

# Mapping the Khlong Toei Slum's Drainage System to Develop Strategies for Reducing the Impact of Flooding



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## **Mapping the Khlong Toei Slum's Drainage System to Develop Strategies to Reduce the Impact of Flooding**

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# Abstract

This project focused on mapping factors that affect the stormwater drainage system and contribute to flooding in the Khlong Toei slum in Bangkok, Thailand. Among the factors we identified were improper waste management and low elevation. Interviews with residents revealed that flooding reduces mobility, increases pest infestations, and causes houses to sink. Our recommendations include implementing waste management programs, raising walkways, and covering drainage trenches with grates to mitigate the effects of flooding in the community.

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# Executive Summary

## Introduction

In 2013, floods accounted for 44 percent of deaths caused by natural hazards worldwide (World Disaster Report). Floods are of great concern because they increase the risks of waterborne pathogens, disease outbreak, and insect-borne infections (Blaikie et al., 1994; Stephens et al., 1994; Kolsky, 1999). In addition to health hazards, floods can reduce mobility to the point where people can no longer do their jobs and can create a constant putrid smell throughout communities.

Informal settlements, such as the Khlong Toei slum in Bangkok, are especially vulnerable to the damaging effects of flooding due to their increased exposure to the environment caused by substandard living conditions. The Khlong Toei slum is susceptible to flooding due to intense rainy seasons, relatively low elevation (The Climate of Thailand, 2012), substandard living conditions, and an inadequate stormwater drainage system.

The legal status of the Khlong Toei slum is a particular concern in regards to vulnerability to flooding because there are no clear responsible authorities for addressing the threats from stormwater. The slum is home to about 100,000 people (Wechsler, 2013), whom are considered squatters on land owned by the Port Authority of Thailand (Swift, 2006). This illegal status has made it difficult for the residents to obtain basic conveniences such as waste collection and proper roadways because of the government's refusal to work with illegal residencies (Nelson, 2015). The Khlong Toei slum's stormwater drainage system, cannot effectively handle runoff because the Department of Drainage and Sewerage has not sufficiently addressed its inadequacies. In addition, the stormwater drainage system is often clogged with waste, leading to unsanitary stagnant water and floods.

While previous projects, sponsored by the Duang Prateep Foundation, have studied many issues related to the health of the residents of the Khlong Toei slum such as garbage collection, drinking water, and legal status, there has yet to be any study of problems associated with stormwater and its management. This is something that needs to be addressed due to the health and safety risks that are, in part, caused by the inadequacy of the current stormwater drainage system.

## Our Goal

In collaboration with the Duang Prateep Foundation (DPF), we sought to identify the causes and consequences of the inadequacy of the Khlong Toei slum's stormwater drainage system and used the maps we developed to develop strategies for reducing the impact of flooding within the community.



## Methodology

After meeting with representatives of the DPF and community leaders, we learned that Lock 1-2-3 is the area of greatest concern with regard to flooding within the slum. In order to achieve our goal, we completed three objectives.

First, we identified the factors that affect the stormwater drainage system of Lock 1-2-3. To understand the causes of the flooding within the slum, we first acquired information regarding the current drainage system during flooding from the community leaders and residents. Then, we used a map of Lock 1-2-3 gathered from the Port Authority of Thailand and with the guidance of community leaders and DPF employees, we identified the major walkways, areas where trash clogged the flow of water, open drainage trenches, the locations of the garbage collection sites, and the lengths and widths of each major walkway within Lock 1-2-3. The community leaders, DPF staff, and residents of the community provided us with additional information about areas of past flooding and the direction of water flow. Using the data gathered, we created digital maps of Lock 1-2-3 to understand the relationships between the factors and for future use by the DPF.

Second, we determined the perceptions of the community regarding the causes and effects of—and possible solutions to—flooding in Lock 1-2-3 to better understand the causes and effects of flooding of the stormwater drainage system. We did this by interviewing residents in an informal setting and analyzing their responses to questions such as “how do floods affect your everyday life?” and “what do you believe causes the floods?” Due to their significant experience and detailed knowledge of their community, they were able to provide us with insight that research and observations alone couldn’t supply.

Third, we developed strategies and recommendations for ways to reduce flooding through both structural improvements and community actions. To accomplish this we did three things. First, we determined through meeting with representatives of the DPF and community leaders that suggested recommendations would be most useful when the cost, location, feasibility, and permeability of the solution were considered. Second, we organized our recommendations into two categories: structural improvements and community actions. Third, we developed implementation strategies for each recommendation.

## Results

Using the information that we gathered from our interviews with the residents of the Khlong Toei slum, the meetings with the community leaders and representatives of the DPF, and the data from our map deliverable, we developed 13 findings. The findings were categorized into causes of flooding, barriers to improving the drainage system, consequences of flooding, and approaches to reduce the impact of flooding.

The causes of flooding that we learned about are:

- **Houses built on the waterway.** From our observations and interviews, we discovered that houses are being built on top of waterways. Not only does this block the flow of water which raises water levels, but it also makes it difficult to unclog trash that accumulated underneath the houses.

- **Improper waste disposal.** The improper disposal of waste clogs up the stormwater drainage system and causes flooding. There are designated trash collection sites and trash collection services available, but garbage is still found on the walkways. There are differing opinions between the short term residents, long term residents, and the DPF of who is responsible for the very obvious litter in Lock 1-2-3,
- **Low elevation.** Pockets of low elevation in Lock 1-2-3 are the most severely impacted by flooding. This is clear from our maps of elevation and areas of past flooding.

The barriers to improving the stormwater drainage system that we learned about are:

- **Narrow walkways.** The walkways of Lock 1-2-3 range between approximately 1 to 2 meters wide, making waste removal a challenge because residents either have to bring their trash to the outside of Lock 1-2-3 so that the BMA can remove the trash or the BMA has to send workers into Lock 1-2-3 to collect trash from residents' garbage bins. Neither of these options currently work because of inconvenience and minimal manpower.
- **Lack of awareness of community willingness to temporarily relocate.** From our interviews with residents of Lock 1-2-3, we learned that some residents were unwilling to temporarily relocate to allow the stormwater drainage system to be improved. The most common reason they gave was that they didn't believe other residents would be willing to relocate, however, the majority of the residents we interviewed were willing to relocate.
- **Minimal community participation in waste management workshops.** When the community leaders had previously held a waste management workshop, only five to six residents attended. Without the knowledge of proper waste management practices, residents will be unable to reduce the amount of garbage clogging the stormwater drainage trenches.
- **Insufficient funding and volunteers for waste collection incentive programs.** Some residents expressed that incentive programs would help reduce flooding by reducing the amount of trash clogging the stormwater drainage system. For example, a program that exchanged garbage for eggs ceased a few years ago because the cost of the eggs was greater than the amount made from sorting and selling the garbage they received.

The consequences of flooding that we learned about are:

- **Sinking homes.** The houses in Lock 1-2-3 were built on swampy land. The floods make matters worse by weakening the material supporting houses. From our observations and from speaking with the community leaders, houses have collapsed into the waterways, in part due to flooding.
- **Increased pests.** From interviews with residents, pests such as Asian water monitors, mosquitoes, and snakes are more numerous near residents' homes due to the floods.
- **Reduced mobility.** From interviews with residents of Lock 1-2-3, we learned that many do not have the means to travel safely through the unsanitary, ankle-deep floodwater. This causes them to remain at home, unable to carry out their daily

activities, and can cause negative health effects if they walk through the unsanitary floodwater.

- **Negative health effects.** From interviews with residents of Lock 1-2-3, we learned that many residents become afflicted with illness or foot diseases. This is caused by the residents' lack of means to safely travel through the unsanitary floodwater.

The current approaches to reduce the impacts of flooding we learned about are:

- **Cleaning around homes to reduce drain blockages and improve mobility.** One of the residents we interviewed told us that he “pick[s] up dog feces around [his] house everyday, every morning,” and he “want[s] people to get involved and cooperate more.” Taking initiatives such as this can help reduce the putrid odor caused by floods, reduce the detrimental health impact of floods, reduce blockages of the drainage system, and inspire other people to keep their community clean.
- **Raising walkways to reduce the impacts of flooding on the surrounding homes.** In order to solve the issue of mobility caused by the floods, certain walkways have been raised with concrete slabs to be above the water level when it floods. This has helped in certain areas, but has not been implemented in many areas, potentially due to the cost of the concrete slabs. It may be useful to do this in areas vulnerable to flooding.

## Recommendations and Conclusions

Our recommendations for structural improvements and community actions are categorized into four main categories: (1) Recommendations to Reduce Waste Clogging the Stormwater Drainage System, (2) Recommendations for Drainage System Improvements, (3) Recommendations for Mitigating the Negative Effects of Flooding, and (4) Recommendations for Next Steps. To assist in further assessment of the recommendations and their implementations, the Duang Prateep Foundation can use the maps of Lock 1-2-3 we developed as a useful reference when planning future structural improvements or attempting to gain support from local government organizations.

Our recommendations to reduce waste clogging the stormwater drainage system are:

- **Designating specific areas for new garbage collection sites.** Using our map of elevation, areas where trash clogs the stormwater drainage system, and the width of walkways, multiple locations for potential new garbage collection sites can be identified that are accessible by the Bangkok Metropolitan Administration (BMA) to collect trash. The idea is to make it more convenient for residents to properly dispose of their garbage in order to prevent trash from clogging the drainage system.
- **Adding grates, grills, nets, or drain covers over the current drainage system.** According to our background research, grates, grills, nets, and drain covers are able to serve as a barriers to waste entering the drainage trench. It should be noted that for this method to be effective, the waste currently clogging the drain must be removed before the grates, grills, nets, or drain covers are put into place. The data we gathered on the lengths and widths of walkways can be used to help estimate the costs and the dimensions of covers needed.

- **Cleaning areas around local residents' homes.** According to DPF representatives, there are a few residents who go out of their way to keep the community clean, doing things such as picking up animal waste along the streets. Cleaning areas around their homes will reduce the amount of waste that enters the stormwater drainage system, reducing blockages and the health risks associated with the floods these contribute to. This can motivate other residents who live nearby by to take part in cleaning the community as well, which could reduce flooding and greatly benefit the community.

Our recommendations for drainage system improvements are:

- **Deepening existing drainage trenches.** Based on our background research, we recommend that the community leaders deepen the existing drainage trenches. This increases the capacity of the stormwater drainage system and therefore reduces the likelihood of flooding of the walkways.

Our recommendations for mitigating the negative effects of flooding are:

- **Raising walkways.** Through observation, areas throughout Lock 1-2-3 that featured raised walkways were less likely to flood. Residents of Lock 1-2-3 have also relayed to us through interviews that the previous walkways that were elevated reduced the impacts of flooding. Using the maps we've created, we recommend that certain walkways are raised in areas of past flooding and areas of major concern to reduce the impacts of flooding on the surrounding homes.
- **Investing in methods of safe travel through unsanitary floodwater.** After interviewing residents from Lock 1-2-3, one of their main concerns about flooding in the community is the lack of mobility that is associated with it. Investing in methods of safe travel through trash contaminated waters, such as boots, will allow the residents to continue living their daily lives and mitigate negative health effects.
- **Developing and implementing flood preparation workshops.** Implementing flood preparation workshops with the residents of Lock 1-2-3 would allow the community to become educated on how to learn to live with the effects of flooding. This short term recommendation would teach the residents techniques such as: using sandbags to divert water flow from entering homes, making small structural improvements to the nearby drainage trenches to reduce flooding, and using mosquito nets to reduce the risk of contracting insect-borne diseases.

Our recommendations for next steps are:

- **Creating new drainage trenches between houses and certain walkways.** By creating more relief channels in Lock 1-2-3, the stormwater drainage system will have a larger capacity, and water that may have once flowed into a pocket of low elevation could flow out of Lock 1-2-3. While planning prospective locations, several factors should be considered: the stability of nearby homes, current widths of the walkways, direction of water flow, and how the addition of new trenches may affect the direction of water flow. The maps of the directions of stormwater flow could be helpful in determining where to create new drainage trenches.

- **Continuing to update and extend the maps of the stormwater drainage system.** Continuing to update these maps will benefit the community leaders as it informs them of areas throughout the Khlong Toei slum that are more flood prone. Overtime, new houses or new drainage trenches may be constructed, or more areas of concern may arise. Updating the maps while involving the community can contribute to a sustainable system for mapping and create a sense of leadership among the residents of the Khlong Toei slum. Extending these maps into Lock 4-5-6 and 70 Rai would allow for a more complete understanding of the entire stormwater drainage system, because these drainage systems are connected.
- **Organizing waste management programs or events.** According to interviews with the community leaders, past waste management projects in the slum, such as the “Garbage for Eggs” initiative, have been successful with proper funding. The programs should educate the residents about the importance of the following concepts related to waste management: (1) teaching them how it affects the drainage system and their everyday lives, (2) holding them accountable for their actions regarding waste disposal, and (3) convincing them to get more involved in cleaning the community to create a sustainable initiative.

