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Eu project COASTANCE **FINAL REPORT**

phase C Component 4

Territorial Action Plans for coastal protection and management

Formulation of territorial Action Plans for coastal protection and management

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)

Dubrovnik Neretva County Regional Development Agency (HR)

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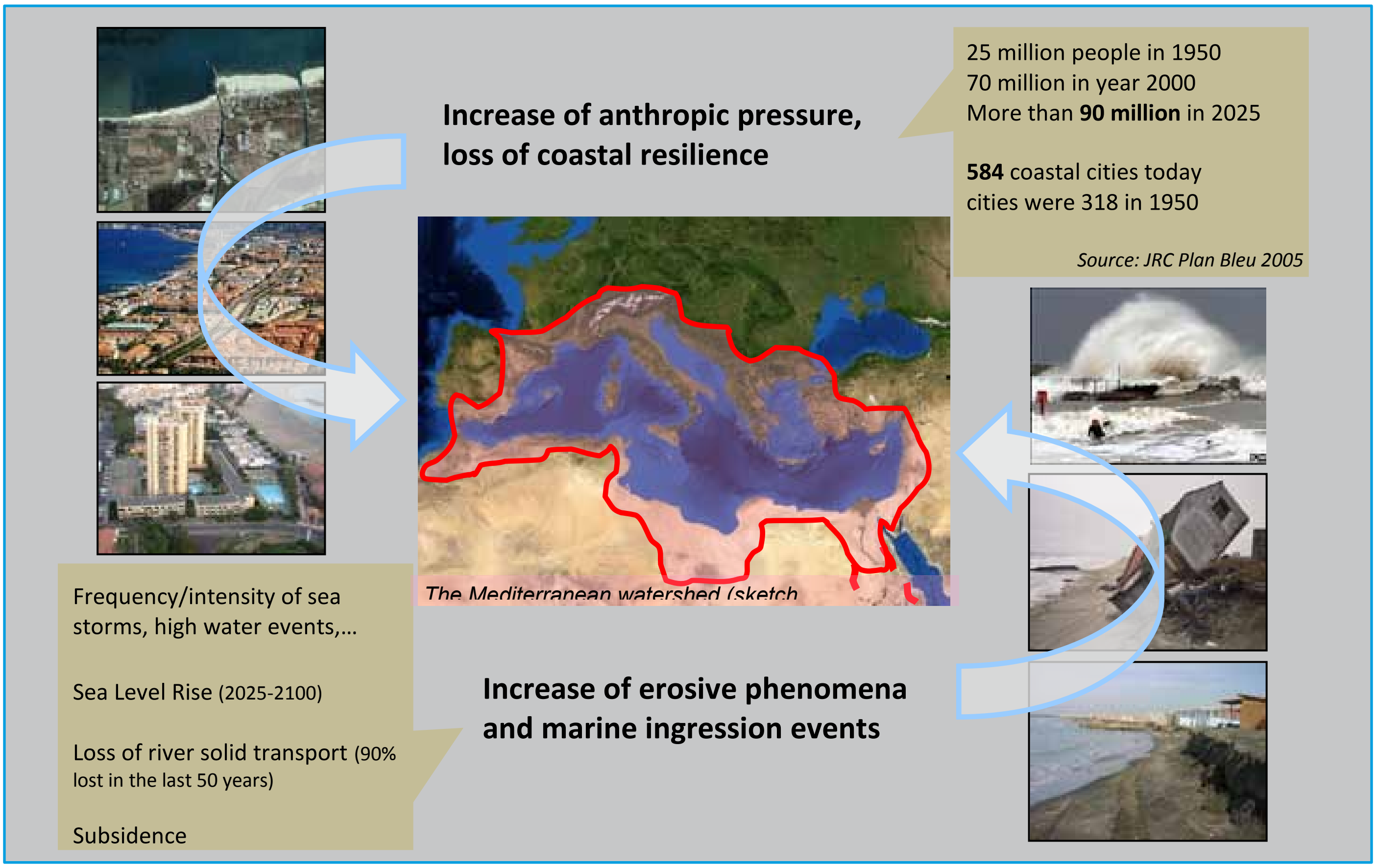
Background and strategic framework

The coastal zones are subjected to the erosion phenomena generated by the action of waves and accentuated by sea level rise. These natural processes, that affect in particular low and sandy littorals, are amplified by severe events, storms and locally combined "high water" phenomena which can be also the cause of marine flooding.

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.
Climate change effects (increasing frequency and magnitude of sea storm events, sea level rise, etc.) have major impacts on low sandy coastal zones, the



Coastal erosion and flooding represent a major threat for the wellbeing and prosperity of the 70mi Europeans living within 500m from the coastline and their assets of 500-1000 bi€. The increase of seriously impacted areas due to erosion is estimated to be 15 km^2/year in the next period. The UN-ones that "unluckily" also have the most attractive appeal for human settlements, tourism and economic activities. For the whole Mediterranean basin, it is estimated (Plan Bleu 2006 and 2008 reports) that in year 2025 the total population in the coastal regions will rise up to 174 million inhabitants (about

31 million more that in year 2000).
Global warming is expected to have strong long-term impacts on the Mediterranean basin with the intensification of extreme climatic events and a warming of less than 1°C by 2025.
The Mediterranean basin is identified by the International Panel on Climate Change (IPCC) as a "hot spot" and "most at risk from flooding, coastal erosion and further land degradation" (COM (2009) 466 - 11/09/2009).
Sea level rise will have a more threatening impacts depending on coastal site-specific characteristics where combination with local erosion trends or subsidence phenomena (land lowering driven by natural and/or anthropogenic causes) can determine severe flood risks and crisis.
According to the EC EUROSION study initiative, the regulatory EIA framework and the knowledge-based traditional measures to control the erosion have been weak or inappropriate.
The increasing erosion phenomena and marine flooding risks arising in the Mediterranean 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.
Coastal erosion is a natural process which has always existed and throughout ages has contributed to shape Europe's coastlines, but there is now evidence that today erosion is far from being a natural process only.
These processes and related risks are worsened by the "artificialisation" of coastal areas and the uncorrect use of vulnerable territories for the development of tourism and urban areas. It is the case of the Gulf of Lion coastline whose sedimentary transit was strongly disturbed since its recent development, or the case of Emilia-Romagna coastline widely urbanised and structured for tourism purposes, where loss sediment alimentation (from rivers) and subsidence phenomena are causing relevant problems.
Human interventions on the coast, attempting to remedy suffering situations, have been heavily based on a static engineered response, whereas the coast is in, or goes towards, a dynamic equilibrium. Hard coastal structures (e.g. breakwaters, seawalls, groynes) are built and persist because they protect urbanised areas, expensive properties or infrastructures, but they often relocate the problem down-drift or anyway to another part of the coast.
Very quickly, the limits of these accommodations appear. Managers are gradually realizing that, far from reducing the environmental constraints, actions already implemented bring the effect to increase them. 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.
Climate change effects (increasing frequency and magnitude of sea storm events, sea level rise, etc.) have major impacts on low sandy coastal zones that, "unluckily", also have the most attractive appeal for human settlements, tourism and economic activities. For the whole Mediterranean basin, it is estimated (Plan Bleu 2006 and 2008 reports) that in year 2025 the total population in the coastal regions will rise up to 174 million inhabitants (about
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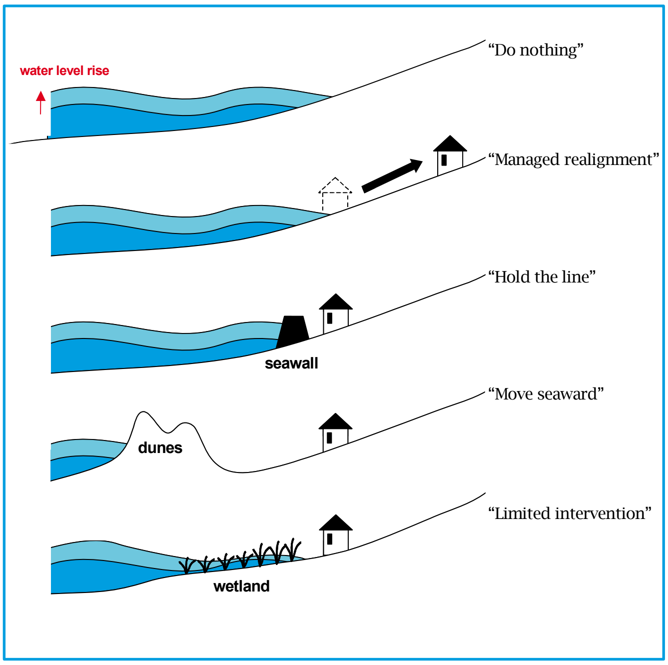


Figure 1. Five policy options defined by Eurosion project, 2004.

The Mediterranean basin is identified by the International Panel on Climate Change (IPCC) as a "hot spot" and is "most at risk from flooding, coastal erosion and further land degradation" (Communication from Commission to Council and the European Parliament – Towards an Integrated Maritime Policy for better governance in the Mediterranean – COM (2009) 466 - 11/09/2009).
Sea level rise will have a more threatening impacts depending on coastal site-specific characteristics where combination with local erosion trends or subsidence phenomena (land lowering driven by natural and/or anthropogenic causes) can determine severe flood crisis.
It is important to realize a territorial analysis in order to take into account the peculiarities of a territory to be developed. During the diagnosis, the importance of natural hazards and socio-economic issues must be taken into account in order to assess the magnitude of risks, identify priority fields for intervention and provide a coherent strategy for actions.

In this frame, for the project purposes and objectives, the COASTANCE partners assume the following policy options framework (defined by EUROSION Project, 2004) for the coast protection and management against erosion and flooding risks which should be considered in the coastal plans formulation.
The five generic policy options are (fig. 1):
Do nothing: the 'do nothing' option, involving no protection, means to let the coast reach the natural dynamic balance on itself. It involves the abandonment of coastal facilities when they are subject to coastal erosion, and either gradually landward retreat or evacuation and resettlement elsewhere. This option is very environmental friendly (although often politically high-costly) but it could need a relevant initial investment depending on the number of coastal facilities, infrastructures, settlements to be displaced and it could mean losing a lot of land to the sea as well as people's houses/

Figure 2. Example of managed retreat: Cesenatico (IT) Master plan.

properties.
Managed retreat (fig.2): managed retreat or realignment is an alternative to constructing or maintaining coastal structures. Managed retreat allows an area that was not previously exposed to flooding by the sea to become flooded. This process is usually in low coasts, low lying estuarine or deltaic areas and almost always involves flooding of land that has at some point in the past been reclaimed from the sea. Managed retreat is often a response to a change in sediment budget or to sea level rise. The technique is used when the land adjacent to the sea is low in economic value. A decision is made to allow the land to erode and flood, creating new sea, inter-tidal and salt-marsh habitats. This process may continue over many years and natural stabilization will occur.

Figure 3. Hold the line through artificial nourishment

The main cost is generally the purchase of land to be flooded. Housings compensation for relocation of residents may be needed. Any other human made structure which will be engulfed by the sea may need to be safely dismantled to prevent sea pollution. In some cases, a retaining wall or bund must be constructed inland in order to protect land beyond the area to be flooded, although such structures can generally be lower than would be needed on the existing coast. Monitoring of the evolution of the flooded area is another cost. Costs may be lowest if existing defenses are left to fail naturally, but often the realignment project will be more actively managed, for example by creating an artificial breach in existing defences to allow the sea in at a particular place in a controlled mode, or by preforming drainage channels for created salt-marsh. Managed retreat can comprise 'setbacks', rolling easements and other planning tools including building within a particular design life. Maintenance of those structures or soft techniques can arrive at a critical point (economically or environmental) to change adopted strategy.
Hold the line (fig.3): holding the line could mean different kind of intervention depending on the coastal site-specific status and function (economic, touristic, defence of inland natural protected areas or low laying areas). Soft options like beach nourishment are in general more acceptable but, in many cases a new hard structures, re-modulation of eventual present hard structures and even their partial dismantlement could be chosen in combination with or be chosen as alternative to nourishment. For instance, the seawall and promenade of many coastal cities in Europe represents a highly engineered use of prime seafront flange-eating space, which might be preferably designated as public open space. Such open space might also allow greater flexibility in terms of future land-use change, for instance through managed retreat, in the face of threats of erosion or inundation as a result of sea-level rise.
Moreover fore-dunes areas represent a natural reserve which can be called upon in the face of extreme events; building on these areas leaves little option instead of undertake costly protective measures when extreme events threaten. Mainly they are two the possible technical approaches:

- Structural or hard engineering techniques, i.e. using permanent concrete and rock constructions to "fix" the coastline and protect the assets locate behind. These techniques – seawalls, groynes, detached breakwaters, revetments – represent a significant share of protected shoreline in Europe (more than 70%), but they are nowadays a heritage of the past, to be managed, possibly to be modified or eventually dismantled when possible and opportune.
- Soft engineering techniques (e.g. sand nouri-

shments), building with natural processes and relying on natural elements such as sands, dunes and vegetation to prevent erosive forces from reaching the backshore. These techniques include beach nourishment and sand dunes stabilisation.

Move seaward: in some cases - where new areas are needed for new economic or ecological development - a move seaward strategy can be adopted. There is an obvious downside to this strategy. Coastal erosion is already widespread, and there are many coasts where exceptional high tides (high water phenomena in northern Adriatic) or storm surges result in flooding on the shore, hitting human activities. If the sea rises (or the land lowers by subsidence), many coasts that are developed with infrastructure along or close to the shoreline will be unable to accommodate erosion. This occurs where the ecological or geomorphological zones that would normally retreat landwards encounter infrastructures, inland defences, urbanised areas etc. Wetlands, salt marshes, mangroves and adjacent fresh water wetlands are particularly likely to suffer from this situation.

The above strategy options can be adopted singularly or in combination, depending on the scale of intervention, local or wide. The decision to choose a strategy is site-specific, depending on pattern of relative sea-level change, geomorphological setting, sediment availability and erosion, as well a series of social, economic and political factors. Anyway growth management can be a challenge for coastal local authorities and decision makers, as far as Integrated Coastal Zone Management approaches are used to prevent development in erosion- or flood-prone areas and to rearrange those areas creating new development opportunities in a sustainable way.

The COASTANCE project

The COASTANCE project proposes innovative techniques and approach for the formulation of mid-long term coastal protection Master Plans and sediments sustainable management plans for 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 are proposed as Governance and Public Policy Tools for erosion control by local, regional and national Administrations.

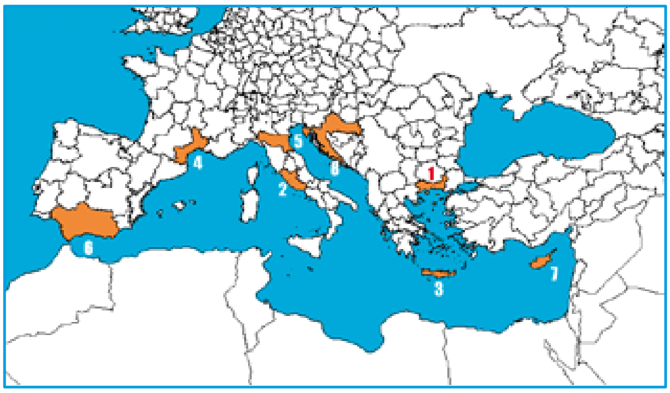


Figure 4. COASTANCE partnership: 1. Region of Eastern Macedonia and Thrace (GR) - Lead partner; 2. Lazio Region (IT); 3. Region of Crete (GR); 4. Départément de l'Hérault (FR); 5. Emilia-Romagna Region (IT); 6. Junta de Andalusia (ES); 7. The Ministry of Communications and Works of Cyprus (CY); 8. Dubrovnik Neretva County Regional Development Agency (HR)

COASTANCE focuses on the entire Mediterranean basin. The partners (fig. 4) 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.

COASTANCE project is based on two main operational purposes:
a) Capitalization of knowledge and resources already acquired in the field of coastal protection:

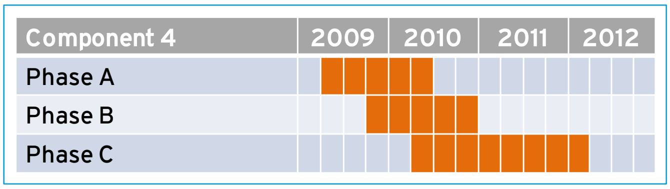
- sustainable Technologies for exploiting sand stocks (behind river barrages, upstream harbour structures, geological sea bottom deposits, etc.) based on Eurosion project, Beachmed, Beachmed-e/GESA/RESAMME Subprojects;
- sustainable Technologies for coastal protection and adaptation (marine-climate survey, beach nourishments, soft structures, use relocation etc.) based on Eurosion project, Beachmed, Beachmed-e/NAUSICAA/MEDPLAN/ICZM-MED Subprojects, Plancoast, Cadseland, Micore 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;
and 2 transversal Components:
C1 - Management & Coordination;
C2 - Communication & Dissemination

The present report focuses on Component 4 results and plans for coastal protection and management developed by project partners. The work within Component 4 developed in three phases, with a budget of about 511.300 € (26% of project total), along the 3 years of the project implementation:



- Phase A - State-of-the-art on experiences and regional policies, knowledge of territory and resources;
- Phase B - Definition of Sediment Management Plans elements;
- Phase C - Formulation of territorial Action Plans for coastal protection and management.

Due to budget constraints and specific missions of project partners, the complete path of Component 4, from Phase A to Phase C, was chosen by a subgroup of them. So that the present report concerns results and plans for East Macedonia & Thrace Region, Crete Region, Cyprus, Department de l'Herault and Emilia-Romagna Region, while the other partners stop at the end of Phase A (please see Component 4 Phase A report on www.coastance.eu) and develop more in depth work in Components 3 and 5 (Andalucia, Lazio Region, and DUNEA).
Within the first sub-group, East Macedonia & Thrace, Crete and Cyprus, after Phase A work completion, focused on specific pilot sites for developing coastal protection plans and sediment management plans, while Emilia-Romagna and Herault developed the work and plans on the whole coast of their competence. Moreover, the Department de

l'Herault extended the analysis for sediment management covering the whole coast of the Lion Gulf, Languedoc-Roussillon Region.
Following the strategy framework indentified by the EC EUROSION initiative, the partners mainly adopted "limited intervention" and "hold the line" options, while also considering in some cases "managed realignment" interventions. Concerning technical approach, all the partners considered to adopt soft engineering techniques, like beach nourishments and sand dunes restoration/stabilisation, as the preferable type of interventions.
A specific focus was made on evaluation of sediments volumes available for beach nourishment, considering different sources: off-shore (submarine sediment deposits), littoral (beaches in accretion, accumulation by hard defence works, accumulation by port and river mouth, etc.), inland (building excavations, ports enlarging, quarries, dam basins, etc.). Moreover, a particular attention was devoted to beach sediment sustainable management, evaluating existing good practices and individuating the most suitable, even adapting them to site-specific conditions. Then it was also considered and outlined possible territorial policies, to be introduced or enhanced, aimed at reducing sediment and quota losses on the coasts or at enhancing natural sediment alimentation towards beaches (i.e. river solid transport).

Component 4 strategy framework

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.
According with the concept that considers the beach as the main defence "structure" for inland areas, actions should be focused on beaches preservation, following the options choice outlined in the previous paragraph. In this frame it assumes 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 entailed on site-specific conditions. So the first Phase (A) of Component 4 was 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. The second Phase (B) provided 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, object of deepening in order to set up proposals/recommendations to be included in Plans coming out from Phase C, for a correct management of beach sediments and for the sustainable exploitation of sediment deposits.
The work was developed keeping into account a strategy framework outlined and share within the Phase A development of low and sandy beaches management is based on two pillars (fig. 5):

- **feeding the system** with sediment coming from external sources or from management of sediment accumulations within the system;
- **reducing sediment losses** from the littoral and beach system through proper management of beach sediment, coupling with river solid transport enhancement and reduction of the subsidence anthropogenic component, when it's the case.

The schemes in figure 5 was adopted taking into account the different situations of partner regions coastal stretches so that representing all the cases of Mediterranean low sedimentary beaches, but it is also applicable to a large number of cases all around Europe coasts and inland territories.
The above framework strategy highlights that, in order to approach the coast protection and management along with a correct and sustainable perspective, there's the need to work on two time scale: one, short-mid term, focusing on contrasting phenomena with direct interventions where critical conditions are manifest or where precarious balance could in a few time bring to local crisis; the second, long time, where specific territorial policies.

