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Methodological Framework for Analysing Cascading Effects from Flood Events: The Case of Sukhumvit Area, Bangkok, Thailand

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Abstract: Impacts from floods in urban areas can be diverse and wide ranging. These can include the loss of human life, infrastructure and property damages, as well as other kinds of nuisance and inconvenience to urban life. Hence, the ability to identify and quantify wider ranging effects from floods is of the utmost importance to urban flood managers and infrastructure operators. The present work provides a contribution in this direction and describes a methodological framework for analysing cascading effects from floods that has been applied for the Sukhumvit area in Bangkok (Thailand). It demonstrates that the effects from floods can be much broader in their reach and magnitude than the sole impacts incurred from direct and immediate losses. In Sukhumvit, these include loss of critical services, assets and goods, traffic congestion and delays in transportation, loss of business and income, disturbances and discomfort to the residents, and all these can be traced with the careful analysis of cascading effects. The present work explored the use of different visualization options to present the findings. These include a casual loop diagram, a HAZUR resilience map, a tree diagram and GIS maps.

Keywords: urban floods; critical infrastructures and services; dependence and interdependence; cascading effects; framework; quality of life

1. Introduction

Floods in urban areas represent a serious and growing problem for the urban population (e.g., [1–6]). However, it has become a well-accepted fact that floods and flood-related disasters are not in fact the results of nature-related processes alone. They are to an ever-increasing degree directly attributable to various social, economic, historical, political and even cultural causes [1–4,7–11]. As observed in [1], the level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their lives to such a risk or simply ignore it. What follows from this is that our search for sustainable flood risk mitigation in urban areas should take into consideration not only economic and technical aspects of potential solutions [12–17], but also how they interact with other objects (e.g., other urban infrastructure) and actors (e.g., utilities, government agencies, community, etc.) that co-exist in urban surroundings (e.g., [3]). This in turn necessitates better understanding of interdependencies and interrelations between different objects and the behaviour of different actors (e.g., land use policies and regulations, infrastructure planning, etc.). The present paper provides a contribution in this direction and describes a new approach for the assessment of cascading effects from floods and the quantification of impacts on other urban infrastructures and their services.

Our efforts to understand cascading effects from disasters, and particularly natural disasters, have grown considerably over the past decade, and this subject matter has evolved into an emerging field of scientific research [18]. Attempts to develop frameworks and methodologies for the analysis of flood-related impacts are gaining particular importance in view of continuous devastation posed by such disasters. Traditional efforts are primarily concerned with assessment of direct and immediate impacts or damages, and efforts are being made to capture their indirect or cascading effects (example [19,20]). The importance of expanding our research into cascading effects comes from the fact that in many cases, such effects have the potential to exceed the magnitude of direct or immediate damages. A typical example is that a floodwater depth of 25 cm may cause little or insignificant direct damage, but at the same time, it can cause serious public health issues if it is mixed with wastewater, as well as the disruption of power and water supply, which can in turn lead to further complications and losses (see, for example, [21–24]).

The present paper describes a methodological framework for analysing cascading effects of floods in urban areas that has been applied in the case study of Sukhumvit in Bangkok (Thailand). Development of the framework evaluation on the Sukhumvit case study was done as part of the FP7 EC funded Preparing for Extreme And Rare events in coastaL regions (PEARL) project (http://www.pearl-fp7.eu/). Sukhumvit area is a residential area with a high population density [25]. It is also the centre of important economic and commercial activities. The methodology applied aims to support flood managers and other urban utility managers in assessing cascading effects from floods, and as such, it can be used in planning effective preventive measures. The present work also takes into consideration the possibilities for presentation and visualization of cascading effects and interdependencies between different infrastructures and services. Visualization of cascading effects and mapping of interdependencies is an important aspect of the work, as the analysis involves participation from different utility operators. Besides the more traditional means for visualization such as GIS maps and causal loop diagrams, the present work also applies the HAZUR software (a tool designed to support design, implementation and management of cities' resilience strategies, http://opticits.com/#hazur) in the assessment of cascading effects in the case study area. The results from the case study work highlight the importance of assessing cascading effects from floods in urban areas, which can have multiple effects on urban infrastructure.

2. Framing the Methodology

2.1. Concepts, Terminology and Literature

The Oxford Dictionary defines infrastructure as "the basic physical and organizational structures and facilities (e.g., buildings, roads, power supplies) needed for the operation of a society or enterprise" [26]. In the context of the present work, an infrastructure is defined as "any installation that can be situated geographically, whose functioning is key to the provision of a service", and examples are: wastewater treatment plant, power transformer, a hospital, etc. [27].

Interdependency refers to the relationship between different infrastructure or services, whereas one is a donor and the other is a receptor, such that when the donor fails, then the receptor fails [27], called a cascade effect of the receptor due to failure of the donor. When the relationship is unidirectional, this is then referred to as dependency, and when it is bidirectional, it is referred to as interdependency [28]. Interdependency of infrastructure, regardless of what type or nature of infrastructure is concerned, is the main cause of the potential for cascading failures and hence amplification of one infrastructure's failure [29].

Critical infrastructure is a term used to describe assets or systems that are essential for functioning of a society. Various researchers and practitioners have come up with a list of the so-called critical infrastructure considering a variety of factors such as social services, economy and security issues. For example, the EU Directive report of 2008 [30] defines critical infrastructure as "those assets, systems or parts thereof that are essential for the maintenance of vital social functions, health, security, safety, economic and social welfare of people, whose destruction or malfunctioning would have as a direct consequence a significant impact on population, as a result of a loss of service of these functions". In the United States, the Department of Homeland Security lists sixteen critical infrastructure sectors whose assets, systems and networks, whether physical or virtual, are considered as vital to the security, national economic security, national public health or safety or any combination thereof. These are: chemical, commercial facilities, communications, critical manufacturing, dams, defence industrial base, emergency services, energy, financial services, food and agriculture, government facilities, healthcare and public health, information technology, nuclear reactors materials and waste, transportation systems, water and wastewater systems [31]. According to Murray and Grubesic (2007), the following can been regarded as typical critical infrastructures needed for basic functioning of the social services and economy of the society: telecommunications, electrical power systems, gas and oil storage, transportation, banking and finance, water supply systems, emergency services (including medical, police, fire and rescue) and continuity of government [32]. Hence, the following Table 1, which was developed following the research studies cited above, summarizes some of the commonly-defined critical services and their infrastructures.

Table 1. Identification of critical services and infrastructures.

No.	Types of Urban Service	Categories or Means of Service	Infrastructure	Exposure to Floods
1	Transportation	Roads transport	Roads network	HL
			Bridges (culverts, drifts)	HL
		Railway transportt	Railway network	HL
			Bridges and culverts	HL
		Air transport	Airports, airstrips	ML
		Water transport	Ports, harbours and marine terminals (docks and bridges)	HL
2	Energy	Electricity	Power generation plants	ML
			Electricity network	ML
			Substations	HL
		Fuel, oil and gast	Refinery plants	HL
			Petrol stations	HL
			Gas and fuel pipe networks	LL
3	Water and Sanitation	Water supply	Water sources and intakes	HL
			Water treatment plants	HL
			Piped networks system	ML
			Pumping stations	HL
			Storage or balancing tanks	ML
		Drainage and sewerage	Wastewater treatment plants	HL
			Pumping stations	HL
			Piped networks	ML
			Open channels or canals	HL
			CSO storage facility	HL
4	Health Services	Health services	Pharmaceutical industries	HL
			Medical stores	HL
			Hospitals healthcare centres	HL

Table 1. *Cont.*

No.	Types of Urban Service	Categories or Means of Service	Infrastructure	Exposure to Floods
5	Financial Services	Financial	Banks' and funds' buildings and their installations	HL
6	Food	Agricultural	Farming lands	ML
			Irrigation schemes	ML
			Fertilizer and pesticide industries	HL
			Food processing industries	HL
			Warehouses or storage	HL
			Ginneries and clothing industries	HL
			Wholesale and retail shops	HL
7	Shelters	Residential, offices, commercial, social, etc.	Residential buildings	HL
			Office use buildings	HL
			Markets and shopping buildings	HL
			Recreational and cultural buildings and places	HL
			Hotels and conference buildings	ML
8	Information and Communications Technology (ICT)	Information and communications technology (ICT)	Telephone lines and wireless signals	ML
			Computers and their installations	LL
			Radio, TV and Internet stations	HL
			ICT structures and devices	ML
9	Emergency Services	Fire brigade	N/A	N/A
		Emergency medical	N/A	N/A
		Security	N/A	N/A
		General rescue	N/A	N/A
10	Education	Schools, institutes, colleges, universities	School buildings	HL
			Educational facilities	HL

Note: HL = high likelihood; ML = medium likelihood; LL = low likelihood; N/A = not applicable; CSO = Combined Sewer Overflow.

Rinaldi et al. [33] (2001) identified four principal classes of infrastructure interdependencies: physical, cyber, geographic and logical. Physical interdependency arises from a physical linkage between the inputs and outputs of two agents: a commodity produced or modified by one infrastructure, as an output, is required by another infrastructure, as an input, for it to operate. Cyber interdependencies connect infrastructure to one another via electronic information such as the outputs of the information infrastructure are inputs to the other infrastructure, and the 'commodity' passed between the infrastructures is information. "Geographic interdependency occurs when elements of multiple infrastructure are in close spatial proximity" [34]. Logical interdependency is bidirectional and does not depend on any physical or cyber connection (e.g., electric power and financial infrastructure) [33]. However, in the work of [35], the authors added two more types of interdependencies in addition to the policy or procedural and societal interdependencies [34].

Current literature defines a cascading failure as a failure when disruption in one infrastructure causes the failure of a component in the other infrastructure, which subsequently causes a disruption in other infrastructure. For example, an incident following a natural event (i.e., earthquake, hurricane, flood, etc.) or an intentional act (e.g., a terrorist action) can result in a failure (or disruption) of an electric utility's generator unit located in the service territory of the gas system. This event then can lead to a shortage of power generation in the area, which can in turn cause further disruptions. Not only is the electricity network so important for the functioning of a community, but also electric power failure could lead to disruptions in other infrastructures [33,35]; see Figure 1.

An impact from a flood event depends on a number of factors, which can be classified as impact parameters, and these may include water depth, water velocity, flood duration and the spatial extent of inundation [36], floodwater contamination, debris or sediments, rate of floodwater rise, frequency of inundation and timing and the resistance parameters, like early warning, robustness of infrastructure, etc. [37].

The UN Office for Disaster Risk Reduction (UNISDR) developed a Disaster Resilience Scorecard to support cities to reduce their disaster losses by 2020 [38]. This Scorecard emphasizes the need to identify the so-called normal level of service provision for a specific area or a town, which is then referred to as a critical service level.

