Risk And Mitigation Analysis of Tidal Flooding Disaster in Medan Belawan Sub-Distric, Medan City

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ABSTRACT

Medan Belawan is one of sub-district in Medan City North Sumatera which is the coastal area. The area is particularly vulnerable to coastal hazard that of all people living near coastal line. The most influential of disaster is tidal flood. Tidal flood almost occurs every year with the total inundation area is 26,25 Km2, for example from 2010 until 2017 recorded that the tidal flood inundated around 0,5 m to 2 m in average. There were 98 113 people and 3000-4000 houses, schools, public health facility (puskesmas), highway, fishponds, and international harbor affected. The disaster is not only threatening the community life but also disturbance their sustainable livelihood especially people with low socio-economic condition. This paper provides risk index analysis of the flood and propose the disaster risk reduction measures to reduce the impact of risk. Regarding the analysis, Medan Belawan Sub-district was categorized into high-risk area to the tidal flood, so that its need disaster risk reduction measures. Disaster risk reduction aims to protect affected communities, reduce damage and losses when the disaster happens and make sure sustainable livelihood. Mitigation is one of disaster risk reduction effort that can be divided into structural and non-structural. In structural measure, one of solution is building the impervious seawall which is designed based on increasing of sea level rise due to some factors such as tidal, wave, wind, climate change, land subsidence, and flood which is caused by rainfall with the high intensity. Overall basic design of seawall can build in Medan Belawan Coastal Area is around 4,95 m for its height and will be in residential area that is directly bounded by the sea. In the other hand non-structural approach can be implemented if people permanently live in that area. They can do some adaptation activities to reduce negative impacts and if possible, for taking any advantages of its positive impacts. People can modify their settlements, public facilities and livelihood. Some area in Medan Belawan sub-district also have mangrove forest, there is around 747 hectares. Combination both of approaches aim to reduce the disaster risk.

***Keywords**: Disaster Risk Index, Tidal Flooding, Mitigation, Seawall, Adaptation, Reforestation*

1. Background

Tidal flooding is one of natural water related disaster which occurs in coastal area. Tidal flooding is the flood which enhanced by tide activity and cause damage of building and many public facilities. Furthermore, this disaster can inhibit community and industry activities [1]. Technically, tidal flooding will occur in coastal area which has land elevation lower than or equal with maximum sea level water. One of place in Indonesia which often occur tidal flooding is Medan Belawan Sub-district, Medan City North Sumatera.

Because of the primary trigger of tidal flooding is tide activity, so the effect of rainfall to that flood is not significantly except for estuary. Medan Belawan Sub-district is a flanked area between Belawan River estuary and Deli River estuary so in this case, the authors think there is an effect from raising of estuary's water level due to rainfall.

Taking from many sources, especially online newsletter like as Antara News, Metro TV News, Antara Sumut News, etc there are the record of tidal flooding occurrence in Medan Belawan Sub-district from 2010 until 2017. In that timeline, the most severe events occurred in 2016 with 1 m until 2 m water depth. If we take the average from year to year 0,3 m until 1 m water depth is possible. Because of this condition (tidal flooding), 3000 until 4000 houses, schools, public health facility (puskesmas), highway, fishponds, and international harbor have been sunken.

There are some research related to tidal flood and physical characteristic of wave in Medan Belawan coastal area. It starts from Frederick et al., (2016) who made map disaster for tidal flooding in Medan Belawan Sub-district. The method which used were comparing between land elevation with maximum sea level water. Based on result of that research, we can say that all of villages in Medan Belawan Sub-district are vulnerable from tidal flooding. In other hand, Putri & Tarigan, n.d. have been analized the forecast of wave in Medan Belawan statistically based on wind velocity data. They used Jonswap method to analyze it. Some of data from them will be cited by this research.

The aim of this research to analyze level of risk for tidal flooding in Medan Belawan and analyze of structural-nonstructural mitigation as disaster risk reduction measures. There are some limitations in this research such as level of risk is analyzed for sub-district level only, all geotechnical data is assumed, and morphology of estuary is assumed. Despite of that limitation, hopefully, this research can give enlightenment about disaster risk assessment and disaster risk reduction measures for tidal flooding in Medan Belawan sub-district.

2. Theoritical Considerations

Conceptual Framework

Conceptual framework, in this case as tidal flooding is made as foundation thinking for integrating primary trigger, level of risk and mitigation. For tidal flooding case, we can make conceptual framework (adopted from *Andy Prasetyo Utomo*) as **Figure 1**.

Disaster Risk Index

Disaster Risk is a function from hazard (H), vulnerability (V), and capacity (C) or in mathematical statement, we can write as [3]

$$Risk = f(H, V, C). \tag{1}$$

To figure out the risk index, we can calculate based on index of component of function (1) in this empirical equation [3]

$$Risk = H\frac{V}{C}. \tag{2}$$

To analyze each part of equation (2), the authors use national regulation, Peraturan Kepala BNPB No. 2 Tahun 2012 about risk assessment, with secondary data which most of them according to Medan City in Figures, 2016.

Hazard Index

Hazard index estimated by historical occurrence. For tidal flooding, there are two important components that become primary measurement. That components are probability of hazard and exposure recorded data.

