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The Run up Tsunami Modeling... (Fauzi et. al)
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The Run up Tsunami Modeling in Bengkulu using the Spatial Interpolation of Kriging Technique

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Abstract

This research aims to design a tsunami hazard zone with the scenario of tsunami run-up height variation based on land use, slope and distance from the shoreline. The method used in this research is spatial modelling with GIS via Ordinary Kriging interpolation technique. Kriging interpolation method that is the best in this study is shown by Circular Kriging method with good semivariogram and RMSE values which are small compared to other RMSE kriging methods. The results shows that the area affected by the tsunami inundation run-up height, slope and land use. In the run-up to 30 meters, flooded areas are about 3,148.99 hectares or 20.7% of the total area of the city of Bengkulu.

Keywords: run up tsunami, inundation, kriging

Abstrak

Penelitian ini bertujuan merancang zonasi bahaya bencana tsunami dengan skenario variasi ketinggian run up tsunami yang didasarkan pada penggunaan lahan, lereng dan jarak dari garis pantai. Metode yang digunakan dalam penelitian ini adalah pemodelan spasial dengan GIS melalui teknik interpolasi Ordinary Kriging. Metode interpolasi Kriging yang terbaik dalam penelitian ini adalah metode Kriging Circular yang ditunjukkan dengan semivariogram yang baik dan memiliki nilai RMSE yang kecil dibanding dengan RMSE metode kriging yang lain. Hasil penelitian menunjukkan bahwa luas inundasi tsunami dipengaruhi oleh ketinggian run-up, lereng dan penggunaan lahan. Pada run-up 30 meter wilayah yang tergenang seluas 3.148,99 hektar atau 20,7 % dari seluruh luas Kota Bengkulu.

Kata kunci: run up tsunami, genangan, kriging

Introduction

Bengkulu is one of cities which is prone to earthquake since it lies on the west shoreline of Sumatera. Based on the tsunami zoning in Indonesia, this city is classsified as an area which is susceptible to tsunami disaster. Suwarsono (2003) states that there are 4 from 9 districts which have tsunami vulnerability.

Tsunami is a disaster caused by earthquakes which happens in an unpredictable time with a very hazardous to both people's lives and properties so that there should be a good management to respond to and cope with such circumtance. Due to the hazardous impacts of the disaster, disaster mitigation efforts are needed to minimalize the losses and one of the ways is tsunami hazard zoning map (Harsanugraha, 2008 dan Damanik, 2008).

The difference of tsunami elevation will lead to a variation of tsunami inundation distribution (Fitria, 2008) which can be mapped spatially based on tsunami run-up height. One of the techniques to determine the tsunami hazard zones is by developing tsunami inundation map which has been experienced by several researchers such as Islam and friends (2014), Maemunah (2011), and Fitria (2008). This research applies geostatistical approach through spatial interpolation technique with kriging interpolation. Fitria (2008) in her research uses kriging interpolation technique based on raster data, while this research is based on vector. Kriging is the best method applied for geostatistic interpolation approach since it has high accuracy (Julzarika, 2009).

This method above is derived from regional variabel theory which has an assumption that geographical data variation can be called as regional variable. Kriging is performed to decrease the degree of interpolation from semivariogram (Surfer, 2009 in Julzarika, 2009). Basically, measurement and semivariogram display are the essence of kriging interpolation method. Semivariogram determines the level of intra data spatial correlation measured in a location, or the level of spatial data correlation which apparently is its regional variable.

Research Method

Research Location

Geographically, Bengkulu is located in 30° 45' – 30° 59' South and 102° 14' – 102° 22' east. This city has a shore range from the west part of Sumatra island which directly faces Hindia ocean. The beach which faces a great energy of wave influenced by swell is predicted to have a natural erotion. This phenomenon, or we can say abrasion of the coast, is potential for creating sediment on the shoreline and it is worsen by the supply of sediment from the watershed around this city.

This city has an administrative land area of 151.7 km², including a 2 Ha island and water area of 387.6 Km² , and consists of 9 districts and 67 villages. The coastal area of this city generally is situated in 0-50m of the water sea surface (dpl). The largest area is situated in 0-10m (dpl) that is around 10, 248 Ha or 70.91% of the total area of this city. Based on the land slope, it is shown that 9.850 ha ofthe shore areas in Bengkulu have the slope of 0-3% or 68.15% of the total areas (Fauzi et al., 2009).

