Annexes

Annex 1. List of abbreviations

BPBD	Badan Penangulangan Bencana Daerah/Local Disaster Management Organisation
BMKG	Badan Meteorologi, Klimatologi dan Geofisika/ Indonesian Agency for Meteorology, Climatology and Geophysics
BNPB	Badan Nasional Penanggulangan Bencana/ Indonesian National Board for Disaster Management
DSS	Decision support system
DMC	Disaster Management Centre
DoM	Department of Meteorology
EOC	Emergency operation Centre
FGD	Focus group discussion
GSMB	Geological Survey and Mining Bureau
IOT	Indian Ocean Tsunami
IOTWMS	Indian ocean tsunami warning and mitigation system ()
IOWave	Indian ocean-wide tsunami exercise
KII	Key informant interviews
MDM	Ministry of Disaster Management
NARA	National Aquatic Resources, Research and Development
NTMC	National tsunami management centre
NTWC	National tsunami warning centre
PUSDATIN	Data and Information Centre
PASTIGANA	Centre For Disaster Alert Situation Analysis
SL-TEWS	Sri Lanka's tsunami warning system
SOP	Standard Operating Procedures
TEWS	Tsunami early warning system
TSP	Tsunami service providers
UK	United Kingdom

Annex 2. The work-load distribution of research teams

Table 1 – Work-load distribution among the research teams

Task/ process within the study	Involved teams	
	Main team in UK	Country teams
Literature review and initial conceptual framework	√	
Study design	√	√
Finalising conceptual framework	√	√
Developing data collection tools		√
Data collection		√
Transcribing and anonymising the data		√
Analysis and reporting		√
Reviewing the analysis and reports	√	
Validation and final review	√	√

Annex 3. The data collection and validation in two case study countries

Once the main areas of explorations were identified through the literature review, the in-country research teams separately worked on data collection tools and procedures. In both countries, the primary data was collected using a detailed desk study, semi structured interviews with key informant and an FGD. For the desk study, the conceptual framework was mapped into a selected list of documents pertaining to the interface of Indonesia's tsunami early warning system (Ina-TEWS). The documents selected for this part of data collection included service guidebook for Ina-TEWS (BMKG, 2012), Evaluation of Ina-TEWS: Outer-rise earthquake, 11 April 2012 and Review of TEWS effectivity in outer-rise Indian ocean earthquake 2 March 2016. In Sri Lanka these documents included national emergency operation plan (NEOP) (DMC, 2015), Sri Lanka's disaster management act (Sri Lanka Disaster Management Act, 2005), Reports from drills and IOWave exercises, and various documents published by the national and international institutions related to TEWS (INCOIS, 2011; IOC/UNESCO, 2015, 2016). The times periods, sample sizes and criteria for sample selection for each tool used in the data collection process are summarised in table 2 below.

Table 2 - Data collection and validation in two case study countries

Data collection Tool	Sri Lanka		Indonesia		Criteria for sample selection
	Time period	Sample size	Time	Sample size	
Desk Study	Jan – Feb 2018	10	Jan – Feb 2018	12	Key interface legal and SOP documents Reports from early tsunami experiences and simulation exercises
FGD	March 2018	25	June 2018	10	National level interface institution representatives
KIIs	May – August 2018	10	April – July 2018	15	Academic experts in the field of early warning Managerial level and specialised technical officers in interface institutions
Validation FGD	11 July 2019	28	13 September 2018	32	Representatives from disaster management ministry/president's office, police and military forces, interface institutions, local government representatives and academic experts

While conceptual framework acted as the basis for developing the tools, it should be noted that each tool was improved after each stage of data collection. Under the basic guidelines provided by the main research team in UK, the country teams presented the conceptual framework to the FGD participants prompting discussions and details were recorded as a part of data collection. The guidelines for the semi structured interviews were also prepared and conducted by the country teams. After the desk study, FGD and interviews, data was analysed by in-country research teams separately, using the same approach; content analysis. According to (Stemler, 2000), content analysis is a systematic method of compressing the large sets of data into manageable and understandable material with the use of coding. It gives the flexibility of using a variety of qualitative techniques to code the data and come to conclusions. In this study, the data obtained were mapped into the framework and were analysed according to the specific context of the country's tsunami warning system and in relation to each other. Draft findings, recommendations and reports were prepared by research teams based on the findings before the validation. The validation FGDs were organised as one day table-top exercises in both countries. The summary findings and the recommendations of the study were prepared under each theme of the conceptual framework and was presented to the participants in sections. The table-top exercises were carried out allowing time for discussion among the groups of participants. The feedback from each group were incorporated in refining the final findings of both cases. The results and recommendations were further improved before reporting in publications and integrating in government policy (Amaratunga, Haigh, & Dias 2019; Haigh et al., 2020; Rahayu, Haigh, Amaratunga, & Sakalasuriya, 2019).

