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Evidence-Based Contingency Planning to Enhance Local Resilience to Flood Disasters

Miho Ohara, Naoko Nagumo, Badri Bhakta Shrestha and Hisaya Sawano

Abstract

The Sendai Framework for Disaster Risk Reduction 2015–2030 addresses the importance of “Enhancing disaster preparedness for effective response and to ‘Build Back Better’ in recovery, rehabilitation and reconstruction” as the fourth priority action. One of the practical tools to achieve effective preparedness for flood disaster response is evidence-based contingency planning, which is based on scientific approaches such as flood simulation and quantitative risk assessment. This method, however, is not always feasible to disaster-prone areas in Asia due to the lack of data on natural and social conditions. This chapter proposes a method with six steps for local communities to conduct contingency planning by assuming the dynamic change of inundation using flood simulation, assessing flood risk with key indicators, deciding response strategies against the identified flood risk and developing a contingency plan beforehand. This method was first applied to one of the Asian flood-prone areas, Calumpit Municipality in the Pampanga River basin of the Philippines, to verify its effectiveness in areas where the availability of natural and socio-economic data is limited.

Keywords: contingency planning, disaster response, flood, risk assessment, simulation

1. Introduction

Preparing a contingency plan before disasters is essential to increase the capacity of personnel in charge of disaster response and enhance local resilience to disasters. The Sendai Framework for Disaster Risk Reduction 2015–2030 [1], adopted at the Third United Nations World Conference on Disaster Risk Reduction in 2015, addresses the importance of “Enhancing disaster preparedness for effective response and to ‘Build Back Better’ in recovery, rehabilitation and reconstruction” as the fourth priority action. More specifically, its paragraph 33 states that national and local governments shall prepare or review and periodically update disaster preparedness and contingency policies, plans and programmes with the involvement of the relevant institutions, considering climate change scenarios and their impact on disaster risk and facilitating, as appropriate, the participation of all sectors and relevant stakeholders [1].

In order to achieve effective disaster response, it is important first to assume possible disasters, then quantify expected disaster damage and conduct contingency planning based on the scenarios of the possible disasters. One of the practical tools to carry out this process is evidence-based flood contingency planning, which is based on scientific approaches such as flood simulation and quantitative risk assessment. This planning method, however, is not always feasible to disaster-prone areas in Asia due to the lack of data on natural and social conditions. To overcome such a challenge, the International Centre for Water Hazard and Risk Management (ICCHARM) focuses on flood disasters and proposes an effective method for local communities to predict the dynamic change of inundation using flood simulation, assess flood risk with key indicators, decide coping strategies against the identified flood risk and develop a contingency plan beforehand. This method is first applied to one of the flood-prone areas in Asia, Calumpit Municipality in the Pampanga River basin of the Philippines, to verify its effectiveness in areas where the availability of natural and socio-economic data is limited.

2. Proposal of evidence-based flood contingency planning

The “ISO22301 Societal security—Business continuity management systems” specifies requirements for all types of organisations to plan, implement, review and improve a documented management system to prepare for, respond to and recover from disruptive incidents [2]. It requires the organisations to select business continuity strategy based on the outputs from the risk assessment and business impact analysis. The risk assessment aims to identify and evaluate the risk of disruptive incidents to the organisations, while the business impact analysis assesses the impacts of disrupting activities that support organisation’s services. To conduct evidence-based flood contingency planning in reference to the procedures employed in the ISO22301, six steps are proposed, as shown in **Figure 1**.

The first step of this planning is to understand the current conditions of the target communities such as topography, land use, population and structures, as well as

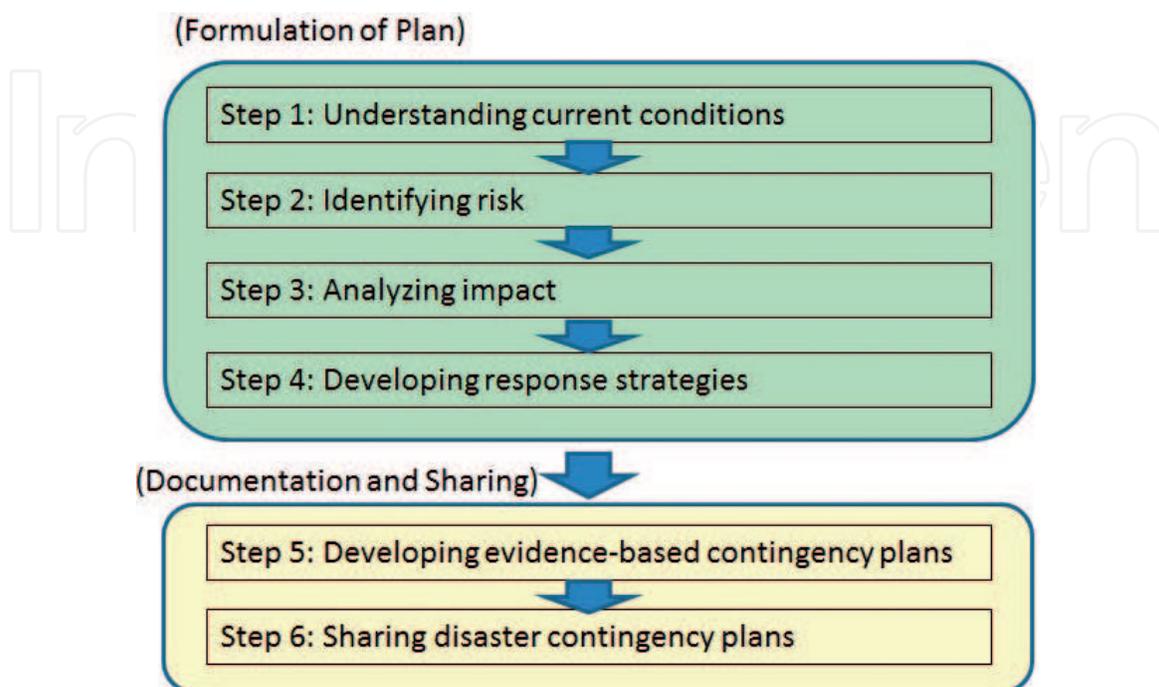


Figure 1.
Six steps of evidence-based flood contingency planning.

