Coastal Environments

Discover Ltd.
"Timbers",
Oxted Road,
Godstone,
Surrey. RH9 8AD

www.discover.ltd.uk

Teacher's Notes

This study will enable students to carry out a detailed study of landforms and management of the coastal environment, and to assess the risks to the Camargue from coastal erosion and flooding. The study takes place within the unique landscape of the Camargue (the Rhône delta), one of the largest wetland areas in Europe, covering 780km^2, and the coastline of Langudoc Rousillion. Designated a Natural Regional Park in 1970, the area has an incredible variety of bird and animal life as well as distinctive human traditions. The journey to the coast from the Eagle's Nest takes about 4 hours (depending on the time of year). Three study sites are used to address aspects of the coastal environments core module. The sand dunes and La Grande Motte are located in close proximity. It is then possible to combine this visit with a trip to the coastal town of Ste Marie De la Mer and the salt marshes at the Etang de Vaccares.

Safety

During the summer the beach area is exposed to intense sunlight. Sunscreen and sensible clothing must be taken together with supplies of fluid. All villages in the area have a policy of "covering up" whilst in the built up areas. It is recommended that students have some form of footwear on at all times. This is ESSENTIAL in the dune system. If swimming is to be allowed, staff should be aware that Discover Ltd staff CANNOT take responsibility for this activity. There are areas with lifeguards and safety flags in summer, so any swimming is recommended in these areas only.

Key Specification Areas

- The coastal system – constructive and destructive waves, tides, sediment sources and cells.
- Landforms of deposition – beaches and associated features: spits, bars, dunes and salt marshes.
- Case study of coastal erosion – specific physical and human cause(s) and its physical and socio-economic consequences.
- Coastal protection objectives and management strategies – hard engineering: sea walls, revetments, rip rap, gabions, groynes and barrages. Soft engineering: beach nourishment, dune regeneration, marsh creation, land use/activity management.
- Case study of two contrasting areas – one where hard engineering has been dominant and one where soft engineering has been dominant. To investigate issues relating to costs and benefits of schemes, including the potential for sustainable management.

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Introduction

Coastlines are dynamic environments which undergo continual change in the short, medium and long term. In the short term, coastlines evolve because of changes to sediment supply, tidal movements and processes such as long shore drift. In the long term, coastal environments could be threatened by climate change – our existing coasts could be amongst the most threatened environments on the planet.

Human activity also threatens our coasts. For years people have been attracted to coastal areas for a variety of reasons. This process of coastalisation (the movement of people to coastal areas) is increasing. The demands of mass tourism, changing lifestyles, industry, fishing and transport all have led to this attraction. Also populations displaced by problems inland (such as drought) have added to this number. Now something like 40% of the worlds population live within 60 km of the coast and the UN estimates that by 2010 80% of the worlds population will inhabit a 100km coastal strip. Already 8 of the 10 most populated cities lie within this area. In France coastal population density is now 272 people/km^2 , compared to the national average of 108 and that of Lozere at 15! This has not been without an impact on the natural environment so that now more than a quarter of the land in France located within 500m of the coast has been remodelled in some way. And it is not just France, from 2000 – 2005, 34% of the coast in Portugal, 27% in Ireland and 18% in Spain has been absorbed by urban development.

All this leads to increased industrial, domestic and agricultural pollution of the seas. Biodiversity has been reduced in the face of this increased human presence. Conversely, humans are also putting themselves at greater risk by moving into a naturally dynamic area. With global climate change coastal dynamics are expected to accelerate and sea levels rise. If the most pessimistic predictions are to be believed , then 150 million people could loose their homes worldwide by 2020.

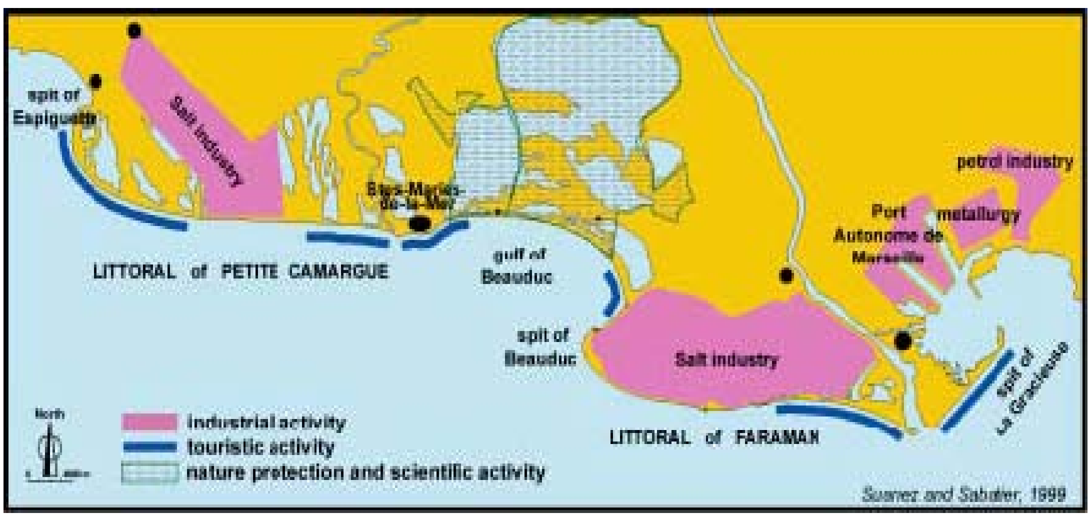
The Camargue

In France there has been a policy of protecting natural coastal sites since 1975, encouraged by the Coastal Conservatory (Conservatoire du Littoral). The growing pressure on this region of southern France caused by the increasing number of visitors led to the development of a “Parc Naturel” – the Camargue. This ensures the protection of this fragile landscape. Much of the Camargue is on the Rhône delta, which has developed as a result of the deposition of sediment from the river Rhône, something like 80,000 hectares over 6000 years. Sandbanks have been formed and built up into a dune system that now separates a number of lagoons from the sea. The abundance of water - both fresh and salt, together with the flatness of the area and abundance of wind have resulted in a unique environment which provides a variety of habitats.

