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ORIGINAL ARTICLE

Flood Investigation and Mitigation Strategies for Taipei City, the Role of Engineering Consultant Services after Flood Events

Yuan-Ching Kuo[1(1)*], Yi-Mei Mo[1(2)], Kuo-Cheng Chen[2(3)]

[1] Department of Water and Environmental Engineering, CECI Engineering Consultants, Inc., No. 323 Yangguang St., Neihu District, Taipei City, 11491, Taiwan (R.O.C.)

[2] Hydraulic Engineering Office, Taipei City Government, No.1, City Hall Rd., Xinyi District, Taipei City, 11008, Taiwan (R.O.C.)

[*]E-mail: (1)YCKuo@ceci.com.tw
(2)mym4@ceci.com.tw
(3)da_kcc@mail.taipei.gov.tw

***Abstract*:** This experience-based study aims at constructing a standard protocol, like "Flood investigation protocol, Norfolk Country Council, 2013" and "Flood investigations, Southampton City Council 2011", for investigating flood schemes and setting guidelines for flood mitigation strategies in modern mega cities. Modern mega cities, such as Taipei City, are usually equipped with well-constructed drainage infrastructures. However, with the increasing frequency of extreme weather events, Taipei City is still threatened by flash flood during summer storms or typhoons. The major characteristic of flash flood in Taipei City is that it diminishes rapidly when the storm attenuates. However, the characteristic of flash flood in Taipei City also makes it difficult to reveal the major cause of the flooding events. Without clear evidence of the major cause of the flooding events, flood mitigation strategies may not be corrected drafted and the flood events will happen again during the next storm or typhoon. CECI engineering consultant incorporation has been serving for Taipei City government for flood scheme investigations since 2012. After we handle more than 80 flood schemes, we find that the major causes of flooding events are usually witnessed by local residents, instead of monitoring cameras, and the events are recorded with smart phones. By interviewing the residents and surveying the flooding images and videos, then check the sewage systems with SWMM (Storm Water Management Model) models and recorded rain data, we usually find out the real causes of flooding events which either caused of extreme weather events or caused of sewer system dysfunction. Moreover, we draft major guidelines for flood mitigation strategies which includes the deployment of mobile pumps, ditch augmentations, flood warning with 10 minutes rainfall records to minimize the loss of the properties of the residents.

Keywords: Flood investigation, flood mitigation, mega city flooding

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1. Introduction

Taipei City locates in the Taipei basin at the north of Taiwan. With area of 270 km^2, Taipei City is surrounded by mountains and is crowed with 2.7million residents. Being the capital of Taiwan (R.O.C.), Taipei City has set more than 540 km storm sewer system (figure1.1) and more than 80 pump stations around (figure1.2) which are set for 5-year return period storm rain with intensity of 78.8mm/hour. However, due to the increasing frequency of extreme weather events (Wright, et al. 2019, Wang, Lijuan, et al. 2019, Konisky et al. 2016, Wang, Xianli, et al. 2015, Cai, Wenju, et al. 2014), Taipei City is still threatened by flooding during summer storms and typhoons. For example, on June 2nd, 2017 Taipei City was struck by storm rain with intensity reached to 100mm/hour which lead to 250 flooding events all around Taipei City.

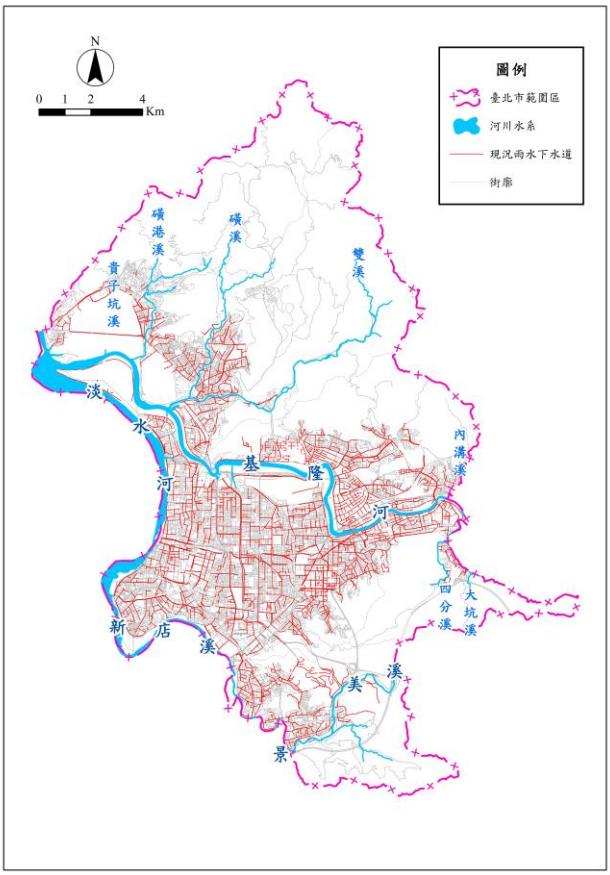

Figure 1.1 Storm Sewer system distribution in Taipei City.

