SHORELINE CHANGE DETECTION BETWEEN KALLAR AND VAIPPAR COAST, TAMILNADU, INDIA, USING GEOSPATIAL TECHNOLOGIES

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ABSTRACT

Coastal zones are constantly undergoing wide changes in shape and environment due to natural as well as human development activities. recreational activities, waste disposal etc. The shoreline change study has become a matter of great concern in the recent years. The measurement of shoreline is a key factor in coastal zone construction. The traditional ground survey is time and cost consuming. An attempt has been made in this paper to evaluate the shoreline change study based on multi-temporal satellite data. The shoreline change information obtained from multi-temporal IRS 1D LISSIII and PAN within period of 5 years difference images registered in GIS environment. All multi-temporal shoreline change vectors provide quantitative information on the coastal hazard due to erosion and accretion. The changes are caused by heavy exploitation of heavy mineral sand, coastal erosion and accretion occurred in some local places. There are two zones namely Kallar and Vaippar vigorously undergoing coastal erosion. It shows that about 473 sq.km areas have been eroded between the north of Kallar and Sippikulam either due to natural process or by human influence.

Key words: shoreline change, high resolution satellite, GIS, Kallar and Vaippar coast.

1.0 Introduction

The shoreline is one of the most important features on earth's surface. They are highly dynamic and ever changing. Changes are over time scales including minutes, hours, decades and Centuries. Spatial scales vary from local to regional to worldwide. Although change is continuously occurring, it doesn't occur in a constant manner. Many factors influence these changes including the type of shoreline (rocky, sandy), wave activity, tidal variations, storms and human impacts. The shoreline change study is necessary for updating the shoreline change maps and management of natural resources. The information obtained through field survey is cost effective and time-consuming process. Recently remotely sensed data acquired at the fixed time interval, multi temporal satellite data provides the changes of natural and human activity on coastal segment. Furthermore the GIS technology is progressively more being used in spatial decision support systems. In the past few years, GIS has emerged as a powerful risk assessment tool and is being put to assess the risk on property and life stemming from natural hazards such as earthquakes, hurricanes, cyclones, and floods. Manipulation, analysis, and graphic presentation of the risk and hazard data can be done within a GIS system, and because these data have associated location information, which is also stored within the GIS, their spatial inter-relationships can be determined and used in computer-based shoreline change models. This assessment is used by insurance companies to help them make decisions on their insurance policy rates, by land developers to make decisions on the feasibility of project sites, and by government planners for better disaster preparedness. The shoreline change detection of Indian coastline was discussed by Various workers (Nayak,(2002),Chauhan et al(1996),Mitra,(2002),Gangadharabhat,(1995),Vinodkumar.(1994), Nair et al ,(1993), Nayak,K,S;Sakai,B.(1985).The coast between Kallar and Vaippar is enriched with black sand concentration. These sands are being exploited regularly for the production of ilmenite and garnet. Due to that natural character of sandy beaches is to change shape constantly and to move landward or seaward. To understand and predict the rate of change due to human activities or by the natural forces, we need to monitor the changes in the shoreline using GIS and remote sensing data. Sediment volume is evaluated from 3D model analysis to understand the stability of beaches in the area.

2.0 Study area

The study area is bounded latitudes 8' .58''- 9'. 00''N and 78'. 13'' to 78'. 17''E and total shoreline length is about 12 km. The relative humidity fluctuates from 51% to 78% with mean annual of 67%. The coldest month is December with Temperature declining to a minimum of 22^{o}c.Between Kallar and Sippikulam the beach is almost flat and narrow with enrichment of black sands. The coast is guarded by chain of islands like Van Tivu, Koswari Tivu, Vilangu Shuli Tivu and Karia Shuli Tivu. They are situated within 10km distance from coastal Segment and offer protection from wave action. The drainage pattern of the study area is mainly controlled by the presence of seasonal rivers like Kallar, Vaippar and Vembar. The Vaippar river basin extends for about 6255sq km. The investigated area is mainly underlain by Precambrian gneisses, charnockites and granites, besides Quaternary sediments (Loveson, 1994).(Fig.1.Location map).