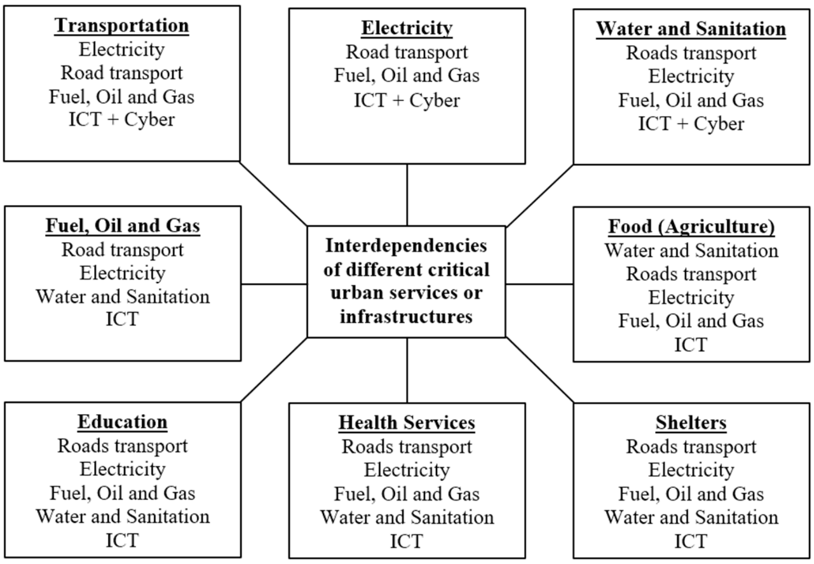

Figure 1. Example of interdependencies between critical urban services and their infrastructures.

2.2. Defining Cascading Effects from Floods

Cascading effects from floods on critical infrastructure services can be such that a critical infrastructure service that is not flooded at all is affected as a result of another infrastructure affected by floodwater. For example, repair work on the water supply network can be delayed due to the flooding of roads that provide access to the affected parts of the network. Another example is the situation when food stores incur losses from flooded roads and the inability of customers to reach their premises. Therefore, indirect losses can occur inside and outside the flooded area [37,39]. However, Merz et al. [37] (2010) argue that indirect economic damages of natural disasters can be negligible if very broad temporal and spatial extents are considered.

In some cases, due to the robustness of a particular system, a flood event might not cause physical damage to the infrastructure, but could result in other crosscutting impacts. For example, for transportation services, the presence of debris on roads, railways and airport runways may cause disruption to particular services. Another example is that if flood water levels overtop the railway tracks, the trains are forced to reduce their speed for safety reasons, which in turn may cause delays.

Jonkeren et al. [40] (2015) define economic losses as stock damage or flow losses (i.e., business interruption losses). In this context, flow refers to the services or outputs of stocks over time, while stocks refer to a quantity at a single point in time. Direct effects are defined as effects sustained by the sector that is hit by a particular hazard. Conversely, indirect effects will make an impact on sectors that are located in the close vicinity of the initially hit sector (indirect stock damage) or that are dependent on the initially hit sector through supply and demand relationships (indirect flow effects) [40].

Tangible damages are typically divided into direct and indirect damages; damages to residences, buildings, roads, utilities and communication infrastructure. As well as business interruption as a result of contact with floodwater are considered direct tangible damages [41]. Indirect tangible damages take place when there is no contact with flood water; the loss or damage is suffered by goods or functions that are distant from the flood area [39].

For the purpose of this paper, the term "cascading effects" refers to situations where the effects from floods on one or more urban infrastructures have single or multiple negative effects on the operating capacity of other urban infrastructures and their services.

2.3. Methodological Framework

The schematization of the methodological framework developed in the present work is given in Figure 2. The framework contains several steps, which are grouped into three parts: preliminary assessment (i.e., assessment of flood hazards), analysis of cascading effects and assessment of impacts (quantitative and qualitative).

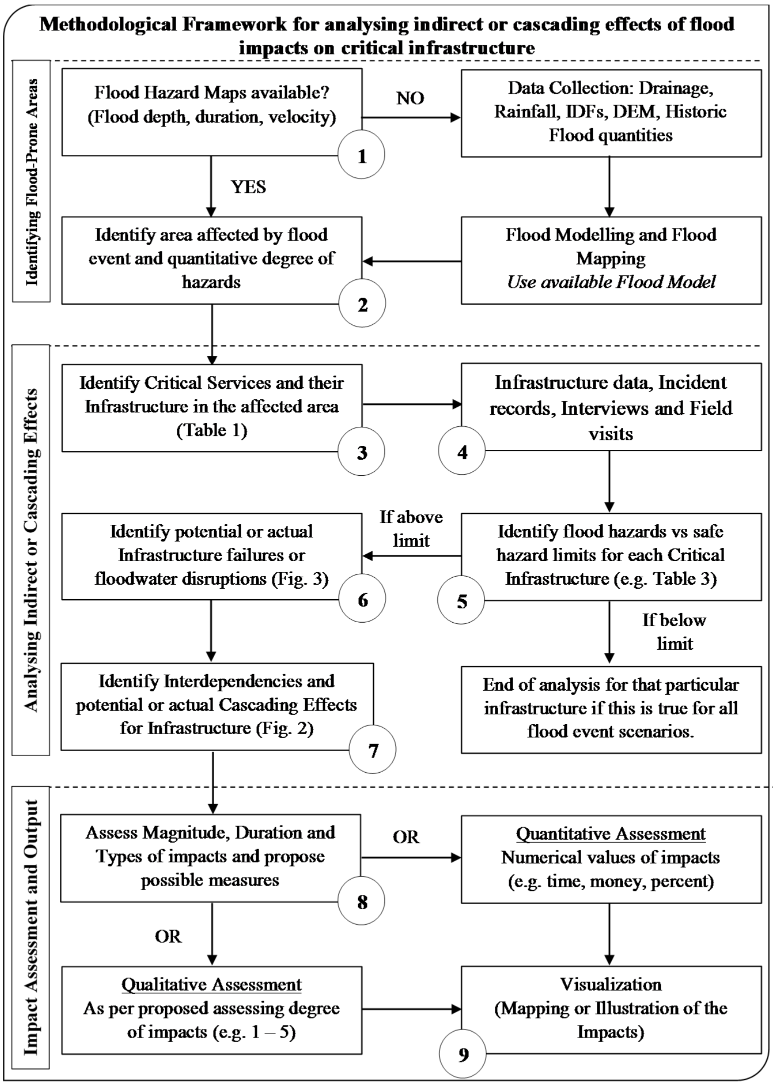

Figure 2. Methodological framework.

The framework depicted in Figure 2 aims to provide a systematic approach for the assessment of impacts from floods on urban infrastructures. The above framework requires a variety of data and information that needs to be sourced from different utilities and service providers. Such data and information are needed to undertake the analysis of cascading effects and to determine appropriate preventive measures.

Steps 1 and 2 of the framework focus on the production of flood hazard information for the area in question. This is typically done through the use of numerical models. The process of identifying critical infrastructure is contained in Step 3. Step 4 is concerned with data collection, interviews and fieldwork. Steps 4–6 of the framework mainly focus on the identification of vulnerable infrastructures and the potential for direct failure or interruption of their services. Step 5 is concerned with the current protection status (i.e., adaptation measures already taken by the infrastructure operators) of the infrastructure against flood hazards. This step is necessary for validating information from flood maps, interviews and field visits. Step 7 is concerned with the identification of interdependencies and the failure propagation potential (i.e., domino effects). To support the practical applicability of the framework, an overview of some common services and their independencies is given in Figure 1, which can serve as a starting point for many applications. Certainly, the information presented in Figure 1 is not exhaustive, and it can be extended further to accommodate local and case-specific situations. Steps 8 and 9 are concerned with the qualification and quantification of identified failures to assess their significance.

3. Application of the Framework

3.1. Description of the Case Study Area

The case study area is located in the eastern part of Bangkok, which is a part of the central business and commercial districts. The geographical location of the Sukhumvit area is 13°44′18.01″ N latitude and 100°33′41.31″ E longitude. The elevation of the study area is between 0.4 m and 4 m above sea level. The area falls within two districts of Bangkok, namely Wattana and Khlong Toei, with a total population of 185,275 inhabitants [42]. Terrain elevations along Sukhumvit Road are approximately equal to sea level and below the Chao Phraya River, which makes the area, besides frequent pluvial floods, also vulnerable to fluvial and coastal floods; see Figures 3 and 4.

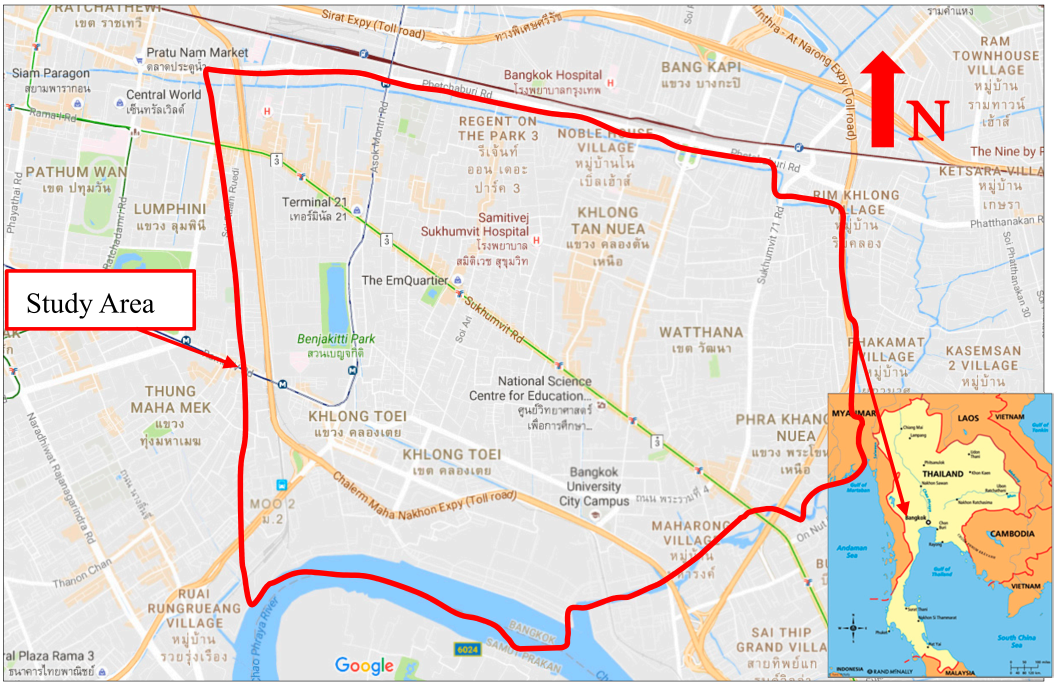

Figure 3. The case study area: Sukhumvit, Bangkok.

