JPIS (Jurnal Pendidikan Ilmu Sosial)

Journal homepage: https://ejournal.upi.edu/index.php/jpis

# Mapping the Potential and Risk of a Tsunami Disaster in Pangandaran with Socio-Spatial Analysis Emphasizes

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## ABSTRACT

Pangandaran Regency, West Java, is one of the districts in the South Sea (Indian Ocean) crossed by the Pangandaran Fault. This means that Pangandaran province is frequently hit by earthquakes and at risk of tsunamis, as it is directly adjacent to the sea. The people of Pangandaran Province will be faced with efforts to prevent and mitigate disasters, especially earthquakes and tsunamis. These efforts should be based on spatial analyzes that reflect the actual spatial conditions on site. Mapping will be carried out in a participatory manner by the community, accompanied by a technical team. In this study, tsunami modeling or tsunami potential modeling was conducted, which consisted of physical mapping, socio-cultural spatial mapping, and evacuation route mapping. Ultimately, it is hoped that the information in the form of a tsunami risk map will inform the people of Pangandaran Province about the risk status of tsunami attacks in their area. Therefore, the range of the tsunami danger zone is set at 40 meters, and the distances are set at 5 meters, 15 meters, 25 meters, and 40 meters, respectively. The overlay is done by combining maps processed with data from the survey results.

## ARTICLE INFO

***Article History:***
*Submitted/Received; 20 Jun 2024*
*First Revised; 06 Jul2024*
*Accepted; 08 Oct*
*First Available online; 30 Des 2024*
*Publication Date; 30 Des 2024*

***Keyword:***
*Disaster, Mitigation, Pangandaran, Tsunami Inundation.*

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## 1. INTRODUCTION

From a geoscience perspective, Indonesia is an attractive region. This condition is part of the meeting of three major plates: the Indo-Australian plate, the Eurasian plate, and the Pacific plate. The impact of this phenomenon in Indonesia has great potential to cause disasters. One of the common disasters in Indonesia is earthquakes that can cause tsunamis. Earthquakes are true vibrations from within the Earth that originate within the Earth and spread to the Earth's surface through violently breaking and shifting cracks in the Earth (Abe,T., Goto, K. and Sugawara, D., 2020). Tsunamis usually occur when an earthquake occurs with large vertical motions on the ocean floor. Tsunamis can also occur in the event of a volcanic eruption or an avalanche at sea. Java Island is Indonesia's largest island and has high earthquake resistance. (Mardiatno, et al. 2020; Martha Alvianingsih et al 2021; Mori, J., 2007; Pranantyo, et al, 2021; Priadi, R et al, 2020; Reese, S. et al 2007; Riyanto, A. M., 2023). Structurally, Java is an island affected by the subduction of the Indo-Australian plate extending into the Eurasian plate. This subduction zone occurs approximately 200 km off the southern coast of Java at a rate of 7 cm per year. An interesting region of Java worth exploring is the geographical location of West Java. Rather than being influenced by the world's wide range of plates, the West Java region is also influenced by east-west fault structures, and most of the fault types are reverse faults, which are slip faults. The three territorial structures that affect West Java province are Cimandiri, Balibis, and Lembang. Although the Pangandaran storm surge is not particularly large, it may be a high wave earthquake that has the characteristics of causing a huge storm surge (Baba T, et al 2017;BNPB, 2023; Djati Mardiatno, et al, 2020; Faiqoh I. et al, 2014). On July 17, 2006, an earthquake occurred south of Pangandaran Beach. The National Earthquake Center of the Meteorology and Geophysics Agency announced that the earthquake that occurred at 3:19 pm in the Pangandaran Beach area occurred on April 17, 2019. The earthquake had a magnitude of 6.8 on the Richter scale (SR), and the epicenter was at 9.4 degrees south latitude and 107. 2 degrees east longitude at a depth of less than 30 km. The exact epicenter of the earthquake was approximately 150 kilometers south of Pamumpuk, in the zone where the Indo-Australian and Eurasian tectonic plates meet at a depth of less than 30 kilometers (Yusdian, et al, 2023). The earthquake also triggered a tsunami that hit the southern coast of West Java, including Silauturung Ciamis, the southern coast of Cianjur, and Sukabumi. The tsunami also hit Cilacap and Kebumen beaches in central Java and the southern coast of Yogyakarta's Bantul. In the Isthmus, part of 300 kilometers of the southern coast was hit by high waves. Of the 668 confirmed deaths, 413 (130 men, 205 women, and 78 children) occurred in and around the resort. Waves up to 5 meters high flooded Pangandaran up to 400 meters inland [20][21][22]. There was severe damage to almost all buildings within a few hundred meters of the coast, consisting mainly of his one-story and his two-story buildings made of unreinforced clay brick. The damage consisted of collapsed partitions, partitions with large gaps where windows and entrances once were, and huge piles of flotsam and jetsam made up of building structures and small pontoons. In this study, tsunami modeling or tsunami potential modeling was conducted, which consisted of physical mapping, socio-cultural spatial mapping, and evacuation route mapping.