Reseach Model

Spatial tsunami inundation modelling in this research refers to the damage description stated by Imamura and Iida (1949) in Diposaptono and Budiaman (2006), by using the application of geographic information system (GIS). This research uses slope, landuse and distance from the shoreline as the parameter. While tsunami inundation modeling refers to the model developed by McSaveney and Rattenbury (Berryman, 2006) using variables: the scenario of tsunami run-up elevation at the shoreline, the roughness coefficient and the slope. Figure 1 shows the diagram of research flow. Scenario of run-up elevation that is used in this research refers to the research developed by Synolakis et al. (2008). The decline of water elevation in each location can be calculated using this formula:

$$H_{loss} = \left({167n^2}/{H_0^{1/3}} \right) + 5\sin S$$

where:

H_{loss} = the decline of water height per meter from the inundation
n = the roughness coefficient
H_0 = the water height at the shoreline
S = the slope

Land roughness coefficient is resulted from the map of land use as a result of land canopy extraction which is related to roughness coefficient values developed by Damanik (2008). Its values are shown in Table 1. The map of the slope is derived from the DEM (Digital Elevation Model) that is the extract of the Indonesian Topographic Map (RBI), sheet of Bengkulu.

Result and Discussion

The remote sensing data of this research uses Google Earth image taken in 2009. From the analysis result in Bengkulu, there is an over-function of land to become shelters. Its composition is described in Table 2.

Tsunami inundation modeling is simulated by calculating its wave propagation which takes the slope, surface roughness coefficient and run up tsunami as a consideration. The surface roughness and the slope are measured by Formula 1 and it results in the decline of tsunami height points. Table 3 shows the sample of points.

