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Spatial Modeling of Tsunami Impact in Manado City using Geographic Information System

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Abstract. Manado City is a coastal area in the shape of a bay. Manado Bay is a water body that protrudes in the area of Manado City where the condition of this region is likely to have a tsunami threat. Manado Bay is home to several rivers such as Tondano River has a geological history of both land and sea. There are several active faults, such as in the sea, subduction of subplate in the north of the island, Mayu mountain plate, and Sangihe plate east of North Sulawesi. The purpose of this study is divided into two parts: General purpose is to describe GIS-based disaster mitigation that can be done to minimize disaster risk if Tsunami disaster occurs in coastal area of Manado Bay, while special purpose consists of 3 parts, namely: 1. mapping of zone- Tsunami vulnerability zone of Manado Bay; 2. mapping the distance and time of the scenario of the Manado Bay Tsunami evacuation route; 3. mapping of the number of buildings and roads exposed to the Manado Bay Tsunami. Data collection techniques use secondary data collection techniques. Secondary data comes from related institutions or institutions, libraries, or individual archives. The data collection is also continued by direct observation. Direct observation is meant by direct observation by using a checklist for secondary data adjustment and then the determination of coordinate point with Global Position System (GPS) at some tsunami location.

1. Introduction

The island of Sulawesi has 24 out of 136 districts/municipalities that enter the priority of disaster management in the Rencana Pembangunan Jangka Menengah Nasional (RPJMN) 2015-2019 by the National Disaster Management Agency (National Board for Disaster Management / BNPB). A disaster is an event or series of events that threaten and disrupt people's lives and livelihoods caused by both natural factors and /or non-internal factors and human factors resulting in the occurrence of human casualties, environmental damage, property loss, and psychological impact (UU No. 24 Tahun 2007 according to Disaster Mitigation). This shows the island of Sulawesi has a high risk disaster in the central region of the economy. One of them on the northern part of Sulawesi Island is Manado City which is








the capital of North Sulawesi Province. This is evidenced by the events of recent years Manado city hit by natural disasters ranging from a flash flood [1], landslides [2], earthquakes [3], to the potential tsunami [4-6]. Manado city is shaped coastal bay area. Manado Bay is a water body that protrudes in the area of Manado City which is classified as tsunami hazard. Tsunami is a series of waves that are capable of spreading at speeds up to 900 km / h, mainly caused by the earthquake which occurred on the seabed. This threat exists because of its geological history from the mainland there are several active faults and in the sea, there are sub plates on the north of the island, Mayu mountain plates, and Sangihe plate in the east of North Sulawesi. Then the volcano tertiary and quarter. The precipitate quarter is decomposed, loose, and yet compact so that the geological conditions can amplify the effect of earthquake shocks [7], required the geographical location and demographic circumstances Manado Bay as coastal areas which became the center of government, economy, education and maritime tourist attraction. Centralized community activities increase the population density inhabiting low land contour areas that are increasingly adding to the needs of development in coastal areas. This condition makes the Gulf of Manado experiencing rapid development changes one of the only beach reclamation. The region has the potential tsunami should have the awareness of disaster preparedness. This alert is necessary because the tsunami is a natural disaster that can devastate a large area [8, 9] and result in exposure effects of people [10], buildings, and roads [11], in the coastal area of Manado Bay. Therefore, disaster preparedness can be applied with disaster mitigation. Disaster mitigation can be managed by using the Geographic Information System (GIS). The purpose of this study is divided into two parts: The general objective is to describe GIS-based disaster mitigation that can be done to minimize disaster risk if Tsunami disaster occurs on the coast of Manado Bay, whereas the special purpose consists of 3 parts, namely: 1. mapping of zones tsunami vulnerability Manado bay; 2. mapping the distance and time scenario of the Manado Bay Tsunami evacuation route; 3. mapping the number of buildings and roads exposed to the Manado Bay Tsunami.

