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MAPPING OF POTENTIAL AREAS TSUNAMI PRONE IN BENGKULU CITY

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ABSTRACT

Bengkulu city including tsunami-prone areas. This study aims to calculate the level of tsunami hazard in the Bengkulu city. The risk level is calculated based on the height from sea level (h), the distance from the shoreline (x), distance from the nearest river (s), the condition of geomorphology (k), the number of buildings per square kilometer (p), and the value of the peak ground acceleration (α). All variables are measured with the rules of research. Tsunami will continue to be a threat in earthquake prone areas. Threats region more concentrated along the coast and moves upstream as far as 10 kilometers. Tsunami threat is more factual determined by height, distance from the shoreline, distance from the nearest river, and peak ground acceleration. The correlation between tsunami potenstial score with each variable tends to be linear.

Keywords: bengkulu city, earthquake, peak ground acceleration, tsunami.

INTRODUCTION

The worst impact of the earthquake is a tsunami. Aceh earthquake 2004 resulting tsunami and deadly more than 100 thousand inhabitants. The tsunami also caused damage to the network infrastructure, public facilities, education buildings and settlements [1].

In general, the tsunami will threaten human life. Thanh and Xuyen (2008) conduct studies about the chances of a tsunami on the coast of Vietnam. Results of the study indicate where very small chance of a tsunami on the coast of Vietnam, but still carried mitigation to secure the social and economic system in the country [2].

Briggs *et al* (2005) modeling about level of tsunami inundation in Southern California, Modeling results provide information about the losses that will be suffered by the state. Losses could reach US $ 4.5 Billion which would result in damage and disruption of port operations, so can have a significant impact on the national and global economy [3]..

Hoechner *et al* (2013) suggested that the Sumatra earthquake of 2004 has been impacted by the tsunami, with inundation length 1600 km in 10 minutes. Very long puddle scope and duration of only 10 minutes after an earthquake has similarities with Tohuku earthquake [4].

Bird and Dominey (2006) expressed the need for tsunami hazard mitigation which must be done by the Australian government after the Aceh tsunami in 2004. Sydney City Council stresses the importance of government preparedness to face the hazard of tsunami due to the earthquake that comes from subduction the Indo-Australian and the Pacific plate [5].

Breaker *et al* (2011) suggested that the tsunami which occurred as a result of the Tohoku earthquake have made huge losses in terms of damage in the Gulf of Santa Cruz Harbor. [6].

Bengkulu city that position parallel with the Aceh province has the same threat to tsunami-affected.

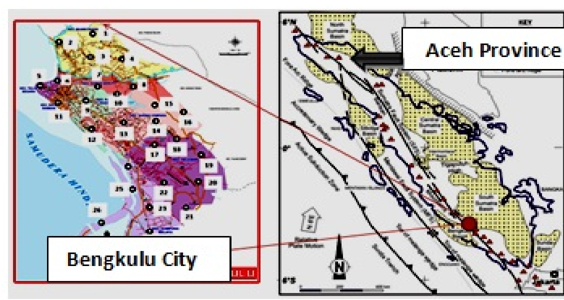

Figure-1. Bengkulu city map.

The position of the Bengkulu city located in coastal areas to add this powerful threat. Dense population, many government buildings, residential buildings, and places of worship would be in case of tsunami victims.

This powerful threat should be used as part of development planning. Tsunami threat will be a function of the height (h), distance from shoreline (x), distance from the nearest river (s), and Peak Ground Acceleration (α).

Other variables that may influence the tsunami threat is geomorphology conditions, population, and the number of buildings per square kilimeter.

