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LIMITATIONS AND CHALLENGES OF EARLY WARNING SYSTEMS

CASE STUDY: PALU-DONGGALA TSUNAMI 28 SEPTEMBER 2018

September 2019

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Published in
Jakarta, Indonesia

Citation: UNDRR and UNESCO-IOC (2019), Limitations and Challenges of Early Warning Systems: A Case Study of the 2018 Palu-Donggala Tsunami. United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific, and the Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization. (IOC Technical Series N° 150)

The findings, interpretations, and conclusions expressed in this document do not necessarily reflect the views of UNDRR and UNESCO or of the United Nations Secretariat, partners, and governments, and are based on the inputs received during consultative meetings, individual interviews, and the literature review by the research team.

This research is dedicated to victims and survivors of tsunamis in Indonesia and in other countries.

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Abbreviations used

AWAS	Tsunami major warning - Areas having between 50-cm to 3-m high wave threat
BAPPEDA	Bappeda kota Ihokseumawe (Regional Development Agency)
BIG	Indonesian Geospatial Information Agency
BMKG	Badan Meteorolgi, Klimatologi, dan Geofisika (Indonesian Meteorology, Climatology and Geophysics Agency)
BNPB	Baden Nasional Penanggulangan Bencana (Indonesian National Disaster Management Board)
BPBD	Badan Nasional Penanggulangan Bencana. (National Disaster Management Agency)
BTS	Base transceiver station
CCTV	Closed-circuit television
DSS	Decision support system
DVD-WRS	Digital video broadcast – Warning receiver system
ETA	Estimated time of arrival
EWS	Early warning system
FGD	Focus group discussion
GITEWS	German Indonesian tsunami early warning system
GPS	Global positioning system
InaTWES	Indonesia Tsunami Early Warning System
IOTIC	Indian Ocean Tsunami Information Centre
KPI	Key performance indicator
KSB	[community] Disaster preparedness group
LAPAN	National Institute of Aeronautics and Space
LIPI	Research Centre for Population
PDT	Ministry for Development of Disadvantaged Region
PRA	Participatory rural appraisal
SIAGA	Tsunami advisory - Area having a higher than 3-m high wave threat
SMS	Short messaging service
SOP	Standard operating procedure
TOAST	Tsunami Observation and Simulation Terminal
TRC	Rapid reaction team
TVRI	Televisi Republik Indonesia
UNESCO	UN Educational, Scientific and Cultural Office
UNDRR	UN Office for Disaster Risk Reduction
UPS	Uninterrupted power supply
WASPADA	Tsunami warning - Area having 50-cm or less high wave threat
WRS	Warning receiver system

Foreword

Located along the most seismically active zone in the world, Indonesia is no stranger to disasters, in particular, extreme weather events and natural hazards. On 28 September 2018, a tsunami struck Palu and Donggala. As the deadliest disaster in Indonesia and the world last year, its lessons should not be ignored.

Indonesia has demonstrated a strong commitment to disaster risk reduction over several decades, including through legislative and regulatory progress, national strategy development, early warning and risk information initiatives. The establishment of institutional and regulatory frameworks for risk reduction at the national and local level was marked by the 2007 adoption of Law Number 24 on Disaster Management, which saw the first shift from disaster management to risk management and the creation of National Disaster Management Authority. The Indonesian Tsunami Early Warning System has issued 22 early warnings since its launch in 2008, saving countless lives. Indonesia has a national strategy on disaster risk reduction, a solid understanding of its risk profile and is clearly acting to improve preparedness, resilient recovery and its ability to build-back-better and build to last.

Despite this progress, the tsunami of Palu and Donggala showed that significant challenges remain. Indeed, every time a destructive tsunami happens in the world, it is a wake-up call for countries to strengthen resilience, improve preparedness and deepen their understanding of risk.

This study, commissioned by the United Nations Office for Disaster Risk Reduction (UNDRR), is an evidence-based documentation of what happened during the event. It captures the lessons learned and makes recommendations that can reduce the risk of potential future events.

What did go right? Early action on the part of community members, in carrying out evacuations based on past knowledge and public education, saved lives. Educational outreach and disaster simulation efforts must be expanded to increase public awareness and strengthen the ability of citizens to self-evacuate.

The findings also highlight the importance of not becoming too dependent on technology and the importance of building on community and indigenous knowledge. Indeed, the community should be the focus and the main subject of tsunami disaster risk reduction efforts. In the absence of community engagement to raise awareness and preparedness, over-reliance on technological solutions has the potential to create a false sense of security which contributes to complacency. Technological solutions need to be embedded in strong community engagement and outreach activities.

The study also found several areas for improvement; namely around the early warning system's ability to detect tsunamis based on triggers outside the conventional scenarios, the level of infrastructure resilience as evident by the power and communication outages, and the level of risk awareness and preparedness at the community level.

Notably, the study shows that the end-to-end early warning system needs to be strengthened to effectively bridge the gaps between the upstream and downstream sides of the early warning chain to ensure timely community action. It is the "last mile" of communication that often determines the difference between life and death in the face of a disaster. It is only through bridging the last mile that we can ensure that no one is left behind.

The study reaffirms several of the recommendations discussed at the UNESCO-IOC International Conference to Commemorate the 10th Anniversary of the Indian Ocean Tsunami back in November 2014, and most recently, the UNESCO-IOC Symposium on Advances in Tsunami Warning to Enhance Community Responses in February 2018. The study benefited from the insights shared at the Asia-Pacific Forum on Sustainable Development in March 2019, and at the Consultative Workshop on Strengthening Disaster Risk Reduction and Early Warning in Indonesia, in May 2019, where study findings were presented.

One of the goals of effective disaster risk reduction is to integrate knowledge into policy and plans to avoid future disasters. We hope governments, stakeholders, and communities throughout the region will incorporate study findings and recommendations into their risk mitigation and preparedness plans. We also hope this report will add value to the existing domain of knowledge on early warning systems and spark renewed interest in focusing on the social aspects of early warning and risk communication.

Nothing undermines development like disaster. Just as risk is evolving, so too must our risk reduction efforts. Disaster risk reduction is a continuous and dynamic process and we should always strive to make it better if we wish to leave no one behind and achieve resilience for all.

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SUMMARY

LIMITATIONS AND CHALLENGES OF EARLY WARNING SYSTEMS: A CASE STUDY OF THE 2018 PALU-DONGGALA TSUNAMI

The Indonesian Tsunami Early Warning System (InaTEWS) commenced operations in 2008 and since that time has issued 22 tsunami early warnings. Most of these warnings were followed by tsunamis of less than one-meter height and in which no significant damage occurred. Only two tsunamis had wave heights in excess of one meter, and both had substantial impact. These were the Mentawai tsunami on 25 October 2010, and the Palu-Donggala tsunami on 28 September 2018.

The 28 September 2018 earthquake in South Sulawesi was a magnitude 7.4 event that occurred at 18:02 hours local time, triggering a tsunami and causing significant liquefaction. The main earthquake was preceded by several foreshocks, including a large event at 13:00 hours local time. An estimated 3,879 people were killed in Palu City. At least 1,252 of the deaths were directly attributed to tsunami impact. This led to questions by national and international media about whether InaTEWS failed to deliver early warnings to the impacted communities.

Facing the critics, the operational body for InaTEWS, the BMKG (Agency for Meteorology, Climatology, and Geophysics) stated that on 28 September 2018 the standard operating procedure (SOP) for delivering information services on earthquakes and tsunamis was adhered to, and claimed there were neither human nor instrumental errors in its delivery of the tsunami warnings to Palu.

BMKG's comments were supported by a statement from members of the German-Indonesian Tsunami Early Warning System, who declared that warning information was sent by BMKG to the National Disaster Management Authority (BNPB), local government, the media and the at-risk communities, and that no problems with respect to the warning transmissions had occurred. Their statement did, however, raise concerns about the local government budget allocation for, and the overall commitment to, the early warning system. The statement argued that aspects pertaining to community response for early warnings was outside the jurisdiction of BMKG, noting that BMKG was responsible for the upstream detection, interpretation, and dissemination of geophysical data; while downstream actions relating to alerting at-risk communities was the responsibility of local government.

The case study examined the effectiveness of InaTEWS by focusing on the downstream aspects of the system, in order to understand the community response to the 28

September 2018 earthquake and tsunami. The case study found that while warning bulletins were issued by InaTEWS, they did not reach the communities in Palu Bay. The case study identified seven key issues.

1. Limitations of tsunami early warning system technology

The philosophy of early warning is to enable enough time to be given to communities at risk so that individuals can save themselves immediately prior to a natural hazard impact. This time period is referred to as 'the golden time'. The longer the golden time, the more effective an early warning is likely to be. In the case of the Palu tsunami, BMKG successfully issued a tsunami early warning five minutes after the earthquake. This is in accordance with their SOP. However, the tsunami arrived sooner than that.

In addition, BMKG's calculation of the tsunami height was lower than the actual event. The height variation was attributed to the causal mechanism of the Palu tsunami, which is thought to have been triggered by a submarine landslide. However, the tsunami model used by InaTEWS does not incorporate this triggering mechanism, which will affect the outcome scenario.

Even if BMKG could model tsunami-triggered underwater landslides and could issue an early warning in less than five minutes, the golden time available to at-risk communities is still very short. This suggests the InaTEWS system has limitations with respect to near-source tsunamis in which arrival times are less than 10 minutes. The InaTEWS system is more effective for tsunami triggered by earthquakes from subduction zones in which the wave arrival time is typically 20 minutes or more. In fact, studies have identified that the last four tsunami events that occurred at Palu Bay (1927, 1938, 1968 and 1996) are all suspected of having epicenters near the shore so arrival times were fast. The implication is that if communities waited for an early warning to be released by the authorities before evacuating, it would not be effective for successful self-rescue attempts.

Tsunami arrival times of less than 10 minutes, as at Palu Bay, have occurred elsewhere in Indonesia. These include Simeulue Island in 1907, the Mentawai Islands in 2010, North Flores in 1992, North Bali in 1815 and 1917, North Lombok in 1856, and Bima in 1818, 1820, and 1836. Most of Sulawesi, the Maluku Islands, North Maluku, and West Papua also have records of tsunami arrival times of less than 10 minutes duration.

2. The failure of the tsunami early warning administrative chain

A significant issue was the failure of the tsunami early warning to adequately reach communities at risk. This reflects inadequate administrative support processes. A particular issue is the large number of agencies involved in the downstream component of the early warning chain. Government Regulation No. 21 of 2008 on Disaster Management, directs that BMKG only has authority to issue a tsunami warning (the upstream component), while the evacuation decisions (the downstream component) are in the hands of local government, which includes the activation of sirens. Under the current procedure, a tsunami early warning from BMKG is communicated to the Komando Pengendalian (Kodal) in the area to get approval for the warning to be delivered to the communities. As a minimum, Kodal members comprise the Governor, the Deputy Governor, the Military Commander (Pangdam), and the Chief of Police (Kapolda). It takes time for these members to not only meet, but to agree on a course of action and then to activate the warning procedure, including sirens. This lengthy process considerably reduces any golden time available to communities at risk: such a delay is potentially lethal when lead times are short. In the past 10 years since the establishment of the tsunami early warning system, there are no cases in which local government has displayed the ability to make quick and precise decisions based on alerts issued by BMKG.

On the technical side, the early warning chain often experienced power outages and interruptions to the telecommunication system. Both these issues occurred during the Palu earthquake and tsunami in 2018. The power cut out shortly after the earthquake, while the UPS and a backup generator at Pusdalop BPBD Palu City were not in working order. These matters are the responsibility of the local government.

Hence, the early warning from BMKG was not received. Due to power outages and telecommunication disruptions following the earthquake, the weak capacity of local government and BPBD operators, the inoperability of the only tsunami siren at Palu City, and the failure of a short message (SMS), the communities received no official advice to evacuate.

3. The tsunami early warning system created a false sense of security

People who held off evacuating until the tsunami siren was activated on 28 September 2018 lost their golden time to save themselves. Ironically, these communities had participated in a tsunami drill in 2012, which included information about InaTEWS: as a consequence they assumed that any evacuation would take place after hearing the tsunami siren. They were unaware that the only tsunami siren at Palu City was not activated following the earthquake.

There are other similar findings, such as the community at Tipo Sub-District in Palu City which mistook a signal booster tower owned by a mobile phone provider to be a tsunami siren. The misunderstanding came about because during the tower's construction and routine maintenance, staff of the tower operator repeatedly advised community members that the equipment was an "earthquake and tsunami detection device" that would sound if there was a tsunami. This allayed initial objections the community members had to the tower construction. When the earthquake occurred on 28 September 2018, most people did not immediately self-evacuate because they waited for the siren.

This false sense of security comes up again at Labean Village, whereby some residents had evacuated following a large foreshock but then returned 2.5 hours later, after receiving information through social media and SMS that there was no potential tsunami. However, no sooner had they returned when the tsunami engulfed them. The lesson of this incident is that delays in information dissemination via SMS can have deadly consequences.

4. Self-evacuation becomes the key to safety

Although the tsunami in Palu Bay occurred without warning, many people managed to escape. Most of the survivors either left the beach area when the large foreshock was felt or shortly after the main earthquake. Many of these, like residents at West Coast Donggala, had knowledge of previous tsunamis and, thinking that the strong earthquake was likely to be followed by a tsunami, they immediately moved away from the coast.

Most of these survivors reported seeing or hearing signs from nature. Many stated they heard an explosion and changes in sea level shortly after the earthquake. Others, like survivors of Loli Saluran Village, witnessed bubble-like boiling water shortly after the earthquake. This encouraged residents to leave, warning family members and neighbors to do the same. Survivors also reported seeing animals, such as cows, goats, cats, and birds, deliberately moving inland shortly after the earthquake and before the tsunami came. Many of the survivors ran along with these animals or immediately after.

While these cues are highly effective, they pose a problem if earthquakes occur after dark when they become difficult to observe. This is an important consideration for many rural communities where residents typically retire to their houses at dusk and children are in bed soon after. It is important therefore to educate community members that a strong earthquake is itself the danger sign and should be responded to immediately by seeking higher ground without waiting for an official order to evacuate or witnessing natural signs first.

5. The importance of unimpeded evacuation routes from beachfronts

When the golden time is short, as it was at Palu Bay, the location of evacuation routes and tsunami shelters is critical. At Donggala, the relatively easy access to the hills was fortuitous, although this was compromised in some areas, such as Small Village 8 in Labean Village, when residents had to cross a creek before reaching the safety of high ground. If evacuation routes do not have direct access from beaches or to tsunami shelters, escape becomes difficult. In Talise Beach, Palu City, for example, the evacuation path from the beach was blocked by buildings and walls: some survivors escaped by jumping over fences but many, especially women and children, could not do this and were trapped.

6. The importance of experience and local knowledge

Numerous residents in West Coast Donggala recognized the 2018 earthquake to be a danger and self-evacuated. They were aware of what happened following an earthquake in 1968, when a three-wave tsunami killed many people. This responsiveness was reinforced by several residents in Labean Village who had experienced that event. This knowledge is referred to as lembotalu or bombatalu, a local term meaning three waves. The local knowledge was reinforced by a series of education and preparedness training programs residents had received. The outcome was that local people had internalized knowledge about the history of tsunami and disaster risk to the community and were aware of what safety measures to take.

The situation was different at Palu Bay. Informants at Palu City generally thought their area was safe from tsunami, believing the topography of Palu Bay inhibited tsunami formation. This belief was widespread after a 2005 earthquake, when many evacuated to higher ground but no tsunami ensued. Although some informants admitted they were told stories by their parents about earlier tsunami impacting the coast of Palu City, such as the event of 1938, they were disregarded as unlikely future events. Only a few eyewitnesses to these earlier events now survive; and disaster-relevant education programs in the area have not been prominent. These situations remind us that local knowledge is dynamic and can change relatively quickly. It is important to educate and update knowledge on tsunami preparedness.

7. Preparedness education should be based on the characteristics of local threats

Most of the knowledge received by communities in Palu and Donggala through outside groups have been based on characteristics of the Aceh tsunami in 2004. Hence, they were taught that a tsunami would be preceded by a receding sea and that the arrival time at the beach would be about 20-30 minutes after the earthquake. Residents were taught to check the condition of the sea, whether it was receding or not, before evacuating. Residents were also advised to await instructions from designated authorities while they check for a receding sea.

Learning from the Palu Bay tsunami in 2018, tsunamis are not always preceded by a receding sea. In addition, tsunami arrival times can be less than 5 minutes. The lesson is that tsunami characteristics vary by location. It is important that training not be based on generic material but to adopts learning material that is relevant to, and grounded in, local conditions.

Conclusion and Recommendations

These findings highlight that the failures of the tsunami early warning system and governmental intervention efforts to build community preparedness at Palu Bay were due mainly to the adoption of a technocratic and top-down approach which ignored social reality. Within this approach, the intervention strategies took over the risk from the communities, leaving at-risk communities to wait for an evacuation order through interventions such as tsunami sirens, which did not work and which were not appropriately located. These findings reinforce earlier research about the failure of early warning systems in other parts of the world, which have concluded that a tsunami early warning system should be society-based, where the approach is to strengthen the capacity of individuals and communities to have the ability to recognize the threat and take action to avoid disaster. This study therefore recommends that Indonesia's tsunami early warning approach be society-based (people-centered) and enhance the capabilities and resilience of communities to protect themselves.

Communities need to be taught that, once they feel a strong earthquake, they should immediately move away from the shore. This should be pursued as part of a continuous and regular public education program, especially for communities known to be at risk. Local knowledge about past tsunamis should be regarded as an important asset and be reproduced, both through formal and informal education channels. In addition, the communities need to be reminded of the value of being alert to signs from nature, such as the behavior of animals moving away from coastlines. This self-evaluation capacity needs to be supported by having unimpeded evacuation routes from beaches.

Although self-evacuation remains the preferred response, the model has limitations, especially when facing a tsunami from a distance, such as that which occurred at Jayapura, Papua in 2011. Hence, an equipment-based tsunami early warning system is required. However, it is important to improve institutional aspects of InaTEWS. The tsunami early warning chain is administratively too complex.

Based on these findings, the following are recommended:

1. That a review and subsequent revision of Government Regulation No. 21 2008 on Disaster Management evacuation be conducted, particularly Paragraph 19 pertaining to decisions taken by local government.
2. That a simplification of the bureaucratic structure for the dissemination of tsunami warnings be undertaken.
3. That BMKG add a KPI (to complement its current KPI to issue a product warning within five minutes post-earthquake), that provides an end-to-end system so that communities can readily receive the warnings it issues. BMKG will need to be resourced appropriately to do this,
4. That the InaTEWS models be revised so as to include parameters more likely to occur within Indonesia, and in particular, can take into account near-source tsunamis and the timeframes within which tsunamis are generated.
5. That the Presidential Decree on the National Multi-Hazard Early Warning System, underway during the preparation of this report, be predicated on the basic philosophy of early warning, that is to save lives as quickly and as effectively as possible and to prioritize the community's ability to take action for self-evacuation. Under this framework, the devices, technology, and structure of a warning system should be designed to support the community's ability to undertake self-evacuation.

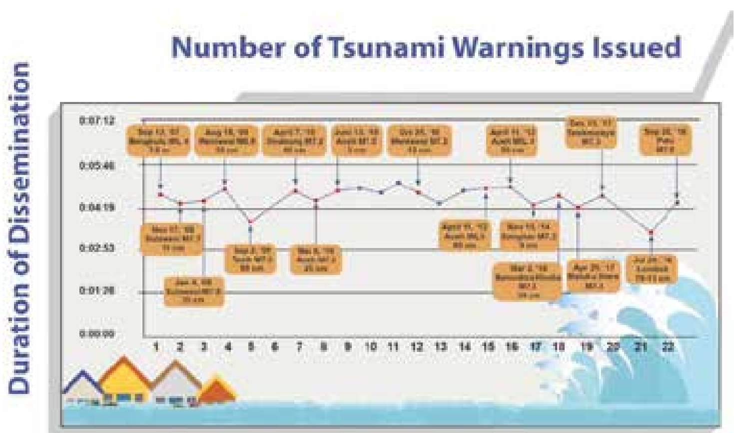
1. INTRODUCTION

1.1 Questioning Indonesia's early tsunami warning system

As many as 3,879 people were killed in the earthquake, tsunami and liquefication that struck Palu, Central Sulawesi on September 28th 2018. From the total number of casualties, it was suspected that 1,252 victims were killed in the tsunami.[1] The victims were added to the long list of deadly impacts of geological disasters, specifically earthquake and tsunami that have happened repeatedly in Indonesia.

