

TSUNAMI DISASTER MODELING FOR NON-MILITARY DEFENSE IN PANGANDARAN REGENCY USING GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT. The tsunami disaster is one of the non-military threats to the State of Indonesia. Pangandaran Regency has a coastline of 91 km which is directly opposite the Megathrust of West-Central Java. The coastal area of Pangandaran Regency is an important center of tourism and economic activity and a high-risk area for tsunamis due to earthquakes. This study was conducted to model the tsunami and analyze the magnitude of the inundation generated in settlements and tourist attractions in Pangandaran Regency as a form of defensive effort in disaster mitigation. The method used is tsunami modeling based on earthquake parameters using winITDB software. After modeling, it will be continued with H-Loss calculations based on tsunami run-up height data parameters, Digital Elevation Model (DEM) data, land use or cover data, and shoreline data using Geographic Information Systems. The results of the tsunami modeling are that the estimation waves height and estimation time arrival from three tide gauges are 15,34 m and 31,13 minutes. The total inundation area is 31.081 ha. The area of inundation according to the classification of land use is the most crucial and includes life, namely settlements and places of activity covering an area of 2.339,2 ha.

Keywords: *Tsunami, Megathrust, winITDB, GIS*

1 INTRODUCTION

The geographical location of Indonesia has positive and negative impacts. One of the negative impacts that often occurs is natural disasters. UU 24 of 2007 represents a disaster as an event or series of events that threatens and disrupts people's lives and livelihoods caused by both natural and/or non-natural factors as well as human factors resulting in human casualties, environmental damage, loss of property, and psychological impacts. Indonesia needs to carry out national defense efforts to anticipate the negative impact. UU No 3 of 2002 describes national defense as all efforts to defend state sovereignty, territorial integrity of the Unitary State of the Republic of Indonesia, and the safety of

the entire nation from threats and disturbances to the integrity of the nation and state. Indonesian National Defense is organized based on a systematic defense system. UU No. 3 of 2002 defines that the national defense system is a universal defense system that involves all citizens, territories and other national resources, and is prepared early by the government and implemented in a total, integrated, directed and continuous manner to uphold national sovereignty, territorial integrity and security. all nations from all threats. This system allows all levels of citizens to be involved in defending the country by utilizing all qualified resources and technology.

Natural disasters are included in the top priority of non-military defense. Minister of Defense Regulation No 54 of

2015 explain non-military defense is carried out by increasing capacity, synergism and the role of Ministries/Agencies (M/A) outside the defense sector as the Main Element in dealing with non-military threats according to the form and nature of the threat, supported by other Ministries/Agencies according to their duties and functions as Other Elements of the National Power. The TNI as Another Element of the Nation's Strength is prepared in an integrated manner to support Ministries/Agencies and Regional Governments in non-military defense. Furthermore, the development of Science and Technology is carried out to increase non-military defense capacity. One of the leading technologies in supporting non-military defense systems in the field of disaster is satellite-based sensing technology which also utilizes geographic information systems.

The tsunami disaster is one of the non-military threats to the State of Indonesia. Megathrust that surrounds Indonesia has the potential to cause a tsunami due to an earthquake. Segmentation with a large subduction Mmax, one of which is Megathrust West-Central Java, namely M 8.7 (Pustlitbang PUPR, 2017). It is feared that the strength of the earthquake will cause a dangerous secondary tsunami disaster. Based on the Indonesian Tsunami Catalog from BMKG in 2019, Indonesia was recorded as having 10 tsunami events that occurred in 1883 to 2018, with the most fatalities. Damaging seismic data on Java Island occurred as many as 48 major earthquakes from 1612 to 2014 (PVMBG, 2014). Several earthquakes with magnitudes greater than 7 are associated with a subduction zone located in the southern part of Java (KR Newcomb and WR McCann, 1987). The subduction zone in the south of Java Island is an active plate boundary that accommodates the collision of the Indo-Australian plate and the Eurasian plate with a normal convergence rate of 58.3 ± 0.5 to 61.8 ± 0.4 mm/year south of West Java (Koulali et al., 2017).

