Natural Disaster Research Report of the National Research Institute for Earth Science and Disaster Prevention, No. 45 ; February, 2011

2009 Typhoon Ondoy Flood Disasters in Metro Manila

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Abstract

From September 25 – 26, 2009, Typhoon #16 (Ondoy) struck southwest Luzon in the Philippines. Flood disasters caused by this heavy rainfall affected 872,097 people throughout the entire metropolitan area, causing 241 fatalities, 394 injuries, and damaging 65,521 buildings (of which 12,563 were completely destroyed). Infrastructure damages (not including agricultural losses) amounted to 570,187,587 Philippine pesos (NDCC, 2009a). We investigated the great urban flood disaster that occurred in the megacities of the developing country, which are expected to grow to a population of 25 million by 2015. The conditions caused by runoff, flooding, and damages as well as mitigation measures relating to the hydrological conditions, land environments, and social economic conditions in the Philippines are reported based on field investigations and interviews with related parties.

Key words: 2009 Typhoon Ondoy, Urban flood, Metro Manila, Pasig-Marikina-Laguna Lake Complex

1. Introduction

From September 25 – 26, 2009, Typhoon #16 (Ondoy) struck the southwest Luzon in the Philippines, causing torrential rainfall. Within 24 hours, 455.0 mm of rain fell at the Quezon City Science Garden, 258.5 mm fell at the Port Area, and 331.8 mm fell in the municipality of Tanay in neighboring Rizal province. The amount of precipitation at the Science Garden reached levels expected only once per century or more (for rainfall in a 24-hour period) or once every 150 years or more (for rainfall in a 12-hour period), and the 92 mm of rain that fell between 11 a.m. and noon was of a level expected only once every 5 – 10 years (PAGASA, 2009).

This heavy rainfall affected 872,097 people throughout the entire metropolitan area, causing 241 fatalities, 394 injuries, and damaging 65,521 buildings (of which 12,563 were completely destroyed). The infrastructure damages (not including agricultural losses) amounted to 570,187,587 Philippine pesos (NDCC, 2009a; NDCC, 2009b). Other such losses were caused by traffic coming to a standstill due to major city center thoroughfares such as Epifanio de los Santos Avenue being cut off by flood water and by the cancellation of domestic and international flights at Manila airport (Manila Shimbun, 27 Sept.).

In this chapter, we discuss the flood disasters that occurred in the Manila Metropolitan Area (Metro Manila), which is a major region in the developing country and one of south-east Asia’s most prominent overpopulated centers with a population of 11.6 million according to the 2007 Census of Population, of which population growth rate is 2.12.

2. Surveyed Area

As **Fig. 1** shows, Metro Manila comprises 16 cities and the municipality of Pateros, all of which lie within the Pasig-Marikina-Laguna Lake Complex (catchment area: 4,678 km^2) except for parts of the north and the southernmost tip which lie along Manila Bay (**Fig. 2**). This chapter concerns the flood disasters that took place in this river basin.

3. River systems and flood-prone areas

3.1 River Systems

As its name suggests, the Pasig-Marikina-Laguna Lake Complex consists of two rivers and one lake. One of these is the Marikina River, which has a catchment area of 516.50 km^2 (at the Napindan junction) and flows out from the Sierra Madre mountain range in the east part of the river basin. The Marikina River meanders its way southwards along the Marikina River flood plain, and floodwater is diverted into the

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Manggahan floodway from the Rosario weir in the left bank, where the Upper Marikina River becomes the Lower Marikina River. The Lower Marikina continues southwards, and at Napindan junction it is joined by the Pasig River that flows north from Laguna de Bay (Laguna Lake).

The Pasig River is the only river that flows out from Laguna Lake. The Napindan channel flows north from the north coast of Laguna Lake, and where it joins the Marikina River, it starts to flow northwest across the central plateau and into the coastal lowland alongside Manila Bay and then out into the bay near the old city district at the center of the lowland area. The Pasig River is joined by the San Juan River as a right tributary, which has the central plateau as its river basin.

With an area of 900 km^2, Laguna Lake is the largest lake in the Philippines, occupying a large region extending from the central to southern parts of the river basin. The lake has a catchment area of 3,820 km^2, which is about 80 % of the total catchment area. This wide and shallow lake temporarily stores the water flowing from at least 20 tributary river basins, and during floods it functions as a retarding reservoir for the Marikina River. Water levels fluctuate from 10.5 m elevations in the summer months to 12.5 m in the rainy seasons. The annual mean is an 11.32 m elevation (Edgardo C. Manda, 2008). When the sea level in Manila Bay is higher than the water level in the lake, the water flows backwards from the sea into the lake.

Fig. 1 Map of Metro Manila (MMDA, 2009).

3.2 Flood-prone areas

The flood-prone areas in the Pasig-Marikina-Laguna Lake Complex can be divided into the following four flood plains as depicted in the flood hazard map in **Fig. 3**:

1) Coastal lowlands alongside Manila Bay: Land with an altitude of 3 meters or less next to Manila Bay and down the Pasig River. This lies at the center of Metro Manila.

2) Marikina flood plain: Alluvial lowland with an altitude of 5 – 30 m along the Marikina River, which is being developed to the north and south at the western end of the river basin. It is bounded to the west by the central plateau that lies between the Manila Bay coastline and the coastal lowland and to the east by the Sierra Madre mountain range from where the Marikina River originates.

3) Laguna Lake Plain: The Marikina flood plain continues on into the Laguna Lake Plain. This is a marshy plain with an altitude of just a few meters, where it is affected by the rise of the water level of Laguna Lake.

4) Valley plains cutting through the central plateau: Narrow lowland areas alongside the Pasig and San Juan Rivers where they cut across the central plateau.

In these flood plains, even floods with an estimated frequency of once every 2 – 10 years (shown in yellow) are liable to cover a substantial part of these areas, while floods with an estimated frequency of once every 50 – 100 years (blue) are liable to cause flood damage over the entire flood plain (**Fig. 3**).

