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# *Utilizing Satellite Imagery And Gis To Determine A Tsunami Self Evacuation Path In The Kuta Coast, Bali*

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**Abstract – The State of Indonesia is a country that is traversed by the Ring of Fire, which means that the State of Indonesia has the privilege that there are many volcanoes in Indonesia. This is also caused by the existence of a subduction line that surrounds Indonesia from the west end to the east end, making Indonesia a country frequently hit by earthquakes. In facing any threat, the state must be prepared in all parameters so that when the threat occurs, the victims incurred are not many. The data used in this study is data for the southern part of Bali Island covering several regencies, including Badung Regency and Denpasar City Regency. Scenario segment determination is made based on the location of an earthquake with a shallow depth which is close to the island of Bali. With the character of a M9 megatrust earthquake and a shallow source of earthquake depth, it will certainly cause deformation of the ocean floor in the southern area of Bali Island. The results of the Kuta village inundation map show that the tsunami water inundation occurred to the mainland due to the geographical conditions of Kuta beach which are sloping and tend to be flat. Rock and gravity analysis shows that there are locations where liquefaction could occur in the Kuta beach area in the south near Ngurah Rai International Airport.**

**Keywords – Inundation, earthquake, subduction, magnitude.**

## I. INTRODUCTION

The State of Indonesia is a country that is traversed by the Ring of Fire, which means that the State of Indonesia has the privilege that there are many volcanoes in Indonesia. This is also caused by the existence of a subduction line that surrounds Indonesia from the west end to the east end, making Indonesia a country frequently hit by earthquakes. Having many volcanoes is a big advantage because the soil in Indonesia is fertile, but on the other hand it also makes Indonesia a country that is "rich" in natural disasters. One thing to watch out for and make an important point is the tsunami natural disaster. Indonesia has a special history of tsunami disasters where in 2004 there was a natural tsunami disaster caused by a fault breaking in the west of Sumatra Island and resulting in a tsunami that devastated Aceh and the surrounding area to Sri Lanka and Thailand.

Threat to state security is a condition that can make the state order become nationally disordered. State threats can be military and non-military. In facing any threat, the state must be prepared in all parameters so that when the threat occurs, the victims incurred are not many. The threat to national security, according to Christopher Schoemaker stated: "national security was seen primarily as the protection from external invasion, an attitude primarily driven by the war. As a result, the original concept had a strong military component". This means that Christopher Schoemaker sees a national threat solely from attacks by foreign countries that carry out military invasions, causing wars and causing loss of life and economy on a measurable scale.

Global Position System research conducted in 1989 regarding the movement of the Indo-Australian Plate against the Eurasian Plate concluded that the Indo-Australian plate is moving towards the Eurasian Plate 67 mm/years in the direction of

N11oE4o (Tregoing et al, 1994) where these results are close to the theoretical results of the model NUVEL-1 is 71 mm/year but in a more northerly direction, namely N20oE3o (DeMets et al, 1990). This condition causes Bali Island to be one of the areas with high seismicity because it is directly facing the Sunda Shelf Subduction Line and the activities of the edge of the Australian continent as well as the continuation of the Sunda Arc line to the east which meets the Banda Arc.

The movement of these plates has an impact on the existence of characteristic types of tectonics from subduction systems such as sea trenches, the Benioff zone, which is a zone that often occurs with fractures, outer arc basins, and mountain paths, then another impact is the existence of an earthquake zone in the form of a slab. with a depth of 100 Km and a slope that reaches 65o where the depth reaches 650 Km below the northern part of the island of Bali.

## II. Literature Review

### 2.1. Geographic Information System

Information systems are components that are interrelated in collecting, processing, archiving and distributing information to assist decision making (Kenneth & Jane, 2005). Meanwhile, a geographic information system is an element that includes software, hardware, geographic data as well as human operators that are interconnected and effectively capture, archive, fix, restore, process, combine, analyze and present data in geographic-based information. In its development, geographic information systems began to develop since 1970, where the human need for data and information in certain locations continues to increase. The development of geographic information systems is supported by the need for continuous data and computational spatial distribution. The use of geographic information systems that continues to grow, is not only limited by data needs, but is also used in decision making and policy. In its use, Geographic Information Systems use systems that are mutually integrated between computers and networks. GIS components include hardware, software and geographic information and data as well as management systems, where hardware as we know it is in the form of PCs, laptops and workstations that can be used and integrated in a network system.

Software in GIS that is currently often used includes Google Maps, Google Earth Engine, ArcGIS and QGIS. Geographical information and data are integrated by a geographic information system, to then be utilized indirectly or directly which can be done by digitizing maps and creating their attributes such as tables, graphs and reports. The last component in GIS is a management system, to be able to manage the system and make designs for its application in real conditions. In its utilization, the data and information produced by GIS are not only used regionally, but can also be viewed in more detail. Various fields of science can take advantage of GIS, such as the health sector, the distribution of natural resources for government assets, to telecommunications and transportation. Data and information generated from GIS become important data in strategy formulation and decision making in government, or used as a reference in sustainable national development policies where existing data and information can be visualized spatially and integrated with each other.

