Assessment of the Flood Forecasting and Warning Systems in Metro Manila, Philippines

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1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC), in its fourth assessment report, summarized the potential impacts of drastic changes in the climate conditions. This merited the call for a world-wide pursuit to develop approaches for climate change adaptation that are based on the scenarios presented in the report. One such scenario implies that massive floods will occur in certain parts of the world due to the continuing increase of the mean sea levels and the increasing amount of precipitation caused by global warming (Nichols *et al*, 2007). The adaptation measures then must include measures that will reduce the devastating effects of extreme floods.

Along the coastal areas of Asia, the mean sea level was estimated to be increasing at a rate of 1 to 3 mm per year. In Southeast Asia, changes in the rainfall patterns have been observed, particularly in the Philippines, where the mean annual rainfall and number of rainy days have variably increased since the 1990s. These changes are indications that tell us extreme flood events will likely occur, especially in highly urbanized low-lying coastal areas like Metro Manila, the most progressive region in the Philippines, where the consequences of unmitigated floods can become very severe (The World Bank, 2010). Fig. 1 shows the location of Metro Manila. It is widely believed that insufficiently planned urban development can contribute directly to uncontrolled run-offs, creating higher flood risks to urban communities (Suriya and Mudgal, 2011). The metropolis has a population density of around 18,000persons/ km^2, many of whom live along coastal flood plains and in areas adjacent to the streams and river channels. Many of the poor residents, especially in the slum areas, rely solely on the flood control structures installed by the government in the river systems and coastal areas for their safety against floods, while some residents are completely unaware that their location is also susceptible to extreme flood events.

On 26 September 2009, during the onslaught of typhoon Ondoy, widespread inundation occurred in Metro Manila, which affected more than 4 million residents and submerged more than 30% of the metropolis (Rabonza, 2009). This event occurred despite the existence of large-scale flood control systems, which clearly proved that the design safety factors of flood control structures and flood protections can be relentlessly overwhelmed by an extreme event. It also proves that the threats of climate change are real. The damaging effects of floods to life and properties, however, can be reduced if the population can sufficiently act prior to the influx of floods. This is usually achieved with the aid of an early flood warning system combined with an effective flood forecasting system.

This paper investigates the nature and effectiveness of flood forecasting and warning systems (FFWS) in Metro Manila using the information acquired by the authors during the post-Ondoy disaster survey done in October 2009. The result of this study may provide decision-makers in Metro Manila and other similar developing countries relevant insights with regards to the mitigation of flood effects as an approach for climate change adaptation.

2 STUDY AREA

Metro Manila (Fig. 1) is the capital region and the center of political and economic activities in the Philippines. It is situated in a semi-alluvial fan which opens to Manila Bay on the west and Laguna de Bay Lake on the southeast (Pineda, 2000). It has a population of about 12 million crammed in an area of about 638 km^2. It consists of 16 highly urbanized cities and 1 densely populated municipality. These towns are further subdivided into 1,705 barangays (the smallest administrative unit in the Philippines) that are distributed in 11 catchment basins. The catchment basins are shown in Fig. 2. Metro Manila's contribution to the country's gross domestic product (GDP) amounts to about 33% of the overall GDP, making it the highest regional economic contributor in the country (National Statistics Coordination Board, 2011). Despite its progress, floods have persistently slowed the region's economic growth. The floods in Metro Manila regularly caused heavy inundation and traffic, which often result to the suspension of office and school works. Floods in Metro Manila can also be devastating, causing the loss of lives and damages to properties and public infrastructures.