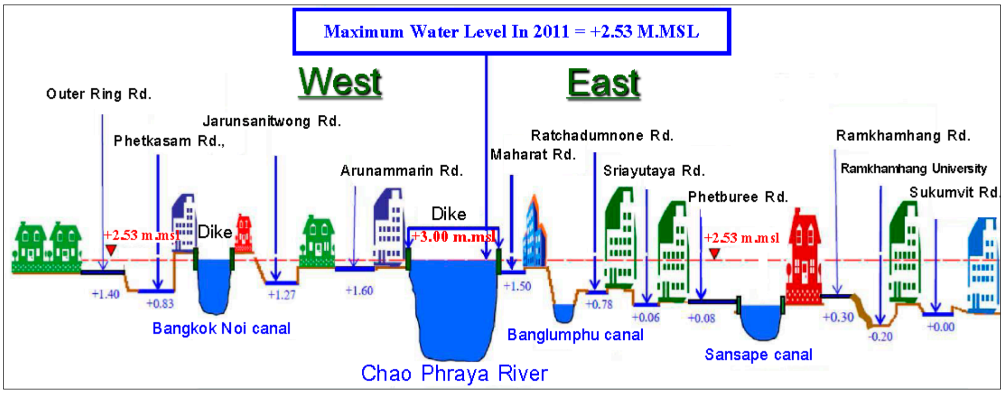

Figure 4. Cross-section of Bangkok (Source: Department of Drainage and Sewerage, Bangkok Metropolitan Authority).

3.2. Identifying Flood-Prone Areas

The use of numerical models is invaluable for the identification of flood-prone areas and quantification of hazards [43–50]. Although the use of numerical models is nowadays a standard practice for many flood specialists, the ability to produce reliable results still poses a considerable challenge to researchers and practitioners. This relates to the selection of data pre-processing and post-processing techniques, as well as to the selection of the most suitable modelling system and modelling approach for the problem at hand (see, for example, [51–55]. The present work uses 1D–2D models within the MIKEFLOOD modelling environment for estimation of hazards; see Figure 5. The 1D–2D coupled model consisted of 3487 manholes and basins and 3858 pipes, with the total drainage area corresponding to 2048 ha. Flood hazards are quantified mainly on the basis of floodwater depths since the local topography is rather flat, and this hazard variable is regarded as the most dominant for the pluvial type of flooding, i.e., changes in the flood velocity are negligible compared to the changes in floodwater depths (see, for example, [56]). The rainfall event used in the analysis is a 100-year return period event [56].

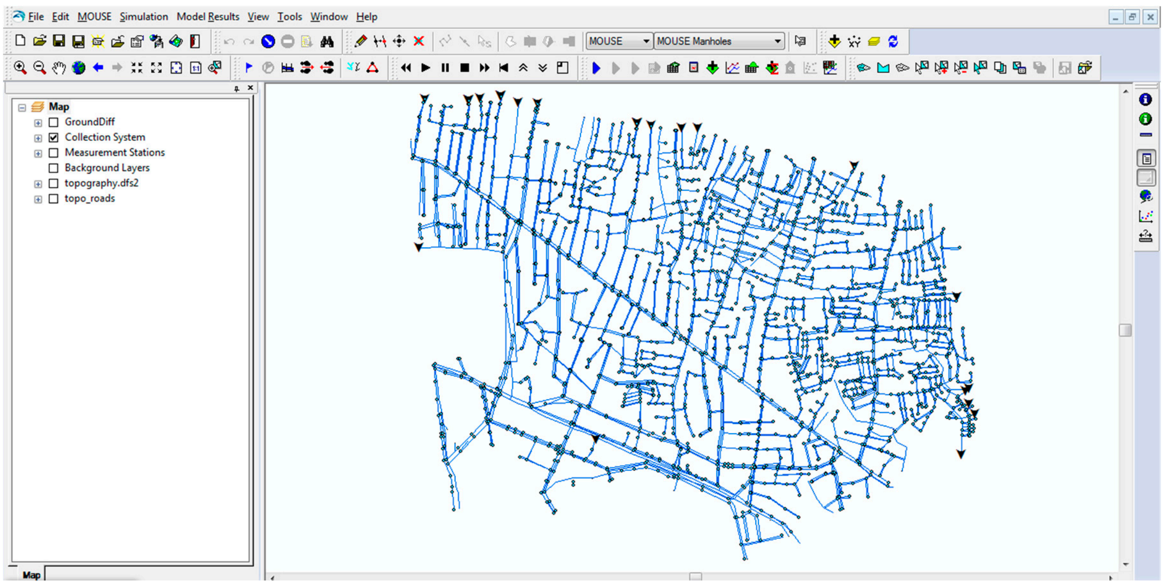

Figure 5. 1D pipe network model coupled with the 2D surface model in MIKEFLOOD.

The model used (is derived from two events from 2002 (one from 5 October and one from 7 October) had been calibrated in a previous study [57]. For the events of 2002, in addition to the rainfall data, time series water level measurements in manholes and streets were recorded at two locations in the Sukhumvit. The same study area and information have been used to calibrate and validate the model presented in [50]. In that particular study, a coefficient of determination was used for calibration purposes, and the values obtained were greater than 0.90 (see [50]).

3.3. Analysing Cascading Effects

The data used in the present work for the analysis of cascading effects come from different sources, which can be grouped into interviews and utility records. The aim of interviews with residents and utility operators in this part of Bangkok was to assess the potential for cascading effects and to define interdependencies between different infrastructures and their services. Two interview surveys were undertaken for this purpose. One survey targeted residents and business owners, and the other survey targeted critical infrastructure operators.

3.3.1. Interviews with Residents and Business Owners

Interviews were conducted with 34 residents and business owners from the following streets: Soi Sukhumvit 26, Soi Sukhumvit 34, Soi Sukhumvit 39 and Soi Sukhumvit 63. Questions in these interviews were related to their experiences with flood hazards such as floodwater depth, duration and frequency of flooding and whether they faced any problems with critical services such as electricity, water supply, wastewater, transportation and food supply (see Appendix A). A summary of the results obtained from these interviews is given in Figures 6 and 7.

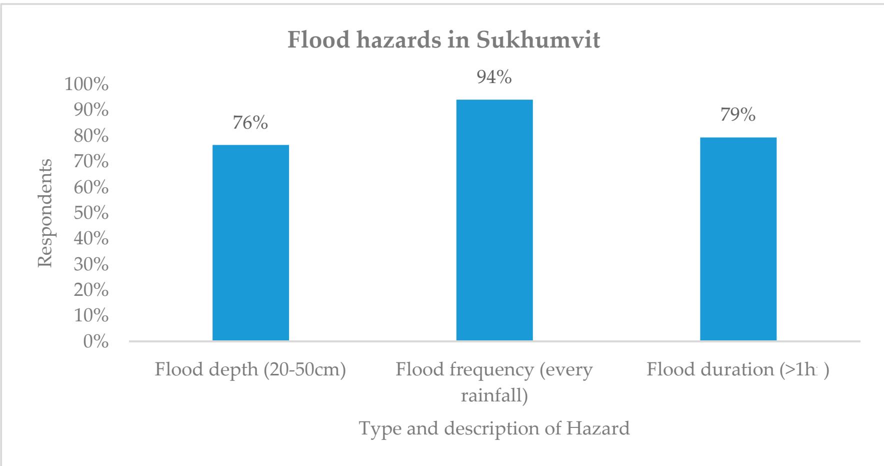

Figure 6. Results from interviews with residents and business owners.

The common finding is that the majority of interviewees experienced problems with flooding, and these were rather frequent. The results concerning critical services are given in Figure 7, where transportation services were impacted the most.

3.3.2. Interviews with Drivers of Vehicles and Motorbikes

Interviews were also undertaken with motorbike drivers (motorbikes are a common means of transportation in Bangkok), taxis, small pickups and buses. Some of the questions were related to experiences with the loss of income and repair costs due to flooding (Appendix B). All interviewees expressed that they incurred losses from flood events. Half of them indicated that the loss of more than 50% of their daily income is affected by floods, and the other half indicated somewhat lesser losses. The results from interviews with motorbike drivers, taxis, small pickups and buses are plotted as relationships between floodwater depths and vehicle speeds, and these are given in Figure 8 (where each data point depicts the average driving speed from survey results; 30 drivers were interviewed) and Figure 9.

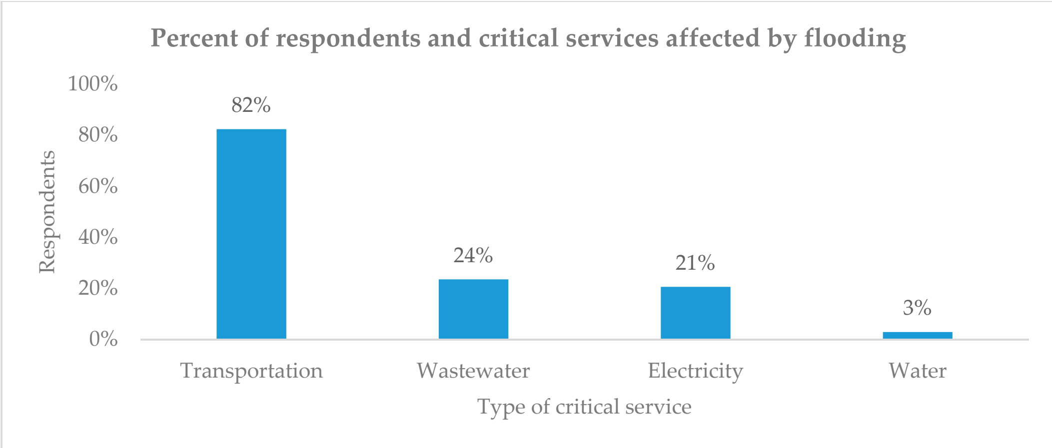

Figure 7. Results of people affected by the failure of critical services due to flooding.

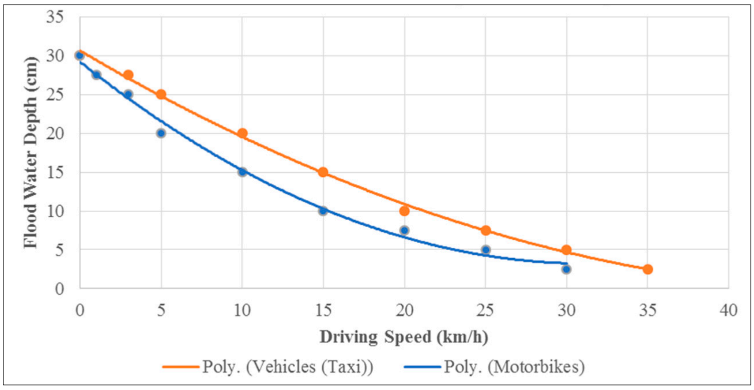

Figure 8. Relationships between floodwater depth and vehicle speed based on interview data.

