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Effects of Bridge Piers on a Tropical Estuary in Goa, India

M. C. Pathak, K. L. Kotnala & N. Prabaharan

National Institute of Oceanography
Dona Paula, Goa 403 004, India

ABSTRACT

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A comparison of surveys made in 1926, 1968 and 1986 shows large morphological changes due to the 13 bridge piers constructed across the Mandovi River, SW coast of India. The changes included the erosion and deposition of river-bed sediments. These types of changes can cause problems in river navigation. The results obtained may be useful for planning and designing of new bridge piers especially in view of the fact that the river is constantly used for barge transportation of iron ore.

ADDITIONAL INDEX WORDS: *Estuary, bathymetry, bridge piers, hazards, marine engineering, navigation.*

INTRODUCTION

A proper assessment of environmental impact and morphological changes on the river-bed due to bridge piers is considered to be of prime importance. The construction of a bridge upsets the natural equilibrium between the sources of sediment and drift pattern due to the alteration in the natural movement of the sediments. Such changes were observed at the site of the Mandovi bridge in India.

The bridge was constructed over Mandovi River in 1968 in the northern part of Goa. The bridge collapsed on the night of July 5, 1986 and a new bridge is to be constructed in place of the older one. Recently on the request of the Government of Goa Daman and Diu, the National Institute of Oceanography has conducted detailed surveys of the area in connection with site selection for a new bridge. This provided an opportunity to compare the results of the present survey with the results of the previous surveys of 1926 and 1968. It is not out of place to mention here that the first two authors were also associated with the 1968 survey.

PHYSICAL CHARACTERISTICS

The Mandovi River, with an interconnecting channel to the Zuari River, is part of a complex estuarine system in Goa (Figure 1). The river Mandovi is a coastal plain estuary with the submerged extension of a former river valley opening towards the sea. Coastal processes have created a narrow entrance which is being kept open by river flow and tidal circulations. Formation of a sand bar has narrowed down the river mouth. The river has a catchment area of 1150 km^2 and is navigable for about 42 km from its mouth which is also the loading point for ore-carrying barges. The river represents drainage from 435 km^2 of forest land. Annual freshwater runoff is approximately 16 km^3 (TCPD, 1978). About two-thirds of the mining activities in Goa are located in the Mandovi basin. There are 27 large mines which generate 1500–6000 tonnes of reject rock per day per mine, a substantial portion of which is expected to be dumped into the river (NIO, 1979).

The width of the river near the bridge area is about 650 metres. Major precipitation and considerable run-off from June to September brings about large changes in the flow pattern. In the absence of freshwater discharge from October to May, the current in the estuary is then mainly dominated by flood and ebb tides. These tides are semidiurnal with a range of 2.5 metres at Panaji. The typical flood and ebb velocities are of the order of 160–108 cm/sec at the surface and 128–98 cm/sec near the bottom (Figure 2). From June to October, the freshwater discharge is maximum. The suspended sediment load (surface) is about 30 mg/litre in

