SHORELINE CHANGES ALONG HANSA AND BROKEN WATER BAY COASTAL TRACT OF PAPUA NEW GUINEA THROUGH REMOTE SENSING AND GIS

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Abstract: This study has been undertaken along 120 Km of coastal tract of Papua New Guinea. The study area lies in the Northern part of Papua New Guinea between the Hansa bay of Madang district and Broken Water bay of Sepik district. The study area is characterized by the sea wave erosion during the past five decades. Topographical map with the scale of 1:250000 is used as the base data set. The recent Landsat TM data set is used to find out the changes of coastal track in the study area after comparing with the topographical map during 1962 to 2010. After geo-rectification of the satellite image with GPS ground control points and topographical reference map, the shoreline is identified through visual image interpretation technology. The coastal processes are the major factors behind the shoreline shifting. The near shore, beach, backshore zones are dominated by one major process or a combination of process. The wave braking zone, breaking type and breaking energy are calculates using the standard equations. The result shows accelerated rate of erosion in the Broken water bay and Hansa bay coastal regions. Coastal track deposition is found in the south-east part of Broken water bay in the study area due to the huge sedimentation by Ramu river. The Broken water bay is under threat of encroaching sea, about 850 m at the northern part and 400 m at southern part during 1962 to 2010. Field observations of those areas also indicate severe damages in construction, natural and planted vegetation and pockets of beach erosion in several places in the study area.

1. Introduction:

Coastal zone is a broad transitional zone between the land and sea. The shoreline is a boundary line between land and sea. Because of its dynamic nature, the shoreline changes gradually. This change is provided by sequences of storm and cyclones, coastal processes, sea level rise, and seismic events, involving a specific range of space and time (Schwartz, 2005). Cumulative effects of all such long and short-term changes cause overall change in shoreline geometry. Accurate determination of shoreline change rate is important for a wide range of coastal studies, such as development of planning, hazard zoning, erosion accretion studies, and regional sediment budgets (Zuzek et al., 2003).

2. STUDY AREA AND DATA USED:

The study area lies in the Northern part of Papua New Guinea between the Hansa bay and Broken Water bay, approximately 120 km coastal track (Figure 1). The spatial extent of the study area lies between 3° 48' 22" S to 4° 14' 17" S and 144° 17' 20" E to 144° 58'10" E. The Hansa bay extended from 4° 7' 55" S to 4° 11' 30" S and 144° 53' 05" E to 144° 55' 36" E in the Madang district and Broken Water bay from 3° 53' 11" S to 4° 01' 11" S and 144° 34' 40" E to 144° 40' 27" E in the Sepik district.

