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Planning for Beach Erosion: A Case Study, Playas de Rosarito, B.C. Mexico

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ABSTRACT

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Rosarito Beach, Baja California, is a recently created municipality where tourism is its most important economic activity, employing 65% of the population. The area includes 11 km of sandy beaches, which constitutes the most important natural asset for the region's economy and provides protection from sea forces. Beach erosion in this municipality is considered a critical problem, because it has resulted in severe damages to recreational and urban infrastructure. However, there is no plan for beach preservation nor policy to protect this resource. In this manuscript, a plan for beach erosion management is presented, encompassing several strategies and actions for beach preservation as a recreation and protection resource. An analysis of the coastal dynamics and vulnerability to erosion along the coast of Rosarito Beach was performed as a basis for the development of the strategies and actions comprising the beach erosion management plan.

ADDITIONAL INDEX WORDS: *Beach erosion, sediment budget, vulnerability to erosion, coastal management, Baja, California.*

INTRODUCTION

Rosarito Beach is a recently formed municipality where tourism is the most important economic activity, employing more than 65% of the economically active population (EURA, 1992). There are 11 km of sandy beach, making it the principal natural resource for tourism, which plays an important role in the region's economy (APPENDINI and LIZARRAGA-ARCINIEGA, 1998). The beaches are not only important for their recreational use, they also provide protection for property and developments adjacent to the shoreline (NRC, 1995). Beach erosion in this municipality has resulted in infrastructure damage along the shore and today it is considered as a critical problem (*Personal communication,* C.P. HUGO TORRES CHABERT, 1997; ECOS DE ROSARITO, 1998). Despite this fact, there is no plan for beach preservation nor a policy to protect this resource. Due to the severity of this problem and the need to mitigate it, the Universidad Autónoma de Baja California (UABC) proposed a beach erosion management plan to the municipality. As a result of this initiative, a binational meeting was held in Rosarito Beach between the municipality, the Shoreline Erosion Committee of the San Diego Association of Governments and UABC. Here the municipality highlighted the importance of the beaches to the region, and UABC presented a program for developing a beach erosion management plan. This paper presents a beach erosion management plan proposal, where a series of beach preservation strategies are described and local responses analyzed.

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BACKGROUND

Beach erosion is a serious problem in urban areas representing a hazard for coastal infrastructure and reducing beach capacity for recreation. The increasing human pressure on the coastal zone has exacerbated erosion problems due to development ignoring dynamic coastal processes and exposing these developments to sea forces (APPENDINI and LIZARRAGA-ARCINIEGA, 1998). Today, most of the 125 countries with coasts around the world suffer erosion problems that result in considerable economic and social losses (UN, 1982).

Usually, human response to coastal erosion includes five categories (POPE, 1997): 1) Use of coastal structures to protect infrastructure (armoring), 2) activities designed to reduce beach erosion rates (moderation), 3) beach nourishment (restoration), 4) acceptance of erosion hazard without taking action (abstention), and 5) regulations and policies for using the coastal system (adaptation). The use of any of these strategies or a combination of them should be made in the context of the littoral cell. In this manner problems are not transferred to other segments of the coast and the beach is preserved as an environmental, recreational and protective asset, which is part of beach erosion management.

Despite the need for beach erosion management, erosion problems in Mexico are commonly addressed on an individual basis, even in highly recognized tourist coastal cities as Cancún, Mazatlán, Huatulco, Acapulco, *etc.* There is a willingness