## **Conclusions**

When we presented our project to representatives from the DPF, the Port Authority of Thailand (PAT), and the Bangkok Metropolitan Administration (BMA) we made an unexpected impact. A representative from the PAT stated how our project provided him with necessary materials and reasons to make the improvements of the drainage system. The BMA representative said that the PAT wasn’t doing anything to improve the drainage system even though they collect funds from the Lock 1-2-3 residents. The BMA representative proposed that if the PAT uncovered and dug up the drainage trenches along Damrong Phiphat road, then the BMA would remove all of the trash clogged in the trench. The representative from the PAT said that he would consider the idea and would need time to think about it. Our presentation got representatives from the PAT and the BMA into the same room and gave them the opportunity to debate the current problems with the stormwater drainage system in Lock 1-2-3. We hope that in the near future this debate spurs actions from both parties, as well as the residents of Lock 1-2-3 to improve the stormwater drainage system in the Khlong Toei slum.

# 1 Introduction

In 2013, floods accounted for 44% of deaths caused by natural hazards worldwide (World Disaster Report). Floods, especially those within informal settlements, increase the risks of waterborne pathogens, disease outbreak, and insect-borne infections (Blaikie et al., 1994; Stephens et al., 1994; Kolsky, 1999). Other impacts include putrid odors and reduced mobility within the community. Urban pluvial flooding, when heavy rain overwhelms the capacity of the drainage system, often leads to these devastating social and environmental impacts. Inadequate stormwater drainage systems increase the likelihood of flooding and thus should be addressed to reduce the negative effects that are associated with flooding.

Although floods occur all around the world, certain areas are especially susceptible to their damaging effects. According to urban geographer Colin McFarlane, slum residents occupying low-lying precarious lands are the most vulnerable to flooding events (McFarlane 2014). The Khlong Toei slum, located in the Khlong Toei district, Bangkok, is susceptible to flooding because of intense concentrated rainy season (The Climate of Thailand, 2012), relatively low elevation, substandard living conditions, and a stormwater drainage system that is often clogged with waste and unable to drain stormwater effectively, as stated by community leaders. The inadequacy of the stormwater drainage system leads to unsanitary stagnant water, which can spread waterborne pathogens, affecting much of the community (Kolsky, 1999).

In order to address these issues, previous projects have improved the stormwater drainage system within slums through structural improvements and community actions. The Kounkuey Design Initiative team combined expertise in urban planning, sustainable design, and community outreach to help prevent flooding in Kibera, a large slum in Kenya (Nelson, 2015). The project employed cellphone mapping and geographical information system software to draw conclusions on how to mitigate the flooding by identifying flooding hot spots and underutilized drainage channels (Nelson, 2015). The processes used and solutions developed by the Kounkuey Design Initiative team and other projects provide potential models for other locations because of community involvement, coordination with local governments, and development of long-term solutions.

While various projects have studied many issues related to the health of the residents of the Khlong Toei slum such as garbage collection, drinking water, and legal status, there has not been any study on stormwater management. This is something that needs to be addressed due to the health and safety risks that are, in part, caused by the inadequacy of the current stormwater drainage system.

In collaboration with the Duang Prateep Foundation, we sought to map factors affecting the performance of the Khlong Toei slum's drainage system and propose strategies to reduce the impact of flooding within the community. Lock 1-2-3 is the area within the slum that is of greatest concern and will be the area of our focus. To accomplish the goal of this project, we carried out the following objectives: First, we identified the factors that affect the drainage system within the Khlong Toei slum. Second, we determined the perceptions of the community regarding the causes and

effects of flooding as well as possible solutions to the flooding in the Khlong Toei slum. Lastly, we developed strategies and recommendations for ways to reduce flooding through both structural improvements and community actions. By accomplishing these objectives, we provided the DPF with maps that show factors affecting the stormwater drainage system as well as recommendations for potential strategies to mitigate the negative impacts of flooding in the Khlong Toei slum. We hope that this information can be used to aid the DPF in their efforts to improve the quality of life for the community.

## **2 Background**

Our project took place in the Khlong Toei slum, located in southern Bangkok, Thailand. In order to assess the slum's current stormwater drainage system, we considered two main areas of focus for our research. First, we discuss the vulnerabilities of the Khlong Toei slum that make it particularly susceptible to the effects of flooding. Second, we describe various challenges slums face managing stormwater as well as their strategies to overcome these challenges.

### **2.1 Vulnerabilities of the Khlong Toei Slum to Flooding**

The Khlong Toei slum is one of the largest and most prominent slums in Bangkok, stretching across a sizeable 2 square kilometers and home to about 100,000 people (Wechsler, 2013). The slum was first established in the 1950's when large numbers of people left their rural, agricultural livelihoods and moved to Bangkok with hopes of a better life and more job opportunities (Wechsler, 2013). Substandard living conditions in the slum increase residents' exposure to the natural elements, making them more easily affected by surrounding environmental conditions such as rain and wind (Wechsler, 2013). In addition, the residents reside on land that legally belongs to the Port Authority of Thailand (Swift, 2006), making the residents not only vulnerable environmentally, but also socially. The following sections discuss how the weather conditions, the poverty of residents, and the legal status of the Khlong Toei slum make the community more vulnerable to the causes and consequences of flooding.

#### **2.1.1 Weather Conditions**

The Khlong Toei slum faces the harsh Thailand rainy season making it more likely to flood. Thailand experiences three main seasons: the rainy or southwest monsoon season which occurs annually from mid-May to mid-October, the winter or northeast monsoon season which typically takes place from mid-October to mid-February, and the summer season between mid-February and mid-May (The Climate of Thailand, 2012); please note there are conflicting statements when exactly the start and end of these seasons are. During the two regional monsoon seasons, intense winds and rainfall occur in their respective regions (Tourism Thailand, 2016). In Bangkok, the rainy season is characterized more by heavy flash precipitation events rather than constant rain (Sapsuwan, 2014). It occurs from July to October (Bangkok Weather, 2016) and

contributes to the flooding that occurs in the Khlong Toei slum, especially when coupled with its "garbage and undrained sewage clogging litter" (Sapsuwan, 2014).

### **2.1.2 Poverty of Residents**

Low income households are more vulnerable to the effects of flooding due to their lack of resources and limited ability to cope (Patankar, 2015). According to Sapsuwan, "in Klong Toey, an average household earns only around half of the national average and only around one-third of the income an average Bangkok household" (2014). The Khlong Toei slum has struggled with poverty dating back to its establishment in the 1950's when impoverished people from Northeastern Thailand migrated to the area looking for work (Wechsler, 2013). Generally, low-income communities settle on land adjacent to waterways due to its availability, relatively low cost, and proximity to job opportunities, increasing their vulnerability to the effects of flooding (Maclean, 2014). The Khlong Toei slum lies between a mere 4.4 and 5.6 meters above sea level, increasing its susceptibility to the effects of flooding because slum-dwellers living on lands of low elevations are more affected by environmental stresses such as flooding (The Guardian, 2014). Conflict often arises when attempting to solve flooding issues in poor areas because what's best for reducing floods is often unaffordable for its residents (Maclean, 2014).

### **2.1.3 Legal Status**

Approximately 20% of people living in Bangkok live in a squatter settlement (Sapsuwan, 2014), which is an illegal habitation of residents on either public, private, or vacant land (Srinivas, 2015). The Khlong Toei slum is a squatter settlement because it was illegally established on land owned by the Port Authority of Thailand (PAT). Because the 100,000 Khlong Toei slum residents are living on the PAT's land illegally, their relationship with the PAT has been one filled with conflict. On numerous occasions, the PAT has attempted to evict its squatter residents through relocations, claims of eminent domain, and fires (Askew, 2002). Today, the PAT remains aware that people are inhabiting their land, but many of the residents pay a small sum of money for rent (Askew, 2002).

The main reason the Khlong Toei residents' status as illegal squatters contributes to their susceptibility to flooding is because in squatter settlements, basic amenities such as waste collection programs and roadways are often neglected due to the government's refusal to work with illegal residencies (Nelson, 2016). Large infrastructural improvements in squatter settlements are also nearly impossible without outside funding because residents are ineligible for upgrading programs due to their illegal status (Phōnchōkchai, 1985). This is one of the reasons why the Khlong Toei slum's stormwater drainage system is in such an inadequate state. The Khlong Toei slum's relationship with the PAT and its legal status hinders its ability to maintain successful waste management programs and effective stormwater drainage system, causing the community to be particularly susceptible to flooding.



## **2.2 Stormwater Drainage Systems in Slums: Challenges and Strategies**

Floods usually occur when there is heavy rainfall, natural disasters, or a combination of these factors, causing devastating effects on those living in makeshift houses (Armitage, 2012). Stormwater drainage systems with open trenches for the discharge of rainwater exist in most urbanized areas, such as the Khlong Toei slum. These trenches usually drain off rainwater into rivers or into agricultural irrigation canals. In slums, drainage systems often fail due to lack of support from outside organizations, improper construction of the system, poor maintenance, and several other social factors (Armitage, 2012).

### **2.2.1 Challenges Affecting Stormwater Drainage Systems in Slums**

In this section we discuss challenges slums face with maintaining effective stormwater drainage systems. Such challenges cover both social and engineering issues. For the purpose of project, we will consider the social issues as the lack of common unity among slum residents and improper waste management within slum communities. On the other hand, engineering issues include the negative effects of the improper waste management within slums and the insufficient geographical data on slums.

#### **2.2.1a Lack of Common Unity Among Slum Residents**

Slums are comprised of a collection of different people with various backgrounds and values, and consequently these communities can lack a sense of common unity. Research in Indonesian slums revealed that having a large population makes it difficult to establish “any formal organization or sense of unity” (Berner and Korff, 1995). Furthermore, the study found that residents identified more with their neighbors than the community as a whole, indicating that their sense of unity may be fractured. In order to work through some of the many challenges that affect residents of slums, such as inadequate stormwater drainage systems, collective action is needed (Armitage, 2012).

#### **2.2.1b Improper Waste Management within Slum Communities**

In low-income Asian countries, the open dumping of municipal solid waste is a serious issue affecting stormwater drainage systems, the environment, and the overall health of communities. Only between one- and two-thirds of the total solid waste generated in urban areas is collected (Zurbrugg, 2002). Waste is often thrown into the streets and drains, in turn blocking drainage channels, and increasing the chance of flooding, pest infestations, and contracting disease (Zurbrugg, 2002). In Khlong Toei, the residents are facing the same issues. Through interviews with community leaders conducted in Poompat Aroonsri’s research (2014) in the Khlong Toei slum, regardless of drainage improvements, the drains get clogged and flood due to some residents’ mistreatment and lack of maintenance of the drainage system.

#### **2.2.1c Insufficient Geographical Data on Slums**

Slums are known to be one of most unsurveyed and untraceable areas of megacities (Paar and Rekitke, 2011). As many slums are squatter settlements, they are

frequently unmapped on official maps and many official documents. Major mapping applications such as Google Streetview and Teleatlas refrain from entering slums, resulting in blank areas showing no street names or formal addresses (Paar and Rekittke, 2011). According to Paar and Rekittke (2011), in Kibera, Kenya, one of Africa's largest informal settlements was illustrated as wild forest on official maps, causing it to be unrecognized by the government for decades. Similarly, the Khlong Toei slum lack accurate and detailed maps due in part to their legal status.

## **2.2.2 Strategies for Addressing the Challenges Affecting the Stormwater Drainage Systems in Slums**

In this section, we examine several strategies used to address the social and engineering challenges the involved stakeholders face in maintaining effective stormwater drainage systems in slums similar to the Khlong Toei slum. As mentioned in section 2.2.1, the strategies presented in this section are aimed to address the social and engineering issues faced in slums.

### **2.2.2a Strategies to Address Social Challenges**

In Santo Domingo, Dominican Republic, a study was conducted to increase participation and partnership in urban environmental rehabilitation and to limit the amount of waste entering the drainage systems in slums (Parkinson, 2007). With the collaboration of outside stakeholders such as non-governmental organizations (NGOs) and community-based organizations (CBOs), the World Bank administered a slum-upgrading project to construct drainage systems. This project encouraged the community to help in the development of the slum by gathering volunteers for cleanup and digging drainage trenches throughout the slum. Throughout the development of the drainage system, outside organizations, such as the Department of Sewerage and Water, helped make the project successful and sustainable (Parkinson, 2007). In order to prevent solid waste from entering the drainage trenches, they covered the trenches with grills. The grills could be easily removed for the cleaning of the waterway if any waste entered the systems. In addition, to ensure the functionality of the newly developed drainage system, the CBOs and NGOs created a "solid waste collection community micro-enterprise" which aims to keep the drainage systems clean and empower the community (Parkinson, 2007). By creating this micro-enterprise within the community, residents are able to come together to address important issues. In addition, in order to address the improper waste management within slum areas, grates served as a tool to block the amount of solid waste entering the drainage system.

### **2.2.2b Strategies to Address Engineering Challenges**

In order to address the engineering challenges faced in slums, the use of accurate maps have allowed people to understand the magnitude of the effects of poor drainage systems. For example, Kibera, Kenya, gained the attention of many outside professionals due to the lack of geographical data in the area. Using both geographical information system (GIS) and technical mobile mapping applications, teachers and children mapped the slum in order to address the issue of flooding. Cellphone mapping software was used to gather data about past flooding issues, flood damages and deaths were logged from interviews with residents, data was gathered into GIS software, and routes of hundreds of

poorly placed drainage channels were traced (Nelson, 2016). In India, UNICEF has sponsored child-based programs encouraging kids to use technical mapping applications on mobile devices to map environmental and health problems near their households. The students used the mobile applications in order to develop an understanding of the area and then using this data, drew maps of their neighborhoods by hand. By utilizing a combination of different mapping methods, such as using GIS and mobile applications, and mobile applications and mapping by hand, mapping can gather useful data and provide a sense of awareness as well as leadership within the community.

