

*Chapter5*

**DIFFERENT BEHAVIOUR AND  
MANAGEMENT OF TWO LITTORAL  
DUNES IN SOUTHERN SPAIN**

***P. Lopez-Garcia, M. Navarro, J. Roman- Sierra,  
G. Gomez-Pina, A. Contreras, R. Martell  
and J. J. Muñoz-Perez***

Coastal Engineering Research Group, Universidad de Cadiz,  
Puerto Real, Cadiz, Spain

**ABSTRACT**

The north-western coast of Cadiz (Spain) presents a variety of coastal engineering and coastal management problems whose solution is not an easy task due to the complexity of the parameters involved. Two cases of dune zone management in this area are described in this paper. Punta Candor beach, a very popular recreational area in Rota municipality, experiences one of the highest dune erosion rates in Spain of more than 1 m/yr. In order to address this coastal degradation, the Atlantic Andalusian Coastal District has performed beach and dune restoration planning, described in this paper as an example of sustainable coastal management. The Valdevaqueros dune area also represents an

important recreational zone. However, after the Spanish Shore Act was approved in 1988, sand extraction was prohibited, and the system began to lose stability resulting in landward dune invasion. As in the previous case, an integrated study of the management alternatives is also presented for the Valdevaqueros dune area, considering all of the problems involved: dune degradation, invasion of the Punta Paloma road by the mobile dunes, excessive recreational pressure on the dune area and adjacent lagoon, parking lot resettlements, and undesirable land use in the surroundings. In particular, a cost-benefit analysis for the different alternatives was carried out regarding the road-dune interaction.

**Keywords:** dune, restoration, coastal management, erosion, beaches, Punta Candor, Valdevaqueros, Spain

## INTRODUCTION

In Spain, there are two dune areas located in Punta Candor and Valdevaqueros (SW Spain) that are close to each other with a similar kind of sand but with different behaviour. The distance to the Gibraltar Strait makes the wind velocity and direction substantially changed.

The littoral zone of SW Spain is characterized by being generally rectilinear with a dominant swell in the SW-NE direction. Tidal conditions respond to a meso-microtidal environment. Winds predominantly come from the west and are often associated with cold fronts, although the east winds are usually stronger. In this environment, many dune systems have been developed along the coast, but the special wind conditions together with other pressures make suitable management difficult.

Dune ecosystem problems in Cadiz have been studied by Ramirez and Ley (1998), Muñoz-Perez et al. (2001, 2009), Roman-Sierra et al. (2004, 2013), and Navarro-Pons et al. (2011, 2016) with special attention to the mobile dunes of Valdevaqueros and Bolonia (Tarifa municipality). Littoral sand dune management in Spain and the causes of dune degradation have been researched by several authors: Bonnet Fernandez-Trujillo (1989), Sanjaume and Pardo (1992), Van Der Meulen and Salman (1995), Ramirez and Ley (1998), and Muñoz-Perez et al. (2001).

The first objective is to describe the different projects carried out in the Punta Candor dunes by the Atlantic Andalusian Coastal District (Spanish National Coastal Authority, Ministry of Environmental Protection). These projects should be regarded as a good example of environmental coastal protection, as opposed to traditional sea wall reparations.

The second objective of this chapter is to present an integrated study of the management alternatives for the Valdevaqueros dune area, considering all the problems involved: dune degradation, invasion of the Punta Paloma road by the mobile dunes, excessive recreational pressure on the dune area and adjacent lagoon, parking lot resettlements, and undesirable land use in the surroundings.

## STUDY AREA

### Punta Candor

The study area is located in the SW Spanish littoral zone, in the southern part of the Guadalquivir estuary north of the Gulf of Cadiz. Punta Candor is located between the villages of Chipiona and Rota (Figure 1).

The coast is composed of straight beaches backed by cliffs. (del Rio et al., 2002). The sector from the Punta Candor headland to Rota village has a broad WNW-ESE orientation and is formed by beaches with well-developed dune ridges at their back.

Sediments are moderately well sorted, with a medium and fine granulometry (Anfuso & Gracia, 2005, and del Rio, 2002). The tidal range, with semidiurnal periodicity, varies between 3.72 m (spring tides) and 1.10 m (neap tides), classifying the coast as a low mesotidal environment.