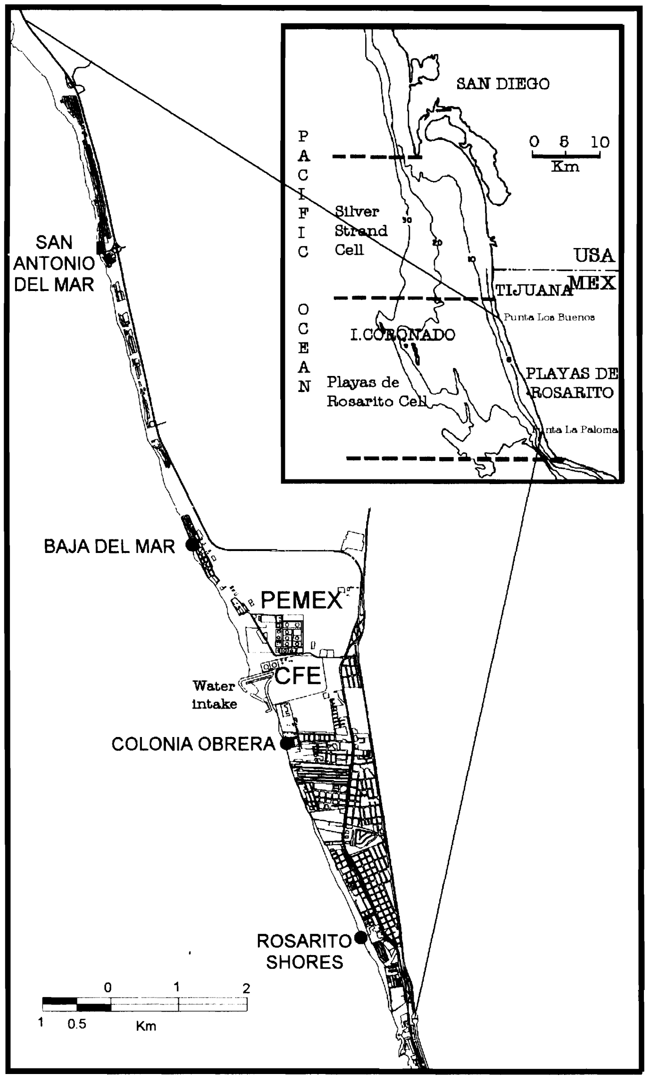

Figure 1. Area of study showing relevant features.

to develop a national strategy for the management of the coastal zone, but to date no effort has occurred (personal communication, ENRIQUEZ-KANFACHI, 1998). The recently formed municipality of Rosarito Beach is one of the many locations where beach erosion is considered a critical problem. Due to recognition of their beaches as their most important natural asset and the interest of the municipality in its preservation, a beach erosion management plan was developed, being the first plan of this nature in Mexico. A description of the management plan is given in this article, including a description of the coastal processes and the vulnerability of the developed shoreline which provides the information for the development of the plan for Rosarito Beach, Baja California, Mexico.

STUDY AREA

Rosarito Beach is located on the northwestern coast of Baja California, Mexico, 20 km south of the US-Mexico Border and 70 km north of the city of Ensenada. Its position is between 32°20′ and 32°23′ north latitude and 117°03′ and 117°05′ west longitude. The area of study in this work is the sandy beach of the municipality of Rosarito Beach, from the northern limit of the municipality to the rocky headland south of the recreational beach of the city, known as Punta La Paloma. However, to facilitate the sediment budget analysis, the area between Punta Los Buenos and Punta La Paloma was studied in the context of the littoral cell (Figure 1).

Table 1. *Percentage of land use and population density along the Rosarito Beach littoral.*

Land Use and Population Density	Density Criteria	% Alongshore
Tourism housing of medium density	11–25 lots/Ha	39%
Commercial and tourism services		12%
Tourism hotels of medium density	51–100 rooms/Ha	11%
Local housing of low density	55–100 inhab/Ha	9%
Tourism housing of low density	1–10 lots/Ha	6%
Industrial		6%
Conservation		6%
Urban Center		5%
Local housing of high density	165–250 inhab/Ha	4%
Local housing of medium density	105–160 inhab/Ha	2%

Source: GEBC, 1995. Data sources preclude using other measures of density.

The coast of Rosarito Beach is characterized by igneous and sedimentary cliffs north of the CFE (Comision Federal de Electricidad) power plant, with an important component of sedimentary cliffs in the area of San Antonio del Mar in the municipality of Tijuana (Figure 1). South of the CFE a no-cliff backed beach prevails, representing the most important beaches for tourism. These beaches where once backed by dune fields, but today development encroaches on the beach, increasing the risk of coastal damages along the shore.

Rosarito Beach started as a cattle ranch in the 1800's but since then it is now a tourist destination for San Diegans. The tourism oriented economy started in the 1920's with the development of two major resorts, and since the 1930's it represents the most important economic activity for the town (PIÑEDA-RAMIREZ *et al.,* 1989), employing most of the active economic population and gaining more revenues than any other activity. Now the primary zoning considered for Rosarito Beach is for urban and tourism development with the consolidation of the hotel zone and the spread of commercial and recreational activities (GEBC, 1995). Beaches are the most important natural resource that supports the tourism vocation of this municipality.

There is a variety of land uses along the shore in the study area, particularly south of the CFE. The prevalent land use is related to tourism, representing 68% of the littoral zone land use. Table 1 presents the land uses and population density percentages along the Rosarito Beach shore.

