THE 28TH SEPTEMBER 2018 PALU EARTHQUAKE AND TSUNAMI

ITST, 07-11 November 2018

POST TSUNAMI FIELD SURVEY REPORT (SHORT)

TEAM MEMBERS / CONTRIBUTORS

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1. INTRODUCTION

The September 28, 2018 Palu Mw7.5 Earthquake in Sulawesi Island in Indonesia triggered an unexpected tsunami that caused damage and loss of lives in the region. In the aftermath of this event, a team of scientists from different disciplines and agencies was assembled, as UNESCO International Tsunami Survey Team (ITST) in collaboration with Indonesian authorities, for the purpose to conduct a post-tsunami field reconnaissance investigation. The team feels deep sorrow and express their condolences to the Indonesian friends and the people for the loss of life and property in Palu, Sulawesi. A field survey by the ITST has been performed between November 07 and 11, 2018 covering the entire coast of Western Palu Bay up to Tanjung Karang cape and the Eastern Palu bay coast up to the earthquake epicenter region. The main objectives of the survey are to document the variation of the tsunami effects along the coast, to obtain any available data on the wave height and inundation extent and to understand the event in detail for the scientific studies of tsunamis. Furthermore, since the observed tsunami far exceeded our expectations from a strike-slip earthquake event, the survey has also focused on searching for possible secondary sources (i.e. landslides). This report presents the results of the field survey observations, tsunami runup and inundation measurements, information obtained from the eyewitnesses and investigations on the tsunami characteristics along the western and eastern coast of Palu Bay up to the earthquake epicenter.

2. FIELD OBSERVATIONS

The survey covered the western coast of Palu Bay between 0.6459S 119.7274E (western side of Tanjung Karang cape) and 0.8464S 119.8212E (Benteng region) and the eastern coast between 0.7886S 119.8641E (Sambugan) and 0.6221S 119.8044E (Bulu Kadia). On the 3rd day of the survey, (November 09, 2018), the Team is divided to two parts for more efficiency. Team 1 has performed a boat survey at the Fisheries Port of Donggala to obtain the bathymetry data at the region where houses sank into the sea. Team 2 has surveyed at West coast of Palu bay. On the 4th day (November 10, 2018), Team 1 and Team 2 surveyed the coasts in the northeastern extension of the coast of Palu. Team 2 surveyed in the regions close to the epicenter in between 0.6222S 119.8044E (Bulu Kadia) and 0.35395S 119.76194E. Team 2 also continued survey on November 11, 2018.

The UNESCO International Tsunami Survey Team (ITST) Post -Tsunami Survey Field Guide 2nd Edition, UNESCO-ITST, (2014) has been followed.

Figure 2.1 depicts the survey locations where eyewitnesses were interviewed and tsunami observations were collected. In Table 2.1, a complete list of these coastal sites and the summary of the measurements at the survey points are given. Figure 2.2 summarizes the results of the tsunami survey in Palu Bay (ERCC, 2018)

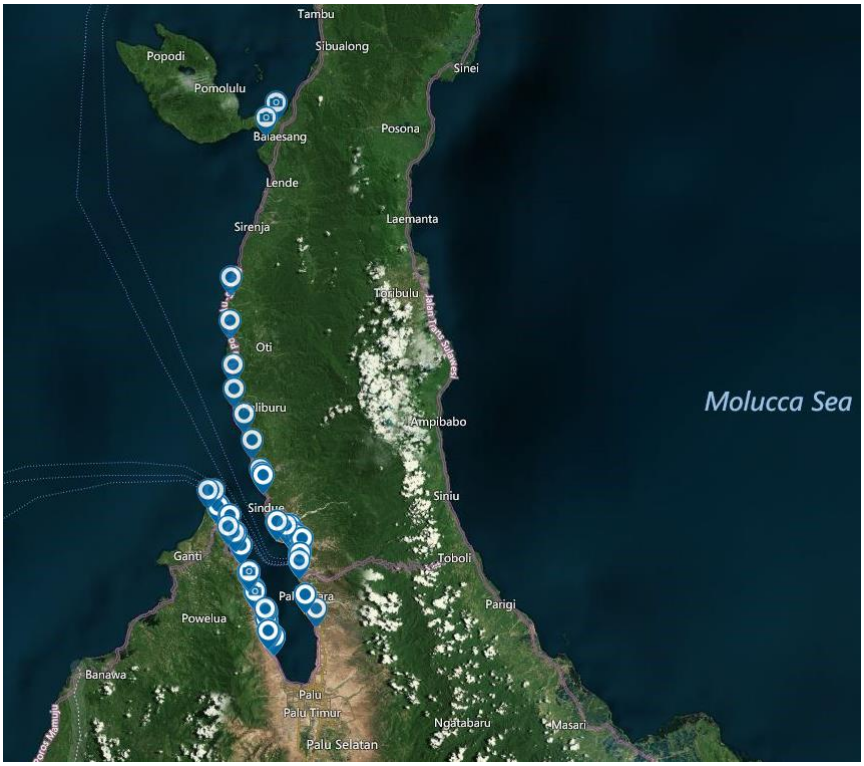

Figure 2.1: Map depicting the surveyed locations where eyewitnesses were interviewed and tsunami observations were collected.