### **2.2.3 Utilizing Aid from the Community to Gather Data**

In order to more effectively implement the strategies discussed above, community involvement needs to be taken into consideration. In the Greenpoint/Williamsburg section of Brooklyn, New York, the Environmental Protection Agency's (EPA) Cumulative Exposure Project (CEP) attempted to map the amount of air pollution exposure in the community (Corburn, 2005). Representatives from the Watchperson Project, a community based organization in Brooklyn, New York, claimed that the CEP's air dispersion model was going to miss hundreds of potential polluters because the polluters did not exist in any state or federal air-quality databases (Corburn, 2005). Additionally, community members commented that the CEP's air dispersion model was not going to include the block-to-block pollution differences that existed in the neighborhoods (Corburn, 2005). The CEP was unable to effectively map the dispersion of hazardous air pollutants because they neglected the input from the community. It is important to include the community in data collection because the community has key information that would be unobtainable without them.

## **2.3 Background Summary**

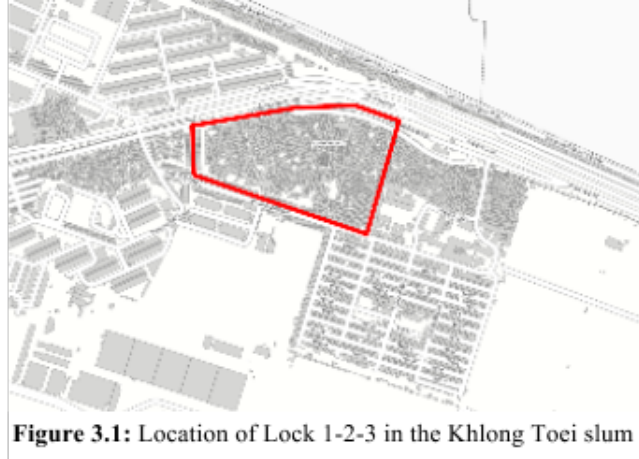
Home to about 100,000 people, the Khlong Toei slum suffers from flooding in their communities due to weather conditions, poverty, and its illegal status. In slums, there are a number of challenges to managing stormwater drainage systems, such as the lack of common unity among the residents, improper waste management, and the insufficient amount of geographical data provided for slums. However, there are a number of strategies to address these issues. While Khlong Toei may not be unique, there are still lots of local conditions that are important to consider when addressing challenges facing the stormwater drainage system, such as the state of the drainage trenches and the interaction among the residents and local stakeholders, to determine feasible solutions.

# **3 Methodology**

After several meetings with community leaders and the DPF, we learned that the area within the Khlong Toei slum that is most impacted by flooding is Lock 1-2-3 (shown in Figure 3.1) due to the well known issue of flooding there during the rainy season.

In collaboration with the Duang Prateep Foundation (DPF), we sought to map the Khlong Toei slum's drainage system to propose strategies for reducing the impact of flooding within the community. In order to meet this goal, we completed the following objectives:

1. *To identify the factors that affect the drainage system within the Lock 1-2-3.*
2. *To determine the perceptions of the community regarding the causes and effects of-and possible solutions to-flooding in the Lock 1-2-3.*
3. *To develop strategies and recommendations for ways to reduce flooding through both structural improvements and community actions.*



**Figure 3.1:** Location of Lock 1-2-3 in the Khlong Toei slum

Our objectives were designed to develop:

1. *Maps of the existing stormwater drainage system in Lock 1-2-3 highlighting factors relevant to flooding.*
2. *An action plan that includes recommendations for mitigating the impacts of flooding, strategies for the implementation of these recommendations, and suggestions for future applications.*

### **3.1 Identifying Factors Affecting the Stormwater Drainage System**

To identify the causes of flooding within the slum, we gathered information on both observable and unobservable factors that affect the stormwater drainage system.

To gather observable information, we used maps of Lock 1-2-3 obtained from the Port Authority of Thailand to record factors such as the locations of open drainage trenches and the locations of garbage collection sites. To gather unobservable information, such as of areas of past flooding and direction of water flow, we spoke with members of the community and recorded what they could tell us. A complete list of the factors we identified is in Table 1. In order to make the information we gathered cleaner and easier to understand, we digitally mapped each factor onto the digital map of Lock 1-2-3 provided by the Port Authority of Thailand using an image editor.

Factor	How it impacts the stormwater drainage system
Trash Blocking Water Flow	Trash blocking the flow of water through the stormwater drainage system can cause water to overflow and flood the walkways.
Direction of Water Flow	To understand the current stormwater drainage system, it's important to know the direction that water flows through it.
Elevation	Elevation of houses and walkways influences the direction of water flow through the stormwater drainage system.
Open Drainage Trenches	Open drainage trenches allow trash to enter the system, which can lead to blockages.
Lengths and Widths of Walkways	The lengths and widths of the walkways are useful for planning additions to the stormwater drainage system.
Garbage Collection Sites	The locations of the garbage collection sites can influence how often residents litter trash in the walkways and empty lots that can enter into the stormwater drainage system and potentially create blockages.

*Table 3.1: Factors affecting the stormwater drainage system*

### **3.2 Determining the Perceptions of the Community Regarding the Stormwater Drainage System**

As the community is impacted the most by the flooding and any implemented strategies to reduce the impacts of the flooding, it is important to take into consideration the community's perceptions before determining recommendations and strategies. In order to better understand how the community perceives, influences, and is influenced by the stormwater drainage system in Lock 1-2-3, we completed the following two steps:

First, we conducted interviews with residents of Lock 1-2-3. We prepared for the interviews by asking representatives of the DPF and community leaders about strategies to make the interviewed residents more comfortable and willing to speak openly about their perspectives. We asked what to wear, how many interviewers should be present, and what questions we should avoid asking them. We also prepared a consent statement. A representative from the DPF guided two team members through Lock 1-2-3 to meet with 13 residents who own their home and 7 residents who pay rent. In our first set of 10 interviews, we discovered that being a home-owner influenced perceptions of the stormwater drainage system, so we decided to hear more perspectives from the residents who pay rent. Our interview format can be found in Appendix D3 and the questions we asked can be found in Appendix D1. We recorded the audio of the interviews, each lasting approximately 10 minutes.

Second, we organized our interview data to determine any common perceptions that could inform our recommendations. The English translations of the responses are in Appendix D6. For each interview question, we listed each resident's response and ordered them by different categories, such as whether they are homeowners or renters and whether they were impacted by the floods or not. This organization helped us determine common perceptions as well as group perceptions.

### 3.3 Developing Strategies and Recommendations

We developed an action plan for the DPF that provided recommendations for strategies to reduce flooding. To do this we completed the following four tasks:

First, we determined a set of criteria for what information would be most useful to provide to the DPF using our background research, interviews with residents, and meetings with the DPF and community leaders. For instance, after meeting with the community leaders, we learned that the cost of implementation is the most useful to know. We determined that the most useful information to provide about our recommendations are:

- **Cost:** Broken up into two categories, low costs needing no outside funding and high costs needing the outside funding.
- **Location:** Recommended location where strategy should be implemented
- **Feasibility:** Tasks that require minimal work will be considered as “easy”, tasks that require the help of a professional or outside stakeholder will be considered as “difficult”. Anything that falls between the two categories, requiring help of outside stakeholders but also requiring an adequate amount of work is considered “medium”.
- **Permanence:** Broken up into two categories, temporary depicting a solution that will last a short period of time, and permanent depicting a solution that will last a long period of time

Second, we organized our recommendations into two categories: one for structural improvements to the drainage system and one for possible community actions. We chose these categories because our background research indicated that these covered most strategies related to reducing impacts of flooding. We developed strategies for structural improvements and community actions based on our literature review and from our empirical study of Lock 1-2-3. For each of the recommendations, we included the set of criteria for useful information. Table 2 shows an example of how the recommended improvements and actions were organized. To fill in the table, we used our background research and our insight into Lock 1-2-3.

<b>Strategy or Recommendation</b>	<b>Possible Cost</b>	<b>Where to Implement in Lock 1-2-3 (Refer to map deliverable)</b>	<b>Feasibility</b>	<b>Permanence</b>
Addition of grates, drain covers, or nets over the drainage system	High initial costs depending on the materials used	Excessively clogged areas	Easy - Medium	Temporary Action

*Table 3.2: Example of Summary Table for Structural Improvements.*

Third, we developed implementation strategies for each recommendation using the knowledge we gained through our investigation of Lock 1-2-3 to provide feasible methods of implementation.

## 4 Results

To assess the Khlong Toei slum’s drainage system and propose strategies to reduce flooding that arise from an inadequate drainage system for stormwater, we created maps of the drainage system and interviewed community leaders, residents, and local stakeholders. In this chapter, we discuss our findings about the causes that lead to flooding, the barriers to improving the drainage system, consequences of flooding, and the current approaches to reducing the impact of flooding in Lock 1-2-3.

### 4.1 Causes of Flooding in Lock 1-2-3

From interviews with residents and community leaders, we were able to identify key causes of flooding in Lock 1-2-3.

#### **Finding #1: The construction of new houses on the waterway contributes to flooding.**

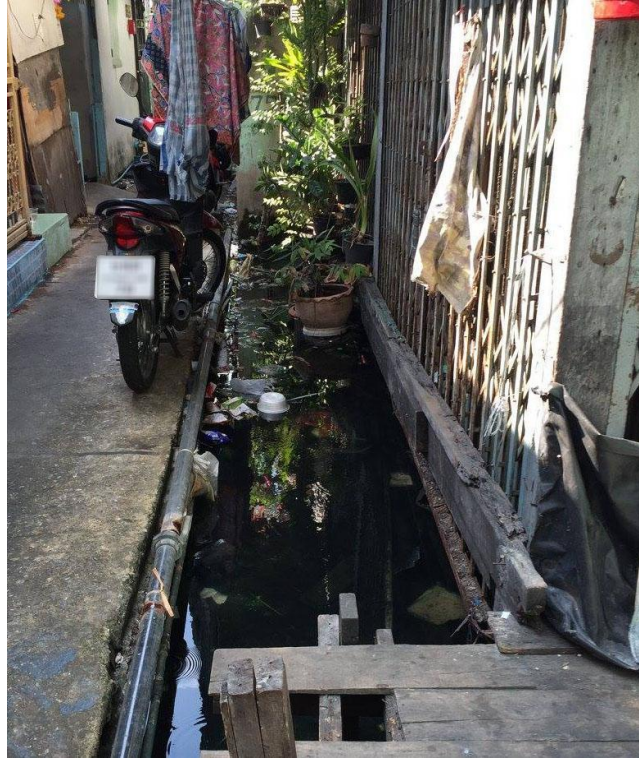
In our interviews (see Appendix E) we asked residents, “what do you believe caused the floods?” Four of the residents’ responses were:

- “there are also building new houses”
- “a lot of trash, poor drainage system, and number of houses built on the waterway”
- “new houses block the natural flow of water”
- “drainage system defectiveness and overload of houses”

These four residents claimed that the growing number of new houses built upon the waterway causes a blockage of the stormwater drainage system and ultimately leads to flooding. These houses were built without regard for the existing stormwater drainage system, as shown in Figure 4.1. Additionally, community leaders mentioned that the construction of new houses has increased dramatically in the past few years. Most of these houses were built on top of the waterways, which run parallel to the major



walkways throughout the slum, resulting in inaccessibility to remove of physical blockages of drainage trenches underneath houses.



*Figure 4.1: A house built on a waterway*

**Finding #2: The improper disposal of waste contributes to the clogging of the stormwater drainage system.**

From our observation and from our interviews with the residents, the community leaders, and the DPF, we found that the improper disposal of waste clogs up the stormwater drainage system and leads to flooding. When garbage enters the stormwater drainage trenches either from being thrown in or entering from the walkways, it blocks the flow of water through the stormwater drainage system. Thus, when it rains the water has nowhere to go, and the clogged drainage trench overflows. Figure 4.2 and Figure 4.3 show two examples of garbage clogging up the stormwater drainage trenches.





*Figure 4.2 and Figure 4.3: Trash in the drainage system*

This garbage be placed in the designated trash collection sites or collected by the trash collection services, which we discovered through our interviews are the two proper methods of garbage disposal in Lock 1-2-3. There are differing opinions between the residents who pay rent, those who own their homes, and the DPF on who exactly is responsible for the very observable litter in Lock 1-2-3.

