MODELLING OF KRAKATOA TSUNAMI WAVE PROPAGATION AND COMMUNITY ENGAGEMENT BASED ON SWOT ANALYSIS IN SOUTHERN LAMPUNG, INDONESIA

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INTRODUCTION

The eruption of Krakatoa which occurred on the 22 December 2018 caused an avalanche from the Gunung Anak Krakatau (GAK) body into the sea, causing a tsunami in the Sunda Strait. The tsunami affected Lampung (Sumatra) and Banten (Java) provinces in Indonesia. Based on the field observations made by Takabatake et al. (2019) in the southern part of Lampung, it was identified that there were severely damaged areas in Lampung; i.e. East Way Muli, Central Way Muli, and Kunjir villages. A numerical model was developed to simulate past and future tsunami wave propagation scenarios. In addition, the strategic planning technique of SWOT analysis was carried out in order to make recommendations for the resilience of local coastal communities for future tsunami events in Southern Lampung.

NUMERICAL MODEL& INPUT DATA

In present study, the CGWAVE module of SMS 10.0 from Aquaveo was applied to simulate the tsunami wave propagation in Lampung province. The CGWAVE module is based on the elliptic mild-slope wave equation and can simultaneously simulate the effects of refraction, diffraction, reflection by bathymetry, coastal structures, energy dissipation due to bed friction and wave breaking, and nonlinear amplitude dispersion (Panchang and Xu, 1995). The governing equations of CGWAVE include the deep and shallow water equations, making this model applicable to a wide range of wave frequencies, including tsunami waves.

Bathymetric data was obtained from GEBCO which is a global terrain model for sea and land with 15 arc-second intervals. The CGWAVE module requires wave period and direction as input parameters, as well as the three-dimensional coordinates of the near-region finite-element mesh (Demirbilek and Panchang, 1998). The offshore wave amplitude was also used as an initial boundary condition of the model. The tidal data from Panjang Tidal Station was used to estimate the arrival time and maximum wave height of the 22 December 2018 tsunami. The first tide arrived approximately 3420 s (57 minutes) after the first eruption at Krakatoa while the recorded maximum wave height was found to be 0.87 m at Panjang (Refer to Table 1; BIG, 2019).

MODELING SCENARIOS & RESULTS

Numerical experiments were carried out based on different tsunami wave conditions (e.g. wave periods, directions and offshore wave amplitudes) for the 22 December 2018 tsunami. The numerical model results were then compared with the field measurements of Takabatake et al. (2019) in order to check the applicability and robustness of the model. It is evident from Table 2 that wave height at Panjang at an arrival time of 3420 s (57 mins) was 0.90 m in comparison to the measured value of 0.732 m. This confirms that CGWAVE numerical model is capable of producing the past tsunami conditions with satisfactory accuracy. Wave heights for various locations in Southern Lampung for two different offshore wave amplitudes and wave periods are shown in Table 2.

Tabel 1 – Tsunami characteristics of the 22 December 2018 Krakatoa tsunami recorded at Panjang tidal station (BIG, 2019)

	Arrival time (UTC)	Wave height* (m)
First tsunami wave	14.52	0.732
Maximum tsunami wave	16.43	0.870
NB: Original time of the volcanic eruption is assumed to be at 13:55:00 UTC on 22 December 2018 with the approximate arrival time for the first wave at Panjang tidal station being at 3420 s (57 mins). *plus sign represents first elevation or depression of tsunami wave.		

Tabel 2 – Wave heights obtained from CGWAVE numerical model for various input conditions

Wave amplitude at offshore boundary (m)		0.5			0.6		
Wave period (s)		3120	3420	3720	3120	3420	3720
Simulated wave height at nearshore boundary (m)	East Way Muli	2.03	1.70	1.49	2.44	2.03	1.79
	Central Way Muli	2.01	1.69	1.50	2.41	2.03	1.80
	Kunjir	1.98	1.68	1.50	2.38	2.02	1.80
	Panjang	0.90	0.90	0.94	1.08	1.09	1.13

The modelling results for an offshore wave amplitude of 0.5 m give a tsunami wave propagation direction that agrees well with the findings of Takabatake et al. (2019), with large tsunami wave heights (hence considerable damage) predicted by the model in the nearshore boundary; East Way Muli, Central Way Muli and Kunjir (Southern Lampung) compared to small wave heights (least impact) in northern areas such as Panjang (Bandar Lampung).

The field measurements in those areas when the tsunami approached were:

1. East Way Muli, H_{runup} = 3.97 m.
2. Central Way Muli, H_{runup} = 5.04 m.
3. Kunjir; $H_{inundation}$ = 4.21 m.

Figure 1 illustrates the wave height distribution and their direction as the main output of the numerical model for the offshore wave amplitude of 0.6 m as one of the potential future scenarios.