LITERATURE REVIEW

Tsunami wave can be triggered by many events such as tectonic earthquakes, under the sea volcanic eruptions, under the sea landslides, avalanches iceberg, and the impact of a meteor crashed into the sea. From these events tectonic earthquakes has contribute most large

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at around 75%. The intensity of a tsunami wave can be connected with the water level (Suppasri *et al*., 2013) [7], which is defined in equation (1).

$$I = \frac{1}{2} + \log_2 H_{av} \quad (1)$$

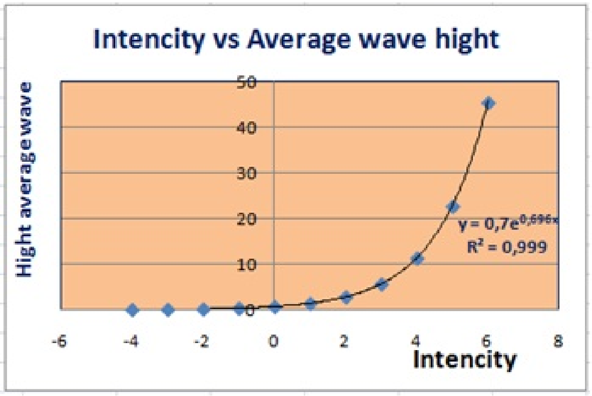

Figure-2. The relationship between the intensity with the average height of the waves.

Nakamura (1979) suggests a relationship between the intensity of a tsunami with a moment magnitude of earthquakes [8]. Its relationship as shown in equation (2).

$$I = 3.55M_W - 27.1 \quad (2)$$

Where M_w is the moment magnitude .

The equations are necessary to be as a reference in the reducing the tsunami effect hazard. Tsunami hazard can be reduced by two approaches, namely structural and nonstructural [9]. Structural approach taken to control the height of the tsunami wave by several types of structures such as sea walls or embankments, dams, thick vegetation, [10].

This structural approach will fail if tsunam high very large and outside the selected design criteria, [11]. Non-structural approach was done by planted trees against waves and mapping before the disaster.

Maeda *et al*., Propose to reduce the speed of tsunami waves must be made the forest control along 0 to 30 [12]. Timber stronger withstand tsunami waves compared to the building of concrete [13]. Paper is made to reduce the risk of tsunami with non-structural approach.

METHODOLOGY

Measurement of the variables that will determine the speed of a puddle by the tsunami is done by direct measurement at each point of interest.

Measurement of height (h) is done directly using altimeter. Measuring the distance from the shoreline to the point of being reviewed (x) is done by measuring directly on a map of the city of Bengkulu using software ArkGis

By using this software a distance on the map can be measured. The map which be used is a map on Google Earth. Measuring the distance from the point in terms of the river (s) do the same as measuring the distance to the shoreline. Calculation of Peak Ground Acceleration (α) was performed using the Kanai attenuation equations.

$$\alpha = \frac{5}{\sqrt{Tg}} 10^{0.61M - (1.66 + \frac{3.6}{R} \log R) + (0.67 - \frac{1.83}{R})} \quad (3)$$

In the equation is required determinant variable, that is dominant ground period (T_g), the moment magnitude (M) and the distance from hipocentrum (R) to a point of interest. The next measurement is geomorphologi condition (G), and a number of buildings (ρ_b) in the square kilometer. Geomorphologi condition of choice is only 2 kinds, that is flat or hilly. All quantities are then quantized. Quantization for altitude is done as follows:

- altitude 0 – 10 meter were scored 6
- altitude 10 – 20 meter were scored 5
- altitude 20 – 30 meter were scored 4
- altitude 30 – 40 meter were scored 3
- altitude > 40 meter were scored 2

The smaller the scor of altitude, the smaller the risk of a tsunami. Quantization for Peak Ground Acceleration is done as follows:

- α > 700 gal is given score 6
- α between 500 – 700 gal is given score 5
- α between 300 – 500 gal is given score 4
- α between 100 – 300 gal is given 3
- α < 100 gal is given score 2

The greater the scor of α will the greater the risk of tsunami. Quantization to the distance from the shoreline is done as follows:

- < 500 meter is given score 6
- 500 -1500 meter is given score 5
- 1500 -2500 meter is given score 4
- 2500 -3500 meter is given score 3
- > 3500 meter is given score 2

The smaller the scores of the coastline will be less risk of a tsunami. Quantization to the distance from the river carried out as follows:

- < 500 meter from the river is given score 6
- 500-1000 meter from the river is given score 5
- 1001-1500 meter from the river is given score 4
- 1501-2000 meter from the river is given score 3
- >2000 meter from the river is given score 2

The smaller the scores of the river the less the risk of a tsunami.