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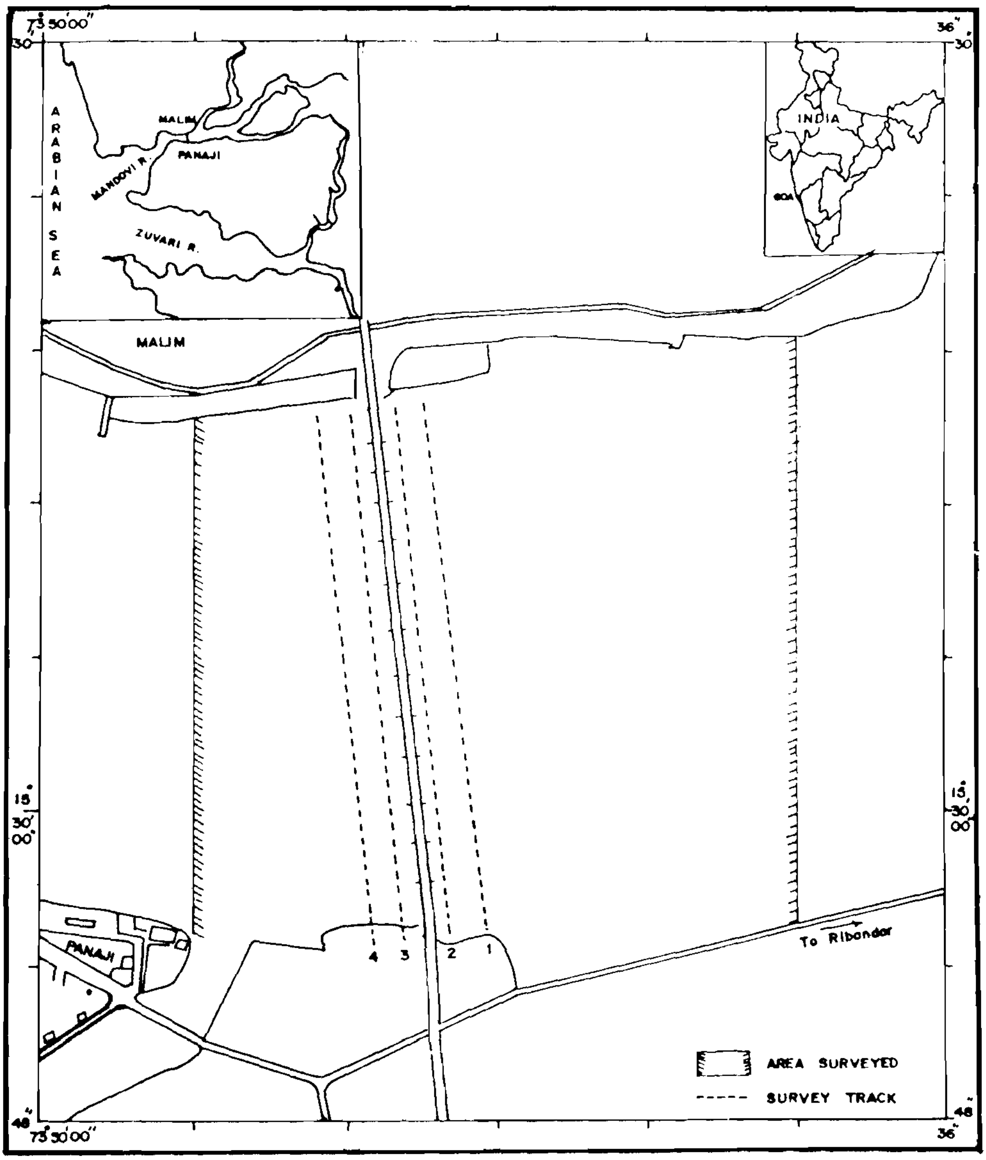

Figure 1. Location map.

fair weather and 100 mg/litre in the monsoon (MURTY and DAS, 1972; MURTY *et al*, 1975). The tidal influence is observed up to Khandepar. The magnitude and direction of the current vary with time and depth.

The Mandovi River is bridged at the eastern extremity of Panaji city as shown in Figure 1. The thirteen-span road bridge has a clearance of 11.56 metre above local mean sea level. The 7th, 8th and 9th spans from Malim have greater depths. The navigable width is 45 metres.

MATERIAL AND METHODS

This presentation is based on bathymetric, sidescan and sub-bottom profiling surveys. The area surveyed is shown in Figure 1. An Atlas Deso-10 echosounder with dual frequencies of

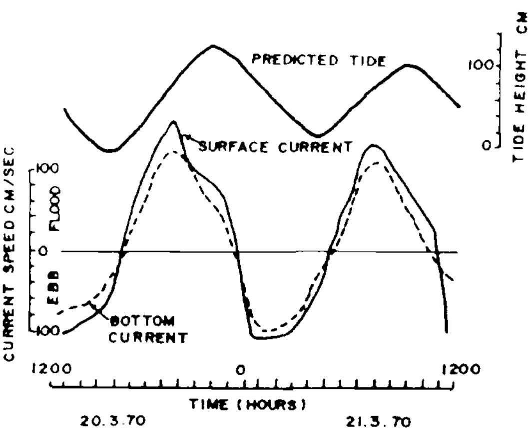

Figure 2. Variation of current with tide (After Murty and Das, 1972)