After the earthquake and tsunami disaster in Aceh, Indonesia, in 2004, that killed 160,000 people, various efforts were undertaken to reduce the risk of tsunami. One of them is the development of the Indonesia Tsunami Early Warning System (InaTEWS). This is a complex system and requires coordination between various departments and ministries. Several countries also supported the development of InaTEWS; and the German government was a major donor providing equally large resources as the Indonesian government. Significant changes and developments have been made since the system was established, including the ability of the Indonesian Meteorology, Climatology and Geophysics Agency's (BMKG) to issue tsunami early warning information within 5 minutes or less.

Since the system was launched on 11 November 2008, InaTEWS had been tested by 22 actual earthquake events, two of which caused significant tsunami impacts. These were the 2010 Mentawai tsunami that caused more than 500 deaths[2] and the 2018 Palu Bay tsunami with Event, where thousands of lives were lost. There were also two other tsunami events



InaTEWS has issued 20 event, and no tsunami 6 events

Image 1 : Real events of earthquake and tsunami in the last 10 years that triggered Indonesia's Early Warning Announcement from BMKG.

1. The estimated number of tsunami victims was gathered from the Palu Development Planning Board's (Bappeda) data on 11 January 2019.
2. According to the Indonesian Disaster Information Data, the recorded number of victims of Mentawai tsunami was 503 people. the data can be accessed on https:/ bnpb.cloud/dibi/laporan5

that originated from outside of Indonesia, (known as distant tsunamis), namely The Great East Japan Earthquake and tsunami of 11 March 2011 with one casualty in Papua, and the Chile tsunami in 2012.

The large number of casualties in Palu Bay brought criticism about the effectiveness of InaTEWS, which was alleged to have operated at a suboptimal level, and which resulted in a failure to produce timely early warnings to the community in the affected area.[3] Facing such criticism BMKG, as the operator of InaTEWS, claimed that the early warning system was working properly. BMKG asserted that they had followed the Standard Operation Procedure (SOP) in providing information regarding earthquake and early tsunami warnings, and there had been neither human errors nor instrument errors in producing and issuing the early tsunami warning in Palu.[4]

BMKG's statement was supported in a newspaper article by Harald Spahn and Jorn Lauterjung of the German-Indonesian Tsunami Early Warning System. They explained that the early warning has been disseminated by BMKG to the Indonesian Disaster Management Agency (BNPB) (at national and local levels), the local government and the wider community. Furthermore, Lauterjung and Spahn stated the problem was more a lack of capacity at regional government, including their political and budgeting commitments. They further argued that the problem was more on the downstream level of InaTWES, starting from the point when local government received the early warning, their decision-making, and the community capacity to respond.[5] These statements (both BMKG and the article of Spahn and Lauterjung) created a debate within the Indonesian academic society. A geoscientist, Eko Yulianto[6], wrote a criticism stating the tsunami early warning system had failed.


Peringatan Dini Tsunami Tidak Gagal


What Went Wrong With Indonesia's Tsunami Early Warning System


InaTEWS: About more than technology

Images 2: Articles on different media outlets both national and international discussing the polemic of the effectivity of the Indonesia's early tsunami warning system

3. One example of the criticism of InaTWES was published in nytimes.com on 2 October 2018 titled: "What Went Wrong With Indonesia's Tsunami Early Warning System." The article can be accessed here: https://www.nytimes.com/interactive/2018/10/02/world/asia/indonesia- tsunami-early-warning-system.html. Another criticism was also published on Reuter.Com on 7 October 2018 under the title, "No siren, no warning: Indonesians caught unawares by devastating tsunami." the article can be accessed here: https://www.reuters.com/article/ us-indonesia-quake-warnings/no-siren-no- warning-indonesians-caught-unawares-by-devastating-tsunami-idUSKCN1MH048

4. The head of the BMKG's Centre for Earthquake Information and Early Tsunami Warning Daryono explained the success of InaTWES in the opinion section of Indonesian-language newspaper Kompas on 13 October 2018 titled "Peringatan Dini Tsunami Tidak Gagal." (Early Tsunami Warning Did Not Fail)

5. Harald Spahn and Jörn Lauterjung's opinion can be read in The Jakarta Post published on 4 October 2018 titled: InaTEWS: About morethan technology. It can also be accessed here: https://www.thejakartapost.com/academia/2018/10/04/inatews-about-more-than- technology. html

6. Kompas 23 October 2018, page 7, titled 'Bola Panas Peringatan Dini' (The Problematic Early Warning).

This series of events over the past 10 years, and especially the Palu Bay disaster, strengthens the need to examine the.

This assessment aims at examining the effectiveness of the tsunami early warning system in Indonesia, especially taking the complex tsunami-genic mechanism of the 28 September 2018 Palu Bay tsunami as a case. The assessment focuses on the downstream aspects, to understand the community's response during the earthquake and tsunami event and highlighting causes of the system's ineffectiveness. Based on the findings, recommendations will be presented on tsunami early warning systems that can save lives.

The research questions of this assessment are: **(1) How did the tsunami warning system function in the downstream part in the Palu Bay case?; (2) Why did the tsunami early warning system fail to save lives in Palu Bay?; (3) How can an early warning system save lives, responding to the complexity of the source of threats and social dynamics in Indonesia**?

1.2 Methodology and location of the assessment

The assessment involved grounded research from the perspective of social science/sociology with a qualitative research methodology that emphasises inductive processes based on empirical field data. This approach enables the researcher to construct a theory based on the analysis and abstraction process of the interview and observation data of the studied community.

In this type of research, the researchers are required to be directly involved with the research subjects. The researchers interviewed 55 members of the community affected by the earthquake and tsunami, along the Palu Bay and Donggala West coast. Their explanations illustrate the actual conditions, including their understanding of Indonesia's tsunami early warning product. The descriptions and narratives of the survivors could explain their attitudes when responding to disasters. The researchers also interviewed various parties who were involved in the operation of the early tsunami warning system both on the national and regional level: in total 70 informants were interviewed. The researchers also held several focused group discussions to verify their findings and collect more data, which included interviewing scientists and disaster risk mitigation

Photo 1 : Interview and field observation, doc. Ardito M. Kodijat, 2018.

practitioners in Palu and Donggala. Field data collection was conducted on 7–15 November 2018 and 18-24 December 2018. The list of informants can be found in the attachment. Assessment locations covered several related organisations in Jakarta, Palu and Donggala, and communities in several Dusun (villages) and Kelurahan (hamlets) in Palu Bay and along Donggala coasts.

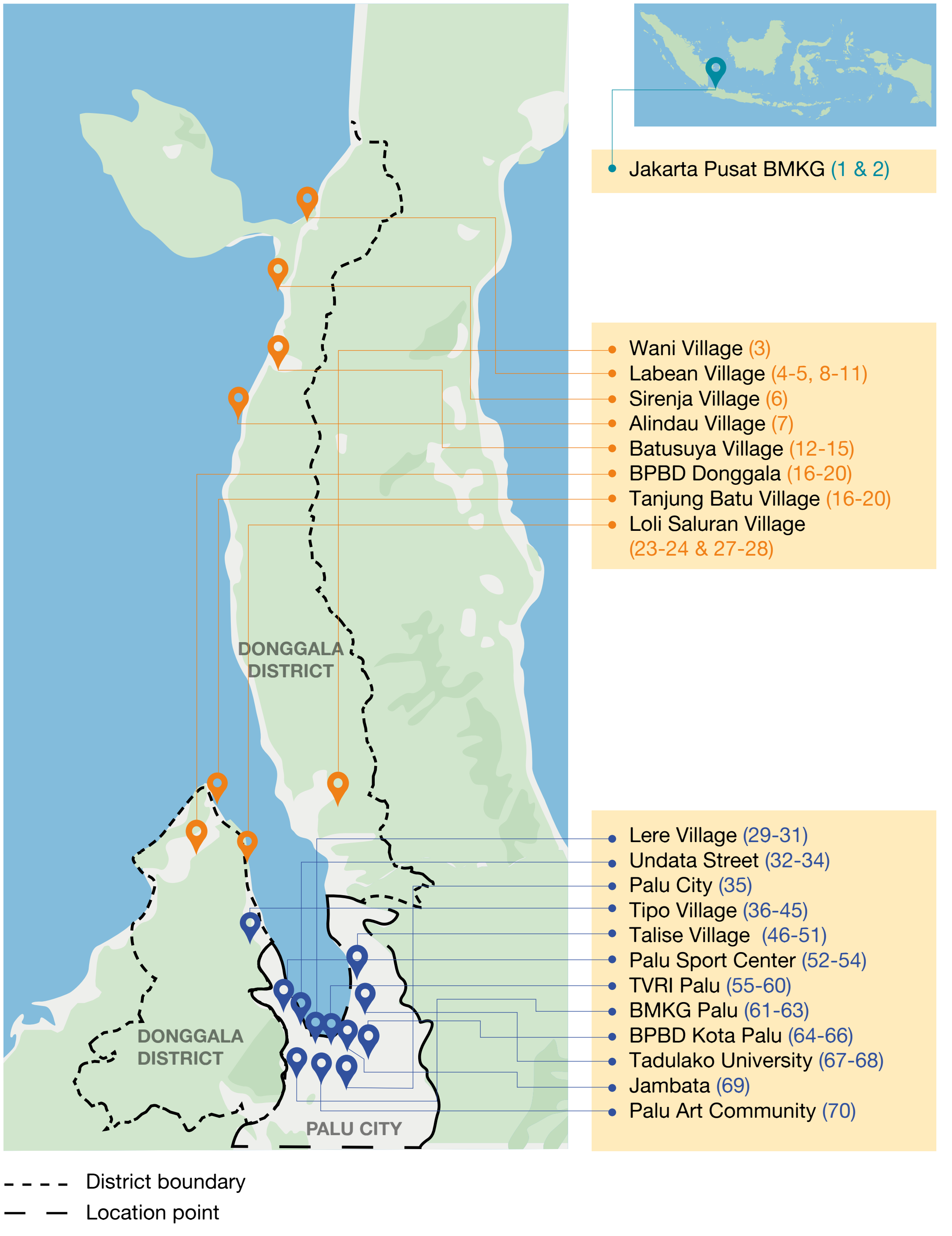


Image 3 : Location point for data collection and informant interview.

2. CONTEXT ANALYSIS

2.1 Palu Bay before the disaster

2.1.1 Tsunami history

The Palu Bay area and Makassar strait have a long history of earthquakes and tsunamis. Before the September 28th 2018 event, in the past 200 years eighteen tsunamis have been recorded. As many as 14 tsunamis occurred between 1820 and 1982 (Soloviev and Go, 1984). Meanwhile, between 1900's and 2001, tsunamis in Palu Bay happened in 1927, 1938, 1967, 1968, 1969, 1984, and 1996.

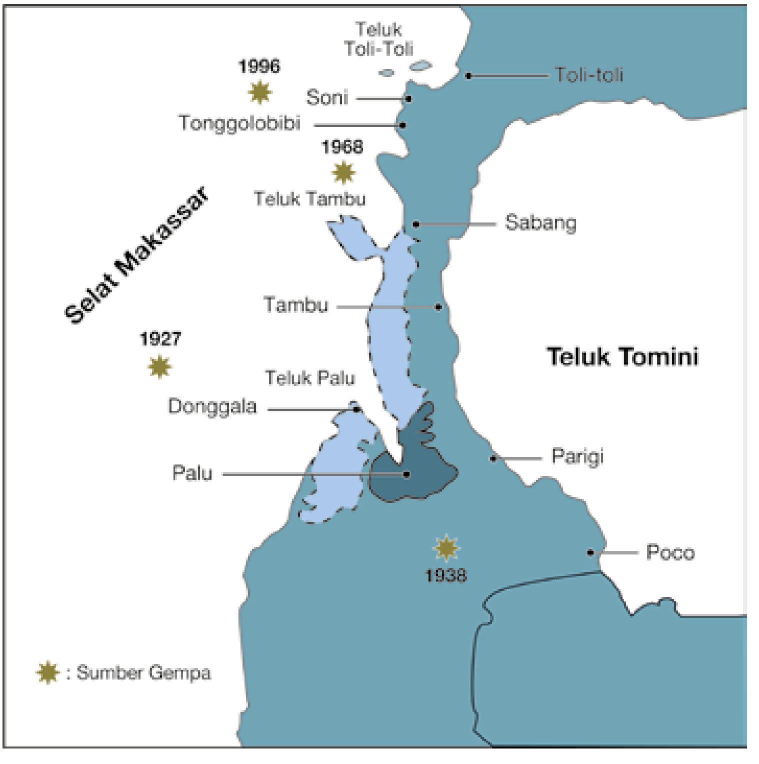


Image 4 : The epicentres of the earthquakes that triggered tsunamis around Palu Bay before 2018. Source: Adopted from Pelinovsky, 1997.

Three tsunamis triggered by earthquakes occurred in the Palu-Koro fault in the year of 1927, 1968, and 1996 (Pelinovsky, 1997; Prasetya, 2001). The tsunami that happened in Palu Bay on December 1st 1927 was triggered by a 6.8-magnitude earthquake event (with coordinates 0.5°S and 119.5°E). It was reported that the tsunami wave reached 15 metres in height (Prasetya, 2001). This disaster has possibly created a local narrative about the 'Air Laut Berdiri' (The Sea Water Stands) in Palu Bay (Abdullah, 2017). The earthquake and tsunami caused major destructions in Palu and Biromaru. In Palu, three large market stalls were destroyed and many other structures were heavily damaged. The main road to the market was also heavily damaged and several parts of the road lowered to half a metre. The Donggala government office building partially collapsed.

Meanwhile, in Tambu on August 14th 1968 a strong earthquake, with the epicentre located in the western offshore of Sulawesi sea, occurred and a tsunami followed soon after. The seawater in Tambu Bay between Tambu and Sabang receded for around 8 metres and a tsunami event occurred afterwards. Several cliffs experienced landslides and parts of the ground cracked, and jets of hot water came out of the cracks. In Sabang, it was reported that when the tsunami occurred, a loud grumbling noise was heard. The same tsunami also hit the area along the Palu coast. It reached 10 metres in height and the run-up went as far as 500 metres from the coastline. The worst affected area was Mapaga area (Donggala regency). In this area, 160 people were killed, 40 people were missing, and 58 people sustained major injuries. Eyewitnesses reported that tsunami waves came in three successions. Local people called it 'bombatalu' or 'lembotalu', which can be translated as three waves.

The tsunami that happened on January 1st 1996 was triggered by a 7.8-magnitude earthquake at around 16:05 local time. The epicentre was located around 180 km north of Palu. The height of the tsunami wave was about 2-4 metres, killing 9 people and injuring 63 people. Reports said that the tsunami waves arrived around 5 minutes after the earthquake event, so although the tsunami waves were not too high, they managed to cause a lot of damage. Eyewitnesses reported that the tsunami waves came in three succession with a 1-3 minutes gap between them (Pelinovsky, 1997). Major damage mainly occurred in Bangkir village, Toli-Toli, Tonggolobibi, and Palu. The earthquake triggered a tsunami with an average of 2 metres in height with run-up that went as far as 400 metres. A proper record was not compiled regarding the time when the tsunami happened, which generally occurred in less than 10 minutes.


Ratusan Tewas Akibat Gempa Bumi Di Donggala

Gempa di Pantai Barat Sulteng

Seorang Wanita Belum Ditemukan

Image 5 : Kompas, Wednesday, August 21st 1968. Page 1.

2.1.2 Disaster preparedness

Considering this long history of tsunami events, Palu and Donggala were indicated as area in the category of having medium-to-high tsunami risk.

The 2016–2020 Palu disaster risk analysis document states that out of eight sub-districts, seven are in the category of high- tsunami risk and only one is considered to be in the low tsunami risk. The total tsunami-prone area is 1.735 ha.[7] The 2016-2020 Donggala disaster risk analysis document states that 14 sub-districts in this regency are in the category of high tsunami risk with a total tsunami-prone area of 5.346 ha[8]. However, even though there are many scientific analyses and historical data detailing repeated tsunamis occurrence in these areas, both documents state that there had never been tsunami disaster in Palu or Donggala[9]. Both documents reflected the lack of historical disaster information which could have been used as reference for the disaster risk reduction policy.

In addition to the disaster risk analysis document, the city of Palu has a contingency plan for earthquake and tsunami disaster that was signed by the Mayor of Palu in 2012. The contingency plan states that the main Palu-Koro fault's movements could generate a tsunami around the Palu coastal area. The contingency plan uses the scenario of an earthquake with the epicentre in the Palu-Koro fault (0.61°S, 119.49°E), 7.4 magnitude, 10 km depth, the duration of 40 seconds, and that tsunami waves would strike Palu Bay in 15 minutes.

Photo 2 : National tsunami drill event in Palu, 2012, doc: Muhammad Ayyub.

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7. Can be accessed at http://inarisk.bnpb.go.id/pdf/SULAWESI%20TENGAH/Dokumen%20KRB%20KOTA%20PALU_final%20draft. pdf
8. Can be accessed at di: http://inarisk.bnpb.go.id/pdf/SULAWESI%20TENGAH/Dokumen%20KRB%20DONGGALA_final%20draft.pdf
9. Ibid

Referring to this contingency plan, the Palu government held a national tsunami disaster management drill. This event was directed by the Indonesian National Disaster Management Agency (BNPB) which included various activities: disaster-related discussions, exhibitions, film screening, and simulation of a tsunami event. There was also community training. Community members who participated in the 3-days training were then appointed as members of the Disaster Preparedness Groups (KSB) of each kelurahan (hamlet).

In the training, community members participated in a tsunami drill. The kelurahan participated in a self-evacuation training a few days before the tsunami drill, which was facilitated by a consortium of non-governmental organisations. The scenario had women, children, old people and pregnant women being transported by cars or motorbikes. A siren was sounded announcing an earthquake had occurred and to signal the people to start evacuating themselves to safety. However, when the actual tsunami event occurred in September 2018, this scenario did not work. Some people still remembered what they did during the drill, which was more of a dramatization of an earthquake event, rather than a disaster preparedness training.

> "……they showed us how to respond to earthquake. For example, I was sweeping the floor, the earth shook, do not run, act as in panic and fell. That was how we practiced. There were persons injured and immediately get assistance brought to the tent". Then she continued "…there were act where the family came crying….. don't cry I am not dead yet… (laughter)…. We practice this for three days (47)".

The Palu Disaster Management Agency (BPBD) had a warning receiver system (WRS), a device to receive earthquake and tsunami information directly from BMKG. Through the WRS they could have got information of the warning levels affecting their area, which is in the level of WASPADA (area having 50-cm or less high wave threat), AWAS (between 50-cm to 3-m high wave threat), and SIAGA (higher than 3-m high wave threat). In addition, the tsunami information that ideally could have been received via the WRS provided advice for evacuation for use by the local government.

There is a single tsunami siren installed in Palu by BMKG in 2011, to cover the entire city coastline. This is clearly insufficient. The siren is located around 1.93 km from the coastline in the most populated area, Pantai Talise. The community living around the area were aware of this siren and knew its function. BMKG conducts a siren test on the 26th of every month, although several sources stated that the siren had not been heard for a few months prior to the 28th September 2019 tsunami disaster.

Photo 3 : BMKG tsunami siren in Palu.

Image 6 : The distance of the siren to the coastline with the most populated area (Pantai Talise). Taken from: Google Map

In several locations in Palu, there was tsunami evacuation signage. However, not everyone understood the meaning of these signs, especially people who had not participated in the evacuation training.

> "… yes, it is written the direction for evacuation. I asked once as in my area as there were a lot of tsunami signage placed, I asked to the person who put it up what is it for. He said: if there is a disaster just run follow the direction. So, there was no activity where the people is gathered and explained and sensitized of what is it for, there is no detailed guidance, not at all…." (57)

Unlike Palu, the BPBD of Donggala does not have a contingency plan and does not own a WRS. They also do not have a tsunami siren. However, in 2008 several regions in Donggala West Coast received an intervention related to tsunami preparedness from local NGOs.

2.2 The tsunami early warning system in Indonesia

The most destructive earthquake and tsunami in modern history occurred on December 26th 2004 in Banda Aceh. This incident triggered the establishment of the Indonesia Tsunami Early Warning System (InaTEWS). At the time Indonesia did not have any tsunami early warning system in place, for this reason there was no tsunami warning given to the communities in Aceh and Nias, which could have mobilised them to safety, even though the tsunami wave took approximately 30 minutes to reach the coastline. Thirty minutes would have sufficed for the people in Aceh and Nias to evacuate and to stay away from the coastline. However, most of the communities did not have any knowledge or preparedness for tsunamis. At that time, BMKG (or BMG at the time) capacity to determine the magnitude of the earthquake and the threat of a potentially tsunami was no less than one hour. In essence, the capacity to detect earthquake and tsunami in Indonesia at the time was weak and could not save lives.