Quantization for geomorphologi condition is performed as follows:

- Flat condition is given 4
- Not flat condition is given score 2

The more flat a location will greater of the risk of tsunami. Quantization to the number of buildings per km2 performed as follows:

- The number of buildings > 2.000 is given score 2

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- The number of buildings between 1.500-2.000 is given score 3
- The number of buildings between 1.000 -1.500 is given score 4
- The number of buildings between 500-1.000 is given score 5
- The number of buildings between < 500 is given score 6

The greater the number of building will impede the flow of water, so that the less exposed to the risk of a tsunami.

From this score, then each point being reviewed have a risk of tsunami different from one another.

With this score, it can be made Map of Tsunami Potential Risk in every region of the Bengkulu city.

RESULTS AND DISCUSSION

Results of the study appear in Table-1 as follows:

Table-1. Tsunami potential score in each region.

Long	Latt	x	s	h	α	G	Score
102,27	-3,94	11,8	21,7	1,5	720	4	36
102,28	-3,93	330	1389	9	488	4	32
102,31	-3,92	2088	62,1	24	624	4	32
102,33	-3,90	3609	2239	21	710	2	24
102,31	-3,90	1195	162	26	712	4	33
102,30	-3,90	6	173	2,9	789	4	36
102,31	-3,89	213	51	2,6	698	4	34
102,30	-3,88	99	469	4,5	223	4	34
102,35	-3,87	5758	4820	30	303	4	25
102,33	-3,87	3952	3069	23	304	4	26
102,33	-3,87	3837	2901	23	656	4	22
102,33	-3,86	2611	1845	18	182	4	28
102,33	-3,85	3702	2959	18	302	4	27
102,30	-3,85	948	229	29	801	4	33
102,30	-3,85	1111	429	26	898	4	33
102,32	-3,84	2960	1773	18	765	4	28
102,34	-3,82	6196	5404	38	315	4	25
102,34	-3,82	6072	5299	26	571	2	25
102,33	-3,83	4575	3812	40	754	2	21
102,24	-3,77	5344	4603	21	386	2	19
102,26	-3,76	4816	4111	38	288	4	21
102,30	-3,75	2681	1914	29	768	4	24
102,27	-3,74	940	218	5,5	425	4	19
102,32	-3,78	3418	2907	38	280	4	25
102,33	-3,78	3889	3354	40	273	4	28
102,31	-3,80	3712	499	38	316	4	29
102,29	-3,80	6946	717	36	422	2	24
102,28	-3,80	4397	567	21	506	4	35
102,27	-3,78	1584	1137	9	302	4	33
102,26	-3,78	1444	1023	22	131	2	30
102,33	-3,82	822	247	8	231	5	22
102,33	-3,82	53	2353	6	469	5	26
102,31	-3,83	1672	197	31	376	5	29
102,29	-3,84	5401	2281	41	116	2	34
102,31	-3,82	3440	322	33	160	2	22
102,31	-3,81	3722	1216	19	242	2	22
102,30	-3,81	7166	4172	42	259	2	27

If displayed in the map can be seen in Figure-3.