30 kHz and 210 kHz was used for the collection of high resolution bathymetric profiles. An E.G. & G. make sidescan sonar with the transducer tow fish was concurrently towed along starboard side of the survey vessel. In an effort to support and verify the interpretation of the bathymetric and sidescan sonar data, subbottom profiling data were collected using the E.G. & G.-make boomer system.

The Miniranger MRS III system was used for position-fixing with an accuracy of ±3 metres. The position was recorded at every 15 sec interval and a corresponding event mark put on all the records. During the evaluation of the record this event mark position were used as the descriptive unit.

The depths recorded have been corrected for tides with the help of tide-gauge reading installed at Panaji port and reduced to chart datum. The cross section represents the topography drawn at depth interval of every two metres. Bottom topography drawn along every track was used as the basis for comparison with the earlier data.

RESULTS AND DISCUSSIONS

In order to represent accurate information of the survey area, the bathymetric and geophysical surveys were conducted at closely spaced (20 m) sounding lines (Figure 1), and thus making possible a precise representation of the locality. The surveys offer sufficiently accurate

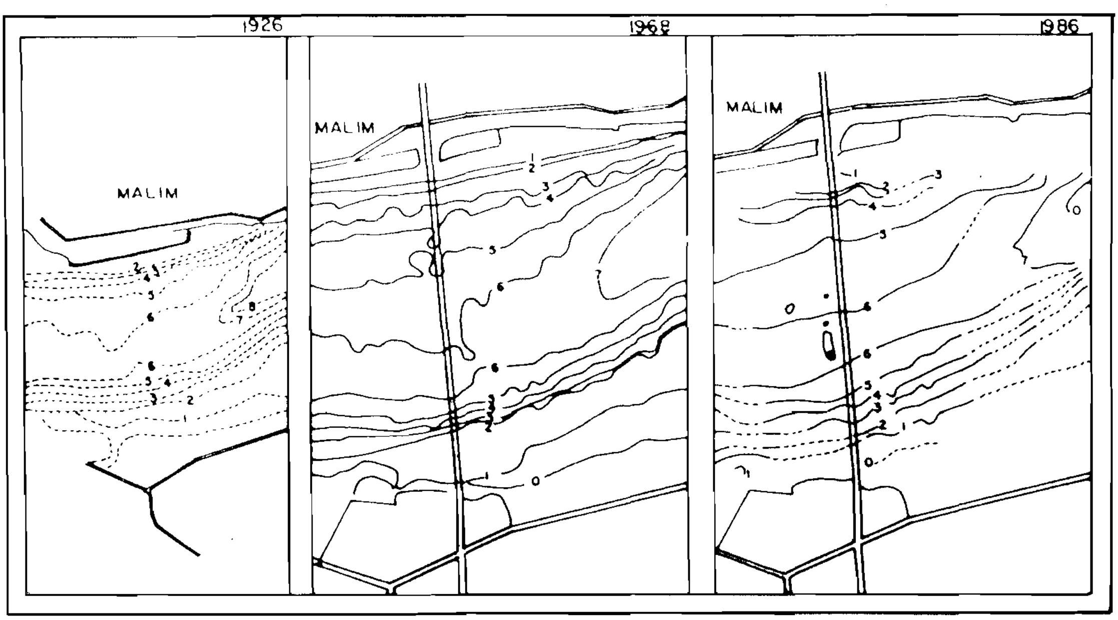

Figure 3. Bathymetry of the area (contours in metres).