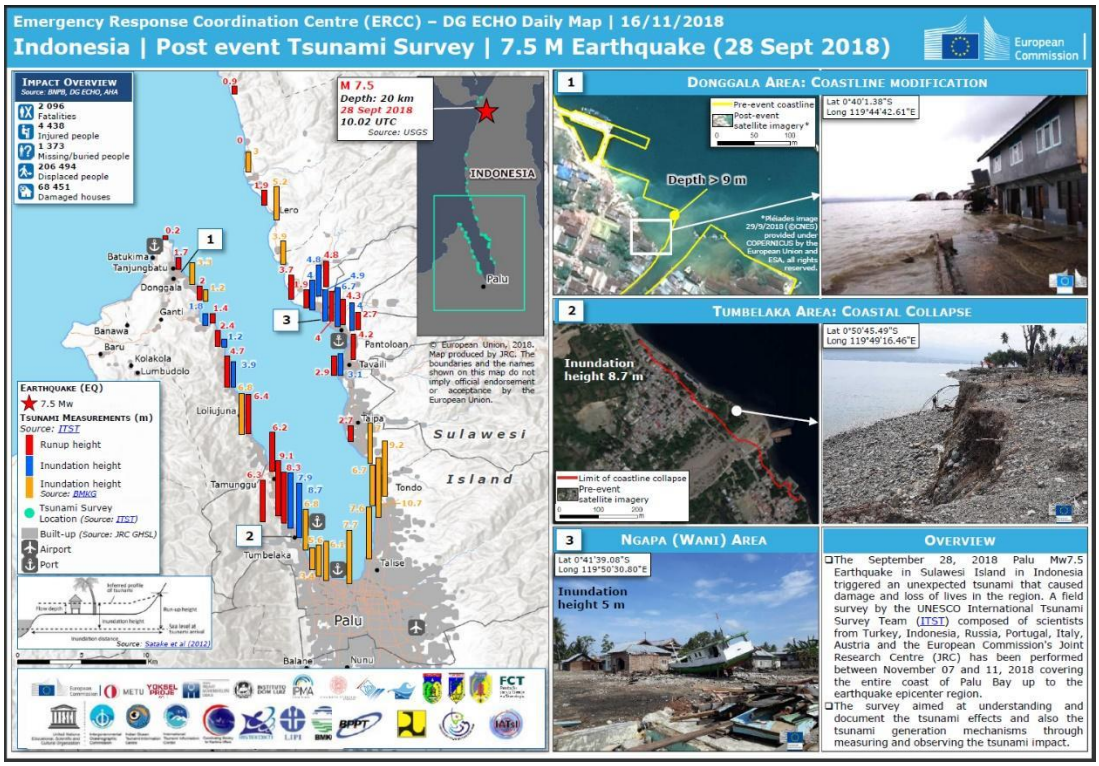

Figure 2.2: Summary Results of Tsunami Survey in Palu Bay (ERCC, 2018)
https://erccportal.jrc.ec.europa.eu/getdailymap/docId/2708

Table 2.1: List of locations and measurement results of Palu Tsunami field survey

