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COASTANCE

Eu project COASTANCE **REPORT**

phase B Component 4

Territorial Action Plans for coastal protection and management

Definition of Sediment Management Plans elements

PARTNERSHIP

Region of Eastern Macedonia & Thrace (GR) - *Lead Partner*

Regione Lazio (IT)

Region of Crete (GR)

Département de l'Hérault (FR)

Regione Emlia-Romagna (IT)

Junta de Andalucia (ES)

The Ministry of Communications & Works of Cyprus (CY)

Dubrovnic Neretva County Regional Development Agency (HR)

INDEX

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Introduction on COASTANCE project and aims

Coastal erosion and flooding represent a major threat for the well-being and prosperity of the 70mi Europeans living within 500m from the coastline and their assets of 500-1000 bi€. The loss of seriously impacted areas due to erosion is estimated to be 15 km^2/year. The UN-IPCC estimates that by 2020, due to Climate Change, 50% of Europe's coastal wetlands will disappear as a result of sea level rise, at a cost of 5,400 mi€/year. According to the EC EUROSION project, the regulatory EIA framework, the knowledge-based and traditional measures to control the erosion control have been weak or inappropriate.

COASTANCE proposes innovative techniques for mid-long term coastal protection Master Plans capitalizing on the Good Practices developed under several European projects (INTERREGIIIB & IIIC RFO).

It focuses on those practices that resulted from scientific studies and the understanding of coastal erosion phenomena obtained in previous experiences. The concrete results – Realistic Submersion Risk Forecast Systems, Specific EIA/SEA Procedures and concrete coastal protection Master Plans will be proposed as Governance and Public Policy Tools for erosion control by regional, national and EU Administrations.

COASTANCE focuses on the entire Mediterranean basin. The partners have jurisdiction on 3700 km of coast of which 1600 km are beaches representing 5 out of 7 EU MED member States that cover 95% of EU MED coastline and all characteristic coastal typologies of the Mediterranean:

- low-land areas around big river mouths with long beaches (East Macedonia-Thrace, Languedoc-Roussillon, Hérault, Emilia-Romagna);
- mixed rocky and sandy coastlines (Crete, Lazio, Andalusia, Cyprus);

By achieving such a complete geographic coverage, the COASTANCE partners have the entire set of characteristics related to erosion phenomena in the Mediterranean and thus their work will lead to the development of coherent, plausible and applicable results.

The increasing erosion phenomena and marine flooding risks arising on the mid-long term related to the climate change effects (sea level rising, extreme storm events, increasing frequency and intensity etc.) pushes Public Administrations towards a strategic approach for the Integrated Coastal Zone Management (ICZM) with a particular emphasis on coastal protection.

The loss of rivers solid transport (due to hydraulic works, bridles, crossbars, dams, on rivers), the presence of hard protection works and harbours along the coasts (that intercept the natural distribution of sediments) and the climate changes effects, increased the vulnerability of coastal stretches, today affected by widespread erosion processes and marine flooding hazards. In this framework, it is evident the need of a strategic and sustainable management of coastal sediments, paying attention to the new environmental aspects involved in the related activities. It is noteworthy that the E.U. project EUROSION stressed both the “Shortage of coastal sediments…” (Finding n°1) and the improperness of the “Current Environmental Impact Assessment (EIA) practices...” (Finding n°2) in addressing coastal erosion matter.

COASTANCE project is based on two main operational purposes:

a) Capitalization of knowledge and resources already acquired in the field of coastal protection:

- sustainable Technologies for exploiting sand stocks (behind river barrages, upstream harbour structures, geological sea bottom deposits, etc.) based on Eurosion project, Beachmed, Beachmed-e/GESA/RESAMME Subprojects;
- sustainable Technologies for coastal protection and adaptation (marine-climate survey, beach nourishments, soft structures, use relocation etc.) based on Eurosion project, Beachmed, Beachmed-e/NAUSICAA/MEDPLAN/ICZM-MED Subprojects, Plancoast, Cadseland projects;
- environmental Impact Assessments of the new technologies (dredging activities, nourishment work etc.) and Strategic Environmental Assessment on coastal plans based on Beachmed, Beachmed-e/EUDREP/POSIDUNE Subprojects.

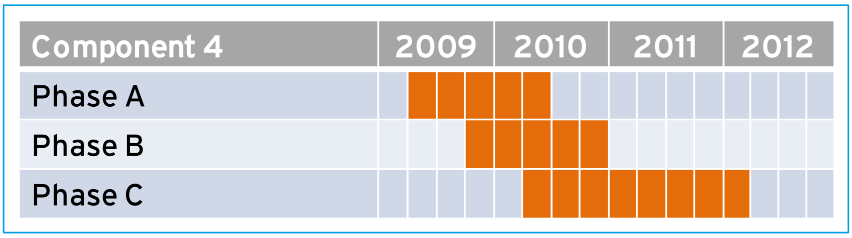
b) Mid to long term planning actions for climate change effects adaptation of coastal zones in line with the EU Directive 2007/60/EC:

- development of Territorial Action Plans for adapting coastal zones to climate change, against erosion effects and submersion risk: Analysis of the erosion and submersion phenomena, Plans for coastal protection management, Guidance and Recommendations for the development of Coastal Protection Management Plans based on previous EU projects findings (eg. Safecoast, Comrisk and Messina);
- definition of Sediment Management Plans (SMPs) for both offshore and littoral deposits exploitation (location, characteristics, radius of competence/beaches to feed, exploitation technology, treatments needed);

- appropriate Environmental Impact Assessment Protocols in order to assure the right procedures in intervening along coastal zone.

COASTANCE project develops in 3 technical Components:
- C3 - Coastal risks: Submersion and Erosion;
- C4 - Territorial Action Plans for Coastal Protection and Management;
- C5 - Guidelines for Environmental Impacts focused on coastal protection works and plans;

plus a Communication & Dissemination Component and a Management & Coordination Component.
The Component 4 is developed in three phases



and has a budget of 511.335,04 € about 26% of project total budget .
The present report is focused on Phase B activities and outputs within the definition of sediments management plans, towards the formulation of territorial action plans for coastal protection and management, foreseen by Phase C

Introduction on COASTANCE Component 4 Territorial action plans for coastal protection and management

The main aim of Component 4 is the formulation of plans for coastal protection and management and adaptation to climate change effects such as erosion and submersion risks. The focus is on low sandy or pebbly coastal zones and their inlands, the most exposed to sea level rise, erosion and submersion risks.

Hard defence structures (e.g. breakwaters, seawalls, groynes), built in the past to remedy suffering situations, often relocated the problem down-drift or anyway to another part of the coast. Very quickly, the limits of these accommodations appeared. New guidelines based on pro-environmental engineering are emerging, focused on the so-called "soft protection" works. Soft options like beach nourishment, while also being temporary and needing regular replenishment, appear more acceptable, and go some way to restore the natural dynamism of the shoreline.

According with the concept that considers the beach as the main defence "structure" for inland areas, actions should be focused on beaches preservation. The strategy framework of low and sandy beaches management is based on two pillars:

- feeding the system with sediment coming from external sources or from sediment accumulations within the system;
- reducing sediment losses through proper management of beach sediment and by reducing the anthropogenic component of subsidence.

In this frame they assume fundamental relevance the knowledge of possible sediment sources (off-shore, littoral and inland) for beach nourishment and the set up of good practices of beach sediment management and preservation.

So the first Phase (A) of Component 4 is focused on the review of state-of-the-art of such knowledge, together with coastal assets and policies of partner's regions, and on littoral management practices nowadays carried on. This Phase provides the information framework and data reorganisation dedicated to plans formulation (Phase C) but also the individuation of information gaps to be filled or practices to be introduced or enhanced. These will be object of deepening in Phase B in order to set up proposals/recommendations, that will be included in Plans coming out from Phase C, for a correct management of beach sediments and for the sustainable exploitation of sediment deposits.

1 Feeding the system (nourishment)	A External sources	Inland extractions	- dam basins dredging - building excavations - quarries
		River solid transport enhancement	- sediment bypass hydraulic works - hydraulic works re-modulation - river vegetation management
		Off-shore deposits on continental shelf	- relict beaches - relict river fans/deltas
	B Internal sources	Littoral accumulations	- by harbour piers, groynes - by breakwaters, landward side - natural accumulation zones
		Submerged accumulations	- active submarine river fans - littoral submarine accumulations
		Hydraulic or navigation managements	- river mouths dredging - harbour mouths dredging - harbour basin enlargement

2 Reducing losses from the system	A beach sediment management	Beach cleaning/ maintenance operations	- in situ sifting or by plant sifting - possible use of landed bio material for dune restoration (branches, boles, etc)
		Aeolian catchments	- break-wind barriers (temp, permanent) - vegetation planting
		Protective winter levees	- sediments from rear beach zone or from out of the system - avoid use front beach sediments
	B subsidence reduction anthropic component	Reduction of u-ground water drawings	- water provision policies - water wells authorisations control
		Reduction of hydrocarbons extraction	- limitation for hydrocarbon-fields extraction near the coast
		Mitigation policies	- fluids re-intro in hydrocarbon-fields - compensative measures

Competence for beach sediments cleaning, maintenance and management

Region of Eastern Macedonia & Thrace and Region of Crete

In Greece the beach sediment cleaning, maintenance and management is a competence of the Ministry of Interior. The Ministry of Interior has granted/assigned this competence to the municipalities.

Some beaches are also managed by private operators, their contracts are renewed periodically.

In most organised beached the public or private operator practices sand cleaning in-situ manually or with the necessary machinery. This is the case in most organised beaches in REMTH and Crete.

In Bati and TOSKA beach, pocket beaches west of Kavala, with private operators, sand sifting is practiced in the beginning of the summer period so as to create more m^2 of sand beach in the same gulf. Summer management of organized beaches usually includes sand cleaning, provision of touristic services, management of touristic facilities, maintenance and operation of showers etc.

Every year, volunteers' organise the cleaning of "free beaches" (not organised beaches with no private operator). This action happens ones a year and it involves manual collection of litter and debris from the beach. The choice of the beaches is random every year.

No winter management has been reported in the REMTH and Crete area.

On the pilot site of Kariani (REMTH) and Keratokampos (Crete) only beach cleaning is performed by the municipality.

In some cases, but not every year, in Keratokampos the mechanical removal of Posidonia from the beach is necessary.

Département de l'Hérault

In France Local authorities have the competences for little winter or summer interventions. But if we consider bigger beachnourishment operation, we can see that they are often made by a group of municipality to generate financial and technical advantage. For example the SIVOM (inter-municipalities syndicate) of Aigues-Mortes lead the beachnourishment works in 2008 in the Aigues-Mortes Baie). In this case this inter-municipalities structure has leaded the works at the Sedimentary Cell scale. This works was cofinanced by the UE, the France State, the Languedoc-Roussillon Region, the Département de l'Hérault and the four Municipalities of the SIVOM dredging activities are automatically registered in the DREAL LR database since 2006, in order to report to the european community

Emilia-Romagna Region

The Regional Emilia-Romagna Tourism Service issues an annual beach ordinance, every year, during the bathing season, whereby Municipalities are required to ensure the cleaning of public beaches, according to art. 3, paragraph 3 letter b) R.L. (Regional Law) 9/02. Bathing establishment managers are required to do likewise. Outside the bathing season, the service is run by the municipalities along the coast, in the framework of subcontracting agreements with the environmental operational service Management Companies (i.e AREA, HERA), who, in turn, directly manage services on their own or outsource them to third parties.
The waste collection, transport and disposal service deriving from beach cleaning activities and cleaning frequency are set out by the Technical Regulations issued by the ATO (Ambito Territoriale Omogeneo) local provincial agency, in the framework of the Agreement on Solid Municipal Waste Service management concluded between the Local Agency and the Area Manager, in accordance with the provisions set forth by R.L. No 25/99 and R.L. No 10/08.

The Ministry of Communications & Works of Cyprus

In Cyprus the Provinces are responsible for licences for beach sediment cleaning, maintenance and management.
The concerned Municipality/Local Collectivity or Private Manager (i.e. Hotel manager) has to request a written licence from the Provincial authorities in advance. These licences are necessary for beach cleaning activities, sand shifting, sand removal and other sediment management practices.
Some beaches require cleaning from the dead Poseidonia on a yearly basis. In these cases the licence is given to the local beach operator (municipality, local collectivity, hotel manager) to carry out the beach cleaning under the supervision of Provincial officers. The cleaning operation is carried out in situ. The unsuitable material (dead Poseidonia) is moved to approved deposition areas, the suitable material (sand) is redistributed in situ or it is deposited in nearby beaches that need nourishment or protection.
On the nearby Alaminos Resort, which will be the sand deposit site, the hotel manager is practising regular beach cleaning and yearly sand shifting.

In the free area of Ammochostos, there are beaches were sand nourishment takes place before the tourist period. At the end of the tourist period the beaches are reprofiled and the sand is stocked landwards so as to be reused for sand nourishment the next year. There is no data on other beach management practices in Cyprus.

Practices for beach sediment maintenance implementation by local operators or public administrations

Region of Eastern Macedonia & Thrace and Region of Crete

In REMTH Coastance Pilot Site, Kariani beach, and Crete Pilot Site, Keratokampos beach, only beach sediment cleaning is practiced. The debris from storms and the litter are removed in situ manually or by special vehicles.
The Posidonia is also collected in-situ manually and mechanically. The collected Posidonia, storm debris and litter are transported to the local landfill.
In the beach of Fanari, Municipality of Egiros, in REMTH, wooden break-wind barriers have been installed on the beach for wind protection during the winter months. This work has been realised in the framework of a pilot project.

Département de l'Hérault

Beach sediments cleaning

Natural debris is deposited on the beach by tides and uprush. This debris consists of algae, *Posidonia* debris, shellfish, matters of animal origin, pieces of wood, bird feathers and cuttlefish bone. These are required for the stability of the coastal system and constitute what is called the "foreshore". In order to determine the cleanup techniques employed by communities, a survey has been carried out with local authorities of Département de l'Hérault. Following the analysis of its results, three cleanup periods can be observed on Hérault coastline:

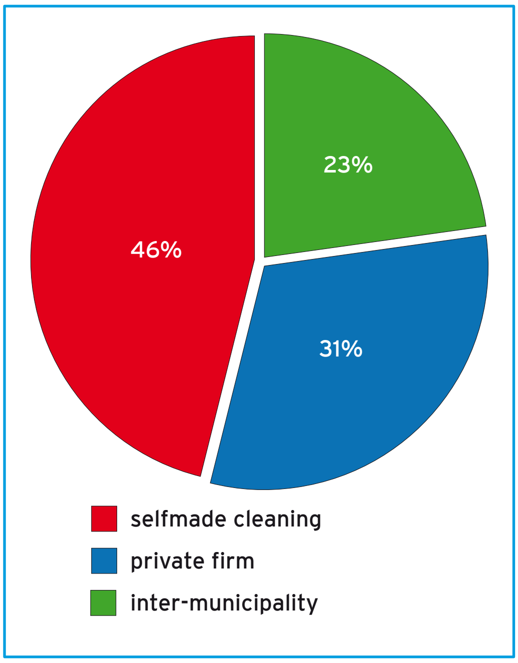
- a pre-cleanup is carried out in March or April to remove major debris consisting essentially of tree trunks beached during bad weather in the winter months;
- from May, the beaches are cleaned on a more frequent basis. Tourists flock to the beaches and communities want to offer them a beach of good quality;
- in exceptional cases, cleanup operations are carried out during winter. This cleanup is carried out following particularly bad winter weather (flooding, storms).

To fight against the proliferation of debris, the communities of Département de l'Hérault are combining the mechanical and ma-

Figure 1

Tractor whit mechanical cleaning system in the municipality of Sète (EID Méditerranée - april 2009)

Figure 2



Mechanical cleaning structure of the 13 coastal municipalities in Hérault (Eid Méditerranée 2009)

nual collection of coastal debris (fig. 1). The first is easy-to-use and is used on sandy beaches that are easily accessible, whereas the second is employed in areas that cannot be accessed by machines (dunes, pebble beaches, etc). The first enables the selection of debris that has been gathered, whereas the other leaves a beach exempt from debris. The latter is considerably harmful to coastal biodiversity and can contribute to accentuating coastal erosion. The Hérault coastline is cleaned systematically without taking into account its characteristics. Improvement solutions are possible, on the one hand by raising awareness among actors involved in the cleanup, and on the other hand by improving debris collection. Manual cleaning seems to be a good compromise between respecting the environment and satisfying tourist demands. Coordinated actions can be carried out globally along the entire coastline, taking into account the specificities of each beach. By respecting this, the Hérault communities will be able to continue to welcome holiday makers while simultaneously preserving coastal biodiversity. Regarding the realisation of winter protective levees in Département de l'Hérault we have just one example in the Portiragnes municipality, done for the scientific analysis.

Emilia-Romagna Region

Beach cleaning service

Among the various coast management strategic objectives pursued by the Regional authority, Emilia-Romagna is committed to reducing sand losses along the sea shore. Reducing the amount of sand that is removed together with waste is a priority action. As a matter of fact, sand accounts for 50-70% of the waste volume removed.

To this end, the Regional authority has undertaken several actions:

- direct agreements with the Municipalities or the Management Companies for the recovery of sand to be reused for nourishment purposes;
- selective cleaning, such as leaving the trunks during winter to protect beaches from storm surges and as natural windbreaks barriers;
- regional regulation for the characterization of sediments derived from beach cleaning for the purpose of environmental and health compliance and transport on the beach.

A good practice scheme has also been put in place in view of reducing losses due to beach cleaning, which shall be directly integrated into the technical specifications of the Solid Municipal Waste management service designed by ATO (Ambito Territoria Ottimario, Optimal Territorial Area) providing for the following items:

Figure 3

Piles of waste on the beach (mostly lumber) awaiting transport to storage

- direct sand screening on the beach during waste collection in the autumn - winter season (fig. 4);
- transport of sand to authorized storage areas, recovery and transport of residual sand for beach nourishment purposes in the short term to sites specified by the regional technical services during spring - summer (bathing season);
- adoption of specific and selective collection methods and machinery for the reduction of sand collection. During the non-bathing season the logs should not be removed in order to create natural defenses against storm surges.

Figure 4

Screening the storage area

Construction of winter defence embankments

The embankments built for protection from winter sea storms are often created by using sand from the foreshore. This operation can create adverse effects on coastal dynamics, since it increases the beach slope, while decreasing its resistance to storm surges.
This issue is regulated by regional law No 9, dated May 31, 2002, entitled "Regulation of the exercise of administrative functions relating to maritime property and territorial sea areas" and subsequent amendments; the Regional Council Resolution No. 468 dated March 6, 2003, entitled "Guidelines for the exercise of administrative functions relating to maritime property and territorial sea areas in accordance with art. 2 paragraph 2 of the R.L. 9/02".
The authorization procedure follows the following steps: the bathing establishment managers or their associations file an application to the competent municipality; the municipality asks for the technician's expert opinion to the Local Technical Service (STB) in charge and forwards the application to the Regional Tourism Office, which authorizes the action (including any STB requirements).
A particular but common case is that of "private" beaches, which are not considered State property and for which no authorization is required.