COASTAL PROCESSES

Waves are the most important source of energy that drives shoreline processes in this region (FLICK and STERRET, 1994). The waves that arrive to Rosarito Beach with the highest energy are generated from extratropical storms in the northern hemisphere during the winter months. These waves are commonly the ones that result in beach erosion at Rosarito Beach. The summer wave climate is dominated by southern hemisphere swells and swells from tropical hurricanes in southern Mexico. These waves are characterized by long periods and commonly represent accreting conditions on the coast of Rosarito Beach.

The littoral cell for Rosarito Beach was defined in this study on the basis of geomorphologic characteristics and criteria used to define other littoral cells. The headland at Punta Los Buenos was considered the northern limit of the Rosarito-Beach littoral cell, where an independent system of pocket beaches exists between this headland and the already defined Silver Strand littoral cell (INMAN and FRAUTSCHY, 1965). Punta Descanso was considered the southern limit of the Rosarito Beach littoral cell due to the presence of El Descanso Canyon and the presence of a rocky bottom with no sand (as testimonies from divers in the area).

The most important sources of sand to the littoral system of Rosarito Beach are the cliffs and arroyos. The arroyos' yields were evaluated following the methodology presented by POU-ALBERU and POZOS-SALAZAR (1992) obtaining a yield of 15,000 m^3/yr for a drainage basin of 235 km^2. The cliff contributions were obtained from field measurements and compared with estimations done by SUNAMAURA (1983) for cliffs with similar characteristics in San Diego, California. A yearly contribution of 38,000 m^3 was established from an erosion rate 0.5 m/yr of the sedimentary cliffs in the littoral cell. The total sediment contributions obtained were of 53,000 m^3/yr.

The longshore sediment transport (LST) was considered an output of sediment from the study area, since the net LST is estimated at 100,000 m^3/yr to the south (APPENDINI, 1995), a volume which is transported out of the study area through Punta La Paloma. The cross-shore transport (CST) of sand does not show a pattern of permanent loss or gain of sediment in the system. This is apparent from beach profiles obtained in the area during the period of 1996-1997 where erosion during winter is about the same magnitude as profile deposition during summer. However, due to the uncertainty of offshore sand loss by CST during intense storms in the area, the CST was not considered in the sediment budget.

Considering an input of sediment of 53,000 m^3/yr and a loss of sediment of 100,000 m^3/yr, a deficit of 47,000 m^3 exists in the study area. This deficit was translated to a shoreline recession rate of 0.2 m/yr using the shoreline change equation as presented by HANSON and KRAUS (1989).

Shoreline changes also were estimated from aerial photographs for the area between the CFE and Punta La Paloma. The photographs analyzed were for the time period of 1972 to 1993 which encompasses both normal and extreme wave conditions. A mean erosion rate of 0.5 m/yr was obtained, a value that is higher than the erosion rate that resulted from the sediment budget. This value suggests that the water intake structures of the CFE result in accelerated beach erosion on the downdrift beach accounting for approximately 50 m beach offset between the north and south sides of the water intake (APPENDINI-ALBRECHTSEN, 1995).

Shorter term shoreline changes resulting from extreme events were estimated from beach profiles during the El Niño year of 1997–1998. A shoreline retreat of 45 m was found between the extreme conditions between January 27 and February 10, 1998. The highest recession of 72 m was found in February, and the profile of maximum deposition was presented during May of 1997.

The shoreline recession due to the relative sea level rise (RSLR) also was assessed following the methodology presented by WEGGEL (1979); using an RSLR value of 2.4 mm/yr as suggested by MOFFAT & NICHOL (1989) a shoreline retreat of 0.15 m/yr was calculated.

As a result of these analyses, an erosion rate between 0.35 and 0.65 m/yr was established; however, rapid erosion of the beach due to occurrence of extreme wave events can result in a shoreline recession of up of 72 m.

VULNERABILITY TOWARDS BEACH EROSION

The vulnerability to erosion indicates the susceptibility for a beach segment to experience damage. Analyzing this exposure to vulnerability allows recognition of critical areas along the shore, and facilitates selection of strategies to be adopted. The following criteria were used to define vulnerability: a) beach loss potential as defined from field data on beach width and morphology, b) probability of damage along the shore based on land use, population density (GEBC, 1995), and presence of coastal structures. The first criterion defines to what extent a beach segment can provide protection, while the second indicates the potential of infrastructure damage if the beach is eroded. The vulnerability towards erosion obtained from the combination of both criteria is presented in Figure 2, where the first column represents beach loss potential (BLP), the second column damage probability along the shore (DPS), and the third column vulnerability to erosion (VTE). Table 2 shows the percentage length of shoreline subject to a high, medium and low BLP, DPS and VTE.