4. Locality of flood disasters

The flooding of Metro Manila varies according to the hydrological conditions and land environments of the flood plain and river basins. **Table 1** shows the characteristics of flooding and flood damage in Metro Manila and how the flood inundation and damage varied between the four flood plains. Inner water inundation may have also occurred in the river basins where there was severe external overflow, but this figure charts the inundation phenomena that caused most of the damage. Furthermore, administrative districts sometimes cross over multiple topological zones and were therefore divided into their main topological areas.

As a result, the flooding of Metro Manila can be divided

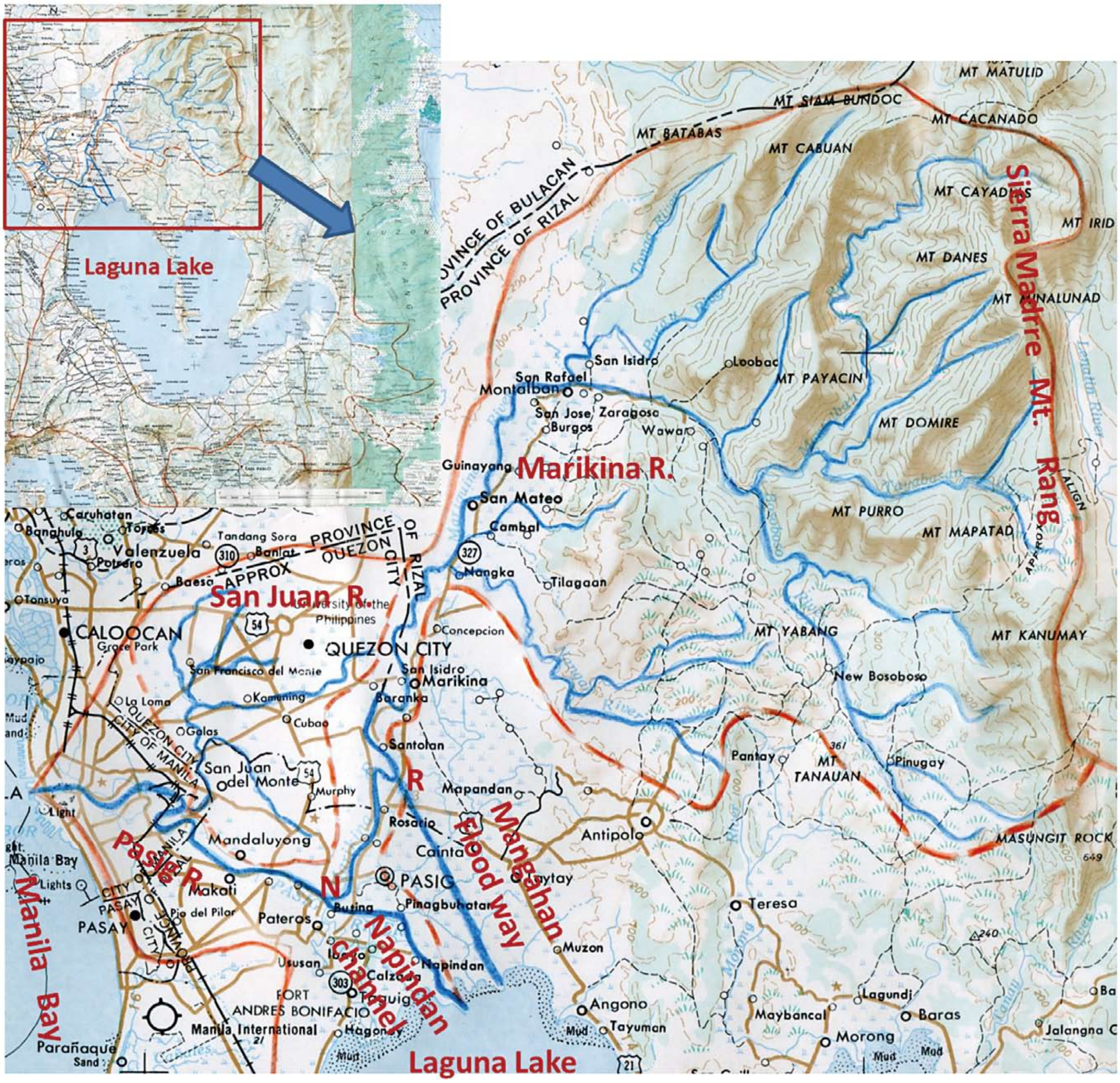

Fig. 2 Maps of the Pasig-Marikina-Laguna Lake Complex (NAMRIA Geographical Map 1:250,000)
R: Rosario weir, N: Napindan Janction.

into regions where increased damage was mainly caused by external flooding and into regions where it was mainly caused by inner flooding. The Marikina flood plain and San Juan valley plain can be placed in the former category and the Laguna Lake Plain and coastal lowlands along the Manila Bay coast can be placed in the latter, which can also be subdivided into the coastal lowlands, which experienced a short flooding duration, and the Laguna Lake Plain, where the flooding persisted for more than two weeks.

4.1 Marikina flood plain

In the Marikina flood plain, where damage was mainly caused by external flooding, overflow well in excess of twice the river channel discharge capacity occurred, and the water level in the river rose rapidly by approximately 3 m in 3 h. The large depth of flood water combined with the sharp increase in water level resulted in a severe inundation that spread across the entire flood plain (**Figs. 4** and **5**). Flood water depths of 7 m were recorded in some places although the flooding was short-lived (JICA, 2009; ADB, 2009; P.B.GATAN, 2009). The flood caused damage on a large scale (**Photos 1**, **2**, **3**, and **4**), affecting many people and causing 121 deaths (half the total for Metro Manila). The flood plain lies mostly in Marikina City, but part of it extends upstream into Quezon City. In Marikina City alone, there were approximately 180,000 people affected by the flooding.

