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Coastal Vulnerability Study Dumai City Riau Province

Studi Kerentanan Wilayah Pesisir Kota Dumai Provinsi Riau

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Abstract

The purpose of this study was to determine the assessment and category of vulnerability level and calculate the parameters that affect coastal vulnerability. The method used is a survey method with direct observation, while the analysis method used is the calculation of CVI, the root of the multiplication of each variable weight. The data required includes primary data by direct observation, and secondary data with data from remote sensing satellites, primary data including coastal geomorphology, land use, tides, and secondary data including DEM (Digital Elevation Mode), coastal slope, shoreline changes, relative water level rise, significant wave height. The results of this study at the observation location obtained 3 categories of vulnerability namely low, high, and very high vulnerability levels found on the Dumai coast. The category of vulnerability in the low class is located in Dumai Barat District in Purnama Village with a value of 4.33-5.00, and the category of vulnerability in the high class is located in Dumai Timur District in Purnama Village grid A2 and A4 at Tanjung Palas grid A12,-A14 with a value of 8.66-10.61, and the category of vulnerability in the very high class is located in Dumai Barat District grid A5-A8, Dumai City District grid A9-A10, and Dumai Timur District in Tanjung Palas Village grid A15 with a value of 12.99-20.00.

Keywords: Coastal Vulnerability, Remote Sensing, Dumai City

Abstrak

Tujuan penelitian ini adalah untuk mengetahui penilaian dan kategori tingkat kerentanan, serta menghitung parameter yang memepengaruhi kerentanan pesisir. Metode yang digunakan adalah metode survei dengan pengamatan langsung, sedangkan metode analisis yang digunakan adalah perhitungan CVI , akar dari perkalian setiap bobot variabel. Data yang diperlukan meliputi data primer dengan pengamatan langsung, dan data sekunder dengan data dari satelit penginderaan jauh, data primer antara lain geomorfologi pantai, tata guna lahan, pasang surut, dan data sekunder antara lain DEM (*Digital Elevation mode*), kemiringan pantai, perubahan garis pantai, kenaikan muka air relatif, tinggi gelombang signifikan. Hasil penelitian ini pada lokasi pengamatan didapat 3 kategori kerentanan yakni tingkat kerentanaan rendah, tinggi, dan sangat tinggi ditemukan di pesisir Dumai. Kategori kerentanan pada kelas rendah terletak pada Kecamatan Dumai Barat di Desa Purnama dengan nilai 4,33-5,00, kategori kerentanan pada kelas tinggi terletak pada Kecamatan Dumai Timur di Desa purnama grid A2 dan A4 pada Tanjung Palas grid A12,-A14 dengan nilai 8,66-10,61, dan kategori kerentanan pada kelas sangat tinggi terletak pada Kecamatan Dumai Barat grid A5–A8, Kecamatan Dumai Kota grid A9–A10, dan Kecamatan Dumai Timur di Desa Tanjung Palas grid A15 dengan nilai 12,99-20,00.

Kata Kunci: Kerentanan Pesisir, Penginderaan Jauh, Kota Dumai

1. Introduction

Coastal areas have an important and strategic role but are vulnerable to environmental changes and human activities. One of the main problems faced by coastal Indonesia is coastal abrasion. Coastal abrasion is a serious problem in almost all coastal areas of Indonesia, not only in Indonesia abrasion also occurs in many other developing countries, some of the factors that cause it include a lack of awareness of hazards and mitigation. (Joesidawati & Ika, 2016).

Aquatic and terrestrial conditions that can cause vulnerability will be vulnerable to environmental changes and human activities, where according to Kaiser (2007), coastal vulnerability is a condition that describes the "susceptibility" of a natural system to coastal disasters. The term coastal vulnerability refers to the geomorphic susceptibility of coastal landscapes to hazards such as waves, tsunamis, erosion, storms, floods, etc. Global climate change and sea level rise, coastal areas will become increasingly vulnerable (Kumar et al., 2010).

According to Sulaiman et al. (2020), preventive forms and efforts in overcoming the damage to coastal areas so that it does not get worse, data and information are needed as a reference and basis for consideration of integrated coastal area management. The development of coastal areas and infrastructure is very vulnerable to damage caused by disasters that occur in coastal areas such as tsunamis, heavy rains that can cause flooding and hurricanes that can damage buildings.

The condition of most coastal areas faces various pressures and developments and changes, and the coastal area of Dumai City is no exception. Dumai City is a city in Riau Province, Indonesia which is located on the East Coast of Sumatra, research by Merian et al. (2016) said that the waters of Dumai City are used for various purposes, so the utilisation for various activities over time to time continues to increase which will have an impact on the decline in the quality of the waters of the coastal areas of Dumai City. Meanwhile, the geographical conditions of Dumai City, make the place an activity such as the Fish Landing Centre (PPI), ship repair and maintenance, ports (general and tanker ships), palm oil mills, oil exploration, management, and other activities.