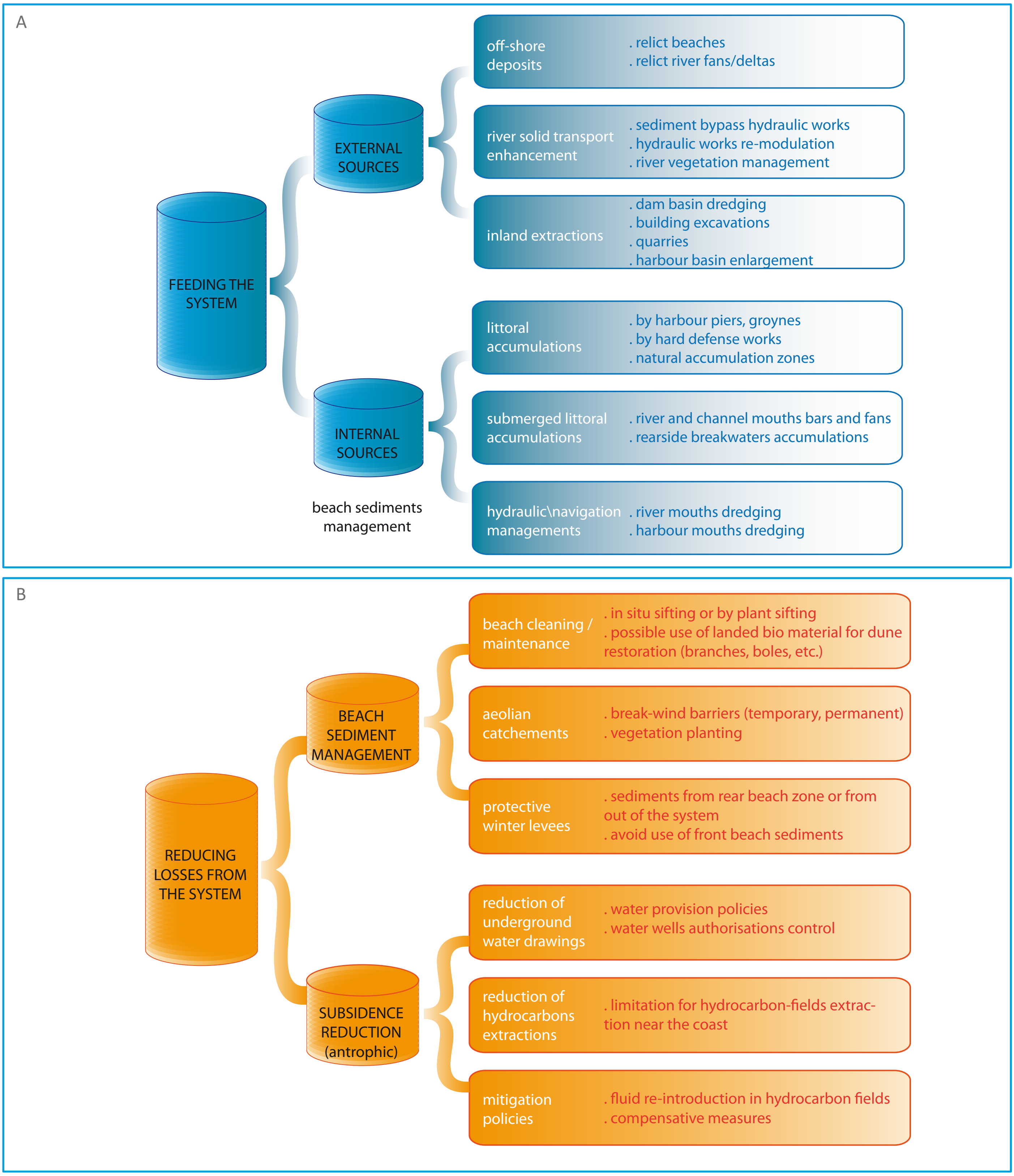


Figure 5. A: feeding the littoral system – the scheme indicates possible sources of sediments for beach nourishment purposes. B: Reducing losses form the system – the scheme indicates possible practices and policies for the correct management of beach sediments and reduction of losses.

Component 4 results: coastal and sediments management plans

The following sections collect and synthesis activities carried out and results, within project Component 4, achieved by COASTANCE partners. Matching his proper strategies with the COASTANCE shared framework, each partner built a specific sediment management and coastal protection plan.
The Départment de l'Hérault further implemented the sediment management plan for the Gulf of Lion. The Emilia-Romagna Region developed a new coastal management system based on littoral cells (SICELL), subdividing the coastal zone in 118 cells, to support sediment management and coastal protection plans.
Ministry of Communications and Works of Cyprus, East Macedonia-Thrace and Crete regions defined new plans of intervention and sediment management on specific pilot sites, in order to be implemented in the near future and to become an example of a new approach for dealing with coastal risks and adaptation to climate change.

Relevance of project's outputs and results in the EU policy framework and perspectives

Project partners as Emilia-Romagna, Lazio, Départment de l'Hérault, Andalucia, basing on their experiences, proposed an integrated approach on diverse aspects (coastal risk assessment, coastal management and protection, environmental impact assessment) that have been shared and tuned up within the partnership, thus defining the COASTANCE concept. The implementation of this integrated approach introduced a substantial change of perspective in coastal management in those areas (Region of East Macedonia-Thrace, Cyprus, Crete and Dubrovnik-Neretva County) where this sector was still developing. Private engineer companies and research centres involvement (with skills in coastal dynamics, risk assessment and environmental impact assessment) had a training effect in particular for public authorities as in Region of East Macedonia & Thrace, Cyprus, Crete, and Croatia, in the implementation of the COASTANCE approach, and allow exchange of good practices within those regional and state authorities in order to define/propose adequate sector policies, methodologies and techniques for coastal protection and adaptation strategies.
In particular, it drove to coastal risk awareness raising, stakeholder participatory process introduction, environmental issues awareness in coastal works design and, basing on this approach new coastal management plans and sediments plans were formulated in REMTH, Crete, Cyprus (pilot sites), Departement de l'Herault (Gulf of Lion) and Emilia-Romagna (regional coast).
COASTANCE project, with a multidisciplinary approach (focused on hazard and risk evaluation, programmes and plans formulation, EIA and SEA on works and plans) complains a basic requirement of ICZM (Integrated coastal zone management) policy as stated into the EC Recommendation (413/2002) and can be considered as a system of operative and effective tools to implement ICZM policy in the specific themes of coastal erosion and marine flooding risk (Directive 2007/60/EC). Moreover it moves from EUROSION initiative (DG ENV) "Recommendations" for sediments and coastal management and "Guidelines" for incorporating coastal erosion issues into Environmental Assessment procedures (2004) and gives a relevant contribution in the implementation of specific provisions of the ICZM Protocol for the Mediterranean 2008, entered into force in 2011.
The diverse cases of coastal areas present in the partnership (open sea sandy beaches, mix rocky and sandy beaches, pocket beaches, etc.) cover the Med basin cases and the COASTANCE integrated approach, methods and tools, can be widely applied and could be the basis to develop a common regional action strategy for the climate change adaptation of the coastal zones in the Med context.
A regional approach must be intended both as a process concerning geographical areas with basic

common peculiarities/opportunities and as a process in which the regional administrations are the fundamental actors of new territorial participatory agreements with local key actors in coastal management and adaptation to climate change.
Moreover, the COASTANCE partnership comprises diverse levels of territorial government (state, regions, provinces) according with local organisation of competences for coastal area management. It developed networking, cooperation and exchange of experience between regions, and other administrative levels, relevant social economic and environmental actors. Its results give a concrete contribution to the EU cohesion policy implementation, policy that will have a pivotal role in delivering the EU 2020 strategy – COM(2010)2020 final – and in promoting climate change adaptation, risk prevention and management, that will be one of investment priorities in the 2014-2020 financial period – COM(2011)614 final; 2011/0275(COD).

Limits and difficulties encountered in implementation and development opportunities

The COASTANCE project introduced a **new comprehensive and sustainable approach to coast protection and management and produced new tools to adequately support analyses and actions.** Moreover it contributed to a substantial change of perspective in coastal management in those Administrations where this sector was still developing. But this represent only a initial step. In order to translate this innovative contribution into practice at the system level in the diverse partner regions and more widely in the Med context, more time and further actions are needed (mainstreaming process development). For those outputs and results concerning sediment management and coastal protection and management plans and supporting tool (SICELL), as well as for the EIA and SEA Guidelines, a mainstreaming process started during the project 3rd year and nevertheless the good perspectives it's far from completion.
Moreover, the submersion risk forecasting tool developed within the project has been tested only in limited cases. The web user friendly interface of this model will be available on-line only by the end of the project (March 2012) and from that starting point only we'll be able to demonstrate its transferability, to make it tested and tune it up in a wider number of cases along the Med area and not only.
For those partners who focused on pilot sites it means first implement the management plans formulated within the project and then, demonstrated the efficacy, make the methodology be adopted and applied in the wider regional context. For those partners who already focused on the wider regional context, the formulated plans shall be adopted at regional level and the administrative process will take time and needs to be followed step by step, as well as for the EIA and SEA Guidelines adoption by competent offices within partner Administrations. These processes have been outlined throughout specific questionnaires submitted to the partners and in all cases partners highlighted the time needed and the path to make project outputs and results assumed by the respective decision making levels (between 1 and 2 years), but their implementation will take more time (till 5 years).
Even one the process started earlier is still under way. It is the case of the adoption of the sediment management approach and in particular of the SICELL tool in Emilia-Romagna within the new regional act concerning the regulation of dredging and nourishment interventions. The work on the new regulation started at the beginning of 2011 and its completion is expected by the second part of 2012 (to be issued by the end of the year). The sediment management plan for coastal protection defined within the COASTANCE project will be implemented after the SICELL updating expected by the end of 2012 (waiting for the completion of the ongoing topo-bathymetric and subsidence monitoring campaign).
In Greece the central government is preparing a "Special Framework of Spatial Planning and Sustainable Development of the Coastal Areas and Islands" and it is expected to be issued in year 2013. It will include a clear definition of the coastal zones and of the activities allowed according to the 2008 Protocol on ICZM in the Mediterranean. It is not clear yet if this Framework will include a policy

on erosion and beaches protection issues. A "Regional Operational Plan on Coastal Zones" elaborated by the regional Management Organisation Unit of Development Programmes is in progress (to be issued by summer 2012) and it will include infrastructural works, schools, fishery infrastructures, environmental protection works, coastal protection works etc., to be funded by the regional level, which will include erosion issues and policy options. REMTH will try to include also the funding of coastal protection works with "soft" measures (beach nourishment) and first of all Kariani's beach project (COASTANCE pilot site). Anyway, since an ICZM National strategy is not yet defined, as well as no particular Department dealing with coastal management, the mainstreaming process of COASTANCE results will be subjected to a long path in the future.

In Cyprus results of COASTANCE project and the protection plan and works (in the pilot site the macro cell 9 Zygi-Kiti) will be put into practice within 5 years together with the realisation and adoption of a customised version of the SICELL. After the completion of coastal works the Ministry of Communication and Works in collaboration with the local Authorities will implement the sediment management plan (beach re-nourishment, sediment transport etc.) that will run for a subsequent period of 15 years.

In southern France, the Departement de l'Herault developed a sediment management plans, for coastal protection and management in the Gulf of Lion. The protection plan should be adopted by local authorities and promoted by national level (DREAL-LR). The sediment management plan will be implemented and put in practice for 5 years period after the adoption of a general agreement between PACA and Languedoc-Roussillon regions, considering that sediment uses in this area involves the two regions territorial competences.

In this frame, nevertheless the mainstreaming process started and the high level of transferability of the outputs and results of the project, there are obvious difficulties to obtain the expected returns and implementation within the end of the project itself. It arose clear then to the partners the need of capitalisation activities in order to complete the processes started, to put into value the results and outputs obtained within the project, to transfer it and possibly to give a concrete contribution to the Med regions community.

With the aim to give response to these needs, the COASTANCE partnership, after a first capitalisation seminar organised by the JTS MED in Rome in June 2011, promoted and started the formation of a project cluster, named FACECOAST - "Face the challenge of climate change in the Med coastal zones" presented officially within the MED Capitalisation Day in Marseille the 30th of November 2011. The aim of the cluster is to design and develop integrated actions at the Mediterranean scale (taking into account the diverse aspects, sectors and policies affecting the coastal areas) inscribed in a wider Macro-Project to be implemented in the 2014-2020 period. The design of the Marco-Project to be carried out within a "capitalisation project", following the MED Programme Capitalisation initiative, in which to integrate and to put into value outputs and results obtained by the adhering projects.

Considering the number of partners being part of the different projects, this will produce a multiplier effect in terms of results transfer capabilities, mainstreaming possibilities and sustainability conditions, and will characterise the initiative with a high potential of innovation in the different fields/ sectors concerning governance, management and protection of the coastal areas. To see advancements and to follow evolution of the FACECOAST cluster please see www.facecoast.eu.

Formulation of Coastal Protection and Management Plans in the Pilot Site: Region of East Macedonia and Thrace

General characteristics of REMTH coastline

The coastline of the Region (the islands are not included) has a length about 240km, and has an East –West orientation. The largest part of the coast (around 85%) is generally relatively low and flat with sandy beaches, but there are also low rocky coast and cliffy coasts (around the cape Maronia), characterized by accumulations of gravel and pebbles.

Figure 6. REMTH Macrosedimentary cells subdivision

In most part the bathymetry for the entire adjacent sea is gentle and the distance of the isodepth of 20m (contour -20 m) from the coastline varies from 1000m to 10000m, i.e. mean slope of less than 2%. The tide is less than one meter (micro tidal range according to tidal classification of coast) and the regional coasts are wave dominated.

Due to the large length of the coast, we can identify many mechanisms which contribute to the morphodynamics of the coastal region (erosion or accretion). For example in the vicinity of the cape of Nea Makri and for a length of about 15 km, we observe natural erosion (retreat 0.5m/year) of the 2-20 m high coastal cliffs, due to high wave energy potential .The erosion in this area is completely natural and independent of anthropogenic or climatic interference.

On the other hand, we observe in the entire study area of the REMTH coastline (230km) a general retreat of the coastline i.e. the total area of sandy erosion is larger than the area of accretion. This fact is correlated with the significant reduction of about 74% of the sediment yield, due to human interference (dams). On top on that we may observe erosion problems created by the construction of fisherman small ports, which intercept the sediment transport along the shore, as in case of our pilot site for the COASTANCE program, at Kariani.

The division of REMTH coast in sedimentary cells has not been attempted before the present program. REMTH does not have data of in situ measurements to study the sediment transport along the shore and the sedimentary exchange with adjacent cells. In a low sandy beach, usually, the first definition of a macro-sedimentary cell is a coastal stretch characterized by very low or null sedimentary exchange with other adjacent cells (due either to natural barriers, like rock capes or anthropogenic interference like ports which intercept the sediment transport along the shore)

Within the COASTANCE programme it's made a first attempt to divide the coastline of REMTH in 5 sedimentary cells (fig. 6), according to the following parameters:

- physiographic characteristics of the coastline;
- natural and anthropogenic factors;
- wave climate;
- main source of sediments.

Starting from the west of REMTH , the first macro-sedimentary cell extends from Strimon (or Strimonas) mouth (letter A in figure 6) up to the cape Vrasidas (B), and has length around 45.5 km. The dominant feature in this cell is the outflow and sediment yield of river Strimon.

The second macro sedimentary cell (BC) extends from cape Vrasidas up to cape Baloustra (Avdira), and has length around 86 km. The dominant natural factor of this cell is river Nestos and the island of Thassos which protects the coast from strong South winds and waves.

The third cell (CD) extends from cape Baloustra up to cape Kalogiros, and has length around 34 km. The dominant natural factor of this cell is the existence of many estuaries and lakes (Porto Lagos,

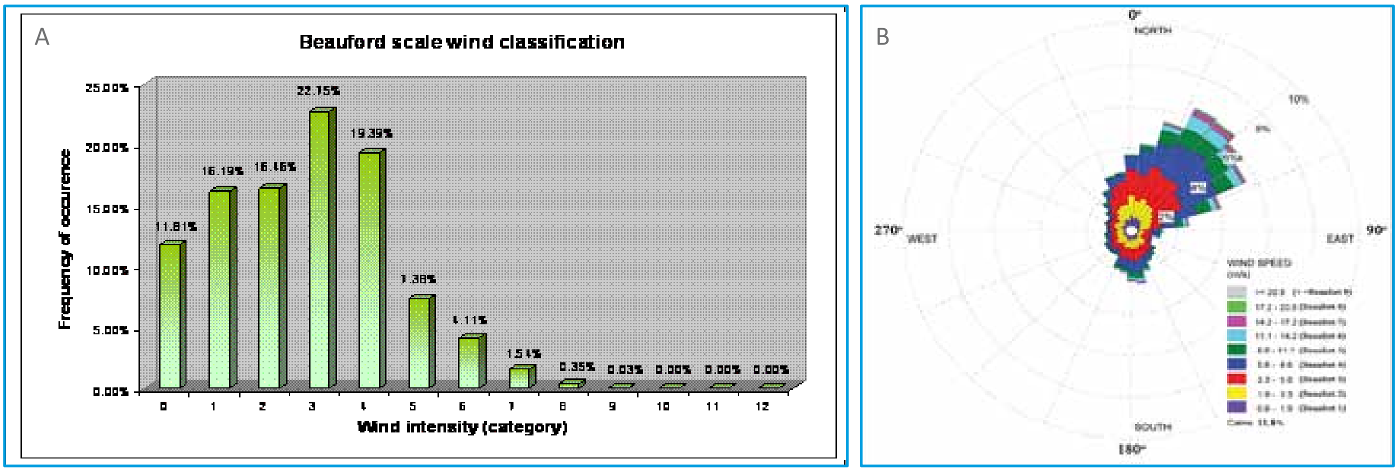


Figure 7. A:Beaufort scale wind classification (frequency of occurrence) for the wind dataset southwest of the Athos peninsula. B: Rose diagram for the wind dataset southwest of the Athos peninsula.

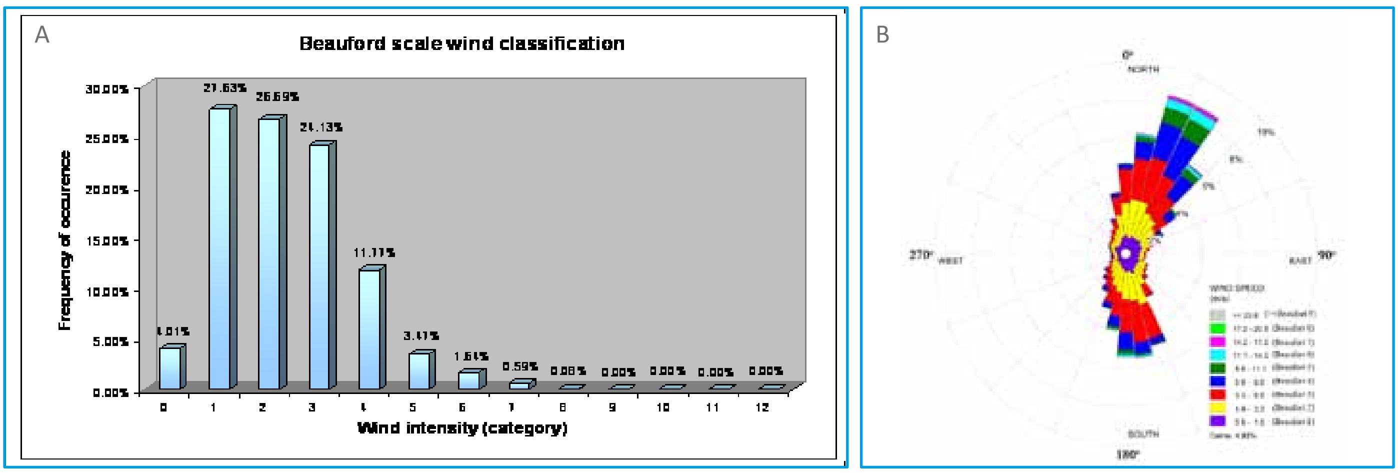
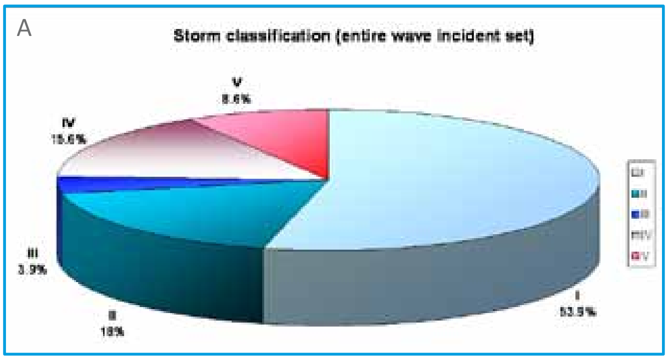


Figure 8. A: Beaufort scale wind classification (frequency of occurrence) for the wind dataset in the area of Nestos river. B: Rose diagram for the wind dataset in the area of Nestos river.