Other problems included a high incidence of infectious disease and environmental damage caused by the runoff of pollutants from small and medium scale factories in the river

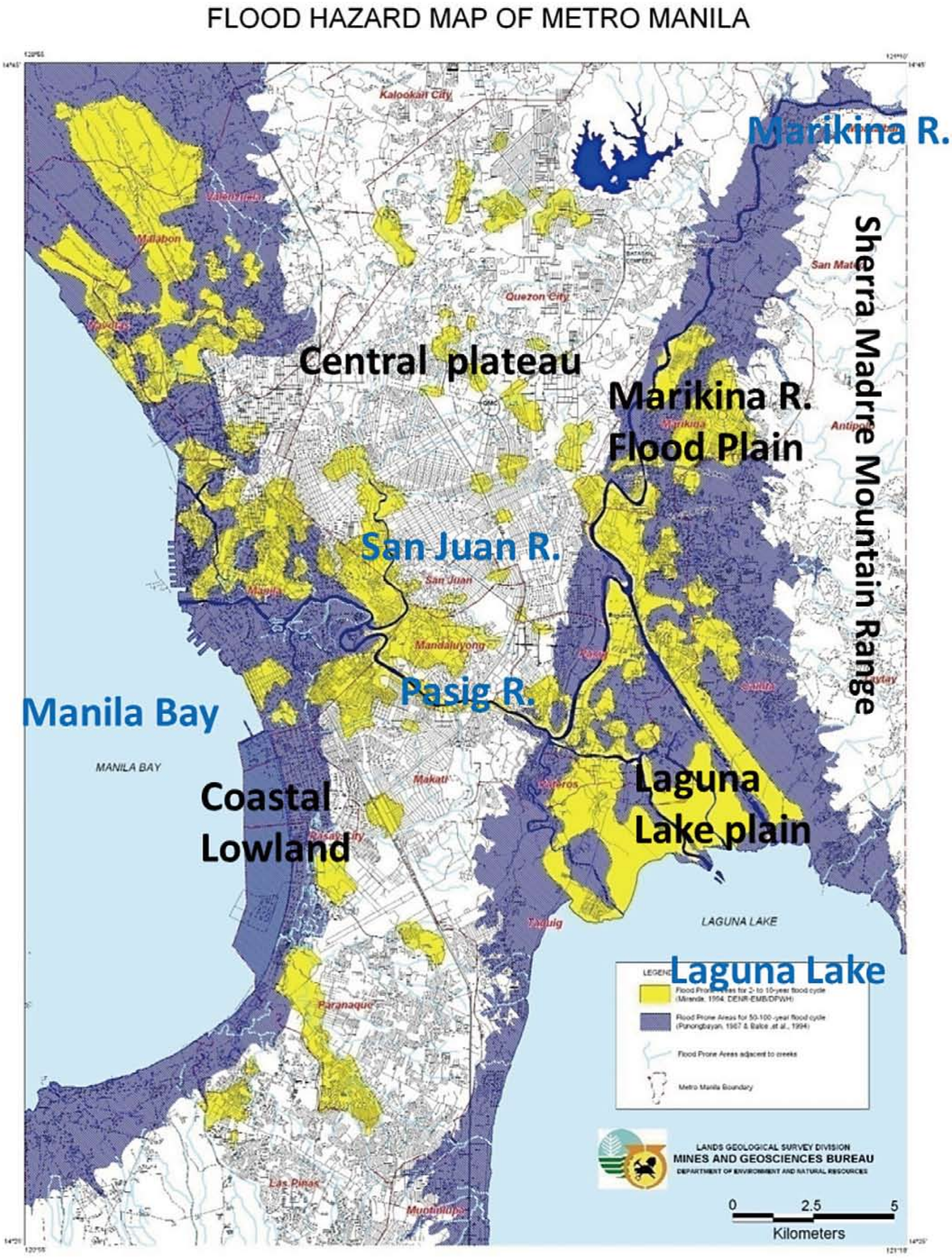

Fig. 3 Flood hazard map of Metro Manila (MGB, 2009).

basin.

4.2 Valley plain along the San Juan River

In the valley plain along the San Juan River (**Photo 5**), where damage was caused mainly by external flooding, there was external flooding from a flash flood from small and medium-sized rivers descending from an altitude of 95 to 3 m. At the Quezon City Science Garden inside the river basin, precipitation rates of 92 mm in 1 h and 455.0 mm in 24 h were observed, showing that this river basin was inflicted by a torrential downpour. Since the catchment area is only about one fifth the size of the Marikina River's catchment area, it is expected that flooding began earlier here than in the Marikina River. Also, since the flooded region of the valley plain is limited, this area is generally prone to more severe flooding with a greater depth of inundation (**Fig. 6**). Maps show that the inundation area expanded to the upper reaches of the plain.

This area suffered the second highest level of destruction behind the Marikina flood plain, and there were 111 fatalities. The number of people affected in this river basin (which includes the cities of Quezon, San Juan, and Mandaluyong) reached 135,000.

4.3 Coastal lowland adjacent to Manila Bay

The coastal lowland adjacent to Manila Bay was affected mainly by inner flooding. This is a low-lying and poorly

Table 1 Conditions of flood disasters caused by Typhoon Ondoy in Metro Manila in relation to landforms.

		Landforms	Related Water Bodies	Flooding: Predominant Type	Flooding: Period	Flooding: Depth	Damage: Cities	Affected Population	Dead	Completely Destroyed House	Economic Loss (Infrastructure)
Pasig-Marikina-Laguna Basin	Southern Part of Metro Manila	Marikina Flood Plain	Marikina R.	Outer Flooding	within three days	up to the 2nd floor	Marikina city	178,985	73	1,083	39,639,300
							Quezon city		48		
							Sub total		121		
		Valley Plain (Central Plataeu)	San Juan R.		within 1day	up to the head	Quezon city	113,420	57	140	58,285,016
							San Juan city	2,234	3	0	24,720,000
							Mandaluyong city	19,660	3	1	6,999,370
							Sub total	135,314	63		
		Coastal Lowland (South Part)	Passig R., Urban Draingage	Inner Flooding	within 1week	up to the chest	Manila city	5,790	9	0	14,521,714
							Makati city	3,395	7	0	409,490
							Pasay city	8,537	0	0	9,524,500
							Sub total	17,722	16		
		Laguna Lake Plain	Lauguna Lake, Passig R., Mangahan Flood Way, Taguig R.		over 2 weeks	up to the head	pasig city	127,110	23	499	37,308,780
							Pateros	32,320	0	0	0
							Taguig city	132,630	0	48	10,139,500
							Mantinlupa city	111,850	3	3,839	16,550,500
							Sub total	403,910	26	4,386	
Other Basins	North Part	Coastal Lowland	-	-	-	-	Malabon city	9,851	1	159	20,354,400
							Nvotas city	194	0	6,748	0
							Caloocan city	89,450	3	0	7,195,896
							(Sub total)	99,495	4		
		Central Plataeu	-	-	-	-	Valenzuela city	8,091	8	35	6,117,375
	Farthest South	Coastal Lowland	-	-	-	-	Paranaque city	2,250	2	8	38,525,642
							Las Pinas city	26,330	1	3	25,658,550
							(Sub total)	28,580	3		
	Unclassified Economic Loss										254,232,534
	Total of Metro Manila							872,097	241	12,563	570,182,587