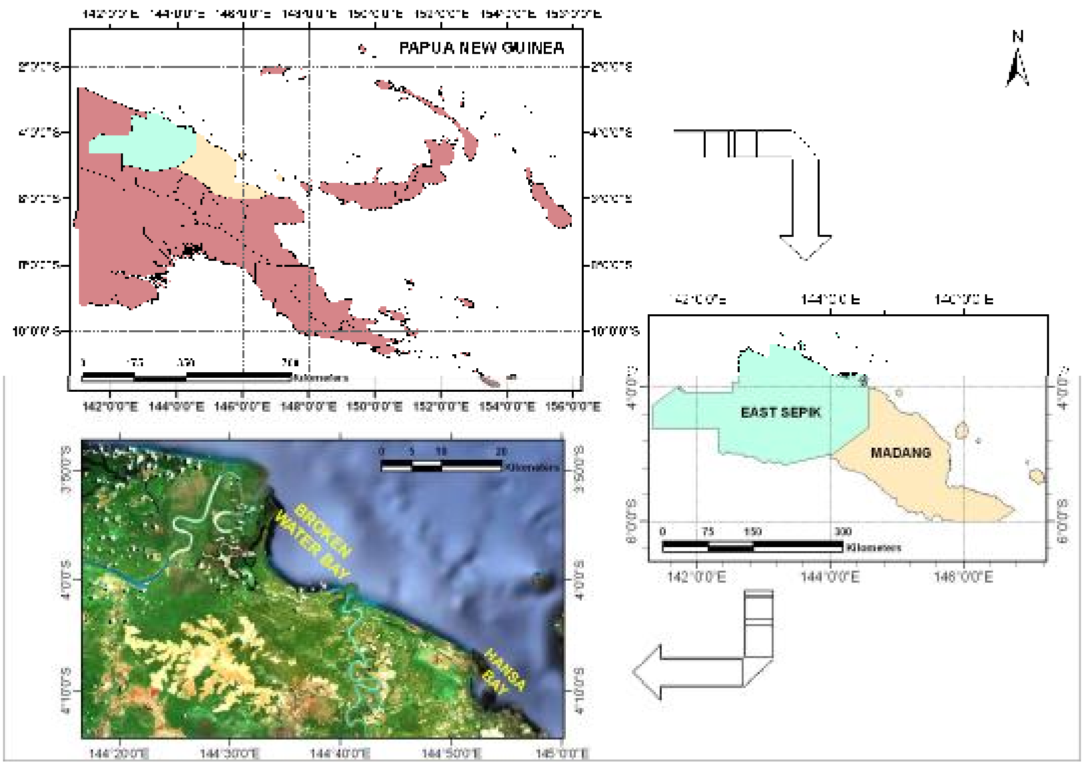


Figure 1. Location map of the study area

Army map service (AMS), US, Washington compiled topographical map for the Papua New Guinea in 1962 in the scale of 1:250000 is used as the base data set. Optical bands with standard false color combination (SFCC) of LANDSAT 7 TM satellite images of 2010 are used to identify the coastal track location of the study area. All other details of the dataset, data spans along with the sources were given in the table 1.

Table1. List of data used in the study

Sl. No.	Collateral data	Scale/ Resolution	Year of publication	Source
1	Topographical maps	1:250000	1960	Army map service (AMS), US, Washington
2	Landsat-7, TM	30 m	2010	UNITECH, PNG
3	Wave data	Location wise	2012	http://www.tide-forecast.com

3. METHODOLOGY:

3.1 Wave climate data

Sea waves represent mechanical energy that has been imported to the seawater by the stress of wind acting on the sea surface. The sea surface shows periodic ups and downs as the wave is propagated across the air-sea interface. The waves are described by the following parameters, which are taken to calculate the breaker zone, breaker type and the breaking wave energy in this area. Wave height (H) is the vertical distance between crest and trough. Wave length (L) is the horizontal distance between two successive wave crests and Wave period (T) is the time between passes of two successive crests is called the wave period (Wiegel, 1960). The quantitative representation of these parameters describes the wave climate of a coast.

Waves in the ocean are difficult to describe. The sea surface often appears as a confused and constantly changing mass of crests and troughs, because of the interaction between waves of different height, period and direction. Statistical distribution of wave characteristics i.e. wave height, period and direction along a given shoreline forms the basis for describing the wave climate of a segment of the coast. Waves propagate from deep sea and the wave parameters (height, length, period, direction) undergo significant changes as they approach shallow water near the shore. It is the change in wave character that affects the littoral zone. Hence, coastal problems are directly related to shallow water wave climate and only indirectly to the characteristics of deep-water wave. It is to be kept in mind that since each coastal has its unique set of physical properties viz. slope and alignment, the shallow water wave climate are naturally extremely varied. Near shore wave's characteristics can change with in a few kilometers along the shoreline, but the deep-sea wave climate data holds good for a considerable portion of the coastline.

3.2 The breaker zone identification

To demarcate the breaker zone, the wave climate data was analyzed, like- dominant deep-sea wave height (Ho), dominant deep-sea wave period (T). These data are varies season to season. The breaker zone also changes in respect of seasons.

The dominant deep-sea wave height (Ho) is 0.789 m. The dominant deep-sea wave period (T) is 9.44 sec. In deep water condition the wave length (Lo) is a function of the deep-sea wave period (T).

The deep-sea wave length (Lo) may be represent as-

$$L_0 = {gT^2}/{2\Pi} = 1.56T^2 \text{ .... } \textbf{\textit{(I)}}$$

Where- g is acceleration due to gravity (9.81m/sec), T is the deep-sea wave period.

Putting the value of deep-sea wave period (T), deep-sea wavelength is calculated.

$$Lo = 1.56 * (9.44)^2$$
$$= 139.02 \text{ m.}$$

Next with the deep-sea wavelength (Lo) the wavelength (L) changes with depth was analyzed as it the wave approaches the coastline and the values were obtained for different depth conditions (d). The calculation of d/Lo is found out, taking various depth values.

