



Once the studies were made, a series of final conclusions were reached from all the information gathered and some precise recommendations were suggested to mitigate the problem

In the following parts of this report, the studies undertaken are commented briefly.

**3. HISTORICAL EVOLUTION OF THE COAST**

The Huelva shoreline can be characterized by the significant movement of sand which takes place, a logical consequence of the huge amounts of sand all along the coast. The proof of this is the fact that the shoreline is made up of only one beach, from Ayamonte on the border with Portugal to Punta del Malandar in the mouth of the Guadalquivir River, the border with the province of Cádiz. This immense sand formation is interrupted only by the mouths of rivers and tidal channels and above all by the Odiel wetlands, located precisely where Punta Umbría and Huelva have access to the sea.

Figure 2 portrays, generally speaking, the evolution of the Huelva coast from ancient times till our days. The present day location of the Punta Umbría spit is indicated by the circle. The arrow indicates the direction of the longshore transport of suspended sediment.

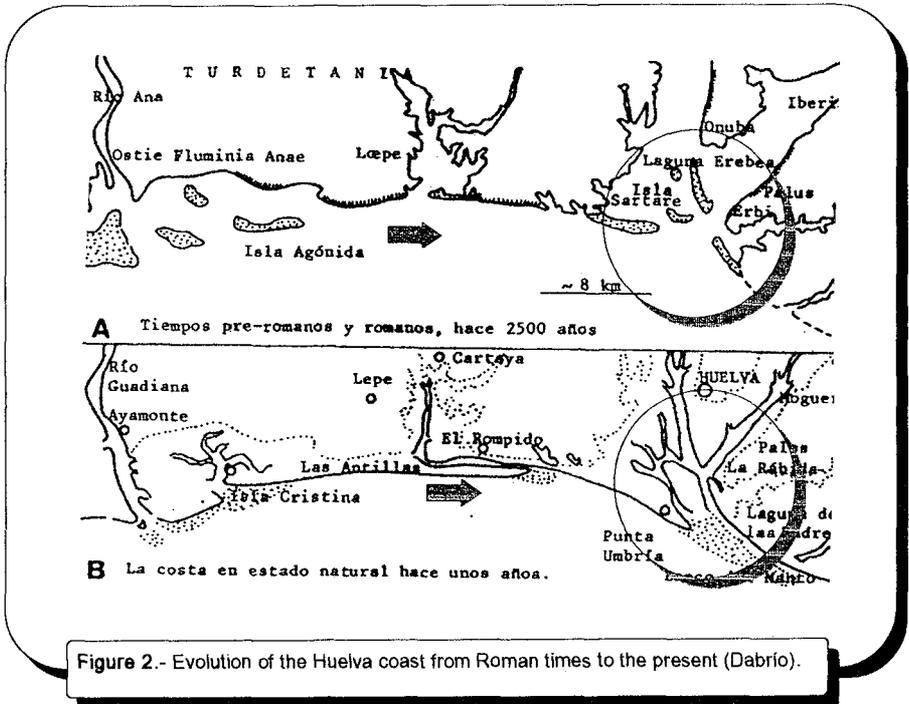


Figure 2.- Evolution of the Huelva coast from Roman times to the present (Dabrio).

As can be seen from the figures, the old rías have slowly undergone a process of sandfill and have been transformed into wetlands, which is what they are today.

<sup>3</sup>Today the General Directorate for Ports of the Ministry of Public Works and Transport.

In antiquity, the coast was made up of estuaries and cliffs and the sea occupied the low lying areas of the river valleys. As a consequence, true rías, like those found in the north-west of Spain (Galicia), were formed in what are now wetlands.

At the same time, the current of net longshore transport, induced by predominant waves from the SW quadrant, among others, and the tide action came together to form two different solid currents. The first current was produced by waves from a W->E<sup>4</sup> direction and the second one by the tide coming from alternating N->S / S->N directions depending on whether the tidal current is flood or ebb.