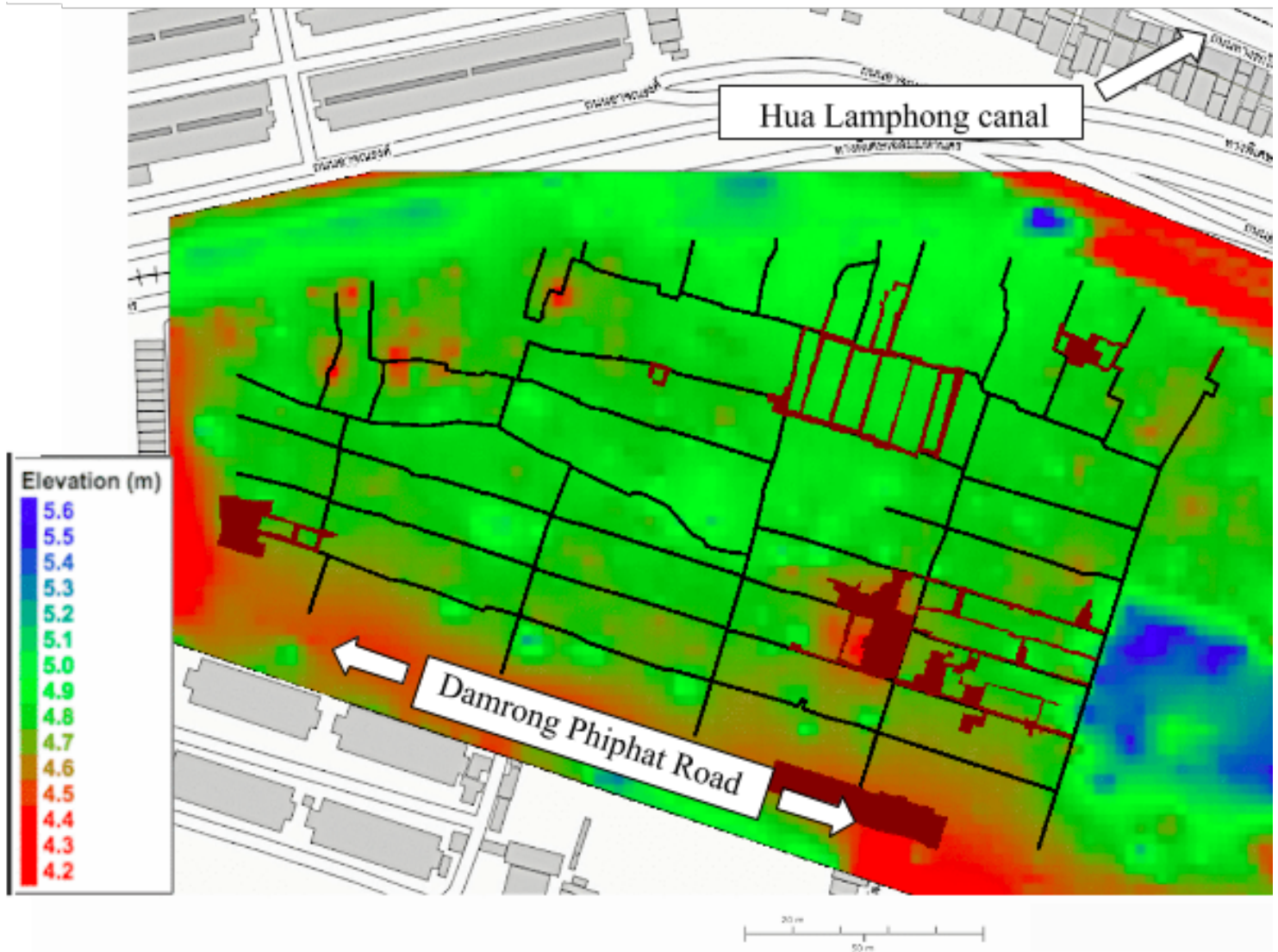
The first ten residents of the Khlong Toei slum that we interviewed are homeowners, and have lived an average of 38.3 years in the slum. This was much longer than the amount of time the residents that pay rent have lived in the slum, which was a reported to be 2-3 years by the community leaders. The average time residents who were renting in the slum was 29.1 years. This time spent may include the renting residents previous time as a homeowner in the slum. In response to the question “what do you believe causes the floods?”, one of the residents stated that the reason that trash clogs the drainage system is because the residents that rent space in the slum toss their trash anywhere they want. Additionally, in response to the follow up questions “do you believe any of these causes are preventable? If so, how?”, three of the interviewed residents said a preventable cause was the behavior of other residents. A community leader stated that because the residents who pay rent are not staying in the slum for an extended period of time, they do not care about their impact on the community. The long-term residents and community leaders of the slum often blame the failure of the drainage system on the actions of the residents who pay rent.

When we asked the residents who pay rent the question “do you remove your own trash, or does someone else?”, everyone responded that they hired someone to take their trash out for them. However, in a meeting we had with the DPF we learned that they believe it’s the teenagers who abuse drugs that are the ones that openly dump waste because they don’t care about the community. There is clearly a difference of opinion between the DPF, the homeowner residents, and those who pay rent about who exactly is responsible for the improper disposal of waste. It’s important to know what demographic

openly dumps waste the most so that education and awareness programs can be targeted towards them.

**Finding #3: Low lying areas of Lock 1-2-3 are more susceptible to flooding.**

The negative effects of flooding are much more severe for residents living in lower elevated areas compared to those living in higher elevated areas, according to our interviews with residents and community leaders. Heavy rain often floods the walkways situated in the lower elevated areas, as it is more difficult for the water to flow out into the drainage trench on Damrong Phiphat Road. Houses closer to Hua Lamphong canal generally do not face as much risk as the houses closer to the roads because those houses are situated in higher elevated areas, as shown in Figure 4.4.

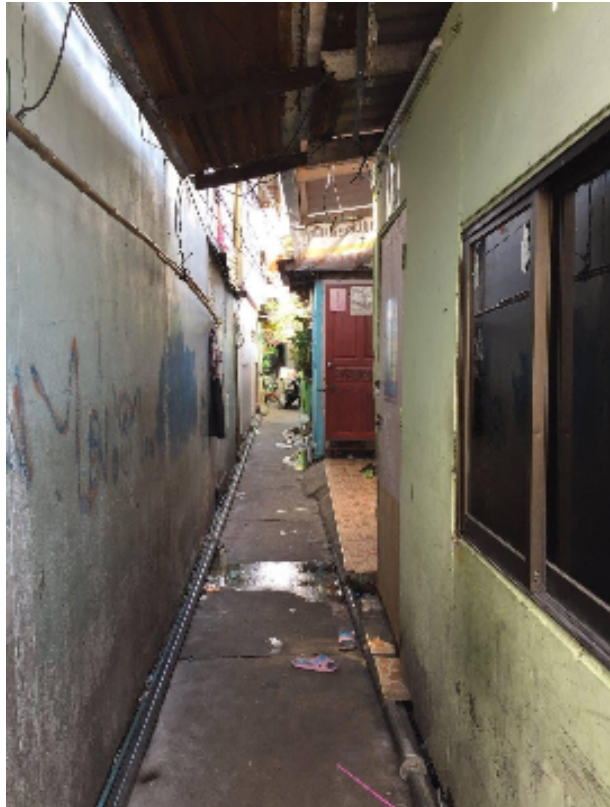


*Figure 4.4: Map of elevation and past flooding in Lock 1-2-3*

## 4.2 Barriers to Improving the Drainage System in Lock 1-2-3

From our interviews with community leaders and local residents and from our own observations, we identified the following barriers to improving the drainage system in Lock 1-2-3: narrow walkways limit drainage system maintenance and trash disposal opportunities in the slum, residents' willingness to relocate to allow the stormwater drainage system to be improved is influenced by their perceptions of others' willingness to relocate, there is minimal community participation in waste management programs, and there has been insufficient funding and volunteers for waste collection incentive programs.

**Finding #4: Narrow walkways limit drainage system maintenance and trash disposal opportunities in the slum.**

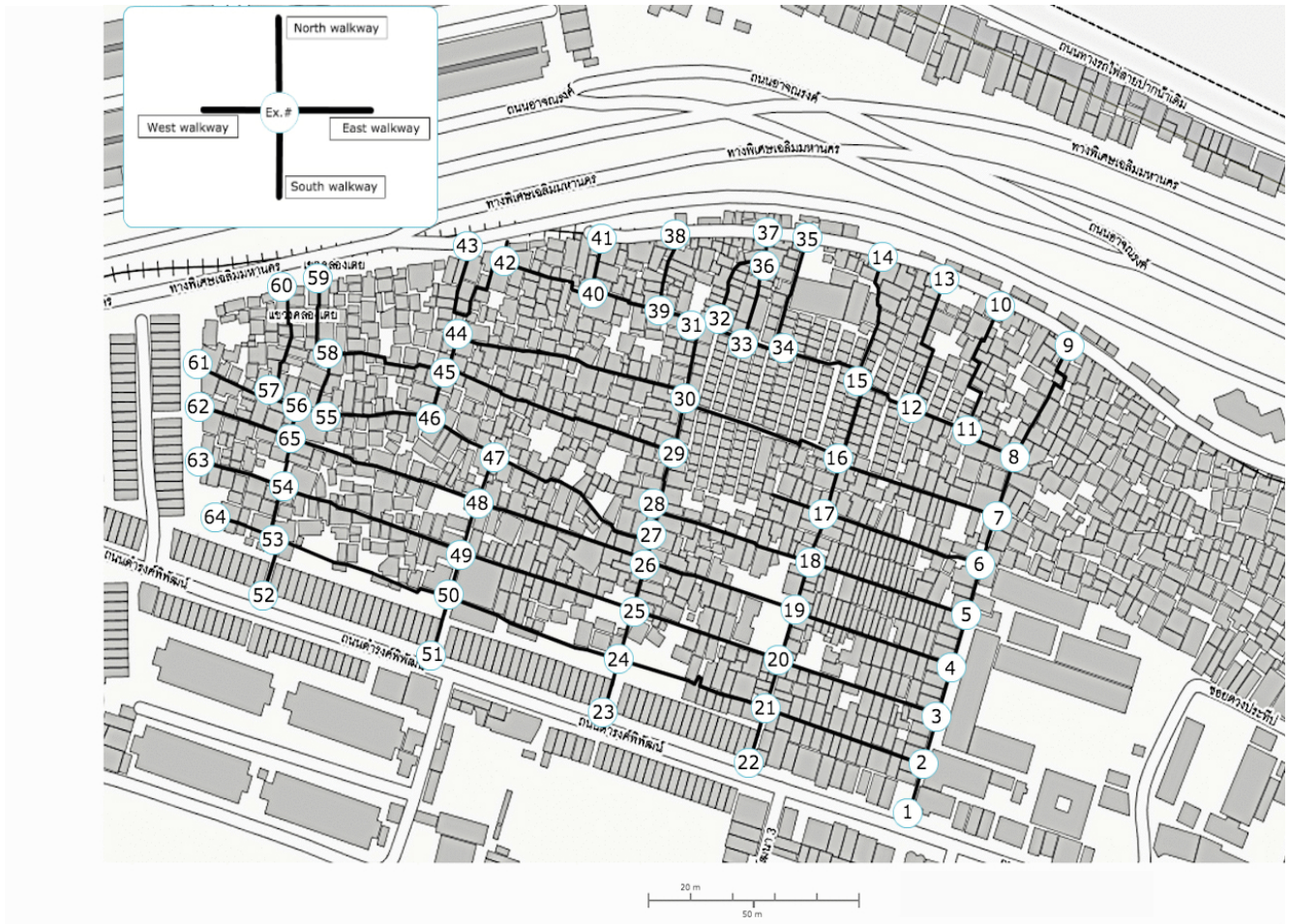


**Figure 4.5: A walkway in Lock 1-2-3**

We observed that access into the slum is very limited due to the narrow walkways. Generally, the walkways have either a stormwater drainage trench or tap water pipes running along either one or both sides, which further decreases the walkways' widths. According to our measurements, the widths of the walkways range from 1-2 meters wide. For reference, Figure 4.5 shows a walkway of Lock 1-2-3 that is a little over 1 meter wide. Additionally, Figure 4.6 and Table 4.1 show part of the width data that we collected for our map deliverable. Figure 4.6 shows the numbers assigned to each



intersection of major walkways in Lock 1-2-3 and Table 4.1 shows a table providing the widths of each road for each corresponding intersection. The narrow walkways limit potential opportunities for waste removal. Additionally, since the widest walkways are approximately 2 meters wide, they physically limit the movement of large machinery to repair broken or clogged stormwater drainage trenches.



**Figure 4.6: Numbered walkway intersections**

Intersection Number:	South walkway (cm)	North walkway (cm)	East walkway (cm)	West walkway (cm)
1.	N/A	190	N/A	N/A
2.	182	182	169	N/A
3.	180	180	157	N/A
4.	170	170	145	N/A

*Table 4.1: Intersection width data*

**Finding #5: Residents’ willingness to relocate to allow the stormwater drainage system to be improved is influenced by their perceptions of others’ willingness to relocate.**

We asked the residents “Would you be willing to relocate where you live in order for the drainage system to be redone? If so, for how long?” Two of the responses were, “no, the people who live here for a long time wouldn’t relocate” and “it is hard and up to the majority of the community.” Some of the residents were unwilling to relocate because they didn’t believe long term homeowners would. Surprisingly, out of the 20 residents interviewed, 11 of them said that they would be willing to relocate temporarily in order for improvements to the drainage system to be made, 8 of which were long term homeowners. This suggests that residents may not be aware of each other’s willingness to relocate and that they are dependent on the decision of the majority. This is a barrier to improving the drainage system because if the residents do not relocate, major changes the current drainage system cannot be made.