From this ratio d/L (ratio of depth and wave length at any given depth) was obtained by the following equation.

$$d/Lo = d/L.\tanh.2\Pi d/L \ldots\ldots\ldots\ldots..(II)$$

The term d/L has been tabulated (Shore Protection Manual, 1984), as a function d/Lo to simplify the solution of wave problem. By this procedure, the wavelength (L) for various depths was calculated. The change in the wavelength (L) of an approaching wave from does not, in itself give any useful information, but its corresponding changes in wave height (H) and their ratio may subsequently use to interpret the breaker line. The H/Ho (ratio of wave height at any water depth and deep water wave height) values have been also tabulated by (Shore Protection Manual, 1984), as a function of d/Lo. The wave height (H) at any water depth is calculated by following ratio-

$$H/Ho \ldots\ldots\ldots\ldots\ldots\ldots.. (III)$$

It should be mentioned that the calculated H values would hold good so long as the wave does not break. In reality however, the near shore wave fail to attain such heights because they break earlier and the wave crest that spill over near the beach gradually die out. For shallow water wave the critical value for breaking wave has been given as $H/d = 0.78$.

3.3 Estimation of breaking wave energy:

Only increase in the width of the breaker zone does not give the entire picture of the formidable increase in wave power during different period of time in a year. The speed at which a wave propagates is termed as the wave celerity (C). Since the distance traveled by a wave during one wave period is equal to one wavelength. The wave celerity (C) can be related to the wave period and wavelength by –

$$C = L/T \ldots\ldots\ldots\ldots\ldots\ldots (IV)$$

Where - T is deep-sea wave period.

With a given wave period and considering the wavelength (L) with depth (d), the wave celerity (C) have been calculated in the table. It can be seen from table that as the wave approaches the shore, frictional drag exerted by the bottom slows down the wave celerity as it approaches the low tide line of the beach (Wiegel, 1964). However, it is the speed and energy of the breaking waves, which actually determines the vigor of the operating process.

The total energy of a wave system is the sum of its kinetic and potential energy. The total average wave energy per unit surface area (specific energy) is given by-

$$E = PgH^2L/8 \ldots\ldots\ldots\ldots\ldots (V)$$

Where- P is density of salt water, g is acceleration due to gravity (9.81m/sec),
L is wavelength, H is wave height.

3.4 Determination of Breaker type:

The breaker type is an important factor affecting the hydrodynamic phenomena of the breaker area, the nature and level of turbulence induced by wave breaking, the long shore

current and the near shore circulation cell. At least three types of breakers are recognized.
1. *Spilling breaker:* The upper crest steepness and spill down the front of the wave.
2. *Plunging breaker:* The wave front over steepness, curies and plunges to words
3. *Surging breaker:* The flat waves do not break; move up and down the beach face.

The breaker type (ξ_0), can be determined in the following way-

$$\xi_0 = \frac{m}{\left(H_0 / L_0\right)^{1/2}} \quad \text{........................ (VI)}$$

Where- m is the beach slope, H_O is deep-sea wave height, L_O is the deep-sea wavelength.

According to these parameters, the breaker type can be classified as follow-

ξ_0 = < 0.5 - Spilling breaker
ξ_0 = 0.5 - 3.3-Plunging breaker
ξ_0 = > 3.3 - Surging breaker

3.5 Shoreline change identification:

The recent Landsat TM data set of 2010 is used to find out the changes of coastal track in the study area after comparing with the topographical map of 1962. The scale of both Landsat TM and the topographical map is 1:250000. The systematic geo-reference process of the satellite image was performed with GPS ground control points and topographical reference map. The high spatial resolution google earth image is used as the base map for the shoreline identification. The shoreline is identified through visual image interpretation technology from satellite image and topographical map. According to the shoreline position digitization is performed for 1962 and 2010.

4. RESULT AND DISCUSSIONS:

4.1 Wave Breaking zone:

When the H/d values cross this threshold, then the wave crest become unstable and they break. From the table 2 it can be seen that the critical limit of 0.78 is exceeded at 1.40 m depths.

Table 2. Computation of wavelength and ratio of wave height at any water depth and deep water wave height Parameters

d	Lo	d/Lo	tan.h.2Π.d/L	L	H/Ho	Ho	H	H/d
25	139.02	0.17983	0.864	120.11328	0.9145	0.789	0.721541	0.028862
20	139.02	0.143864	0.8076	112.272552	0.914	0.789	0.721146	0.036057
15	139.02	0.107898	0.7307	101.581914	0.9269	0.789	0.731324	0.048755
10	139.02	0.071932	0.6217	86.428734	0.9676	0.789	0.763436	0.076344
9	139.02	0.064739	0.5954	82.772508	0.9815	0.789	0.774404	0.086045
8	139.02	0.057546	0.5626	78.212652	0.9676	1.001	0.968568	0.121071
7	139.02	0.050352	0.531	73.81962	1.023	0.789	0.807147	0.115307
6	139.02	0.043159	0.4964	69.009528	1.05	0.789	0.82845	0.138075
5	139.02	0.035966	0.4577	63.629454	1.086	0.789	0.856854	0.171371
4	139.02	0.028773	0.4138	57.526476	1.133	0.789	0.893937	0.223484

