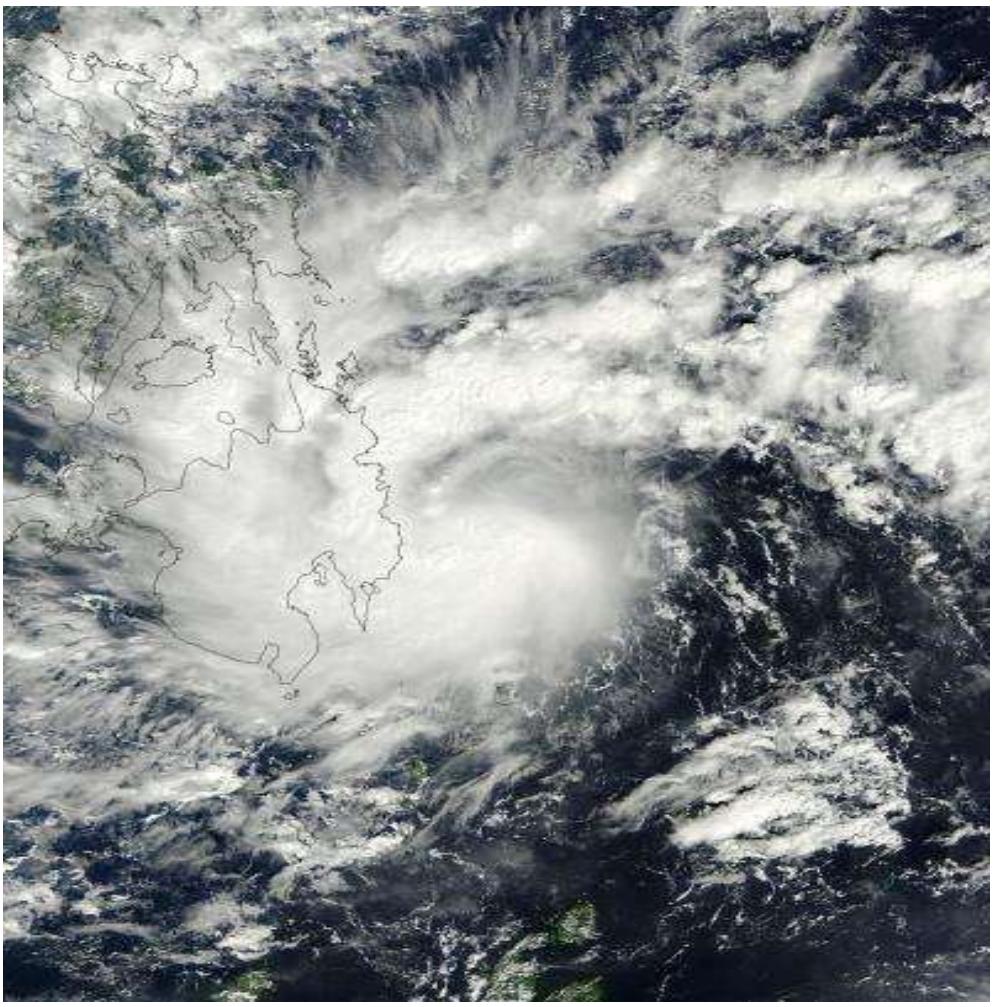
Initial Assessment of the Development of Tropical Strom Sendong (Washi) over the Philippines

December 15-19, 2011



Satellite visible image of TS Sendong (Washi) crossing the Philippines on 16 December 2011
(Source: http://www.goes.noaa.gov/sohemi/)

At the end of December 2011, the Philippines were struck again by a Tropical Storm named Sendong (Washi). After gaining strength over the open ocean since December 12, it moved west north-westwards and made its first landfall in the vicinity of Hinatuan, Surigao del Sur in Mindanao province on December 16. After crossing Mindanao Island it made its second landfall near Puerto Princesa City, Palawan on December 18. That day, TS Sendong (Washi) moved out of the PAR heading towards Vietnam. According to the weather bulletin from PAGASA, the strength of Sendong (Washi) ranged from 55 to 65km/h with gust up to 80 km/h and with displacement speed from 24 to 30km/h. The winds were only a minor factor compared to the precipitation amounts that generated heavy rainfall throughout its passage, leading to several floods and landslides. Sendong (Washi) caused confirmed 9576 casualties and more than 3438,000 persons were affected in 13 provinces (310 municipalities) as reported by the National Disaster Risk Reduction & Management Council (NDRRMC) on December 210, 2011. The estimated agricultural damage amounts to almost more than 2one million PhP.