Area	E/W	Point #	Point ID	Lat	Lon	Measurement - detided (m)	Type (RH=Runup Height, IH=Inundation Height, Other)
Alindau	E	1	E01.01	-0.35395	119.76194		
Bulu Salugoo	E	2	E02.01	-0.41283	119.76123		
Kaliburu	E	3	E03.01	-0.50688	119.76654		
Bulu Sigalari	E	4	E04.01	-0.54152	119.77979	0.9	RH
Enu	E	5	E05.01	-0.576	119.79038		
Bulu Kadia	E	6	E06.01	-0.61711	119.80202	1.9	RH
Bulu Kadia	E	6	E06.02	-0.62206	119.80442	1.8	RH
Bulu Kadia	E	6	E06.03	-0.62508	119.80626	1.2	RH
Labuan	E	7	E07.01	-0.68803	119.82413	1.5	RH
Labuan	E	7	E07.02	-0.68846	119.82472	2.4	RH
Labuan	E	7	E07.03	-0.68888	119.82536	3.7	RH
North Ngapa	E	8	E08.01	-0.69341	119.83815	1.8	RH
North Ngapa	E	8	E08.02	-0.69341	119.83815	1.9	RH
Ngapa (Wani)	E	9	E09.01	-0.69345	119.84258	4.7	RH
Ngapa (Wani)	E	9	E09.02	-0.69345	119.84258	4.8	RH
Ngapa (Wani)	E	9	E09.03	-0.69396	119.84213	4.0	IH
Ngapa (Wani)	E	9	E09.05	-0.69400	119.84205	4.8	IH
Tongge	E	10	E10.01	-0.70052	119.84512	3.6	RH
Tongge	E	10	E10.02	-0.70131	119.84492	3.7	IH
Tongge	E	10	E10.03	-0.70137	119.84438	3.9	RH
Tongge	E	10	E10.04	-0.70140	119.84438	4.0	IH
Tongge	E	10	E10.05	-0.701933	119.845994	4.0	RH
Panda	E	11	E11.01	-0.70707	119.85292	3.9	RH
Panda	E	11	E11.02	-0.7072	119.85204	4.3	RH
Panda	E	11	E11.03	-0.70724	119.85160	4.9	IH
Pantoloan	E	12	E12.01	-0.71065	119.85852	2.4	RH
Pantoloan	E	12	E12.02	-0.71069	119.85892	4.0	IH
Pantoloan	E	12	E12.03	-0.710718	119.858905	2.7	RH
Pantoloan	E	12	E12.04	-0.71101	119.85819	2.4	RH
Pantoloan (South)	E	13	E13.01	-0.7275	119.85716	4.0	RH
Pantoloan (South)	E	13	E13.02	-0.73141	119.85616	4.2	RH
Pantoloan (South)	E	13	E13.03	-0.73141	119.85616	6.7	IH
Bamba	E	14	E14.01	-0.7406	119.85586	2.9	RH
Bamba	E	14	E14.03	-0.74087	119.8548	3.1	IH
Sambugan	E	15	E15.01	-0.78863	119.86406	2.7	RH
Tanjung Karang	W	1	W01.01	-0.644865	119.730361		
Tanjung Karang	W	1	W01.02	-0.64576	119.73892	0.2	RH

Donggala	W	2	W02.01	-0.66646	119.74395	1.6	RH
Donggala	W	2	W02.02	-0.66648	119.74395	1.7	RH
Donggala Kota Wisata, Ujung	W	3	W03.02	-0.67972	119.75997	2.0	RH
Nambo	W	3	W03.03	-0.69457	119.75741	1.5	RH
Kabonga Besar	W	4	W04.01	-0.70263	119.76599	0.4	RH
Kabonga Besar	W	4	W04.02	-0.70400	119.76805	1.4	RH
Kabonga Besar	W	4	W04.03	-0.70450	119.76836	1.9	IH
Kabonga Besar	W	4	W04.04	-0.70491	119.76864	1.2	RH
Parigga	W	5	W05.01	-0.71933	119.77466	1.2	IH
Parigga	W	5	W05.02	-0.72029	119.77517	2.1	RH
Parigga	W	5	W05.03	-0.72056	119.77511	2.4	RH
Lolidondo	W	6	W06.01	-0.75721	119.78611	2.7	IH
Lolidondo	W	6	W06.02	-0.75774	119.78524	3.9	RH
Lolidondo	W	6	W06.03	-0.75837	119.78547	4.7	RH
Lolidondo	W	6	W06.04	-0.75883	119.78643	3.9	IH
Lolisaluran	W	7	W07.01	-0.78036	119.79317	5.1	RH
Lolisaluran	W	7	W07.02	-0.78113	119.79318	6.4	RH
Lolisaluran	W	7	W07.03	-0.78303	119.79373	3.0	RH
Lolisaluran	W	7	W07.04	-0.78408	119.79532	3.5	RH
Tamunggu	W	8	W08.01	-0.80727	119.80934	6.2	RH
Tamunggu	W	8	W08.03	-0.809486	119.80981	5.9	RH
Tamunggu	W	8	W08.04	-0.80987	119.80996	5.3	RH
Tamunggu	W	8	W08.05	-0.81330	119.81055	5.4	RH
Tamunggu	W	8	W08.07	-0.81558	119.81068	3.9	RH
Watusampu	W	9	W09.01	-0.8216	119.8099	6.3	RH
Watusampu	W	9	W09.02	-0.82207	119.81024	5.7	RH
Watusampu	W	9	W09.03	-0.8222	119.81013	5.4	RH
Watusampu	W	9	W09.04	-0.82511	119.81090	1.5	RH
Watusampu	W	9	W09.05	-0.82513	119.81087	2.0	RH
Watusampu	W	9	W09.06	-0.82648	119.81115	0.3	RH
North Benteng	W	10	W10.03	-0.83772	119.81371	7.9	IH
North Benteng	W	10	W10.05	-0.83782	119.81317	4.7	IH
North Benteng	W	10	W10.06	-0.83784	119.8125	8.3	RH
North Benteng	W	10	W10.07	-0.83997	119.81594	1.8	RH
Benteng	W	11	W11.01	-0.84491	119.81947	4.2	RH
Benteng	W	11	W11.02	-0.84514	119.82011	5.2	IH
Benteng	W	11	W11.03	-0.84562	119.82067	8.7	IH
Benteng	W	11	W11.04	-0.84591	119.82061	3.8	RH
Benteng	W	11	W11.05	-0.84642	119.82117	9.1	RH