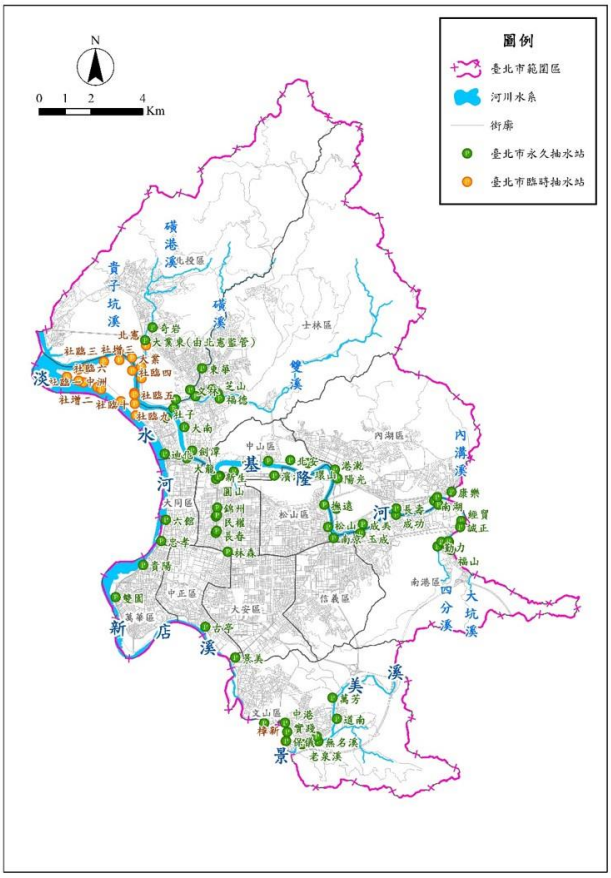

Figure 1.2 Distribution of the pump stations of the storm sewer system of Taipei City.

The rainfalls of the summer storms at Taipei City in recent years are short in duration but high in intensity (Chou, Jui-Sheng, et al. 2013, Teng, Wei-Hsien, et al. 2006). The average rainfall duration of the summer storms are 4 to 6 hours but the rainfall intensity may reach to 80mm/hour to 135mm/hour and the rainfall intensity vary significantly between each region in Taipei. The high rainfall intensity lead to local flooding events but the flooding phenomena diminished right after the rainfalls intensity attenuated. However, the flooding events are not only triggered by extreme weather events and excessive rainfall intensities, flooding events are also caused of geological characteristics, sewerage system dysfunction or pump system manipulation error. Therefore, finding the exact causes which lead to flood events is the key for drafting future flood mitigation strategies and for clarifying the responsibilities of the authorities.

2. Methodology

The complete flooding events investigation process includes field drainage and sewer system inspection, flood victims' and residents' interview, SWMM (Storm Water Management Model) examination, flood mitigation strategies drafting and local briefing (see figure 2.1).

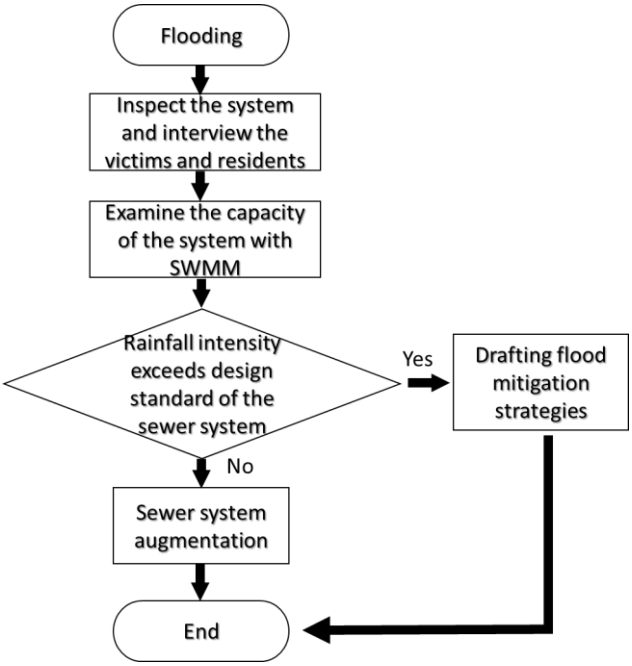

Figure 2.1 The flow chart of flooding events investigation process.