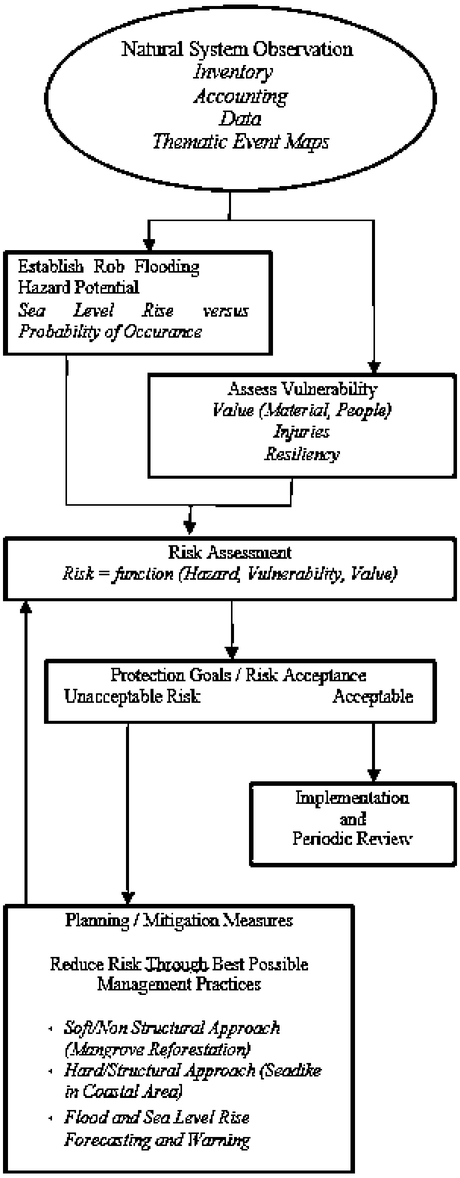

Figure 1. Conceptual Framework for Tidal Flooding

Type of Index	Sub-Index	Parameter	Classification
Hazard Index	Hazard based on depth of pond	Depth of pond < 0,76 m	Low
		Depth of pond between 0,76 m - 1,5 m	Moderate
		Depth of pond > 1,5 m	High
	Hazard based on duration of pond	Duration of pond < 1 day	Low
		Duration of pond 1 s/d 2 days	Moderate
		Duration of pond > 2 days	High

Table 1. Hazard Index Scoring Parameter (Adopted from Perka BNPB, No. 2 Tahun 2012, with adjustment)

Vulnerability Index

Measurement of vulnerability index is more complicated than hazard index because in this analysis distinguished to four sub-indices as follows:

1. Demography vulnerability
2. Economic vulnerability
3. Physical vulnerability
4. Environmental vulnerability

As explained before, all of index calculated by Perka BNPB, No. 2 Tahun 2012 procedures. Therefore, we can compile vulnerability index scoring parameter in **Table 2**. In Medan Belawan sub district lived around 98.11 thousand people who most of them as fisher who manage fishpond along coastal area. To determined total score of vulnerability index, Perka BNPB, No. 2 Tahun 2012 has been inform that vulnerability index can be calculated as

$$V = 0.4V_1 + 0.1V_2 + 0.25V_3 + 0.25V_4. \qquad (3)$$

In this equation V_1 until V_4 parameter denote demography vulnerability, environmental vulnerability, physical vulnerability, and economical vulnerability.

Capacity Index

Capacity terms mean as the resilient level of sub-district and communities to take overcoming disaster. Usually, to get and calculated capacity index, interviewing communities and other stakeholders are very necessary. **Table 3** shows basic parameters for calculate capacity index. In this case, authors use the middle score for capacity index because of unavailability information about interview result.

Type of Index	Sub-Index	Parameter	Classification	Score
Capacity Index		Institutional Rules About Mitigation Disaster	Low	1
		Early Warning System and Study of Disaster Risk	Moderate	3
		Educational of Disaster	High	5
		Reduction of Base Risk Factor	For All Parameter	
		Awareness Development in All Stakeholder Level		

Table 3. Capacity Index Scoring Parameter (Adopted from Perka BNPB, No. 2 Tahun 2012, with adjustment)

Tidal Forecasting

Based on the trigger, tidal wave is raised by interaction force between earth, moon, and sun. Therefore, tidal wave has repetitive characteristics, even because of this characteristics, tidal wave can be forecasted by Fourier Series [4]. The aim of tidal forecasting is to determine values of Mean Sea Level (MSL), both of average on Low Water Level (LWL) and Maximum Water Level (MWL).

In this research, to determine MSL, MLWL an MHWL, authors use **admiralty method**. According to previous explanation, tidal wave has repetitive characteristics, therefore the analysis can use the monthly tides record data. In this case, the most important data are daily and hourly record data.

Wave Forecasting

Wave has a significant role to tidal flooding because, wave is most trigger of wave set-up. Wave set-up is water level raising because of wave. In fact, measurement of wave level periodically is very difficult work because we have to set-up the equipment in deep sea, and it has many risks especially damage on equipment. For fix this problem, usually we can forecast the wave in deep sea from wind velocity data that measured in land (3 m above zero point of water level). We can use the method written on Coastal Engineering Manual. The steps of wave forecasting based on wind data are follows:

Type of Index	Sub-Index	Parameter	Classification	Score
Vulnerability Index	Demography Vulnerability	Population Density		
		< 500 Peoples/Km^2	Low	1
		500 - 1000 Peoples/Km^2	Moderate	3
		> 1000 Peoples/Km^2	High	5
		Ratio of Gender		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
		Ratio of Poverty		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
		Ratio of Disabled		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
		Ratio of age group		
		< 20%	Low	1
		20% - 40%	Moderate	3
		> 40%	High	5
	Economic Vulnerability	Productive Lands		
		< 50 Million	Low	1
		50 - 200 Million	Moderate	3
		> 200 Million	High	5
		GDRP		
		< 100 Million	Low	1
		100 - 300 Million	Moderate	3
		> 300 Million	High	5
	Physical Vulnerability	Living House		
		< 400 Million	Low	1
		400 - 800 Million	Moderate	3
		> 800 Million	High	5
		Public Facility		
		< 500 Million	Low	1
		500 Million - 1 Billion	Moderate	3
		> 1 Billion	High	5
		Critical Facility		
		< 500 Million	Low	1
		500 Million - 1 Billion	Moderate	3
		> 1 Billion	High	5
	Environmental Vulnerability	Protected Forest		
		< 20 Ha	Low	1
		20 - 50 Ha	Moderate	3
		> 50 Ha	High	5
		Natural Forest		
		< 25 Ha	Low	1
		25 - 75 Ha	Moderate	3
		> 75 Ha	High	5
		Mangrove Forest		
		< 10 Ha	Low	1
		10 - 30 Ha	Moderate	3
		> 30 Ha	High	5
		Scrub		
		< 10 Ha	Low	1
		10 - 30 Ha	Moderate	3
		> 30 Ha	High	5
		Swamp		
		< 5 Ha	Low	1
		5 - 20 Ha	Moderate	3
		> 20 Ha	High	5