UNESCO stipulates the definition of a local tsunami to be a tsunami phenomenon originating from a nearby location around 100 km or less from the coastline, or a tsunami that will hit the coastline in one hour or less. Local tsunami can be caused by an earthquake, an underwater landslide, or lava flow from a volcanic eruption. In Indonesia, almost every tsunami case that

Photo 4 : The impact of earthquake and tsunami in Palu-Donggala, doc: Ardito M. Kodijat, 2018.

has occurred is a local tsunami. The typical time for a tsunami wave to reach the Indonesian coastline is much faster than the UNESCO definition, which in some cases is less than 5 minutes.

In 2005, a cross-institutional initiative was pursued under the coordination of the Indonesian Ministry for Research and Technology to develop a tsunami early warning system. Through a grand design InaTEWS was developed involving several ministries, institutions, and universities with the initial stage emphasizing structural aspects (upstream). The upstream aspects highlighted detection and monitoring capacity based on technology, monitoring devices, and automatic decision-making system (based on computation modelling). The output was information of tsunami early warning that could be produced in a short time, less than 5 minutes, and could be disseminated immediately. Several countries provided support in the development of InaTEWS, including the German government. Under the GITEWS (German Indonesian Tsunami Warning System) cooperation project, InaTEWS was built in a comprehensive and complex perspective, known as an 'end-to-end' tsunami early warning system. Aspects pertaining to community receipt and local decision-making of the warnings (the downstream aspect) came later, mainly in the final phase of the GITWES project.

This end-to-end system was implemented under the Ministerial Decree of the Coordinating Minister for the People's Welfare No. 21/2006 (21/KEP/MENKO/KESRA/IX/2006) with the appointment of government agencies as the focal point and the establishment of the Indonesia tsunami early warning system development team. The InaTEWS end to end system included earthquake monitoring, potential tsunami decision-making mechanism, dissemination of early warning bulletin, and the capacity of regional government to provide directions, as well as the capacity of communities to respond and initiate self-help actions.

The Coordinating Ministry for the People's Welfare held the role of the Executive Head of the National Disaster Management Coordination Agency (Bakornas PB). Within the legality of this Ministerial decree, it could mobilise related ministries, agencies, and universities. The Ministerial Decree also covered the legality for the coordination and development of InaTEWS at the advisory board (Ministry and Military officials), the directive board (at the level of echelon 1) and the executive team (at the level of echelon 2).

Several working groups were established. On the operational components (seismic monitoring, oceanographic monitoring, crustal deformation monitoring) were the Dart Buoy Centre - BPPT; Tide Gauge Centre - Bakosurtanal; GPS centre - LAPAN; and Seismic- BMKG, and BMKG as the National Tsunami Warning Centre. For capacity building, there included the Ministry for Research and Technology, LIPI, and several ministries and agencies. Included in the mitigation, emergency response, rehabilitation and reconstruction activities were LIPI, the Ministry for Research and Technology, the Ministry of Home Affairs, and other ministries and agencies.

The InaTEWS end to end system covered two components, the upstream and downstream. The upstream component included seismic data monitoring devices (seismograph/ seismometer) which provide the main input after an earthquake event. In this context, there are two important components. First, an earthquake parameter measuring device (seismometer/seismograph) produces an estimation of the parameter of the earthquake from the measurement data. Second, the tsunami model database that indicates the potential tsunami from the measured earthquake parameter. The recorded earthquake parameter is inputted into the Decision Support System (DSS) and produces a tsunami prediction based on the referred model. It would recall the closest tsunami model on the database according to the recorded earthquake parameter. Following this step, devices that detected changes in sea level surface, such as buoys, tide gauges and GPS are designed to confirm the tsunami and provide updates in case of a tsunami for the tsunami early warning system.

The output of the upstream part is the earthquake parameter and information regarding potential tsunami and tsunami prediction. The potential of tsunami (which is the tsunami wave height and estimation time of arrival) is categorized in 3 levels: Siaga, Waspada, and Awas (Advisory, Warning, and Major Warning). If the earthquake parameter can be estimated accurately in less than 3 minutes, then the pre-calculated tsunami model in the database closest to the measured earthquake parameter can be recalled. All information regarding earthquake (and potential tsunami) can be disseminated within five minutes after an earthquake occurrence. The dissemination of this information in less than 5 minutes is considered as success indicator of the early warning at the upstream level.

The downstream component is the interaction with the public through dissemination processes. Dissemination is conducted by related stakeholders via the use of tools in the form of a warning receiver system (or a receptor of early warning bulletin), tsunami siren, and other supporting measures that are considered appropriate within the context and needs of the community. In line with this, the downstream covers training and education supported by understanding the risks, such as hazard maps, risk maps, evacuation procedures. The downstream component emphasises evacuation as a response of the early warning information and is in line with evacuation and contingency planning.

InaTEWS was officially launched on November 11th 2008 by the Indonesian president at that time, President Susilo Bambang Yudhoyono.

Since 2008, the performance indicator for the dissemination time of less than 5 minutes by InaTEWS was considered to be really good (Pariatmono, 2011; Daryono 2018). However, there were some issues in the accuracy parameter of the seismic data processing result (Rafliana dkk, 2014; 2016), which was caused by the limited number of tools, human resources, and analysis time.

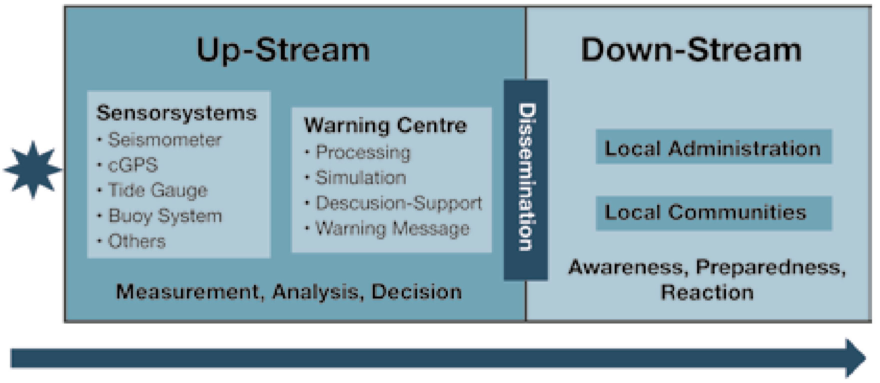

Image 7 : Approach scheme of the German-Indonesian Tsunami Warning System that is divided into Upstream and Downstream components. Image source: Lauterjung, J., Letz, H. (Eds.) (2017): 10 Years Indonesian Tsunami Early Warning System Experiences, Lessons Learned and Outlook, Potsdam: GFZ German Research Center for Geosciences, 68p

Issues in the upstream part affected significantly on the downstream part. The limited capacity of DSS, especially in detecting atypical tsunami (for example, tsunami caused by submarine landslide) as well as tsunami modelling data base of tsunami prone areas, affected the accuracy of the information to the public. Another example is limitation of warning dissemination: although it met the 5-minute performance indicator at the upstream level, downstream information dissemination to the community as the end user takes a longer time due to the limited number, conditions and quality of infrastructures as well as the capacity of local government and community. The problems and challenges in the upstream and downstream aspects of InaTEWS could not be separated as they are interrelated.

Although InaTEWS had been in operation for more than a decade, the system depended on earthquake information received from several earthquake-monitoring stations. This information determines whether the Tsunami Early Warning bulletin 1 (PDT-1) and Tsunami Early Warning bulletin 2 (PDT-2) should be issued or not. PDT-1 is issued in less than 5 minutes informing of the earthquake parameter and whether there is any potential for tsunami. The earthquake parameter is used to select the possible tsunami scenario from a database of pre-calculated tsunami modelling. This database will indicate if a certain area faces a tsunami threat or not. The DSS proposed from Seiscomp3 and TOAST (Tsunami Observation and Simulation Terminal) becomes the basis of a PDT-1 issuance with information of the earthquake's epicentre, depth, coordinates information and a statement if the earthquake has 'potential tsunami'.

Several minutes later, at least 10 minutes, after the earthquake focal mechanism is set, the PDT-2 is issued. PDT-2 updates the earthquake parameter information as well as the tsunami threat information (the estimated time of arrival and the estimated tsunami height. PDT-2 products are also based on modelling.

The follow up information is the Tsunami Early Warning bulletin 3 (PDT-3). PDT-3 information is based on observation of the sea level monitoring system of dart buoy(s) in the open sea and/or tide gauge(s) on the coast. PDT-3 information will confirm if a tsunami has been generated based on the sea level information parameter that can be used to identify the speed, direction, the estimated time of arrival to the coast, and the estimated tsunami height when it reaches the coast. PDT-3 will be updated every time there is new information received from the sea level monitoring system. However, since its inauguration until now, the dart buoy has never been integrated to InaTEWS. This means there has not been a real case where PDT-3 is issued based on information from dart buoys since InaTEWS was established. At present, PDT-3 relies on the tide gauge(s) network managed by the Indonesian Geospatial Information Agency (BIG).

The Tsunami Early Warning bulletin 4 (PDT-4) pertains to the conclusion of a tsunami early warning created by the earthquake that triggered PDT-1. PDT-4 informs the tsunami threat is over. PDT-4 can be issued without the issuance of PDT-3 if after the PDT-2 it is considered not to be a tsunami event. The PDT-4 information is mainly useful for emergency response teams to assess the affected area and conduct search and rescue missions, which only can be done if there is no tsunami threat and it is safe to go to the affected area. Based on a conservative estimation, PDT-4 usually is issued two hours after the last wave threat is considered passed. After the earthquake and tsunami in Lombok, August 2018, BMKG changed its standard operational procedure for PDT- 4 issuance. PDT-4 now can be issued faster based on the internal consideration of BMKG officials.

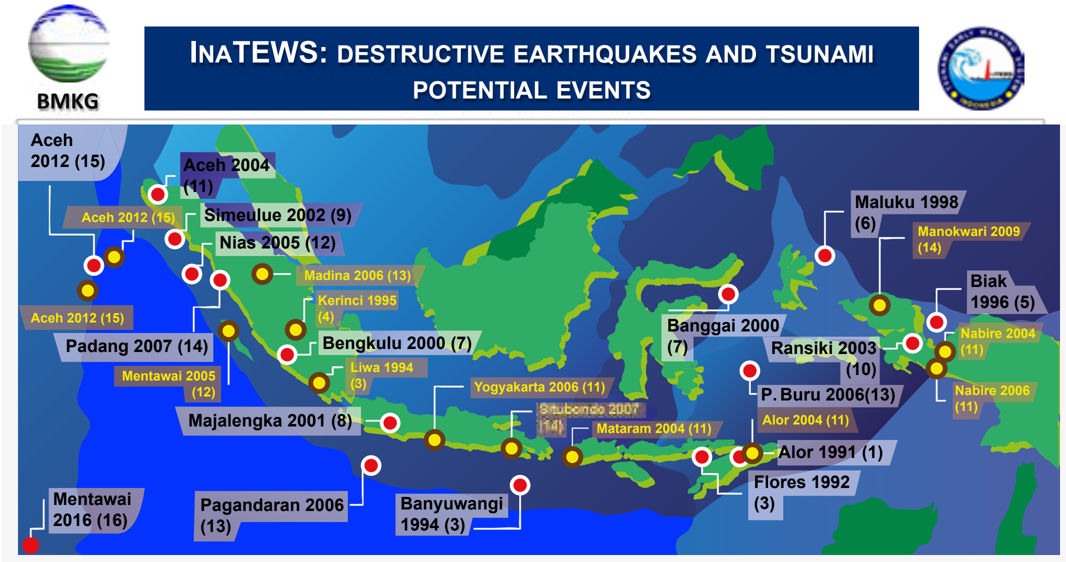

Image 8 : Earthquake and tsunami events in Indonesia. Source: BMKG.

In the past 10 years, the behaviours and cultural relations of the community in terms of technology and the science of earthquake, tsunami, and disaster risk reduction have changed. The behavioural changes have been affected by the development of social media and other easiness offered by information technology. These have created new communal dynamics that close the gap between the downstream and upstream components.

By the end of 2018, the Indonesian government accelerated the formulation of its Presidential Regulation on the Strengthening of the National Multi-Hazard Early Warning System (Sistem Nasional Peringatan Dini Multi Ancaman Bencana - SISNAS PERDIMANA), which includes the tsunami early warning. The objectives of the Presidential Regulation are as follows:

a. Building an early warning system that is reliable, integrated, trustworthy, interoperable, updated, and to bebased and centred on the community, utilising local knowledge, which includes the entire territory of the Republic of Indonesia;

b. Supporting taking rapid and precise actions, especially in making decisions related to risk-based early warning to reduce the impacts of disasters and to prepare emergency management actions;

c. Improving the synergy between various ministries/institutions in the early warning system chain into the national early warning system of multi-threat

d. Strengthening the capacity of the disaster-prone communities inclusively to prepare to act fast and proper in order to reduce the number of potential victims and damage.

Photo 5 : The after-effect of earthquake and tsunami in Palu Bay, doc. Irina Rafliana, 2018.

This analysis is trying to push forward point 4 d to become the first and foremost philosophy in every disaster risk reduction effort, including the basic philosophy of tsunami early warning, considering that Indonesia's territory has many nearby epicentres, which can cause a tsunami in a short time. Therefore, the basic philosophy of SISNAS PERDIMANA, especially regarding tsunami, must put forward the community's capacity to self-evacuate, supported by a reliable and trustworthy early warning system along with a fast and proper decision- making process for evacuation. It is not to suggest that people wait for a siren and tsunami early warning bulletin to start evacuating. A series of events, such as the Mentawai tsunami on October 24th 2010, the Outer-rise earthquake on April 11th 2011, the Wharton Basin earthquake on March 2nd 2018, the Palu tsunami September 28th 2018, the Sunda Strait tsunami December 22nd 2018, as well as hundreds of other events have shown that Indonesian communities only have a short interval between the occurrence of tsunami-genic phenomena and the first tsunami wave arrival. Therefore, it is necessary to change the basic viewpoint and establish a better context for assessing the role of InaTEWS and self-evacuation, especially for Indonesian context.

2.3 Self-evacuation practices in Indonesia

The 2004 earthquake and tsunami in Aceh was a humanitarian tragedy for Indonesia as well as the world, with human casualties reaching more than 160,000 in Indonesia. This is the highest number of casualties in the history of natural hazard induced disasters in modern Indonesia. Most victims were from the coast of Sumatra, mainly in Banda Aceh, with one quarter of its population killed in the disaster. The community had no knowledge of the tsunami threat before the disaster struck. As stated before, at that time Indonesia did not have the tsunami early warning system.

Nevertheless, despite the tragedy, there was a success story of community evacuation in Simeulue island. This island is the closest landmass, around 60 km, from the epicentre of the 9.1-magnitude earthquake in the Indian Ocean. The tsunami wave reached Simeulue very fast, approximately 5-10 minutes, while it took approximately 20-30 minutes for the tsunami to reach the mainland in Banda Aceh. Although thousands of houses in Simeuleu were destroyed by the earthquake and tsunami, the number of casualties was very low (only 7 people). Right after the earthquake shook the island, the people of Simeulue island (80,500 people) immediately left the coastal area and evacuated to the hills. This self-evacuation action was possible because the community possessed knowledge that strong earthquakes might trigger tsunami waves, which in the local term called *smong*,.

The knowledge of *smong* has been handed down from their ancestors who experienced a similar event on January 4th 1907. Gutenberg and Richter (1954) stated that a 7.6-magnitude earthquake in 1907 occurred in Simeulue. Many community members in the island retain the knowledge that the smong incident had killed many of their ancestors. Some sources even said that more than half of the total island (2,052 km2) population was killed in 1907. According to the story, many people were killed at the time because when the water receded after the earthquake, many went to the beach to get fish (Arif, 2012).

People who did not get killed told the story of the 1907 smong tragedy in various ways, from songs to bedtime stories. Besides narrating the tragedy, they handed down the story of how to save themselves. Alfi Rahman's analysis (2018) concluded that the smong story is an indigenous knowledge that can protect the community from the threat of tsunami in the future. This indigenous knowledge of the Simeulue islanders was awarded the 2005 Sasakawa Award by the United Nations Office for Disaster Risk Reduction (UNDRR) because it provides a clear contribution that establishes the role that culture can play in saving lives from tsunami.[10]

However, the successful experience of Simeulue islanders in evacuating themselves during the 2004 tsunami was not shared extensively in Indonesia, especially after InaTWES was developed (2005) and operational (2008).

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10. Also see https://www.unisdr.org/files/5602_IndonesiacommunityUNaward.pdf

Modern knowledge intervention in the community has also shown some success. Self-evacuation practices that saved lives during the Mentawai tsunami on October 25th 2010 were successfully conducted by the people of Tumalei hamlet, Silabu village, Pagai Utara sub-district. The Tumalei hamlet experienced the 2007 earthquake and in 2009 received an intervention of a 3-day training facilitated by Surfaid. The training provided actions that were implemented by the people in Tumalei in 2010. Despite the short time to evacuate, less than 10 minutes after the earthquake happened that evening, 100% of the population successfully evacuated to the hills.

Photo 6 : The after-effect of the earthquake and tsunami in Palu-Donggala, doc: Ardito M. Kodijat, 2018.

3. TSUNAMI EARLY WARNING PERFORMANCE AND COMMUNITY RESPONSE IN PALU BAY

3.1 Tsunami early warning system chronology in Palu Bay

This section tells about end-to-end tsunami early warning system performance. Although the purpose of this study is to focus more on conditions in the downstream, portrayals at the upstream level to see how early warnings are produced and then distributed will help understand gaps.

3.1.1 Daytime Preliminary Earthquake in Palu and Donggala

A 7.5-magniture11 earthquake that struck Central Sulawesi on Friday, September 28th 2018 at 18:02 local time was preceded by weaker earthquakes throughout the afternoon. The first earthquake was recorded by BMKG's seismometer station near Palu and Donggala at 15:00 local time. The station automatically sent the data to BMKG office in Jakarta office (National Tsunami Warning Centre). The data was then processed, and the earthquake was recorded to have a 5.9 magnitude and its parameters were known. After more seismometer data from various regions came in, the earthquake was updated to 6.1 magnitude12. The epicentre was inland (in Sirenja), with coordinates of 0.35°S and 119.82°E, around 8 km northwest of Donggala or 61 km north of Palu with a 10-km deep hypocentre.

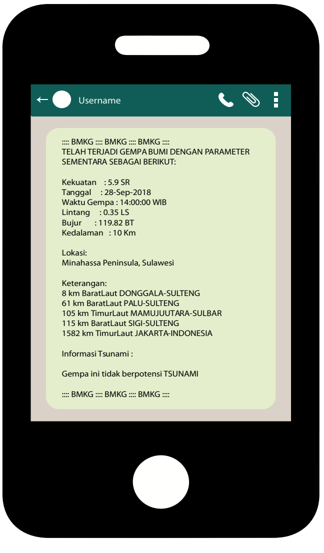

Image 9 : Earthquake news at 15:00 local time that was shared via SMS and received by most of the affected community members

Then, a 4.4-magnitude earthquake occurred at 15:11 and was followed by 27 more earthquakes, before the strongest earthquake happened at 18:02 local time. The foreshocks were in the range of 3.1 -5.1 magnitude with its epicentre close to the first earthquake's.

11. The earthquake's magnitude was based on the latest BMKG's information. Previously, it was informed that the earthquake was 7.7 magnitude and then it was corrected to 7.4 magnitude. However, after a quality control process, BMKG revised it to 7.5 magnitude.
12. Previously BMKG stated the magnitude was 5.9 but then it was updated to 6.1.

For further details, the number of earthquakes can be seen in Table 1 and locations can be seen in Graphic 10.