## 2. LITERATURE REVIEW

### 2.1 Disaster

Mitigation is a series of efforts to reduce the risk of disasters, either through physical development as well as awareness and capacity building facing the threat of disaster (BNPB:

DOI: https://doi.org/10.17509/jpis.v32i1.55969
e-ISSN: 2540-7694 |p-ISSN: 0854-5251

2012). Disaster is an event or series of events that threatens and disrupt people's lives and livelihoods due to both factors. natural, non-natural factors and human factors. Thus, resulting in the emergence human casualties, environmental damage, property losses and impacts psychology. (Suratman Woro Suprojo, Proceedings of Remote Sensing and Systems Geographic Information 2012). Disasters can be fires, tsunamis, earthquakes, volcanic eruptions, floods, landslides, tropical storms, and others. According to Law Number 24 of 2007, it is stated that the meaning of mitigation can be defined as a series of efforts to reduce disaster risk, either through physical development as well as awareness and capacity building facing the threat of disaster. Disaster mitigation is a term used to refer to all ctions to reduce the impact of a disaster that can be taken beforehand when a disaster occurs, including preparedness and risk reduction measures long term (Maryani: 2002). According to Article 1 paragraph 6 PP No. 21 of 2008 concerning Implementation Disaster Management Disaster mitigation is a series of efforts to reducing disaster risks, both through physical development and awareness and increasing capacity to face disaster threats. Disaster mitigation activities including: Disaster risk recognition and monitoring;Participatory disaster management planning; cultural development disaster aware;Application of physical, non-physical efforts and disaster management arrangements;Identification and recognition of sources of danger or threat of disaster;Monitoring natural resource management;Monitoring the use of high technology;Supervision of the implementation of spatial planning and environmental management life;Other disaster mitigation activities. Disaster risk monitoring can be done through disaster risk mapping. Disaster risk mapping can be assessed based on the size of the threat level and vulnerability in a region. Disaster risk mapping can be carried out analysis using a Geographic Information System (GIS) based mapping method.

**2.2 Tsunami**

A tsunami is a sea wave that occurs due to impulsive disturbances on the sea. Tsunami waves have speeds between 500 and 1,000 km/hour(approximately 0.14-0.28 kilometers per second) in open water. Nevertheless, Tsunami events can still be detected early, namely by detecting vibrations. The earthquake caused the tsunami. Earthquake vibrations have a speed of about 4 kilometers per second (14,400 km/h). Earthquake vibrations are detected more quickly rather than tsunami waves, it is possible to make tsunami forecasts, so that Early warnings can be immediately announced to areas in danger tsunami. Then you can immediately take steps to prevent casualties lives, by evacuating residents to areas that are safe from the threat of a tsunami. The field of study for tsunami disaster mitigation includes assessment disasters, warning guides and emergency response education and training. Tsunami Disaster Assessment: Tsunami disaster assessment is needed to identify population areas at risk of being affected. Historical data on past tsunami events serves as Empirical methods in identifying dangerous areas. Tsunami Disaster Warning: The second element of this conceptual model is an appropriate warning system to inform people on the coast that a tsunami could occur suddenly. In the Pacific, depending on the source of the earthquake that generates it, tsunamis can occur classified into three types, which are then expressed into three time systems warning, namely:1 hour warning system (area distance >750 km from the earthquake source);Regional warning system; i.e. within 10 minutes (the distance the area is

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e-ISSN: 2540-7694 p-ISSN: 0854-5251