In particular, the delta is an internationally important area for migrating birds - over 300 species have been recorded at different times of the year. A Nature Reserve was created in 1928 in the Etang de Vaccares where human activity is limited. The coast is made up of a series of etangs (lagoons) and sandbars. Economic development is limited and is mainly concerned with tourist resorts. Embankments along the two arms of the river Rhône and a sea defence dyke were completed in 1859, making the Camargue an area of largely artificial water levels. The idea was to desalinate the water and create a wheat belt similar to that of the Nile Delta. However, this did not take account of salt water infiltration through the underground water table. Now the area can be largely divided into three zones, salt-water pools in the south used by the salt industry, brackish areas in the centre classified as nature sanctuaries and agriculture now concentrated in the north. Thus it maintains a natural appearance through its size and diversity of ecosystems, even though neither the sea nor the river floods across it anymore.

The rich and diversified land of the Camargue has always been populated. Currently about 9000 people live in the area with about 40% of the land farmed, usually on the higher ground of the former riverbeds. Cereals and fodder crops on the non-irrigated land; vineyards and since 1950 rice paddies on the improved, irrigated land. These paddies covered up to 20,000 hectares and considerably changed the face of the Camargue. This dominance led to overproduction and therefore a deflated price, so since 1970 only one-third of the rice paddies have been used. However, the use of these fields for rice meant that the salt was removed from the soil, thus preparing the way for other crops. There is an abundance of fruit growing and market gardening.

Pastoral farming also takes place. About 80,000 sheep graze on the high ground moving to the alpine pastures during the summer months (transhumance). On the lower salt steppe, the black bulls are bred. A herd comprises 100 to 250 head of cattle. The best bulls are used for the "Course a la Cocarde", a symbol of the Camargue tradition. Also found here are the white horses, these are indispensable to the cattle herders - they are also used in the tourist industry for pony trekking. Fishing is a traditional activity of the Camargue and is mainly carried out in the lagoons. However, there are few professional fishermen. Salt forms another major industry - sea water is pumped from the sea at Beauduc, slowly circulating through the lagoons, known as evaporators, gradually increasing in density until it finally reaches the settling beds completely saturated with salt. It covers a distance of 50 km between Beauduc and the beds where the salt crystallises near Salin de Giraud where it is harvested from the end of August. An average annual harvest is 600 000 tonnes - the largest in Europe. Salt production can be seen near Aigues-Mortes.



Aims

- To investigate coastal environments on the Camargue – salt marshes and sand dunes;
- To understand the constructive nature of the waves on this coastline;
- To visit coastal protection schemes on the Camargue and study examples of hard and soft engineering approaches;

- To gather case study information on two contrasting approaches to coastal management on the Camargue.
- To assess the risk of erosion on the Mediterranean coast.

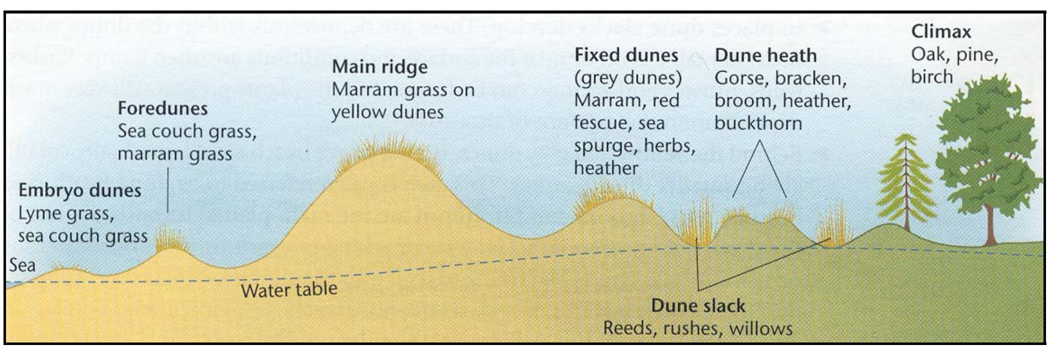
Objectives

- To identify coastal landforms and ecosystems in the area and understand what management strategies are in place and assess their effectiveness.
- To measure wave action and long shore drift and understand what risks are associated with the coast in close proximity to the studied resorts.
- To determine the problems of coastal erosion within the area, and carry out Cost-Benefit Analysis and Environmental Impact Assessment in Ste Marie de la Mer.

Exercise 1: Investigating depositional landforms - sand dunes and salt marshes.

When winds blow from the sea, this dry sand will be moved up the beach by saltation. This process is interrupted when sand is trapped by obstacles on the berms or at the point of the highest spring tides. Gradually these sand deposits will build up and become colonised by plants, such as marram grass, which are adapted to the salty conditions and have long roots to enable them to survive on the shifting sands The grasses trap more sand and their long roots help hold the dunes together, stabilising the area This results in embryo dunes, which can grow in size and link to form a ridge. Over time these dunes stabilise and show distinct changes inland as shelter from the wind increases and the supply of sand is reduced. Further from the beach the dunes are often larger with a greater variety of vegetation.