DATE	TIME (CENTRAL INDONESIA TIME)	MAG	TYPE
9/28/18	**7:00:01**	**6.1**	**FORE SHOCK**
9/28/18	7:11:17	4.4	FORE SHOCK
9/28/18	7:17:14	4.8	FORE SHOCK
9/28/18	7:27:00	4.7	FORE SHOCK
9/28/18	7:28:37	5	FORE SHOCK
9/28/18	7:43:40	3.2	FORE SHOCK
9/28/18	7:50:43	4.7	FORE SHOCK
9/28/18	7:57:23	3.7	FORE SHOCK
9/28/18	7:59:12	4.3	FORE SHOCK
9/28/18	8:00:27	4.4	FORE SHOCK
9/28/18	8:06:40	3.8	FORE SHOCK
9/28/18	8:07:27	3.7	FORE SHOCK
9/28/18	8:20:27	4.2	FORE SHOCK
9/28/18	8:25:01	5.1	FORE SHOCK
9/28/18	8:38:49	3.2	FORE SHOCK
9/28/18	8:42:30	3.5	FORE SHOCK
9/28/18	8:47:00	4	FORE SHOCK
9/28/18	8:52:14	4.3	FORE SHOCK
9/28/18	8:53:22	4.4	FORE SHOCK
9/28/18	8:58:17	4.3	FORE SHOCK
9/28/18	9:11:14	4.5	FORE SHOCK
9/28/18	9:20:33	4.5	FORE SHOCK
9/28/18	9:22:49	4.8	FORE SHOCK
9/28/18	9:32:19	3.8	FORE SHOCK
9/28/18	9:42:48	3.5	FORE SHOCK
9/28/18	9:49:07	3.1	FORE SHOCK
9/28/18	9:57:39	4.7	FORE SHOCK
9/28/18	**10:02:45**	**7.5**	**MAIN SHOCK**

Table 1 : Foreshocks and main shock in Central Sulawesi on September 28th 2018. Source: BMKG, 2019.

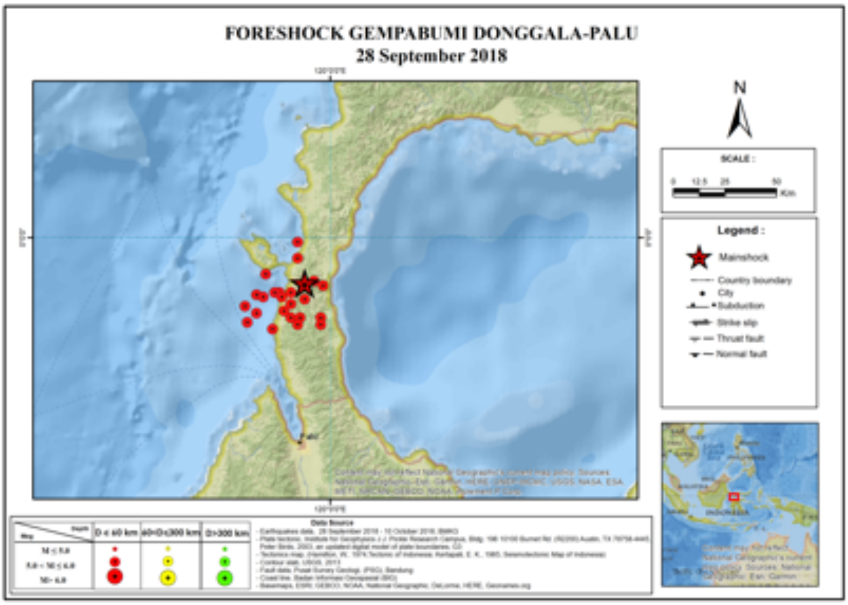

Image 10 : The spread of foreshocks in Palu - Donggala. Source: BMKG, 2018.

At the first earthquake, the electricity in some areas of Palu and Donggala was temporarily cut off, but the landline was still working. At that time, the BMKG office in Jakarta managed to send information of the earthquake parameter via the WRS to the city of Palu. As the Donggala regency did not have BMKG's WRS device, they did not receive this information. After BMKG's earthquake news was issued, the information was disseminated via a text message blast (SMS) to mobile phone users within in the range of the telecommunication base transceiver stations (BTSs) in the area. Several community members and regional government staff received the text message.

Communities living near the epicentre, especially on Donggala West Coast, felt the strong shaking. BMKG recorded the afternoon earthquake's intensity as approximately III- IV MMI, in the area surrounding Palu and Donggala. The Rapid Response Team (TRC) officials of the Donggala Disaster Management Agency (BPBD) stated that the SMS they received from BMKG indicated that the earthquake did not potentially generate a tsunami. The officials disseminated this information to all OPD (local government organisations) and the community. Not long after, BPBD received information from Sirenja village about victims due to the recent earthquake. The TRC team made their preparation to travel to Sirenja on the west coast (it takes more than 4 hours travel). They decided to depart after the Maghrib praying time (around 18:00).

After these foreshocks, BMKG officials in Palu were assigned to check conditions in Sirenja. They were on their way to Sirenja when the main earthquake truck at 18:02:44 local time.

3.1.2 The issuance of tsunami early warning bulletins from BMKG

After the foreshock that started at 15:00 local time, the main earthquake with 7.5 magnitude shook Palu and Donggala, Central Sulawesi, at 18:02 local time (Friday 28/9/2018). The earthquake's epicentre was located 0.22°S and 199.85°E, 11-km deep, and 26-km north of Donggala or 80-km northwest of Palu.

The epicentre is on the Palu-Koro fault, one of the most active faults in Indonesia. Although the epicentre was inland, the earthquake was shallow, and the movement was horizontal (strike-slip), the earthquake triggered a tsunami that hit the coastline of Palu and Donggala. The cause of the tsunami, whether it was an underwater landslide or a horizontal thrust movement, is still being discussed scientifically.

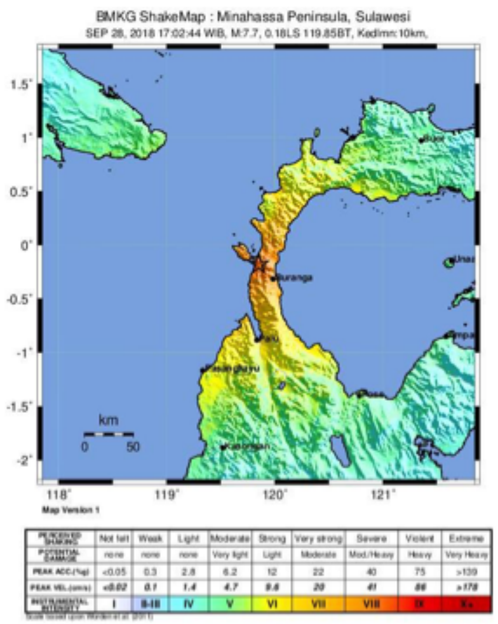

Image 11 : Shock in Palu - Donggala, BMKG, 2018.

The main earthquake did not fall into the conventional scenario, considering the seismometer data from around the epicentre showed that it was inland and a strike-slip earthquake. However, an early warning bulletin was issued based on the conventional preconditions, where a 7-magnitude thrust fault is assumed to have tsunami potential. Nevertheless, the earthquake information was immediately processed by DSS machines of Seiscomp3 and TOAST.

> "This was using the pre-calculated model, that is available. All earthquakes above 7 magnitude in sea or land with the epicentre around 200 km from the coast would trigger the tsunami early warning; our system could not recognise strike-slips as everything is designed for thrust fault with tsunami potential… worst case is always considered" (2).

In 4 minutes and 13 seconds, BMKG established the earthquake parameters and a tsunami early warning was ready to be disseminated. In PDT-1, the earthquake was indicated as an earthquake with tsunami potential of a SIAGA (Warning) level for west Donggala. The tsunami wave was estimated to reach 0.58-metre (58 cm) high and the estimated arrival time was 17:22:42 West Indonesian time (18:22:42 local time).[13] The SIAGA level meant that the local government is recommended to initiate evacuations. Meanwhile, Northern Donggala (West coast of Donggala), Palu and Northern Mamuju were under WASPADA (Advisory) level and their advice was to avoid the coastline / stay away from beaches. The modelling reference based on the simulation database ID 10078 for the threat of tsunami wave or runup for northern Donggala is 38 cm, ID 10202 for western Palu is 36 cm, and ID 10218 for northern Mamuju is 31 cm. BMKG PDT-1 product can be seen in the graphic as follow.

Image 12 : Early Warning bulletin that was issued by BMKG for Palu.

The tsunami early warning bulletin was disseminated by BMKG through the Warning Receiver Systems (WRS), installed in the interface agencies, the national broadcasting media and the national and regional disaster management agencies. In addition, under a cooperation agreement between BMKG and the Ministry of Communication and Information, the information was made possible to be sent directly to the affected community via SMS blast.

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13. Informasi didapatkan dari materi Press Release BMKG tanggal 28 September 2018 No. UM.505/9/D3/IX/2018

3.1.3 Disrupted chain of early warning bulletins to the community

Although BMKG issued the tsunami early warning bulletin just five minutes after the earthquake, this warning was not received by the affected community and neither by the local government in Palu and Donggala. This is likely to be because approximately two minutes after the earthquake, Palu and Donggala experienced a blackout. Hence, the WRS system in the BPBD in Palu office was not functioning due to the power cut off; moreover the backup generator was not available. The blackout also shut down the main cellular network provider, Telkomsel. However, another provider, XL, was still functioning for a couple of hours after the earthquake. Cellular phone users in Palu and Donggala, who received the SMS information of the foreshock (the 15:00 earthquake), did not receive the SMS that was sent about the 18:02 earthquake. After the strong earthquake, the BMKG office in Jakarta could not contact their office in Palu.

> "…. due to a communication problem. We didn't have information of what happened in Palu, even the head of BMKG Palu office (who was in Jakarta at that time) couldn't contact his wife. We could communicate again 8 hours later."[14]

The staff of BMKG Palu office who were on their way to Sirenja (Donggala west coast) by car also did not receive the tsunami warning information. They admitted the confusion they experienced.

> "…I was shocked because the docked boats were already in the neighbour's yard. People didn't know that there was a tsunami… We couldn't go to Sirenja, just to Pantoloan, and the road was already flooded. I thought it was due to a tidal wave. But when we turned around, everything was already flooded, we couldn't drive through. We turned around and went into the custom office. It was just like a dead town; the office was flooded ..." (69).

The inability to coordinate and communicate between BMKG office in Jakarta, BMKG office in Palu, and the local government of the affected areas was also confirmed by an explanation of BPBD Donggala and BPBD Palu staff. That afternoon, a BPBD team in Donggala was getting ready to go to Sirenja as the main earthquake struck. They knew about the tsunami after the disaster occurred.

The head of BPBD in Donggala, who at the time of the incident was in Palu, received the information of a tsunami disaster around 21:00 local time (3 hours after the incident).

> "I heard about the tsunami at 9 p.m. I received the information from the community members, and after that, I went to Talise, and yes, a tsunami did happen." (18)

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[14] At that time, the head of Palu BMKG was in Jakarta. It was reported that he couldn't contact his family in Palu moments after the earthquake happened. This information was confirmed during the FGD conducted in Palu on December 18th 2018.

Image 13 : The chronology of Palu - Donggala Tsunami 28 September 2018.

He received the information of a 7.7-magnitude earthquake (and then updated to 7.5 magnitude) with tsunami potential issued by BMKG through the WhatsApp approximately three hours after the earthquake.

Right after the tsunami happened, many people evacuated to the BPBD Donggala office as it is located on a higher ground. People reported the seawater risen. Based on this information, the Rapid Response Team (TRC) BPBD Donggala went to the coast and saw that the tsunami had happened. As the evening continued, more people evacuated to the BPBD Donggala office (on the street and field across the office). They realized how badly the city of Palu had been hit by tsunami after the backup generator and the electricity came back on, and the Wifi reconnected, enabling them to access the internet.

The staff of BPBD Donggala stated that during the earthquake and tsunami, they did not communicate at all with the BMKG Palu office, BMKG Jakarta, or the Emergency Operation Centre (EOC - Pusdalops) BNPB. The last information they received from BMKG was the earthquake that happened earlier at 15:00 local time.

BPBD Palu also did not have any communication with BMKG. Even though they have a Warning Receiver System (WRS), at the time of the disaster the system did not work. The on-duty officer of BPBD Palu explained that the WRS did not work because the electricity cut off approximately 2 minutes after the earthquake, while the backup generator had been broken for some time.

Photo 7 : Donggala Disaster Management Agency. Doc: Irina Rafliana, 2018.

Photo 8 : Interview with BMKG Jakarta. Doc. Irina Rafliana, 2018.

BPBD Palu is in the Tanamodindi area, approximately 4 kilometres from the coast, so it was not affected by the tsunami. The on-duty officer of the EOC of BPBD Palu panicked and evacuated from the office. He then received a call from his mother in Balaroa advising that their house was destroyed and requested to pick up her mother. He faced a dilemma of either going to his mother in Balaroa or stay in the office. Ten minutes after the earthquake the head of BPBD Palu and the Secretary of BPBD Palu arrived, however there was no electricity and the cellular network was down. Although there is BMKG's tsunami siren tower in Palu, at that time, sounding the siren was not in the BPBD Palu official's mind. The siren could also have been triggered by BMKG in Jakarta. However, at that time BMKG was not aware of the tsunami threat to the Palu coast, and so they did not activate the siren. It is also not clear if the electricity cut off affected the siren. Based on information gathered from sources near the siren in Palu, they had not heard the siren for several months before the disaster (64).

In addition to the tsunami warning information not being sent to Palu, BMKG Jakarta could not receive any situation reports from the affected area. BMKG Palu staff could not communicate with BMKG Jakarta. BMKG Jakarta had no knowledge of what had happened in the area when they decided to issue the PDT-4 (ending of the tsunami warning15) at 18:36:12 local time, 34 minutes after the earthquake.

> "… that is how I explained to the Ombudsman (agency with the authority to monitor services provided to the public by government agencies). To everyone, nobody knew there was a tsunami in Palu. (We knew) 2-3 hours later… When asked, do you know that there was tsunami in Palu? Nobody knew, nobody knew. But then I was sure that it was a tsunami that hits Palu" (1).

BMKG Jakarta officials were informed later that a tsunami had destroyed the coast of Palu in the evening, approximately at 21:00 Jakarta time. They knew after watching videos that were shared through various social media. This was confirmed by the head BMKG Palu who was in Jakarta at the time.

> "I showed the video (to the head of BMKG Palu), I played it until the end. Is this in Palu? Yes, Sir! I know this place, this is the mall, he must have filmed the video from the parking area" (1).

The decision to end the early warning by BMKG Jakarta was made after receiving a report of the sea level observation and tide gauge in Mamuju (±237 km from Palu), that recorded a 6-cm sea level rise, at 17:13 Jakarta time. There is another tide gauge operated by BIG in Pantoloan harbour in Palu. However, at the time of the disaster, the tide gauge station[15]. Based on the press release from BMKG No: UM.505/9/D3/IX/2018 and statement from

[15] Based on the press release from BMKG No: UM.505/9/D3/IX/2018 and statement from BMKG in Kompas, Tuesday, 02 Oct 2018, p.2

BMKG in Kompas, Tuesday, 02 Oct 2018, p.2 in Pantoloan was inactive, so no observation was reported. Other considerations in ending the warning, in addition to the Mamuju tide gauge observation, was the earthquake source mechanism, which was a strike-slip that happened on land and which usually does not generate a tsunami.

3.1.4 The tsunami was faster and higher than the early warning

CCTV recording from an informant living in Wani 1 village, Tanan Tovea sub-district, Donggala, showed the first waves arrived while the earth was still shaking, a few minutes after the start of the earthquake. The informant's house was located around 40 metres from the coast. The earthquake was recorded at 18:02:52 local time and the recorded time when the tsunami hit their house was at 18:06:28, 3 minutes 36 seconds after the earthquake.

The tsunami arrived sooner than the early warning and the wave height was higher compared to the estimated height of BMKG's PDT 1. The warning indicated the highest potential wave would be 0.58 metre with an estimated time of arrival 20 minutes after the earthquake. Based on the survey conducted by Widjo Kongko and Tim, from Operasi Bakti Teknologi (technological operation team), the tsunami height in Palu was between 1.4 - 7.8 metres, the runup reached 1-9.7 metres and the tsunami inundation reached 383.6 metres in land.

BMKG's tsunami early warning system did not accommodate the complexity of tsunamigenics in Palu Bay which may involve an underwater landslide that can cause local tsunami very

Photo 9 : Interview with disaster preparedness group and tsunami survivors in Palu. Doc: Irina Rafliana, 2018.

close to shore. BMKGs tsunami early warning system is based on tsunami modelling caused by tectonic earthquake. Although experts have not reached an agreement on the cause of the tsunami in Palu Bay, evidence shows that an underwater landslide occurred after the earthquake. Meanwhile,

> “Since the tsunami early warning is based on modelling due to earthquake, while in reality there was landslide, then it didn’t match. The earthquake was strike slip then these were the areas at risk. This was the maximum result we got. In reality, it is different.” (1)

3.2 Different forms of community responses

This section will explain how the community responded in Palu and Donggala to illustrate differences in the impact in both areas. Although the epicentre was in Donggala, Palu had a higher number of casualties. Based on the data of BPBD Donggala, the number of casualties and missing persons in the area is 212 persons. Forty-eight people were killed by the tsunami. Others were killed by collapsed structures. The highest number of casualties by tsunami was found in Wani village, reaching 12 people. Meanwhile, although Loli village experienced major damage, the number of tsunami casualties was the lowest, only 8 people. In Tanjung Batu, 17 people were killed, which included dockers who came from outside Donggala. Eleven other people were missing or killed due to land subsidence where the ground sunk into the sea immediately after the earthquake.

Based on provisional data from the Palu development planning agency (Bappeda), the number of casualties and missing people in Palu was 3,679 people. The tsunami killed 1,252 people and 1,204 people were killed by the earthquake. The remaining were killed by liquification.16 Although this is still temporary data, the number of casualties due to tsunami in Palu was much higher than in Donggala.

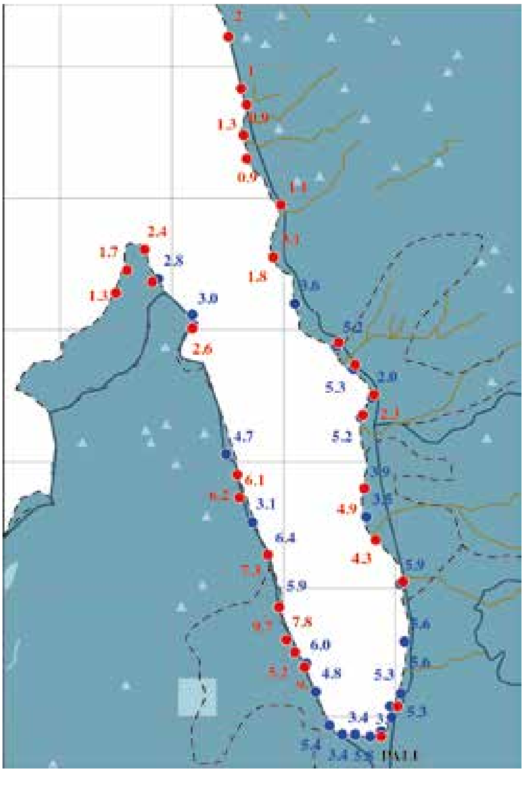


Image 14 : Tsunami height in Palu Bay, doc: Widjo Kongko, 2018.

This larger number of casualties was caused by the height of the tsunami waves, the

[16] See the victim data at http://bappeda.palukota.go.id/?p=4202

denser population in Palu, and the community response during the disaster. The different responses between the communities in the two affected-tsunami areas are as follows:

3.2.1 Donggala community

3.2.1.1 Self-evacuation after the first foreshock

The earthquake that occurred at 15:00 local time was felt by the community in West Coast of Donggala. The people in Sirenja sub-district, Donggala regency, which was closest to the epicentre, felt the shaking. Based on data from the Donggala disaster management agency (BPBD), one person was killed and 10 people injured due to collapsed.[17]

One community member of Labean village explained,

> "The first earthquake (was) in the afternoon, around three o'clock. I was on the boat and it felt like the boat was lifted up. I knew immediately that there was an earthquake. Half an hour later, I went back. I saw the dyke on the beach had collapsed. Some houses also collapsed." (6)

Many eyewitnesses on West Coast of Donggala stated there were water bubbles around the coast. Some people also heard a rumbling noise, which made them uneasy.

> "The neighbour who is originally from here told (me): there might be a strong earthquake later. Furthermore, now it is Friday, the previous tsunami also happened on Friday. The neighbours evacuated their family, so I did it too" (8).

Facing the situation at the time, some people who lived on the coast started to evacuate their family to higher ground.

> "At three o'clock (local time), I already told everyone to run. Many people have already evacuated to the mountains. Even my children, my grandchildren, ran to the mountains. I said just bring some clothes, a bit of rice, and the ripped tents." (9)

In Batusuya village, a lot more people managed to evacuate.