past flood records in the area. At the second step, flood hazards and risks are identified through flood and inundation simulations conducted by national or provincial governments. Flood scenarios are presented with two key components, i.e. a flood inundation map and a time-series inundation water chart, to illustrate dynamic changes in inundation depth for residents to easily understand how the inundation may expand, linger and recede in their communities. The third step is flood impact analysis, in which the numbers of residents and houses at risk are estimated based on the average ground-floor height of houses, and possible problems the community may face due to the flood are identified. At the fourth step, the communities in the target area should develop a response strategy. Necessary actions should be discussed according to the time sequence of “before the flood”, “during the flood” and “after the flood”. The fifth and sixth steps are documentation and sharing of the plan among the community members. It is also important that the produced plan should be updated constantly through the Plan-Do-Check-Act cycle.

3. Case study area

Among the Asian flood-prone areas, a municipality called Calumpit was selected as the first case study area. It is in Bulacan Province in Pampanga River basin located northwest of Metro Manila in Central Luzon Island, Philippines. The municipality lies at the junction of several rivers, including Pampanga, Angat and Labangan, as illustrated in **Figures 2** and **3**. This topography makes Calumpit one of the most flood-prone municipalities in the Philippines. As of 2010, 101,068 people live in an area of 5625 ha, or 2.03%, of the province. The municipality has 29 barangays, the smallest administrative units. The recent largest flood was caused by Typhoons

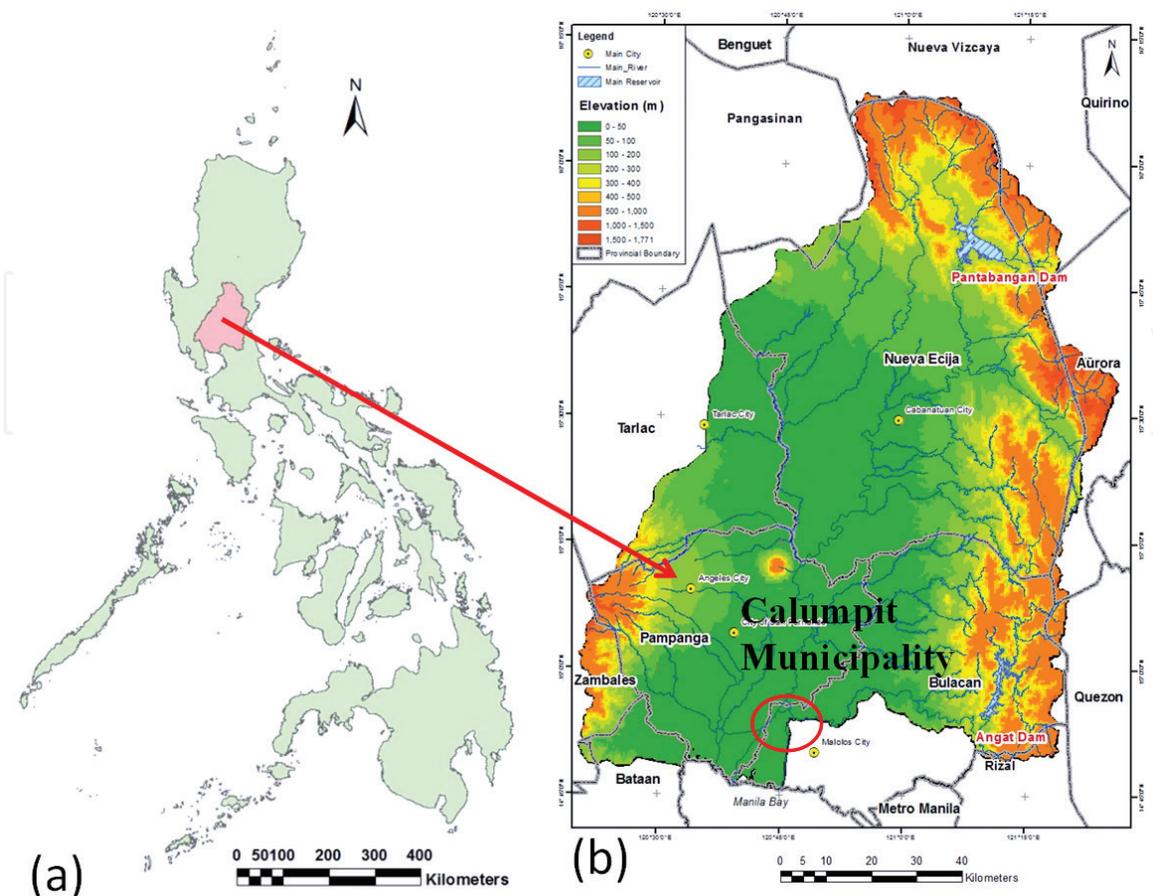


Figure 2. Location of Calumpit in Pampanga River basin. (a) Luzon Island and (b) Pampanga River basin.