Vistonis, Xirolimni, Karatza,Aliki, Ptelia), protected by Ramsar convention and by Natura. The sources of sediment feeding are the rivers Kosinthos and Komsatos which outflow to Vistonis Estuary.
The fourth cell (DE) extends from cape Kalogiros up to cape Maronia and has length around 30 km. The source of sediment in (DE) is dominated by river Filiouris. Within the cell (DE) there are two fisherman ports, the port of Imeros and port of Maronia, which in addition to the action of cape, interrupt the sediment transport along the shore.

ford scale for both datasets, and the rose diagrams. For the first dataset, the Beaufort Scale 3 winds hold the maximum frequency of occurrence (22.75%) with the ones of 1, 2 and 4 Beaufort trailing, maintaining though frequencies steadily above 15%. For the second dataset, the 1, 2 and 3 Beaufort winds hold almost equally high frequencies of occurrence. Percentages referring to "Calm" periods (periods of 0 Beaufort intensity) are 11.81% and 4.01% for the stations in the areas of Athos peninsula and Nestos river, respectively, while it is remarka-



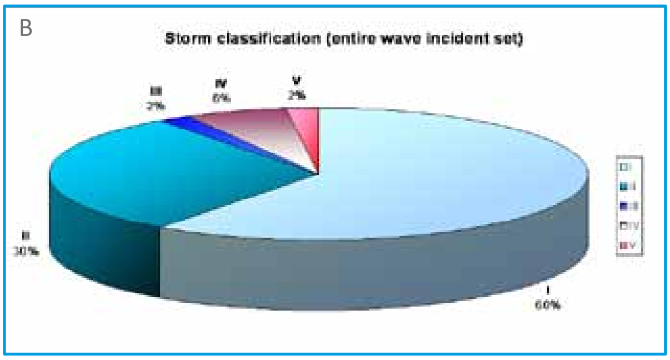


Figure 9. A: Storm classification for the entire wave incident set southwest of the Athos peninsula. B: Storm classification for the entire wave incident set in the area of river Nestos.

The fifth cell (EF) extends from cape Maronia up to river Evros, and has length around 51 km. The dominating source of sediments in cell (EF) is river Evros. Within the cell (EF) there are is one big port -that of Alexandroupoli- and a smaller fisherman port in Nea Makri, that both interrupt the sediment transport along the shore.
For both wind and wave classification regimes, two databases are used. The databases comprise wind speed, wind direction, significant wave height, mean wave direction and mean peak wave period records every 3 hours from the POSEIDON network's wave buoy sited southwest of the Athos peninsula (2000 - 2006) and from a station in the area of river Nestos in the N. Aegean (1995-2004). The first database is a limited one with a significant amount of missing data.
For both stations considered, winds are categorized based on the Beaufort scale, considering as an event every record in the wave buoy's measurement archive. Figure 7 and figure 8 present the frequency of occurrence for each wind intensity of the Beau-

ble that there are no records of intensity greater than 9 Beaufort for both stations. For both stations NE winds are observed to be more frequent and of higher intensity. Wave incidents at both stations are categorized based on the storm classification scale proposed by Mendoza and Jimenez (2006). This scale comprises five categories representing storms of increasing intensity, which are also characterized by increasing wave height and energy content. According to this approach, "storms" are defined as events exceeding a minimum significant wave height of 2.0m and a minimum duration of 6 hours. The results of storm event classification are shown in figure 9. The diagrams' study infers that category "I" storms hold the maximum frequency of occurrence for both datasets (proportions of 53.9% and 60%, respectively). The rest of the scale's categories are characterized by significantly lower frequencies of occurrence. Category "III" events are limited for both stations, while there are some events of category "IV" and "V" observed southwest of the Athos peninsula.

Selection of pilot site

Three sites were proposed for the Coastance project (fig. 10). The main criteria for their proposition were the important erosion problems and the social need for limiting erosion:

- Kariani beach, east of Strymonas river delta;
- Nestos river delta, (east of Dasochori village);
- Limenaria beach.

Figure 10. Location of the three potential Coanstance pilot sites.

Kariani beach

Kariani beach has the following characteristics as a potential pilot site:

- the ability to capitalize on previous work developed under the Beachmed-e project. - **MEDIUM.** The pilot site studied in the context of Beachmed-e project (West of Nestos river delta) lies ~100km E from Kariani beach and, therefore, is not influenced by the same local parameters. However, the general erosional pattern is similar with currents from E to W as it is the case in the entire continental coastline in REMTH;
- acuteness of the erosion problem. - **HIGH.** The acuteness and the urgent character of the erosional problem is evident with coastline retreat in the order of 100m within the last 80 years, as it can be seen from the Figures 9, 12, 13, 14, 15, 16, 17 and 18;
- environmental restrictions pertaining for the potential pilot area and their impact on prospective interventions. - **LOW** The pilot site does not lie within the limits of a specifically protected area under Ramsar, Natura 2000 etc;
- vulnerability in view of climate change - **HIGH.** The hinterland area is very flat and an eventual sea level rise would lead to further retreat of the coastline and the loss of coastal property;
- data availability - **MEDIUM.** The data availability of the particular site (meteo-marine, sediment reserves, evolution of topography, and satellite pictures) is considered satisfactory and will allow a timely completion of the project with a high quality level for the final project deliverable;
- similarities with other locations in order to reapply the remedial concept in those other locations in the future. **HIGH.** The erosional pattern and general characteristics apply to>100 km of coastline in REMTH at a significant number of locations. Therefore, it would be beneficial to study Kariani beach so that the solutions applied at such a typical site that has characteristics repeatedly present in other sites, can be standardized and applied after the completion of the Coastance project to those other sites at a reduced cost and with increased technical efficiency;
- intervention and remedy potential – Soft measures, Beach nourishment - **HIGH.** The site allows for the application of all remedy measures with «soft» interventions thanks to ease of access and linear coastline. The efficiency and long term durability of beach nourishment as well as its exposure to extreme weather events that can destroy any possible «soft» interventions are to be examined;
- involved Stakeholders – Economic Value of the area - **HIGH.** The area is of high economic value and is becoming among the most expensive coastal areas in the REMTH due to the vicinity to Egnatia Highway and the decrease of access time from all major cities of northern Greece, primarily from Thessaloniki. Therefore, there is urgent pressure from the local stakeholders for remedial measures in order to uphold the current loss trends of coastal land.

Nestos river delta

Nestos river delta area E of Dasochori beach has the following characteristics as a potential pilot site:

- the ability to capitalize on previous work developed under the Beachmed-e project. - **HIGH.** The pilot site studied in the context of Beachmed-e project is adjacent to this stretch and is therefore influenced by the same local parameters. The general erosion pattern is similar with currents from E to W as it is the case in the entire continental coastline in REMTH;
- acuteness of the erosion problem. - **HIGH.** The acuteness and the urgent character of the erosion problem is evident especially after the completion of dams in the upstream of Nestos river especially close to the Avdira fishermen's port;
- environmental restrictions pertaining for the potential pilot area and their impact on prospective interventions. - **HIGH.** The pilot site lies within the limits of a Special protected area under Ramsar and Natura 2000 treaties etc. Therefore, any type of intervention is expected to have a considerable impact and may have to face significant restrictions and time delay for environmental reasons;
- vulnerability in view of climate change - **HIGH.** The hinterland area is very flat and an eventual sea lever rise would lead to further retreat of the coastline and the loss of environmentally sensitive coastal area;
- data availability - **HIGH.** The data availability of the particular site (meteo-marine, sediment reserves, evolution of topography, and satellite pictures) is considered very satisfactory thanks to the work done during the Beachmed-e project. It will therefore, allow a timely completion of the project with a high quality level for the final project deliverable;
- similarities with other locations in order to re-apply the remedial concept in those other locations in the future. **HIGH.** The erosional pattern and general characteristics apply to>100 km of coastline in REMTH at a significant number of locations. Therefore, it would be beneficial to study the section E of Nestor river delta so that the solutions applied at such a typical site that has characteristics repeatedly present in other sites, can be standardized and applied after the completion of the Coastance project to those other sites at a reduced cost and with increased technical efficiency;
- intervention and remedy potential – Soft measures, Beach nourishment - **HIGH.** The site allows for the application of all remedy measures with «soft» interventions thanks to ease of access and linear coastline. The efficiency and long term durability of beach nourishment as well as its exposure to extreme weather events that can destroy any possible «soft» interventions are to be examined;
- involved Stakeholders – Economic Value of the area - **LOW.** The area is of low economic value due to the restrictions applied for environmental reasons (Ramsar/Natura 2000). Therefore, for economic reasons the confrontations and eventual opposition in view of applying remedial measures within the framework of a pilot EU project are expected to be low. However, for environmental reasons the confrontations and eventual opposition are expected to be high.

Limenaria beach

Limenaria beach has the following characteristics as a potential pilot site:

- the ability to capitalize on previous work developed under the Beachmed-e project. - **LOW.** The pilot site studied in the context of Beachmed-e project are far from this stretch and is influenced completely from different local parameters;
- acuteness of the erosion problem. - **HIGH.** The acuteness and the urgent character of the erosional problem is evident as shown in the pictures especially at the opposite side (W) to the local fishermen's port;
- environmental restrictions pertaining for the potential pilot area and their impact on prospective interventions. – **LOW.** The pilot site does not lie within the limits of a Special pro-

tected area under Ramsar and Natura 2000 treaties etc. Therefore, any type of intervention is expected to have minimal impact and is not expected to face significant restrictions for environmental reasons;

- vulnerability in view of climate change - **MEDIUM.** The hinterland area is relatively flat and an eventual sea lever rise would lead to further retreat of the coastline and the loss of coastal sensitive coastal area;
- data availability - **MEDIUM**. The data availability of the particular site (meteo-marine, sediment reserves, evolution of topography, and satellite pictures) is considered satisfactory but not to the degree of potential pilot sites 1 and 2. It is expected however, that the data available will allow a timely completion of the project with a high quality level for the final project deliverable;
- similarities with other locations in order to reapply the remedial concept in those other locations in the future. **LOW**. The erosional pattern and general characteristics apply to very few sites along the coastline in REMTH. Therefore, it cannot be used as a model for the typical coastal erosion system in the rest of continental coastline in REMTH. It would not be as beneficial to study the Limenaria beach, since any solutions developed within the Coastance project would have limited applicability in other erosion prone areas in REMTH;
- intervention and remedy potential – Soft measures, Beach nourishment - **HIGH**. The site allows for the application of all remedy measures with «soft» interventions thanks to ease of access and linear coastline. The efficiency and long term durability of beach nourishment as well as its exposure to extreme weather events that can destroy any possible «soft» interventions are to be examined;
- involved Stakeholders – Economic Value of the area - **HIGH**. The area is of high economic value since it is highly touristic and earning most of its income from the tourists visiting the island's beaches. Therefore, for economic reasons the confrontations and eventual opposition in view of applying remedial measures within the framework of a pilot EU project are expected to be high, and may delay or even jeopardize the entire project. Therefore, it is important to examine the local stakeholders' view in order to reach consensus especially for the application of such measures to an area of high economic value.

From these three proposed sites **Kariani beach** and fishermen's port was selected based on the following criteria:

- has a high ability to capitalize on previous work developed under the Beachmed-e project as it is influenced by the same local parameters;
- has a high acuteness of the erosion problem with impressive loss of coastal zone in the order of 100m.;
- the environmental restrictions pertaining are not prohibitive;
- vulnerability in view of climate change is high, making the need for action even more urgent;
- the availability of data is sufficient and will certainly allow a timely completion of the project with a high quality level for the final project deliverable;
- the similarities with other locations in order to reapply the remedial concept in those other locations in the future are high since the erosional pattern and general characteristics apply to>100 km of coastline in REMTH at a significant number of locations;
- the intervention and remedy potential for soft measures, beach nourishment etc. is high;
- the economic value of the area and the relative importance of the local stakeholders –are relatively high and are expected to support remedial measures proposed in the framework of the Coastance project.

Characteristics of the pilot site: Kariani beach

Kariani beach is located south of Kariani village and is part of the Municipality of Orfano, in the Prefecture of Kavala. The beach lies 12km east of the Strymonas river delta (fig. 11). The beach is almost linear with parallel to the coastline isobathic lines and a slope of 2.5%. The beach is oriented SSW and is covered by thin sand.

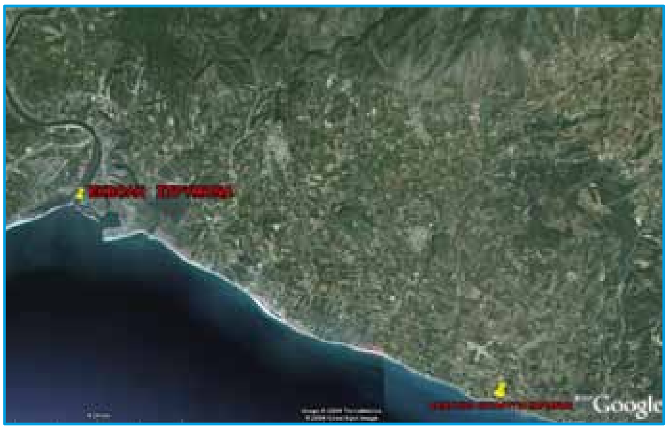


Figure 11. Satellite photo of the area: Strymonas river Delta at the W and the location of the fishermen's port at the W.

Figure 12. Kariani beach (12km east of Strymonas river Delta). The circle shows the shooting bunker constructed in 1939 that was found in the year 2000 at a distance of roughly 100m from the coastline due to erosion. The picture was taken before the construction of the local port in 2008.

The main currents are from E to W. The beach is exposed to S, SE, and SW waves and winds that are the generating the strongest gales during winter periods.

The pilot site does not lie within the limits of a specifically protected area under Ramsar, Natura 2000 etc.

Figure 13. Photo of the fishermen's port

At 12km West of Kariani beach, at the Strymonas river delta, the river supplies and accumulates significant quantities of sand. However, due to the E to W currents, the area suffers from severe erosion (fig. 12). Fortification works constructed in 1939 along the coast are now almost completely submer-

Figure 14. Erosion W of fishermen's port in Kariani.

Figure 15. Erosion W of fishermen's port in Kariani. In the background the W breakwater of the port.

Figure 16. Erosion W of fishermen's port in Kariani. Picture taken from the E (left side) towards the W (right side).

Figure 17. Sand accumulation E of the fishermen's port port in Kariani. Picture taken from W (left side) towards the E (right side).

ged and at a distance >20m from the existing coastline. As shown at the cadastral maps and tables of the Municipality, a number of coastal properties are now entirely submerged due to the retreat of the coastline. The acuteness and the urgent character of the erosional problem is evident with coastline retreat in the order of 100m, as it can be seen from figures 14 to 17.

The fact that the area is under erosion, was a decisive factor for the selection of Kariani beach for the construction of a fisherman's port, in order to avoid an eventual need for constant dredging of the port, due to sand accumulation in the port basin. After the port construction in 2008, the solid transport from E to W was interrupted, resulting to sand accumulation at the E breakwater while the erosion problems at the west side of the port deteriorated even further.

The hinterland area is very flat and an eventual sea level rise would lead to further retreat of the coastline and the loss of coastal property.

The area is of high economic value and is becoming among the most expensive coastal areas in the REMTH due to the vicinity to Egnatia Highway and the decrease of access time from all major cities of northern Greece, primarily from Thessaloniki. Therefore, there is urgent pressure from the local stakeholders for remedial measures in order to uphold the current loss trends of coastal land.

No measures have been taken yet for the protection of the coast

Main trends of sediment transport

The area of Kariani beach is situated in the west part of the AB sedimentary macrocell (From Strimon River Mouth to Cape Vrasida). The chosen pilot site is situated from the Strimon River Mouth to Cape Apollonia and it covers approximately 21 km. In the area the long shore sediment transport is influenced by two factors, the Strimon River Mouth, which is a continuous source of inland sediment and the SE to NW sediment transportation due to the winds, currents and natural bathymetry.

The major natural sources of sediment in area are two:

1. the Strimon river sediment yield, which has been reduced by 90% from 1932 when the dam of Kerkini was built (before 1931, the sediment discharge was about 5 million m^3 annually). The sediment yield is still important (0.5 million m^3 per year). The naval 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 -20 m isobaths to the -50m isobaths, see Figure 20 and Figure 21. 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;
2. the dominant east to west longshore sediment transport;

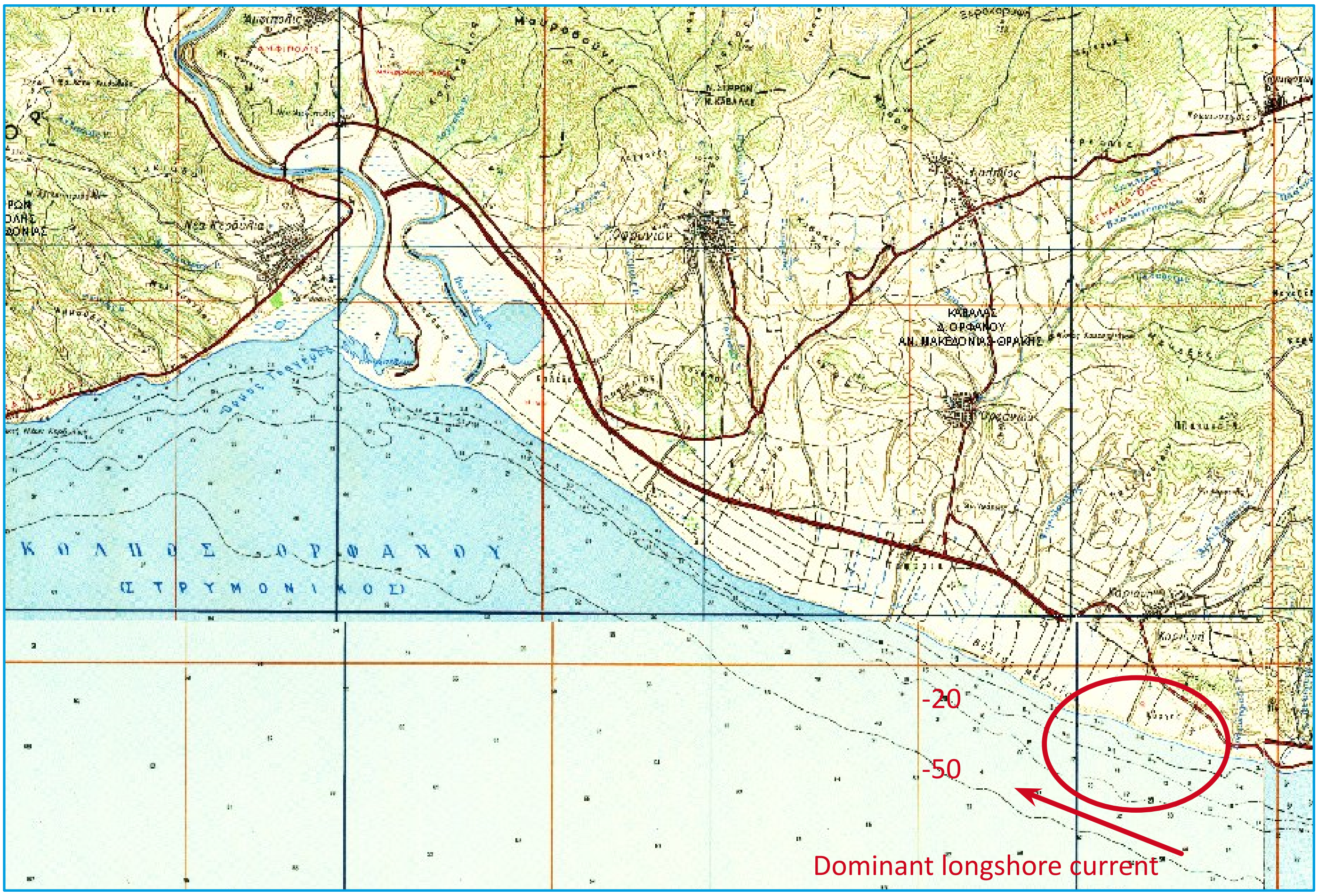


Figure 18. Extract of the naval map of Strymonikos gulf. Kariani beach in red circle. The gentle slope is apparent.

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

Sedimentary Microcells and erosion/accretion rates

The pilot site has been divided into 5 sedimentary (as it shown in Figure 19) sub-cells not because there is no sedimentary transportation between them but according to their sediment regime (accretion, stability, erosion) and the sediment dynamics. The sediment transport, before the construction of the fishermen's port at Kariani was unobstructed from Cape Apollonia to Strimon river and beyond to the entire Strimon gulf.
Sedimentary cell ab is the Strimon River Mouth. Sedimentary cells bc, cd and ef are gentle beaches. Sedimentary cell de is the fishermen's port. The shore in all these sub-cells is characterized by sandy beaches. From existing few measurements, the mean grain size varies from 0.1 to 0.25 mm.
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. 20). Coastlines of 1975, 2003 and 2007 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 the georeferenced coastlines of

Figure 19. Division of the pilot site in sedimentary cells

years 1931 and 2007 (76 years time span) and for each coastal sub cell we calculated the sand volume evolution (fig. 21). 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.