Pangandaran Regency has a long coastline reaching 91 km which is directly opposite the West-Central Java Megathrust. In 2006 there was an

earthquake in Megathrust West-Central Java with a magnitude of 7.7. The earthquake generated a tsunami with an estimated run-up height of around 4 - 6 m (Mori et al., 2007) and claimed 664 lives (BMKG, 2019). Coastal tourism in Pangandaran Regency is a potential economic center and continues to grow from year to year. Data shows the number of tourists coming to Pangandaran Regency in 2019 reached 3,227,296 people and in 2021 it rose to 3,604,128 people (Central Bureau of Statistics for West Java Province, 2021). Based on these data, Pangandaran Regency is the district with the highest average number of tourist visits compared to Tasikmalaya Regency, Garut Regency, Cianjur Regency and Sukabumi Regency. Quoted from detik Jabar Fadillah (2022) on his website www.detik.com noted that based on information from the Regent of Pangandaran Regency, as of 3-8 May 2022 the number of visitors to the tourist attraction reached 665 thousand people. The number of tourist visits consists of tourists to the beach of Pengandaran, Karapyak beach, Batuhiu, Green Canyon and Batukaras, plus data compiled in the Central Bureau of Statistics for West Java Province (BPS), Pangandaran Regency has the number of international and domestic tourists in 2021 as many as 3,604 .128. From these data it indicates that Pengandaran Regency has a very large number of tourist traffic. Quoted from the official website of BPBD Pangandaran Regency, Pangandaran Regency has been intervened by various institutions both domestic and foreign related to disaster socialization by BNPB, the establishment of Tsunami Ready Community by UNESCO IOT, and as a place for academic research in the field of disaster. However, amid the many activities in the disaster sector that have been carried out, Pangandaran Regency does not yet have a Tsunami Disaster Contingency Plan. In fact, the coastal

area of Pangandaran Regency is a crucial center of tourism and economic activity as well as a high-risk area for earthquakes and tsunamis.

Tsunami modeling is done using winITDB software with the advantage of fast data processing. The modeling scenario is determined based on the earthquake parameters which are expected to represent the tsunami accurately. The results of tsunami modeling in the form of tsunami run-up will become data for calculating H-Loss in determining the estimation of inundation in the coastal area of Pangandaran Regency. The H-Loss calculation uses various parameters such as tsunami run-up height data, Digital Elevation Model (DEM) data, land use or land cover data and coastline data. Processing of these parameters is carried out using a Geographic Information System which can combine physical and social phenomena to support an assessment regarding the area of inundated settlements with ideal results. This study was conducted to model the tsunami and analyze the magnitude of the inundation generated in settlements and tourist attractions in Pangandaran Regency as a form of defensive effort in disaster mitigation.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

Pangandaran Regency is one of the regencies located in the south of West Java. The total area of Pangandaran Regency is 1,010.92 km². The population of Pangandaran Regency is 427.61 thousand people with a population density of 423.57 people/km² (BPS Pangandaran Regency, 2022). The geological aspect of the study area is a support in the process of determining the level of vulnerability to a tsunami event. Physiographically, West Java is divided into four zones based on morphology and tectonic characteristics, namely the Bogor zone, the Bandung zone, the Jakarta coastal plain, and the

southern mountainous zone of West Java (Van Bemmelen, 1949). Based on the engineering geological mapping carried out around the Pangandaran coastal area, the geological conditions are dominated by sedimentary rocks, clay rocks, tuffs, sandstones, breccias, and limestones (Sutrisno, 1983 in Budiono & Raharjo, (2016)). Geological structure and seismicity on the Pangandaran coast did not find geological structures in the form of folds and faults, but regionally the southern region of West Java was strongly influenced by the movement of tectonic plates.

This study uses one type of data, namely secondary data. Secondary data is taken from official institutions or agencies including earthquake parameter data, Digital Elevation Model (DEM) data, land use or cover data, coastline data and settlement data. Details regarding data and data sources can be seen in the following table 2-1.

2.2 Sampling Method

The population in this study is the coastal area in the Pangandaran Regency. The sample in this study is an observation area that is determined based on the sample objective (purposive sampling) which focuses on residential areas and tourism. The sample points were determined as many as 3 points spread across the coastline of Pangandaran Regency.