It was found that most of the Rosarito Beach littoral has a high beach loss potential but a low damage probability, leading to a medium vulnerability to erosion for most of the littoral as well as significant proportions having either high and low vulnerability. The medium and high vulnerability to erosion that characterizes 79% of the littoral is of great concern to the municipality due to the economic importance of the beaches for tourism infrastructure. On the other hand, although there is only high damage probability (DPS) of 14% for the littoral, there has been severe damage during extreme events in localized areas (Figure 3).

BEACH EROSION MANAGEMENT STRATEGIES

Local and state authorities have given an important thrust to tourism development in Rosarito Beach. Recognition of the role that recreational beaches play in the economy of the municipality has led authorities to declare that beach preservation is a priority for the municipality (GEBC, 1995; CPDMPR, 1996). Therefore the possibility of the abstention alternative ("do nothing") is unacceptable.

The established sand deficit along with erosional processes together with onshore developments represent a vulnerability to storm hazard, where the diminished beach width re-

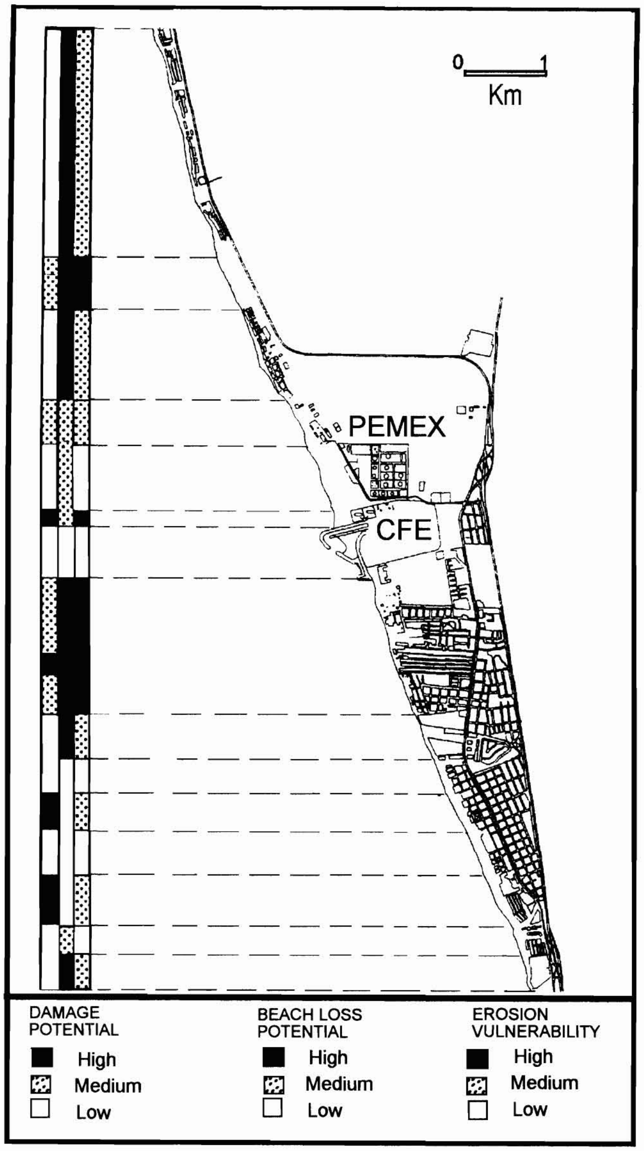

Figure 2. Vulnerability towards erosion in Rosarito Beach, Baja California.

duces its capacity for protection during extreme storm events (APPENDINI and FISCHER, 1998). There are basically three problems related to beach erosion in Rosarito Beach that need to be addressed in the management plan:

1. There is long term beach erosion due to a sediment deficit.
2. There is localized beach erosion south of the CFE power plant as a direct effect of its water intake structures acting as a groin.
3. There is localized infrastructure damage due to induced erosion during extreme events. According to older dwellers in the area, as well as the exposure of several houses founding during the winter 1998, 8 to 12 residences have been destroyed in recent years. During winter 1998 two houses were destroyed (see Figure 3) and two others were abandoned permanently by owners.