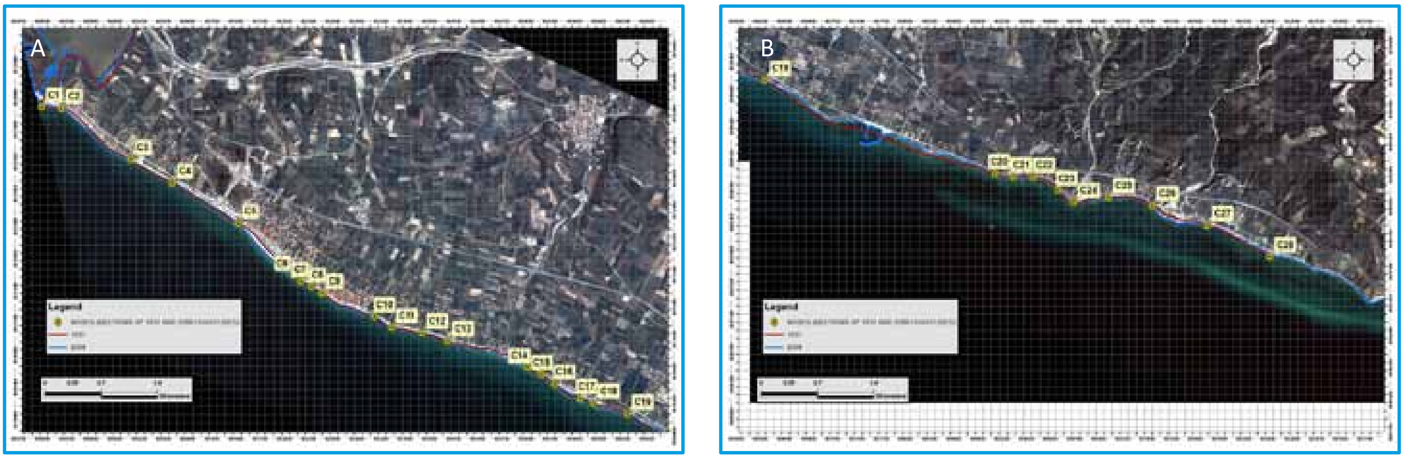


Figure 20. A: The intersection of the coastlines of years 1931 and 2009, define the nodal points C1 to C28 and 27 sedimentary sub cells. B: The intersection of the coastlines of years 1931 and 2009, define the nodal points C1 to C28 and 27 sedimentary sub cells.

The sub cell C19,20 has a length approximately of 3 km and includes 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 22. 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.

The higher erosion rate of sub-cell C19,20 from 1931 to 2003 was one of the reasons for selecting this area for the construction of the new fishermen's port, in order to avoid as much as possible the silting of its basin.

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.

Although overall on sub-cell C19-C20 there is accretion at both sides of the port, right next to it, on the west side there is still significant erosion.

The comparison of the retreat of the coastline in different time periods from 1930 to 2009 in different positions in the sub-cell C19-20 gives valuable information:

- most of the retreat took place from 1930 to 1975, as a response to the creation of the Ker-

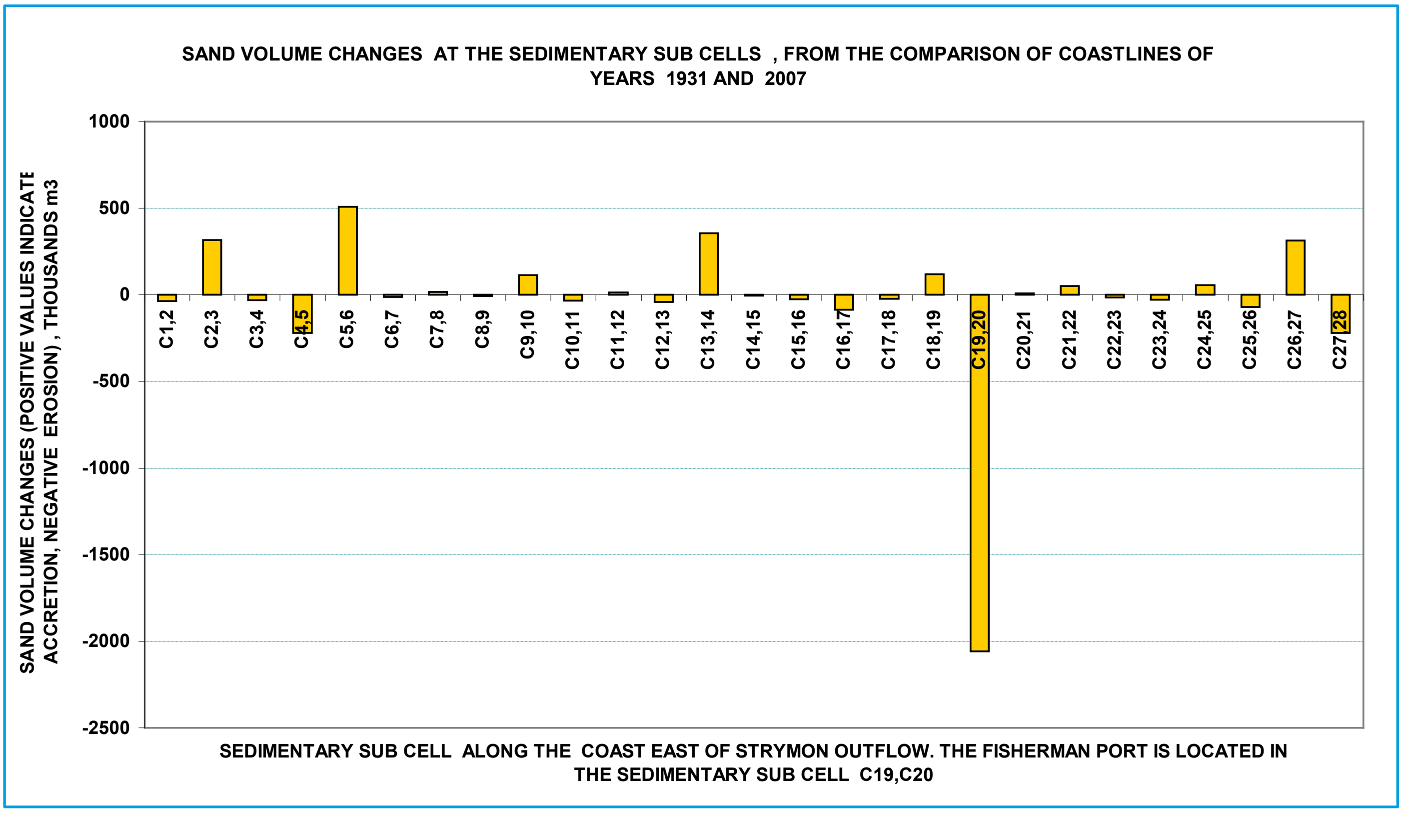


Figure 21. The sand volume changes between the years 1931 and 2007 for various sedimentary sub cells.

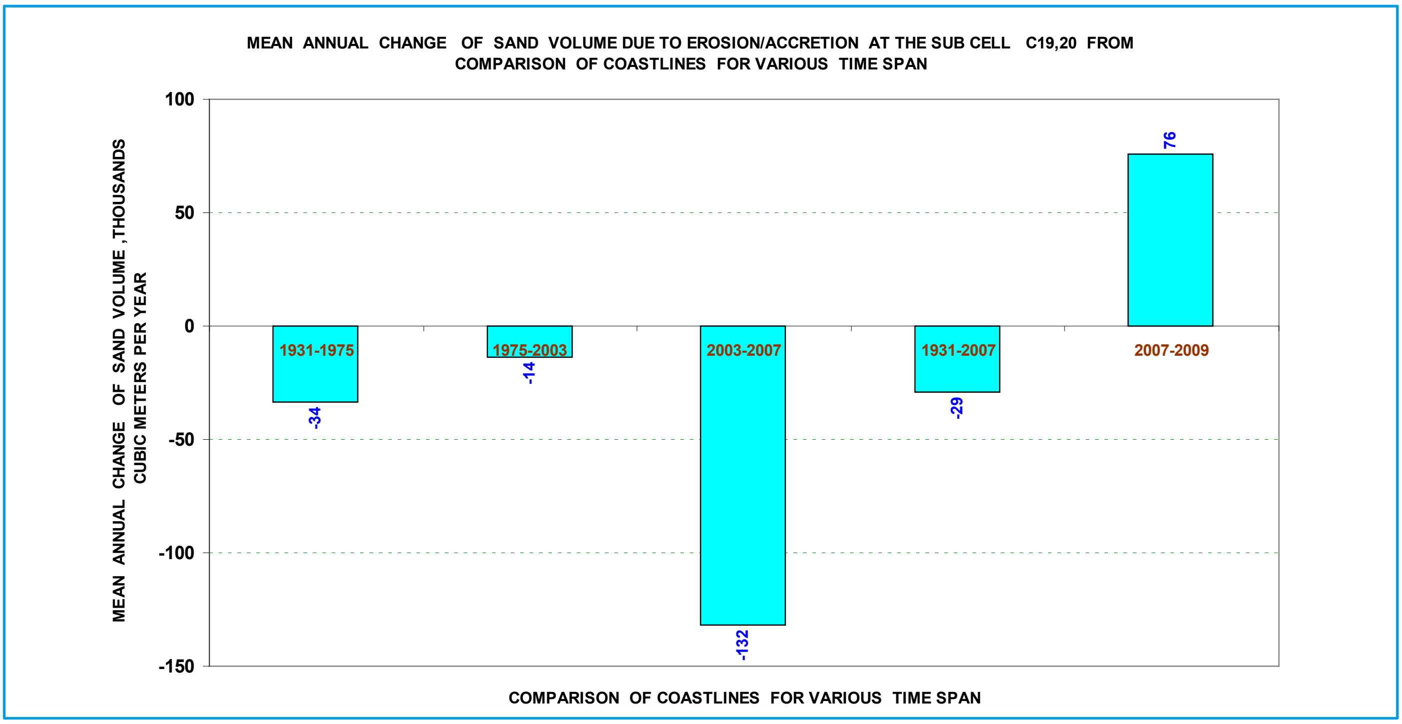
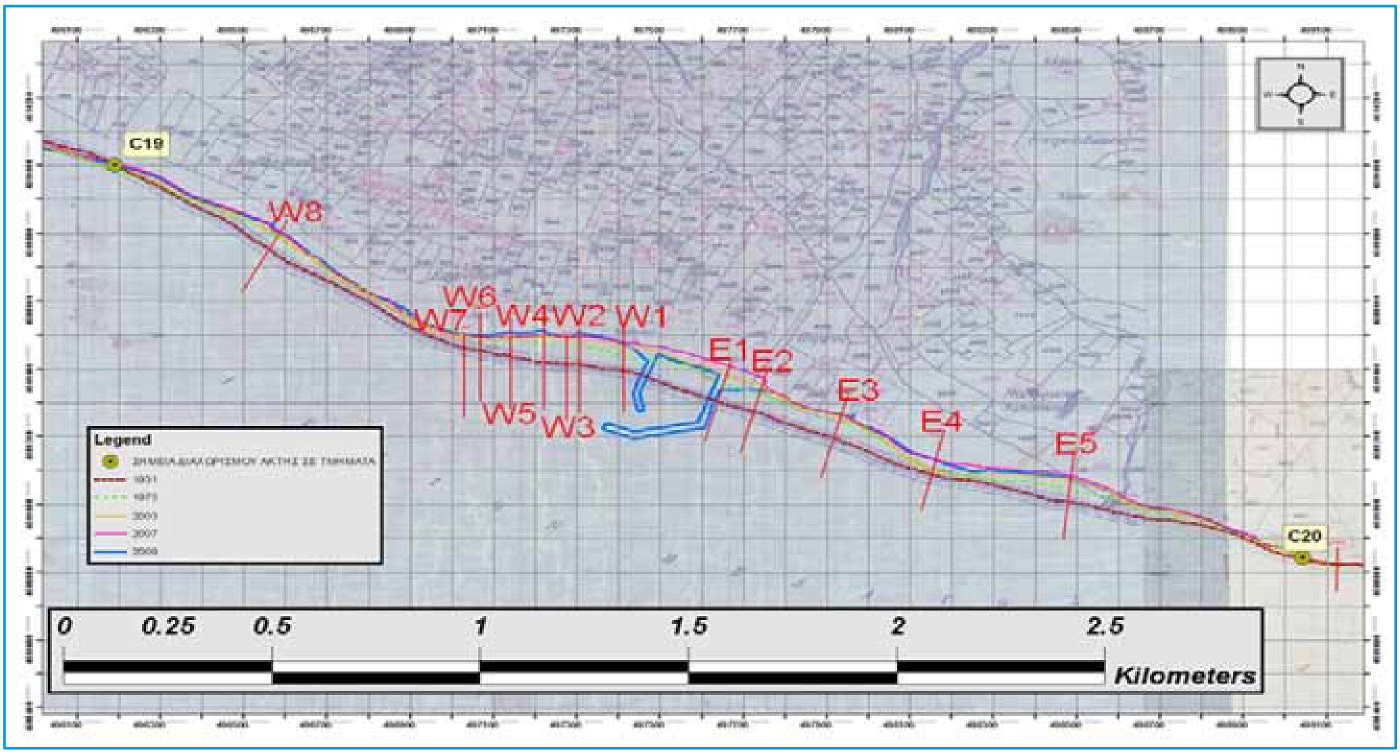


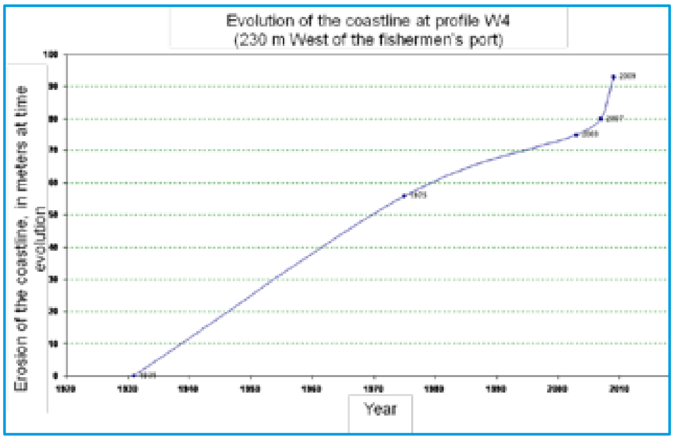
Figure 22. The mean annually eroded volume of sand at various time span, before and after the construction of fishermen's port. We observe that after the construction of the fishermen's port, the change of sand volume is positive, due to sand accretion east and west of the port.

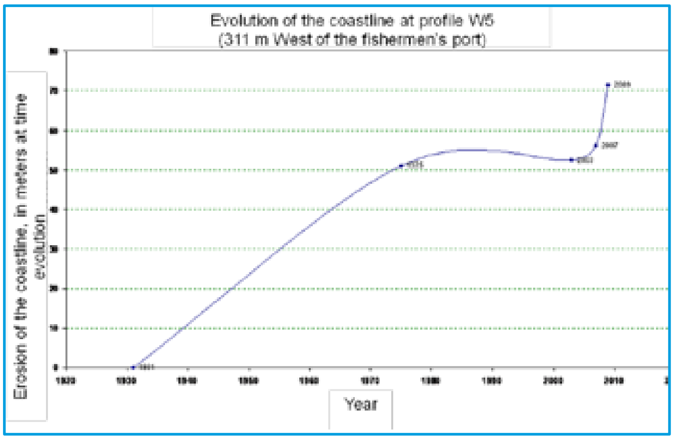
kini dam in 1931 and the reduction of the sediment yield;

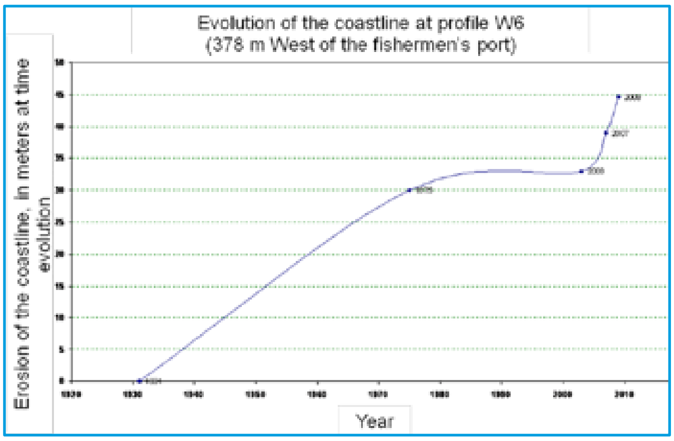
- after 1975, the erosion rate is slowing down and the beach seems to reach a new equilibrium;
- the February 2005 storm event caused important erosion;
- East of the port and close to it there is accretion, whereas at its west there is erosion;
- the entire stretch C19-20 is vulnerable to single events that cause significant erosion;
- **protection should focus on reducing the impact on the shore of single but strong events/storms.**

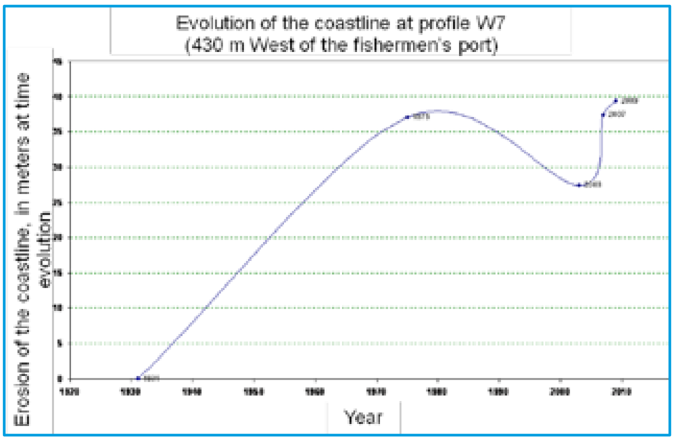


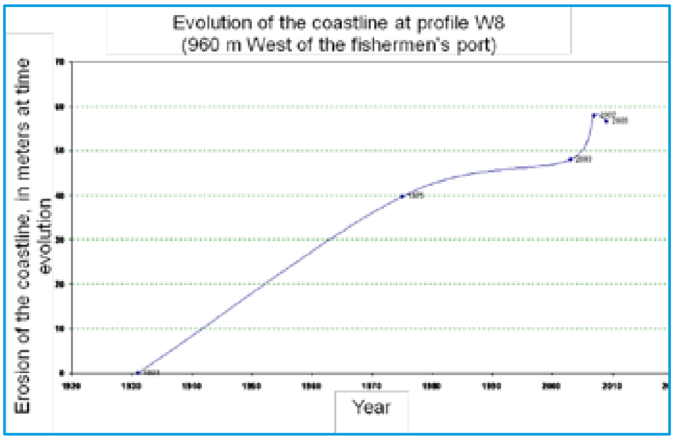
Selected profiles in Kariani beach for erosion rate comparison

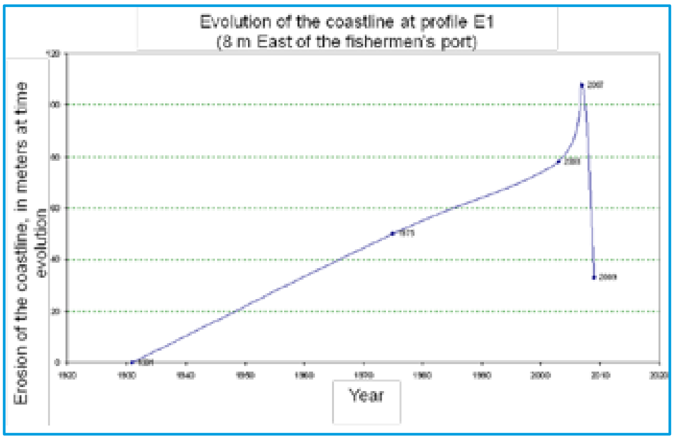


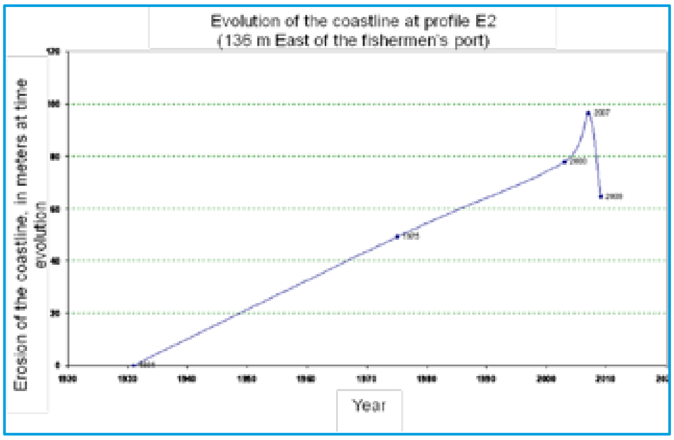


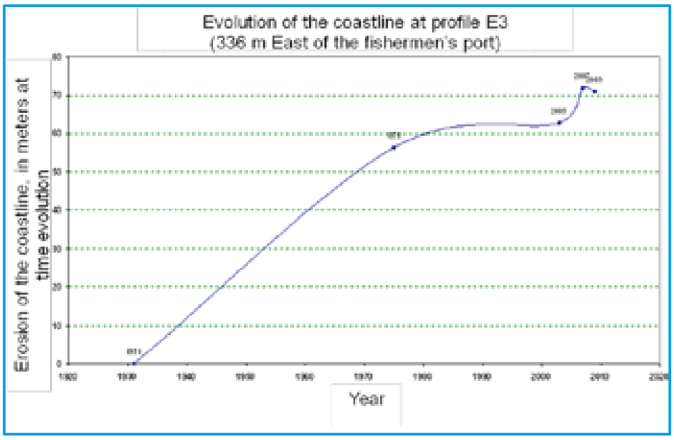

Evolution of the coastline at profile W6
(378 m West of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year