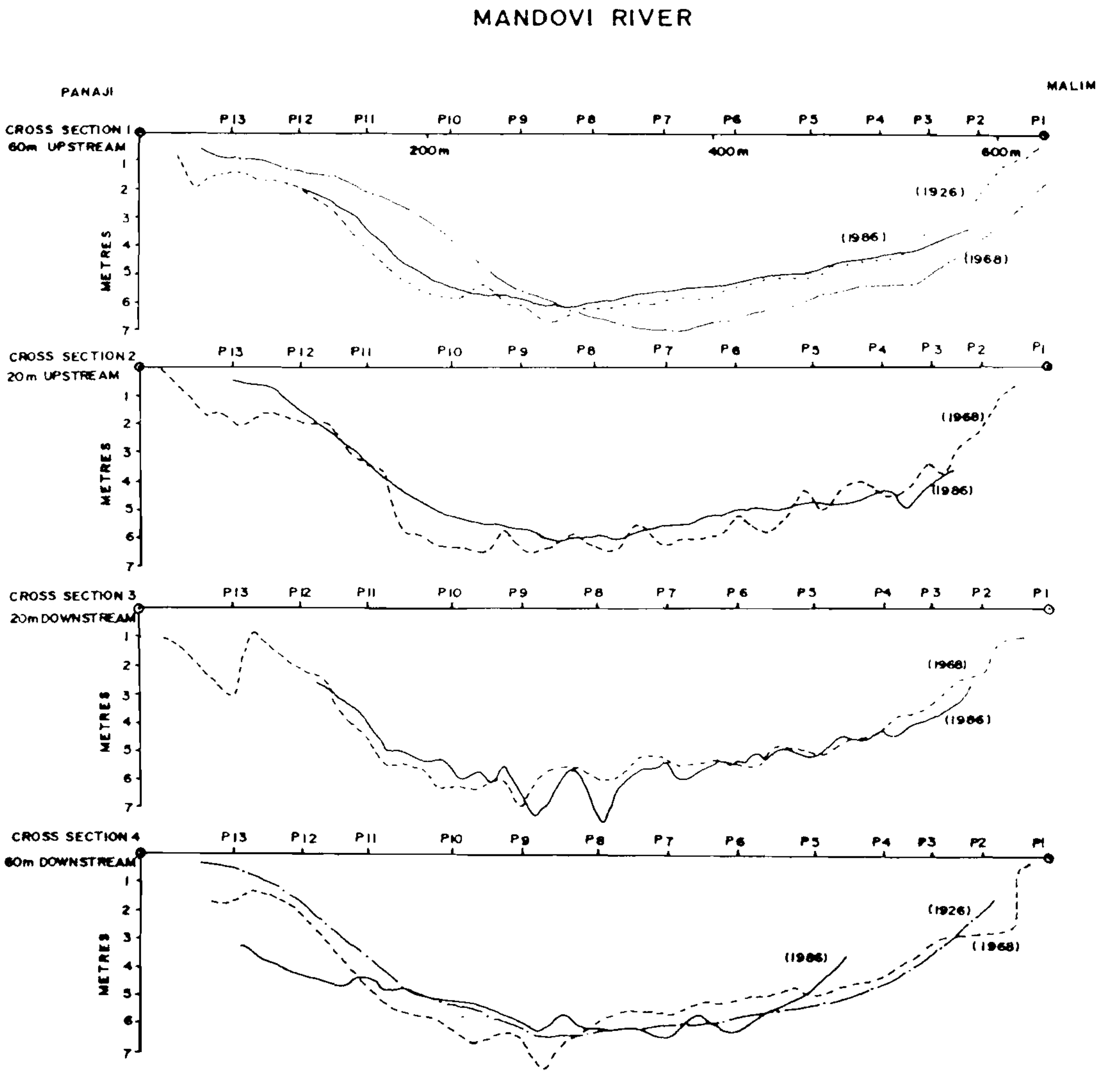

Figure 4. Cross sections showing the comparison of different surveys (Location of the line is shown in Figure 1).

information to permit possible correlation between topography and submarine structure.

