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Closure of tidal inlets in a wave dominated, micro tidal environment along south Konkan coast of Maharashtra

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Abstract

The seasonal closure of tidal inlets is a common and important coastal phenomenon along the south Konkan coast of Maharashtra. The closure of tidal inlets usually starts at the beginning of the fair weather or dry season around November when the average river flow drops down significantly. Hereafter persistence in wave direction and wave conditions remain more or less uniform for several days. River generated flood currents decline at the end of the rainy season and wave energy is reinstated as the dominant sedimentary process. Sediment from offshore sand bars are transported onshore and alongshore resulting in gradual narrowing and shallowing of tidal inlets.

In all tidal inlets on this coast the existence and persistence of an entrance is dependent on the relative strength of tidal currents and river generated currents which maintain the inlet entrance as well as close the entrance by depositing marine sediment. The balance between these processes determines the nature and the persistence of an inlet or a river mouth. A conceptual model of closure of tidal inlets on South Konkan coast is suggested based on these two main mechanisms of inlet evolution involved in the process.

The paper documents the features related to seasonal opening and closure of tidal inlets and river mouths in a wave-dominated, micro-tidal environment along the South Konkan coast of Maharashtra. The sedimentary forms developed and the temporal morphological changes in such forms under typical conditions dominant in the dry and the wet season respectively are discussed. The interpretations are based on satellite images and field observations. This study of the mechanism of gradual, seasonal closure of inlets on Konkan coast considers the role of long shore and on shore sediment transport. It also includes the parameters like wave approach, inlet cross section geimetry, tidal prism and inlet plan form.

Introduction

Tidal inlet is a restricted, relatively narrow channel developed along the coast where tidal currents are accelerated (Woodroffe 2002). Seasonal closure of tidal inlets usually occurs in micro tidal wave dominated coastal environment. It is characteristic of the inlets where there is strong seasonal river flow which weakens in dry season. Such inlets close every year after monsoon due to the formation of sand bar across the inlet entrance or growth of sand spit from up drift to down drift. Such a closure of tidal inlets has many negative impacts on discharge capacity of the inlet, navigation and fishing. To find sustainable solutions to the problems it is necessary to gain more insight into the morphodynamics governing seasonal opening and closure of such inlets. Inlets of small river catchments with small tidal prism are closed in dry season and reopen only in Monsoon. River dominated estuaries are characterized by large river discharges throughout the year .Their entrances are kept open permanently.

In all tidal inlets opening and closure of the inlet is dependent on relative strength of littoral currents and river currents. The littoral currents and waves produce littoral transport system in near shore zone.

Littoral transport takes place in the form of movement parallel to the shore (long shore transport) and movement perpendicular to the shore (onshore-offshore transport).The material transported in this manner is called littoral drift. The onshore - offshore transport is determined by wave steepness, sediment size, and beach slope. The long shore transport results from stirring up of sediment by the breaking waves and the wave approach with respect to the shore (Woodroffe 2002, Pethic 1992, Masselink et al 2003).

It has been reported that Maharashtra coast experiences negligible annual long shore sediment net transport and the direction of annual net transport is towards south (Kunte et al 2001). At Mirya bay, southward drift is estimated to be between 75,000 m^3 and 150,000 m^3 per year. The annual net transport direction varies along the west coast. It is southerly at Ratnagiri and northerly along Vengurla and Goa (Kunte et al 2001). Based on the field measurements estimated long shore sediment transport rates at Ratnagiri, Ambolgarh and Vengurla are reported to be 119,000 m^3, 190,000 m^3 and 53000 m^3 per year respectively (Kunte *et al.* 2002).

Study Area

The seasonal closure of tidal inlets is a common and important coastal phenomenon along the South Konkan coast of Maharashtra (Fig 1). The closure of tidal inlets usually starts at the beginning of the fair weather or dry season around November when the average river flow drops down significantly. Hereafter persistence in wave direction and wave conditions remain more or less uniform for several days. River generated flood currents decline at the end of the rainy season and wave energy is reinstated as the dominant sedimentary process. Sediment from offshore sand bars is transported onshore and alongshore resulting in gradual narrowing and shallowing of tidal inlets.

The river floods only occur in monsoons in study area but they exert a strong control on the form and evolution of inlets. Under flood conditions, flood currents cut through the sand-spits bordering the tidal inlet mouths. The flood currents also erode accumulated sediment and start deepening the channel. An abundant supply of sediment is always available for ready redistribution in monsoons (Karlekar 1996, 2009).