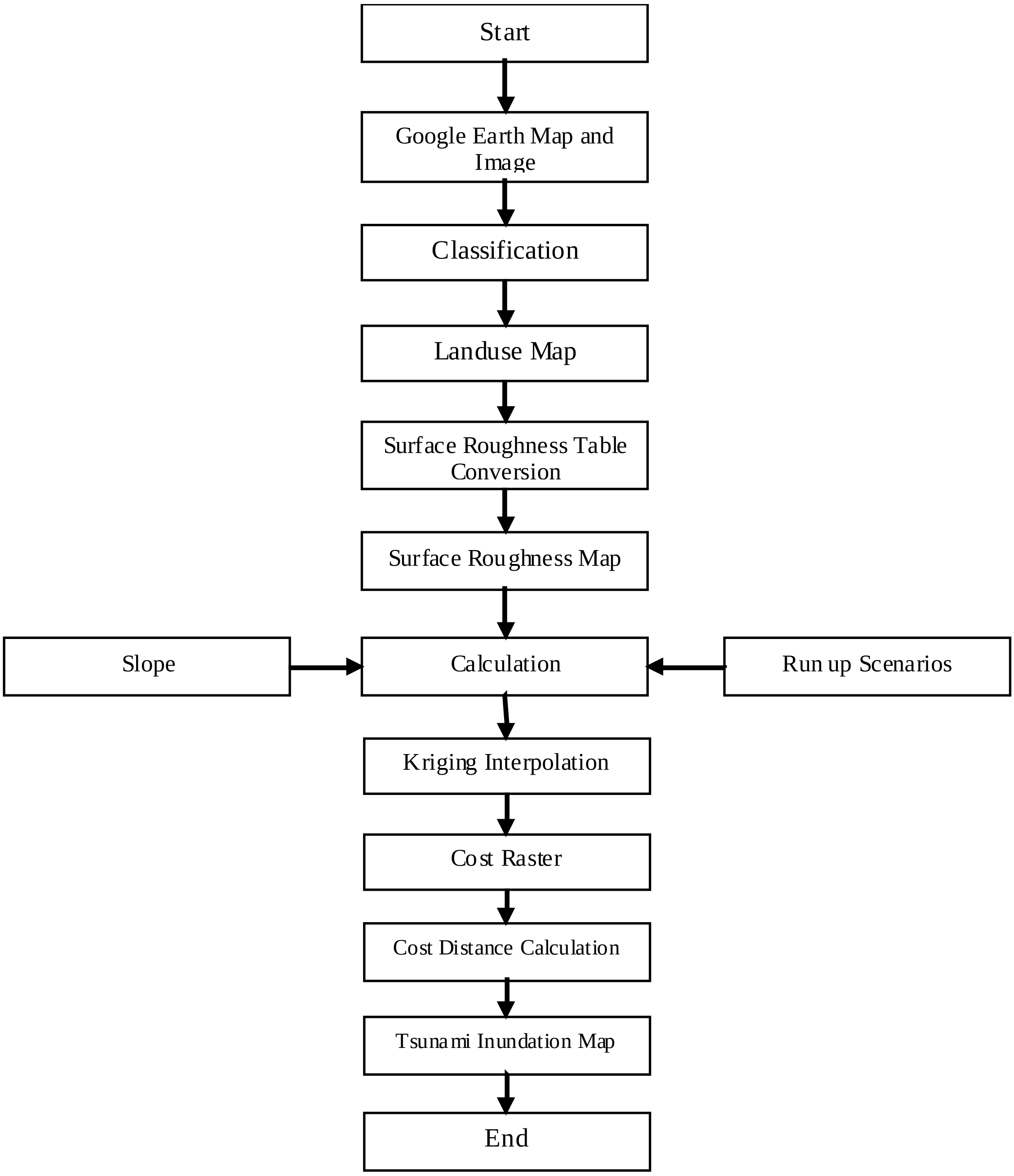
Tsunami Inundation Analysis

The tsunami-run up measurement results in the decline of tsunami height which is considered as an input of the working map. The input process of height point to the map is based on the tsunami inundation distance to the land that this is the result of buffer process to the coastal line in Bengkulu. Then, the result that is the height point is spatially interpolated by using the Ordinary Kriging Interpolation which involves extension Kriging Interpolator 3.2 SA

Kriging method which is implemented in this research uses semivariogram experimental Eksponensial, Sperical, Gauss, Circular and Linier models. The best of those five semiovariograms which has the smallest RMSE value for run-up of 5 meter, 15 meter and 30 meter is choosen and the result of the calculation is expressed in the Figure 2.

The result of the calculation by using Log value of interval 100 is the variance value and RMSE from each method as shown in Table 4. Based on the Table 4, the smallest value of RMSE of the five methods is resulted from circular method so that interpolation process of tsunami inundation on run up scenario uses this method. Tsunami inundation map of Bengkulu city with circular Kriging method is expressed in Figure 4(a), (b), (c).

The risk level of tsunami inundation based on run up elevation scenario shows about the various inundation



Gambar 1. The Research flow

Table 1. Surface Roughness coefficient

No	Land use	Surface roughness coefficient
1	Very populous community	0.08
2	Middle populous community	0.05
3	High densed vegetation	0.07
4	Low densed vegetation	0.04
5	Other lands	0.02

Table 2. Composition of land use of research location

No	Landuse	Width	
		(Ha)	%
1	Community	3,473.80	22.9
2	Mixed garden	2,616.90	17.2
3	Beach Jungle	460.6	3
4	Open Land	1,986.10	13.1
5	Rice field	3,169	20.9
6	Bush	2,777.80	18.3
7	Tourism Park	183	1.2
8	Others	505	3.3
	Amount	15,172.20	

Table 3. Number of samples of Hloss points

Run up	Number of sample
5 meter	495
15 meter	988
30 meter	988

Table 4. Semivariogram value And RMSE with run up

Metode	AIC			BIC			SSE			RMSE		
	5	15	30	5	15	30	5	15	30	5	15	30
Circular	205.01	417.19	417.19	214.7	426.88	426.88	3	9	9	0.13	0.22	0.22
Exponential	424.55	519.37	519.37	434.25	529.07	529.07	9	16	16	0.23	0.29	0.29
Gaussian	632.49	659.55	659.55	642.18	669.24	669.24	29	33	33	0.39	0.42	0.42
Linear with Sill	524.16	480.12	480.12	533.86	489.81	489.81	16	13	13	0.3	0.26	0.26
Spherical	238.09	455.65	455.65	248.58	564.34	564.34	3	11	11	0.14	0.25	0.25

height. From the result of tsunami inundation modeling, it is shown that the areas of tsunami inundation is linear with tsunami run up elevation (Figure 3). In tsunami run up elevation of 5 meter the inundated area is only 2.2 % of the total area of Bengkulu, in run up of 15 meter is 5.7% and in run up of 30 meter is 20.7% (Table 5). Therefore water can travel to the land quite far.