3.0 Methodology

The satellite data was processed using ERDAS Imagine 8.3.1 software. The IRS 1D PAN data, Survey of India Toposheets,IRS LISSIII data are used to obtain shoreline changes along the coast between Kallar and Vaippar. IRS 1D PAN (5.8m) is georeferenced (master image) by taking various ground control points (GCP) from the Survey of India Toposheets (SOI). The projection used here for few references is polyconic with spheroid and modified Everest data. Subsequently Image to image registration by PAN image into different years (1996,1997,1998,2001) and SOI toposheet of 1968 as base map was registered. LISS III infrared band (0.70 - 0.90 um) is best suitable for delineation of water bodies. It also provides better contrast on land, water and transitional zones (Nayak 2002, Mitra, 2002 and Smith and Zarillo, 1990) The different image enhancement techniques like Edge enhancement, Level slicing, Normalized Difference Vegetation Index have been used for extraction of land/water interface using ERDAS Imagine 8.3.1 software. The extracted land/water raster boundary files were converted into vector polygon files as Arc info coverages. The arcinfo boundary vectors are weeded using spline function. These vectors files are cleaned, and established polygon topology. Similarly by the muti-temporal shoreline vectors are segmented or converted into homogeneous subunits by recording the location of a change and distance along the Shoreline from a specified origin Attributes of each shoreline segment Lengths (1968,1996,1997,1998,2001) are also calculated (Li et al, 1999).

The satellite data is covered the shoreline, fore dune, secondary dunes and ocean front structures. A digital elevation model within 2m x 2m grid is constructed from PAN merged data points. The data collected using mean heights are measured relatively to modified Everest datum. The heights above the polyconic spheroid projection must be converted into height above the sea level data, before the shoreline is extracted from the DEM. The height of the waterline along the beach is displayed in the transformed grid, and is compared with waterlevel recorded by the Tuticorin Harbour Marine Survey Department. This comparison has allowed the correlation of grid height to height relative to a local tidal data. The comparison of ground surveyed beach profiles and wet/dry line as shown by LISSIII sand PAN merged data (Fig.2), which are acquired at the same time as the LISSIII and PAN topography data, are used to pick1m above mean sea level as the level to represent the shoreline. The transformed DEM is contoured and the +1m contour line extracted as the shoreline. To calculate the area of the shoreline changes, an arc info grid module is used. Here the shoreline changes area is converted into grid. Shorelines are coded as 1968 and 2001 respectively. All other cells are coded as no data. Grids provide powerful tools for the analysis of geographical data that vary continuously over a region. Euclidean distance command is employed to generate the third grid, which represents the Euclidean distance from source grid (1968 shoreline). Euclidean distance is calculated for each cell in distance function (ESRI, 1992), for each source cell by calculating the hypotenise with the x_max and y_max as the other two legs of triangle. This calculation derives the Euclidean distance instead of cell distance. The shortest distance to a source is determined and it is less than the specified maximum distance. The value is assigned to the cell location on the output grid. Next, we can either use graph (Arcplot module) command or import the last grid file into Arc view to quantifying the shoreline changes.

3.1. Cut and fill Analysis for sediment volume calculation

Cut and fill analysis determines how much sand has been lost or gained in a study area by comparing two surface profiles of the area. Cut and fill summarizes the areas and volumes of change during operation on an area represented by two TIN, i.e. before and after the cut-and-fill operation. It is inferred that an elevation of a surface is modified by the addition or removal of the surface material. The first step of the process is to build an accurate Beach profile terrain topography for an entire coast. Here the terrain model surface contours are generated to view the perspective nature of the beach profile. This is typically the case for topography data used for beach profile area and volume calculation. In addition, to triangulated irregular network, (TIN) three-dimensional surfaces was created. This can represents the surface using contiguous, non-overlapping triangular faces, with a height value each triangular node, and attribute information crated. The area is represented in surface models by establishing TIN-masking function to clipping of TIN features are attempted to eliminate the unwanted area.Afterwards to compute cut and fill volumes a iterative process is used to select the excavation hing line. The excavation hing line is nothing but as the line above, which material is removed from generated beach profile. In the TIN surface in to create new slope, an elevation of the excavation hing line can be constant, or vary across the beach profile. The volume is calculated between the excavation hing line and the maximum z value in the TIN. A hing line greater than z max results in a volume of zero. The different excavation hing line settings on beach profile and their volumes are shown in fig. (3a to 3d).

