Flood Risk Management: An Illustrative Approach

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ABSTRACT

Widespread flooding with significant damage in many countries, such as the Philippines in 2013, highlights the ongoing need for effective flood risk management (FRM). This hinges on comprehensive access to and dissemination of information about the elements and the people at risk. Simulations, real-time graphs, and maps illustrate the spatial distribution of flood risks, spatial allocation and dissemination of flood effects, if flood risk reduction measures are not implemented, as well as the benefits to be derived from the effective implementation and maintenance of flood risk management measures not realized. Using precipitation, river water, and tide levels, a real-time monitoring site was set up for the Shirakawa River, Kumamoto, Japan. The data gathered from the July 2012 flood event is used as a demonstrator, illustrating a flood event as well as how to utilize the information provided on this site to determine the future time and possibility of flooding. Additionally, an electronically generated flood hazard map making process is being developed for distribution across Japan. These illustrative approaches can be utilized in cities and communities around the globe.

Keywords: flood risk management, flood risk mapping, flood vulnerability mapping, numerical simulation, integrated risk and vulnerability assessment

1. INTRODUCTION

Widespread flooding with significant damage in countries such as Canada, China, the US, and the Philippines in 2013, highlights the ongoing need for effective flood risk management (FRM). This hinges on comprehensive access to and dissemination of information about the elements and the people at risk. Risk sensitization, therefore, plays an important role as only if the relevant authorities, agencies, and people are aware can they then evaluate, mitigate, and respond to these risks. Risk sensitization is brought about and enhanced through communication. Therefore, flood risks need to be established (through risk and vulnerability assessments) and communicated to the people, the authorities, and agencies (Lummen & Yamada, forthcoming). Risk sensitization is then a relevant component of the decision-making processes centered on flood risks and FRM and can be enhanced with visual and spatial tools. Simulations, real-time graphs, and maps graphically illustrate the spatial distribution of risks, spatial allocation, and dissemination of flood effects, if flood risk reduction measures are not implemented as well as the

benefits to be derived from the effective implementation and maintenance of FRM measures not realized.

FRM is multifaceted and can take many approaches, most common of which is resilience based. That is, people are encouraged to live with the risk of floods instead of completely focusing on and fighting floods (Baldassarre, Castellarin, Montanari, & Brath, 2009; Matsuo, Lummen, & Yamada, 2013). This approach is based on the belief that risks cannot be totally eliminated, and attempts to reduce risks are done at the expense of other societal goals. FRM endeavors to reduce the consequences of floods in such a way that its achievement is not counterproductive but balances with other societal considerations. Since FRM aspires to minimize losses and damages associated with flooding, measures, such as reduction in the rate of exposure of people and property, flood defense measures, flood control measures, flood probability mapping, spatial planning and implementation of measures aimed at lowering the overall rates of occupation of flood prone areas, effective risk analysis and assessments, as well as clear dissemination of

information through educational and communicational channels, are advocated.

Such a multifaceted approach takes advantage of the various ways in which different measures can reinforce each other while achieving the same goal, effective FRM. Structural measures can be combined with nonstructural measures, and governmental resources can augment local and scientific resources and knowledge. FRM is complicated by the dynamics of earth's natural systems and everyday systems, such as a changing climate, cyclical changes in geomorphology, and ongoing political and socioeconomic systems. FRM should, therefore, be a series of ongoing activities that continuously monitor and upgrade its processes, such as flood risk assessment; revision, formulation and, implementation of measures and policy instruments aimed at reducing flood risks and exposures; monitoring the effects of implemented policies, etc. For those reasons, FRM embodies a need for constant adaptation to match ever-changing geophysical and societal circumstances (De Bruijn, Green, Johnson, & McFadden, 2007). This paradigm is distinct from the traditional "implement and maintain" philosophies of previous flood defense approaches.

Figure 1. The disaster cycle (Source: Alexander, 2002)

Figure 2. Multiple disaster clocks (Source: Okada, 2012)

2. CONCEPTUAL APPROACHES TO FRM

In 2002, David Alexander proposed a disaster cycle, looking at the various components of a disaster and the different measures that should be considered before, during, and after such an event (Figure 1 Alexander, 2002)). This cyclical approach to disaster management gained momentum and was adopted in several parts of the world because of its practical and comprehensive approach.