Table 2. *Littoral length percentage of beach loss potential (BLP), damage probability along the shore (DPS) and vulnerability to erosion (VTE).*

	BLP	DPS	VTE
High	62%	14%	25%
Medium	15%	25%	54%
Low	23%	61%	21%
Total	100%	100%	100%

For the development of strategies and the actions that sustain them, the littoral was divided into three segments that present different natural and social characteristics as well as vulnerabilities to erosion (see Figure 1):

1. North zone: area between the north boundary of the study area and the CFE.
2. Central zone: area between the CFE and the Arroyo Guaguatay.
3. South zone: area between the Arroyo Guaguatay and the south boundary of the study area.

The strategies proposed in this study encompass sand management, protective devices and regulations. Each strategy is based on a set of actions.

Sand Management Strategies

Although there is a sand deficit in the area, the result of the processes that control the inputs and outputs of sand continue without interruption. This means that new increments of sand or maintaining sand on the beaches for a longer time is a management alternative of interest.

Increase and/or Maintain Natural Sediment Contributions to the Littoral System

Arroyos and cliffs are the main sand contributors to the littoral system in the study area, so it is important for beach preservation to maintain these inputs. To increase sand contributions from arroyos it is necessary to facilitate water flow by minimizing or totally removing obstacles that retain sand, such as small "dams", trash and human settlements. It is proposed that the arroyos be constantly cleaned and that settlements established along the arroyos be relocated (these settlements are also in a high risk area). The most important sedimentary cliffs that contribute sand to the system are those located north of San Antonio del Mar in the municipality of Tijuana. To ensure continued flow of beach sediment, an agreement is proposed between Tijuana and Rosarito Beach that would regulate human settlements on cliffs and prohibit the construction of seawalls or revetments along the beach.

Artificial Beach Replenishment

This strategy increases the sand volume in the littoral system by artificially adding sand in order to maintain a desired beach width. The material used in the replenishments must

Figure 3. Localized damage in a high vulnerability area, February, 1998.

be from outside the littoral system so that it represents a net increase in sand volume (SANDAG, 1993; NCR, 1995). It is important that the material used is similar to the characteristics of native sand so that responses to coastal processes are fairly equal and aesthetically adequate. It is important to inform the public and beach users that beach replenishments increase the sand volume in the littoral system, although there is an apparent loss of sand shortly after the replenishment while the profiles adjust to equilibrium. This loss of sand is considered in the beach design, and informing the public helps reduce false expectations. For successful beach replenishment, a maintenance program is needed that restores the desired beach width in the first phase and then continues the replenishment to preserve beach width. This strategy is a long-term commitment and the maintenance program is essential for it to be effective.

The locations where this strategy could be useful are in the center and south zones, due to the importance of these beaches for recreation and protection. The less demanded recreational use of the beach in the north zone, its historically narrower beach (about 10 to 30 m during high tide), and the numerous seawalls built to protect property suggest that the beach replenishment strategy there is inappropriate (Figure 4).

Also, this zone is mostly armored and the net LST is to the south and replenishment sand would migrate downcoast (NCR, 1995) to reach the water intake of the CFE and could increase shoaling problems without addressing the erosion problem south of the CFE.

The potential sources of sand for this strategy are:

(1) Rodríguez Dam in Tijuana, BC. This dam retains high quantities of sand, having the biggest watershed of the region (2,630 km^2). Because the sediment in the dam is fluvial the quality for beach nourishment is probably high (NCR, 1995). Dredging of the dam for obtaining sand to replenish beaches is not only a benefit for Rosarito Beach, but also for Tijuana because the water capacity of the dam is increased. As a result, an agreement between Tijuana and Rosarito Beach could be made to implement a dredging and beach replenishment plan by both municipalities.
(2) Sand from upland sources. The geology of the region shows high contents of sand in some areas and since its textural characteristics resemble native sand, this material may be adequate for beach replenishment. The cost for beach replenishment would be considerably reduced if the sand used was a result of existing construction.