These figures compare how volume is calculated with different hing line settings. The shaded areas indicate the regions used for volume calculations. The cut volume indicates the cut and fill volumes associated with that particular hing line. The cut volume is calculated by removing material to reach desired slope line and fill volume is calculated by filling in the below line to reach desired slope. The hang line can either have constant elevation (such as contour around the perimeter of beach profile), or elevation can vary along its perimeter. Once a series of polygons (the regarded surfaces) and their elevations have been created, the script generates a TIN from the polygons. A cut/fill calculation is then performed by subtracting the regarded surface (series of polygon) from the existing surface, and determined the amount of material removed to the desired slope. The cut volume is compared with fill volume to check for mass balance. Finally the area and volume of different periods of shoreline changes are calculated.

4.0 Results and Discussions

Using the above methods, we are able to investigate the relationship between sediment volume change and other various factors. Overall, the shoreline between Kallar and Vaippar is retreating (Fig.4, 5 and 6). However, there are several scales of along shore variability in the annual rate of shoreline change. Sum of this variability is occurred by beach sand extraction for processing the placer minerals. The artificial Harbor structure have changed sediment budget by trapping the sands in the littoral drift direction on both sides of the sediment pass.

As results, shoreline position is more stable for the distance of few Kilometers between Kallar and Kalaignanapuram (Fig.4, 5 and 6). The overall retreating of shoreline is probably enhanced because of the sands trapping by the artificial and Natural barriers prevailed in the area (ex. Harbor, coral reef platform). The purpose of calculating average annual rate of shoreline change is to provide indication likely future changes due to human activities mainly the sands extraction. Therefore, shoreline is used to determine average annual rate of shoreline changes in 1968, 1996, 1997&2001.Erosion and accretion have been calculated and tabulated (Table.2). During the periods between 1968 and 1996 the highest shoreline length difference are observed at Kallurani shown in table 1, where as the lowest shoreline lengths are noticed near Vaippar zone. Similarly the shoreline area changes for the past 33 years are calculated zone wise and have shown in Table.2 and also different shoreline change maps were prepared and shown in Figures 4, 5 and 6. With a span of 33 years the total land area is accreted during that period is 499.31 m^2 where as the total land area is eroded is 473.42 m^2 .The rate of accretion is 15.36 m^2. As well as the rate of erosion is 14.4 m^2 per year. It is noted that data reveals the long-term coastal processes. Such changes show a relationship between geological materials of shoreline and retreating rate. Where a shore is composed of thick black sands (Chandrasekar et al, (2001) refraction rates are higher and have greater ranges of values than the shore is composed of white sands. The shoreline modification is due to the development of coastal mining and urbanization. Similarly the offshore bar system (coral reef platform) has also distributed the modification of shoreline. It leads to accumulation and deficits of sand on opposite sides of longshore structures, geologic or barrier islands or within pocket beaches in response to seasonal net wave energy directional changes (Everts et al 1983; Morton, 1993).

Generally shoreline with higher slope should have higher recession rate. But inspecting the ground, we couldn't definitely tell whether the transect with higher near shore slope angle have higher recession rate. However, we could account with the enrichment of black sand concentrations. Coastal Terrain Model is created to depict the shoreline elevation. This is generated using the methods followed by Li (2001). This has helped us to delineate the land and water boundary (Fig.7). The extraction of the shoreline is based in the mean high waterline on LISS III images. Time segmenting and interpretation of the results have been made here with these known processes in mind. In our opinion, the changes of the shoreline mainly based on the major coastal process occurring at the local and regional level.

Cut and fill analysis summarizes the area and volume of change in the study area. Here the elevation of a surface is modified by the addition or removal of beach sand material. Material is removed from section of the beach due to erosion by wave action or sand mining and deposited as fill in nearby location as accretion caused by the wave activity, littoral drift and artificial structures. Based on these volume, of sediment is depicted on zone wise (Table 3,4 &5).

