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IDENTIFY THE LOCATION OF THE TEMPORARY TSUNAMI EVACUATION SITE IN AMBULU SUB DISTRICT, JEMBER REGENCY

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ABSTRACT

Sumberejo Village in Ambulu District is a village located on the south coast of Jember Regency which has a high level of tsunami hazard. During the Banyuwangi tsunami in 1994, tsunami waves also hit Payangan and Watuulo beaches in Sumberejo Village. Until now, Sumberejo Village does not yet have a Tsunami Temporary Evacuation Site (TES). This study aims to identify a vertical TES location for a tsunami. Identification of TES locations is carried out with a Geographic Information System (GIS) using the overlay tool of several thematic maps. The results of the analysis show that several spots on the hills in Sumberejo met the requirements as TES locations when the tsunami occurred. Altitude is a very important variable in planning the location of a temporary tsunami evacuation site. Hilly locations with elevations above 20 meters and close to existing settlements can be developed as first priority TES locations, while hilly locations with elevations above 20 meters but far from existing settlements can be developed as second priority TES locations.

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1. INTRODUCTION

The southern coast of Jember Regency, which borders the Indian Ocean, is potentially affected by the threat of tsunami hazards, triggered by tectonic earthquakes in the East Java megathrust zone (M 8.7, a = 5, b = 1.08) (Kongko 2020). The coastal area of Jember Regency has experienced at least 4 tsunami disasters in the last 200 years, namely in 1818, 1921, 1930 and 1994 (Nakamura 1978); (Supartoyo Surono, dan Putranto 2014), (BMKG 2019) (Tabel 1).

Tabel 1 Earthquake that Caused the Tsunami

No.	Date	Longitude	Latitude
1	November 8, 1818	117	07
2	September 11, 1921	111	11
3	July 19, 1930	114	09
4	June 3, 1994	112	10

Sources: Nakamura 1979, Supartoyo, Surono and Putranto 2014
BMKG 2019

The tsunami disaster on June 3, 1994 that hit Banyuwangi Regency also affected fishing settlements in coastal villages in Jember Regency. It was recorded that 12 people died, 46 houses were completely destroyed, 19 boats were damaged (Nugrahadi 1997). The earthquake that occurred in South Malang Regency on April 10, 2021 with an epicenter at 112.48 East Longitude and 8.45 South Latitude at a depth of 25 km with a magnitude of 6.7 did not have the potential for a tsunami (www.bmkg.go.id).

Based on the research conducted, it shows the simulation of 2 tsunami run-up models on 7 beaches in Sumberejo Village, Ambulu District, Jember Regency (Maemunah, Sulaeman, and Robiana 2011). In the simulation of model-1, the maximum tsunami run-up of 3.06 meters occurred at Tanjung Seruni Beach. While in the simulation of model-2, the maximum tsunami run-up of 2.87 meters also occurred at Tanjung Seruni Beach (Figure 1).

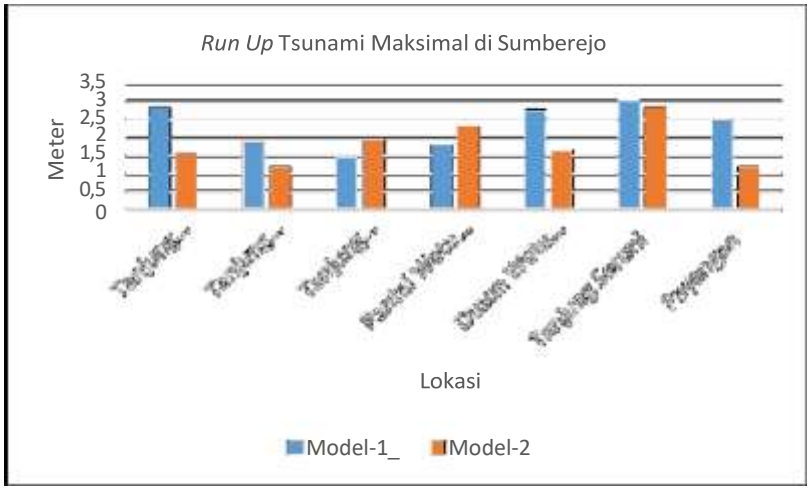

Figure 1 Maximum Tsunami Run-up Height in Sumberejo Village, Ambulu Sub District

Referring to the Regulation of the Head of the National Disaster Management Agency No. 2 of 2012 (BNPB 2012), a tsunami inundation height of <1 meter is categorized as a low tsunami threat index. A

tsunami inundation height of 1-3 meters is categorized as a moderate tsunami threat index. A tsunami inundation height of >3 meters is categorized as a high tsunami threat index.