In all tidal inlets on this coast the existence and persistence of an entrance is dependent on the relative strength of tidal currents and river induced currents which maintain the inlet entrance as well as close the entrance by depositing marine sediment. The balance between these processes determines the nature and the persistence of an inlet or a river mouth. These two main mechanisms of inlet evolution are involved in the process.

These inlets are partially closed to the ocean for a number of months every year due to the formation of sand bars and sand lenses across their entrances. The annual closure of these inlets inhibits ocean access for boats and could also cause deterioration of water quality in the estuary connected to

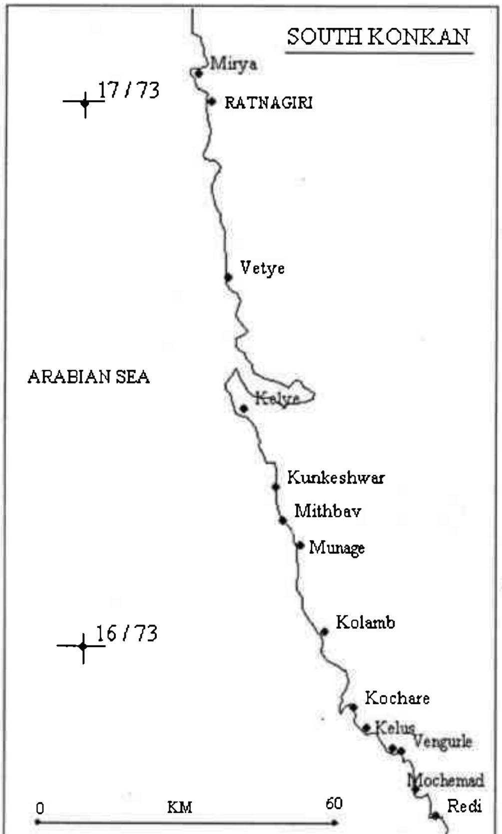

Fig 2

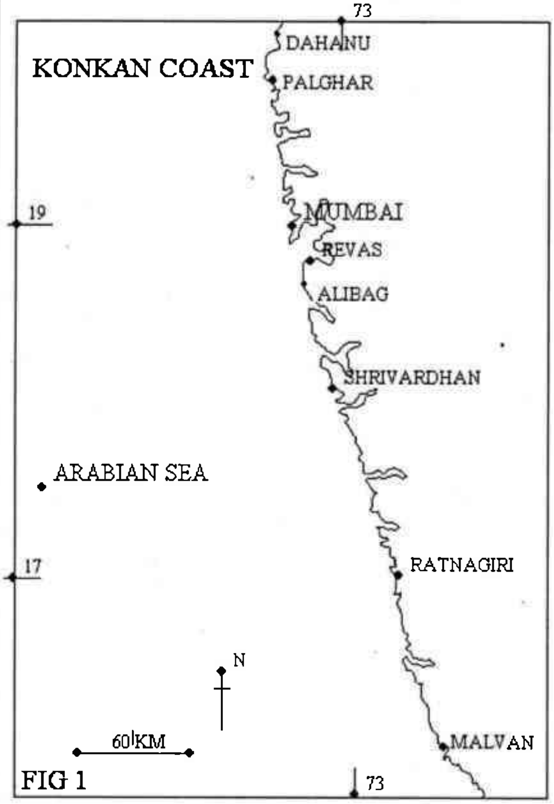

FIG 1

the inlet. Lagoons like conditions are created in the lower sectors of the estuaries. As these estuaries are commonly used as harbors or for recreational facilities there is increased interest in keeping the inlets permanently open

The south Konkan region is drained by rivers originating in Western Ghats. High rainfall intensity and flood discharge in monsoon has greatest effect on tidal inlets.

The wave action is strong in monsoons and relatively less effective in long dry season. The tides are semi diurnal and height ranges from 1.2 to 2 m only creating a micro tidal environment.

A 500 km long coastline and a narrow coastal plain stretching from north to south along the western boundary is a distinct physiographic region of Maharashtra, and is called Konkan. The coastal region of Konkan south of Savitri river is called South Konkan (Dikshit 1986). This stretch of south Konkan where tidal range is up to 2m is considered for the present study of seasonal closure of tidal inlets. It stretches from Redi (15.75 N /73.66E) in the south to Mirya (17.04 N/73.28 E) in the north (Fig 2).