The present survey has produced 9 line km of ecosounding, 2.98 line km of sidescan and 2.98 line km of acoustic profiling. The interpretation, correlation and contouring (Figures 3 and 4) were based on cross sections originally made for each track to a horizontal scale of 1:2000.

The cross sections are shown in three separate profiles (Figure 4): (a) in the period prior to 1968 when there was no construction (1926); (b) in the period of 1968 when the bridge was under construction; and (c) in the period after the bridge construction (1986).

DESCRIPTION OF PROFILES

Bottom topography profiles were first drawn along every track. A comparison was made in between the present data and the previously acquired data of 1926 (before the construction of the bridge) and 1968 (when the bridge was under construction) (Figure 3).

Cross section 1 (Figure 4) which was taken 60

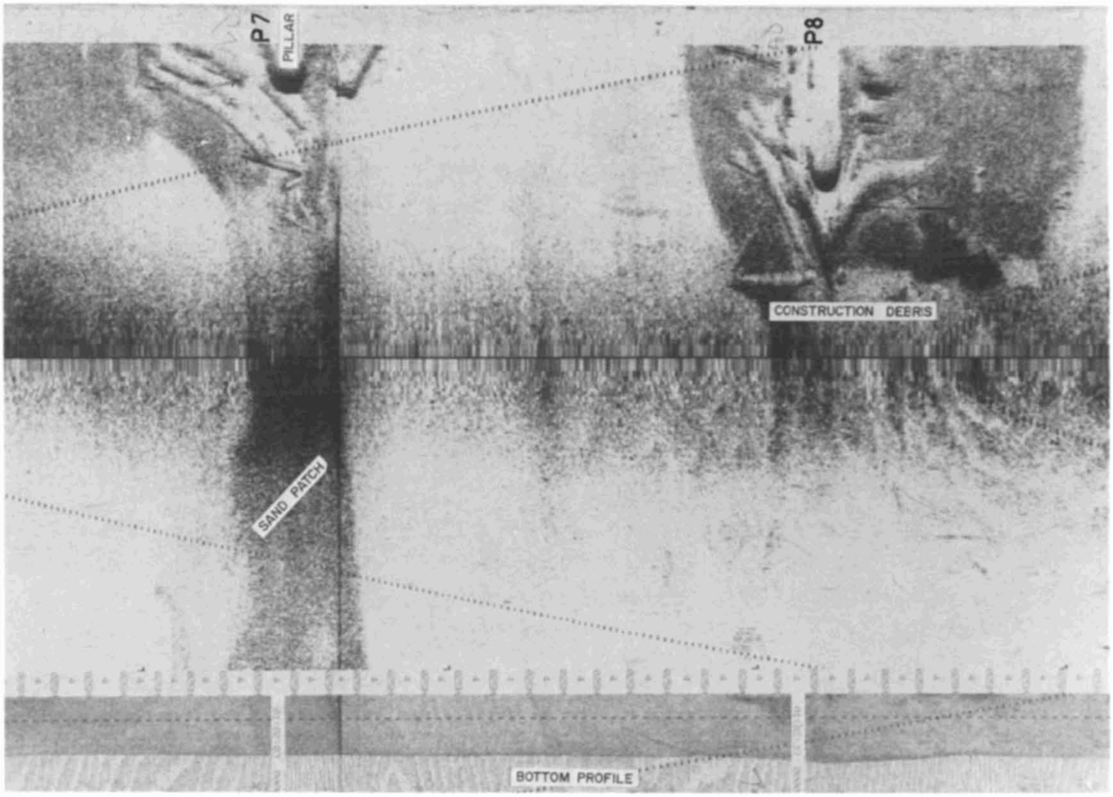

Figure 5. Sidescan sonar record showing the sand ribbons.

metres upstream of the existing bridge shows that river bed in 1926 was deeper towards the Malim (north) side and shallow towards Panaji (south) side. In contrast, the profile of 1968 shows that the Panaji side had become deeper and the Malim side shallower. This indicates that the flow of the river had changed, perhaps due to construction of the bridge piers. The profile of the same area surveyed in 1986 shows that due to deposition, the river bed has become shallower upstream of the bridge. The river Mandovi is funnel-shaped and tends to deposit sediment along its course (Figure 1). Shallow seismic records of the upstream area also shows the deposition of sediment.