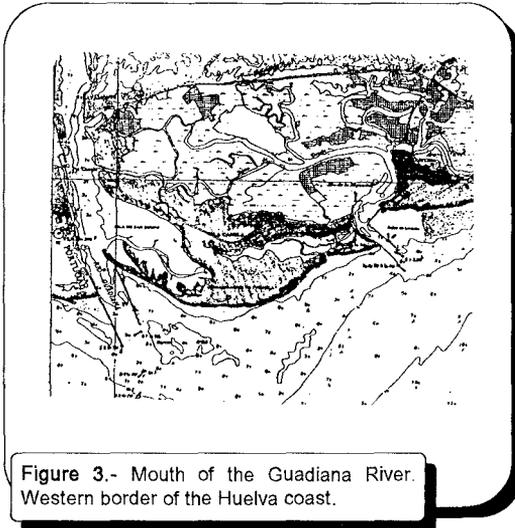


Figure 3.- Mouth of the Guadiana River. Western border of the Huelva coast.

Consequently, sand bars began to appear: the Agónida island (See figure 2A) in the mouth of the Ana river (the present day Guadiana, from the Arabic, "wadi Ana") became the present day Isla Cristina; the ría of the Piedras River became a tidal valley and began to take the shape of the Rompido spit.

Numerous ancient texts exist which date from the VI Century B.C. which confirm the existence of a great estuary in the confluence of the Tinto and Odiel rivers, called "Laguna Erebea" (See figure 2A) by some authors. The growth of the present day Punta Umbria spit in a NW->SE direction aided in the filling of the estuary and the formation of the present

Odiel wetlands, which, in turn, helped to make the spit wider. At the same time, an extensive dune field was formed on the berm.

Barrier islands and the wetlands formed in their shelter existed already in the 19th Century. Straits, narrows or "rompidos" (a local Spanish word that means "little mouth") were formed between the islands.

The net longshore transport current is at present quite significant. The progressive accumulations of sand to the West of the Punta Umbria and Huelva breakwaters, as well as in the Rompido Spit, testify to that fact. In the end of the Rompido Spit (the Punta del Gato), the sand has advanced an average of around 35 m/year. This point has been confirmed by the geological studies consulted<sup>6</sup>, as well as by measurements made on photogrammetric series in the CEPYC.

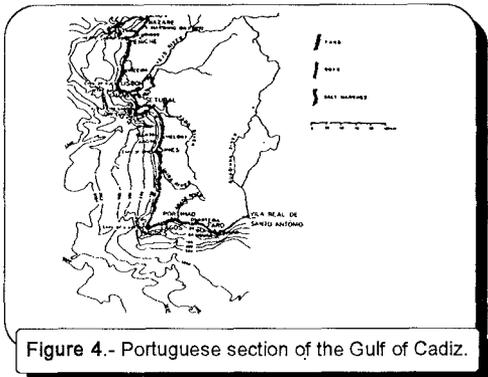


Figure 4.- Portuguese section of the Gulf of Cadiz.

#### 4. MORPHOLOGY OF COASTAL AREA

The Huelva coast extends from the mouths of the Guadiana and Guadalquivir rivers, as was previously mentioned. It is 145 km. long, forms a gentle arc, concave towards SW, and its western end faces a N-80-W direction while its eastern end faces an E-70-S direction. The waters of the Gulf of Cádiz wash its shores.

Owing to historical geological processes, sufficiently treated in the previous part, the coast is made up of coastal formations, typical of the mouths of rivers, and has a gentle equilibrium profile in its last part. The formation of sandbars, points, spits and muddy bogs are also frequent along the coast.