A cross-section of coastal sand dunes at La Grand Motte (Barker, Redfern and Skinner, 2008)



Wind blown sand accumulates around the bases of the plants; this stabilises the dune and starts the process of soil structure improvement. As succession proceeds the plants deposit more organic matter. This increases the capacity of the soil to hold water and nutrient ions.

Embryo-Dunes	**Yellow “mobile” dunes**	**Grey ‘fixed’ dunes**
Colonised by grasses, e.g. marram grass	Dunes grow rapidly as marram grass accumulates wind-blown sand, and grows through it. Sea spurge, clematis and chamomile may become established.	Sand stabilised by flowering plants, e.g. Helichrysum, artemesia, sea stock and members of the dandelion family.

Whilst dunes can, in theory, achieve a state of relative equilibrium, it is very easy to upset the balance. Paths cut by humans and animals often expose areas of sand within the dune system. As the wind funnels along these tracks, “blowouts” may form. This can be controlled through fencing off an area and allowing the dunes to re-stabilise. Other problems may arise through dune migration - the inland movement of sand that has the potential to damage settlements and agriculture. Fencing can be used to restrict such movement.

Method and Organisation Of Study

Task 1: Sand dune study.

It is possible to carry out a brief investigation into the development of sand dunes and the vegetation which colonises dunes, as outlined below. This study takes approximately 1 ½ hours and investigates the primary succession (psammosere) which is found on sand dunes, recording sheet 1.

Task 2: Soft Engineering Solutions - Sand Dune stabilisation and beach extension schemes.

Next to the main road junction is an area which has been actively managed to repair the seriously deteriorated dunes. There was a major dune blow out at this site which may have occurred as the site is opposite the slip road from the dual-carriage way connecting La Grande Motte and Montpellier. For people coming from either direction, this would be the first area of beach they came to, and therefore had the greatest visitor pressure on it. Trampling removed the vegetation from the dunes in this area, destabilising the dune and eventually the sand blew away. The removal of the dunes, which would have trapped sand before it blew onto the road, lead to the road being blocked by sand after strong on shore winds. This became an economic issue for the local council who have to maintain the roads.

To restabilise the dune, sand was piled up to form an artificial dune. Chestnut fences were erected in lines parallel to the beach on the new dune and marram grass and Italian poplar and tamarisk trees planted between the rows of fences, to speed up the natural colonisation of the dunes by native species. The local council has erected notices on the stabilised dune to educate people about their aims:

In the summer of 2008, plans were announced for the improvement of the beach at La Grande Traverse. This is likely to involve soft engineering approaches such as beach nourishment, and the regeneration of dunes and active management of public access to the sand dune system. This has already begun, with the erection of fences along the beach front from La Grande Motte to Carnon-sur-Plage. Take digital photographs of the beach and measures for regenerating and protecting the sand dunes, for annotating later. Annotations should include the positioning of fences, any damage to the dunes evident from your position (litter, signs of trampling, dune blow outs, etc.) and the approaches used for dune stabilisation.

What methods are going to be used to accomplish this scheme? The scheme is estimated to cost in the region of 10 million euros. What are the likely benefits of this scheme to the following stakeholders: 1) Local chamber of Commerce? 2) Tourists? 3) Conservatoire du Littoral (conservation body in the Camargue area)?

Complete the bipolar evaluation of the costs (actual and aesthetic) for this scheme:

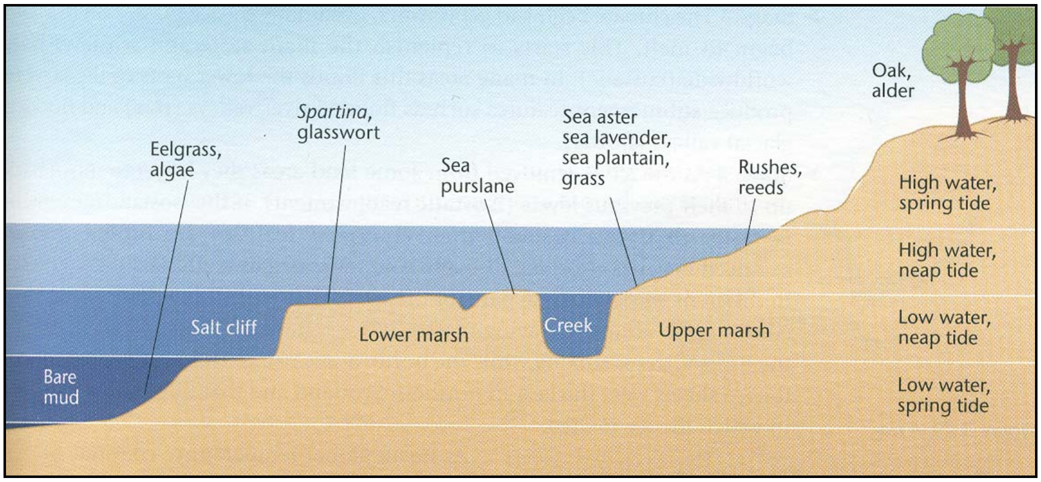
	Score						
Negative Factors	-3	-2	-1	+1	+2	+3	Positive Factors
Vulnerable to erosion (unable to hold the line)							Effective protection against erosion.
Vulnerable to overtopping or storm surges							Effective against overtopping and storm surges
Low aesthetic value							High aesthetic value
Poor access to beach							Good access to beach
High risk safety hazard to public							No obvious risk to public
Short lifespan or high maintenance costs							Good life expectancy and/or low maintenance
High level of disturbance during construction							Low level of disturbance during construction
Disturbs natural coastal process							Maintains natural coastal process