Beach replenishment must be performed when deposition conditions prevail on the beaches, so that the material is not eroded immediately after the replenishment; that is, when summer wave conditions begin and onshore transport becomes more important. The sand from the Rodríguez Dam could be dredged, trucked to the beach, and used for replen-

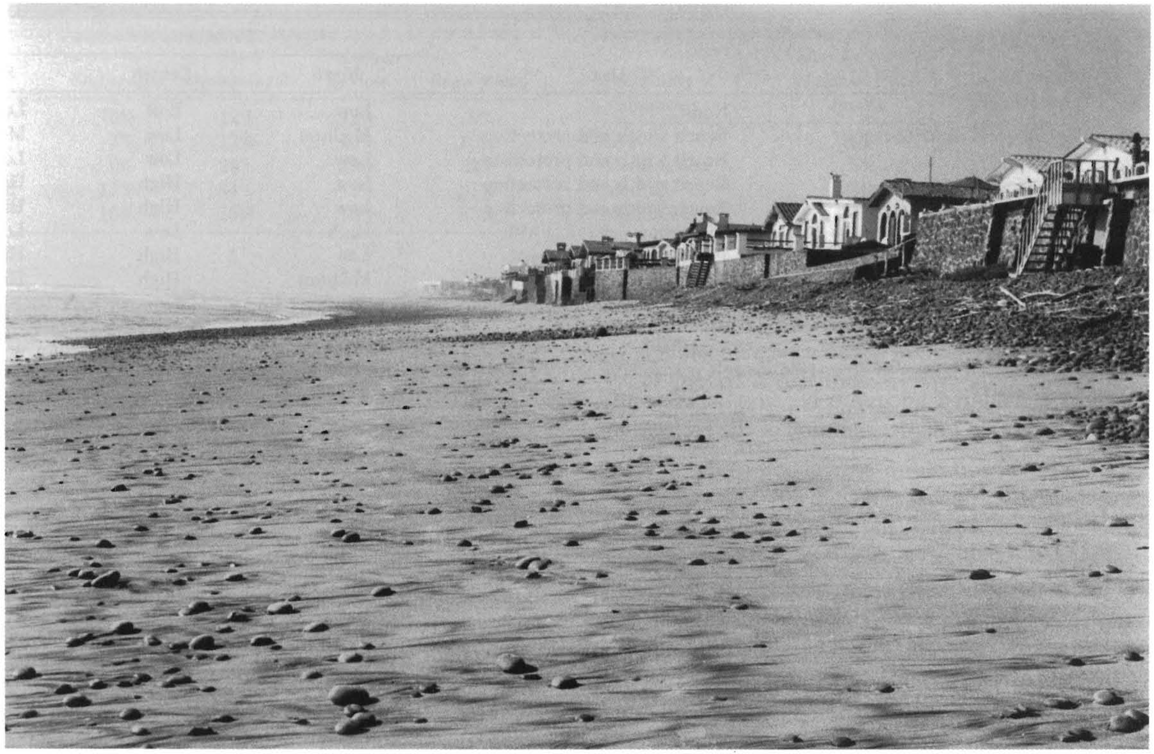

Figure 4. Numerous seawalls in the back beach characterize the north portion of study area.

ishment at the end of the rainy season when the dam has retained the highest volume of sediment yielded by the Tijuana River. Whenever the construction sand is available this material could be used so that it is not lost. Performing beach replenishment at the center zone also will be a benefit to the adjacent south zone because of the net LST to the south. It is recommended to perform beach replenishment in the central zone because this area is the most affected by beach erosion.

Redistribution of Sand in the Littoral System

The redistribution of sand in the littoral system is the action of sand bypassing from one littoral zone to another, and although it does not represent a net volume gain of sand, it can alleviate the erosion problem in a critical area. Since the water intake of the CFE power plant acts as a trap for sediment in motion along the beach (APPENDINI *et al.,* 1998), it represents a potential source of sand to replenish other areas of the littoral system and alleviate the beach erosion problem. Regular maintenance at a required depth in the water intake channel of the CFE is required. While the CFE performs continuous dredging, most of the material is discharged to the beach at the north side of the plant. The volume of 52,000 m^3/yr estimated by APPENDINI *et al.* (1998) is susceptible to shoaling in the water intake and could be discharged to the beach south of the CFE so as to simulate the natural distribution of sand and alleviate the erosion problems in the central zone. The shoaling rates are higher during the winter months and the net LST is to the south, so that it is proposed to place dredged spoil in the central zone, which also would benefit the south zone. This way a bypassing system implemented by the CFE would result in great benefits to the municipality with fairly low costs.

To retain the sand longer in Rosarito Beach a groin could be constructed in front of Punta La Paloma. This groin would not have adverse effects downdrift because the pocket beaches to the south are not as important for recreation, and they are mostly backed by igneous cliffs.