Table 2. Vulnerability Index Scoring Parameter (Adopted from Perka BNPB, No. 2 Tahun 2012, with adjustment)

1. Find the wind velocity in 10 m above zero point of water level using equation [5]

$$U_{10} = U_z \left(\frac{10}{z}\right)^{1/7}. \quad (4)$$

   U_z is inland wind velocity (usually measured on 3 m above zero point of water level). Therefore, z is elevation of measurement.
2. Convert the result of step 1 as wind velocity in deep sea using R_L and R_T factor using equation [5]

$$U = U_{10} R_L R_T. \quad (5)$$

   R_L is conversion factor for location of measurement and then R_T is conversion of difference temperature between in land and in deep sea.
3. Calculate effective fetch, F_{eff}. Fetch is yaitu distance of wave from the land where wind speed and direction are constant. Fetch measured in every 6° until 42° where 0° is wind direction [6], [7]. Use equation

$$F_{eff} = \frac{\sum X_i \cos\alpha}{\sum \cos\alpha} \quad (6)$$

   to calculate the value of F_{eff}. X_i is the distance between point of measurement in shoreline to closest land area in every 6° until 42°.
4. Calculate wind stress factor U_A for every wind velocity using equation [5]

$$U_A = 0.71. U^{1,23}. \quad (7)$$

5. Estimate wave height (H) and wave period (T) in deep sea using Coastal Engineering Manual Method. Consider both of condition *Fetch Limited* and *Time Duration Limited* to choose final value (choose smaller value between that condition). To analyze this step, use equations

$$t_{x,u} = 77{,}23 \frac{\left(F_{eff} x 1000\right)^{0,67}}{u^{0,34} g^{0,33}}, \quad (8)$$

$$C_d = 0.001(1.1 + 0.035U), \quad (9)$$

$$u_* = \sqrt{C_d} U, \quad (10)$$

$$\frac{gH_o}{{u_*}^2} = 4.13 \times 10^{-2} \left(\frac{gF_{eff}1000}{{u_*}^2}\right)^{\frac{1}{2}}, \quad (11)$$

$$\frac{gT_p}{u_*} = 0.751 \left(\frac{gF_{eff}1000}{{u_*}^2}\right)^{\frac{1}{3}}. \quad (12)$$

Statistical Analysis

Eventually, after we determine wave height and wave period in every timeline of data, we have to conduct that result to statistical analyze. The objective of this step is determining the wave design in many returns period. Usually, the statistical method for this analyze are using Fisher Tippet I distribution. Fisher Tippet I distribution is one of method which developing relationship between wave height design and statistical parameter into regression equation [6]. In this distribution we can use equations

$$\hat{H}_{sm} = \hat{A}. y_m + \hat{B}, \quad (13)$$

then y_m is figured out by

$$y_m = -ln\{-\ln F(H_s \leq H_{sm})\}, \quad (14)$$

and

$$F(H_s \leq H_{sm}) = 1 - \frac{m - 0{,}44}{N_T + 0{,}12}. \quad (15)$$

Wave height design in many returns period is calculated by equation

$$H_{sr} = \hat{A}. y_r + \hat{B}. \quad (16)$$

whereby,

$$y_r = -ln\left\{-ln\left(1 - \frac{1}{L.T_r}\right)\right\}, \quad (17)$$

$$\hat{A} = \frac{N \sum y_m. H_{sm} - \sum y_m. \sum H_{sm}}{N \sum {y_m}^2 - \left(\sum y_m\right)^2}, \quad (18)$$

$$\hat{B} = \frac{\sum H_{sm}}{N} - \frac{\sum y_m}{N}\hat{A}. \quad (19)$$

Wave Deformation

Wave which spread from deep sea could be deformed because of depth difference and bathymetry. Wave refraction is wave deformation because of bathymetry formation. Wave propagation from deep sea will form perpendicular with depth contours. **Figure 2** provides the refraction process ilustration.

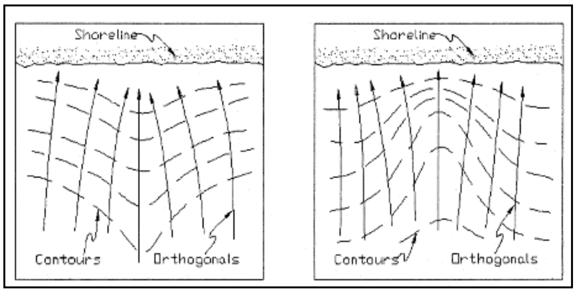

Figure 2. Wave Refraction Process
Sources: CERC (2008)

We can estimate the value of refraction coefficient in equation [6]

$$\sin\alpha_{i+1} = \frac{C_{i+1}}{C_i}\sin\alpha_i. \quad (20)$$

$$K_r = \sqrt{\frac{\cos\alpha_i}{\cos\alpha_{i+1}}}. \quad (21)$$

Where, α is the angle that formed between wave angle and bathymetry profile.

If the wave propagates from deep sea to transition or shallow sea, then in any certain location in that sea, the wave will be break [6]. Breaking wave condition depends on slope of bathymetry profile, *m*. There are some equations which correlate depth of breaking wave d_b and breaking wave height H_b such as [6], [7]

$$\frac{d_b}{H_b} = \frac{1}{b - (a.H_b/g.T^2)}. \quad (22)$$

$$a = 43{,}75(1 - e^{-19.m}). \quad (23)$$

$$b = \frac{1{,}56}{(1 + e^{-19{,}5.m})}. \quad (24)$$

Wave Set-Up and Wind Set-Up

Wave set-up is sea water level rising because of the wave. This phenomenon estimated from equation

$$S_w = 0{,}19\left[1 - 2{,}82\sqrt{\frac{H_b}{gT^2}}\right]H_b. \quad (25)$$

In other hand, wind set-up is sea water level risig because of the storm wind. This phenomena estimted from equation

