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# AN ANALYSIS OF TSUNAMI INUNDATION IN MANDALIKA TOURISM AREA (STAGE I) CENTRAL LOMBOK, WEST NUSA TENGGARA

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**ABSTRACT**

*West Nusa Tenggara was hit by an earthquake / tsunami in August 19,1977 particularly in Lunyuk Sumbawa. This earthquake epicentrum was in 11.1 Southern Latitude (SL) 119.0 East Longitude (EL) with magnitude 7 Richter Scale, 33 km depth that hit Sumbawa, West Nusa Tenggara impacted to Kuta village area including Mandalika Tourism Area (MTA), Central Lombok. This research was conducted based on previous research accomplished by Kusuma (2014) with calculation of tsunami wave propagation time from tsunami epiCentral to research point with duration 18 minutes. Research method employed in this research were bathymetric data, existing topography, topography of infrastructure development plan and Lot area data based on Detail Engineering Design (DED) Masterplan using Global Mapper application software, Comcot V 1.6, Surffer V.13 and ArcGis 10.3. Analysis of run-up of tsunami waves using 4 (four) wave height scenarios, i.e. 3.5 meters of existing condition and 3.5 meters, 5 meters, 7 meters of each condition after the development. The result of run-up of the tsunami wave in the widest 3.5 meters width occurred at minute 28 and 3.5 meters after built with the widest inundation at minute 33. Simulated run-up simulation showed differences and changes which occurred in MTA decreased by 855,617,12 $m^2$. The impact that occurred on the supporting village, Kuta increased by 3,278 $m^2$.*

**Key words:** Run Up Tsunami, Inundation, Mandalika Tourism Area.

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## 1. INTRODUCTION

Mandalika Tourism Area (MTA) is located in Lombok Island, West Nusa Tenggara, Indonesia. It's location on the southern coast is close to a subduction zone which is directly adjacent to the Indian Ocean that is identical with its potential risk of tsunami. The earthquake / Tsunami hit West Nusa Tenggara in August, 19 1977 particularly in Lunyuk Sumbawa. This

earthquake epiCentral was in 11.1 Southern Latitude (SL) 119.0 East Longitude (EL) with magnitude 7 Richter Scale, 33 km depth and it impacted to Kuta village area including MTA.

A research on the analysis of Tsunami inundation is aimed at identifying the impact and extent of run-up area in the Mandalika Tourism Area (MTA) and the impact on Kuta as the supporting area of MTA. This run-up analysis used 4 wave height scenarios, i.e. 3.5 meters of existing condition and 3.5 meters, 5 meters, 7 meters of each condition after the development plan. Each scenario is analyzed and evaluated using Comcot V 1.6, Surffer V.13 and ArcGis 10.3 applications for determining the boundary of the study site, simulating the run-up time of the tsunami wave and analyzing the puddle pool data on KPM spatial layout. The basis of analysis and evaluation is the time of tsunami waves to the shore, the deepest and widest pools. This study aims at discovering the prediction of tsunami wave travel time, run up altitude, inundation depth and to know the impact of tsunami inundation on MTA land use and Kuta village as a supporting village.

## 2. LITERATURE REVIEW

Pradjoko *et.al,* (2015) conducted a post-tsunami survey in Kuta Village Lombok related to the distribution of tsunami water increases on spatial conditions using GPS technology to identify elevations and rising positions of tsunami water. Based on the field survey, it revealed that water rose about 1.5 meters with a position almost close to each other. The simulation results showed that the tsunami wave propagation time is about 20-30 minutes. The resulting increase in depth of water was received as compared to the results of a 1.6 m field survey and a tsunami rise of 300-800 m from the coastline. In this research, simulation analysis used existing data and there was no development in MTA.

Kusuma (2014) accomplished an analysis of tsunami hazard by simulating the 1977 tsunami incident. This study is used as a reference to determine tsunami prone areas. The tsunami incidence data as well as the depth of the 1977 tsunami run-up were obtained from interviews with victims. By stating the time of tsunami wave spreading from earthquake source to the research point was 18 minutes, the result of simulation was concluded.