2.1 Field drainage and sewer system inspection

When a flooding instance occurs, prior to the SWMM examination on the capacity of the sewer system, the function of the drainage systems, sewer systems and the pump stations' operational records must be inspected (See photo 2.1 to 2.3) to ensure that the drainage system functioned normally during the storm. The drainage systems are often choked by foreign objects such as fallen tree branches or building waste which was washed by overland flow. Moreover, pump stations may be ambushed by summer storms which change dramatically without significant warning. Therefore, the pump stations' operational records must be examined to clarify the responsibility and the cause of flooding instance.

Photo 2.1 Traffic control during storm sewer system inspection.

Photo 2.2 Storm sewer system inspection after a flooding instance.

Photo 2.3 A choked pipe which has been marked with painting on the wall during storm sewer system inspection.

2.2 Reviewing the monitoring videos

Taipei City government set more than 167 thousand monitoring cameras for security purposes. By reviewing the camera record, we may roughly estimate the duration and the time of occurrence of the flooding event. Although the cameras are usually

fixed and the resolution of the cameras are too low to recognize the detail of the flood development. (See photo 2.4 and 2.5)

Photo 2.4 Monitoring camera record (before flooding).

Photo 2.5 Monitoring camera record (during the flooding event on. June 2nd, 2017).

2.3 Interviewing flood victims and local resident

Flood victims are usually the witnesses of the development of the flooding and they usually hold electronic evidences recorded by smart phones. Moreover, they are usually eager to share their fury as victims. Therefore, engineering consultants, instead of the government authorities, can gather important information about the whole course of the flooding event without being accused of incompetent (see photo 2.6). The electronic records (photo 2.7) include the development, the height, the area, the development and the frequency of occurrence of the flooding events.

Photo 2.6 Interviewing flood victims for the development of the flood on. June 2nd, 2017.

Photo 2.7 A precious flooding image provided by an enthusiastic flood victim.

2.3 SWMM examination on the capacity of the sewer system

The area of Taipei City is about 270 km^2, but the surface elevation of Taipei City varies from 1120m (the surrounded mountains) to about 2m. Therefore, the rainfall intensity vary significantly between each district (see fgure 2.2 for example).

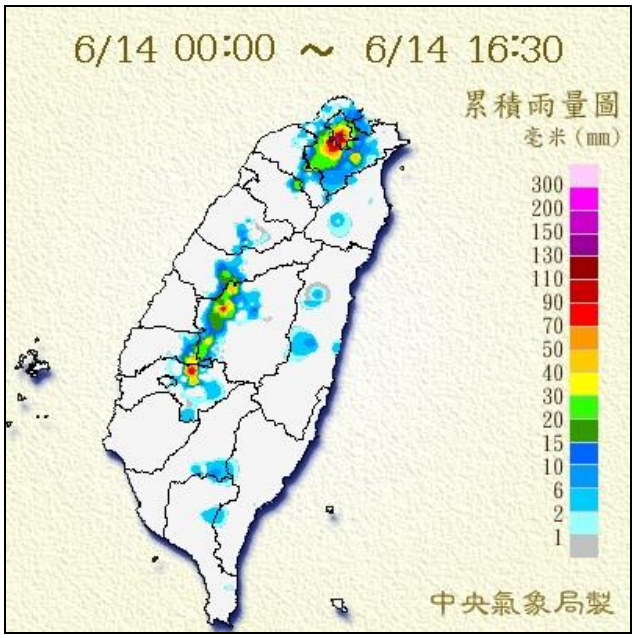

Figure 2.2 The accumulated rainfall distribution of the storm rain event on June 14th, 2015. (adopted from Central Weather Bureau, R.O.C. https://www.cwb.gov.tw/V8/C/index.html)

Taipei City government has set 35 rain stations for monitoring rainfall intensity distribution (see figure 2.3) and 152 water level gauges in the storm sewer system. To clarify if the rainfall intensity has exceed the capacity of the storm sewer system, we examine the SWMM with the recorded rainfall intensity.

