

# Analysis of tsunami hazard potential in north Bali due to the Flores back arc thrust earthquake using TOAST

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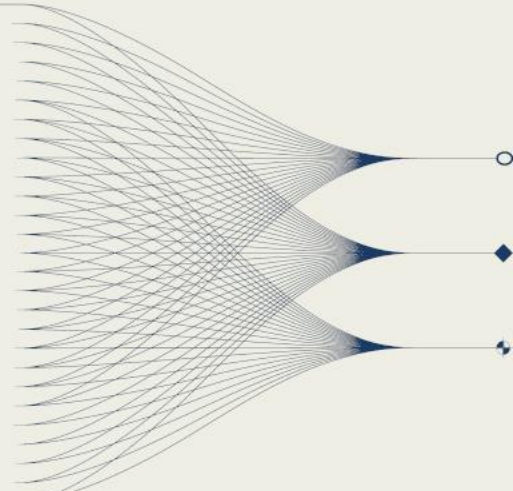
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## INTRODUCTION AND MAIN RESULTS

Research on tsunamis in northern Bali is limited; however, records indicate that the 1815 event ( $M \sim 7.0-7.3$ ) resulted in the deaths of 10,253 people in Buleleng–Singaraja. Easywave-TOAST simulations indicate eastern Buleleng faces a major warning with a 3.43 m run-up and 1 min ETA, while western Buleleng has a 1.92 m run-up and 4.5 min ETA. Population exposure: 2,831/km<sup>2</sup> east, 1,683/km<sup>2</sup> west.



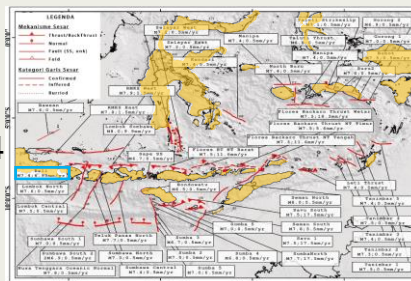
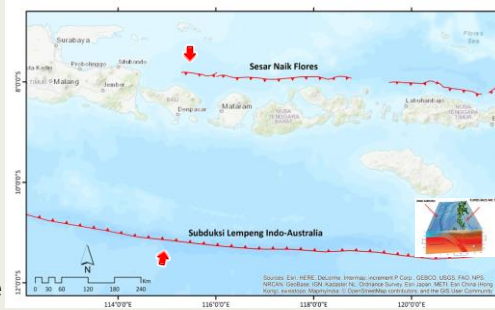


## Introduction

Bali is one of the regions in Indonesia that is prone to earthquakes. Bali is flanked by two earthquake sources, namely the subduction zone in the south of Bali, which is the meeting point of two plates. The Indo-Australian plate moving from south to north and the Eurasian plate moving from the north to the south. The northern part of Bali has a back-arc trust zone that stretches from northern Bali to Flores. The Flores Fault stretches across the northern sea of Bali Island through Buleleng Regency. The end of the Flores Fault is located right above the northern sea in Buleleng Regency (McCafrey et al., 1987).

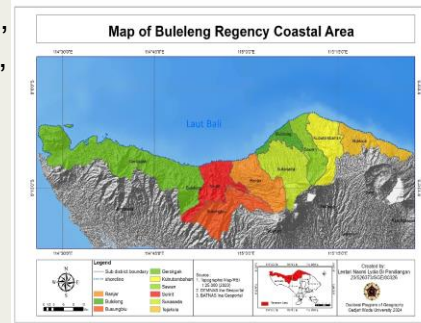
The potential magnitude of the earthquake from the Flores backarc thrust The Bali segment is M7.4 with a movement of 6.95 mm/year (Pusgen 2017).

Tsunami events are relatively rare but cause significant losses and damage in the affected areas. Tsunami modeling for vulnerable areas is a crucial mitigation strategy that can be used as a reference in developing preparedness plans in the future.