＊Dead in the Quezon City is devided into 2 according to the landforms.
＊Flooding period refferred from JICA (2009) & Manila News Paper.
＊Damage reffered from NDCC Report No.42.

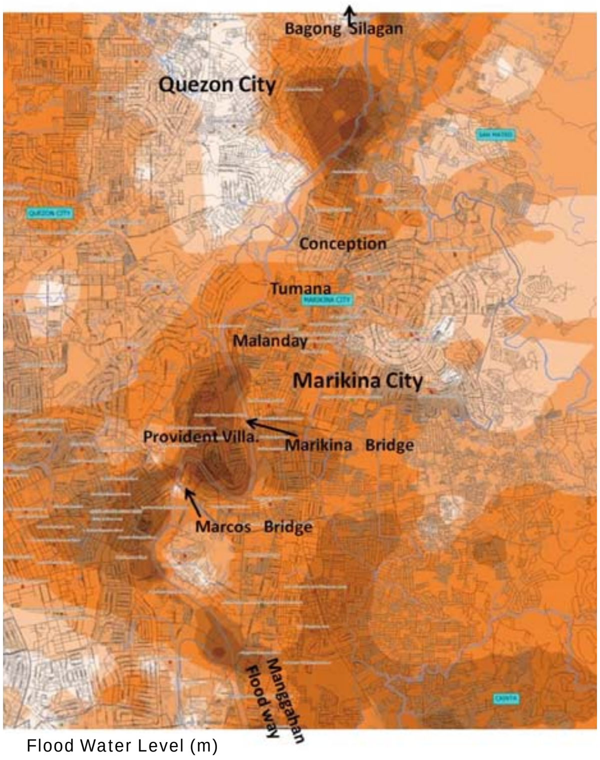

Fig. 4 Inundation depth by Typhoon Ondoy in Marikina River flood plain (NAMRIA, 2009).

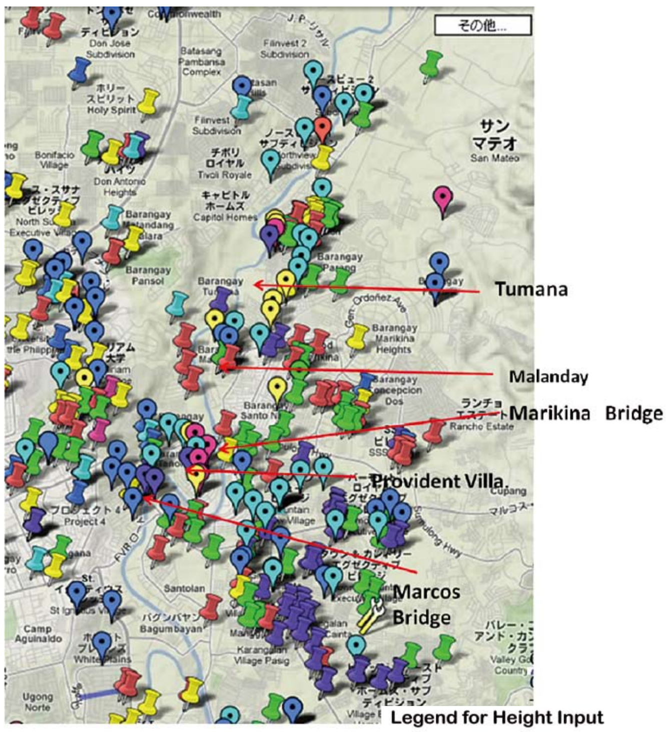

Fig. 5 Maximum inundation depth in Marikina flood plain (Google, 2009).