4.1. Sediment volume change between 1968-1996

Within span of 28 years the higher erosion sediment volume is observed at Vaippar zone, (6469.5$m^{3)}$. Maximum accretion of sediment volume is noticed at Kallar zone 4227.08 m^3). In addition the net loss of sediment volume is higher than accretion. It clearly indicates that the erosion activity is higher than accretion activity.

4.2. Sediment volume change between 1996-1997

This one-year period has experienced erosion. Sediment volume computed at kallar, Kallurani and Vaippar zone are about, 137.02 m^3, 132.6 m^3 and 247.8 m^3 respectively. The total gain of sediment volume is higher at Kallar zone 280.28 m^3 .

4.3. Sediment volume change between 1997-1998

Between these periods the volume of erosion is higher at Vaippar zone, (262.5 m^3), similarly the accretional sediment volume is higher at Kallurani zone 381.94 m^3.

4.4Sediment volume change between 1998-2001

During these periods the erosion sediment volume of Kallar,Kallurani and Vaippar are computed about 572 m^3, 562.9 m^3, and 715.2 m^3respectively. Accretional sediment volume is about 661.7 m^3, 399.36 m^3 and 349 m^3 respectively.

4.5.Sediment volume change between 1968-2001

Within span of 33years the volume of Kallar,Kallurani and Vaippar is about 4839.64 m^3,848.9 m^3 and7638.9 m^3.The accretional sediment volume was aabout 4948.32 m^3,5159.7$m^3$and 3316.2 m^3 respectively.

5.0 Conclusion

This coastal belt is straight to constant changes due to internal and external influents. A method of interpolating DEM of the shoreline is used for studying sediment volume changes over a period of 33 years. We have found the volume of sedimentary shoreline depends on the balance between the volume sediment volume available and capacity of net on-shore and along shore sediment transport system. It is also found that linear relationship exists between shoreline profile change over the active zone and linear change of coastline. Cut and fill analysis clearly indicates the elevation of beach surface and shoreline configuration is modified by the addition or removal of material from the beaches.

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Table.1 .Shoreline length (m) change between Kallar and Vaippar zone

Station	**1968-1996**	**1968-2001**	**1996-1997**	**1997-1998**	**1998- 2001**
Kallar	169.51	312.1	16.43	20.14	179.16
Kalluarani	423.66	399.84	69.14	94.05	187.01
Vaippar	10.04	39.08	2.84	26.37	58.25

Years	**Kallar zone**			**Kallurani zone**			**Vaippar zone**			**Total Shoreline change**		
	Erosion In m^2	**Accretion In m^2**	**Net In m^2**	**Erosion In m^2**	**Accretion In m^2**	**Net In m^2**	**Erosion In m^2**	**Accretion In m^2**	**Net In m^2**	**Erosion In m^2**	**Accretion In m^2**	**Net In m^2**
1968-1996	158.25	162.58	+4.33	32.14	156.14	+124	215.65	102.54	-113.11	406.04	421.26	+15.22
1996-1997	5.27	10.78	+5.51	5.1	8.32	+3.22	8.26	4.57	-3.69	18.63	23.67	+5.04
1998-2001	22	25.45	+3.45	21.65	15.36	--6.29	23.84	11.66	-12.18	67.49	52.47	-15.02
1968-2001	186.14	190.32	+4.18	32.65	198.45	+165.8	254.63	110.54	-144.09	473.42	499.31	+25.89

Table.2 Shoreline changes during 1998-2001

Time Period	Erosional Sediment Volume (m^3)	Accretional Sediment Volume (m^3)	Net Sediment Volume (m^3)
1968-1996	835.64	4059.64	+32224
1996-1997	132.6	216.32	+83.72
1997-1998	162.76	381.94	+219.18
1998-2001	562.9	399.36	-163.54
1968-2001	848.9	5159.7	+4310.8

Table.3 Shoreline Sediment Volume change at Kallar

Time Period	Erosional Sediment Volume (m^3)	Accretional Sediment Volume (m^3)	Net Sediment Volume (m^3)
1968-1996	4114.5	4227.08	+112.58
1996-1997	137.02	280.28	+143.26
1997-1998	172.9	321.62	+148.72
1998-2001	572	661.7	+89.7
1968-2001	4839.64	4948.32	+108.68