> "Everyone ran away. Nobody was on the beach. Everyone went uphill." (14)

This self-evacuation prior to the main earthquake, according to the community,

Photo 10 : Interview with one of the tsunami survivors in Labean village, Donggala. Doc: Irina Rafliana, 2018.

[17] See also http://www.tribunnews.com/regional/2018/09/28/gempa-di-sulteng-1-orang-meninggal-dunia-10-orang-luka-luka Downloaded on January 8th 2019, at 23:01 WIB

had reduced the number of casualties.

However, in Labean village, not everyone evacuated after the first foreshock, especially people who did not live near the beach. At the time, there were university students pursuing activities on the village's courtyard. After the first foreshock, most of them, especially students from Palu, and the village's officials continued their activity, although some children and women self-evacuated.

Although they did not evacuate, most people had taken precautions after the first earthquake.

> "I did not evacuate after the first earthquake. I was told that if there will be a tsunami the seawater will recede and birds [will] fly away from the beach. There was once a tsunami training here. Although I knew the people on the beach evacuated, I stayed on guard (alert) at home." (5)

There was a case in Labean where people evacuated after the first foreshock, however they returned to the village not long before the main earthquake occurred. They decided to return after receiving BMKG's SMS blast concerning the foreshock that the earthquake parameter stated it happened inland and no tsunami potential had been detected. This late SMS was received around 17:30 local time.

> "First earthquake information came with the coordinate points. A friend in East Palu said that the epicentre was in Otih, the depth was 10 km, not in the sea but in the mountain. I thought, well, the coordinates were clear. So, I felt fine." (38)

Feeling reassured with this information, the informant then took his family and returned home. At first the family was reluctant, but he convinced them by referring to BMKG information that the earthquake happened inland would not trigger a tsunami.

Unfortunately, by the time the family reached their house, the strong main earthquake occurred. The earthquake that happened at 18:02 local time was felt really strong.

> "The earthquake was so strong. I could not stand. People lied if they said they could stay upright during the earthquake. At the time I was getting ready to pray (Maghrib) at the mosque, I took off my clothes, when it happened, I ran outside naked" (11).

According to BMKG's data, the earthquake intensity was between III and VIII MMI. Under these conditions, buildings can collapse and it is difficult for people to stay upright; simple structures can collapse and buildings experience light to medium damage.[18]

These actions can be compared to those of the community on the west coast of Donggala. Here, the community living along the Palu Bay coasts from Loli to Banawa did not conduct

[18] Can be accessed on https://www.bmkg.go.id/gempabumi/skala-mmi.bmkg

any self-evacuation after the first earthquake. Most of them left the beach after the main earthquake that happened at 18:02 local time. However, the number of casualties in these areas was relatively low compared to Palu City as most people went away from the beach while the ground was still shaking, and they saw a strange phenomenon on the sea surface. In addition, access to the hills from their house is relatively close and it is not blocked by other buildings.

3.2.1.2 Observing natural signs

Many survivors self-evacuated after observing strange phenomenon of the sea surface immediately after the earthquake. Informants from Loli Saluran village, Banawa sub-district explained the phenomenon as water bubbles appeared on sea surface soon after the earthquake.

> "The seawater was like boiling water in a pan. Really boiling" (23).

One survivor was several metres from the coast. He was preparing his boat when the strong earthquake started. He also saw the "boiling" seawater.

> "After that, we ran, that way. When we were there, around 10 metres from the beach, the wave came. About 3 metres (in height)."

The waves crashed into and collapsed his children's house.

While running away, he shouted to warn other family members, he was worried that a larger tsunami would come. He said that he remembered the story from his parents, that the wave could come three times.

> "…when I saw my children's house collapse, I shouted, 'Run now', and then they ran. The tsunami wave came, and it was a big one. When we reached the fence over there, we heard crashes and loud noises from behind," (23).

The resembling of boiling sea surface was an important sign that saved many lives in Loli Saluran. Although dozens of houses were destroyed by the tsunami waves, the number of casualties was low, with four people killed, while the total of casualties in the Loli area was 8 people. However, the resembling of boiling sea surface as tsunami sign would be difficult to notice after dark/in the evening.

> "Fortunately, it happened around 6 o'clock. If it happened at 8 or 7, then a lot would have been killed… as it would have been too dark to see. Some people would have been asleep, a lot of kids go to bed at 7." (23).

Besides noticing the sea surface phenomenon, other survivors said that they saw animals moving away from the beach and used this as the trigger to evacuate. A lot of people in Donggala saw animals, mainly cows, run away from the beach immediately after the earthquake.

Photo 11 : One of living eyewitnesses of the'68 tsunami . Doc: Irina Rafliana, 2018.

"Immediately after the earthquake, the cows ran away from the beach. The earthquake has just happened. Although I didn't see it myself, some people said the seawater receded." (9).

The informant explained that cows were running away in panic.

"Because he (the head of the hamlet) asked me to monitor the sea. I saw the cows running away from the beach and they were like this [the informant jumped around], and so I went uphill as well. I didn't went to see the sea." (44).

Other animals were reported fleeing from the beach during the earthquake, such as goats and birds.

"I was going to perform my ablution when the earthquake happened. I ran to the middle of the road (in front of the house). I saw birds and goats ran away from the beach" (24).

The informant lived around 50 meters behind a healthy mangrove forest on the coast. He saw a flock of birds suddenly flew from this mangrove forest, going away from the coast.

"Goats (and) cows crossed the street to the hill when the earthquake was still shaking, and no one evacuated yet no one is saying the seawater rising" (41).

Only after the earthquake stopped, did he hear people running away from the coast shouting about the sea water rise.

"While we were waiting for the shaking to stop, our neighbours shouted that the seawater rises, the seawater rises!" (41).

According to the informants in West coast Donggala, a similar phenomenon with animals happened during the 1968 tsunami. Some of the 1968 survivor said they were running together with the cows. Some people even fell and were trampled by the cows.

“Our parents’ message, if there is a strong earthquake, and all animals ran, we should run too” (8)..

3.2.1.3 Knowledge from the 1938 and 1968 earthquakes

Self-evacuation after the first earthquake, by the West Coast Donggala community was influenced by their knowledge of past tsunami events. Their parents, who experienced the 1968 tsunami, handed down this knowledge.

“The coastal people remember the 1968 tsunami. Our parents warn us following the small earthquake there might be a bigger one. This is why they, who lived near the beach, went uphill after the 3 o'clock earthquake” (8).

Photo 12 : A community member’s house in Labean village, Donggala. Doc: Ardito M. Kodijat, 2018.

The West Coast Donggala community remembered the story of the 1968 tsunamni as most survivors are still alive and still talk and tell the story. People in this community have their own word for tsunami, as stated by one of the survivors

"We called it lembotalu, which means three waves. I think at the time in 1968, people in this area didn't have the word tsunami yet (event), so our parents called it lembotalu" (8).

Another word is bombatalu, which also means three waves.

"Bombatalu comes from the language of Mandar people in the south. And now it happened here too, so it fits, bombatalu then was used here too, three waves." (10).

Another eyewitness account tells the story of the recent tsunami have three waves:

"After the earthquake, we heard noise from the outside. It came from the front, sounded like mountain eruption, probably 5 miles from the coast. After that, it went quiet for a while, and the wave came. That was the first wave. The seawater was actually receded first, my house was on the beach. The seawater receded around 50 meters from the normal coastline. As the first wave came, we started running. Not long after that, around 200 meters away from the beach, another (wave) came. It was not too high. We were

> here, in the front of this house, and then the third wave came. After the event, I went to help to find victims. More than 200 people died but only 59 were originally from here, the rest came from the south" (10).

The story of the 1968 earthquake is quite well known, even newcomers who did not have any association with the disaster were also affected by the story, as told by one of the informants,

> "I'm from Toli-toli. I already lived here for 15 years. I did not know about the 1968 tsunami on the west coast. However, I did hear many stories from other villagers, so I knew it was true" (6).

Other than the 1968 earthquake, some people in Loli Saluran village still remembeedr a story of the tsunami event in 1938. One eyewitness was still alive to tell the story. He is 88 years old.

> "I was approximately 10 when it happened. This earthquake was stronger. However, the wave was higher that time" (28).

According to his testimony, the tsunami was preceded by receding seawater.

> "… the water took longer to come. It was dry at first, and then water came and went up there…" (28).

At that time, houses in Loli Saluran village were not made of solid brick material, but wooden stilt houses. The tsunami destroyed the houses. After the disaster, he and other community members migrated to the hills. They moved back to the coast after Indonesia's independence in 1945. Slowly, the village grew back to the coastline of Palu Bay, including in Loli Saluran.

This 1938 knowledge prompted him to immediately leave his house and run to the foot of the hill where the water line was in 1938. He refused to evacuate to the hills, as it was his belief that the tsunami wave would not reach further than it had the last time. Moreover, based on his experience, after an earthquake event landslides from the hills might occur.

> "Yes, I remembered. We just evacuate here. I do not know how, but my parents said that too many people wanted to climb up through that path, they all died on the hill. This small hill. I said, do not go to that hill, there is a sacred burial ground. Do not go there, if the land shakes it cracks open and you are dead. That was what I said" (28).

The evacuation point was a small hill that is designated as the village's cemetery, around 200 meters from the beach. According to him, the place has been designated as an evacuation place for a long time.

> "My parents once told me, 'If something happens, you run over there. Do not go to the mountain over there. Just the one next to it. It might be lower, but the water won't reach it" (28).

It is possible that his parents experienced other tsunami disasters before the 1938 tsunami that he experienced. In this recent disaster, he lost one of his children who went back to the house after the earthquake to get some important belongings they had left behind. He survived the tsunami; despite his old age and relatively slow movement the wave did not touch him.

Photo 13 : One of the living eyewitnesses of the '38 and '68 tsunami disaster in Donggala. Doc: Ahmad Arif, 2018.

Unfortunately, although he experienced the 1938 tsunami, he had never mentioned this past tragedy to his children or to other people. Even his wife learned about his 1938 tsunami story when her husband told her after the recent 2018 tsunami happened.

3.2.1.4 Influence of external interventions

The local knowledge of the West Coast Donggala community based on the 1968 tsunami was then strengthened by external interventions on disaster education. In 2008 a local NGO, Jambatan, supported by Oxfam, conducted tsunami preparedness training in West Coast Donggala. One participant explained:

> "It was the early implementation of the 2007 Law on Disaster Management and the approach was very bureaucratic and more emergency based. The community was the object and not subject. After a long discussion, besides preparing the concept, we also looked for a location that represent the area's characters. Areas that had been hit by quite significant disaster event, there are living survivors. So, we got several villages to work with, which included Labean and Batusuya" (68).

In addition to guiding the community to recognize disaster risk by discussing historical earthquakes and tsunami they had experienced, Jambatan worked with a number of academics from Yogyakarta who taught participants to recognize tsunami signs and what to do when confronted with a tsunami.

> "…using the PRA (Participatory Rural Appraisal) method, they made a sketch of the village. PRA involves mapping. We used this method because it was considered to be easier for them to understand and accept it. They were then able to describe their area. We created the risk map and then the evacuation map" (68).

In several villages, roles and responsibility were assigned to the community members in case of an emergency. Although this program was discontinued, the knowledge remained. BPBD Donggala conducted a tsunami preparedness training in 2016. Some participants in Labean village said that they remembered the details of the intervention.

> "It was about tsunami signs. We must be alert when an earthquake happens. They taught us what we should prepare in the event of tsunami" (8). Other informants stated, "It was very beneficial, and we know when an earthquake happens, we must evacuate and find a high place" (14).

During the training, the community members were instructed to leave their house immediately when an earthquake happened. If they could not leave their house, then they should find safety in a secure place.

> "After the shaking ended, everyone gathered in the courtyard and then walked to the evacuation place. Avoiding the tsunami. The evacuation route is through this alley. Because evacuation is to avoid tsunami, we were directed to the hill next to us. Over there" (14).

The training had encouraged most people in Batusuya village to go and stay outside after the foreshock, especially considering some buildings had collapsed due to the foreshock.

> "Everyone went outside after the 3 o'clock earthquake. Some didn't leave their houses, but they went to their yard. Some left their houses, but they stayed on this road" (14).

This resulted in almost no casualties after the evening main earthquake in Batusuya, despite many buildings collapsing.

> "We didn't have anyone who was killed on site in the village. One person was injured when the building collapsed, and he was taken to the evacuation place. But he died early in the morning at 3am" (13)

Other than going outside of the house, one of the training information was the tsunami

Photo 14 : National tsunami drill event in Palu, 2012. Doc: Muhammad Ayyub.

signs, which the seawater will recede after a strong earthquake. Several people practised in Batusuya, and they went to the coast to check the seawater conditions (12). In reality, not all tsunamis start with a receding seawater. This was the case in Palu Bay where the tsunami waves arrived really fast, only minutes after the earthquake, which means it increased risk of the people if they wait to see the receding seawater. The survivors realized this after the 28 September 2018 tsunami.

> "Actually, the instruction to check if the seawater recedes or not is dangerous. Because it might be too late to save themselves. Do not check seawater, as in the case of the last tsunami, it came almost at the same time with the earthquake" (12).

3.2.1.5 Evacuation

In Donggala, although many people live on the coast, there are many hills not too far away. This topography enables people to evacuate easily. However, one hamlet in Labean village, is located quite far from the hills. The safe evacuation places for these residents can only be reached by crossing a river near the estuary. The absence of a bridge forced people to use a small boat to reach the evacuation place, although some swim to cross the river.

> "Some evacuated using boat. When the earthquake happened at 6 o'clock, there were many people swam across. They swam immediately that way, crossing the trawl, and then were swept by the strong current over there. When they saw a tree branch, they grabbed it. Luckily they survived" (11).

The river estuary (river mouth to the sea), presented a very high tsunami risk.

Some people from Dusun 8 (Village 8) tried to evacuate to reach the neighbouring village using vehicles through a road that runs parallel to the coastline.

> "I ran from here and when I arrived at the TPI (small fish port), the wave arrived. Suddenly someone said, 'Come over here… help to lift this barricade (a tree) and we can take the car together.' There were some people, hundreds of them start running to different directions. We tried lifting the barricade. but we could not so we had to run that way. I got a motorbike with no headlight" (11).

3.2.2 Community in Palu

3.2.2.1 The ignored first foreshock

The community in Palu also felt the 15:00 foreshock. However, in Palu they responded differently than in West Coast Donggala. After the foreshock, there was no self-evacuation

> "That afternoon (the first foreshock) was strong, but we didn't know that there would be more earthquakes" (46).

Another informant said that although he felt the shock, it didn't make him leave the house. He continued watching TV with his family (44).

At the Talise quay, the first earthquake was so strong it shocked a lot of people.

> "The earthquake was strong. We all stood up. There were people already start saying prayers: Allahu Akbar, Allahu Akbar" (42).

However, this earthquake did not force the informant to evacuate as he needed to continue selling at his stall. At that moment, many people already gathered at the Talise beach to see the Palu Nomoni festival. The organisers and participants were getting ready, and many traders were present, more than on a normal day. According to him none of the people left after the 15:00 foreshock.

Almost every informant in Palu did not consider that the afternoon foreshock would be followed by an even stronger earthquake. However, the following foreshocks did make some informants anxious, especially some who had heard that a tsunami had hit Donggala West Coast.

> "At three o'clock I saw on Facebook, a friend said there was a tsunami in Sirenjo at three o'clock" (43).

The informant's younger sibling felt restless and asked to go back home. However, since he had to continue selling his goods, he stayed and his younger sibling go back home.

Another informant also said that after the foreshock, her mother said she needed to take important documents with her and move away.

> "My mother said, 'Hey, collect all the papers'. And after that, I was told if there's an earthquake I shouldn't run to the house but straight up hill to my grandmother's house" (49).

After the first foreshock, Palu community felt the continued foreshocks.

> "When I woke up, I could feel the continued tremor. I told my mother I think there's an earthquake. Closing to Maghrib, I was going to pray, (my mother said) if there is another earthquake, just get ready we run" (49).

3.2.2.2 Responses after the main earthquake

The majority of Palu community residents reacted only after the strong earthquake occurred. One informant who was selling in her stall at the Talise quay said that the ground shook very violently. At the time, the Talise quay was very crowded and collapsed onto the beach, and not long after the seawater rose (43).

Another eyewitness said that the earthquake was unusual. Although earthquakes happen quite often in Palu, what was felt at that time was different. He was in the car when he felt a very strong shock.

> "(Seperti) diblender, gitu. Jadi langsung keluar dari mobil, lari. Saya lari" (55).

That time, the car that he was driving was on the way to the beach, around 20 meters from the sea. As soon as the shaking stopped, he went out of the car and ran to his house, located a bit farther from the beach, to check on his family.

> “I did not think about tsunami. Just as I was running, I heard a loud noise. I glanced over to the beach and everything was dark already. I just ran, ran until I reach home” (55).

Another informant stated that he heard a loud booming noise.

> “The second shock, it sounded like a loud booming noise, and then everything went dark. I thought it was the end of the world. Doomsday, that’s what I thought. I saw the wave came, although still far away. The wave still looked white. As it came closer it became higher. But I didn’t see water coming from over there (pointing to a location). The wave came from there, there, and there. Although it was still white, it was a bit high, so I ran. I ran, I did not tell the people that the wave was coming. I was speechless. I couldn’t speak” (46).

Almost every informant who lived and were doing activities near the beach stated they heard the loud booming noise as a sign.

> “Only the earthquake’s sound, a loud boom. When it happened, it boomed, just once. Like a bomb explosion.” (46).

The state of panic forced everyone to save themselves and not think of other people.

> “I couldn’t shout, could not. Just silent. I ran. I ran to the street, people shouted: The seawater is rising! Everybody run! We were all running. First my mother fell, then I with my in law, and then my older sibling. We found our mother eight days after in an alley, she passed away, we were very sad of her condition. All was because we didn’t know what was happening, everyone was panicking, and we were all running” (46).

The tsunami wave arrived fast, even when the ground was still shaking, so fast it shocked everyone. At the quay, as most of the platform sank, many people were suddenly in the water.

> “The land was still shaking and immediately there was water. I sank. People saw this, God! water all over. It was tall and dark, they were all drowned” (42).

An informant said that she was swept away by the seawater even before the shaking stopped.

> “I did not see how high the wave was, it was just dark. It felt rock smashing into me. I was lucky that I was conscious. I was brightness, I swam up” (42).

She then swam to the shore, taking advantage of floating objects.

> “Wooden blocks, boards from the meatball carriages, I used them as my buoy.”

Photo 15 : Interview with one of the tsunami survivors in Kelurahan Tipo, Palu. Doc: Ardito Kodijat, 2018.

While floating she saw dead bodies on the water.

> "Next to me, there was a body floating, he is dead, just floating, Dear God!" (42).

She tried to swim ashore, but the current pulled her back to the sea. She tried twice and failed.

> "I just thought about my child. I prayed my child is safe. Thinking of my child kept me strong" (42).

Her third attempt brought her within reach of a tree on the beach; the coast was already completely inundated.

> "I tried to climb up to the tree, but I couldn't. There was a woman on the tree with her clothes torn. She extended her leg for me, like this, so I could climb onto the tree" (42).

She managed to climb onto the tree, where there were five survivors, waiting for help.

> "I survived with my clothes torn apart. All the survivors were female with their clothes torn" (42).

While waiting for help, she saw floating victims, most of them were women.

> "Yes, they were all women. One person in the water, close to my feet… I tried to help her. She said 'No, child, I'll die soon' She did not want to hold on, she felt into the water again. God! She fell again. All dead bodies were on the water" (42).

Several hours later, she could not remember exactly how long, several young persons arrived to help them evacuate.

> "The five of us were pulled over, using a rope" (42).

The same night she managed to go back to her village, surviving with a head injury.

The story of the girl asked by her mother to secure important documents after the first foreshock, she still remembered her mother's advice about earthquake.

> "… when the main earthquake happened. The Olympic (name of store) and the show room building collapsed. After that I went to the house to grab my sister, the papers and my phone. As I got to the front of the house, I saw the wave. I saw my mother and kept on running. We ran until the water reached that road, and there was a small alley that

Image 15 : Floor Plans and Self-Evacuation Reconstruction on Talise Beach.