$$\Delta h = F_{eff}c\frac{(U\ \sin\alpha)^2}{2gd}. \quad (26)$$

Flood Forecasting

Hydrological analysis runs trought watershed area. In this case, Medan Belawan Sub-district located between two watershed, Belawan and Deli Watershed. There are maximum daily rainfall data from three rain monitoring station around the watershed, such as Pancur Batu, Bulu Cina and Polonia. They are the fundamental equation on Thiessen Polygon Method analysis. This analysis results the maximum daily rainfall data for each of watershed. The polygons formed by the perpendicular bisectors of the lines joining nearby stations (**Figure 3**). In regard to find out the representative rainfall of the watershed, executing the equation [8], [9]

$$P = \frac{P_1A_1 + P_2A_2 + P_3A_3 + \cdots + P_nA_n}{A_1 + A_2 + A_3 + \cdots + A_n}. \quad (27)$$

is necessary. The term of P_n is rainfall weight at all of rainfall station and A_n is the area that the rainfall station represents to.

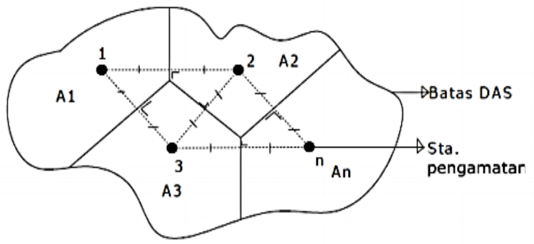

Figure 3. Thiessen Polygon Method

The advanced calculation is the distribution analysis. Distribution analysis must run first before calculating the rainfall for planning and design. In statistic science there is known some methods that can be used to hydrological analysis, such as normal, log normal, log Pearson III and Gumbel distribution [9] which is the analysis use maximum daily rainfall data at Medan Belawan Sub-district. This research took Gumbel distribution in analysis as the subject to the extreme value. Gumbel distribution follows the equation [10]

$$X_T = \bar{x} + KS_x, \tag{28}$$

$$K = \frac{y_T - \bar{y}_n}{S_n}. \tag{29}$$

as the fundamental procedure in analysis. The term of $\bar{x}$ and S_x are the mean value and deviation standard of rainfall data in sequence. In another hand, K deals with the reduce mean $\bar{y}_n$, reduce devaition standard S_n and reduce variate y_T as the Gumbel's frequency factor [9], [10].

The unit quantity of effective rainfall is taken as 1 mm or 1 cm and the outflow hydrograph is expressed by the discharge ordinate. Nature of hydrograph depend on rainfall and watershed characters. In this case it will be use ***Synthetic Unit Hydrograph Nakayasu.*** The ordinate can be calculated by steps below [8], [11]:

1. Rising limb ($0 < t < T_p$)

$$Q_t = Q_p \left(\frac{t}{T_p}\right)^{2.4}. \tag{30}$$

2. Recession limb ($T_p < t < T_p + T_{0.3}$)

$$Q_t = Q_p 0.3^{\frac{t-T_p}{T_{0.3}}}. \tag{31}$$

3. Recession limb ($T_p + T_{0.3} < t < T_p + T_{0.3} + 1.5T_{0.3}$)

$$Q_t = Q_p 0.3^{\frac{t-T_p+0.5T_{0.3}}{1.5T_{0.3}}} \tag{32}$$

4. Recession limb ($t > T_p + T_{0.3} + 1.5T_{0.3}$)

$$Q_t = Q_p 0.3^{\frac{t-T_p+1.5T_{0.3}}{2T_{0.3}}} \tag{33}$$

3. Result and Discussion

Disaster Risk Index Analysis

As explained in **Figure 1**, we must know the level of risk of tidal flooding disaster in Medan Belawan. In this case, authors using Perka BNPB, No. 2 Tahun 2012 as a guidance. From table 1, table 2 and table 3, we get each index for hazard, vulnerability, and capacity.

There is each index as result of analysis as follows:

1. Hazard index: 5
2. Vulnerability index: 3,64
3. Capacity index: 2,2

Therefore, we can calculate the estimate of risk index based on equation 2 and yield **8.27** as risk index.

Tidal Analysis

From the result (risk index: 8.27) we can say that the tidal flooding disaster risk in Medan Belawan Sub-District is categorized as **high risk**. To reduce that risk (from **Figure 1**), there are two approaches in mitigation, structural and non-structural mitigation. In structural mitigation, in this case seawall designed, we must consider sea level design first. To estimate sea level design, consider the condition below:

1. Mean high water level (MHWL)
2. Wave set-up
3. Wind set-up
4. Estuary water level
5. Land subsidence
6. Climate change

MHWL analysis runs from tides analysis using admiralty method. **Table 4** is result of admiralty method to estimate each tides components based on tides record data.

Water Level Components	Tides Components									
	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
A (cm)	149,94	60,44	37,10	5,69	20,09	4,63	0,20	0,39	10,02	6,63
g^0	0	330,86	36,593	300,87	341,59	227,66	164,59	230,92	36,593	341,59
MSL	150 cm	1,50 m	Mean Sea Level							
HHWL	272 cm	2,72 m	Highest High Water Level							
MHWL	235 cm	2,35 m	Mean High Water Level							
MLWL	65 cm	0,65 m	Mean Low Water Level							
LLWL	28 cm	0,28 m	Lowest Low Water Level							

Table 4. Result of Admiralty Method

Wave Forecasting

The next step to estimate water level design is, wave forecasting. From wind velocity data, we conducted distribution analysis of wind, wave forecasting and then find wave set-up and wind set-up. Distribution analysis results the information about most dominant of wind direction in Medan Belawan coastal area from wind rose. Figure 4 describes the spread of wind direction and velocity as the wind rose. This wind rose generated from WR-Plot software.