The results show that floodwaters with a depth of 30 cm and higher would significantly cause traffic delays in the Sukhumvit area. This was found to be in line with the previous work of [19].

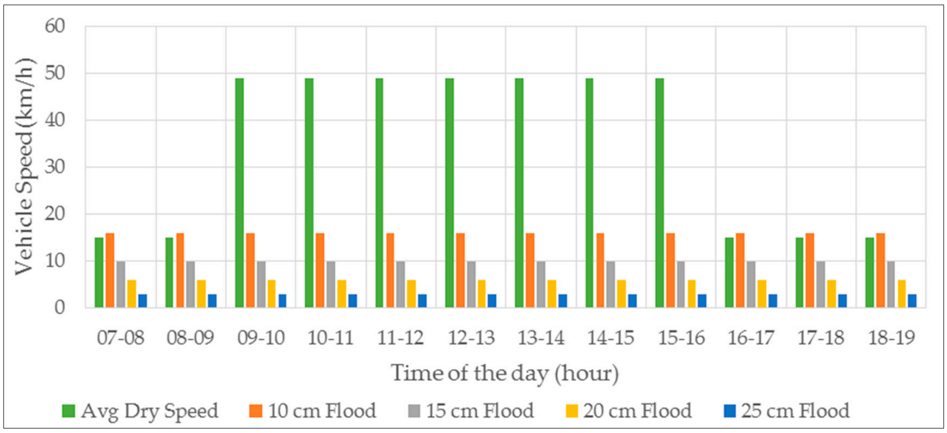

Figure 9. Vehicle speed in relation to floodwater depths.

3.3.3. Analysing Data from Critical Infrastructure Operators

Four critical infrastructure (CI) operators were interviewed: Traffic and Transportation Department (TTD), Metropolitan Electricity Authority (MEA), Metropolitan Waterworks Authority (MWA) (Appendix C) and Department of Drainage and Sewerage (DDS). Besides their answers to the questions, the utility operators also provided some other useful data (e.g., incident records, data from street cameras, etc.), which were used in the present work. These are presented in Figures 10 and 11.

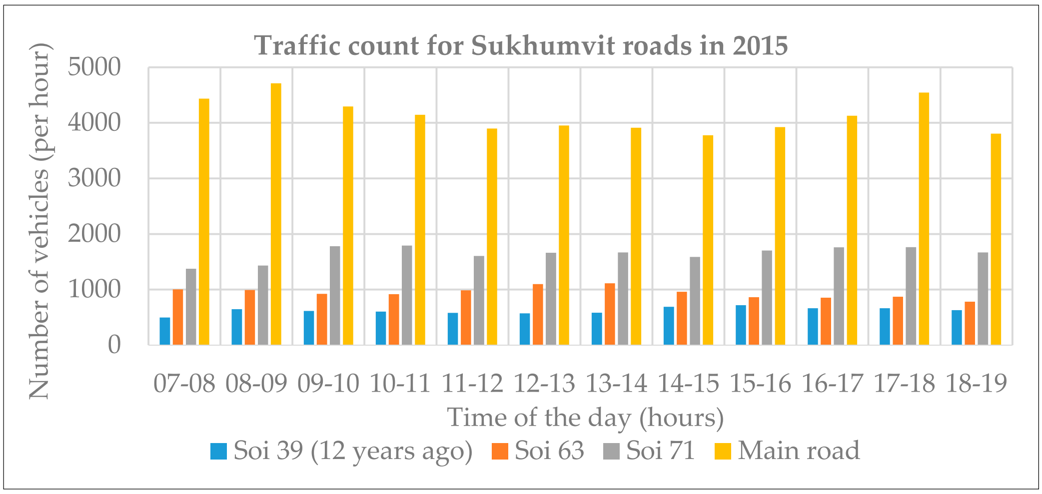

Figure 10. Average traffic counts.

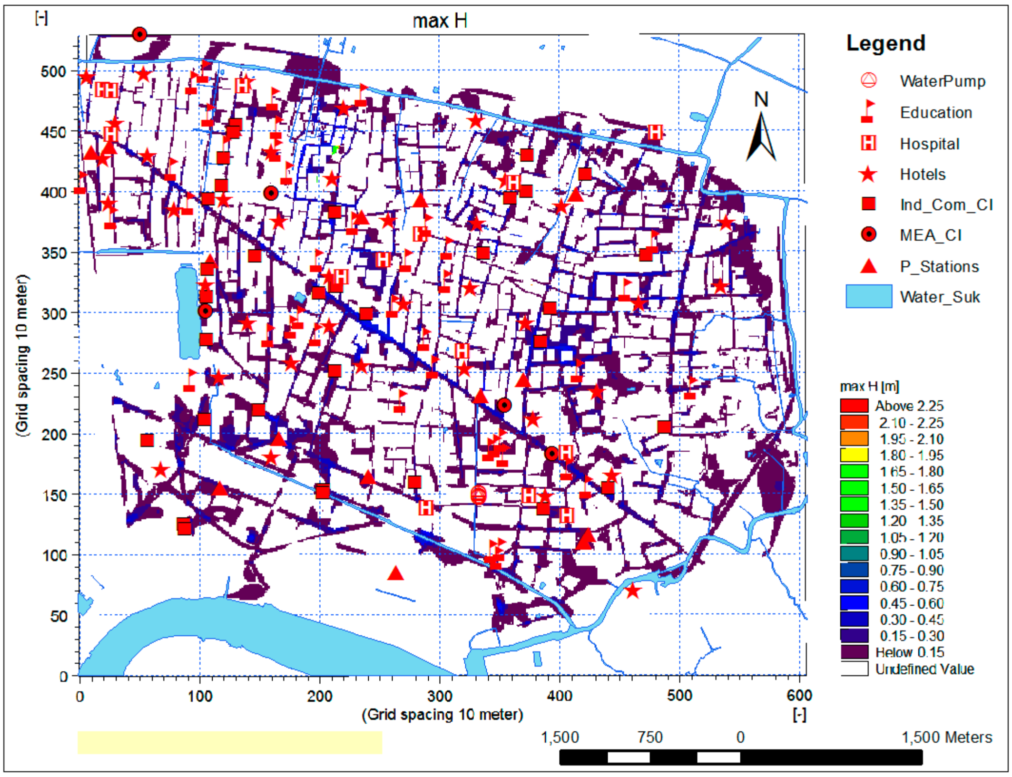

Figure 11. Proximity of critical infrastructure in relation to flood prone areas: 1D–2D MIKEFLOOD model result for 100-year rainfall return period (for information concerning local rainfall characteristics, see [56]). MEA, Metropolitan Electricity Authority. (Ind_Com_CI stands for *Industries and Commercial Critical Infrastructures* and P_ Stations stands for *Petrol Stations*).

The data presented in Figures 9 and 10 are taken from Soi Sukhumvit 39, Soi Sukhumvit 63 and Soi Sukhumvit 71 and along the main Sukhumvit Road. Figure 9 shows that the driving speed during rush hours (07–09 and 16–19) in dry conditions is almost identical to the driving speed when flood depths of 10 cm occur in the same timeframes. This implies that the driving speeds during rush hour are akin to that of perceived safe driving speeds in flooded conditions where the water level on the road is at a 10-cm depth. In contrast, outside of rush hour traffic, there is a significant difference between dry and wet driving speeds.

The Bangkok Metropolitan Administration (BMA) through DDS indicated six main causes of flooding in the case study area. These are: heavy rainfall intensity, overflow due to high discharge from the northern part of Bangkok, high tides and storm surges, land subsidence, inadequate capacity of the local drainage system and the lack of storage area. BMA divides Bangkok flood protection into two systems: flood protection based on "polders", an approach that prevents discharge from upstream areas and during high tide, and local drainage, which aims to prevent local pluvial flooding. The interview results were further used to define the safe limits (minimum permittable flood depths before being impacted) of the critical infrastructure in the case study area; see Table 2.

Table 2. Safe limits of critical infrastructure in relation to floodwater depths in the case study area.

Infrastructure	Categories or Types of Service	Safe Limit of Flood Depth (cm)
Roads transport	Traffic (motorbikes and vehicles)	30 *
	Pedestrians (footpath level)	20
Electricity	Customer electric meters	200 **
	Ground Electric cables	80
	Distribution Transformers	250 **
	Substations	350 **
Water Supply	Valve chambers	20
	Piped networks system	20
	Pumping stations	50
Drainage and Sewerage	Pumping stations	50

Note: * Below a 30-cm floodwater depth, traffic can continue operating at low speed. ** Infrastructures are elevated above ground level to avoid floodwater effects.

3.3.4. Overlaying Flood Hazard Data with Critical Infrastructure Data

Flood hazard data were overlaid with critical infrastructure data to assess their proximity in relation to flood-prone areas; see Figure 11.

A summary of flood depths in relation to critical infrastructure is given in Table 3.

Table 3. An overview of flood depths in relation to critical infrastructure investigated.

No.	Infrastructure	Investigated	In Flood Depth	
			<50 cm *	>50 cm
1	Hospitals	14	8	4
2	Schools and university	41	32	7
3	Hotels (39 locations)	282	216	36
4	Petrol stations	15	10	3
5	Industries and malls	34	23	9
6	Electricity substations	4	2	1
7	Water pump stations	1	1	0
8	Roads	All	All	0
9	Bus station	1	1	0

Note: * The 50-cm threshold is based on flood depths reported by local authorities, the flood model results (e.g., 1:100 year) and the safety levels presented in Table 2.

3.4. Impact Assessment

From the analysis of safe limits of critical infrastructure (see Table 2) in relation to floodwater depths for a 100-year return period, it was found that transportation and water supply services were likely to be most affected by floodwater depths out of all other infrastructure services.

3.4.1. Assessment of Impacts on Transportation Services

Travel distance, cost and time are considered as major factors for the use of transportation services [58]. Increased travel distance, cost and time can then be regarded as cascading effects, as well; these effects may also result from the presence of flood water on the road where the low flood depth will affect travel time and cost, while the high flood depth will result in some sporadic road segment closures. This will therefore affect economic and social activities intended at the destination. Impacts of flood on traffic can also be estimated in terms of lost business hours, additional fuel consumption and additional CO_2 emissions [59].