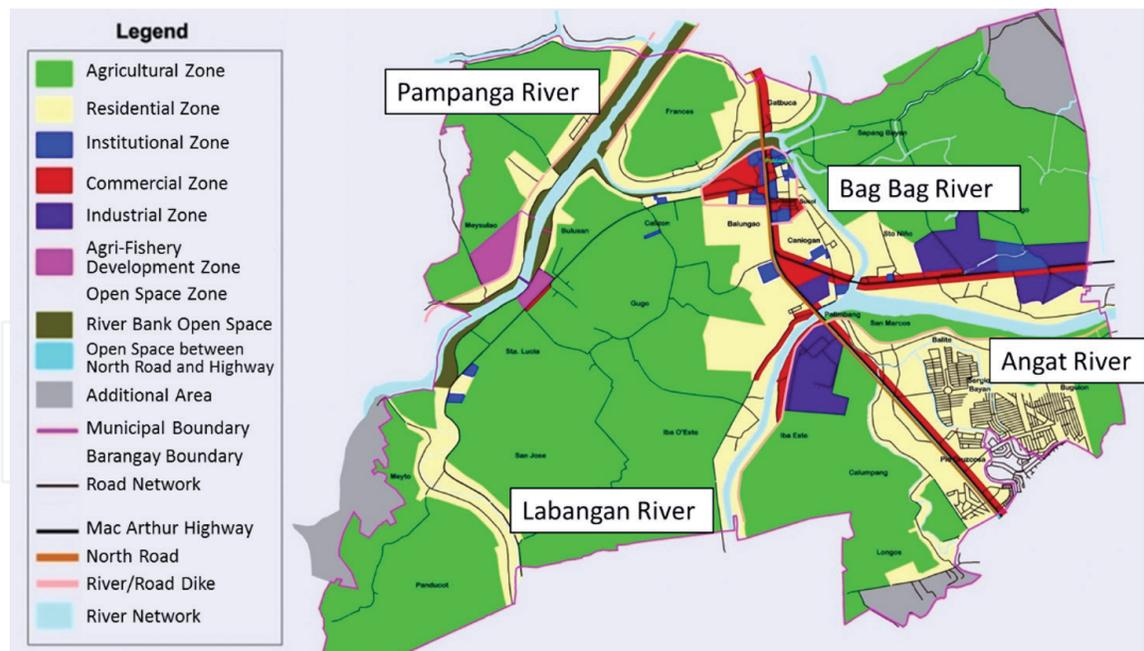


Figure 3.
Land use map of Calumpit [4].

Pedring and Quiel in September 2011, and a large area of the municipality suffered massive flood damage. Due to an inundation of 1.2–1.5 m deep, Calumpit lost its government functions, which consequently impeded emergency response.

The Philippine Disaster Risk Reduction and Management Act (Republic Act No. 10121) [3], enacted in 2010, provides for the development of policies and plans and the implementation of actions and measures related to all aspects of disaster risk reduction and management. It defines the National Disaster Risk Reduction Management Council (NDRRMC) as the national organisation to coordinate, integrate, supervise, monitor and evaluate disaster policymaking. It also mandates the establishment of the Disaster Risk Reduction and Management Office in every barangay, municipality, city and province.

Calumpit has the Municipal Disaster Risk Reduction Management Council (MDRRMC) and the Barangay Disaster Risk Reduction Management Council (BDRRMC) in its 29 barangays. The act defines MDRRMCs and BDRRMCs to perform functions such as designing and coordinating disaster risk reduction and management activities, supporting risk assessments and contingency planning activities at the local level [3]. Following this act, the MDRRMC of Calumpit published a contingency plan [4], which describes governmental emergency response in case of a flood. It assumes casualties, structural damage and impacts on livelihood, infrastructure and facilities in the worst-case scenario, based on the experience during Typhoons Pedring and Quiel in 2011. However, the scenario based on the past flood experiences makes it difficult to assume future floods of different scales which have never occurred before. It is therefore recommended to make contingency plans by quantifying a spatial distribution of expected damage and necessary needs in consideration of dynamic changes in inundation depth provided from flood inundation simulations performed for each community.

4. Case study of evidence-based flood contingency planning

The proposed method was applied to Calumpit Municipality in Bulacan Province.

Figure 4 illustrates overall activities related to the six steps to be proposed. The first and second steps were applied to the whole area of the municipality in April 2014. At the third and fourth steps, two flood-prone communities were selected as model sites, and their flood contingency plans were jointly developed through workshops with community leaders and members. In the workshops, the participants discussed problems they may face during the flood of each scale and proposed necessary response actions in order to make response strategies. The final workshop was held in March 2016, inviting all the community leaders in the municipality, and the experience in the workshops was shared among the participants. The following subchapters detail each step:

4.1 Step 1: understanding current conditions

In areas where the availability of natural and socio-economic data is limited, administering interviews and questionnaires to local government officials, community leaders and local people is useful to understand the current conditions of their localities. In this study, interviews were conducted at MDRRMO and selected communities [5]. The surveys found that population census data at the barangay level was available, while the spatial distribution data of buildings was not. Then, a questionnaire survey was administered to all 29 barangay leaders to understand the building conditions in each barangay. The houses in the 29 barangays were classified and tallied according to construction types and storeys. Of those, 62.5% were a one-storey structure, while the rest were two-storey.

Interviews at the selected individual households were also conducted to understand recent flood damage, including the damage status of house structures, property and family members and their behaviours during the recent floods. During the interviews, the survey staff measured the heights of the first floor, ceiling and flood marks from the past floods with the permission of family members. From the household survey, it was found that the average first-floor height of the one-storey houses was 0.54 m from the ground, while that of the two-storey houses was 0.17 m, as shown in **Figure 5**. **Table 1** summarises the conditions of the houses at five inundation levels using the thresholds from the household interviews. Different damages to the livelihood of the residents are listed according to inundation levels. Inundation level 1 with a water depth of 0.17 m or lower did not inundate inside the house. At

