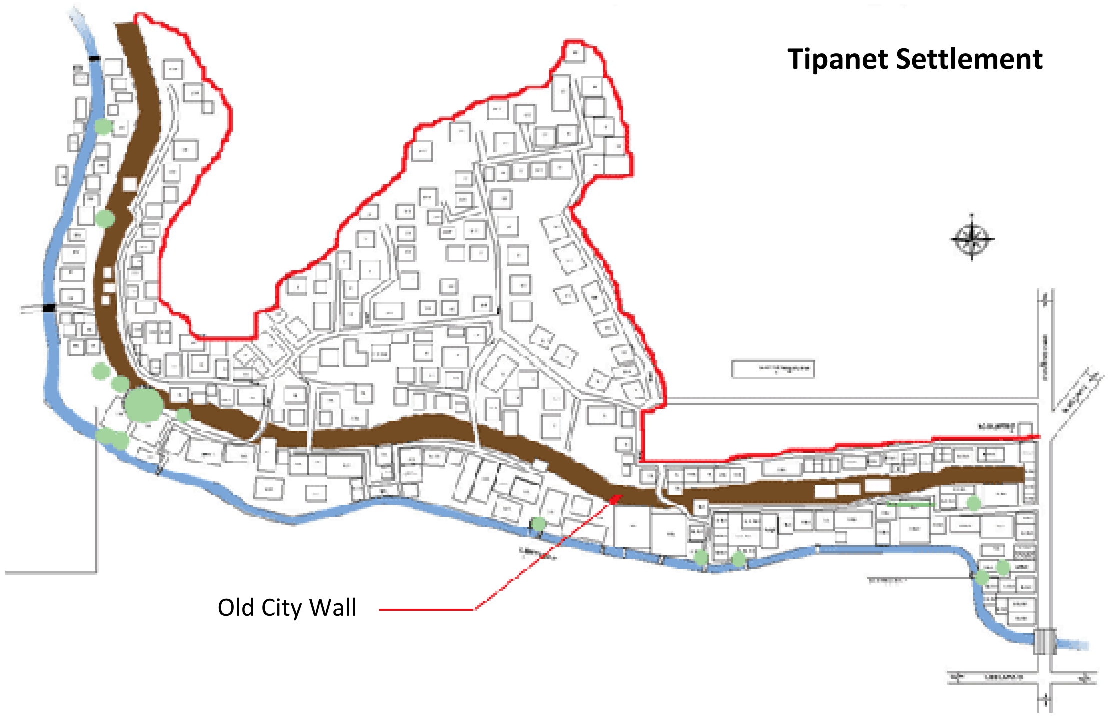
Source: Own picture taken nearby the Tha Pae road by the Mae Kha. The lake that used to be located at the top of the Mae Kha is indicated in this map

Annex 15 Map of Ha Tanwa re-settlement

Source: CODI, n.d. Those houses located in the Ku Wai (green) or on the wall (brown) had to be removed and resettled into the community.