Research data (Maemunah, Sulaeman, and Robiana 2011) also produced a tsunami vulnerability map. Sumberejo Village is divided into 3 levels of tsunami vulnerability, namely; Disaster Prone Area (KRB) high tsunami (run up > 3 meters, KRB medium tsunami (run up 1-3 meters) and KRB low tsunami (run up <1 meter) (Figure 2). The worst case scenario of a tsunami disaster (worst case scenario), occurs when two megathrust segments that stretch across the south of Java Island break simultaneously, indicating that the tsunami wave (flow height) can reach a height of around 20 m on the south coast of western Java Island and around 12 m on the south coast of eastern Java Island, with an average maximum tsunami wave height of 4.5 m along the south coast of Java Island (Widiyantoro et al., 2020). If the worst case scenario as mentioned above occurs, the tsunami threat index in Sumberejo becomes a high tsunami KRB category. So the criteria for the location of the Temporary Evacuation Site must have a height above the tsunami wave (> 20 meters).

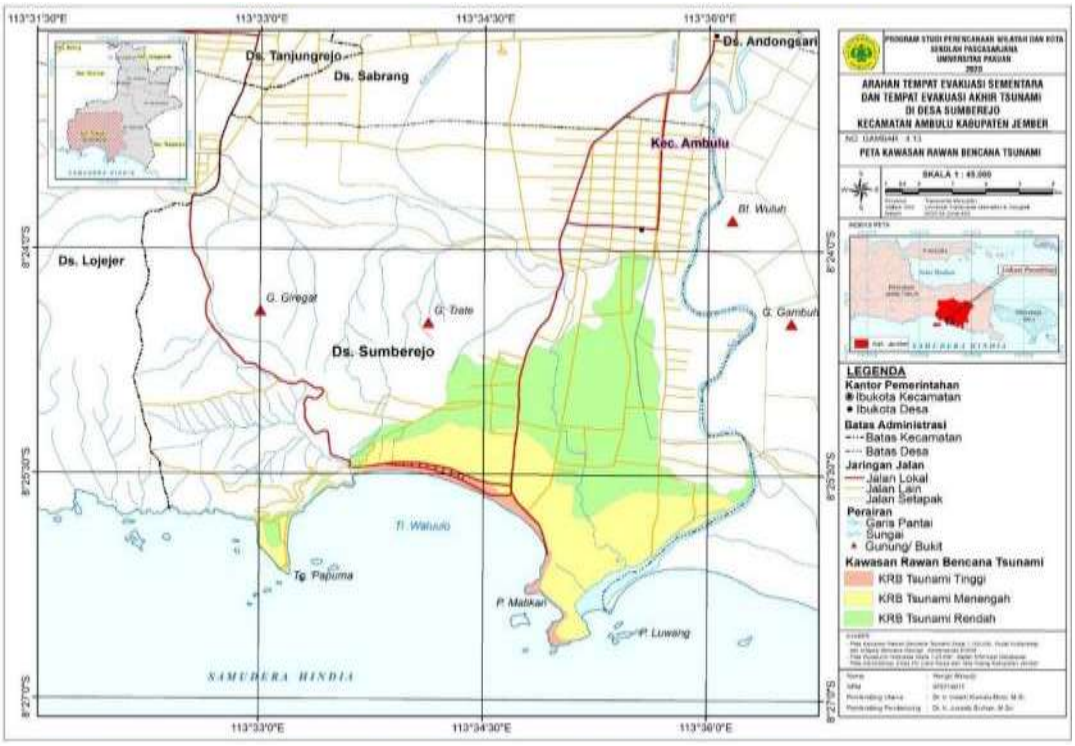

Figure 2 Map of Tsunami Disaster Prone Areas in Ambulu District (Maemunah, Sulaeman, Robiana, 2011)

The problem that occurred was that Sumberejo Village on the southern coast of Jember Regency experienced 4 tsunami disasters in 1818, 1921, 1930, 1994 and Sumberejo Village did not have a tsunami evacuation site that met BNPB requirements.