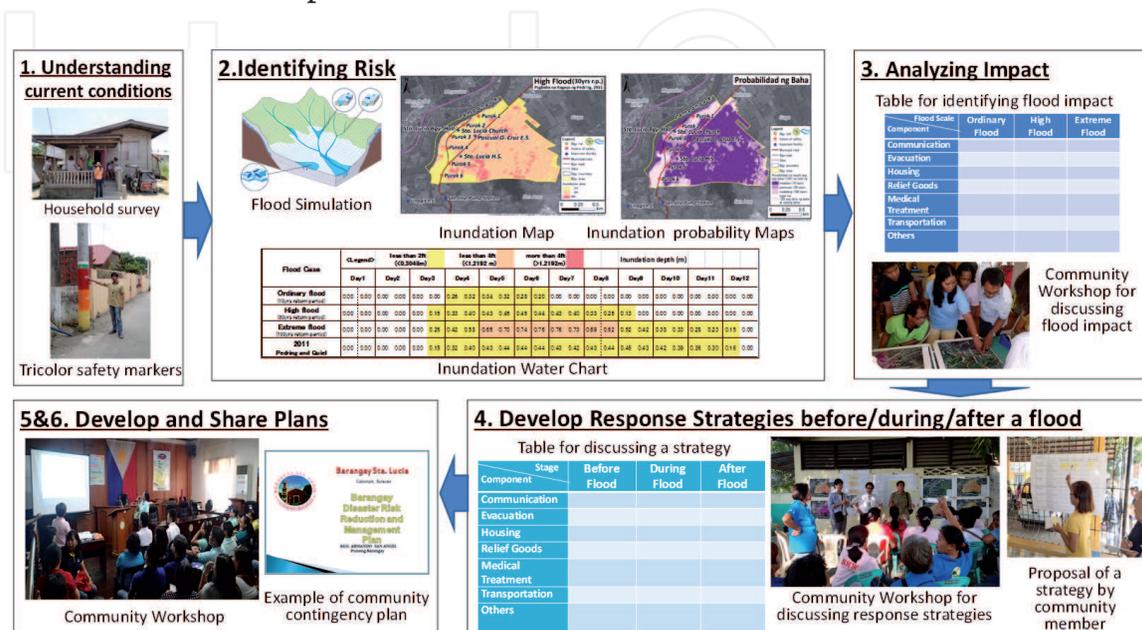


Figure 4. Activities at six steps of evidence-based flood contingency planning.

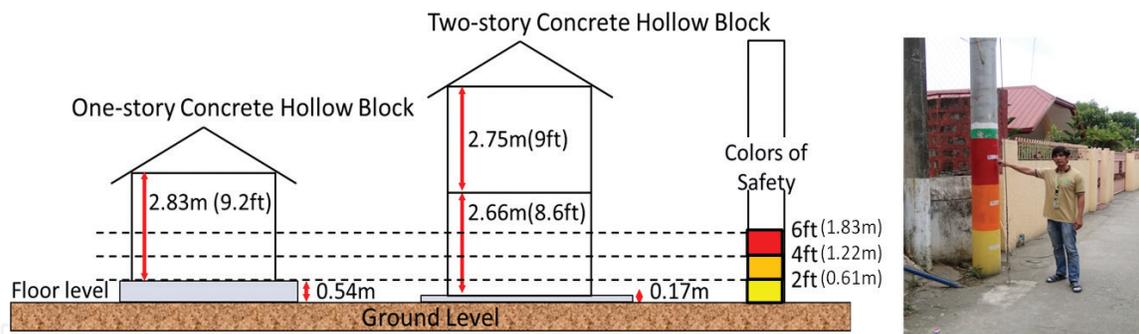


Figure 5.
Threshold of inundation based on measurement results.

inundation level 2, the two-storey houses started being inundated. At inundation level 3, at which the water depth exceeds 0.54 m, both one- and two-storey houses suffered from inundation above the first floor, which suggests that the residents had to stay somewhere above the water level or evacuate to safer places near their houses.

The household interviews also found that the inundation above electric plugs caused severe damage to daily life. The height of electric plugs averaged 1.27 m and that of LP gas tanks 0.60 m. The residents usually move LP gas tanks to the second floor or to the rooftop to use them for cooking during an inundation. Inundation level 4 was set, based on the observed average height of electric plugs, as the condition cutting local people off from power. At inundation level 5, the inundation depth exceeds 2.83 m, the height of the second floor of a house. Under this situation, they could not find an evacuation space due to the rarity of buildings having three storeys or more, which means an inundation of this scale is likely to be a potentially life-threatening crisis for the residents.

Calumpit Municipality has its own community flood warning system called “colours of safety”. This system uses power poles painted in three colours (yellow, orange and red) by every 2 ft to visualise the level of danger and help residents make decisions on evacuation. At present, 193 electric poles in the municipality are tricoloured for this purpose. The residents are advised to evacuate before the water reached the red colour.

4.2 Step 2: identifying flood risk

In this step, the expected flood inundation area was delineated by flood inundation simulation using the rainfall-runoff-inundation model (RRI model), developed

Level	Inundation Height (m)	One story house	Two story house
Level 1	0.0-0.17	No inundation	No inundation
Level 2	0.17-0.54	No inundation	Start Inundation
Level 3	0.54-1.55	Inundation	
Level 4	1.55-2.83	Inundation (Cannot use electricity)	
Level 5	Above 2.83	Inundation (A house is submerged)	Inundation (Inundation exceeds average height of second floor)

Table 1.
Conditions of houses at each inundation level.

by ICHARM. The RRI model is a two-dimensional model capable of simulating rainfall, runoff and flood inundation simultaneously Sayama et al. [6]. The model deals with slopes and river channels separately. It applies a 2D diffusive wave model to flows on slope grid cells and a 1D diffusive wave model to channel flows. The software of the model can be downloaded from the ICHARM website [7] for free.

We used the RRI model that Shrestha et al. [8] locally customised to conduct flood simulation for the Pampanga River basin and performed hazard mapping for Calumpit Municipality, following the eight sub-step procedures [5] presented below:

Sub-step 1: acquisition of input data for the model.

Sub-step 2: acquisition of flood mark records.

Sub-step 3: flood inundation simulation during Typhoons Pedring and Quiel in September 2011 (grid, 200 m).

Sub-step 4: calibration of the model by comparing observed and simulated discharges in sub-step 3.

Sub-step 5: validation of the model by comparing the simulation results with flood mark records.