This methodological approach was further developed and refined by Okada in 2012 where he proposed multiple disaster clocks (Figure 2). Professor Okada, purports that effective disaster management can be achieved through effective time management across multiple sectors. As illustrated in Figure 2, before a disaster strikes, the focus is on mitigation and preparation; once the disaster occurs, emergency response and recovery takes over. During these phases, risk communication is central. Effective mitigation and preparedness can be achieved through risk mapping, a participatory process which is enhanced and achieved through risk communication.

Just before the disasters occurs, early warning systems will be activated, an essential component of the cycle. Since early warning is a one-way delivery system, citizens are expected to comply with the warning within the prearranged timelines. After the event, the lessons learnt are discussed and reviewed along with the existing systems. Good practices are noted and carried over to the next generation through disaster education. For this phase, communication is focused on lessons learnt at the community and individual level, drawing on the use of local knowledge. These three phases are not independent but deeply related and dependent on each other—three clocks with intertwining, interdependent systems. Good preparedness will lead to good reaction to early warnings, which, in turn, will lead to good response and recovery; lessons from past impacts will be used in disaster education.

In reality, whenever a disaster occurs in one area, it has far reaching implications in other areas; response and recovery are dependent on intervening external assistance, and prevention (reduction of future possible devastating impacts) through mitigation is largely dependent on collaboration. Been able to manage such ongoing collaborations during each phase of the disaster is central to effective disaster management. The many collaborations and phases involved in the disaster management cycle and Professor Okada's disaster clocks mirror what occurs within FRM.

Effective FRM can be understood in this context of multiple disaster clocks, especially since it involves

collaborative action across governments, the public sector, businesses, voluntary organizations, and individuals. In FRM, it is imperative that strategies are developed and implemented in such a way that the advantages of each measure augments the advantages of another while balancing the disadvantages of others, and vice versa; such ongoing collaborative efforts require effective communication, effective time management, and an enforced system clearly delineating the processes. These can be understood through the multiple disaster clocks as well as achieved and enhanced with the use of illustrative approaches proposed in this paper.

3. ILLUSTRATORY APPROACHES

Floods are episodic events and can be considered as: a large, medium, or small flood event. The size of a flood event can be determined through probability testing and is described as the chance that it will occur in any one year (its annual probability). Once probability is determined, exposure should be assessed, that is, the elements at risk: people, property, and the socioeconomic systems. Additionally, the extent, duration, and depths of a flood should be considered to determine what, if any, detrimental effects the flood waters may have, risks, and vulnerability assessments. Simulations, real-time graphs, and maps graphically illustrate the spatial distribution of flood risks, spatial allocation, and dissemination of flood waters and their effects.

3.1. Real-Time Monitoring Sites

Using precipitation, existing aggregated river volume and tide levels data, a real-time monitoring site was set up for the Shirakawa River, Kumamoto, Japan. This site illustrates the existing water levels within the river, inputs the current precipitation data, as well as the tide levels, and, using an algorithm, it calculates water depth and determines the future time of a possible flood event. Additionally, the data gathered from the July 2012 flood event is used as a demonstrator, illustrating this flood event as well as how to utilize the information provided on this site to determine the possibility of flooding, assist with evacuation lead times, and have more effective FRM decision making.

3.2. Flood Simulation

The effects of flooding are extensive and significant. This highlights the need for accurate identification of previous inundation areas as well as prediction of future floods and potential inundation areas. Therefore, it is not surprising that numerical simulations are often used by FRM managers to create and/or recreate flood events in an effort to better understand flood risks and exposure as well as develop mitigation strategies (Butler & Pidgeon, 2011; Hall, Meadowcroft, Sayer, & Bramley, 2003; Yamada, Kakimoto, Yamamoto, Fujimi, & Tanaka, 2011). The

Intergovernmental Panel on Climate Change (IPCC) 2012 report projected that climate change will inevitably lead to an increase in rainfall, which may result in frequent and more intense floods of various types (IPCC, 2012). Using numerical simulations will assist in better flood risk assessments and the identification of more effective FRM measures. Thus, the July 12, 2012, flood event was modeled and analyzed, (Lummen, Tominaga, Tsukamoto, Hokamura, Nakajo, & Yamada, 2013) and new FRM measures were proposed to the Kumamoto City government.

