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Beach morphology and coastal protection along Ennore coast in the north of Chennai city, southeast India

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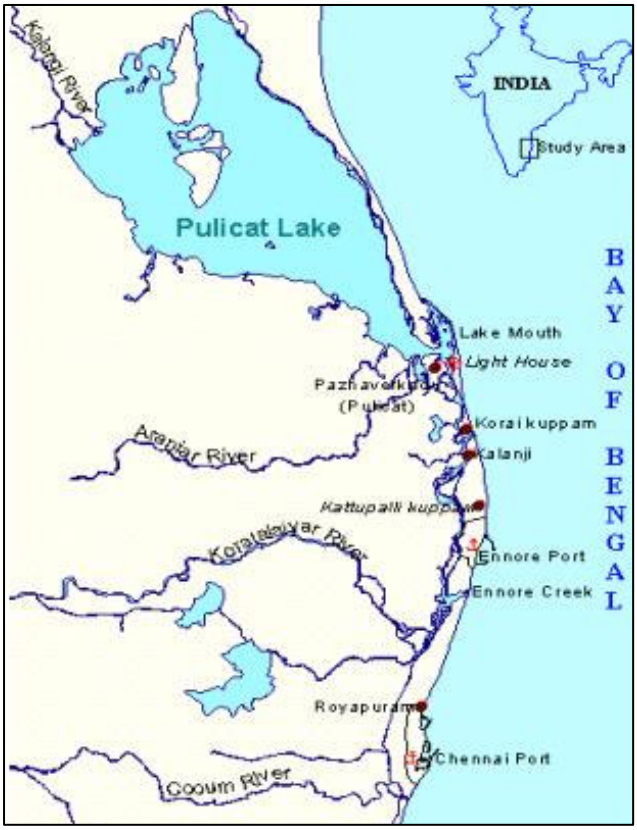
Abstract: Baseline information on the beach morphology along the Ennore coast, an industrial hotspot region in the East coast of Bay of Bengal, is presented. In order to assess the effect of human interference on the coastal zone, a baseline survey of the coastline is considered important. Such information enables to predict the future coastal morphology and settings. Based on the baseline data created, this study predicts that the accretion noticed in the southern side of the Ennore port will affect the port entrance channel in the future course. Therefore it warrants for immediate mitigation measures to curtail such accretion and also recommends for keeping the Ennore creek mouth open permanently. Ennore creek also serves as the coolant source for the two thermal power plant units. The study also put forward certain other mitigation measures which are relevant in the present event of developments. Adjacent to Pulicat Lake, the erosion is continuously taking place at an alarming rate making vulnerable for a striking storm to wash away the villages under the sea. It may also lead to the merger of the Pulicat Lake into the Bay of Bengal, thereby the brackish water ecosystem of the lake may altogether disappear causing several ecological and social problems. The study concludes that a long-term integrated coastal monitoring is the need of the hour.

Introduction

Throughout the world, coastlines are the brutal victims of the anthropogenic activity. Coastal erosion, partially due to rising sea levels, is often exacerbated by human interference that disrupts the natural sediment transport processes along the coastline. For such a sort, the North Chennai coast, particularly in the Ennore coastal stretch, could form a typical case study. It is the narrow spot in the East coast of Bay of Bengal affected by point pollution. Ennore coast is abode of industrial hotspot. It is not unusual for such development to take place without prior environmental impact studies. In order to assess the anthropogenic interferences on the coastal zone, a baseline survey of the coastline must be established. Coastal morphology is the starting point for the development of such a baseline and it can serve as an initial step for assessing future environmental impacts. Further, it facilitates the process for a sustainable management of the coastal zone and for planning the future developments. The objective of this work is to present baseline information on beach morphology along the highly developed industrial region – the Ennore coast.