Based on the explanation above, it is the reason why it is necessary to research vulnerability in the coastal area of Dumai City using remote sensing technology. in addition, knowing the areas that receive impacts and losses due to climate change can also make disaster risk management in coastal areas quite important and diverse, where activities in the coastal area of Dumai have the potential to factor in the vulnerability of the coastal area of Dumai City. This analysis is conducted to determine the level of coolness that occurs in the coastal area of Dumai City using remote sensing for 10 years and predict the level of vulnerability of coastal areas in Dumai City.

2. Material and Method

2.1. Time and Place of Research

This research was conducted in February 2022 located along the coast of Dumai City in West Dumai District, Dumai Kota District, and Dumai Timur District, Riau Province. Data analysis was conducted at the Physics Oceanography Laboratory, Faculty of Fisheries and Marine, Universitas Riau.

2.2. Methods

The method used is survey research; this method is carried out by direct observation and ground check (field survey) of the research object. The analysis method used in this research is the coastal vulnerability index. The determination of the CVI value is done by combining several risk parameters to produce an indicator. The calculation of the vulnerability index score value is based on the originality of the concept of calculating the vulnerability index value in the CVI method, which is the root of the multiplication of each variable weight value divided by the number of variables as follows (Thieler & Hammar-Klose, 2000).

2.3. Procedure

Data collection was conducted in primary and secondary ways. Primary data were obtained from field surveys, aiming to find out the existing conditions of the research location and explore information about parameters that affect coastal vulnerability to disasters. Secondary data was obtained by downloading on sites that provide data needs in this study, the secondary data needed include DEM data, coastline, sea level rise, and wave height and are classified according to class categories that can be seen in Table 1.

Observations at the location of the research station were determined using a grid conducted in ArcGIS, taking into account the division of areas exposed to the impact of the coast which is divided into 15 grids. Among them is Dumai Barat Subdistrict which includes Purnama and Pangkalan Sesai Villages on grids A1 - A8, Dumai Kota Subdistrict includes Laksamana and Dumai Kota Villages on grids A9 and A10, and Dumai Timur Subdistrict includes Buluh Kasat and Tanjung Palas Villages on grids A11 - A15. The determination of location point is determined using the purposive sampling method where each location point can already represent the general condition of the waters.

Table 1. Coastal vulnerability parameter classes

No.	Parameters	Class: Not very Vulnerable (1)	Not Vulnerable (2)	Medium (3)	Vulnerable (4)	Highly vulnerable (5)	References
1	Geomorphology	Cliff	Talus, stable with vegetation	Talus, stable without vegetation	Sandy beach,	Brackish swamp, Mudflat, Delta, Mangrove, Coral	Dhiauddin et al. (2017)
2	Shoreline Change (m/year)	>(2.0) Accretion	1,0-2,0 Accretion	+1,0-(-1,0) Stable	(-1) - (-2) Abrasion	<(-2,0) Abrasion	Thieler & Hammar-Klose, (2000) ; Gornitz, (1991)
3	Elevation (m)	>30,0	20,1-30,0	10,1-20,0	5,1-10,0	0,0-5,0	
4	Tidal (m)	<(1,0) microtidal	1,0-1,9	2,0-4,1	4,1-6,0	>6,0 Macrotidal	
5	Sea Level Rise (m/year)	<(-1,0)	(-0,99)-1,0	1,0-2,0	2,1-4,0	>4,0	
6	Wave (m)	0-2,9	3,0-4,9	5,0-5,9	6,0-6,9	≥7,0	
7	Beach Slope (%)	>1,90	>1,30-1,90	>0,90-1,30	0,60-0,90	<0,60	Handartoputra et al. (2015); Royo et al. (2016)
8	Land Use	Protected Area	Empty Land	Settlements	Industrial	Agriculture	

The data that has been collected is then processed to obtain a form of spatial data. The data was compiled into a spatial database for coastal vulnerability assessment. Data processing for each parameter went through different stages. The scheme of data processing and research implementation can be seen in Figure 1.