3	139.02	0.02158	0.3632	50.492064	1.201	0.789	0.947589	0.315863
2	139.02	0.014386	0.2984	41.483568	1.327	0.789	1.047003	0.523502
1.5	139.02	0.01079	0.2598	36.117396	1.403	0.789	1.106967	0.737978
1.4	***139.02***	***0.01007***	***0.248***	***34.47696***	***1.435***	***0.789***	***1.132215***	***0.808725***
1.25	139.02	0.008992	0.2356	32.753112	1.471	0.789	1.160619	0.928495
1	139.02	0.007193	0.2082	28.943964	1.561	0.789	1.231629	1.231629

Lo =139.02 m, Ho =0.789 m, T =9.44 sec

Lo -Dominant deep-sea wave height in m   Ho -Dominant deep-sea wavelength in m.
T - Dominant deep sea wave period in sec   d-Different depth to words the coast line in m
L - Wave length according to depth to words the coastline
H - Wave height according to depth to words the coastline

4.2 Braeking wave velocity and energy:

The breaking wave velocity is about 3.65 m/sec, shown in the table 3. The computed "specific energy" for this particular beach shows that at breaking, the wave processes energy of 55821.69J/m. The high energy waves on one hand and the increase in width of the breaker zone on the other hand gives a clear idea about the quantum of sand that is set into motion and transported to words the shore. The wave energy also gives one the idea about the erosive threat that the wave posses.

Table 3. Computation of wave celerity and energy

d	L	H	P	C	E
25	120.1133	0.721541	1030	12.72387	78982.23
20	112.2726	0.721146	1030	11.89328	73745.65
15	101.5819	0.731324	1030	10.76079	68620.24
10	86.42873	0.763436	1030	9.155586	63623.81
9	82.77251	0.774404	1030	8.768274	62695.67
8	78.21265	0.968568	1030	8.285238	92673.05
7	73.81962	0.807147	1030	7.819875	60742.59
6	69.00953	0.82845	1030	7.310332	59821.59
5	63.62945	0.856854	1030	6.740408	59004.9
4	57.52648	0.893937	1030	6.093907	58062.79
3	50.49206	0.947589	1030	5.348735	57263.69
2	41.48357	1.047003	1030	4.394446	57436.53
1.5	36.1174	1.106967	1030	3.825996	55898.75
1.4	***34.47696***	***1.132215***	***1030***	***3.65222***	***55821.69***
1.25	32.75311	1.160619	1030	3.469609	55724.75
1	28.94396	1.231629	1030	3.066097	55454.14

P = 1030 kg/m^3, T =9.44 sec

T - Dominant deep sea wave period in sec.   P - Density of salt water in kg/m^3
d - Different depth to words the coast line in m.
L - Wave length according to depth to words the coastline in m.
C- The wave celerity in m/sec.