Table.4 Shoreline Sediment Volume change at Kallurani

Time Period	Erosional Sediment Volume (m^3)	Accretional Sediment Volume(m^3)	Net Sediment Volume (m^3)
1968-1996	6469.5	3076.2	-3393.3
1996-1997	247.8	137.1	-110.7
1997-1998	262.5	340.8	+78.3
1998-2001	715.2	349.8	-365.4
1968-2001	7638.9	3316.2	-4322.7

Table.5 Shoreline Sediment Volume change at Vaippar

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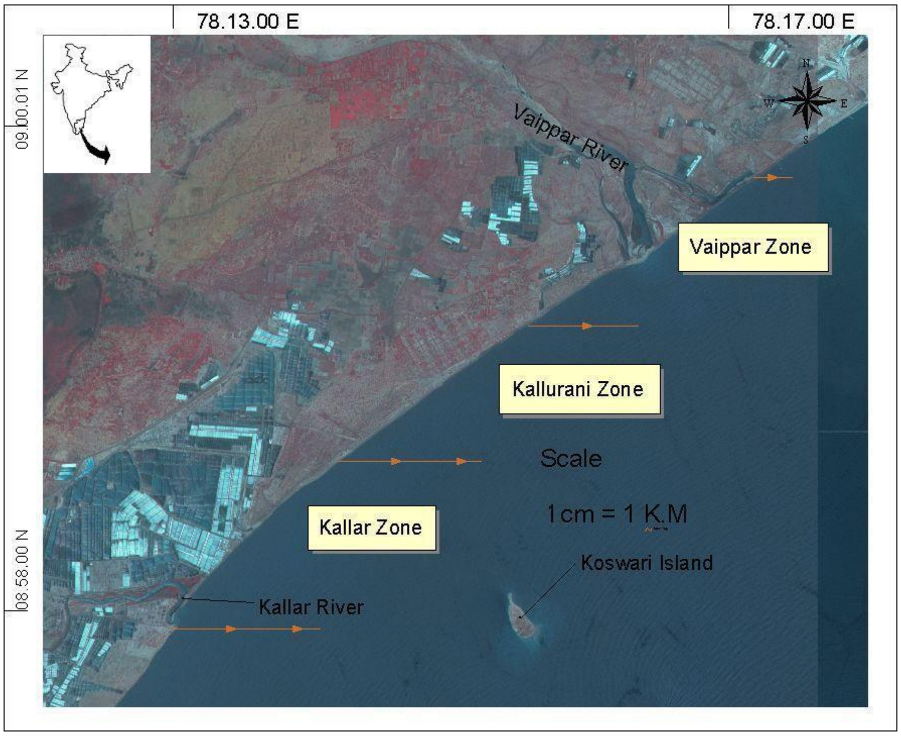