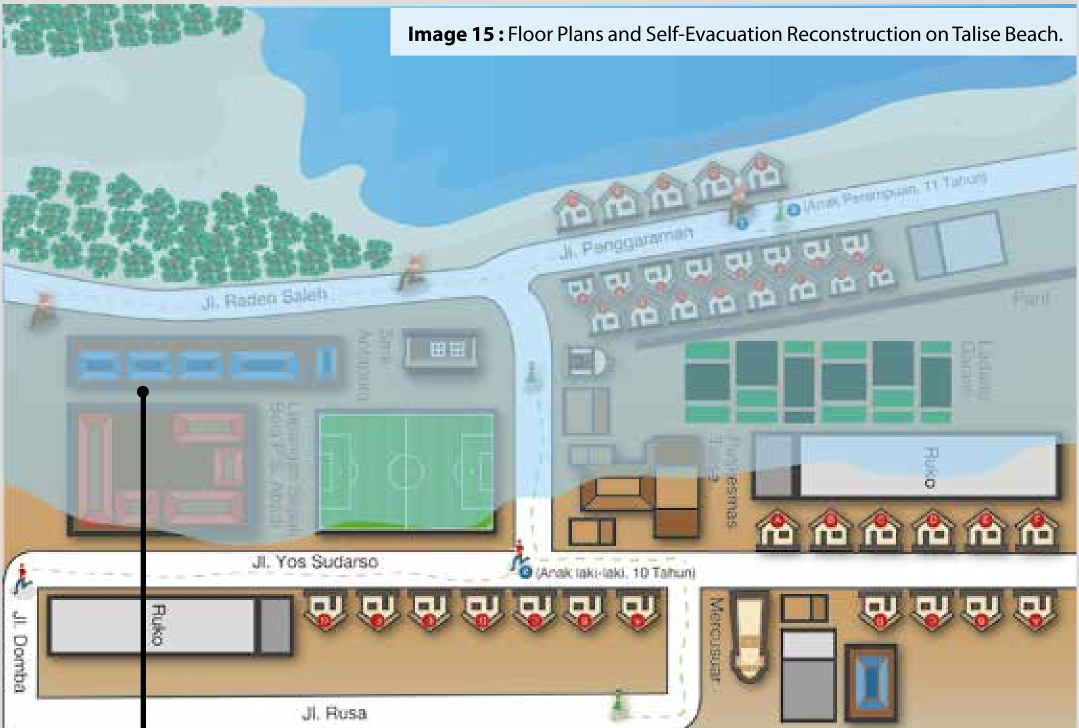


Photo 16 : Sailing academy at Talise beach. Doc: Irina Rafliana, 2018.

Photo 17 : PS Abadi football pitch at Talise beach. Many people, including children, were playing football when the earthquake and tsunami occurred. Doc: Irina Rafliana, 2018.

Photo 18 : A large ditch behind a community's settlement close to the salt farm that blocked a straight evacuation line, perpendicular to the beach. Many victims fell into this ditch when they were trying to save themselves. Doc: Irina Rafliana, 2018.

> went to Rusa street. From Rusa street and we continue walking all the way to Macan street continued to Hang Tuah intersection. I went through all these alleys..." (49).

She and her mother survived, while her older sibling and father were killed in the tsunami.

The challenges of self-evacuation at the salt farm of Talise Beach

Self-evacuation is a difficult challenge faced by the community who live on the Palu city coastline. Mostly they are migrants who did not know the local knowledge or the history of disasters in Palu. Moreover, there are no continuing training or education on preparedness by the local government. Although there was a national tsunami preparedness training in Palu in 2012, not all community member participated.

Furthermore, there are no proper perpendicular evacuation routes from the beach within the city. This contributed to the high number of casualties in the city, especially considering how fast the arrival of the tsunami was.

The difficulty to evacuate in the city was told by four survivors who lived at Jalan Penggaraman, Talise beach, as illustrated in Image 15. Three survivors were from vulnerable groups, namely children and old people.

Their front yard faced the sea, around 10-20 meters away from the water. To do perpendicular evacuation from the beach is almost impossible. On the back of their house, there were several obstacles: a large ditch, a salt farm, and a row of 2-storey shop buildings forming a big wall that blocked the access to the main road, Yos Sudarso street.

Those who survived just had better luck, while other were very cautious after the foreshock in the afternoon.

An 11-year-old girl (49) managed to grab a bag with important documents and took it with her while running with her mother after the main earthquake. Her mother asked her to collect all the important documents in a bag just after the foreshock (15:00 am). They survived despite the fact they had to jump over a large ditch in the back of their house and run along the road that was parallel to the coastline because there was no straight road going away from the beach. Luckily, both survived the tsunami, they managed to reach Rusa street. Very unfortunately, her father and brother were found dead after the tsunami.

A 43-year-old female survivor was close to the salt farm that afternoon. Her house faced the salt farm, separated by a large ditch. She did not hear any siren but heard the loud booming noise of the earthquake. She immediately ran crossing the ditch through the alley and road. She fell into the ditch but managed to get back onto the road and ran. As soon as she reached Yos Sudarso street, she stopped a car and asked the driver to take her to the hills. At the same time the surrounding people were already shouting that the seawater was rising. She said that during the earthquake her house shook but it did not collapse. The tsunami destroyed her house.

Another survivor, a 10-year-old boy (50) was at the PS Abadi soccer field when the earthquake happened. As he was in an open field, he could see clearly the beach and the incoming tsunami wave. After the earthquake, he immediately ran away from the beach. However, since there was not a perpendicular access to the beach evacuation route, he had to run on the road, Yos Sudarso street, that is parallel to the coast. He was lucky he reached the Domba street to save himself.

Another story was of a 77-year-old man (51), an immigrant from Makassar. He felt the strong earthquake when he was performing his ablutions for his Maghrib prayer. Not long after the earthquake, the tsunami waves came, and he did not have time to escape. The water reached the hut where he lived, facing directly to the sea. He held onto a bed that was swept towards him. He was swept several hundred metres along the coast until the courtyard of the Sailing Academy. He said:

"Someone told me to run. But how could I run; the waves were suddenly there. I just prayed…"

When he reached the Academy, he tried to climb to a nearby roof house. He survived because he was lucky. The man met his family the next morning. Although all these informants survived, their houses were completely destroyed.

3.2.2.3 Waiting for the tsunami siren

Some informants said that they received information of the tsunami early warning information two days after the disaster.

> "We received information about the earthquake via SMSs. There were two, the first one was 7.7 magnitude and the second was 7.4 magnitude. We received them two days

Photo 19 : TVRI Interview with journalists and media crew from TVRI. Doc: Ahmad Arif, 2018.

> after the earthquake. Immediately after the disaster, all telecommunication network and power went off. The power was cut off, the cellular network did not work" (59).

Although there is a siren in Palu, all none of the informants interviewed heard the tsunami siren. The people who participated in the 2012 tsunami preparedness training were very disappointed that no siren sounded during this disaster.

> "This wasn't a real tsunami. There was no sound of siren, the water also did not recede. We said this must be a hoax" (29).

In Tipo, the community waited for the sound of the siren from a tower that they thought was a tsunami early warning system. However, the tower was actually a telecommunication base transceiver station (BTS) belonging to one a cellular network provider. During its construction, and during regular maintenance activities, the officer responsible for the tower told the community that it was a tsunami early warning system tower.

> “When it was constructed, I asked to the contractor, ‘What is it for?’ He said, ‘It’s a tsunami detector.’ He said there are more than one, one in Taman Ria and another one in Talise near the horse statue” (37).

Even after the disaster, a maintenance officer who came to the tower still claimed the tower was part of the tsunami early warning system.

Survivors in Palu did not mention of any animal’s behavioural changes after the earthquake. It might be due to cows or goats can rarely be found in the beach area of Palu city.

One survivor on the staff of BPBD Palu said that he knew the earthquake would be followed by a tsunami, and he immediately stayed away from the beach. That day he was assigned to represent his institution at the opening of the 2018 Palu Nomoni event at Talise beach. He felt two strong tremors with a few seconds gap in between. When the earth first shook, many people fell onto the ground. He managed to stand up and immediately ran to the TVRI office, which was located around 50-100 meter from the beach. As he passed the gate, he saw the quay had collapsed. He then went to the second floor of the building. When the second tremor started and the ground was still shaking, the first tsunami wave came crashing (66).

Many people were still standing after the first tremor. There were several seconds in between the first and second tremor. If only the people did not linger and had immediately run away from the beach, more people would have survived.

3.2.2.4 Evacuation access

Considering the fast arrival of the tsunami waves after the main earthquake hit Palu Bay, a quick response and immediate evacuation from the beach to high place is very crucial. Unfortunately, the coastal area of Palu City, such as Talise beach, did not have an evacuation route that is perpendicular to the coast.

> “When the earthquake happened, the houses in the front (that blocked the evacuation access) were still there. Those houses were destroyed by tsunami. During the earthquake, the fence of the Dirlantas (Traffic Directorate Office) collapsed. The gate over here did not. Many people went through this gate, as it was the only way to evacuate. Luckily, at the time, the gate was open as parking space for the event. If not, well…” (58).

According to one informant who was near the quay of Talise beach, many people did not know where to run. There was no vertical evacuation point. They could not run from the beach because buildings and shops blocked the way. Instead, people were running on a road that was parallel to the beach.

> “…this is an entertainment area for the community, but there is no evacuation route. They have to run over there, it is far away and takes a long time. It is too far to run over there” (58)

This area was suspected to have the highest number of victims: even the tsunami run-up only went as far as 200 metres. When the disaster happened, many people were on the Talise beach quay for the Palu Nomoni festival, part of the celebration of Palu city's anniversary. Many people came from different areas. They did not know the immediate location well and were unaware of the shortcuts to get away from the beach.

3.2.2.5 External intervention and its influence

In Palu, the 1968 tsunami story is not in the community's mind. This was because the 1968 tsunami affected the Donggala regency more, especially around Labean village.

Nevertheless, Palu city has been the recipient of many tsunami preparedness interventions. Palu city was once considered to be the best city with respect to the implementation of disaster risk reduction efforts. In 2012 the mayor at that time, Rusdi Mastura (2005-2015), finalized and signed an earthquake and tsunami Palu city contingency plan. This achievement brought Rusdi Mastura to Mumbai, India, to present the city achievement in disaster management. The then mayor recognized the importance of tsunami preparedness, based on the experiences of the tsunami impact in Aceh, in 2004. Unfortunately, this disaster policy was not continued. After a change of leadership, disaster preparedness was no longer a priority in Palu city. The city's earthquake and tsunami contingency plan has not been implemented or translated into more detailed policy (35).

Actually, the scenario taken in the contingency plan was very similar to the September 28th 2018 earthquake and tsunami event. It means that the threat and possible outcomes of an earthquake and tsunami event have long been discussed. The contingency plan used the scenario of a 7.4-magnitude earthquake with tsunami in Palu that occurred early morning local time (2 a.m.). The plan predicts the number of casualties, missing and swept away reaching to 3,301 people; with the number of people needed to be evacuated predicted to reach 35,692 people.

The contingency plan also included a tsunami early warning segment with a scenario that the

Photo 20 : Interview with former Palu mayor from the 2005-2015 period. Doc: Ahmad Arif, 2018.

strong earthquake caused a tsunami arriving 15 to 20 minutes after an earthquake. However, the plan did not discuss any scenario involving an underwater landslide, or the possibility of a faster tsunami arrival time. Based on Dr. Gegar Prasetya et all. (2007) the tsunami arrival time in Palu Bay could be very short due to an underwater landslide that not far offshore. The underwater landslide has been considered a specific characteristic threat for Palu Bay. It can be concluded that the 2012 contingency plan still lacks this substantial information.

In addition to having this contingency plan, in 2012 the city held a national tsunami drill under the coordination of the National Disaster Management Agency (BNPB). The drill is still remembered by a number of Palu community members, mainly those from around Talise. At least there were 10-15 people recruited from each kelurahan to receive training and to participate in the tsunami drill.

> "… some came from Talise, some from Tonjo, there were many of them. There was a briefing because there were a lot of us. There were many (emergency response) vehicles. They were providing assistance. There were also special boats to provide assistance at sea. Everything was there and participating in the tsunami drill…" (47).

When they were asked what the benefits of the intervention and training were, they stated that it was very beneficial. The training they got also included what to do during an earthquake.

> "… However, it seems that in reality it wasn't the same" (47).

People participated in the three days "dramatization type" of tsunami event also received an incentive in the form of transport reimbursement, food and drinks.

> "……they showed us how to respond to earthquake. For example, I was sweeping the floor, the earth shook, do not run, act as in panic and fell. That was how we practiced. There were persons injured and immediately get assistance brought to the tent". Then she continued "… there were act where the family came crying ... don't cry, I am not dead yet… (laughter)…. (47)".

The drill was very different compared to what happened in reality. The disaster was a great shock to most people in Palu, especially those who had never experienced a tsunami or only heard or saw a tsunami from different sources (i.e. media).

> "In the training we waited for the earthquake to stop first, but it didn't stop, and then the waves came. It was as high as the house over there. Oh! this is the tsunami. We ran and shout 'tsunami!'. We did not know what tsunami looked like before. We just realised that it was indeed tsunami. I have never experienced it. We just saw it on the TV, right?" (54).

Besides some methodology issues and training content that was apparently different from the real event, after the large-scale training supported by BNPB in 2012, the people in Palu did not receive any other training or drills to prepare themselves

Photo 21 : National tsunami drill event in Palu, 2012, doc: Muhammad Ayyub.

4. DISCUSSION: LIFE-SAVING TSUNAMI EARLY WARNING SYSTEM

Indonesia has invested large resources in developing a tsunami early warning system to reduce disaster risks, specifically to reduce the number of human casualties. The lessons from the 2004 tsunami encouraged many parties to put trust in the system's ability to save people facing a deadly tsunami risk.

In the Indonesian tsunami early warning system grand design, the main focus was on development of the structural or upstream aspect. In the GITEWS program, the downstream aspect, also referred to as the 'last mile', was considered at the end phase of the project. The term 'last mile' also signifies that the focus of the system was on technocratic features, i.e. once the structural aspects had been developed successfully then work on the other end, the community response and local government capacity, would begin. To ensure the community would take on the system, a top-down social engineering approach was applied to make sure the design of the upstream/structural components would be responded to properly at the downstream level.

In reality, this design approach is problematic, and it is confirmed in a number of events, where end-to-end systems do not work functionally, such as the Mentawai earthquake and tsunami in 2010; the outer-rise earthquake in 2012 and 2016 (Rafliana dkk.); as well as in the current Palu earthquake and tsunami. Understanding the responses of survivors of the Palu 2018 disaster, we can take valuable lessons to encourage changes in the Indonesia Tsunami Early Warning System (InaTEWS) to enable the it to save the lives of communities at risk. The lessons are as follows.

4.1 Limitations of tsunami early warning technology

The philosophy of an early warning is to provide enough time ("golden time") for people to save themselves during a disaster event. The longer the golden time, the better the performance of the early warning will be, as it will give more time for people to take actions to save themselves. In the case of the Palu tsunami, it is clear that InaTEWS did not succeeded in providing the golden time to the community. Although the warning was issued within five minutes after the earthquake in accordance to the SOP, the tsunami arrived earlier in Palu Bay. This was because InaTEWS was not built to anticipate all types of tsunami generation cases. The Indonesian system was developed to detect tsunamis triggered only by tectonic earthquakes, while the tsunami in Palu Bay was triggered by underwater landslide caused by an earthquake.

Photo 22 : Tsunami impacts in Palu - Donggala. Doc: Ardito M. Kodijat, 2018.

Photo 23 : A broadcasting tower owned by TVRI in Palu. This tower became a life saver for hundreds of people who were near Talise beach. At least 100 people survived because they climbed this tower. Doc: Ardito Kodijat

UNESCO's definition of local tsunami is tsunamis that arrives in less than one hour. In most of the tsunami prone areas in Indonesia, especially in the eastern parts, the arrival time is very short, often less than 5 minutes. Building capacity for community preparedness for tsunami that arrive in less than 5 minutes would be different to areas where tsunami typically arrive in less than an hour. Locations with tsunami arriving in less than 5 minutes must be precisely identified because this emphasises the importance of self- evacuation, without waiting for early tsunami warning information to be sent through official channels.

In addition to waves arriving earlier that the tsunami warning information, the estimation of the wave height is also lower than reality. Due to limitations of the system to only detect tsunami caused by tectonic earthquake, the warning given to Palu and part of Donggala was at "Waspada" (advisory) level with potential tsunami less than 0.5 metres (West Palu 36 cm, North Mamuju 31 cm, North Donggala 38 cm). In some parts of the Donggala east coast, the warning was at "Siaga" (warning) level with a potential of tsunami high between 0.5 – 3 meters (East Donggala 0.56 metres). Based on Widjokongjo's survey (2018), however, the tsunami height in Palu and Donggala reached 0.9 - 9.7 m.

This significant difference was due to the tsunami generating mechanism: it was suspected to be triggered by an underwater landslide (Widjokongko, 2018). As stated earlier, this mechanism is not within the tsunami modelling used by InaTEWS.

Even if InaTEWS had tsunami modelling based on underwater landslide, and if the warning was issued approximately in five minutes, in some areas these attributes would still have been insufficient to provide golden time for the community to evacuate. This suggests that the current InaTEWS has limitations to anticipate tsunami that arrive in very short timeframes. Presently, InaTEWS might be effective for tsunamis triggered by earthquakes in subduction zones with estimated arrival times of more than 10-20 minutes. This is based on estimations that a warning can be issued in 5 minutes plus the downstream time needed within the warning chain for local government and the community to react once the upstream warning has been issued. The implication is that, if people must wait for an official warning from authorities, it would not be an effective way to save lives.

A study by Gegar Prasetya dkk (1997) detailed that four tsunami events in Palu Bay (1927, 1938, 1968, and 1996) were also suspected to have an epicentre near the beach and that tsunami arrival times were very short. The conclusion is that the present system is not built to take into consideration tsunami threats with very short lead times. This is supported by a number of scientific studies.

Similar to Palu, there are also studies which indicate tsunamis arrive in less than 10 minutes in several places in Indonesia. Areas indicated as having fast arriving tsunami are Simeulue island in 1907 and 2004; Mentawai Islands in 2010; North Flores in 1992; North Bali in 1815 and 1917; North Lombok in 1856; and Bima Island in 1818, 1820, and 1836. Most parts of Sulawesi, Maluku islands, North Maluku, and West Papua also have a long history of early arriving tsunamis.

4.2 The failure of the warning chain

The event in Palu and Donggala is beyond the capacity of the current early warning system. However, the disconnection of the warning chain is a repeated problem which reflects the failure of the supporting bureaucracy of the system.

Since it was developed (2005) and started operating (2008), InaTEWS has issued 22 tsunami early warning bulletins. Most of these bulletins heralded small tsunami and did not cause significant damage. Two tsunami events were significantly damaging, namely the Mentawai tsunami on October 25th 2010 and the Palu-Donggala tsunami on September 28th 2018.

In these two events, evidently InaTWeS did not operate end-to-end, starting with detection and ending with at-risk communities responding to that warning by evacuation. Similar phenomenon also occurred during the earthquake in the investigator fracture zone (IFZ) also known the Indian Ocean outer-rise event in 2012 and 2016. Fortunately, there was no large tsunami at that time. Studies by Eko Yulianto, et al. (2012) and Irina Rafliana, et al. (2016) stated within the two Indian Ocean outer-rise earthquake events (2012 and 2016) the early warning chain was disrupted and did not reach the communityies In 2012, in Aceh the tsunami siren was sounded only 81 minutes after the earthquake due to technical and administrative failures.

Technical problems within the warning chain were primarily due to electricity and telecommunication cut offs. This also happened in Palu, where the electricity cut off two minutes after the earthquake. The uninterrupted power supply (UPS) system, as well as the backup generator at the Emergency Operational Centre (EOC), did not work because of maintenance issues. Consequently, both the EOC and the community were unable to receive the warning. In addition, the warning information send via text messages did not

Image 16 : Near source tsunami history in indonesia with ETA in minutes.

get through to the community. The one and only siren in Palu was not sounded to warn the people, because of a lack of capacity of the local government and BPBD personnel.

The length of the warning chain was another cause of administrative failure. According to Government Regulation No. 21/2008 on Disaster Management, BMKG, as the National Tsunami Warning Centre only has the authority to issue a tsunami early warning bulletin. Evacuation of at-risk people is the responsibility of local government, which also includes activating the siren as the evacuation call.

The procedure is that BMKG provides the warning information to the local EOC which will coordinate with the local incident command to get approval to convey the warning to the community. The members of the incident command are the head and vice head of the district/province/city, head of the local armed force, head of the local police force and several other members. This decision-making process requires more time before any decision can be reached that might lead to the siren being activated. This means a reduction of the golden time available for the community to evacuate. Since the operation of InaTEWS, there is no evidence that local government has been able to make timely and accurate decisions based on the tsunami early warning issued by BMKG.