2. Methods

The research location is along the coastal areas of the Bay of Manado North Sulawesi province with astronomical layout is 1°33'25.79 " North Latitude and 124°48'30.31" East Longitude to 1°27'24.81" North Latitude and 124°47'47.26" Longitude East. Tools and materials used are Global Positioning System (GPS), ironing board, computer, software Quantum GIS, OpenStreetMap software [11], software InaSAFE, map city of Manado scale of 1: 20,000, Landsat 8 OLI, satellite image Aster and Bing Map around Manado Bay. Retrieving data using secondary data collection techniques that are quantitative. Secondary data comes from related institutions or institutions, libraries, or individual archives. The data collection is also continued by direct observation. A direct observation which meant that direct observation by using a list of records for the adjustment of secondary data and then determining the coordinates [12] with a Global Position System (GPS) on several locations of areas to be modeled the Tuminting District. Application of Secondary Data Analysis (ADS), which is managed by Quantum GIS software (QGIS) which provides InaSAFE plugin toolbar that has the function of analyzing spatial data of tsunami disaster [11]. So the Bay of Manado tsunami vulnerability can be classified based on the classification of the tsunami by Bandung Institute of Technology (ITB) namely (see Table 1):

Table 1. Tsunami classification.

Zone Name	Color	Value (meters)
dry zone		>0.00≤0.10
low hazard		>0.10≤1.00
medium hazard)		>1.00≤3.00
high hazard		>3.00≤8.00
very high hazard		>8.00≤9999.00

3. Results and Discussion

3.1. Tsunami threat zone in the Bay of Manado

As shown in Figure 1, the Hazard Zone of the Manado Bay Tsunami is divided into 4 zones: dry, low, medium, high, and very high.

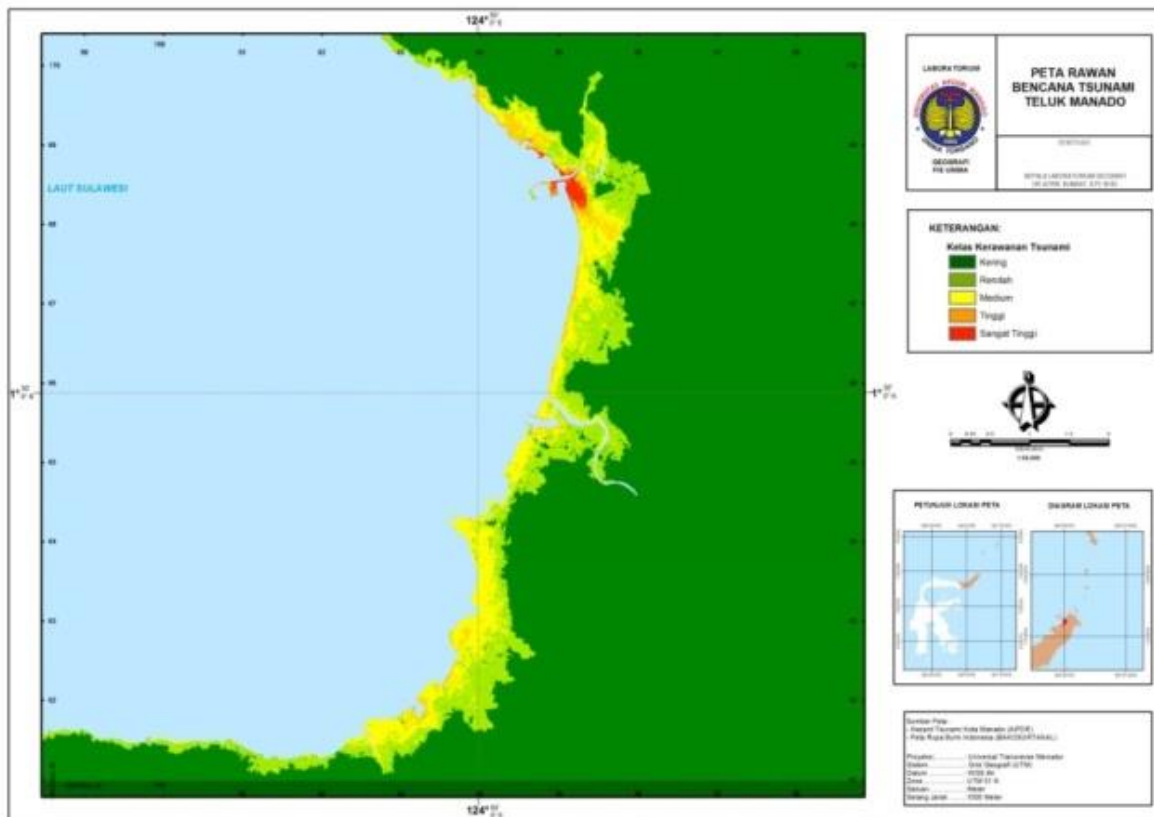


Figure 1. Manado Bay Tsunami Hazard Map.