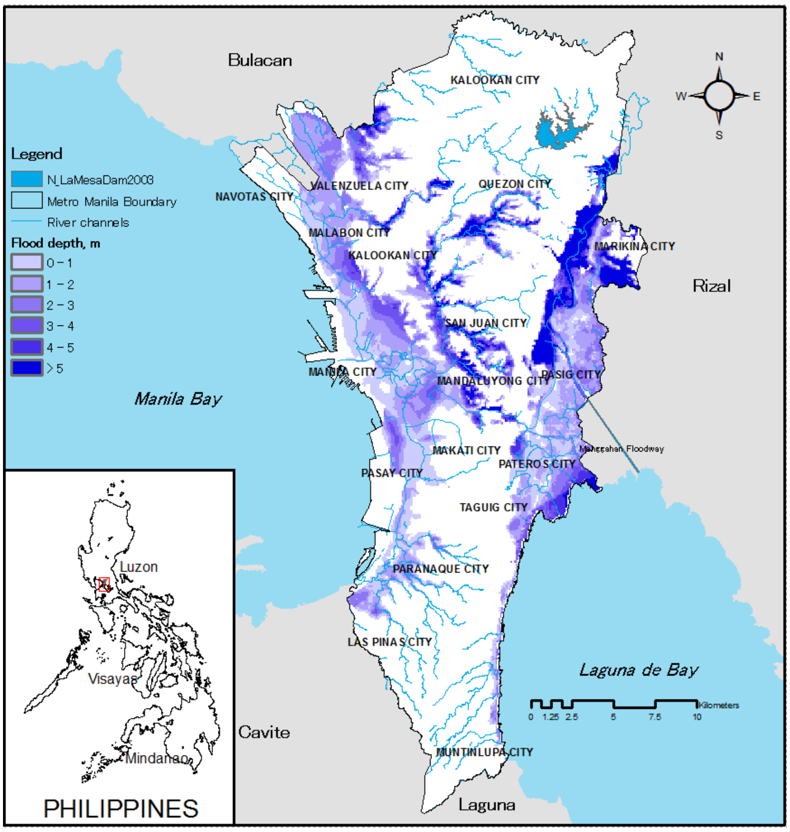

Figure 1. Location map of Metro Manila with maximum inundation depths during typhoon Ondoy

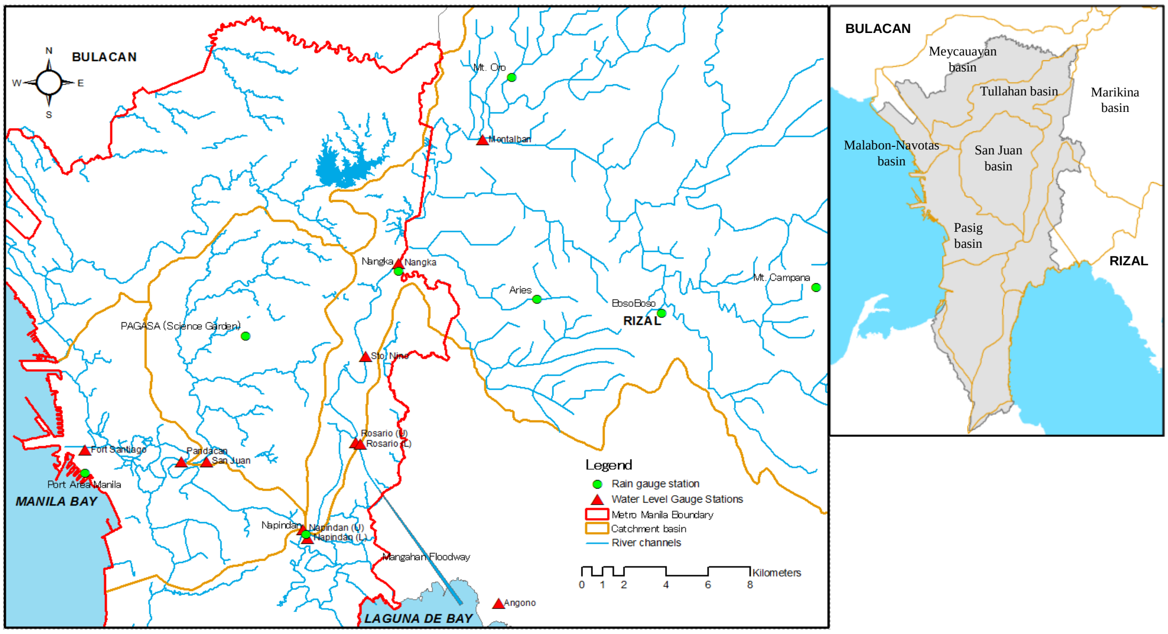

Figure 2. Map of the rainfall and water level gauges of the Effective Flood Control Operation and Early Warning System (EFCOS) and the catchment basins in Metro Manila (source: EFCOS)

Large-scale projects aimed to reduce floods in Metro Manila, both structural and non-structural measures, have been commissioned by the Philippine government since the 1990s. Structural measures such as river dikes, flood gates and pumping stations were built to prevent and control the storm water run-offs in the river channels. Non-structural measures such as the telemetered FFWS along the Marikina, Pasig and San Juan Basins were installed by the Department of Public Works and Highways (DPWH) to reduce the effects of flood in the surrounding communities (DPWH, 2009). On 26 September 2009, typhoon Ondoy submerged more than 30% of Metro Manila affecting around 4.9 million residents and leaving behind 464 dead, 529 injured and 37 missing individuals with some USD 240 million worth of damage in property, infrastructure and agriculture (Rabonza, 2009). Effective FFWS would have been useful to reduce the amount of damage by this extreme flood event.