2.3 Work Step

In this study a modification was made to find the run-up height of the tsunami by modeling from earthquakes (BNPB, 2016). Earthquake parameter data is processed by calculating the formula to produce fault length and width as input for tsunami modeling using WinITDB 6.25 which is validated beforehand. Tsunami modeling will produce output in the form of wave propagation time and tsunami run-up height. The modeling output becomes one of the H-Loss calculation inputs along with other parameters such as

Digital Elevation Model (DEM), land use or cover, coastline to produce accurate inundation areas. The H-Loss calculation results are then integrated

with settlements in the coastal area of Pangandaran Regency. Tsunami modeling and H-Loss calculations can be seen in the description of Figure 1.

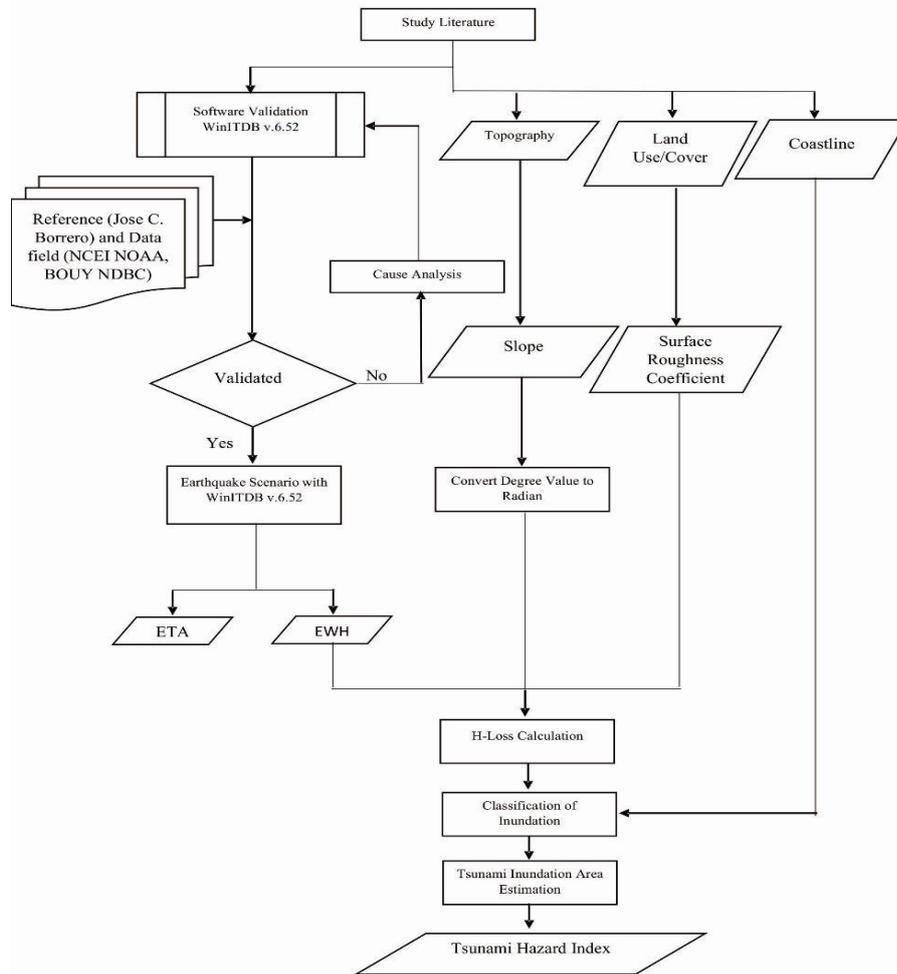


Figure 2-1. Flow Chart

2.3 Methods

The data analysis method used is quantitative analysis which interprets the results of tsunami modeling and H-Loss calculations. Tsunami modeling produces wave propagation time and tsunami run-up height. The H-Loss calculation will produce a tsunami hazard index. These results became the initial assessment of disaster mitigation to strengthen the non-military defense of the tsunami disaster in Pangandaran Regency. Details of tsunami modeling and calculation of H-Loss can be seen in the following description:

A. Tsunami Modeling

At the tsunami modeling stage, it was carried out using the WinITDB v.6.52 application. Application validation was carried out prior to tsunami modeling to strengthen the output results and determine the accuracy of the WinITDB v.6.52 application. The validation process is carried out by comparing EWH (Estimated Wave Height) data from modeling results with wave run-up from field observations and research data, namely data from research results from (Borrero et al., 2015), NCEI-NOAA data, and BOUY NDBC. The validation process uses the field benchmark method and approaches using equations (Aida, 1978), which is the process of comparing field data with simulated data and verifying the level of accuracy of the

simulation results. Equality (Aida, 1978) can be shown as follows:

$$K_i = \frac{x_i}{y_i} \dots\dots\dots(1)$$

$$\text{Log } K = \frac{1}{n} \sum_{i=1}^n \log K_i \dots\dots\dots(2)$$

$$\text{Log } k = \left[\frac{1}{n} \sum_{i=1}^n (\log K_i)^2 - (\log K)^2 \right]^{1/2} \dots\dots(3)$$

The tsunami modeling phase uses earthquake parameter data from Global CMT earthquake historical data. These parameters consist of magnitude, depth, longitude and latitude. Apart from these earthquake parameters, there are other parameters that need to be entered into the source parameters of the Win.ITBD v.6.52 application, including the coordinates of the earthquake, the length and width of the fault and the azimuth angle. In determining the length and width of the fracture can use the equation (Papazachos et al., 2004) as follows:

$$\text{Log } L = 0.55 M - 2.19 \dots\dots\dots(4)$$

$$\text{Log } W = 0.31 M - 0.63 \dots\dots\dots(5)$$

where L is the reapture length (km), W is the reapture width (km), while to determine the average displacement or dislocation, the following equation can be used:

$$\text{Log } U = 0.64 M - 2.78 \dots\dots\dots(6)$$

Then in finding the azimuth value it will always be related to the strike angle, which can be found using the equation:

$$\text{Azimuth} = 360^\circ - \text{angle strike}^\circ \dots\dots(7)$$

Tsunami modeling was carried out using winITDB v.6.52 software with fault parameter data input. After entering the data, modeling can be carried out and will produce data in the form of estimated wave heights and estimated wave arrival times. The following is an earthquake scenario used in the research:

B. H-Loss Calculation

This study applies H-Loss calculations based on Berryman's

Description:

K_i = average comparison of field data with modeling data

x_i = tsunami height field data

y_i = tsunami height estimation data from modeling results

analysis which is the reference in Perka No. 2 BNPB 2012 namely National Guideline for Tsunami Disaster Risk Assessment (BNPB, 2016). In the Perka, Berryman has determined the value of the roughness coefficient (n) according to the type of land cover or use, as follows:

H-Loss is the loss of tsunami height per 1 m of induction distance (inundation height) based on the distance to the slope and surface roughness (BNPB, 2016). The H-Loss calculation formulated by Berryman in Perka No. 2 BNPB concerning National Guidelines for Tsunami Disaster Risk Assessment (BNPB, 2016) is as follow:

$$H_{loss} = \left(\frac{167 n^2}{H_0^{1/3}} \right) + 5 \text{ Sin } S \dots\dots(8)$$

description:

H_{loss} : loss of tsunami height per 1 m of induction distance

n^2 : surface roughness coefficient

$H_0^{1/3}$: tsunami wave height along the coast (m)

S : magnitude of surface slope (degrees)

The run-up height from the tsunami modeling using winITDB v.6.25 software is the height of the tsunami waves near the shoreline (H_0). The run-up height used as input for calculations in this study is the average run-up height of the three sample points for each scenario.

Table 2-1: Data and Source Data

No	Data	Data Cirteria	Time	Data Source
1	Historical Sunda Strait Earthquakes	>6 M – 9 M	1977-August 2019	The United States Geological Survey (USGS)
2	Earthquake Paramaters	>6 M, Latitude: -10, -5 Longitude: 100, 110 Depth: 1000	1977-August 2019	Global Centroid Moment Tensor (Global CMT)
3	Digital Elevation Model (DEM)	Topography Batimetri	2020	Geospatial Information Agency (BIG)
4	Land Use or Cover	Shapefile	2014	Geospatial Information Agency (BIG)
5	Coastline	Shapefile	2014	Geospatial Information Agency (BIG)

Table 2-1. Tsunami Modeling Scenario

Fault	Value
Latitude ($^{\circ}LS$)	-9.1400
Longitude ($^{\circ}BT$)	107.8200
Lenght (km)	393.55
Wide (km)	116.68
Dislocation/slip (m)	6.13
Magnitude (Mw)	8.7
Strike ($^{\circ}$)	287
Dip ($^{\circ}$)	70
Slip ($^{\circ}$)	-97
Depth (km)	20.6
Azimuth ($^{\circ}$)	73

Source: earthquake history USGS, (Papazachos et al., 2004), Global CMT, (Pustlitbang PUPR, 2017).