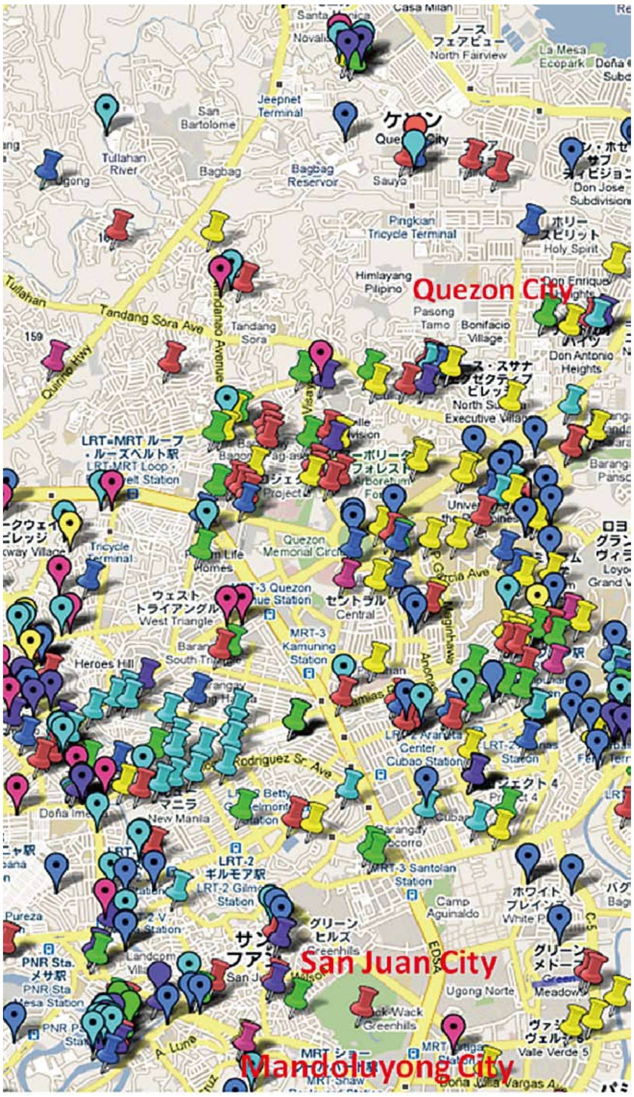

Fig. 6 Maximum inundation depth by 2009's Typhoon Ondoy in San Juan River flood plain (Google, 2009).

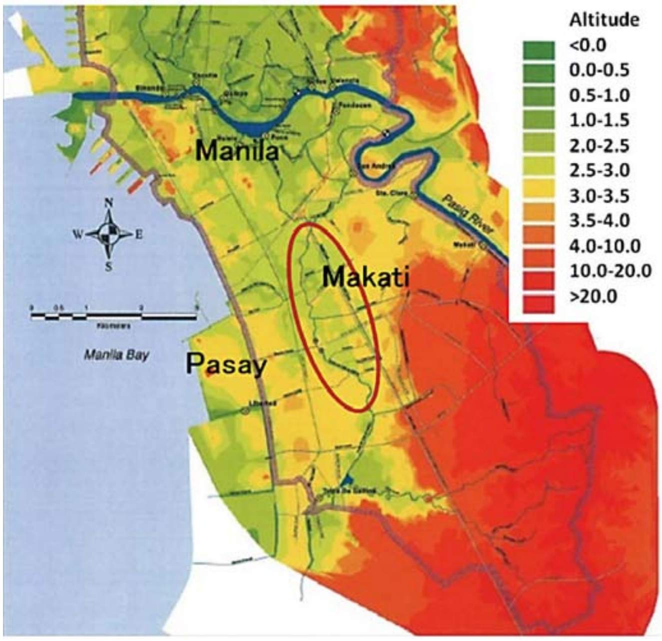

Fig. 7 Geographical map of the low land along Manila Bay (JICA, 2004).

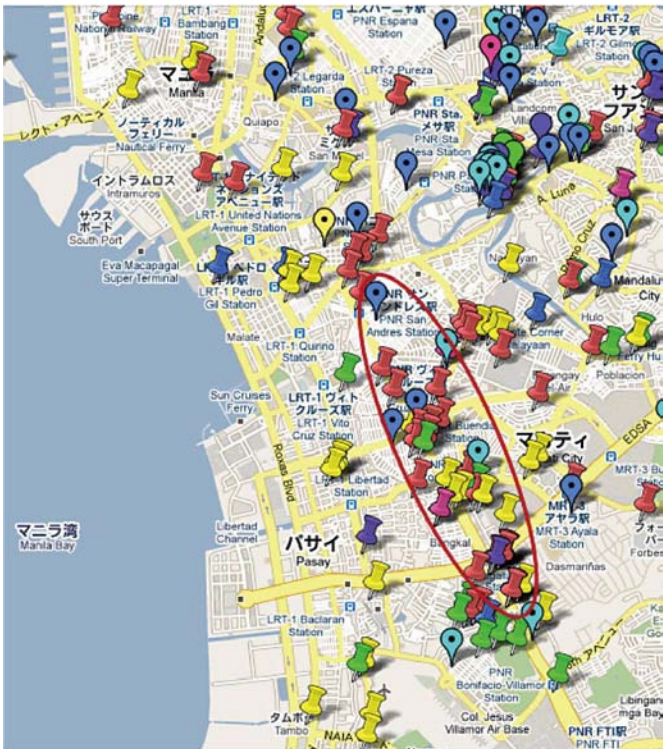

Fig. 8 Maximum inundation depth by 2009's Typhoon Ondoy in the Laguna Lake Plain (Google, 2009).

drained land environment with an elevation of 3 m or less (**Fig. 7**). Here, the Pasig River was partly overflowed, but it was possible to continue operating the pumps that expel inner water from lowland areas. However, in the lowland areas, it was not possible for the heavy rainfall to drain away, and inner water inundation occurred (**Fig. 8**). The inundation depth was deep enough to reach up to one's head, but flooding was fairly short-lived (from half a day to a few days). As a result, the number of people affected in the coastal lowland was only about 2 % of the total for Metro Manila as a whole, and there were only 19 fatalities in this area (**Photos 6** and **7**).

The Pasig River, flowing through the central areas of

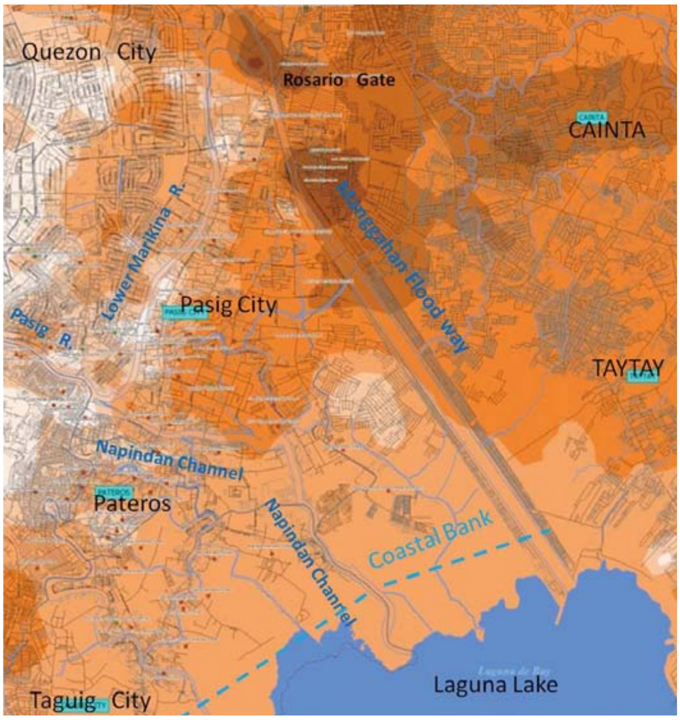

Fig. 9 Inundation depth in Laguna Lake Plain (NAMRIA, 2009).