3 DISASTER PREPAREDNESS SYSTEM IN METRO MANILA

Prior to typhoon Ondoy, Metro Manila follows a national disaster preparedness system that consists of links between the local government units (LGUs) and a designated government body, the disaster coordinating council (DCC). Fig. 3 shows the organizational network of the DCC. The LGU consists of all the country’s administrative divisions, namely, barangays, municipalities, cities and provinces, which are headed by their respective government executives. The DCC consists of the national disaster coordinating council (NDCC), which serves as the nerve center for the entire DCC network. The NDCC is directly linked to the 17 regional disaster coordinating councils, representing each of the administrative regions. The NDCC is composed of national government agencies that represent the stakeholders in the event of natural and man-made disasters. The DCC network is led by the secretary of the Department of National Defense (DND) and supervised by the Office of Civil Defense (OCD) through the NDCC operation center (Opcen). The coordinating councils of each LGU are empowered to carry out flood warnings and emergency measures necessary during and in the aftermath the disasters. This is with the intention of ensuring the welfare and benefits of the people. Thus the NDCC’s task of providing early disaster warnings (including flood warnings) and emergency response essentially terminates at the regional level. In Metro Manila, the disaster preparedness system is decided independently by the LGUs, from barangay to provincial level, thus, varying approaches to disaster preparedness, including flood forecasting and warning, can be observed in each LGU. Some flood prone LGUs does not even have FFWS. Fig. 4 shows a typical organization chart of DCC in the barangay level. Independent operating teams are usually created to avoid the overlap of responsibilities during an emergency response. The only “proactive” unit in this chart is the communications and warning team, which would normally include the flood forecasting and warning team. Similar organizational structure exist in the municipal/city and provincial DCC levels. The similarities in the organizational structures will allow parallel operation in all LGU levels during and after a disaster. However, the redundancy in some operations can cause delay, or even confusion, when the task involved is information dissemination, such as in the case of flood warning.

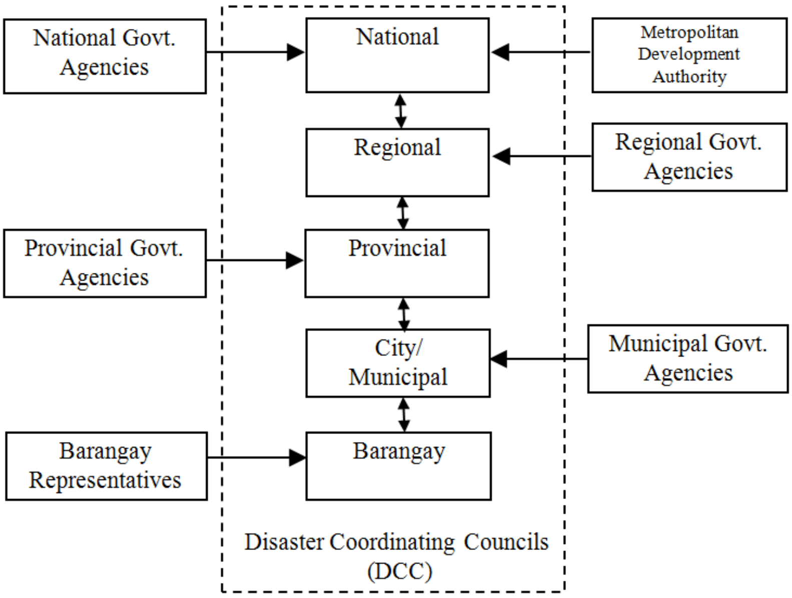

Figure 3. Organizational network of the disaster coordinating council (source: Office of Civil Defense (OCD))