Final Report
December 2011

Contents

1 Chronology of the Tropical Storm Sendong (Washi)

On December 12, 2011, a low pressure area (LPA) was detected to persist near Chuuk (Micronesia). The next day, December 13, the LPA intensified prompting the Joint Typhoon Warning Center (JTWC) to issue a Tropical cyclone formation alert (CFA). On the same day, the JTWC and The Japan Meteorological Agency (JMA) upgraded the low pressure to a tropical depression and designated as 27W.

On early 15 December, The Philippine Atmospheric, Geophysical & Astronomical Services Administration (PAGASA) designated it Sendong as it entered the Philippine Area of Responsibility (PAR) east of Mindanao. After passing Palau on December 15, both the JTWC and the JMA upgraded the system to a tropical storm and named it Washi as it increased its threat to Northeastern Mindanao and Eastern Visayas area.

On December 16, Sendong (Washi) slowed down slightly and made landfall in the vicinity of Hinatuan, Surigao del Sur, a province in Mindanao, southern Philippines. Several hours later, Sendong (Washi) arrived to the Sulu Sea and regained its strength quickly due to slight land interaction with Mindanao. Late on December 17, Sendong (Washi) crossed Palawan arriving into the South China Sea.

On December 18, Sendong (Washi) made its second landfall around 4:00 p.m. in the vicinity of Puerto Princesa City, Palawan, before heading towards the west of Philippine Sea. At 8:00 p.m. it moved out of the PAR moving towards Vietnam.

According to the weather bulletin from PAGASA, the strength of TS Sendong (Washi) ranged from 55 to 65km/h with gust up to 80 km/h and its movement was from 24 to 30km/h. While the strength of TS Sendong (Washi) was only 65km/h, its estimated amount of rainfall was heavy within the 400km diameter which caused heavy rainfall in Mindanao areas.

The tropical storm posed a rather unusual threat on the Philippines, as it headed for the often spared south of the country. According to the National Disaster Risk Reduction & Management Council (NDRRMC) report number 11, on December 20, 2011, Sendong has caused at least 9576 fatalities, and 469 people are officially listed as missing. The majority of the deaths were in the cities of Iligan (Lanao del Norte) and Cagayan de Oro (Misamis Oriental). Five people were killed in a landslide, but all others died in flash flooding. More than 2,000 have been rescued, according to the Armed Forces of the Philippines. The flash flooding occurred overnight, following 10 hours of rain, compounded by overflowing rivers and tributaries. In some areas, up to 20 centimeters of rain fell in 24 hours.

At least 20,000 people were staying in 10 evacuation centers in Cagayan de Oro.

More than 3438,000 persons have been affected in 13 provinces (310 municipalities) and 120,131345 houses have been damaged as reported by NDRRMC. The estimated agricultural damage amounts to almost one2 million PHP.

