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MAPPING OF TSUNAMI VULNERABILITY POTENTIAL IN SABANG CITY, ACEH PROVINCE

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ABSTRACT : This research addresses the tsunami risk vulnerability of Sabang City, Aceh, which is located near the Sumatran megathrust zone, one of the areas of highest seismic activity in the world. Sabang City is at high risk of tsunamis, with most of its area falling within the high to very highrisk zone. Through a Geographic Information System (GIS) approach, this study analyzed five main parameters: slope, elevation, land use, distance from coastline and distance from river to map tsunami vulnerability and evacuation routes. The analysis showed that more than half of Sabang City falls into the high and very high tsunami vulnerability categories, emphasizing the importance of effective mitigation and preparedness strategies. The evacuation route mapping produced in this study depicts five routes in Sabang City, Route 1 is the longest route, 35.21 km long and passes through eight villages in the eastern part of the city. Route 2 is the shortest route with a length of 0.85 km, located only in Iboih village in the northwest. Route 3 is 2.13km long and runs along the border between BateeShok and Paya Seunara villages in the central and northern parts. Route 4 is 1.29km long and is only found in Jaboi village in the southeast. Route 5 is 7.68 km long, passing through three villages (Keunekai, Paya, and BateeShok) in the southern part of the city.

KEYWORDS ***–****Vulnerability, Tsunami Risk, Sabang*

I. INTRODUCTION

Earthquakes and tsunamis are natural disaster that dangerous human life. These natural disasters occur unpredictably and can have significant consequences for coastal areas and islands around the world (Usman, 2019). Tsunami waves are generated by a variety of causes, including earthquakes, underwater volcanic eruptions, large sea landslides, and outer space object (meteorite). Nearly 90% of the many tsunamis that occur on the earth's surface are caused by earthquakes on the seabed. Like the gentle swaying of ocean waves, tsunami waves cannot be felt or even observed in the middle of the vast ocean. However, when they reach land, these waves become violent waves that destroy everything in their path. Often these disasters are a threat to areas whose geology is related to active plate movements.

In Indonesia, there have been a total of 110 tsunamis. Of these amouts, 100 tsunamis were caused by earthquakes, nine tsunamis were triggered by volcanic eruptions, and one tsunami was caused by sea landslides (Arief, 2011). Earthquakes are the main cause of tsunamis in Indonesia. The centers of these earthquakes are often located near subduction zones, which causes many earthquakes to occur along these subduction zones (Naryanto, 2008).

Due to its geological position, the country is located on the Pacific Ring of Fire, as is Indonesia. This geological condition causes Indonesia to become an archipelago. The largest part of this area is ocean and has the second longest coastline in the world (Pramana, 2015).

The consequences of the tsunami were not only exacerbated by geographical factors, but also by the social and economic conditions of the Indonesian people. For example, high population density on the coast and inadequate infrastructure for disaster management (Rakuasa, 2022). According to data from the World Risk Report 2018, Indonesia is ranked 36th out of 172 countries most affected by natural disasters in the world with a risk index of 10.36. (Hadi, 2019)

BNPB (Indonesia: Badan Nasional PenanggulanganBencana/National Disaster Management Agency, (2021) (Badan Nasional Penanggulangan Bencana (BNPB), 2021) Says that Disaster risk aims to collect information about how high the risk of disaster is in a particular area. The risk level is determined by a combination of three (3) elements: Hazard, Vulnerability, and Capacity. These three elements are determined by appropriate parameters. The risk resulting from the combination of these three components provides information on the relationship between disaster vulnerability and regional capacity. In other words, the risk level indicates how well the area is able to reduce the consequences of disaster damage, it can be seen that Tsunamis are caused by tectonic activity on the seabed. This changes the volume of seawater and causes seawater to enter the land at high speed. The tsunami hazard is assessed from the potential for land inundation, which is based on the maximum wave height that can reach the coastline.