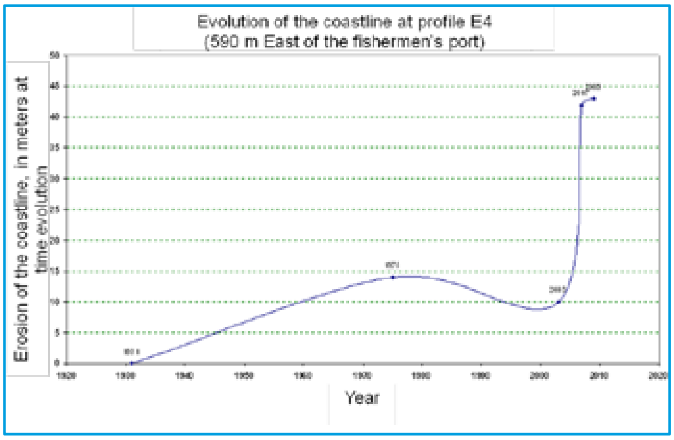

Evolution of the coastline at profile W7
(430 m West of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year

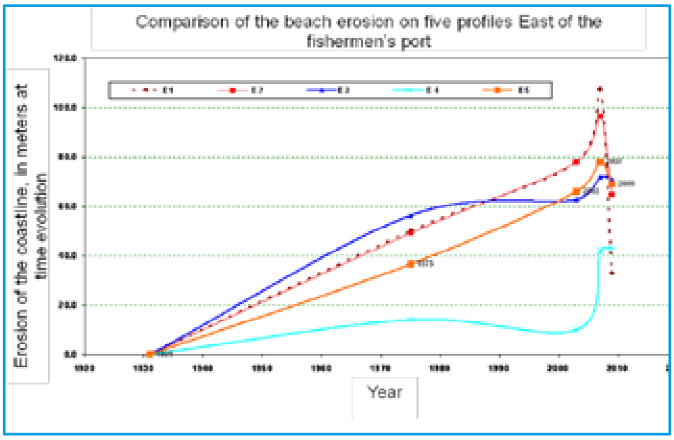

Evolution of the coastline at profile W8
(960 m West of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year


Evolution of the coastline at profile E1
(8 m East of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year


Evolution of the coastline at profile E2
(136 m East of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year


Evolution of the coastline at profile E3
(336 m East of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year


Evolution of the coastline at profile E4
(590 m East of the fishermen's port)
Erosion of the coastline, in meters at time evolution
Year


Comparison of the beach erosion on five profiles East of the fishermen's port
Erosion of the coastline, in meters at time evolution
Year

Socio-economic characteristics of the pilot site

The REMTH coastline in general is an area of Greece that until recently was developed only locally. The flat coastline was mainly used for agriculture and tourism was until recently developed only locally. The geographic position on REMTH, far away from Athens and in the sensitive position of the borders with the ex-communist countries, discouraged the economic development of the area.
Although REMTH disposes of many Km of sandy beaches, rich cultural heritage and many sites of natural beauty, tourism was not as developed. as in the rest of Greece.
Pressure for coastline use has increased after the opening of the Egnatia Highway and the opening of the Eastern Block countries to the rest of Europe.
The opening of the north borders of Greece with the ex-communist countries and especially with Bulgaria, the development of Bulgaria and the other Balkan countries, the admission of Bulgaria and other east-European countries in the European Union, made REMTH a cross road. Balkan and east-Europeans come to REMTH for tourism and commerce. The port of Alexandroupoli has become and important commercial gate for all Balkans.
In the same time Egnatia Highway has been completed, connecting northern Greece from the west borders to the east borders. Egnatia Highway is of international importance connecting Asia to Europe. Egnatia Highway is also connecting all important cities of REMTH and it is connected with 4 vertical axes (and more connections are under construction) to the Bulgarian borders.
The renewed geo-political status of REMTH is encouraging the local development of commercial activities, the construction of depots and transfer hubs.
The construction of Egnatia Highway, and access roads facilitated the access from the REMTH cities to the coastline and from Thessaloniki to the REMTH, boosting the local tourism and the construction of many secondary-vacation houses near the coastline. The REMTH beaches have become the nearest coast of the Aegean sea for the Balkans and east-European countries.

Thus the socio-economic stakes today are those of mainly under-developed beaches with some agricultural activities that are being transformed to rapidly developed beaches with national and international tourism activities. Locally there is also pressure for commercial activities.

Socio-economic characteristics of Kariani beach

Kariani beach is located in the municipality of Orfano, which covers an area of 200 square kilometers, mostly agricultural land. The municipality of Orfano includes 7 rural villages and 25 km of coastline, most of it is sandy beach (fig. 23).
The municipality has approximately 5.500 permanent inhabitants, living in the 7 villages (population of each village between 300 and 800 permanent inhabitants). The main economic activity of the municipality is agriculture (80%), 10% services and 4% processing of agricultural goods (olive oil mils, flour mils, etc.). Fishing represents only 2% of the local economic activity.

Figure 23. The limits of Municipality of Orfano and the location of the 7 villages. The municipality covers mostly agricultural land and disposes 25 km of coastline almost all is sandy beaches.

During the last decades the coastal area is under development, concentrating more buildings than the inland settlements (see figure 24 and 25). The agricultural land is quickly been transformed into secondary/ vacation houses, camping sites, small hotels, tourist restaurants and cafes. The summer population of the Orfano municipality is estimated to be 5 times more than the winter population i.e.

27,500 inhabitants. This seasonal population i.e 22,000 inhabitants is concentrated mostly on the coastal zone (300 m distance from the coast).

Figure 24. The west part of the coastline of Orfano Municipality. The urbanization of the coastal zone is rapid. The location Paralia Ofryniou (Ofrynio's beach) concentrates more buildings than the agricultural inland villages.

Figure 25. The east part of the coastline of Orfano Municipality, where Kariani village and Kariani beach lies. The urbanization of the coastal zone is rapid, where the agricultural land is transformed into secondary/vacation houses and tourist zone.

Transportation infrastructure

The most important infrastructure in the municipality of Orfano, is the Egnatia Highway. It is a Highway of international importance (connecting the ports of Ionian sea to Asia) and National importance, connecting all the major cities of north Greece from Ipiros to Macedonia to Thrace. Egnatia Highway, within the municipality of Orfano, runs at a minimum distance of 1.3 km from the coast. It runs 6.2 km far from Kariani fishermen's' port and it is the main way of access to the beach from other municipalities and other countries. The Highway itself is far away from the erosion and submersion zone. The flood hazard maps (component 3) have shown that it will not be affected by future Mean Sea Level Rise and extreme storm events.

The other important road infrastructure is the national road that connects the city of Thessaloniki to the city of Kavala. This road is positioned near the coast, within the municipality of Orfano. Its maximum distance from the coastline is 600 m while the minimum distance from the coastline is 200m, east of the Kariani port. The flood hazard maps have shown that:

- some parts of the road near the coast are "sprinkled with water" during frequent storm event in the present day;
- in the future, with MSLR, some parts of the road will be under submersion.

The remaining roads, including a coastal road, are of local importance.

Social Infrastructure

The municipality of Orfano, disposes schools and municipal buildings that are all positioned in the 7 inland villages and, therefore, are not threatened by coastal erosion and submersion, since they are all, situated at least 60m above MSL.

Local industrial buildings

Flour mils, olive oil mils etc. are situated inland. The municipality of Orfano doesn't have any hospitals or medical centers. So it is safe to say that no important social infrastructure is under risk of erosion and submersion due to sea storms.

According to the flood hazard maps, secondary houses, small hotels, camping sites, restaurants and cafes and agricultural land will be flooded in the future because of MSLR and extreme storm events.

At present, the historical erosion rate in the municipality of Orfano is not very important, except for

the location of Kariani beach.
The creation of the fishermen's port in 2007 has helped in reducing the erosion rate, east of the port while at its west it has accelerated it (fig. 26), in a 300 m long zone west of the fishermen's port where buildings (vacation houses) are under serious threat. This is the zone where protection works are proposed.

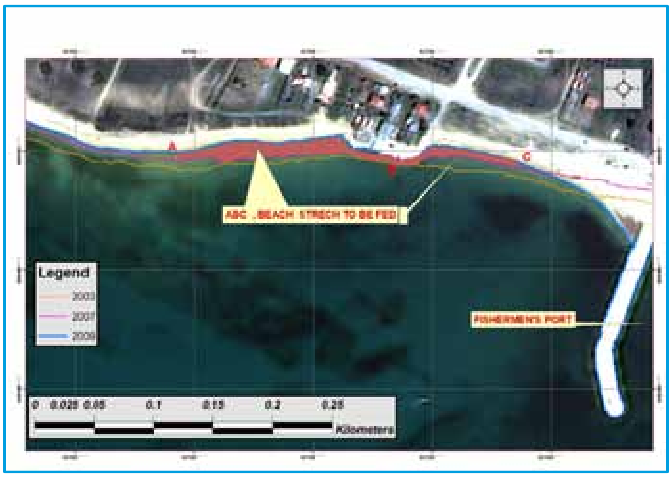


Figure 26. The critical coastal stretch which is taken as pilot case to be fed with sediment (marked with the letters ABC). Length 300 m, area 3,000 m^2 and mean width 10 m. Volume of sand for beach nourishment 30,000 m^3.

Illustration of policy options assumed in relation to pilot site specific characteristics

Taking in consideration the recent data on the rate of erosion, the flood hazard maps and the socio-economic stakes, it has been decided to choose the policy option 5: Limited intervention.
This policy will have three axes:

- beach nourishment in order to protect a limited length of beach (300 m) which is under erosion and where coastal property (vacation houses) is under immediate threat of erosion. This periodic beach nourishment can eventually be coupled by soft, beach stabilisation works;
- monitoring by orthophotomaps and satellite images processing. The comparison of orthophotomaps from the pilot area in an annual basis can show how the beach nourishment site is retreating and which volumes of sand is lost every year. It can also show if other beaches in the area are effected from the project or other reasons;
- long term management of the coastal area based on the flood hazard maps. The flood hazard maps have shown that important part of the coastal buildings (secondary/vacation houses, small hotels, restaurants and cafes) face severe flood risk. This flood risk can be limited by:
    1. taking passive flood protection measures for the existing houses (watertight doors, fences etc.);
    2. limiting important buildings at a 300 m width strip from the coast;
    3. requiring new buildings to take reinforced flood protection measures: no basement, buildings on pilotis etc.;
    4. allowing the beach to have the necessary width for wave energy attenuation during storm events (no hard structures in the winter wave zone).

This policy of limited intervention is considered appropriate for most of the REMTH coastline, we therefore, propose:

- monitoring by orthophotomaps and satellite images processing. The comparison of the orthophotomaps can show which coastal zones are under erosion and where building, road infrastructure or other vulnerable areas are under threat of erosion and submersion. This monitoring procedure can pinpoint the critical zones where protection measures are necessary;
- creation of flood hazard maps and adequately planning of the coastal zone development so as to limit future coastal flood risk;
- "Soft" erosion protection measures in the critical zones: beach nourishment, beach stabilisation, sand dunes regeneration;
- sediment extraction (by hydrosuction or other methods) from the river dams so as to limit the sediment trapping in the river dams and re-establish sediments balance in the area;
- limiting the sand extraction from the rivers for construction or other uses so as to improve sediment yield of the rivers. If sediment removal is necessary in some sites, the removed sedi-

ment should be deposited downstream in the same water body.

The REMTH coastline is not fully developed yet and it disposes large undeveloped areas and a flat agricultural hinterland that can serve for the implantation of all kinds of important infrastructure. In this stage of development, the option 5 policy "Limited intervention" can offer to REMTH the occasion for:

- better future planning;
- future development protected against coastal flooding
- limitation of future coastal flood risk,
- sustainable touristic development of the coastal zone.

The annual monitoring by orthophotomaps and satellite images processing is a very cost effective way for the early localization of coastal zones under erosion and the application of "soft" measures.

lic capacity and create flooding problems;

- sediment management on the other rivers, so as to limit the abstraction/blockage of sediments upstream.

Objectives for coastal stretches geometry arrangement

Erosion rate depends on many parameters:

- long term sediment starvation because of river sediment yield decrease;
- long term sediment starvation because of updrift barriers (ports, groynes, etc.);
- long term erosion because of long shore sediment transport (frequent storm events);
- long term erosion because of rip currents (frequent storm events);
- rapid erosion during extreme storm events.

Figure 27. Schematic of the distribution of the beach width: in green beaches with width varying from 40 to 70 m, in orange beaches with width varying from 20 to 40 m and in red beaches with less than 20 m beach width.

The major long term problem to resolve, in the REMTH area, is how to increase the rivers sediment yield so as to increase the natural sources of beach nourishment.

This is an issue of international importance. Bulgaria, Turkey and Greece have to collaborate for the better management of river sediment management of the transnational rivers (Strimon, Nestos, Ardas, Evros):

- sediment management/ sediment evacuation etc. from river dams and reservoirs;
- sediment removal (towards downstream) from islets on river Evros that are limiting its hydrau-

The calculation of this erosion rate is possible by simulating long time series of wave climate on detailed mathematical or physical models of the coastline.

Another way of estimating the erosion rate is by observation of the multiannual erosion. In the case of Kariani beach during the time period 2003-2009, there was erosion because of the usual wave action, because of the February 2005 storm event and because of sediment starvation since the fishermen's port construction in 2007. In the period from 2003 until 2009 the beach width lost due to erosion was approximately 10 m.

Orfano municipality, where Kariani beach lies, has 25 km linear sandy beach. Except from Kariani's fishermen's port, no other works affect the coastline, therefore, the existing coastal width in areas without buildings and roads, reflects the natural coastal width forged under the local coastal dynamics: wave climate, longshore sediment transport, natural erosion and accretion etc.

These "natural" coastal zones can be divided into two categories according to their width (fig. 27):

- the large beaches with width between 70m and 40m;
- the "medium" beaches with width between 40m and 20 m, (majority);
- the "slim" beaches with width less than 20m. These are beaches confined by the road or buildings that limit their natural development;
- Beach slope plays an important role in the natural beach width.

From these observations we can consider that in the municipality of Orfano, a 40 m to 20 m beach width is "normal". It offers enough space for sun bathing and protection from erosion.

For Kariani beach project (fig. 28), a 10 m width is appropriate for the beach nourishment plan and it will provide at least a 5 years erosion protection. In case of more severe storm events or an exceptional multitude of storm events, the 10 m width nourishment may be inadequate. For that reason, we propose annual monitoring of the beach nourishment project and annual or biannual top-up to the original 10 m width project.

Figure 28. Schematic of the proposed beach nourishment with average beach width of 10m

As REMTH beaches are so irregular, a different width of beach nourishment is necessary in different sites.

Program of interventions, including priorities, with project preliminary indications

Figure 29. The critical coastal stretch which is taken as pilot case to be fed with sediment (marked with the letters ABC). Length 300 m, area 3,000 m^2 and mean width 10 m. Volume of sand for beach nourishment 30,000 m^3.

The selected intervention for the pilot site of Kariani beach is beach nourishment accompanied by beach stabilisation works. Further details of the intervention:

- beach nourishment of a coastal stretch of approximately **300 m length and 10 m width;**
- in addition, it is proposed to stabilize the **restored beach by submerged breakwater** or similar technology installed parallel to the coastline at a depth of approximately 4m to 5m (outside the surf zone) and with a crest elevation at -2m. In order to limit costs alternative materials should be considered such as industrially manufactured elements (pipe sections, textile tubes, pre-cast concrete elements etc.)
- required **volume of sand for initial nourishment is about 30,000 m^3**. 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 m³**. However, we expect that with appropriate beach stabilization, the annual need of nourishment will be much less.

Two are the possible sediment sources:

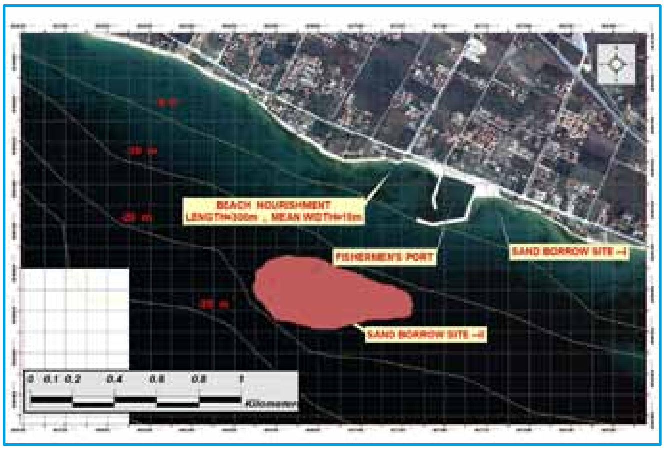


Figure 30. Beach nourishment site and sand borrow site I and II at Kariani Beach

- 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 27,000 m^3 per year and it is a renewable sand deposit for periodical dredging (sand borrow site I, see figure 30). 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 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 seabed 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 shallow 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 dipping south -east with extremely mild slope (average bottom slope of 0.4 %). Due to the mild slopes of the seabed of Strymonikos Gulf, the dredging of sand will not pose problems on the seabed 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, in figure 30. 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 estimate that rip currents transport partially the eroded sand from sub cell C19,20 to the off shore region, marked as sand borrow site II.

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 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 seabed 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.

As already mentioned, Kariani beach is a pilot site and the first beach nourishment project in REMTH. As such, the experience from this project will be used for the protection of other REMTH's critical coastal stretches.

Estimation of economic resources needed

The cost of the beach nourishment project is estimated between 7-20 Euros/m^3, total cost of 210,000 to 600,000 Euros. The final price of the project depends greatly on the availability of a suitable dredger in the vicinity of the project, because it is a very small beach nourishment project. The lower price reflects the solution of sediment extraction by mechanical means of the nearby beach (borrow site I) or a very inexpensive dredging near the coast (borrow site II) from a local dredging boat or a contractor that has many projects in the area. The higher price reflects to dredging from borrow site II by a dredger that will come from another area.

Addition, annual re-nourishment projects of 15,000 m^3 will cost 105,000 to 300,000 Euros.

The use of borrow site II will necessitate an exploration campaign with a cost in the order of approximately 50,000 Euros. The exploration campaign can be useful for other projects of beach nourishment.

A preliminary study is necessary in order to estimate the cost of beach stabilization works.

	Borrow site I	Borrow site II
Study + EIA	60,000	60,000
Exploration campaign		50,000
Sand Nourishment (1st)	105,000-200,000	
(for 15.000 m^3)	210,000 -600,000	
(for 30.000 m^3)		
Sand Nourishment (annual)	105,000-200,000	
(for 15.000 m^3)	105,000-300,000	
(for 15.000 m^3)		
Stabilization works	-	-
Annual Monitoring	2,000	2,000

Table 1: Overall cost of the beach nourishment and stabilization project

As borrow site I cannot offer enough sediment for the initial beach nourishment a mixte solution is possible:

- initial sand nourishment from Borrow site II (off-shore deposit);
- annual re–nourishment from Borrow site I (close by beach);
- this way the cost of the re-nourishment will be less expensive and it will not depend on the availability of a dredger boat locally.

Possible financing sources:

- EU funds;
- National funds;

- Regional funds.

The inhabitants and business owners of the Municipality of Orfano will primarily enjoy the economic and social benefits of erosion protection measures for the Kariani beach. It is, therefore, reasonable and socially justifiable that at least part of the costs must be borne directly by the local community. The direct financial involvement of the local community may be done in various ways, for example through a special purpose local tax or one-off payments. Such a move will also engage more actively the local community in confronting erosion issues. Communities in REMTH are a typical example of such co-participation where 50% of total costs for coastal protection works are borne by the local communities.

Indications on sustainable exploitation of sediments stocks

In the case of sand borrow site I, 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 30). 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. For the initial nourishment this volume is not sufficient.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 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 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 far from the beach stretch to be fed. Because of the important volume of this sand borrow site, and its partial renewal by Strimon river, it is not expected that it will be exhausted in the mid-term (30-50 years), if used only for this project. However, the cost of beach nourishment will be elevated because of the greater distance the dredging boat will have to cover every time, looking for appropriate sediment further away from Kariani beach.

In situ investigations are also needed to obtain an 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.

Then an overview on possible environmental and technical constraints and a choice of technologies, good practices and exploitation techniques shall be indicated for each sediment stock to be used.

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 areas

The extraction of sand from the sand borrow site I (beach east of fishermens' port) will require an Environmental Impact 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;

It is expected that the excavated sediment from the two sediment deposits (off-shore and Kariani beach) will not demand any treatment. The local wave climate will induce a natural selection of the appropriate sediment side. Both sand deposits have sand of similar characteristics to the beach nourishment site.

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

- Front shovels;
- Hydraulic excavators;
- Long Reach Excavation Loaders;
- Track loaders;
- Compact Track Loaders.

The transportation of the sand will be done by trucks.
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 dredging ships will be adequate:

- Trailing suction hopper dredger;
- Cutter suction and suction dredger.

In both cases, for the profiling of the of the sand nourishment site 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.
Environmental restraints and methods of excavation do not influence the available volume of sand to be extracted.