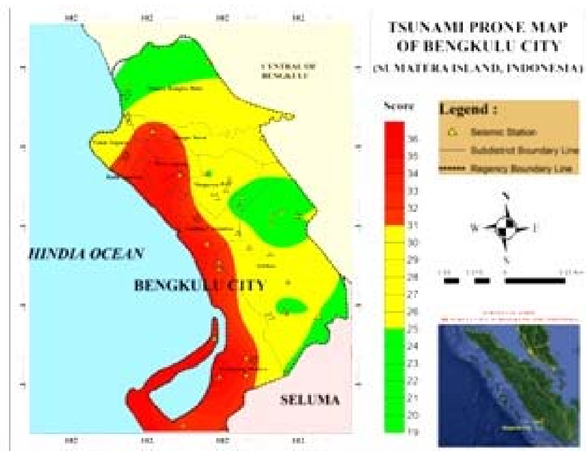

Figure-3. Tsunami potentian map Bengkulu city.

The red area is the area which potentially affected by the tsunami. The reach of the tsunami with altitude 30 meters could reach 10 km, this is in accordance with simulation 30-meter high tsunami inundation by Yulian [14] as Shown in Figure-4.

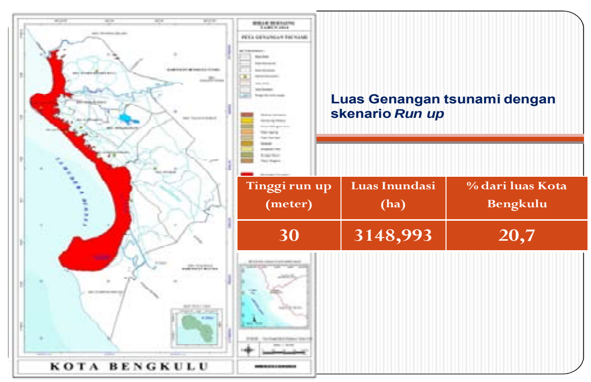

Figure-4. Tsunami flood areas with a height of 30 meters (Yulian, 2013).

With a range so far predictable amount of assets that were heavily damaged buildings can reach 40,000 units, including residential buildings, offices, hotels, hospitals, and houses of worship.

The number of people affected by the tsunami could reach 100,000. Losses incurred by the government of the city of Bengkulu is not only the soul but also the property.

Map of potential tsunami in Figure-3 is not the same as the map puddle in Figure-4. In Figure-3, a map of the potential tsunami of red color has not stated complete. For the most northern areas of the city not depict the actual conditions. In this area has not surveyed its maximum, ie there is no data in the region, so that the northern part of Bengkulu city still appeared yellow.

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In coastal areas of Bengkulu City has a flat geomorphology that will further facilitate the movement of water entering the mainland. City areas being brought upstream more undulating and has a height which varies greatly, so it will be easier to inhibit the movement of water.

Of all the variables that predicted in determining the level of a potential tsunami, would only altitude (h), distance from shoreline (x) and distance from the river (s) are significantly become major variables in determining the level of potential tsunami disaster, as shown in Figure-5, Figure-6 and Figure-7.

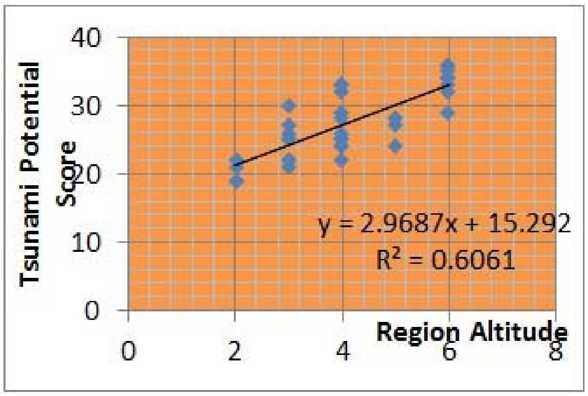

Figure-5. The correlation between Tsunami potential score with region altitude.

The correlation between the tsunami potential score with altitude region tend to linear correlation with a regression coefficient of 0.606. Regression coefficient for 0606 is enough to justify that the correlation between the tsunami potential scores with altitude region is a linear corelation.