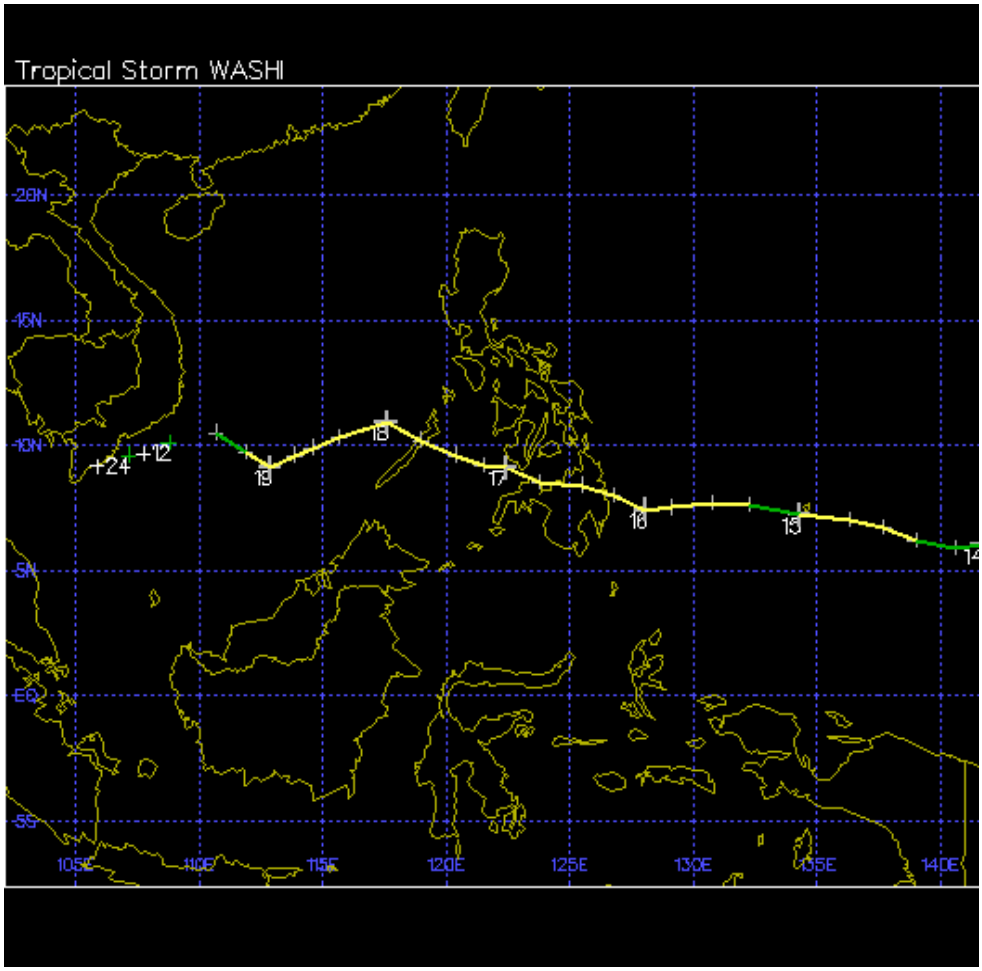


Figure 1.1 Typhoon Track, (Source: http://weather.unisys.com/)

2 Setup of the Typhoon Trigger and Assessment of Monitored Data

2.1 Assessment of the Monitored Data

A novel insurance product aims to protect cooperatives in the Philippines from insolvency following typhoons. DHI provides online real-time monitoring of weather events all over the country, serving as the basis for the insurer's payout scheme.

Wind and rainfall were previously identified by DHI Water & Environment (S) Pte. Ltd. (DHI) as the two major causes of insurance loss and threshold values – so called triggers – set up for these two parameters. That enables DHI to categorize the severity of a weather event into a 10-year, 15-year or 20-year event.

In order to supply the most accurate information, DHI's so-called "Typhoon Trigger" integrates different kinds of independent data, thereby forming a coherent picture of the actual weather situation in the Philippines.

The Typhoon Trigger recognizes a typhoon event from the moment a tropical depression hits the PAR with maximum wind speeds superior to 30 knots (55.6 km/h).

2.1.1 Rainfall Data

The rainfall trigger is based on satellite data provided by the Tropical Rainfall Measuring Mission (TRMM), a joint mission of National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. Data are available on a three-hour basis in grids of 0.25°, which are approximately squares of 27x27 km. Hence, the Philippines are covered by 852 data squares, each containing the level of rain for this area. Thereby, TRMM offers a dense coverage of the Philippines, both in time and space.

Raw data from the TRMM satellite use eight different stations to validate local data and make the necessary calibration. The closest validation station for the Philippines is located in Taiwan. After quality control operations, TRMM data are regarded as a reliable qualitative and totally independent data source useful to the hazard analysis and the development of the trigger.

It is important to keep in mind that the direct comparison between rain gauges and the TRMM rainfall data is very difficult due to the different approaches in the measurement of rainfall.

2.1.2 Categorisation and Triggering

In order to evaluate the rain trigger, an extreme value analysis is carried out on the 24-hour TRMM rainfall data for each municipality. Comparing the maximum 24-hour rainfall to the calculated 10-year, 15-year or 20-year rain events, the event return period is calculated for each of the municipalities. Finally, checking each of the municipalities against the trigger criteria, the triggered municipalities are sought out.

2.1.3 Tracking Tropical Strom Sendong (Washi)

DHI's system was able to track Sendong's (Washi's) precipitation over the affected areas of the Philippines during the approach of the Tropical Storm and following landfall in the vicinity of Hinatuan, Surigao del Sur, Mindanao's province.

As shown in Figure 2.1 to Figure 2.6, the monitoring system clearly reveals the Philippine's southern areas that have been affected by the heavy rains during the approach of Sendong (Washi) on December 16 and first landfall on December 17, before crossing over the mountainous areas of Mindanao island.

