Case study: Lido of Sète (France)

Technique: Dune rehabilitation

Note:

This report has been based mostly on a report assessment made by BCEOM in 2000-2001 named "Étude générale pour la protection et l'aménagement durable du lido de Sète à Marseillan" (i.e. General Assessment for protection and sustainable management of the lido from Sète to Marseillan). This assessment has been committed by the Sète town council in order to define a strategy for protection and development of this part of the coast strongly used and under serious threat of dissapearing.

Location

The town of Sète is located in the coast of the french region of Languedoc-Rousillon, near the city of Montpellier. The coastal area is characterised by the presence of several lagoons, the most important of which is the Thau lagoon. The lido of Sète to Merseillan can be defined as the narrow sand spit which separate the Thau lagoon from the Mediterranean Sea, between Sète to the east and Merseillan to the west. The referred perimeter extends through 12km, between the Grau du Xvème at the west (Municipality of Marseillan) and the channel of Quilles at the east (Municipality of Sète).

Coastal morphology and dynamics

The Gulf of Lion constitutes a vast oberture of the french coast to the Mediterranean sea, of 200km linear coast in which a large variety of morphologies and environments take place. Its littoral is characterised by long sandy bodies (barrier islands) interconnected by rocky capes. These barrier islands, through the effects of longshore currents, are the responsible of the formation of the many coastal lagoons present. The gulf can be divided into 5 independent transport cells (from the Rhone delta to Cape Creus), the second of which corresponds mostly to Sète's coastal front. In this cell the overall sediment transport is done from NE to SW.

From a geological point of view, the study area is formed by three sedimentary series recently constituted (from the BRGM geological chart) :

- Mount St. Clair (rocky shores): Jurassic limestones.
- Thau lagoon (sedimentary shores): modern alluvial sediments, with a recent barrier spit, also known as lido.
- Cap d'Agde (rocky shores): basalt flows and tuffites.

After the last Pliocene orogenic stages in the region, the genesis of the coastal formations was done simultaneously to the Quaternary transgressive and regressive episodes. Then, the sand bodies were stretched between the rocky capes of Cap d'Agde and Mount St. Clair. The last transgressive event (Versilian, 5000BP) appointed the closing of Mediterranean bays. The total isolation of the Thau lagoon from the sea by a barrier spit took place in late XIVth century. The emerged body (barrier spit) is constituted by 20m of sand and silt, which lie over a conglomeratic basement. The upper fraction of the sedimentary body is constituted by muddy sands and silt of 1-2m thick, lying over brown sands and under a thin layer of fine sand, that can be easily transported by wind. The submerged sediments are characterised by fine sands, of aproximately 1m thick in the submerged sandbars.

The data from tide gauges and satellite observations show that the mean sea level raised 15cm since the beginning of the XXth century, at a mean speed of 1.5mm/yr. The most frequent predictions (IPCC, 1998) considered an elevation of the sea level from 20 to 40cm (horizon 2050). The extreme values measured for Sète are about 1m, behind the storms of november 1982 and december 1997. The sea level variations depend on various factors, combinable between them, as seen:

- astronomical tide (mean level variation of 20cm),
- meteorological factors (wind),
- hydrodynamic factors (shoreline currents),
- atmospheric pressure,
- morphological factors (coastal shape).

The wind is an essential morphodynamic factor of the Mediterranean coastlines, responsible of the formation of dunes. In the area of the Thau lagoon, the most important wind directions are:

- NNW: 300º – 340º; wind from land, formerly known as tramontane or cers; represent 36% a year.
- NE: 20º - 30º; wind from land, known as mistral; represent 15%.
- SE: 120º - 140º; wind from the sea; represent 15%.

The transported volumes depend basically on the sediment characteristics (particle size) and on the wind speed, but also on the beach moisture, among others. The mean eolian transport in the site of Sète (J.F. Rueda, 1985) is about 250m3/m/yr, based upon observations made in the period from 1978 to1983. A typical Mediterranean sedimentary coastal system can be divided into three compartments working in close relation. The submerged part is limited all wide by the breaking zone, whereas the "active beach" or emerged beach comprise the shoreface, foreshore and backshore. The terrestrial part are the single or multiple functional dune strips, a true barrier for marine stormwaves, which are separated from the fossil dunes by foredune basins. The functioning of these systems is based upon two dynamic factors: the southeastern storms and the land winds. The first push the sediments hold in the submerged system onto the backshore (or conversely, depending on the capacity of energy absorption of the beach), and the second return the sediments to the beach, hence restoring the shoreline.