The correlation between the tsunami potential score with a distance of shoreline also provide clear information. The distribution of the dots give a tendency to a linear function as shown in Figure-6.

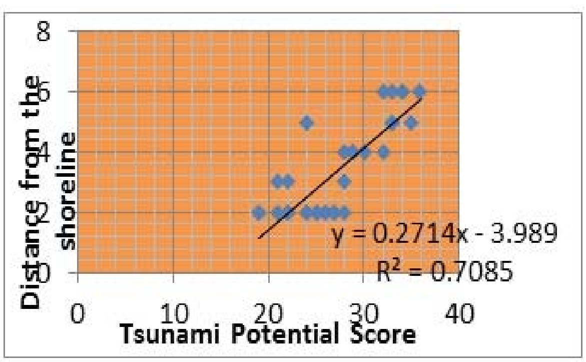

Figure-6. The correlation between Tsunami potential score with distance from the shoreline.

Regression coefficient for 0708 is very strong to justify that the correlation between the tsunami potential scores with the distance from the shoreline is a linear corelation.

The corelation between the tsunami potential score with the distance from the river also provide clear information. The distribution of the dots give a tendency to a linear function as shown in Figure-6.

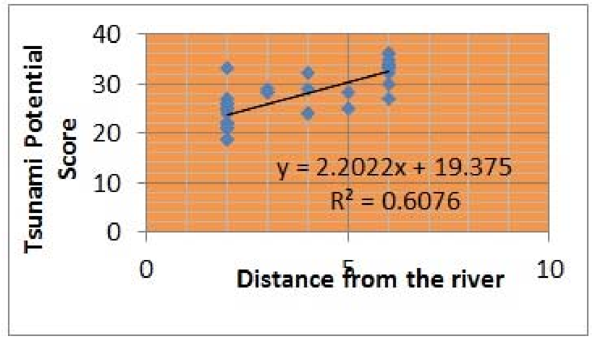

Figure-7. The correlation between Tsunami potential score with distance from the river.

Regression coefficient for 0607 is enough to justify that the correlation between the tsunami potential scores with the distance from the river provide a linear correlation.

The correlation between the tsunami potential score with Peak ground accleration also tend to be a linear corelation, with a regression coefficient of 0522 as shown in Figure-8.

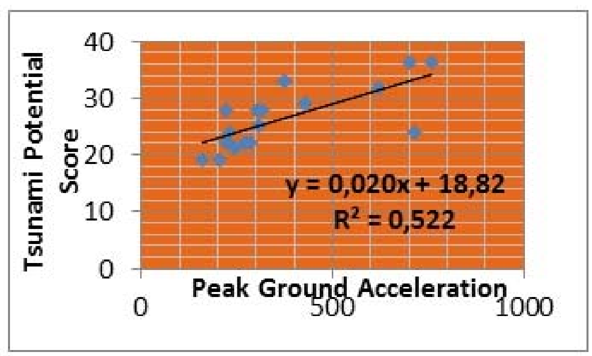

Figure-8. The correlation between Tsunami potential score with peak ground acceleration.

Regression coefficient for 0522 provide information that is optimistic about the linear correlation between the tsunami potential scores with the Peak Ground Acceleration. For densely populated areas does not determine the level of tsunami danger, ut give a greater risk, especially during the day, because human ativitas.

CONCLUTIONS

Tsunami will continue to be a threat in earthquake prone areas. Threats region more concentrated along the coast and moves upstream as far as 10 kilometers. Tsunami threat more strongly determined by the altitude, distance from the shoreline, distance from the nearest river, and. peak ground acceleration . The correlation between tsunami potenstial score with each variable tends to be linear. The correlation between the tsunami potential score with a geomorphological conditions, the number of buildings per square kilometers, and the number of people do not give clear information.

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