All these tidal forms show a considerable filling of their tidal mouth sectors in fair weather from November to May. The river currents erode and flush out the accumulated sediment in monsoon from June to September and start deepening the channel.

Methodology

The most exciting development in coastal studies recently is the use of satellite images. It gives an entirely new view of our coastlines and allows the accurate quantification of coastal processes especially the sediment transport. (Plate 1, see page 35) Seasonal Closure and opening of tidal inlets is well illustrated by goggle images of the coastline. The interpretations given here are based on google and IRS LISS images and field observations. It also considers the role of long shore and cross shore sediment transport and includes the parameters like wave approach, wave heights and periods, long shore current directions and velocities inlet cross section, tidal prism and inlet plan form and beach slopes.

The sediment transport direction was determined using geomorphic indicators by remote sensing techniques; Satellite images of the southern Maharashtra coast were studied to determine the shore drift. For this purpose, coastal landform indicators like stream mouth diversion, spit growth, beach width and mid-bay bars were studied. Tonal variation, texture and pattern were used to identify the distribution and movement of sediments. On the satellite image, the sediment transport direction was inferred from sediment plumes. Movement of plumes towards south all along the coast during March and towards north during October was noticed.

Longshore current velocities were determined by observing float movements. During monsoon season, floats moved towards north. During the rest of the year, floats moved partly towards north but mainly in offshore-onshore directions and at times towards south.

Discussion

In all tidal inlets opening and closure of the inlet is dependent on relative strength of tidal currents and flood currents. In monsoon flood currents cut through the sand spits and transport the material to offshore region. Even the small streams cut through the sand accumulation temporarily deepening the channel. At the end of monsoon, waves are reinstated as dominant process. Average river flow drops down significantly. Specific wave approach (W, W-NW) persists for several months. Material from offshore moves into the inlets by waves and currents, narrowing and shallowing the inlets. By the end of monsoon, offshore and near shore sand bars get exposed to wave attack. They emerge and material is slowly transported landward into inlets. This gives stunted appearance of ebb tide delta to near shore bars. Offshore sandbars merge into sand spit bars usually on the up drift side. Subsequent landward migration under wave attack produces many sand bodies which fill the entrance zone of inlets.

The long shore current velocity along south Konkan coast is 30 TO 40 cm / s in monsoon and 8 to 20 cm /s in fair weather. The spits extending to the north as well as beaches to the south indicate the prevalence of long shore sediment transport in both the directions.

A conceptual model

It was noted that at almost all locations where this study was carried out on south Konkan coast onshore offshore littoral drift follows a similar pattern. With onset of SW monsoon strong river currents allow erosion at rapid rate and off-shore transport continues (Phase 1) till August when inlets have minimum sediments storage. (Plate 2, see page 36) Later, the wave climate during post-monsoon season encourages on-shore littoral transport of sediments (Phase 2) during November-December. During April/May (premonsoon) on-shore littoral transport accumulates maximum sediment in the tidal inlets (Phase 3). At some locations excess on-shore transport of material is favored. The study suggests that the alongshore processes are not main the cause of inlet closure. The onshore sediment transport due to wave conditions in fair weather appears to govern seasonal closure of the inlets.

Conclusion

The study showed that the shore drift and sediment transport is bi-directional and season dependent. The long shore current direction is predominantly southward from Ratnagiri, to Ambolgarh and is found to be variable at Vengurla.

It was also concluded that waves approaching from W and WSW generate onshore-offshore flows and the converging and diverging longshore currents generate circulation cells in the near shore regions. The observations showed that the sediments get re-circulated between the two promontories, under the influence of the prevailing currents and the associated circulation pattern in the surf zone.

The sediments are brought into suspension due turbulence generated by wave breaking processes and get re-circulated in the area under the influence of this circulation. These currents and associated circulation of water help in siltation in the river mouth areas.

The main mechanism causing siltation in the tidal inlets is deposition of suspended sediments due to onshore movements and sand movement due to littoral drift. It was seen that during the southwest monsoon period, strong currents erode protruded sectors of the coast and deposit eroded material, along varying sectors. During the rest of the year, under the influence of a southerly current, accretion is taking place along retreating sectors. It was therefore inferred that although sediment-transport is bidirectional mainly in monsoon, net major sediment transport is southward along this coast. The discharge through the inlets is determined by tidal prism. The measurements of tidal currents show that the current accelerates during flood as well as ebb tide. It literally ceases at the time of high tide due to size and configuration of these tidal inlets. These asymmetries have resulted in complex net sediment fluxes.