Cross section 2 (Figure 4) which is located 20 metres upstream of the bridge shows that the river bed became shallower after the construction of the bridge piers. Sidescan sonar record also confirms the formation of sand ribbons nearer to the piers (Figure 5).

Cross section 3 (Figure 4) is located 20 metres downstream of the bridge and shows that erosion seems to have taken place due to the channelling of bridge piers. Significant changes in this area were observed in the river bed. Sediment is being deposited on the Panaji side and eroded at the deepest channel area of the Malim side. The profile is characterized by a prominent saw toothed appearance and other irregularities (Figure 6). Cross section 4 (Figure 4) which is 60 metres downstream of the bridge also confirms the erosion and deposition.

The sediment is transported over varying distance by the currents and gets deposited where the current abates. Due to the piers, the velocity of the current gets reduced on the upstream side of the piers, but due to the channelling

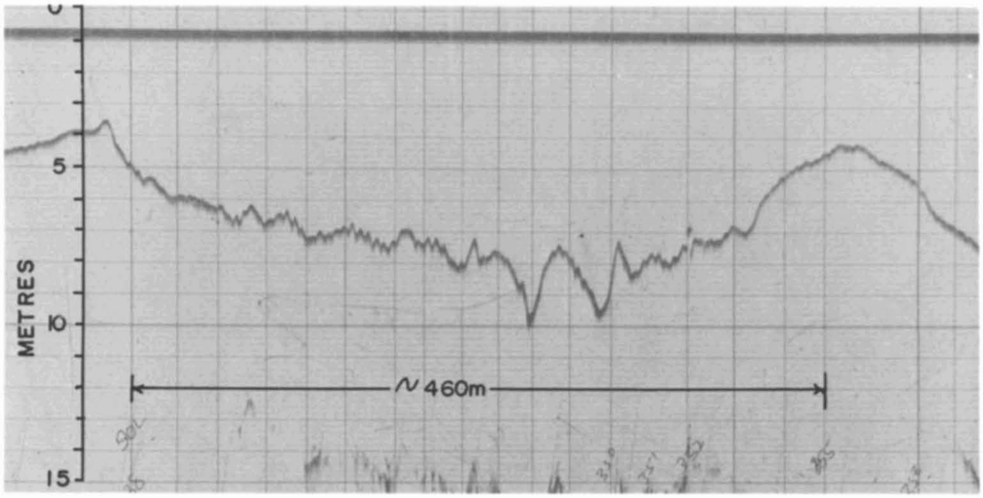

Figure 6. Echosounder record showing irregular topography.

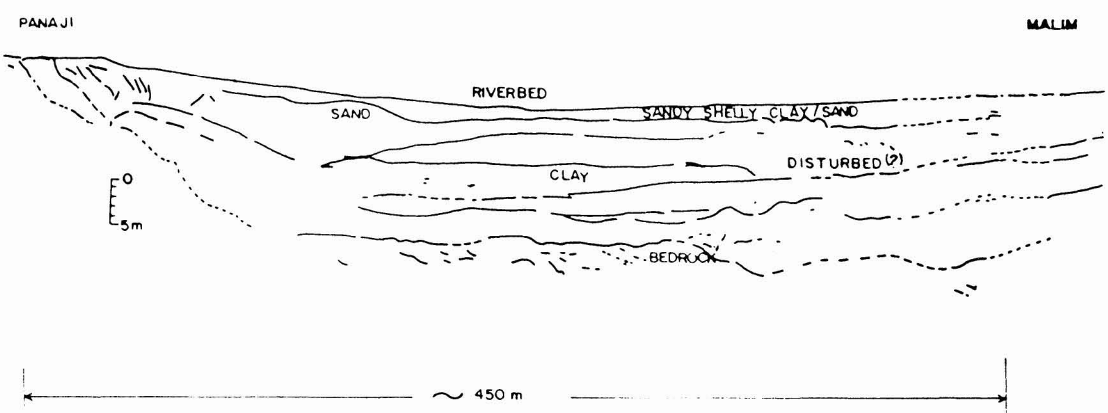

Figure 7. Subbottom profiling record.