Figure 5

Left: not properly built winter defence enbankments, by removing the sand from the foreshore. Right: properly built winter defence enbankments, with sand coming from other sources.

Embankments are generally put in place by the bathing establishment managers, by removing the sand from the foreshore; this method entails changes in the cross-shore profile of the beach with a consequent slope increase and width reduction (fig. 5 left). After to the excavation, the sea reshapes the natural contour of the shoreline, yet at the expense of the nearshore seabed, which gets deeper. Thus, the effect that is produced is the damping of the wave motion even in the event of an ordinary sea storm. A generally steep embankment is constructed and the height is then generally increased as against the high tide event. The wave action, which is reflected or breaks against the side of the dune, quickly takes away the sand that is not well compacted at the foot by increasing its slope, which tends to become quite vertical. As a consequence, the erosion process is rapidly increased and leads to the partial or total dismantling of the defence work.

These works are obviously more frequent on the beaches of limited width under erosion, more exposed to the sea and, if protected by breakwaters, only a portion of the material mobilized by sea storms is re-used for the nourishment of the eroded beach; a part of the material is dispersed along barriers, on deep seabeds, and can hardly be recovered and brought back to the beach.

These works are dismantled in spring and the material is spread over the beach. It can often be observed that sand is also spread in water in order to increase the surface of the backshore, which leads to an even greater sediment mobilization.

In 2006, the Region issued technical guidelines addressed to municipalities, to improve the quality of these temporary defence works and to reduce sediment loss due to an incorrect action management, which suggested to prevent the construction of embankments with sand from the foreshore and to use instead (fig. 5 right):

- sand coming from other sources (eg. resulting from authorized excavations or from recovery by sieving sand collected during beach cleaning);
- sand from the beach itself, by digging in the backshore and by carrying it forward;
- alternative methods, such as the installation of barriers and windbreaks along the beach. This method is effective even on narrow beaches (with a limited width of 40 m) and leads to the formation of a symmetrical dune, having a 60-70 cm. height and of 4-6 m. base width;

Finally, as far as the size and shape of the embankment is concerned, a height not greater than +2.5 m, a mean sea level and a seaward slope of not less than 1 in 4 was required. The embankment should then be located on the backshore, preferably above the ordinary storm line.

Creation of windbreaks

Given a loss of sand from the backshore due to wind erosion amounting to 60,000 m^3/year along the regional coastline, and given the lack of legislation enabling the public authorities to require the installation of barriers, in 2006 the Region put forward a technical directive on windbreak barriers to municipalities.

Figure 6

Left: negative effects caused by the absence of windbreaks. Right: a windbreaks properly built

It is a valid alternative to the winter embankments used for the protection of bathing establishments and to minimize loss of sand from beaches. Furthermore, it should also be pointed out that sand is blown by the wind and it piles up also in backyards and along the streets, thus running down into the sewage system, with consequently higher disposal costs.

On low narrow beaches, it might be useful to position them on top of embankments. An effective windbreak should be made of plastic nets, similar to the ones used for gardening, with a 1 to 1.5 m. height and 1-2 mm porosity, supported by iron posts or wooden frames, located in front of the bathing establishment and as far away as possible from the shore, oriented towards NE and SE, namely towards the prevailing wind direction. Welded wire meshes, concrete barriers and plastic sheets, as well as barriers located off the beach or behind the bathing establishment should not be regarded as windbreaks.

Annual monitoring has positively pointed out the increased use of windbreak nets only, a clear sign showing that bathing facility managers, at our request, have verified the benefits arising from it: much lower installation costs than sand dykes, reduced losses of sand from the beach due to the wind effect, effective defense from winter sea storms because of the formation of leeward sandy deposits. There is still much skepticism about the effectiveness of windbreak nets; hence, it is necessary to continue to raise the awareness and involve operators, by means of direct surveys.

The Ministry of Communications & Works of Cyprus

In the COASTANCE Pilot Site, Agios Theodoros beach, no beach sediment maintenance has been ever practiced.
On the nearby Alaminos Resort, which will be the sand deposit site, the hotel manager is practising regular beach cleaning and yearly sand shifting. These operations have multiple purposes:

- beach cleaning from dead *Poseidonia;*
- sediment removal for safe access to the marina;
- sediment removal for re-establishing the usability of outer docks;
- beach nourishment in front of the tourist resort

On other beaches of Cyprus beach sediment cleaning is practiced is carried out *in situ*. The unsuitable material (dead *Poseidonia*) is moved to approved deposition areas, the suitable material (sand) is redistributed in situ or it is deposited in nearby beaches that need nourishment or protection. For this sand cleaning procedure and sand deposit procedure a special licence is required from the Provincial Authorities.
There are few sites is Cyprus where beach reprofiling takes place before and after the winter period: sediment is moved landwards before the winter period and the same sediment is moved seawards after the winter period.
No data exist for other beach sediment maintenance techniques.

Regional regulation on the implementation of beach sediment management good practices

Region of Eastern Macedonia & Thrace and Region of Crete

In the REMTH and Region of Crete no regional or national regulation/guidelines/operational rules exist on beach sediment management practices.
If a beach sediment management manual of good practices would be issued it could include the following guidelines.
The first step is the diagnostic of sediment loss and calculation of sediment loss rate.
If on a beach there is an erosion problem the following steps could be taken for estimating of the reasons of beach erosion.

- all the coast should be divided in sediment cells and coastal stretches according to the sediment transportation dynamics from inland and near the shore;
- the main sources of sediment should be identificated: river sediment transport, local rock erosion, sea sediment etc.

in order for the rate of the sediment loss to be estimated local data are necessary:

- comparison of satellite photos of different years;
- periodic measurement of beach profile with inland stable measurement stations.

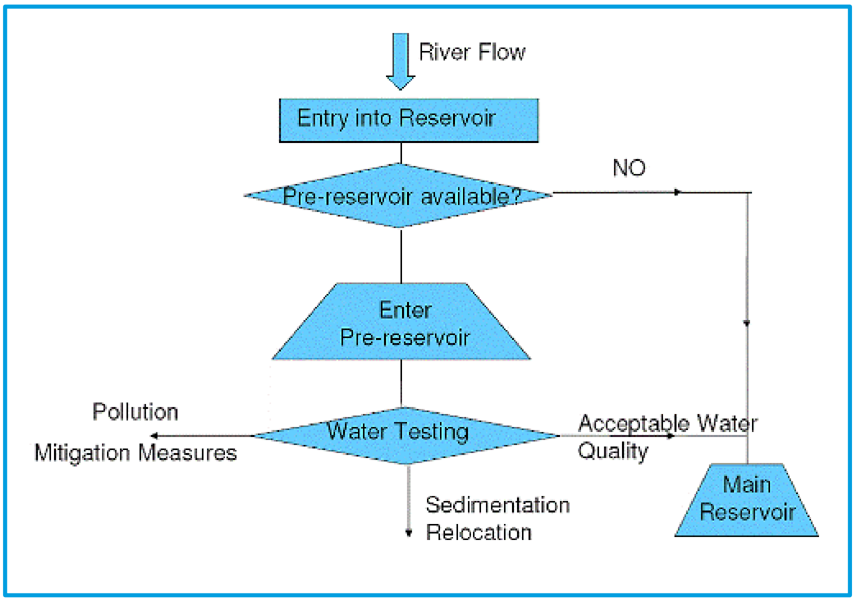
Data should be collected periodically every year so as to establish if the existing practices or new practices are efficient.
The objective of the diagnostic phase is to estimate which are the main reasons for beach erosion:

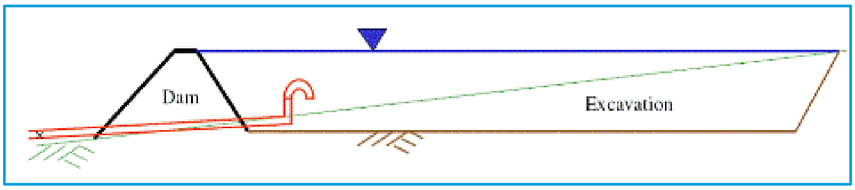
- construction of dams and other inland works that have stopped the river solid transport;
- new coastal works that have disturbed the natural long-shore sediment transport;
- extreme weather events (storms);
- natural phenomena (waves, sea currents, etc.).

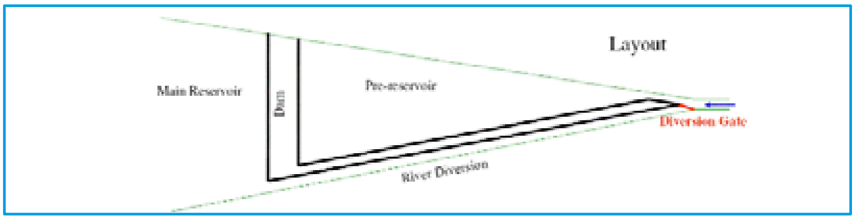
In each case different practices can give sustainable results.
In case of the dams, increase of the river sediment yield is necessary (fig.7). This can be achieved by:

- dams flushing: flushing sediment out of the reservoirs;
- sediment traps or check dams: building small rock sediment traps upstream the dams in order to collect the coarse sediment and then transport the sediment form the sediment

Figure 7







Pre-reservoir project and design

traps to the beaches;

- pre-reservoirs: small reservoirs upstream the main reservoir for sediment collection and then mechanical collection of the sediment for beach nourishment.

If the above solutions are not technically feasible then sand transport from other sources should be considered

In case of new coastal works, the sediment transport dynamics should be studied so as to determine by which mechanism the new works are creating beach erosion. In this case the following practices are possible:

- create a sand by-pass from the new coastal works;
- add supplementary works that helps re-establishing the sediment transport dynamics;
- periodic mechanical sand transfer from the new sand accumulation locations to the new sand erosion locations;
- if the above solutions are not technically feasible then sand

transport from other sources should be considered.

In case of extreme weather events (storms), the storm dynamics and the mechanisms of sediment loss should be studied so as to:

- protect the beach with artificial reefs or other works;
- remove the sand from the beach during the winter period and re-profile the beach in the beginning of the summer period;
- install wind-break barriers;
- if the above solutions are not technically feasible then sand transport from other sources should be considered.

In case of natural phenomena (waves, sea currents), the sediment transport mechanisms of the site should be studied so as to determine where the sediment loss goes (nearby beaches, sea bottom etc.). In this case the most appropriate practices are:

- to protect the beach with vegetation (dunes) so as to reduce the erosion rate;
- to protect the beach with wind-break barriers and vegetation;
- to study the feasibility of periodically excavating sand from its new position (nearby beaches, sea bottom) for beach nourishment;
- if the above solutions are not technically feasible then sand transport from other sources should be considered.

Other good practices useful in many cases:

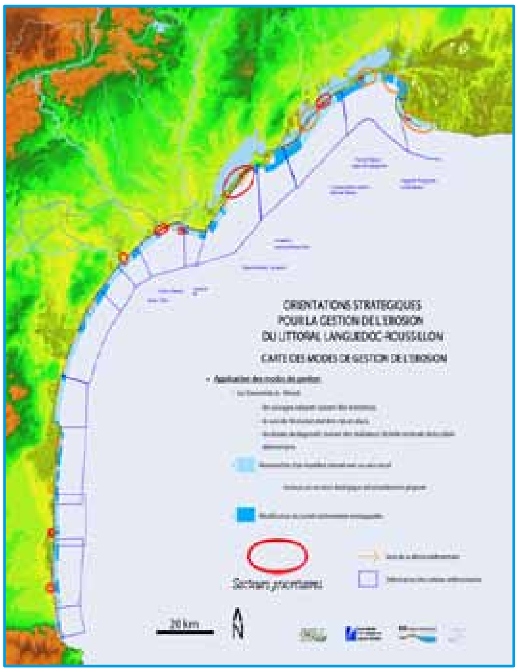
- in case of sand cleaning the pebbles and other heavy sediments should not be removed from the beach;
- in case of beach cleaning from *Posidonia* and debris, attention should be given so as to not remove sand, pebbles and other local sediment from the beach. If necessary, the removed volumes of *Posidonia* and debris should be treated/screened in-situ and the removed sediment should be re-distributed on the beach;
- in case of organized beaches, natural vegetation should not be removed from the beach and, if possible beach vegetation should be added;
- dunes creation should be facilitated by stopping seasonal or permanent dune flattening, adding vegetation and other natural sand stabilising materials (wooden fences, nets, etc.);
- in case of port dredging or other dredging activities in the area, the extracted sediment should be used for beach nourishment, if appropriate (grain size and pollution load control);
- artificial reefs near shore can be used as a measure to reduce sediment transport towards the deep waters and increase marine biodiversity;
- a local sand depot should be assigned so as to store sand and other material appropriate for sand nourishment originating from excavation works, dredging works etc. This resulting sand volume could be treated/screened and used for sand

nourishment.

- Detached breakwaters (submerged or not) should only be used in extreme cases with great caution and only after special study that will assess the possible side effects of the proposed works.

Département de l'Hérault

Figure 8



Methods of erosion management in the Languedoc-Roussillon littoral

Since the year 2000, a new type of coastal management has been developing in Languedoc-Roussillon. Following the disappointing results of the very local management of erosion, a more global vision of the problems of coastline recession has been implemented. On a regional scale, a methodological study has been lead in order to define strategic guidelines for coastal management. In June 2003, the County Assembly approved these general guidelines of the sustainable development charter and committed itself, with the instigation of the interdepartmental mission of coastal development in Languedoc-Roussillon, to participate in the implementation of the coastal sustainable development plan (cf. annex). This plan, combined with the general guidelines, is the reason behind the launching of studies in the region on the subject of the protection and promotion of the coastline, lead with the aim to prepare the future management of the coastline with the creation of a master plan. This is why today the Département's beaches are areas undergoing major promotion projects.
General studies for promoting the coastline have entailed the implementation of various ambitious action programs, the most significant of which are illustrated on the map to the right. While waiting to be able to implement strategic coastal retreat, erosion must be managed in problem areas. Beach nourishment is a "gentle" technique. This method is particularly suitable as it is does not worsen downstream problems due to the fact that it does not disrupt sediment transportation.

Emilia-Romagna Region

In Emilia-Romagna it is in progress a regional regulation governing authorisation for dredging and nourishment activities on emerged and submerged beaches, or nearby areas.
The regulation, that will be adopted by the Regional Government (regional act), assumes the COASTANCE subdivision and classification of regional coast in 118 littoral Cells and the relative information and management system, as a basis references.
The regulation considers interventions regarding the following categories:

1) Beach nourishment using material from:

- emerged and submerged coastal deposits, as river mouth and port mouth bars, littoral accumulations and accumulations near coastal hard defences;
- harbour dredging;
- off-shore deposits;
- deposits in a confined area;
- beach cleaning/sifting;
- building and works excavations;
- inland quarries;

2) limited entity nourishment interventions; periodical interventions for beach profile maintenance after seasonal meteomarine events, subjected to a foster authorisation procedure;

3) handling of the seabed and/or lagoon or brackish areas or coastal emerged and submerged land, consisting of transferring, moving, relocation of sediments from benches, hills, river mouths and port mouths bars, littoral accumulations and nearby coastal defence accumulations.

4) recovery of material from the following activities: submerged reclaimed areas, collection area or other containment structures put in the coastal area containing the materials listed above.

5) deliberate immersion of inert material in the sea

The regulation identifies the characteristics of the areas from which to retrieve suitable material for beach nourishment operations and methods for the its characterization and classification, that will drove to define the compatibility of this material for the different purposes (emerged or submerged beach nourishment, in order to homogenise and standardize procedures.

With this regulation, the Region, recognises beach nourishment as a priority for coastal defence and thus encourages local authorities adopting necessary acts to preserve the material suitable for beach nourishment, to ensure an optimisation of resources exploitation useful for beach nourishment.

The Ministry of Communications & Works of Cyprus

In Cyprus a special licence from the Provincial Authorities is required for every beach maintenance and sediment removal/deposit/nourishment operation. According to the legislation, the Provincial Authorities, can ask the preparation of an Environment Impacts Study which is commented/approved by the Environmental Department of the Ministry. The Provincial Authorities can also ask comments on the project from other ministerial departments: Coastal Unit (Public Works Department), Fishery and Sea Research Department etc.

From 1996, Cyprus disposes of a Master Plan for beach management. The project “Coastal Zone Management of Cyprus” was cofounded by European Union, through the MEDSPA Program and the Government of Cyprus. It was carried out by Delft Hydraulics, supported by the staff of the Coastal Unit of the Public Works Department. (Project duration: 1993-1996).

The project divided all Cyprus coast (area under Turkish occupation is not included) in 12 sedimentary cells (fig.9). 6 of these 12 sedimentary cells were characterised as critical based both to natural erosion process, human interventions that caused erosion (inland dams, coastal works, portuary activities) and pressure for tourist development. For each of these 6 sedimentary cells, general coastal protection studies have been carried out:

- for Larnaka, Limassol and Paphos the general coastal study and detailed study for 3 Km of coastline per cell was carried out by Delft Hydraulics, under the project "Coastal Zone Management of Cyprus"(1993-1996);
- for Zigi-Kiti, Poli Xrisoxou, Kato Pyrgos the general coastal study and detailed study for 3 Km of coastline per cell was carried out by National Technical University of Athens, under a separate national coastal protection project (2000-2003).

The current national policy on coastal protection is to proceed to detailed studies (funded by the central government) for all coastal stretches. Priority is given to areas with severe erosion problems and touristic development. The construction of coastal works is financed 50% by the central government and 50% by the local government (municipalities). Eventual private coastal works should be aligned with the existing general planning. This policy includes all beach management and sediment management projects.

In 2007 the research project "SUSTAINABLE MANAGEMENT OF SEDIMENTS TRANSPORTED BY STORM WATER AND TRAPPED IN DAMS IN CYPRUS" was realized by Koronida Research and Development Centre Ltd, funded by the Research Promotion Foundation. The PWD Coastal Unit participated in this project. The project proposed pre-reservoirs for the sediment capturing up-steam of the main dam and the use of the suitable sediment for beach nourishment. The project is presented in detail in Deliverable Component 4 D1.

The three above mentioned projects and the data from monitoring campaigns and from the control and supervision of coastal works and sediment management operations (sand shifting, beach nourishment, beach reprofiling, sand cleaning), serve as a reference to the PWD Coastal Unit so as to give the appropriate guidance to each project.