Indications for possible upgrading of policies and interventions for river solid transport enhancement and subsidence mitigation

The major long term problem to resolve, in the REMTH area, is how to increase the rivers sediment yield so as to increase the natural sources of beach nourishment.
Strimon river sediment yield, has been reduced by 90% from 1932 when the dam of Kerkini was built (before 1931, the sediment discharge was about 5 million m^3 annually). The sediment yield is still important (0.5 million m^3 per year).
For enhancing the river sediment yield two measures are possible by REMTH:

- periodical sediment extraction (by hydrosuction or other methods) from the river dam of Kerkini so as to limit the sediment trapping;
- limiting the sand extraction from the rivers for construction or other uses so as to improve sediment yield of the rivers. If sediment removal is necessary in some sites, the removed sediment should be deposited downstream in the same water body.

Since many other dams are situated upstream in Bulgaria, improved river sediment management can also be the issue of international negotiations.

Formulation of Coastal Protection and Management Plans in the Pilot Site: Region of Crete

General characteristics of CRETE coastline

Crete is one of the most touristic areas in Greece and one of the favorite vacation destinations in Europe. The last decades of touristic development have shaped the Cretan shoreline according to the needs of tourism. Crete has become the Greek region with the most numerous and more important in terms of size coastal defense works.

Many coastal works are planned only for ship and boat mooring but in practice they create protected beaches and they disturb the natural sand drift. Other works have been designed especially for coastal defense. Many hotel resorts and some municipalities have taken the initiative to build local coastal defense works. Sand nourishment is practiced in many beaches but no official records exist.

There is no official record resuming all coastal works in the region of Crete. In the framework of this project (Component 4, deliverable D1 and D2) an effort has been made to create a first inventory of all coastal works and categorize them. For the purpose of the inventory, Crete has been divided into four sectors, North, East, West, South as shown in figure 31.

Figure 31. Division of Crete for the inventory purposes.

The inventory is site based: every site is treated separately. One site can have more than one coastal works. The inventory has been based on data of the year 2009.

In total 125 sites with coastal works have been identified. In these sites there are 12 ports, 6 marinas, 56 fishermen's' ports, 29 docks, 6 piers, 33 single jetties/breakwaters, 29 single groynes, 18 single jetties, 95 jetties in series, 59 groynes in series, 13 beaches with sand nourishment, 31 artificial beaches (created or enlarged by human intervention), 70 sites with sea walls, 11 sites with revetment either for protection of roadwork or for land protection, 16 sites with land reclamation mostly related to port construction and 5 detached breakwaters parallel to the coast.

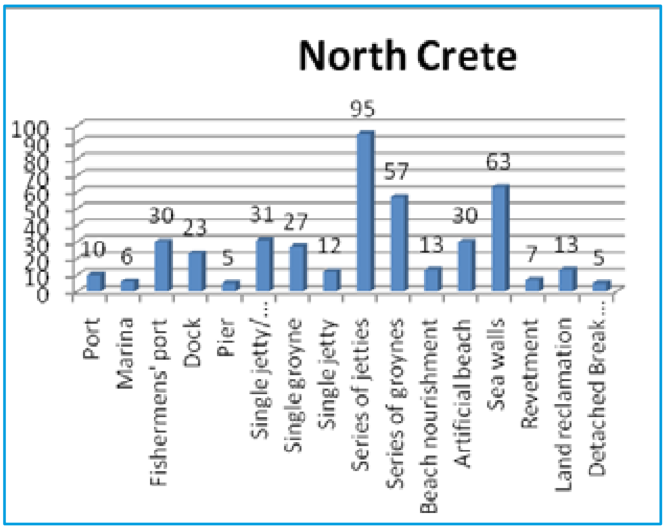
Figure 32 summarizes the results of this inventory. This inventory gives a first idea of the multitude of the existing works and the difficulty to collect precise data for each site.

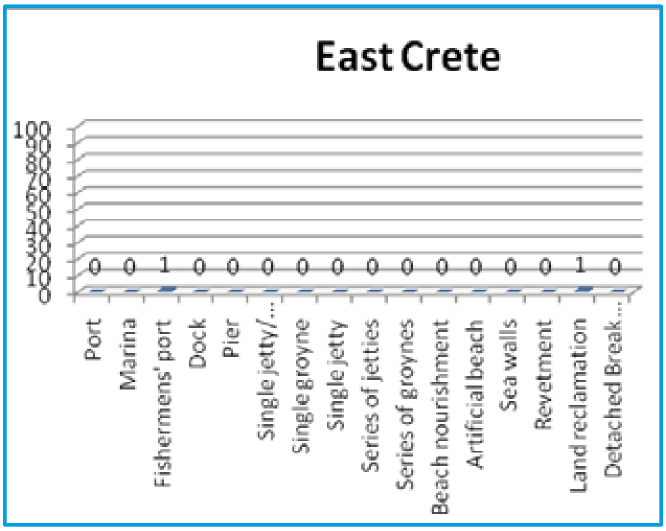
The vast majority of the coastal works is concentrated on the North coast of Crete. North Crete has easy access and long stretches of beaches which have favored the installation of many tourist resorts. Local economy is very much centered on tourist activities and the building of coastal protection works is a local priority.

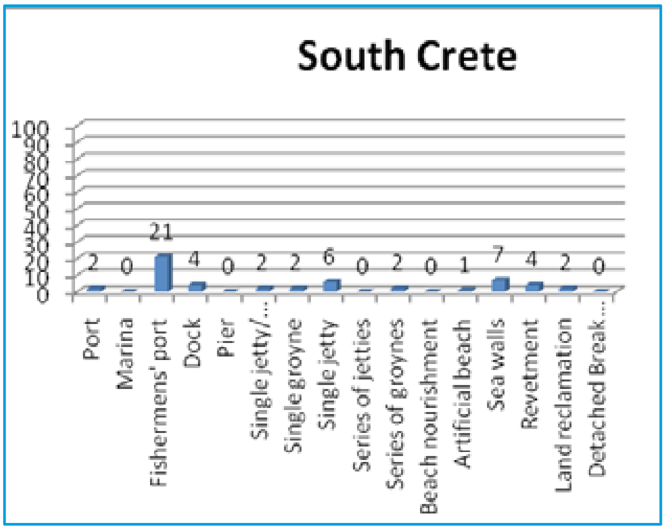
East Crete has only one fishermen's port. An important part of the East coast is a Natura 2000 protected area and the rocky geomorphology and difficult access have not favored the implantation of settlements and tourist resorts.

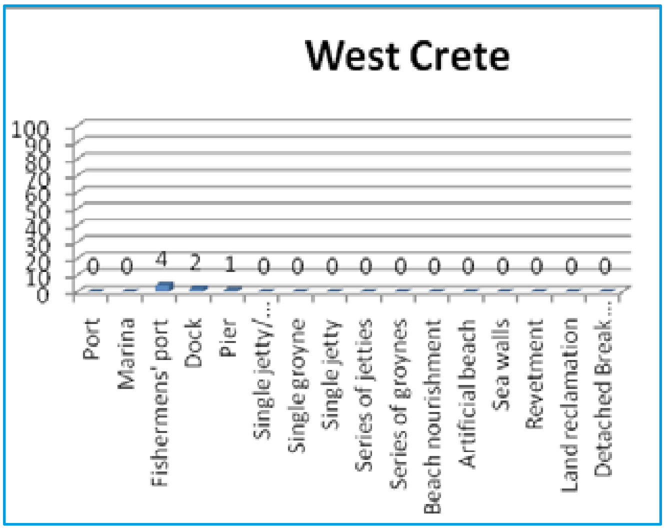
South Crete has also many coastal works, mostly fishermen's ports. Hotel resorts and coastal defense works are few but as the access to these areas is improved and the north coast is saturated, more coastal works will see the day. South coast has narrow valleys ending in beaches but also long stretches with rocky geomorphology and no tourist activities.

West Crete is also very rocky with very few fishermen's ports and docks.









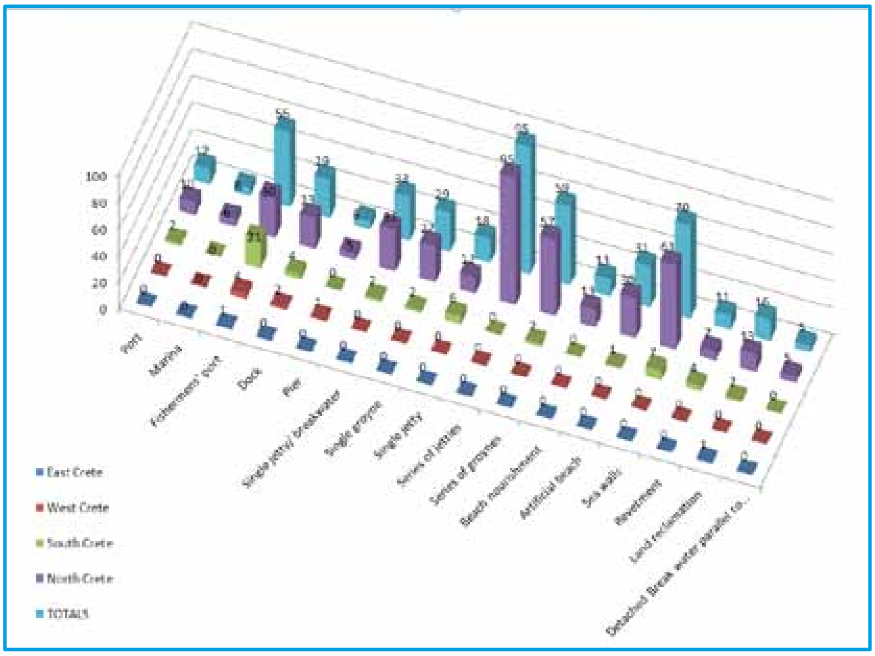


Figure 32. Distribution of Coastal works in Crete

Selection of pilot site

Three sites were proposed for the Coastance project (fig. 33). The main criteria for their proposition was the important erosion problems and the social need for limiting the erosion. The attention was focused on the South Crete, where private investments are still limited and tourist development is still low. This situation gives to the regional authorities enough space for a pilot site. The three proposed sites were small settlements on south Crete with intense erosion problems:

- Tsoutsouras;
- Keratokampos;
- Arvi;

Figure 33. Location of the tree proposed pilot sites: Tsoutsouros, Keratokampos and Arvi gulf

From these three proposed sites Keratokampos beach and fishermen's' port was selected based on the following criteria:

- has a high acuteness of the erosion problem with impressive loss of coastal zone and erosion of two buildings (vacation houses);
- the environmental restrictions pertaining are not prohibitive;
- vulnerability in view of climate change is high, making the need for action even more urgent;
- the availability of data is sufficient and will certainly allow a timely completion of the project with a high quality level for the final project deliverable;
- the similarities with other locations in order to reapply the remedial concept in those other locations in the future are high since the erosional pattern and general characteristics apply at a significant number of locations of south Crete;
- the intervention and remedy potential for soft measures, beach nourishment etc. is high;
- the economic value of the area and the relative importance of the local stakeholders –are relatively high and are expected to support remedial measures proposed in the framework of the Coastance project.

Characteristics of the pilot site: Keratokampos

The Pilot site sedimentary cell lies between Kerkellos Cape in the west and Xerokampos Cape in the east. This sedimentary cell includes Tsoutsouras Gulf, Anapodaris river mouth, which is the most important river of the area and most important sediment source, and Keratokampos Gulf. Accordingly, the sedimentary cell has been divided into three coastal stretches: Tsoutsouras gulf, Anapodaris river mouth and Keratokampos Gulf. The limits of the Anapodaris river mouth, have been defined to be two natural rock reefs, which disturb the longshore sediment transport (fig. 34).

Figure 34. Pilot site coastal stretches

The Coastance pilot site lies in Keratokampos Gulf. In the pilot site sedimentary cell, the erosion phenomena are critical (fig. 35). The most critical erosion effects are documented in the two coastal settlements of Tsoutsouras and Keratokampos where buildings and the coastal road are threatened by erosion.

Figure 35. Positioning of the Pilot site critical coastal stretch

Figure 36. Photo of a house being destroyed by coastal erosion in Keratokampos (photo taken on 16/10/2010)

According to local authorities (Mayor of Viannos) as well as from testimonies by the local dwellers, the central section of 1.5 Km of Keratokampos gulf was under erosion even before the construction of the fishermen's port. After the construction of the fishermen's port in 2001, a small beach started to be formed in the west side of the fishermen's port. Meanwhile, the fishermen's port entrance started to accumulate sediment and a 1100 m long zone starting approximately 200 m east from the fishermen's port started to show more rapid erosion effects.
In the pilot site of Keratokampos gulf, this zone of approximately 1100 m length is considered to be the most critical, both because of the rapid erosion rate but also because of the presence of buildings near the actual shoreline (fig. 36). Although there are no satellite images to evaluate the evolution of each section, erosion is estimated in the order of 1m to 15m over 10 years.

Sediment Characteristics of the pilot site: Keratokampos

For the pilot site a sampling campaign took place on May 2009 . The results are presented on the table 2. The sediment is characterized as fine sand, which is very easily transported by wave induced currents

n°	dep	Gravel	Sand	Silt + Clay	D_{50}	D_{84}	D_{16}
	m	%	%	%	mm	mm	mm
1	0	0	99	1	0.23	0.36	0.17
2	0	0	99	1	0.23	0.36	0.17
3	0	1	97	2	0.23	0.33	0.16
4	0	0	98	2	0.23	0.33	0.10
5	-3	0	98	2	0.23	0.33	0.10
6	-1,5	0	98	2	0.21	0.36	0.13

Table 2. Grain size analysis result.

Wave climate and dominant sediment transport on the pilot site: Keratokampos

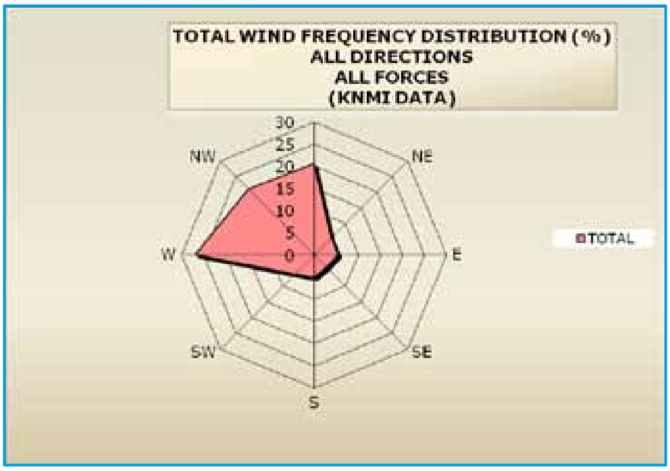


Figure 37. Total Wind Frequency Distribution (%) all direction, all forces (KNMI DATA, location south Crete open sea)

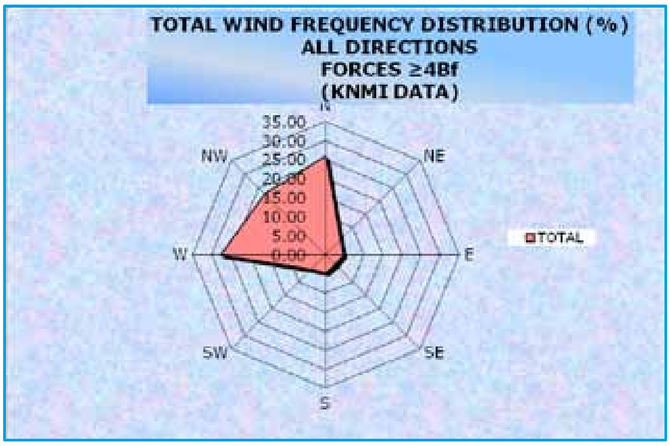


Figure 38. Total Wind Frequency Distribution (%) all direction, forces ≥ 4Bf (KNMI: Measurements' period 1961 - 1999)

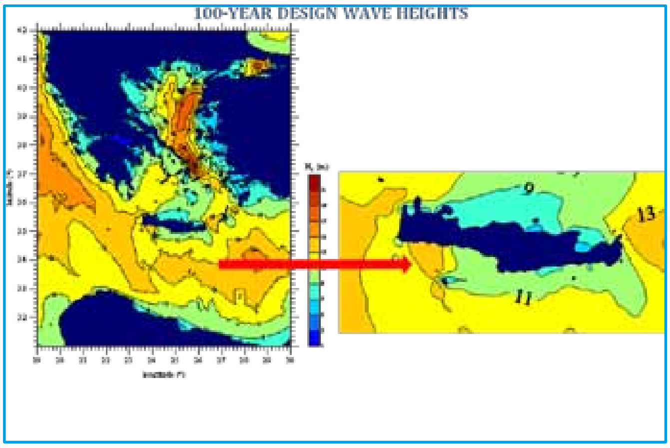


Figure 39. 100-year Design Wave Heights (Source: Hellenic Centre for Marine Research(H.C.M.R))

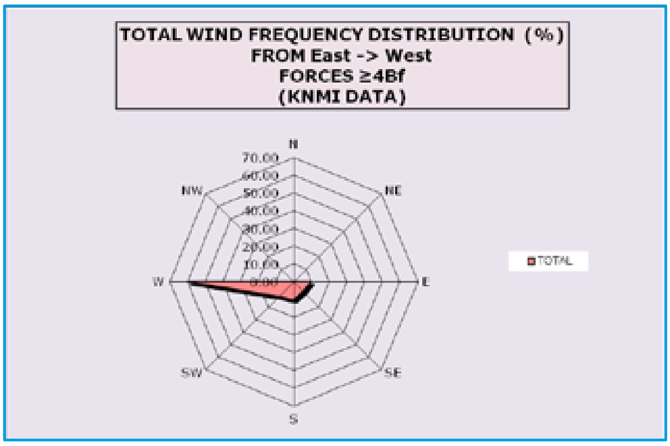


Figure 40. Total Wind Frequency Distribution (%) all direction, forces ≥ 4Bf (KNMI: Measurements' period 1961 - 1999)

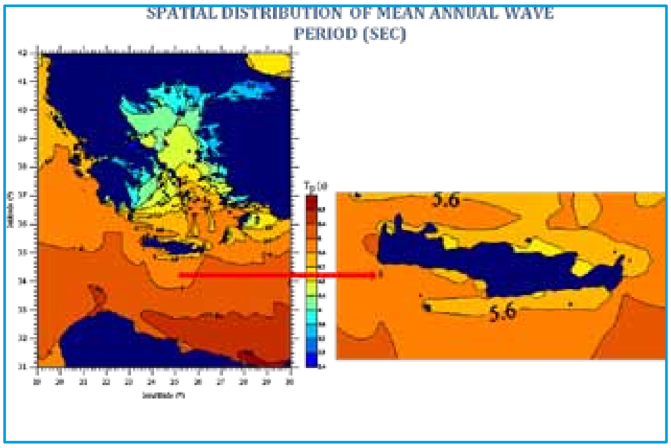


Figure 41. Spatial Distribution of Mean Annual Wave Period (sec) (Source: Hellenic Centre for Marine Research (H.C.M.R))

The predominant winds of the area are shown in the figures from 38 to 41.

The Keratokampos site is protected from the North, NorthEast and NorthWest winds. Therefore, it is important to study the distribution of winds ranging from East to West (90o to 270o Northing).

The mountains protect the coast from the North winds so the coast is affected by East, Southeast, South, Southwest and West winds. These winds create the near shore wave climate (fig. 42) and affect the sediment transport.

According to the coastal engineering study realized for the Port Authority of Heracleion in 2010 which used the KNMI meteorological data from 1961 to 1999:

- the East and Southeast waves create a longshore sediment transport from east to west (fig. 43);
- the West and Southwest waves create a longshore sediment transport from west to east (fig. 44);
- the South waves create two longshore sediment transport currents from the edges of Keratokampos gulf to the centre of the gulf and a sediment transport from the centre of the gulf towards the deep waters.