Table 5. The width of Tsunami Inundation with run up scenario

No	run up height (meter)	Inundation width (ha)	% of width of Bengkulu city
1	5	328,065	2.2
2	15	874,993	5.7
3	30	3,148,993	20.7

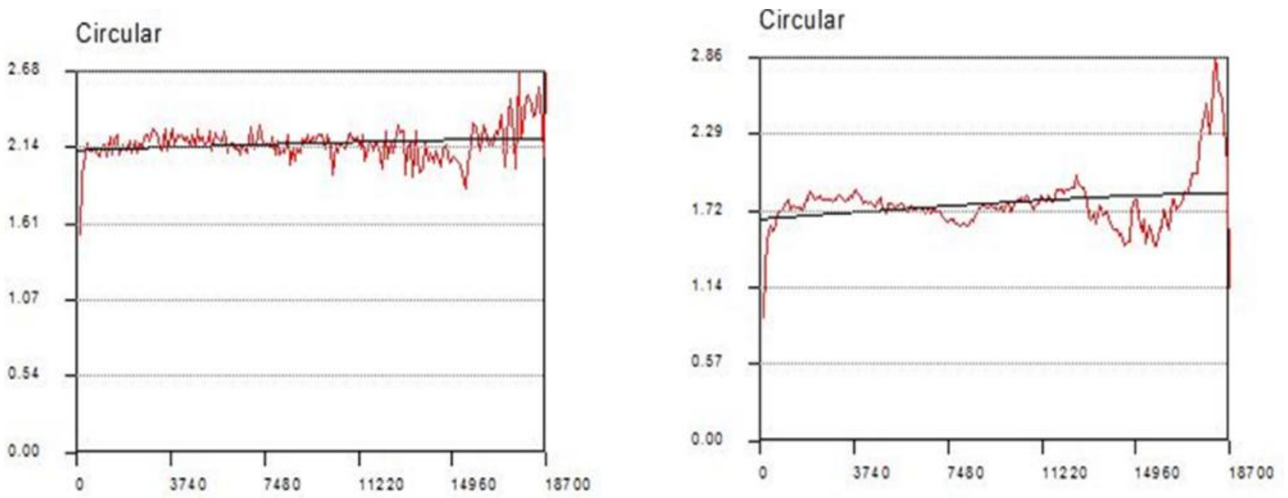


Figure 2 Semivariogram in Run up scenario

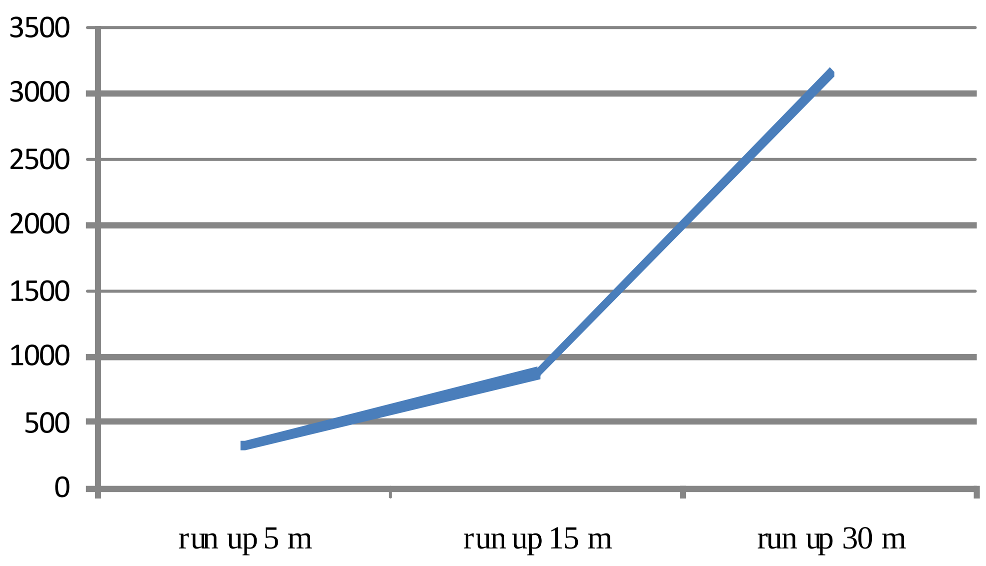


Figure 3. The relationship between Tsunami heights and inundated area widths

Generally, the result of the modeling shows the effect of land roughness factor to tsunami penetration to the land. The higher surface roughness coefficient value that the land has, the bigger barrier that tsunami will face to penetrate to the land. The slopes give distribution as well to be the barriers for tsunami penetration.

Based on the simulation result and tsunami inundation mapping in Bengkulu, it is shown that district Sungai Serut, Ratu Samban, teluk Segara and Kampung Melayu are prone to tsunami disaster. The inundation distance ranges from 50-600 meters on flatter slope, while on flat areas the tsunami can reach 1.6 kilometers to the land. This is because the surface roughness on that area has a considerably smaller coefficient value compared to other areas so that tsunami can penetrate easily to the areas with small barrier factors such as empty land, middle size community and low rapid vegetation. With these condition, its wave elevation is relatively low and give distribution as well to be the barriers for tsunami penetration.

Conclusion

1. Tsunami estimation based on variation of run-up elevation can be calculated by using spatial modeling and SIG through Kriging Interpolation technique.

2. The modeling result of tsunami risk level in Bengkulu shows that the inundation areas of run-up scenario of 30 meters is 3,148.9 ha or 20.7% of Bengkulu area

