Shoreline erosion management program for Rosarito Beach, Baja California, Mexico

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Abstract

Rosarito Beach has a population of nearly 50,000 and was recently created as a municipality where tourism is its most important economic activity. The town area includes 11 km of sandy beaches which constitutes the most important natural asset for the region's economy and provides protection from marine forces. Recently the beach width along the sandy stretch has decreased due to shoreline erosion, resulting in damages to recreational and urban infrastructure. Although beach erosion is considered a critical problem by the municipality, there is no coastal policy to address this problem nor a plan for beach preservation. A shoreline erosion program was elaborated by the local university to promote beach preservation. As a first step, a sediment budget for the area was generated and the shoreline was characterised as a function of coastal morphology, land use, population density and shore protection structures. From this information an erosion hazard analysis was conducted to define erosion vulnerability of the entire beach. A set of strategies and policies for erosion management was established for discussion with key actors in the community of Rosarito Beach in order to develop a plan accordingly to their interests.

1 Introduction

Rosarito Beach is a recently formed municipality on the Northwestern coast of Baja California, Mexico, located 20 km south of the Mexico-US international border (Fig. 1). The most important economic activity of the municipality is tourism, employing 65% of the economically active population[3], and it is the economic impulse for the region. The 11 km of sandy beaches represent a natural asset which generates the tourism vocation of the municipality, having an important role in the regional economy and providing protection to the infrastructure and developments adjacent to the beach areas. Despite the importance of the sandy beaches for the municipality, there is a lack of coastal management and accelerated development is threatening this important asset[1]. Beach erosion is now considered a critical problem by the local government since severe damages have occurred along the shore. The local residents have responded to erosion on an individual basis, but the problem has not been addressed in an integrated manner, considering the whole stretch of sandy beach.

2 Area description

The coast of Rosarito Beach is characterised by the presence of cliffs and low lying beaches. Cliffs are mostly igneous in the north zone of Rosarito Beach, although there is an important component of sedimentary cliffs north of Rosarito. The low lying beach is present in the rest of the area and was once backed by extensive dune fields (as described by local residents), but today development encroaches on the beach (Fig. 1).

The littoral cell for Rosarito Beach has not been established, but this study considers only the sandy beaches of the town of Rosarito Beach, although the littoral cell most likely begins at a headland some kilometres north of Rosarito Beach and ends several kilometres to the south. It is considered that in the study area there is a sandy sediment input and output through the area boundaries.

The primary land uses adjacent to the beach of the study area are residential in the north zone, industrial (represented by the Mexican oil company PEMEX and a thermal electric power plant of the electricity company CFE) and local housing in the central zone, and residential, mass tourism and local housing in the south zone[1].

