Investigation of Sediment Disasters caused by Heavy Rainfall on November–December 2004 in Quezon Province, Philippines

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Introduction

From mid-November to early December 2004, the Philippines experienced a series of typhoons and tropical storms which resulted in catastrophic flooding and sediment disasters, such as landslides and debris flows. The number of death and missing exceeded 1600, with the cost of damage estimated at US$78.2M. Among the affected areas, the coastal towns of Quezon Province in eastern Luzon suffered the most damage, with numerous landslides occurring in the town of Real and debris flows burying the towns of Infanta and General Nakar. This paper outlines the results of the reconnaissance works conducted at the affected sites following the disaster, with emphasis on hydro-geological causes of the disaster and on damage to civil engineering structures and other infrastructures.

Rainfall Characteristics

Initially, typhoon Muifa (local name: “Unding”) struck the north-central Philippines in mid-November 2004. This was followed by tropical storm “Violeta” that passed over Luzon on the 22nd of November. Next, another tropical storm “Winnie” also hit Luzon on the 29th. Finally, typhoon Nanmadol (local name: “Yoyong”) made landfall in Luzon on the 2nd of December. Although the Philippines experiences 20 typhoons and storms a year on the average, these 4 tropical cyclones resulted in flooding and landslides which led to considerable loss of life and devastating damage to property and environment, particularly in Quezon Province of eastern Luzon.

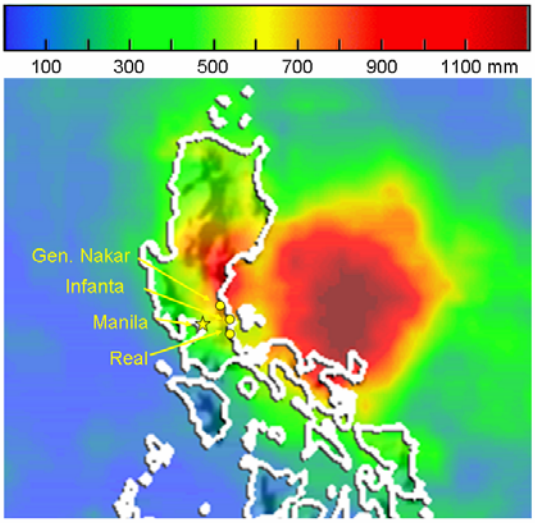

Fig. 1: MPA rainfall totals for the period 2004/11/16 to 2004/12/03 (modified from http://trmm.gsfc.nasa.gov).

The multi-satellite precipitation analysis (MPA) rainfall totals for the period between November 16-December 3 as obtained by the combined NASA/JAXA project is shown in **Fig. 1**. It can be observed that there are two distinct regions with the highest amount of rainfall: one is off-shore east of Luzon Island with rainfall in the order of 1250mm; and the other is just north of Dingalan Bay along the eastern side of Luzon, with rainfall totals exceeding 1100mm during the 2-1/2-week period. Records obtained by PAGASA rain gauge showed that in the morning of November 29 during the passage of storm Winnie, 342mm of rain fell during a 9hr period in Infanta station, after which no more rainfall data was available because floods washed away the rain gauge. According to PAGASA records from 1951-2002, the average annual precipitation in Infanta is about 4016mm while the average monthly rainfall during the rainy season (Oct-Dec) is 610mm. These indicate that about 30% of the average annual precipitation and about twice the average monthly precipitation fell within this 2-1/2-week period. Such torrential downpours over the eastern slopes of the mountainous and hilly terrain in eastern Luzon led to massive mudslides and flash floods and accounted for the greatest loss of life.

Landslides in Real Town

Real is a coastal town located at the northeastern coast of Quezon Province, about 75km east of Manila. It is located between Lamon Bay, the wide expanse of the Pacific Ocean and the mountain ranges of Sierra Madre. The town was founded when early settlers cleared the forests and planted the area with variety of products. At present, most of the built-up areas are concentrated along the well-paved asphalt mountain road which cuts across the Sierra Madre mountains. Basaltic volcanics are the primary formation in the upland regions of the Sierra Madre, while the soil covers are generally from weathered deposits. Springs are prevalent along the mountain road and are used by residents as source of water supply. The slopes of the mountains are generally steep, with gradients on the order of 30-50%.

Fig. 2: View of landslide in Real town where more than 100 people were killed.