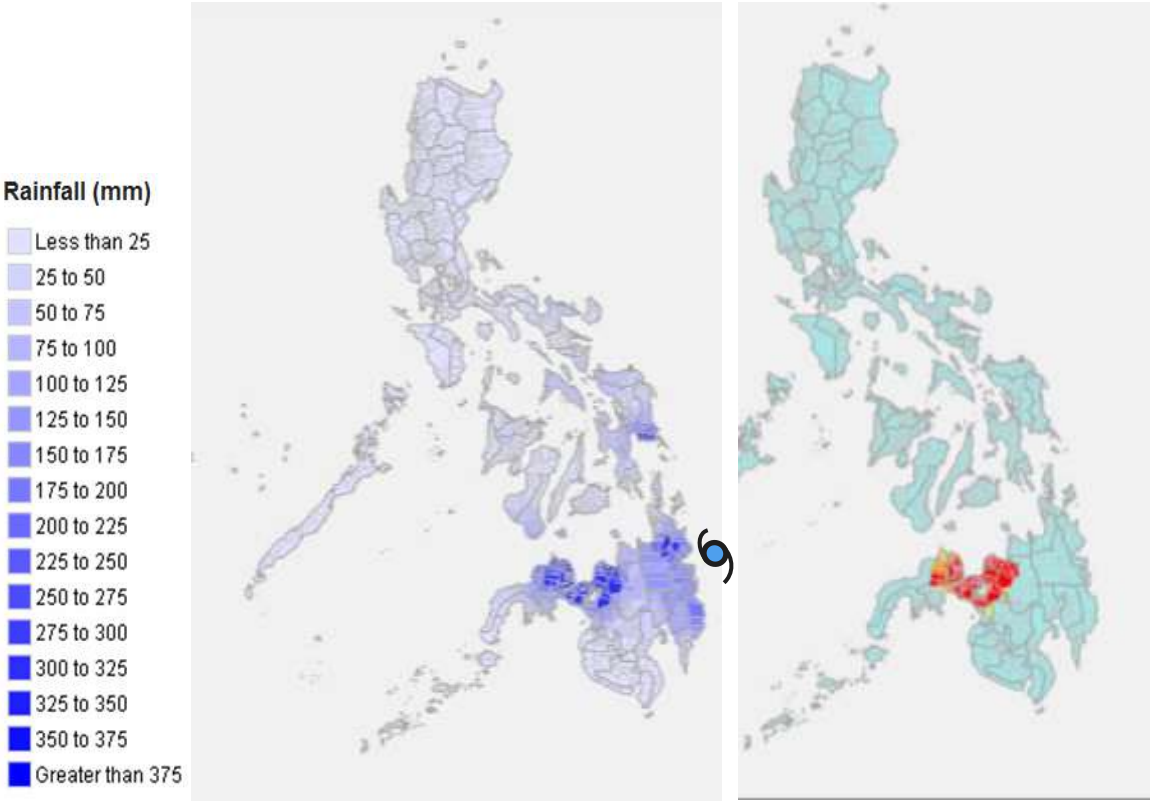


Figure 2.1 DHI's rainfall real-time monitoring system on December 16, 2011 (left panel) and the triggered events in colour (right panel). Heavy rainfall is represented in dark blue and the legend displays the maximum 24hr rainfall values measured by satellite TRMM.

: Approximate location of Sendong (Washi) on December 16, 2011.

The tropical storm posed a rather unusual threat on the Philippines, as it headed for the often spared south of the country. This explains why the municipalities that have been triggered are the ones more to the southern-central area of Mindanao, while the closest to the coast are not triggered even if they have also received high amounts of rain (see Figure 2.1 and Figure 2.5).

Figure 2.2, Figure 2.4 and Figure 2.6, Figure 2.6 show a close-up over the area that has been affected the most by the high amounts of precipitation accumulated over 24h.