2. RESEARCH METHODOLOGY

Jember Regency was chosen as the research location because it has the 2nd highest tsunami risk level in East Java (Wiguna et al. 2021). This research was conducted in Sumberejo Village, a coastal village

with a coastal fishing settlement in the administrative area of Ambulu District, Jember Regency, East Java Province in March-April 2021 (Figure 3).

To determine the location of the Temporary Tsunami Evacuation Site, a simulation was used using data on requirements, standards (FEMA 2019) and existing conditions. The analysis technique used to identify the location of the Temporary Tsunami Evacuation Site (TES) in Sumberejo Village is the Geographic Information System (GIS) analysis technique.

The software used is ArcGIS version 10.3 with query tools, reclassify and overlay tools for several polygon attribute data (Purbani et al. 2014). This capability characterizes geographic information systems from other information systems (Akhmadi, Kumalawati, and Deasy 2017). This study uses secondary data from various agencies as attribute data, namely:

1. height sourced from DEMNas;
2. slope sourced from DEMnas data analysis;
3. KRB tsunami sourced from the Center for Volcanology and Geological Disaster Mitigation BG-ESDM;
4. liquefaction hazards from the Center for Groundwater and Environmental Geology BG-ESDM.
5. land use from Google Earth satellite imagery recorded in August 2019,
6. land status from the website (page) www.bpn.go.id.

Each attribute data/parameter has a certain class and score. Each attribute data parameter is grouped and weighted (Table 2).

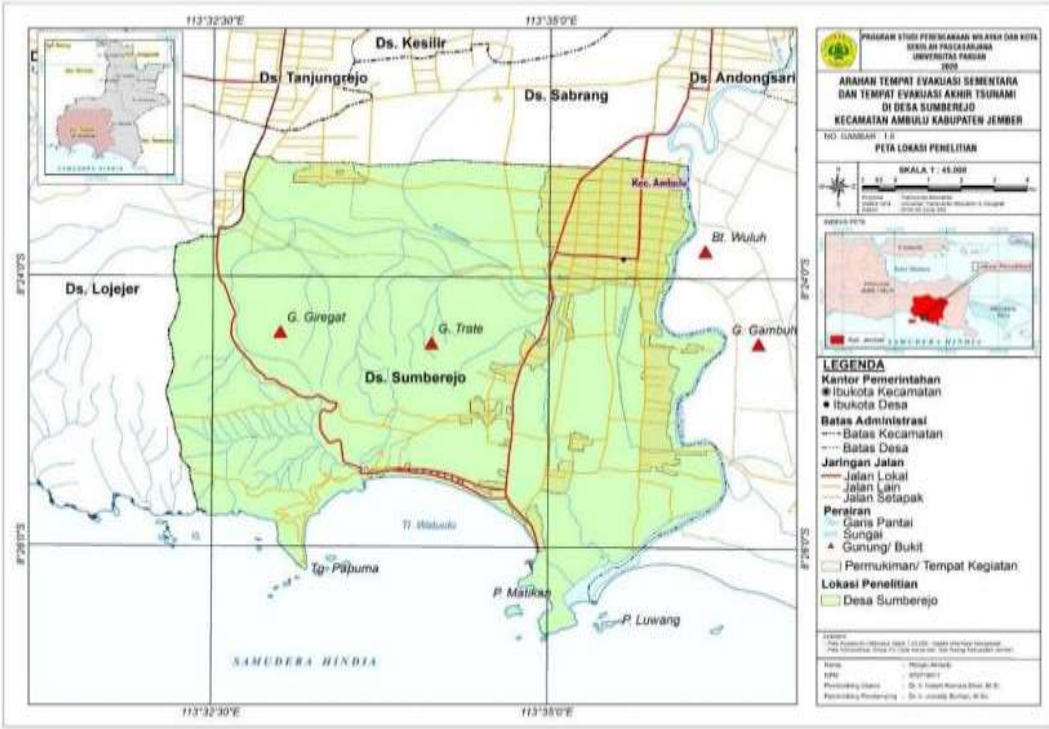

Figure 3 Map of Research Location of Sumberejo Village, Ambulu District (Jember Regency Government 2021)