The west winds account for 26.7% of all wind events and for 14.26% among those ≥ 4Bf (see wind rosette for KNMI meteorological data). Given that the area is protected from the North, the winds that affect the Keratokampos area range from E to W (90 to 270 northing). Among the wind events from E->W

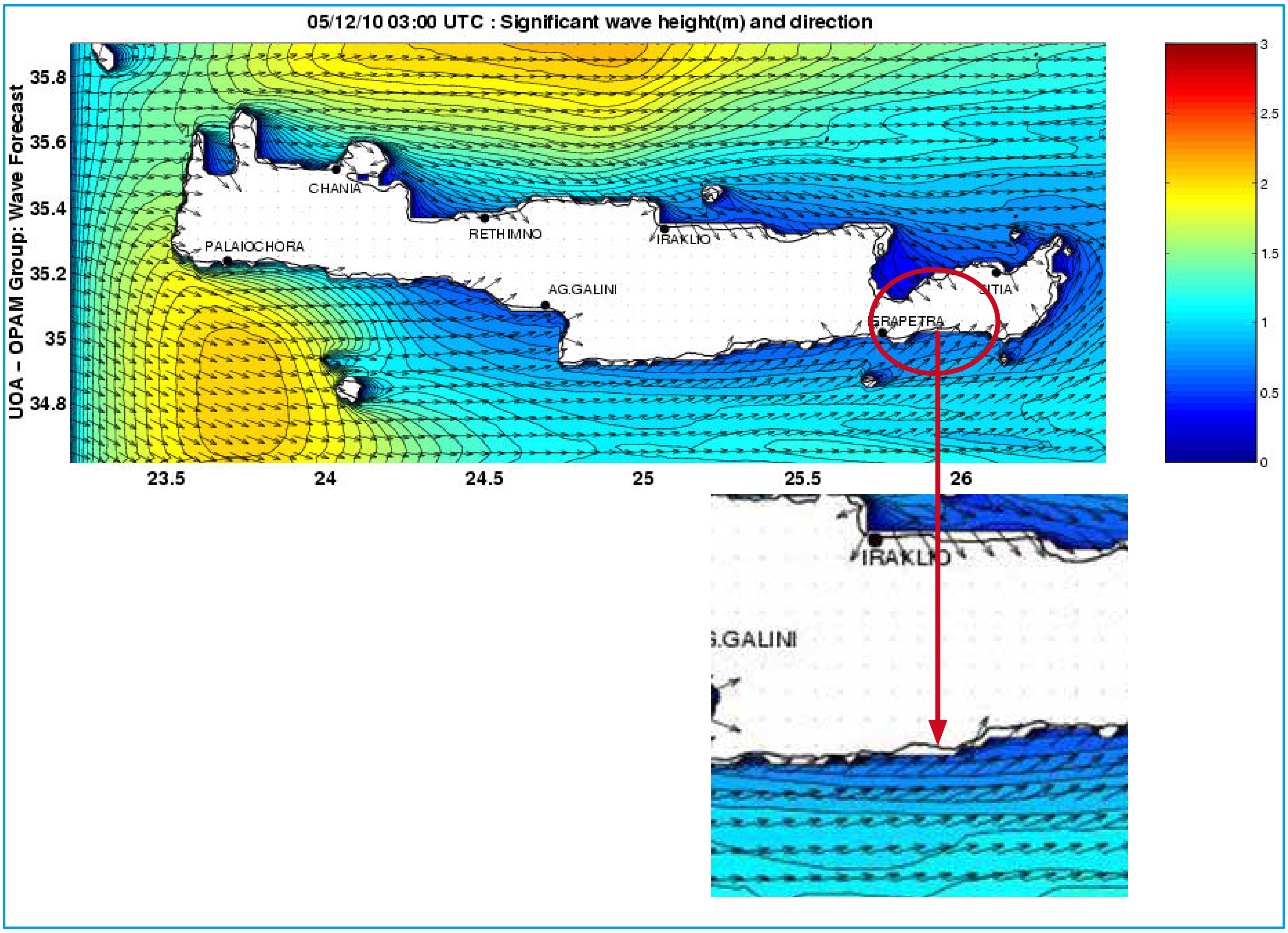


Figure 42.Spatial Distribution of Significant wave height and direction for specific date with W winds. Data issued from Triton Wave Forecast System (http://www.oc.phys.uoa.gr/page4.html). It is shown that the Keratokampos area is exposed to west winds that produce waves with W, SW direction.

Figure 43. Longshore sediment transport under East and Sou-theast winds.

Figure 44. Longshore sediment transport under West and Sou-thwest winds.

Figure 45. Longshore sediment transport and rip currents under south winds.

with force>=4Bf that can cause sufficient wave induced currents for sediment transport, W winds account for 60%. Therefore, the W winds define the predominant wave induced sediment transport conditions in the area of Keratokampos. However, the effect of west winds in wave induced currents and sediment transport is not considered in that study. Due to the morphology of the area, its exposure to both East and West winds and the high frequency of West winds, it is estimated that the wave induced currents due to west winds contribute significantly in the overall cumulative sediment transport in the area.

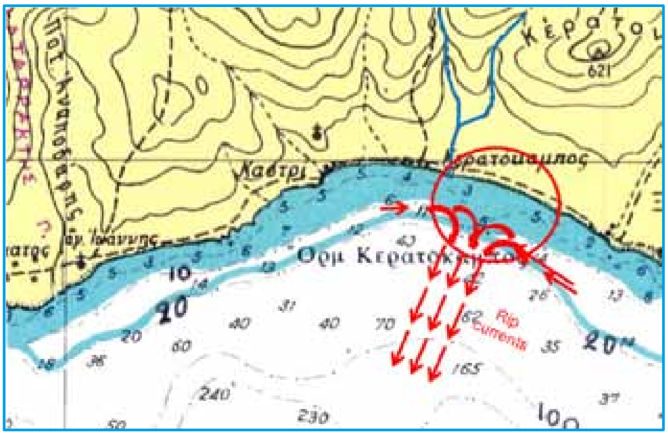


Figure 46. Zoom in the naval map, at Keratokampos stream outlet. It is shown that the sediment deposit from the stream is located east from the stream outlet and not directly in front of it. This is an indication of the combined action of:
a) the prevailing in the area longshore currents from West to East, causing an offset of the sediment volume towards east,
b) the rip currents under South winds, causing accumulation of sediment at the junction point of the opposite rip currents

Socio-economic characteristics of Crete

Crete is a favorite vacation destination in Greece and in Europe. Tourism is a great driver for the local economy. Another important driver of the local economy is agriculture and livestock. 37,8 % of the active population works in the primary sector (agriculture and livestock), 12,5 % in the secondary sector (artcrafts, manufacture, small industry mainly related to the primary sector: winery, oil mils, fruit products, meat products) and 49,7% in the tertiary sector (public services, education, health, commerce, tourism).
Tourist brings to Crete an important new income while the revival of the agriculture via green houses, biological agricultural products and large exports of agricultural and meat and dairy products, keeps the inhabitants to the small villages.
The coastline, from the 50ies, attracts more population for all kinds of activities. The new cities expansions and the new settlements are located close to the sea and concentrate most financial activities: tourism, commerce, public services, ports etc. Even green houses have being positioned near the shoreline so as to benefit the relatively small slopes and the warm winter temperatures.
Most of the population and the financial activities are gathered on North Crete, where largest cities are situated and connected by the north national highway. Central, south and west Crete are rather mountainous and isolated. An important part of the East coast is a Natura 2000 protected area and the rocky geomorphology and difficult access has not favored the implantation of settlements and tourist resorts. West Crete is also very rocky with very few small settlements.
The access to South Crete is difficult through the mountainous. However, the natural small beaches are starting to attract tourists and the very warm and dry climate is ideal for greenhouses and other agricultural activities. South Crete has also many coastal works, mostly fishermen's ports. Hotel resorts and coastal defense works are few but as the access to these areas is improved and the north coast is saturated, more coastal works will see the day. South coast has narrow valleys ending in bea-

ches but also long stretches with rocky geomorphology and no tourist activities.

Socio-economic characteristics of Keratokampos

Keratokampos lies in the Viannos municipality. Viannos municipality covers 221.000 square kilometers of mostly mountainous area, has approximately 7.000 inhabitants and disposes of 45 km of coastline (fig. 47).
The Viannos municipality was created in 1997, grouping 16 municipal communities and 47 villages. The largest of these villages is the historical mountain village of Ano Viannos with approximately 1,000 inhabitans, and the capital of the municipality. The second largest village is the coastal settlement of Arvi, with approximately 500 inhabitants.
Most of the villages are situated on the mountains between 400 m and 800 m altitude. Historically these villages were created in the mountains for the protection from the pirates. Till, 1950, in the coastal area, only few “depots” existed for the storage of agricultural goods and they served as “stations” for the marine commerce, practiced with small boats.

Figure 47. The limits of Municipality of Viannos and the location of the 16 villages. The municipality covers mostly mountainous land and disposes 45 km of coastline.

After 1950, 5 new settlements were created in the coastal area (from west to east): Kastri-Keratokampos, Arvi, Faflagko, Psari Forada, Tertsa. The new settlements were more attractive from the historical mountainous villages and attracted mostly inhabitans from these mountainous villages. The coastal settlements provide work in tourism: small hotels, restaurants, cafes, vacation houses, rental vacation houses but also in agriculture as most of the greenhouses are located in the relatively flat coastal area. Arvi is known for the production of small bananas.
Kastri-Keratokampos is the second important coastal settlement with approximately 200 inhabitants and many seasonal visitors mostly from Crete but also from all Greece and Europe.

Social Infrastructures

Most of the services and social infrastructure are located in Ano Viannos: Town Hall, Health Centre, High school- Junior High, Banks. The coastal settlements of Kastri-Keratokampos, Arvi and Psari Forada dispose only Elementary schools.

Transportation Infrastructures

The regional road also reaches Ano Viannos, connecting it to Heracleion. The rest of the road network is of local importance connecting the settlements and villages.
The distribution of the population and the infrastructure reflects the historical importance of the mountainous villages and the dynamics of the coastal settlements which attract inhabitants and from the mountainous villages but also from other parts of Crete.
In this context, the protection and development of the beaches is crucial for the development of the local economy and the attraction of inhabitants.

Illustration of policy options assumed in relation to pilot site specific characteristics

Taking in consideration the resent data on the rate of erosion and the local socio-economic stakes, it has been decided to choose the policy option 5: Limited intervention.

Figure 48. Critical Coastal Stretch of Keratokampos gulf under severe erosion

Figure 49. Sand deposits and beach nourishment zone in Keratokampos gulf

Figure 50.Beach nourishment zone in Keratokampos gulf

This policy will have three axes:

- beach nourishment in order to protect a limited length of beach (200 m) which is under erosion and where coastal property (vacation houses) is under immediate threat of erosion. Two buildings have already collapsed. This periodic beach nourishment can eventually be coupled by soft, beach stabilisation works;
- monitoring by orthophotomaps and satellite images processing. The comparison of orthophotomaps from the pilot area in an annual basis can show how the beach nourishment site is retreating and which volumes of sand is lost every year. It can also show if other beaches in the area are effected from the project or other reasons;
- exploration campaigns for off-shore deposits, so as to find adequate volumes of sand appropriate for sand nourishment.

The area has important slopes and Mean Sea Level Rise and storm events have a localised effect (narrow beach area of 10 to 50 m) without threatening the hinterland.

Coastal erosion is the most important local threat, putting at risk the beach and beach houses. The erosion is mostly due to natural phenomena. River sediment yield has been reduced only by 12%. There are no available Inland sediment sources for sand nourishment. Longshore sediment sources (dredging of the local fishermen's port and sand excavation from the beach west of the fishermen's port) are restricted. Therefore exploration campaigns for the quantification of off-shore deposits are essential for drawing a long-term plan of beach management.

This policy of limited intervention is also appropriate for other Cretan sites. For the Cretan coastline we propose:

- inventory of coastal works and private beach nourishment or sand shifting projects;
- monitoring by orthophotomaps and satellite images processing. The comparison of the orthophotomaps can show which coastal zones are under erosion and where building, road infrastructure or other vulnerable areas are under threat of erosion and submersion. This monitoring procedure can pinpoint the critical zones where protection measures are necessary;
- creation of flood hazard maps and adequately planning of the coastal zone development so as to limit future coastal flood ris;
- "Soft" erosion protection measures in the critical zones: beach nourishment, beach stabilisation, sand dunes regeneration, beach nourishment coupled with submerged structures;
- limiting the sand extraction from the rivers for construction or other uses so as to improve sediment yield of the rivers. If sediment removal is necessary in some sites, the removed sedi-

ment should be deposited downstream in the same water body;
- exploration of off-shore sediment depots.

The Cretan coastline is not fully developed yet and Crete disposes important elevated (from Mean Sea Level) hinterland that can serve for the implantation of all important infrastructure. In this stage of development, the option 5 policy "Limited intervention" can offer to Crete the occasion for:
- better future planning;
- future development more resilient to coastal flooding;
- limitation of future coastal flood risk;
- sustainable touristic development of the coastal zone.

The annual monitoring by orthophotomaps and satellite images processing is a very cost effective way for the early location of coastal zones under erosion and the application of "soft" measures.

The major long term problem to resolve, in Crete, is how to regulate the touristic development of the coastal area so as to protect the beaches, offer high quality vacation destinations and good quality of leaving for the local population.

Objectives for coastal stretches geometry arrangement

Erosion rate depends on many parameters:
- long term sediment starvation because of river sediment yield decrease;
- long term sediment starvation because of updrift barriers (ports, groynes, etc.);
- long term erosion because of long shore sediment transport (frequent storm events);
- long term erosion because of rip currents (frequent storm events);
- rapid erosion during extreme storm events;

The calculation of this erosion rate is possible by simulating long time series of wave climate on detailed mathematical or physical models of the coastline. Another way of estimating the erosion rate is by observation of the multiannual erosion.

Because of lack of data it is not possible to estimate the local rate of erosion in Keratokampos. But the erosion is so critical that recent infrastructure: buil-

Figure 51. Natural beaches in Keratokampos gulf. In front the Keratokampos-Kastri settlement the road and buildings are not permitting the creation of a natural balanced beach

Figure 52. Natural beaches West of Keratokampos settlement with average width 10 m.

Figure 53. Natural beaches East of Keratokampos settlement with width varying from 10 m to 40 m.

dings and roads build after 1970 have been totally destroyed.

The coastline of Keratokampos gulf is caracterised by important land slopes and a relatively narrow beach: 10 m to 40 m width (figures 51, 52 and 53).

From these observations we can consider that in Keratokampos gulf a 10m to 20m beach width is "normal". It offers enough space for sun bathing and protection from erosion.

For Keratokampos beach project, a 5 m width has been selected due to the scarcity of beach nourishment sediment and it will provide at least an erosion protection. For that reason, we propose annual monitoring of the beach nourishment project and annual or biannual top-up to the original 5 m width project. The beach nourishment should be extended in the future to the whole critical stretch of 1100 m.

The beach nourishment should eventually be coupled with submerged protection works.

Program of interventions, including priorities, with project preliminary indications

The selected intervention for the pilot site of Keratokampos beach is beach nourishment accompanied by beach stabilisation works. Further details of the intervention:

- beach nourishment of a coastal stretch of approximately 200 m length and 5 m width (fig. 50);
- in addition, it is proposed to stabilize the restored beach by submerged breakwater or similar technology installed parallel to the coastline at a depth of approximately 2m. In order to limit costs alternative materials should be considered such as industrially manufactured elements (pipe sections, textile tubes, pre-cast concrete elements etc.);
- required volume of sand for initial nourishment is about 11,000 m^3. The annual need for nourishment is highly dependent on the extreme wave climate, and the details of the design for beach stabilization. However, we expect that with appropriate beach stabilization, the annual need of nourishment will be much less;
- the availiable sand volumes will not be enough to cover the entire length of 1100 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 1100m long stretch;
- the beach nourishment pilot site should start from the area with the densest 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.

The estimation of Useful Sand Volume per year (7,000 m^3/y) 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.

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 Heraklion 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 above mentioned volumes are necessary. As the available sand volume is restricted, the width of the created beach will be limited to 5 m demanding 53 m^3 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 = 211.32m).

Estimation of economic resources needed

The cost of the beach nourishment project is estimated between 7 – 10 Euros/m^3, total cost of 98,000 to 140,000 Euros. The final price of the project depends greatly of the availability of a suitable dredger in the vicinity of the project, because it is a very small beach nourishment project. The lower price reflects the solution of sediment extraction by mechanical means of the nearby beach and a very inexpensive dredging of the port from a local dredging boat or a contractor that has many projects in the area. The higher price reflects to dredging of the port by a dredger that will come from another area. It has to be taken in consideration that the bi-annual dredging of the port is necessary for assuring the functionality of the port. So the extra cost for the beach nourishment is not so high.
Bi-annual re-nourishment projects of the same cost as the initial project will be necessary.
As inland and longshore sediment deposits are very restricted, a sustainable protection of the beach and further development of tourist and recreational activities necessitates the use of off-shore sand deposits. In that case, whole critical coastal stretch of 1,100 m, will be protected by the creation of a 10m width beach, necessitating 106 m^3/m. A total of 1,100 x 106 = 166,600 m^3 for beach nourishment. Considering a 20% losses during the dredging and nourishment processes 139,920 m^3 of sand dredging will be necessary.
The necessary bi-annual top-up is estimated at the half of the initial volume: 69,960 m^3.
The use of off-shore sand deposits will necessitate an exploration campaign with a cost in the order of approximately 50,000 Euros. The exploration campaign can be useful for other projects of beach nourishment.
An important cost factor, is the cost of the stabilization works (probably submerged protection works). A special study is necessary in order to define the technical characteristics of the stabilization works and their cost.

	Sand excavation from the beach and sand dredging from the port	Off-shore sand deposit
Study + EIA	60,000	60,000
Exploration campaign		50,000
Sand Nourishment (1st)	98,000-140,000 (for 11,200 m^3)	1,399,200 -2,798,400 (for 139,920 m^3)
Sand Nourishment (bi-annual)	98,000-140,000 (for 11,200 m^3)	699,600-1,399,200 (for 69,960 m^3)
Stabilization works	-	-
Annual Monitoring	2,000	2,00

Table 3. Overall cost of the beach nourishment and stabilization project

The final cost of the project will also serve as one of the important factors to assess in which cases beach nourishment projects are cost effective (how high the social economic stakes have to be).
Possible financing sources:

- EU funds;
- National funds;
- Regional funds.

The inhabitants and business owners of the Municipality of Viannos will primarily enjoy the economic and social benefits of erosion protection measures for Keratokampos. It is, therefore, reasonable and socially justifiable that at least part of the costs must be borne directly by the local community. The direct financial involvement of the local community may be done in various ways, for example through a special purpose local tax or one-off payments. Such a move will also engage more actively the local community in confronting erosion issues. Communities in Cyprus are a typical example of such co-participation where 50% of total costs for coastal protection works are borne by the local communities.

Indications on sustainable exploitation of sediments stocks

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 Component4 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.

This volume is not enough for the protection of the whole critical coastal stretch.

An exploration campaign of off-shore sand deposits and in situ investigations are 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.

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 Heraklion. The sand excavation from the beach and the port will require a permit from the Port Authority of Herakleion. 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 fishermen's 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.

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;
- the dredged material will dry-up before the beginning of the tourist period (June) and the nourished beach will be available for bathing.

The sediment deposits characteristics from the port dredging and the beach west to the port, are practically identical with sediments of beaches to be fed, because both are sediments transported by the long shore currents.

No information is available on the environmental characteristics of off-shore sediment deposits. An EIA will be necessary when the appropriate sand deposit are selected.

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 transportation of the sand will be done by trucks.

Port dredging will be accomplished by appropriate small dredgers.

The off-shore sand excavation will be accomplished by dredgers.

Small types of the below dredging ships will be adequate:

- Trailing suction hopper dredger;
- Cutter suction and suction dredger.

In all cases, for the profiling of the of the sand nourishment site 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.

Environmental restraints and methods of excavation do not influence the available volume of sand to be extracted.

Formulation of Coastal Protection and Management Plans in the Pilot Site: Ministry of Communications and Works of Cyprus

General characteristics of Cyrpus coastline

Tourism is a very important vector of Cyprus economy. In 2008, the tourist industry had more than 1.8 billions of profit with 2.4 millions of tourist and contributing the 11% of the Gross Domestic Product (GDP). Tourism employs directly more than 9% of Cyprus manpower with multiplier effects on all sectors (primary, secondary and tertiary).

Figure 54. 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)

Cyprus with approximately 770.000 inhabitants has a ratio of 3 tourists: 1 inhabitants. Cyprus has an all year around tourism but 40.7% of tourists arrive during the July-September period. These data imply that Cyprus is mostly a "Sea and sun" destination. (Data taken from the National strategy for Sustainable Development, April 2008, source: Cyprus Tourism Organization).

In the light of these data, it is obvious that Cyprus' coastline is a substantial source of income and a pillar for Cyprus' economy.

Cyprus' beaches are currently facing three severe threats:

1. erosion from natural phenomena and sea level rise;
2. sediment starvation and consequent erosion from the construction of dams;
3. erosion and "artificialisation" from numerous individual coastal projects that are promoted from hotel owners for the improvement of the beach locally without taking in consideration the rest of the coastal stretch.

Cyprus' authorities are aware of these problems and have launched studies and works in order to improve this situation.

The first effort to implement ICZM in Cyprus was through the project "Coastal Zone Management of Cyprus". The project was co-founded by European Union, through the MEDSPA Program and the Government of Cyprus. The project was carried out by Delft Hydraulics, supported by the staff of the Coastal Unit of the Public Works Department. (Project duration: 1993-1996).

The main objective of this study, was primarily to find proper methods to protect the coastline and improve the quality of the beach where necessary without any serious consequences for the environment.

During this study a moratorium was established on coastal works. Since the completion of the Master Plan all coastal works need to be aligned with the existing Integrated Coastal Zone Management in order to be licensed.

The project "Coastal Zone Management of Cyprus" divided all Cyprus coast (area under Turkish occupation is not included) in 12 sedimentary cells (fig. 54). In each sediment, fixed landmarks were positioned as measuring stations (a measuring station was positioned every 500m – 800m and at important points ex. capes, river mouths etc.). Every measuring station was coded with a letter with reference to the sedimentary cell, and a number: ex. in sedimentary cell 1 measuring stations are numbered from A1 to A50, to sedimentary cell 2 measuring stations B1 to B40 etc. In these measuring stations reference data were collected periodically: beach and sea bed profiles, sediment samples, photos etc.

Six 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:

Figure 55. A part of the Limassol waterfront on January 2003 (from GoogleEarth). The individual groynes interrupt the seafront.

- for Larnaka, Limessol 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.