3. SUMMARY OF FIELD OBSERVATIONS ALONG THE WESTERN AND EASTERN COAST OF PALU BAY

In this section, the observations of the post event survey along the Western and Eastern coast of Palu bay are summarized. Figure 3.1 presents the points/survey locations, where coastal collapses/landslides were observed along the Western coast and Eastern Coast of Palu Bay respectively.

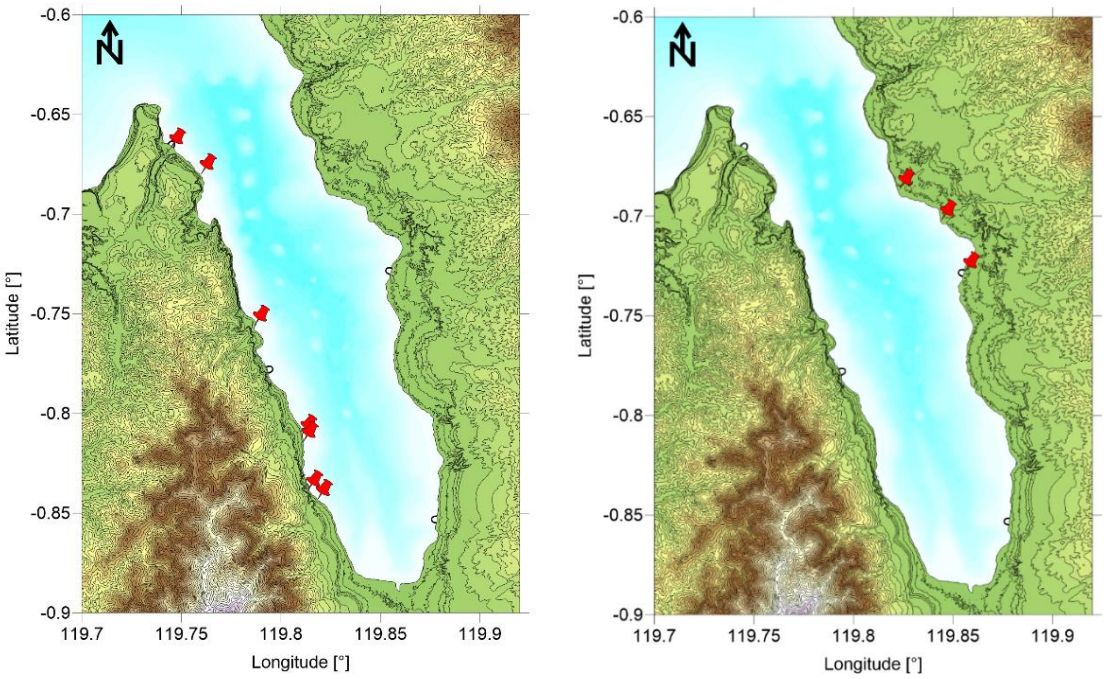

Figure 3.1. Coastal collapses/landslides observed along the Western and Eastern coast of Palu Bay

Point: W-01.1 Western tip of Tanjung Karang

At the western side (tip) of the Tanjung Karang cape of Palu Bay (0.64596S 119,72738E). According to eyewitnesses (people living a sea-side house, Figs 3.2) no tsunami was observed in this location. This was confirmed by an in-situ survey conducted by the team that found no tsunami traces along the shore.

Figure 3.2. The eyewitnesses telling his observations during the event at W-01.1 survey point

W-01.2 Eastern tip of Tanjung Karang

This survey point is located on the eastern side (tip) of the Tanjung Karang cape of Palu Bay (0.64576S 119.73892E) where there are some diving resorts and beaches as shown in Figure 3.3.