Table 2-3. Coefficient Value of Type Land Use or Cover

Land Use or Cover	Roughness Coefficient Value (n)	
	n	n ²
Water	0.007	0.000049
Shrubs	0.04	0.0016
Forest	0.07	0.0049
Garden/Plantation	0.035	0.001225
Open Vacant lots	0.015	0.000225
Farmland	0.025	0.000625
Settlements/Built-up Lands	0.045	0.002025
Mangrove	0.025	0.000625
Pond	0.01	0.0001

Source: Berryman, 2006 in (BNPB, 2016)

3 RESULTS AND DISCUSSION

This research is different from previous research which has determined the tsunami height from historical tsunamis by comparing three types of Digital Elevation Model data in Pangandaran Regency (Ikhwandito et al., 2018). Based on this research, the highest tsunami height scenario is 15 m and produces an inundation of 2025.35 ha for the TerraSAR DEM, 4279.23 ha for the ASTER DEM, and 4027.33 ha for the SRTM DEM. Subsequent research discusses the propagation and determination of the run-up height of the tsunami in Pangandaran bay using the COMCOT software (Aeda et al., 2017). The earthquake's strength parameter is 8.0 Mw. The simulation results of the travel time of the tsunami waves to reach land ranged from 39 minutes - 43 minutes with the maximum height of the tsunami occurring in the range of 44 minutes - 47 minutes. The maximum tsunami run-up height is 9.13 m. Subsequent research reconstructed the tsunami that occurred on 17 July 2006 (Alfaris et al., 2020). The tsunami was caused by an earthquake with a magnitude of 7.7 resulting in the arrival time of the first wave 30 minutes after the earthquake occurred. Same with previous research, research (Khoiridah, 2014) also reconstructed the 17 July 2006 tsunami. The study applied the IRIS scenario which describes the direction of the fault plane to the North-South with an earthquake of 7.7 on the Richter scale. The duration of the tsunami lasted 144.82 seconds.

This research started with tsunami modeling to find the height of the tsunami run-up with one type of Digital Elevation Model data, namely the Digital Elevation Model National issued by BIG with a resolution of 5 m. The modeling scenario uses historical earthquakes with the largest magnitude of 7.7 on the

Richter scale to determine the epicenter. However, the earthquake parameter used for the magnitude of the earthquake was 8.7 Mw which was taken from the National Center for Earthquake Studies in 2017. The research was carried out in two stages, namely tsunami modeling to calculate the Estimated Wave Height (EWH) and Estimated Wave Time (ETA). The next stage is the calculation of H-loss to calculate the area of tsunami inundation on land use on the coast of Pangandaran Regency.

The tsunami simulation was carried out in Pangandaran Regency based on earthquake parameter data with the epicenter point in the megathrust zone south of Java Island. The results of the simulation are in the form of recorded mareograms consisting of Estimated Wave Height (EWH) and Estimated Wave Time (ETA). The shape of the tsunami propagation can be determined based on the parameters of the earthquake that caused the tsunami. The interpretation of the level of hazard generated by a tsunami can be determined based on the EWH. The simulation phase was carried out using winITDB ver. 6.52 previously validated the software with the aim of assessing the level of accuracy of the software in conducting tsunami simulations. This process is carried out by comparing the tsunami height field data with the simulation results in the winITDB software and approaching it using the Aida (1978) with the aim of determining the level of accuracy of a model. Validation data uses height parameter data from references and field data and tsunami height from simulations.

Validation was carried out using field data comparison methods and validation with the equations made by Aida (1978). The equation is an equation to verify a form of simulation or can be used to measure the accuracy of a

simulation using two parameters, namely K and k. K is the average comparison of field data with modeled data and k is the standard deviation. The input used in this equation is x_i which is the tsunami height data from the results of field data or references, and y_i is the estimated tsunami height data from the simulation results.