The conclusion is that the end-to-end InaTEWS is not working, as the local government is not able to respond appropriately to save people based on tsunami warnings issued by BMKG.

Photo 24 : Fishermen with their catch of the day at the beach of Donggala, showing that the local economy is slowly recovering. Doc: Irina Rafliana, 2018.

4.3 Tsunami early warning system creates false sense of security

InaTEWS, which has been operational since 2008, is not completely understood by communities in the affected areas. This can readily be seen in Palu. The complexity of the tsunami early warning system is simplified to a tsunami siren that can detect a tsunami and emit a warning when there is imminent threat. However, the siren has not been working and the warning chain has always been disrupted.

Nonetheless, communities rely on the early warning system and will wait for an evacuation order from the tsunami siren. In 2018, this caused them to lose the valuable golden time needed to save themselves. In Palu, the communities which received tsunami preparedness training in 2012 were informed that any evacuation would start with the tsunami siren sound. In 2018 they did not think the earthquake had triggered a tsunami, as they waited for the siren to go but it did not.

Another finding was at the Kelurahan Tipo (Tipo hamlet) in Palu. Here again, the community waited for the siren to go before evacuating. Unfortunately, the tower they thought to be a tsunami siren was a base transceiver station (BTS) owned by a cellular network provider. This misunderstanding had occurred because the contractor responsible for the tower's construction and the personnel responsible for maintenance continued to inform the community that it was a tsunami detection tower that would activate when a tsunami happened.

Photo 25 : BTS repeater that was thought at a tsunami detector. Doc: Ardito Kodijat, 2018.

The communitywas told this to enable the construction of the tower in public land on top of a gutter. During the earthquake of September 28th 2018, some people did not immediately evacuate because they were waiting for the siren to go off.

This showed there are problematic information gaps about the InaTEWS within the community.

This information gap creates a false sense of security and prevented appropriate decision-making within the community to self-evacuate.

In Labean village several people that evacuated after the foreshock of 15:00 local time decided to return to the village after receiving an SMS blast about that earthquake (with no tsunami potential) 2.5 hours later. However, as they arrived in their villages, they experienced the strong earthquake and tsunami at 18:02 local time.

The conclusion here is that, while timely upstream information can be disseminated by BMKG, it can be delayed and end up being received too late by the at-risk community and can lead to grave misunderstandings.

4.4. Self-evacuation is the key to survival

Although the tsunami in Palu Bay arrived fast and there was no tsunami early warning, many people nevertheless evacuated themselves. Many survivors left the beach while feeling the tremor or immediately after the tremor ended. Eyewitnesses having knowledge and history of past tsunami events, such as in Donggala West Coast, immediately suspected that the strong earthquake might be followed by a tsunami, which triggered them to evacuate. The strong earthquake was their sign that a tsunami might occur.

Numbers of survivors left the beach after they saw or heard natural signs. Many stated they heard a loud booming noise and saw changes in seawater after the earthquake. Many survivors in Loli Saluran, who lived on the coastline, said that they saw the seawater bubbling after the earthquake. This natural phenomenon prompted them to immediately leave their house and warned other family members and neighbours to do likewise.

Photo 26 : Survivor from Donggala regency who independently evacuate. Doc: Irina Rafliana, 2018.

Photo 27 : Research team interviewing an informant in Labean village. Doc: Irina Rafliana, 2018.

Other survivors responded to animal behaviour (cows, goats, cats, and birds) as natural signs. This triggered them to leave the beach after the earthquake and before the tsunami arrives. The survivors in West Coast Donggala suspected that when animals starting running away from the beach, it was a sign that a tsunami was coming.

Responding to these natural phenomena has its own weaknesses though. If the earthquake happened after dark, any physical signs such as changes of seawater and animals' behaviour would be difficult to observe. Survivors stated that most people would typically stay in their homes after the Maghrib prayer time. This common practice is likely to have created higher numbers of casualties if it happened after dark.

Photo 28 : The salt farm that prevented people from escaping quickly and affected the community's economy in Talise. Doc: Irina Rafliana, 2018.

Therefore, the tsunami Palu re-iterated the importance of community education, emphasizing that a strong earthquake is a sign that should be responded to by immediate evacuation from the beach without waiting for official evacuation calls or looking for natural signs, such as receding seawater levels.

The success of the West Coast Donggala community to evacuate is similar to the success of the survivors from the 2004 Aceh tsunami in Simeulue island. In this case, self-evacuation can be described as the local community's effort to save themselves by staying away from the beach without waiting for an official warning or being ordered by other parties.

4.5 Evacuation route perpendicular to the beach

In order to survive a tsunami with a short golden time, such as in the Palu case, in addition to an immediate evacuation response, another important aspect pertains to the evacuation route and/ or high-ground tsunami shelters. The low casualties in Donggala was also due to the relatively easy access of the hills, except for a community in Hamlet 8, Labean village, whose members had to cross an estuary to get to the hills.

Without an evacuation route that is perpendicular to the coast or having tsunami shelters on higher ground, evacuation would be difficult. This situation happened in Talise beach in Palu where evacuation must follow roads running parallel to the coastline, since the exit route perpendicular to the coast was blocked by buildings, walls or fences. Some survivors managed to jump the fence; however, many failed, mostly were women and children.

4.6 Internalizing experience and local knowledge

The community in Donggala West Coast undertook self-evacuation after a strong earthquake, which they perceived as a sign that a tsunami might follow. They self-evacuated after the first foreshock at 15:00 local time. By the time the main earthquake occurred, many already left their home. Although many structures collapsed, the villages located the closest to the epicentre, on average had low numbers of casualties. This was likely because the knowledge of the 1968 tsunami was well-remembered.

Moreover, some eyewitnesses of the 1968 tsunami were still alive in Labean village. Local people have a local name for tsunamis, lembotalu or bombatalu, which means three waves, referring to three tsunami waves that came in succession and killed many people at the time. This local knowledge was strengthened by a series f education and preparedness training programs. Internalising the knowledge of tsunami history and disaster risks are both important for the community to gain the ability to conduct independent evacuation.

Photo 29 : A canoe used to cross the river to the nearest safe hill since no other routes are available. Doc: Irina Rafliana, 2018.

Photo 30 : One of survivors from Batusuya village being interviewed by the team. Doc: Irina Rafliana, 2018.

Meanwhile, in Palu, most people did not evacuate after the foreshock. This could be due to a lack of knowledge regarding tsunami risks. Informants who lived in Palu believed that their locality was safe from tsunami as they are convinced that the topography of Palu Bay prevented tsunami from occurring. This belief was based on an earthquake that happened in 2005 which did not generate a tsunami, although some people did evacuate to the hills. Even though some informants said they had heard stories from their parents about tsunami on the other coast of Palu Bay, they considered it only as a story from the past and would not recur. Historically, a tsunami happened in this area in 1938. However, this knowledge was not common knowledge and there only a few eyewitnesses still live in the area. Just as significant, the 1938 tsunami event was not incorporated into any of the local disaster education programs. This indicates that local knowledge is dynamic and can change according to people's experience. Hence, it is important to update tsunami education and knowledge for preparedness.

It is important to consider local knowledge of every event in building community preparedness. In other words, local community education materials should be based on local historical evidence.

Photo 31 : A damaged house in Labean village after the earthquake. Doc: Irina Rafliana, 2018.

4.7 Preparedness education based on local characteristics

The education and intervention conducted by several parties in Palu and Donggala mainly referred to the characteristics of the 2004 Aceh tsunami. Based on this, the community was told that a tsunami would be preceded by receding seawater and could arrive on the coastline approximately 20-30 minutes after an earthquake. Some people were instructed to monitor the seawater and to confirm whether it was receding or not. In a number of training activities, participants were advised to wait for instructions from the authorities before initiating individual actions. In reality, the tsunami in Palu Bay occurred fast and the seawater did not recede. In Donggala, the number of casualties was relatively low because the tsunami waves were lower compared to the tsunami that occurred in Palu City coast.

In addition to the 1968 tsunami experience and knowledge, several villages in the area received disaster risk reduction intervention in 2008. Although the participants received good education information, some information did not relate to real events in 2018, such as receding seawater after an earthquake and before the arrival of a tsunami.

The tsunami event in Palu Bay in 2018 reiterated that tsunami do not always precede at coastlines by receding seawater, and that the arrival time can be less than 5 minutes. Such characteristics will vary by location throughout Indonesia. Therefore, it is important for intervention actors not to focus on generic preparedness materials for every location. Local context must become the main information for this material.

Photo 32 : A house/shop that is lopsided, possibly because of underwater landslide. Doc: Irina Rafliana, 2018.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This chapter responds to the three main questions of posed by this assessment: (1)*how did the tsunami warning system work down to the downstream level in Palu Bay?; (2) why did the tsunami early warning system fail to save lives in Palu Bay?; and (3) how can an early warning system save lives in Indonesia, responding to the complexity of the source of threats and social dynamics in the country?*

Based on the data and information collected in the field through interviews with resource persons, especially the survivors in Palu and Donggala, and comparative analysis with previous disaster events, several conclusions can be made:

a. The end-to-end Indonesian Tsunami Early Warning System (InaTEWS) did not function properly. Evidently, communities in Palu and Donggala could not receive any early warning information (in any form: SMS, television broadcast, tsunami siren) about the earthquake and tsunami.

b. InaTEWS was not built to consider modelling and scenarios of cases such as those which occur in Palu, where the tsunami was suspected to be triggered by submarine landslide. The tsunami arrival time in Palu and Donggala was too fast for the current capacity to detect and issue tsunami warning (based on tectonic earthquakes) which is within 5 minutes. It is possible that this situation could also happen in different places in Indonesia where the estimated time of arrival of the tsunami is within a few minutes.

c. The system failure to reach the last mile was also exacerbated by a power outage and telecommunication failure that disrupted the warning chain to the community. The tsunami siren, an important part for evacuation call, has not proven to be an effective means due to a number of technical issues, such as maintenance, the current decision-making process for activation, the range of coverage, number of sirens needed. It is clear that one siren in Palu is inadequate. An alternative way for evacuation calls to emanate should be considered to replace the siren. Learning from Palu, it is important to reduce the dependency on technology that requires continuous and expensive maintenance, that evidently is unsustainable.

d. The failure of the downstream early warning system at the community level also reflects concerns at the upstream level. Looking back to previous cases, the development of the tsunami early warning system is technocratic and follows a top-down approach, which ignores the social complexity downstream. With the current approach, the government and its intervention actors tend to take away the risk understanding of the community. People are directed to wait for an evacuation call through the tsunami siren, which did not function. This finding supports earlier analysis by Andrew Collins (2009)[18] on the failure of early warning systems in major disaster events around the world.

5.2 Recommendations

These recommendations aim to provide inputs for a more effective early warning system looking at the complexity of tsunami generation sources and social dynamics in Indonesia. The recommendations could be inputs for planning the multi-hazard early warning system that is now in progress. The recommendations are as follows:

a. The failure of the tsunami early warning system in Palu-Donggala to give warning to the downstream level and referring to Collins' assessment on early warning system (2009), the first recommendation is to put more focus and emphasis on people-centred tsunami early warning approaches in Indonesia. Building capacity and resiliency of the community to protect themselves is paramount. Emphasis should be on building individual and communal capacity to recognize threats and taking actions to avoid disaster (for example, a strong earthquake is a sign to immediately evacuate from the coast). Continuous education and training for people should be undertaken and not limited to or linked to periodic or ceremonial events. Local knowledge of past tsunami event should be regarded as an important asset and should be continuous and widely shared, both formally and informally. Moreover, the community's capacity and ability to recognise natural signs, such as animal behaviour should continue to be improved. The capacity to self-evacuate must be supported by clear, safe and direct evacuation routes, especially with direction perpendicular to the coast.

b. Capturing lessons learned from the self-evacuation in the West Coast Donggala community, self-evacuation should become the main priority in tsunami disaster risk reduction efforts in Indonesia. Self-evacuation starts from the capacity to recognize signs of danger and leads up to evacuating immediately without waiting for an official evacuation order. In addition to the possibility of very short arrival time of a tsunami (in minutes), the potential of a warning chain failure in a top-down tsunami early warning system is high, as seen in many cases including the Palu-Donggala tsunami event. As many tsunamis in Indonesia are caused by earthquake epicentres close to the coast, where the estimated time of arrival is less than 10 minutes, consideration must not only be given to address potential downstream technical system failures , such as power and telecommunication outages , but to also reinforce self-evacuation as a key element for survival.

c. Self-evacuation is also recommended in areas where the tsunami's estimated time of arrival time is between 20-30 minutes. Although BMKG has the capability to issue a tsunami early warning bulletin within 5 minutes after an earthquake event, there is no guarantee that an evacuation call can reach the community in an equally timely manner, mainly because of a lack of decision-making capacity at local government (Law No 21/2008). Various technical issues could also happen that will disrupt the dissemination of information such as power and telecommunication failures. Even though self-evacuation is emphasized, it does not

[18] Collins, Andrew (2009) Early Warning: a people centred approach to early warning systems and the 'last mile'. In: World Disaster Report 2009, International Federation Red Cross and Red Crescent Societies, Switzerland, pp 39-67

mean that the early warning bulletin from InaTEWS should be ignored. This warning information will continue to play an important role in confirming the hazard threat. After people have evacuated, the early warning information will help them decide on subsequent actions they should take, including when it is safe for them to return.

d. Although self-evacuation should be the main emphasis in saving lives from tsunami, this has potential limitations, especially for distant tsunamis, such as the case in Jayapura, Papua, in 2011. Equipment-based tsunami early warning system is also important to detect and anticipate tsunami earthquakes, i.e. tsunami that is generated with a weak tremor (slow tsunami) that still can generate high tsunami waves, such as the tsunami disaster in Pangandaran in 2006.

e. Learning from Palu and other similar events, it is important to re-consider the complexity of the existing warning chain. Government Regulation No. 21/2008 stipulates that local government is the one with the authority to issue an evacuation call in the event of a disaster threat. This regulation prevents BMKG from issuing a warning directly to the community for it to immediately evacuate in the case of a tsunami threat. Despite the above, BMKG continues to improve its capabilities and to ensure their warning information is accessible to at-risk groups. BMKG warning information can be obtained via text messages (SMS) or the website, as well as through BMKG Apps for smart phones. Through the BMKG mobile Apps, people can receive warning information almost in real time immediately after BMKG has issued the warning. It seems, however, that under the current Regulation, whether the warning bulletin reaches the community or not, whether it can save lives or not, it is not the responsibility of BMKG. Based on this, a key performance indicator (KPI) of the BMKG on its early warning rests on its ability to issue the first warning, based on earthquake detection and tsunami modelling, within five minutes after a earthquake. Unusually, however, there is no KPI on how the system can save lives.

f. This study recommends a review of Government Regulation No. 21/2008 article 19 on Disaster Management concerning the evacuation decision to be made by local government. This is related especially for tsunamis. The purpose of such a review is to simplify the warning chain and evacuation calls. In addition, the KPI for end-to-end tsunami early warning must consider measuring the performance of how fast the bulletin reaches affected communities as well as to whether it is responded properly.

g. This study also recommends the development of the President Regulation on the National Multi-hazard Early Warning System to put emphasis on the philosophy of an effective early warning that can save lives. The focus should be on building the capacity of the community to make decisions and to self-evacuate, and to achieve this with the support of equipment, technology and related structural systems.

6. ANNEXES

1. List of informants

NO	AGE/GENDER	ADDRESS/AFFILIATION	DATE OF INTERVIEW
JAKARTA/NATIONAL AGENCY			
1	Male	BMKG Jakarta, Head of Earthquake Information and Tsunami Warning System (NTWC)	17 December 2018
2	Male	BMKG Jakarta	27 January 2019
DONGGALA DISTRICT			
3	Male, 53 yo	Wani Village, Tawaeli District, Donggala	12 November 2018
4	Female, 82 yo	Labean village	13 November 2018
5	Female, 39 yo	Labean village	13 November 2018
6	Male, 37 yo	Tanjung Padang, Sirenja village	13 November 2018
7	Male, 58 yo	Alindau Village	20 December 2018
8	Female	Labean Village	20 December 2018
9	Female, 63 yo	Labean Village	20 December 2018
10	Male, 65 yo	Labean Village	20 December 2018
11	Male, 41 yo	Labean Dusun 8 hamlet	20 December 2018
12	Male, 44 yo	Batusuya Village Secretary	20 December 2018
13	Male, 41 yo	Batusuya Village	20 December 2018
14	Male, 50 yo	Lembaga Adat/folk group Batusuya Village	21 December 2018
15	Male, 55 yo	Head of hamlet Dusun 1, Batusuya Village	21 December 2018
16	Male	Rapid Response team BPBD (Local Disaster Management Agency) Donggala	20 December 2018
17	Male	Head Emergency Response BPBD (Local Disaster Management Agency) Donggala	20 December 2018
18	Male	Rapid Response team BPBD (Local Disaster Management Agency) Donggala	21 December 2018
19	Male	Head BPBD (Local Disaster Management Agency) Donggala	21 December 2018
20	Male	Rapid Response team BPBD (Local Disaster Management Agency) Donggala	21 December 2018

21	Male, 66 yo	Tanjung Batu Village, Donggala	21 December 2018
22	Male, 41 yo	Tanjung Batu Village, Donggala	21 December 2018
23	Male, 65 yo	Loli Saluran Village, Kecamatan Banawa, Donggala	21 December 2018
24	Female, 36 yo	Loli Saluran Village, Banawa Sub district, Donggala Donggala	21 December 2018
25	Male, 37 yo	Kabonga Kecil Village, Banawa Sub district, Donggala Donggala	21 December 2018
26	Male, 37 yo	Pangga Hamlet, Kabonga Besar Village, Banawa Sub district, Donggala	21 December 2018
27	Male, 46 yo	Loli Saluran Village, Banawa Sub district, Donggala	21 December 2018
28	Male, 88 yo	Loli Saluran Village, Banawa Sub district, Donggala	21 December 2018
PALU CITY			
29	Female, 30 yo	Lere Village Palu City	9 November 2018
30	Female, 40 yo	Lere Village Palu City	9 November 2018
31	Female, 25 yo	Lere Village Palu City	9 November 2018
32	Male, 38 yo	Jalan Undata, Besusu Barat Palu City	9 November 2018
33	Male, 62 yo	Jalan Undata, Besusu Barat Palu City	9 November 2018
34	Male, 39 yo	Jalan Undata, Besusu Barat Palu City	9 November 2018
35	Male	Tipo village, Palu City	21 December 2018
36	Male, 58 yo	Tipo village, Palu City	22 December 2018
37	Male, 49 yo	Tipo village, Palu City	22 December 2018
38	Male, 58 yo	Tipo village, Palu City	22 December 2018
39	Male, 59 yo	Tipo village, Palu City	22 December 2018
40	Male, 45 yo	Tipo village, Palu City	22 December 2018
41	Female, 53 yo	Tipo village, Palu City	22 December 2018
42	Female, 30 yo	Tipo village, Palu City	22 December 2018
43	Male, 39 yo	Tipo village, Palu City	22 December 2018
44	Male, 8 yo	Tipo village, Palu City	22 December 2018
45	Male, 32 yo	Tipo village, Palu City	22 December 2018
46	Female, 43 yo	Talise village, Palu City	22 December 2018
47	Female	Talise village, Palu City	22 December 2018

48	Female	Talise village, Palu City	22 December 2018
49	Female, 11 yo	Talise village, Palu City	22 December 2018
50	Male,10 yo	Talise village, Palu City	22 December 2018
51	Male, 76 yo	Talise village, Palu City	22 December 2018
52	Female, 50 yo	Food Vendor at Palu Sport Center, near BMKG siren tower	22 December 2018
53	Female, 33 yo	Food Vendor at Palu Sport Center, near BMKG siren tower	22 December 2018
54	Female, 40 yo	Food Vendor at Palu Sport Center, near BMKG siren tower	22 December 2018
55	Female	Reporter, Televisi Republik Indonesia (TVRI), Central Sulawesi	22 December 2018
56	Male	Chief Technician Televisi Republik Indonesia (TVRI), Central Sulawesi	22 December 2018
57	Male	Cameraman Televisi Republik Indonesia (TVRI), Central Sulawesi	22 December 2018
58	Male	Cameraman, Televisi Republik Indonesia (TVRI), Central Sulawesi	22 December 2018
59	Male	General Affairs, Televisi Republik Indonesia (TVRI), Central Sulawesi	22 December 2018
60	Male	Head section News, Televisi Republik Indonesia (TVRI), Central Sulawesi	22 December 2018
61	Male	BMKG Palu	8 November 2018
62	Male	BMKG Palu	18 December 2018
63	Male	BMKG Palu	19 December 2018
64	Male, 25 yo	BPBD (Local Disaster Management Agency) Palu City	24 December 2018
65	Male	BPBD (Local Disaster Management Agency) Palu City	9 November 2018, and 24 December 2018
66	Male	BPBD (Local Disaster Management Agency) Palu City	9 November 2018
67	Male	Tadulako University	24 December 2018
68	Male	Tadulako University	24 December 2018
69	Male	Ex Jambata officer (non-government organization)	24 December 2018
70	Female	Forum Sudut Pandang (Palu Art Community)	24 December 2018