Sub-step 6: frequency analysis using rainfall data.

Sub-step 7: flood inundation simulation using design rainfall assumed with 10-, 30- and 100-year return periods.

Sub-step 8: development of inundation depth maps in Calumpit with 10-, 30- and 100-year return periods (grid, 5 m).

The simulation used the high-resolution digital elevation model (DEM) of 5 m grid, observed by the interferometric synthetic aperture radar (IFSAR) and provided by the National Mapping and Resource Information Authority (NAMRIA) in the Philippines without a fee. Inundation simulation for the River basin was first conducted using DEM data of 200 m grid created by IFSAR. After the flood inundation simulation, a grid of Calumpit with the inundation depth of 5 m was developed by obtaining the difference between the floodwater surface level of 200 m grid and the ground-level surface level of 5 m grid by IFSAR. As a result of the flood inundation simulation, three kinds of flood inundation maps with 10-, 30- and 100-year return periods were produced for ordinary, past largest and extreme floods. From the frequency analysis using past rainfall data, a return period of the flood caused by Typhoon Pedring in 2011 was estimated to be 28.3 years. The occurrence of flood inundation with a 30-year return period means the reoccurrence of the 2011 flood.

Figure 6 shows the inundation maps produced in this step.

Municipal personnel pointed out that the word “return period” is too technical for residents to understand. Thus, to help them understand the flood scale easily, floods were named according to their scales as “ordinary flood” for 10-year return period floods; “high flood” for 30-year return period floods, whose scale is roughly equal to the largest recorded flood in 2011; and “extreme flood” for 100-year return period floods.

Based on the flood simulation results, maps and a chart were created for each barangay, as shown in **Figure 7**. As mentioned above, Calumpit Municipality has its own community flood warning system called “colours of safety” in which power poles are painted in three colours by every 2 ft to visualise the level of danger and help residents make decisions on evacuation. The inundation maps for each barangay (**Figure 7b**) adopted this locally familiar tricolour system to show the inundation depth.

In addition to inundation maps with three different return periods, inundation probability maps, time-series inundation charts and resource maps were also developed for each barangay. The inundation probability map (**Figure 7c**) was created to help people understand the most frequently inundated areas, by combining the information of three inundation maps with 10-, 30- and 100-year return periods.

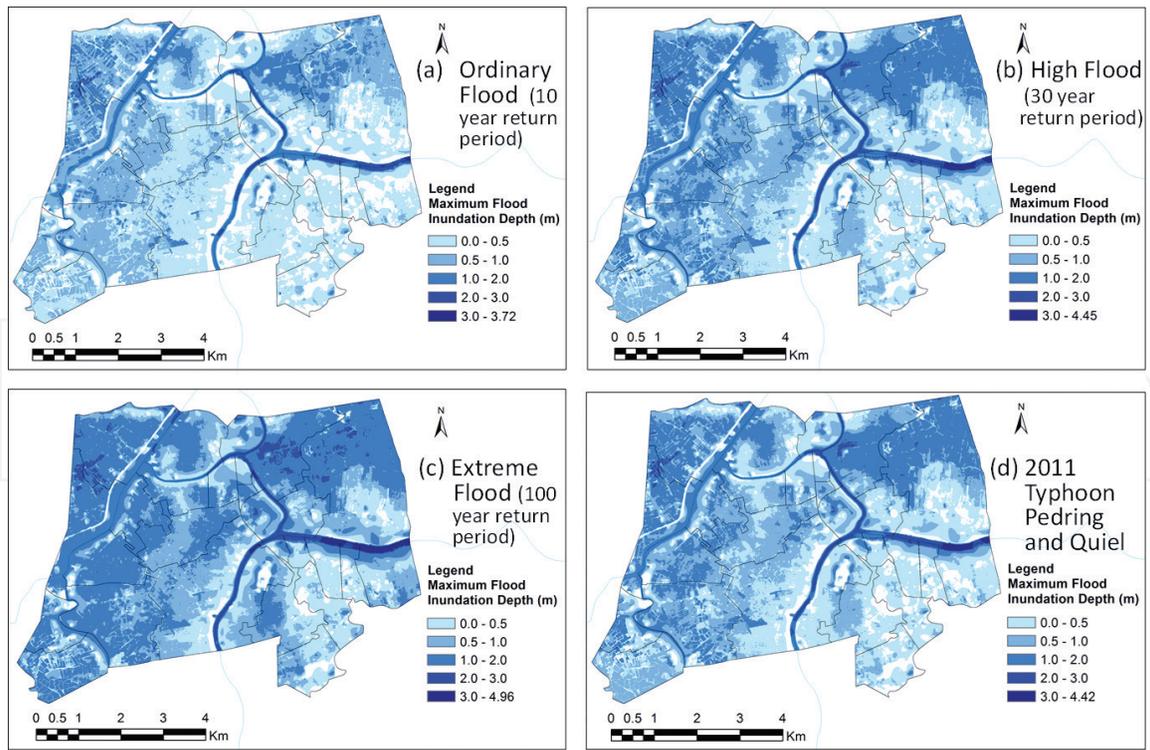
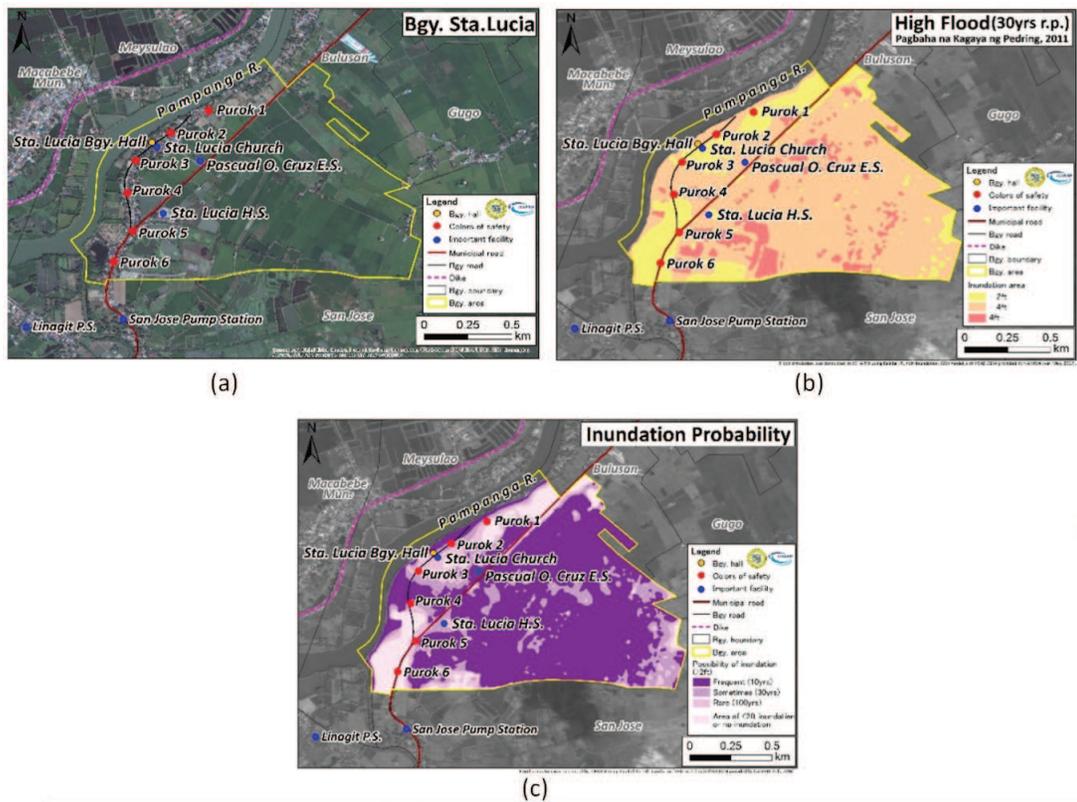