**Finding #6: There is minimal community participation in waste management workshops.**

From our interviews and discussions with community leaders we learned that previously the community leaders had held a waste management workshop to teach the Lock 1-2-3 residents about proper waste management. Unfortunately, on the day of the program only 5-6 residents showed up. This is a barrier to improving the stormwater drainage system because if the residents do not learn proper waste management practices, the clogging of the drainage system will only get worse.

**Finding #7: There has been insufficient funding and volunteers for waste collection incentive programs.**

When we asked residents whether they had anything they wanted to comment about, two of the responses were, “find sponsors to support projects like Garbage for Eggs” and “some trash that can no longer be recycled could be exchanged for useful rewards like eggs. This will be very useful in decreasing the amount of trash so that there will be less flooding.” Garbage for Eggs was a waste management incentive program

where residents could trade in their unwanted trash for eggs. This program encouraged residents to throw out their trash and not litter. Garbage for Eggs was continued by the DPF until around 2014, when it stopped due to the lack of funding for eggs and volunteers to sort the trash. We discovered through meeting with representatives of the DPF that the amount of money they made by sorting and selling the valuable trash was less than the cost of the eggs they gave away. This loss couldn't be sustained, and the fact that they had few volunteers to sort the trash only made it worse. In order for incentive programs such as Garbage for Eggs to be sustainable, the revenue and the cost must at least break even either from external funding or from a reduction of incentive costs.

### **4.3 Consequences of Flooding in Lock 1-2-3**

From interviews conducted with local residents and community leaders, we learned of four consequences of flooding that are of particular concern for the residents of the Khlong Toei slum: the sinking of homes, the infestation of pests, the reduction of mobility, and the increase in negative health impacts.

**Finding #8: Some residents attribute the slow sinking of their homes to flooding.**

We learned from the community leaders and interviews with the residents that some of the residents attribute the sinking of their homes to flooding. From observation, it was clear that many homes were standing over bodies of water scattered with trash. Due to an inadequate stormwater drainage system infrastructure, these houses have continued to sink as the homes flood with water during the rainy seasons. We even observed first-hand the remains of a house that had recently collapsed into the water.

**Finding #9: Some residents suffer from pests such as mosquitos, snakes, and Asian water monitors.**

When we asked residents “how do floods affect your everyday life?”, some residents said that Asian water monitors and snakes would enter their houses in order to escape the flood water. Figure 4.7 shows an example of an Asian water monitor we found in the slum while we were collecting data for our map deliverable. Another response was that the floods lead to more mosquitoes laying eggs, which make the residents' life much more difficult and can become a health hazard.



*Figure 4.7: Asian water monitor in Lock 1-2-3*

**Finding #10: Mobility is reduced because some residents lack the means to safely travel through the unsanitary floodwater.**

When we asked the residents we interviewed how floods affected their everyday lives, some replied with:

- “I don’t even want to walk around because it is very dirty. I have to put boots on because the water comes up till my ankles and it becomes very hard to work”,
- “it is difficult to walk in the dirty water because this water can cause foot diseases”,
- “I have to use the walkways even when the water level is at my ankle and trash is floating on top of the water”, and
- “it affects my everyday life so much because I have to walk in the dirty water and it can cause me to be sick.”

Some of the residents that we interviewed did not have the means to safely travel through the unsanitary water, which led them to either stay at home or walk through the dirty water and potentially get sick.

**Finding #11: The health of residents is negatively impacted.**

When we asked residents how floods affected their everyday lives, some of them responded with:

- “it affects my everyday life so much because I have to walk in the dirty water and it can cause me to be sick”

- “it is difficult to walk in the dirty water because this water can cause foot diseases”

When the Khlong Toei slum floods, the some residents feel it’s necessary to walk through the unsanitary floodwater even though they lack the means to safely travel through it. This may lead to some of the residents getting sick and contracting foot diseases because the water can contain animal feces and harmful chemicals.

## **4.4 Approaches to Reduce the Impacts of Flooding in Lock 1-2-3**

From our interviews with the Khlong Toei slum residents as well as our meetings with the community leaders, we learned of two approaches that have been used to reduce the impact of flooding in Lock 1-2-3.

### **Finding #12: Some residents clean up around their homes.**

When we asked residents whether they had anything they wanted to comment about, one resident said that he “want[s] people to get involved and cooperate more” and that he “pick[s] up dog feces around [his] house everyday, every morning.” We observed that the walkways surrounding the homes of the residents who do this were much cleaner than those in other areas of Lock 1-2-3. Taking small initiatives like picking up solid waste around homes can help increase cleanliness, reduce smell, and reduce the likelihood of flooding due to drainage trench blockages in the community. This also shows that there are some residents who are willing to work to keep their community clean.





*Figure 4.8: A raised walkway in Lock 1-2-3.*

**Finding #13: Certain walkways have been raised to increase mobility.**

Some of the main walkways running through the Lock 1-2-3 have been raised by the community leaders above the level of the floodwater to allow residents to move around more freely when floods occur. Figure 4.8 shows an example of a raised walkway in the slum. The raised walkways mitigate the effects of flooding because the surface of the walkway is built higher than the level the water rises to during flooding. Only certain walkways have been raised due to the width of the walkway, because space needed for the walkway and water to flow on each side. Additionally certain walkways have been raised due to the height of the floodwater and the material available to raise the walkway. The current raised walkways of Lock 1-2-3 were determined by the community leaders. The need for raised walkways resulted from the need for mobility created by flooding.

## **5 Recommendations and Conclusions**

We have formulated a set of recommendations for the Duang Prateep Foundation, community leaders, and local residents of the Khlong Toei slum for methods to reduce the impact of flooding within Lock 1-2-3. The Summary Table in Appendix H shows the link between the causes of flooding, the barriers to improving the stormwater drainage system, and our proposed recommendations. Despite the fact that the proposed suggestions are aimed at Lock 1-2-3, these recommendations can be considered for other areas of the slum as the stormwater drainage systems are interconnected throughout the slum. The recommendations provided are based on both structural improvements to the

stormwater drainage system and actions the community can take. Our recommendations are separated into four main categories: (1) Recommendations to Reduce Waste Clogging the Stormwater Drainage System, (2) Recommendations for Drainage System Improvements, (3) Recommendations for Mitigating the Negative Effects of Flooding, and (4) Recommendations for Next Steps.

## **5.1 Recommendations to Reduce Waste Clogging the Stormwater Drainage System**

From our observations of Lock 1-2-3 and from speaking with community leaders, it is clear that waste plays a large role in clogging the stormwater drainage system in Lock 1-2-3. Reducing household waste that enters the stormwater drainage system in the community would decrease the amount of clogging, and thus decrease flooding. The following are recommendations that can be implemented in order to reduce the clogging of drainage trenches with waste in Lock 1-2-3.

### **We recommend designating specific areas for new garbage collection sites.**

From our interviews with community leaders, we found that there are currently five garbage collection sites located under the tollway outside of Lock 1-2-3 and one site located by the DPF, almost all of which are inconveniently located for the residents. From the conducted interviews (See Appendix E), half of the residents said they hire someone to dispose of their waste for them. Moreover, from these interviews we determined that residents do not like having trash cans near their homes due to aesthetic reasons, smell, and other residents disposing of large amounts of waste in these trash cans.

We recommend designating higher elevation areas surrounding Lock 1-2-3 for new garbage collection sites. Prospective sites can be identified with the help of the map on elevation in Figure 4.4. From interviews with community leaders, we learned that higher elevation areas are less prone to flooding. Another factor to consider is placing garbage sites near clogged locations. Looking at areas of clogging on the map, it is evident that clogging occurs in areas that are far away from the garbage sites, with the exception of the garbage site near the DPF. Designating new areas for garbage collection sites can lead to a decrease in drainage system clogging in the future.

### **We recommend adding grates, grills, nets, or drain covers over the current drainage system.**

The addition of grates, grills, nets, or drain covers over the drainage trenches will reduce the amount waste and occurrence of flooding in the Khlong Toei slum in the long term. It should be noted that for this method to be effective, the waste currently clogging the drain must be removed before the grates, grills, nets, or drain covers are put into place. As previously mentioned in section 2.2.2, the addition of grates, grills, nets, and drain covers are able to serve as a defense against waste entering the drainage trenches. Figure 5.1 shows the lengths of each walkway, and Figure 5.2 shows the areas where there are uncovered drainage trenches. These can be used with the stormwater drainage trench widths that we measured at each intersection (see Figure 4.6 and Table 4.1) to help determine the necessary amount of cover needed for the drainage system.

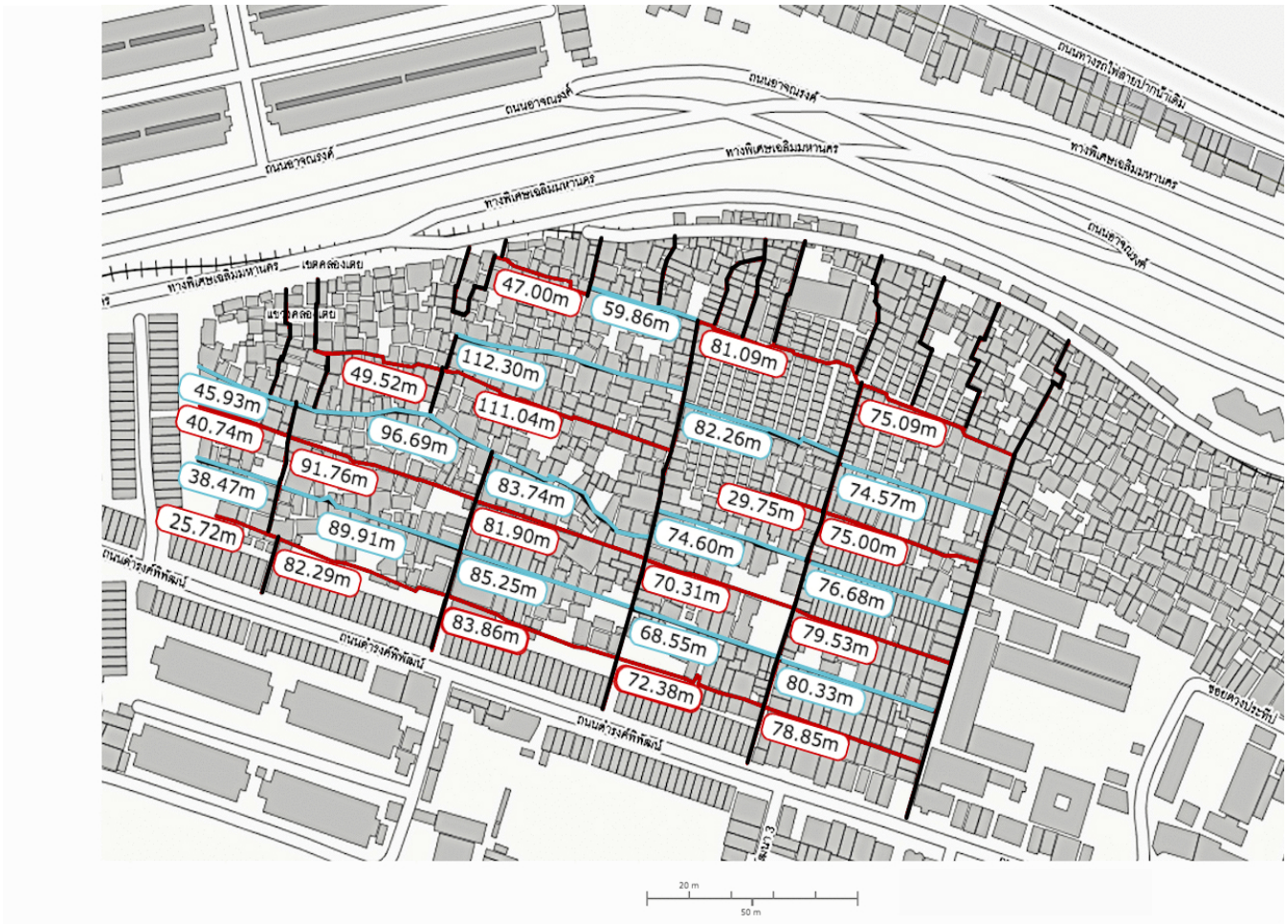
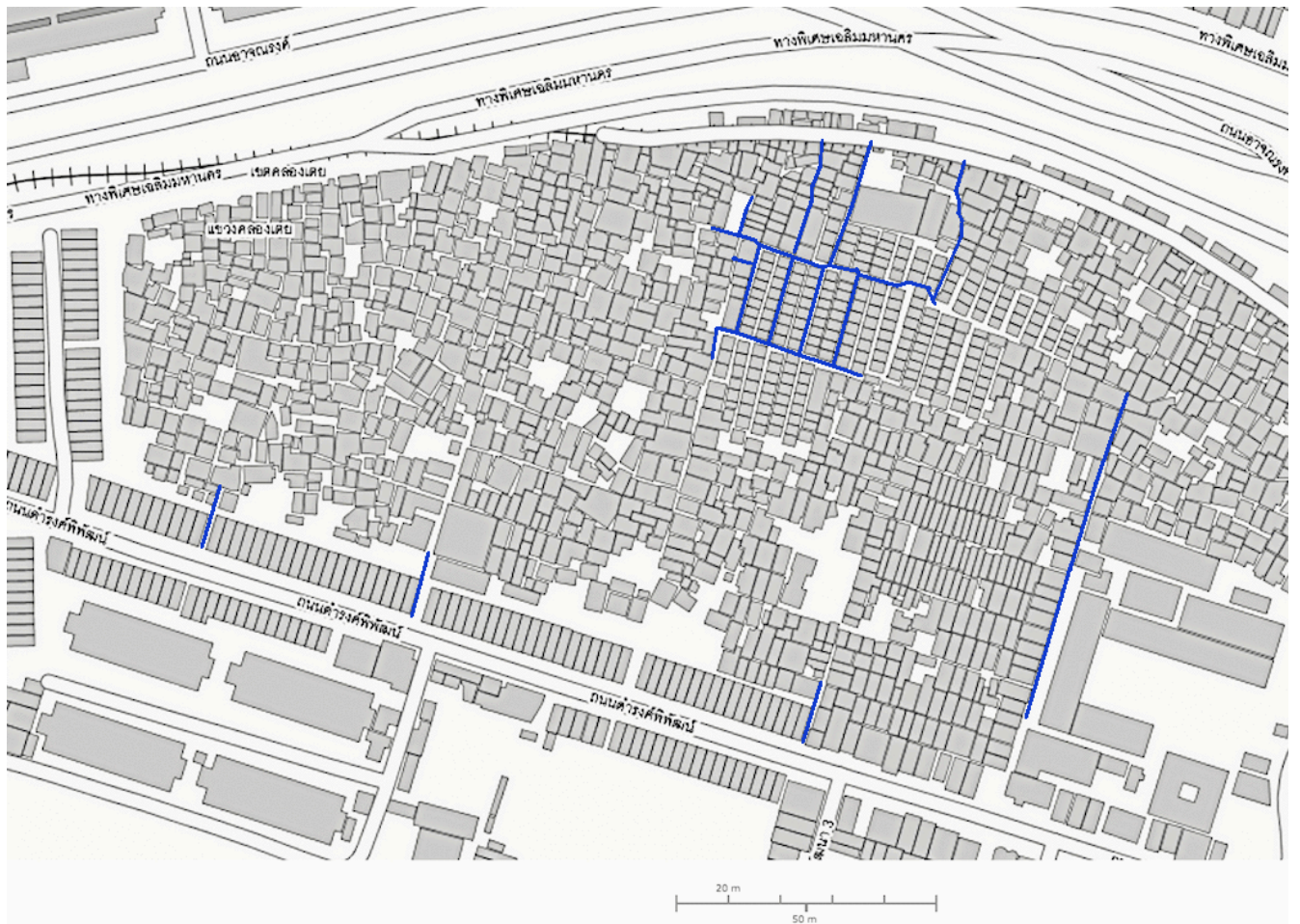