The effects of traffic delays are very much site specific because there are many causes of traffic delays with a major one being traffic congestion. The present work makes several assumptions for the estimation of traffic delays and monetization of damages, and these are based on interviews from road users, as well as on data obtained from the Traffic and Transportation Department of Bangkok Metropolitan Administration. The key assumptions are:

1. In case of no flood, the vehicles will drive at the average speed for that particular hour.
2. The vehicles using alternative routes during flood events will also experience the same delay effects. Therefore, all vehicles in the area will be considered affected.
3. The average number of vehicles passing through the road affected by the floodwater is given hourly in Figure 10.
4. Larger vehicles will adjust to the speed of small vehicles despite their ability to drive faster through affected roads.

Delays are calculated as follows:

delay time in hours $t_d = \frac{D}{V_f} - \frac{D}{V_d}$,

where:

$$\begin{aligned} D &= \text{flood length (km)} \\ V_f &= \text{speed of vehicle on flooded road (km/h)} \\ V_d &= \text{speed of vehicle on dry road (km/h)} \end{aligned} \tag{1}$$

Work by Weisbrod et al., 2001 [60], expressed the monetary value of delay time as a percentage of wage rates (derived from the National Statistics Office (NSO) of Thailand). Within that study, when the main purpose of the trips is related to business, the losses are estimated as 100% of the hourly wage rate. This assumption has been applied in this study.

According to NSO, the average per capita monthly income in the case study area is found to be 15,087 baht [25]. Therefore, the hourly income is 94.29 baht (15,087 baht/20 days/8 h = 94.29 baht, assuming 20 working days per month and eight working hours per day).

The Department of Traffic and Transportation (DTT), in Bangkok data (Figure 12) consists of all vehicle types including motorbikes, cars, vans and passenger busses. To represent vehicles as the number of people, we assume five passengers per vehicle. During office hours, we make the additional assumption that the delay time corresponds to 100% loss of average (per capita) hourly income. An overview of the quantification (i.e., estimation of costs) of delay for different floodwater depths taken at different hours for Sukhumvit Soi 71 is given in Figure 12.

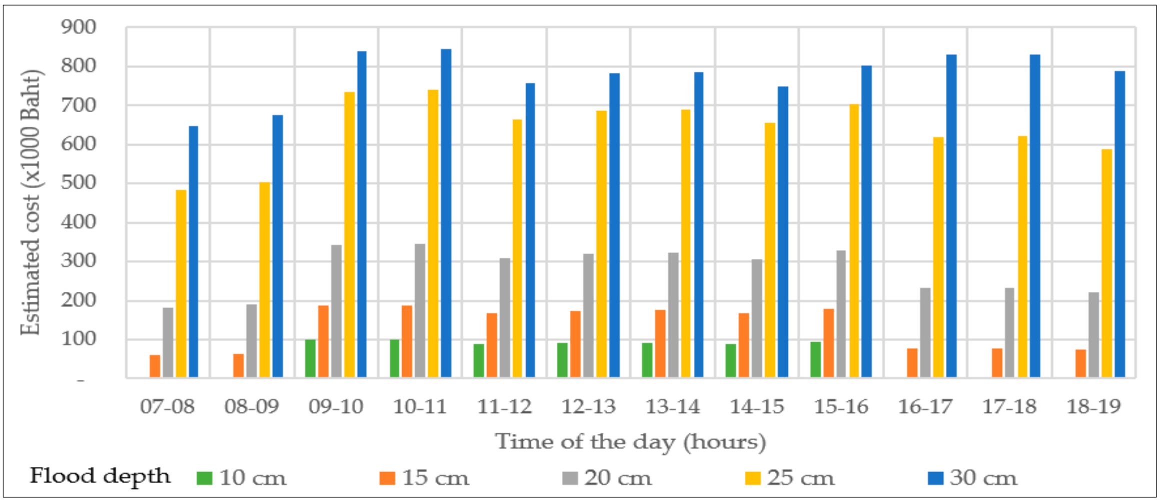

Figure 12. Quantification of impacts: cost of delay time vs. flood depth for Soi Sukhumvit 71.

Figure 12 shows that during the peak hours, a floodwater depth of 10 cm does not result in any delays cost. This is because the average driving speed during the peak hours for dry conditions is almost the same as the average driving speed for an event of 10 cm of flood water. As losses are calculated per hour, for the floodwater durations of less than one hour, the respective duration fraction should be multiplied by the monetary values applicable to that particular hour. The difference in cost ranges for each road for different times of the day, and it also depends on the traffic congestions, as well as on the effective length of the road or traffic. For situations where the floodwater depth is 30 cm and higher, it is assumed that the road will be closed completely, and subsequently, all users will be affected. The traffic count used in the analysis did not consider motorbikes, although the estimated affected population, which is five people per vehicle, might have considered them instead of cars. The average speed of about 49 km/h is considered for off-peak hours according to the interview data and an average speed of about 15 km/h for peak hours (in accordance with the Traffic and Transportation Department (TTD) of Bangkok Metropolitan Administration (BMA) database obtained for the period 2011–2015 for Sukhumvit area).

3.4.2. Assessment of Impacts on Water Supply Services

The present study also addressed the possibilities of floodwater intrusion into the water supply system and contamination during the intermittent water supply periods. Water supply pipe leakages in Sukhumvit (Figure 13) range from five hundred to eight hundred leaks per month. Furthermore, the official announcement of MWA (http://gisonline.mwa.co.th/GIS1125/index-desktop.php) shows numerous instances of intermittent water supply for operational and maintenance purposes, which carry the risk of floodwater intrusion into the water supply system (e.g., in September 2016, there were 1472 cases of this nature; in October 2016, there were 873 cases; in November 2016, there were 987 cases, etc.). Figure 14 depicts the locations of leakages in relation to flood-prone areas, and Figure 15 depicts the locations of leakages in relation to potential Escherichia coli concentrations in the floodwater (see also [30]). These two figures were obtained from the results of the 1D–2D model simulations.

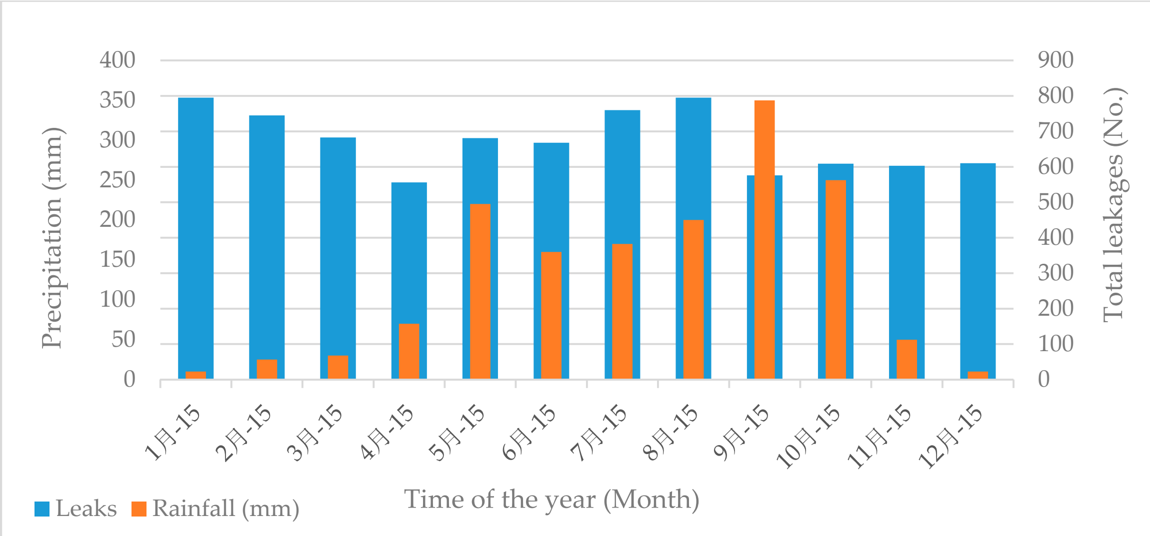

Figure 13. Pipe leaks and rainfall trends in Sukhumvit 2015.

Figure 13 shows that during the period of May–October (the rainy season), due to the number of leakages in the water supply system, there can be the possibility of floodwater intrusion into the water distribution network and contamination. Particularly sensitive areas are those with high leakage rates (see Table 4).

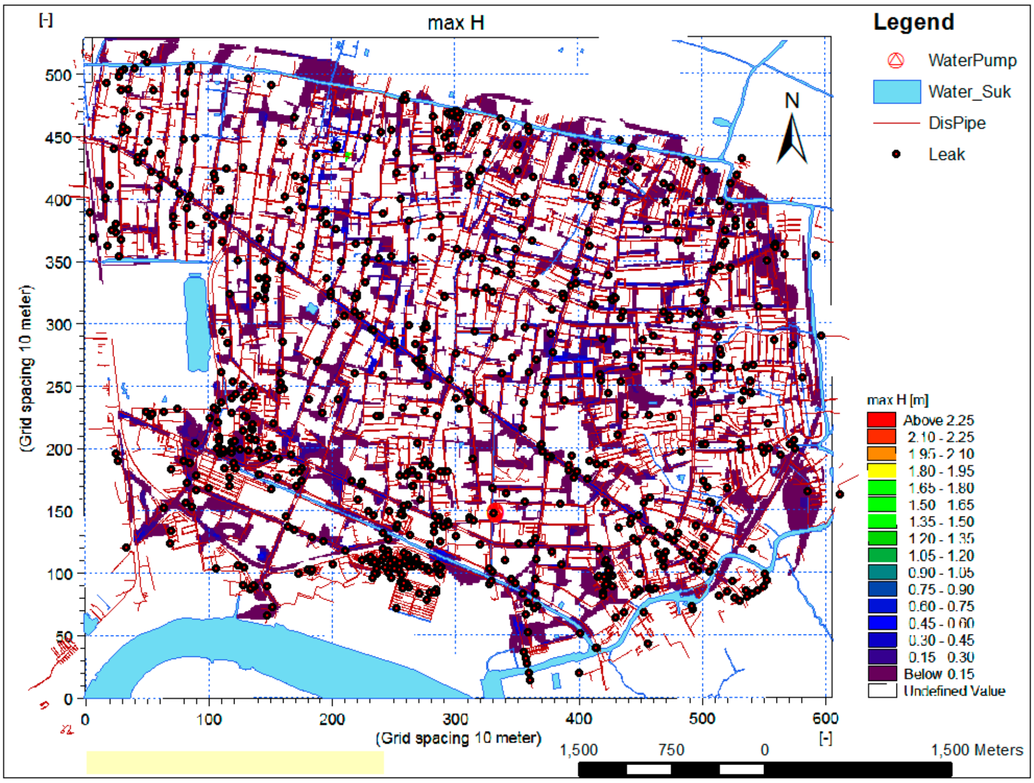

Figure 14. Water supply leakage locations overlaid with the 100-year return period flood map; see also [57].