Figure 6. Maximum inundation depth maps.



Flood Case	Inundation depth (m)									
	Legend		less than 2ft (<0.3048m)		less than 4ft (<1.2192 m)		more than 4ft (>1.2192m)		Day8	Day9
	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
Ordinary flood (10yrs return period)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
High flood (30yrs return period)	0.00	0.00	0.00	0.00	0.15	0.33	0.40	0.43	0.45	0.45
Extreme flood (100yrs return period)	0.00	0.00	0.00	0.00	0.26	0.42	0.58	0.65	0.70	0.74

(d)

Figure 7. Maps and chart for each barangay (example of Barangay Santa Lucia).

The map shows the probability of inundation that may exceed 2 ft. (0.61 m) or higher, the depth almost equal to the height of the first floor of a one-storey house. The area in dark purple colour indicates that one-storey houses in the area may be inundated above the first-floor level in case of a 10-year return period flood. The time-series inundation chart (**Figure 7d**) shows the chronological development of inundation in a barangay using different colours. From this chart, people can understand how many days the area may be inundated according to different flood scales. In the resource map (**Figure 7a**), the locations of barangay halls, evacuation centres and electric poles for “colours of safety” were plotted.

In order to quantify flood risk at each community, the number of affected residents was estimated based on damage levels by overlaying inundation maps on the population distribution map of each barangay. Since most of the municipal area of Calumpit is used for agricultural purposes, we considered it reasonable to assume that the population is not uniformly distributed over the municipal area but disproportionately distributed in the built-up areas. For this reason, the built-up areas were identified. The identification of the built-up areas was made using satellite images because no digital land use maps were available. If accurate land use maps are available, they can be used for the purpose. The population in each barangay was assumed to be evenly distributed in its identified built-up areas. Then, the number of affected residents in each barangay was estimated according to inundation levels (**Table 1**). As a result, the total ratio of affected residents living in the area with inundation levels 3–5 was calculated to be 55.9% for a 100-year flood, while 34.6% for the past maximum flood case, as shown in **Figure 8**. That well over 55% of the population may suffer at inundation level 3 or above in a 100-year flood means both one- and two-storey houses are very likely to be inundated above the floor.

Figure 9 shows the estimated number of affected residents in each barangay in both flood cases. In case of a 100-year flood, more than 90% of the residents in barangays of Sapang Bayan, Corazon, Bulusan, Gugo and San Jose may suffer from an inundation of level 3 or above. They should prepare for prompt evacuation in case of such a severe flood. In this case study, only the number of affected residents was analysed due to a lack of spatial distribution data of buildings. If the data is available, the number of damaged houses and the repairing cost could be estimated. Moreover, the number of affected residents or those who need to evacuate outside their houses could be calculated more accurately based on the number of damaged houses.

4.3 Step 3: analysing flood impact

The third step is flood impact analysis, in which possible problem communities may face in the event of a flood are identified. The most important thing is for

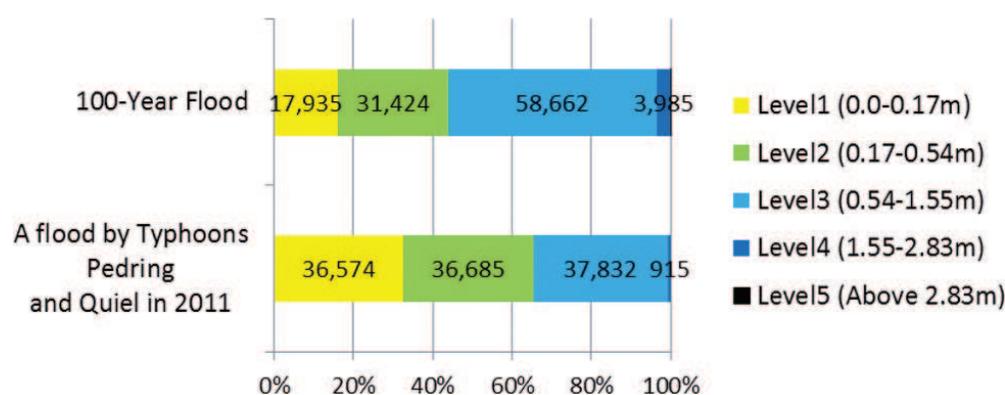


Figure 8.
 Estimated number of affected residents in Calumpit.