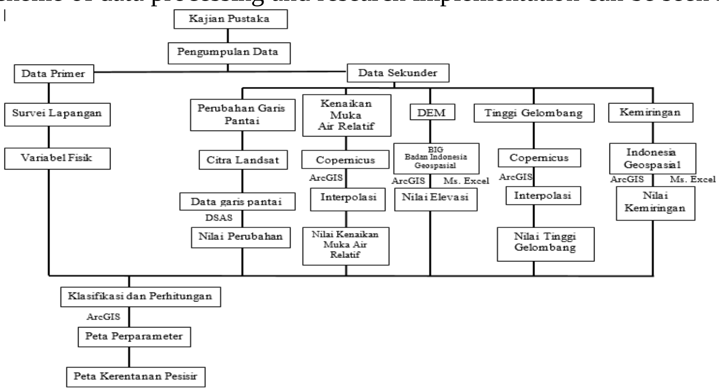

Figure 1. Research flow chart

3. Result and Discussion

3.1. General Condition of the Research Area

Geographically, Dumai City is located at 10° 51' 30"- 10° 59' 8" North latitude and 114° 24'-114° 34' East longitude with an area of 1,727.38 km^2 and an ocean area of 1,302.40 km² consisting of seven sub-districts namely Dumai Kota, Dumai Barat, Dumai Timur, Dumai Selatan, Bukit Kapur, Sungai Sembilan, and Medang Kampai (Arief & Pradini, 2019). Currently, Dumai City is developing into a service and industrial city. The rapid development of Dumai City has caused the flow of migration to this city to also increase.

3.2. Geomorphology

Coastal geomorphological observations were made visually by observing the shape of the coastal geomorphology from the observation point to the land. The observation results were recorded in the observation form according to the classification in Table 1. From field observations seen in some parts of the research location, there are muddy beaches that grow mangroves and mangrove conservation areas such as in the PAB (Pecinta Alam Bahari) Purnama area, because it is very fertile for coastal plants such as mangrove trees. The geomorphological shape of the coast of each grid can be seen in Table 2.

Table 2.Type of beach in each grid

No.	Grid	Beach Type	No.	Grid	Beach Type	No.	Grid	Beach Type
1	A1	Mangroves	6	A6	Muddy	11	A11	Muddy
2	A2	Mangroves	7	A7	Muddy	12	A12	Muddy
3	A3	Mangroves	8	A8	Muddy	13	A13	Muddy
4	A4	Muddy	9	A9	Muddy	14	A14	Muddy
5	A5	Muddy	10	A10	Muddy	15	A15	Muddy

3.3. DEM (Digital Elevation Mode)

DEM values are obtained from topographic map interpretation data that are overviewed along the coast of Dumai Barat, Dumai Kota, and Dumai Timur with a 30 m STRM DEM downloadable at the source Tides.big.go.id/DEMNAS/. The results can be seen in Figure 2.

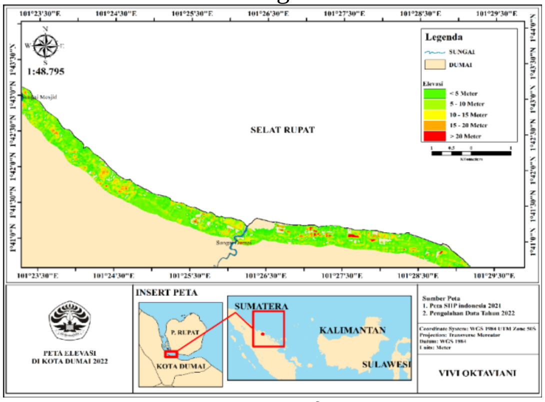

Figure 2. Elevation of Dumai City

Figure 2, it can be seen that the location of the Dumai area is dominated by the height of the land surface at >5 m above sea level. The elevation value of the Dumai Coast ranges from 0.35 - 3.14 m (Table 3).

Table 3. Elevation value of each grid

No.	Grid	Value (m)	No.	Grid	Value (m)	No.	Grid	Value (m)
1	A1	2,21	6	A6	0,35	11	A11	1,98
2	A2	2,25	7	A7	1,79	12	A12	1,68
3	A3	1,59	8	A8	2,09	13	A13	2,93
4	A4	2,38	9	A9	3,14	14	A14	1,89
5	A5	3,06	10	A10	1,92	15	A15	2,23

In Table 3, it is said that the level of coastal vulnerability category based on the Elevation value is in the very high category. The very high-class category is at 0.0 to 5.0 metres. Data processing on the Elevation vulnerability parameter class uses the category provisions put forward by Handartoputra et al. (2015) which states that muddy beaches and mangroves are at a very high category level and can be seen in Figure 3.

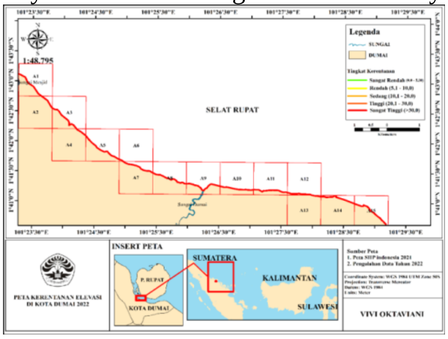

Figure 3. Vulnerability map of coastal elevation or height

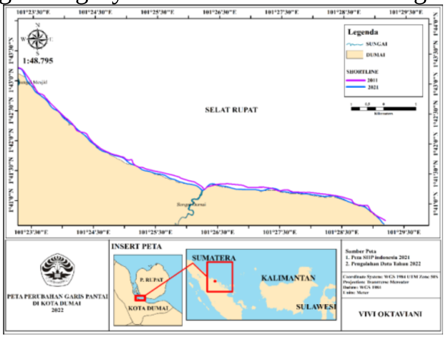

Figure 4. Map of Dumai shoreline change

3.4. Shoreline Change

In this parameter of shoreline change using Landsat 7 and 8 images with Landsat data in 2011 and 2021 located on Path 127 and Row 59, the data can be downloaded from the *Earth Explore-USGS* source. Calculation of the rate of shoreline change using the EPR method in ArcGIS (Figure 4). Figure 4 shows changes in the coastline in 2011 and 2021. In the description of the EPR value, it can be seen in Table 4 that shoreline changes in the eastern part of Dumai have a dominant value at a stable level.