## 3. RESEARCH METHODOLOGY

### 3.1. Data Collection dan Simulation

Raster digital data collection; satellite images, aerial photographs and vector data; existing topography and conditions after development. Satellite image and aerial photography data are intended as existing information medium, while topographic data provides elevation information as the basis for analysis, evaluation and calculation of inundation areas. The process of analyzing the contour / topographic elevation data in this study employed the Multigrid Coupled Tsunami Model (COMCOT) V 1.6, using shallow wave theory in Cartesian coordinate system when the depth is smaller than the wavelength. The tsunami modeling program (COMCOT) V 1.6 is able to simulate waves of run-up, run-up, and run-down in coastal areas. The wave propagation equation is presented in Eq.1-Eq.3 as follows:

$$\frac{\partial \eta}{\partial t} + \left\{\frac{\partial p}{\partial x} + \frac{\partial Q}{\partial y}\right\} = 0 \quad (1)$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left\{\frac{p^2}{H}\right\} + \frac{\partial}{\partial y}\left\{\frac{PQ}{H}\right\} + gH\frac{\partial \eta}{\partial x} + F_x = 0 \quad (2)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left\{\frac{PQ}{H}\right\} + \frac{\partial}{\partial y}\left\{\frac{Q^2}{H}\right\} + gH\frac{\partial \eta}{\partial x} + F_y = 0 \quad (3)$$

Clarification of symbols:

$\eta$ = water level elevation (m)

P = h.u = water volume flux x axis (m2 / sec)

Q = h.v = water volume flux y (m2 / sec)

g = acceleration of gravity (m2 / sec)

h = water depth (m)

H = h + η = total water depth (m)

$F_x$ = bottom friction in x direction

$F_y$ = bottom friction in y direction

To analyze COMCOT v 1.6 this study used the simulation process data as follows:

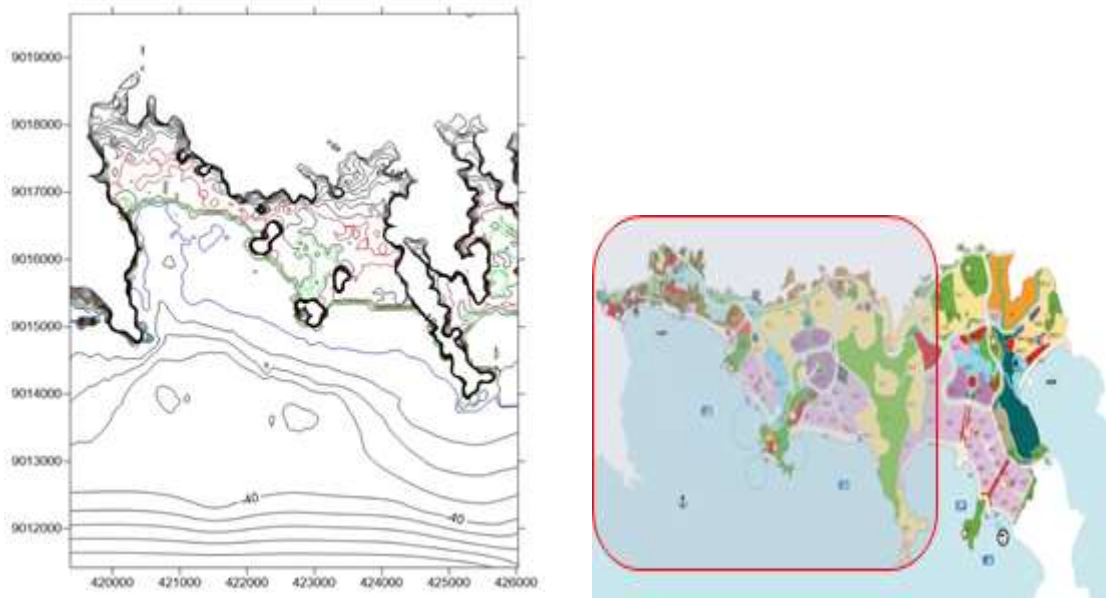
- The total duration intended to discover in the simulation results in seconds, using a value of 1800 seconds (30 minutes).
- The time interval of the simulation results intended to be viewed in seconds, using 60 seconds (1 minute).
- The process of run-up and tsunami wave analysis using SURFER v.13 by making the following grid boundaries are described as follows:
- Ix is the total number of grid x (west to east), this data is equated to the value at the time of the grid making that is 643 grid.
- Jy is the total number of grid y (south to north), this data is equated to the value at the time of grid making that is 824 grid.