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Table 2 Parameters and Classes and Scores for Determining Temporary Tsunami Evacuation Sites

No.	Parameter	Class	Score
1	Height[1)]	5-10 m	1
	Weight = 3	10-15 m	2
		15-20 m	3
		>20	4
2	Slope[2)]	>8 %	1
	Weight = 2	2-8 %	2
		<2 %	3
3	Tsunami disaster vulnerability[3)]	Red Zone	1
	Weight = 2	Yellow Zone	2
		Green Zone	3
		Outside the tsunami zone	4
4	Liquefaction disaster vulnerability[4)]	High Vulnerability Zone	1
	Weight = 2	Medium Vulnerability Zone	2
		Low Vulnerability Zone	3
		Outside of Vulnerability Zone	4
5	Land use [5)]	Dry land Farming	1
	Weight = 1	Shubbery	2
		Vacant land	3
6	Land ownership[6)]	Fee hold Land	1
	Weight = 1	Land Use Right	2
		Non Registered Land	3

Notes :
1) Perka BNPB No. 4 Tahun 2008
2) Permen PU No. 41 Tahun 2007
3) Parameter dalam beberapa penelitian terdahulu
4) PATGL-BG-Kementerian ESDM 2019
5) BNPB 2013
6) BNPB 2013

Temporary tsunami evacuation sites are vertical evacuation sites, meaning that evacuees not only move away from the coastline where the tsunami occurred, but also have to find a place that is high enough to avoid tsunami waves that can reach tens or even hundreds of meters in height.

Several previous studies have stated that altitude is an important variable in determining the location of temporary tsunami evacuation sites (Park et al. 2012); (Rachman and Suryo 2015); (Sutikno and Murakami 2015); (Handoyo, Putro, and Subardjo 2017); (Kemal, Yosritzal, and Aulia 2017); (Vadreas et al. 2019); (Usman and Sari 2019), (Aji 2019); (Lakosa and Alhadi. 2019); (Ismiati, Damayanti, and Dimyati 2020); (Arifal and Ashar 2021); (Souhuwat, Situmorang, and Taki 2021); (Fachri, Malik, and Murtianto 2022).

Several other researchers say that the criteria for a temporary tsunami evacuation site are locations that are considered to have a safe enough distance from the tsunami waves. At least the location has a height above the estimated tsunami run-up (Rahmadhani, Suprayogi, and Sabri 2013); (Kirana,

Istijono, and Hidayat 2016); (Kusuma, Rachmawati, and Sari 2017); (Widilestari, Munirwansyah and Yunita 2019).

One thing that is also important is that the temporary tsunami evacuation site must be safe from the threat of other disaster hazards, such as floods, landslides, liquefaction and others (Rumondor, Sentinuwo, and Sambul 2019). This is also implied in the Technical Guidelines for Planning Temporary Tsunami Evacuation Sites (Rahayu and Anita 2013). Liquefaction is a potential collateral hazard that can occur as a result of a tsunami as the main hazard (Dewi 2019). Liquefaction as a collateral hazard occurred during the earthquake accompanied by a tsunami in Palu City (Central Sulawesi) in 2018 (Buana et al. 2019).

The analysis process using the overlay technique of the 6 thematic maps produced areas that had a level of suitability for the location of TES development. The description of the GIS subsystem in this study is as seen in the diagram in Figure 4.