Protection Devices

Seawalls and Revetments

Protection devices such as seawalls and revetments are used when the beach is too narrow to provide protection, and those structures are needed to reduce or mitigate property damage (SANDAG, 1993). The construction of such devices establishes a limit to the beach system which stops it from receding, but in areas under erosion they promote beach narrowing. When using these structures along sedimentary cliffs their sand contribution is reduced and the sediment deficit in the area is increased.

Most of the area north of the CFE contains a narrow beach with cliffs protected by seawalls. It is proposed to protect the remaining unprotected stretches of cliff. The adverse effects of protecting cliffs are a reduction of the sand contribution by these cliffs; however, the contribution of these cliffs is low (less than 1,000 m^3/yr).

Table 3. *Probability of success of the beach erosion management strategies for Rosarito Beach, Baja California.*

Strategy	Use	Probability of Success		
		North	Center	South
Status Quo	None	Low	Low	Low
Increase and/or maintain sand contributions	Beach width and protection	Medium	Low	Medium
Reduce losses	Beach width and protection	Low	Low	Low
Artificial beach replenishment	Beach width and protection	Low	High	High
Redistribution of sand	Beach width and protection	Low	High	High
Seawalls and revetments	Protection	High	Low	Low
Artificial dunes	Protection	Low	High	High
Regulations	Beach width and protection	Medium	High	High

In the central and south zones of Rosarito Beach protective devices were not considered adequate because of their impacts on sand distribution and degradation of the recreational value of the beaches.

Artificial Dunes

Dunes are structures that serve as a sand reservoir and provide protection to the infrastructure situated behind them (SANDAG, 1993). Their natural or artificial occurrence is particularly helpful when energetic storm conditions attack the coast; this was observed during the winter 1998 along the Rosarito Beach Hotel beach where artificial dunes were built.

It is suggested that dune construction would be an important strategy for the central and south zones, as the recreational value of the beach is enhanced as well as its protective ability. Dunes must be stabilized with vegetation and vehicular traffic over them prohibited to maintain their beauty and protective ability. Expanding this strategy to medium and high vulnerability areas would increase the overall attractiveness of Rosarito beaches.

Regulations

Setback Lines

Defining a setback line allows a buffer zone for the beach to recede without representing a hazard to infrastructure and allowing a wider beach area for recreation. Considering the erosive events of 1998 as extreme, the recession experienced by the beaches is at a maximum for management purposes. Thus, a setback line of 70 m could be established. An additional 20 m is proposed so that the beach may be used in case of an extreme event such as the storms in 1998. Because of the existing development along the shore and the different legal status of the backshore, the setback line may vary. This strategy was considered more suitable for the central and south zones, with the exception of the stretch of shoreline between the CFE and Santa Mónica, where the setback also could be implemented.

Relocation

It is common to find construction over the beach, particularly in the central zone where abandoned houses, unfinished construction and storm wave destroyed houses are found. These structures occupy beach space and represent a health hazard. It is proposed to remove such structures and to relocate habitable houses from high vulnerability areas, so that the beach space is increased, health hazard reduced, and beaches look more aesthetic. To implement this strategy the creation of government incentives would be necessary.

Property Buyout

Buyout of individual developments by the government of properties located in high vulnerability areas is proposed in order to regulate the use of these areas and to maintain beach space both for recreation and protection. Since the 20 m strip of land from the highest tide is, by law, federal government property, the use of this strip is available only through 1–100 year concessions depending on the proposed use (SEDUE, 1991), so that conceivably they could be recuperated or removed at low cost. However, most concessions are based in part on political connections so that buyout may not be possible.

Upland Regulation

The cleaning of the arroyos and the relocation of human settlements from these areas would increase sediment deliveries to the beach. This action is critical to enhance the environmental quality of the beaches and help relocate human settlements from high risk areas. The regulation of small dams and the extraction of construction materials (sand and cobbles) that are part of the littoral system could then be implemented.

Table 3 summarizes the discussion of the beach erosion management strategies. The probability of success of each strategy is presented for each littoral segment, on the bases of the vulnerability to erosion, beach uses and natural characteristics.