References

Berryman, K. 2006, Review of Tsunami Hazard and Risk in New Zealand, New Zealand: Institute of Geological and Nuclear Science. Lower Hutt.

Damanik. M.R.S, 2008, Pemodelan Tingkat Risiko Tsunami Kota Denpasar Menggunakan Citra ASTER dan Sistem Informasi Geografis. Artikel PIT MAPIN VII, Bandung

Diposaptono S dan Budiman. 2008. Hidup Akrab dengan Gempa dan Tsunami. Bogor: PT. Sarana Komunikasi Utama

Fauzi, Y., Susilo. B dan Mayasari. Z.M, 2009, Analisis Kesesuaian Lahan Wilayah Pesisir Kota Bengkulu Melalui Perancangan Model Spasial dan Sistem InformasiGeografis (SIG). Jurnal Forum Geografi, Vol. 23, N0. 2, hal: 101-110.

Fitria, N. 2008, Kajian bahaya Tsunami pada Variasi Ketinggian Run-Up dan Arah Tsunami. Artikel PIT MAPIN VII, Bandung

Harsanugraha. W.K dan Julzarika. A, 2008, Analisa Pemodelan Tsunami dengan Pembuatan Peta Kerawanan dan Jalur Evakuasi dari Turunan SRTM90 (Studi Kasus: Kota Padang). Artikel PIT MAPIN, Bandung.

Islam. F., Subiyanto. S., dan Sabri. L.M. 2014, Penentuan Resiko Dan Kerentanan Tsunami Di Kebumen Dengan Citra Alos, Jurnal Geodesi Vol. 3, No. 1, hal: 141-154

Julzarika. A, 2009, Pemodelan 3D Pulau Batu Mandi Menggunakan Digital Elevation Model (Dem) Turunan Digital Surface Model (Dsm) Shuttle Radar Tophography Mission (Srtm) 90 Dengan Interpolasi Cokriging, Jurnal Penginderaan Jauh Vol. 6, hal: 22-31

Maemunah. I., Sulaeman. C dan Robiana. R., 2011, Identifikasi potensi kerawanan tsunami di wilayah Kabupaten Jember, Jawa Timur. Jurnal Lingkungan dan Bencana Geologi, Vol. 2 No. 2 hal: 141 - 152

Permana, D., 2010, Analisis Pemodelan Inundasi Tsunami Terhadap Jenis Tutupan lahan di Kota Bengkulu. Tesis S2, Prodi Pascasarjana Pengelolaan Sumberdaya Alam dan Lingkungan Universitas Bengkulu, Bengkulu.