Figure 5.1: Length of walkways





**Figure 5.2: Areas with uncovered drainage trenches**

**We recommend cleaning areas around local residents’ homes to limit the amount of household waste entering the stormwater drainage system.**

From the interviews we conducted with local residents, we found that the walkways and drainage trenches surrounding the homes of residents who claimed to clean the walkways every morning contained less trash. According to DPF representatives, there are a few residents who go out of their way to keep the community clean, doing things such as picking up animal feces along the streets, which could motivate the residents who live nearby to do likewise. We recommend that the local residents who don’t leave the slum or work from home during the day take cleaning initiatives around their homes. By involving the community, every resident can encourage one another to take responsibility for the cleanliness of the community. Less waste on and around the walkways means a fewer clogs of the drainage system that lead flooding.

## **5.2 Recommendations for Drainage System Improvements**

In order to improve the stormwater drainage system, we recommend performing the following structural improvements.

### **We recommend deepening certain drainage trenches.**

Deepening drainage trenches increases the capacity of the stormwater drainage system and allows a greater volume of stormwater to pass through at once. By examination, the sizes of drainage trenches vary from location to location. After measuring the walkways of Lock 1-2-3, we observed that all walkways are narrow and have limited space for mobility. We recommend that the community leaders deepen certain drainage trenches around the slum without limiting mobility and using the information provided in our set of maps. From our maps and limited knowledge, we could not determine precise locations where it would be possible to deepen the drainage trenches. However, the maps include essential information on the lengths and widths of the walkways, which is useful for determining where to deepen the drainage trenches. Other factors to consider include the structural soundness and possible depth of existing drainage trenches.

## **5.3 Recommendations for Mitigating the Negative Effects of Flooding**

Although the goal for Lock 1-2-3's community is to stop flooding from occurring altogether, with lack of funding and the other vulnerabilities facing the Khlong Toei slum, this goal is not quickly achieved. We propose the following recommendations in order to help the residents live with the effects of flooding in the short term, while striving to work towards long term solutions that would prevent flooding altogether.

### **We recommend raising certain walkways.**

Areas throughout Lock 1-2-3 that feature raised walkways are less likely to flood. Residents of Lock 1-2-3 have also relayed to us through interviews that the previous raising of walkways has helped reduce the impacts of flooding. This is a general recommendation based on the efforts presented by the community leaders. Through our interviews with the community leaders we could not deduce the impacts of raising the walkways, therefore we could not determine precise locations where this recommendation could be implementable. We do know, however, that this is a solution that has worked in the past. Some factors to consider when determining where to raise the walkways are flood water levels and the elevations of houses on either side of the walkways. We recommend raising certain walkways in order to reduce the impacts of flooding on the surrounding homes using the maps we developed to help determine which specific walkways.

**We recommend investing in methods of safe travel through unsanitary floodwater.**

After interviewing residents in Lock 1-2-3, we learned that one of their main concerns about flooding in the community is the lack of mobility that is associated with it. We recommend that the Duang Prateep Foundation and community leaders invest in methods of safe travel through trash contaminated waters, such as boots, for the residents so that they are able to continue living their daily lives even when the walkways flood.

**We recommend developing and implementing flood preparation workshops.**

After conducting interviews with residents of the community, it was found that flood water had entered the home of at least one of the interviewed residents. Flood preparation workshops are critical for the community because they empower the residents to create feasible change without having to rely on the support of outside organizations. We are aware that there is limited funding for projects that would improve the drainage system in the Khlong Toei slum, therefore we recommend informing residents of low cost ways that may reduce the impacts of flooding through flood preparation workshops. Several methods used to cope with flooding and its effects that would be highlighted in these workshops include using sandbags to divert water flow from entering homes, using mosquito nets to reduce the contraction of insect-borne disease, and making small structural improvements to the stormwater drainage trenches.

## **5.4 Recommendations for Next Steps**

In order to ensure our project is sustainable and addresses flooding issues more widely in the Khlong Toei slum, additional steps can be taken. The following recommendations are intended so that the community continues to work towards an effective stormwater drainage system in order to reduce flooding in the community.

**We recommend creating new drainage trenches along certain walkways.**

We learned that creating new trench relief channels helps evenly disperse the amount of stormwater entering the drainage system. We also learned that residents attribute flooding to the slow sinking of their homes. The combined actions of littering solid waste and pouring cement into the drainage trenches leads to an overflow of water and ultimately the sinking of homes.

We recommend that the community, the Duang Prateep Foundation, and outside stakeholders work together in order to plan out suitable locations for new drainage trenches. This recommendation aims to decrease the amount of stormwater entering the residents' homes and decrease the risk of flooding. We do not recommend the addition of trenches throughout all the walkways as there are important factors to consider. While planning perspective locations, it is important to consider the stability of adjacent homes in relation to the drainage trenches, the current widths of the walkways, and the direction of waterflow and how the addition of new trenches would affect this. To supplement these considerations, members could use both the direction of waterflow map and the elevation map.

**We recommend continuing to update the maps and extending mapping into Lock 4-5-6 and 70 Rai.**

We developed a set of maps that detail the factors affecting the drainage system of Lock 1-2-3 such as direction of water flow, areas where trash clogs the drainage trenches, and the lengths and widths of walkways. One reason that these maps benefit the community leaders is because it informs them of areas throughout the Khlong Toei slum that are prone to flooding. We recommend the community leaders continue to update the maps of the Lock 1-2-3's drainage system because over time new houses or new drainage trenches may be constructed or more areas of concern may arise. Should the community leaders continue to record and update the maps, they will better understand the effects of any potential improvements made and will remain informed of areas that need to be improved in the future. This ties into the DPF's mission of empowering the community as well, because by involving the community when updating the maps as we did when creating them, community members help develop solutions to the issues they face.

**We recommend organizing waste management programs or events.**

Through background research, observations, and interviews conducted with residents of the slum, we learned that some residents improperly dispose of waste. Improper waste management is a large problem in the Khlong Toei slum because the waste clogs the drainage system, causing drainage trenches to overflow and flood during the rainy season. According to interviews with the community leaders, past waste management projects in the slum, such as the "Garbage for Eggs" initiative, have been successful with proper funding. Although there have been successful programs in the past, there has also been unsuccessful programs due to insufficient funds and minimal community involvement. To address these issues we recommend that Duang Prateep Foundation implement three types of waste management programs: informational sessions, workshops, and one on one programs. Informational sessions and workshops are to attract large groups, whereas one on one programs would create a more personal and informative setting for the resident. These programs aim to educate the residents about the importance of waste management by (1) teaching them how it affects the drainage system and their everyday life, (2) holding them accountable for their actions regarding waste disposal, and (3) convincing them to get more involved in cleaning the community in order to create a sustainable initiative.

## **5.5 Summary**

The proposed recommendations in this section are intended to provide the Duang Prateep Foundation, community leaders, and local residents and stakeholders of the Khlong Toei slum a basis for working towards an effective and sustainable stormwater drainage system to reduce the impact of flooding in Lock 1-2-3. Our recommendations focus on both structural improvements and community actions. By introducing the community and representatives to these ideas, we hope to empower residents to better manage their waste, take action to protect themselves from the effects of flooding, and to place a greater importance on the cleanliness and well being of their community and environment.

## 5.6 Conclusions

We found that the major causes of flooding in the slum are areas of low elevation and blockages within the drainage system which were created by the construction of houses on top of waterways, residents filling the stormwater drainage trenches with cement, and waste entering the drainage system by improper disposal practices. From the creation of our map deliverable, we were able to observe a correlation between the level of elevation within the slum and reports of previous flooding. After interviewing residents, we learned that while not everyone's lives are impacted by the flooding, some don't want to go onto the walkways because they are covered in unsanitary flood water, some attribute the slow sinking of their homes to flooding, and some attribute pests infestations such as mosquitoes, snakes, and Asian water monitors to flooding. We also discovered that the willingness of the residents to temporarily relocate to allow for improvements to be made to the drainage system, is influenced by their perception of other residents' willingness to relocate, and that many were unaware that other residents would agree to relocate(see Appendix E).

We gave the Duang Prateep Foundation the maps we developed of Lock 1-2-3 as they can serve as a reference when planning future structural improvements or attempting to gain support from local government organizations. We also compiled an action plan based on our recommendations for structural stormwater drainage system improvements and possible actions the community can take.

When we presented our project to representatives from the DPF, the Port Authority of Thailand (PAT), and the Bangkok Metropolitan Administration (BMA) we made an unexpected impact. After the Thai students had finished presenting, a representative from the PAT stated how our project provided him with necessary materials and reasons to make the improvements of the drainage system he was planning on making. Surprisingly, a representative from the BMA aggressively spoke out against the PAT representative. The BMA representative said that the PAT is not doing anything to improve the drainage system even though they collect funds from the Lock 1-2-3 residents. The BMA representative proposed that if the PAT uncovered and dug up the drainage trenches along Damrong Phiphat road, then the BMA would remove all of the trash clogged in the trench. The representative from the PAT said that he would consider the idea and would need time to think about it. Our presentation got representatives from the PAT and the BMA into the same room, a rare occurrence, and gave them the opportunity to debate the current problems with the stormwater drainage system in Lock 1-2-3. We hope that in the near future this debate spurs actions from both parties, as well as the residents of Lock 1-2-3 to improve the stormwater drainage system in the Khlong Toei slum.

## 6 Personal Reflections

Previous to our arrival to Bangkok, we were given a short prompt to base our project on. The Duang Prateep Foundation (DPF) recognized that the air quality within the Khlong Toei area is a major public health concern. In order to evaluate the air quality



in the area, we considered the many causes of poor air quality in addition to strategies used to address these issues. Upon our first meeting with the DPF, we learned that there was a more crucial issue developing in the Khlong Toei slum: the effect of flooding on the community of Lock 1-2-3 due to the inadequate drainage conditions. Despite knowing that we would be losing 7 weeks of research to a new topic, we immediately and collectively decided that we were here to help our sponsor and the community, therefore it was clear that a change of focus was in order.