3.3. Electronic Flood Risk Maps

Based on the recreated simulation of the 2012 flood event, as well as existing city governmental data, policies, and maps, electronic flood risk maps were generated for communities in the Kumamoto City area. This map-making process, modeled from the city's existing physical, handmade process, was then demonstrated to the local community members. Local data was then collected and input into the electronic system to generate flood risk maps using the techniques taught. The generated flood risk maps are then uploaded to the system and made available to community members via the Internet. City Hall currently distributes their hard copies to each household head who are all encouraged to periodically practice evacuation drills within their respective households.

4. APPLICATION OF ILLUSTRATORY APPROACHES

Kumamoto City is located in the central part of Kyushu Island in western Japan, as shown in Figure 3. It is the fifteenth largest prefecture in Japan and covers an approximate area of 7,405 square kilometers, inclusive of Kumamoto City (389.54 km²). Sixty percent of the land is forested. The north is characterized by gently rolling hills, while the east and south are mountainous with areas reaching heights of 1,000 meters. The Shirakawa River flows through Kumamoto City, and its total length and watershed area is 74 km and 480 km², respectively

Figure 3. Map of Kumamoto, Kyushu, and Japan (Source: Lummen, Nakajo, & Yamada, forthcoming)

Figure 4. Shirakawa River watershed (Source: Lummen et al., forthcoming)

a. Every 10 minutes

b. Every hour

Figure 5. Real-time monitoring of the Shirakawa River basin

(Figure 4). The designed capacity of the Shirakawa River, set by the Ministry of Land, Infrastructure, and Transport of Japan is 3,400 m³/s. An active volcano, Mount Aso, is located in the upper reaches of the Shirakawa River watershed. There are no dams on the Shirakawa River, and, as such, a significant percentage of the precipitation that is received upstream flows downstream uninterrupted.

On July 12, 2012, the community of Mt. Aso received 500 millimeters (20 inches) of rainfall, resulting in severe flooding and landslides. In neighboring towns,

such as Minami-Aso, several houses were washed away and/or covered with debris. Several communities downstream, such as the Tatsuda Jinnai and Tatsuda Ichi Chome areas, were inundated. Thousands of persons were evacuated to shelters, while several houses and cars were dragged into the raging river. Rainfall within the Mount Aso area takes approximately two hours to travel downstream the Shirakawa River. Communities downstream can be inundated even if there is no rainfall experienced downstream. As such, all stakeholders and community members need access to flood risk information, such as the elements at risk, people, property, and the socioeconomic systems, to help them in their disaster planning. This can be achieved through risk sensitization and risk communication. FRM can only be achieved when the relevant authorities, agencies, and people are aware of the intervening risks, exposures, and vulnerabilities. This awareness helps them to evaluate, mitigate, and respond appropriately to these risks. Therefore, flood risks need to be established (through risk and vulnerability assessments) and communicated to the people, all relevant authorities, agencies, and stakeholders. Risk sensitization is a relevant component of the decision-making processes centered on flood risks and FRM and can be enhanced with visual and spatial tools. In the city of Kumamoto, several such measures are being implemented.

4.1. Real-Time Monitoring Sites

Following the July 12, 2012, flood event, the Implementation Research and Education System Center for Reducing Disaster Risk (IRESC) was developed by Professor Fumihiko Yamada of Kumamoto University. The philosophy of the center is the deployment and sustained early realization of a disaster mitigation-oriented society that can respond flexibly and quickly to disasters by widely promoting research and educational activities related to disaster prevention and mitigation. The group's efforts extend beyond the university campus, as they seek to place and practice within communities as well as connect seamlessly with the aid and use of social technology. They aim to work to develop, as well as contribute the human resources necessary, to achieve sustained results from research and development as well as the construction of a disaster mitigation-oriented society.