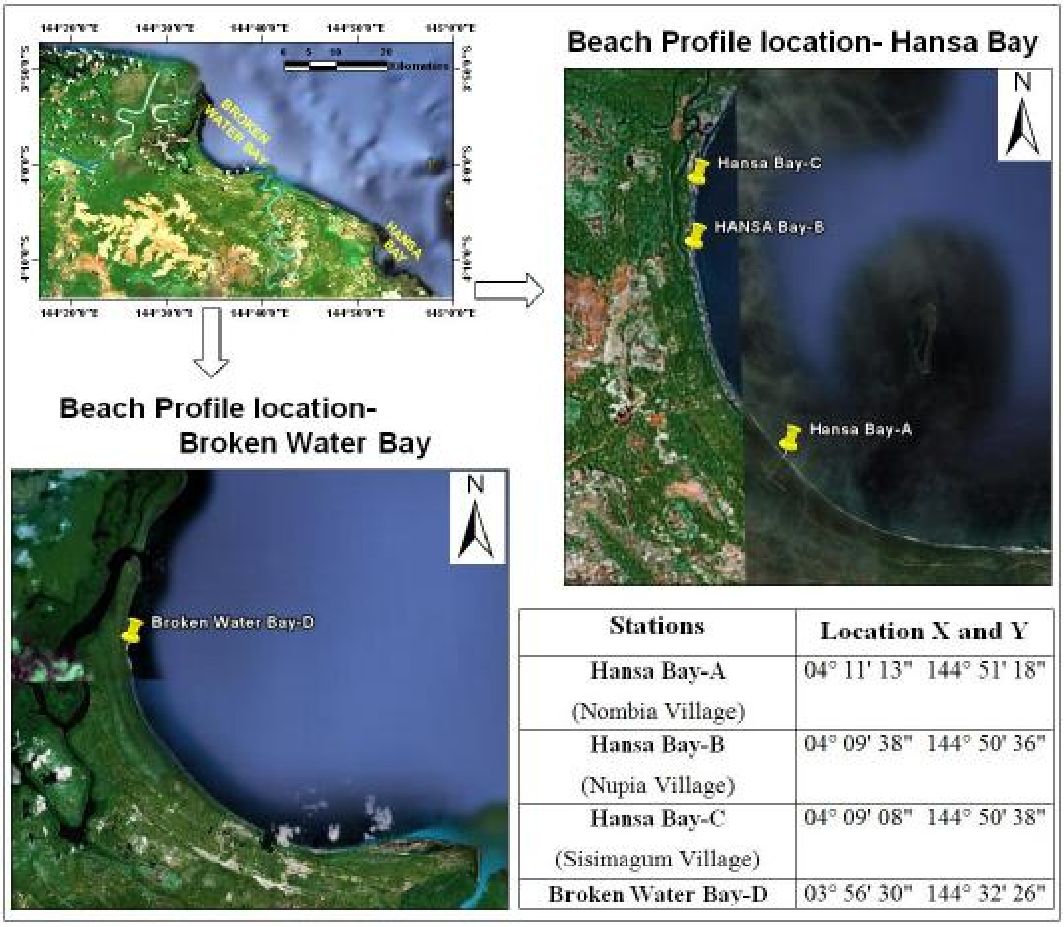
H - Wave height according to depth to words the coastline in m.
E – Wave energy in different depth in J/m.

4.3 Wave breaker type:

In the Hansa bay and Broken water bay coastal beach spilling breaker and plunging breaker types are found mostly, due to high beach slope as measured in different location (Table 4 and Figure 2).

Table 4. Computation of wave breaker type

Stations	Location X and Y	Ho	Lo	Slope (m)	ξo	Breaker type
Hansa Bay-A (Nombia Village)	04° 11' 13" 144° 51' 18"	0.789	139.02	0.0238	0.316	Spilling breaker
Hansa Bay-B (Nupia Village)	04° 09' 38" 144° 50' 36"			0.0416	0.552	Plunging breaker
Hansa Bay-C (Sisimagum Village)	04° 09' 08" 144° 50' 38"			0.0625	0.830	Plunging breaker
Broken Water Bay-D	03° 56' 30" 144° 32' 26"			0.150	1.990	Plunging breaker



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Hansa Bay-C (Sisimagum Village)	04° 09' 08" 144° 50' 38"
Broken Water Bay-D	03° 56' 30" 144° 32' 26"

Figure 2. Location map beach profiles measured at different place in the study area

4.4 Shoreline changes during 1962 to 2012

Accelerated rate of erosion is found in the study area. The Broken water bay is under threat of encroaching sea towards land, about 850 m at the northern part and 400 m at southern part during 1962 to 2010. Due to the huge sedimentation by Ramu river, the coastal track deposition is found in the south-east part of Broken water bay or left side of the Ramu river's flow direction in the study area (Figure 3). The coastal track erosion also found in the Hasna bay. There is no sign of deposition in the Hansa bay coastal region. Table 5 is showing the coastal track erosion or deposition pattern during 1962 to 2010. In the figure 5 yellow line represent the coastline position of 1962 derived from topographical map and the red line represent the coastline position of 2010 derived from TM image.