As part of the IQP experience we are able to work directly with the sponsor and community leaders in order to address the effects of the drainage system within the Khlong Toei slum to reduce the risk of flooding. Throughout our site visits to the area, we were all astounded by the inadequate living conditions of many residents. Here, we saw real world issues that people face everyday, we saw some residents who have given in to these lifestyles, but also others who strive to cope with these issues. Seeing that had not only opened our eyes to life other than what we knew, but it had strengthened our team in that it sparked passion for our project, knowing that what we would produce could have the potential to improve the quality of life for this community. Our final presentation to the DPF, where residents, community leaders, and local organizations came together to discuss our project and the pressing issue of flooding in the community, was truly life changing. It was such a rewarding experience to not only see our 7 weeks of research come together, but to see our project cause such a discussion in the community. We are glad that our IQP experience was not simply an academic exercise but our created map deliverables will be able to provide the necessary information that the DPF, the community leaders, the PAT, and the BMA will need to improve the Khlong Toei slum drainage system. We were honored to have had an opportunity to create real change for a community in need.

Crossing cultures, as WPI students we learned how to adapt to a new and different culture and lifestyle. As BSAC students we have improved our communication skills in the English language. As a team, we have learned to interact amongst each other, how to overcome language barriers, and most importantly we learned how to present ourselves professionally in front of governmental organizations. In the end, this project has been insightful in terms of our capabilities as an individual and professional.

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# Authorship

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Appendices.....Ajavavarakula, Audibert, Donyatammatat, Espinal, Fraioli, Karouy

*\*\*All members of the project team edited every section of this report\*\**

# Appendix A: Interview Questions for the Khlong Toei Residents

Interviewee:

Interviewer:

Location: Khlong Toei, Bangkok

Date:

Introduction Statement: Hello we are students from Faculty of Science, Chulalongkorn University and Worcester Polytechnic Institute, United States. We are researching possible drainage system improvements in the Khlong Toei slum area. We would like to ask you a few questions regarding the flooding. All responses will be kept anonymous.

Questions:

General:

- What is your name?
- What is your age?
- Are you the owner of a house in Lock 1-2-3? If so, how long have you lived there?

Floods:

- Have you experienced flooding around your house? **If yes:** Could you describe your experience with floods around your house?
- How often do floods occur? wpi
- How do floods affect your everyday life?
- What do you believe causes the floods?
- Do you believe any of these causes are preventable? If so, how?
- When it rains, does your house get flooded? **If yes:** What do you do to solve this? How would you stop this from happening again?

Drainage System:

- Do you think the drainage system in Lock 1-2-3 needs improvement? **If yes:** What needs to be improved? How could it be improved?
- Would you be willing to relocate where you live in order for the drainage system to be redone? If so, for how long?

Waste Management:

- Where does your trash go?
- Do you remove your own trash, or does someone else?
- How often is your trash removed?
- Would you be willing to pay 20 baht per month for someone else to remove your trash?
- Next month there will be a weekly clean-up event, would you want to participate?
- Is there anything you want to make a comment about?
- Do you have any questions for us?

Closing Statement: Thank you for your time and participation. Just as a reminder, everything that was said in this interview will remain anonymous unless otherwise permitted. If you have any questions or concerns for us in the future, feel free to contact us at [bkk16air@gmail.com](mailto:bkk16air@gmail.com).

# Appendix B: Interview Questions for the Duang Prateep Foundation

Interviewee:

Location: Khlong Toei, Bangkok

Questions:

Drainage system:

- What are your concerns about the drainage system in the community?
- How many drainage system was built in the community?
- Do you have any plans to improve the drainage system in Khlong Toei slum? If so, how is it going?
- How long does it take for water to drain out from the community when raining?
- What are the impacts from flooding?
- What do you think is the cause of standing water?
- Have there been programs ran by the community to solve the problem? What did you do so far? Is it effective enough to become the major solution?

Waste management:

- How do you manage to remove trashes in the slum?
- How often do you remove trash out from the slum?
- Which areas are waters or trashes clogged in the slum, why?
- Do you recycle bin in the slum?
- Do you have plans to recycle trash in the slum?
- Do you have trash collection areas in the slum? If not, why?

Past Project:

- How many projects have been done in the process of improving the quality of life for people in the community? Was there any projects focusing to improve drainage system in the community?



# Appendix C: Informed Consent Worksheet

## **Informed Consent Agreement for Participation in a Research Study**

**Investigator:**

**Contact Information:**

**Title of Research Study: Evaluating the Drainage System in the Khlong Toei Slum**

**Sponsor: Duang Prateep Foundation**

**Introduction:**

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

**Purpose of the study:**

The purpose of this study is to determine what the residents of the Khlong Toei slum consider to be the causes and effects of flooding within the slum.

**Procedures to be followed:**

1. We will first introduce who we are.
2. We will then ask the participants to introduce themselves.
3. We will then tell the purpose of this study and what exactly it will entail.
4. We will then obtain their informed consent
5. We will then proceed with the interview.

**Risks to study participants:**

There is no physical or mental risk to the participants.

**Benefits to research participants and others:**

Information about the reduction of flood risk.

**Record keeping and confidentiality:**

Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Information obtained in this study will be stored on a secure flash drive and then stored on a restricted Google Drive.

**Compensation or treatment in the event of injury:**

You do not give up any of your legal rights by signing this statement. There is no risk for injury because only questions will be asked of you.

**For more information about this research or about the rights of research participants, or in case of research-related injury, contact:**

IRB Chair (Professor Kent Rissmiller, Tel. 508-831-5019, Email: [kjr@wpi.edu](mailto:kjr@wpi.edu))

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Pimchanok Karouy, Tel: 087-036-4442, Email: [pimme.k248@gmail.com](mailto:pimme.k248@gmail.com)

**Your participation in this research is voluntary.** Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

**By signing below,** you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

\_\_\_\_\_

Study Participant Signature

Date: \_\_\_\_\_

\_\_\_\_\_

Study Participant Name (Please print)

\_\_\_\_\_

Signature of Person who explained this study

Date: \_\_\_\_\_

# Appendix D: Department of Drainage and Sewerage Semi-Structured Interview Protocol

Interviewee: Department of Drainage and Sewerage

Interviewee: Anonymous Representative

Location: BMA City Hall, Dindaeng, Bangkok

Date: January 15, 2016

Introduction Statement: Hello we are students from Faculty of Science, Chulalongkorn University and Worcester Polytechnic Institute, United States. We are researching possible drainage system improvements in the Khlong Toei slum area. We would like to ask you a few questions regarding Khlong Toei. All responses will be kept anonymous.

Questions:

**Have you done any work in or around the Khlong Toei slum recently?**

They can't get access into the slum. They would need to dig underground and there are houses, and they don't have access. Also, since the Khlong Toei slum is in a lower elevation, they've dealt only with higher elevated areas in the drainage system.

**Do you have any maps or information about the drainage system within the Khlong Toei slum?**

Yes, they had some maps. They only have maps around the roads. To get the maps of the drainage system in the slum, we might have to go to the district office. They had maps above and below the slum, but we think the district office has maps of the slum's drainage system.

**Two issues with the drainage system in the Khlong Toei slum are low elevation areas and waste clogging the water flow. Do you have any low-cost recommendations for improvements to the current drainage system?**

The metal grating idea is really good. Unclogging the trash out of the drainage system would be helpful. Each house could have a water filtration system to catch and store and reuse rainwater to reduce the flooding.

Closing Statement: Thank you for your time and participation. Just as a reminder, everything that was said in this interview will remain anonymous unless otherwise permitted. If you have any questions or concerns for us in the future, feel free to contact us at [bkk16air@gmail.com](mailto:bkk16air@gmail.com).

# Appendix E: Summary of Interviews with Khlong Toei Residents

## *Interviewees*

Name: Resident 1 a. Age: 48 b. Status: House owner c. Period of stay: 48 years	Name: Resident 2 a. Age: 52 b. Status: House owner c. Period of stay: 20++ years
Name: Resident 3 a. Age: 58 b. Status: House owner c. Period of stay: 35 years	Name: Resident 4 a. Age: 50 b. Status: House owner c. Period of stay: 50 years
Name: Resident 5 a. Age: 73 b. Status: House owner c. Period of stay: 50 years	Name: Resident 6 a. Age: 58 b. Status: House owner c. Period of stay: 50 years
Name: Resident 7 a. Age: 60 b. Status: House owner c. Period of stay: 60 years	Name: Resident 8 a. Age: 70 b. Status: House owner c. Period of stay: 22 years
Name: Resident 9 a. Age: 76 b. Status: House owner c. Period of stay: 40 years	Name: Resident 10 a. Age: 42 b. Status: House rent in 70 rai c. Period of stay: 8 years
Name: Resident 11 a. Age: 27 b. Status: House renting c. Period of stay: 27 years	Name: Resident 12 a. Age: 36 b. Status: House owner c. Period of stay: 20 years
Name: Resident 13 a. Age: 33 b. Status: House owner c. Period of stay: 20 years	Name: Resident 14 a. Age: 47 b. Status: House owner c. Period of stay: 20 years
Name: Resident 15 a. Age: 46 b. Status: House renting c. Period of stay: 6 months	Name: Resident 16 a. Age: 69 b. Status: House renting c. Period of stay: 55 years

Name: Resident 17 a. Age: 62 b. Status: House owner c. Period of stay: 62 years	Name: Resident 18 a. Age: 51 b. Status: House renting c. Period of stay: 44 years
Name: Resident 19 a. Age: 26 b. Status: House renting c. Period of stay: 2 years	Name: Resident 20 a. Age: 67 b. Status: House renting c. Period of stay: 67 years

### ***Results***

#### **1. Have you experienced flooding around your house? If yes: Could you describe your experience with floods around your house?**

1. Yes, the water went inside the house.
2. Never.
3. There is never a flood since I live here
4. There are both flood and fire which scares me a lot.
5. It floods a lot around my house because water stands under the house for a long time.
6. There was a lot of floods last 2 months. After some improvements on drainage system, it is better like there are less floods happening. In upcoming April, there is a plan on continuing on development on drainage system. Some houses use their kids to walk to the under troll way for dumping trashes. Kids may become tired carrying the trashes and give up by dumping along the side of the walkway.
7. Yes, to fix the problem i use concrete plate to build up the layers of the house costing 300baht per sheet.
8. There are waters clogged under the house.
9. Yes, but later the floor is raised.
10. Yes, in front of the school. I have to walk through the flood.
11. Yes, when it rains.
12. No, it is because the walkway was built higher.
13. Yes, when it rains.
14. Yes, it has been happening for about 2 years.
15. Yes, it floods when water drains out slowly, and I need to dig the ground between the house and the walkway to let water flow underneath the house.
16. Yes, around my house.
17. Yes, but the water level isn't that high.
18. Never.
19. Floods occur when it rains.
20. It does not flood around my house.

#### **2. How often do floods occur?**

1. Every time it rains, the heavier the rain falls, the more flood. In the past, it doesn't flood this much. There are standing waters in the past when there are no drainage system pipe.
2. -
3. None.

4. Every time it is raining, it floods all over the stair and my shoe get dragged to somewhere else.
5. The water is not going anywhere due to houses that built upon the water way stopping water from flowing.
6. Every time there is water clogged under the house plus the rain.
7. -
8. Once in a while. Some standing water.
9. No more floods nowadays.
10. Almost every time it rains and standing water. It's better nowadays.
11. It floods every time the river level rises.
12. -
13. Every time there is a heavy rain.
14. When it rains and then the water goes into my house.
15. When there is a heavy rain.
16. When there is a heavy rain.
17. When there is a heavy rain.
18. -
19. When it rains.
20. -

### **3. How do floods affect your everyday life?**

1. I don't even want to walk around because it is very dirty. I have to put boots on because the water comes up till my ankle and it becomes very hard to work. In the past the water couldn't flow out at all but when the leaders come and dig the road around 70 rai, it becomes a lot better.
2. -
3. Never
4. It affects my life so much that a lot of mosquito just happen to lay eggs all the time.
5. The house keep collapse making me unable to live. I need to use woods put on the floor to make the floor higher so that i can live.
6. Snakes and Asian water monitor are all over the road and roof to avoid water.
7. It doesn't flood around here.
8. In the past it affects a lot of my everyday life but now it's getting better.
9. -
10. Very bad odor and it's too dirty.
11. Yes, the mobility is bad but luckily I've got a motorcycle.
12. It does not affect me that much.
13. It is hard to walk in and out of my house. I have to use the walkways even when the water level is at my ankle and trash is floating on top of water.
14. It affects my everyday life so much because I have to walk in the dirty water and it can cause me to be sick.
15. There are a lot of mosquitos around here and it is dangerous for my child.
16. It is difficult for me to walk through the community.
17. It doesn't actually affect my everyday life so much because the walkway was built higher.
18. There is a lot of mosquitoes and my children are staying here, which is dangerous for them.
19. It is difficult to walk in the dirty water because this water can cause foot diseases.