The boundary and grid making process at research point with SURFER v.13 application using Universal Transverse Mercator coordinate (UTM) with reference coordinate result are described as follows:

- On the smallest X-axis value : 419370.2706
- On the largest X-axis value : 425786.7106
- On the smallest Y-axis value : 9011419.513
- On the largest Y-axis : 9019651.187

The Use of Global Mapper is required to overlay maps according to the binding points used in spatial analysis applications on MTA. The use of ArcGIS is intended to process the calculation of the extent data on the MTA Lot to run up and inundation of the tsunami. MTA masterplan spatial data is required for the analysis and evaluation of the tsunami inundation on the overall development of the area in stage I consisting of :

- Data of Lot of MTA based on Detail Engineering Design (DED) Masterplan
- The infrastructure data includes: road ROW / DMJ (road owned area) 90, 60, 45, 30 and 15 meters, utilities and landscape.
- Data of buildings (hotels, villas, residential and other supporting buildings)




(a) (b)

**Figure 1** (a) Map of Masterplan Mandalika Stage-1 and (b) initial contour map for analysis and calculation of tsunami run-up.

In the process of analysis, calculation, and simulation of inundation are conducted on the use of COMCOT v. 1.6 and SURFER v.13, while the analysis and evaluation of area calculations used ArcGis v.10.3 with 3 (three) time variations and 4 (four) depth variations.

### 3.2. Analysis of Tsunami Run Up

In analyzing tsunami run up, this study used the limitation of 3 variations of run-up time of the tsunami wave, at each 3.5 meter wave height of existing condition, 3.5 meters development to know the run up data gap, the extent and depth of inundation. Additional variations of wave height 5 meters and 7 meters development in this research is intended to know the condition of run up and inundation in MTA and supporting village, 3 variations of time explained as follows:

- When tsunami run up wave reach the beach and start to enter the mainland.
- When the run-up has entered the mainland with the highest depth of inundation (deepest) at a particular location.
- When run up reached the maximum widest inundation and the flow has not shown back towards the coast.

On each time variation and wave height with 4 variations of inundation depth were used for the analysis and calculation of run-up of the tsunami inundation within the MTA and the location of the supporting village.

The time scenario of this study refers to Kusuma's previous research (2014) in which the duration of the analysis result from the source of the earthquake in 1977 to the starting point of the research is 18 minutes will be added by the results of simulation of run-up wave simulation in line with the duration of the study, as shown in Figure 2 as follows:

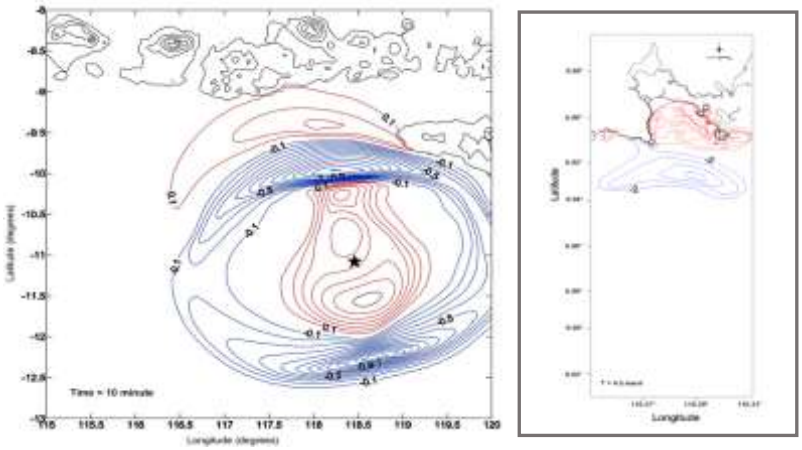


**Figure 2** Illustration of tsunami wave in MTA as the location of this research

## 4. RESULTS & DISCUSSION

Based on analysis and evaluation of research with high scenario of tsunami wave 3.5 meter existing condition, result of run-up process of tsunami wave simulation and analysis of inundation data, the result can be shown in Figure 3 and Figure 4 below.