The littoral zone is mainly affected by winds and waves (both “sea” and “swell” wave conditions) approaching from the SW to WNW (Figure 2). Atlantic winds blowing from the W and WSW are responsible for most of the important winter storms in the area.

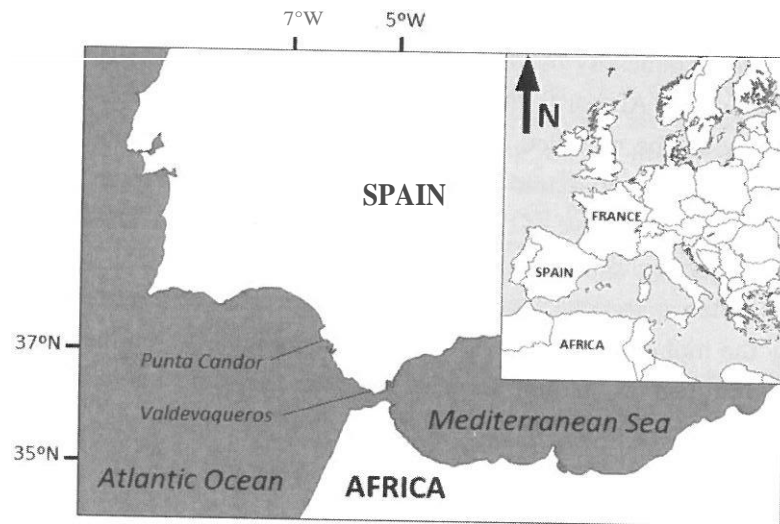


Figure 1. Location of the study areas, Punta Candor and Valdevaqueros.

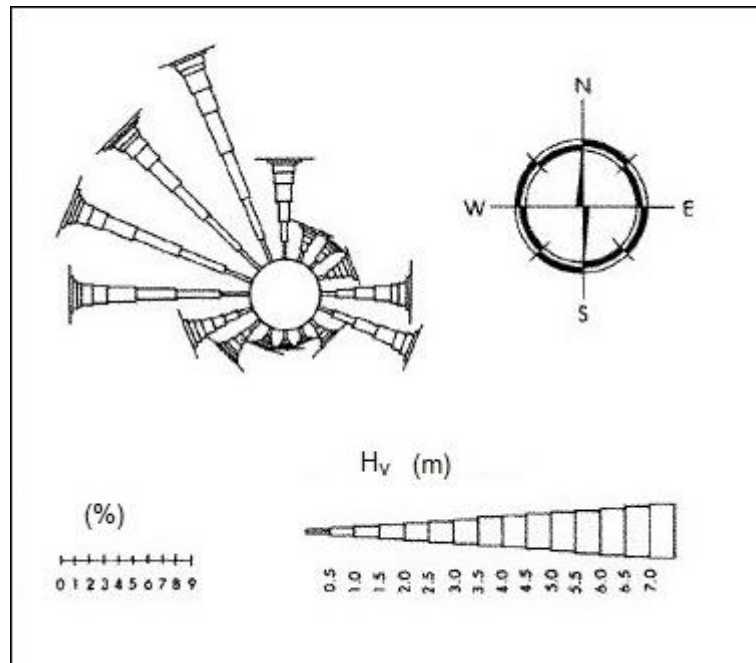


Figure 2. Wave direction rose diagram for the study area. Where  $H_v$  is the significant wave height.

Waves approach the coast mainly from the west (45% of the annual frequency), with an average height of less than 1 m and a significant wave height associated with storms of 3 m ([www.puertos.es](http://www.puertos.es)).

The highest wave height values are recorded during the winter months (November-January), followed by the spring period (April-May). The wave period is different from January–March (with values of 10 – 20 s), November-December (6 – 8 s), and during the summer months, which are characterized by low periods (5 – 6 s).

Because of the coastline orientation, the prevailing littoral drift currents in the zone flow to the SE. A secondary, opposite drift is also occasionally recorded, associated with wind-driven waves generated by strong winds blowing from the S and SE (Anfuso & Garcia, 2005). The annual tendency of the dominant sediment transport drift (NW-SE) has an average net volume of 25 – 30.000 m<sup>3</sup> year.