3.2. Run up

Tsunami-prone zoning then overlapped with a 1meter IFSAR contour resulted in a contour dry zone of 14 - 19 meters, contour low zone 8 s / d 13 meters, medium contour 5 - 7 meter, contour zone height 2 - 4 meters, and very high zone contour <1 meter. So that can be identified wave height (run up) when the tsunami happened that reaches 7 meters. Contour identification can be assumed that run-up at the tsunami can reach 7 meters, this is because very high zones, high zones, and middle zones are classified as impacted areas whereas low and dry zones are classified as unaffected (Figure 2).

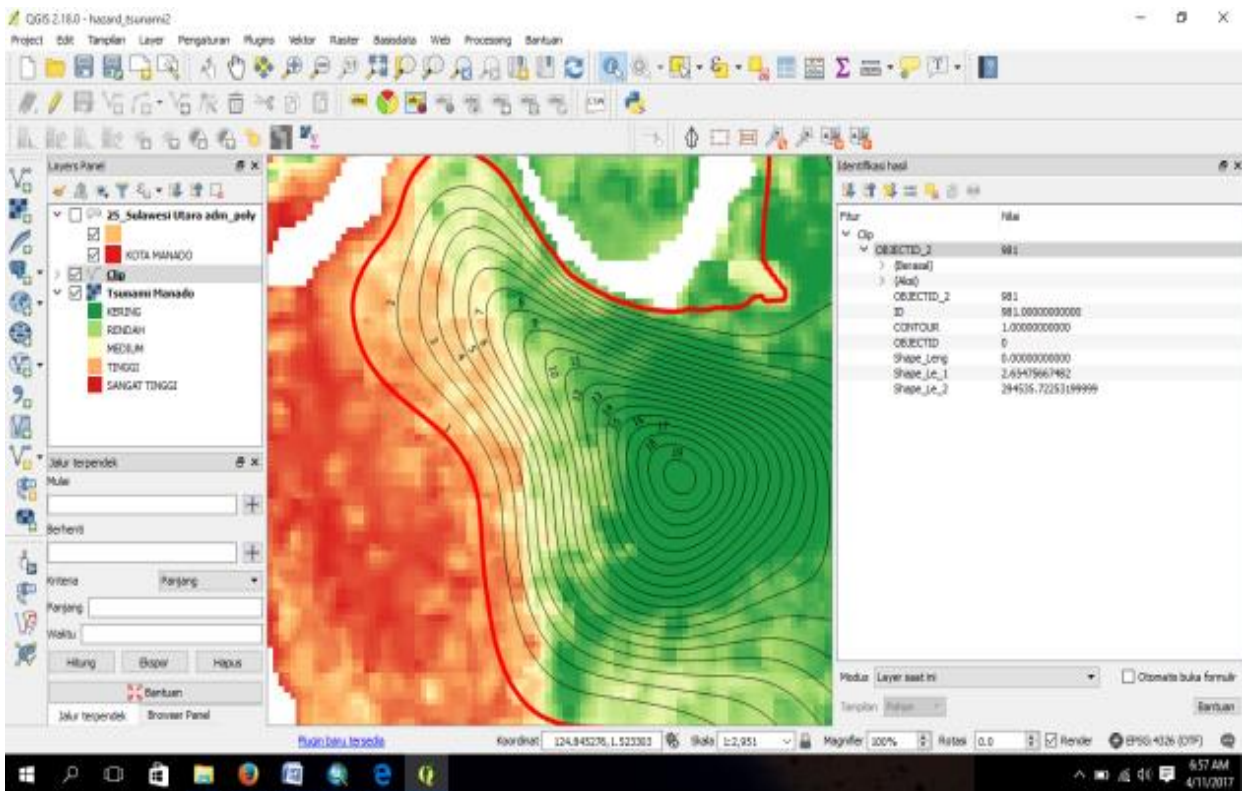


Figure 2. Results of image panel identification quantum GIS software.