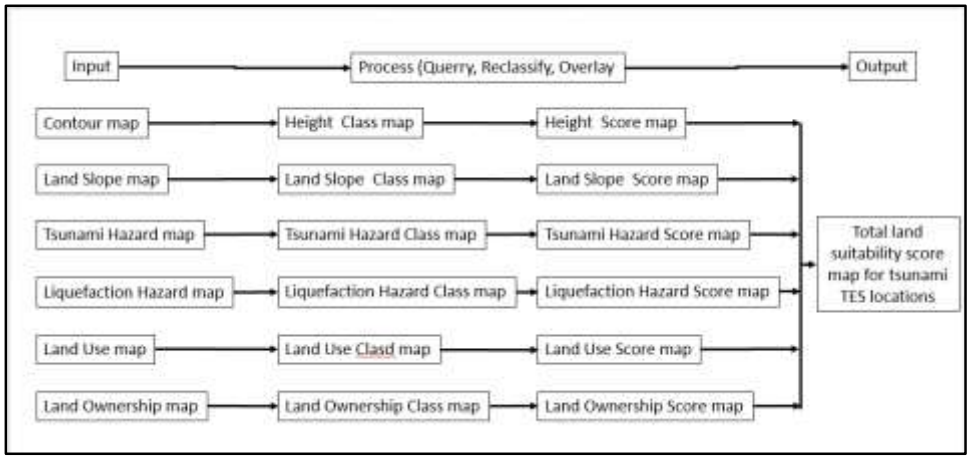

Figure 4 GIS subsystem for spatial modeling of location determination for Tsunami TES Development in Sumberejo Village, Ambulu Sub District

Then, to determine the level of suitability, the interval class was first determined from all existing data (1,363 data) using the Sturgess method (Rachmah, Rengkung, and Lahamendu 2018).

$$k = 1 + 3.22 \log n \quad \text{.....(1)}$$

Where:
k = interval class
n = number of data
So we get
k = 1 + 3.22 Log 1.363
= 10 interval classes

The suitability level of the tsunami TES development location is determined by using the top 3 interval classes to classify locations with high suitability levels, medium suitability levels and low suitability levels. Meanwhile, the other 7 (seven) interval classes are classified as unsuitable for TES development locations.

3. RESULTS AND DISCUSSION

Height is the 1st important parameter to determine the best location for TES. The nature of the tsunami disaster is that it spreads from sea to land which can reach a height of 20 m above sea level. In FEMA (2019), it is stated that TES must be above the freeboard which takes into account the height of the tsunami waves (run up). So that a height of 20 m above sea level is considered the minimum height for the TES Location and gets the highest score.

The slope level is the second important parameter in determining the TES Location. Basically, the tsunami TES is an emergency location that must be able to function as a disaster evacuation site. So as a TES, it must meet the requirements of a low slope level (<3%) as required in PU Regulation Number 41 of 2007.

Tsunami disaster vulnerability is the 3rd important parameter in determining the location of the tsunami TES. In the sense that the ideal tsunami TES location is outside the area declared as a tsunami disaster prone area as the main priority, but if there is no location outside the tsunami disaster prone area, the TES can still be built in a low-level tsunami disaster prone area, but by building an artificial hill (escape hill) with sufficient height as a tsunami TES.

Liquefaction disaster vulnerability is also the 4th important parameter in determining the location of the tsunami TES. Several locations in coastal areas have the potential for liquefaction disasters if a tsunami occurs, such as what happened in Palu City in 2018. In determining the location of this TES, an analysis was carried out on the liquefaction vulnerability map published by the Geological Agency of the Ministry of Energy and Mineral Resources.

Land use is the 5th important parameter in determining the location of the tsunami TES. The use of land that is suitable for developing a TES is the use of empty land, or scrub land that is not cultivated by the community. So that it is easy to install refugee tents during the emergency response period.

Land ownership is the 6th important parameter in determining the location of the tsunami TES. The tsunami TES location should be on land owned by the government/regional government or village land. Land ownership is important because TES activities during emergency response can possibly last for quite a long time. If the tsunami TES uses land owned by the community, it is feared that it will disrupt the socio-economic conditions of the landowner.