As a result, the study area and the dune system located at its northern end present very high erosion rates, with a retreat of 40 m in the last 30 years (Muñoz-Perez & Enriquez, 1998).

In this study area, several coastal engineering and coastal management problems have been identified whose complex solution is not an easy task. Some of these problems are:

- The presence of reef areas that affect the beach morphodynamics as they prevent the connection between the beach and the sediment below the rocky platform.
- High dune erosion rates (0.5 – 1 m retreat per year) due to the nature of the beach and cliff sediment (Figure 3).
- The existence of environmentally rich rocky areas to be preserved from beach nourishment projects.
- The location of still-preserved dunes under natural geological erosion.
- Urbanization and dune occupation prior to the approval of the Spanish Shore Act in 1988.
- The high degree of tourism development on an eroded coastline.

- The almost null possibility at present of using the only known high quality sand borrow area due to the radical opposition of local fishermen.
- The impressive presence of the "corrales," stone man-made ponds built during Roman times that act as fishing ponds as well as protective semi-submerged breakwaters under a 3.5-m tidal range (Muñoz-Perez et al., 2007).
- The existence of endangered species linked to the littoral ecosystems.

Moreover, the continuous retreat of the coastline provokes other problems, such as the modification of the limits of the public domain.

## Valdevaqueros

The Valdevaqueros dune area is located in Tarifa (36°N 5°W) and is a good example of a free mobile dune field (Figure 1).

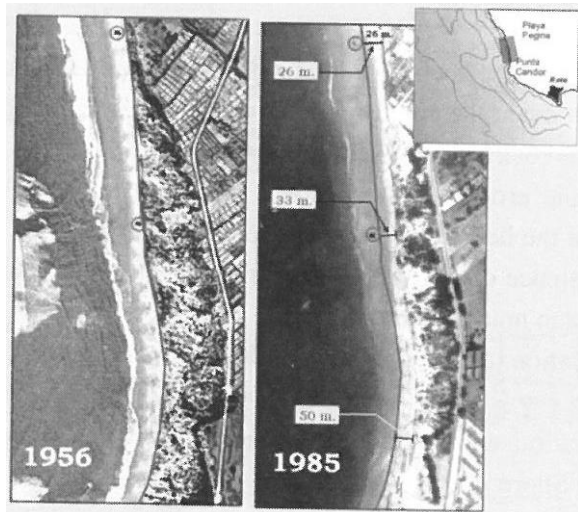


Figure 3. Coastline retreat within a 30-year period.

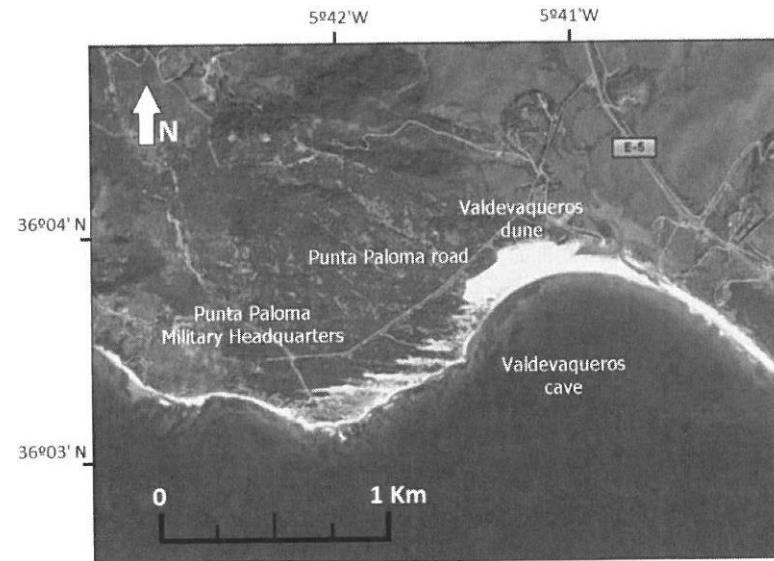


Figure 4. Aerial view of Valdevaqueros cove.