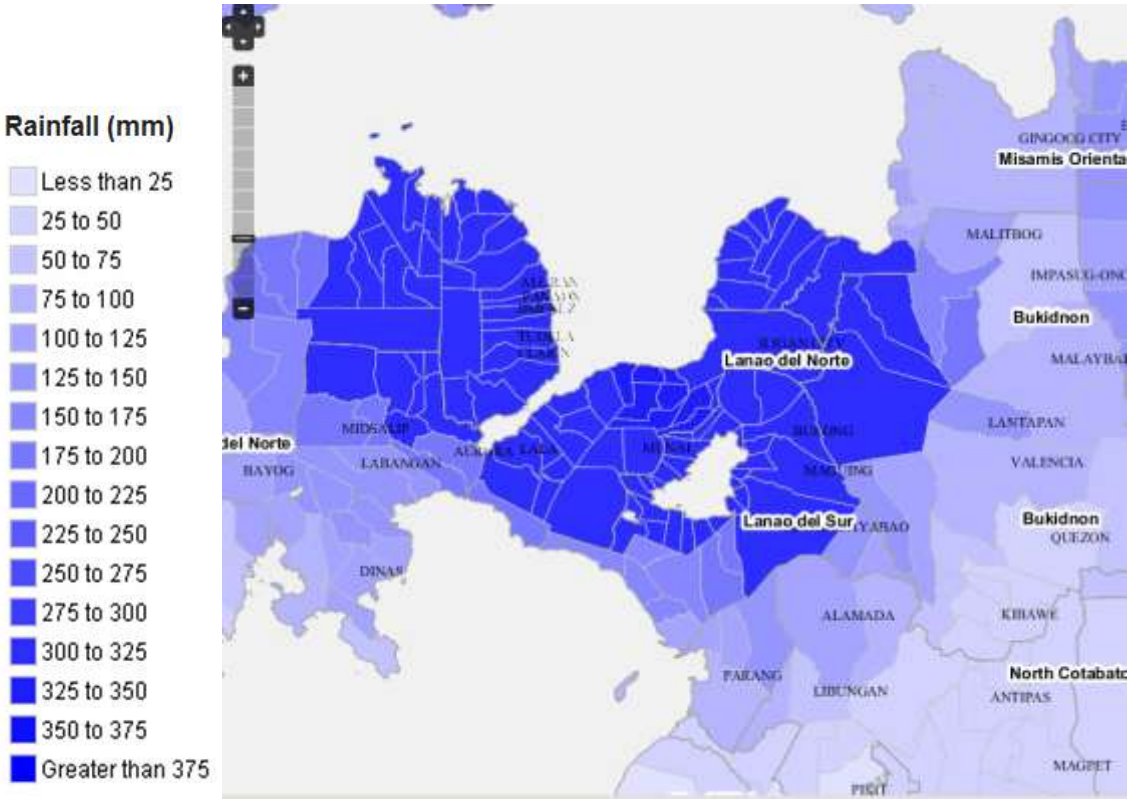


Figure 2.2 Close-up of DHI's rainfall monitoring system on December 16, 2011, over the most affected area. Heavy rainfall is represented in dark blue and the legend displays the maximum 24hr rainfall values measured by satellite TRMM.