Based on calculations using GIS, the research area of 3402.62 hectares was analyzed with the 6 (six) parameters explained above, resulting in 1,363 data units with a total score range of 13 to 37. Then an interval class was created from all data scores using the Sturgess method into 10 interval classes. Furthermore, the top 3 interval classes were selected as the range for the tsunami TES suitability classification, namely; very suitable, moderately suitable and low suitable. While the 7 lowest interval classes were stated as the range not suitable for the construction of the tsunami TES.

Based on the analysis using GIS, it is known that the suitability area for TES development in Sumberejo Village with a high level of suitability with a total score of 35-37 covering an area of 82.41 Ha (3.42%), an area with a moderate level of suitability with a total score of 32-34 covering an area of 462.73 Ha (13.60%) and an area with a low level of suitability with a total score of 29-31 covering an area of 829.59 Ha (24.38%). The area that is not suitable for TES development (total score 13-28) covers an area of 3,093.45 Ha (90.91%) (Table 3) and (Figure 5)

Table 3 Levels of Location Suitability Tsunami TES Development

No.	Total Score	Area (Hectare)	%	Level of Suitability for TES
1	35-37	82,41	3,42	Very Suitable
2	32-34	462,73	13,60	Moderate Suitable
3	29-31	829,59	24,38	Low Suitable
4	26-28	150,54	4,42	Not Suitable
5	24-25	84,04	2,47	Not Suitable
6	22-23	490,84	14,43	Not Suitable
7	20-21	993,30	29,19	Not Suitable
8	18-19	271,29	7,97	Not Suitable
9	16-17	30,82	0,91	Not Suitable
10	13-15	7,06	0,21	Not Suitable
		3.402,62	100,00	