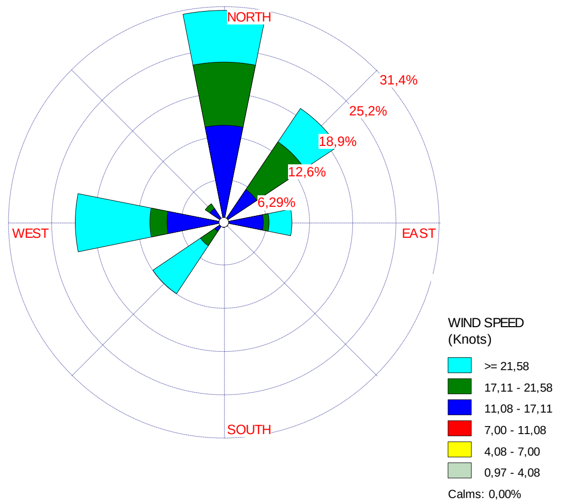

Figure 4. Wind Rose

From wind rose in **Figure 4**, we can say that there are 3 directions of wind. Further, we only choice one of them based on wind frequency. This result exposes on the **Table 5**. Although wind direction from north is more frequent based on description in wind rose, but most of maximum wind velocity are from northeast direction, so finally we use this direction in next analysis if needed.

Num	Year	Velocity		Dir
		Knot	m/s	
1	2006	22	11,31	NE
2	2007	20	10,28	NE
3	2008	46	23,64	NE
4	2009	40	20,56	NE
5	2010	25	12,85	NE
6	2011	18	9,25	NE
7	2012	20	10,28	N
8	2013	25	12,85	E
9	2014	28	14,39	N
10	2015	30	15,42	N

Table 5. Maximum Wind Velocity and Direction

Table 5 became the primary information for wave forecasting analysis. It starts from wind velocity in which measured in land converted into wind velocity in deep sea. Using equation 5 to convert into wind velocity in deep sea and using equation 7 to consider wind stress factor in sequence. As a plot result in Coastal Engineering Manual graphic, authors got R_L value in each wind velocity. In other hand it was assumed there aren't temperature difference between island and deep sea, so authors got 1.1 as R_T value for each wind velocity.

z : 3 m								
Num	Year	Velocity (U_z)		U_{10}	Correction Factor		U	Wind Direction
		Knot	m/s	m/s	RL	RT	m/s	
1	2006	22	11,31	13,43	1,06	1,10	20,99	NE
2	2007	20	10,28	12,21	1,10	1,10	19,49	NE
3	2008	46	23,64	28,08	0,91	1,10	42,99	NE
4	2009	40	20,56	24,42	0,91	1,10	36,20	NE
5	2010	25	12,85	15,26	1,03	1,10	23,65	NE
6	2011	18	9,25	10,99	1,13	1,10	17,60	NE
7	2012	20	10,28	12,21	1,10	1,10	19,49	N
8	2013	25	12,85	15,26	1,03	1,10	23,65	E
9	2014	28	14,39	17,09	0,95	1,10	24,61	N
10	2015	30	15,42	18,31	0,97	1,10	27,49	N

Table 6. Conversion Result of Wind Velocity

Table 6 describes the result of conversion wind velocity. The value in *U* column is held the final conversion (the conversion including calculate wind stress factor), therefore it's become prediction wind velocity in deep sea.

Next analysis calculating wave height (H_o) and wave period (T_p) based on final conversion of wind velocity using equation 8 to 12. There are 2 approaches to analyze it, fetch limited approach and time duration limited approach. In fetch limited approach analysis, authors calculate the value of effective fetch using equation 6. Consider the statement of **Table 5**, effective fetch in which is only analyzed for northeast direction. **Figure 5** describes spread of fetch in northeast direction in every 6 degrees to 42 degrees. For estimate effective fetch value, use equation 6 to calculate it and the result described on **Table 7**.

F_{eff} used for calculating wave height and wave period in fetch limited condition. In time duration limited approach, we must take the value of maximum average duration of wave occurs, because of limitation information about this, so in this analysis, assumed 4 hours for wave duration as duration limited value. **Table 8** is the result of this analysis. Analysis distinguished in fetch limited and time duration limited condition. As a result, we must select the condition in which give smaller value and for this case time duration limited approach is selected. Based on this result we can make the graph of relationship between wave height and wave period (**Figure 6**).

Figure 5. Spread of Fetch in Northeast Direction

α (°)	cos α	X_i (Km)	X_i cos α
42	0,7431	0	0
36	0,8090	280	226,52
30	0,8660	594	514,42
24	0,9135	376	343,49
18	0,9511	285	271,05
12	0,9781	284	277,79
6	0,9945	256	254,6
0	1	225	225
6	0,9945	221	219,79
12	0,9781	205	200,52
18	0,9511	214	203,53
24	0,9135	226	206,46
30	0,8660	233	201,78
36	0,8090	227	183,65
42	0,7431	241	179,1
Summary	**13,511**		**3507,71**
F_{eff}	**259,62 Km**		

Table 7. Analysis of Effective Fetch

Year	Wind Velocity (m/s)	Wind Direction	Fetch Limited				Time Duration Limited		
			T_d (s)	T_d (hr)	H_o (m)	T_p (s)	F_{eff} (Km)	H_o (m)	T_p (s)
2006	20,99	NE	58598	16,277	6,353	10,435	37,240	2,288	5,282
2007	19,49	NE	60102	16,695	5,811	10,129	35,850	2,054	5,063
2008	42,99	NE	45926	12,757	15,500	14,047	53,672	6,702	8,032
2009	36,20	NE	48690	13,525	12,442	13,055	49,167	5,149	7,250
2010	23,65	NE	56274	15,632	7,335	10,947	39,571	2,723	5,655
2011	17,60	NE	62222	17,284	5,150	9,7294	34,034	1,773	4,780
2012	19,49	N	100736	27,982	8,544	13,097	35,850	2,054	5,063
2013	23,65	E	52608	14,613	6,976	10,586	39,571	2,723	5,655
2014	24,61	N	93046	25,846	11,322	14,385	40,385	2,888	5,786
2015	27,49	N	89616	24,893	12,965	15,050	42,726	3,402	6,169