Table 5. Coastal track erosion or deposition pattern during 1962 to 2010

Stations	Erosion pattern	Shifting of coastline (towards land)
Hansa Bay-A	Medium	160 m
Hansa Bay-B	Medium	150 m
Hansa Bay-C	Medium	125 m
Broken Water Bay-D	High erosion	850 m

Left Bank of Ramu	Deposition	Average 450 m sea wards

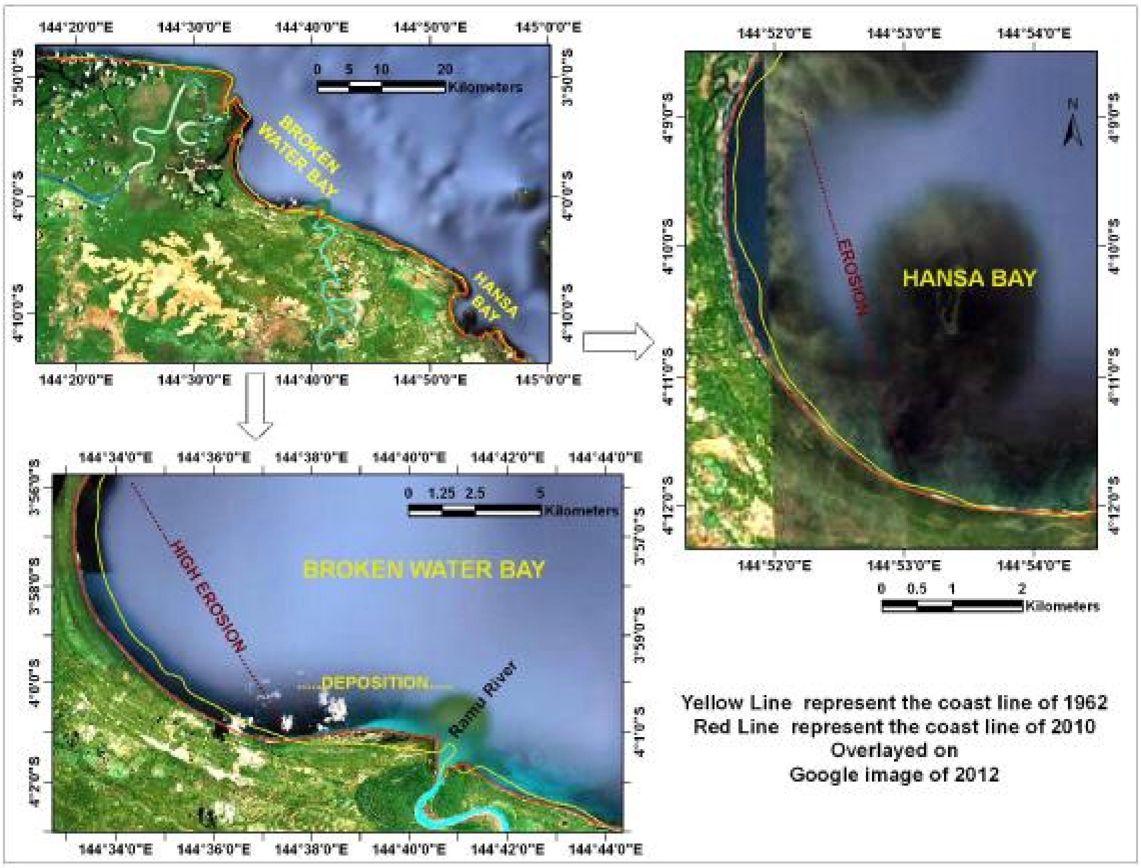

Figure 3. Shore line change during 1962 to 2010 in the study area

5. CONCLUSION AND RECOMMENDATION:

The sea wave average breaking zone/water depth is calculated as 1.40 m, where the wave velocity is 3.65 m/sec and the breaking wave energy is 55821.69 J/m. The plunging breaker is found almost all the place of the coastal track area. Due to high wave velocity, high breaking wave wave energy and the high beach slope, the erosion pattern is remarkable high in the Broken water bay and Hansa bay. A small part of the left side of Ramu river is characterized by deposition due to rapid sedimentation process of the river. Severe damages in construction, natural and planted vegetation and pockets of beach erosion in several places in the study area are found through field observations.

To protect the coastal environment developmental activities in coastal zone have to be restricted by following Coastal Regulation Zone (CRZ). The area Up to 50 m from HTL towards land is under CRZ-I, up to 200 m from HTL towards land is under CRZ-II and area between 200 m-500 m from HTL towards land is under CRZ-III. The zone of 200 m from HTL should be kept as “no development zone”. In the zone between 200 m and 500 m landward from HTL, construction of low-rise houses limited to 7.5 m for hotel or beach resorts. Primary protective zone or CRZ-I is zone no human activities should be allowed except social forestry. More social forestry or plantations to be carry out to protect the rapid erosion in the study area.

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