No other official document exists in Provincial nor National level

Figure 9

Division of Cyprus in 12 sedimentary cells (area under Turkish occupation not included) in red the critical sedimentary cells, marked in the green line the sedimentary cells studied by the Delft Hydraulics (1993-1996) and in magenta the sedimentary cells studied by NTUA (2000-2003)

Elements for the sustainable exploitation of sediment stocks for beach nourishment

Region of Eastern Macedonia & Thrace

COASTANCE Pilot site

For the beach nourishment of the pilot site (coastal stretch west of the fishermens' port of Kariani) three alternative sources (sand deposits) are available (fig. 10):

Table 1

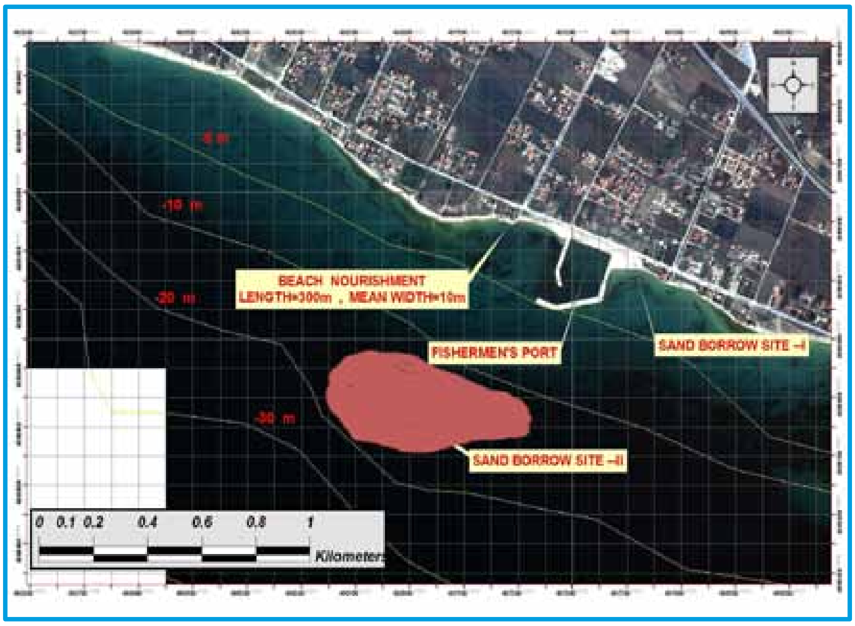
Parameter	Borrow site I Beach on the east side of Fishermen's Port	Borrow site II Off shore deposit	Borrow site III Strimon delta sand deposits
Area (m^2)	5,582	150,000	1,000,000
Depth (m)	0	-12 to -16	0 to -5
Silt coverage (m)	0	~0.4	To be examined
Grain Size D_{10}	0.28 mm	To be examined	To be examined
Grain Size D_{50}	0.46 mm	To be examined	To be examined
Grain Size D_{90}	0.87 mm	To be examined	To be examined
Useful Volume (m^3)	~15,000 per year	~450,000	~1,000,000

Beach nourishment borrow site

These are the available sand deposits located close enough to Kariani beach so as to provide a viable/economic source of sand.
In order to estimate the influence of sand extraction to the other beaches, we studied the long term (1931-2009) sand accumulation-erosion patterns. The coastal stretch under study is situated approximately 15 km east of Strymon river outflow. The major natural sources of sediment in area are two:

- the Strimon river sediment yield, which has been reduced by 90% from 1932 when the dam of Kerkini was built. The sediment yield is still important (0.5 million m^3 per year). The na-

Figure 10



Beach nourishment site and sand borrow site I and II at Kariani Beach

val maps, the comparison of aerial photos of different dated, and in-situ investigations, show that major part of this sediment is deposited near the river outflow creating a submerged plain with very small slope. The formation of this plain is shown on the naval map from the -20m isobaths to the -50 m isobaths (fig. 11). This plain covers the sea bed in front of the river delta and the coasts of Strimonikos gulf. This natural sediment stock is feeding the beaches all over Strimonikos gulf, including Kariani beach;

- the dominant east to west longshore sediment transport.

On the other hand, there are rip-currents that induce sediment lost towards the deep sea and create zones of erosion.

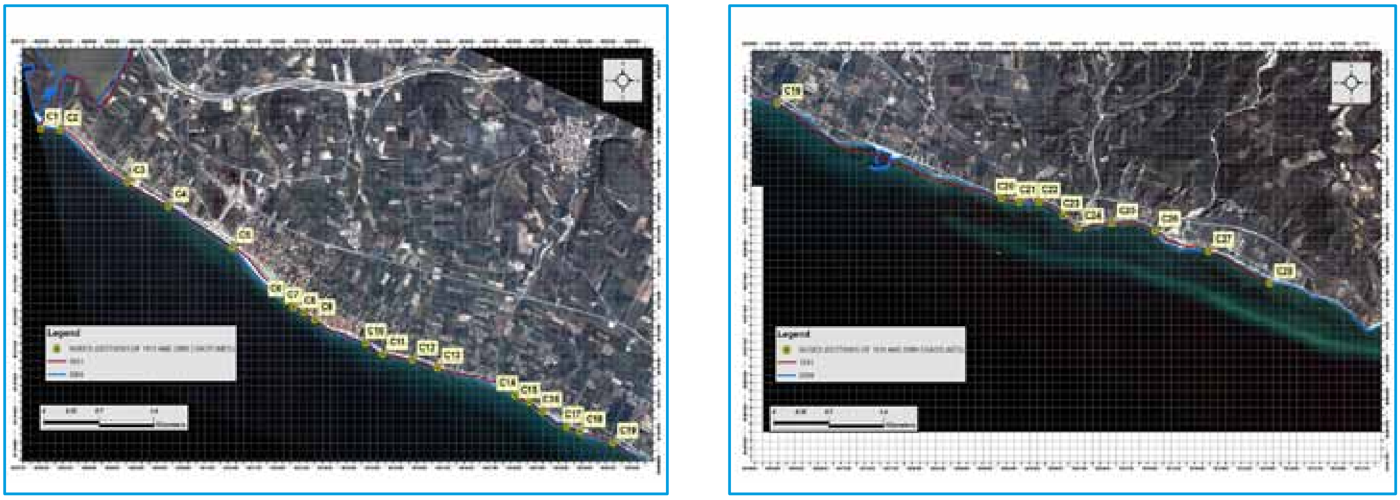
Figure 11

Beach nourishment site and sand borrow site I. Kariani beach in red circle. The gentle slope is apparent.

The georeferenced coastlines of years 1931, 1975, 2003, 2007 and 2009 were compared in order to estimate the zones of erosion, the zones of accretion and the rates of erosion. The coastline of year 1931 intersects with coastline of year 2009 at 28 points (that are subsequently called nodes), which divided this coastal stretch in 27 coastal sub stretches (fig 12). 1975, 2003 and 2007 coastlines also intersect pretty close the 1931 coastline at these nodes. These nodes are areas which present minimum erosion or accretion from 1931 to 2009.

Since the fishermen's port was constructed on 2007, we compared

Figure 12

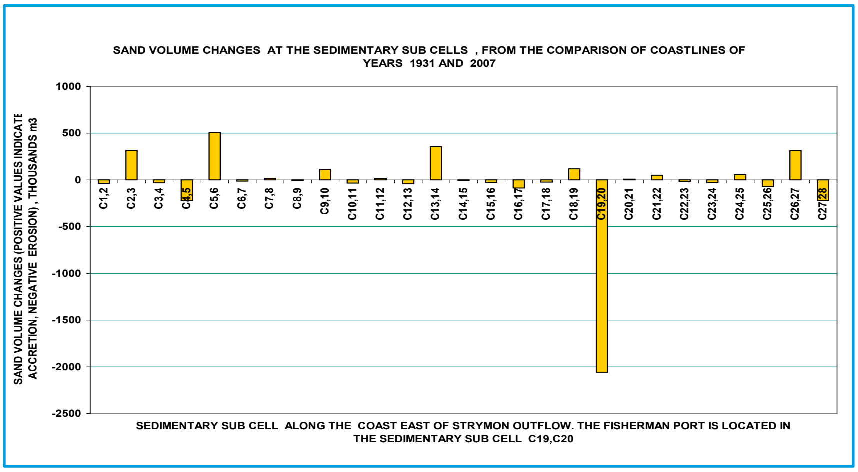


The intersection of the coastlines of years 1931 and 2009, define the nodal points C1 to C28 and 27 sedimentary sub cells.

the georeferenced coastlines of years 1931 and 2007 (76 years time span) and for each coastal sub cell we calculated the sand volume evolution. The results are shown in figure 13. Four sedimentary sub cells present accretion, 22 sub cells present relatively small accretion or erosion, and only the sub cell C19,20 presents important erosion (about two million m^3 for 76 years or about 26,000 m^3 per year). The total annual sand accumulation in all sub cells in accretion is half of the volume of sand erosion in the sub cell C19,20.

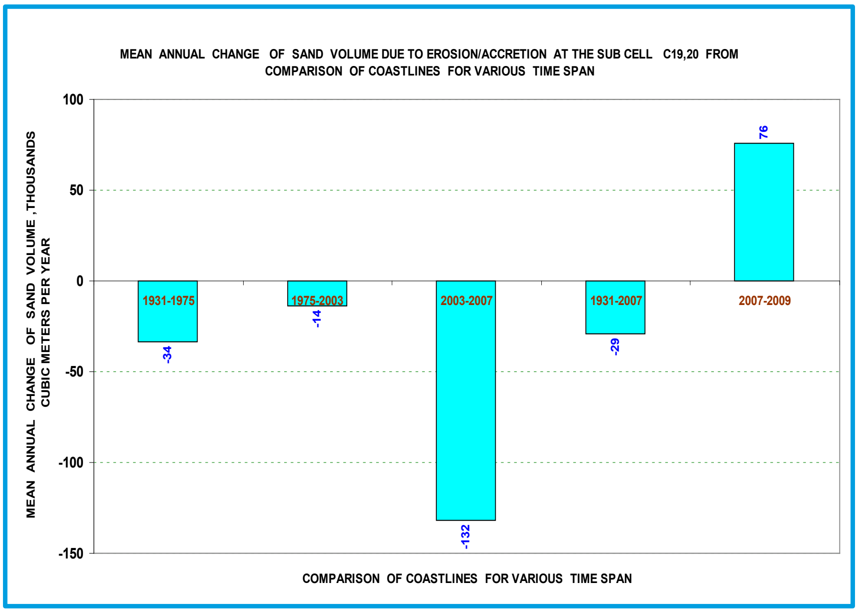
The sub cell C19,20 has a length approximately of 3 km and inclu-

Figure 13



The sand volume changes between the years 1931 and 2007 for various sedimentary sub cells.

Figure 14



The mean annually eroded volume of sand at various time span, before and after the construction of fishermen's port. We observe that after the construction of the fishermen's port, the change of sand volume is positive, due to sand accretion east and west of the port.

des Kariani beach and the fishermen's port constructed in 2007. For this sub cell C19,20 mean annual erosion volume was calculated for different periods and the results are presented in Figure 2.1.6. This sedimentary sub cell was constantly eroding during the last 76 years: from 1931-1975 at a rate an average rate of 34,000 m^3/year, and from 1975-2003 the average erosion rate was 14,000 m^3/year. From 2003 up to 2007 the rate of annual sand loss was much larger than previously, due to an extreme wave climatic episode on February 2005, which produced many damages to the ports of the area and important sea erosion. From 2007 up to 2009 (after the construction of fisherman's port), there is a small accretion (and not erosion). The positive balance, after the construction of the port, is mainly due to accretion west (about 12,500 m^3 per year) and east (about 25,000 m^3 per year) of the fisherman's port. It is interesting to observe that the construction of fisherman's port has as result positive sand balance at the sedimentary sub cell C19,20.

Taking in consideration the above hydrodynamics of the area we conclude that:

Strimon river delta should be avoided as sand borrow site because, its sediment yield is dispersed naturally to the Strymonikos gulf beaches and this natural sediment balance should not be disrupted. Any material removed from the delta and the nearby beaches from maintenance dredging and sand excavation from accretion sites for practical reasons (facilitating the access to the beach) should be deposited locally so as to maintain the local natural sediment balance. It has been reported that about 25,000 m^3 of sand have been excavated in the 2005-2010 period, so as to reestablish the river flow in several points in a zone 3 to 5 km upstream of the river outflow.

The sand accretion east of the port (about 15,000 m^3 per year) can be used for sand nourishment in close-by sites. The annual rate of sand accumulation (sedimentation rate), is estimated equal to 27000 m^3 per year and it is a renewable sand deposit for periodical dredging (sand borrow site I, see figure 10). Dredging of about 15,000 m^3 per year will not harm the beach east of fishermen's port, due to annual natural replenishment. We estimate that deposit recharge time (the time which is needed to restore the volume we need for nourishment) is of the order of one year. The sediment deposits characteristics from sand borrow site I, are practically identical with sediments of beaches to be fed, because both are sediments transported by the long shore currents. The sand grain size is shown in table 1. The volume of the available sand is restricted but due to the vicinity to the area under erosion it can be an economically effective sand source.

The Strymonikos Gulf has large volume off-shore sand deposits that can be used to restore multiple sites which are under erosion. The Strymonikos Gulf covers an area of 490 km^2, and has a maximum depth of 70 m, and mean width about 20 km. After the construction of Kerkini Dam on 1931, the sediment discharge of the Strymon River at Strymonikos Gulf is about 500,000 m^3 annually (before 1931, the sediment discharge was about 5 million m^3 annually). The Strymon river sediment discharge created the last thousands years important off-shore deposits at Strymonikos Gulf. We estimate that the last one thousand years the Strymon river deposited one billion m^3 of sediments at Strymonikos Gulf.

Due to the high sediments discharge at the semi–enclosed Strymonikos Gulf, the Gulf bottom as well as of the surrounding area is smooth with very low gradient, and the Gulf bottom seems almost flat. The bathymetry of the Strymonikos Gulf is taken from the bathymetric charts of the Greek Naval Hydrographic Service with scale 1:75,000. The sea depth, even at large distances (10 km) from the coast, is low and does not exceed 65 m. It is interesting to observe that the swallow zone adjacent to the coastline, defined by the isobath of 20 m, is approximately 500-950 m away from the coastline, giving mild slope (about 2-4%). The isobath of 50 m is located at a distance of 1500-2700 m from the coastline (slope 2-3%). After the isobath of 50 m, there is an elongated undersea platform at an average depth of 60 m with South-East direction, with extremely mild slope (average bottom slope ~ 0.4 %).

Due to the mild slopes of the bottom of Strymonikos Gulf, the dredging of sand will not pose problems on the bottom stability.

On the basis of the existing data, Strymonikos gulf is considered as a huge reservoir of deposited sand and can be considered as an alternative sand borrow site II. For the purpose of this report and as an alternative to borrow sand for the pilot nourishment, we indicated roughly the area of off shore deposit (fig 10). This indicated sand borrow site II is beyond the closure depth (depth >8 m) and is located between the isobaths 10 m and 20 m. Judging from the curvature of isobath of 20 m, we speculate that rip currents transport partially the eroded sand from sub cell C19,20 to the off shore region, marked as sand borrow site II.

Figure 15

The critical coastal stretch which is taken as pilot case to be fed with sediment (marked with the letters ABC). Length 300 m, area 3000 m^2 and mean width 10 m. Volume of sand for beach nourishment 30000 m^3.

The superficial unconsolidated sediments of the Strymonikos Gulf floor are dominated by the terrigenous component (up to >90%) due to the large terrigenous riverine fluxes (Poulos 2009). Information's regarding the geotechnical parameters of the sediments of Strimonikos Gulf can be found in Pehlivanoglou (1997) and Konispoliatis (1984). The spatial distribution of the fine-grained terrigenous material discharged by river Strymon is dominated by the overall circulation pattern and long-shore currents of the Strymonikos Gulf, and the processes of settling.
Although in situ investigations are necessary, on the basis of previous publications (Pehlivanoglou 1997), we estimate that the floor of Strymonikos Gulf bellow a layer of deposited silt (less than 0.5 m), consists of a layer more than 3 m deep and with more than 85% of sand.
The sand borrow site II has an area of about 150,000 m^2 and the volume (for a 3 m layer) of available sand is estimated about 450,000 m^3. This sand deposit is about 1,000 m away from the beach stretch to be fed. In situ investigations are also needed to find accurate and reliable estimate of the available sand volumes, to explore the sediment deposits characteristics and to verify the compatibility with sediments of beaches to be fed.
In the COASTANCE project, we focus on the protection of the pilot

site, Kariani beach located in sub cell C19,20. After the construction of the port, we observe accelerated erosion at distances about 100 to 400 m west of the port. This 300 m critical coastal stretch is selected as beach nourishment pilot case and it is shown in figure 15 marked with the letters ABC. On the same figure we have plotted the 2003, 2007 and 2009 coastlines. The selection of this coastal stretch is based on its rapid and continuous erosion and the need for protection of the seafront properties and houses. Because of the cost of the operation, its pilot character and the existence of many nearby beaches, we selected to restore a minimum length of about 300 m at a mean width of about 10 m, creating a beach of about 3,000 m^2.
Since the entire Strymonikos Gulf and the beaches are sandy, the restored beach profile should be an equilibrium profile. Therefore, it is estimated that the required volume of sand for initial nourishment is about 30,000 m^3. In addition, it is proposed to stabilize the restored beach by submerged sand filled textile tubes or similar technology installed parallel to the coastline at a depth of approximately 2 m. The annual need for nourishment is highly dependent on the extreme wave climate, and the details of the design for beach stabilization. On the basis of the rate of erosion of previous years, it is estimated that, without beach stabilization, the maximum annual need of nourishment is 15,000 m^3. However, we expect that with appropriate beach stabilization, the annual need of nourishment will be much less.
Further studies and modelling will be required in order to assess the necessary annual restoration sand volumes in conjunction with the stabilisation techniques (geotubes, artificial reefs etc.)

Environmental aspects

The delta of Strymonas river is a Natura 2000 site categorised both as “Site of Community Importance/SCI” and as “Special Protection Area/SPA”. The accumulation of sediment on the river mouth is a natural phenomenon which has been reduced by construction of the upstream dam of Kerkini.
Kariani beach and the off-shore deposit are not included in the protected area
The extraction of sand from the sand borrow site I (beach east of fishermens’ port) will require an Environmental Impacts Study specifying:

- which sand deposits could be removed (locations);
- how many cubic meters of sand could be removed on yearly basis;
- the best methods of sand extraction (period of the year, roads and machinery used) so as to limit the Environmental Impacts;

- measures of precaution taken before, during and after the sand extraction to limit the Environmental Impacts.

Sand extraction from Strymonas river mouth will require an Environmental Impacts study with more detailed data on the protected flora and fauna and more measures of precaution/restrictions for minimising the disturbance of the Natura 2000 site.

Attention should be given to the fact that Strymonas river sediment yield is now been distributed by natural means to the nearby beaches and effects the sediment balance of the whole gulf. The selected sand deposit sites, for sand extraction, should be far away from the river banks and the surf zone.

The continuous sand flow on the river mouth and sand accumulation makes the sand deposits very poor in living vegetation.

It is expected that the excavated sediment from all sediment deposits (Strimon river mouth, off-shore and Kariani beach) will not demand any treatment. The locale wave climate will induce a natural selection of the appropriate sediment side. All three sand deposits have sand of similar characteristics to the beach nourishment site.

Exploitation technologies

The littoral sand excavation will be accomplished with tradition excavation machinery:

- front shovels;
- hydraulic excavators;
- long Reach Excavation Loaders;
- track loaders;
- compact Track Loaders

The off-shore sand excavation will be accomplished by dredgers. Simple dredgers with suction will be satisfactory as the extraction depth is low (10 m to 30 m) and the necessary sand volume limited (30,000 m^3).

Small types of the below dredging ships will be adequate:

- trailing suction hopper dredger;
- cutter suction and suction dredger.

The transportation of the sand will be done by trucks and the profiling of the sand nourishment by:

- compactors;
- graders;
- motor Graders.