The Valdevaqueros dune area represents a singular coastal geomorphologic formation with extraordinary natural scenery and a sand reserve for beach equilibrium. The beach and lagoon are both valuable for their unique and natural beach sceneries. Valdevaqueros beach has good water and sand quality for beach users and constitutes a year-round paradise for flying (wind and kite) surfing activities. Moreover, this area is located very close to other similar spots, such as the Bolonia or Tarifa beaches.

Nevertheless, the actual unstabilized situation of the Valdevaqueros dunes represents a problem for the nearby population and military headquarters. Since the prohibition of sand extraction in 1988, the dunes have significantly increased their advance towards the only road to Punta Paloma. A view of the Valdevaqueros area can be seen in Figure 4.

The 1988 Spanish Shore Act ("Ley de Costas") arose with the aim of regulating the coastal activities and preventing littoral destruction, as before 1988, Spanish coastal dunes were totally unprotected. The Spanish Shore Act protects all coastal dunes, effectively banning sand-mining, development on the public domain, and also changes in land use. However,

this law alone does not prevent some other negative activities from occurring. Furthermore, the complexity of the existing boundaries of the different authorities involved in coastal zone management policy makes integrated dune management a difficult task.

The special characteristics of the Valdevaqueros dunes together with their natural and scenic values confer on Valdevaqueros cove a great attraction. The frequent local Levante wind regimes give rise to high wind speeds of up to 100 km/h (Gomez Pina et al., 2002) and represent a paradise for flying-surfers. The high longitudinal aeolian transport is responsible for building up a huge mobile dune on the northern side of the beach. Wind conditions together with the direct burden caused by beach visitors make it difficult to establish permanent vegetation on this dune. As a result, the dune becomes unstable, showing continuous rapid movement towards an adjacent pine grove and the local Punta Paloma road (Figures 5 and 6). Before 1988, when dune sand mining was a profitable business, the mobility of the Valdevaqueros dunes was relatively well controlled and the adjacent local road rarely was blocked by the mobile dunes. However, the frequency and high velocities of Levante winds make it very difficult and costly to keep the adjacent local road cleared.



Figure 5. Encroachment of the Punta Paloma road by the Valdevaqueros mobile dune.



Figure 6. View of the dunes invading the pine grove.

Some of the beach and land uses amount to an added problem to the dune situation due to anthropic behaviour. Kite and windsurfing represent a high recreational pressure for the area due to the lack of adequate regulation of these activities. Other uses, such as the existence of inadequate parking lots and off-road vans present in the zone for extended periods, as well as camping, "chiringuitos" (refreshment stands), a pig farm, etc. make satisfactory management of the area more difficult.

Although several restoration works have been carried out by the Coastal Department in recent years, the special wind conditions that affect the dunes do not facilitate control of their mobility. Dune restoration works started with the reshaping of the dune profile in order to obtain a better aerodynamic stability complimented by the experimental use of wooden fences to decrease erosive surface patterns. Also, experimental transplanted vegetation techniques (*Ammophila arenaria* sowing) were used in certain potentially stable areas. These experimental dune activities have been carried out several times in order to lessen the frequency of the occupation of the local Punta Paloma road by the mobile dunes, still an unsolved problem.

Controlled sand bypassing operations with the remaining sand have been beneficially used to nourish some beaches in Tarifa County. In 1990,

sand by-passing was performed and willow fences were established on the dunes. Later on, sand extraction and by-passing continued to be necessary to decrease the advance of the dunes towards the pine grove. Nowadays, some wooden fences have been established on several points of the dunes to help with dune fixation, although this does not seem to be the final solution to the dune invasion problem.

## METHODOLOGY

### Punta Candor

In order to achieve a sustainable beach and dune restoration project, some design aspects must be taken into account. Technical, economic, environmental, constructive, aesthetic, recreational, and safety elements are necessary to achieve effective management of the system that allows for satisfactory use by all public sectors.

Several projects on this coastline have been successfully performed. One of the most important restoration works was applied in Punta Candor where erosion destroyed a protruding paved area in 2004 (Figure 7).

Wave processes have been analysed in order to understand local negative effects. The location of these concrete structures at the shoreface of the beach created a wave reflection from the wall, generating constructive interference of the reflected wave with the incident wave. The new wave produced by this interference, a standing wave, turned out to be more erosive than the original incident wave. When the incident wave was oblique to the wall, it produced lateral erosion. Storm waves can cause the eroded material to be swept out to sea by rip currents or to be transported down the coast by the oblique reflection of swell waves from these structures (Silvester & Hsu, 1997).