Table 4. Slope value of each grid

No.	Grid	EPR	Value	No.	Grid	EPR	Value	No.	Grid	EPR	Value
1	A1	3,23	Accretion	6	A6	-1,31	Abrasion	11	A11	-2,01	Abrasion
2	A2	3,07	Accretion	7	A7	0,82	Stable	12	A12	0,45	Stable
3	A3	2,51	Accretion	8	A8	0,96	Stable	13	A13	0,48	Stable
4	A4	2,52	Accretion	9	A9	0,57	Stable	14	A14	0,59	Stable
5	A5	1,45	Accretion	10	A10	-3,52	Abrasion	15	A15	0,52	Stable

Based on the EPR values in Table 4, the vulnerability category of the shoreline change parameter can be seen in Figure 5.

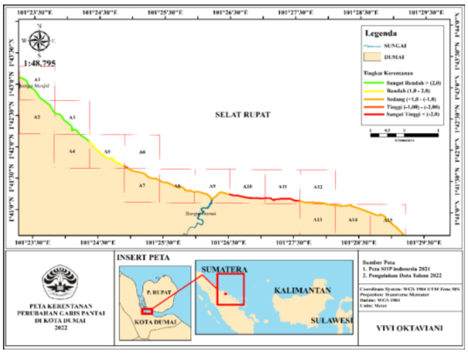

Figure 5. Dumai coastline change vulnerability

3.5. Tidal

The tidal data used is from the prediction data conducted by the Geospatial Information Agency (BIG) which can be downloaded at https://tide.big.go.id. The tidal data obtained is 15 days of data to see the value of the tidal range by looking at the difference between the highest tide and the lowest tide at full tide (Figure 6).

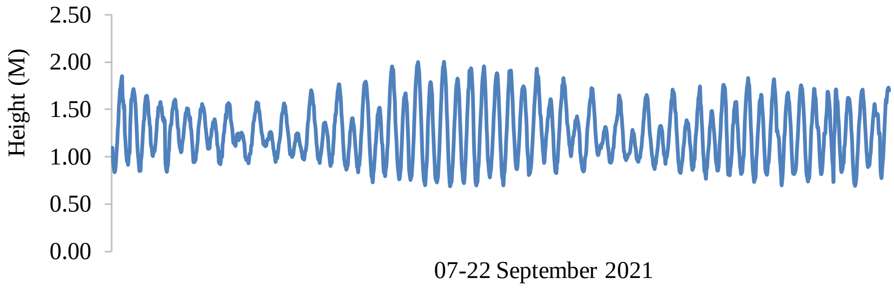

Figure 6. Dumai tidal chart

In Figure 6 it can be seen that the highest tide value in Dumai at full tide is 3.2 m, while the lowest tide or low tide is at -0.51 m elevation, so the tides are included in the low category. Based on calculations using the admiralty table, the value of the Formzal number (F) of Dumai is F = 0.5, this value indicates that the type of mixed tide tends to be double daily (mixed tide, prevailing semi-diurnal) which means that in each day there are two tides and two tides in different height and period.

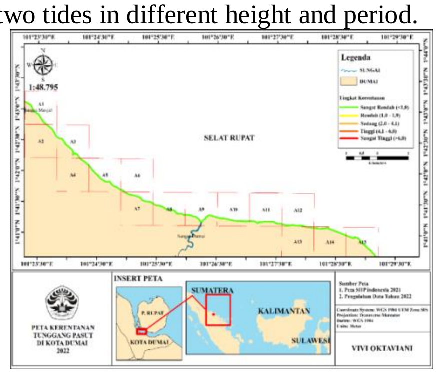

Figure 7. Tidal ridges vulnerability

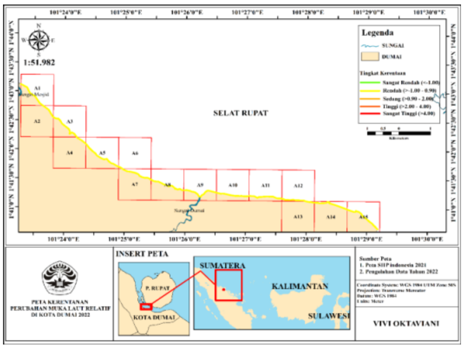

Figure 8. Vulnerability map of relative water level rise

The average value of the tidal ridge in the study area is required in determining the coastal vulnerability index. Figure 7, the average value of the tidal ridge obtained, the weighting of coastal vulnerability variables on the tidal ridge parameter is included in the Very low category, with a score <1.0. This refers to the weighting of coastal vulnerability variables by Gornitz (1991) in Table 2, where the average value of tidal ridge is in the range of 0.80 metres, classified as Very Low.