Figure.1 Location map of the study area

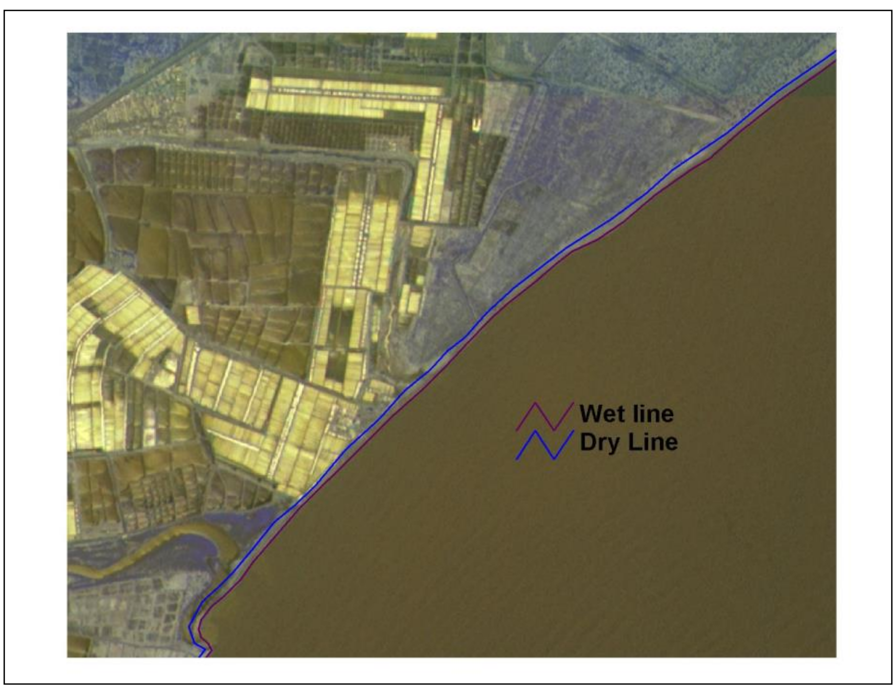

Figure.2 Wet and Dry line Extracted from the LISSIII and PAN merged data

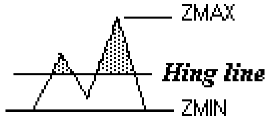

Fig.3a {Hang line}=ZMIN

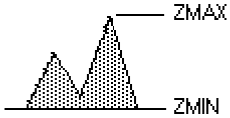