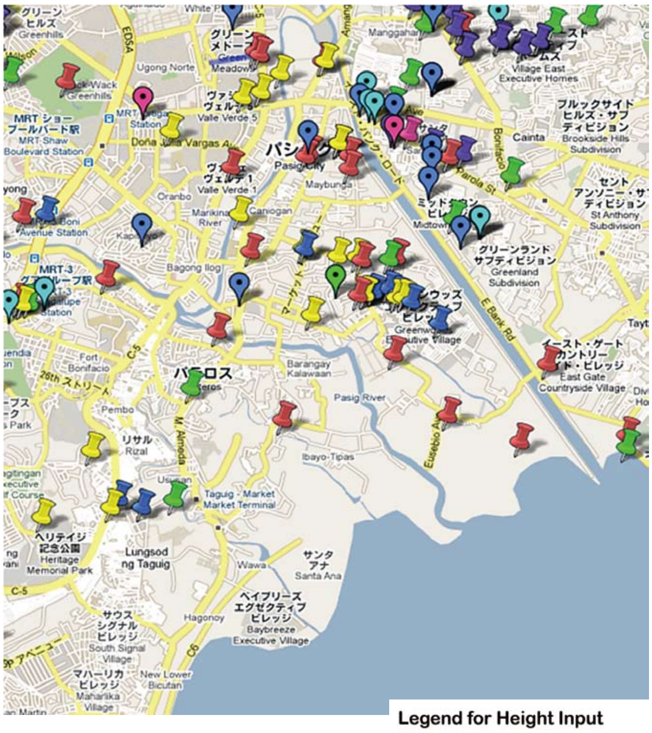

Fig. 10 Maximum inundation depth in the Laguna Lake Plain (Google, 2009).

Metro Manila, was spared from flooding due to the flooding of the Marikina River further upstream and due to the fact that the floodwater was diverted into Laguna Lake from the Manggahan Floodway and Napindan channel so that the flood discharge of the Pasig River was kept down to 600 m^3/sec, which is just about within the river channel discharge capacity (500 – 600 m^3/sec) (MMDA, 2009; P. B. GATAN, 2009). In the city drainage channel, where drainage capacity has decreased to the point where it can only cope with rainfall levels estimated to occur once every 2 – 5 years, it was not possible to protect the city from the inner flooding caused by the heavy rainfall of Typhoon Ondoy.

4.4 The Laguna Lake Plain

The Laguna Lake Plain was affected mainly by inner flooding and remained flooded for a long period of time (**Figs. 9** and **10**). It is a low-lying marshy area with an elevation of just a few meters that was affected by the increased water level of Laguna Lake and was deeply flooded, with regions close to the lake shoreline remaining submerged for more than a month (**Photos 8** and **9**). Although the flood inundation was not as severe as that in the Marikina flood plain, the flood water rose to a considerable depth, and the prolonged flood inundation resulted in the greatest number of affected people in the whole metropolitan area, reaching 400,000 people, or 45 % of the total. However, there were 26 fatalities in this region, which is about one fifth that of the Marikina flood plain.

5. Society’s resilience to flood disasters

5.1 Reducing the flooding

(1) Flood control facilities

The key component of Metro Manila’s flood control is the Manggahan Floodway (**Photos 10** and **11**), which has a drainage capacity of 2,400 m^3/sec and is designed for a once-per-century flood discharge. By diverting 70 % of the Marikina River flood discharge into Laguna Lake from the Rosario weir to reduce the flood discharge that continues downstream to the Pasig River, it is possible to reduce the flood inundation of the Pasig River flowing through the city center. When Typhoon Ondoy struck, flood water was diverted from the Marikina River into Laguna Lake at a rate of 3,000 m^3/sec, and only a partial external overflow occurred in the Pasig River, so it was possible to continue operating the inner water drainage pumps (MMDA, 2009; P.B.GATAN, 2009) .