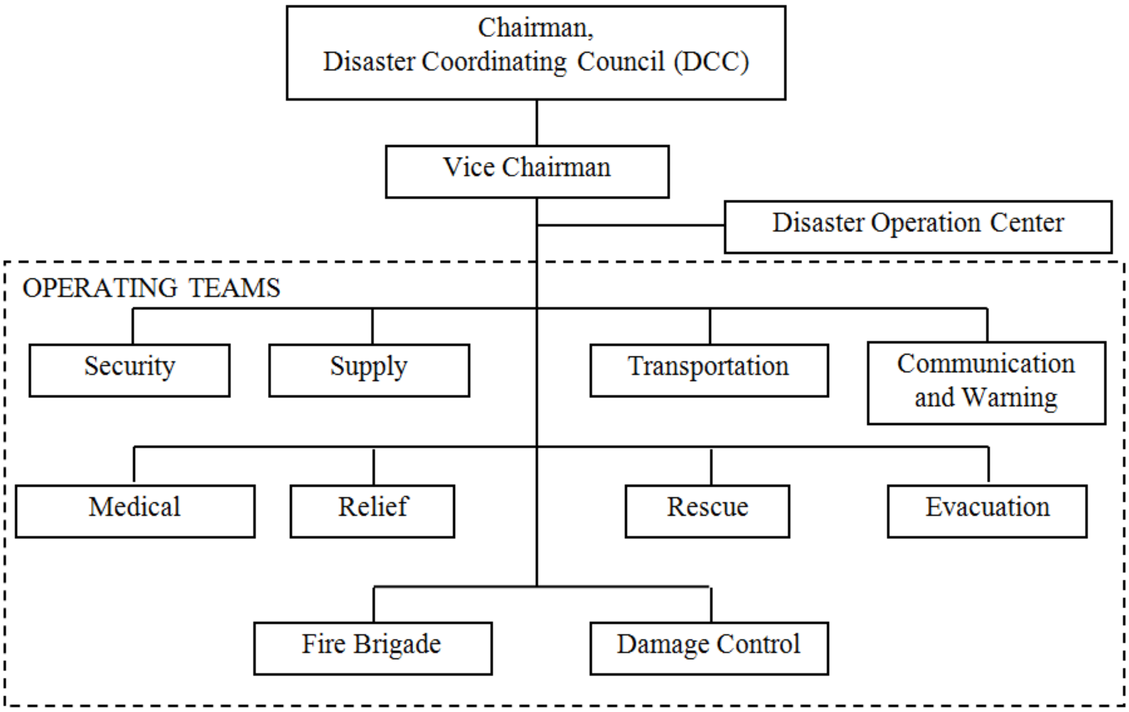

Figure 4. Typical organizational structure of the DCC in the barangay level (source: OCD)

After typhoon Ondoy, the NDCC was reformed into national disaster and risk reduction management council (NDRRMC), which adds the establishment of in the disaster management framework the establishment of national and regional training institutes for disaster management, and additional funding for the national and local disaster risk reduction management fund (DRRMCF). However, a clear disaster management framework for each LGU, particularly for flood disasters, has not yet been established.

4 FLOOD FORECASTING SYSTEM

4.1 Regional scale

The Philippines is known to be prone to a number of natural disasters, such as earthquakes, landslides, volcanic eruptions, typhoons and floods. The task of monitoring and issuance of disaster alerts falls under the umbrella of the NDCC. For flood forecasting, warning and monitoring, the responsibility is held by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), which is a sub-member of the disaster coordinating council through its mother office, the Department of Science and Technology (DOST). PAGASA is the primary source of information when it comes to rainfall/storm intensity and possibility of floods in Metro Manila. PAGASA however has very limited capability when it comes to flood forecasting. It predicts floods based on rainfall intensity, water level in major reservoirs, and past history of flood occurrence. PAGASA's forecasting capability during the typhoon Ondoy was particularly limited to the following: prediction of the storm intensity (i.e. wind speed, gustiness, etc.); prediction of floods in selected river basins using rainfall depths and water levels; and giving real-time updates on the status of major dams for possible water release and flash floods. PAGASA's flood forecasting system includes: a) basin flood forecasting, and b) flood forecasting and flood warning system for dam operation (FFWSDO). For the basin flood forecasting, only four river basins in Luzon are being monitored, which unfortunately does not include Metro Manila. On the other hand, the FFWSDO covers four major dams in Luzon, but again, does not include the major flood prone areas of Metro Manila.