Fig.3b ZMIN< {Hang line}<Z MAX

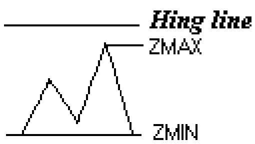

Fig.3c {Hang line} < ZMIN

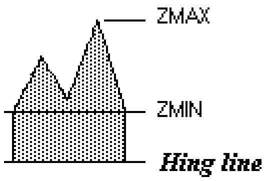

Fig.3d {Hang line} >= ZMIN

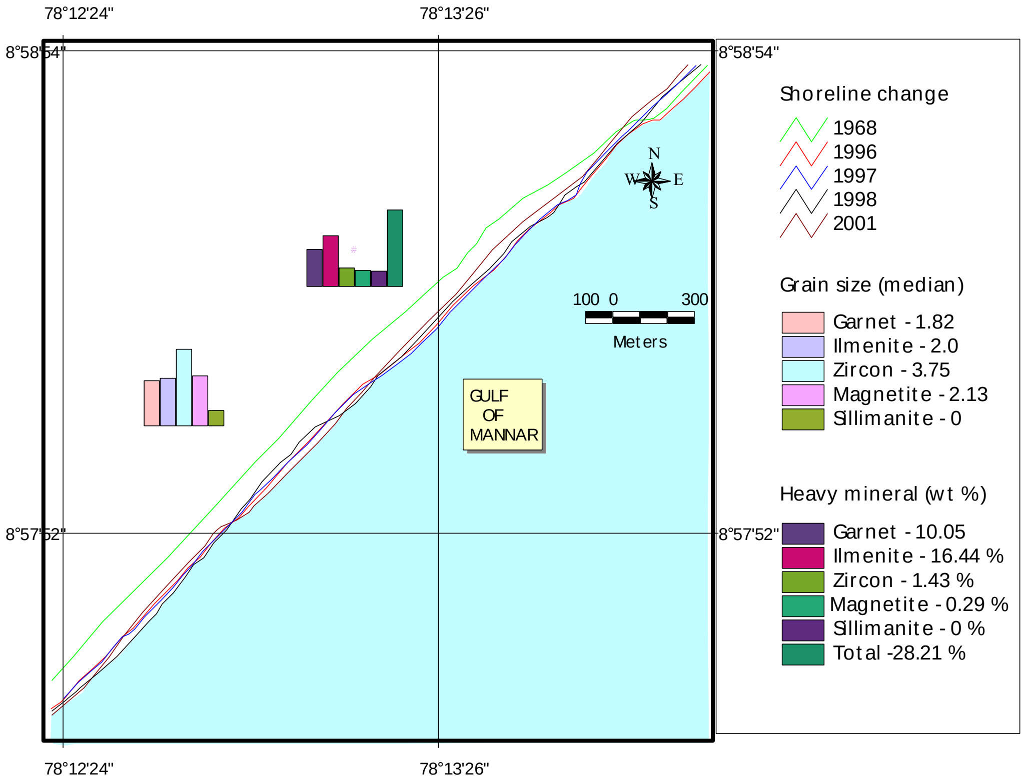

Figure.4 Shoreline change at Kallar zone