Annex 4. Warning issuing in Indonesian tsunami early warning system (Ina0TEWS)

As per figure 3, the BMKG (Badan Meteorologi, Klimatologi dan Geofisika/ Indonesian Agency for Meteorology, Climatology and Geophysics) acts as the national tsunami warning organisation and receives the earthquake and tsunami information from the regional information providers, and the interface mechanism initiates at the national level. BMKG is also one of the three TSPs for the region. The Decision Support System (DSS) is used by the Indonesian authorities to guide the situation assessment of the tsunami threat and identify and disseminate the correct warning pertaining to the level of risk. After the occurrence of the earthquake, the other TSPs transmit data to BMKG for processing, which BMKG can combine with its own information. The BMKG's automatic seismic data processing system calculates the earthquake parameters, and they are transferred to the DSS. The DSS automatically generates a proposal of impact, which is approved by the DSS operator and sent to be disseminated within the warning chain. Based on parameters given by DSS, BMKG issues four types of warnings as specified in the Ina-TEWS service guidebook (BMKG, 2012).

1. Warning 1: Disseminated based on earthquake parameters and the estimated impact of the tsunami reflected by warning level (Major Warning - Awas, Warning - Siaga or Advisory - Waspada) for every affected district.
2. Warning 2: Contains updated earthquake parameters and, in addition to the warning levels in Warning 1, also the tsunami wave's estimated time of arrival (ETA) on shore.
3. Warning 3: Contains tsunami observation information, updated warning levels and tsunami arrival times, which may be disseminated several times depending on the tsunami observations at the tide gauge stations, the buoys, the CCTVs, and the tsunami radars.
4. Warning 4: Announces that tsunami early warning has ended (end of threat).