The table 3-1 shows the validation results using the Aida (1978) equation which found that in the 2004 Aceh tsunami height estimation data, the simulation results were validated with tsunami height field data (K values: 1.144195 and k: 1.009912411), with an average error rate of 35%. Whereas in

the 2011 tsunami in Japan, the tsunami height estimation results were validated with tsunami height field data (K value: 0.99166 and k: 1.00011997), with an average error rate of 2%. in the 2004 Aceh tsunami data were validated because there were some field data located in coastal areas. So that WinITDB v.6.52 can still record or read the data, although there are some other data caused by shifting observation points that are on land. The most validated data is the 2011 Japan tsunami event, because the data obtained from BOUY data recordings on the high seas. Therefore, WinITDB v.6.52 can produce more accurate data than other field data.

Table 3-1. Validation of Tsunami Height Estimation Data from Simulation Results with Tsunami Height Field Data Using the Aida Equation (1978)

Tsunami Events Due to Earthquake	Validation Comparison	K	k	K Value Validation	K Value Validation	Description
Aceh 2004	Data Field NCEI NOAA	1.144195	1.009912411	Validated	Validated	Validated
Jepang 2011	Data Field Jose C. Borrero (2015) and BUOY NDBC NOAA	0.99166	1.00011997	Validated	Validated	Validated

The validation results that have been carried out using both the comparison method and the accuracy equation of a model show that there are differences between the validation results using field data and BUOY data. This results in an assumption that the level data, which is the estimated tsunami height from the WinITDB v.6.52 simulation results, is influenced by the location of the observation station points, the epicentre of the earthquake and the type of ocean or coastal bathymetry. This can be shown from the results of the average error rate that the BOUY data has a very small value compared to other field data, which is 2%. The results of tsunami modelling using WinITDB v6.52 can be seen in the following figure:

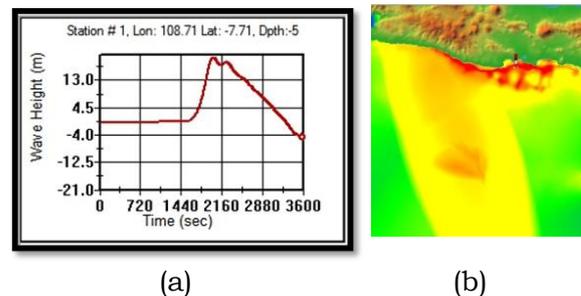


Figure 3-1. Tide Gauge at station T1

The results of the scenario at the observation station point T1 with an earthquake strength of 8.7 Mw, the highest tsunami waves occur in the first wave. The wave run-up height is 20.21 m with a arrival time of 33.6 minutes. Then the second wave came with a run-up height of 19.87 m with an arrival time of 34.08 minutes. The tsunami waves continued to descend and were not detected by observation stations after the arrival of the second wave. This happens because the waves have passed

the observation station and are blocked by the morphology of the beach.

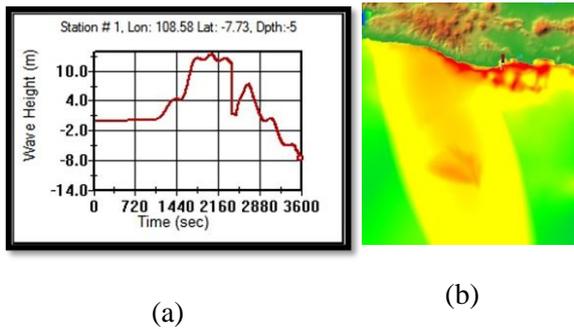


Figure 3-2. Tide Gauge at station T3

The scenarios at observation station point T2 with an earthquake magnitude of 8.7 Mw produced several wave heights. The results of the scenario at observation station point T2 with the highest tsunami wave occurred in the third wave. The wave run-up height was

13.46 m with an arrival time of 33.9 minutes. At observation station T2 the first wave arrived with a run-up height of 4.29 m and an arrival time of 24.16 minutes. The second wave run-up height was 11.81 m with an arrival time of 28.78 minutes. The fourth wave run-up height was 11.95 m with an arrival time of 36.07 minutes. The fifth wave run-up height was 7.37 m with an arrival time of 44.68 min..