The final choice of machinery will be done by the contractor according to the location and volume of the sand deposits to be excavated and the availability of local machinery.

Département de l'Hérault

Name / Title / Owner	Description and possible use
CALMAR seismic campaigns IFREMER database	All seismic and core boring campaigns carried out on the Gulf of Lion continental shelf enabling potential sources of fossil sand to be identified. **Advantage**: seismic coverage is uniform. **Disadvantage**: it is difficult to estimate the volumes of material from seismic lines
Database of altimetric and bathymetric profiles (EID)	All altimetric measurement campaigns on the sand barrier and bathymetric profiles and DTM in the shore face. Longitudinal density of the profiles, from around one hundred metres to one kilometre, depending on the zone. Variable recurrence, depending on the zone. **Advantage**: the DREAL database gives global coverage of the Languedoc-Roussillon region. (DREAL= Regional Directorates of Environment, Land Settlement and Housing)
Altimetric and bathymetric profiles (DREAL)	Idem, with very variable data densities.
Lengthwise dune ridge profile. GLADYS.	All ground-level GPS measurement campaigns measuring the maximum height of the dune ridge, longitudinally. Measured since 2008, only in the Maguelone/Aresquiers sector. **Advantage**: it is a new type of data. **Disadvantage**: it has no history, and no global coverage.
UPVD/BDSI database	All seismic and bathymetric measurement campaigns. Advantage: it is the only source of seismic data on the inner continental shelf.
Seismic campaigns CALAMAR 3 and 4 in the Golfe d'Aigues Mortes (Perpignan University)/GLADYS	All seismic and bathymetric measurement campaigns. Hectometric spatial resolution in some small coastal boxes, and kilometrics further out to sea. **Advantage**: it is the only source of seismic data in the surf zone and lagoon. **Disadvantage**: absence of total coverage.
Golfe d'Aigues Morte bathymetric campaigns (Hérault department)	Topo-bathymetric measurement. Acquisition for the Hérault department.
Map collection. BRGM	Database of land boreholes, some of which are in the coastal zone. Poor accuracy. Information concerning the presence of sands on the dune ridge and in the lagoon deposits. **Advantage**: it is a genuine database of boreholes. **Disadvantage**: the description of the material is sometimes unusable in terms of the knowledge of stock. Few of the points are located in strictly coastal zones.
Seismic IX Survey. CG34	Shore face seismic data campaigns using 'flute' technology as part of BEACHMED-e. Pluri-kilometric spatial resolution. Between 3 metres and 20 metres bathymetry coverage.
Geoscience core borings (Borehole hydrogeophysics)	All core borings of pluri-decametric depth in strictly coastal zones. **Disadvantage**: only in Aresquiers/Maguelone, and shortly the south sector.

Existent data on sediment stocks characteristics

Environmental aspects

The main negative impacts of dredging activities on the marine environment can be summarized as follows:

- direct substrate extraction leads to the destruction of associated habitats and species. Indentured species on the seabed (benthic) or those with certain life cycle stages (reproduction, alimentation, etc) which are indentured on the seabed will be the most sensitive;
- modification of the seabed topography and hydrography, and consequently local destruction of habitats and an increased risk of stress for the species present;
- alteration of sediment composition, i.e. the characteristics of the substrate close to the dredging area, resulting in a change in the nature and diversity of benthic communities (decline in individual densities, the abundance of species and biomass);
- local resuspension of particles and increase in turbidity. According to experience acquired in recent years and as highlighted in the ENV1 protocol "Protocole Méthodologique, Spécifique

pour l'Etude des Aspects Environnementaux en vue de l'Utilisation des Dépôts Marins Sableux du Large et du Remblayage des Plages » (Methodological protocol, Specific to the Study of Environmental Concerns with a view of Using Sand Marine Sediments off the Coast and Beach Nourishment), this increase in suspended sediment is one of the most important aspects to consider in terms of dredging activities as these are likely to have considerable effects upon the environment;

- the increase in turbidity close to the seabed (plume de fond - seabed plume), generated by the direct action carried out by the sucking head of the dredger on the seabed. The size of the seabed plume is generally between 4 or 5 times smaller than that of the superficial plume (Hitchcock et al., 1999);
- possible impacts on human activities practiced in the dredging area (fishing, water sports, etc) should also be taken into account but given the short duration of the operations, expected disturbances to these are minor.

The extent of the environmental impacts of dredging (and notably the level of sediment resuspension and the impacts associated to this) evidently depend upon the physical and chemical characteristics of the sediment, the characteristics and sensitivity of the dredging area concerned, as well as the scale of the operation and the technique employed. The impacts of dredging activities are strongly affected by sediment contamination and local factors such as the depth of the water, currents, wave action, the type of seabed, and the concentration of sediment in the water column in normal conditions.

Figure 16

from above: small stationary dredgers; trailer hopper dredgers; jumbo dredger

Exploitation technologies

In Département de l'Hérault, 3 types of dredging can be used to make nourishment operations a success (fig. 16):

- small stationary dredgers for dredging in ports and river mouths, as was the case for the dredging of Grau d'Agde (Hérault) in order to find a flow depth that was sufficient to guarantee the security of boats during their access to the fish market before the beginning of the Autumn storms in 2008 (volume of approximately 20,000 m^3 of sand);
- trailer hopper dredgers such as those which were used during the nourishment of the Gulf of Aigues-Mortes in 2008. The main purpose of the works was a massive nourishment of sand (1 million m^3) across several sectors of the same sediment cell. The sand comes from the underwater prolongation of the Pointe de l'Espiguette, which has simultaneously enabled the silting-up of the entrance to the Port Camargue to be

avoided;

- the use of a jumbo dredger (like that of Pearl-River) is to be studied in the future to carry out renourishment on a larger scale. For this; the steps are in place to raise awareness among the various potential developers of the Gulf of Lion. The results of the COASTANCE project are important in the development of this process, especially thanks to the implementation of a global management plan shared by all.

Emilia-Romagna Region

The offshore sources

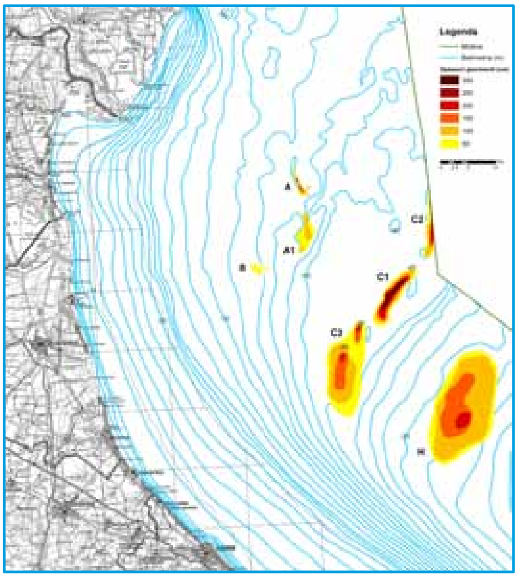
Six underwater sand deposits (A, A1, B, C1, C2, C3, fig 17), and an extensive silty-sandy body (H) (Idroser, 1985, 1990, 1996, ARPA, 2001; Correggiari et al., in press; Beachmed-e, 2006-2008) have been identified to date on the northern Adriatic continental shelf, off the coast of Emilia-Romagna.

These offshore sand sources are a finite non-renewable resource, which should be used according to a sustainable management model. Overall, the presence of about 195 million m^3 of sand has been estimated in the first 6 deposits and further 195 million m^3 of sandy silt has recently been discovered in the H deposit. Yet, a portion of material should be subtracted from these overall figures, since it cannot be used for the reasons that are described here below.

Indeed, a layer of sand must be left at the base of the deposit, so as to prevent the removal of the underlying pelites, both for environmental and practical issues, related to the fact that the discharge of clays on the beach might entail not negligible economic damage. Although the debate among technicians is still going on regarding the proper sand layer thickness, they have agreed on leaving at least a 50 cm thick layer in place. According to this reference limit, the volume of available sand amounts to about 120 million m^3 and silt to about 100 m^3.

Furthermore, the volume of material that cannot be excavated for safety reasons must be subtracted from these values, since it is situated in the pipeline buffer zone where no excavation activities are allowed. Currently, the only sand deposit crossed by one of these pipelines is the northernmost: i.e. the A sandy body. Two more pipelines run very close to the A1 and H sand deposits.

Figure 17

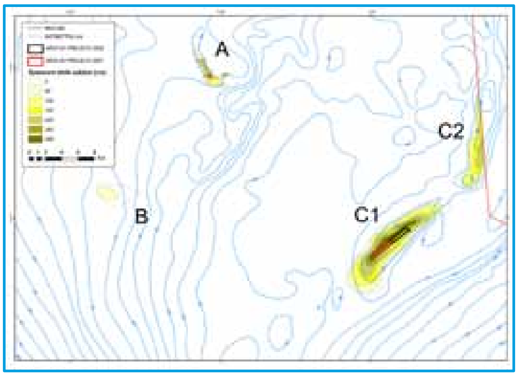


Six underwater sand deposits (A, A1, B, C1, C2, C3)

The two underwater sand nourishment projects

In 2000 and 2006, respectively, two major emergency safety ac-

Figure 18



Sand harvesting sites for beach nourishment: 2002 and 2007 operations

tions were carried out along critical stretches of the Emilia-Romagna coast, through nourishment by means of underwater sand, referred to as Project 1, and Project 2. The Emilia-Romagna Regional authority has entrusted the regional agency ARPA with the task of identifying the sand harvesting sites from off-shore underwater sand deposits and carrying out the detailed design and post-intervention physical and environmental monitoring, both in the off-shore underwater sand harvesting sites and on the beaches subject to nourishment (ARPA, 2009 a, b, c).
Sand mounds C1 and A were selected as harvesting sites (fig 18). The C1 sand site has been mined both during the 2002 and 2007 campaigns, while site A only during the 2007 campaign (Correggiari et al., In press).
In 2002, 800,000 m^3 of sand were harvested from C1 site, and in 2007, further 815,000 m^3 were harvested in part from A and in part from C1 sites (Figure 18).
The first campaign concerned 8 different beaches (Preti, 2002; Preti et al., In press a), the second one seven beaches, partially the same ones nourished by means of underwater sand. (ARPA, 2009; Preti et al., In press b).

Underwater sand deposit harvesting methods and techniques

Figure 19

Ham 316 dredge during dredging

The same technologies and means were used for sand harvesting, transport from offshore to inshore, discharging of sand and profiling of the beach, during both nourishment campaigns carried out on the eroded beaches along the Emilia-Romagna coast by means of sand harvested from off-shore underwater sand deposits.
More than 1.6 m^3 of sand have been harvested by means of a Trailing Suction Hopper Dredge - THSD, Figure 2).
Given the location of sand deposits to be exploited (at a 35 - 40 meter depth at 45 - 55 km offshore), the two main requirements to be met by the dredge were a hydraulic power with a water and sand mixture suction capability from a 40 m depth and onboard safety equipment and certificate to operate more than 20 nautical miles offshore.
The dredging method that was used consisted in passing back and forth along the harvesting site, by lowering the suction pipe, until it reached the sandy bottom. The dredging speed ranged between 1-3 knots. Dredging occurred along elliptical trajectories allowing the dredge to work continuously. Figures 3, 4 and 5 clearly show the traces left by the dredge in the sandy deposit areas during the 2002 and 2007 harvesting campaigns. (Aguzzi et al., In press).
The dredge used in Emilia-Romagna (Ham 316) has a load capacity of over 9,500 m^3, a navigation speed of 15 km (28 km/h) and a fully loaded draft of 9 m.

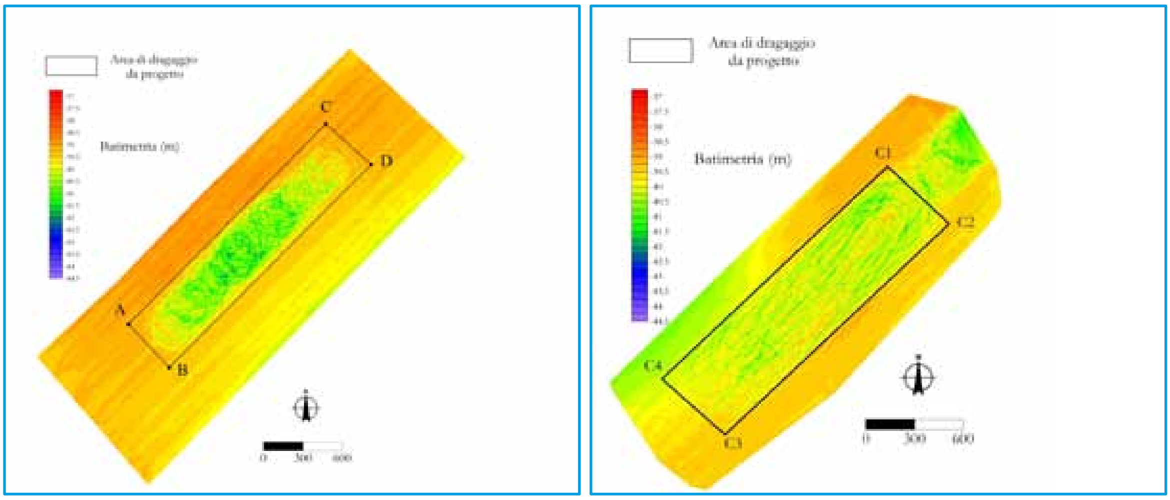


Figure 20
left: C Area dredged in 2002: clearly visible traces left by the dredging operations. right: C Area dredged in 2007: clearly visible traces left by dredging operations. At the top, outside the area dredged in 2007, very marked traces left by the dredging carried out in 2002 are still visible.

In order to operate under good safety conditions, the load was limited to 6,000 m^3 and the approach to land was limited to a depth of not less than 10 m.
The dredge was connected to an underwater steel pipeline, by means of a floating pipeline, which allows the sand discharging on the beach (fig. 21, Preti, 2002).
Since the beaches to be nourished are characterized by different slopes, the company performing the operation has decided to assemble two pipes: a 2 km long pipe and another about 4 km long pipe to be used respectively for the more or less steep beaches
A very important and challenging work phase was the assembly of two pipelines. They consist of 9 to12 m long pipes welded together, having a diameter of 800 mm and a thickness of 20 mm. Welding operations were carried out in two beaches chosen as construction site.
To ensure the pumping of sand through these long pipelines, the water and sand mixture was diluted up to an 80% water content.
Mechanical equipment, such as bulldozers and excavators, were used onshore to level the backshore and shoreface according to the project profile.
When the beach nourishment operation was completed, the construction site was moved immediately to the nearest beach to continue the beach nourishment.
Transporting the two pipelines by sea was a very sensitive operation, since any wrong manoeuvres could cause the failure of the welds.
Upon the completion of the nourishment of all sites, the two pipelines were brought back onshore, cut and stocked away (fig. 22)
The beach nourishment production cycle by means of sand coming from underwater sand deposits can be summarized in the following stages (in parentheses the average time taken for the implementation of each stage in the operation conducted in Emi-

Figure 21

Dredge Ham 316: Connection operation between the dredge and the floating pipeline

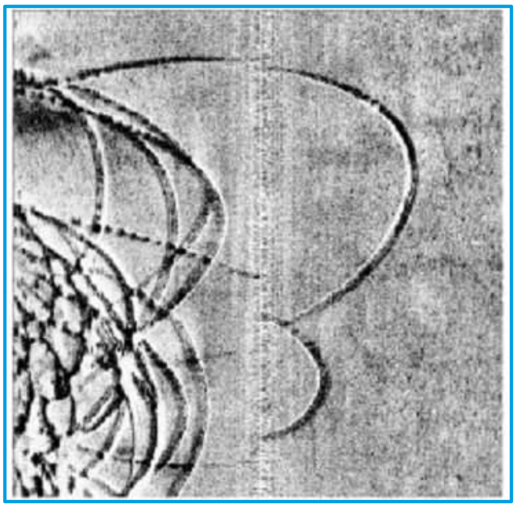
Figure 22

clockwise: bulldozers and excavators in operation for the profiling of the beach; excavator in action for the recovery of the pipe; transport of pipes from the beach to the construction site by means of mechanical means; pipe loading operation for transport to storage

lia-Romagna in 2002):
· loading of sand on the dredge (169 minutes);
· travelling at full load from the offshore borrow area to the beach nourishment site (138 minutes);
· sand discharging on the beach (120 minutes);
· attachment and detachment of the pipe to the dredge rapid coupling device (20 minutes);
· cleaning the pipes (19 minutes);
· return trip to the harvesting site (133 minutes).

Dredging operation control techniques

Figure 23



C Area dredged in 2002: acoustic reflection from the dredging furrows detected by the Side scan Sonar (December 2004)

The dredging operation was followed by careful monitoring activities to verify that the sand harvesting would take place within designated areas of the project. The dredge was equipped with GPS tracking equipment, so that the Harbour Authority could check in real time its route and location.
In addition, on behalf of the Regional Authority, ARPA Emilia-Romagna has carried out the monitoring of harvesting sites using Side Scan Sonar (fig. 23, ARPA, 2005) and Multibeam surveys, carried out before, during and after dredging operation. In particular, the multibeam surveys have allowed to verify compliance with the dredging areas, methods , thickness and volume (fig. 24).
Geophysical surveys are not only useful for the morphological evolution analysis of the seabed but also have a useful application related to the calculation of the extracted material quantity.
When comparing the DTM of the areas subject to harvesting obtained by surveys carried out before and after dredging, the amount of sediment collected from each site has also been calculated, as

well as the gap between these values and the dredging volumes quantified by means of the surveys carried out on the beaches by the site manager, in agreement with the contractor in charge of the operations of dredging, transporting and unloading of sand on the beach.

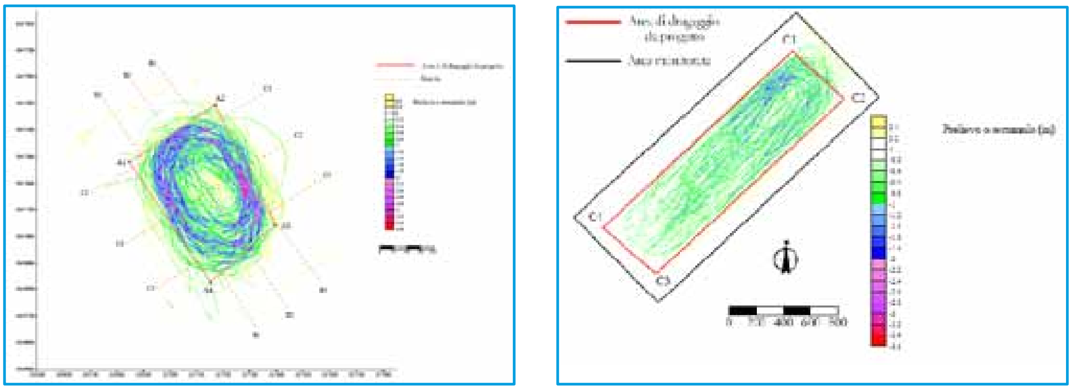


Figure 24

beach level map before and after dredging of A area (left) and C Area (right) in 2007

Based on these calculations, there is a good match with the amount of sand that has actually been dredged in the two harvesting sites of 2007 and a slight difference in harvesting site of 2002, due to the different instruments used for the surveys before and after the first operation (Aguzzi et al., in press).
As a whole, the results that have been obtained show that this approach can be regarded as a useful tool to assess the volume of beach nourishment, usually measured on the ground or on the dredge, to quantify the amount owed to the contractor in charge.