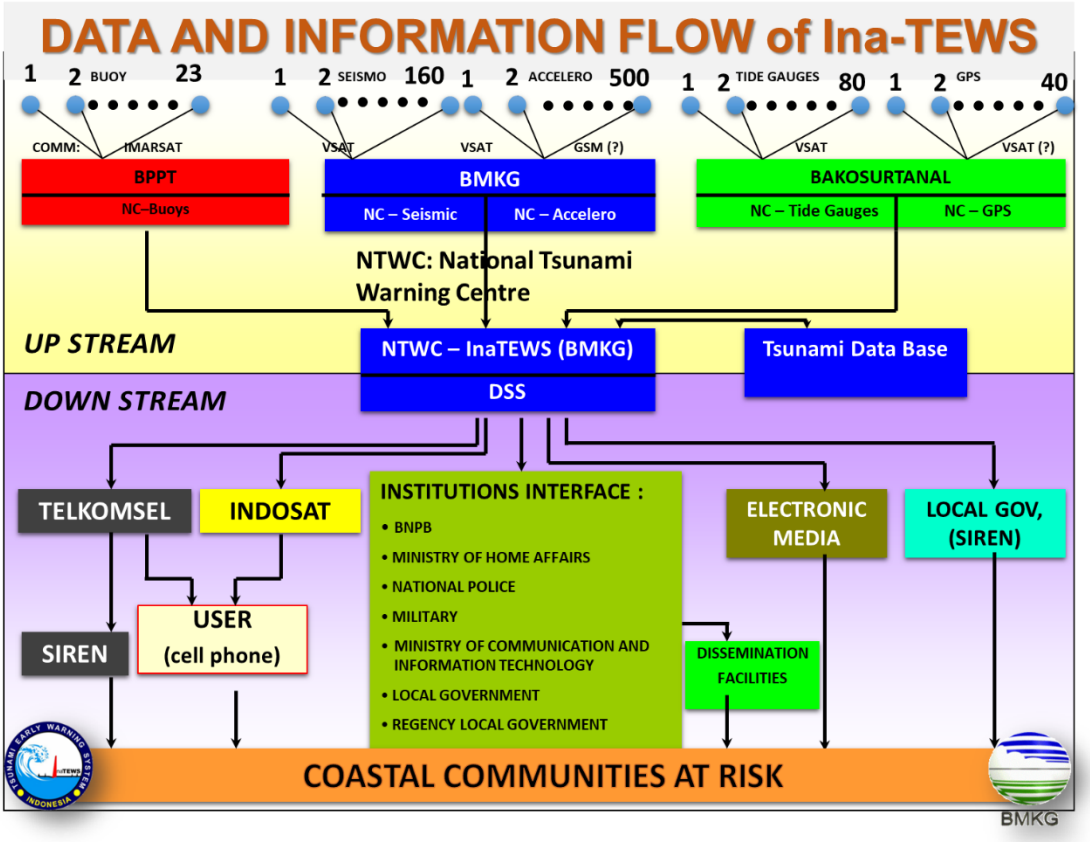

Figure 3. Communication Flow of Ina TEWS (1) (Source: BMKG, 2012)

Key:

BPPT - Technology Assessment and Application Agency (Badan Pengkajian dan Penerapan Teknologi)

BMKG - Agency for Meteorology, Climatology and Geophysics (Badan Meteorologi, Klimatologi, dan Geofisika)

BAKOSURTANAL - National Survey and Mapping Coordinating Board
NTWC - National Tsunami Warning System
DSS - Decision Support System
BNPB - National Disaster Management Agency (Badan Nasional Penanggulangan Bencana)
TELCOMSEL - Indonesian multinational telecommunications conglomerate.
INDOSAT - internet provider

Annex 5. Warning issuing in Sri Lanka's tsunami early warning system (SL-TEWS)

In the case of Sri Lanka's tsunami warning system (hereafter referred to as SL-TEWS), the earthquake and tsunami information are received from TSPs, and the Department of Meteorology (DoM), which acts as the national tsunami warning organisation. In addition to the information provided by the regional TSP, the DoM receive information and updates from United States Geological Survey (USGS), California Integrated Seismic Network (CISN), GSMB and Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) (figure 3). The magnitude of the earthquake and its location are the main criteria for deciding the potential risk of a tsunami. The risk of a tsunami is deemed possible if the earthquake has occurred within the Macran ocean zone, its magnitude is greater than 6.5 Richter scale and the depth is less than 100 kilometres. If these three criteria are fulfilled, the DoM sends the tsunami bulletins to Disaster Management Centre (DMC), who then communicates the warnings and if appropriate, evacuation orders to all the other national and local stakeholders.