### 2.2. Natural Disaster Mitigation

There are three types of disasters, namely natural disasters, non-natural disasters, and social disasters. Indonesia is a country that has three types of disasters. Various kinds of natural disasters that occurred in Indonesia such as earthquakes, tsunamis, volcanoes, ground movements, floods, droughts, erosion, abrasion, and extreme weather and extreme waves. Non-natural disasters that can occur are examples of technological failures, epidemics and disease outbreaks. And what is meant by social disaster includes social conflict and terrorism. The pattern of disaster management gained a new dimension with the issuance of Law Number 24 of 2007 concerning disaster management which was followed by several related regulations, namely Presidential Regulation Number. 08 of 2008 concerning the National Agency for Disaster Management, Government Regulation Number 21 of 2008 concerning Implementation of Disaster Management, Government Regulation Number 22 of 2008 concerning Funding and Management of Disaster Aid, and Government Regulation Number 23 of 2008 concerning Participation of International Agencies and Foreign Non-Governmental Organizations in Disaster Management.

A tsunami evacuation route is a road that has been jointly designed to be used during a tsunami evacuation to a temporary evacuation site (TES) or a final evacuation site (TEA). This route is useful in directing the community away from tsunami-prone areas to a safe place. In order to comply with evacuation needs, evacuation routes must be planned involving the participation of the community, stakeholders and decision makers.

A tsunami evacuation route is designed through the existing road and away from the coastline, river mouths, river bodies, and waterways that empty into the coast, especially those near coastal areas. If you are forced to cross the bridge, the evacuation route planning through the bridge must use a bridge that meets the technical requirements for roads and bridges and is earthquake and tsunami resistant.

Areas prone to tsunamis need to be equipped with signs to make it easier for residents to know and be aware of the tsunami hazard in their environment, and to be able to save themselves or evacuate to the Final Evacuation Site (TEA) and Temporary Evacuation Site (TES) which have been agreed upon in the preparation of a tsunami evacuation plan. Signs can take the form of various symbols depending on the need. Like an arrow symbol to indicate the direction of evacuation, a building symbol to indicate an evacuation site, a wave symbol to warn of a tsunami hazard, and so on.

### 2.3. Tsunami Simulation Modeling for Evacuation Routes

(Horspool, et al., 2014) has developed a PTHA (probabilistic tsunami hazard assessment) in the Indonesian region with only tsunami generated by earthquakes as a source of tsunami generators. Based on PTHA results, the Bali and Lombok regions have a greater than 10% chance of experiencing a tsunami with a height of more than 0.5 meters on the coastline. The height of a possible tsunami depends on the magnitude of the earthquake that occurs.

Purnama 2019 modeled the tsunami runway in the Bali area using the TOAST (Tsunami Observation And Simulation Terminal) software using 3 earthquake scenarios in the past that caused tsunamis around Bali. Case studies of the earthquake in southern Bali on April 13, 1985 with a magnitude of 5.9, the Flores earthquake on December 12, 1992 with a magnitude of 6.6, and the Flores earthquake on July 31, 1989 with a magnitude of 7.7. based on the results of the research that has been done, it can be concluded that the resulting run up will be higher if the magnitude of the earthquake is greater and the arrival time will be faster if the source of the earthquake is near the observer area. The north coast of Bali has shallower sea conditions than the south coast of Bali so that it has a greater frictional force and affects the run up that occurs. Tsunami modeling in Indonesian territory has been carried out a lot, one of which is by using the TUNAMI N-2 software. The Tunanami Device is a development of a non-linear model in its application to the wave equation of shallow waters (Imamura, et al., 2006). Ulutas 2011 used TUNAMI N2 to model the 2010 Pagai tsunami, this modeling includes the generation, propagation and arrival time of the tsunami waves in the coastal areas affected by the tsunami. Tsunami modeling using TUNAMI-N2 requires earthquake source parameters namely strike, dip, rake and slip to minimize uncertainty in the fault zone parameters.Tsunamis are included in the shallow water wave equation. So in this research modeling using the theory of shallow waters. Because the gravitational acceleration is greater than the vertical acceleration of water, the vertical acceleration of water is neglected. The vertical movement of water particles has no effect on the pressure distribution (Imamura, et al, 2006).

### The Disaster

Disasters are generally divided into 3 types, namely natural disasters, non-natural disasters and social disasters. Natural disasters are disasters caused by nature such as earthquakes, tsunamis, volcanic eruptions, floods, landslides, droughts and hurricanes. While non-natural disasters, also called man-made disasters, are non-natural disasters/events which include technological failures, disease outbreaks, modernization failures and epidemics. The third type of disaster is a social disaster which is a disaster caused by a series of events caused by humans such as social conflicts between groups or between communities.

An earthquake is a sudden release of seismic wave energy. The release of energy occurs due to the deformation of tectonic plates that occur in the earth's crust. Howel (1969) argues that an earthquake is a vibration or series of vibrations of the earth's crust that are temporary and spread in all directions. According to the theory of plate tectonics, Subardjo and Ibrahim (2004) argued that in the theory of plate tectonics, the outermost crust of the earth which is composed of tectonic plates is always moving. The uppermost crust of the earth, called the lithosphere, is composed of several materials that have limited elasticity and is up to 80 km thick on land and about 15 km under the ocean. Meanwhile, under the lithosphere there is a dense asthenosphere and its material can move due to pressure differences.