Recording sheet 1: Sand Dune Succession Investigation (Stratified Sampling Technique)

Species	Site 1. Top of first dune ridge					Site 2. Bottom of first dune ridge					Site 3. Wet slack community.					Site 4. Climax woodland.				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Marram grass																				
Sea spurge																				
Chamomile																				
Clematis																				
Helichrysum																				
Sea wormwood																				
Sea stock																				
Rush species																				
Reed species																				
Mosses																				
Pine																				
Bramble																				

Microclimate variables:				
Air humidity (%)				
Air temperature (oC)				
Wind speed (m/s)				
Soil factors:				
Soil pH				
Soil Temperature (oC)				
Soil moisture (collect sample)				

Task 3: Salt marsh ecosystems – visit to the Etang de Vaccares and la Capilliere Reserve.



Salt marsh ecosystem and succession (Barker, Redfern and Skinner, 2008)

The Camargue is the delta of the River Rhone. The true Camargue lies between the two major tributaries of the River Rhone, the Grande Rhone and the Petit Rhone, which diverge at the town of Arles. In the 30km between this split and the sea, the Rhone splits into many channels to form a delta, where the river drops its heavy alluvial material into the Mediterranean, which has a limited tidal range. As the river enters the sea, its velocity is reduced and deposition occurs. When the freshwater of the river meets the salt water of the sea, an electrical charge is produced, which causes the suspended clay particles to coagulate and to settle onto the sea bed. ('flocculation'). The finest particles are carried furthest from land and eventually settle to form bottom-set beds. These are then covered by coarser material which is deposited to from a slope. These are called fore-set beds. The upper layers nearest the land are made of the coarsest sands and gravels, and are called top-set beds.

The Camargue is made up of many distinct ecosystems: cultivated areas of rice and market garden crops and fruit trees dominate the north, furthest away from the sea and its salt influence. There are brackish, salt water and temporary marshes, coastal salt meadows 9the 'sansoire') and beaches and dunes.

You will take a walk through the reserve, La Capilliere, and take notes on the different stages of the salt marsh ecosystem, guided by your group leader. You will pass through a range of Camargue ecosystesm, representing some of the stages in a halosere succession sequence.

The Camargue Salt Marsh Ecosystem: a dynamic halosere.

Salt water lagoons and margins: Many of the lagoons to the south of the Camargue, nearest the sea, are brackish. Where sand bars and spits have separated these lagoons from the sea, their salinity is lower than that of sea water, due to the ingress of water from the Rhone and irrigation of the Camargue. Around the edges of these brackish lagoons, mud is deposited which is colonised by a series of halophytic plants such as glasswort and spartina.

Sansoire: Seasonally flooded salt-meadows. These areas are flooded only in Winter and Spring, when the water level of the river Rhone rises. Plants which dominate this area are halophytes such as glasswort, annual sea blight and sea purslane. The area is grazed by the Camargue bulls (used for meat and bull fighting in the Camargue and Spain)

Freshwater marshes: Found in the upper and middle Camargue, there are where depressions surrounded by levees have become inundated with fresh water. These marshes are supplied by irrigation water pumped from the river Rhone – rain water alone is not enough to sustain them. In these marshes are areas of open water, which may have water crowfoot floating in them. Emergent plants such as reeds, iris, bull rush and reed mace may be seen.

Grassland: This ecosystems lies between the sansoire and the riparian woodlands. The influence of salt is less than in the sansoire – the meadows do not get flooded annually, but every summer on the Camargue there is drought, and the salinity of the soil does increase as capillary action draws water up through the soil, and with it, salt. In the winter, the freshwater table rises and the influence of freshwater from rain dominates again. Plants here include sea lavender and the tamarisk tree, which transpire salt water and leaves the salt on its leaves.

Riparian (river bank) woodland: Forests used to cover all the higher (above 2m!) regions of the Camargue, to the north and on river levees, areas which not influenced by salt water. Now many of these areas are under cultivation, and only forest on the edges of the freshwater watercourses survive. Dominant species include white poplar, willow and ash, elm, dog wood and bramble. This ecosystem represents the final stage in succession in the halosere, and plants here do not tolerate salty water, so the area is far from the influence of salt water.

Exercise 2:   Assessing risk on the Mediterranean coast by Measuring Wave Action.

The coast is a narrow zone where the land and sea overlap and directly interact. Of all the natural environments, coasts are the most varied and rapidly changing as they are influenced by atmospheric and marine process interactions. The most source of energy at the coast is the action of the waves, generated by the wind. The frictional effect of wind on the water surface produces motion in the upper layer. However this motion is only a wave shape and not the actual forward movement of water. Individual water particles move in a circular motion as the wave shape passes across the water surface. Waves are created by the transfer of energy from the wind blowing over the surface of the sea. As the strength of the wave increases, so too do frictional drag and the size of the waves. The energy acquired by waves depends upon three factors:-

- The wind velocity
- The period of time during which the wind has blown
- The length of the fetch

The fetch is the maximum distance of open water which the wind can blow, and so places with the greatest fetch potential receive the highest energy waves. As a wave reaches the shore the circular motion is affected by proximity with the seafloor, velocity and wavelength decrease, whilst wave height increases. Individual particles achieve a forward momentum and the wave steepens and breaks on the shore. The type of wave produced will depend upon the steepness of the wave and gradient of the shore.