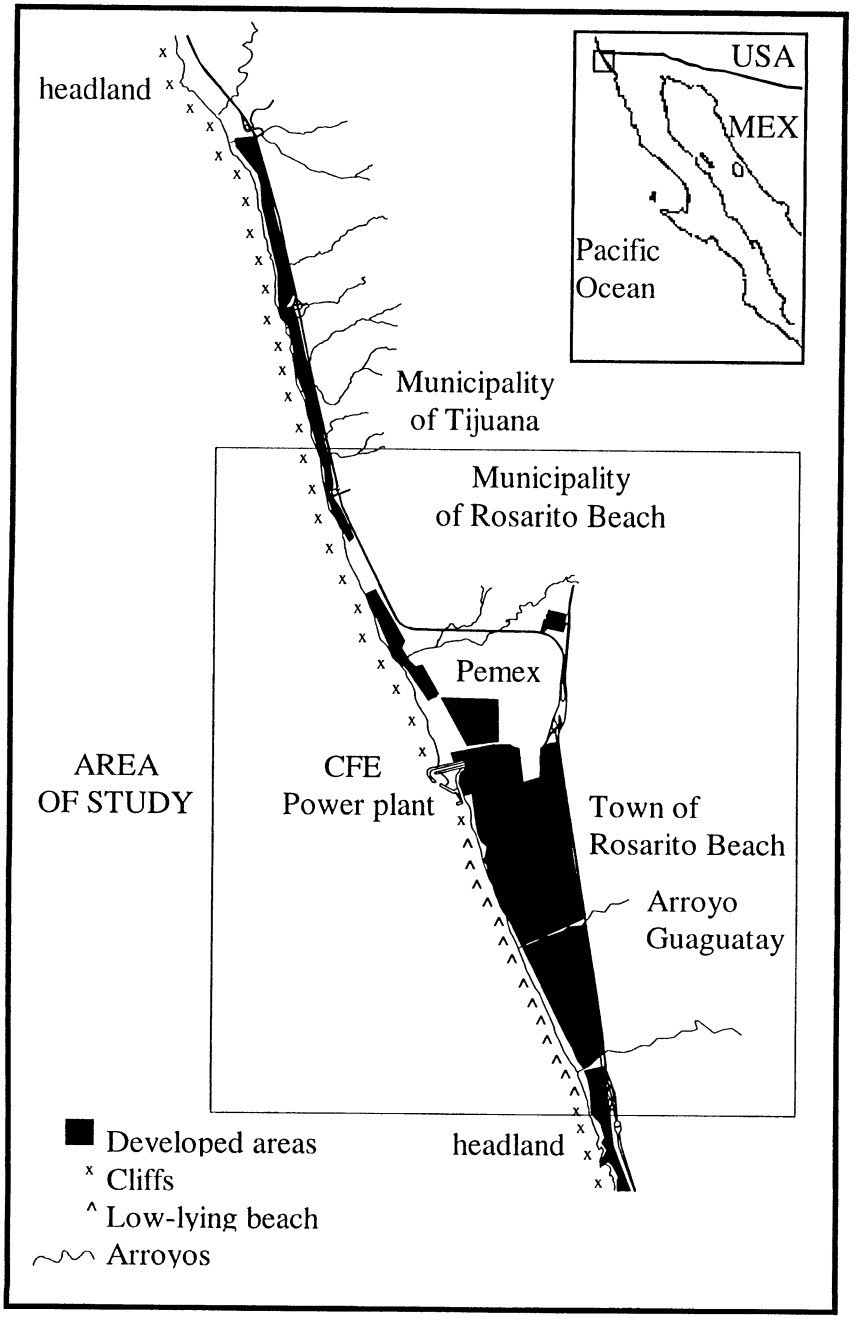

Figure 1. Map of the study area showing most relevant features.

3 Coastal processes

The waves that arrive to Rosarito Beach[7] are: 1) the winter waves (October-March) arriving at the coast from a westerly and northerly direction; 2) the summer waves (July-September) arriving at the coast from a south and southwestern direction ; and 3) a transitional period between winter and summer waves (April-June).

The sediment sources to the area are basically from the arroyos, cliff erosion and longshore sediment transport (LST) from adjacent areas. The arroyos combined have a drainage area of 235 km^2 and their contributions were estimated to be 15,000 m^3/yr following the methodology presented by Pou-Alberú & Pozos-Salazar[5]. The contribution of sand by cliff erosion was estimated to be 38,000 m^3/yr, considering the height and extension of the sedimentary cliffs and an estimated erosion rate of 0.5 m/yr. This rate closely resembles the rates presented by Sunamura[6], where he established an erosion rate between 10^{-1} and 10^{0} for Pliocene deposits, as the ones present in this area. An estimation of net LST has been done by Appendini, et al.[2] and is in the order of 100,000 m^3/yr.

Other inputs and outputs of sand, i.e. the cross-shore transport, could not be established, although Lee and Osborne[4] have indicated that sand from the continental shelf up to a depth between 17-20 meters might be brought to the beach.

Considering the sources of sand, we have a sand supply of approximately 53,000 m^3/yr, so there is a deficit of 47,000 m^3/yr to satisfy the LST of 100,000 m^3/yr. This calculation shows that one of the problems in Rosarito Beach is the lack of sand in the system, leading to beach erosion. To give a broad idea of the erosion at Rosarito Beach, this sand deficit can be translated into an erosion rate of 0.21 m/yr using mass conservation; however, there are parts where the erosion may be higher or lower. Due to the lack of beach information these rates cannot be established for a long term.

Extreme erosion in Rosarito Beach exists in the short term resulting in a shoreline retreat up to 60 m in less than a month. This erosion is considered as a part of the beach cycle where the onshore summer transport later returns the sand to the beach. Although the beach show erosional-depositional cycles, extreme events as the ones in January and February of 1998 have transported the sand to depths more than 20 m, so it may be difficult for the beach to recuperate, exacerbating the sand deficit problem in the area.