The nearshore bottom in front of the lido of Sète is characterised by the presence of a set of longshore bars, parallel to the shoreline. South of Marseillan, three longshore bars have been identified: an distal bar at -4m depth, a proximal bar at -2m and the shoreface. In front of the lido of Sète the sea bed present only two bars: the distal one which is a prolongation of the aforementioned, and the proximal one, close to the shoreline. The progression of the bars is closely related to a sequential dynamics, by a succession of deposits over the bar slopes (E. Akouango, 1997).

The sedimentary movements which produce variations in the beach profiles are the resultant of the action of the hydrodynamic factors on the available sediments. These factors comprise the waves and wind, which are the most important, and with minor importance the tide-generated currents. These profile evolutions mean modifications of the beach and sea bottom levels, and hence on the distribution of sedimentary materials all along the profile. The resultant of the coastal sediment transport is a longshore drift which runs from north-east to south-west, with an average volume of carried load of 20,000 - 40,000m3/yr. The evolution of the coastal strip between Sète and Cap d'Agde has been analysed using aerial photographs, comparing them with the topo-bathymetric profiles done by the Service Maritime during 15 years. A generalised loss of beach surface has been stated, near 23.5ha in places without engineering protection, and a maximum shoreline retreat of 50m for the period 1954 – 2000 (like Plage de la Corniche – breakwaters). For this reference period, the central part of the lido present a stable configuration of the shoreline, with little accretion, whereas the north and south sectors suffer strong erosion, particularly off protected areas. In the central part a positive variation of volume (accretion) has been stated.

Purposes of dune rehabilitation and expected results

The object of the *"Étude générale pour la protection et l'aménagement durable du lido de Sète à Marseillan"* consist on define a strategy for protection against marine erosion, efficient on the long term, and the opportunities raising from sustainable management with respect to the following objectives:

- Define a strategy of protection against erosion using techniques as soft as possible,
- Maintain the natural conditions and behaviour of the beach,
- Propose those solutions of sustainable management compatible with the existing protection techniques.

The scheme for protection and sustainable management of the lido from Sète to Marseillan has been based upon several prerrogatives, some of which are:

- Restore the normal behaviour of the beach and assure a durable protection against erosion,
- Assure an efficient protection of the inner wetlands,

…among others.

The actions to carry out for restoring the natural conditions of the beach and dunes are the reshaping of the beach profile (to 70 – 80m width), as well as the reconstrution of the dune cordon (3m high per 20m width) behind the backshore.

Basic principles

To be completed.

Expected benefits

Environmental benefits

The BCEOM assessment draw few good impacts of the measures planned to take in the different sectors defined below. The environmental benefits found are the increase of the capacity for soften incident waves (breaking and storm waves), the upgrading biodiversity, as well as enrichment of landscape quality.

Social and economical benefits

No information available.

Technical and financial benefits

No information available.

Designing dune rehabilitation scheme step-by-step

*Collecting baseline information (in reference to **comp 2**)*

No information available.

*Assessing the "do nothing" scenario (in reference to **comp 3**)*

Different alternatives arise from the several studies consulted, as well as from expert opinions, interviews and focus groups with local stakeholders (Report of Sète for Component 3 Messina). The main objective of the alternatives is to define a strategy to protect the lido from the coastal erosion that is suffering from long time ago. The displacement of the road is the element as a key component to define different philosophy of action. On this basis, four main lines have been established:

- Do nothing and maintaining the current situation,
- Hard-engineering coastal defences on the shoreline and reduced intervention on the lido,
- Move the road backward until the limit west of the ancient dunes,
- Move the road backward just close to the railway.

The "Do nothing" alternative implies remaining in the current situation. Coastal erosion is only faced with high monetary-cost, emergency procedures like repairing the road when it is damaged by a storm, maintaining the breakwaters in front of the Lazaret beaches and cleaning the road and dunes periodically. This alternative implies maintaining costs every year and does not match the objective of long term and sustainable protection of the lido.