Figure 3.3. Flat area that the waves reached according to eyewitnesses at W-01.2 survey location

Taking in consideration the eyewitnesses description, the survey team measured a runup height of 0.2m (after detiding) and an inundation distance of 49m at this location. The wave direction is reported as either from Wani or Palu (110^{o} from North) indicating the waves coming from inside of the bay.

Point: W-02 Donggala

Figure 3.4. Damaged structures due to coastal collapse/landslide at W-02 Donggala

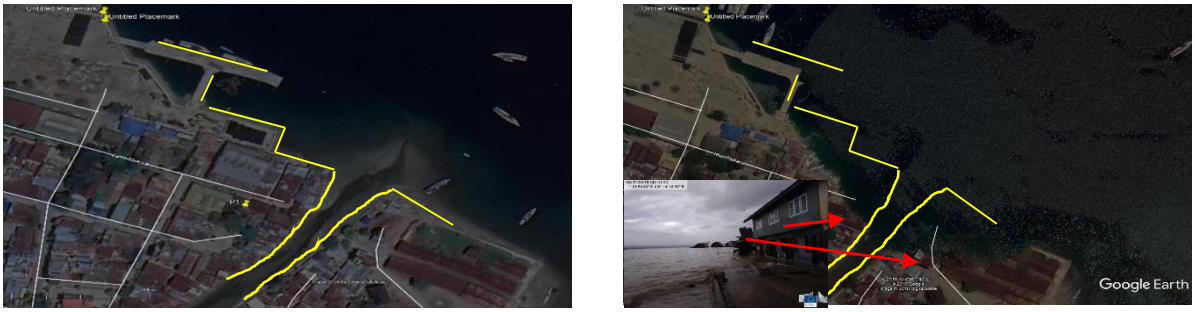

Figure 3.5. Satellite image before (left) and after (right) the event showing Port of Donggala and the river mouth (survey location W-02)

On the 3rd day of the survey, the team performed a bathymetric survey by sonar measurements at several points in this region (Port of Donggala) to investigate the size of the landslide/coastal collapse and obtain the nearshore bathymetry of the area.

Figure 3.6. Bathymetric survey measurements at Port of Donggala region

Point: W-03.1 Donggala Kota Wisata, Ujung

This survey point is another landslide/coastal collapse region where some part of the coastal structure at Donggala Kota Wisata (0.67972S 119.75997E) went down to the sea and the small seawall was damaged by the tsunami according to eyewitnesses

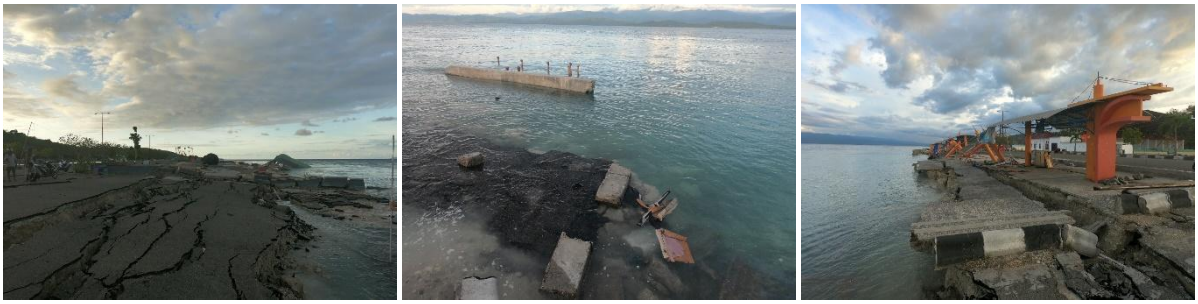

Figure 3.7. Damage on the coastal structures at Donggala Kota Wisata (W-03.1)

Point: W-03.2 Nambo

This survey point is located in a mangrove coast region (0.69457S 119.75741E) and eyewitnesses showed the location, where small waves reached at the road along the shore.

Figure 3.8. Runup measurement according to eyewitness reports at Nambo (W-03.2)

This survey point (0.75837S 119.78547E) revealed the presence of a potential landslide/coastal collapse, for which a GPS tracking of the rim of the head-scarp was performed (Figure 3.9)