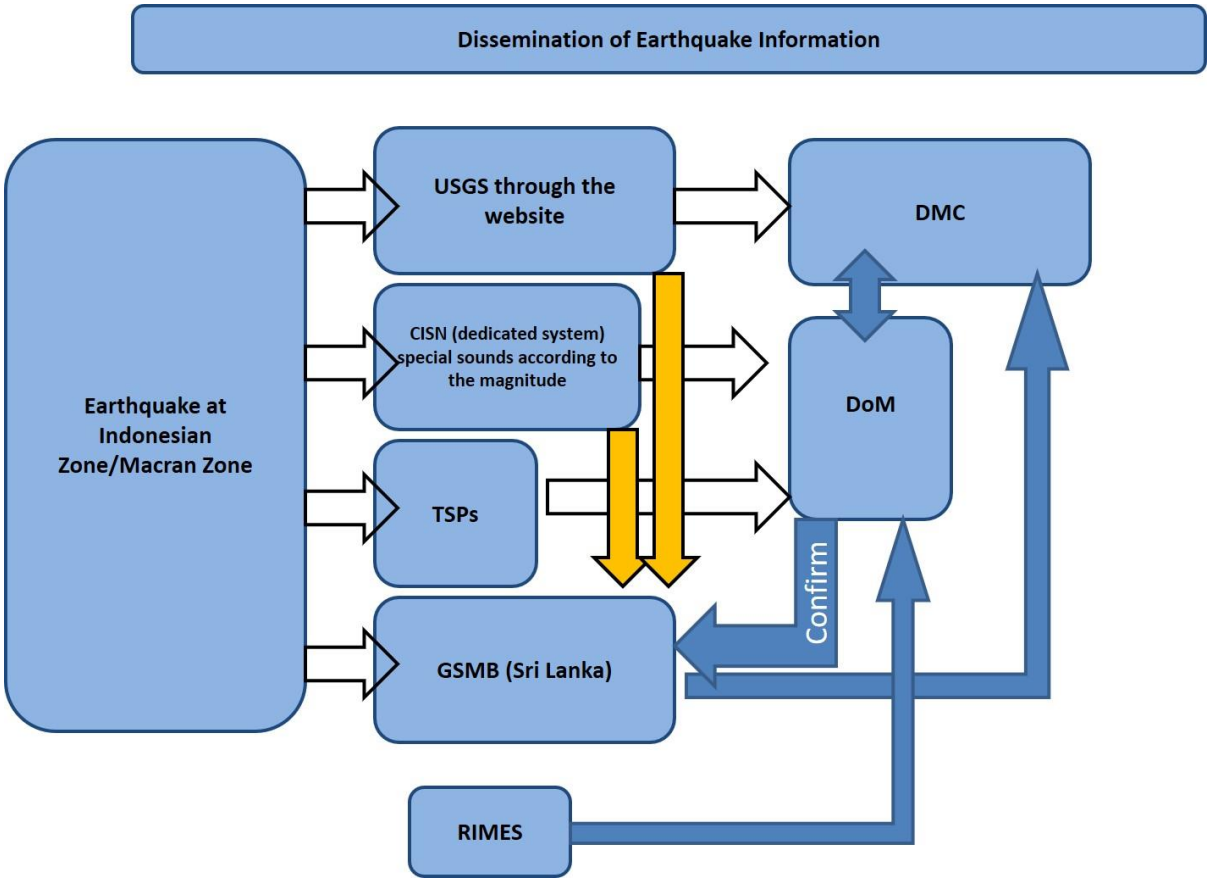

Figure 4. Flowchart of dissemination of earthquake information, Sri Lanka (authors' composition)

Key: USGS - United States Geological Survey
CISN -California Integrated Seismic Network
TSP - Tsunami Service Provider
GSMB - Geological Survey and Mining Burau
RIMES - Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
DMC - Disaster Management Centre
DoM - Department of Meteorology

References

Amaratunga, D., Haigh, R., & Dias , N. (2019). Standard Operating Procedures for Tsunami Warning and Emergency Response for Sri Lanka – Table Top Exercise. Retrieved from https://pure.hud.ac.uk/en/activities/standard-operating-procedures-for-tsunami-warning-and-emergency-r-2

BMKG. (2012). *Tsunami early warning service guidebook for Ina-TEWS*. Jakarta

DMC. (2015). *Sri Lanka National Emergency Operation Plan - Volume 1 (NEOP)*. Sri Lanka DMC and MDM In collaboration with UNDP,

Haigh, R. P., Sakalasuriya, M. M., Amaratunga, D., Basnayake, S., Hettige, S., Premalal, S., & Arachchi, A. J. (2020). The upstream-downstream interface of Sri Lanka's tsunami early warning system. *International Journal of Disaster Resilience in the Built Environment, Volume 11*(Speical Issue 2020 - Special Issue: "End-to-end tsunami early warning systems" in collaboration with IOC-UNESCO IOTWMS).

INCOIS. (2011). *Indian Tsunami Early Warning Centre User Guide, Version-2*. Retrieved from https://incois.gov.in/documents/tsunami/NTWC-Userguide.pdf

IOC/UNESCO. (2015). *IOTWMS Factsheet (2015)*. Retrieved from http://unesdoc.unesco.org/images/0023/002336/233627e.pdf

IOC/UNESCO. (2016). IOTWMS Standard Operating Procedures Workshop. Pre-IOWave16 Workshop on Standard Operating Procedures for Tsunami Warning and Emergency Response for Indian Ocean Countries Retrieved from http://www.ioc-unesco.org/index.php?option=com_oe&task=viewEventDocs&eventID=1837

Rahayu, H. P., Haigh, R., Amaratunga, D., & Sakalasuriya, M. (2019). A briefing paper for the interface of Ina-TEWS: Improving the upstream-downstream interface in the Indonesian end to end tsunami early warning and mitigation system (Ina-TEWS).

Sri Lanka Disaster Management Act, No. 13 of 2005, (2005).

Stemler, S. (2000). An overview of content analysis. *Practical assessment, research, evaluation, 7*(1), 17.