Selecting the adequate dune rehabilitation techniques

The town of Sète, after analysing the fourth hypothesis drawn-up by the assessment, proposed the hypothese nº3 of creating a "sanctuary" in the lido between the reconfigured Castellas camping and the Villeroy bottling company. This hypothese of management lay on the principle of strategic realignment for a sustainable protection of the lido, that is to say, moving the coastal road close to the railway. One of the techniques proposed in this hypothese is the reconfiguration of the dune field between the 'Plage de la Corniche' and Marseillan.

The actions to carry out were divided into different sectors of the lido:

- *Lazaret beach between the Corniche point and 'le grau des Quilles'*

  The dune of Lazaret will be reconfigured in order to create a dune formation simulating a natural morphology composed by a large beach, a first dune cordon (active) and some others (ancient). This reconfiguration will be made simultaneously to a new structure made with ganivelles, allowing to maintain the new dune in place. On the long term, a monitoring of these structures will permit on one hand to carry out functional adaptations of this morphology to dynamic modifications, and on the other hand, assure a background of experience. In addition, to limit the wind-blown inputs of sand on the dune of Lazaret some ganivelles will be placed perpendicular to the shoreline and to the dominant winds as well.

- *La Corniche beach to PK[1] 30,25*

Among other actions to be carried out in this place, a dune equiped with ganivelles at the height of 3m above NGF, with a beach slope of 2/1 and rear-dune slope of 5/1.

- *La Corniche beach from PK 30,25 to PK 30,75*

The reclamation of the upper beach and the creation of a dune cordon will permit in addition to soften the effect of breaking waves which could overpass them, including storm waves. The management works can be divided in two phases, the first of which is prioritary, which consist in the suppression of the coastal road and the reconstruction of a large beach and a dune ridge.

- *The coast between PK 30,75 (ZAC de Villeroy) and PK 32,5 (bottling company)*

The prioritary works to be carried out here are the moving of the coastal road close to the railway and the reconstruction of a large beach and a dune ridge.

- *The coast from PK 32 to PK 40*

The reallocation of the road close to the railway will permit to link the ancient dunes with the active ones (with those subsisting), creating a vast dune field of about 150m long. At shoreline level, in order to recreate a coastal system in equilibrium on the long term, that is to say, capable to respond to the present hydrodynamic characteristics and to anticipate the future trends (sea level rise, increasing storminess, …), it will be necessary to reconfigure the beach profile responding to the next criteria:

- a dune cordon of 2 or 3m height, and 30m long;
- an active beach of 70m width;
- a beach slope of 1/50 to 1/70 (mean grain size of 0.22mm).

The reconstitution of a large beach will be made possible by the backward placement of the dune baseline. The softening capacity of incoming waves and the sedimentary exchanges throughout the profile will be then increased, necessary for maintain an active dune field. Associated to an efficient management of the dunes, this new configuration better resist the sea assaults.

- *The coast from PK 32,5 to PK 37,2 (Camping Castellas)*

All through this 5km of coast, the system can be directly linked to the large dune field (20 to 80m) bordering the vineyards of Listel Company. The suppression of the coastal road help to recreate a coherent beach profile. At the time of dune cordon creation, the places presently used as parking areas will be filled in to be incorporated to the new dunes, being necessary a little sand input. These dunes, reinforced by a series of ganivelles, will be stabilised by vegetation, using as much as possible local species.

- *The camping of Castellas (PK 37,2 to PK 40)*

The place recovered will be used for reshape the active beach, similar to the previous section, of about 70 to 80m width, using as much as possible the autochthony material after the removing of the road pavement. The dunes will be equiped with ganivelles (with public pathways) and will be entirely vegetated, with the aim to increase its stability and resistance in front of marine attacks.

- *The coast from Camping Castellas (PK 40) to Port du Marseillan beach (PK 41,2)*

The solution is the same for the planned for the northern sector of the camping.

- *The ancient dunes of the lido of Sète*

The displacement of the coastal road that will be translated into a beac restoration (80 to 100m width), allow to consider the reconstruction of a true dune system. Moving the dune baseline backwards, the ancient dunes will serve as foundation to the new dune cordon. The beach width will assure a consequent softening of breaking and stormy waves. The continuous dune cordon,

[1] PK=kilometric point

maintained by ganivelles, will allow to catch out windblown sediments and will limit marine intrusion.