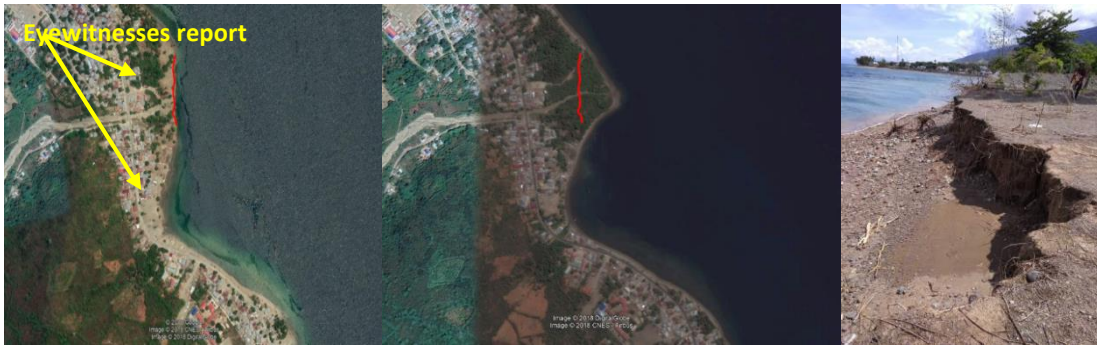

Figure 3.9. GPS track showing the landslide/coastal collapse at Lolidondo (W-06) (the red segment outlines the edge of the collapsed/sliding coast (0.755728S 119.786732E)

Eyewitnesses from both sides of the landslide area mentioned hearing, after the earthquake shaking, a kind of explosion coming from the collapse location. They also observed the sea retreating before escaping towards the hill. A small wave arrived first after ~1min then followed by a largest and destructive one.

Point: W-08 Tamunggu

At this survey point (0.80948S 119.80981E) the team has identified another landslide/coastal collapse and performed a GPS tracking of its headscarp rim as shown in Figure 3.10. The measured runup is 6.2m according to both observations and eyewitness reports. The inundation distance is 75m.

Figure 3.10. Observed coastal damage at Tamunggu (W-08)

Point: W-09 Watusampu

This survey point is nearby region of the Naval Base at Watusampu (0.82207S 119.81024E). Several measurements were performed in this region since the damage was high, the inundation was high and the runup height is measured as 6.3m (after detiding). The inundation distance is measured as 74m at one of the measurement points according to eyewitness (householders) reports (Figure 3.11).

Figure 3.11. Tsunami inundation according to eyewitnesses at Watusampu (W-09)

Point: W-10 North Benteng

At this survey point a highly tsunami impacted area between Benteng and Watusampu (0.83772S 119.81371E) was observed but no eyewitnesses could be found there. The measurements were performed according to the traces and signs. The summary of the measurements and the observed damage are given in Figure 3.12.

Figure 3.12. Summary of the measurements and impacted coasts at North Benteng (W-10)

Point: W-11 Benteng

At this survey point a large landslide/coastal collapse area nearby a river mouth at Benteng (0.84591S 119.82061E) was identified by the team that performed a GPS tracking of its head-scarp rim (Figure 3.13).

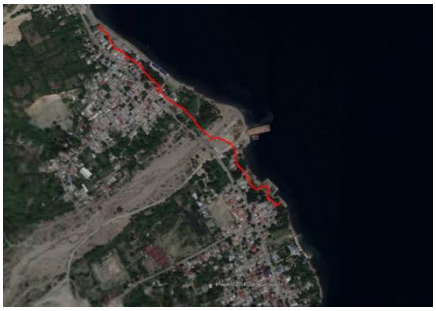

Figure 3.13. GPS track showing the landslide/coastal collapse at Benteng (W-11)

Point: E-01 Alindau

The eyewitnesses at this survey location in Alindau (0.35395S 119.76194E) reported no tsunami observation. They stated that the water first receded (in less than 1 min after the quake) but regained to its normal position. In Figure 3.14 the eyewitness shows the water level which fits with the tide level at the time of tsunami.

Figure 3.14. The eyewitness showing the water level at the time of tsunami

Point: E-02 Bulu Salugoo

According to the eyewitnesses, there was very small wave motion (the water receded and came back) at this survey location (0.41283S 119.7613E), runup was 0.5m.

Figure 3.15. Eyewitness telling and showing his observations at Bulu Salugoo (E-02)

Point: E-03 Kaliburu

The eyewitnesses reported no tsunami observation at this survey location (0.50688S 119.7665E).

Figure 3.16. Eyewitness telling no tsunami observation at the coast at Kaliburu region (E-03)

Point: E-04 Bulu Sigalari

The eyewitnesses in this location (0.5415S 119.7798E) stated that they saw large waves offshore (in the bay) but they were moving to Palu direction. According to the observations and eyewitnesses' interviews, there has been small subsidence as the shore slope inclined at this location (Figure 3.17).

Figure 3.17. Surveyed coast at Bulu Sigalari region (E-04)

Point: E-05 Enu

The eyewitness in this location (0.57598S 119.79038E) stated that he saw waves in white color in offshore (in the center of the bay) and they were moving to Palu direction. He stated that he saw this situation just after the earthquake and reported no tsunami observation at this location. He said that the color of the first wave was white but the color of the second wave was dark.