Alternative beach nourishment and dredging techniques vs. those used in Emilia-Romagna

During the design phase of the 2002 beach nourishment project, different alternatives were taken into account to overcome the problems arising from the use of 4 km long pipelines, which increased costs and time.
The most interesting solution was the use of a state-of-the-art high productivity and high loading capacity (more than 16,000 m^3) dredge: i.e. the Jumbo Trailer; finding a sand storage area close to the coast, at a depth of at least 12-14 m, to ensure closer inshore dredging operations under total safety conditions; the use of smaller vessels, with lower load capacity, to collect the sand, as close as possible to the coast, and discharge the sand on the beach. This would enable to use much shorter pipes, save time and facilitate the sand discharging operations.
In agreement with the Region, designers have ruled out this solution, because the 12 - 14 m deep seabed, along the Emilia-Romagna coastline, is made of soft mud (Preti, 2002). To reclaim the sea

bottom, huge amounts of sand would be required, and in any case, during the sand harvesting phase, there would still be the risk of moving the muddy layer together with the sand, thus affecting the good quality of sand found in underwater deposits, which are actually free from any silty and clayey fraction.
With the discovery in 2008 of the H underwater sand deposit (fig. 17), made up of very fine material, new techniques could be tested along the Emilia-Romagna coast.
This material is incompatible with that of the backshore, but it can still be used to reinforce or even create new submerged bars along sites where they no longer exist. This operation does not entail any accretion in the backshore, but it dampens the wave energy and consequently the beach erosion rate.
Another beach nourishment method with sand coming from underwater deposits, which deserves to be mentioned, is harvesting by means of dredges and nourishment with sand discharge directly on the beach to be nourished. For this type of technique, dredges or barges with an opening in the hull are used. This action is possible only on beaches with high slope and deep enough waters allowing the transit of the vessel. The Emilia-Romagna beaches are characterized by shallow waters and not very steep forshores, so this beach nourishment method is practically inapplicable for this type of coastline.

Environmental aspects related to the harvesting of sand from offshore deposits

ARPA Specialized Sea and Coast Unit (USMC) has conducted a structured physical and environmental monitoring campaign of the 3 dredged areas, with the support of several research institutes, universities and specialized companies.
These surveys have been carried out both in order to study the environmental impact from dredging operations and to meet the many issues raised by fishermen, concerned about the impact that these operations would have on sea life and on fisheries.

Monitoring of impact on demersal fish fauna

During this first nourishment campaign, in 2002 the Central Institute for Scientific and Technological Research Applied to the Sea (ICRAM STS) of Chioggia was responsible for analyzing the demersal fish fauna in the harvesting site (fig. 18). The area concerned by dredging and two additional sites were sampled by means of trammel nets and trawling gear during the pre-and post-dredging periods (Franceschini et al., In press).
Overall, the samples showed no significant differences in species

composition or abundance of catch before and after dredging. Clear positive indications emerged about the recovery of at least the portion of trade, compared to pre-dredging situation.
In the overall evaluation of the results obtained so far, this item must anyway be taken into account in a framework where the starting environmental conditions (limited size of the area concerned by the operation, lack of nurseries within the dredging area, presence of mainly commercial demersal or nektonic species) were such as to minimize the impact of the beach nourishment operation on commercial fishing.
Finally, the study area is an area where the fishing pressure is relatively low because of the distance from the coast (about 30 miles offshore) and the lack of stocks of commercial value (Franceschini et al. in press).

Monitoring of impact on benthic species

During both nourishment operations by means of underwater sand, the Department of Animal Biology, of the University of Modena and Reggio Emilia carried out a study on the effects of sand extraction on macrozoobenthic communities in the areas under question (fig 25; Simonini et al., in press a, in press b).
As is well known, the dredging of underwater sand can cause significant changes in the benthic environment. The effects of sand extraction can be of two main types: direct or indirect. The first type of risk is associated with the burial of organisms living in areas adjacent to the excavation, due to the sedimentation of suspended matter and the other even more serious risk is associated with the removal of sediment and of the organisms present in the excavation site, which normally undergoes a nearly complete defaunation.
Between 2001 and 2004 the medium term effects on sand extraction (first operation in 2002) and on the macrozoobenthos of the C1 site were analyzed.
The monitoring campaigns were performed before, during and after dredging. Three affected stations and seven control stations were examined.
Sand harvesting activities have led to the almost complete defaunation of the areas subject to dredging. Since the sea bottom of the C1 area is mainly composed of sand, no organism burial phenomena were detected: a mainly direct impact of relict sand extraction was observed, related to the removal of organisms from the seabed, which concerned only the dredged area, without causing substantial changes in particle size characteristics of the seabed. This specific aspect facilitated the recolonization/recovery process, which was completed within 30 months of dredging. (Si-

Figure 25

A few sampling operations and sediment sample preparation phases for the study of the macrozoobenthos on board the Daphne motor ship

monini et al., In press a).
The 2007 operation concerned both the C1 and A areas, located closer to the mouth of the Po River (fig. 25).
The study of the A area was particularly interesting. It consisted of sand not outcropping at the water-sediment interface, but it was covered with a 30 to 50 cm thick mud layer.
It is a particularly interesting subject since the particle size of the surface sediment plays an important role in determining the magnitude and duration of the impact of sand harvesting on benthic ecosystems in the areas involved in the excavation or immediately adjacent to them. During the excavation of the A site, in addition to a direct impact, further indirect effects were envisaged, related to the sedimentation of the suspended fine material produced by the dredging operations, which could lead to the burial of the organisms in the areas immediately adjacent to the excavation.
The A site has been monitored and a rapid recolonization and full recovery has been detected 2 years after the dredging operations. Contrary to all expectations, the rapid recolonization and recovery process that has been observed, suggests that the exploitation of sand deposits covered with a thin pelite layer, such as the A site, is even more sustainable for the benthic population, compared to dredging areas with exposed sand, such as the C1 area (Simonini et al., in press b).

Study of the turbid plume spread

With regard to the A borrow site, further experimental investigations were carried out in 2007 within the European BEACHMED-e RFO (2006-2008; Eudrep sub-project). The investigations have focused on monitoring the spread of the turbid plume generated by dredging of sand from this sand deposit that, unlike C1, is covered with a few decimetre thick pelitic layer. USMC ARPA, ARPA also Daphne DISTART Cesenatico and the University of Bologna have been involved in these activities. ACDP probes were used, CTD, water samples were collected and two flights were made during the dredge loading operation.
Maximum 100 mg/ l. concentrations were detected in the vicinity of the dredged area. After about two hours, the turbidity plume was completely scattered by currents and the residual concentration decreased to 0.1 mg/ l (fig. 26 and fig. 27).
The lowest concentrations that have been detected and the rapid spread of the plume suggest that the dredging operations on sand deposits covered by decimetric politic layers do not significantly change the turbidity of the water (Martinelli et al., 2007; Beach-med-e, 2006 - 2008).

Figure 26

Plume turbidity generated by dredging operations

Chemical-physical monitoring of the water column and sediment

The ARPA Daphne Oceanographic Unit of Cesenatico has carried out the chemical-physical monitoring and characterization of the water column and sediment (particle size analysis and organic carbon content) of the areas to be dredged during both campaigns (fig. 28). Surveys have shown that dredging did not affect the trophic status of the areas concerned either in the aftermath of the operations or in the following years after dredging (ARPA, 2005, 2009).

Bathymetric and morphological seabed monitoring

In the 2001-2009 period, before, during and after the 2002 and 2007 dredging operations, several geophysical monitoring campaigns were carried out in the three pilot areas by means of (multibeam and single beam) echo sounder and side scan sonar with the instrumental and technical support of ISMAR-CNR, Ancona (ARPA, 2005, 2009; Aguzzi et al., in press).
The findings have shown that the dredge has worked within the area boundaries set by the executive project, and the previously flat and smooth seabed featured circular grooves after dredging, with a maximum 2 m depth on the C1 borrow site and a 3 m depth on the A borrow site (fig. 20).
In the following years, after the two harvesting campaigns (7 years after the first operation and 2 years after the second operation), repeated monitoring have shown no significant attenuation of the grooves produced by dredging.

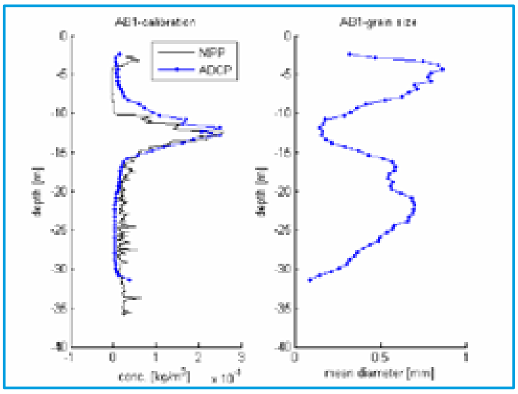
Onshore sources away from the coastal system

Onshore quarries

Land-based quarries have been the first sand on-shore source used in Emilia-Romagna for beach nourishment purposes. This operation has proved to be environmentally, economically and strategically unsustainable and therefore it had to be ruled out.
Substantial evidence is at the basis of this conclusion:

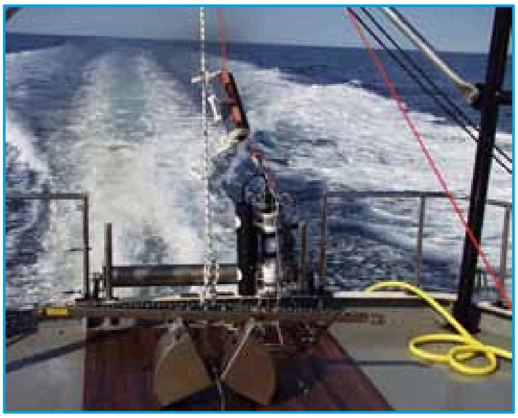
- land-based quarries have an extensive and heavy landscape and environmental impact, thus scarring the flat land with "big" holes (fig. 20);
- a large amount of sand is taken away from the construction aggregates market;
- the unit price of sand, which is already very high, increases substantially (about 20 Euro/m^3);
- the transport of sand from the quarry to the beach can be

Figure 27



Example of profile obtained by ADCP probe (Martinelli et al., 2007)

Figure 28



Bucket, CTD probe and Niskin bottle on board of the Daphne motor ship

Figure 29

Area south of Ravenna along the Adriatic road: in black the areas used as sand quarries.

Figure 30

Beach nourishment by means of sand from land-based quarries undoubtedly is the solution with the heaviest environmental impact

made only by means of trucks, thereby causing a strong impact and serious traffic problems along the road network (fig. 30).

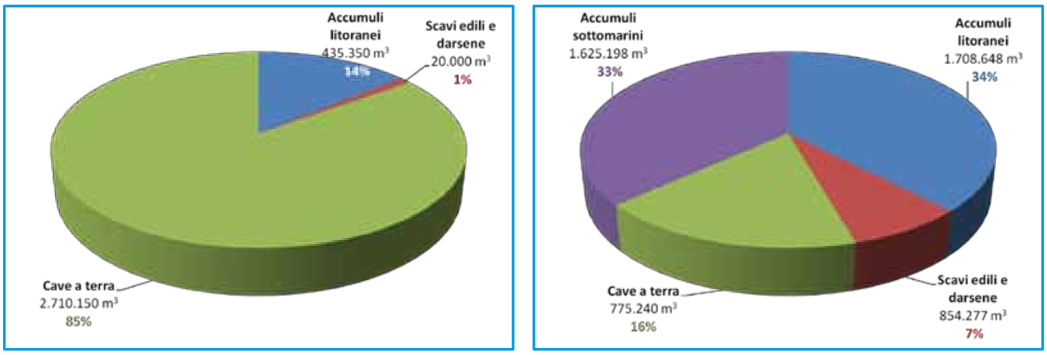
These observations, reported in the 1996 Coast Management Plan, have been taken into account by the Region, with a gradual reduction of sand coming from land-based quarries and a greater use of other sources (fig. 31).

The use of sand from the land-based quarries is now reduced to a few thousands of cubic metres per year, and only a few municipalities, such as in particular Ravenna, resort to it for urgent maintenance purposes.

Excavation works

During the 1990's the Municipality of Riccione put forward the idea to use material from excavations near the coast and in sandy soils, from foundations for buildings and construction infrastructures, for beach nourishment purposes. The Municipality issued a legally binding building regulation whereby manufacturers were required to carry sand from building site excavations to the Riccione southern beach under serious erosion.

Figure 31



Sand extraction sources for beach nourishment purposes in the periods ranging from 1983 to 1999, from 2000 to 2007. Green: inland quarries. Blue: littoral accumulation. Red: excavation. and new docks. Violet: off-shore sources

Originally, a few thousand cubic meters of material per year were transported on the beach. Then, between 2000 and 2003, following the construction of large public works, such as the Conference Hall and an underground parking, built beneath the seafront, the amount increased in a exponential way, by exceeding a total of 200,000 m³ (fig. 32).

From an economic point of view, it should be pointed out that it is the least expensive beach nourishment operation, because the only costs involved are those related to the spread of the material on the beach.

Over the past few years, the Region has involved other Municipalities and invited them to follow the example of Riccione to address other urgent beach nourishment requirements. Cesenatico has recently approved a regulation to that effect.

Figure 32

South of Riccione: sand coming from the building excavation before nourishment by means of underwater sand in spring 2007.

New Docks

Sand deriving from the excavations for the construction of new docks must be mentioned among the various coastal sand sources. Over the past ten years two yachting marinas, one in Rimini (2002) and one in Cattolica (2007) have been built along the Emilia-Romagna coast.

The Rimini dock was built near the north quay of the port-canal, by enclosing a stretch of sea and part of the San Giuliano beach by means of offshore sea defence works (ARPA, 2005). The basin covers a 300 m wide over 400 m long area (fig. 33, Preti et al., 2008).

The following quantities of material were obtained after the excavations that were carried out in the new dock area, to ensure a head of water necessary to allow the navigation and mooring of vessels:

- 100,000 m^3 of sand brought for nourishment purposes from the 440 m. long remaining San Giuliano beach. This action resulted into an average 80-100 m beach accretion (fig. 34). The sandy material was transported in part by means of dumper trucks and in part directly pumped on the beach from a dredge in the dock;
- 51,450 m^3 of material made of 1/3 of lime, 1/3 sand and 1/3 of gravel used for beach nourishment purposes of the shoreface in front of the rock armour of Porto Verde (Misano Adriatico). The material was collected and deposited by means of a dredger.

The port canal of Cattolica is located in the final stretch of the Tavollo river, whose mouth is protected by the Western and Eastern docks. In 1934 a fishing dock was built near the west pier.

In 2006, the new offshore sea defence works of the yachting marina of Cattolica were built in front of the old “fishing harbour” (fig. 35, ARPA, 2009).

Excavation works were carried out within the offshore breakwaters, to reach the required depth for the mooring of vessels, as was done in the dock of Rimini.

At the end of 2008, the following quantities were dredged and used for beach nourishment purposes:

- 3,500 m^3 of sand used for the nourishment of the Misano beach;
- 7,800 m^3 of sandy material, consisting of 70% sand and 30% silty material for the nourishment of the beach adjacent to the new square;
- 8,700 m^3 of mixed gravel, sand and clay for the nourishment of the area adjacent to the downdrift embankment. The fine component of the material represented accounted for about 40% (ARPA, 2010 a).

Figure 33

San Giuliano Beach, before and after the construction of new marina near the pier north of the port canal

Figure 34

Rimini (August 5, 2003): San Giuliano beach two years after nourishment by means of sand coming from the new dock

Figure 35

Cattolica: At the top the "fishing harbour" (2005), at the bottom, the new dock built behind the existing one (2009)

Figure 36

Bellaria-Igea Marina (May 12, 2009): section of the offshore reef perimeter of the new dock built in Spring 2009

The dredging and subsequent beach nourishment operations were carried out by means of a barge equipped with a crane and bucket The quantities of sand available in the future ensuing from the construction of new docks are not quantifiable and anyway remain a temporary source. At present, no new docks are envisaged to be built along the coast, except for the dock of Bellaria Igea Marina at the mouth of the Uso river. The construction works were stopped in the spring of 2009. The only work that was carried out was a stretch of offshore reefs south of the Uso river mouth (fig. 36, ARPA 2010b). In the design phase, in view of the building of this work, several thousand cubic meters of sand were to be dredged and used as beach nourishment material for the adjacent beaches.

The use of the dredged material used to build the docks for beach nourishment purposes has two advantages, an environmental and an economic one. As a matter of fact, on the one hand, this operation allows to recover material that would presumably be dumped away and, on the other hand, the price charged to the community is equal to zero, since the material dredging, transport and storage operations are at the dock owner's charge.

Dredging of the Port of Ravenna

The port of Ravenna is one of the major national North Adriatic ports (fig. 37). All activities, including dredging operations, are managed by the Port of Port Authority of Ravenna, which was founded in the 1990's.

The port of Ravenna is largely situated inshore, within the coast, along about a 10 km long waterway flowing from Porto Corsini to Ravenna city, and stretching in the spaces opened in the south-western area of Piallassa di Piomboni.

It is an inland port, facing the sea space enclosed by long jetties (2,600 m) hosting a yachting marina.

A ferry and cruise ship landing pier has recently been built on the north side (2009–2010), between the offshore breakwater and the old protective pier.

Over the past 20 years about 7 million m^3 of material have been dredged to expand the port area and to deepen the seaway. It was mainly made up of fine material, but it also included some sand layers.

In any case, for time and cost related reasons, no selective dredging has ever been carried out, so part of the undifferentiated dredged material has been stored in huge containers, in view of being put on sale or used to raise the port area level, after a few years, since over the past 60 years, the area where the port is lo-

cated has subsided by 150 cm. The dredged material has not all been stored. As a matter of fact, between 2004 and 2010, more than 1 million m3 of material has been used for the nourishment of the seabed and of the beach located between 2 and 5 km north of the offshore breakwater of Port Corsini.
Between 2004 and the first half of 2010, the three dredging projects, which are briefly described below, were developed by the Port Authority, with the approval of the Region.
· The first 2004 project consisted in the dredging of about 250,000 m^3 of fine sand, in the port area which was pumped out through a pipeline 4 km north of the Porto Corsini jetty, in front of the revetment protecting the Foce Lamone-Casal Borsetti stretch of coast.