3.6. Relative Water Level Rise

Relative water level rise in dumai waters is obtained based on reanalysis data from the Copernicus Climate Change Service which can be downloaded at https://cds.climate.copernicus.eu/cdsapp#!/home TOPEX / POSEIDON Jason 1-Jason 2 satellite images within 10 years, namely in 2011-2021. The following is the vulnerability map of the relative water level rise parameter in determining the vulnerability of the relative water level rise parameter (Figure 8).

In Figure 8, the dominant vulnerability level of the research location does not experience relative water level rise, where in each observation grid the average value is >0.90. In the processing, it is known that the value of relative water level rise ranges from 0.703 - 0.900 m/year, the value can be seen in Table 5.

Table 5. Relative water level rise value of each grid

No.	Grid	Value (m/year)	No.	Grid	Value (m/year)	No.	Grid	Value (m/year)
1	A1	0,833	6	A6	0,865	11	A11	0,726
2	A2	0,860	7	A7	0,782	12	A12	0,812
3	A3	0,867	8	A8	0,781	13	A13	0,876
4	A4	0,858	9	A9	0,703	14	A14	0,88
5	A5	0,898	10	A10	0,753	15	A15	0,900

3.7. Significant Wave Height

Significant wave height data can be obtained based on reanalysis data from the Copernicus Climate Change Service which can be downloaded at https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?ta in a period of 10 years, namely in 2011-2021. In the processing, it is known that the value of significant wave height ranges from 0.11-0.23 m/year, the value can be seen in Table 6.

Table 6. Significant wave height value of each grid

No.	Grid	Value (m/year)	No.	Grid	Value (m/year)	No.	Grid	Value (m/year)
1	A1	0,20	6	A6	0,14	11	A11	0,20
2	A2	0,22	7	A7	0,09	12	A12	0,18
3	A3	0,19	8	A8	0,12	13	A13	0,18
4	A4	0,19	9	A9	0,11	14	A14	0,20
5	A5	0,17	10	A10	0,23	15	A15	0,19

Based on the values in Table 6, the vulnerability map of the significant wave height parameter in determining the vulnerability of this parameter can be seen in Figure 9.

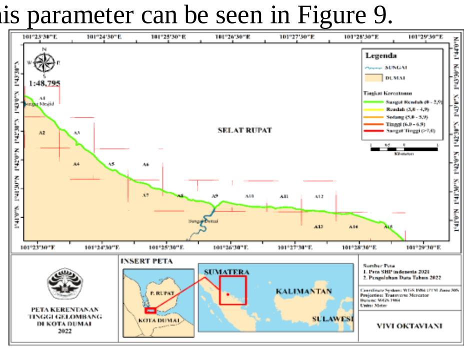

Figure 9. Vulnerability map of significant wave height parameter

In Figure 9 the research location of the dominant vulnerability level does not experience significant wave height which is in the very low category, wherein each observation grid the average value is at 0-2.0 according to the classification of vulnerability categories according to Gornitz *in* Thieler & Hammar-Klose (2000) which states that the very low-level category is at a value of 0-2.9.

3.8. Slope

Slope value is obtained by measuring data downloaded from https://tanahair.indonesia.go.id/demnas/#/batnas, by making slope points with measurement distances. Beach slope values located on the Dumai coast can be seen in Table 7 with values converted to % in *Excel* according to research needs. The conversion results show the coastal slope in the category ranging from 0.60-1.90 with a solid vulnerability value seen in Table 7.

Table 7. Slope value of each grid

No.	Grid	Value (m/year)	No.	Grid	Value (m/year)	No.	Grid	Value (m/year)
1	A1	1,02	6	A6	0,83	11	A11	1,25
2	A2	0,94	7	A7	0,83	12	A12	1,43
3	A3	0,89	8	A8	0,83	13	A13	1,44
4	A4	0,84	9	A9	1,06	14	A14	1,37
5	A5	0,84	10	A10	1,33	15	A15	1,14

The dominating coastal slope value is included in the High category with a weighted value of 0.60-0.90 referring to the category characteristics according to Handartoputra et al. (2015) which states that the value is a high-level category. The vulnerability value of the solid grid slope is seen in Figure 10.