The Coastal Engineering Manual (CEM, 2002) displays five alternative ways to mitigate the damage of coastal storms, namely, accommodation, protection, beach nourishment, retreat, and, of course, the do nothing alternative. In many locations, elevated structures combined

with some type of armouring or shoreline stabilization structures together with beach nourishment are employed for shore protection.

Punta Candor Beach had several deficiencies:

- Lack of free zones for parking use.
- Fenced space and location of concrete structures.
- Weaponry bases.
- Difficult access for the physically disabled.
- Existence of invasive plants (*Carpobrotus edulis*).

In order to solve these problems, the Atlantic Andalusian Coastal District performed joint projects aimed at beach and dune restoration.

Chronologically, these works were the following:

- Demolition of the old paved area "protected" by a vertical wall (finished in 2003).
- Dune restoration, Phase 1 (finished in March 2007).
- Dune and surrounding area restoration, Phase II (starting May 2007).



Figure 7. Destruction of Punta Candor protruding paved area after the storm of December 2004.

## Valdevaqueros

The Coastal Department, after having analysed the problem that the continuous dune advance represents for the Mas Palomas inhabitants, has proposed three alternatives. Alternative I consists of changing the level of the affected zone of the existing road (Figure 8). The work would be performed along a road length of approximately 500 m and the road would be elevated by about 8 m. This would decrease the dune advancement, and sand extractions would be easier to carry out in the future.

Alternative II is based on the protection of the road by the creation of a false tunnel (Figure 9). The aim is to allow the high dune advancement rate to continue without the necessity of sand extractions. As a result, dune natural development would not be interrupted.

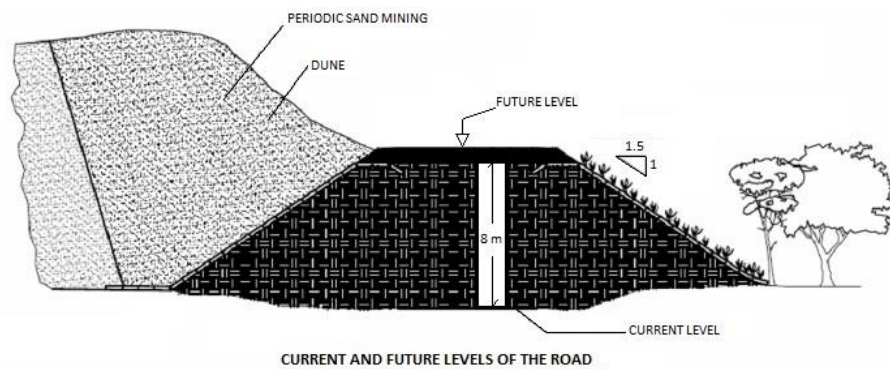


Figure 8. Alternative I. Elevation of the existing road.

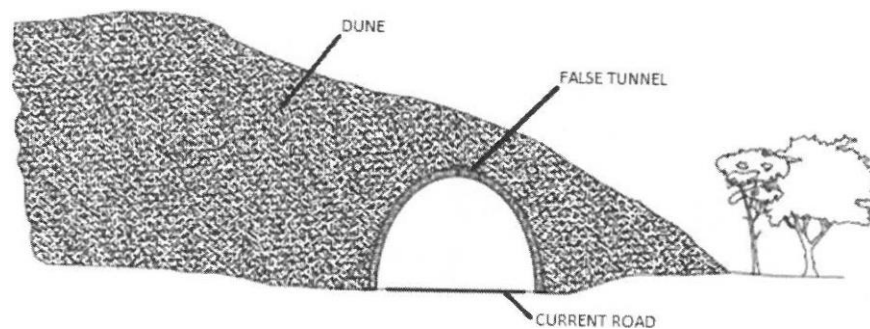


Figure 9. Alternative II. Creation of a false tunnel.