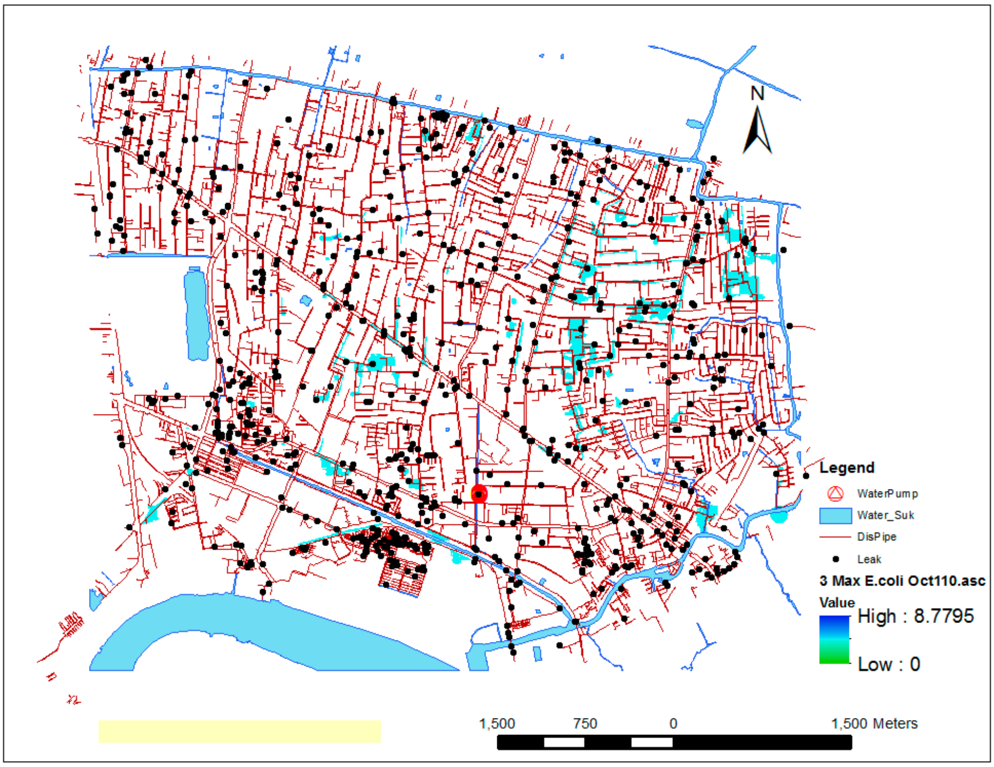

Figure 15. Pipe leakage locations in relation to *E. coli* concentrations in floodwaters [42]. Concentrations were obtained from coupled 1D/2D model simulations.

Table 4. The number of pipe leakage locations in most flooded streets.

S/N	Street	Pipe Size (mm)	Leakage Locations
1	Main Road	300–1000	38
2	Ekkamai	300–1000	12
3	Sukhumvit 39	300–600	11
4	Sukhumvit 22	300–700	9
5	Asok	300–800	4
6	Sukhumvit 24	300	3
7	Sukhumvit 26	150–300	1
8	Other streets	150–1000	>100

Table 4 gives an overview of the streets in the Sukhumvit area that are estimated to be the most frequently- and severely-flooded areas. Further to the results obtained, these locations should have high priority for rehabilitation and prevention measures by the local utility operators. The total number of leakage locations in Sukhumvit area is 773, out of which, 324 locations are distribution pipes (100–400 mm diameter) and nine are the main pipes (>400 mm diameter). From the analysis of data collected, the total number of leakages in the period October 2014–September 2015 was found to be comprised of 1439 locations that are distribution pipes and five main pipes, while in the period October 2015–September 2016, it was found that there were 833 and 309 locations, respectively.

It can be also noted that leakage frequency was found to be in the order of 3–4 leaks per location per year. This suggests that leakage holes may become bigger due to pipe deterioration processes, and this would cause a greater chance for floodwater intrusion during intermittent water supply periods. Furthermore, some leakage locations are found to be in areas were the floodwater has high potential to contain large concentrations of *E. coli* (Figure 16), which in turn introduces a higher risk to public health.

From Figure 14, it can be observed that 47 leakage locations (i.e., 10% of all leakage locations) are in flood-prone areas and 6% are in highly polluted floodwater locations. The possible way forward for utilities to address these issues is given in Figure 16.

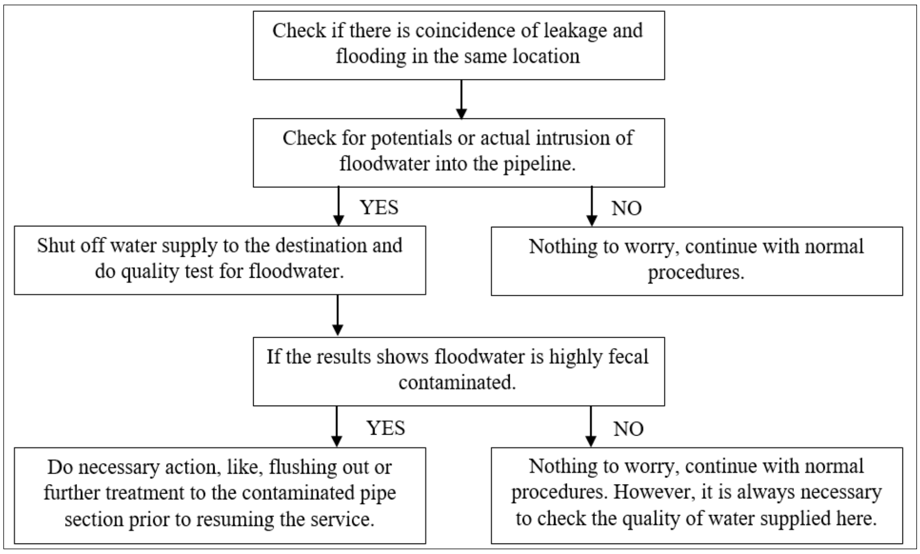

Figure 16. The possible actions to mitigate floodwater intrusion into the water supply system.

3.4.3. Assessment of Impacts on Power Supply Services

The present study investigated the possibility of floodwater impacting electricity generators during flood events. The positions of critical infrastructures (including electricity generators) and their proximity to flood waters are shown in Figure 11. Instances where flood water is in contact with electricity generators may not necessarily result in energy generation failure as some generators have additional protection by being raised by 2–2.5 m and substations raised by 3.5 m (Table 2), as well as the underground cables are water proof. One of the issues reported by the Metropolitan Electricity Authority (MEA) is that the cable chambers along Sukhumvit Road however are always found full of water during the rainy season. This generates an additional workload and risk (e.g., health risk since the drainage system is combined and surface flood water has a high concentration of water-borne pathogens) to the operation and maintenance team workers and can be considered as business interruption tasks; however, no additional questions were included in the surveys to address this issue in further detail. Some of the typical impacts from power disruption in the case study are:

- interruptions in parts of communications services;
- inconveniences due to high temperatures and cooling (i.e., the use of air-conditioning);
- impacts on perishable foods, unless there are backup generators;
- traffic jams due to power failure or outage at traffic lights;
- water supply and sewerage services' disruption (due to power supply failure at pumping stations).

4. Presentation and Visualization of Results

The presentation and visualisation of results play an essential role in communicating information to different stakeholders about cascading risk effects. Effective communication of information and knowledge is key to support those concerned so that the necessary preventive actions can be developed jointly. The present work considers several means for presenting/visualising the findings from the cascading risk work undertaken for Sukhumvit area in Bangkok. These are: causal loop diagram, tree diagram, GIS maps and HAZUR diagrams.

4.1. Causal Loop Diagram

Vensim is a (www.vensim.com) visual modelling tool that allows one to conceptualize, document, simulate, analyse and optimize models of dynamic systems. For this study, we have used the free downloadable version from Ventana Systems, Vensim PLE. By connecting words with arrows, relationships among system variables are entered and recorded as causal connections. The resulting schematic of interdependences between different infrastructures and their services is given in Figure 17.

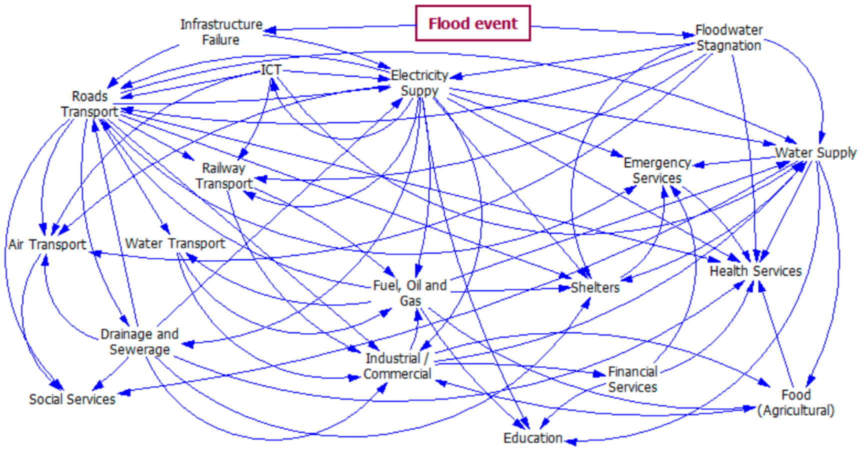

Figure 17. Example of a casual loop diagram showing interdependences between different services and infrastructures in relation to flood events in Sukhumvit area (and those interconnecting areas) in Bangkok.

This form of visualization of cause and effect connections allows for the identification of feedback loops (with temporal components such as delay times) between different parts of the system in the study area. In addition, this helps with the identification of sectors or services affected outside the flooded areas by backlog or domino effects. The identification of the different sectors potentially affected can serve as a planning tool for logistics, response and recovery efforts and also raise the awareness of issues for other stakeholders that may have previously been hidden.

4.2. Tree Diagram

Another possible and easy to follow option for presenting cascading failures is a tree diagram, which can show the steps of failure from the main or primary infrastructure or service. These steps of failure can be termed as orders of cascading effects as shown in Figure 18 below.