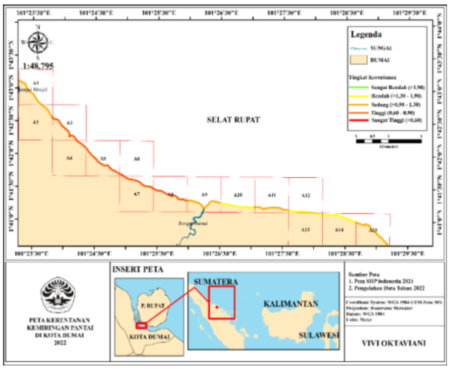

Figure 10. Vulnerability map of coastal slope parameters

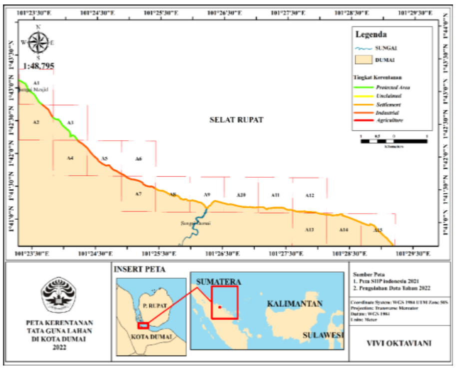

Figure 11. Vulnerability map of land use parameters

3.9. Land Use

From the observations of land use in Dumai Barat, Dumai Kota, and Dumai Timur sub-districts settlements and industries dominate. Residential areas are mostly found in Dumai Timur and Dumai Kota Sub-districts, while industry is found in Dumai Barat Sub-district in each observation where the division can be seen in Figure 11 land use map and information in Table 8.

Table 8. Land use of each grid

No.	Grid	Land	No.	Grid	Land	No.	Grid	Land
1	A1	*Protected area*	6	A6	*Industrial*	11	A11	Settlements
2	A2	*Industrial*	7	A7	*Industrial*	12	A12	Settlements
3	A3	*Protected area*	8	A8	Settlements	13	A13	Settlements
4	A4	*Industrial*	9	A9	Settlements	14	A14	Settlements
5	A5	*Industrial*	10	A10	Settlements	15	A15	Settlements

3.10. CVI

The stage to determine the value of the coastal vulnerability index is to combine the values of each of the parameters that have been known to the weight value of each variable which is multiplied from 1 to 5, and then calculate the value of the CVI coastal vulnerability index. Based on the CVI index value in this study, the minimum value of CVI is 4.33 and the maximum value is 20.00. The CVI vulnerability index map can be seen in Figure 12.

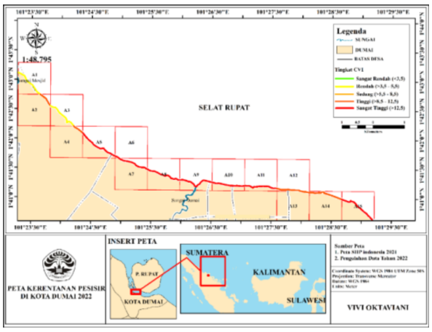

Figure 12. CVI Vulnerability Index map

Table 9. CVI vulnerability value of each grid

No.	Grid	Very Low	Low	Medium	High	Very High	CVI
1	A1		■				4,33
2	A2				■		8,66
3	A3		■				5,00
4	A4				■		10,00
5	A5					■	14,14
6	A6					■	20,00
7	A7					■	17,32
8	A8					■	15,00
9	A9					■	12,99
10	A10					■	13,69
11	A11					■	16,77
12	A12				■		10,61
13	A13				■		10,61
14	A14				■		10,61
15	A15					■	12,99

Based on Table 9, it can be seen in more detail for the vulnerability level category. It can be said that the location of this study dominates in the very high category, by looking at the characteristics of the category according to Gomitz (1991) in Table 3. Seen on grids A5-A11, precisely in Dumai Barat sub-district in East Purnama Village, Dumai Kota sub-district in Laksamana Village, and Dumai city, Dumai Timur sub-district in Buluh Kasat Village.

3.11. Coastal Vulnerability Analysis

The value of coastal vulnerability in three sub-districts of Dumai City is between 4.33-20.00 for 15 observation grids. This value falls into the very high category. The vulnerability value obtained shows that along the coast of the study area is classified as having almost the same category level, due to the study location which is not too wide, resulting in a very small difference in value. Physical vulnerability in the study area is influenced by geological variables consisting of coastal geomorphology, coastal elevation or height, shoreline changes, and coastal slope. As well as physical ocean process variables consisting of tides, wave height, and relative water level rise.

Based on the variable value of each parameter that affects the level of coastal vulnerability in the study area, the elevation and geomorphological parameters that express vulnerability fall into the very high category, the parameters of coastal slope and coastline fall into the medium category, while the parameters of relative water level rise, significant wave height, and tidal ridge fall into the very low category.