Purbani. D, 2012. Strategi Mitigasi Tsunami Berbasis Ekosistem Mangrove Dalam Aplikasi Pemanfaatan Ruang Pantai Timur Pulau Weh. Tesis S2, Sekolah Pascasarjana IPB. Bogor.

Suwarsono, 2003, Tingkat Pengetahuan Mitigasi Gempa Bumi dan Tsunami Ibu Rumah Tangga di Kota Bengkulu, Jurnal Akselarasi Universitas Muhammadiyah Bengkulu, Vol. IX No. 5.

Synolakis, C. E., Bernard, E. N., Titov, V. V., NogLu, U. Ka., And. Gonzalez, F. I., 2008, Validation and Verification of Tsunami Numerical Models, Jurnal Pure Appl. Geophys. 165 page: 2197–2228

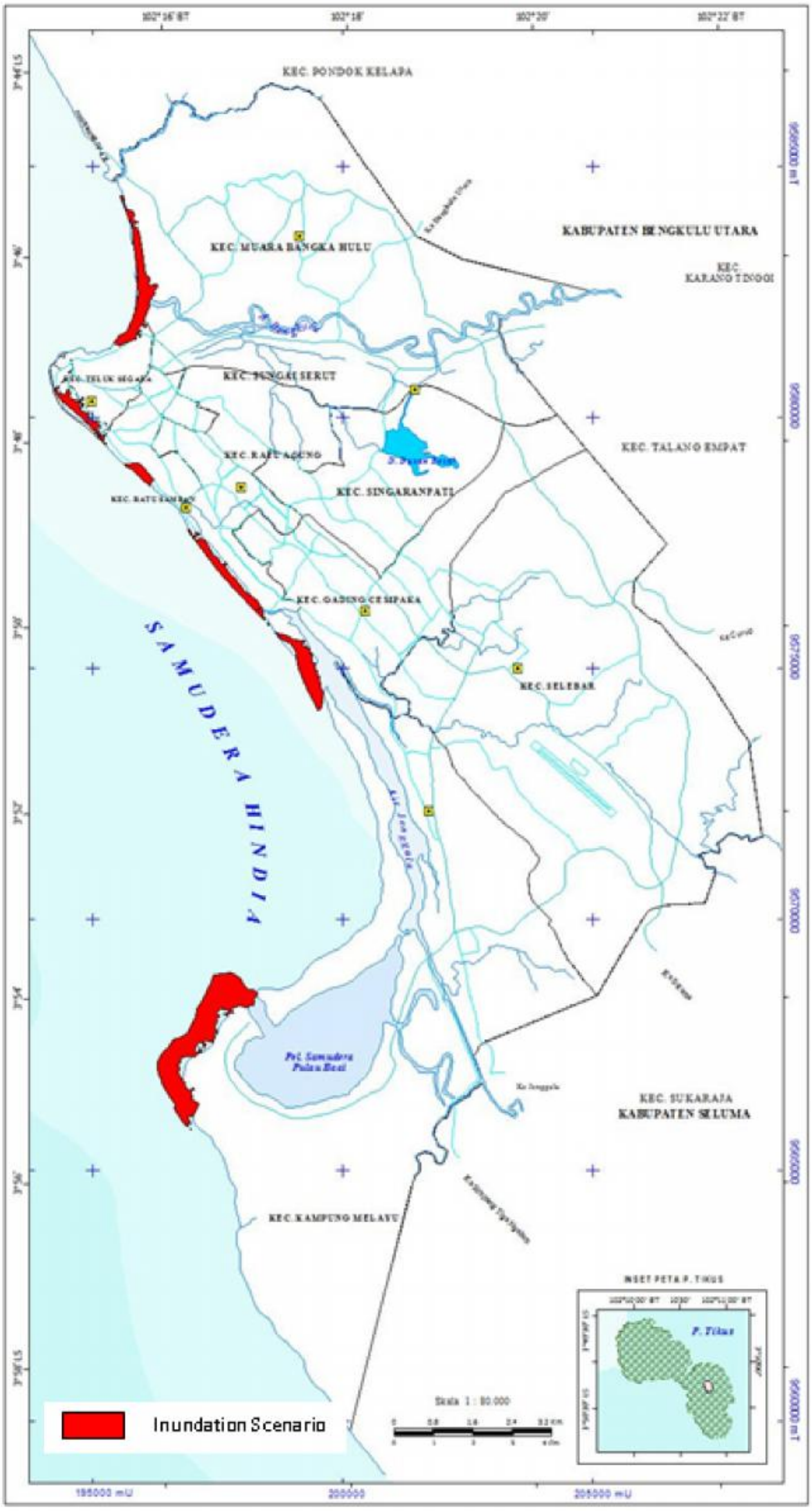