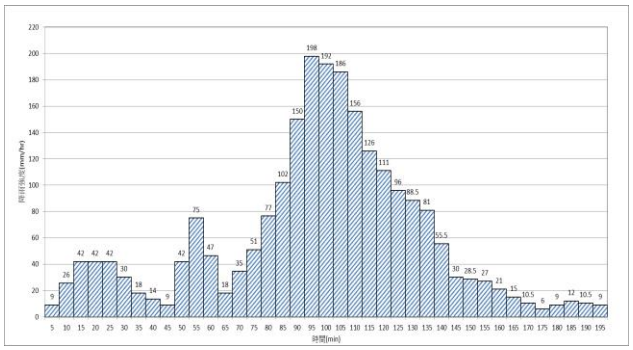

Figure 2.3 The recorded rainfall intensity (130mm/hr) at Gongguan Station on June 14th, 2015.

2.4 Drafting flood mitigation strategies

Flood events usually take place at where the storm sewer is relatively weak or the places with low surface elevation and thus flood events often take place repeatedly. However, modern cities like Taipei City are usually crowded with residents and cars and thus are difficult to expand the capacity of the storm sewer system. To mitigate the flood, we draft strategies of different stages. Considering that engineering procedures including detail design and constructions. Therefore, short term strategies are mobile pump deployment (photo 2.8) and early warning system to alert residents.

Flood events usually take place at where the storm sewer is relatively weak or the places with low surface elevation, the midterm strategy is to augment the sewer system till the whole sewer system meet the design standard. Moreover, the water at the relative low places should be detent at the parks with LID devices. The side ditches at the flooding area may be augmented to enlarge the capacity of the drainage system if it is necessary (photo 2.9).

Long term strategy is to review the sewer system generally with extra attention to the places where the storm sewer is relatively weak. The flow chart for flood mitigation strategies is drafted in figure 2.4.

Photo 2.8 The deployment of mobile pump for assisting the capacity of the drainage system.

Photo 2.9 Ditch augmentation process to enlarge the capacity of the drainage system.

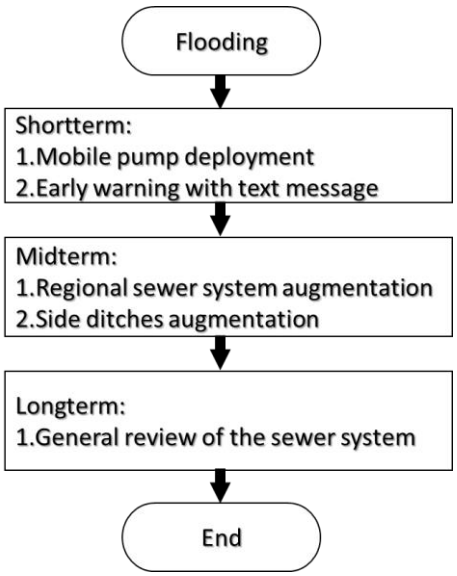

Figure 2.4 The flow chart for flood mitigation strategies.

3.Flooding events in recent years

The sewer system of Taipei City is designed for 5 year return period storm rain with intensity of 78.8mm/hour. However, due to the increasing frequency of extreme weather condition, strong storms with heavy rain hit Taipei almost every year in recent years. The intensity of the storm rain may reached to 80mm/hour to 130mm/hour as shown in Table 3.1.

Strong storm with heavy rain may have exceed the capacity of the capacity of the sewer system, but heavy rain is not the only factor that lead to flood, but it reveals the weakness of the sewer system. The flooding usually takes place at the place with relative weak draining ability. One heavy rain event may lead to 14 flooding events around Taipei. However, due to manpower shortage of the authority, it is difficult for the authority to investigate every flooding scheme and clarify the cause of flooding. Therefore, Taipei City government utilize open contract for flood scheme investigations. CECI engineering consultant incorporation has been serving for Taipei City government for flood scheme investigations since 2012 and has handled more than 90 cases (see figure 3.1). During the investigations, it is found that, despite of the heavy rain, only 10% of the flooding is caused of the shortage of the capacity of the sewer system. 6% of the flooding is caused of choking by fallen tree branches and the rest 84% of flooding is caused of regional sewer system dysfunction and may be fixed with engineering augmentations.