The analysis found that elevation, geomorphology, coastal slope and shoreline conditions contributed highly to the level of physical vulnerability. While relative water level rise, significant height, and tidal ridge contribute little to coastal vulnerability. This is in line with the statement of Sulma (2012) where the elevation condition gives the highest contribution to the high level of physical vulnerability in the study area, in addition, the rate of relative water level rise which is an oceanographic variable also contributes highly to physical vulnerability in the study area and while overall the smallest contribution is in the average tidal stump.

3.12. Coastal Vulnerability Low Category (grids A1 and A3)

Factors that affect vulnerability in the low category can be seen from various aspects, one of which is the aspect of changes in the coastline experiencing accretion. According to Mufriadi 2019, accretion is the addition of land towards the sea, the phenomenon of accretion is influenced by low wave energy, which causes other aspects to be affected such as wave height, tides, and sea level rise with low values.

Significant wave height based on secondary data observations can be known values ranging from 0.09-0.18 m/year, and on field observation data ranging from 0.10-0.30 m. This value is categorised as very low vulnerability. This value is included in the category of very low-class vulnerability, this is also reinforced according to Wati et al. (2019) in the full moon phase, significant wave heights range from 0.12-0.90 m and according to Girsang & Rifardi (2014) by not considering the condition of the tidal phase under normal conditions the wave height in the Rupat Strait ranges from 0.07-0.21 m, and in the Malacca Strait, it ranges from 0.10-0.40m.

Based on the information above, the high waves in the Rupat Strait are caused by the waters which are semi-enclosed. Semi-enclosed waters will affect the wave height, which is influenced by current speed, wind speed, length of wind, and distance without obstacles (fetch). Therefore, in closed waters, the waves are much smaller than in open waters. Field observations of current speed in the waters of the Rupat Strait ranged from 0.03-0.57 m/s. When the tide occurs, the current will propagate from north to south which turns to the east and will rejoin the current in the Malacca Strait to the southeast, also partially into the Bengkalis Strait, and vice versa. Therefore, the current speed in the Rupat Strait varies, but in general, the current speed at low tide is higher than at high tide.

Meanwhile, according to Isty et al. (2017), the speed of the tidal current reaches 1.22 m/s. So from these conditions, the Rupat Strait current moves towards the Malacca Strait through the north and east of the Rupat Strait. The lowest speed is in the middle of the eastern part of the Rupat Strait which is a shipping lane with a depth of 18.6 m. According to Nedi et al. (2010), the current speed in the Rupat Strait ranges from 0.22-0.82 m/s. The current that occurs in the waters of Rupat Strait is a current generated by the undulating movement caused by the tides that propagate from the Strait of Malacca.

Current velocity can affect the level of relative water level rise, where the value is at a low level of vulnerability ranging from 0.703-0.900 m/year. Relative water level rise is caused by climate in the process of global warming, global warming causes sea levels to rise as a result of melting polar ice caps (IPCC, 2018). Low sea level rise is influenced by very low tidal ridges.

Based on the processing results show that the tidal formzhal number value is 0.5. The value is based on Sadik et al. (2017) including the category of mixed tide type inclined to double daily (mixed tide, prevailing semi-diurnal). The mixed tide type inclined to double daily is a double daily tidal pattern that has an important influence on environmental conditions, especially on marine activities such as sea transport, and especially strait-to-sea traffic. The above is following the statement of Febrian (2015) where the type of tide on the Dumai coast is included in the mixed tidal type tends to double daily, which is called mixed semi-diurnal tide, which occurs 2 times high tide and 2 times low tide for 24 hours. In the observation of the coastal slope in the moderate category, the slope of the beach affects the stability and shape of the beach. Coastal stability is a factor of land use planning, land use in the observation grid is Protected Area, Protected Area is a coastal area that is under legal protection such as a conservation area. based on these factors, the coastal vulnerability in the city of dumai is in the low category.

3.13. Coastal Vulnerability High Category (grids A2, A4, and A12-A14)

One of the factors that support a high level of vulnerability is the geomorphological shape of the muddy beach, muddy beaches are the result of coastal erosion which has an impact on sea level rise, which can cause ROB flooding. The occurrence of erosion is due to the low elevation value (height) at the observation site. a low elevation value will cause the frequency of flooding and inundation to increase. Coastal areas that cause erosion and these impacts will damage the balance of the coastal profile which will result in a shift in the coastline (Numbri *in* Rusdi, 2014).

Shoreline changes dominate the value at a stable level, a stable beach is the same as an abraded beach, where the behaviour of a stable beach is constant. This means that the profile volume fluctuates, but overall the volume does not change with time. Changes in the coastline can also be caused by land use dominated by settlements and industry, this causes vulnerability to be in the high category, because it affects the condition of the lowering of the groundwater level due to the increase in buildings.