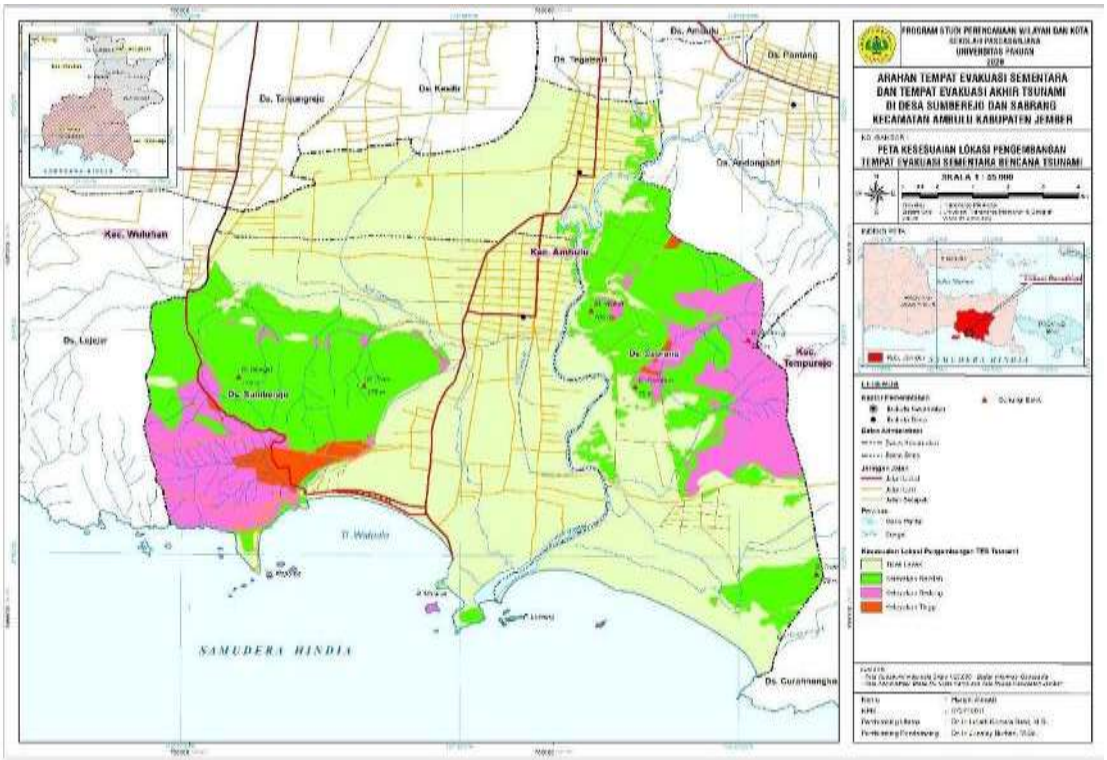

Figure 5 TES Development Location Suitability Map

To determine the location of TES development in detail, further detailed calculations were carried out using data on a minimum height of 20 meters above sea level and a maximum slope of 2%. The minimum height is 20 meters (BNPB 2008) Meanwhile, the maximum slope is 2% (Department of Public Works 2007). The final results of this study obtained 5 (five) locations suitable for the development of natural tsunami TES in Sumberejo Village, namely; 1) Papuma Hill TES covering an area of 13,219 m2, 2) Semboja Hill TES covering an area of 3,747 m2, 3) Love Bay Hill TES covering an area of 6,992 m2 4) Trate Mountain-1 TES covering an area of 8,707m2 and 5) Trate Mountain-2 TES covering an area of

9,306 m2 (Table 4 and Figure 6).

Tabel 4 TES Tsunami Development Location for TES in Sumberejo Village Ambulu Sub District

No.	TES Tsunami	Elevation (meter above mean sea level)	Area (sqm)	Level of Suitability
1	Papuma Hill (113° 33' 30" E, 8° 25' 09" S)	12,5-25	13.219	Very Suitable
2	Trate Mountain -1 (113° 34' 04" E, 8° 25' 01" S)	12,5-50	8.707	Very Suitable
3	Semboja Hill (113° 34' 50" E, 8 26' 15" S)	25-50	3.747	Low Suitable
4	*Love Bay Hill* (113° 25' 04" E, 8° 26' 30" S)	12,5-37,5	6.992	Very Suitable
5	Trate Mountain-2 (113 34 58 E, 8 24 08 S)	6,5-25	9.306	Very Suitable