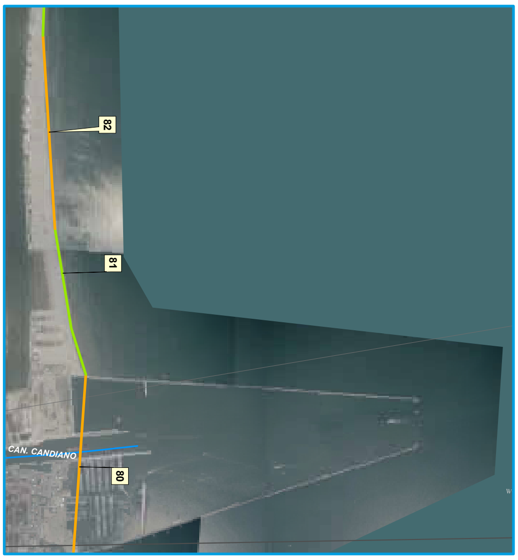
cell	name	V of sand harvested between 2000-2006 (m^3)
80	Port of Ravenna	250,000

The beach facing this revetment has disappeared since many years. Thanks to a beach nourishment project, a 30-40 m wide by several hundred meter-long beach has been created. Because of the very fine size of the sand material, within two years this new beach has again been eroded.

- the second 2007 beach nourishment project consisted of 700,000 m^3 of fine sand material, mostly (by over 90%) dredged in the ship canal lying within the offshore jetties, transported and discharged by means of a dredger with a capacity of a few thousands m^3, 2-3 km north of the port, between 5 and 8 m depth.
- the third project was completed in the spring of 2010 and consisted of the dredging of 200,000 m^3 of sand coming from the area in front of the port where the new cruise ship dock has been built. In this case the material consisted of very fine sand. Sand was directly pumped from the dredge through a pipeline located along the beach, while the storage area was the shoreface north of Marina Romea.

A 100 m wide and 1 km long artificial reef was built between –1 and -3 m depth, starting from Foce Lamone south.
As far as the operation management is concerned, very fine sand and silt have been used, after the necessary chemical quality tests, to nourish a stretch of coast that has suffered massive damage due to subsidence and that, in the absence of natural feeding, is in a very critical situation.
Also from an economic point of view, all these projects are very attractive because the cost is borne by the Port Authority. It must, however, be pointed out that with a view to introducing the se-

Figure 37



Port of Ravenna. Cell n°80

lective dredging to recover a portion of sand, ad hoc agreements have been negotiated between the Port Authority and the Region to share the cost. These choices are very important for coast management purposes because the new recently approved Master Plan of the port of Ravenna envisages the dredging of 11 million m^3 of material partly deriving from the deepening of the seabed and partly from extensions.

Figure 38

Lido degli Estensi. Cell n°100

On-shore sand sources

Beaches under natural nourishment

The 1996 Coast Plan has identified other stretches of coast under constant accretion that could be used as an internal source of sand for beach nourishment purposes.

The Coast Plan indications have been implemented by the Region after 2000.

In 2004, the regional Po di Volano Technical Service, responsible for the area of Ferrara, launched a project based on the harvesting and transport, via pipelines, of 250,000 m^3 of sand from the Lido degli Estensi beach to the beaches north of Porto Garibaldi (fig. 38).

Several complex technical innovations have been introduced by the project:

- crossing the Port canal of Porto Garibaldi, which is exposed to strong tidal currents, required the ballasting of the pipeline;
- the transport by means of trucks of dry sand harvested from a borrow hole on the beach, by mixing it with water and pumped into the pipe by means of a special pump;
- the use of intermediate pumping stations to make sure that the sand could reach the most northern shore, Lido delle Nazioni, 7 miles north of the point of departure;
- beach nourishment concerns a stretch of coast longer more than 5 km;
- the aim is to carry out the transfer of sand with a minimum environmental impact and, therefore, to avoid the use of road transport.

Over the past few years sand harvesting operations have been carried out in Porto Corsini beach (fig. 39).

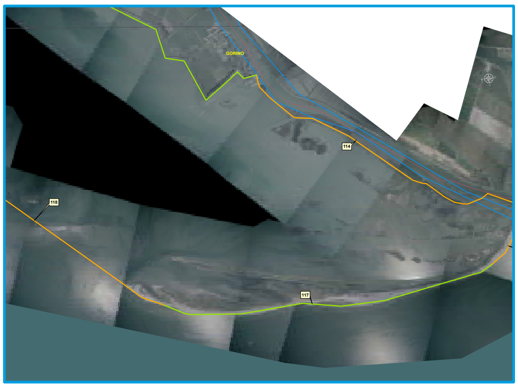
Figure 39

Porto Corsini beach. Cell n°81

In this case, however, sand has been transported by means of lorries along the beach to the northern coast of Marina Romea 2-3 km further north. Over the past 20 years, sand has occasionally been harvested from Scanno di Goro in the southern part of the Po river delta (fig. 40). It is a narrow wing-shaped strip of sand that extends over a 7 km long coastline, from east to west, starting from the Po di Goro river mouth.

It is made up of sandy materials carried to the sea through the southern branches of the Po river and thanks to its length and extension into the open sea. It is the element that has generated the Sacca di Goro, a marine lagoon with a wide mouth connecting it with the open sea. Over the past 50 years, the Scanno di Goro has undergone various ups and downs: when it is fed by materials carried by the Po river floods to the sea it expands and lengthens, since the sand grains are blown westward by sea storms, but when the supply is reduced, it is flattened out by the sea and its level is maintained below one meter and in a few spots it is eroded and a few openings are created. In the first half of the 1990's, the Scanno di Goro reached a 9 km length, so that its tip was just over 1 km away from Volano nord beach. The Po di Volano Basin Technical Service thus designed a plan based on a 30 to 40,000 m^3 sand harvesting from the end of the strip and its transport by barge to the beach north of Lido di Volano. From there the sand was then loaded onto trucks and transported further south to feed eroding beaches. As a result of various human interventions in the following years, this bar of sand was interrupted at about 7 km from its root and in a few years a 20 m gap turned into 700 m opening under the tide pressure. Later, the relict beach stretch further west, which was no longer fed, became almost completely eroded, while the materials coming from the mouths have accumulated to the east of the opening. 800,000 m^3 of sand were harvested here in 2002 and over one million m^3 of material was collected in 2009 and then redistributed within the Sacca area to revitalize its bottom and increase the growth of shellfish (a project funded by the shellfish producers' cooperatives).

Figure 40



Scanno di Goro. Cell n°117

Table 2

Cell	Name	Macrocell	V harvested 2000-2006 (m^3)
13	Misano Scogliere	M1	18450
23	Fogliano Marina	M1	0
24	Miramare	M1	32700
25	Rimini Centro	M1	9650
30	Rivabella	M2	0
31	Viserba Zona Sud Sortie	M2	0
34	Viserba Nord	M2	0
48	Cesenatico	M2	15000
79	Marina di Ravenna	M4	0
81	Porto Corsini	M5	29255
100	Lido degli Estensi	M5	246800
110	Scannone di Volano	M7	123500
117	Scanno di Goro	M7	0

Coast cells suitable for sand harvesting to be used for beach nourishment purposes of beaches under erosion, related macrocells and volumes of sand harvested in the 2000-2006 period

The work was carried out by means of dredgers that have pushed the sediment to inner areas within the Sacca through pipelines.
The data analysis related to the April 2000 and April 2006 period, contained in the coastal cell management database, has allowed to select 13 cells shown in table 2, as stretches of coastline that could be potentially used for sand harvesting purposes.
Out of 13 cells, 4 cells belong to Macrocell 1 (Cattolica–Rimini stretch), and the other 4 cells belong to Macrocell 2 (Rimini–Cesenatico stretch).
The miles of beach considered to be potentially exploitable for the harvesting of the sand falling within the first macrocell are about twice as much as those located north of Rimini, within M2 (table 3 and fig. 41).
The remaining cells can be used for sand exploitation purposes and are distributed along the stretch between Foce Savio and Porto Garibaldi and in northernmost cell related to the Po river mouth.

Table 3

stretches of beaches that can potentially be used for sand harvesting purposes; situation of defence works and related macrocell.

Macrocell	Emerged Breakwaters (m)	With no defence (m)	Total (m)
M1	755	8,117	8,872
M2	4,837		4,837
M4		2,991	2,991
M5		2,544	2,544
M7		3,043	3.043
Grand Total	5,592	16,694	22.286

Most of the cells in question have no defence works in place, except for only about 750 m long stretch, along Misano beach (cell 13), the section north of Rimini, corresponding to Rivabella and Viserba, and cell 48 Cesenatico (M2), which are protected by longshore emerged breakwaters.
In 2000-2006, M5 (Corsini Porto - Porto Garibaldi) was the most exploited macrocell: approximately 250,000 m^3 of sand were collected in Lido degli Estensi.
Most of the selected cells are characterized by a 50 - 100 m wide backshore with an inshore 1 - 2 m closure (fig. 42).
The only cell characterized by a wider beach is the 200 m wide Lido degli Estensi (M5).
The highest closure depth (about 2.2 m) has been recorded at Misano, along the stretch protected by breakwaters (M1).

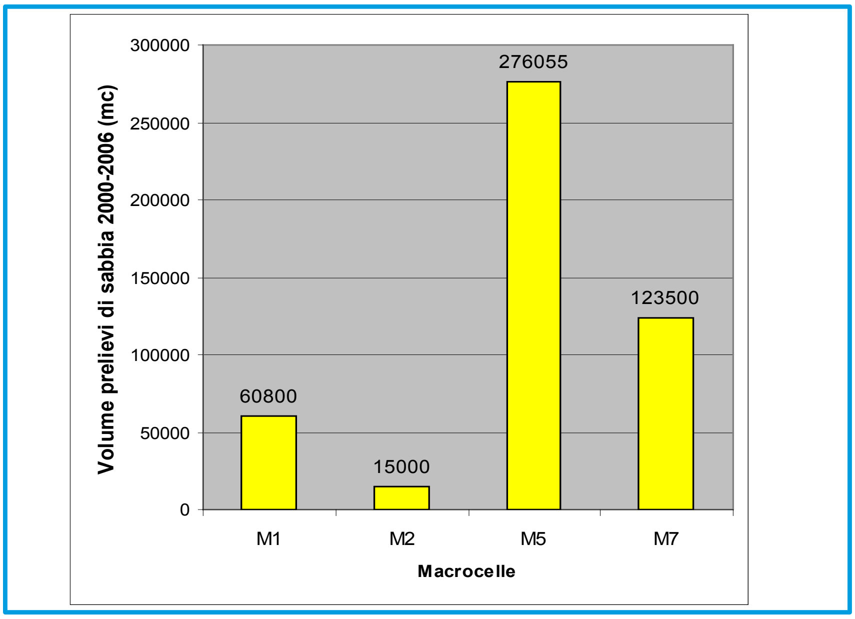
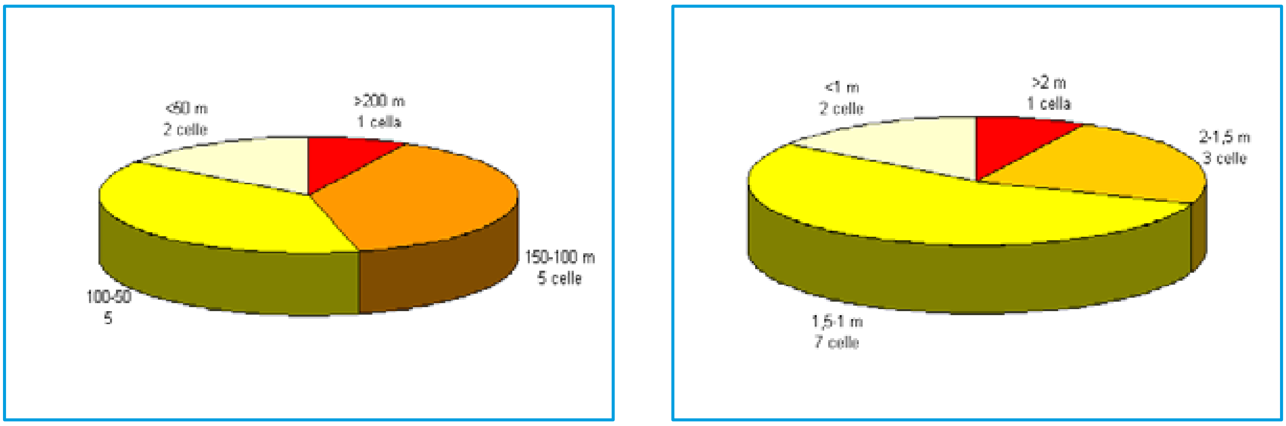


Figure 41

Volume of sand harvested from the 1, 2, 5 and 7 macrocell, in the 2000-2006 period

Figure 42



Left: average backshore width of the 13 cells that are potentially suitable for sand harvesting Right: the average inshore closure depth of the beach of the 13 cells that are potentially suitable for sand harvesting

Port dredging

Several ports are located along the 130 km long coast of the Emilia-Romagna Region. They have often been built either using the river mouths or by building an artificial canal cutting through the backshore and shoreface.

This was the only way to link the inner basin, serving as shelter or mooring for boats, to the open sea. For these reasons, all the Emilia-Romagna ports fall in the category of port-canals (i.e. harbour entrances with parallel jetties).

All port-canals are subject to silting up, depending on their location, the length of the piers and direction of coastal solid sediment transport.

The materials silting up in the vicinity of the port-canal entrances are mostly made up of beach sand drifting along the coast transported by coastal currents.

In a coastline, such as that of Emilia-Romagna, the opening of an underwater canal to facilitate access of vessels to the port translates into a change in the morphology of the seabed, which inevitably is short-lived, since the wave motion lifts and drifts the underwater sand, thus silting up the canal and restoring the initial sea bottom situation.
The best way to dispose of sand silting up the canal is to use it for the nourishment of eroding beaches not far from the port entrance, provided that it is not polluted. Yet, until 1996, the sand dredged at the port entrance was transported and discharged into the sea a few miles offshore.
The law regulating the dredging and dumping of material in the coastal area has been updated by the Ministry of Environment Decree dated 24 January 1996, which provides for severe technical and legal procedures to be applied to any handling activity.
To avoid, on the one hand, any waste of resources and, on the other hand, any uncoordinated action by any Municipality or Local Authority being interested in dredging a port, or harvesting or discharging sand along the coast, the Emilia-Romagna Regional government has decided to design a single reference framework collecting all the available knowledge and information about all the sites involved and has entrusted this task to the Idroser technical group (ARPA, 1997).
This new work has provided the regional authority with the opportunity to draft a general project based on the 1996 Coast Plan, which was completed and submitted in the spring of that year. In compliance with it, it was necessary to assess the material dredged from the following regional and local ports, for beach nourishment purposes:

- access canal to the Port of Goro;
- Port of Porto Garibaldi;
- Port of Cervia;
- Port of Cesenatico;
- Port of Bellaria;
- Port of Rimini;
- Port of Riccione;
- Port of Cattolica.

The private marina of Porto Verde, located in the Municipality of Misano, must be added to this list, even though the annual dredged quantities amount only to a few thousand cubic metres.
Riccione has been the first Municipality that has adopted the 1996 Coast Plan provisions, regarding the use of material dredged at the port entrance.
The docks at the port of Riccione do not stretch out into the sea at a great distance and the coastal dynamics is characterized by a very intense direct south-north drift, resulting into a constant

silting up of the port entrance. To address this problem, once it was assessed that the dredged sand could be used for beach nourishment purposes, the Municipality purchased a small dredger to be operated whenever the sea is calm (with the exception of the tourist season).
The dredged sediments are deposited on the beach in a temporary pool and then resumed after a while to be transported along the eroding beach 3.5 km southwards.
In this way sediments have been dredged for many years and resulted into about 10,000 m^3/year of sand used for beach nourishment purposes, with a low cost (3-4 €/m^3) and a low environmental impact.
Later on, the dredging techniques applied at the entrance of the harbour and sand nourishment on beaches adjacent to the port have also been extended to other port canals of the region.
With regard to the techniques used, the one implemented by the city of Cervia for many years is worth mentioning.
To clear the passage way to the sea, obstructed externally to the docks by a large longshore bar, the municipal authority decided to move the sand away by means of a large pontoon propeller, rather than dredging the sand and discharging it offshore, or to another site. In the 2000s, this technique, which led to short-term results, was replaced by traditional pontoon-based dredging techniques and barge transport to the beach under erosion in Milano Marittima, 3.5 km north of the port.

Table 4

Cell	Name	Harvested Volumes between 2000-2006 (m^3)
101	Entrance of Porto Garibaldi	0
1	Bocca Tavollo (Porto Cattolica)	0
57	Port Canal of Cervia	33500
49	Port Canal of Cesenatico	0
26	Port Canal of Rimini	0
18	Port Canal of Riccione	48200
9	Port Canal of Porto Verde	16000
	Total	97700

Harvested volumes of sand dredged between 2000 and 2006 from the ports

In some cases, the sediments dredged from the harbours have been discharged into the shoreface. This practice leads to less noticeable results, but it is more cost-effective in terms of beach nourishment. The discharge of material at a depth of 2 to 3 m, in fact, proves to be effective because it raises the sea bottom, by reinforcing the submerged bars, thus resulting into a dampening

of the wave energy on the backshore.
Overall, from 1996 to 2010, and about 460,000 m^3 of sandy material were collected from the Emilia-Romagna ports and were used for nourishment purposes.
Analyzing the database of coastal cells, reporting data related to the April 2000 and April 2006 period, 97,700 m^3 of sand were dredged from the ports of Cervia, Riccione, Porto Verde.

Mouths and bars of rivers and canals

The 130 km long coastline of the Emilia-Romagna Region features the presence of a river mouth or canal every 10-15 km. The river mouths tend to get silted up during the dry season, mainly when the coastal dynamics prevails over the river dynamics.
During floods, the strong river current easily removes the sand that was deposited in the mouth and carries it to the sea where, due to the different energy interplay, settles down not far from the shoreline, thus giving rise to the formation of submerged deposits. These deposits are then reshaped by the sea and in the case of rivers with low flow during summer, get shaped up as longshore submerged bars, located several hundred meters offshore. This is the case of the Po delta branches.
Over the last 15-20 years, the dredged material at the mouth of rivers and canals has largely been used for beach nourishment purposes.
The following river mouths from which significant amounts of material have been used for beach nourishment purposes are, from south to north:

- Marano River mouth (Riccione);
- Uso river mouth (Bellaria);
- Lamone river mouth (Ravenna);
- Logonovo Canal mouth (Comacchio);
- Po di Goro River mouth.