A sudden rise in the seabed can cause a tsunami, because the deformation of the underwater surface can disrupt the balance of seawater masses. One of the causes of subsea surface deformation is due to undersea faults, especially faults with a rising or falling source mechanism. Faults with this mechanism are capable of disturbing seawater masses on a large scale compared to shear faults.

The parameters of the tsunami are the arrival time of the waves, the height and the tsunami slope. The arrival time of the tsunami waves is very important when it comes to the field of science and disaster management. The arrival time of the tsunami waves is calculated based on the arrival time of the first wave when it passes the coast. Tsunami height is the vertical distance between the reference point (mean sea level) and the tsunami crest. The runway is the maximum distance traveled by the tsunami, calculated by the difference between the distance between the coastline and the farthest distance traveled by the tsunami. (IOC 2016)

Based on IOC 2016 the value of wave speed and wave height values are inversely proportional. Tsunami waves have a maximum speed when they are in the deep sea with a speed of 950 km/$jam2$ at a depth of 7000 m. In addition, the speed at a depth of 10 m tsunami has a speed of 40 km/$jam2$. However, tsunamis have higher wave heights in shallow water than in deep water.

## III. Research Methods

This research was compiled with a quantitative approach. The data used are earthquake catalog data for the island of Bali and its surroundings, historical tsunami data for the island of Bali and its surroundings, geological data for the sheet of Bali Island, and gravity data and satellite imagery data.

This research was conducted to develop an independent tsunami evacuation route on the Kuta coast based on GIS so that it can help the community to be able to access it directly quickly and assist local governments in providing education and mitigation of natural disasters so that they can reduce the loss of life that can result from a natural disaster tsunami.

The research began with problem formulation, literature study, data collection and determining research methods, data processing and analysis so that an appropriate tsunami self-evacuation route map for the Kuta coastal area could be produced. Discussion

### 3.1. Administrative Map Of Bali Island

According to the Indonesian Tsunami Catalog book 416-2017 (Earthquake and Tsunami Center Team, 2019), there were 2 major earthquakes and large tsunamis that had an impact on the south of Bali Island, namely the Banyuwangi earthquake and tsunami on June 2, 1994 and the Sumba tsunami on August 19, 1977. The Banyuwangi earthquake M7.8 generated a tsunami with the highest run-up of 13.9 meters in Rejakwesi-Banyuwangi. For the island of Bali, the highest run-up records were on Antap-Tabanan beach 4.1 meters, on Soka-Jembrana Beach 3.7 meters, Klating-Tabanan 3.5 meters, Pekutatan-Jembrana 2.8 meters, Rambut Siwi-Jembrana 2, 7 meters, Tanah Lot-Tabanan <2 meters and Kuta Beach 1 meter. There are no tsunami records in the Denpasar area. However, according to local residents, there was a high tide with an inundation of about 5 meters from the beach. The M8.0 Sumba earthquake with the highest run-up on Sumba was 3 meters high. For the island of Bali, the tsunami occurred on Kuta Beach killing 1 person and 3 people missing, Sanur Beach, waves swept away the helipad, sank a beachside shop, and damaged a boat and hundreds of fishermen were seriously injured. and raises tidal waves tens of meters. The information on the Sumba tsunami is odd because the run-up in the nearest area only reached 3 meters, while in Nusa Penida it reached tens of meters, which is not in accordance with existing theories. This is because the information is limited to the subjective experience of society.