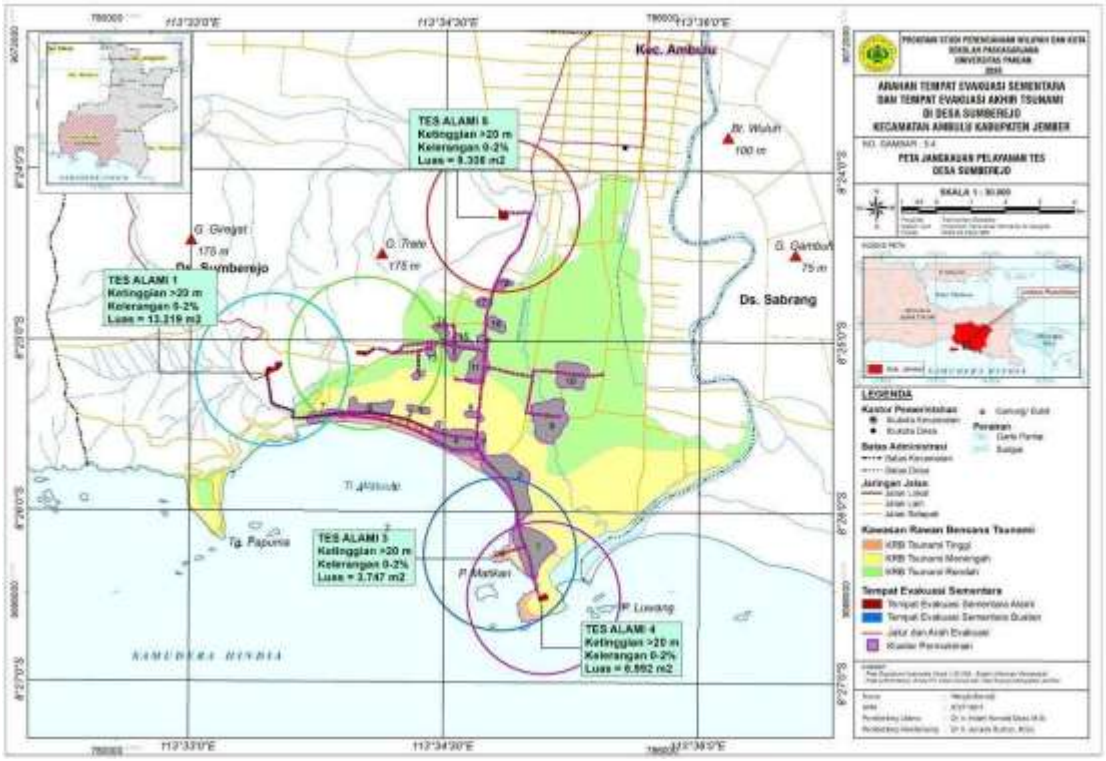

Figure 6 Alternatif Locations TES in Sumberejo Village Ambulu Sub District

The five locations for the development of natural tsunami TES in Sumberejo Village were then assessed for their feasibility using the Technical Guidelines for Designing Hills as Temporary Tsunami Evacuation

Sites (BNPB 2013) with Tsunami TES Planning criteria that include geographical aspect criteria and technical design/design aspects.

In general, the five locations for the development of natural tsunami TES in Sumberejo Village have met the geographical aspect criteria, except for TES Seroja Hilland TES- Love Bay Hill, because they do not meet the criteria (1) far from the potential for large, dangerous debris (2) far from the place where the tsunami wave broke, (3) accessible to people with physical limitations (4) Discussions with community leaders are planned.

Meanwhile, from the technical design/design aspect, all locations for the development of tsunami TES do not meet the technical design/design criteria, because they have not been prepared and planned as tsunami TES. Only TES Semboja Hill and TES Love Bay Hill are relatively free from obstacles, considering that these two hills have been utilized by the surrounding community (Table 5).

Tabel 5 Feasibility of Tsunami TES Development in Sumberejo Village Ambulu Sub District

No	BNPB Criteria	TES Tsunami in Sumberejo Village				
		1	2	3	4	5
Geography Aspect						
1	Travelling time	Y	Y	Y	Y	Y
2	Elevation	Y	Y	Y	Y	Y
3	Poisson material	Y	Y	Y	Y	Y
4	debris potential	Y	Y	N	N	Y
5	Land slide prone	Y	Y	Y	Y	Y
6	Prone to collapse	Y	Y	Y	Y	Y
7	Tsunami wave breaks	Y	Y	N	N	Y
8	Disable people	Y	Y	N	N	Y
9	Social behavior	Y	Y	Y	Y	Y
10	Participatory planning	N	N	Y	Y	N
11	Land ownership	Y	Y	Y	Y	Y
Engineering/Design aspects						
1	Normal person's hiking trail	N	N	N	N	N
2	Disable person's hiking trail	N	N	N	N	N
3	Obstacle free hiking trail	N	N	Y	Y	N
4	Hiking trail width	N	N	N	N	N
	∑ feasible (Y)	10	10	9	9	10
	∑ Not feasible (N)	5	5	6	6	5

Keterangan :
Y= Yes
N = No

4. CONCLUSION

Currently, Sumberejo Village does not have a Tsunami Temporary Evacuation Site (TES) that meets BNPB's technical requirements. The purpose of this study is to determine the location for the development of TES that meets BNPB's technical requirements. By using the variables of height, slope, tsunami-prone areas, liquefaction-prone areas, land use and land ownership status with certain weights, it produces 5 (five) locations that are suitable for the development of natural TES in Sumberejo Village, Ambulu Sub District, namely TES-1 Papuma Hill, TES-2 Trate Mountain-1, TES-3 Semboja Hill, TES-4 Love Bay Hill and TES-5 Trate Mountain-2.

Suggestions:

- Jember Regency BPBD must prepare tsunami evacuation direction signs at the Watuulo-Ambulu road intersection and the Curahrejo Village road to the TES-2 location.
- Further research studies are needed related to the development (planning and construction) of TES in Papuma Cape Hill into a TES that is ready and suitable to accommodate refugees in the event of a tsunami disaster. Further research includes; calculation of TES development space requirements, calculation of clean water and sanitation facilities and infrastructure requirements. Forest area borrowing study, and site planning study.

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