Figure 1. Map showing the study area



Environmental setting

The environmental setting of the area is first presented. Then the spatial variability of beach morphology along the beaches is examined. Finally, the role of different types of coastal structures in altering beach morphology is explored. A coastal stretch of about 30 km length, lying between 13º 12' 30" N and 13º 30' 00" N latitude and between 80º 00' 00" E and 80º 27' 30" E longitude extending from EID Parry factory on the southern side of Ennore Creek to the inlet of Pulicat Lake along the coast of Bay of Bengal has been chosen as the study area (Figure 1). This area falls under Tiruvallur district of Tamil Nadu state bordering Andhra Pradesh state in the north, southern India. The area also assumes much importance due to its typical nature, comprising diversified coastal ecosystems and the unique presence of all kinds of complicated natural and man-made coastal features such as ports, thermal power stations, creeks, lagoons, shoals, sand barrier islands, barrier spits, inlets, etc. This area is also vulnerable to erosion and deposition due to natural and man-made phenomena. Due to Chennai port, the north Chennai coast is under threat even though protection measures have been implemented in the past. In addition, a new port (Ennore port) has also been constructed on the same coast, which may cause significant impact on further downdrift coast. North Chennai coast from fisheries harbour is located just north of Chennai port to the Pulicat lagoon. It is fragile and sensitive to the environmental changes. Mean annual rainfall in this region is around 120 cm (30 years average) with 2/3rd of rainfall occurring during northeast monsoon period (October to December). From March to September, continuous strong winds (average speed of 9 to 16.4 km/h) are observed regularly which play a major role in the circulation of water in the Bay of Bengal.

Materials and methods

Coastal profiles are usually measured perpendicular to the shoreline and may be shelf profiles, nearshore profiles or beach profiles (CERC, 1998). Different methods are followed to measure the beach profiles. Profiles are two-dimensional vertical sections showing how elevation varies with distance. In this study, 3 transects along the coastline of the study area were identified between Ennore creek and Pulicat Lake mouth. Beach profile survey have been carried out during April 2000 and May 2001 up to the offshore depth of 5 m from the beach for all the four transects using dumpy level/KGPS and wave sled in order to compare and identify the changes in the beach profiles. Beach profiles surveyed during these two years for the four transects are compared and from the cross-sections of the beach profiles, erosion and accretion quantities were estimated using Beach Morphology Analysis Package (BMAP) Version 2 of the Coastal Engineering Research Center (CERC), U.S.A.

Dry beach profile data were collected using land-surveying techniques (tachometer and level stations). These profiles extended from the reference line through the top of the berm to a waterline. In addition, nearshore profiles were collected through a wave sled. Arrangements of the wave sled utilized for the beach profile survey is presented in Figure 2.

Figure 2. Arrangements of wave sled (Ennore port in the background)

In this method, on the bottom mounted heavy weight frames, a G.I. mast of about 5 m height is fixed and tied by the nylon ropes to all the corners of the bottom frames for stability and straightness. During survey, one end is linked to the boat another to the shore by means of rope and is pulled to the offshore by boat till the sufficient depth is reached, in this case, up to 5 m below sea level. Then wave sled is pulled towards the shore by the human force on the shore and depth is noted after reading

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the level from the shore by confirming through the leveling instrument, in this case a dumpy level. After wave sled is reaching the zero line of the shore, the survey is continued with dumpy level or Kinematic Global Positioning System (KGPS) up to the reference point. Data collected were reduced to chart datum by applying tide correction based on the tide tables for the Chennai coast.

Table 1. Shoreline changes and volume of sediment changes

Beach profile	Shoreline Changes (m)	Volume m^3/m			
		Datum	Erosion	Accretion	Net
Transect 1	+44.25	Above	-	114.628	256.37
		Below	-	141.744	
Transect 2	+13.29	Above	-36.107	-	-295.29
		Below	-259.178	-	
Transect 3	-5.70	Above	-48.849	-	-69.36
		Below	-20.511	-	

Sampling in the nearshore and offshore regions has been carried out utilizing the Coastal Research Vessel, CRV Sagar Purvi of the Department of Ocean Development, Government of India. Totally 34 water samples were collected from 17 locations (surface and bottom samples at each location) during pre-monsoon period of 1999 in five transects at depths ranging from 4m to 20m with control sampling stations in between. Simultaneously bed sediment samples were also collected at these locations. Water quality analysis has been done using standard procedures. Grain size analysis was done through the "Particle Size Analyzer" (Malvern make) and mechanical sieve shaker and D_{50} values were obtained.

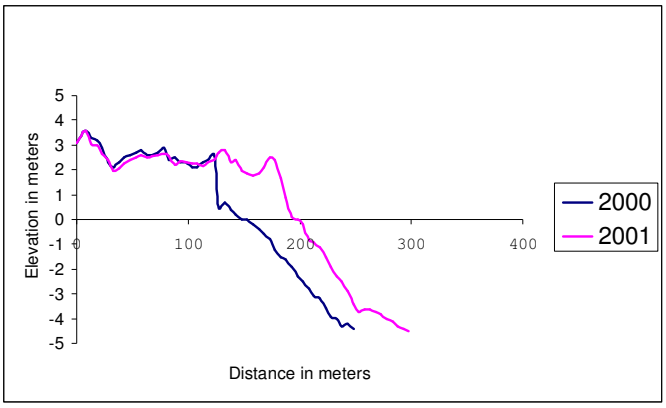
The bathymetric records were manually digitized, and after being integrated with the positioning data, the water depths were corrected for tidal variation. Further, the different types of coastal structures and their extension were identified from aerial photos and surveys. In general, the following categories of coastal structures were identified: (i) groins, (ii) breakwaters, and (iii) seawalls along the coastal stretch of Ennore.