Numerous landslides were noted in the southeastern part of Sierra

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Madre, even in areas which are heavily forested. Trees were uprooted from these mountains and slid down the slopes together with great masses of soils. Most of the landslides involved only surficial soils and were not deep-seated. Rockslides and rockfalls were also observed near mountain streams. In one of the worst hit areas, about 100 persons were trapped when a three-storey building being used as an evacuation site collapsed under the impact of one landslide. The site is shown in **Fig. 2**. Moreover, five road bridges were destroyed by the sediment- and debris-laden flood waters, and logs and debris blocked major portions of the national highway, rendering Real and adjacent towns inaccessible to traffic for several weeks. One of the washed-out bridges is depicted in **Fig. 3**.

Fig. 3. One of the bridges washed-out by debris-loaded floodwater.

Debris flows in Infanta and General Nakar Towns

The towns of Infanta and General Nakar are coastal areas located north of Real. The thick alluvial deposits in the region indicate that the towns were formed at the delta of Agos River. Due to the heavy rainfall, slope failures occurred on the southeastern flank of the mountain ranges. Debris flows were then mobilized and these quickly filled up and overflowed the banks of Agos River, burying the two low-lying towns. Interviews with local residents indicate that some portions of the region were covered by about 3m high heavily-silted floodwater, necessitating the evacuation of the affected area. The estimated area covered by flows is illustrated in **Fig. 4**, while typical damage to residential buildings is shown in **Fig. 5**. The volume of mud and debris that covered the two towns is estimated to be almost 20 million m^3. Three months after the disaster, some far-flung villages were still covered by mud, rendering vast tracts of farmlands useless.

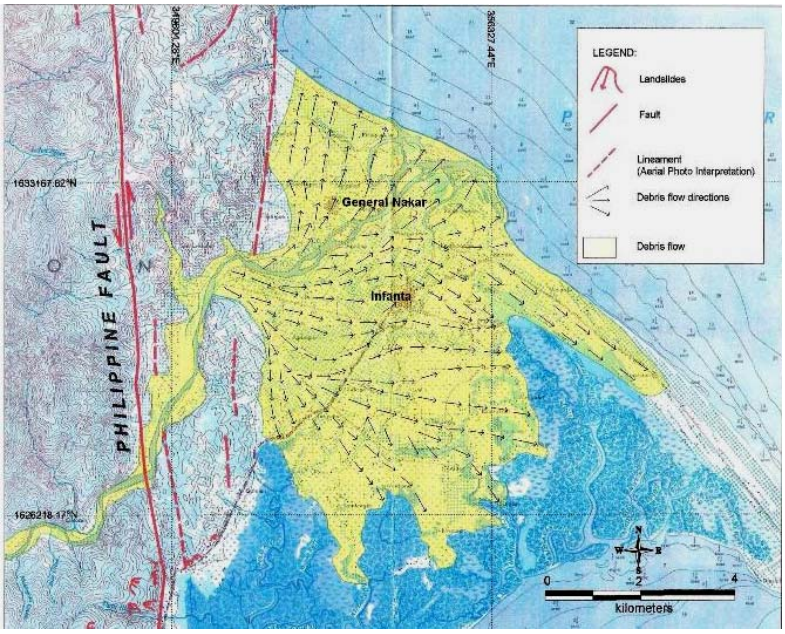

Fig. 4: Areas affected by mudflows in Infanta and Gen. Nakar, Quezon Province.

Causes of Sediment Disasters

In the aftermath of the disaster, government officials blamed the logging activities in the southeastern portion of Sierra Madre mountain ranges as the main cause of landslides and floods in the affected areas. However, aerial photos showed that in the southwestern portion of the mountain ranges, which have almost similar geologic and topographic features, very few landslides occurred although forest cover was very little. Further inspection reveals that landslides were prevalent in steep slopes, whether forested or not. The results of preliminary investigations suggest that the heavy rainfall preceding the disaster is the main cause of the slides. The heavy rainfall saturated the slopes, leading to loss in shear strength and resulted in failures. The existence of highly fractured rocks, steep slopes and thick soil cover also contributed to the mobilization of slope failures. Environmental conditions, particularly land use and logging, were not the main cause of the landslides, but may have contributed to the impact and scale of the disaster.

Fig. 5: A house buried by logs and mud in Infanta.

Concluding Remarks

Heavy rainfall due to a series of typhoons and tropical storms in the Philippines caused extensive damage to life and property, particularly in the coastal towns of Quezon Province. Ocular inspections after the disaster showed that the landslides and mudflows resulted in significant localized changes in physical landscape of the affected areas. Moreover, slope stability appears to have been compromised in many areas due to the landslides. Therefore, appropriate countermeasures are necessary in order to minimize further landslides and to prevent similar disasters in the future.