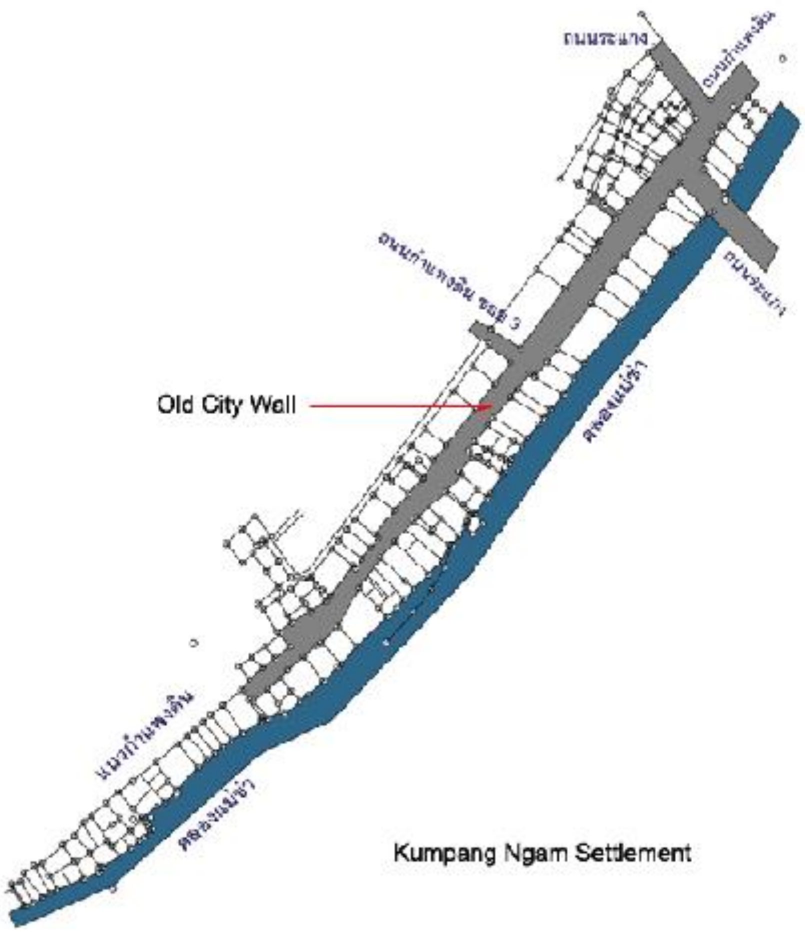
Annex 16 Tipanet Settlement

Annex 17 Tipanet settlement



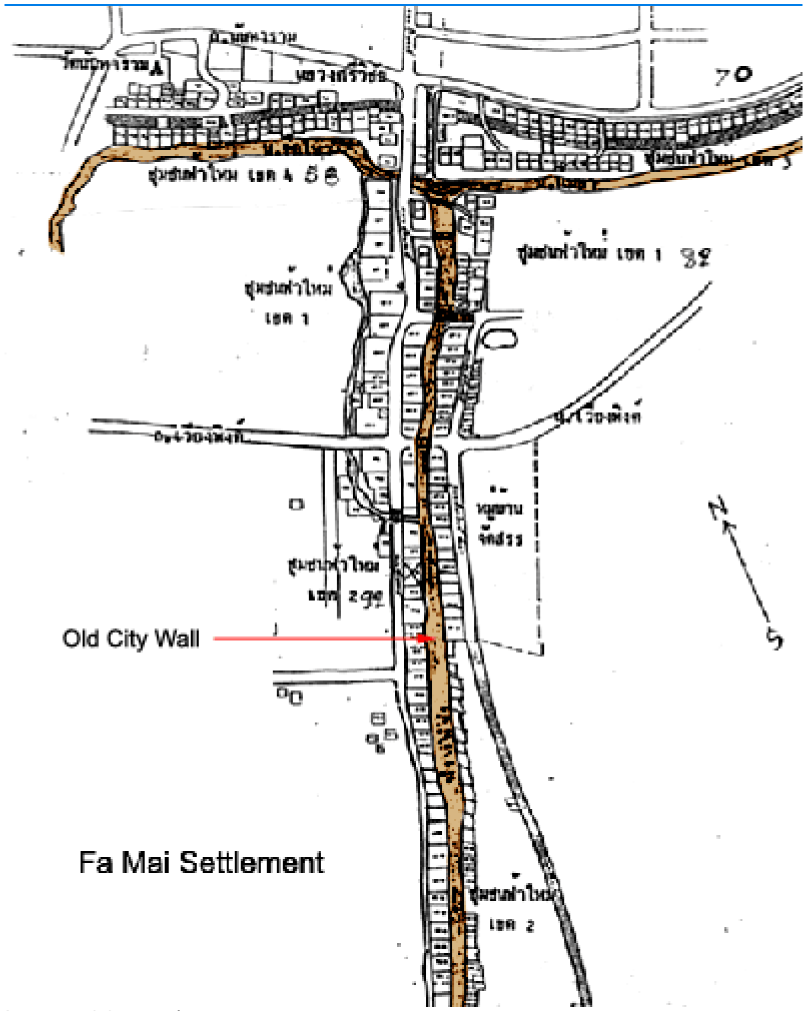
Source: CODI, n.d.

Annex 18 Kampaeng Ngam



Source: CODI, n.d.

Annex 19 Fa Mai Settlement



Source: CODI, n.d.