Results and discussion

At all locations in the study area the predominant breaker wave types are plunging and collapsing. Net sediment transport direction is predominately northwards, however during strong winds and storms with waves approaching from NE-E the local sediment transport can change direction towards the south.

Beach profile survey was carried out between Ennore and Pulicat in order to identify the status of beach morphology. All the levels were adjusted to mean sea level and related to the phase of the tide. The location of transect was fixed with real time Kinematic GPS (RTK) through established permanent reference station at Ennore South Breakwater. Beach profiles surveyed during these two years for the four transects are compared and presented in Figure 3. Length of shoreline changes and quantities of erosion and accretion from the cross-sections of the beach profiles are calculated using Beach Morphology Analysis Package (BMAP) Version-2 of the Coastal Engineering Research Center (CERC), USA and presented in Table1.

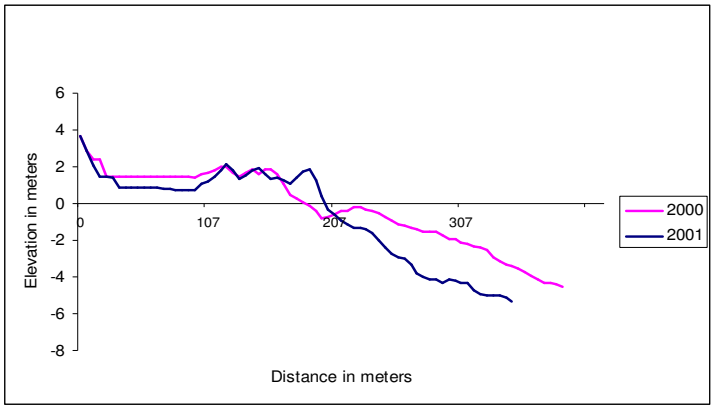
Figure 3. Beach profile at transect 1 (south of Ennore Port)



The cross-section of the profile- transect 1 located on the southern side of south breakwater of the Ennore Port is shown in Figure 3. The coast is accreting and the magnitude of accretion is more compared to the previous transect. At this location the rate of accretion is 44.25 m during the study period. Since the Ennore Creek is located in the southern side, naturally the accretion has to take place. Similarly, frequent closuring of mouth of the Creek is taking place and the Thermal Power Plant authorities are dredging the mouth continuously to keep the Ennore Creek mouth open to draw cooling water for their plants. At this location 114.628 m^3/m of sand is accreted above the datum and 141.744

m^3/m of sand is accreted below the datum (offshore side). The net accretion volume is 256.372 m^3 /m during the study period. The reason for the accretion is the transect that located on the southern side of the south breakwater. The breakwater acts as an obstruction for the movement of transporting materials and the sediments get deposited resulting in the accreting coastline on the southern side of the port. This has been confirmed earlier by various studies along the east coast and also worldwide (Vernom-Harcoart, 1881; Spring, 1919; Johnson, 1957; Cornick, 1969; Shepard & Wanless, 1971; Komar, 1998; Sahadevan, 1996).

Figure 4. Beach profile at transect 2 (north of Ennore port)



From the Figure 4 it is understood that on the northern side of the port (Transect 2), the coast is eroding. Even though it exhibits an apparent accretion which is not the actually a case as this zone is regularly nourished by the dredged spoils of the port as artificial beach nourishment in order to balance the erosion effects. It is clearly seen from the offshore profiles in the figure exhibiting the erosion which has started in the north. It is clearly demonstrated that even though the shoreline shows an accretion trend, the volume rate indicates an erosion trend from both the profiles above and below datum. At this location, 36.107 m^3/m of sand is eroded above the datum and 259.178 m^3/m of sand is eroded below the datum (offshore side). The net erosion volume at this location is 295.285 m^3 /m during the study period.