Figure 4a. tsunami inundation based run up elevation of 5 m

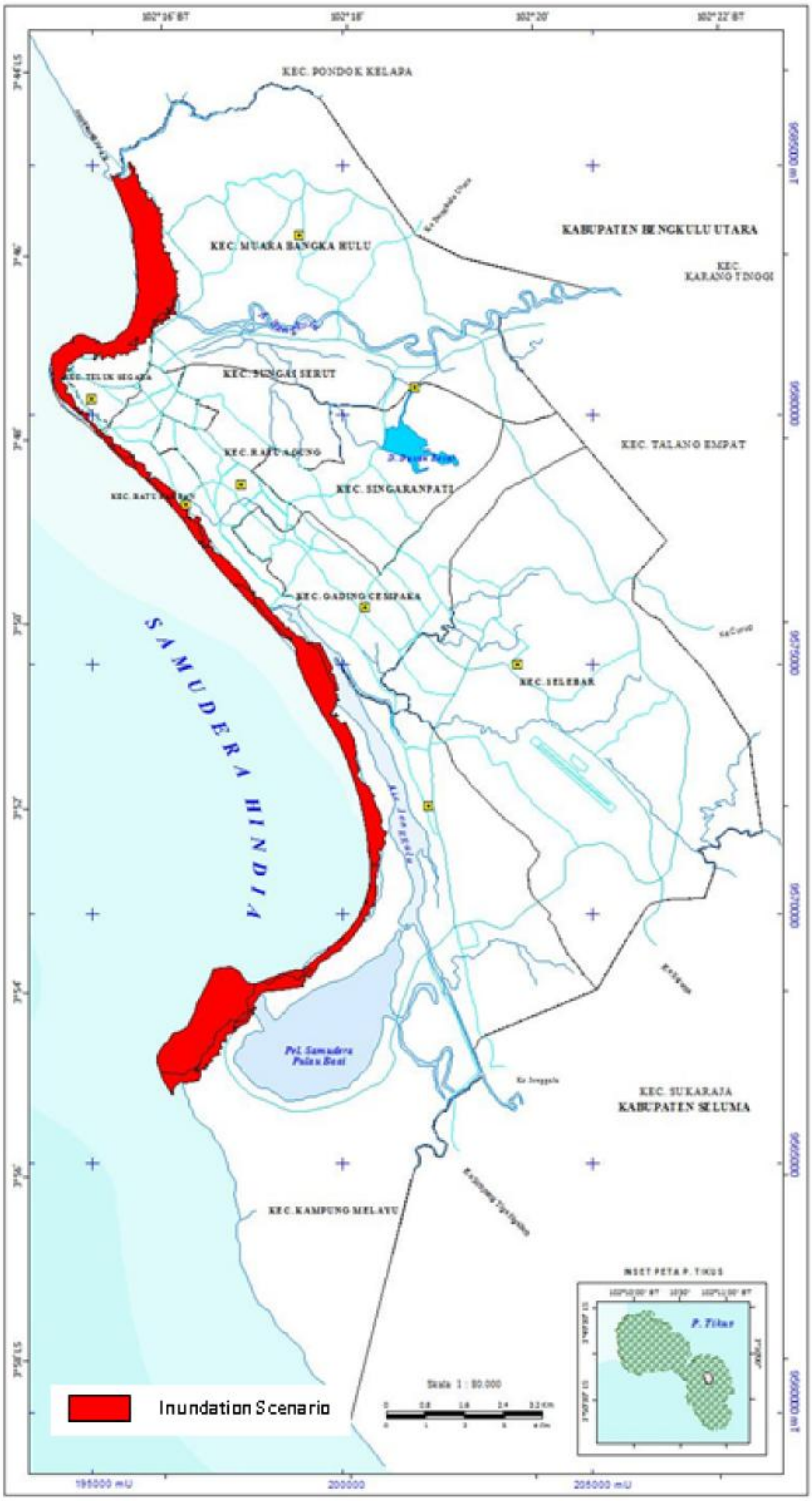


Figure 4b. Tsunami inundation based on run up elevation of 15 m

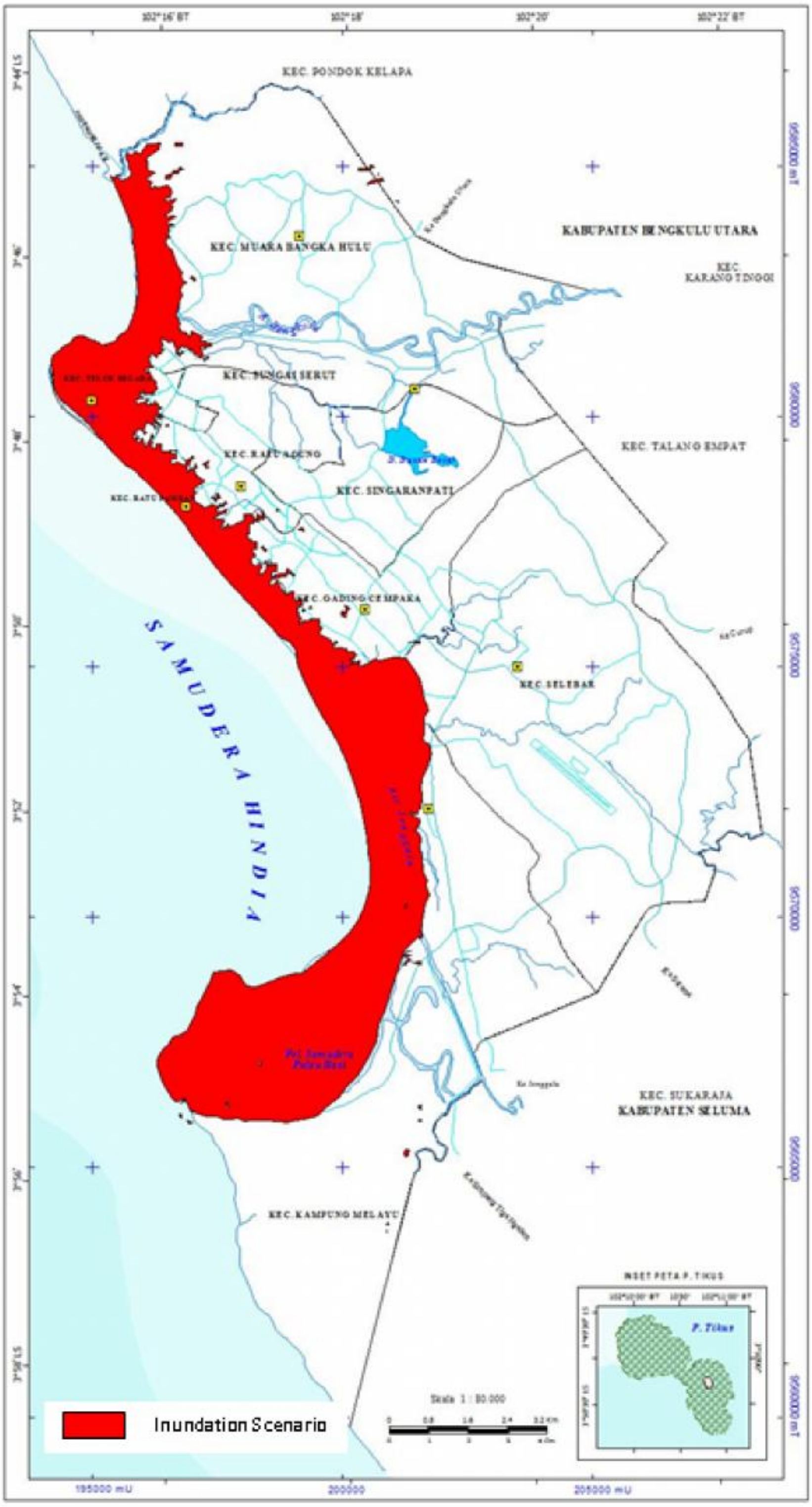


Figure 4c. tsunami inundation based on *run up* elevation of 30 m