located between 100-750 km from the earthquake source);Local warning system:(area distance)These three systems are very relative and vary from place to place due to distance the source of the earthquake, the size of the earthquake source and the speed of propagation of the tsunami wave. It varies greatly in each place depending on the characteristics of the place (island distribution, bathymetry and coastline configuration). These three warning systems using earthquake magnitude as a warning trigger and tide gauge recede to verify that a tsunami exists. This is because the system is activated by the magnitude of the earthquake and not all earthquakes can generate tsunami so that false alarms can be avoided. Emergency Response and Education in Facing the Tsunami Disaster The right reaction in facing a tsunami disaster requires: Knowledge of areas that can be hit/swept away by waves tsunami (from disaster risk map);Knowledge of warning systems (when it is time to evacuate and when the area is safe to re-occupy) Without the two knowledge above,the reaction that arises becomes less appropriate and mitigation of the tsunami impact becomes fail. For this reason, the production of disaster risk maps must be socialized and used as material in training or emergency response systems for tsunami disasters. Apart from that, map standardization is also needed in the form of uniform markings for zone, affected by the tsunami and zone for evacuation. Evacuation routes are routes intended to get people to move respond when a disaster occurs and not panic when a disaster occurs but can position what they will do by looking at the direction of the arrow or another sign to reduce the number of victims caused by panic when it occurs disaster. Determining evacuation route points and assembly points is designing an evacuation map by determining the shortest path towards the assembly point. Determining the shortest path pay attention to alternative routes that can be taken to the gathering point (assembly point). The shortest distance is the fastest path to the point assemble (assembly point). There is a map of evacuation routes, namely in the form of arrows. Evacuate to the designated place (arrow) . Simulation models will also carried out to evaluate the direction of the route in the implemented evacuation route map. Designing an evacuation route map is by determining the trajectory using using arcgis software.

## 3. METHOD

Pangandaran is located on a peninsula on the south coast of Indonesia's West Java province. Pangandaran Regency is one of the areas at high risk of tsunami disasters in the South Java Sea, as it is located in the subduction zone between the Indo-Australian plate and the highly active Eurasian plate. The South Java Sea subduction zone is a source of tectonic earthquakes and a potential source of tsunamis. This can be seen in historical tsunami events in southern Java, such as September 11, 1921 (M7.5) and July 17, 2006 (M7.7), both of which included Pangandaran province. It affected several areas in southern Java. Apart from this, almost the entire coast of Pangandaran province is a tourist destination for domestic and foreign tourists. According to the Indonesia National Disaster Management Agency's report from 2015 to 2023, Pangandaran's disaster risk index value ranges from 129.21 to 215. 20, which puts it in the medium to high risk zone.

DOI: https://doi.org/10.17509/jpis.v32i1.55969
e-ISSN: 2540-7694 |p-ISSN: 0854-5251