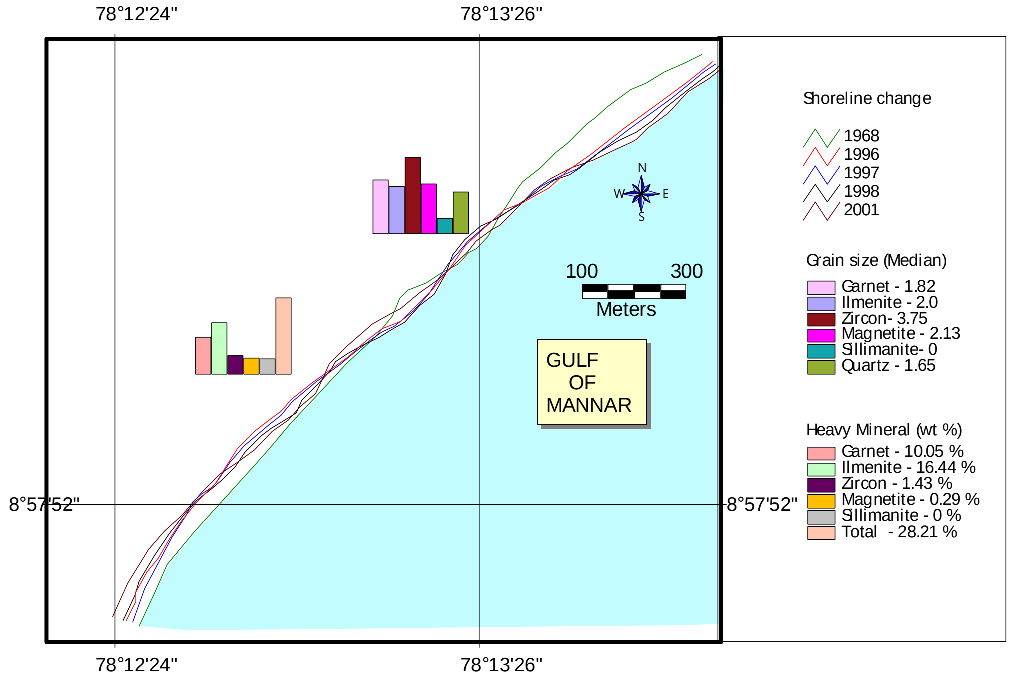

Figure.5 Shoreline change at Kallurani zone

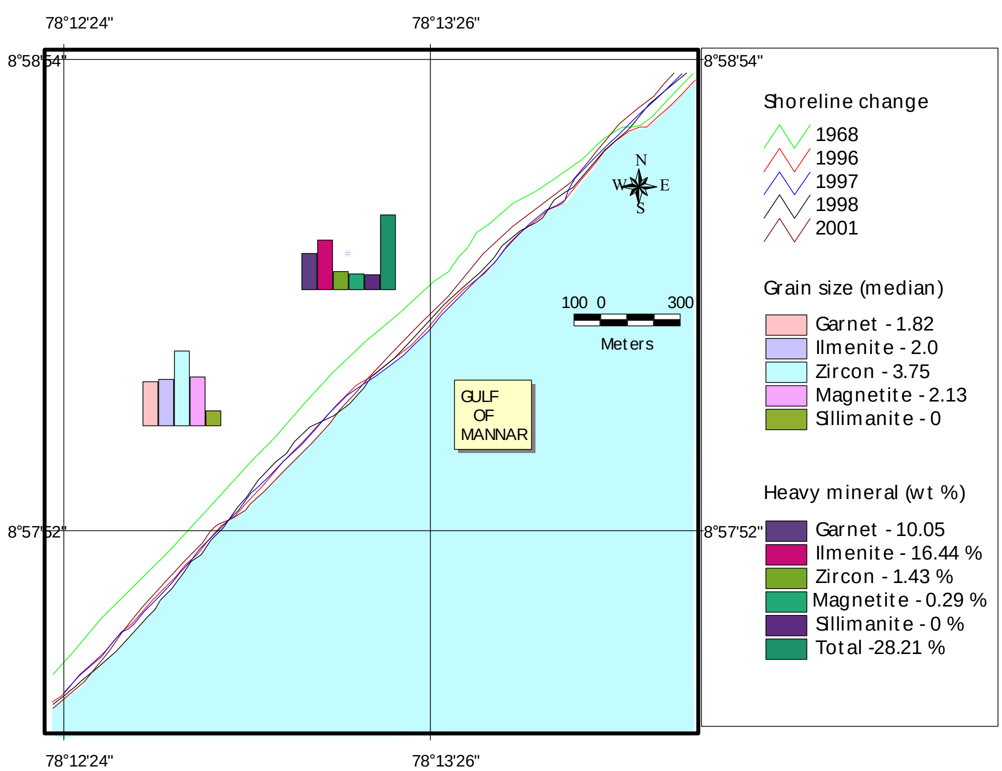

Figure.6 Shoreline change at Vaippar zone

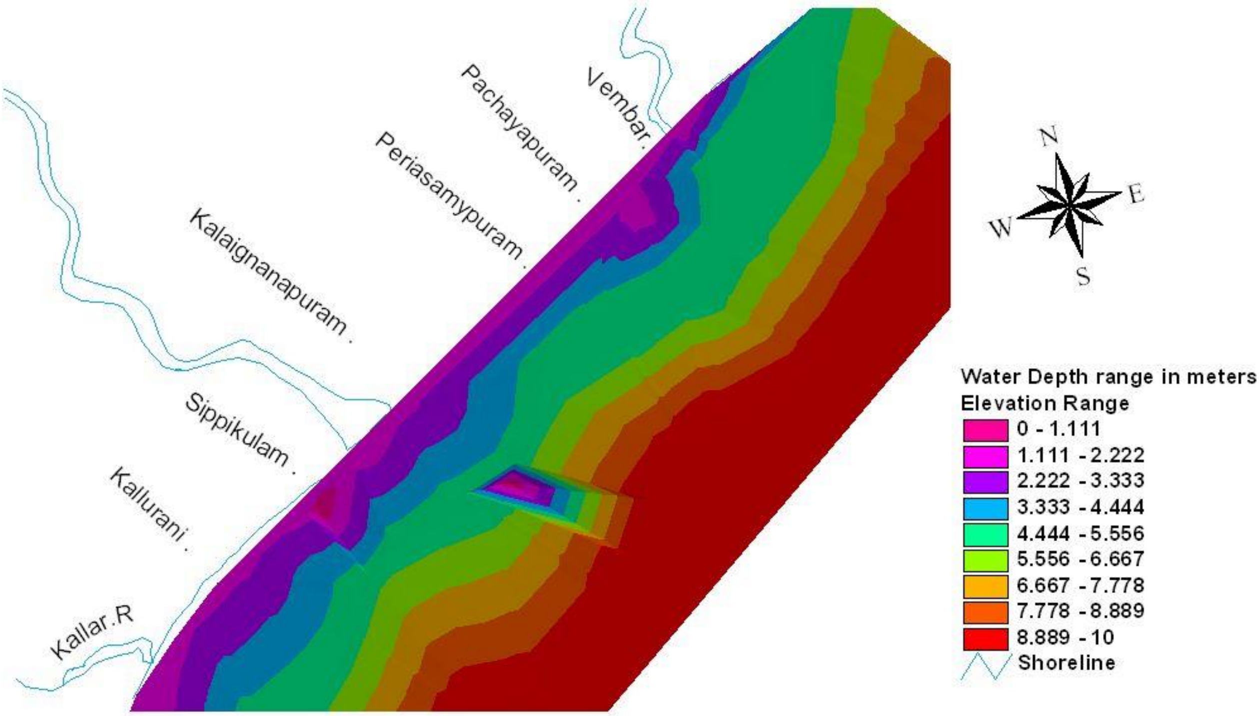

Figure.7 Coastal Terrain Model based on 1968 hydrographic chart