In the area under study, the coastal profile has two features which should be highlighted:

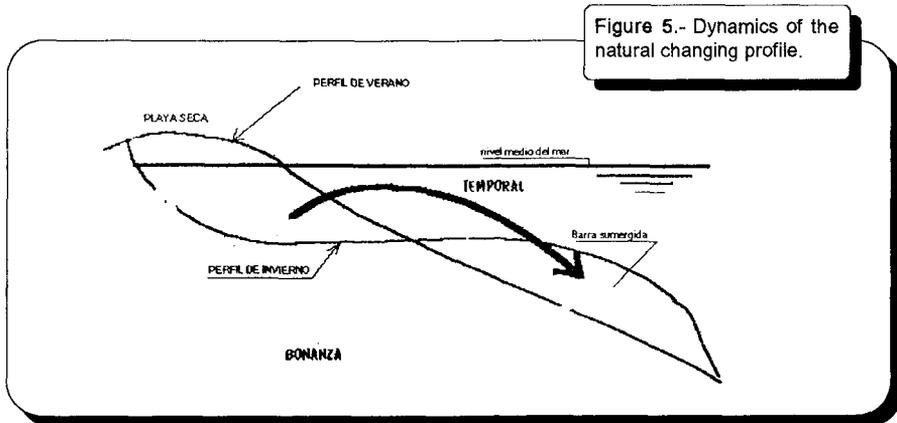


Figure 5.- Dynamics of the natural changing profile.

On the one hand, the mouths of the rivers have considerable extensions of tidal flats which are separated from the sea by sand barriers. These formations are created by the action of the shore current.

On the other hand, a strip of recent sand sediment has been formed between Ayamonte and Punta Umbría. This strip shelters the cliff of siliceous sand, making it inactive and unable to contribute material to the shore dynamics, at least in a direct way, since it is not attacked by the sea.

The city of Punta Umbría was built directly on a spit in the mouth of the Tinto and Odiel rivers occupying the zone of public domain in numerous cases. The design of the numerous streets of the city confirms how the city adapted itself gradually to the growth of the spit. Due to the importance of this type of formations for shore dynamics, it is worth dealing with this point a bit more in detail.

<sup>4</sup>It is interesting to observe at present how an actual river of sand is formed on days when there are storms from the West, even if the storms are not very strong. This river hugs the jetty, which forms the right bank of the Huelva channel, and becomes progressively narrower till it reaches a width of about 30 m.--depending on the intensity of the storm--at the roundhead. Later the river of sand expands throughout the width of the entrance.

<sup>5</sup>C.J. Dabrio, Historia de la Dinámica de Nuestra Costa, Cartaya, 1982.

### Spits, coastal sand formations and their influence on beach profile

Spits are sand bars built up in the direction of the current and are connected to land at one end. They are generally related to the mouths of rivers where sand formations of various types (live dunes, dead dunes, wind-deposited mantles, etc.) are generated. They develop on a small or medium scale anywhere along a coast which combines the topographical conditions and the adequate dynamics. They are more frequent along the Atlantic coast.

Due to their own physical characteristics, coastal sand formations have a very important role in the ecosystem and shoredynamics: they play the role of coastal defence, probably the most effective one that can be found, in contact with the sea and cushion the action of the sea, especially during severe storms. At the same time, they serve as a sand reserve for the beaches.

In addition, the presence of dune fields located on the berm has a determinant effect on the annual cycle of the evolution of the beach which is described in a general fashion in the next section.

### Diagram of the evolution of the beach profile

#### a) Summer profile

As waves approach the coast, they let their effects be felt on the bottom of the sea approximately from the moment where the depth is lower than half a wavelength. From that point on, the sand particles begin to shake back and forth alternatively. The beach profile undergoes modification until the force on the particles is balanced yielding a net result which generally implies a forward movement towards the shore. The finest sand particles are suspended in the area of the surf zone and are thrown along the width of the strand by the waves. Some return to the sea, but the net result still favors deposits on the strand.

#### b) Winter profile

When there is a storm, more waves reach the shore. Thus, more water is transported than in summer and consequently the sand is saturated. This forces the groundwater level to rise. This implies less filtration and eventually produces greater return currents which cause greater erosion. The beach recedes but the sand is deposited on a submerged bar, parallel to the beach and not very far from the shore. This bar acts as a filter for the waves, since it does not allow waves greater than a certain height to pass and obliges them to break due to the effect of the bottom, though this depends on the size of the sandbar.