Establishing environmental mitigation strategies

No information available.

Designing long-term monitoring

For the different management strategies taken into account, it will be necessary to make a long term monitoring of the coastal zone (beaches and dunes). This monitoring will allow to observe the evolution of the managed sectors, especially after storm events, and to assess the need for implement the measures prescribed in the second phase in the area comprised between ZAC de Villeroy and the bottling company in front of Castellas camping.

- *Topo-bathymetric survey*

A series of topo-bathymetric profiles (one per kilometre), twice a year (end of winter and end of summer), will be done between Sète and Agde. These profiles will cover the edge dunes, the beach and shoreface until the –10m depth. After exceptional storm events, several profiles will be done immediately after the storm and 1 to 2 weeks after, in order to evaluate the recovering speed. The same work will be done in foreshore areas.

The collected data will be analysed for comparing sand volume variations, morphological changes of the berm, dune foot, dune ridge and beach slope.

- *Quality of the bordering dune*

A qualitative survey of the state of the edge dunes will be done twice for comprehension of flora evolution as well as for assess the state of the measures taken (ganivelles). This survey will be made taking pictures along the same profiles mentioned before, between Sète and Marseillan-Plage.

- *Aerial photographs*

An aerial survey taking georreferenced vertical pictures of the coast between Sète and Agde will be realised following the same premises used for the one made in 2000. The comparison between aerial flights will allow to assess, in particular, the evolution of beach width.

Factors influencing the success of dune rehabilitation schemes

No information available.

Assessing and monitoring the environmental and social impact of dune rehabilitation schemes

Impact on shoreline stability

In order to assess the efficiency of the management strategies proposed (and evaluate its impacts), that is, the slight emerged detached breakwaters in front of ZAC de Villeroy and bottling co. (PK 30,25 to PK 32,5) and the reconstruction of the dunes (PK 32,5 to PK 40), two types of models have been developed using COSMOS 2D and BEACHPLAN (HR Wallingford).

COSMOS 2D is a software of numerical modeling of physical processes acting on the breaking zone and beaches. This model simulates the next processes :

- transformation of the waves due to refraction, effect of shoaling, breaking and friction with sea bottom,
- forces induced by waves and its formation,
- vertical dispersion of cross-shore currents,
- longshore transport of sediments,
- sea-floor modifications.

For the present example, the possibilities given by COSMOS 2D will permit to analyse the behaviour of the beach after a storm event, present situation and after measures taken.

BEACHPLAN is an application for simulate the evolution of waves. It will help to predict the evolution of the shoreline after coastal protection works (placement of breakwaters, groins or beach nourishments). The next processes are taken into account :

- transformation of waves due to refraction, effect of shoaling and diffraction,
- the artificial restoration of sediment transport around hard structures and the wave transmission through them,
- the solid transport (CERC formule) and the allocation of shoreline transport along the beach profile,
- the techniques of beach maintenance like beach nourishment or sand extraction.

For the present case, BEACHPLAN offer the possibility to illustrate the effects of breakwater construction on shoreline evolution.

The results arising from the simulations of COSMOS 2D and BEACHPLAN confirm the effects of the management measures proposed for the lido. The creation of a wide beach, of light slope (1/70 to 1/80), limited by a dune cordon help to soften the effects of storm waves. The erosion recorded in the profiles is important (foreshore retreat, full-length erosion) but markedly lower than in a backshore limited by longitudinal structures like rock revetments. The placement of breakwater-like structures lead to a regressive evolution of the shoreline between neighbouring structures. The subsequent nourishments done could contribute to reduce the negative impacts but they must be done periodically.

Impact on natural habitats

No information available.

Impact on coastal vegetation

No information available.

Social perception

No information available.

Budgeting dune rehabilitation schemes

Two stages of the scheme for protection and sustainable management of the lido from Sète to Marseillan are distinguished herefold (URBANIS, 2004).

Feasibility costs

Feasibility studies include:

- Realisation of technical studies (topographic surveys, bathymetric surveys, preliminary geotechnical assessment) necessary for a good definition of the project;
- Definition by the master of works of the pre-project besides the project is submitted to inter-administrative evaluation and public announcement;
- Collection of administative procedures (dossier Water Law, dossier EIA, dossier Public Inquiry) until the scheme's declaration of public utility or of general interest;
- Consultation to enterprises for beginning of works.