The type of waves determines whether they are likely to build up or degrade the beach. There are two extreme forms:

Constructive Waves are waves that result from swell and, being flat and gentle, will move material up the beach. They are low in height (usually less than 1 metre), have long wavelengths with up to 100 metres between crests and a low frequency (6 – 8 per minute). These tend to occur on gently sloping, sandy beaches. As the swash moves up the beach it rapidly loses volume and energy due to percolation through the beach material. This results in a weak backwash that has insufficient energy either to transport material down the beach or impede the swash of the following wave. The beach is therefore slowly being built up.

Destructive Waves are waves that are steeper, have a height of more than 1 metre, have a shorter wavelength of about 20 metres between crests and a greater frequency (10 – 14 per minute). The steep plunging nature of the wave produces a powerful backwash that can move material down the beach. At the same time this backwash can reduce the effect of the following swash. These usually occur on steeply sloping coasts. (See Figure 1)

WAVE PERIOD (T) – is the time taken for a wave to travel through one wavelength. If the number of waves striking a coast is less than 13 per minute, the waves are constructive; if more than 13 strike the coast, the waves are destructive.

WAVE LENGTH (L) – is the distance between two successive crests. Constructive waves have a long wavelength (up to 100 metres between crests) and destructive waves have a shorter wavelength (about 20 metres between crests).

WAVE HEIGHT (H) – is the distance between the crest and the trough. Higher waves are often associated with having more energy and therefore a destructive nature.

Figure 1: Diagram illustrating the process of longshore drift:

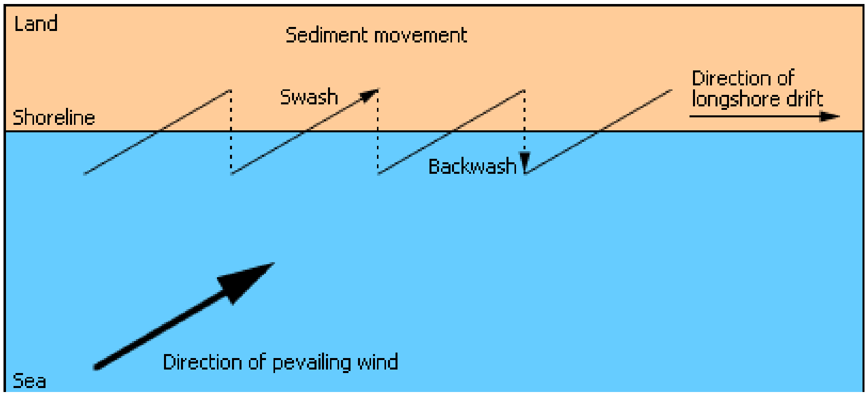
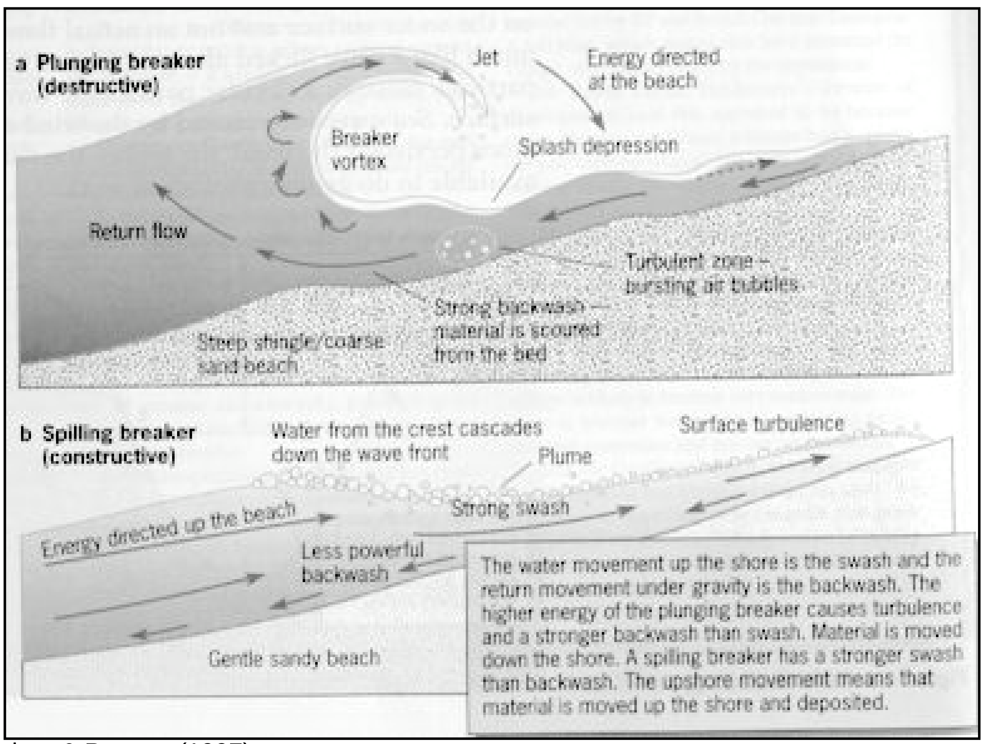


Figure 2: Differences between destructive and constructive waves



Bishop & Prosser (1997)

Constructive waves occur on beaches with a low gradient, therefore they have a wide area to cross and so the energy in the swash (water rushing up a beach) is soon dissipated, leaving a weak backwash (water moving down a beach). Beach material (sand and shingle) is slowly but constantly moved up the beach, gradually increasing the gradient and forming a berm at its crest. Destructive waves are associated with storm conditions and steeply sloping shingle beaches. They plunge over when breaking and their energy is concentrated on a small area of the beach. Where the beach material does not allow rapid percolation the backwash will be at least as strong as the swash. Waves are more likely to be destructive on beaches with a steep gradient and where they approach the coastline at right angles. As material is constantly combed downwards the profile becomes increasingly gentle in its lower section.