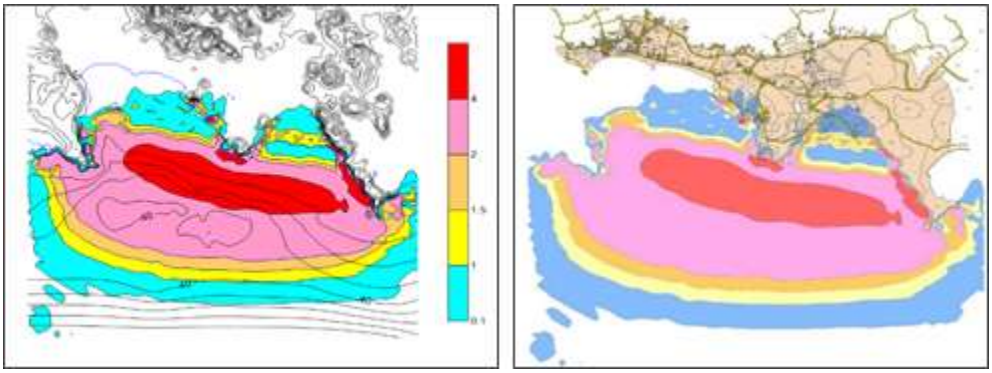


**Figure 3** Tsunami wave height illustration 3.5 meters existing condition

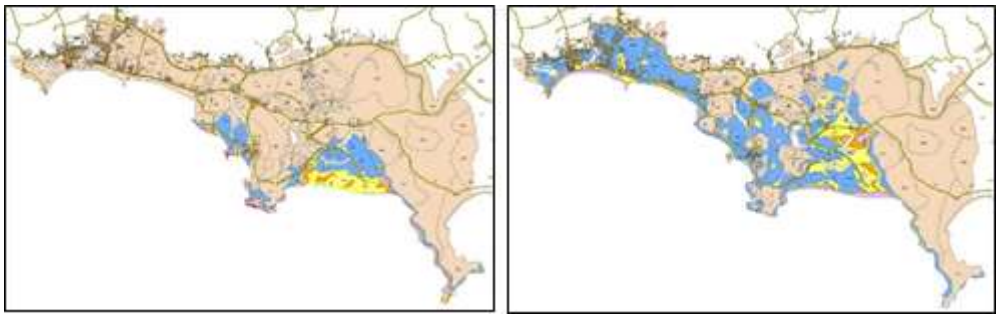


**Figure 4** Results of run-up and inundation simulation process with wave height 3.5 meters of existing condition

Based on analysis and evaluation of research with the scenario of the height of tsunami wave 3.5 meters under the condition of development in MTA, the results of run-up process of tsunami wave simulation and analysis of inundation data are shown in Fig 5-Fig 6 as follows:

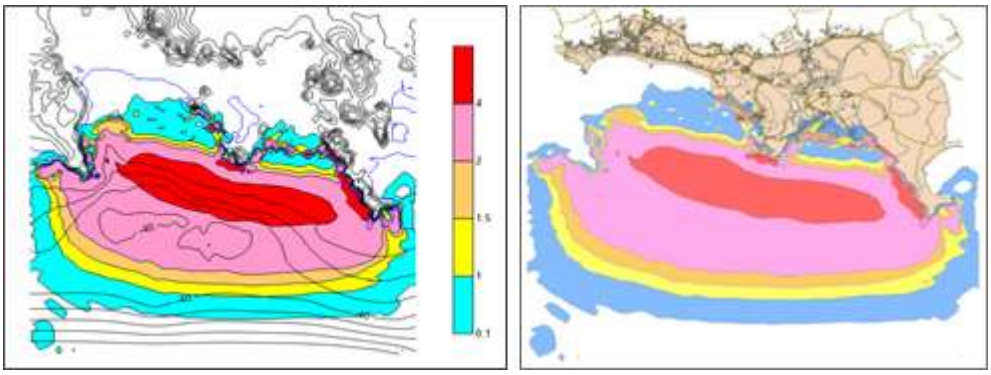


**Figure 5** Tsunami wave height illustration 3.5 meters under Development conditions

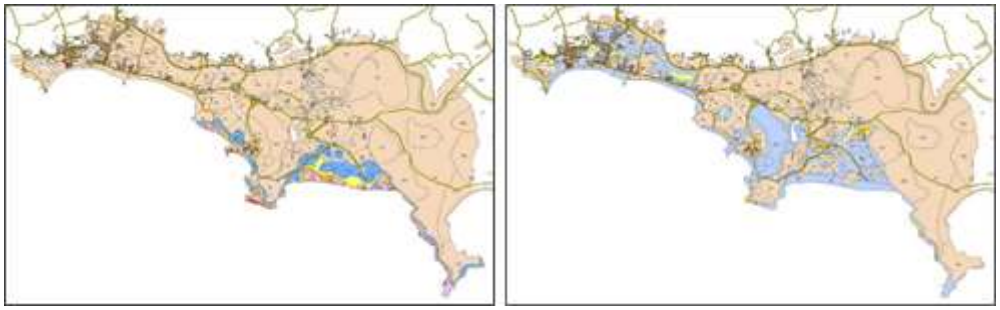


**Figure 6** Results of run-up and inundation simulation with wave height 3.5 meters under development conditions

The impacts of run-up of tsunami waves occurring in MTA are presented as follows:

- The minimum inundation area occurs at simulated wave height of 3.5 meters under condition in which the development and pilling up based on the elevation of the plan, with the extent of the inundation of 1,789,765.12 m2 (31.70%).
- The maximum inundation area occurs at simulated wave height of 7 meters under condition in which the development and pilling up based on the elevation of the plan, with the extent of the inundation of 3,274,025,83 m2 (40.93%).

Details as shown in Table 1 below:

**Table 1** Recapitulation of run-up and tsunami inundation analyzes in MTA

| NO | WAVE SCENARIO | INUNDATION AREA ($M^2$) | | | | | TOTAL ($M^2$) |
|---|---|---|---|---|---|---|---|
| | | 0.1-1.0 M | 1.0-1.5 M | 1.5-2.0 M | 2.0-4.0 M | > 4.0 M | |
| 1 | Existing Wave 3.5 Meters | 2,149,028.07 | 383,380.87 | 88,379.37 | 24,593.93 | - | 2,645,382.24 |
| 2 | Development Wave 3.5 Meters | 1,577,308.53 | 136,740.02 | 53,124.66 | 22,550.76 | 41.15 | 1,789,765.12 |
| 3 | Development Wave 5 Meters | 1,303,315.31 | 476,120.29 | 327,905.00 | 427,589.75 | 1,066.69 | 2,535,997.04 |
| 4 | Development Wave 7 Meters | 1,116,178.39 | 606,455.13 | 487,885.00 | 944,110.95 | 119,396.37 | 3,274,025.83 |

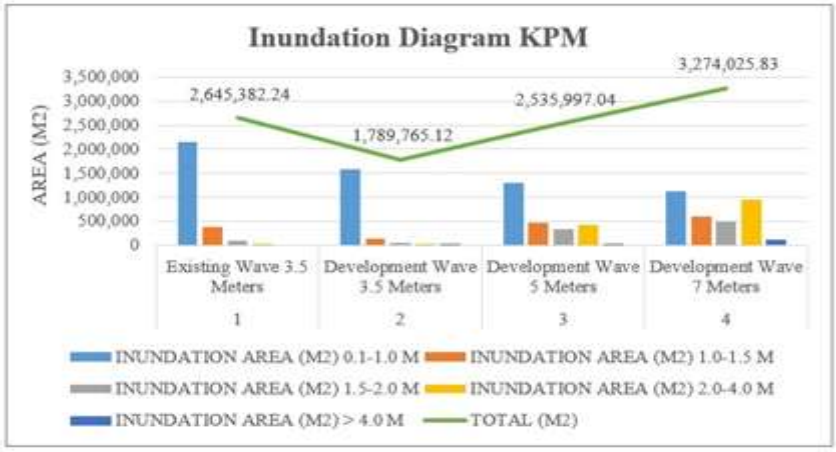



**Figure 7** Diagram of Inundation on MTA

The impacts of run-up of tsunami waves that occurred in Kuta Village are described as follows:

- The largest tsunami run-up run in the simulation of 7 meters 27 minutes waves with area: 352.384.56 m2 with a depth of 0.1 to 1 meter.
- The smallest tsunami run-up occurs in the 3.5-meter wave simulation after built on 27 minutes with an area of: 8,612.35 m2 with a depth of 1-1.5 meters.
- The tsunami run up inundation occurred in simulation of 7 meter development wave height 27 minutes min by 2 - 4 meters depth with 72,034.11 m2 area.
- Total area of the largest inundation run-up of tsunami waves that inundated the area of Kuta village outside MTA was 665,748.43 m2 with depths ranging from 0.1- 4.0 meters occurred at 7 meters wave height development 27 minutes.
- Different area between existing condition and development on wave 3.5 meter: 3.278 m2.