Table 8. Wave Height and Period Forecast Result

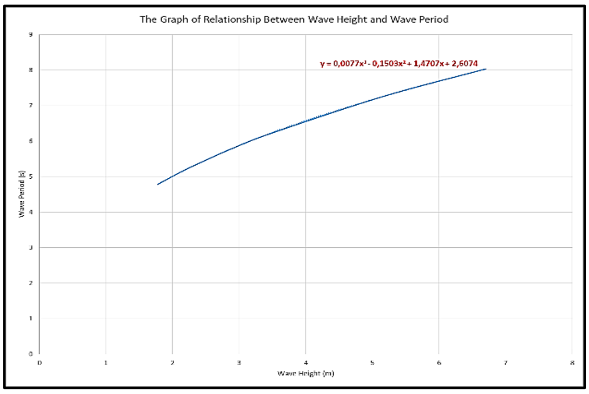

Figure 6. The Graph of Relationship Between Wave Height and Wave Period

Statistical Analysis

The result of **Table 8** will be transform become wave height and period data. This data is analyzed statistically using Fisher Tippet I distribution. Using equation 13 to 19 we got the result of wave height in some return periods. **Table 9** contains the prediction of wave height in some retunrn period according to Fisher Tippet I analysis.

Return Period, T_r	y_r	H_{sr}
2	0,367	2,956
5	1,500	4,384
10	2,250	5,330
25	3,199	6,525
50	3,902	7,411
100	4,600	8,291

Table 9. Wave Height in Some Return Periods

Wave Deformation

The aim of wave deformation analysis is to conduct wave height value when it starts to brake. Using method in equation 21 to 23, we yield 6.37 m wave height in 8.19 m depth of water. For near shore (in depth of water is 0.50 m), we yield wave height is 0.42 m. This value will be used in wave force calculation. This value is based of figuring out in return period of wave height, in this case, authors select 25 years in return period ($H_{1/25}$).

Wind Set-Up and Wave Set-Up

This is the final coastal hydrodynamic analysis before we conduct design of seawall. Using equation 24 and 25 in sequence, we got the value of wave set-up is 0.86 m and in other hand the value of wind set-up is 0.28 m.

Hydrological Analysis in Estuary

Medan Belawan Sub-district located in estuary area which is between Belawan and Deli sub-watershed. In the north side stream Belawan River and Deli River in the south side. The analysis of Thiessen Polygon results maximum daily rainfall data (**Table 10** and **11**) for both of watershed.

Year	R_{max}
2003	113.803
2004	77.948
2005	155.683
2006	210.442
2007	162.7
2008	107.593
2009	87.213
2010	148.855
2011	178.483

Table 10. Maximum daily rainfall data of Belawan Watershed

Year	R_{max}
2003	93.098
2004	92.452
2005	86.799
2006	137.654
2007	85.658
2008	85.802
2009	105.937
2010	142.706
2011	173.246
2012	94.026

Table 11. Maximum daily rainfall data of Deli Watershed

In this case Gumbel Method is proper method to calculate rainfall return period. The Result of the frequency analysis appears on **Table 12** and **Table 13**.

Return Periods	Ytr	Yn	Sn	R24 (mm)
2	0.3668	0.4952	0.9496	135.9316786
5	1.5004			187.5963057
10	2.251			221.8054352
25	3.1993			265.0248829
50	3.9028			297.0873963
100	4.6012			328.9174736

Table 12. Frequency Analysis Using Gumbel Method

Return Periods	Ytr	Yn	Sn	R24 (mm)
2	0.3668	0.4952	0.9496	105.603123
5	1.5004			142.1067822
10	2.251			166.2772538
25	3.1993			196.8139688
50	3.9028			219.4677481
100	4.6012			241.9572996

Table 13. Frequency Analysis Using Gumbel Method

Synthetic unit hydrograph methods are popular and play a significant role in water resources design especially in the analysis of flood discharge of ungagged watersheds. There is Nakayasu Synthetic unit hydrograph that will be used to analyze flood for planning. It uses watershed and river data such as area of the watershed and river length. Belawan watershed has area around 417.63 km^2 and length of the Belawan river around 74 km and Deli watershed has area around 459.86 km^2 and length of Deli River around 73 km. The Nakayasu hydrograph for Belawan and Deli watershed figures on **Figure 7** and **Figure 8** sequently.

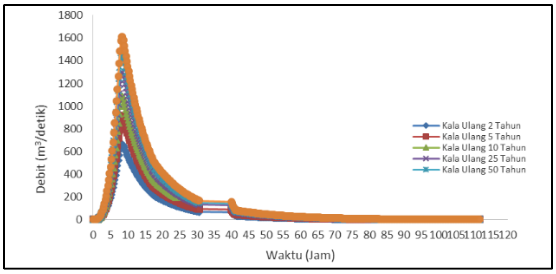

Figure 7. ***Flood Discharge of Belawan Watershed***

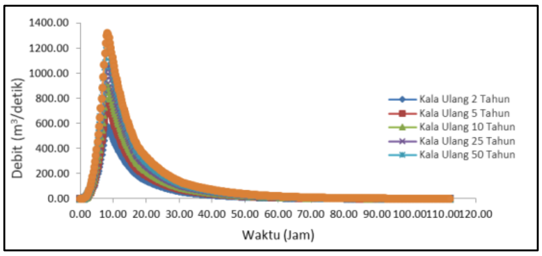

Figure 8. Flood Discharge of Deli Watershed

For design requirement which use 25 years return period data to calculate level of flood at Belawan and Deli Estuary Area. Level of flood was calculated by Manning Equation, and it result level of flood around 2.95 m at Deli Estuary area and 3,45 m. Finally, it was chosen the highest value for design which is 3.45 m.

Structural Mitigation Approach

The previous paragraphs explains that to reduce tidal flooding risk in Medan Belawan, we could make two approaches, structural and non-structural. In structural approach, we propose an idea to build seawall in communities' region. In this text, authors conducted design of cantilever seawall. In design of seawall, the seawall must consider 3 conditions in safety factor value analysis [12]:

1. Stable in risk of overturning.
2. Stable in risk of sliding.
3. Stable in risk of uplift pressure.

To achieve the seawall design, at least there are some analyses throught to. The first analysis is sea water level design. **Table 14** expalins the components of sea water level design. Both value of land subsidence and climate changes assumed hypothetically.