Alternative III consists of the reconstruction of the road affected by the dune. This means that the road will be abandoned and the dune will be left to develop without intervention. The new route would take advantage of an existing military road to Punta Paloma, and the new distance covered would be 5.74 km, versus the 2.67 km of the existing road. It would be necessary to asphalt or repave the military road for this purpose.

In order to absorb anthropic pressure in the Valdevaqueros zone, other complementary solutions were proposed. Currently, the parking area and its accesses seem to be insufficient for the high influx of visitors to the area. When there are many visitors, cars are parked in the dune zone, which contributes to the degradation of the area. Moreover, other activities derived from the existing pig farm produce toxic substances that pollute the river and create eutrophication problems in the lagoon waters.

The improvement and rearrangement of these infrastructures by the construction of new parking pockets as well as new beach access routes are good options to take into account. These works would require the demolition of the current parking area and the expropriation of part of the camping area and the adjacent pig farm.

Restoration of the degraded dune zone and the creation of a new dune field of approximately 500m<sup>2</sup> have also been proposed.

## RESULTS

### Punta Candor

The first phase of the Punta Candor restoration was quickly completed over a 6-month period, as there were political interests due to the closeness of the local Town Hall elections (Figure 10). The new Punta Candor beach facilities finally achieved an EU blue flag thanks to this restoration project.

Dune restoration work began in the spring of 2007 with dune replenishment from a sandpit and the installation of longitudinal willow fencing, and cross-walks (Figure 11). The new sand had a different colour from the natural Punta Candor dune sand, but this feature changed after 3

months, recovering its natural colour. To prevent ecological problems linked to the existence of chameleon nests, the installation of the willow sand fences was carried out by hand. All of these actuaciones allowed better access from the newly created parking area to the beach and provided for dune protection and stabilization as well as the sustainable use of the ecosystem.

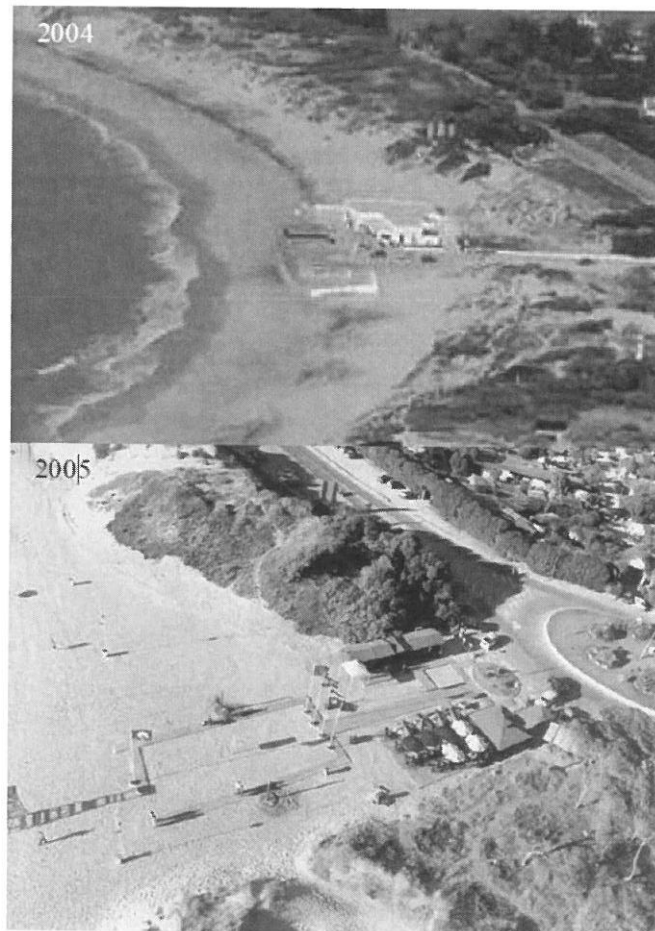


Figure 10. Comparison between pre- (2004) and post-restoration works (2005) at Punta Candor.