Community Participation

A meeting of key stakeholders was invoked by the municipality of Rosarito Beach for the presentation of the above beach erosion management plan. A total of 22 key stakeholders attended the meeting, representing the City Council, Tourism Secretary, CFE, Procuraduría Federal de Protección al Ambiente (Profepa), Hotel owners, Ports, home owner associations representative and the press. Here the options for beach erosion management were explained in detail and each person present was given a questionnaire concerning their opinion of the degree of success for implementing each one of

Table 4. *Community opinion of probability of success for beach erosion management strategies.*

Probability of Success	Status Quo	Sand Management	Protection Devices	Regulations
Low	70%	12%	12%	9%
Medium low	5%	12%	10%	15%
Medium	0%	26%	25%	22%
Medium high	15%	34%	43%	31%
High	10%	15%	10%	23%

the strategies. The results obtained from the questionnaire at the end of the presentation are shown in the following tables:

From Table 4 it is seen that the status quo alternative is considered to have a very low probability of success, which indicates that the community sees the need to mitigate beach erosion. The strategies of the beach erosion management plan were considered to have a high probability of success, where 50% or more considered the strategies presented with a high or very high probability of success. Within the sand management strategy the following results were obtained:

The alternatives to increase and/or maintain sand deliveries, as well as sand redistribution, were considered by 60% or more to have high and very high probability of success, while beach replenishment was considered to have a medium probability of success. For actions to increase and/or maintain sand deliveries, more probability of success was attributed to cleaning arroyos than by maintaining cliff contributions, which had an almost equal opinion of probability of success between medium, high and very high. As for the sand sources for beach replenishment, a medium probability of success was attributed to both the dam material and upland sources. In addition, 40% considered the dam material with a low and very low probability of success.

Sand bypassing in the water intake of the CFE was considered an alternative with the greater probability of success. Along with the construction of a groin in Punta La Paloma, 50% of the key stakeholders considered both options with a high probability of success.

The use of protective devices was considered with high and very high probability of success by more than 50%. Artificial dunes where considered with high probability of success by 50%, while seawalls were only considered with high probability of success by 35%.

Eighty percent of the group viewed a setback management option as having a high or very high probability of success. Forty percent considered relocation with a high probability of success. Government buyout resulted in a divided opinion, without showing any preference. Upland regulations were considered to have a medium probability of success by 50%, while 45% considered it had a high and very high probability of success.

In general, most of the proposed actions of the beach erosion management strategies were considered to have high and very high probability of success, showing a general acceptance of the plan proposed in this study. The low probability actions of success were government buyout and beach replenishment with material from both the dam and upland

Table 5. *Community opinion of probability of success for sand management strategies.*

Probability of Success	Increase and/or Maintain Sand Inputs	Artificial Replenishment	Sand Redistribution
Low	10%	10%	15%
Medium low	5%	25%	5%
Medium	25%	40%	15%
Medium high	38%	15%	50%
High	22%	10%	15%

sources. Since cost estimates of low, medium and high were used along side each beach management alternative, the cost factor played a role in these two alternatives being ranked low. Thus, beach erosion management would seem to be important by these stakeholders.

From questions on who would fund the plan all the stakeholders in Rosarito Beach, agreed it was their responsibility except for the residents not living along the shore. Few considered the beach users and the Tourism Agency as stakeholders that should finance part of the plan. Most felt local government, CFE, hotel owners and residents along the shore should fund the plan. From these groups only the local government opinion for willingness to pay was considered as representative, and they showed a high willingness to pay for actions that would conform to the three strategies of the beach erosion management plan: sand management, protective devices and regulations.

Several commentaries were added to the questionnaire that noted implementing such a plan would require the coordination of the three levels of government in order to share funding of the plan along with the most important beach stakeholders (CFE, hotel owners and beachfront residents).

CONCLUSIONS

Rosarito Beach is a municipality where the sandy beach represents the most important resource for the region's economy. Beach erosion has become a critical problem in recent years making the implementation of a beach erosion management plan important to preserve this resource.

Beach erosion in Rosarito is estimated to be between 0.35 and 0.65 m/yr, but extreme wave events can result in a shoreline recession of 72 m in a short period of time. The most critical area to beach erosion is from CFE to the Arroyo Guaguatay, where also the water intake structures of the CFE have an effect over beach erosion. The area north of the CFE is mostly armored and with a narrow beach not important for recreation, while the area south of CFE is the most important for recreational use. South of the Arroyo Guaguatay the beach has not experienced damages along the shore, although the beach width has diminished considerably during extreme events.

The beach erosion management plan presented in this paper is comprised of strategies related to sand management, the use of protection devices and regulations. These strategies are composed by actions which must be implemented by the Municipality of Rosarito Beach to preserve its beaches, being the first plan of this nature in Mexico. The economic feasibility of each of the actions that form the beach erosion management plan still needs to be evaluated so that the sandy beach is preserved as the most important economic resource for the municipality of Rosarito Beach.

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