One such research and development project was the creation of a real-time monitoring site for the Shirakawa River. This site utilizes current rainfall levels (measured), the river's water level (measured), and tide levels (prediction) to determine the probability of flooding. Streaming live, it inputs precipitation data uploaded from Japan's meteorological center's web page, existing aggregated river volume, and tide levels data in an algorithm that predicts changes within the river basin given changes in precipitation inputs (Figure 5).

a. Measured value every 10 minutes

b. Measured value every hour

c. Verification graph every 10 minutes

d. Verification graph every hour

Figure 6. Recreation of the flood situation on July 12, 2012.

The black line indicates the tide levels, and the blue line shows the river water level. The blue and orange lines running across the graph represent the threshold values. Changes in precipitation will cause an increase in river water levels and create a change in the water monitoring stations lines. If these go above the designated threshold values, then the different emergency evacuation warnings are issued accordingly.

This site is now up and running and can be accessed by the public at any time to assess rainfall and river water levels in their communities. For now, only the Shirakawa River in Kumamoto City is monitored; however, with time, this process will be replicated across others communities within Japan. The real-time monitoring site can be found at <http://www2.kumamoto-bousai.jp/anpi/sirakawa/>.

4.2. Flood Simulation

The July 12, 2012, flood event in Kumamoto City was modeled and the chronology and pathway of the flood event examined. This model is now used as educational training material on the real-time monitoring site (Figure 6 [Lummen, et al., 2013]).

This is a four-step process where members from City Hall will arrange a community meeting. At the meeting they will train the community members how to make the maps using materials provided by the city. One base map and four clear layer sheets are provided. On each layer, as indicated in Figure 7, the relevant flood risk, exposure, and elements at risk information are added. A final field version of the

Figure 7. City Hall's flood hazard map making process (Source: Kumamoto City Hall, 2012)

map can be seen in Figure 8. The final map is then taken back to city hall where it is replicated and updated with the relevant map features such as a title, legend, and axis (Figure 9) after which it is distributed to heads of households.

In keeping with IRESC's policy of creating a disaster mitigation-oriented society with the use and aid of social technology, the group decided to create electronic community-based flood risk maps. Accordingly, the manual process established by the city was recreated electronically (Figure 10).

This map-making process is now been taught to community members in tandem with City Hall. By doing this, community members can become familiar with the process, the accuracy of the information contained, and the legitimacy of the source. Therefore, when these maps are made public, there will be no hesitancy to access and utilise them. These maps will be made public in a short time span. Community members can, at that time, access the previously created maps to determine flood path and movement within their respective areas.

All of above mentioned illustrative approaches, in addition to the other FRM measures that each city or country utilises to understand and manage risks, vulnerabilities, exposures, etc., can be understood in the context of multiple disaster clocks. Since all approaches are ongoing, they usually embody collaborative efforts as well as take place in different time and space scales on various clocks. This systematic cyclical understanding highlights the complexity of FRM and the need for effective measures that are easily understood, communicated, implemented, monitored, and constantly updated and upgraded as research and development take place. Measures such as the real-time monitoring site, the electronically generated maps, and numerical simulations are but a few examples.

Figure 8. Final stage of City Hall's handmade flood hazard map (Sourced:Kumamoto City Hall, 2012)

Figure 9. Flood hazard map distributed by City Hall to community members, made by hand (Source: Kumamoto City Hall, 2012)

a. Relevant information is mapped

b. Illustrative photographs taken

c. All data combined to produce final map

Figure 10. Electronically generated flood hazard map

5. CONCLUSION AND FUTURE WORKS

This systematic approach can be utilized in cities and communities around the globe. The city of Kumamoto is currently using the real-time site setup to monitor water levels within the Shirakawa River. With time, this process will be replicated across different river communities and towns. The electronically generated map-making process is being developed for distribution across Japan as well. Additionally, we are currently undertaking a new

project that seeks to synchronize distress calls with our real-time monitoring site and numerically generated flood path models. This new approach is called the triage system. Whenever some calls in from a disaster zone, the person who logs the call will obtain relevant information. This information is then mapped and uploaded onto the real-time site, allowing FRM managers to determine the location of the caller in relation to the actual on-the-ground situation, thereby determining the urgency of the situations and how to respond.

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