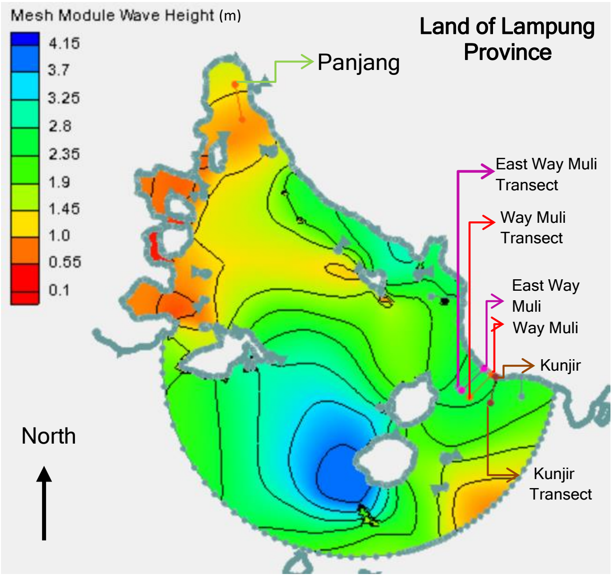

Figure 1 - Numerical model output of wave height distribution and their direction based on an offshore wave amplitude of 0.6 m and wave period of 3420 s (57 mins) as a potential future scenario

SWOT ANALYSIS

The SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is a decision making technique used for making recommendations by critically assessing the four aspects for a given project. It considers the merits of a particular project and reduces the probability of risk by understanding what the shortfalls are. For this study we develop a SWOT analysis using a combination of CGWAVE numerical model output results, previous research studies, published information and annual scientific/administrative reports of Lampung Province.

The following figure illustrates the SWOT analysis of tsunamis generated by Krakatoa in Southern Lampung.

Strengths (S) - Local government of South Lampung has an active communication with provincial councils - Has diverse and high quality of fisheries and potential for tourism
Weaknesses (W) - Urban planning in the 3 villages (East Way Muli, Central Way Muli & Kunjir) is not done properly - Understanding of tsunamis and their impact has not been fully understood by the residents
Opportunities (O) - Tourism is one of the main income generation schemes in Lampung Province - South Lampung is the main entrance to Sumatra island by Merak-Bakahueni Ferry
Threats (T) - The capital of South Lampung is about 40 km from the Anak Krakatau volcano and the nearest inhabited islands (e.g. Sebesi and Sebuku) are located 25 km from the volcano - Has tectonic and volcanic tsunami prone status - Based on **CGWAVE model outputs** for villages in Lampung, tsunamis generated by Krakatoa can be destructive and cause damage to residents and infrastructure in future

Figure 2 - SWOT analysis results - Key points from the published information and numerical model output

By considering the strategic components mentioned above, it is apparent that several factors are key for community engagement in disaster mitigation, including for tsunamis, in the area (Jokowinarno, 2011). These are: [1] understanding the characteristics of natural disasters and damage to coastal areas, [2] understanding the level of risk and vulnerability, [3] understanding the environmental/coastal conditions, socio-cultural aspects, and local knowledge when a disaster happens, [4] understanding mitigation measures - both structural and non-structural, [5] increasing institutional capacity and law enforcement, [6] sustainability of policies and regulations. The key priority in this area is to protect the coastal community, marine life and its vegetation from tsunamis. Community protection can be achieved by planning shelters in appropriate locations such as at coastal sites less vulnerable to tsunamis (e.g. using CGWAVE numerical model outputs), identifying evacuation routes and reviewing standards and design guidelines for infrastructure (roads, buildings, tsunami defences) close to the coastline. The focus should be on helping local people prepare. For instance, the development of an early warning system would help people to evacuate at the right time in the event of a tsunami. Understanding the societal and cultural background will help disaster risk experts to explain such mitigation procedures. These efforts are most effective when local government, schools, universities and other community organisations work together.

CONCLUSIONS

The CGWAVE numerical modelling suite was applied to simulate tsunami wave propagation due to the December 2018 Sunda Strait Tsunami in Indonesia. A number of different offshore wave conditions were considered in modelling past and future tsunami scenarios. Model output (wave heights) for the 2018 Tsunami in Southern Lampung compared with recorded data at Panjang tidal station. Based on our SWOT analysis for villages in Southern Lampung, we recommended;
a). Active collaboration between the government departments and local tertiary institutions to disseminate disaster mitigation plans and carry out trauma healing programmes for the victims of the Krakatoa 2018 tsunami; b). The formation of disaster preparedness teams / active focus groups for every village in Southern Lampung; c). A review being undertaken of the regional urban planning criteria for future development of infrastructure (houses, roads, fisheries port etc.), which are of paramount importance for the area.

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