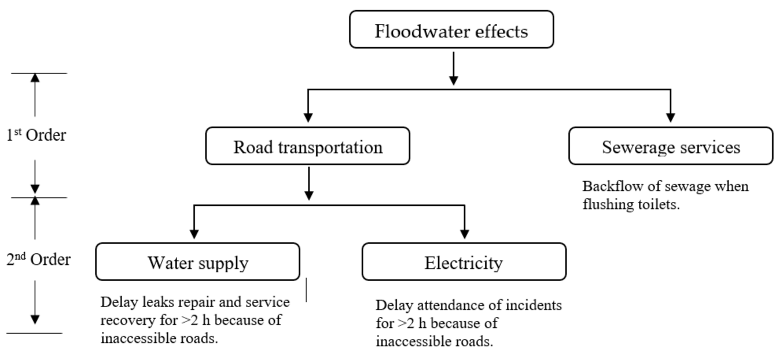

Figure 18. Cascading effects for four critical services for Sukhumvit area in Bangkok. The two orders (i.e., first order and second order) relate to time and other subsequent effects (second, third effect, and so on; see also [34]).

The tree diagram approach is a more simplistic and easy to follow means to identify the main affected services or infrastructure. This visualization method can be used to identify thresholds on each component in the tree and used as a decision support tool by planning and response teams.

4.3. GIS Maps

The GIS maps offer a great support for presenting and visualizing the results from cascading risk work. Examples given in Figures 11, 14 and 15 show that geo-referenced results from 1D–2D coupled models can readily be used to communicate the risk of flooding and to gain insights into the nature of floods and their cascading effects. However, the use of GIS maps requires technical expertise, and they are commonly used by professionals to identify affected areas, for planning and risk assessment. These styles of maps are not always the easiest form of communication with the general public, and some level of expertise of the audience may be needed for that purpose.

4.4. HAZUR

Besides the above means, the present work also applies the commercial HAZUR software (http://opticits.com/) aimed at exploring measures to enhance resilience in cities. The example given in Figure 19 shows a typical donor to receiver matrix that the HAZUR software uses. Different colours in the matrix show different messages. Red means that the receiver service will stop its operations; yellow means a reduced service; and green means that it is not affected (i.e., normal operations).

The use of display colours in the matrix that are like traffic lights can aid decision makers to quickly define dependencies and the sectors and services. This tool therefore aids in engaging different stakeholders and can be used together with other means of visualization for planning purposes and the identification of measures to lower the impacts.

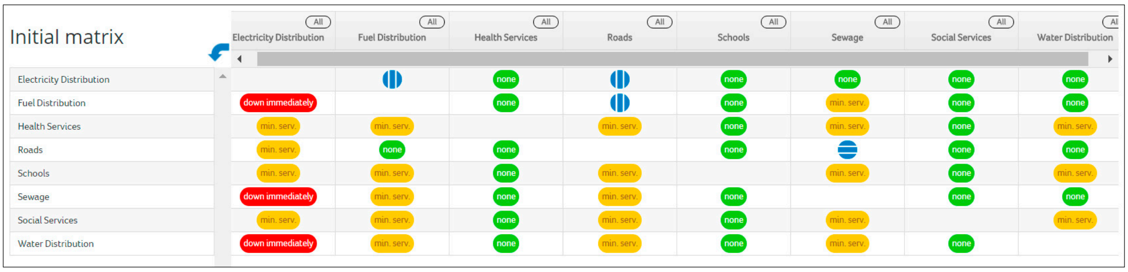

Figure 19. HAZUR matrix.

HAZUR also produces the so-called resilience map. An example of the resilience map for eight services for Sukhumvit area is given in Figure 20.

Figure 20 enables the visualisation of interdependencies between services and infrastructure. In the event of a disruption such as flooding, the users are able to assess the status of the services that have been affected both directly and indirectly.

All the visualization tools presented here aim to highlight various means of depicting interdependencies and subsequent cascading effects that flood events (or other scenarios) have on services and infrastructure in an urban area. These can be beneficial to different users and audiences. For example, tree and causal loop diagrams can serve as a starting point in stakeholder engagement to define interdependencies and open up discussions between different utility operators. These can be easily produced in face-to-face workshops. Specialist software such as HAZUR can provide a more comprehensive means for the analysis of different infrastructure assets and the overall resilience of an urban area. Although GIS maps can play an essential role in combining and analysing different sources of spatial data, they do require a greater level of technical understanding and human/computational resources. However, a good GIS system can fit multiple purposes, from spatial planning to assessing consequences, the evaluation of solutions, emergency responses and logistics.

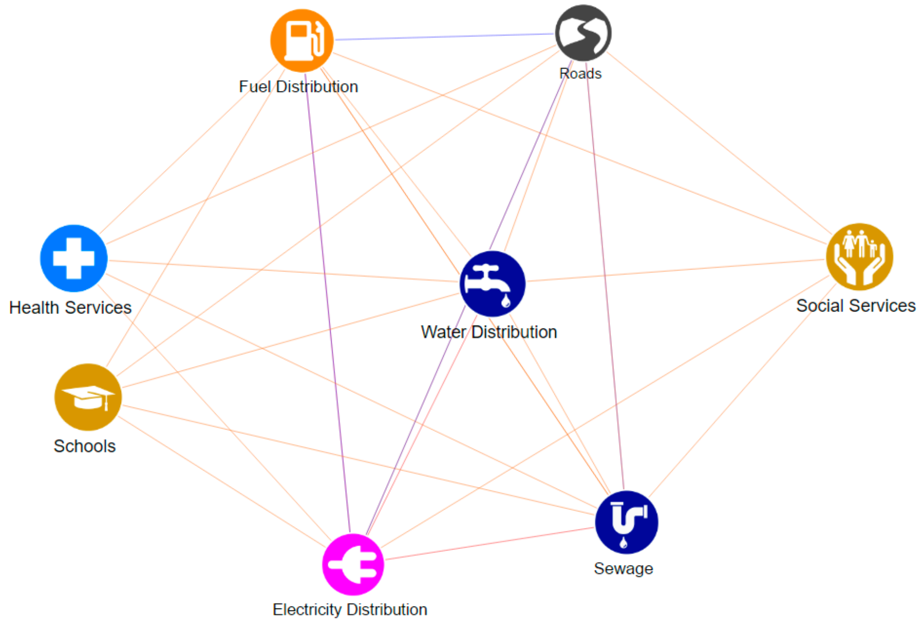

Figure 20. HAZUR resilience map for eight Sukhumvit services.

5. Conclusions

Urban areas contain a network of various infrastructures that altogether provide services that are necessary for the life of the urban population. The ability to undertake analysis of cascading effects from flooding on critical infrastructure can be very valuable for planning infrastructure improvement works. However, due to the complexities involved, this is not a straightforward task and requires a great amount of data and information. The present work describes a systematic approach for the assessment of cascading effects from floods and quantification of impacts on other urban infrastructures and their services.

The methodological framework developed and applied in the case of Sukhumvit area in Bangkok is rather generic, and with some smaller modifications, it can be applied to many other urban situations. The methodological framework can be used as a systematic guide for assessing interdependencies between different urban infrastructures, their cascading effects and for planning preventive resilience measures. The data used in the present work come from different sources such as numerical models, field investigation, interviews and utility records. The flood hazards were estimated using the 1D–2D MIKEFLOOD model developed in the previous work.

This study demonstrates that the wide-ranging impacts from floods, which can include loss of critical services, assets and goods, delay time, loss of business and income, inconveniences, disturbances and discomfort, can be traced with the analysis of cascading effects. The work undertaken for the case study area of Sukhumvit in Bangkok (Thailand) indicates that the roads in this area are prone to flooding, and as such, they can cascade to many other infrastructures and services, as well as the potential losses can be substantial. This has been confirmed through the feedback of residents and businesses in Sukhumvit area, whereby delays to schools, work places, business and also delay or cancelation of purchase orders and business appointments were their main concerns.

The cost of delay to restore water and electricity services can be considered as a net loss of income by a company due to extended loss of services and loss of business for the affected population measured in hourly per capita income. For instance, MWA had a concern about delaying the repair of the leakages and hence recovering service for at least two more hours compared to their agreed key performance indicator because of flooding problems. Therefore, the loss of income from water provision for these two hours could be a substantial loss, but the inconvenience for the population due to the absence of water supply is even greater.

Public health risk is another important aspect addressed in the present work. Such risk can come as a result of direct contact with polluted floodwater and also through intrusion of polluted floodwater into the water supply system.

The present work considered different visualization options for cascading effects, which include the use of a casual loop diagram, a HAZUR resilience map, a tree diagram and GIS maps. While the casual loop diagram and tree diagram could serve as a means for depicting interdependences between different infrastructures and their services, the GIS maps have the power of presenting the results in different spatial locations and scales. Altogether, these approaches can enable a wide range of material to be easily generated, analysed and tailored for the target audience.

The work presented here shows that by analysing the possible cascading effects of floods on critical infrastructure, we may substantially widen traditional perspectives of flood impact assessment. Instead of just taking at face value the direct or immediate flood damages, the inclusion of cascading effects enables us to extend the analysis further to other potentially affected services and businesses that may lie outside the directly flood-affected area. This recognition opens a new way of analysis, which goes beyond the traditional approaches and enables understanding of relationships between hazards, objects and actors, which is a holistic way of working.

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Author Contributions: This paper is a result of master degree thesis for Geofrey Hilly and all co-Authors were supervisors. All Authors were involved in production and writing the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Questionnaire for Assessing Flood Cascading Impacts on Critical Infrastructure in Sukhumvit Area, Bangkok (Residents and Businesses).