3.3. Building exposure analysis

Building exposure (Figure 3) or tsunami hazard analysis in QGIS software must first complete the InaSAFE keyword then focused Tuminting District which has been analyzed to produce 6,900 buildings classified impacted 3,800 buildings, not affected 530 buildings, and not exposed 2,600 buildings, for roads totaling 90,600 meters classified impacted 25,700 meters, not affected 5,600 meters, and not exposed 59,400 meters.

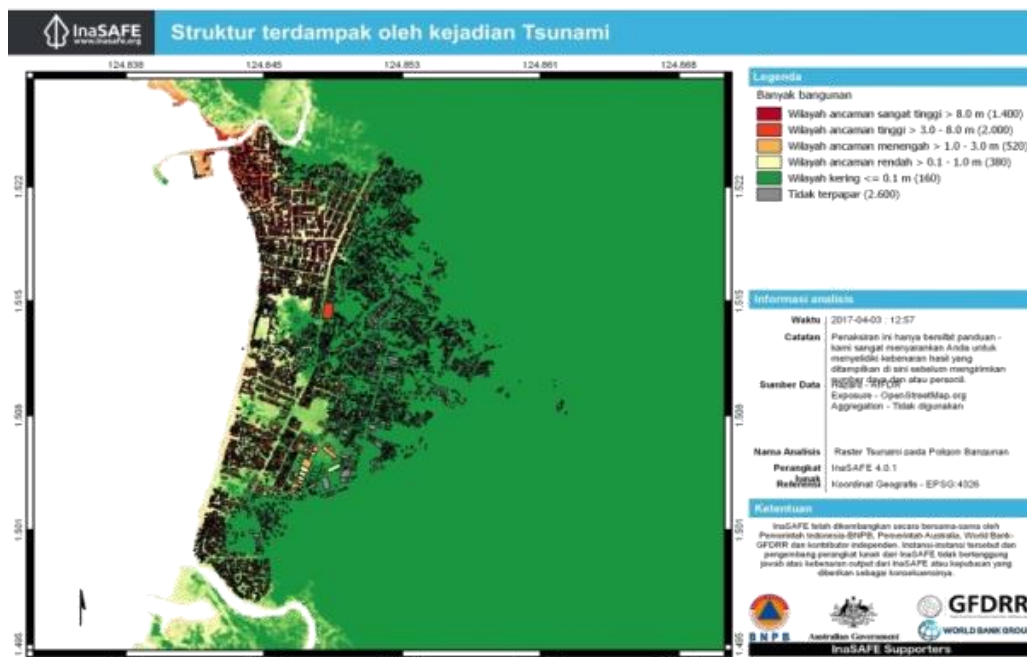


Figure 3. Building exposure analysis.