Terry Cannon (1994) said as quoted in (Sarapang & Hanny, 2019) Vulnerability refers to the characteristics of individuals or groups living in a particular environment, which are influenced by social and economic factors. This vulnerability varies depending on their position in society, causing some groups or individuals to be more vulnerable than others.

Sabang City has a very high tsunami potential considering its geographical position close to the Sumatran megathrust zone and the great Sumatran fault line(Apriyadi & Cipto Kuncoro, 2021). This zone is one of the most seismically active areas in the world and is the main source of earthquakes that have the potential to trigger tsunamis(Kurniawan & Rasmid, 2016).

From the title raised from the tsunami risk vulnerability in the Sabang City, Aceh, the picture has a high tsunami risk vulnerability and only a few are exposed to very high levels of what has been mapped in 2024, and on the tsunami risk vulnerability potential map in the Sabang City, Aceh has five tsunami vulnerability classifications. For more details, it is presented in the results section.

Geographic Information Systems (GIS) play a vital role in tsunami evacuation analysis and planning, with a focus on mapping evacuation routes and safe shelter locations. Effective evacuation routes are crucial to saving lives when a tsunami strikes, especially for people living in areas predicted to be inundated. This process involves predicting inundation areas based on topographic maps and analyzing assumed run-up height data. Contour lines are used to identify high-risk areas (Suharyanto, 2012).

Geographic Information Systems (GIS) are used to collect, save, process, analyze, and visually display data containing geographic or spatial information. To produce useful and easy-to-understand information, GIS uses computer technology and special software to combine spatial data such as maps, satellite imagery, topographic data, weather data and attributive data such as demographic, economic, social and environmental data (Fuad, Effendi, & Dewi, 2022). Technological advances have made it possible to analyze vulnerability to disasters using Geographic Information Systems (GIS). A map is created that shows the hazard class if disaster strikes (Putra, Suprayogi, & Sudarsono, 2019). Including the tsunami vulnerability map in the Sabang City, Aceh which will be shown in 5 classes and also find out how big the potential tsunami vulnerability is in the city of Sabang.

Efforts must be made to minimize the risk of disaster, because the losses caused by the tsunami disaster are very large. The government has considered reducing the risk of tsunami disasters in the Disaster Management Law. This stipulates that disaster management must be decentralized and carried out by involving the community (Pudjiastuti, 2019).

The use of satellites for remote sensing and Geographic Information Systems (GIS) has become an integrated, well-developed and powerful tool. It has been successfully integrated into disaster research and is well developed to ensure effective risk management and mitigation of existing disasters (Sambah, Miura, & Guntur, 2018).

GIS is used for various purposes, including mapping, environmental monitoring, natural resource management, disaster risk mapping, market analysis, and others of the same kind (Tonini, et al., 2021) GIS can also be used to map tsunami vulnerable areas to identify areas potentially affected by a tsunami and to determine disaster prevention measures (Febrina & Fitra, 2020).

II. RESEARCH METHOD

The location of this research was conducted in Sabang City, which is part of Weh Island, Aceh Province, Indonesia. Weh Island is located in the Indian Ocean and has a latitude coordinate of around 5° 52' 46" N and a longitude of around 95° 17' 59" E. This research location was chosen because this location was hit by a tsunami in 2004, so there was a high risk of tsunami and there was no effective evacuation route map in dealing with the potential for a tsunami disaster.

In this study, the level of tsunami hazard in the Coast of Sabang City was determined using five main parameters, that is slope, height, land use, coastline, and distance from the river. These five parameters were analyzed with the help of Geographic Information System (GIS) technology through the overlay analysis method. Can be seen in table 1.