3.14. Coastal Vulnerability Very High Category (grids A5-A11 and A15)

Very high category vulnerability is influenced by muddy geomorphological forms, muddy beaches fall into a very high vulnerability category, this is also reinforced according to Jadidi et al. (2013) classifying coastal geomorphology with muddy forms as a high level of vulnerability to coastal disasters. This is also following what Choirunnisa & Giyarsih (2016) stated that the vulnerability value for beach types in coastal areas with muddy beach shapes is in a very vulnerable category. In this case, the shape of the beach greatly affects the vulnerability of coastal areas as said by Treman (2009) the various geomorphological forms of the coast, are the result of various processes that shape and control them which have an impact on coastal vulnerability.

Muddy beaches occur in coastal areas where many river mouths carry large amounts of suspended sediments to the sea. This is reinforced according to Mubarak (2018) that the sediment content mask into the waters, through a model that can be seen from changes in bathymetry in these waters. It is also stated that if there is a coastal building, it affects the pattern of current circulation and sediment distribution. In addition, it is known that the wave conditions on the beach are relatively calm, so it is not able to carry (disperse) the sediment to deep waters in the high seas.

The suspended sediment can spread over a large area of water to form a wide, flat and shallow beach. The slope of the seabed or beach is very small. By the statement according to Rifardi (2008) states that the type of beach and topography of Dumai City is relative with a slope of 3% and the height from sea level ranges from 1-4 m. In Dumai City, the height is >5 metres above sea level. Based on this, the vulnerability is included in the very high category with the provisions stated by Handartoputra et al. (2015) that the vulnerability of coastal areas can be seen in the height of the land surface which is at a very low level, where the height of the land surface is almost not far above sea level, then it can cause ROB flooding due to low land surface.

The elevation value that shows in the High category is caused by several factors where the influence of sediment particle size will also affect the change in coastal slope. Statement according to Ramadhan et al. (2020), low elevation values will cause increased opportunities for coastal erosion. According to Thambrand (2015), Sediments with muddy beaches will have a very small slope reaching 1: 5000 and a larger sandy beach slope between 1: 2-1: 50 while the slope of the pebble beach can reach 1: 4.

The research area can be said to be a sloping area. This is also reinforced by Oksana et al. (2019) stating that, Dumai City includes an area with a slope level of 0-<3%, where the north of Dumai City is typical of sloping land and the southern area is more wavy. Another thing is also stated by the Ministry of PUPR, (2021) that, especially in the East Dumai, Dumai Kota, and West Dumai Districts, the slope is 0-2% and there are around 41,032 Ha. According to Dengen et al. (2019), the slope is a measure of the slope of land relative to a flat plane, which is generally expressed in percent or degrees. Land that has a slope of more than 15o can cause more coastal vulnerabilities such as flood disasters, this is also stated by Nurrizqi & Suyono, (2012) also stated that flood disaster that occurred shows that residential land in areas that are in a lower position than the position sea level when the sea is high. Land use is dominated by industrial and residential areas that make vulnerability at a very high level. This also affects the decline in groundwater levels and changes in coastlines, which is reinforced by Marfai (2014) which states that areas that experience a decrease in groundwater levels will form a basin morphology. The formed basin will be inundated during high tide, and this condition is called tidal flooding.

Changes in coastal shorelines in the observation grid dominate the level of abrasion, where abrasion is caused by significant wave height, resulting in the phenomenon of erosion of the beach by waves (Rusdi, 2014). Areas that do not have mangrove vegetation are directly affected by waves and will accelerate the abrasion process Nurhuda et al. (2019), by statement from Setyawan et al. (2021) where shoreline changes in coastal areas can be divided into several factors, namely physical environmental factors from the sea such as wind, waves, currents. As well as the type of beach material and also due to human activity factors on land, where this phenomenon has resulted in a decrease in the ecological environment of coastal areas (Sener et al., 2010). So from these events, beach material will increasingly disappear or be eroded deeper carried by coastal currents in a body of water (Wati et al., 2019).

Based on the explanation above, the very high vulnerability value is influenced by the height of the beach above the water surface as well as the geomorphological shape of the beach in the form of a muddy beach, which will result in forming a wide, flat and shallow beach. Another factor is the placement of land use which is still not neatly arranged because there are still many buildings that are less than 50 metres from the coastline. This will affect the tides, as the tide will easily reach the buildings; because of its low height and slope. As well as seeing the high rate of abrasion at several observation points.

4. Conclusions

The Dumai Coastal research area on the physical vulnerability index (CVI) is divided into 5 categories of vulnerability classes namely very low, medium-low, high, and very high. Low, high and very high vulnerability levels are found in coastal Dumai. The category of vulnerability in the low class is located in Dumai Barat District in Purnama Village with a value of 4.33-5.00, and the category of vulnerability in the high class is located in Dumai Timur District in Purnama Village grid A2 and A4 in Tanjung Palas grid A12-A14 with a value of 8.66-10.61, and the category of vulnerability in the very high class is located in Dumai Barat District grid A5-A8, Dumai City District grid A9-A10, and Dumai Timur District in Tanjung Palas Village grid A15 with a value of 12.99-20.00.

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