4 Vulnerability to erosion

To establish erosion management strategies and policies it is necessary to assess the beach's vulnerability to erosion. The factors that were considered to define vulnerability were potential beach loss and probability of damage to infrastructure. The potential beach loss was established from beach width and morphology, while probability of damages was obtained considering land use, population density, and coastal protection. The combination of both factors gave a sense of the vulnerability toward beach erosion (Fig. 2). The percent length of shore subject to a high, medium and low beach loss potential, damage probability and vulnerability to erosion are shown in Table 1.

Table 1. Beach loss, damage probability and erosion vulnerability coast length percentages along Rosarito Beach.

	Beach loss potential	Damage probability	Vulnerability to erosion
High	62%	14%	25%
Medium	15%	25%	54%
Low	23%	61%	21%
Total	100%	100%	100%

From this analysis we see that most stretches of beach have a high potential to be eroded, which has a direct repercussion for the recreational capacity of the beaches, and thus on the tourism industry. The probability of damage is mostly low, since large stretches of coast show some type of protective structures, in particular in the north where tourism housing on cliffs is present. The northern part presents a medium vulnerability toward erosion in most parts, and although damage probability may be low, the loss of beach for recreation is likely to occur. Immediately south of the power plant, there is high vulnerability in an area extensively used for recreational activities (both local and tourism), and there are also local houses in a very vulnerable position to erosion. As a result, many of them where damaged during the El Niño waves in February 1998. The southern part presents medium and low vulnerability to erosion, in part, because this area still has a wide beach available to provide protection.

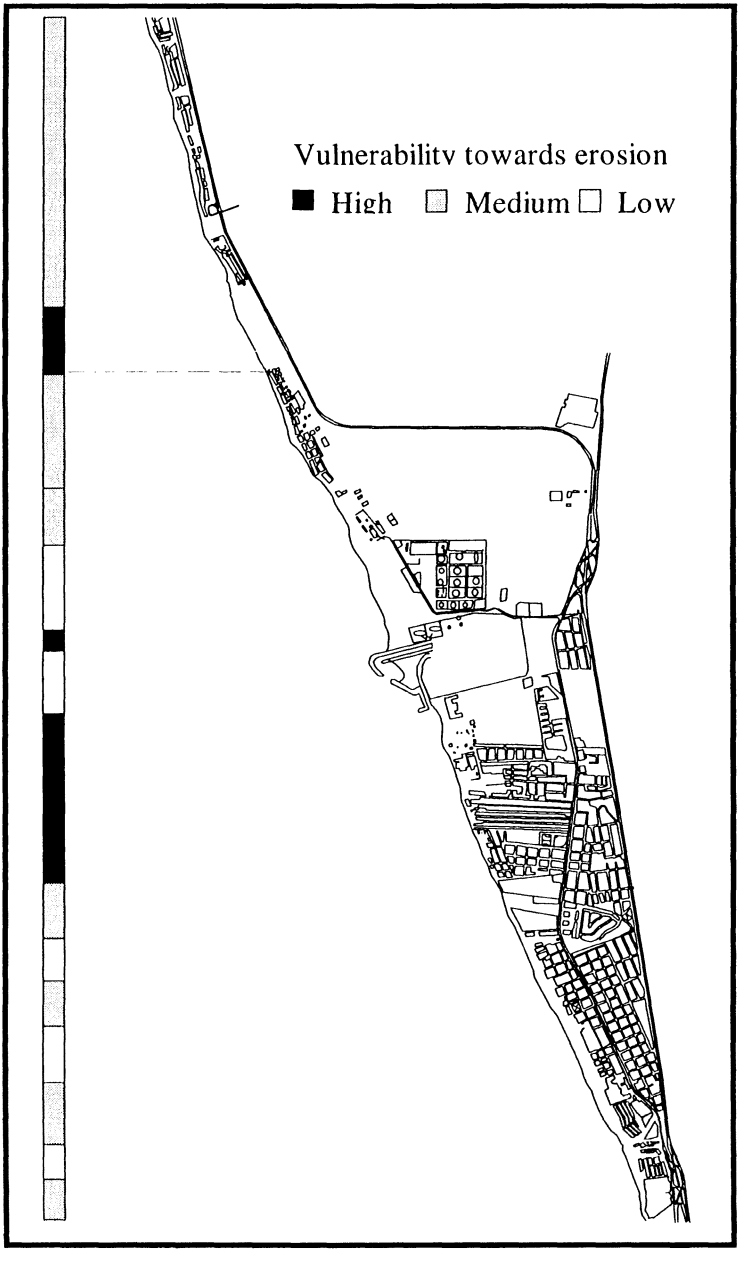

Figure 2. Erosion vulnerability on Rosarito Beach.