The Pasig and Marikina Rivers are designed to withstand a

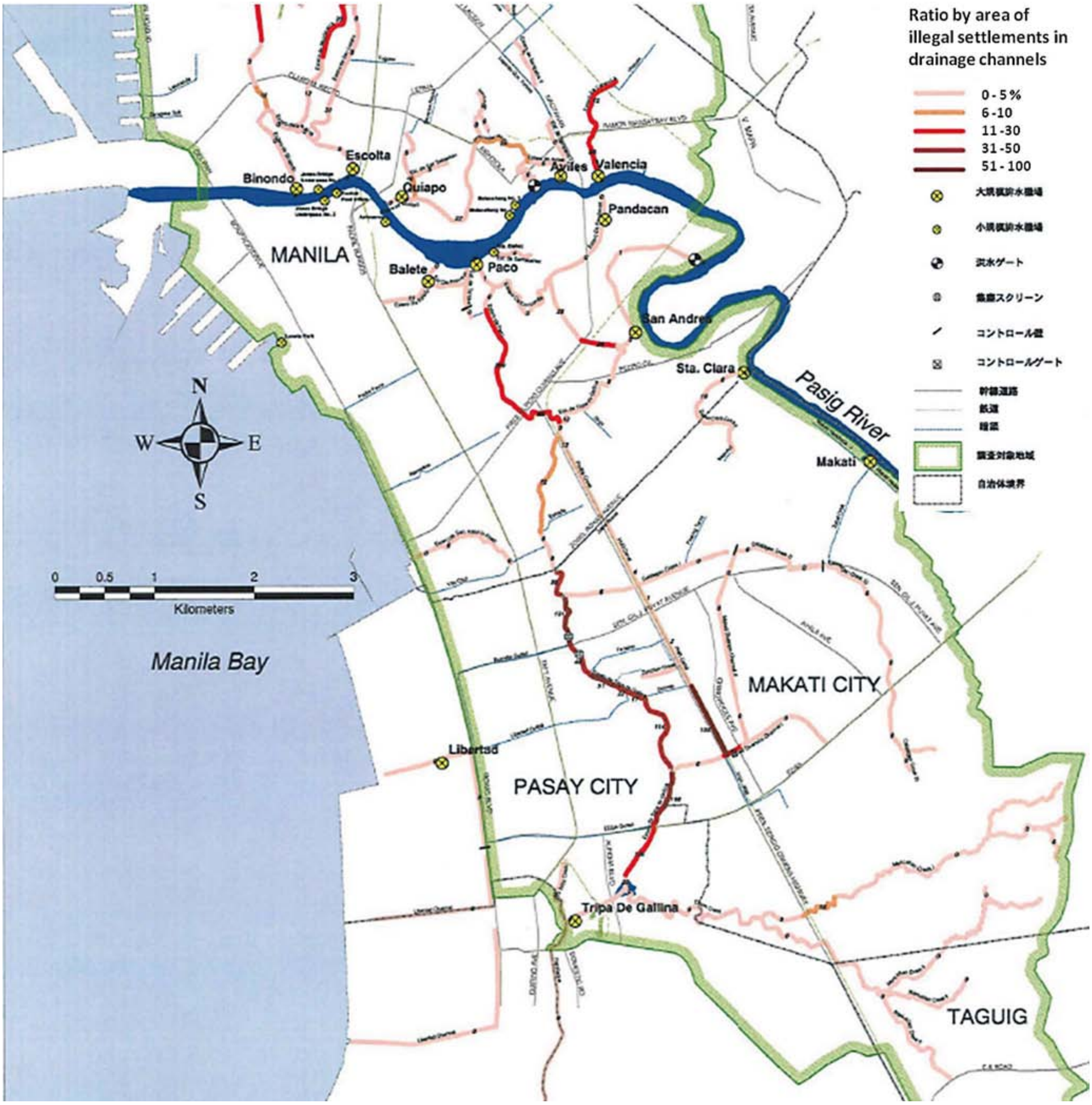

Fig. 11 Illegal settlements in the city drainage channels (Jica, 2005).

once-in-30-years flood (Marikina River: 2,600 – 2,900 m^3/sec ; Pasig River: 500 – 600 m^3/sec in the middle section and 1200 m3/sec in the lower reaches), but the designed discharge capacity is actually achieved only in the middle section of the Pasig River. The drainage of the other areas is incomplete. For example, the current discharge capacity of the Marikina River is 1,500 – 1,800 m^3/sec, which is smaller than the design scale.

To protect the regions that open out onto the Laguna Lake Plain to the west of the Manggahan Floodway (the cities of Taguig, Pateros, and Pasig) from becoming inundated due to a rise in the water level of Laguna Lake, work is under way to construct a 9.5 km coastal bank along the lake, 8 weirs, and 4 drainage pump stations (MMDA, 2009; P.B. GATAN, 2009). These inner water drainage facilities helped to reduce the flooding duration of the inner water inundation caused by Typhoon Ondoy (JICA, 2009).

(2) Maintenance of flood control systems

While flood control maintenance is continuing, various problems have arisen such as the reducing functionality of flood control facilities. Drainage performance is being impaired due to the disposal of garbage (**Photos 12** and **13**) and construction of shanty towns in drainage channels. **Fig.11** shows that the ratio by area of illegal settlements in the city drainage channels is high (JICA, 2005). As a result, in the city drainage channels, where the drainage capacity has decreased to the point where it can only cope with rainfall levels estimated to occur once every 2 – 5 years (JICA, 2005), it was not possible to protect the city from the heavy rainfall caused by Typhoon Ondoy. In the same way, shanty towns narrow the width of the Manggahan Floodway.

(3) Development of the river basin has increased flood discharge

The changing patterns of land use associated with haphazard development are changing the scale of floods. For example, in the city center district that is developing in the low-lying areas along the Manila bay, urban discharge channels for discharging inner water were constructed every ten years, having a coefficient of discharge of 0.4 – 0.5. An increase of the coefficient of discharge up to 0.95 has decreased the degree of the safety of the drainage system (JICA, 2005). In the Marikina River Basin, a decrease in forests by slash-and-burn farming, illegal harvesting, disorderly cultivation, the bulldozing of livestock farms, and the development of housing areas have been increasing flood discharge (JICA, 1994).

To mitigate flood disaster risks, maintaining flood control facilities and managing land usage are requisites.

5.2 Development of flood plain and damage potential

(1) Development and an increase in damage potential

A common problem of rice-growing areas in the Asian monsoon region is that urbanization driven by population growth can lead to building development on low-lying flood plains that are used for rice paddy fields and such, resulting in a greater potential for loss in the event of a flood disaster. Metro Manila is no exception.

For example, half a century ago (around 1966), the residential areas in the low-lying Laguna Lake Plain were confined to the natural levee and a high coastal terrace (4 – 7 m above sea level), but gradually they have encroached into lower-lying areas while filling in the poorly-drained back marshes, and development has now reached as far as the delta on the shores of the lake. The change in landscape brought about by filling in these marshes has also created an artificial flood-prone basin and changed the spatial distribution of flooding, which has affected the hazard situation (Hara *et al.*, 2002).

(2) Illegal settlements and an increase in damage potential

Another factor behind the increased damage potential is the growth of illegal settlements. For example, in the Manggahan Floodway, buildings have been erected in places such as floodwater channels that have an extremely high risk of flood damage, thus giving rise to a larger number of disaster victims. At the margin of Laguna Lake, which is vulnerable to rising water levels, many people living there were injured.

(3) Infectious disease and an increase of death

Furthermore, there are many places in the flood plains where flood water is not adequately drained away. This results in water being retained for long periods of time, causing environmental contamination that has an adverse effect on living conditions and can lead to major outbreaks of infectious disease after a flood disaster has struck. After Typhoon Ondoy, an outbreak of Leptospirosis caused 178 fatalities in the Metro Manila area (NDCC, 2009a).