To analyze in seawall configuration design, we must decide the typical of wave force. In this text authors use Saintflou formula [13] to figure out the wave force. According to **Figure 9**, there are some configuration forces:

1. p_1: wave pressure at the still water level, corresponding to wave crest.
2. p_2: water pressure at the base of the vertical wall.
3. p_3: wave pressure at still water level, corresponding to wave through.

In other hand, there are supplementary pressure from lateral soil pressure (active), p_4 and lateral pressure from seismic (assumed 40% of self weight), p_5. Other assumption in this analyze is negleting the lateral soil pressure (passive).

Measured From Zero Point in Bathymetry			
Num	**Parameter**	**Unit**	**Value**
1	MHWL	m	2,35
2	Wave Set-Up	m	0,86
3	Wind Set-Up	m	0,28
4	Estuary Water Level	m	0,53
5	Land Subsidance	m	0,30
6	Climate Changes	m	0,11
7	Freeboard	m	0,50
Sea Water Level Design		**m**	**4,43**
Seawall Height Design		**m**	**4,93**

Table 14. Analysis of Seawater Level Design and Seawall Height Design

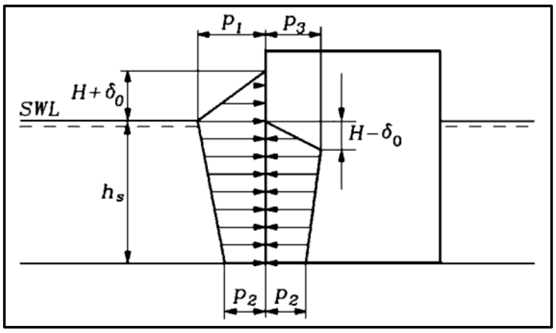

Figure 9. Saintflou Approach to Analyze Water Pressure

Eventually, after this analysis (water pressure, lateral soil pressure, seismic pressure and bearing capacity), the configuration of seawall is obtained as descripted in **Figure 10**. From **Figure 10**, there are impermeable rocks because authors involving seismic force in design. **If seismic force doesn't involve in design and analysis, the impermeable rock isn't necessary**. The final condition after structural mitigation can be described as **Figure 16**.

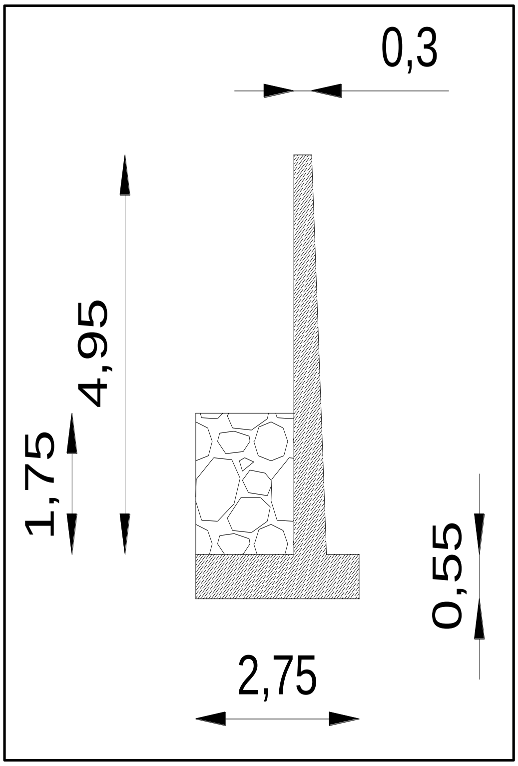

Figure 10. Configuration of Seawall

Non-Structural Mitigation Approach: Community Adaptation

Adaptation is essential to reduce the damages and take advantages of new opportunities in-light of the rapid climate change already occurring and expected future impacts. Even though structural mitigation has implemented, but tidal flood still surges Medan Belawan sub-district area. Affected people need adaptation strategy to face tidal flood. They must adapt if the flood occurs and swamp their settlements. Adaption is action or process to change the conditions, structures, and responsive activities to keep balancing along environmental fluctuation condition for short and prolonged period [14].

Cultural ecology scientist give description related to adaptation, that it is strategy of adapting that people can use to response any social and environmental phenomenon. There are some actions that community can implementation to adapt their house when tidal flood occurs:

1. They can adapt their house, raising the floor of house (**Figure 11**).
2. Establish tidal in front of the door.
3. Raising the floor of the house with assembled wood (**Figure 12**).
4. Elevate goods/furnishings; avoid furniture made from wood and prefer a plastic material.
5. Build drainage around the house.
6. Establish rainwater harvesting installation.
7. Move to another place

Figure 11. Raising the Floor of The House

Figure 12. Raised the Floor of the House with Assembled Wood

Adaptation strategies to avoid fishpond damage are:

1. make the embankment
2. putting a smooth net around the pond
3. elevate of embankment
4. Mangrove planting also serves to reduce the impact of other tidal floods such as land loss and coastal abrasion.

On the other hand, it also can design house on stilts for new house (**Figure 13**) and raising the road by blowing and making concrete castings at the cost by themselves (**Figure 14**), and if possible local government can allocate their budget to empower coastal community to adapt with the tidal flood condition.

Figure 13. Establishing House on Stilts for New House

Figure 14. Raising the public road

In Sicanang Village there is mangrove forest reach 747 Ha which have some function including to reduce tidal flood impact. The aim of mangrove forest conservation are follows:

1. as a shelter for organisms.
2. as a stabilizer for the deposition of sludge.
3. as buffer area to protect land from wave, wind, and any pollutant from the sea. Mangrove forest as green belt whose phisyc, biological and chemical functions.
4. to reduce tidal flood impact

There are some requirements to cultivate mangrove along coastal area or riverside.