For this section of coastline, one would expect constructive waves as the presence of a sandy beach and dune system is a strong indicator. Sand beaches usually have a gentle gradient because the small particle size allows the sand to become compact when wet which severely limits the rate of percolation. Percolation is also hindered by the storage water in pore spaces in sand that enables most of the swash to return as backwash.

Longshore Drift is the movement of sediment along the coast by wave action. When waves approach the shore at an angle, material is pushed up the beach by the swash of the breaking wave in the same direction as the wave approach. As the water returns down the beach, the backwash drags material more directly down the steepest gradient which is generally at right angles to the beach line. Over a period of time, sediment moves in this ‘zig-zag’ fashion down the coast. Obstacles such as groynes can interfere with this process, trapping the sediment.

Exercise Aims

To investigate the action of the sea to determine whether the waves at La Grande Motte dunes are constructive or destructive, and the extent of long shore drift.

Equipment

Ranging pole	Watch
Meter rule	Float
Tape measure	Recording Sheet

Method And Organisation Of Study

1. Wave Height (amplitude). (H)

Measure wave height beyond where the waves are breaking. Stand in the water with a ranging pole. Mark how far up the pole the wave crest reaches and how low the wave trough dips. The distance between the two marks is the wave height (amplitude). Repeat ten times and calculate the average.

2. Wave Period (T)

Count the number of waves breaking on the beach in 1 minute. This is the wave period. Repeat ten times and calculate the average per minute. *The wave length is calculated using the equation in Data Processing and Analysis.*

3. Length of Run-Up/Swash/Backwash

Measure the length of the run-up zone (the zone between the point where the waves break and the maximum reach of the swash). Hold a metre rule vertically touching the sand in the centre of the run-up zone. Record the depth of water in the swash and backwash.

4. Long shore Drift

If the waves are not breaking directly onto the beach, the extent of long shore drift can be measured. Place a ranging pole in the sand to mark the starting point. Drop a cork into the centre of the run-up zone and record how far it moves in 10 minutes. Alternatively, measure the distance travelled in 1 minute and repeat the process 10 times.

Recording Sheet 1: Constructive or Destructive Waves?

Date: ______________ Location: ________________________

Weather Conditions: ____

Note: The column written in italics (wave length) will be completed later.

Reading	Wave height (H) (cm)	Wave Period (T)	*Wave Length (L)*	Length of Run-Up (m)	Depth of Swash (cm)	Depth of Backwash (cm)	Long shore drift
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Mean							

Calculate the Wave Length (L) using the formula: ***Wave length = 1.56 x T2***
(where T is the wave period)

WAVE PERIOD (T) – is the time taken for a wave to travel through one wavelength. If the number of waves striking a coast is less than 13 per minute, the waves are constructive; if more than 13 strike the coast, the waves are destructive.
WAVE LENGTH (L) – is the distance between two successive crests. Constructive waves have a long wavelength (up to 100 metres between crests) and destructive waves have a shorter wavelength (about 20 metres between crests).
WAVE HEIGHT (H) – is the distance between the crest and the trough. Higher waves are often associated with having more energy and therefore a destructive nature.

Exercise 3. Coastal protection schemes in Ste Marie de la Mer

Background

At first glance it is difficult to imagine any reason for the need for coastal protection schemes on the French Mediterranean coastline. The Mediterranean has only a small tidal range (0.3m) and the length of fetch limits the amount of wave energy. Also reference to a map will show the formation of the Rhone delta (the Camargue), which together with historical evidence (such as the port of Aigues Mortes now being 3km inland), suggests that large quantities of sediment are available. However, a more detailed investigation will account for why a number of settlements have engaged in coastal protection.

Changes in the supply of sediment

One of the main reasons for the sandy beaches and sand dunes in the area is the amount of material moved by the River Rhone. This river has a normal discharge of 1500m^3/s, which increases to 6000m^3/s in high flow conditions. As a consequence, large quantities of material have been moved by the Rhone since the last glacial advance. However this supply of sediment has been greatly affected by human activity over the last 100 years. In 1900 the river moved approximately 17million m^3 of material per annum, or 100,000 tonnes every day (try to imagine 5000 lorries carrying a 20 tonne load). This figure has fallen through the 20th century as the Rhone has become increasingly managed to prevent flooding and for hydro-electricity production. In 2000, the river was only carrying 1.5 million tonnes per annum, or about 1/10th of its original load.

Climate Change

Although maybe not proven to be linked to human activity, the increases in global temperature are having an effect upon the Mediterranean. A rise in sea levels plus increased storm activity would make many of the coastal settlements, on low lying land vulnerable to inundation. Although the Mediterranean tidal range is small, winds from certain directions (110 to 130 degrees) can result in exceptional wave surges. In November 1982, Sete was struck by waves up to 11m high after winds reached 150km/h due to extreme temperature differences.