Point: E-06 Bulu Kadia

The eyewitness in this location (0.6221S 119.8044E) was in his boat at the time of the earthquake and he experienced that first the sea receded and then 3 times up and down motion of the sea. He showed the inundation point of the waves as given in Figure 3.18.

Figure 3.18. The eyewitnesses showing the inundation point at Bulu Kadia region (E-06)

Point: E-07 Labuan

This survey point is at a river mouth in Labuan region (0.6885S 119.8247) where there has been coastal collapse/landslide as shown in Figure 3.19. The eyewitnesses observed a first negative (leading depression) wave.

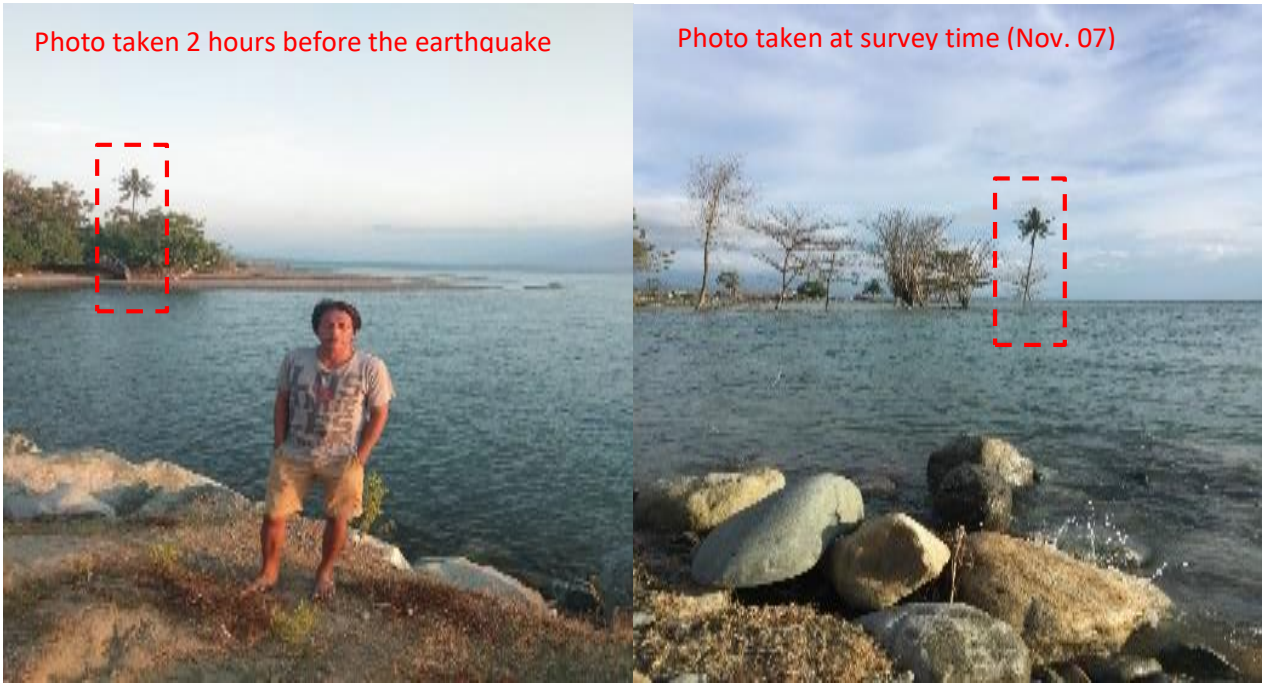

Figure 3.19. Observed coastal collapse/landslide phenomenon at Labuan region (E-07). The person on the left picture is Mr. Andi. The picture on left was taken by Mr. Renaldi. The picture on right was taken by team member Gozde Guney Dogan.

Point: E-08 North Ngapa

Eyewitnesses reported waves coming from two different directions (one from southern side and one from western side) at this survey point in North Ngapa (0.69341S 119.83815E).

Figure 3.20. Observed damage at North Ngapa (Point E-08)

Point: E-09 Wani

This survey point is the location that CCTV video records https://www.youtube.com/watch?v=oBvx32WgxnY&t=1s https://www.youtube.com/watch?v=m3QOX3GxxVQ during the earthquake and tsunami wave arrivals are available from two camera points on the house (0.6939S 119.8421E). The team analyzed the video images before surveying this location. According to the video images, the earthquake shaking started at 18:02:54 (time at camera record) and ended at 18:03:40. The advancing flow started at 18:06:29 and stopped at 18:06:51 according to the time at camera record. In the second part of the video (from another Camera) the wave arrives at 18:06:32 and, advancing flow stops at 18:06:59. Figure 3.21 shows the locations of these two cameras in the house.