Table 3.1 the rainfall intensity record in recent years

Date	Rainfall Intensity(mm/hour)	District
2015/Jun/14	130	Daan
2016/Jun/17	117	Nanggang
2017/Jun/2	87.5	Neihu
2018/Sep/8	128.5	Shihlin
2019/July/2	136.5	Daan

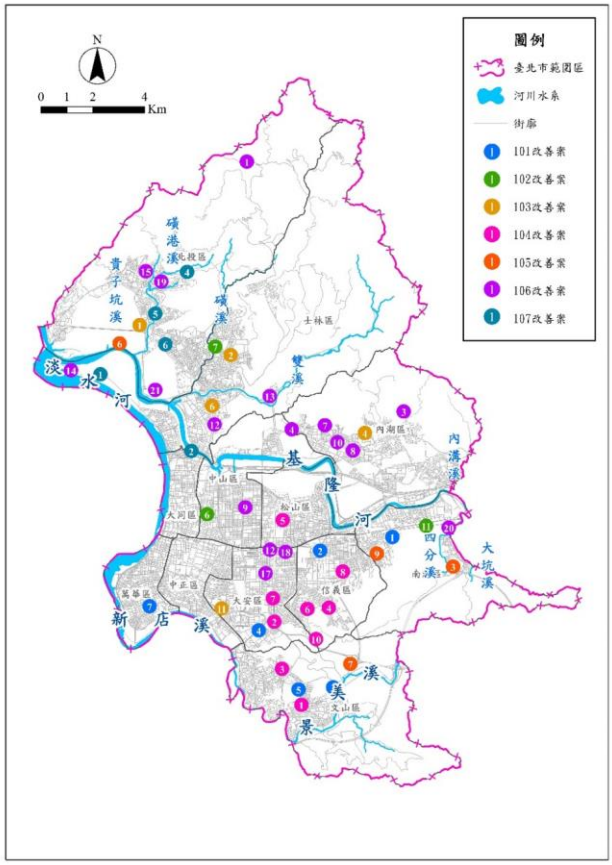

Figure 3.1 Flooding Schemes investigated by CECI engineering consultant incorporation since 2012. .

Photo 3.1 Flooding Schemes on June 2nd, 2017 at Neihu district.. .

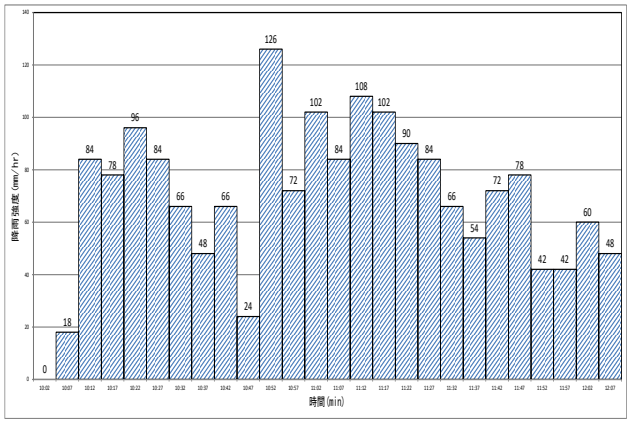

Figure 3.2 The recorded rainfall intensity (87.5mm/hr) at Neihu on June 2nd, 2017.

3.1 Flooding events at Neihu district on June 2nd, 2017

To explain the role of engineering consultants after flooding events and the investigation process, a flooding event on June 2nd, 2017 at Neihu district (at the north part of Taipei City) is presented.

On June 2nd, 2017, a storm rain with intensity of 80.5mm/hour hit Neihu district and lead to a severe flooding instance (photo 3.1 and figure 3.2).

Following the investigation process shown in Figure 2.4, we investigated sewer system to check if it functioned normally during the storm, we found that the flooding was caused by a transition channel which connects silting basins and the sewer system and the channel overflowed during the storm (photo 3.2).

By interviewing the flooding victims (photo 3.3), we were told that trash and tree leafs choked the entrance and lead to the flooding event.

Photo 3.2 The transition channel and the entrance of the sewer system with trash racks at the opening.

Photo 3.3 The transition channel and the entrance of the sewer system with trash racks at the opening

To clarify the cause of the flooding event, we utilized a SWMM to reproduce the flooding event with the recorded rainfall intensity (figure 3.3). We found that, though the rainfall intensity exceeded the design capacity of the sewer system, the sewer system should be able to drain the runoff without overflow. Therefore, the entrance of the sewer system choked by foreign objects is the major cause of the flooding event.