The beach profile at the location near Pulicat Lighthouse (Transect 3) is shown in Figure 5. It is evidenced (also vide Table 1) that the erosion is taking place at this location at a rate of 5.70 m per year. Here, 48.849 m^3/m of sand is eroded above the datum and 20.511 m^3/m of sand is eroded below the datum (offshore side). The net erosion volume at this location is 69.36 m^3 /m during the study period. From the beach profiles of transects 2 and 3, it is clearly demonstrated the erosion has started on the northern side due to the construction of Ennore Port. It is possible that erosion will take place further north in the forthcoming years. The reason for the lesser rate of erosion compared to the impacts of Chennai port on Royapuram coast is the presence of Ennore shoals on the offshore region north of Ennore port, beach fills in 2 sq. km on the northern side of north breakwater and the presence of Pulicat shoals. These naturally formed shoals extend up to a length of about 14 km with widths varying between 500 m and 1500 m and depth varying between 3 m and 6 m. The wave energy is attenuated as the waves travel over these shoals. As waves travel from deep water into shallow water, they generally lose energy even before breaking (Vincent, 1981). They also change height and direction in most cases. The changes may be attributed to refraction, shoaling, bottom friction, percolation and nonlinear deformation of the wave profile (CERC, 1984). That is the reason the rate of erosion on the northern coast of Ennore port becomes minimum. If erosion of shoals has to take place in future, the consequences will be similar to that of Royapuram coast for Chennai port.

In the Kattupalli Island, starting from north of Kaalanji village up to Pulicat Lake mouth, the width of the sand bar is very narrow. Particularly near the Kaalanji and Koraikuppam villages, the width of the sand bar between the lake (channel) and the sea is only about 100 m and 140 m respectively. If the erosion is to continue at this rate or a big storm has to strike this zone, it would make these villages vulnerable for getting washed away under the sea. It may also lead to the merger of the Pulicat Lake into the Bay of Bengal, thereby the brackish water ecosystem of the lake may disappear causing several ecological and social problems.

In order to know the foreshore slope of the coastal region, the data collected at six different transects by M/s RITES Ltd during 1996 (Ramanamurthy *et al.*, 2001) was compared. Beach profile data indicate that the entire area is having a steep slope varying

between 1:20 and 1:30 in the surf zone and off shore bar formation is noticed. Transect 3 on the northern side of the north breakwater shows a gentle slope owing to the Ennore & Pulicat shoals and beach fills of dredged materials as artificial nourishment. Steep slope is observed near the barmouth of Pulicat Lake, which may be due to regular tidal flow in the inlet. Longshore currents are more on the south side of the port compared to north side. Berm width and foreshore slope of beach profiles obtained at different locations are presented in Table 2. It reveals that there is a

Figure 5. Beach profile at transect 3 (near Pulicat inlet)

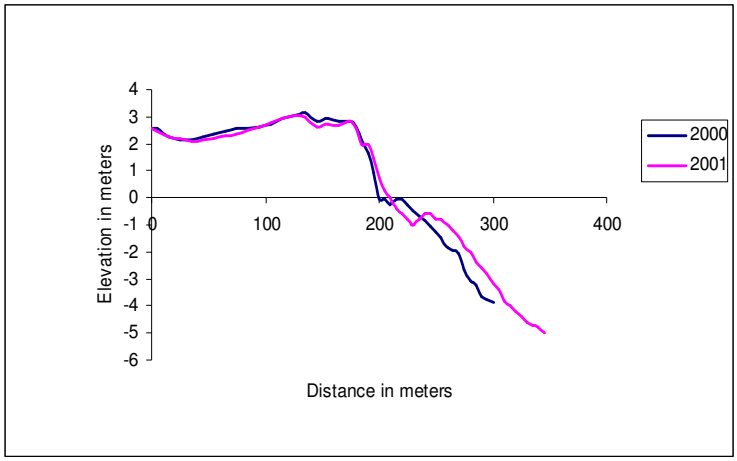


Table 2. Berm width and foreshore slope of study region

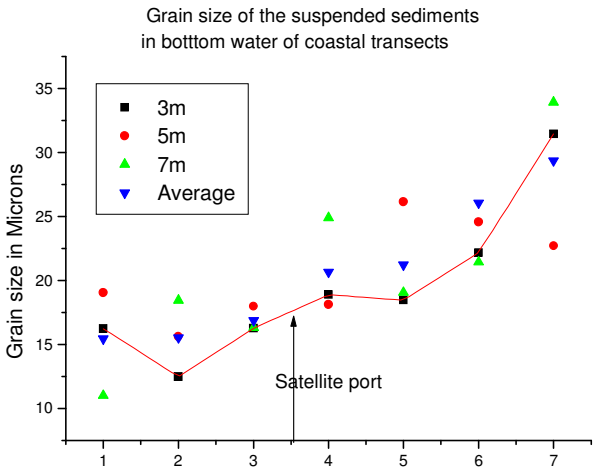
S.No	Location	Berm width (m)	Foreshore slope
1	South of Ennore Creek	90	1:13
2	South of Ennore Port	120-180	1:17
3	North of Ennore Port	190	1:30
4	Pulicat Light House	190	1:23