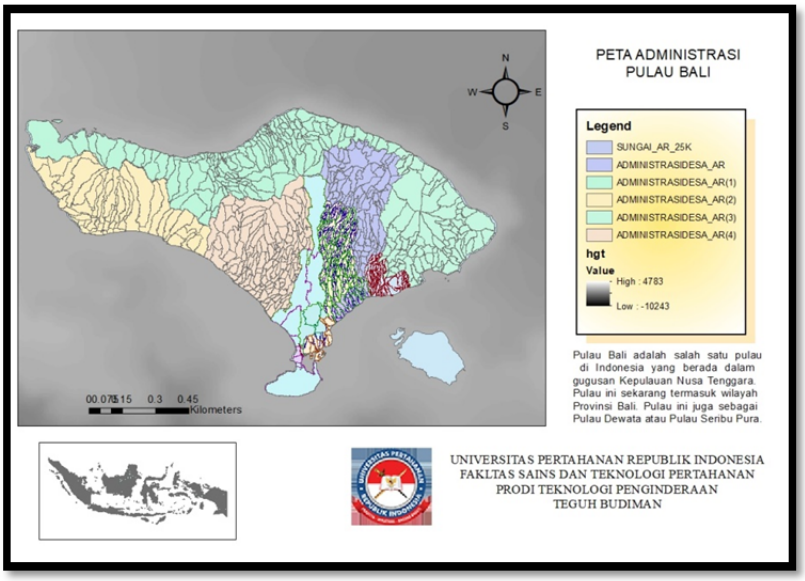


Fig. 1. Administrative Map Of Bali Island

Badung is the southernmost district in Bali Province which has stunning beauty. The area of Badung Regency is around 418.52 km² (7.43% of the area of Bali Island) dividing the island of Bali in the middle, stretching from north to south and directly adjacent to Tabanan Regency to the west, and Buleleng Regency to the north, then in to the east it is bordered by Bangli, Gianyar and Denpasar regencies. Based on Government Regulation of the Republic of Indonesia Number 67 of 2009, on November 16, 2009 Mangupura was designated as the Capital City of Badung Regency. The entire land area of Badung Regency with an area of 418.52 Km² or 41,852 Ha is located at coordinates 08º 14′ 20" – 08º 50′ 48" South Latitude (southern latitude) and 115º 05′ 00" – 115º 26′ 16" East Longitude ). Kuta is one of the most popular destinations in Indonesia for both domestic and foreign tourists abroad. This area is considered the center of tourism activities in Bali. on average, an estimated 60 to 70 thousand people visit Kuta every month. This region densely populated and grappling with the same problems as many urban areas in Indonesia: overloaded traffic system, lack of urban planning, and unplanned increase in population. Kuta is located on the coast of the Indian Ocean and its main attraction is its sandy beaches. Which less known by visitors and the public in general is that fact the coastline is also prone to tsunamis, as Bali is located close to the impact zone between the Indo-Australian Plate and the Eurasian Plate which presents the main source local tsunami that could hit this island. It is estimated that the tsunami waves it only takes 20 to 80 minutes to reach the beach. The areas in section south of Bali threatened by the tsunami was marked and mapped during the process hazard assessment in 2008/2009.


Fig. 2. Administrative Map Of Badung

The Geospatial Information Agency (BIG) has processed high-resolution satellite imagery specifically for the Republic of Indonesia known as the National Digital Elevation Model (DEMNAS). This basic geospatial data can be used in the interests of hydrological analysis, spatial analysis of infrastructure disasters, agriculture, forestry, environmental mapping and other purposes. The quality and accuracy and precision in modeling are obtained because of the high resolution and high accuracy of the DEM data itself. Research on the Tsunami Independent Evacuation Routes requires a map of DEMNAS so that the data needed is better in determining evacuation routes. The National DEM is made from several data sources including IFSAR data (5m resolution), TERRASAR-X (5m resampling resolution from 5-10m original resolution) and ALOS PALSAR (11.25m resolution), by adding mass point data used in making topographical maps. Indonesian (RBI). The spatial resolution of DEMNAS is up to 0.27-arcsecond, using the EGM2008 vertical datum. The released DEMNAS data is truncated according to the Map Sheet Number (NLP) on a scale of 1:50k or 1:25k, for each island or archipelago. A summary of the DEMNAS characteristic data set, as follows:

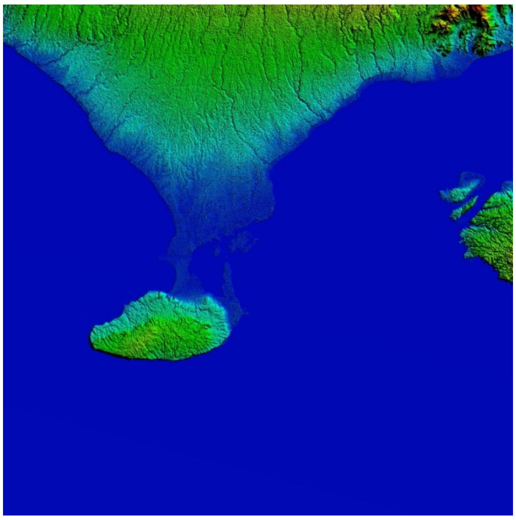

Fig. 3. DEMNAS Maps

Table.1. product specifications of DEMNAS

| **Item** | **Keterangan** |
|---|---|
| Nama file | DEMNAS_1707-33_v1.0 |
| Resolusi | 0.27-arcsecond |
| Datum | EGM2008 |
| Sistem Koordinat | Geografis |
| Format | Geotiff 32bit float |

Institutions such as BIG, NGDC, BODC, BPPT, LIPI, P3GL and other institutions have conducted single or multibeam research in sounding data to be combined in inversion of gravity anomaly data resulting from altimetry data processing to form a National Bathymetry image. The value of the spatial resolution of BATNAS data reaches 6arc-second using the MSL datum. The development of the National Bathymetry gridded data model begins with the calculation of free-gravity air anomaly data, to become bathymetry data using the Gravity-Geological Method (GGM). Hsiao et al (2016) found details on the use of the GGM model, while Becker et al (2009) for the sounding data assimilation method into bathymetric data. The results of the accuracy test show that the marine gravity model that has been developed has an adequate level of accuracy, as a basis for modell bathymetry estimation at 1 minute resolution before the iteration of sounding data assimilation, from 1 minute to 6-arcsecond resolution.