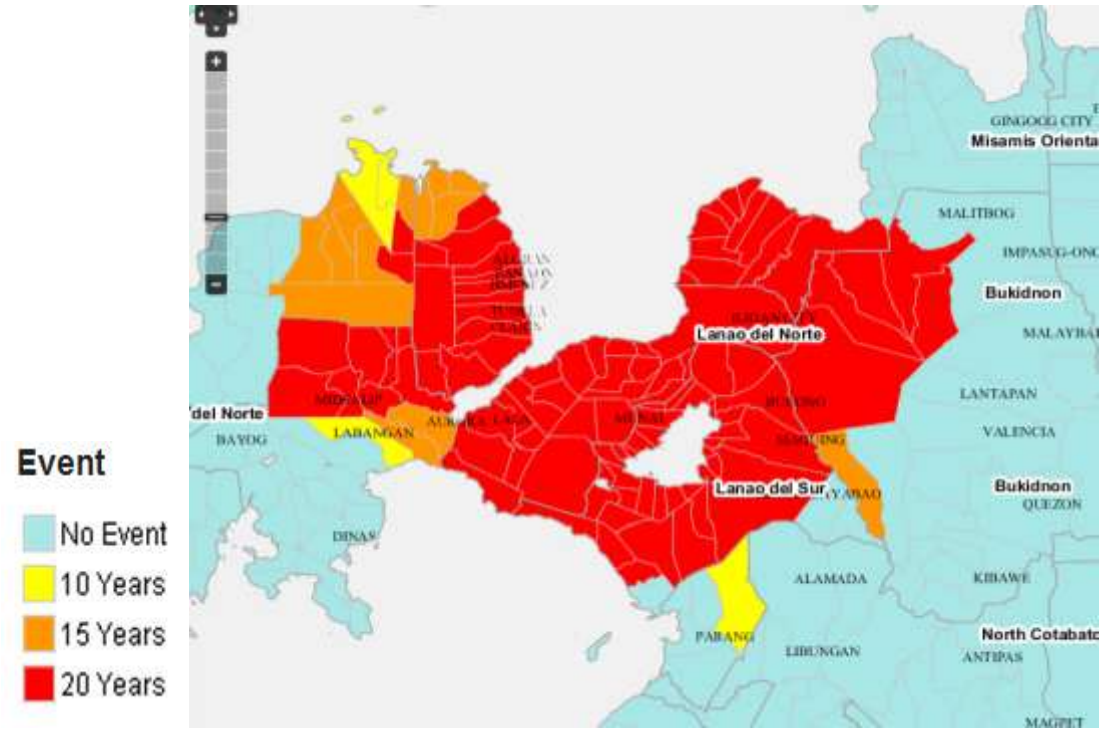


Figure 2.3 Close-up of DHI's rainfall monitoring system on December 16, 2011, shown in function of the category of the triggered event as a function of the return period

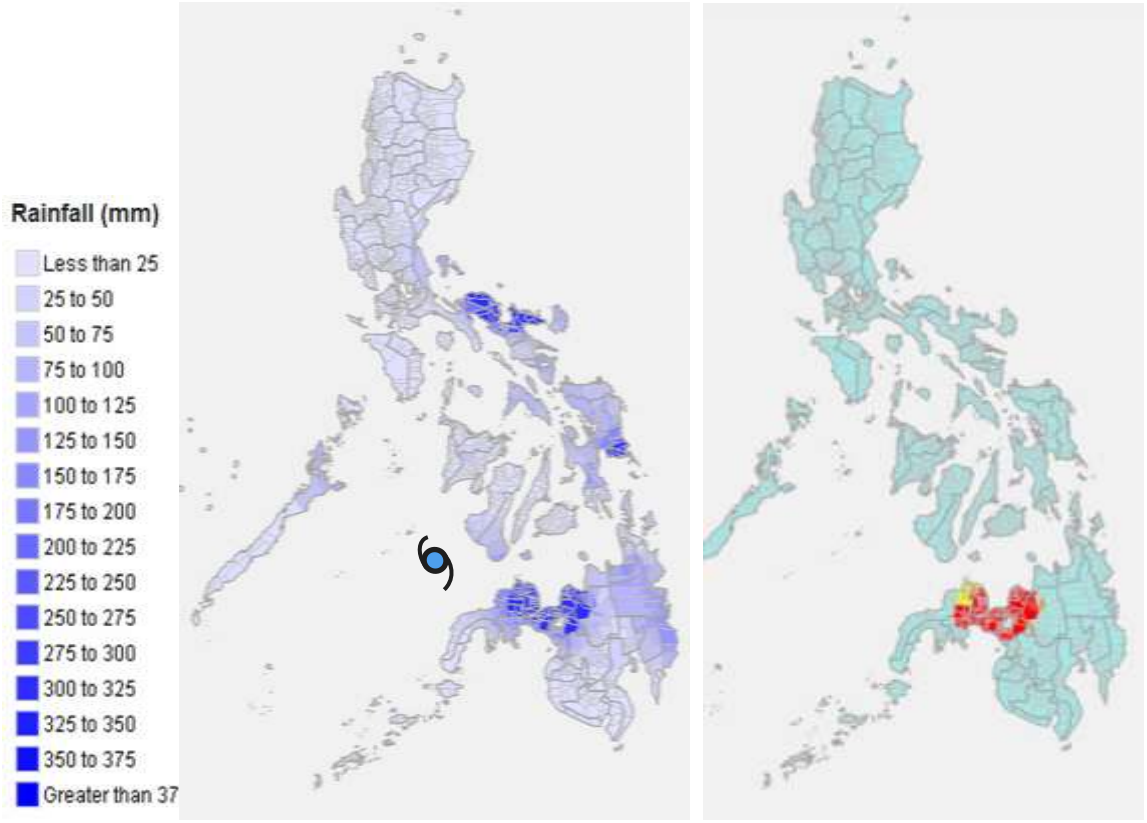


Figure 2.4 DHI's rainfall real-time monitoring system on December 17, 2011 (left panel) and the triggered events in colour (right panel). Heavy rainfall is represented in dark blue and the legend displays the maximum 24hr rainfall values measured by satellite TRMM

: Approximate location of Sendong (Washi) on December 17, 2011.