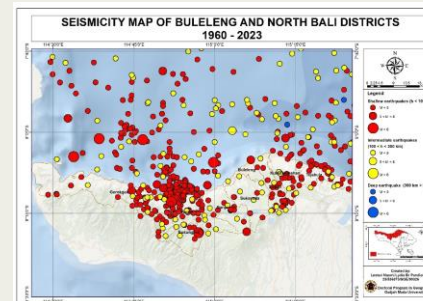


## Methods/Data

The location area is the coastal area of Buleleng Regency. Total of coastal area: 996.33 km<sup>2</sup>. Total of Coastal area subdistricts: 7 Sub-districts (Gerogak, Seririt, Banjar, Buleleng, Sawan, Kubutambahan and Tejakula). Total Population: 676,590 people, Population density: 604 people/km<sup>2</sup>.



Seismicity map of Buleleng regency and North Bali using earthquake data from USGS, BMKG and ISC for the period from 1960 to 2023 shows seismic activity in Buleleng regency is Indeed very high and dominated by shallow earthquakes (red circle).

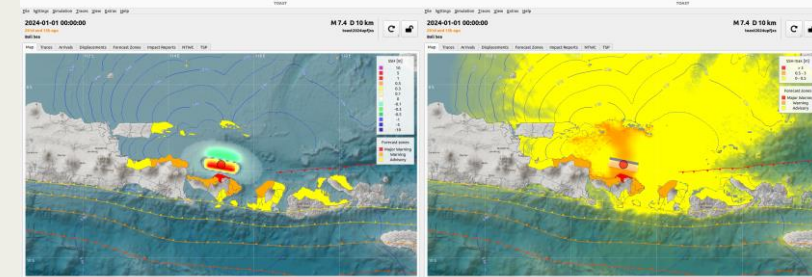


The scenario is due to Bali segment referring to the BMKG tsunami catalog (416-2018) and the National Earthquake Center (PUSGEN, 2017).

This study uses TOAST (Tsunami Observation and Simulation Terminal) modeling to predict tsunami run up, forecast zone and estimated time of arrival.

## Results

SSH (sea surface high) is the height of the sea surface below the reference ellipsoid. The contours of the sea surface can be determined from this SSH, as well as the characteristics of the surface waves influenced by wind or gravity.



North Bali Earthquake & Tsunami Scenario (M 7.4, 22 Nov 1815 – Worst Case).

- Eastern Buleleng (Buleleng, Sawan, Kubutambahan, Tejakula): Run-up height 3.43 m, ETA 1 min.
- Western Buleleng (Gerogak, Seririt, Banjar): Run-up height 1.92 m, ETA 4.5 min.

No	Sub-district/ Status Level	Total Area (km <sup>2</sup> /per sq.km)	Population (thousand)	Population Density (per sq.km)
<b>Eastern Buleleng (Major Warning)</b>				
1	Buleleng	46.94	153.930	519
2	Sawan	92.52	84.760	916
3	Kubu Tambahan	118.24	71.760	607
4	Tejakula	97.68	77.080	789
	<b>Total</b>	<b>355.38</b>	<b>387.530</b>	<b>2.831</b>
<b>Western Buleleng (Warning)</b>				
5	Gerogak	356.57	101.140	284
6	Seririt	111.78	98.380	880
7	Banjar	172.60	89.540	519
	<b>Total</b>	<b>640.95</b>	<b>289.060</b>	<b>1.683</b>

Forecast Zones	Run up (m)	Estimated Time of Arrival
<b>MAJOR WARNING</b>		
BALI Eastern Buleleng Sawan Kubutambahan Tejakula	3,432	0:01:00
<b>WARNING</b>		
BALI Western Buleleng Gerogak Seririt Banjar	1,921	0:04:30

Tsunami Hazard Zones

- MAJOR WARNING Zone: 4 sub-districts, 355.38 km<sup>2</sup>; 387,530 people (density 2,831/km<sup>2</sup>).
- WARNING Zone: 3 sub-districts, 640.95 km<sup>2</sup>, 289,060 people (density 1,683/km<sup>2</sup>)



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## Appendix.

The scenario is due to the Flores back-arc thrust earthquake from the Bali segment, referring to the BMKG tsunami catalog (416-2018) and National Earthquake Center (PUSGEN, 2017).