Figure 5 illustrates this mechanism.

From the previous paragraphs, it becomes clear that if a beach is not wide enough to permit the adopting of a winter profile with a sandbar (for example, if construction was permitted too close to the shoreline), the waves will continue passing through and erode the remaining berm. For that reason, it is **essential** that each beach have a natural deposit of sand (which is usually a dune field) in the back of the beach.

## 5. PUNTA UMBRIA. A CASE STUDY

### Nature

Sand along the Huelva coast is readily available, a fact which will always be a constant problem in many points of the shore due to the resulting lack of depth for navigation. At the same time, however, it provides an efficient defence for the coast in most of its zones, as long as the sand is allowed to evolve as naturally as possible.

### Urban development

Punta Umbría has witnessed the rapid growth of its urban structure, as have the majority of coastal cities whose most important income comes from tourism. The city has grown, like other cities along the Spanish coast, without regard to coastal sand formations, either because of a lack of knowledge concerning their functioning<sup>6</sup>, or because of other reasons which do not take Nature into account.

The growth of the city has always been connected to the growth of the spit, as is reflected in the layout of the streets, which are parallel to the successive alignments of the shoreline.

The problem of the regression of the Punta Umbría beach appears to be provoked artificially by the historical invasion of the sand reserve within the public domain by the sea-front construction. This construction makes it difficult or hinders the formation of the full storm profile of the beach and, consequently, the ulterior regeneration of the summer profile.

### The construction of the jetty

The present day Punta Umbría jetty causes the dominant waves to strike the beach with very little obliqueness. This facilitates the halting of the current, almost completely, which has as its consequence the settling of the material in suspension. This material is at the mercy of the flood and ebb tidal currents which allow it to enter and deposit in the ría by the diffraction of the waves and the tidal current.

The layout of the Punta Umbría jetty has literally cut off the growth of the spit. This has caused the transformation of the part of the spit situated to the east of the jetty into a shoal which is today called Bajo de Nueva Umbría.

The aim pursued initially (to achieve the advance of the beach) has been totally successful. However, the movement of sand was not taken into account, particularly in view of the effect caused to the east of the jetty, in the mouth of the channel. The effect sought after by the construction of the jetty was based on the creation of a partial barrier to the passage of sediments, not only along the bottom but also in suspension, thus facilitating their deposit to the west. Nevertheless, the diffraction provoked on the waves produces a current due to the wave height gradient which leads the sediment into the channel. At the same time, the deficit of longshore transport is compensated by the movement of sand from the shoal, Bajo de Nueva Umbría.

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<sup>6</sup>It should not be forgotten that Coastal Engineering is still a young and developing science. Some of its fields, such as the understanding of the evolution of the cross-shore profile of a beach, are not sufficiently developed.

The hydrodynamics of the mouth of the channel are not acceptable today, since the ebb tide almost always affects the longshore transport current induced by the obliqueness of the breaking waves, creating a problematic point in the mouth of the ría.

#### Sea level rise

A rise in the sea level brought about by climatic changes would have a greater importance along low lying coasts, as would be the case in Spain along the Gulf of Cádiz and in the Ebro Delta, as well as in other isolated areas in other regions. However, this factor has not been taken into account in this study, since it has a long term effect. A SLR vulnerability assessment for this region is now being carried out at the CEPYC.

## **6. STUDIES UNDERTAKEN**

#### Maritime climate

A study of the maritime climate, based on visual observations of waves, permitted the drawing up of the wave rose, SEA and SWELL type waves. Its aim was to determine the storms which were to be studied.

#### Wave propagation

A study of the wave propagation was accomplished by using a refraction-diffraction parabolic mathematical model<sup>7</sup> based on the resolution of the Berkhoff equations and on the jobs by Kirby and Dalrymple (University of Delaware, U.S.A.). The model permitted the definition of the behavior of the waves as they approached the coast. Various storms of varying directions and periods and in high and low tide were used to achieve this definition.