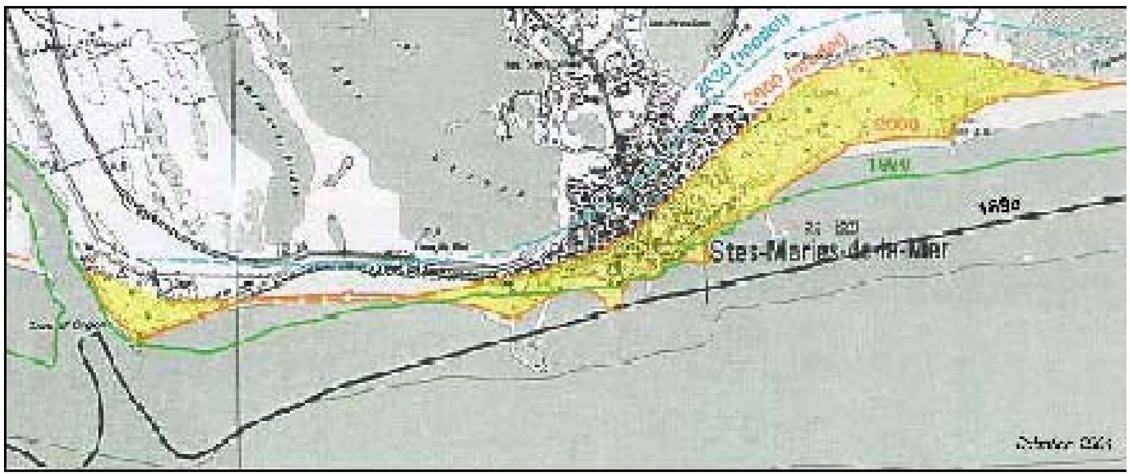
It has been predicted that rising sea levels could result in the coastal strip of Ste Marie de La Mer being isolated from the land by 2035. This is in spite of 15 million euros worth of coastal protection undertaken since the 1990's.

The Nature of the beaches

Whilst the area is blessed with many km of sandy beaches, the low tidal range means that these are actually quite narrow in nature. Therefore any settlement wishing to improve its protection and increase the sand potential for tourists must increase the depth of its beaches.

Coastal Erosion – Ste Marie de la Mer.

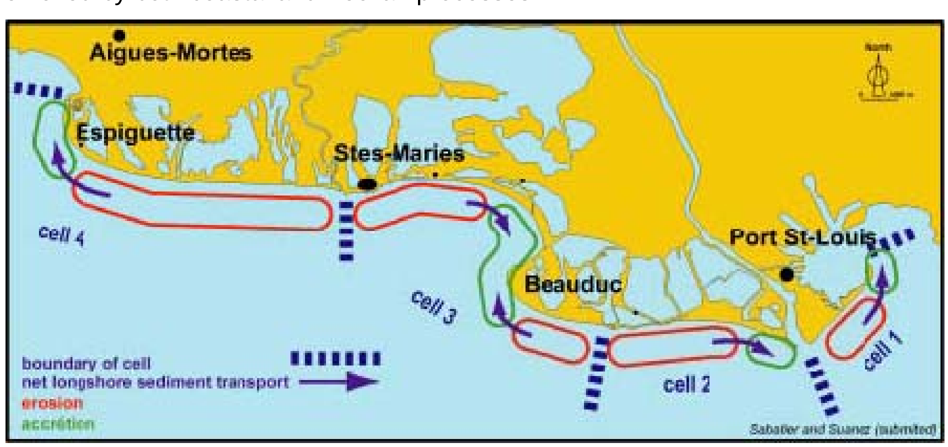
A combination of factors has resulted in the area around Ste Marie de la Mer experiencing some of the fastest rates of erosion in the area (up to 8m per year). It is probably the urban area under greatest risk of erosion in the Camargue.



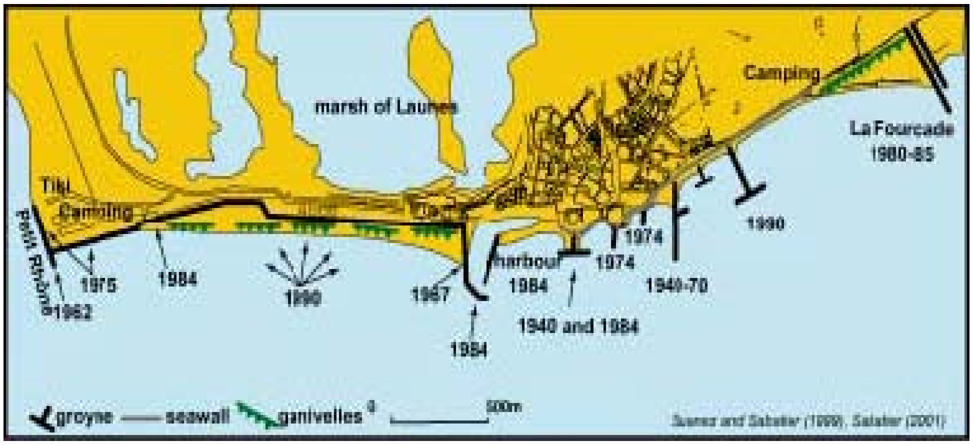
Predicted erosion rates from 1890 coastline to 2030 if no protection schemes had been introduced.