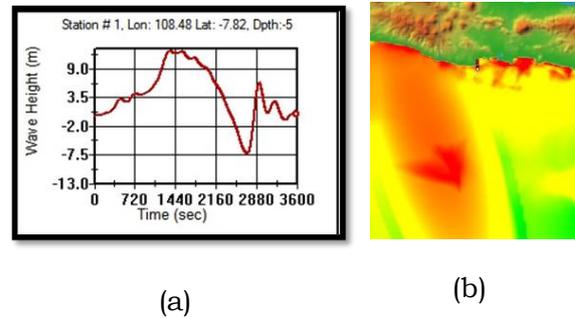


Figure 3-3. Tide Gauge at station T3

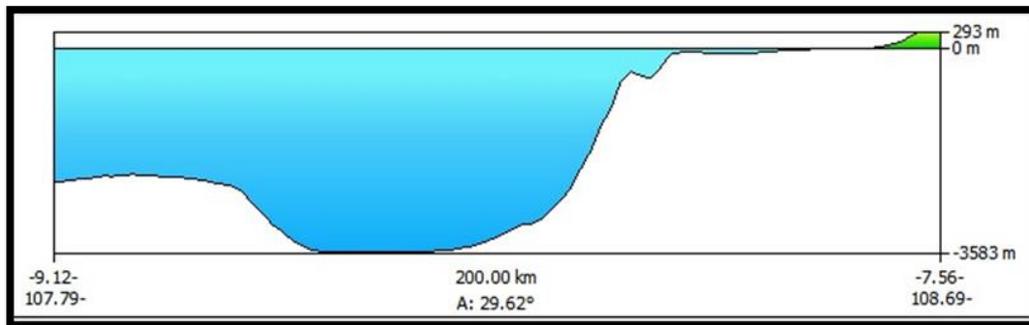


Figure 3-4. Bathymetry Profile

The scenarios at observation station point T3 with an earthquake magnitude of 8.7 Mw produced several wave heights. The results of the scenario at observation station point T3 with the highest tsunami wave occurred in the third wave. The wave run-up height was 12.36 m with an arrival time of 25.9 minutes. At observation station T3 the first wave arrived with a run-up height of 3.19 m and an arrival time of 8.20 minutes. The sixth wave experienced a significant decrease in height of -7.24 m at 45.26 minutes. The wave then rose again with a run-up height of 6.38 m at 48.92 minutes. From the simulation results, three observation stations with different coordinates were determined. The tsunami run-up height for each point is 20.21 m, 13.46 m and 12.36 m, respectively. These heights are

influenced by coastal bathymetry, coastal slope and epicentre distance.

The height of the tsunami occurred due to the concave bathymetry profile measured from the epicentre to the Pangandaran coast. Tsunamis that propagate from the epicentre initially have a high speed, which is influenced by the depth of the sea, so that they form long waves. As it approaches the coast, the wave speed decreases, which then changes to the tsunami run-up height. The propagating waves are suddenly compressed due to the collision with the existing bathymetry and the change of kinetic energy into potential energy. The slope that has the most influence on tsunami run-up height is the flat slope classification of 0

- 8%. The inundation area in this classification is 17,267.2 ha. This flat slope classification is located on the coast of Pangandaran Regency,

especially in the concave morphological area that protrudes inward. This further increases the tsunami inundation area.