5 Management strategies

For the management strategies the area was divided in three reaches based on characteristics and erosion vulnerability: 1) the north reach, which goes from the northern boundary to the power plant, 2) the middle reach, which encompasses the beach south of the power plant to the Arroyo Guaguatay, and 3) the south reach, from Arroyo Guaguatay to the south (Figure 1). This division was established because each has different characteristics and vulnerability towards erosion. The beach at the north reach is not as important as the south reach beach for recreation and tourism, and it is not as important as the middle reach beach for protection and recreation.

Three basic problems exist in Rosarito Beach: 1) there is a long term shoreline erosion associated with a sand deficit in the littoral system; 2) there is localised shoreline erosion at the beach south of the power plant due to the direct effect of water intake structures[2]; and 3) there are severe impacts for infrastructure during storm induced erosion.

The possibility of a "do nothing" alternative could be unacceptable for Rosarito Beach because of the costs and public safety hazard associated with property and infrastructure damage during storm conditions and tourism decline. Thus, an erosion management plan is needed. As a first approach, three management strategies are indicated: 1) sand management, 2) protective devices and 3) regulations.

5.1 Sand management

Due to the sand deficit in the area, it is indispensable to increase the volume of sand in the littoral system. This may be attained by artificial beach nourishment or increasing natural deliveries. Cleaning of the arroyos' watershed and the water course itself as well as maintaining the cliffs' contribution north of Rosarito Beach (in the municipality of Tijuana) would be an important factor. Beach nourishment is the only management alternative that actually increases the sand volume in the littoral system. This alternative is more needed in the middle and south reaches, due to the beach's importance for tourism and protection. Also, this area is the one that historically has suffered more damage and is directly affected by the power plant water intake structures. Infrastructure in the southern part has not suffered damage, but the loss of the recreational beach is evident, requiring nourishment.

The use of opportunistic sand sources is needed because funding for dedicated sand is difficult. The possible sources of sand are: 1) the Rodríguez Dam in Tijuana which retains a vast amount of sand as it is the largest watershed area in the region; 2) the water intake structures of the power plant which generate shoaling rates in the order of 50,000 m^3/yr[2]; and 3) upland developments, where the spoil of construction may contain high amounts of sand due to the geology of the area.

5.2 Protective devices

The use of protective devices to retain the sand on the beaches was not considered appropriate for most of the beach reaches, although a groin at the southern headland may help in retaining sand with minimum downcoast effects since only pocket beaches exist that are not important as recreation sites. An alternate protection for the middle and south reaches would be the construction of artificial dunes and their stabilisation with vegetation, since they function as a protective device and increase the sand in the area. This option could be considered as a sand management strategy. Most of the northern reach is already protected with seawalls, and it is proposed to protect the remaining unprotected stretches of cliffs. Since their sand contribution to the system is small and the beach is not important for recreation in this area, the walling of this reach is of little importance.

5.3 Regulations

Because most of the coastline is already developed, the establishment of setback construction lines should be used as a measure for planned retreat. A minimum setback line in low-lying beach areas should be at least 70 m from the LMWL, which is the erosion observed during the extreme events in 1998 (60 m), plus a 50 year long term beach recession (10.5 m). Incentives for relocation of infrastructure should be set after severe damages occur to prohibit reconstruction. Construction (houses) in the beach areas provide too few benefits for the municipality (taxes), no public benefits, and do not contribute to beach preservation, so a planned retreat is needed. Buying out property by the local government is an alternative for a planned retreat, but most of the land in this area are concessions from the federal government (federal zone is 20 m from the mean HHWL) so this option may be politically difficult. However, it is

an alternative that needs further exploration. Watershed management regulation is another necessity, since there are irregular settlements in the arroyos as well as illegal water detainment structures that may be contributing to sand loss on the beaches and pollution, increasing the public's safety hazard.

6 Conclusions

In Mexico there are no established policies for coastal management. Due to the economic importance of the beaches of Rosarito Beach, a management plan for handling erosion is highly needed. The sand deficit in its littoral zone clearly shows the need for beach nourishment. Protective structures are acceptable only in the north part where the beach is not an important recreational asset. Sand management, in particular nourishment, apparently is the most adequate option for the middle and southern beaches. It is clear that a need exists to establish policies for development in the beach areas and watershed management in order to sustain the beaches of the municipality as its most important natural and economic asset.

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