No.	Request for Information
1	Have you ever been affected by flood event or flood water in your house or business? คุณเคยได้รับผลกระทบจากน้ำท่วม หรือ บ้านของคุณเคยถูกน้ำท่วมหรือไม่? ☐ Yes เคย ☐ No ไม่เคย
2	How often does the streets or your house get flooded? คุณได้รับผลกระทบจากน้ำท่วมขังบริเวณถนน หรือ น้ำท่วมในที่พักอาศัยบ่อยแค่ไหน? ☐ Every rain event/season ทุกช่วงเวลาที่ฝนตก ☐ Every 2 years ทุก 2 ปี ☐ Every 5 years ทุก 5 ปี ☐ More than 5 years มากกว่า 5 ปี
3	What flood water depth did your street or house experience? ระดับน้ำท่วมสูงแค่ไหน? ☐ Less than 5 cm น้อยกว่า 5 ซม. ☐ 5–10 cm 5–10 ซม. ☐ 10–20 cm 10–20 ซม. ☐ 20–50 cm 20–50 ซม. ☐ More than 50 cm มากกว่า 50 ซม.
4	How long does the flood water take to drain away from your street or house? ใช้เวลานานเท่าไร ในการระบายน้ำออกจากบริเวณที่น้ำท่วมขัง? ☐ Few minutes ไม่กี่นาที ☐ Few hours ไม่กี่ชั่วโมง ☐ A day หนึ่งวัน ☐ More than 1 day นานกว่า 1 วัน Other: ……………… อื่น ๆ
5	What type of loss did ever flood water cause to you? How much in Thai Bath can it be? คุณได้รับเสียหายอะไรบ้างที่เกิดจากน้ำท่วม? มูลค่าเสียหายโดยประมาณเท่าไร? (บาท)

Table A1. *Cont.*

6	What type of public services get interrupted because of flood? Answer more than one สิ่งสาธารณูปโภคชนิดใดบ้าง ที่ได้รับผลกระทบเมื่อเกิดน้ำท่วม ? ตอบได้มากกว่า 1 ข้อ Electricity Water Wastewater Glossary shopping Road/Bridge ระบบไฟฟ้า ระบบประปา ระบบระบายน้ำทิ้งของห้องน้ำ ร้านค้า การสัญจร(ถนน/สะพาน)
	Please give some examples: ช่วยยกตัวอย่าง
7	How long did it take to get the public services back? ระยะเวลานานเท่าไร ที่สาธารณูปโภคจะใช้งานได้เหมือนเดิม หลังจากที่ได้รับผลกระทบจากน้ำท่วม? Few minutes Few hours A day More than 1 day Other:……… ไม่กี่นาที ไม่กี่ชั่วโมง หนึ่งวัน นานกว่า 1 วัน อื่น ๆ
	What loss or effect have you got because of disruption/absence of that service? คุณได้รับผลกระทบ/ความเสียหาย อะไรบ้าง ที่สาเหตุเกิดจากสาธารณูปโภคต่างๆ ใช้งานไม่ได้ เมื่อเกิดน้ำท่วม?
8	Did any flood event affected school attendance of your children? How often? น้ำท่วมส่งผลกระทบต่อการขาดเรียนของบุคคลในครอบครัวของคุณหรือไม่? ถ้าใช่ บ่อยแค่ไหน?
	Yes เคย No ไม่เคย How often? บ่อยแค่ไหน?
9	Did any flood event prevented you from going to hospital when you or your child was sick? คุณ หรือบุคคลในครอบครัว เคยเจ็บป่วยและพบอุปสรรคในการเดินทางไปพบแพทย์ ในช่วงเวลาที่เกิดน้ำท่วมหรือไม่? Yes เคย No ไม่เคย
10	What type of water do you use for drinking? คุณบริโภคน้ำอย่างไร ? Directly from tap Boil or filter first Buy Bottled water บริโภคจากก๊อกน้ำ ต้ม หรือกรองก่อนบริโภค ซื้อน้ำขวดบริโภค
	Please give your reason? บอกเหตุผล?
11	Any other things you can tell us about flood problems in Sukhumvit? เรื่องอื่นๆ ถ้ามี (เล่าปัญหาน้ำท่วมบริเวณสุขุมวิท)

Name (ชื่อ):…………………………… Street (ถนน):………………………. Date (วันที่):………..……………….

Appendix B

Table A2. Questionnaire for Assessing Flood Cascading Impacts on Critical Infrastructure in Sukhumvit Area, Bangkok (for Motorbikes, Taxis, 4WD and Buses).

Motorbik (รถจักรยานยนต์) **Taxis (ท็กซี่)** **SUV (4WD) (กระบะ)** **Bus (รถบัส)**

No.	Request for Information
1	What is your experience and opinion about flooding problem in Sukhumvit area? ความคิดเห็นเกี่ยวกับปัญหาน้ำท่วมบริเวณสุขุมวิท เล่าประสบการณ์ที่เคยเจอ
2	Do you normally drive your transportation device on a flooded roads? คุณเคยขับรถในช่วงที่น้ำท่วมถนนหรือๆไม่ Yes เคย No ไม่เคย
3	At what flood water depth you normally drive your equipment? Can mark more than oneระดับน้ำท่วมที่คุณเคยพบ ในขณะขับรถ (ตอบได้มากกว่า 1 ข้อ) Less than 5 cm 5–10 cm 10–20 cm 20–30 cm More than 30 cm น้อยกว่า 5 ซม. 5–10 ซม. 10–20 ซม. 20–50 ซม. มากกว่า 50 ซม.
4	What is your normal average driving speed when the road is dry ความเร็วขณะขับรถ ในช่วงที่ถนนแห้งเป็นปกติ
	During Peak Traffic (07:00–09:00 and 17:00–19:00) Hours ในช่วงการจราจรติดขัด (07:00–09:00 and 17:00–19:00) During Off-Peak Traffic Hours (09:00–17:00 and at night) ในช่วงการจราจรไม่ติดขัด (09:00–17:00 and เวลากลางคืน)
5	What is your driving speed (in km/h) for different flood water depth? Can answer more than one ความเร็วขณะขับรถ ในช่วงที่น้ำท่วม Less than 5 cm 5–10 cm 10–20 cm 20–30 cm More than 30 cm

Table A2. *Cont.*

	น้อยกว่า 5 ซม. ☐ 5–10 ซม. ☐ 10–20 ซม. ☐ 20–50 ซม. ☐ มากกว่า 30 ซม. ☐
6	Does these frequent flooding have any impact in your transportation business? How much loss can you estimate that you get during flooding days? (Can put in Baht or in percentage) ปัญหาน้ำท่วมส่งผลต่อการประกอบอาชีพของคุณหรือไม่? ช่วยประเมินค่าความเสียหาย (ราคาเป็นบาทหรือ%)
	Income loss compare with dry days? รายรับลดลงเท่าใด เมื่อเปรียบเทียบกับช่วงน้ำท่วมและน้ำไม่ท่วม ☐ Increase maintenance and repair cost? ค่าใช้จ่ายที่เพิ่มขึ้นในการซ่อมแซม/บำรุงรักษารถยนต์ เท่าใด ? (บาท) ☐ Do you get more passengers after rain? คุณได้ผู้โดยสารเพิ่มมากขึ้นหรือไม่ หลังจากที่ฝนหยุดตก ☐

Name (ชื่อ):................................ Street (ถนน):........................... Date (วันที่):...........................

Appendix C

Table A3. Questionnaire for Assessing Flood Cascading Impacts on Critical Infrastructure in Sukhumvit Area, Bangkok (Service Providers).

Utility Name: **Metropolitan Waterworks Authority (MWA)** Type of Service: **Water Supply**
ชื่อหน่วยงาน ประเภทของบริการ

No.	Request for Information
1	Have your service provision ever been affected by flood event or flood water? หน่วยงานของท่านเคยได้รับผลกระทบจากการทำงานในขณะน้ำท่วม หรือไม่? ☐ Yes เคย ☐ No ไม่เคย
	Please give some examples? ถ้าเคย ช่วยยกตัวอย่างด้วย
2	How often does your service infrastructure get flooded? หน่วยงานของท่านได้รับผลกระทบจากน้ำท่วม บ่อยแค่ไหน? ☐ Every rain event/season ทุกช่วงเวลาที่ฝนตก ☐ Every 2 years ทุก 2 ปี ☐ Every 5 years ทุก 5 ปี ☐ More than 5 years มากกว่า 5 ปี
3	At what flood water depth does your service infrastructures get affected? ระดับน้ำท่วมเท่าไร ที่ส่งผลกระทบต่อการปฏิบัติการในหน่วยงานของท่าน? ☐ Less than 5 cm น้อยกว่า 5 ซม. ☐ 5–10 cm 5–10 ซม. ☐ 10–20 cm 10–20 ซม. ☐ 20–50 cm 20–50 ซม. ☐ More than 50 cm มากกว่า 50 ซม.
4	How long does the flood water take to drain away from your infrastructure and restore service provision? ใช้เวลานานเท่าไรในการระบายน้ำท่วมขังในหน่วยงานของท่าน? ☐ Few minutes ไม่กี่นาที ☐ Few hours ไม่กี่ชั่วโมง ☐ A day หนึ่งวัน ☐ More than 1 day นานกว่า 1 วัน Other: อื่น ๆ
5	What operational components are more affected or vulnerable to floods and at what water level? ในหน่วยงานของท่าน วัสดุ อุปกรณ์ หรือ เครื่องมือใดบ้าง ที่ได้รับผลกระทบจากน้ำท่วม? ระดับน้ำเท่าไร?
6	How long and at what average cost does it take to restore the service provision? น้ำท่วมนานเท่าไร ? มูลค่าความเสียหาย หรือค่าใช้จ่ายที่ใช้ในการซ่อมแซมวัสดุ อุปกรณ์ต่างๆให้สามารถกลับมาใช้งาน และเปิดให้การบริการได้เหมือนเดิม เท่าไร?
7	What kinds of prevention and mitigation measures have you taken so far to avoid future service interruptions due to floods? E.g., flood defence structure, use of water proof units. หน่วยงานของท่าน มีมาตราการบรรเทาความเสียหาย ที่เกิดจากน้ำท่วมอย่างไรบ้าง เช่น ทำกำแพงกันน้ำท่วม ฯลฯ
8	Customer complaints about water turbidity level after flood events มีการร้องเรียนจากผู้ใช้น้ำ เรื่องน้ำประปาไม่สะอาด มีสีขุ่น หลังจากที่เกิดน้ำท่วมหรือไม่
9	Dependence in electricity from MEA to supply water (pumping systems) and failure history. Standby generators? มีปัญหาเรื่องไฟฟ้าดับในขณะทำการสูบน้ำบ้างหรือไม่ ถ้ามี มีวิธีแก้ไขอย่างไร ใช้ระบบไฟฟ้าสำรองหรือไม่
10	Effects of useful life of water assets associated with exposure to floodwater ผลกระทบที่ได้รับจากน้ำท่วมมีอะไรบ้าง
11	Failure of water supply service provision due to flood events (2001–1215). What is the affected area when water is shutoff? Beyond Sukhumvit area? ขอทราบปัญหาในการจ่ายน้ำขัดข้อง โดยมีสาเหตุมาจากน้ำท่วม ในช่วง พ.ศ. 2544–2558
12	What do you think are the current constraints in managing your assets' service during emergencies in flood events? ข้อจำกัดในการทำงานที่เกิดขึ้นในช่วงน้ำท่วม
13	In your opinion, is the public aware of flood risk and its potential impacts on your services? คุณคิดว่า ประชาชนตระหนักถึงความเสี่ยงจากน้ำท่วม และผลกระทบที่อาจเกิดขึ้นในการให้บริการของคุณ ในช่วงน้ำท่วมหรือไม่ อย่างไร
14	Any other things you can tell us about flood problems in Sukhumvit? เรื่องอื่นๆ ถ่ามี (เล่าปัญหาน้ำท่วมบริเวณสุขุมวิท)

Officer's Name (**ชื่อ เจ้าหน้าที่**): . Date (**วันที่**):

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