Next tables show the detailed budget plan for feasibility stage:

Table 1: Estimations for the design phase.

Topographic surveys and percel dossiers, preliminary geotechnical assessment, EIA, Water Law study and dossier of public inquiry (Table 1A)	**230 000 €**
Juridical and technical assistance for setting-up a Syndicat Mixte	**30 000 €**
Assistance to Master of Works in the design phase (AMO[2] principal and AMO specific) (Table 1B)	**476 000 €**
Archaeology	**130 000 €**
Design of works	**1 538 811 €**
TOTAL COSTS except various expenses and unanticipated	**2 404 811 €**
Various expenses and unanticipated (10%)	**240 481 €**
TOTAL COST	**2 645 292 €**

Table 1A: Detail of the estimated cost for technical studies.

Topographic survey	**30 000 €**
Preliminary geotechnical assessment	**10 000 €**
EIA	**100 000 €**
Water Law assessment	**40 000 €**
Dossier of public inquiry	**50 000 €**
TOTAL COST	**230 000 €**

[2] AMO: Assistance à Maîtrise d'Ouvrage (Assistance to Master of Works)

Table 1B: Decomposition of Principal AMO and Specific AMO's.

Principal AMO (60% in design phase)	**246 000 €**
AMO Communication council	**50 000 €**
AMO Juridical assistance	**20 000 €**
AMO Expertise salaries	**30 000 €**
AMO Geotechnics	**100 000 €**
AMO Coordinator Security & Health Protection	**30 000 €**
TOTAL COST	**476 000 €**

Environmental mitigation costs

No information available.

Investment and engineering costs

Taking into account the imprecissions of certain number of available data (topography, geology,…), the financial estimations for this phase are aproximated. An error margin has been logically integrated in the estimations, with important uncertainties.

Herefold is depicted the financial estimation for the different actions to carry out:

Table 2: Financial estimations per action to carry out.

Land acquisistion	**630 000**
SUB TOTAL	**630 000**
Strategic realignment and protection against erosion	
Preliminary works	410 000
Reallocation of the coastal road	13 050 000
Demolition of the road close to the beach	810 000
Restoration of dune cordon and beach	6 230 000
Requalification of rear dune fields	730 000
Reorganization of the local residents network linked with the coastal road reallocation	1 115 000
Partially emerged detached breakwaters in sensible areas	8 000 000
SUB TOTAL	**30 345 000**
Parking, bicycle paths and TCSP way	
Reoganisation of parking areas by integrated parking areas management	3 190 000
Bicycle paths	1 900 000
Transport road between neighbouring communities a shuttle vehicle along the beach	1 470 000
SUB TOTAL	**6 560 000**

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Requalification and restoration of remarcable natural spaces and habitats	
Requalification of the accesses at saltspans of XVème	**100 000**
Reclamation of the dykes of Villeroy and Xvème saltspans	**200 000**
SUB TOTAL	**300 000**
Reception and public sensitisation equipments	
Infrastructures of reception and interpretation	520 000
Rehabilitation of the Redoute du Castellas	50 000
Signals	50 000
Aid stations	80 000
SUB TOTAL	**700 000**
Private works	
Restructuration of Castellas camping	2 500 000
SUB TOTAL	**2 500 000**
TOTAL	**41 035 000**
Various expenses and unanticipated (11,9%)	4 888 894
Assistance to Master of Works (AMO's), Master of Works, works of communication phase	570 225
Mastery of Works phase works (3,75%)	1 538 813
TOTAL COSTS IN €	**48 032 932**

Maintenance and monitoring costs

Regarding the maintenance costs of dune spaces, the *Communauté d'Agglomération du Bassin de Thau* expected an estimated cost of 38 500€ per year for diverse works of dune maintenance and restoration of ganivelles. In Marseillan, these costs are estimated around 10%, being 3 850€ / year. The relative costs of dune maintenance will increase in the coming years due to increase in the number of ganivelles installed, which usually shall be maintained, repaired and changed. Some predictions hold the hypothesis of a cost multiplication per 4, being 168 000€ per year.

Limitations

No information available.

References

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