20. There are a lot of mosquitoes and it is difficult to walk in and out of the community.

#### **4. What do you believe causes the floods?**

1. The trash that is clogging the water path, some residents does not care (people who rent house). There are also building of new houses. Trashes go under the house and when it floods, the trash float on the water.
2. Defectiveness of drainage system. If it is improved, it will be just fine.
3. -
4. The clogging of water under the house and the built up of the walkway that make water not able to flow out of the house. Some people do the laundry business that is not suitable in the area because there are still problems on drainage system in the community.
5. The main reason causes floods are the heavy rain and the clogged water way.
6. A lot amount of trash, poor drainage system, and number of houses built on the water way.
7. Trashes that are clogged and new houses block the natural flow of water.
8. Trashes that are clogged. When it floods, trash will float on the water. In the past, the Port Authority dig soils in this area and sell it so that also cause low elevation. Sometimes it just floods on the new bridge that are built.
9. Drainage system defectiveness and overload of houses.
10. Trash clogging the drainage system, heavy rain, and drainage system defectiveness.
11. Rainfall together with the rising river level is the main factor that causes flooding.
12. Trash clogging because of the behavior of some people in the community. Rain also is another factor.
13. Trash clogging the drainage system and a poor drainage system.
14. Trash clogging the drainage system and a poor drainage system.
15. Trash.
16. Trash and rainfall.
17. Trash and the river level rising.
18. The drainage system is getting worse because of trash that clogs along the waterway.
19. Trash.
20. The drainage system is bad because of trash clogging along the waterway.

#### **5. Do you believe any of these causes are preventable? If so, how?**

1. Yes, by doing volunteer works, projects, finding more budgets.
2. Yes, with better drainage system. If it floods around my house, I will hire someone to help push the water to under the house.
3. -
4. Yes, it is preventable if people love the community and help one another.
5. To improve drainage system in the community.
6. People are being lazy and dumping trashes along the side of the walk way.
7. -
8. Yes, with the ongoing development and improvement. Now there are lesser floods.
9. Arrange or relocate the houses and use the community area for other purpose.

10. It's difficult because people eat and just throw it everywhere. There is also lots of trash in front of the school.
11. I do not know, but I saw community leaders working on improving the drainage system.
12. Motivate people to love and care for their community. The district office can also help with taking the trash underneath houses out.
13. Make people dump their trash in the dumping areas.
14. Yes, it is possible if people in the community help remove trash together.
15. Yes, if there is no trash clogging the drainage system.
16. -
17. -
18. It is hard because the behavior of people is something that is difficult to change.
19. Yes, it can be prevented even if it is hard.
20. If people in the community help on picking up trash that clogs, it will help improve drainage system at some point.

**6. Do you think the drainage system in Lock 1-2-3 needs improvement? If yes: What needs to be improved? How could it be improved?**

1. Yes, I strongly agree. The lifestyle of the people and their behavior should change first and the trash problem will be easier. People are very careless.
2. I don't really know.
3. The leaders are improving it.
4. It probably need an improvement because trash is the most problematic issue to be addressed. This may need help from sponsors like DPF or big companies.
5. Yes, it needs improvement. Community leaders have done some parts improvement by various methods, but it still has not help that much.
6. Yes, we must improve the drainage system by dealing with trashes and cleanness of the community.
7. Yes.
8. -
9. Needs lot of improvement but it's difficult.
10. The leaders are improving it.
11. Yes, if the drainage system is improved.
12. If it is possible to improve the drainage system, it will be great because all of the houses are built on top of water.
13. Yes, it should be improved because there are many houses built on top of the waterway.
14. Yes, it absolutely needs an improvement.
15. Yes, it should be improved.
16. Yes, it will be great.
17. Yes, please do.
18. Yes.
19. Yes.
20. Yes.

**7. Would you be willing to relocate where you live in order for the drainage system to be redone? If so, for how long?**

1. Yes, but who will rebuild the houses for us? But if everything is for free, people would be willing to move.



2. No, nobody will relocate. But if they are going to cut off the roads to improve the drainage system I will be okay.
3. Yes, no problem.
4. I had done a lot of moving request in the past, but there is still no response. I would love to be relocated, but I need to take care of my grandchild.
5. I am willing to be relocated if it makes a better place for us.
6. Sure, I want to go because it is enough for me to face problems like this.
7. If there are jobs for me to do, I will definitely move but I don't think everyone is going to agree.
8. No, people who live here for a long time wouldn't relocate.
9. Yes.
10. Yes, no problem.
11. It is hard and up to the majority of the people living in the community. If it will be improved I hope that it can be something like 70 Rai community.
12. For me, the flooding does not affect my house, but for the majority of the community, they get affected a lot. I think it is hard to relocate because some people in the community are poor and do not want to rent a house for a higher price.
13. No, it is hard for me because I do not know where to stay and my child also studies at the school nearby.
14. Yes, if it will help in preventing the floods around this area.
15. No, because we do not want to move.
16. It is hard to do because there are a lot of people staying here.
17. It is hard.
18. No, it is because we are scared that we will have no place to live.
19. Yes, it is okay if it will make the community a better place.
20. If it floods a lot, we may need to move.

## **8. Where does your trash go?**

1. Trash site under the tollway.
2. There are big trash cans around my house.
3. Under the tollway.
4. Under the tollway.
5. Under the tollway.
6. Under the tollway.
7. Under the tollway.
8. Under the tollway.
9. -
10. People come and collect it from the big trash can around the school hiring 150BHT/month. At the end of every month someone from the BKK district comes and picks it up.
11. Under the tollway and behind the school.
12. Behind the school.
13. I hire someone to take out the trash for me, so I do not actually know.
14. I hire someone else to remove my trash.
15. I hire someone else to remove my trash.
16. I hire someone else to remove my trash.
17. I hire someone else to remove my trash.
18. Under the tollway.
19. I hire someone else to remove my trash.

20. Under the tollway.

**9. Do you remove your own trash, or does someone else?**

1. My husband takes the trash out on his way to work.
2. I hire people 40BHT/month.
3. By myself.
4. By myself.
5. By myself.
6. By myself.
7. By myself.
8. By myself, but sometimes there are people who help me out.
9. By myself.
10. Someone else.
11. I hire people for taking the trash out.
12. By myself.
13. I hire someone to do it for me.
14. I hire someone to do it for me.
15. I hire someone to do it for me.
16. I hire someone to do it for me.
17. I hire someone to do it for me.
18. I hire someone to do it for me.
19. By myself.
20. By myself

**10. How often is your trash removed?**

1. 1 time/day.
2. Every day.
3. -
4. It is around two to three times a day.
5. Every day.
6. It is about three times a day.
7. Every day.
8. Once every 2 days.
9. Once a week.
10. -
11. Every two to three days.
12. Every morning, but it can be up to two times a day if there is a lot of trash.
13. One to two times day
14. Every day
15. Every day
16. Every day
17. One to two times a day
18. Everyday
19. Two to three times a day
20. Once a week

**11. Would you be willing to pay 20 baht per month for someone else to remove your trash?**

1. We just do it ourselves. There are some house that pay 40BHT/month to let someone come pick up the trash. **Some residents do it for a job collecting trash from each house for 5BHT every time they pick up the trash bag.**
2. -
3. -
4. I want to have the service, **but the person who is responsible for taking the trash does not come.**
5. No, I can do it by myself.
6. -
7. -
8. -
9. Yes.
10. -
11. Yes.
12. I used to hire someone for taking the trash out, but after some period of time, the one who was hired closed his business. Thus, I have started taking trash to the dumping site by myself.
13. Yes, I need to pay 20 baht when I want to remove trash.
14. Yes, I pay 10 baht a day.
15. Yes, I pay 20 baht a day.
16. Yes, I pay 40 baht a month.
17. Yes, I pay 40 baht a month.
18. I used to hire someone to remove trash for me.
19. Yes, 20 baht per trash removal.
20. I used to hire people to remove my trash.

**12. Next month there will be a weekly clean-up event, would you want to participate?**

1. Sure.
2. Sure.
3. Sure.
4. Sure.
5. Sure, but I am old and need to take care of my grandchild.
6. Sure.
7. Sure but some houses would not.
8. Sure.
9. Sure.
10. Sure, teachers are a major part of the program.
11. Sure.
12. Sure, if I am free.
13. Sure
14. Sure
15. Sure
16. Sure
17. Sure
18. Sure
19. Sure
20. Sure

**13. Is there anything you want to make a comment about?**

1. Want people to get involved and cooperate more. I pick up dog feces around my house everyday, every morning.
2. **Maybe renovate some blank areas to something more beneficial to the community.**
3. -
4. The community can be a better place to live if people keep doing good things and think above the others.
5. -
6. Find sponsors to support on the project like trashes for egg
7. Improving would be difficult. My children are all moving out for better future. Trash and drainage system need big improvement.
8. -
9. -
10. Drugs and the behavior of people would be really hard to improve or change.
11. -
12. People all have different personalities and it's impossible to tell them what to do and hope they will do it. More importantly, people should have self reflection and realize that trash needs to be dumped at the dumping site. **Some people have no education and do not see the effects of dumping trash along the walkway.**
13. -
14. Some trash that can no longer be recycled can be exchanged for useful rewards like eggs. This will be very useful in decreasing the amount of trash so that there will be less flooding.
15. -
16. -
17. -
18. Taking trash out of the community because **trash helps the spread of fires**
19. -
20. -

# Appendix F: Notes From Informal Meeting with the Khlong Toei District Office

## District

- Few local people living in the community love and care for the cleanliness of the slum.
- People who come in and rent houses doesn't bother to look after the community and openly dump waste.
- The Port Authority built an apartment for the people to move in. Some people now rent from them to live in the slum.
- The residents themselves come back to the houses in the slum to live for free.
- The Port Authority once planned to destroy every house and renovate it into a public park, and then move the slum residents to a better place.
- Some parents were put in jail because of drugs, and their children were left in the slums with behavior problems.
- People have to eat in order to live, so they buy food from outside and then throw the wrappers/containers anywhere they want.

## Trash

- Beds were found in the Khlong almost every week.
- The big-size trash were clogged, hard to pick it up.
- Big mirror sheets were scattered near the roads.
- Parking lots were turn into trash area.
- Some trash site were turned into parking areas.

## Trash pick up

- Pick up trashes 2 times a day
- Needs more truck more than available
- Pick up only at dumping sites (under tollway)

## Campaigns

- Outside organizations come help clean up.
- Soldiers and the leaders also come but people don't cooperate at all.
- Teach how to make effective microorganisms (to clean khlongs) at home but doesn't work.

# Appendix G: Notes From Informal Meeting with the Port Authority of Thailand

- The area of Lock 1-2-3 that faces the worst flooding is where water used to be stored to fight fires.
- There is an issue with people entering the slum and building their own houses.
- Concrete is added to the walkways in order to change the elevation and thus the direction of water flow.
- They believe that nets/grates put over the drainage trenches would be broken.
- They want us to plan a new drainage system and/or determine ways to reduce flooding.
- The highest elevation is in the middle of Lock 1-2-3, and the lowest elevation is on the sides.
- The community leaders have shown the residents what to do to keep their community clean, but the residents ignore them and litter anyways.
- The “Garbage for Eggs” project, funded by the DPF, worked well in 70 Rai. Plastic and Foam were exchanged for eggs.
- Residents only make 200 baht a year, and so they don’t want to pay 20 baht per month to get their trash taken away.
- Residents don’t want communal dumping areas to be outside their houses.
- A good idea could be to assign someone to take people’s trash to the towing area, but no one has the budget to create that job.
- They believe it would be a good idea for us to educate the children in Lock 1-2-3 about waste disposal.

# Appendix H: Summary Table

## Causes of flooding and our recommended solutions

<u>Cause:</u>	<u>Recommended Solutions:</u>
<p><b>Finding #1: The construction of new houses on the waterway contributes to flooding</b></p>	<ul style="list-style-type: none"> <li>• <b>Cleaning areas around local residents' homes to limit the amount of household waste entering the stormwater drainage system</b></li> <li>• <b>Developing and implementing flood preparation workshops</b></li> </ul>
<p><b>Finding #2: The improper disposal of waste contributes to the clogging of the stormwater drainage system.</b></p>	<ul style="list-style-type: none"> <li>• <b>Designating specific areas for new garbage collection sites.</b></li> <li>• <b>Adding grates, grills, nets, or drain covers over the current drainage system.</b></li> <li>• <b>Cleaning areas around local residents' homes to limit the amount of household waste entering the stormwater drainage system</b></li> <li>• <b>Organizing waste management programs or events.</b></li> </ul>
<p><b>Finding #3: Low lying areas of Lock 1-2-3 are more vulnerable to flooding</b></p>	<ul style="list-style-type: none"> <li>• <b>Raising certain walkways.</b></li> <li>• <b>Investing in methods of safe travel through unsanitary floodwater.</b></li> <li>• <b>Developing and implementing flood preparation workshops.</b></li> <li>• <b>Creating new drainage trenches between houses and certain walkways.</b></li> </ul>

## **Barriers to improving the stormwater drainage system and our recommended solutions**

<u>Barrier:</u>	<u>Recommended solution:</u>
<b>Finding #4: Narrow walkways limit drainage system maintenance and trash disposal opportunities in the slum</b>	<ul style="list-style-type: none"> <li>• Designating specific areas for new garbage collection sites.</li> <li>• Organizing waste management programs or events.</li> </ul>
<b>Finding #5: Residents' willingness to relocate to allow the stormwater drainage system to be improved is influenced by their perceptions of others' willingness to relocate</b>	<ul style="list-style-type: none"> <li>• Organizing waste management programs or events.</li> </ul>
<b>Finding #6: Minimal community participation in waste management workshops</b>	<ul style="list-style-type: none"> <li>• Organizing waste management programs or events.</li> </ul>
<b>Finding #7: Lack of funding and volunteers for waste collection incentive programs</b>	<ul style="list-style-type: none"> <li>• Organizing waste management programs or events.</li> </ul>