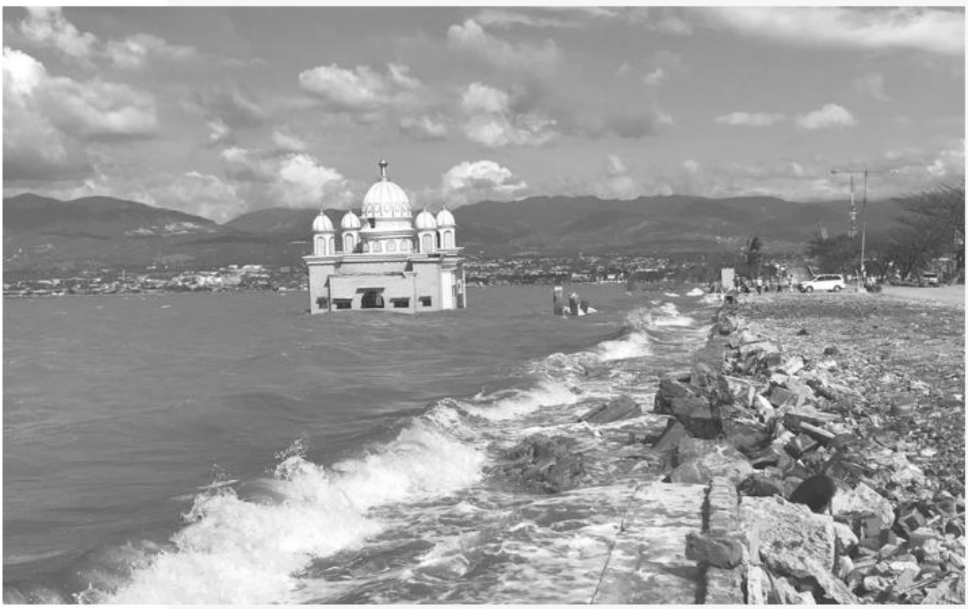
Table 2 : List of research sources

2. Technical Annex

PRELIMINARY REPORT

IN-DEPTH ASSESSMENT ON THE LAST MILE OF INDONESIAN TSUNAMI EARLY WARNING SYSTEM (INATEWS)

BASED ON PALU EVENT, 28 SEPTEMBER 2018



PREPARED BY

AHMAD ARIF, IRINA RAFLIANA, SYARIFAH DALIMUNTHE, ARDITO M. KODIJAT

Introduction

The 7.4 magnitudes that struck Palu, Central Sulawesi on 28 September 2018, combined with tsunami and liquefaction have wrought massive destruction in the coastal city. Tens of thousands of building along the shoreline destroyed, and the 'last-mile" was badly affected by the tsunami. The InaTEWS was under scrutiny, and the nation is looking for the answer for the effectiveness of the systems. Building on low attention on the situation on the last – mile in the post-crisis UNISDR undertook a study on "The Last Mile of The Indonesian Tsunami Early Warning System". The study sought the downstream and the upstream perceptions and experiences of the warning systems, and their recommendation on how to address the issues on the operational level they identified.

On 18th December 2018, a workshop on research design held as a kick start of the study. Faculty of Engineering – Tadulako University act as the host. The research design workshop aimed to consult the initial idea of the research, methodology and create a list of the potential participant for the study. The workshop followed with a focus group discussion (FGD). The second activity aims to gather general information on the expert first-hand experience on the early warning system and to draw information on the current situation in the field. Overall there are 15 participants within two activities.

Methodology

The Focus Group Discussion was undertaken as part of the research methods. Each FGD had one facilitator and one documenter. FGD protocol developed prior to the activity (Annexe III). The 18th December FGD was the first amongst various activities until the end of the study time frame. In recognition of the different experiences and perspectives of the early warning system, the participant invited was from academia, NGO, journalist and researcher. A total of 15 participants actively involved during this first FGD. The FGD explored questions below:

Question 1. To what extent do you think, the current tsunami warning systems save people lives on 28 September 2018?

Question 2. How do you see the EWS works with numbers of actors and sectors involved; will they able to deliver the information to people effectively?

Question 3. With the event experienced in Palu, how do you suggest an ideal system to develop in an address such a unique characteristic of the tsunami?

Question 4. Thinking about activities related to EW, in what way the system will able to cater to the dynamic of the social, cultural condition within the society?

Key Findings

The main findings from data generated from the fgd are summarised below. The consultation brought valuable discourse, information and concerns that display the situation on the last-mile. There are top three three issues raised during the discussion, the summary elaborated below.

What happened on the last mile?

"I was surprised there is no bathymetry map available on Palu? Palu should be the capital of tsunami research" FGD Participant, Male, Academic

Building EW should start by understanding the characteristic tsunami in the local level. Therefore investment in research and technology for Palu is essential. Another need is to create an enabling environment for self-sufficient / independent local researches. The advanced technology and research on tsunami should be based in Palu. In the coming future, the local researcher will able to investigate efficiently and thoroughly without waiting for the outsourced researcher.

" the modelling scenario provided by BMKG should be revised based on a comprehensive study to meet the local geological characteristic and the coastal social dynamics." FGD Participant, Male, Govt

The participants frequently mention the phrase "There is no one size fits all" in responding to the tsunami scenario. Current tsunami modelling provided by BMKG shows no scenario of the landslide tsunami. Such a top-down approach by BMKG has prescribed five minutes as the time frame to saves life. As it happened, given scenario would not apply to the whole country. Local geological characteristic should be investigated in more detail. In the future, each location will have their contingency plan based on locality.

" I was the only person left; I am the only one at the command centre own the nerve to push the button in 2012, none of the stakeholders dares to do so!" FGD Participant, Male, Govt

Another problem is the chain of administrative level causing delay and hesitancy in a decision-making process. An example from March 2012, the tsunami struck Donggala as the tide gauge showing the measure a decision to issue a warning made. However, in this critical situation, none of the stakeholders has the courage to the siren button. The lives dependent to such warning was at stake. Therefore, an evaluation on

Table 1 List of field work activities

No.	Date	Agenda	Informants and stakeholders involved
1.	17/12/18	Discussion with relevant officials from BMKG/National Tsunami Warning Center, and IOTIC UNESCO: Understanding the chronology of the upstream component during the 28/10 event	Head of National Tsunami Warning Center/ Earthquake and Tsunami Warning, BMKG (Meteorology, Climatology and Geophysics Agency) Rahmat Triyono, ST, Dipl.Seis, M.Sc BMKG Office Jakarta
2.	18/12/18	Focused Group Discussion on the Research Design at Tadulako University, Palu City 15.00 – 18.00	Attendees: Prof. Dr Amar, S.T. Dean of The Faculty of Engineering 1. Dr Abdullah (Palu-Koro Researcher, Faculty of Mathematics Univ. Tadulako) 2. Hendra Setiawan (Faculty of Engineering Univ. Tadulako) 3. A.Rusidin (Faculty of Engineering Univ. Tadulako) 4. Alamsyah Palaga (Faculty of Engineering Univ. Tadulako) 5. Jefrianto Mercusuar (Media) 6. Neni Muhidin (Nemu Buku – CSO) 7. Cahyo N (BMKG Sta. Geof - Palu) 8. Moh. Herianto (Historia Sulawesi Tengah – CSO) 9. Nurdian (KSHT) 10. Dicky Fernando (student Tadulako University) 11. Dr. Herry Yogaswara (Research Center for Population LIPI) 12. Inayah Hidayati (Research Center for Population LIPI) 13. Ayu Surtiari (Research Center for Population LIPI) 14. Ahmad Arif, M.Si (Kompas) 15. Irina Rafliana (ICIAR LIPI) 16. Syarifah Dalimunthe (LIPI/Nagoya University, through Skype)

3.	19/12/18	Workshop on Post Disaster Research in Palu: Strengthening Role of Social Sciences to Reduce Risks 09.30 – 16.00	Break groups and indepth discussions: 1. Research on livelihood and relocation 2. Research on the last mile of warning system 3. Research on governance 4. Other proposed topic Participants: 120 attendances from universities, NGOs, local government. Hosted by Research Center for Population – LIPI and Tadulako University, with support from the assessment team (on Break group 2), and Universitas Gajah Mada (on Break group 3)
4.		Focused Group Discussion with Journalists in Palu 17.30 – 20.30	Participants: 8 attendees from Journalists in Palu, Aliance for Independent Journalists, University of Brawijaya – Faculty of Communication, Forum Sudut Pandang (CSO) Output: Immediate inputs for the draft of Presidential Regulation on Indonesian Tsunami Warning System, particularly on the downstream aspect. Discussions results was resumed and sent to Head of BMKG.
5.	20/12/18	Field observation, and indepth interview in west coast Donggala (Labean, Batu Suya) 09.00-18.00	Interviewer: 1. Ahmad Arif 2. Irina Rafliana 3. Ardito Kodijat 4. Martasono Stambuk (Univ. Tadulako student, anthropology) Informants: 9 persons, 7 male, 2 female
6.	21/12/18	Field observation, and indepth interview in Donggala District (Tanjung Batu hamlet, capital of Donggala, Loli) 09.00-16.00	Interviewer: 1. Ahmad Arif 2. Irina Rafliana 3. Ardito Kodijat 4. Martasono Stambuk (Univ. Tadulako student, anthropology

			Informants: 15 persons, 14 male, 1 female
7.		In-depth interview with ex Mayor of Palu City (at office from 2005-2015), particularly on the governance and DRR policies, warning systems and contingency planning 16.30-18.00	Interviewer: 1. Ahmad Arif 2. Irina Rafliana 3. Ardito Kodijat 4. Martasono Stambuk (Univ. Tadulako student, anthropology) Informants: Rudi Mastura (male), Mayor Palu City (2005-2015)
8.	22/12/18	Field observation, group discussions and indepth interview in Palu City (Tipo village and Talise village,including TVRI, and vendors in Palu sport center near BMKG Siren tower) 08.30-19.00	Interviewer: 1. Ahmad Arif 2. Irina Rafliana 3. Ardito Kodijat 4. Martasono Stambuk (Univ. Tadulako student, anthropology Informants: 23 persons, 15 male, 8 female
9.	23/12/18	Workshop with Journalists and Alliance for Independent Journalists (AJI), at AJI Office Palu 19.00-23.00	Resource persons: 1. Ahmad Arif 2. Irina Rafliana Participants: Journalists, media organizations, CSOs
10.	24/12/18	In depth interview with BPBD office Palu City, and Focused Group Discussion wih public education practitioners 10.00-14.30	Interviewer: 1. Ahmad Arif 2. Irina Rafliana 3. Martasono Stambuk (Univ. Tadulako) Informants: BPBD EOC staffs Participants: Tadulako University lecturers, Forum Sudut Pandang, ex Jambata/Oxfam worker. Informants: 6 persons, 5 male, 1 female

LAST MILE OF THE INDONESIAN TSUNAMI WARNING SYSTEM

FOCUS GROUP DISCUSSION REPORT

Tadulako University, Palu, Central Sulawesi 12/18/18

Introduction

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On 18th December 2018, a workshop on research design held as a kick start of the study. Faculty of Engineering – Tadulako University act as the host. The research design workshop aimed to consult the initial idea of the research, methodology and create a list of the potential participant for the study. The workshop followed with a focus group discussion (FGD). The second activity aims to gather general information on the expert first-hand experience on the early warning system and to draw information on the current situation in the field. Overall there are 15 participants within two activities.

Methodology

The Focus Group Discussion was undertaken as part of the research methods. Each FGD had one facilitator and one documenter. FGD protocol developed prior to the activity (Annexe III). The 18th December FGD was the first amongst various activities until the end of the study time frame. In recognition of the different experiences and perspectives of the early warning system, the participant invited was from academia, NGO, journalist and researcher. A total of 15 participants actively involved during this first FGD. The FGD explored questions below:

Question 1. To what extent do you think, the current tsunami warning systems save people lives on 28 September 2018?

Question 2. How do you see the EWS works with numbers of actors and sectors involved; will they able to deliver the information to people effectively?

Question 3. With the event experienced in Palu, how do you suggest an ideal system to develop in an address such a unique characteristic of the tsunami?

Question 4. Thinking about activities related to EW, in what way the system will able to cater to the dynamic of the social, cultural condition within the society?

Key Findings

The main findings from data generated from the fgd are summarised below. The consultation brought valuable discourse, information and concerns that display the situation on the last-mile. There are top three three issues raised during the discussion, the summary elaborated below.

What happened on the last mile?

"I was surprised there is no bathymetry map available on Palu? Palu should be the capital of tsunami research" FGD Participant, Male, Academic

Building EW should start by understanding the characteristic tsunami in the local level. Therefore investment in research and technology for Palu is essential. Another need is to create an enabling environment for self-sufficient / independent local researches. The advanced technology and research on tsunami should be based in Palu. In the coming future, the local researcher will able to investigate efficiently and thoroughly without waiting for the outsourced researcher.

" the modelling scenario provided by BMKG should be revised based on a comprehensive study to meet the local geological characteristic and the coastal social dynamics." FGD Participant, Male, Govt

The participants frequently mention the phrase "There is no one size fits all" in responding to the tsunami scenario. Current tsunami modelling provided by BMKG shows no scenario of the landslide tsunami. Such a top-down approach by BMKG has prescribed five minutes as the time frame to saves life. As it happened, given scenario would not apply to the whole country. Local geological characteristic should be investigated in more detail. In the future, each location will have their contingency plan based on locality.

" I was the only person left; I am the only one at the command centre own the nerve to push the button in 2012, none of the stakeholders dares to do so!" FGD Participant, Male, Govt

Another problem is the chain of administrative level causing delay and hesitancy in a decision-making process. An example from March 2012, the tsunami struck Donggala as the tide gauge showing the measure a decision to issue a warning made. However, in this critical situation, none of the stakeholders has the courage to the siren button. The lives dependent to such warning was at stake. Therefore, an evaluation on warning protocol needed to be revised based on experience in Palu. How an effective decision making can be made with the shorter official line, it will help the local stakeholder - at the city level to accomplish the goal of the tsunami warning system.

"We were able to installed sirens in Padang (6) and Bali (12), they respond enthusiastically. In Palu, we installed one siren, and they ignore it after the installment" FGD Participant, Male, Govt

Accusing all the problems to national government mainly BKMG was difficult to avoid after 28 September. Participants questioned, why there is only one siren in Palu; when there is need more sirens to be installed along the coastline. The discussion reveals the fact that the local government choose to put the siren as the least concern of their development list. Therefore, building an effective EW require more active participation of local government. Understanding the local political and economic context is also important in understanding the government and community response towards the infrastructure.

"Early warning systems should be defined beyond human reliance on technology."

FGD Participant, female, Researcher

The instigation of tsunami act (PERPRES) has to leave the definition of EW exclusively on engineering improvement. However, the existing knowledge and previous experience of the past event was excluded from the act. *Smong* has saved thousands of people lives in Simelue. Smong has nothing to do with modern technology. It is a part of lullabies stories with a coherent message "when the sea is acting weird when nature launches warning signals; you need to escape uphill. Do not ask questions, do not look back". Therefore, the participants urge to re-integrate such knowledge as a part of EW.

Communicating tsunami risk to the last mile

"Self-evacuation is a top priority in saving lives" FGD Participant, Male, Govt

Tsunami in Palu was not business as usual. Three minutes of tsunami time arrival never cross the expert while developing the scenario. People at the coastline was at risk and would be vulnerable if they are highly dependent on the EWS as the tsunami arrival risk areas may vary. Changing mindset on waiting for EW and government command to saves a life is required. The people should be encouraged to be able to perform a self-evacuation, by running away from the coast looking for a higher ground without waiting for information from the Government or BMKG. Performing this awareness could diminish the number of casualties caused by the tsunami.

"... do not forget the reach rural! public education, particularly to the remote rural area is the key to saves life" FGD Participant, Male, NGO

A participant pointed out the most deserted issue within public education effort was reaching to the last-mile who fall into the category of the least tech-savvy. Within the urban sphere, modern tsunami risk communication using electronic media and smartphone was well established. However, most activities left the rural and the remote area behind. Transference of tsunami risk and necessary information that saves a life should be a priority. The remote rural community are the most vulnerable group due to minimum evacuation infrastructure in place. For example evacuation place was not available, the multi-story building was not available around the area. Higher ground was far from the village, it makes the elder, children and disables person at risk during the catastrophic event. Early warning system with less dependency on electricity will be more reliable when the power down in the area.

Apart from infrastructure and technology, investing more in education should be considered in the future evaluation of EW. One of participant pointing out the example in Japan, how EW is beyond preparedness on the ground. It was a continuing rehearsal to face the future catastrophe in daily life start from early education. Another factor that needs to be considered more comprehensively in Indonesian settings is the religious and cultural dimension. An example of how culture may delay risk awareness is how the number of the participant for tsunami drill was less than the number of the participant for a mass prayer asking God, not to sent tsunami to the area. Indonesia has a distinct culture from Japan. Therefore a need to understand the risk culture and tailor messages to meet specific audience might provide a way out to reduce the risk.

"Integrating risk education to livelihood activity." *FGD Participant, Female, Researcher*

Elite and experts continuously scrutinise the links between livelihoods and disaster risk. Modifying risk information to integrate with livelihood based knowledge will be able to generate risk perception that leads to personal protective actions.

"Top-down approach leads to local knowledge abandonment" *FGD Participant, Male, NGO*

Public participation measures are probably the most effective means to create awareness of potential disaster. However, the current practices neglected local knowledge and specific locality that may contribute to effective risk communication and emergency preparedness. It is essential to recognise the role of traditional and local knowledge in enhancing the resilience of local communities. Lessons can be derived from the traditional and local practices that have been applied by communities over centuries to cope with disasters. One participant points out a community living in Tanah Runtuh (local area) has a local belief that allows to save them from the past tsunami. However, in order to integrate this knowledge into disaster management strategies, they must be understood and scientifically assessed.

Workshop & Focus Group Discussion Participants

List of Participant

RESEARCH DESIGN WORKSHOP & FOCUS GROUP DISCUSSION ON

“The LAST MILE OF THE INDONESIAN TSUNAMI WARNING SYSTEM”

Ruang Senat Fakultas Teknik, Tadulako University

Tuesday, 18th December 2018

No.	Name	Institution
11.	Prof. Dr Amar, S.T.	Dean of The Faculty of Engineering
12.	Dr Abdullah	Palu-Koro Researcher
13.	Hendra Setiawan	Faculty of Engineering
14.	A. Rusidin	Faculty of Engineering
15.	Alamsyah Palaga	Faculty of Engineering
16.	Jefrianto	Mercusuar (Media)
17.	Neni Muhidin	Nemu Buku (NGO)
18.	Cahyo N	BMKG-Sta.Geof - Palu
19.	Moh. Herianto	Historia Sulawesi Tengah (NGO)
20.	Nurdian	KSHT
21.	Dicky Fernando	Student
22.	Dr Herry Yogaswara	Research Center for Population – LIPI
23.	Inayah Hidayati	Research Center for Population – LIPI
24.	Dr Deny Hidayati	Research Center for Population – LIPI
25.	Ayu Surtiari, M.Si	Research Center for Population – LIPI
26.	Ahmad Arif	Kompas/UNISDR
27.	Irina Rafliana	ICIAR LIPI

Workshop Schedule

RESEARCH DESIGN WORKSHOP & FOCUS GROUP DISCUSSION ON

“The LAST MILE OF THE INDONESIAN TSUNAMI WARNING SYSTEM”

Ruang Senat Fakultas Teknik, Tadulako University

Tuesday, 18th December 2018

15:00 - 15:15	**Registration**
15:15 – 15:30	**Opening Speech** Dean of the Faculty of Engineering
15.30 -16.15	**Research Design “Last Mile of The Indonesian Tsunami Warning System”** Ahmad Arif., M.Si & Irina Rafliana M.Si
16.15-16.30	**Research Method** Syarifah Dalimunthe, M.Sc
16.30-18.00	**Focus Group Discussion** Irina Rafliana, M.Si
18.00-18.50	**Remarks and Closing**

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