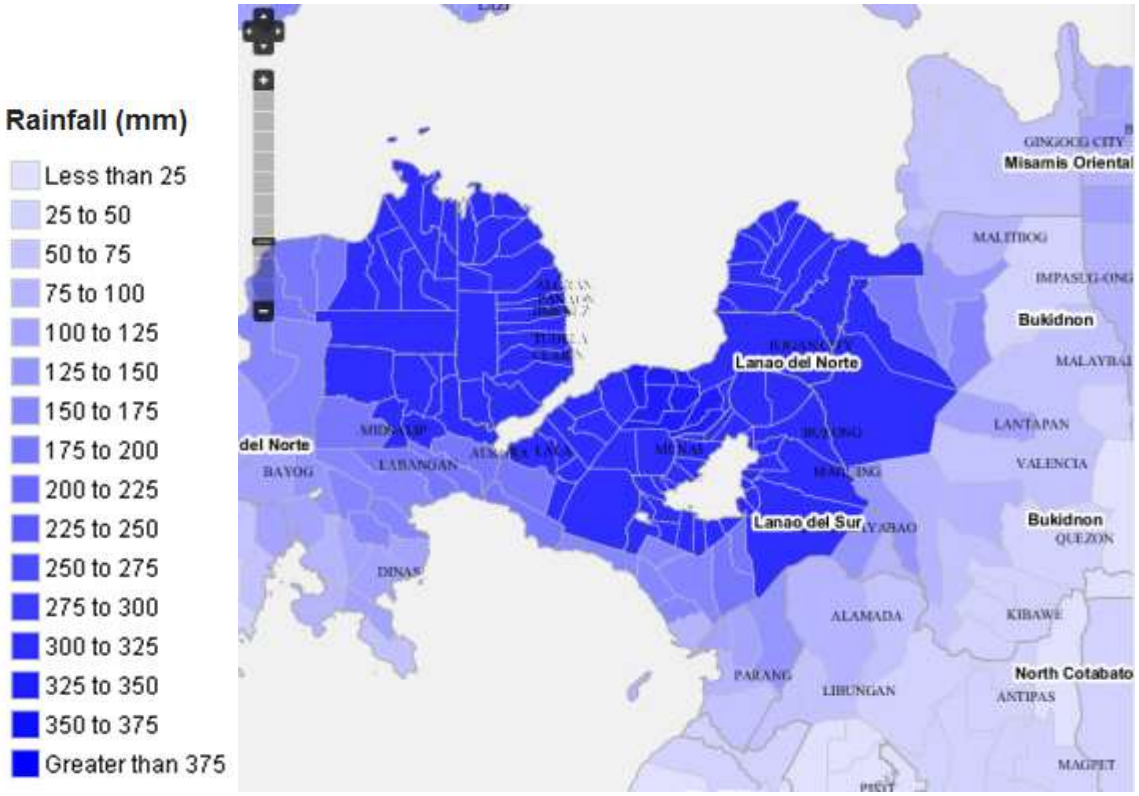


Figure 2.5 Close-up of DHI's rainfall monitoring system on December 17, 2011, over the most affected area. Heavy rainfall is represented in dark blue and the legend displays the maximum 24hr rainfall values measured by satellite TRMM.