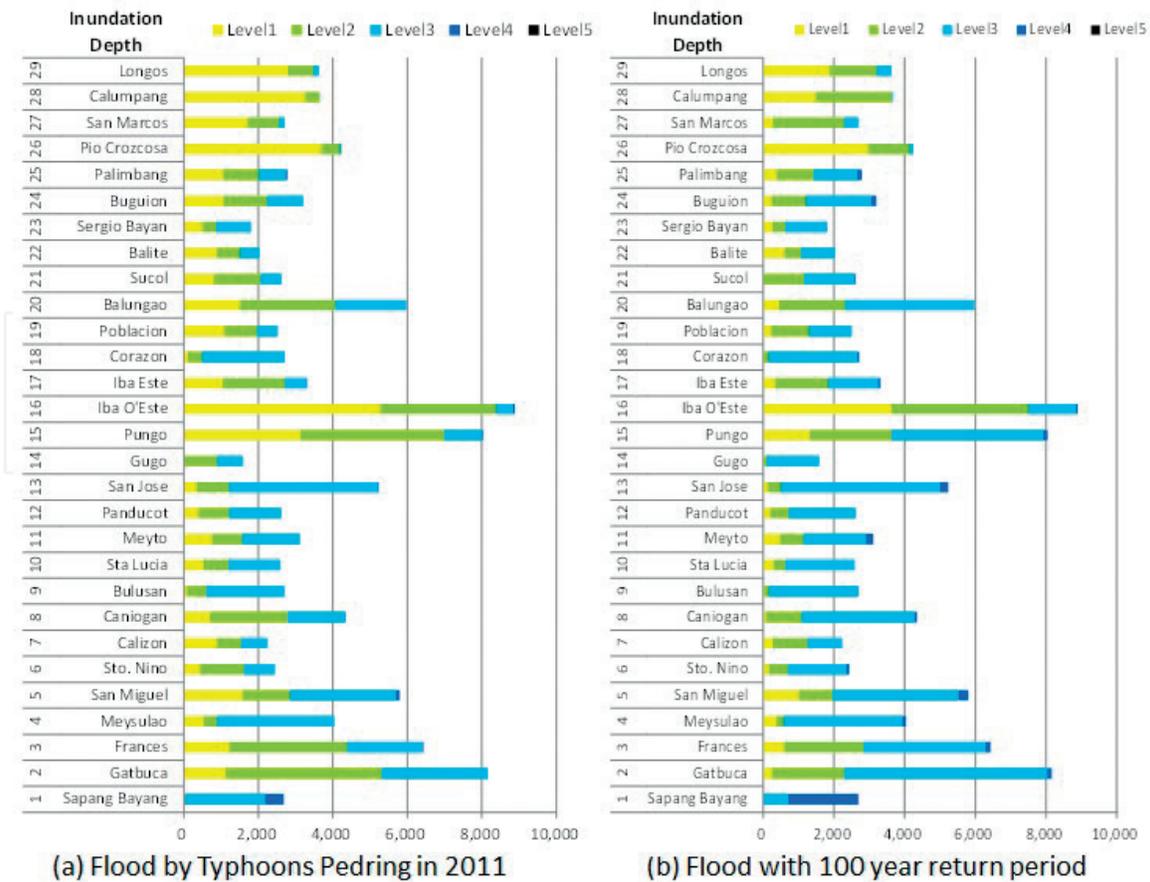


Figure 9. Estimated number of affected residents in each barangay.

communities to understand how flood impact becomes severer according to flood scales so that they can take sensible measures to increase disaster preparedness by themselves. Two flood-prone barangays were selected as model sites to develop flood contingency plans with barangay leaders and members through workshops. The participants of the workshops discussed problems on key components, such as information communication, evacuation, housing, water, food, relief goods, medical treatment and transportation, for three flood patterns identified in step 2: ordinary flood, high flood and extreme flood.

Table 2 summarises the impact of floods identified at the workshops in the two barangays. In case of high flood, many houses may be inundated, and the residents may experience various types of damage to their livelihood, while only non-elevated houses may be inundated in ordinary foods. The participants anticipated problems associated with information acquisition, capacities of evacuation centres, supplies of water, power, relief goods, availability of medical treatment and transportation. In case of extreme flood, they anticipated difficulty in repairing houses as a considerable number of inundated houses may well mean the shortage of construction materials. A photo in Figure 10 shows a scene of a workshop.

4.4 Step 4: developing response strategies

At this step, necessary actions associated with the flood impact on each key component identified in step 3 are discussed at each community according to the time sequence of “before the flood”, “during the flood” and “after the flood disaster”. For this purpose, the second workshop was held at each of the two barangays. At the workshop, the participants were requested to share opinions on necessary actions by

Flood Scale / Component	Ordinary Flood	High Flood	Extreme Flood
Information Communication		-No battery charge for telephone/mobile phone -Lack of information about inundation /damage situation.	
Evacuation		-Fast speed of rising water during inundation. -Evacuation center doesn't have enough capacity.	
Housing	-Only non-elevated houses get inundated.	-Difficulty in cleaning houses -Many houses get inundated.	-Difficulty in cleaning houses -Many houses get inundated. -Need of more construction materials for repairing houses.
Water, Food, Relief Goods	-No/less water supply. -No electricity.	-No water supply, no electricity -Delay of relief goods -Relief goods get wet. -Need of portable restroom	
Medical Treatment		-Need of medical mission, providing medicines for leptospirosis, fever etc.	
Transportation		-Difficult to go to center area because access road to the elevated road are inundated.	
Others		-Damage of Rice field -Delay in education in school	