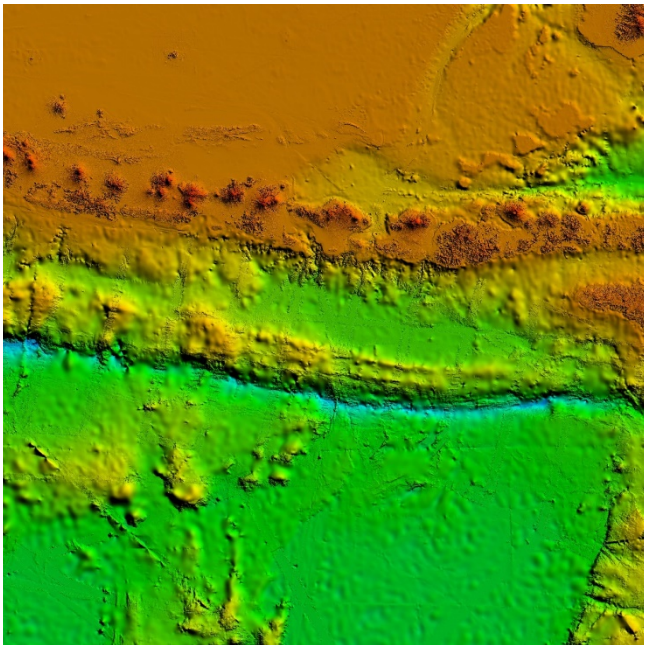

Fig. 4. BATNAS Maps

Hydrographic survey results on Digital Marine Resource Mapping (DMRM) can be used as a data validator for the National Bathymetry gridded model, from 1 minute, 30-seconds, and 15-seconds resolution. This accuracy test was also carried out with existing global bathymetry data for comparison, for example GEBCO30s 2014 edition, SRTM30 and SRTM15 plus. Most of the validation on the beach has been added to the survey data from the Marine and Coastal Environment Center (PKLP), BIG, is no longer needed. The assimilation of sounding data in shallow water areas and areas around the coast makes the gridded bathymetry data that has been developed by the DEMNAS BIG Team, will have the best accuracy in the coastal areas of the Indonesian Archipelago, compared to other bathymetric model data.

The National Bathymetry with a resolution of 30 seconds has a bias error of -12.22 minutes while the SRTM30plus and GEBCO30s data are -18.51m and -24.7m, respectively. Then the standard deviation of BATNAS, SRTM30plus, and GEBCO30s is around 47.32 minutes, 151.4 minutes and 171.53 minutes, respectively. Whereas at 15s resolution, the BATNAS data has a bias error of -9.21 minutes and a standard deviation of 39.75. For SRTM15plus it has a bias error of -15.71 minutes and a standard deviation of 146.53m. BATNAS data specifications can be seen in the table below:

Table 2. product specifications of BATNAS

| **Item** | **Keterangan** |
|---|---|
| Nama file | BATNAS_110E-115E_10S-05S_MSL_v1.5 |
| Resolusi | 6-*arcsecond* |
| Datum | EGM2008 dan MSL |
| Sistem Koordinat | Geografis |
| Format | Geotiff 32bit float |

### 3.2. Earthquake Source Data

Based on the National Center for Earthquake Studies (PuSGeN) in 2022 the maximum earthquake potential for southern Bali caused by the Bali megathrust segment reaches M9.0 (National Earthquake Study Center Team, 2022). Initially, the maximum earthquake potential by South Bali Megathrust reached M7.8 then in 2022 an update will be carried out to M9.0 (figure 5).

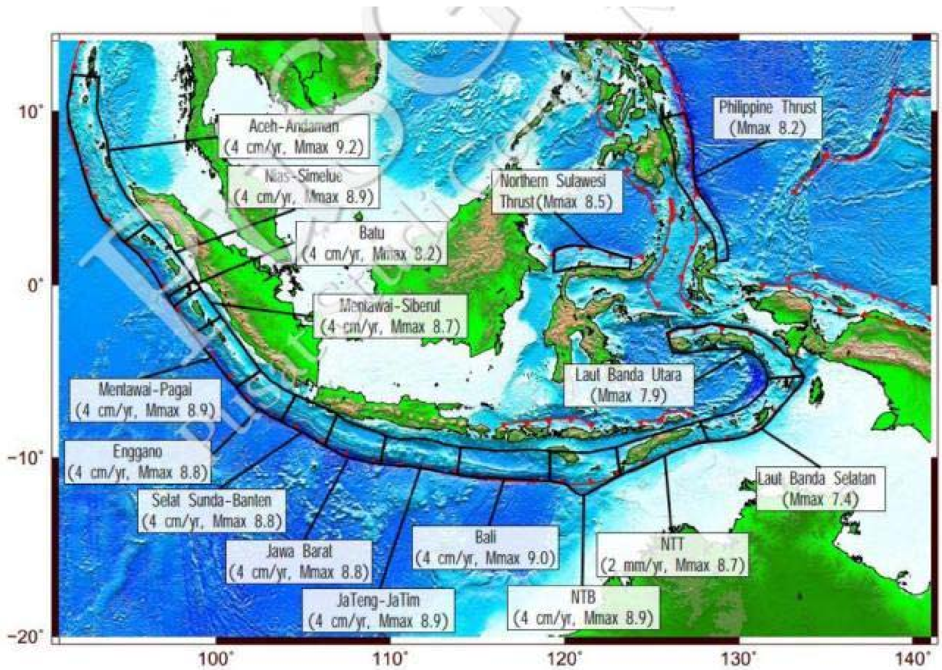


Figure 5. updating of the 2022 national earthquake map megatrust segmentation (National Earthquake Center Team, 2022)