(4) Flood water contamination

The flood water accelerated water contamination by washing out pollutants from small and medium-scale factories in the river basin into the Marikina River and Laguna Lake (UNEP/OCHA, 2009).

6. Conclusions

The Typhoon Ondoy flood disasters of 2009 occurred in the Metro Manila region, which has a growing population of over 11.6 million in a developing country, that has the following characteristics:

1) The flood control plan to protect the population of 11.6 million people from floods is to cope with a once-in-30- years flood. The flood control facilities are still under construction, and these differences in the state of development were one of factors behind the differences of flooding in the four flood plains of Metro Manila, along with hydrological conditions and land environments of the flood plain and river basins.

In the flood plains of the San Juan Rivers and the Marikina River where the discharge capacity of the river channel does not meet the design scale, a severe large-scale external flooding occurred and caused many deaths. In the Laguna Lake Plain and the Coastal Lowlands of central Metro Manila, parts of the external overflow remained behind, with inner flooding becoming the main inundation cause, and the inundation was not as severe as in the flood plains where external flooding was prominent. The Manggahan Floodway especially played an important role in protecting the central part of Metro Manila from severe external flooding by reducing the flood discharge of the Pasig River.

2) After flooding, an outbreak of infectious diseases was caused by the floodwater standing for long periods of time, largely affecting humans. To reduce human damage in Metro Manila, it is important to take actions to steadily reduce this sort of damage.

3) In Metro Manila, flood risks continue to increase. As the population grows, the river basin is further developed. This brings about changes in the flood runoff and inundation characteristics, increases the potential for damage, and reduces the functioning of flood control facilities due to illegal settlements and the dumping of refuse into channels. Also, the illegal dwellings of poor inhabitants encroach into river zones and lakeshores vulnerable to water related hazards, thus increasing the number of people affected by

Table 2 Flood Control Projects in Metro Manila by Foreign Assisted Projects (P.B. Gatan, 2009).

1	Mangahan Floodway Project (Yen Loan, completed in 1988)
2	Effective Flood Control Operation and Warning System Project (EFCOS: 10th Yen Loan, completed in 1992) The Project for Rehabilitation of Flood Control Operation and Warning System (EFCOS) in Metro Manila (Japanese Grant, completed in December 2001)
3	Metro Manila Flood Control Project – West of Mangahan Floodway (21st Yen Loan, completed in August 2007)
4	KAMANAVA Area Flood Control and Drainage System Improvement Project (Special Yen Loan, construction to be completed in 2009)
5	Pasig-Marikina River Channel Improvement Project (26th Yen STEP Loan, construction of Phase I started in September 2009)
6	Valenzuela-Obando-Meycauayan Area Drainage System Improvement and Related Works Project (Requested for Yen Loan)
7	Integrated Drainage Improvement Project in Ninoy Aquino International Airport and its Vicinity (Study was completed in March 2004: JETRO)
8	Drainage Improvement in the Core Area of Metropolitan Manila (Study was completed in March 2005: JICA) East Mangahan Floodway Area Flood Mitigation Project (Study was completed in June 2007 and to be requested for implementation to JICA)
9	San Juan River Flood Control Project (Feasibility Study was completed in 2002: JICA)
10	Upper Marikina River Channel Improvement Project (Feasibility study was completed in 2002: JICA) ・1980~1983: Napindan Hydraulic Control Structure: ・1974~1997: Manila Drainage System Improvement ・2000~2007: Drainage pumping stations (15), flood gates, drainage channel improvement West of Mangahan Floodway ・2002~2009: Lake dike (9.4 km), drainage pumping stations (7), Napindan river channel dike/parapet wall (6.1 km), Floodgates (8), Drainage channel improvement
11	KAMANAVA Area Flood Control and Drainage System Improvement project ・1978, 1992, 2000~2002: Ring dike (8.6 km), Drainage pumping stations (5), EFCOS Project ・2009~ : Pasig-Marikina river improvement

flooding.

To reduce flood risk, it is necessary to make an effort to find a solution to these complex issues with transdisciplinary cooperation, involving a variety of social, economic, and governmental factors and researchers.

4) In interviews on the 2009 Ondoy Flood with governmental bodies and other such organizations, we were told about the importance of working to improve the ability of communities to mitigate disasters and about the activities of disaster relief volunteers. We hope that these movements become more active in introducing a more diverse and wider range of human resources.

5) Improving flood control structures is essential for reducing the flood risk in Metro Manila, but it is difficult to reduce damage solely by flood control facilities. To reduce the flood risk of this region, it is also necessary to institute comprehensive measures targeting whole river basins and whole components of flood risk. For example, hazard control measures in flood plains by local people, land use management for reducing damage potential in flood plains, and the decrease of flood runoff from flood plains, etc. In addition, comprehensive measures need the cooperation of various concerned bodies including social scientists.

Japan has contributed to the improvement of flood control in Metro Manila (**Table 2**). Through many experiences, Japan has accumulated a considerable amount of knowledge on the characteristics of flooding, land environments, social structures, and so on. When taking the next step forward in mitigating the flood risk of Metro Manila from a new perspective, we expect that Japan's experiences will be useful.

Photo 1 & 2 Provident village damaged by flooding (Courtesy of the PNRC-Rizal, 2009).


Photo 3 & 4 Provident village damaged by flooding (Courtesy of the PNRC-Rizal, 2009).

Photo 5 Floodwall along San Juan River.


Photo 6 & 7 Inner flooding in Makati City (taken by Kazutami Shiga).


Photo 8 & 9 Flooding along Laguna Lake on Nov. 30, 2009 in Taguig City.

Photo 10 Manggahan Floodway (Courtesy of the MMDA, 2009).

Photo 11 Rosario weir at the Manggahan Floodway (Courtesy of the MMDA, 2009).

Photo 12 & 13 Dredging urban drainage channels in Metro Manila (Courtesy of the MMDA, 2009).

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(Accepted: November 25, 2010)