Table 2.
Impact of floods on barangay identified at workshops.

writing them down on Post-its and show them to other participants. Then, the actions presented by the participants were sorted out into two categories: actions that a barangay should implement immediately as self-help and mutual support and requests that a barangay should make to municipal, provincial or national governments as public assistance. This activity will help clarify actions to be taken by themselves and requests to be made to higher administrative organisations. **Tables 3** and **4** summarise the results of the discussions at the two barangay workshops on what they should do before, during and after the flood and what they should request. The participants found the importance of response strategies on actions such as informing water levels regularly to the municipal office, leading residents to evacuate quickly to a safer place, keeping relief goods dry, saving children and seniors and supporting residents in getting back to normal life quickly.

Although self-help and mutual support among residents are the priority for community disaster management, actions available for them are often limited due to budget and manpower constraints. At the series of workshops, the participants listed the requests they would like to make to higher administrative organisations, as shown in **Table 4**. **Figures 11** and **12** are photos taken at workshops.



Figure 10.
Workshop at Barangay Bulusan.

Time Key Component	Before Flood	During Flood	After Flood
Information Communication	-Communicate with MDRRMO(Municipal Disaster Risk Reduction and Management Office)	-Inform water level at “Colors of safety” regularly to MDRRMO. -Keep communication with outside of the Barangay by using generator for charging battery for mobile phone. -Inform obtained information to Barangay people.	-Identify water level, duration, source of flooding.
Evacuation	-Make residents evacuate quickly to safer place -Quantify vulnerable individuals /families	-Make residents evacuate quickly to safer place -Quantify affected individuals /families	
Housing			-Support residents to clean houses for getting back to normal life quickly.
Water, Food, Relief Goods		-Get/provide relief goods and keep them dry.	
Medical Treatment		-Save children and elder people	
Transportation		-Use Bangka	

Table 3.
Results of discussion on actions to be taken in the barangay.

Time Key Component	Before Flood	During Flood	After Flood
Information Communication	-Strengthen communication with MDRRMO -Provide 2-way radio	-Needs for getting information from MDRRMO about flood status during power outage	
Evacuation		-More evacuation space	
Housing	-Quick procedures for getting building permission for upgrading to second story house.		-Provide construction material for house repair quickly
Water, Food, Relief Goods		-Needs for food, water supply, generator, soap, battery, flash light, etc. -Needs for portable C.R.	
Medical Treatment	-Needs for medicines such as leptospirosis, etc.	-Needs for medicines such as leptospirosis, cold, fever, diarrhea, etc. -Needs for medical mission	
Transportation		-Needs for motorized Bangka (small boat)	
Others	-Needs for deep excavation of rivers		

Table 4.
Results of discussion on requests to higher administrative organisations.

4.5 Step 5: developing a contingency plan

After performing steps 3 and 4, the selected two barangays developed a contingency plan by themselves based on the results of steps 1–4. During the plan development, ICHARM provided them with necessary maps explained in the previous sections and several suggestions to barangay members in charge of the plan. **Table 5** is the final contents of their developed plans. Following the message from the barangay leader in the first chapter, the basic information and explanation of risk identification and the contingency plan are presented. In the chapter on risk identification, the inundation maps and chart in **Figure 7** are included, and the impact due to three types of floods discussed in **Table 2** is explained. The chapter



Figure 11.
 Workshop at Barangay Santa Lucia.



Figure 12.
 A resident presenting an opinion on Post-its to other participants at the workshop.

Category	Contents
1.Message	-Message from Barangay Leader
2.Basic Information	-Barangay Profile (Population etc.)
3.Risk Identification	-Past flood -Inundation maps -Time series Inundation chart -Number of vulnerable people -impact due to three floods
4.Contingency Plan	-Organization chart -Resource map -List of equipment -Response strategy -Sectoral Plan -Annual activity plan

Table 5.
 Contents of contingency plan.

of the contingency plan consists of six parts: an organisation chart, a resource map which shows the locations of the important facilities in the area (**Figure 7**), a list of equipment, a response strategy as a result of step 4 (**Table 3**), a sectoral plan for each section to follow in order to achieve necessary actions listed in step 4 and an annual activity plan.

4.6 Step 6: sharing a contingency plan

In the final step, the main focus is to share the developed contingency plan among community members and with other municipalities. Inviting the leaders and related members of the 29 barangays and Calumpit Municipality, a workshop was held to share all the activities. As the project had drawn much local attention, over 100 people attended the meeting. The representatives from the two model barangays introduced their contingency plans and explained how they developed a barangay contingency plan by themselves, as shown in **Figure 13**. At the end of the workshop, ICHARM provided printed maps developed in step 2 to all the 29 barangays so that every barangay could also make an evidence-based contingency plan of their own (**Figure 14**).



Figure 13.
Presentation on contingency plan from representatives from two barangays.



Figure 14.
Participants of final workshop in Feb. 2016.

5. Conclusions

This study proposed an effective method to implement evidence-based flood contingency planning for local communities by assuming the dynamic change of inundation using flood simulation, assessing flood risk with key indicators and deciding response strategies against the identified flood risk before a flood occurs. The method was applied to a flood-prone municipality called Calumpit in the Pampanga River basin of the Philippines as the first case study to verify its effectiveness in areas where the availability of natural and socio-economic data is limited. The case study revealed that the proposed method can be successfully applied to data-limited regions. However, the method needs testing in different flood-prone communities for further verification.

As for the limitations of the study, the process of risk identification through flood inundation simulation was conducted by ICHARM although this process should be completed by the provincial or national governments of the country. In order for them to carry out the risk identification process by themselves, training of flood simulation and risk assessment should be provided for managers and engineers in flood risk management.

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