Faults	Strike (km)	Length (km)	Width (km)	Source Location Earthquake		Magnitude ( Mw )	Dip (°)	Rake (°)	Depth (km)
				Latitude (°LS)	Longitude (°BT)				
Reverse	280,954	74,47	26,54	7,849	115,23	7,4	30	90	10

## Tsunami wave propagation simulation

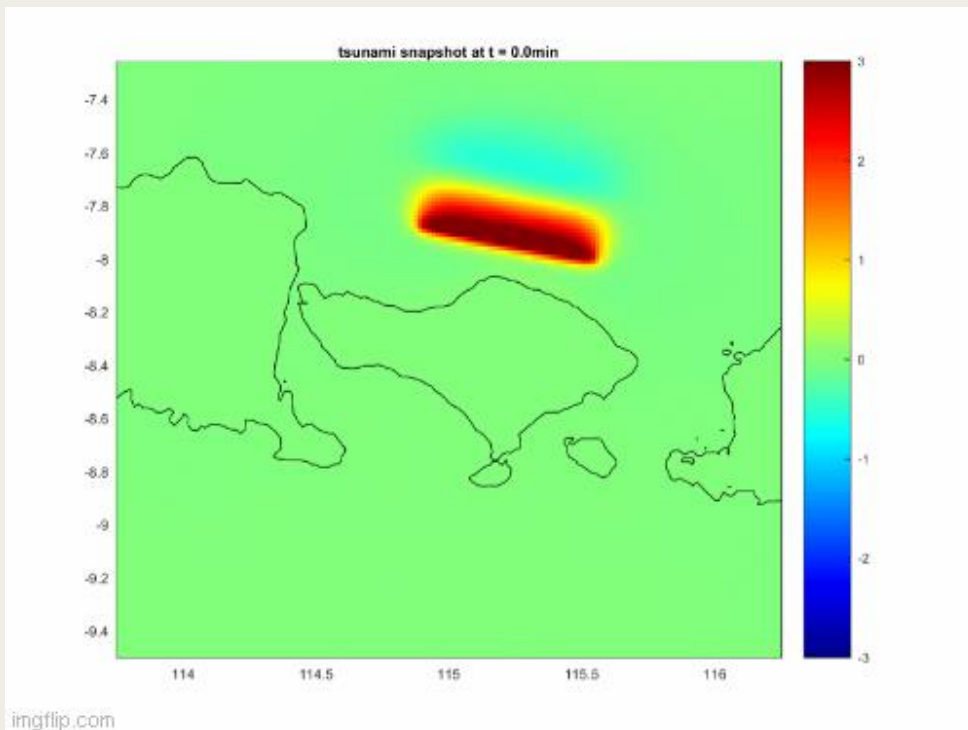


Table Result of Easywave Simulation Forecast Zone with TOAST Modeling

P1.3-060

Easywave		Run up (m)	ETA
MAJOR WARNING			
BALI	Eastern Buleleng	3,442	0:01:00
WARNING			
BALI	Western Buleleng	1,921	0:04:30
BALI	Northern Karang Asem	1,636	0:02:00
NTB	Northern – West Lombok	0,728	0:10:00
NTB	Mataram City	0,583	0:17:00
BALI	Klungkung	0,581	0:22:15
BALI	Southern Karang Asem	0,580	0:10:45
JATIM	Situbondo	0,523	0:09:45
ADVISORY			
NTB	Southern - West Lombok	0,419	0:16:15
JATIM	Sumenep	0,394	0:15:15
BALI	Denpasar - Sanur Beach	0,393	0:34:15
NTB	Northern - East Lombok	0,388	0:17:15
BALI	Klungkung Nusapenida Island	0,362	0:20:45
NTB	Sumbawa	0,352	0:29:30
NTB	Eastern – East Lombok	0,348	0:34:15
NTB	Northern Sumbawa	0,329	0:27:15
NTB	Bima	0,265	0:32:30
BALI	Gianyar	0,237	0:30:45
BALI	Badung - Kuta Beach	0,232	0:38:30
SULSEL	Center Lombok	0,227	0:33:45
SULSEL	Maros	0,212	1:31:15
JATIM	Probolinggo	0,205	1:29:15