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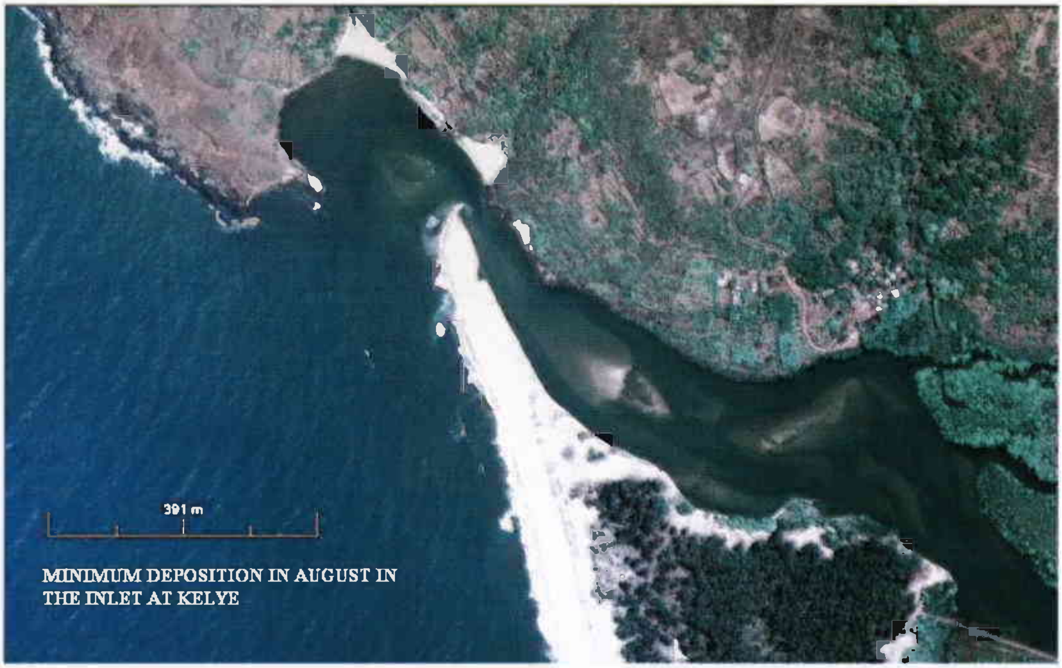
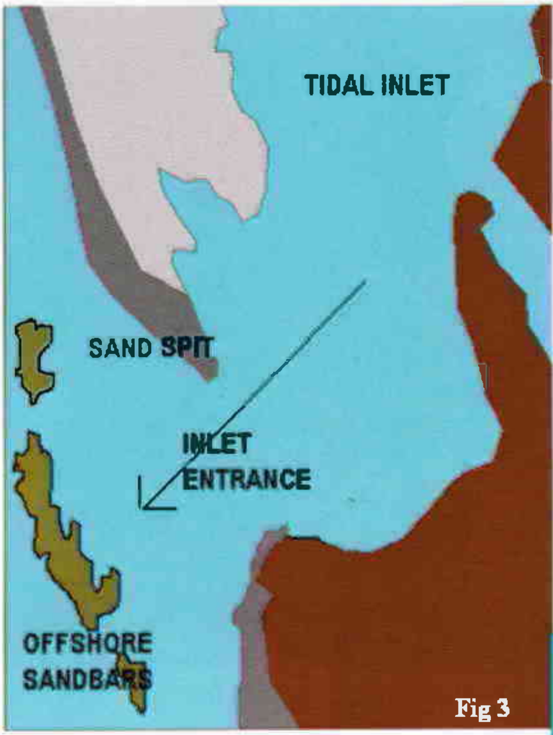


MINIMUM DEPOSITION IN AUGUST IN THE INLET AT KELYE

IMAGE SHOWING INLET CLOSURE AT KELYE IN DECEMBER



Phase 1: Opening in July to September
Breaching of sand spit barrier, enlargement of inlet entrance, creation of submerged offshore sandbars (Fig. 3)

Phase 2: Beginning of Inlet closure - November-December
Offshore bar breaks, material moves inside the inlet by onshore inlet transport Inlet starts shoaling (Fig. 4)

Phase 3: Closure of Tidal Mouth (April/May)
Narrowing of entrance due to extension of spitbar, final closure by shoaling of inlet in fair weather (Fig. 5)