Figure 3.21. Camera locations in the house

The measured runup height after detiding is 4.8m at this location according to the information obtained from eyewitnesses as well as traces observed.

Figure 3.22. Observed damage at Wani (Point E-09)

The team also conducted several eyewitness interviews to understand what happened at the time of the event with the owner of the house of video recordings at Wani and also with a fisherman who was in his boat at the event time and another householder in this location. The fisherman stated that first the sea receded around 3m since he was in his boat around this depth and just hit the ground. The other two people also confirmed the first motion of the wave was negative which indicates a leading depression wave. The eyewitnesses reported three positive waves, first a small wave and the second wave was the largest. The eyewitnesses reported that the waves were coming from two different directions (from South and West directions) (Figure 3.23).

Figure 3.23. Eyewitness and local helper showing the wave directions observed at Wani (Point E-09)

Point: E-10 Tongge

In this survey point (0.70137S 119.84438E) a landslide/coastal collapse is observed and can also seen in satellite images before and after the event as given in Figure 3.24.

Figure 3.24 Satellite images before and after the event at Tongge region

Eyewitnesses stated that there was a coastal structure approximately 100m in length at this location which ships moored (Figure 3.24) and it has disappeared (went down to the sea) during the earthquake.

High damage was observed in Tongge region and according to the eyewitness reports, many people (they actually said as “all people”) died in this survey point. Figure 3.25 shows the damage and situation of the area at the time of the survey.

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Figure 3.25. Observed damage at Tongge region (E-10)

Point: E-11 Panda

The runup height is measured as 4.3m (after detiding) at this location (0.7072S 119.8520E) according to observations and tsunami traces. The eyewitnesses mentioned that the wave direction was from northern side and they estimated the loss of lives with more than 100 in this area. Figure 3.26 shows the observed damage in this surveyed area.

Figure 3.26. Observed damage at Panda (E-10)

Point: E-12 Pantoloan

This survey point (E12, 0.7108S 119.8585E) is the Port of Pantoloan where stands the tide gauge that measured the tsunami. The location of the tide gauge in the port is shown in Figure 3.27.

Figure 3.27. The location of the tide gauge in the Pantoloan port

The wave direction was reported as from northwest at this location. The runup height is measured as 2.7m after detiding according to both observations and eyewitnesses. The inundation distance is measured as 73m.

Figure 3.28. The location of the house/building eyewitnesses reported flow depth and splash

Point: E-13 South of Pantoloan

This survey point is near the northern side of a river mouth at the South of Pantoloan (0.7314S 119.8567E). The eyewitnesses reported that the waves reached the roof of the house shown in Figure 3.29. Therefore, the splash height is measured as 5.5m at this location. They also stated that houses were collapsed and damaged and even some of them were washed away by the tsunami. They reported two directions of the incident waves (one from Pantoloan (Northern) side and one from southern side).

Figure 3.29 The house eyewitnesses reported splash up to the roof (E-13)

Point: E-14 Bamba

This survey point is at the southern side of the river mouth at Bamba region (0.7408S 119.8548E). The eyewitnesses reported that the first wave arrived to the coast 2-3 minutes after the earthquake. (Figure 3.30).

Figure 3.30 Observed coastal collapse/landslide phenomenon at Bamba region (E-14)

Point: E-15 Sambugan

The eyewitnesses at this survey point E-15 (0.7887S 119.86405E) reported that the wave came from the opposite side of the bay. The arrival of the first wave around 2 minutes after the earthquake according to a householder at this location. The flow depth is measured as 1.5m on the walls of this house as shown in Figure 3.31.

Figure 3.31. Water signs on the walls of a house at Sambugan and coastal damage (E-15)

Points Balaesang

Figure 3.32 Survey points close to the earthquake epicenter

The earthquake triggered several landslides that affected the regional road. After one month, many construction works were ongoing. It lasted more than 3 hours to reach the target area from Palu.

Figure 3.33 Difficulties to reach the area

The eyewitnesses from both bays at these two survey points reported:

- Slow increasing of the sea level few mins after the earthquake
- Oscillation of the max tide height for 3 days
- The level of the high tide is still around 1 m above the pre-earthquake level.

The variation of the sea level height has been measured: - 1.3 m (previous level: based on eyewitnesses reports; actual level: based on the trace on the external wall of the house)

Figure 3.34 Variation of the sea level height (left: Pre-EQ max tide level based on eyewitness's report; right: post-EQ max tide level, based on the trace on the external wall of the house)

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