The other flood forecasting system in Metro Manila is the Effective Flood Control Operation and Warning System (EFCOS) whose components are installed in the Marikina, Pasig and San Juan river basins. The EFCOS was originally installed in 1978, was improved in 1993 and was rehabilitated in 2001. The main purpose of the EFCOS is to reduce the incidents of floods in the cities of Marikina, Pasig, San Juan and Manila through the operation of its weirs (at the Rosario station) and hydraulic control structures (at the Napindan station), which are aided by the EFCOS's water level forecasting system (Fig. 2). EFCOS is also designed to prevent channel overflow in the east and west banks of the Manggahan floodway (DPWH, 2009). The forecasting capability of EFCOS is embedded in its data processing system located at the control station near the Rosario rainfall gauge station. Real-time rainfall depths and water level data are used for flood simulation (updating every 10 mins) through a telemetry system that connects the rain gauges in Mt. Campana, Mt. Oro, Boso-boso, Aries, Nangka, Science Garden and Napindan; and the water level gauges in Montalban, Nangka, Sto. Niño, Rosario, Napindan, Angono, Pandacan, and Fort Santiago (Fig. 2). The operation of the Rosario weir, which opens to the Manggahan floodway, is based on the predicted water level at the Sto. Niño water level gauging station.

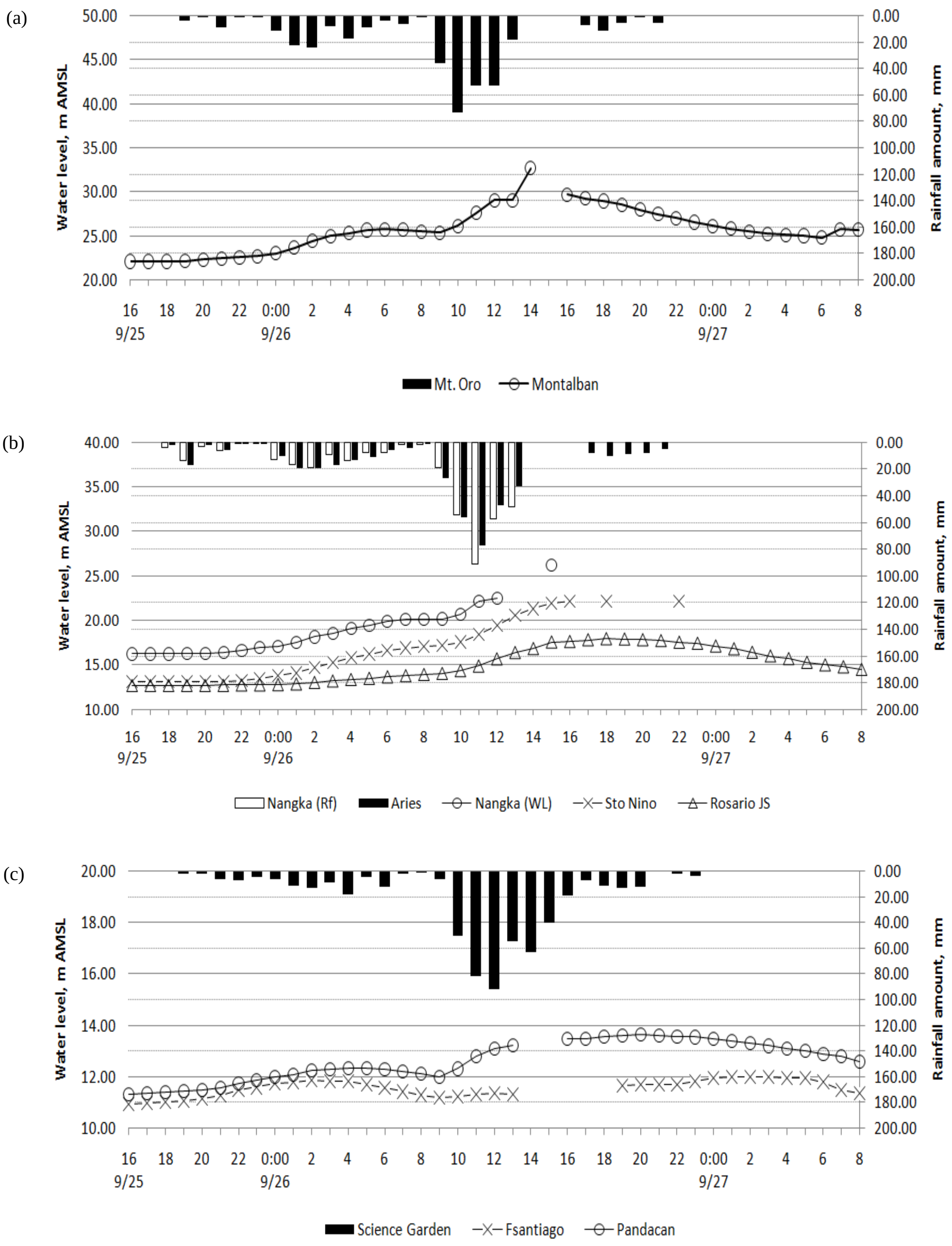

Figure 5. Hyetographs and water level graphs representing the a) upper stream, b) middle stream, and c) lower stream of the EFCOS during typhoon Ondoy (data source: EFCOS)

Fig. 5 shows the hyetographs and water level graphs of selected rainfall and water level gauging stations located at the upper stream, middle stream and lower stream of the EFCOS. When the water level at the Sto. Niño station is predicted to reach 15.2 m, and the corresponding tidal level in Manila Bay is 11.4 m (Badilla, 2008), the gates at the Manggahan floodway will be opened to redirect some of the water towards the Laguna de Bay Lake. Unfortunately, the operation of the flood forecasting system has been stopped in 2003 due to the technical incongruity of the simulation model and financial constraints. Since then, what remains in the EFCOS is the monitoring of water levels and rainfall depths with no predictive output. Metro Manila essentially did not have an accurate flood forecasting system along the Pasig-Marikina River Basin when the typhoon Ondoy came. On 25 September 2009, rain started to occur at around 6PM to 12AM; and On 26 September 2009 at around 3AM, the water level at the Sto. Niño station reached a level of 15.27 m (Fig. 5b) with a level of 11.83 m in Fort Santiago (the water level gauging station close to the river mouth near Manila bay), but the gates at the Manggahan floodway was not immediately opened. The rains continued at around 7AM of September 26, and further intensified until 12PM. Consequently, the water rose to at least a height of 21.6 m at the Sto. Niño station, and the water level at the Rosario weir exceeded the normal level by at least 5m which may have caused the very high inundation at the upper stream of EFCOS, within Marikina City.