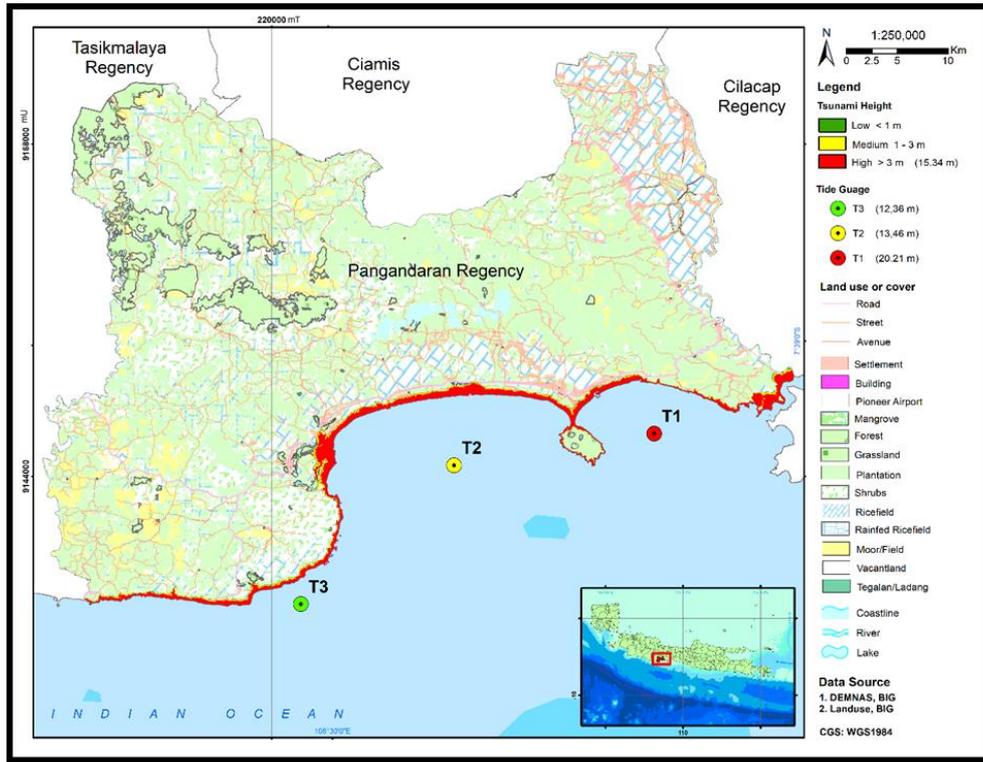


Figure 3-5. Map of The Potential Tsunami Zone Pangandaran

Table 3-2. Affected Land Use or Cover

No	Land Use or Cover	(m)	(ha)
1	Rainfed Rice	136934000	13693.4
2	Moor/Field	25880000	2588
3	Rainfed Rice Fields	70000	7
4	Paddy	42623000	4262.3
5	Pioneer Ajr Lkr	239000	23.9
6	Buildings	88000	8.8
7	Lake/Situ	766000	76.6
8	Meadow	8926000	892.6
9	Mangroves	19150000	1915
10	Forest Jungle	10275000	1027.5
11	Shrubs	12822000	1282.2
12	Settlements and Places of ac	23392000	2339.2
13	River	20664000	2066.4
14	Pond	3094000	309.4
Total		304923000	30492.3

Source: Research result

The height of the tsunami run-up affects the calculations that result in the inundation area. Observation station point one detected the highest run-up height of 20.21 m with a station distance from the epicentre of 224.709 km. The second observation station detected a run-up height of 13.46 m with a station distance from the epicentre of 214.753 km. The third observation station detected a run-up of 12.36 m with a station distance to the epicentre of 199.85 km. This study took the average value of tsunami run-up height from the three observation stations. The average tsunami run-up height from the three observation stations was 15.34 m. The classification of run-up height is divided into three, namely high > 3 m, medium 1-3 m and low < 1 m. The inundation resulting from the run-up height of 15.34 m was 31,081 ha with an average arrival time of 31.13 minutes. The inundation inundated the land use or land cover in

coastal Pangandaran Regency with the following details.

The most affected land use in coastal Pangandaran Regency is plantation, which is 13,693.4 ha. Followed by paddy fields with an area of 4,463.3 ha. The next affected land use is settlements and activities with an area that occupies the third position, namely 2,439.2 ha. The least affected land use is buildings and structures with an area of 8.8 ha. Based on these results, the tsunami hazard in Pangandaran Regency is very high. Tsunami poses the greatest threat to people living in the coastal areas of Pangandaran Regency.

4 CONCLUSIONS

Defense science really takes into account threat assessment, in this case, disaster threats to facilitate strategy formulation and reduce the negative impacts that may arise. This study modelled a tsunami with a magnitude of 8.7 Mw. The tsunami run-up height and mean arrival time of the three observation stations were 15.34 m and 31.13 min, respectively. The total inundation area is 31,081 ha. The inundation area according to the classification of the most crucial and life-encompassing land use, namely settlements and places of activity, is 2,439.2 ha. The results of this study can be used as a basis for non-military defence that can provide basic information for the formulation of disaster mitigation strategies in Pangandaran Regency. Non-military defence against tsunami disaster in Pangandaran Regency needs to be conducted on an ongoing basis. based on these results, the tsunami hazard in Pangandaran Regency is very high. Tsunami is the biggest threat for people living in the coastal areas of Pangandaran Regency.

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