In the case of the Marano River mouth, the material was harvested from the beach on either side, rather than inside the area within the river mouth. About 4-5000 m^3 every 4-5 years are harvested, by means of mechanical shovels and transported to the eroding beaches in Riccione by truck.
The Logonovo Canal mouth separates Lido di Spina from Lido degli Estensi and therefore it is located within a very wide beach under constant accretion.
The Logonovo Canal connects the Valli di Comacchio with the open sea. Keeping its mouth clear of sediments is therefore a necessity.
Towards the late 1980s, ERSA (Regional Agency for Rural Development) of Ferrara identified this site as the most suitable one for

harvesting sand to be used to rebuild dunes eroded by the sea in the south of Lido di Spina.
After a few years, large quantities of sand from Logonovo, amounting to 20 to 40,000 m^3 every 4-5 years, were repeatedly harvested by the Po di Volano Basin Technical Service.
Another interesting case is the harvesting of sand from the Po di Goro river mouth bar.
A few hundred metres off the river mouth, there is a very large sand bar resulting from the material transported by the Po di Goro and Po di Gnocca delta branches to the sea.
Hence, in the late 1990s, a large quantity of sand, amounting to 400,000 m^3, was collected and transported by a barge to Cesenatico. There it was unloaded at the northern dock to be further transported by trucks to the western beach to be nourished.
Although the sand particle size was especially suited, the unit cost was very high, because a 70 km distance had to be covered between the port of Cesenatico and the Po di Goro River mouth, the vessel capacity was small and a further truck loading and unloading operation had to be carried out.
In 2009, an additional well managed sand harvesting operation from this bar took place.
The beach facing the lighthouse tower, which can be seen on the left side of the Po di Goro River mouth, has been completely eroded. For this reason, the Po di Volano Basin Technical Service has carried out a nourishment intervention by dredging sand from the submerged bar and discharging it on the beach to be restored through a pipeline.
Recent analysis performed on the data contained in the database of the coastal cells to allowed to select 16 cells, corresponding to the river and canal outlets, suitable as borrow sites to be used as sand for beach nourishment purposes for beaches under an erosion (table 5).
Between 2000 and 2006, from 6 of these cells appear to have been taken 476,000 m^3 of sand.
If the river dynamics and coastal areas remain unchanged, it is assumed that over the next 10 years it will be possible to take cells from these 6 other 790,000 m^3 of sand. Very likely, these will add up the volumes of sand from at least some of the other 10 cells regarded as suitable for collection.

Table 5

From database of coastal cells in possible to select 16 cells, corresponding to the river and canal outlets, suitable as borrow sites

Cell	Name	Harvested V between 2000-2006 (m^3)	Expected V to be harvested over the next 10 years
99	Foce Logonovo	247800	413000
95	Foce Gobbino	57000	95000
87	Canale Destra Reno	0	0
62	Canale di Via Cupa	0	0
59	Canalino delle Saline	0	0
115	Foce Po di Goro	120000	200000
111	Foce Po di Volano	0	0
84	Foce Lamone	0	0
5	Foce Ventena	16800	28000
74	Foce Fiumi Uniti	0	0
7	Foce Conca	14150	23583
64	Foce Savio	0	0
44	Foce Rubicone	0	0
40	Foce Uso	20400	34000
29	Deviatore Marecchia	0	0
22	Foce Marano	0	0
	Totale	476150	793583

Tomboli behind the breakwaters

Between 1947 and 1980, several emerged longshore breakwaters were built, for a total of 40 km in length, to protect many stretches of beach under erosion.
The longest barrier is the one built between the port of Rimini and the port of Cesenatico piers, 20 km apart from each other.
The emerged longshore breakwaters are able to stop and dampen more than 80% of the wave motion energy, thus reducing the sea energy within the basin enclosed between the breakwaters and the shoreline. As a result even the material sedimentation process is significantly altered in favour of finer particles.
The area where the energy is most dampened is that behind the main body of the work. In this area the largest sedimentation takes place. Hence, in many cases, if the breakwaters have been built at a short distance from the shoreline and there is enough flow of material, the beach gets connected with the offshore reef and it takes on the characteristic shape of a “tombolo”.
If the offshore breakwaters are distant and/or there is a small

quantity of material, submerged deposits pile up close to the reefs.
For over 20 years the Municipality of Cattolica and the bathing establishment owners have removed sand from the beach behind the first 10 southern reefs and have transported it to the northern stretch of the beach of Cattolica and Misano Adriatico undergoing a slight erosion. This operation was necessary because a constant accretion was underway in the southern stretch of the beach, so that without any harvesting, the shore would have become connected with the reefs, thus limiting the bathing area only to the clearings separating one reef from the other. It has been estimated that over the past 20 years 3000-4000 m^3 of sand have been removed.
About 20 years ago, they started harvesting sand from the underwater deposit, behind the main body of the reefs, which is primarily composed of very fine sand and in some cases of lime, in Bellaria North and San Mauro.
The City of Bellaria has purchased a small dredger to dredge and pump the material directly on the backshore, through a pipe, every spring.
In this way, the beach has been widened by 15-20 m solely to facilitate bathing. The initial experiences have, however, shown that this type of intervention was short-lived and that it would last only a few months, only for the bathing season.
Nevertheless, this type of nourishment is not only still applied, but has spread to the Ravenna coast.
In Gatteo a Mare, scrapers are operated only during low tide. Whereas, in Lido di Savio and Lido Adriano, the contractor in charge has designed an "artificial wagon", to transport a standard excavator equipped with a pumping system, which is able to pump water and sediment and spread it on the beach by means of a pipe.

The Ministry of Communications & Works of Cyprus

COASTANCE Pilot site

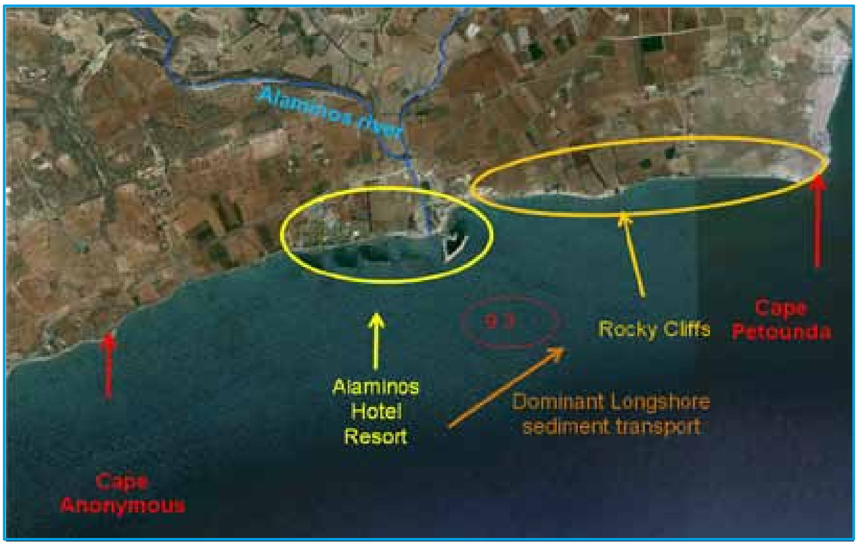
The figures 43 and 44 show the Coastance Pilot Site, Agios Theodoros beach, in sedimentary sub-cell 9.2.3 and the main sand deposit site Alaminos Hotel Resort. In Agios Theodoros beach, a maximum retreat of 23 m has been documented from 1973 to 2003. This coastal stretch of approximately 1,5 km requires beach nourishment of at least 5 m width.
The Alaminos hotel resort construction and the accompanying coastal works, started in 1996. In 2001, most coastal works were in place. The hotel resort is operational and it is going to be expanded towards the east (towards the marina). The coastal works

have created an important sandy beach and shallow bathing waters. The marina was initially planned as an "island" structure, positioned off-shore, leaving a narrow sea passage with a small bridge for access and docking places for small boats on the east side of the narrow sea passage. For the marina's construction, an access path was created into the sea, which has not yet been excavated and dredged to re-open the sea passage. The works have created sand accumulation and the marina structure is in practice a "peninsula". The docking places at the east of the planned sea passage are cancelled since they are filled up with sand. The hotel manager is practicing sand shifting every year, within the hotel boundaries, with the permission of the Provincial Authorities in order to preserve the access to the marina.

Figure 43

Satellite photo (Google Earth) of the sedimentary sub-cell 9.2.3.

Figure 44



Satellite photo (Google Earth) of the sedimentary sub-cell 9.3.

It is estimated that 12,000 m³ of sediment are accumulated every year in the Alaminos Resort. The Hotel Manager is moving every year approximately 4,500 m³ of sediment. This volume could be

used in annual basis for beach nourishment on another site.
From the available sand volumes we estimate that a 20% of the total sand volume will be either lost or non appropriate for beach nourishment. Therefore, the available volume for beach nourishment is estimated to be 3.600 m^3 per year.
The new beach profile in order to be stable needs sand nourishment of the submarine profile as well. In practice, some of the sand deposited on the beach will be eroded till a stable profile will be created. The calculation must therefore provide the total sand volume that is required in order to obtain a stable profile.
According to Dean (Dean, 1991), in order to create a stable beach profile from homogeneous sediment with $D_{50} = 0.12$ mm (approximately as it is the case in Alaminos sediment) the chart in figure 46 provides the volume, m^3 per m along the coastline, required. As the available sand volume is restricted, the width of the created beach will be limited to 5 m demanding 31 m^3 of sand volume per meter along the coastline. Hence, enough for creating every year a beach of approximately 110 m length (3,600 m^3/ 31 m^3 = 117.74m).
The availiable sand volumes will not be enough to cover the entire length of 1.500 m of critical coastal stretch under severe erosion. Therefore, beach nourishment should be applied on a rotating scheme, by changing the stretch that is nourished each time based on the evolution of the phenomenon and the need to resupply parts of the 1500 m long stretch.
The combination of beach stabilisation works (groynes, artificial reefs, geotubes, submerged breakwaters) with beach nourishment will be studied so as to prolonge the life spam of every beach nourishment operation.
There are two propositions for the first beach nourishment site (fig. 47):

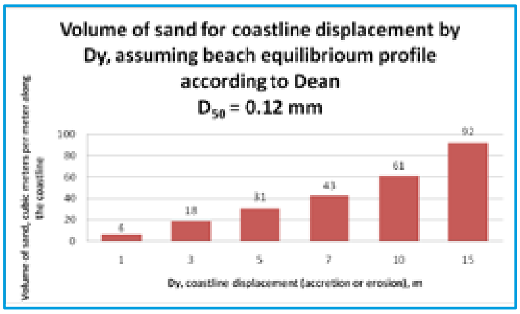
- the beach nourishment should start from the west border of the pilot site, just after the existing private revetment works, so that the natural longshore sediment transport drifts the sediment towards the centre of the pilot site and thus minimise the sediment that will be lost from the coastal stretch.
- the beach nourishment should start from the midle of the pilot site, where the maximum erosion has been documented.

After the first beach nourishment campaign, monitoring will be necessary so as to measure the erosion rate. If after one year the beach is in a satisfactory condition, the newly availiable sandy material will be used for beach nourishment in neighbouring zones, according to the future erosion status of the whole coastal stretch.
It is recommended to create a stock of suitable sandy materials (sand, gravel) extracted from excavations in public and private works near the shoreline. The material stocked will be periodically

Figure 45

Sketch of the positioning of the excess sediment near the Alaminos Marina. In red the positioning of excessive sand that has to be removed so that the external docks of the marina to become operational again

Figure 46



Volume of sand for coastline displacement

Figure 47

Orthophotomap of the Coastance pilot site (Cyan line). Zoom on the pilot site. Evolution of the coastline, Yellow line: 1973 coastline. Red line: 1993 coastline. Green line: 2003 coastline. (Source: Public Works Department of Cyprus (PWD)). In yellow are shown the proposed beach nourishment sites.

used for beach nourishment in the critical coastal stretch.
Monitoring surveys are necessary before and after the sand excavation at the borrow site and the beach nourishment site in order to establish more accurate data on:

- sand volumes available from the sand deposits;
- sand volumes necessary for the beach nourishment (according to the latest bathymetry survey);
- erosion rate of the beach nourishment site.

Environmental aspects

In Cyprus a special licence from the Provincial Authorities is required for every beach maintenance and sediment removal/deposit/nourishment operation. According to the legislation, the Provincial Authorities, can ask the preparation of an Environment Impacts Study which is commented/approved by the Environmental Department of the Ministry. The Provincial Authorities can also request comments on the project from other ministerial departments: Coastal Unit (Public Works Department), Fishery and Sea Research Department, etc.
It is up to the discretion of the Environment Department to decide if an Environmental Impact study is necessary, according to the importance of the works.
The Coastance pilot site is not included in the Natura 2000 protected zones.

Exploitation technologies

The littoral sand excavation from the beach east of the port will be accomplished with tradition excavation machinery:

- front shovels;
- hydraulic excavators;
- long Reach Excavation Loaders;
- track loaders;
- compact Track Loaders.

For the port sand dredging, a small dredging vessel will be used.
The screening of the dredged material, for sand cleaning and removal of *Posidonia*, will be accomplished by mechanical in-situ screening.
The transportation of the sand will be done by trucks and the profiling of the sand nourishment by:

- compactors;
- graders;
- motor Graders.

The final choice of machinery will be done by the contractor according to the location and volume of the sand deposits to be excavated and the availability of local machinery.

Region of Crete

COASTANCE Pilot site

The estimation of Useful Sand Volume per year has been made according with the data from past dredging of Keratokampos fishermen's port and the rate of sand accumulation at the beach located at the west side of Keratokampos since the port's construction. It is estimated that this beach works like a sand trap. The more the port protrudes from the coastline the more sediment is trapped in the beach.

Tabel 6

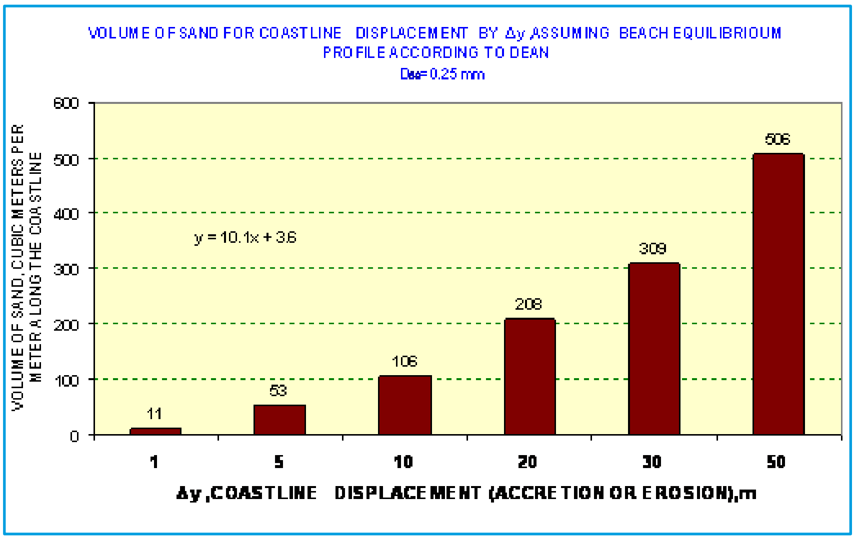
Deposit	Fishermen's Port Dredging	Beach on the west side of Keratokampos
Area (m^2)	9040	2704
Depth (m)	-2 to -3	0
Silt coverage (m)	2%	1%
Grain Size D_{50}	0.23 mm	0.23 mm
Useful Volume (m^3) per year	5500	1500

Volumes of sand available on COASTANCE Pilot site

The volumes in the table 6 are conservative (lower side). Because of the small volume of sand, it is the port dredging frequency, for navigation purposes, that will dictate the frequency of sand excavation. The Port Authority of Iraklion states that the fishermen demand dredging every year. The port access is completely blocked every two years. Considering the cost of dredging and the great distance of Keratokampos from other dredging and excavation sites, it is proposed that port dredging and sand excavation from the nearby beach takes place every two years during spring time.
From the available sand volumes we estimate that a 20% of the total sand volume will be either lost or non appropriate for beach nourishment. Therefore, the available volume for beach nourishment is estimated to be 5,600 m^3 per year or 11,200 m^3 every two years. The new beach profile in order to be stable needs sand nourishment of the submarine profile as well. In practice, some of the sand deposited on the beach will be eroded till a stable profile will be created. This sand volume necessary to create a stable sand profile has to be calculated.
According to Dean, in order to create a stable beach profile from homogeneous sediment with D_{50} = 0.25 (approximately as it is the case in Keratokampos sediment) the volumes mentioned in figure 45 are necessary. As the available sand volume is restricted, the

width of the created beach will be limited to 5 m demanding 53 m3 of sand volume per meter along the coastline. Hence, enough for creating every two years a beach of approximately 210 m length (11,200 m^3/ 53 m^3 = 211.32 m).

Figure 48



Volumes of sand for coastal displacement. Assuming beach equilibrium profile according to Dean

The availiable sand volumes will not be enough to cover the entire length of 1,100 m of critical coastal stretch under severe erosion (fig. 49). Therefore, beach nourishment should be applied on a rotating scheme, by changing the stretch that is nourished each time based on the evolution of the phenomenon and the need to resupply parts of the 1,100 m long stretch.
It has been chosen that the beach nourishment pilot site should start from the area marked in the figures 50 and 51.
The selected beach nourishment zone, is the one with the most dense construction, where two buildings have already been destroyed by sea erosion. After the first beach nourishment campaign, monitoring will be necessary so as to measure the erosion rate. If after 2 years the beach is in a satisfactory condition, the next dredging and sand excavation material will be used for beach nourishment in neighbouring zones, according to the future erosion status of the whole coastal stretch.

Figure 49

Critical Coastal Stretch of Keratokampos gulf under severe erosion

It is highly proposed to create a stock of suitable sandy materials (sand, gravel) extracted from excavations in public and private works near the shoreline. The material stocked will be periodically used for beach nourishment in the critical coatal stretch.
Monitoring surveys are necessary before and after the sand excavation and the beach nourishment in order to establish more accurate data on:

- sand volumes available from the sand deposits;
- sand volumes necessary for the beach nourishment (according to the latest bathymetry survey);
- erosion rate of the beach nourishment site.

Figure 50

Sand deposits and beach nourishment zone in Keratokampos gulf

Figure 51

Beach nourishment zone in Keratokampos gulf

Environmental aspects

It is estimated that the total available sand volume compatible for beach nourishment is in the order of 7,000 m^3/year (See deliverable reports Component 4 D1 and D2). About 11,000 m^3 are dredged every two years from the port of Keratokampos to reestablish the port function. Another 1,500 m^3 can be dredged every year from the new beach west of Keratokampos port.
From the available sand volumes we estimate that a 20% of the total sand volume will be either lost or non appropriate for beach nourishment. Therefore, the available volume for beach nourishment is estimated to be 5,600 m^3 per year or 11,200 m^3 every two years.
This volume can be increased if the accumulation rate west of the Keratokampos port is greater. Both sand deposits have been created due to the Keratokampos fishermen's port construction. The third possible deposit site (sand deposit East of Keratokampos stream outlet) will not be used because its removal can affect the nearby beaches which are under erosion. Moreover, this third, natural sand deposit is positioned in the surf zone and it can be distributed to the nearby beaches by natural forces.
The Keratokampos gulf is not included in the Natura 2000 protected zones. The closest protected zone is Asterousia, 12 Km west from Keratokampos gulf. The port dredging is under the jurisdiction of the Port Authority of Iraklio. The sand excavation from the beach and the port will require a permit from the Port Authority of Irakleio. Both sand deposits are small and recently (after 2001) "man made", so they do not include rich natural vegetation.
The sand excavation from the beach and Keratokampos fishermens port will require an Environmental Impacts Study specifying:

- which sand deposits could be removed (locations);
- how many cubic meters of sand could be removed on yearly basis;
- the best methods of sand extraction (period of the year, roads

and machinery used) so as to limit the Environmental Impacts;

- precautionary measures taken before, during and after the sand extraction to limit the Environmental Impacts;
- the wet dredged material (mainly from the Keratokampos port) is expected to have organic material and drying and screening will be necessary before the sand nourishment process.