The flow of data processing uses input data sourced from the southern Bali tsunami catalog data based on the history of tsunamis that have occurred (Earthquake and Tsunami Center Team, 2019). Due to limited catalog data, it is necessary to pay attention to the potential for the South Bali Megathrust (National Earthquake Study Center Team, 2022). Then, for modeling using Digital Elevation National (DEMNAS) topographical data with a resolution of 90 meters and BATNAS bathymetry with a resolution of 1 arc minute or the equivalent of 1.8 . The fault parameters that have a major influence on the height of the tsunami run-up are the dip, slip parameters (Wahyu, et al., 2018) where the fault parameters that dominate in southern Bali are ascending faults with a gentle dip or less than 45 degrees (Global CMT, 2020). These parameters are input in the specified grid as the boundaries of the modeling area (Figure 6).

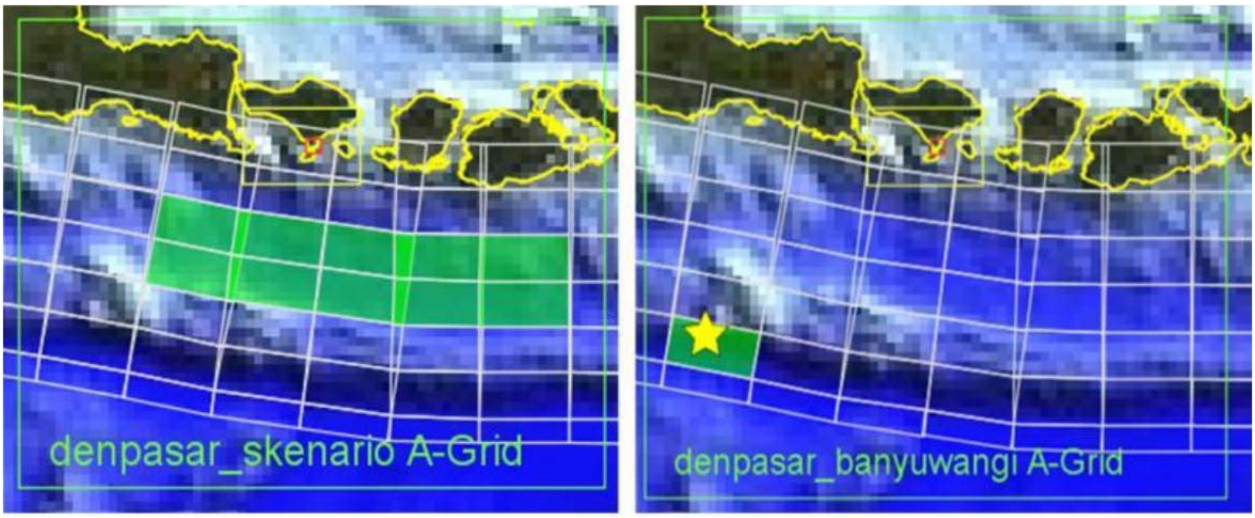


Figure 6. The fault segment used in the Mmax 9.0 tsunami scenario (left) and the 1994 Banyuwangi tsunami (right) as well as the tsunami modeling grid.

If seen from Figure 6, it takes 10 segments to make an earthquake with a magnitude of 9 from an earthquake with a magnitude of 9.0. Scenario segment determination is made based on the location of an earthquake with a shallow depth which is close to the island of Bali. With the character of a megatrust earthquake with a magnitude of M9 and a shallow source of earthquake depth, it will certainly cause deformation of the ocean floor in the southern area of Bali Island.

### 3.3. Data Processing Results

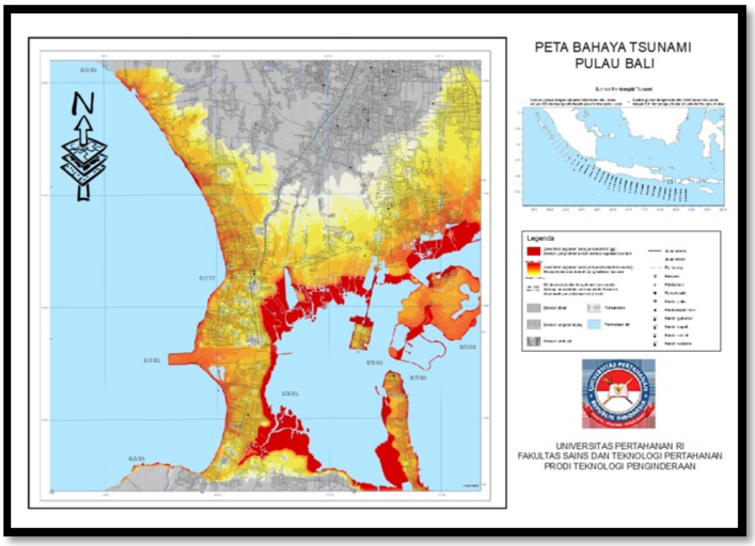


Figure 7. Bali island tsunami hazard map

Map in figure 7. displays the tsunami hazard zone related to the tsunami warning level used in the Decision Support System at the BMKG Early Warning Center. Warning levels are defined as follows:

Table 1. Indonesian Combat Aircraft Specifications

| *Kategori Tsunami* | *Level Peringatan* ***BMKG*** | *Tinggi gelombang di pantai* | *Zona Bahaya* |
|---|---|---|---|
| Tsunami | Peringatan | ≤ 3 meter | |
| Tsunami Besar | Peringatan Utama | > 3 meter | |

High probability hazard zones (dark red) on the map indicate an area with a high probability of being hit by any tsunamis in the area (at warning and main warning levels). The moderate to low tsunami probability zone (red to yellow) is an area that will only be hit by tsunamis with waves higher than 3 meters (main tsunami warning). For this tsunami hazard zone, the visualization of possible tsunami hazard is displayed continuously from moderate tsunami probability (red) to low tsunami probability (yellow). These hazard zones were obtained from the analysis of the tsunami model with moment magnitudes of 8.0M, 8.5M and 9.0M. for the area indicated on the map. The threshold for the minimum estimated arrival of a tsunami is set at the first percentile of the ETA of all tsunami models.

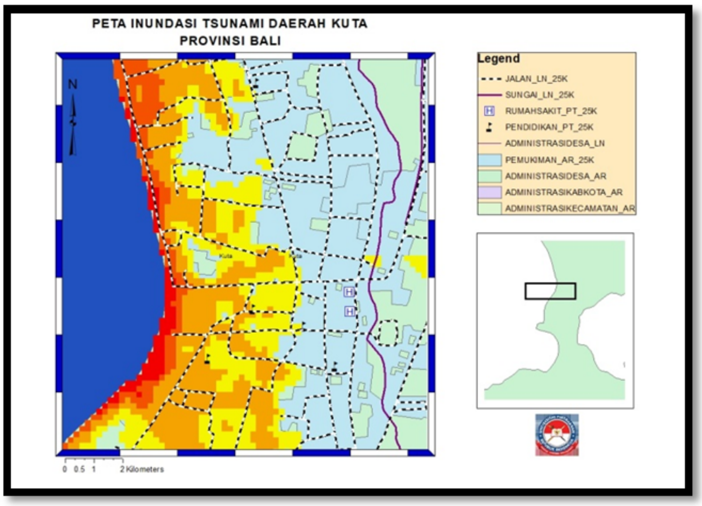


Figure 8. Inundasi map of Kuta

The tsunami inundation map for the Kuta area, Bali Province, was compiled using megatrust maximum earthquake source modeling, namely magnitude 9, using topographic data from DEMNAS and bathymetry data from BATNAS from Tanah Airku BIG. With this data entered into the Comcot system, a tsunami inundation map is obtained as shown in Figure 4.14 above. Areas that have an inundation height of 6-10 meters (red color) and areas that have an inundation height of 3-6 meters (brown color) are spread evenly from the south of Kuta to the north due to topographical differences where the southern region has lower plains than the areas on the north coast. . This also causes inundation that is far enough to reach land more than 200 meters inland, while in the north there are also inundations that are quite far but not as far as in the south.

The Kuta area beach is a well-known destination and is always crowded with both local and international visitors. The character of the beach is also sloping so that it can cause tsunami inundation to reach far.

Things to do before an earthquake and tsunami occur

1. Install clear evacuation route signs so that people can easily see and recognize them.
2. The evacuation route must be passable by crowded people and not narrow.
3. Evacuation routes must be recognized by many people so that people can easily find the designated evacuation routes.
4. Always carry out demonstrations or activities to introduce evacuation routes on a regular basis so that people are used to going to evacuation routes independently.

What to do when a tsunami occurs

1. Immediately stay away from the beach according to the evacuation route signs that have been made.
2. Stay away from rivers because amplification of the tsunami waves can occur so that it will be more dangerous
3. Stay away from billboards, tall buildings, electric poles and large trees so that they are not crushed. When a tsunami occurs it can cause tall buildings to become fragile and easily collapse.
4. Run calmly and don't panic to avoid jostling and trampling on each other which can cause fatalities.