1. river mouth with width of 100 m the requirement of width of green line is 20 m.
2. river mouth with a width of 60-70m, the regulated mangrove thickness is 6 m.
3. estuary of river with width 50-60 m, requirement of width of green line is 5 m.
4. river mouth of a width of less than 5 m, the thickness of mangrove as the required green line is 3 m.
5. in a tsunami potential area that reaches a wave height of more than 10 m, according to the purpose and function of the protected area, the effective mangrove green line width is 400 meters (maximum) [15].

The mangrove green trails can be planted with a spacing of 1x1 m with mangrove vegetation types with the sequence of planting is Avicennia (Avicennia alba), Sonneratia (Sonneratia caseolaris), Rhizophora (Rhizophora apiculata), dan Bruguiera (Buguiera gymnorhiza) (**Figure 15**).

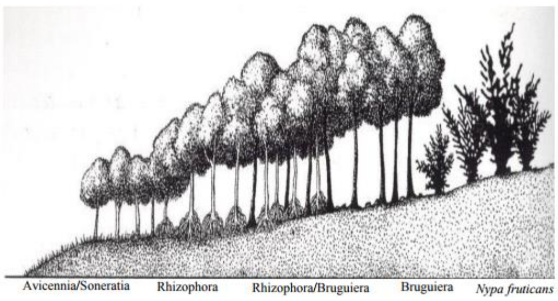

Figure 15 Zoning Pattern Mangrove Forest from the Seaside towards the Mainland (Bengen, 2004)

Mitigation Zone Mapping

This part is final concept of mitigation zone. In determination of mitigation zone, we must consider land use existing, for example if we want to build seawall, we can't build it in harbor zone because usually there are some hydraulic structures like as jetties and it was directly bounded by the sea. Therefore, in this text, authors decide some consideration in mitigation zone mapping like as:

1. Seawall applies in communities' region only.
2. Mitigation in community's region is not only structural approach, but also non-structural.

Mangrove forest reforestation adopts in Sicanang village (**Figure 17**).

4. Conclusion

There are some conclusions including our limitation in this text:

1. Medan Belawan Sub-District has tidal flooding hazards which of all community living near coastal line.
2. Tidal flood risk index in high risk level.
3. Considering the condition of land use, the proper disaster mitigation are seawall as structural mitigation and adaptation including reforestation of mangrove forest as non-structural mitigation.
4. Zone mapping of mitigation distinguished into two region follows structural mitigation (urban area which nearby with belawan port) and non-structural mitigation as mangrove conservation in Sicanang village.
5. Structural mitigation exists coincide with non-structural mitigation in community adaptation pattern.

The largest limitation in this text is all geotechnical information is assumed, so in extend analysis (if needed), geotechnical information should be available. the unavailable longer rainfall data is also our limitation in this research.

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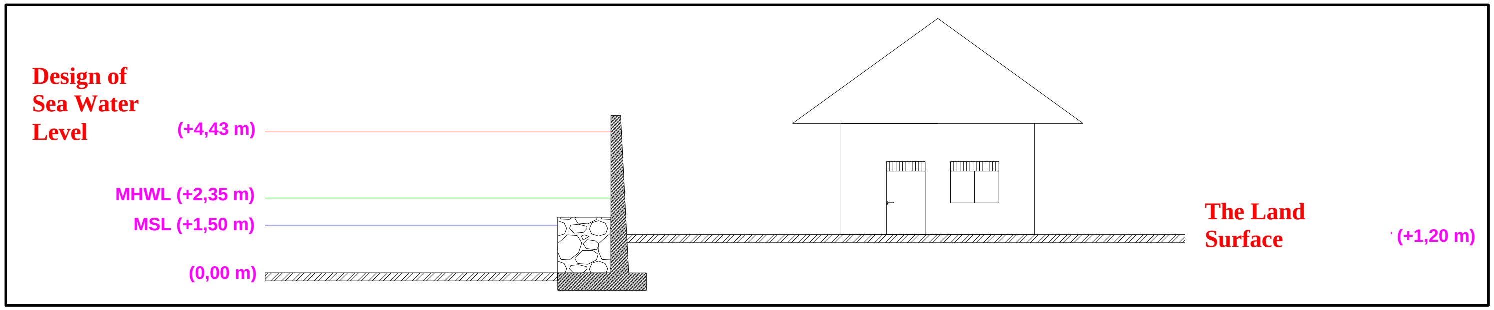

Figure 16. Description of Condition After Seawall Built on

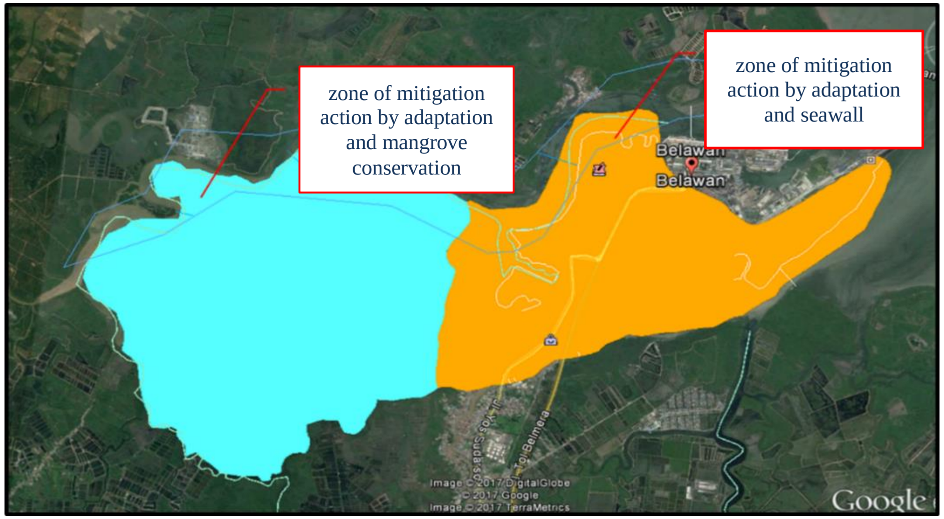

Figure 17. Mitigation Zone Mapping in Medan Belawan Sub-Distric