The rainfall stations of EFCOS, though continuously operational, have stopped sending real-time information to PAGASA since 2006 due to a damaged link between them. This link has not been re-established up to the time when typhoon Ondoy came. Thus, a flood warning based on these data was not released by PAGASA during the storm.

4.2 Community-based flood forecasting

At the local government unit level, flood forecasting is typically done without using sophisticated equipment like the one those used in EFCOS. Manual monitoring of staff gauge (usually installed at bridge columns in the rivers) and local rainfall gauges are commonly done by volunteers known as flood watchers. The manner of forecasting is very simple and crudely based on the judgment made by the observing volunteers. The measurement in the staff gauge indicates the flood stages of the river. When a certain water level is reached, the flood watchers will communicate the information back to their respective LGUs (either the barangay or municipal units). Those that use the rainfall gauges for flood forecasting base their judgment on the estimated rainfall intensity. However, most of the LGUs do not have flood forecasting capability, and rely solely on the information communicated by PAGASA.

5 FLOOD WARNING SYSTEM

5.1 Regional scale

In Metro Manila, flood warnings serve as advisories for evacuation and/or other emergency response procedures such as temporary flood proofing of establishments and households. Flood proofing is usually done by installing sand bags or other materials that would prevent flood waters from entering the establishments, or by protecting the valuables by transferring these to higher elevation. The effectiveness of flood warning systems depends heavily on the timely and accurate transmission of forecasted floods. In areas where flood forecasting capability is not available, the presence of high inundations in the nearby zones is taken as warning signal to start the evacuation. On the regional scale, flood warnings are communicated by PAGASA through the local media (i.e. radio, television and internet). The warning released by PAGASA is usually based on prolonged high rainfall intensity as monitored in their weather stations. These warnings are not based on hydrological simulation. PAGASA also take information from LGU-based DCCs. Flood reports from mobile news media (i.e. for radio and television) are also used by the public as source of flood warning using the reported inundation levels and extent of flooding reported in the nearby areas. On 25 September 2009, PAGASA issued a flood bulletin on Typhoon Ondoy for Metro Manila on the basis of storm warning signals (i.e. wind speed). Accurate prediction of the location and extent of flooding was not available. Although EFCOS has a built-in warning system, these are installed only along the east and west banks of the Manggahan Floodway. The warning system of EFCOS consists of speakers (megaphones) and radios. Flood warning is disseminated when the Rosario weir is about to be opened. A message announcing the release of water is sent to all the nine warning stations along the Manggahan floodway. However, since the EFCOS is no longer operational, the warning system was not effectively used during typhoon Ondoy. Advanced warning systems do not exist in other flood-prone areas; however, community-based early warning systems are adopted by some small communities as a means to cope with frequent flooding.