The reasons for this are:

- ❖ The Petite Rhone to the West now brings very little sediment into the sea and most of that is carried away further to the West;
- ❖ The area is at the junction of two coastal erosion cells that are removing beach material both to the east and to the west;
- ❖ Although the fetch in the Mediterranean is small, because it is an enclosed sea, large waves can be generated during storms as it is more difficult for energy to be dispersed;
- ❖ Beach material in the area is often composed of very fine sand (less than 0.2mm) which can easily be removed by both coastal and Aeolian processes.



This problem was realised as early as the 1930's, when a series of wooden groynes were constructed. However since then a number of other protection schemes have been introduced under the policy of "holding the line". These include the construction of stone groynes and breakwaters, granivelles (wooden fences designed to trap wind blown sand, sea walls, and rubble mound armouring (rip-rap). Whilst these have currently halted erosion of the coastline and without them Ste Marie de La Mer would almost certainly be under the sea, they have done nothing to prevent underwater erosion. This is more difficult to measure than pure coastal erosion but will eventually undermine the current protection schemes. The effects of these works will therefore be subjected to greater pressure over time. They have also contributed to the trapping of sediment that would have been carried by longshore drift to beaches further to the east.



When deciding upon Coastal Protection it is normal to carry out a cost benefit analysis (CBA). Under this any costs are forecast (such as building or maintaining defences) and then compared with the expected benefits (the value of what would have been lost). However some of the costs and benefits are intangible e.g. environmental or visual impacts. These are normally covered under an Environmental Impact Assessment (EIA). It is normal to consider any CBA over a fifty year time period

Four options could be considered for Ste Marie de la Mer:

- Do nothing and allow the existing defences to collapse. Erosion would continue at a rate of around 4m per year resulting in all property within 200m of the existing coastline being lost.
- Hold the line, continue to keep the coastline in its current position using existing hard engineering solutions. This would require repairs and ongoing maintenance to the existing structures.
- Advance the line by building more artificial breakwaters out at sea and carrying out beach feeding to increase the width of the existing beach area.
- Retreat the line by allowing the coastline to erode back to a defined line about 100m further inland.

Environmental Impact Assessment

An Environmental Impact Assessment should also be carried out for each option to consider other costs or benefits. Each criterion in the table should be scored from -3 to +3 depending upon whether it will have a positive or negative effect.

	Criteria				
Physical Factors	Erosion				
	Sediment Movement				
	Pollution				
	Wildlife				
	Visual Impact				
Socio-Economic Factors	Safety				
	Property Value				
	Tourism				
	Traffic				
	Business				

Bipolar Evaluation of Coastal Defences

Location: ……………………….. Type of Defence: ……………………………………..

	Score						
Negative Factors	-3	-2	-1	+1	+2	+3	Positive Factors
Vulnerable to erosion (unable to hold the line)							Effective protection against erosion.
Vulnerable to overtopping or storm surges							Effective against overtopping and storm surges
Low aesthetic value							High aesthetic value
Poor access to beach							Good access to beach
High risk safety hazard to public							No obvious risk to public
Short lifespan or high maintenance costs							Good life expectancy and/or low maintenance
High level of disturbance during construction							Low level of disturbance during construction
Disturbs natural coastal process							Maintains natural coastal process

Location: ……………………….. Type of Defence: ……………………………………..

	Score						
Negative Factors	-3	-2	-1	+1	+2	+3	Positive Factors
Vulnerable to erosion (unable to hold the line)							Effective protection against erosion.
Vulnerable to overtopping or storm surges							Effective against overtopping and storm surges
Low aesthetic value							High aesthetic value
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Short lifespan or high maintenance costs							Good life expectancy and/or low maintenance
High level of disturbance during construction							Low level of disturbance during construction
Disturbs natural coastal process							Maintains natural coastal process

Cost Benefit Analysis:

	Do Nothing	***Hold the line***	***Advance***	***Managed Retreat***
Costs	None	Repair existing structures at 20,000 euros per m.	Build new breakwaters (1 million euros each) Carry out beach feeding (1000 euros per m.)	Build new defences 100m inland. (costs of 3million euros per km)
Losses	All property within 200m of current shoreline (assuming erosion at 4m per year)	None	None	All property within 100m of current shoreline.
Benefits	None	Value of all property within 200m of existing coastline	Value of all property within 200m of existing coastline	Value of property between 100m and 200m of existing coastline.
Other considerations including intangible costs and benefits				
Cost-Benefit value				

Coastal Protection Options and associated Costs

Protection Type	Hard or Soft engineering?	How does it work?	Cost per m	Life span in years
Concrete Sea wall			£2500	50
Rock armour or rip-rap			£1000	40
Gabions			£1000	20
Groynes (wood) (stone)			£1000 £1500	25 35
Concrete or stone breakwater			£1.5m each	40
Offshore islands or reefs			£0.5m each	40
Beach nourishment			£1000	5
Sand dune recovery			£1200	15

Coastal Protection in Ste Marie de La Mer

What measures have been taken to protect and increase the size of the beach?

How has this changed the beach?

What negative effects may this have?

How have some of these been addressed?

Walk around the sea defences at Ste Marie de la Mer. Locate and label on this map the following hard and soft engineering solutions on this Google earth image:

- Groynes;
- Rock armour (Rip Rap);
- Recurved sea wall (describe its shape here);
- Sand dune stabilisation

Now try to answer the following questions:

What evidence is there that seaward erosion is occurring at Ste Marie de la Mer?

What are the sources of information which could help you investigate coastal erosion?

What may happen here if these measures are unsuccessful?