What to do after an earthquake

1. Remain in the temporary evacuation site or final evacuation site
2. Stay away from tall buildings and trees
3. Stay away from high cliffs that have the potential for landslides

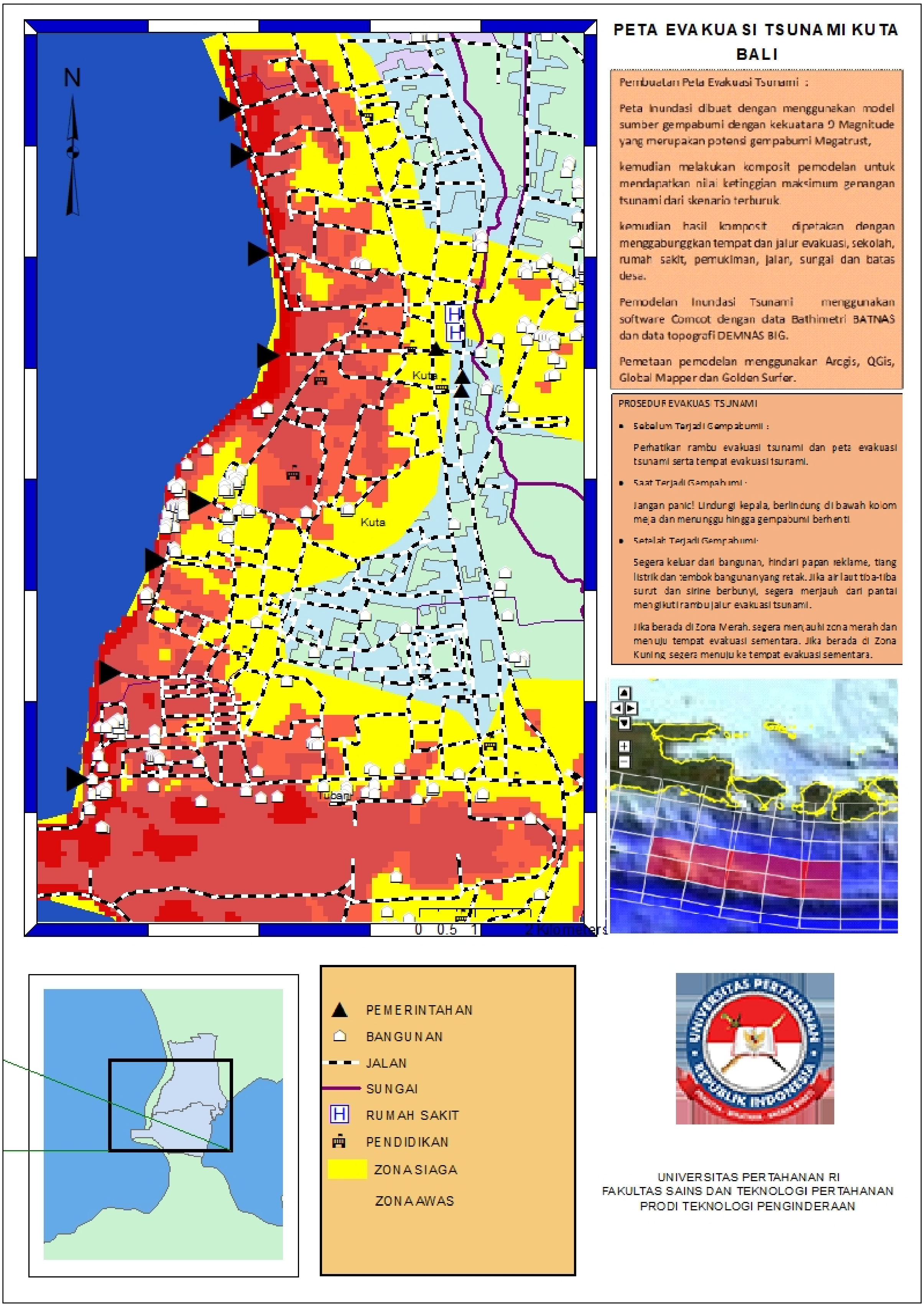


Figure 9. Kuta beach Bali self-evacuation map

## IV. CONCLUSION

Indonesia is a country prone to tsunami natural disasters. With complex geological and tectonic conditions, Indonesia must be prepared to face natural disasters such as earthquakes and tsunamis. The maximum magnitude that can be generated by the megathrust is reaching 9 magnitude, where the great power is enough to destroy the island of Bali. With proper mitigation, Indonesia, especially the island of Bali, can avoid large losses from the tsunami natural disaster.

The self-evacuation map is very important to deal with the tsunami natural disaster. In this study, the tsunami inundation reached its maximum height in the coastal area of Kuta beach and protruded inland for approximately 200 meters. In the red alert area, the tsunami height can reach 6-10 meters. Meanwhile, in the alert area, which is colored yellow, the height of the tsunami can reach 3-6 meters. For alert and alert areas, the public is urged to immediately stay away from the coast through the evacuation route that has been provided to an evacuation site or a tall building or a high hill.

There is a need for a recent study related to the existing tsunami evacuation map considering there is an update on the potential for earthquakes in accordance with PuSGeN 2022 and socialization regarding tsunami evacuation to areas in Bali with potential.

For this reason, it is necessary to update the tsunami evacuation map and draft an evacuation plan that involves various parties. Collaboration between BPBD and BMKG especially in tsunami evacuation maps and their socialization needs to be improved. This research can be a pioneer for updating tsunami evacuation maps in the Kuta area.

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