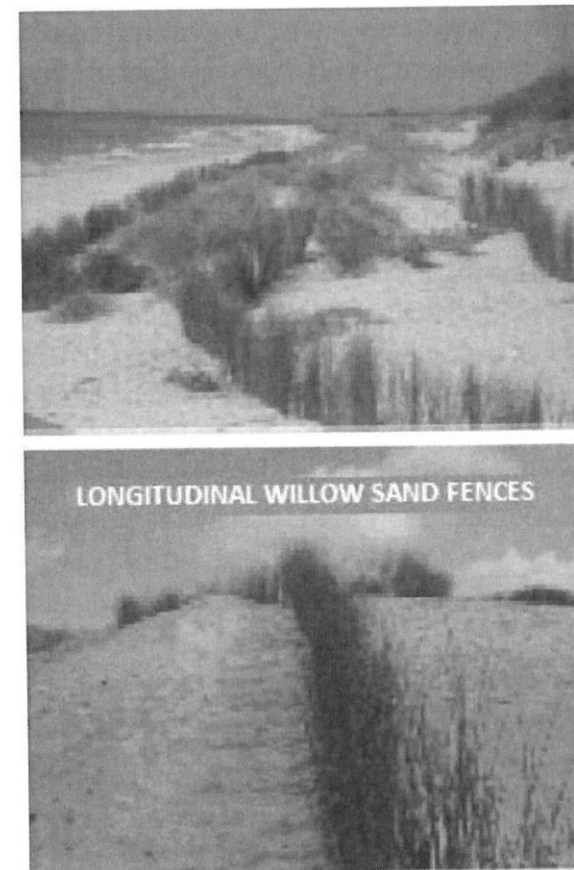


Figure 11 . Dune restoration works in Punta Candor.

Furthermore, the demolition of a typical World War 11 bunker and the Punta Candor Military Headquarters was performed within the proximity of the beach, although there are still some old military buildings yet to be demolished.

### **Valdevaqueros**

Once the alternatives had been proposed, a viability analysis of each one was carried out, taking into account all of the advantages and



disadvantages of their application. It is important to consider that all of these alternatives regarding the road-dune interaction have been studied starting from the idea that road invasion by the dune represents a serious problem for the development of the area.

Alternative I (elevation of the road) would assure road communication and would facilitate sand extraction and by-passing from the new road. On the other hand, dune advancement would not be completely stopped. As a result, this option would not allow the environment to reach an equilibrium situation. The cost of execution is estimated to be 4.6 million Euros.

Alternative II (creation of a false tunnel) would permit natural dune development without any technical interference over a long time period. However, the cost for this work is considered to be too high (5.2 million Euros) for a road with such a low traffic density.

Alternative III (reconstruction of the road) seems to be the least costly alternative, with a technical budget of 3.3 million Euros. Although the new road would be longer, it would be possible to take advantage of the existing military road. This option would preserve the natural dune environment and the problem would disappear in the medium term.

## CONCLUSION

### Punta Candor

The existence of protruding paved walls at the shoreface produces grave negative effects, not only on the beach but also on dune equilibrium. This aspect turns out to be even more severe in the case of the study area, where the erosion rate is close to 1 m/year.

On one hand, undertaking restoration work seemed to be a very "brave" act as there were no previously known solutions to the initial problem. However, this example of the application of integrated coastal management can be very useful for other locations since the same problem appears in many parts of the world. Furthermore, dune restoration

experiences based on other dune systems in Cadiz allowed us to apply the best available techniques to control and stabilize the dune system.

Nevertheless, solutions to other "minor" problems, such as the new location of the refreshment stand, chameleon problems, the initial sand replenishment colour, etc. made this a complex task. The result of all these works, however, finally proved to be a satisfactory resolution of the problems for the people involved within the project.

Although this project is a good example of an Integrated Environmental Dune Restoration, erosion problems in Punta Candor still remain unsolved due to the continuous retreat of the coastline. Therefore, it will be necessary to periodically carry out seasonal sand replenishment in order to maintain this successful situation.

### Valdevaqueros

Once natural dune behaviour starts to affect anthropic infrastructures, these interactions can become a problem. Besides several new actuaciones to improve the accessibility of Valdevaqueros beach, three alternatives have been analysed to address the encroachment of the Punta Paloma road by the Valdevaqueros dunes. In this case, the least costly alternative consists of designing a new road connecting the Punta Paloma local road with the main road. In this way, the mobile dunes could develop a more sustainable natural stabilization. Nevertheless, this alternative is still under consideration by the Tarifa Town Hall and Punta Paloma military headquarters.

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