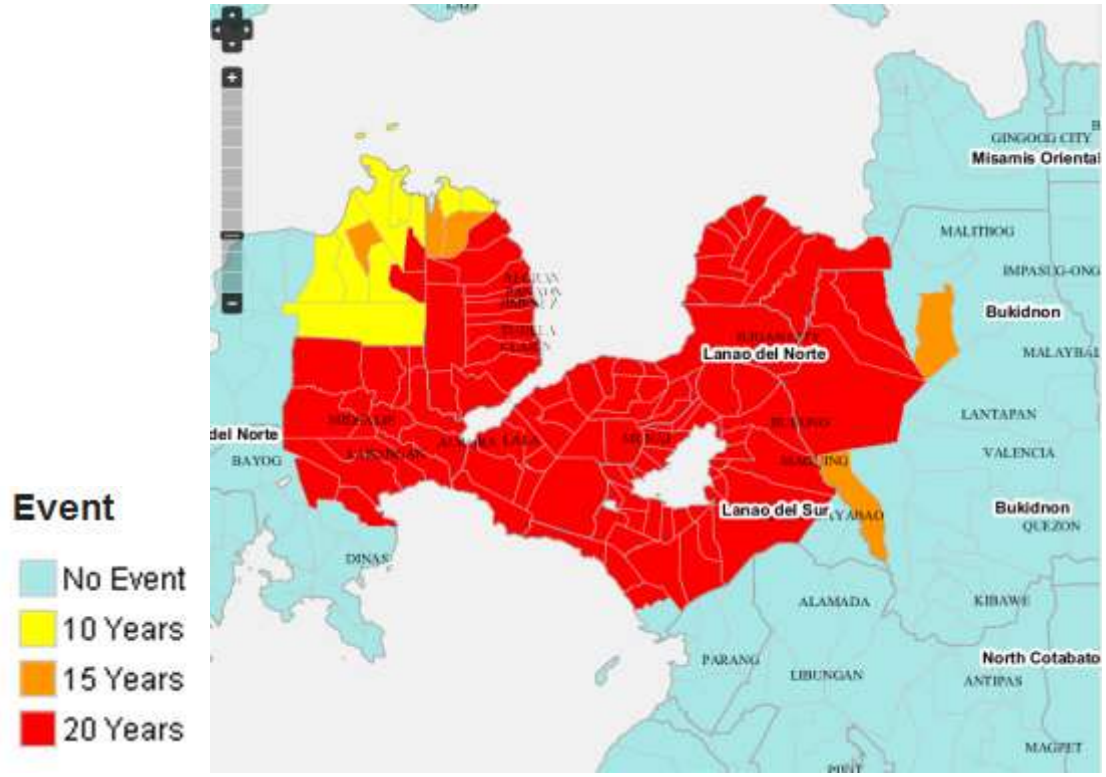


Figure 2.6 Close-up of DHI's rainfall monitoring system on December 17, 2011, shown in function of the category of the triggered event as a function of the return period.

3 Linking Damage to Triggered Municipalities/Provinces

During December 16 and 17 , 2011, several areas of southern Philippines received between 200mm and almost 400mm of rain over 24hours, experiencing several types of flood and landslide casualties as reported by NDRRMC (see Figure 2.2 and Figure 2.5 for a close up on the region).

The Typhoon Trigger covers the Philippines at municipal level based on the probability of both rain and wind exposures during a typhoon event. The real-time monitoring system updates the data every three hours, at the same time adjusting the affected municipalities and well as the event category for each of them.

Several 10, 15 and 20-year rain events had been triggered by DHI's monitoring system during the passage of Tropical Storm Sendong (Washi), which had been quite widespread but poorly organized bringing more intense precipitation than strong winds. The areas most affected by the heavy rains had been Lanao del Norte, Lanao del Sur, Misaris Oriental, Zamboanga del Sur and some parts of the northern areas of Camarines Norte.

Table 3.1 lists some of the municipalities triggered by DHI's system due to the passage of Tropical Storm Sendong (Washi) on December 17, 2011, and that have also been mentioned in the NDRRMC report where different casualties had been reported. The table also shows the maximum values estimated by DHI's monitoring system, from TRMM satellite over 24hours, and the corresponding event triggered.

Table 3.1 List of affected municipalities as reported by NDRRMC and DHI's monitoring system during the passage of Tropical Storm Sendong (Washi).

Municipality (Province)	Measured rainfall (mm/24 hr)	Estimated rainfall event (Return period in years)
Dipolog city (Zamboanga del Norte)	212	10
Polanco (Zamboanga del Norte)	213	10
Libona (Bukidnon)	198	20
Baungon (Bukidnon)	224	20
Iligan (Lanao del Norte)	300	20
Clarin (Misaris Occidental)	259	20
Ozamis city (Misaris Occidental)	268	20
Cagayan de Oro (Misamis Oriental)	238	20
El Salvador(Misamis Oriental)	257	20
Lugait (Misamis Oriental)	291	20
Manticao (Misamis Oriental)	291	20
Kapai (Lanao del Sur)	318	20
Monkayo (compstella Valley)	100	-

4 State of Calamity Reported by NDRRMC

Folllowing the last report (Sitrep No. 13) issued on December 21, 2011, at 5:00 a.m. by NDRRMC, the state of calamity was reported in the cities of Dumaguete and Valencia in Negros Oriental, Iligan City in Lanao del Norte (national declaration) and Cagayan de Oro in Misaris Oriental (national declaration) during the passage of Tropical Storm Sendong (Washi).