Table 1. Tsunami Hazard Level Parameters

Parameter	Magnitude	Hazard Class	Score	Weight
Land Slope (%)	0-2	Very High	5	20
	2-5	High	4	
	5-15	Medium	3	
	15-40	Low	2	
	>40	Very Low	1	
Land Elevation (m)	<10	Very High	5	25
	>10-25	High	4	
	>25-50	Medium	3	
	>50-100	Low	2	
	>100-350	Very Low	1	
Land Use	Settlements, rice fields, swamp forests, rivers	Very High	5	15
	Terrestrial gardens/Farm	High	4	
	Fields	Medium	3	
	Lake, reeds, bushland	Low	2	
	Forest, rocks, limestone	Very Low	1	
Distance from Coastline (m)	0-500	Very High	5	20
	>500-1000	High	4	
	>1000-1500	Medium	3	
	>1500-3000	Low	2	
	>3000	Very Low	1	
Distance from River (m)	0-100	Very High	5	20
	>100-200	Low	4	
	>200-300	Medium	3	
	>300-500	Low	2	
	>500	Very Low	1	

The tools and materials used in this research include:

Research Tools

The tools used in this research are divided into 2, namely: 1) using hardware and 2) using software.

a. The hardware used is: :

1) Laptop.

2) USB Flashdisk as a means of data transfer.

3) Smartphone for object documentation.

b. The software used in this study is :

1) GPS Essentials application to find out/take coordinate points.

2) Software ArcGIS Desktop 10.8 is used for data processing (Eisner, 2005).

3) Microsoft Office Word 2010 software for word processing.

4) Microsoft Office Excel 2010 software for tabular data processing.

Research Materials

The materials used in this study are as follows:

a. Spatial data

b. Documentation of infrastructure facilities photos that can be used as temporary evacuation sites in Sabang City.

Data collection techniques in this study are :

1. Field survey: Conducting a direct survey in the coastal area of Sabang City to collect data on road infrastructure, buildings, and information related to existing evacuation routes.

2. Visual observation: Observing geographical conditions, road accessibility, locations of important buildings such as schools, health centers, and places of worship that have the potential as evacuation points, as well as potential locations for evacuation routes.

3. Interviews: Interviewing relevant stakeholders such as the Regional Disaster Management Agency (BPBD) to obtain information regarding the evacuation routes that have been established and their input regarding the potential for a tsunami disaster.

4. Secondary data analysis: Collecting and analyzing secondary data such as topographic maps, population density data, historical tsunami disaster data, and relevant infrastructure data from trusted sources.

5. Use of GIS technology: Utilizing GIS software to integrate and analyze collected spatial data, map potential disasters, map recommended evacuation routes, and evaluate the effectiveness of existing evacuation routes.

Data Presentation Technique

In this study, the results of data analysis will be displayed in an effective tsunami disaster evacuation route map by displaying evacuation routes and the destinations of the evacuation routes. Data presentation is done with a map because with a map it is easy to find out the positions of routes and temporary shelter facilities so that they can be used effectively in times of emergency.

III. FINDING

To reduce the impact of the tsunami disaster, various efforts can be made, including implementing alternative methods that are more appropriate to the needs of the local community. Reducing the risk of loss of life and careful planning can be achieved by mapping coastal areas that are safe from the impact of the tsunami, which will later be used as evacuation points. This data can then be used to design effective evacuation routes, so that the fatal impact of the tsunami disaster can be minimized (Febrina & Fitra, 2020).
Because the tsunami disaster will harm the community, the community must be vigilant and alert in facing the threat of disaster. However, this attitude must be accompanied by a correct understanding, including an understanding of self-rescue procedures because a wrong understanding of a wrong understanding will actually endanger themselves. One way is to mitigate earthquake disasters that have the potential for tsunamis (Putra & Mutmainah, 2016).

In an effort to educate the community about disaster mitigation, a tsunami vulnerability map and evacuation routes are needed so that the community can find out which areas have a high level of vulnerability and which routes must be taken so that if a tsunami strike at any time, the community does not panic and the evacuation process can run smoothly, this will be able to minimize the level of casualties when a tsunami strike.