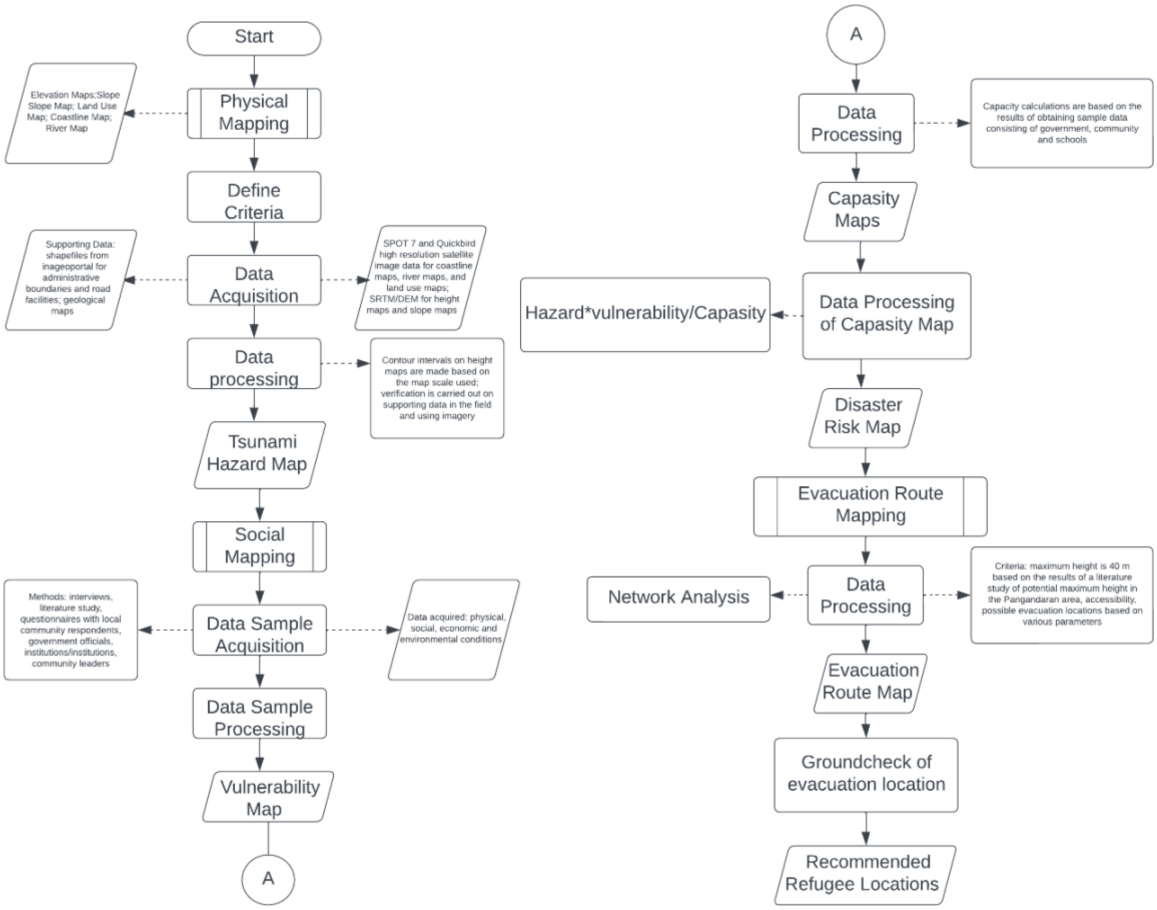


**Diagram 1. Research and Workflow**

The purpose of evacuation route planning is to minimize the negative effects of a disaster and find the shortest route to safety for people living in disaster-prone areas. Evacuation routes in the event of a disaster are determined based on the condition of the road network, place of residence, areas where disasters are unlikely to occur, distance to disaster-prone areas, land use of evacuation sites, etc. Before conducting research surveys at the archaeological sites in Pangandaran region, experts first collected secondary data. Secondary data needs are used to create tsunami hazard maps using scoring and weighting methods. This data includes road network maps, land use maps, slope maps, elevation maps, river network maps, coastline maps, administrative boundary maps, and rapid bird satellite imagery. A social survey was conducted to spatially support social, economic and cultural factors. Its purpose is to obtain data that is later processed into processing power and vulnerability maps. This social survey was conducted by visiting each resident's home and conducting interviews. The results of the social survey are vulnerability and capacity maps created based on interview responses from local communities, schools, and government (village offices). The method used is the same scoring and weighting method used to create hazard maps. Interview results contain valuable aspects when creating capacity maps.

## 4. RESULTS AND DISCUSSION

Based on the tsunami inundation model with a tsunami wave height (tsunami run-up) of 40 meters, the results of the Pangandaran tsunami hazard index map were determined.Depending on the tsunami hazard zone category, you will get three zones: low hazard risk zone (green zone), medium hazard risk zone (yellow zone), and high hazard risk zone (red zone). These zones can be used to estimate the expected loss of property, objects,

DOI: https://doi.org/10.17509/jpis.v32i1.55969
e-ISSN: 2540-7694 p-ISSN: 0854-5251

and lives in each zone, as well as land cover and population data, assuming no measures are taken to contain or manage the tsunami disaster. An analysis is performed to calculate. The number of residents and tourists in the tsunami hazard area are taken into account.

One of the important maps as basic data for processing to analyze the degree of tsunami risk in a region is a land slope map, and elevation is important for the speed of water moving over the earth's surface. A land slope map can be created by creating a detailed situation map and conducting a field soil survey using the land method. When delineating the tsunami risk zone, the parameters are based on past events, i.e. during the magnitude 6.8 SR earthquake. Therefore, the range of the tsunami danger zone is set at 40 meters, and the distances are set at 5 meters, 15 meters, 25 meters, and 40 meters, respectively. The overlay is done by combining maps processed with data from the survey results. Creating an evacuation route We will create an evacuation route based on the results of a disaster risk map divided into three levels: high, medium and low. The purpose of evacuation route planning is to minimize the negative effects of a disaster and find the shortest route to safety for people living in disaster-prone areas. Evacuation routes in the event of a disaster are determined based on the condition of the road network, place of residence, areas where disasters are unlikely to occur, distance to disaster-prone areas, land use of evacuation sites, etc.

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As part of this study, various parameters, socio-spatial data and maps were identified, especially tsunami hazard area maps. These maps show that the areas marked with red symbols are the areas most affected by the tsunami within the danger zone. Part of Chikemburan, Pangandaran, Pananjung, and Babakan villages. The threat level tends to increase at lower altitudes, and conversely, the threat level decreases as surface height or elevation increases or as obstacles such as dense vegetation or obstacles are present on the surface. In this study, data analysis revealed that not only locations that tend to be close to the ocean, but also locations that are spatially distant from the ocean, may be at the same risk. Some land areas are close to the sea, but analysis suggests zones of moderate to low risk. Further analysis of this revealed that the area was at a high altitude. Another finding is that despite the long distance between the coast and the sea, the velocity increases when a tsunami reaches land that does not have land cover in the form of vegetation or objects other than obstacles. The threat will increase, the presence of rivers that cause the acceleration of

DOI: https://doi.org/10.17509/jpis.v32i1.55969
e-ISSN: 2540-7694 |p-ISSN: 0854-5251

tsunami water. The next analysis performed was to calculate the number of affected buildings located in the danger zone, medium danger zone and low danger zone along the Pangandaran beach line. A total of 630 buildings were found to be in danger zones. This is certainly a good insight as disaster planning and mitigation processes can be carried out based on the results of this insight.