It is proposed that:

- the dredging activities take place during the spring after the end of the winter season (completed at the latest before end beginning of May);
- the dredged material is used for beach nourishment in the Keratokampos gulf, in areas with severe erosion problems;
- he dredged material will dry-up before the beginning of the tourist period (June) and the nourished beach will be available for bathing.

BIBLIOGRAFY

Departmente de l'Herault

Aloïsi, J., Monaco, A., Planchais, N., Thommeret, J. & Thommeret, Y. (1978). – The Holocene 282 transgression in the Golfe du Lion, southeastern France: paleogeographic and paleobotanical evolution. Geogr. Phys. Quat., 15, 145-162.

Bouchette, Frédéric, Briqueu, Louis, Lauer, Christine & Pezard, Philippe (2003) Rôle des phénomènes catastrophiques (tempêtes et crues sédimentaires) dans la formation d'une lagune de littoral sableux. Exemple de l'Holocène du Golfe d'Aigues-Mortes (Gard/Hérault, France). Proceedings of 9th congrès Français de Sédimentologie, ASF, 38, 67.

Bard E., Hamelin, B., Fairbanks, R. & Zindler, A. (1990). – Calibration of the C timescale over the past 30000 years using mass spectrometric U-Th ages from Barbados corals. – Nature, 345, 405-409.

Brambilla, E., Bouchette, F., Certain, R. & Sylaios, G. (2009) Observations of sediment resuspension and transport in the nearshore zone, Gulf of Lion, France Geophysical Research Abstracts, 11, EGU2009-4626.

Cattaneo A. & Steel, R.J. (2003). – Transgressive deposits: a review of their variability. – Earth-Sci. Rev., 62, 187-228.

Certain, R. (2002) Morphodynamique d'une côte sableuse micro- tidale à barres : le Golfe du Lion (Languedoc–Roussillon). Thèse de Doctorat, Univ. Perpignan, 209 pp.

Chappell, J. & Polach, H. (1991). – Post-glacial sea-level rise from a coral record at Huon Peninsula, Papua New Guinea. – Nature, 349,147-149.

Dean, R.G. & Dalrymple, R.A. (2002) Coastal processes with engineering applications. Cambridge University Press, 476 pp.

Denamiel, C. (2006) Three dimensionnal coupled modeling of swell- and wind/buoyancy driven currents at the midshelf scale during storm events. PhD thesis, University of Montpellier II, France, 350 pp.

Dronkers, J. (2005) Dynamics of coastal systems. Advanced Series on Ocean Engineering (Eds World Scientific), 25, 520pp.

Durrieu de Madron, X. & Panouse, M. (1996) Advective transport of suspended particulate matter on the Gulf of Lions continental shelf. Summer
and winter situations. Comptes rendus de l'Académie des sciences, 322(12), 1061-1070 pp.

Ferrer, P., Benabdellouahed, M., Certain, R., Tessier, B., Barusseau, J.-P., and Bouchette , F. (2010). The Holocene inýll of the Thau lagoon (Western Gulf of Lions, Mediterranean sea, France. a record of coastal sandy barrier dynamics under climate, sediment availability and eustatic forcings. Bulletin Société Géologique de France, 181(2), 197-214.

Guilcher, A. (1961) Le « beach-rock » ou grès de plage. Annales de Géographie, 70(378), 113-125.

Hesp, P. and Hilton, M.J. (1996) Nearshore- surfzone limits and the impacts of sand extraction. Journal of Coastal Research, 12(3), 726-747.

Kleinhans, M.G. (2004) Sorting in grain flows at the lee side of dunes. Earth-Science Reviews, 65, 75–102.

Larue, J.-P., Bouabdallah, M. & Étienne, R. (2009) Un littoral sableux en progradation : le lido entre Leucate et Port-la-Nouvelle (Aude, Golfe du Lion, France). Physio-Geo, 3, 151-173.

Pye, K and Allen, J.R.L. (2000) Coastal and Estuarine Environments: sedimentology, geomorphology and geo-archeology. Geological Society, London, Special Publications, 175, 436 pp.

Raynal, O., Bouchette , F., Certain, R., Sabatier, P., Séranne, M., Loý, J., Dezileau, L., Briqueu, L., Ferrer, P., and Courp, T. (2009). Holocene evolution of languedocian lagoonal environment controlled by inherited coastal morphology (Northen Gulf of Lions, France. Bulletin Société Géologique Française , 181(2), 211-224.

Raynal, O., Bouchette , F., Certain, R., Séranne, M., Dezileau, L., Sabatier, P., Loý, J., Bui Xuan Hy, A., Briqueu, L., Pezard, P., and Tessier, B. (2010). Control of alongshore-oriented sand spits on the dynamics of a wave-dominated coastal system, Holocene deposits, northern Gulf of Lions, France. Marine Geology , 264(3-4):242ý-257.

Reynaud, J.Y., Tessier, B., Berné, S., Chamley, H., Debatist, M. (1999). Tide and wave dynamics on a sand bank from the deep shelf of the Western
Channel approaches. Mar. Geol., 161, 339-359.

Sabatier, P., Dezileau, L., Barbier, M., Raynal, O., Loý, J., Briqueu, L., Condomines, M., Bouchette , F., Certain, R., Van Grafenstein, U., Jorda, C., and Blanchemanche, P. (2010). Late-holocene evolution of a coastal lagoon in the Gulf of Lions (South of France). Bulletin de la Société Géologique de France , 181(1):27ý36.

Sabatier, P., Dezileau, L., Condomines, M., Briqueu, L., Colin, C., Bouchette , F., Le Duý, M., and Blancheman-che, P. (2008). Reconstruction of paleostorms events in a coastal lagoon (hérault, South of France). Marine Geology , 251:224ý232.

Sabatier, F., Samat, O., Brunel, C., Heurtefeux, H., Delanghe-Sabatier, D. (2009). Determination of set-back lines on eroding coasts. Example of the beaches of the Gulf of Lions (French Mediterranean Coast). Journal of Coastal Conservation, 13(2-3), 57-64. doi: 10.1007/s11852-009-0062-y.

Short, A. (1999). Handbook of beach and shoreface morphodynamics. Wiley and Sons, 380 pp.

Silvester, R. and Hsu, J.R.C. (1999) Coastal stabilization. Advanced Series on Ocean Enginnering (Eds World Scientific), 14, 578pp.

Stive M.J.F., and A.J.H.M. Reniers (2003) Sandbars in motion. Science. 21, 1855-1856.

Stoddart, D.R., Cann, J.R. (1965) Nature and origin of beach rock. Journal of Sedimentary Petrology, 35(1), 243-247.

Sun, J. and Muhs, D.R (2007) Dune fields, mid latitudes. Encyclopedia of Quaternary Science, 607-626.

Todd, B.J. (2005). Morphology and composition of submarine barchan dunes on the Scotian Shelf, Canadian Atlantic margin. Geomorphology 67, 487- 500.

ALOÏSI J.C., (1986). Sur un modèle de sédimentation deltaïque : contribution à la connaissance des marges passives. Thèse de Doctorat, Université de Perpignan, 162 p.

AUGRIS C. et CRESSARD A.P., (1991). Les matériaux marins. Mines et Carrières, vol. 73, www.ifremer.fr, http://www.ifremer.fr/drogm/Realisation/Miner/Sable/presentation.htm

BOYER J., DUVAIL C., LE STRAT P., GENSOUS B., TESSON M., (2005). High resolution stratigraphy and evolution of the Rhône delta plain during postglacial time, from subsurface drilling data bank. Marine geology 222-223, 267-298.

CONKWRIGHT R.D., WILLIAMS C.P., CHRISTIANSEN L.B., (2000). Offshore Sand Resources in Northern Maryland Shoal Fields. Coastal and Estuarine Geology File Report n°00-2, 94 p., www.mgs.md.gov, http://www.mgs.md.gov/coastal/pub/OF00_2.pdf

DURAND N., avec la collaboration de BERNE S., BOYER J., CARBONNEL P., CHOPPIN L., GENSOUS B., GUENNOC P., LABAUNE C., LENOTRE N., SATRA C., TESSON M., (2004). Evaluation des stocks sédimentaires dans le Golfe du Lion. Phase A : inventaire des données existantes pour le Golfe du Lion. Rapport final. BRGM/RP-52777-FR, 138 p., 32 fig.,

GENSOUS B., (1995). Analyse en stratigraphie séquentielle des dépôts transgressifs et de haut niveau associés à des cycles haute fréquence : les dépôts postglaciaires sur la plateforme du Rhône. Mémoire d'Habilitation à Diriger des Recherches, Université de Perpignan, 55 p.

GENSOUS B. et TESSON M., (1997). Les dépôts postglaciaires de la plate-forme rhodanienne : organisation stratigraphique et conditions de mise en place. C.R. Acad. Sci. Paris, Sciences de la terre et des planètes 325, 695-701.

GENSOUS B. et TESSON M., (2003). L'analyse des dépôts postglaciaires et son application à l'étude des séquences de dépôt du Quaternaire terminal sur la plate-forme au large du Rhône (Golfe du Lion). Bulletin de la Société de Géologie Française n°4, 401-419.

GUENNOC P., IDIER D., LENOTRE N., GUERIN K., SATRA C., BOYER J., BERNE S., TESSON M., avec la collaboration de BASSETTI M.A.,

ALIX A.S., LABAUNE C., GENSOUS B., (2004). Evaluation des stocks sédimentaires dans le Golfe du Lion. Phase C : Campagne en mer
sur les sites pilotes. Partie 2 : Analyse des données. Programme INTERREG III-B MEDOCC – Projet Beachmed. BRGM/RP-53367-FR, 108 p., 14 fig., 4 tabl., 3 ann.

LABAUNE C., (2005). Architecture, genèse et évolution du littoral du Languedoc- Roussillon : impact des facteurs physiques au cours du Quaternaire terminal. Thèse de Doctorat, Université de Perpignan, 301 p.

a- LABAUNE C., JOUET G., BERNE S., GENSOUS B., TESSON M., DELPEINT A., (2005). Seismistratigraphy of the Deglacial deposits of the Rhône prodelta and of the adjacent shelf. Marine Geology 222-223, 299-311.

b- LABAUNE C., TESSON M., GENSOUS B., (2005). Integration of high and very highresolution seismic reflection profiles to study Upper Quaternary deposits of a coastal area in the western Gulf of Lion, SW France. Marine Geophysical Researches 26, 109-122.

LOBO F.J., TESSON M., GENSOUS B., (2004). Stratal architectures of late Quaternary regressive-transgressive cycles in the Roussillon Shelf (SW Gulf of Lions, France). Marine and Petroleum Geology 21, 1181-1203.

MEAR Y., (1984). Catalogue des carottages. Plateau continental du Golfe du Lion. Publication LSGM, Université de Perpignan.

PENLAND S., SUTER J.R., RAMSEY K.E., McBRIDE R.A., WILLIAMS S.J., GROAT C.G., (1990). Offshore sand resources for coastal erosion in Louisiana. Gulf Coast Association of Geological Societies 40, 721-31.

RABINEAU M., (2001). Un modèle géométrique et stratigraphique des séquences de dépôt quaternaires sur la marge du Golfe du Lion : enregistrement des cycles climatiques de 100 000 ans. Thèse de 3ème cycle, Université de Rennes I, 455 p.

RABINEAU M., BERNE S., LEDREZEN E., (1998). 3D architecture of lowstand and transgressive Quaternary sand bodies on the outer shelf of the gulf of Lion, France. Marine and Petroleum Geology 15, 439-452.

REGIONE LAZIO, GENERALITAT VALENCIANA, DÉPARTEMENT DE L'HERAULT, REGIONE LIGURIA, REGIONE TOSCANA, UNIVERSITA' DEGLI STUDI DI FIRENZE, EUROPEAN DREDGING ASSOCIATION, AGENCE DE PROTECTION ET D'AMENAGEMENT DU LITTORAL TUNISIE, (2004). Le projet Beachmed : Récupération environnementale et entretien des littoraux en érosion avec l'utilisation des dépôts sablonneux marins (Convention 2002-01-4.3-I-028) - 1er cahier technique (phases A, B & C).

TESSON M., (1996). Contribution à la connaissance de l'organisation stratigraphique des dépôts d'une marge siliciclastique. Etude de la plate-forme continentale du Golfe du Lion. Mémoire d'Habilitation à Diriger des Recherches, Université de Perpignan, 110 p, 159 fig.

TESSON M., GENSOUS B., NAUDIN J.J., CHAIGNON V., BRESOLI J., (1998). Carte morpho-bathymétrique de la plate-forme du Golfe du Lion : un outil pour la reconnaissance et l'analyse des modifications environnementales récentes. C.R. Acad. Sci. Paris, Sciences de la terre et des planètes 327, 541-547.

TESSON M., LABAUNE C., GENSOUS B., (2005). Small rivers contribution to the Quaternary evolution of a Mediterranean littoral system : The western gulf of Lion, France. Marine Geology 222-223, 313-334.

TESSON M., POSAMENTIER H.W., GENSOUS B., (2000). Stratigraphic organization of Late Pleistocene Deposits of the Golfe du Lion shelf (Languedoc shelf), Western Mediterranean Sea, using high-resolution seismic and core data. AAPG Bulletin 84-1, 119- 150.

Emilia-Romagna Region

Aguzzi M., De Nigris N., Fabi G., Manoukian S., Preti M., Tedeschi R. (in stampa) - Monitoraggio morfologico di aree al largo della costa emiliano-romagnola da cui è stata prelevata la sabbia utilizzata per il ripascimento del litorale regionale. Studi Costieri.

ARPA (1997) – Programma regionale dei dragaggi dei porti e degli accumuli sabbiosi del litorale emiliano-romagnolo: analisi e indicazioni progettuali per l'utilizzo delle sabbie ai fini del ripascimento delle spiagge. Relazione

ARPA (2001) -. Progetto esecutivo. Ricerca e individuazione dell'area di prelievo in mare. Intervento di messa in sicurezza dei tratti critici del litorale emiliano romagnolo mediante ripascimento con sabbie sottomarine, Relazione Specialistica pp. 43.

ARPA (2005) – Intervento di messa in sicurezza dei tratti critici del litorale emiliano-romagnolo mediante ripascimento con sabbie sottomarine – Monitoraggio 2002-2005 -: Area di prelievo: annualità 2005. Relazione

ARPA (2005) – Monitoraggio degli effetti prodotti sul litorale dalla costruzione della nuova darsena di Rimini: Campagne di rilievi 2000-2004. Relazione conclusiva.

ARPA (2009a)– Interventi di messa in sicurezza di taluni tratti critici del litorale emiliano-romagnolo, interessati da erosione e subsidenza, mediante ripascimento con sabbie sottomarine – Ricerca di depositi sabbiosi in adriatico e stima dei volumi disponibili,7 campagna. Relazione.

ARPA (2009b)– Interventi di messa in sicurezza di taluni tratti critici del litorale emiliano-romagnolo, interessati da erosione e subsidenza, mediante ripascimento con sabbie sottomarine – Monitoraggio 2007-2009 delle spiagge oggetto di intervento. Relazione.

ARPA (2009c)– Interventi di messa in sicurezza di taluni tratti critici del litorale emiliano-romagnolo, interessati da erosione e subsidenza, mediante ripascimento con sabbie sottomarine – Monitoraggio 2007-2009 delle aree di prelievo. Relazione.

ARPA (2009d) – Monitoraggio degli effetti indotti sul litorale dalla costruzione della nuova darsena di Cattolica. 1a e 2a campagna di monitoraggio - Anni 2007-2008. Relazione.

ARPA (2010a) – Monitoraggio degli effetti indotti sul litorale dalla costruzione della nuova darsena di Cattolica. 3a campagna di monitoraggio - Anno 2009. Relazione.

ARPA (2010b) – Monitoraggio degli effetti indotti sul litorale dalla costruzione della nuova darsena di Bellaria. Prima campagna di monitoraggio – Novembre-Dicembre 2007. Relazione.

BEACHMED-e (2006-2008) - Operazione Quadro Regionale, La gestione strategica della difesa dei litorali per uno sviluppo sostenibile delle zone costiere del Mediterraneo. Sito internet: http://www.beachmed.it

Correggiari A., Aguzzi M., Remia A. e Preti M. (in stampa) - Caratterizzazione sedimentologica e stratigrafica di giacimenti sabbiosi in Mare Adriatico settentrionale finalizzata all'individuazione delle aree di prelievo. Volume Speciale a Cura M. Preti. Studi costieri.

Franceschini G., Fanelli E., Panfili M., Giovanardi O. (in stampa) – Osservazioni sulla fauna demersale in un'area di dragaggio (Alto Adriatico) per rinascimento: risultati dei campionamenti pre e post-escavo. Volume Speciale a Cura M. Preti. Studi costieri.

IDROSER Spa (1981) – Piano progettuale per la difesa della costa adriatica Emiliano-Romagnola. Relazione Generale, pp. 388.

IDROSER Spa (1985) - Ricerca di depositi sabbiosi sul fondo del Mare Adriatico da utilizzare per il ripascimento delle spiagge in erosione. A cura di Preti M., Villani B. e Colantoni P.. Bologna, Ottobre 1985.

IDROSER Spa (1990) - Ricerca di depositi sabbiosi sul fondo del Mare Adriatico da utilizzare per il ripascimento delle spiagge in erosione. 2° Campagna di ricerca. A cura di Preti M., Villani B. e Colantoni P. Bologna, Ottobre 1990.

IDROSER Spa (1996) – Progetto di piano per la difesa dal mare e la riqualificazione ambientale del litorale della Regione Emilia-Romagna., Relazione generale, pp. 365.

Preti M. (2002) – Ripascimento di spiagge con sabbie sottomarine in Emilia-Romagna. Studi Costieri, 5: 107-135.

Preti M, De Nigris N., Morelli M., Monti M., Bonsignore F., Aguzzi M., (2008) – Stato del litorale emiliano-romagnolo all'anno 2007 e piano decennale di gestione. I Quaderni di ARPA.
Preti M., De Nigris N., Morelli M. (in stampa a) - Il monitoraggio delle spiagge nel periodo 2002-2005. Volume Speciale a Cura M. Preti. Studi costieri.

Preti M., De Nigris N., Morelli M. (in stampa b) - Il monitoraggio delle spiagge nel periodo 2007-2009. Volume Speciale a Cura M. Preti. Studi costieri.

Martinelli L., Preti M. e Guerrero M. (2007) - Effect of off-shore sand dredging on turbidity. The Eighth International Conference On The Mediterranean Coastal Environment. Medcoast. Alexandria, Egipt. 13-17 November 2007 pp. 829 - 840.

Simonini R., Grandi V., Iotti M., Massamba N'Siala G., Prevedelli D. (in stampa a) - Ricolonizzazione e recupero delle comunità macrozoobentoniche in seguito all'estrazione di sabbie relitte del 2002. Volume Speciale a Cura M. Preti. Studi costieri.

Simonini R., Grandi V., Iotti M., Massamba N'Siala G., Prevedelli D. (in stampa b) - Ricolonizzazione e recupero delle comunità macrozoobentoniche in seguito all'estrazione di sabbie relitte del 2007. Volume Speciale a Cura M. Preti. Studi costieri.

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