effect, the river bed is eroded on the downstream side. The most important oscillatory flows in these estuaries are normally due to the tides.

The result of stream flows capable of causing erosion and transportation corresponds to the morphological conditions of the river channels at the narrower end of the funnel-shaped estuary while it tends to deposit sediment on the sides. The turbulence due to the tidal currents, results in new configurations in the middle of the river bed and typical flood tide and ebb tidal channels develop. In one of the channels of the bifurcated river the ascendancy is gained by the current which moves in one direction. The secondary branching due to bridge piers always endangers the morphologic stability of the area. A very similar case in the river Gogoiva flowing into the Japan Sea was reported by NAGAI and SEO (1973).

The results of the survey showed that the direction of the flow of the river corresponds with the two kinds of unconsolidated material in the river bed. These consist of (a) fine sediment mainly composed of the clay minerals and (b) coarse sediment composed of sand and gravel (Figure 7). The maximum velocity stream lines appear to be directed from left bank side towards the centre of the river after the construction of the bridge piers. From these results it may be concluded that the construction of new bridge piers are bound to alter the trend of flow downstream of the new bridge.

CONCLUSION

In order to ascertain the magnitude and direction of the current in an estuary such as Mandovi, extensive measurements were needed of the tidal currents, which vary from one tide cycle to the next and according to the time after high water and also with depth. Such surveys were essential before the construction of a new bridge.

The piers of the bridge reduce the velocities and alter the direction of the flow. It is advisable to have model studies of such a bridge prior to its construction, so that the best alignment and the navigational hazards can be predicted. This will help in planning and designing of a new bridge.

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□ RESUMEN □

Comparando datos de 1926, 1968 y 1986 de la costa SW de la India se han comprobado grandes cambios morfológicos originados por la construcción de 13 puentes a través del Rio Mandovi. Estos cambios incluyen erosión y sedimentación de sedimentos de lecho del rio, causando problemas en la navegación del rio. Los resultados obtenidos pueden ser de interés para futuros diseños de pilas de puente.—*Department of Water Sciences, University of Santander, Santander, Spain.*

□ RÉSUMÉ □

La comparaison des campagnes effectuées en 1926, 1968 et 1986 révèle d'importantes modifications morphologiques dues à la construction de 13 piliers de pont au dessus de la Mandovi River (Côte SW de l'Inde). Ces modifications se traduisent par des phénomènes d'érosion et de dépôt de sédiments alluviaux qui peuvent provoquer des problèmes de navigation. Les résultats obtenus pourraient être utiles á la construction de noveaux piliers, compte-tenu du fait que la rivière est constamment utilisée par les barges qui transportent du minerai de fer.—*Catherine Bressolier, EPHE, UA 910 CNRS, Montrouge, France.*

□ ZUSAMMENFASSUNG □

Ein Vergleich von Vermessungen aus den Jahren 1926, 1968 und 1986 offenbarten starke morphologische Veränderungen im Flußbett, die durch 13 Brückenpfeiler im Mandovi River, an der SW-Küste Indiens, verursacht worden sind. Die morphologischen Veränderungen beinhalten Prozesse der Erosion und der Akkumulation von Flußsedimenten. Da dies Probleme für die Schiffahrt schafft, deren wesentliche wird es nützlich sein, die Forschungsergebnisse bei der Planung und Gestaltung neuer Brücken mit einzubeziehen—*Ulrich Radtke, Geographisches Institut, Universität Düsseldorf, F.R.G.*