5.2 Community-based flood warning

Based on the provisions of the country's disaster preparedness system, the local government units have the prerogative to institute their own flood warning system. The community-based warning systems are typically linked to a flood forecasting system. The warnings are issued based on the thresholds reached during the monitoring of water level and rainfall. Table 1 shows examples of thresholds used in small communities for flood forecasting using water level and rainfall values. When a threshold is breached, the flood watcher informs the heads of the local DCCs by mobile communication, and the local DCCs in turn disseminates the warning throughout the community by means of megaphones, sirens and/or church bells.

Table 1. Typical flood warning scheme used in a community-based flood warning system (source: PAGASA)

Warning Levels	Sample Threshold for water level	Sample threshold values for rainfall	Flood Warning	Required actions
Level 1	1.1 m	Continuous rainfall at 15-20 mm/hr	"Ready"	Public is informed of the possibility of flood. This warning serves as an advisory for the public to be vigilant and to wait for further instructions. The public may begin flood proofing their households and establishments
Level 2	1.5 m	Continuous rainfall at 60-80 mm/ 3hrs	"Get set"	Flooding is imminent. This warning serves as an advisory to prepare for possible evacuation
Level 3	2.0 m	Continuous rainfall for 3 hrs with intensity of at least 80 mm/ 3 hrs	"Go"	This warning serves as an advisory to move to higher grounds or to proceed to evacuation sites.

During typhoon Ondoy, many residents along the flood prone areas in the Marikina and Pasig basins have been effectively warned and evacuated; this is through the efforts of the local disaster coordinating councils, many of whom were using the manual flood forecasting approach. However, many still were not informed and evacuated on-time due to the limitation of coverage of their flood warning equipment. Most residents who live in multi-storey houses, decided not to evacuate since based on their past experience flood water has never gone beyond their first floor level. A portion in Marikina has been submerged up to the second storey level. At the north-western part of Metro Manila, some residents in the Meycauayan and Malabon-Navotas river basins were not able to evacuate on time, either because the residents would not leave despite the warnings of the local DCC or the warning was not delivered on time due to lack of an effective flood forecasting system.

6 SUMMARY AND CONCLUSION

The general state of FFWS in Metro Manila can be summarized as follows:

- Metro Manila, as a region, does not have a well established FFWS. Not all LGUs have flood forecasting and/or flood warning capabilities. Some of the local DCC does not even have the training to proactively respond to flood situations.
- The existing flood forecasting systems during typhoon Ondoy were not sufficient to provide accurate and on-time flood prediction.
- The common limitation of the flood warning systems in Metro Manila is the geographical coverage of their warning equipment. The information about the flood warnings cannot reach all the affected residents, especially those in the remote/ inaccessible areas.
- Financial constraint is given as a reason for the lack of FFWS equipment and manpower.
- There is a lack of organized and coordinated works between the national, regional and local (provincial, municipal and barangay) DCCs. The assignment of responsibility for flood warning dissemination should

be specific and clear to the public to avoid confusion.

The experience with typhoon Ondoy provided the Philippine government as well as the Metro Manila residents valuable insights on disaster preparedness and emergency response. The people now see the importance of early flood warning systems as a component to flood mitigation. The old disaster response approach, which is based on "personal judgment", is no longer sufficient, especially during the time of climate change. However, a lot of work is still needed to address the constraints in the regional and local FFWS identified during typhoon Ondoy. To address some of the important issues, a highly effective flood forecasting system using precipitation and run-off simulation models combined with accurate spatial flood estimation must be established in all basins. Communication networks must be well established to have a wider coverage necessary for flood warning dissemination, both in the regional and local scales. Adopting a basin-wide disaster risk reduction management approach may also improve the efficiency and effectiveness FFWS.

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