**Table 2** Recapitulation of tsunami run-up results in Kuta Village

| NO | WAVE SCENARIO | INUNDATION AREA ($M^2$) | | | | | TOTAL ($M^2$) |
|---|---|---|---|---|---|---|---|
| | | 0.1-1.0 M | 1.0-1.5 M | 1.5-2.0 M | 2.0-4.0 M | > 4.0 M | |
| 1 | Existing Wave 3.5 Meters | 2.149.028.07 | 383,380.87 | 88,379.37 | 24,593.93 | - | 2,645,382.24 |
| 2 | Development Wave 3.5 Meters | 1.577.308.53 | 136,740.02 | 53,124.66 | 22,550.76 | 41.15 | 1,789,765.12 |
| 3 | Development Wave 5 Meters | 1,303,315.31 | 476,120.29 | 327,905.00 | 427,589.75 | 1,066.69 | 2,535,997.04 |
| 4 | Development Wave 7 Meters | 1,116,178.39 | 606,455.13 | 487,885.00 | 944,110.95 | 119,396.37 | 3,274,025.83 |

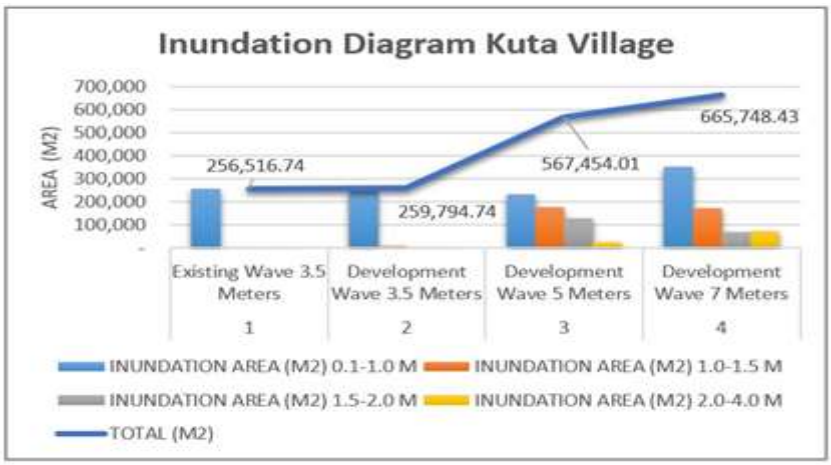



**Figure 8** Diagram of Inundation in Kuta Village

## 5. CONCLUSIONS

Referring to the results of the research and simulation analysis of run-up of tsunami wave with 3.5 meter wave height of existing condition, 3.5 development, 5 meter development and 7 meter development, it can be concluded as follows:

***The tsunami run up wave in MTA***

| | |
|---|---|
| Wave 3.5 meters under existing condition | : 2,645,382,24 m2 |
| Wave 3.5 meters under development condition | : 1.789.765,12 m2 |
| Wave 5 meters under development condition | : 2,535,997,04 m2 |
| Wave 7 meters under development condition | : 3,274,025,83 m2 |

Based on the result of simulation analysis of run-up of tsunami inundation in the existing condition 3.5 meter wave scenario and 3.5 meter under development, it can be concluded that there is a difference of area or decrease of 855,617.12 m2.

***The tsunami run up wave in Kuta Village***

| | |
|---|---|
| Wave 3.5 meter under existing condition | : 256.516,74 m2 |
| Wave 3.5 meter under development condition | : 259.794,74 m2 |
| Wave 5 meter under development condition | : 567.454,01 m2 |
| Wave 7 meter under development condition | : 665.748,43 m2 |

Based upon the result of simulation analysis of run-up of tsunami wave in existing condition 3.5 meter wave scenario and 3.5 meter development, it can be claimed that there is difference of area of 3.278 m2 and there is an increase of extent in wave 3.5 under development condition.

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An Analysis of Tsunami Inundation in Mandalika Tourism Area (Stage I) Central Lombok ,West Nusa Tenggara.

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