Evacuation routes play a crucial role in the rescue process when a tsunami strike. It is important for people living in areas that are expected to be affected by a tsunami to clearly understand the correct procedures when the disaster strike (Suharyanto, 2012).

During evacuation, not everyone can immediately reach the evacuation area without stopping. Vulnerable groups such as the elderly, pregnant women, children, and people with disabilities require special attention and will be evacuated to a safe evacuation site. Therefore, a temporary resting place or shelter is very important in this evacuation process.

(Adilang, Tungka, & Warouw, 2022) mentioned that one example of disaster mitigation can be done by creating an evacuation route map. This shelter also functions as a temporary shelter if the tsunami arrives faster than the estimated evacuation time (Eisner, 2005). The hope is that when the tsunami approaches and the evacuation process is still ongoing, people can save themselves by taking temporary shelter in the shelter area. Shelters are ideally located along the evacuation route, have buildings with strong structures, can accommodate many people, and are estimated to be safe from the impact of earthquakes and tsunamis. Examples of buildings that can be used as shelters include houses with more than two floors, schools, hotels, offices, and mosques (Suharyanto, 2012). Based on Figure 1. Map of Tsunami Disaster Evacuation Routes in Sabang City, shows that there are five tsunami evacuation routes in Sabang City. The five routes are spread across the city of Sabang. These routes pass through many villages, which can facilitate the evacuation of residents during a tsunami disaster. The routes are named with a numerical system (numbers). (1) Route 1 is located in the east of Sabang City, and the route starts from Balohan village, then passes through Anoe Itam village, then moves north through Ujoeng Kareung village, le Meulee village, Kuta Ateuh village, West Kuta village, then moves south through Cot Ba u village, Cot Abeuk village, and ends back at Balohan village. The total number of villages passed by route 1 is eight villages and the total length of route 1 is 35.210,50 m or 35,21 km; (2) Route 2 is in the northwest of Sabang City, which is only found in Iboih village, the total length of route 2 is 853,76 m or 0,85 km; (3) Route 3 is in the middle and north of Sabang City. This route is on the border between Batee Shok village and Paya Seunara village, where the route starts from Batee Shok village. The total length of route 3 is 2133,82 m or 2,13 km; (4) Route 4 is in the southeast of Sabang City, which is only found in Jaboi village, the total length of route 4 is 1296,13 m or 1,29 km; (5) Route 5 is in the south of Sabang City, and passes through 3 villages, namely Keunekai village as the beginning of this route, then passes through Paya village and ends in Batee Shok village. The total length of route 5 is 7681,22 m or 7,68 km. Can be seen in figure 1.