significant change in the foreshore slopes at Transect 1 (south of Ennore creek) and south of Ennore port. This change is attributed to the severe accretion that takes place at these locations. The results are in good agreement with Shih and Komar (1994) who have suggested that beaches with steep slope are subjected to larger seasonal changes in elevation.

Grain size of the suspended sediments in the bottom water ranged from 11 micron to 34 micron, which falls in the coarse silt size fraction. The bivariate plot of size with respect to transects show gradual coarseness of the grains towards north. The grain size of the bed sediments ranges from 100 to 500 microns. General trend of the grain size shows (Figure 6) almost constant result with a mean grain size of 178 microns of fine sand except three samples that were collected at a depth of 3 m. Grain size distribution along the coastal region revealed that coarser grains are observed in the region and it confirmed that the beaches are reflective in nature and are subjected to significant seasonal variations on beach profiles as concluded by Shih and Komar (1994) on the Oregon coast. Sediment characteristics in the north of port indicate the presence of coarser sediment along the offshore boundary of shoal and finer sediments on the coastline. The naturally formed Ennore shoals extend up to a length of about 14 km with widths varying between 500 m and 1500 m and depth varying between 3 m and 6 m. The wave energy is attenuated as the waves travel over these shoals. As waves travel from deep water into shallow water, they generally lose energy even before breaking (Vincent, 1981). They also change height and direction in most cases. The changes may be attributed to refraction, shoaling, bottom friction, percolation and nonlinear deformation of the wave profile (CERC, 1984). This clearly demonstrates that the shoal while interacting with large waves around offshore boundary reduces the energy of the incoming waves resulting in deposition of coarser sediments. Finer fragments of the sediment are carried over the shoal by relatively low energy waves and deposited adjacent to the coastline. Suspended sediment concentration in coastal waters ranges between 12 mg/l and 243 mg/l. However, these values are less compared to the values (25 to 321 mg/l) noted for Chennai coastal waters by Gowri (1997) and are higher than the values (32.8 to 131.5 mg/l) obtained by Satpathy and Nair (1996) for Kalpakkam coastal waters. Among seven transects, suspended sediment concentration observed on surface waters at transect 2 and 4 were higher. The reason could be cited as the dredging operations near

transect 2 and beach fills near transect 4 on the Ennore creek and north of Ennore port respectively. The Ennore coast was accreting earlier to the construction of the port also. It has been reported that accretion has occurred over a distance of 9 m during the past 20 years period i.e., 1978 to 1998 (IHH REPORT, 2000). It is particularly important to have a sufficiently wide beach so that temporary beach erosion will not cause erosion of the coast (Mangor, 2005). The lessons learnt and experiences gained from the earlier cases along the Chennai coast suggests that the issues are not resolved as the measures are highly localized in nature. The behavior of coastal processes in this region is not understood completely due to lack of proper monitoring mechanism (Kasinatha Pandian *et al*., 2004).

Figure 6. Grain Size of the Suspended Sediments in Bottom Coastal Waters



Conclusions

This work described qualitatively the coastal setting for the Ennore coastal region of North Chennai coast. The data collected created a baseline for evaluating future evolution of the coastal region. The grain size distribution along the coastal region shows that coarser sediments are present along the offshore shoal region and the finer sediments along nearshore region. Accretion noticed in the southern side of the Ennore port will affect the port entrance channel in the future and therefore immediate mitigation measures are to be implemented to curtail the accretion and also to keep the Ennore creek mouth open permanently. Necessary coastal structures such as groynes and jetties may be introduced after proper design study.

Our study confirms that the coast north of Ennore port is eroding. Therefore, it warrants for necessary protection measures to save the eroding coast at the earliest. Similar to the case of Ennore creek, adequate measures have to be taken to keep the mouth of the Pulicat Lake open, which is the only conduit for moving the fishing vessels from inland into Bay of Bengal. Being a sensitive coastal belt, it is concluded that a long-term monitoring is essential to plan for the perfect coastal defense in the region.

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