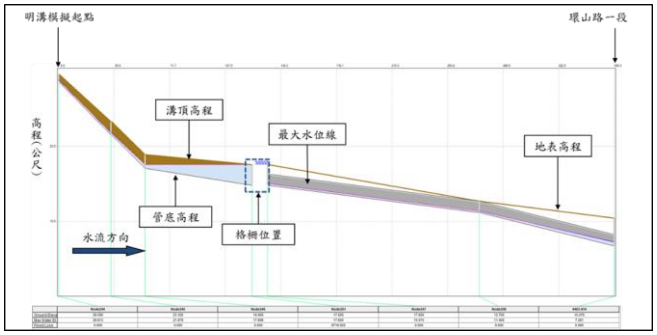

Figure 3.3 Reproducing the flooding event with a SWMM.

Since the flooding event was caused of an improper set of trash rack, we suggested the modification on the trash rack (photo 3.4) and check with the SWMM.

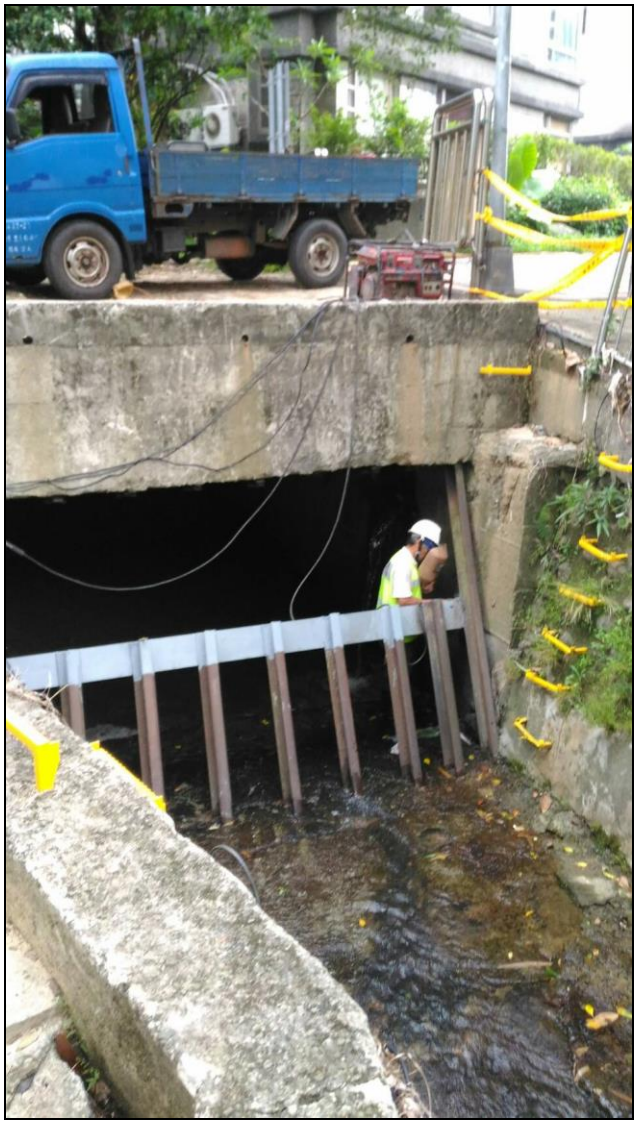

Photo 3.4 Modification on the trash rack at the entrance of the sewer system.

We also attended local briefings to comfort flood

victims and explain the flood mitigation strategies (photo 3.5).

Photo 3.5 A local briefing held by the Taipei City council member.

On September 8th 2018, another storm hit Taipei City with heavier rain (88mm/hour) than the one on June 2nd, 2017 (87.5mm/hour). With the modified trash rack, the channel was safe from flooding.

4 Conclusion

All modern mega cities are still suffering from flooding events under extreme weather conditions (Dewan and Ashraf 2013). Therefore, it is necessary to draft a systematic protocol for government authorities or engineering consultants to investigate the development and the cause of the flood events.

On the basis of CECI engineering incorporation's serving experience for Taipei City government, a standard protocol for investigating flood schemes has been constructed and guidelines for flood mitigation strategies are set for modern mega cities.

The protocol has been employed for over 90 flooding events and the flooding phenomena have been mitigated for most cases with regional engineering augmentations and are thus safe from flooding in the future storm events.

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