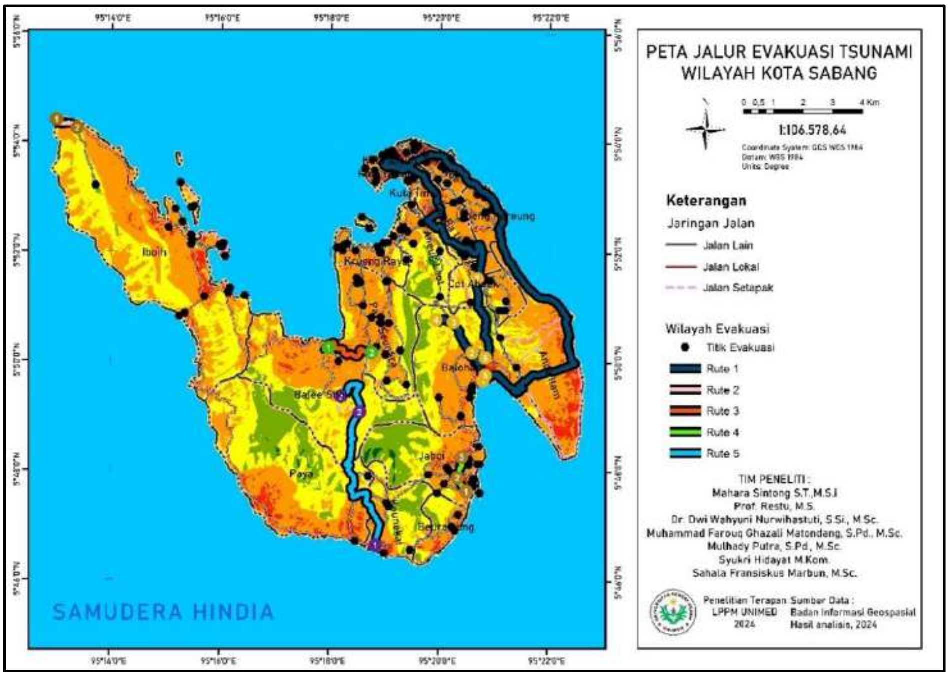

Figure 1. Map of Tsunami Disaster Evacuation Routes in Sabang City

Based on the results of the overlay of scores and weights of the parameters that have been carried out, there are five classes of tsunami vulnerability levels shown in the figure. From this analysis, it can be concluded that the level of tsunami vulnerability in Sabang City is dominated by orange, which indicates a high risk class, and yellow, which indicates a moderate risk class. Areas with low vulnerability levels (green) are generally located on higher ground compared to other areas. Otherwise, areas with very high tsunami vulnerability levels (red) are found in many coastal areas of Sabang City. Meanwhile, areas with very low tsunami vulnerability levels (dark green) are only found in a few areas of the highlands. Can be seen in table 2.

Table 2. Level of Tsunami Disaster Vulnerability in Sabang City

Vulnerability Level	Area (ha)	Percentage (%)
Very High	959,64	7,73
High	5852,46	47,14
Medium	4140,44	33,35
Low	1299,32	10,47
Very Low	162,63	1,31
Total	12414,49	100

Based on the data presented in the table, it can be seen that the Sabang City area has a significant variation in the level of vulnerability to tsunami disasters, which is divided into five main classes.

Very Low Vulnerability Level

The area that including into this category only covers 162,63 hectares or 1.31% of the total area of Sabang City. This shows that a small part of the city is in a relatively safe zone from the threat of tsunami.

Low Vulnerability Level

Covers an area of 1.299,32 hectares, or around 10.47% of the total area. Although the risk in this area is higher compared to the very low zone, overall it is still relatively safe. However, vigilance and appropriate mitigation measures are still needed.

Medium Vulnerability Level

Has a wider coverage, which is 4.140,44 hectares, which is equivalent to 33.35% of the total area of Sabang City. This area indicates a significant risk from the threat of a tsunami. Therefore, preparedness and mitigation planning must be prioritized in this area to minimize potential losses.

High Vulnerability Level

Covering the largest area, which is 5.852,46 hectares or 47.14% of the total area. This shows that almost half of the Sabang City area is in a high tsunami risk zone. This condition requires serious attention in the preparation of disaster mitigation policies, including the preparation of adequate infrastructure and early warning systems.

Very High Vulnerability Level

Covering 959.64 hectares or 7.73% of the total area. Although the proportion is smaller compared to other zones, this area is at the most serious risk and requires very intensive mitigation measures.

Overall, more than half of the Sabang City area (54.87%) is in the high to very high tsunami vulnerability category. This underlines the urgency of implementing a comprehensive mitigation strategy to reduce the impacts that can be caused by a tsunami disaster in the area, one of which is a tsunami evacuation route map.

IV. CONCLUSION

Sabang City has a significant level of vulnerability to tsunami disasters, with more than half of its area (54.87%) in the high to very high risk category. Coastal areas show the greatest vulnerability, while areas with lower risks are generally located on higher ground. Tsunami vulnerability maps and evacuation routes are essential to minimize the risk of loss of life and ensure effective evacuation. The provision of shelters along evacuation routes is also crucial, especially for vulnerable groups. Mitigation efforts and public education must be prioritized to deal with this potential disaster.

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