3.4. Road exposure analysis

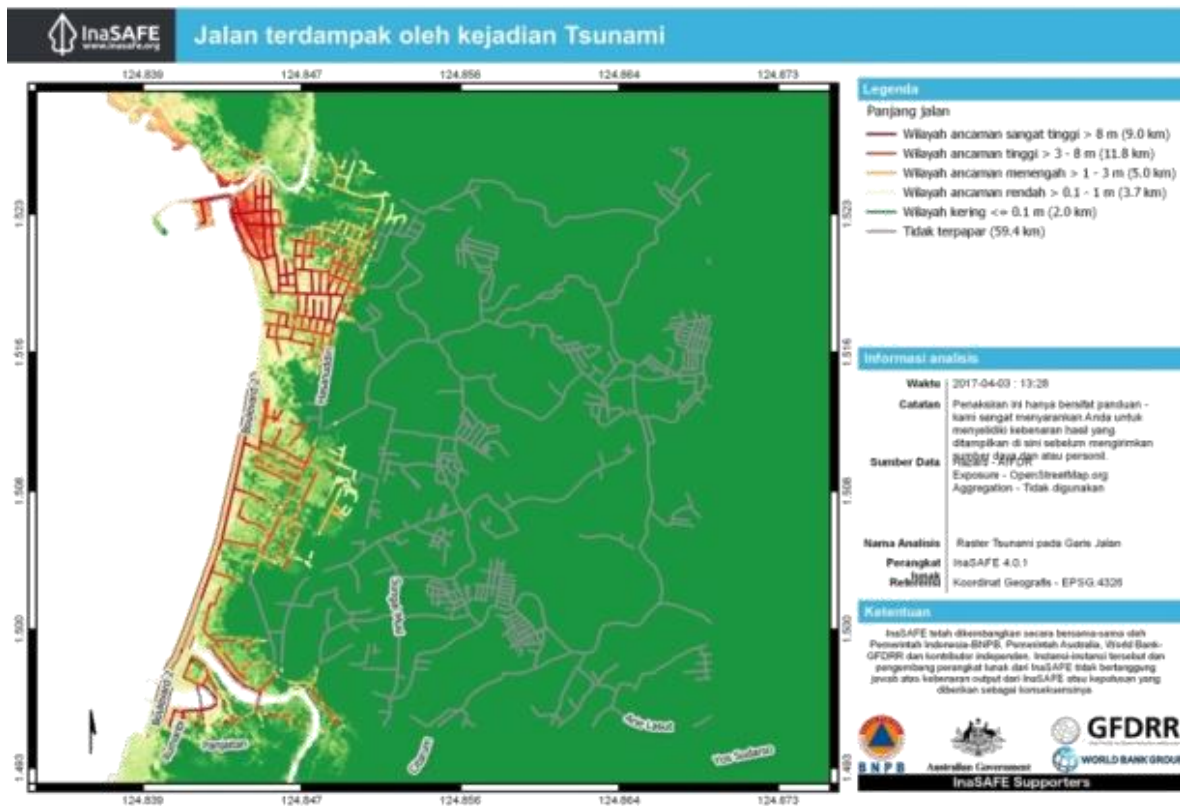


Figure 4. Road exposure analysis.

In figure 4, the analysis of road exposure using QGIS software basically has the same stages as the tsunami hazard analysis and the previous building exposure analysis. It's just that there are still some differences in keywords for information on tsunami threats and road exposure. In InaSAFE analysis obtained for roads have a length of 90,600 meters classified impacted 25,700 meters, not affected 5,600 meters, and not exposed 59,400 meters.

3.5. Tsunami evacuation route

The determination of the evacuation path is the selection of the fastest path (time) and the shortest path (distance). In QGIS software has been equipped with Road Graph plugin (road graph). The Short Route with the starting point of Tarus Road 1 and the stop point of Nike Road is then adjusted to the local tsunami evacuation time 30 minutes to obtain the formula:

V: 45 km / h; T: 30 minutes = 0.5 hours;

Then: $s = v.t$

$$= 45 \text{ km} \times 0.5 \text{ hours}$$

$$= 22.5 \text{ km / h or } 23 \text{ km/h}$$

Speed 45 km/h then obtained the road length of 1.44 km and time of 0.032 hours. Based on 45 km / h, within 30 minutes (0.5 hours), the mapping of the road evacuation path is 1.43 km and the time is 0.062 hours.

4. Conclusions

Based on the results of research and discussion that has been described previously, then got some conclusions as follows: Tsunami-prone zone of Manado Bay is classified into 5 zones of dry zone, low zone, medium zone, high zone, and very high zone; Overlapping results of hazard data of Manado Gulf tsunami source AIFRD with 1 meter IFSAR contour vector data show that potential tsunami threats

could devastate buildings, inundate many roads and casualties along the coastal areas of Manado Bay. This is because the sea level (run up) of Manado Bay tsunami can reach 7 meters which is the highest contour in the affected area; Based on the analysis of OpenStreetMap vector data of buildings and roads in InaSAFE in Manado Bay area Tuminting Sub-district resulted in building (structure) exposed 530 of 3,600 and 25,700 meters of exposed road from 90,600 meters; Mapping the scenario of the evacuation route from the very high threat zone of Tarus 1 Road to the low threat zone of Nike Road with the Road Graph plugin calculation(graph of the road) within 30 minutes after the spice to escape. Human running speed at a maximum of 45 km / h so that within 30 minutes (0.5 hours) obtained the evacuation route 1.43 km long road in 0.062 hours which is the fastest and shortest path as the initial act of self-salvation to go to the existing shelter.

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