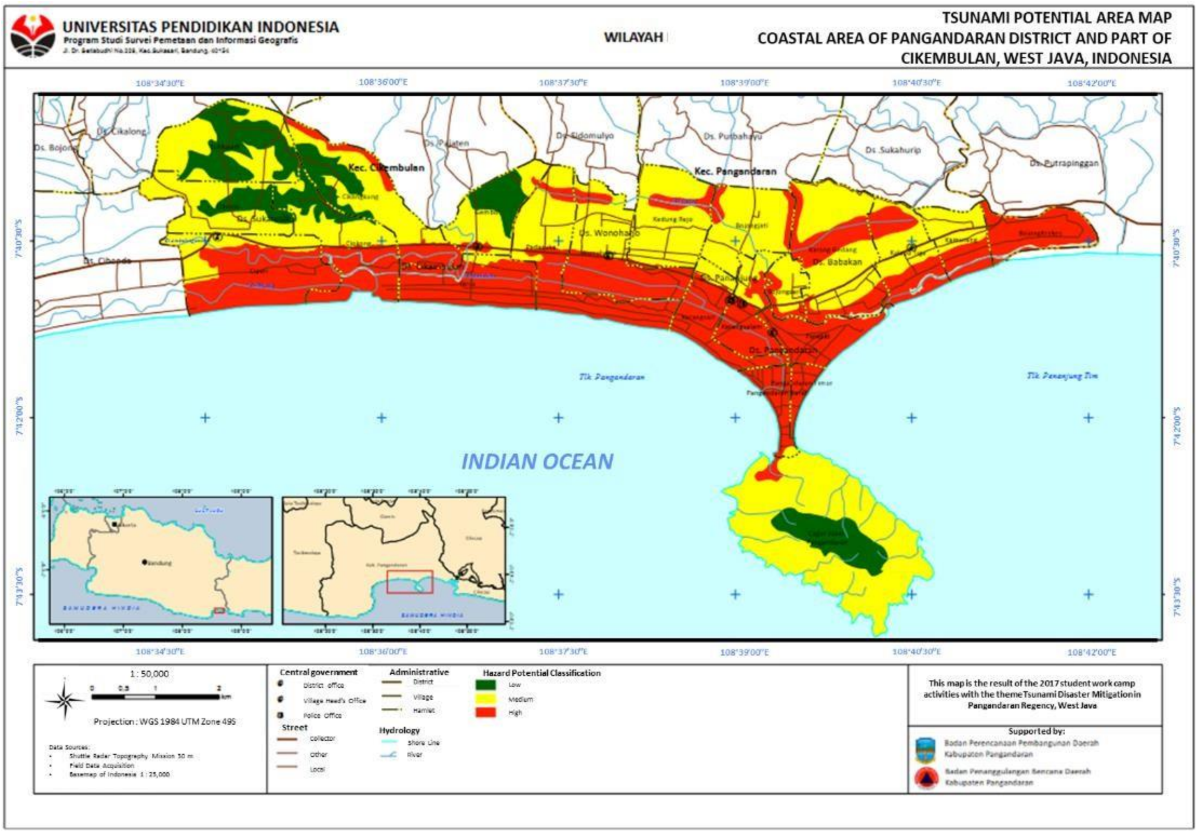


**Diagram 1. The Map of Tsunami Potential Area in Pangandaran**

Both are recommendations regarding evacuation routes, plans for the construction of building structures, plans for the construction of special shelters, installation of tsunami warning devices in strategic locations, and placement of damage prevention elements before, during and after a disaster. Infrastructure development is also adapted to the results of threat maps and vulnerability maps based on physical and socio-cultural spatial aspects. This includes the process of land use mapping, particularly the implementation of ground management and spatial analysis related to the number of public facilities within the hazard zone. 120 public facilities were determined to be potentially affected and in danger zones. This is important not only for calculating post-disaster impacts, but also for planning the relationship between the structure and human, physical and environmental impacts of nearby public infrastructure equipment.

## 5. CONCLUSION

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