#### Hydrodynamic behavior of tidal currents

With the help of the MIKE21<sup>8</sup> mathematical model, a simulation of the tide conditions in the wetlands system of the mouth of the Odiel river was undertaken. To accomplish this, the tidal prism, which even included the Huelva ría, was taken into account.

## **7. POSSIBLE SOLUTIONS**

First of all, it is essential to bear in mind that an ideal solution does not exist. Unfortunately, the over abundance of sand along the coast means that dredging can not be avoided.

Notwithstanding this, it is believed that an ideal solution for minimizing the existing problems would involve restoring the primitive channel out to the sea, since it is the natural outlet for the ría. The best way to accomplish this would be to construct an embankment (as shown in figure 6), dredge the former course of the channel and dump what was dredged between the jetty and the embankment, according to the outline indicated in the previous figure. In this way, the spit would be restored and the incident angle between the two currents would be minimized.

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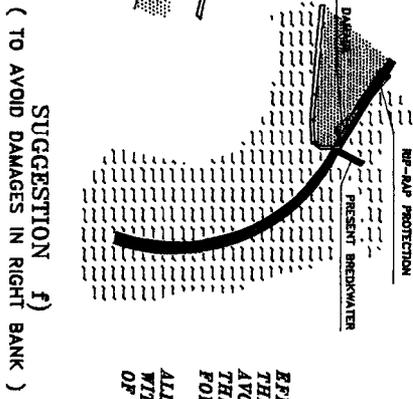
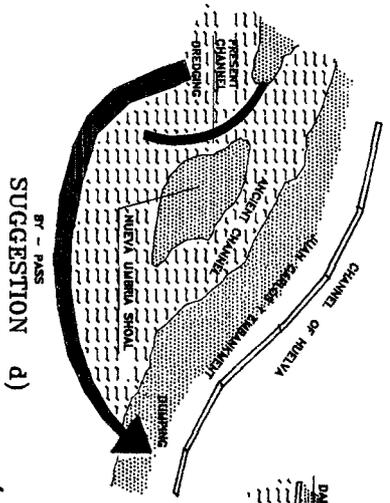
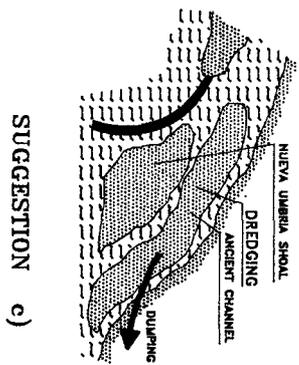
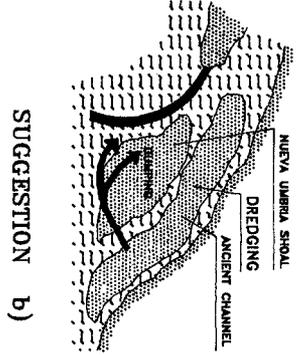
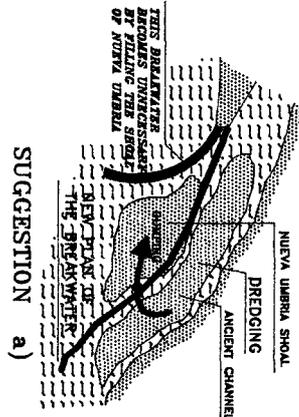
<sup>7</sup>José María Grassa Garrido, Ports and Coasts Research Center, Madrid, 1990.

<sup>8</sup>Danish Hydraulic Institute.

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# POSSIBLE SOLUTIONS SUGGESTED



SUGGESTION g)

*EFFICIENT PROTECTION OF THE PUBLIC DOMAINE TO AVOID THE DESTRUCTION OF THE DUNES AND OTHER SAND FORMATIONS.  
ALLOW THE SEA TO PERFORM WITH FREEDOM THE CHANGING OF CROSS-SHORE PROFILE.*