A good example of this policy is the Limassol water front renewal project (fig. 55 and 56). The public authorities demolished the existing groynes and constructed detached breakwaters for uniform linear beach protection. A public "promenade" was also constructed along the shoreline. The whole project improved greatly the Limassol waterfront.

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.

Figure 56. The same part of the Limassol waterfront on July 2008 (from GoogleEarth). The individual groynes have been replaced by detached breakwaters.

Because of the water scarcity and uneven rainfall distribution (long dry periods) the water policy of Cyprus, from the 60' was "No drop of water to be lost at sea". This policy led to the construction of a total of 108 dams (56 of them of them more than 15 m high) of a total of 331,933,000 m^3 of stora-

Figure 57. Map of the dams in Cyprus (Source: Water Development Department of Cyprus)

ge capacity. It is noted that Cyprus has the largest number of dams per area in Europe. Dams play a very important role in the Cyprus economy. The majority of the large dams are located close to the river deltas in order to maximize the size of the catchment area and hence maximize the potential quantity of stored water and in the same time they minimize the sediment transport towards the sea. The Koronida project proposed pre-reservoirs for the sediment capturing up-steam of the main dam and the use of the suitable sediment for beach nourishment.

Selection of pilot site

Taking in consideration the above studies and works, the criteria for selecting the Cyprus' Coastance pilot site were the following:

- select a site that faces severe erosion;
- select a site that has already been characterized as critical in the project "Coastal Zone Management of Cyprus"(1993-1996, Delft Hydraulics);
- select a site were no costal works are under study or construction;
- select a site with "low" social pressure, mainly seafront development, so as to minimise the disturbance of future pilot works;
- select a site with "high" tourist potential, so that pilot works can contribute to the future development of the site and serve as an example to other sites.

The selected pilot site fulfilled all these criteria.

Characteristics of the pilot site

For the Coastance project a coastal stretch of sedimentary cell No 9 at Zigi - Kiti was selected.

Tourism has only recently started in this sedimentary cell, and is spreading from the Kiti area (Perivolia) along the coast in western direction. The industry is concentrated in the westernmost embayment, with the Vasilikos cement and fertilizer plants, including local harbor facilities covering several km of coastline.

The south/southeastward facing sedimentary cell 9 of Zygi-Kiti stretches over some 36 km between Cape Dolos in the west and Cape Kiti in the east (fig. 58). The coast is gently sloping agricultural land generally relative low and flat, largely consisting of the elevated marine sedimentary terraces or "raised beaches" containing sand and gravel deposits, with eroding appearance, lined with a narrow beach of mainly gravel and some sand. The coastline forms a continuous chain of five, each 5 to 10 km long, shallow bights separated by slightly protruding points which are either rocky headlands or gravel deltas.

The bathymetry shows a gentle slope from the coastline to approximately the 20 m depth contour. The distance between the coastline and the 20 m depth contour is about 1,600 m indicating a fairly gentle overall slope of approximately 1:80. Slightly over -20 m a steeper drop occurs to a depth over 500 m.

Figure 58. Satellite photo of sedimentary cell 9 Zygi-Kiti (GoogleEarth)

The selected coastal stretch has a very rapid erosion rate (approximately 23 m maximum beach erosion comparing orthophotos of 1973-2003). The inland area, in most places is elevated (on terrace) from the sea level, consisting mostly of soft soil and igneous sedimentary pebbles. The erosion of these earth cliffs is leaving behind a narrow strip of pebbly beach. At the east of the same sedimentary cell, there is a hotel with detached breakwaters and a small marina. These coastal works have now created a sufficient beach for the hotel use and the hotel manager is practicing sand shifting every year, in order to keep the marina's accessibility.

The sedimentary cell is exposed to waves between east and south-west. In all other directions the fetches are limited by the coast of Cyprus. The most frequent waves are observed from southwesterly directions. However, during winter eastern waves occur more frequently. The highest waves come from the south-south-west.

From the existing coastal works and long term measuring campaigns of the Coastal Unit, it is documented that the dominant longshore sediment transport has an eastward direction (from the west to the east) as shown in figure 59.

Five medium size rivers debouche into the sea, from west to east:

- Vasilikos (damned in 1981 and 1985);
- Potamos tou Ayiou Mina or Maroni;
- Pendashkinos (damned in 1973 and 1985);
- Pouzis;
- Tremithos (dammed in 1964 and 1977).

Only two rivers are not dammed. The total storage capacity of the dams affecting Sedimentary Cell no 9 is 48,435,000. In the course of the Coastance project, the percentage of catchment areas that

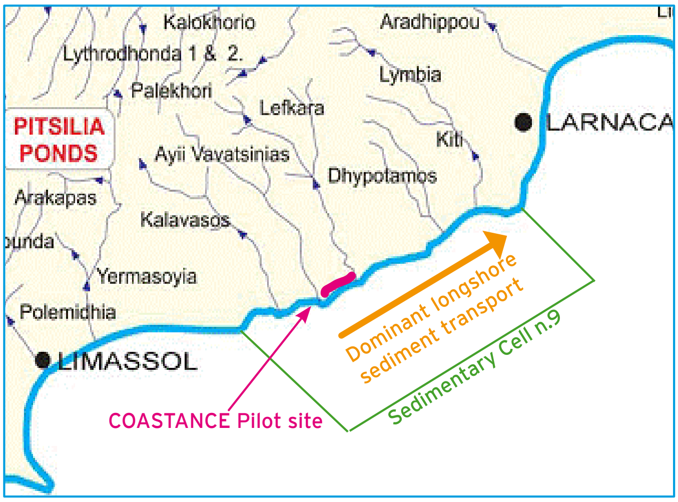


Figure 59. Dams affecting the sedimentary cell 9 Zygi-Kiti (Source: Water Development Department of Cyprus)

Figure 60. Map of the major water works affecting the Zygi-Kiti sedimentary cell (Source: Water Development Departement of Cyprus). In Green the irrigated zones.

A/A	NAME	YEAR	RIVER	TYPE	HEIGHT (m)	CAPACITY (m^3)
1	Kiti	1964	Tremithos	Earthfill	22	1,614,000
2	Lefkara	1973	Syrgatis (Pentaschoinos)	Earth/Rockfill	71	13,850,000
3	Lympia (new)	1977	Tremithos	Gravity	12	220,000
4	Agioi Vavatsinias No1	1980	Off - stream	Earthfill	17	55,000
5	Agioi Vavatsinias	1981	Vasilikos	Arch	19	53,000
6	Agioi Vavatsinias No2	1984	Off - stream	Earthfill	25	43,000
7	Kalavasos	1985	Vasilikos	Rockfill	60	17,100,000
8	Dipotamos	1985	Pentaschoinos	Rockfill	60	15,500,000
					Total	48,435,000

Table 1. List of dams affecting the sedimentary cell 9 Zygi-Kiti (Source: Water Development Department of Cyprus)

have been dammed and the percentage of solid sediment transport that has been cut off, at the scale of sedimentary cell No 9, will be assessed specifically for the rivers/torrents that affect the pilot site in sedimentary cell No 9 (table 1).
The measuring stations installed up-stream and downstream of the dams show that practically all water and sediment flow is stopped from reaching the sea. The water is used for drinking water supply in Larnaka and for irrigation.

Sedimentary sub-cells

The sedimentary cell 9 has been divided in 3 sub cells (9.1, 9.2, 9.3) under the study of NTUA 2000-2003 (fig. 61).
Each sub cell has been also divided in homogenous coastal stretches. The division was based on field measurements taken by the Coastal unit (Public Works Departement PWD) and also from comparison of aerial photos of 1973-1993-2003.
The following figures show the sub cell division and the location of the Coastance pilot site.

Figure 61. Division of Sedimentary cell 9 Zygi-Kiti in sub cells

Sedimentary sub-cell 9.1

Sedimentary sub cell 9.1 (fig. 62) lies between Cape Dolos (west) and Cape Vasiliko (east). In the first part of the sedimentary cell (from west to east) there are high elevated marine sedimentary terraces or

Figure 62. Satellite Photo(Google Earth) of sub cell 9.1

"raised beaches" containing sand and gravel deposits which are under severe erosion. The Governors beach, lies east and it does not present erosion problems. The largest part of this sub-cell consists of industrial and portuary installations (power plant and cement factory).

Sedimentary sub-cell 9.2

Sedimentary sub cell 9.2 is lies between Cape Vasiliko and the Cape west of Alaminos tourist Resort. It is divided in three coastal stretches (fig. 63):

Figure 63.Satellite photo (Google Earth) of the sedimentary sub cell 9.2 and its coastal stretches.

- coastal stretch 9.2.1, is situated between Cape Vasiliko and the outflow of Maroni river. It is an area with strong human interventions, severe erosion and lack of fine sediment. The fishermen's shelter of Zigi and a small ship yard lie in this coastal stretch.

- coastal stretch 9.2.2 (fig. 64), is situated between the outflow of Maroni river and Pentashinos river. The coastal stretch has elevated marine sedimentary terraces or “raised beaches” containing sand and gravel deposits which are under severe erosion. Some farmers and house owners have constructed rock revetments and small groynes to protect their land. The local road is threatened by erosion as well.

Figure 64. Orthophotomap of the sedimentary sub-cell 9.2.2. Evolution of the coastline, Yellow line: 1973 coastline. Red line: 1993 coastline. Green line: 2003 coastline. (Public Works Department of Cyprus)

- Coastal stretch 9.2.3 (fig. 68), where the Coastance pilot site lies, is positioned between Pentashinos river outflow in the west and the Cape west of the Alaminos hotel resort in the east. The coastal stretch has elevated marine sedimentary terraces or “raised beaches” containing sand and gravel deposits which are under severe erosion. Some house owners, on the west

Figure 65. Sub-cell 9.2.2. Zoom on the area where the road is threatened by erosion (37m coastline retreat from 1973 to 2003). The rate of coastal erosion after 1993 seems to be slower.Green line: 2003 coastline. (Public Works Department of Cyprus)

Figure 66. Satellite photo (Google Earth) of the sedimentary sub-cell 9.2.3.

Figure 67. Orthophotomap of the Coastance pilot site. Zoom on the area with maximum documented erosion. Evolution of the coastline, Yellow line: 1973 coastline. Red line: 1993 coastline. Green line: 2003 coastline. (Source: Public Works Department of Cyprus (PWD)). The rate of coastal erosion after 1993 seems to be slower.

part of the coastal stretch have constructed small piers and rock revetment to protect their properties. The Coastance pilot site chosen is the stretch between these works and the first cape. This coastal stretch in mainly agricultural land and the maximum documented erosion from 1973 to 2003 is 23 m (fig. 67).

Sedimentary sub-cell 9.3

Figure 68. Satellite photo (Google Earth) of the sedimentary sub-cell 9.3.

Sedimentary sub-cell 9.3 (fig. 68) is positioned between the Cape west of Alaminos hotel resort and Cape Petounta. This sedimentary sub-cell is strongly influenced by the coastal works of the Hotel resort (fig. 69): four detached breakwaters and a small marina. East of the hotel resort there are steep rocky cliffs till Cape Petounda, that are not subject to erosion.

The 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 offshore, 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 (fig. 70). 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 PWD Coastal Unit in order to preserve

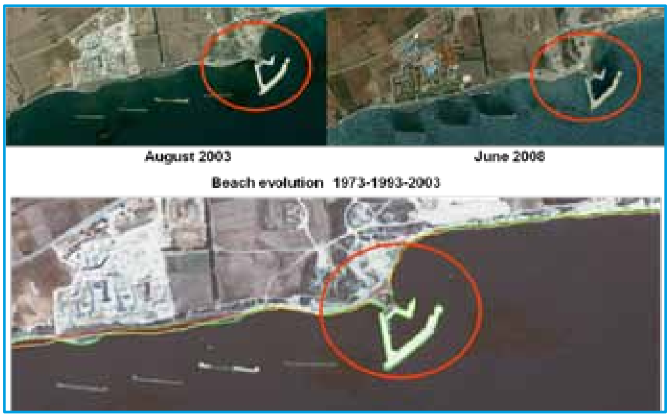


Figure 69. Satellite photos (Google Earth) and Orthophotomap (PWD) of the Alaminos hotel resort showing the sand accumulation. Evolution of the coastline, Yellow line: 1973 coastline. Red line: 1993 coastline. Green line: 2003 coastline

Figure 70. 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.

the access to the marina.
The Coastal Unit is planning to reach to an agreement with the local authorities and other governmental Departments so as to remove on a yearly basis the excess of sand and use it for sand nourishment in the Coastance pilot site.

Sedimentary sub-cell 9.4

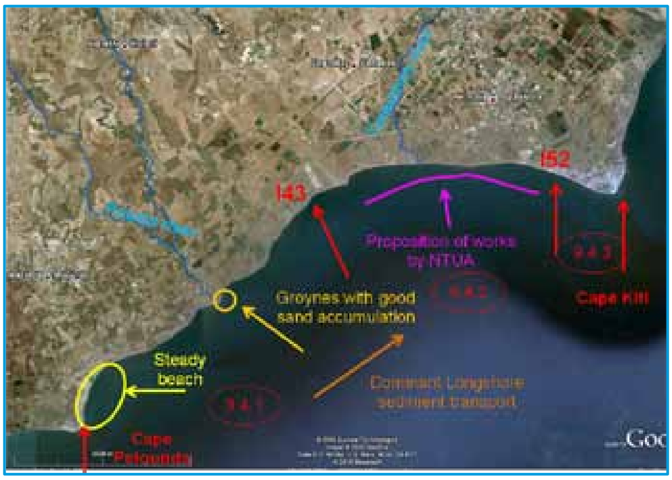


Figure 71. Satellite photo (Google Earth) of the sedimentary sub-cell 9.4 and its coastal stretches

Figure 72. Satellite photo (Google Earth) of the sedimentary cell 9.4, zoom on the groynes

Sedimentary sub cell 9.4 (fig. 71 and 72) is positioned between Cape Petounta and Cape Kiti.
It is divided in two coastal stretches.

- coastal stretch 9.4.1 which is situated between Cape Petounta at the west and measuring station I43 (PWD) at the east. In this area, from west to the east, are situated a sandy beach with satisfactory sediment balance, an area with erosion, and areas with groynes that cumulate sediment;
- coastal stretch 9.4.2 which is situated between measuring station I43 (PWD) at the west and measuring station I52 (PWD) at the east.In this area there are some beaches with good sediment quality but most of the coast is under erosion. The NTUA 2000-2003 study has proposed hard structures for the protection of this coastal stretch (groynes/ detached breakwaters). The works are planned to commence soon;
- coastal stretch 9.4.3.which is situated between measuring station I52 (PWD) on the west and Cape Kiti on the east where no coastal works are needed.

Critical coastal sub-cells and areas exposed at risk by erosion and submersion

In the NTUA study of 2000-2003, the cell 9 and its sub-cells were categorized according to the erosion problems, beach quality and existing works (table 2).

Sub cell	Coastal stretch	L (Km)	Description	Erosion	Necessity of works Priority
9.1	9.1.1	1		Yes	No
9.1	9.1.2	5	Power Plant Ciment	No	No
9.2	9.2.1	4.8		Yes	Second Priority
9.2	9.2.2	4.6		Yes	Second Priority
9.2	9.2.3	6.2	Coastance pilot site	Yes	Second Priority
9.3	9.3	2.5	Alaminos hotel resort	No	No
9.4	9.4.1	6.5		Yes	Third Priority
9.4	9.4.2	4.5		Yes	First Priority
9.4	9.4.3	1.3		No	No

Table 2: General description of coastal stretches of sedimentary cell 9.

Beach sediment characterization (Results taken from Coastal Zone Management for Cyprus, Delft hydraulics, 1993-1996, Phase II Final Report)

In the sedimentary cell 9, the coastal zone is often rocky, characterized by accumulations of pebble and gravels with few tiny and poor sandy beaches. The material accumulated at these beaches originates either from nearby rocks or from the inland bedrock (igneous-extrusives and sedimentary). The elevated marine terraces are composed of conglomerate with well rounded pebbles, mostly of igneous origin.
Five main rivers which originate in the easternmost part of the Troodos Massif and which cut mainly through the extrusives/lavas (with the exception of the Vasilikos river which originates in the Limassol Forest), are reaching these shores. These rivers introduce sediments to the beaches with high percentages of pebbles of igneous origin.
The sediment samples of the area have a characteristic grey colour while the shape of the pebbles and grains range from well rounded to subangular. The igneous rocks represent the main component of the beach gravels with their percentages ranging from 50% to 79%. The main rock types represented on the beach are diabase, lava (basalt), plagiogranite and gabbro. The sedimentary rocks, mainly chalk, silicified chalk and chert represent up to 20% of the beach material. About 50% of the sand grains studied under the microscope were identified as igneous rocks and 10% as sedimentary rocks. Bioclastics were also observed (less than 5%). The weathering resistant minerals are mainly pyroxene, quartz, jasperm chalcedony, plagioclase and some magnetite, representing 35% of the sample.
In table 3 are presented the more recent results of

sediment sampling in sedimentary cell No 9 Zygi-Kiti. The results of D_{50} correspond to the samples taken at +/-0.00 level, as samples from different depths are taken in each measuring position.

A/A	Sampling Position	D_{50} (mm)
1	I8	0.42
2	I10	16.00
3	I13	18.00
4	I15	26.00
5	I17	20.00
6	I20	20.00
7	I23	28.00
8	I28	27.80

Table 3: Results of sediment sampling period summer 2000 for the sedimentary cell 9 (Source: Coastal Unit PWD).

Socio-economic characteristics of the pilot site

The selected pilot site has today relatively “low” socio-economic stakes.

- the main highways connecting Larnaka to Limessol (A5) and Nicosia to Limessol (A1) are positioned far away from the coast;
- the other roads including the coastal road are of local importance;
- coastal property threatened by erosion is mainly agricultural land with few greenhouses;
- the existing villages, Agioi Theodoroi and Alaminos, near the pilot site, are small communities (approximately 300 inhabitants each) with social infrastructure of local importance: community center, elementary school, etc and are positioned in a distance from the coastline and are not threatened by erosion and submersion;
- there are some tourist developments (hotels and tourist villas) in the area. The tourist developments positioned on the coastline have built their private coastal protection works.

But in the future the pilot site and the entire sediment cell 9 Kiti - Zygi will face “high” socio-economic stakes:

- the coastal area of Kiti-Zygi is well positioned between the coastal cities of Larnaka and Limessol which both attract many tourists;
- the coastal area of Kiti-Zygi is easily accessible by the highways A1 and A5 from Nicosia, Limessol and Larnaka and close positioned to the airport of Larnaka;
- in the coastal zone and the hinterland there are relatively flat zones of agricultural land (large properties) ideal for tourist development;
- it is permitted, by the planning authorities, to build large hotels, vacation resorts and grouped vacation villas is this coastal area.

The permitted land uses in the pilot site are the followings (fig. 73):

- seasonal Residence: the building coefficient is 0.15, the cover rate is 0.15, the no of floors 2 and the building height 8.30 meters;

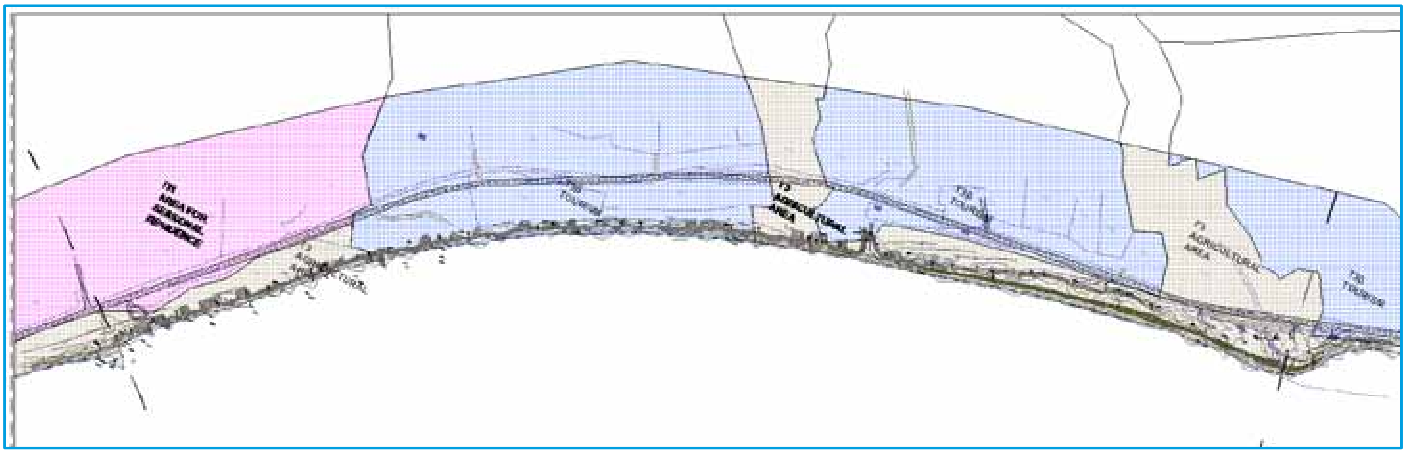


Figure 73. Permitted land use in the pilot site.

- tourism zone: for hotels the building coefficient is 0.30, the cover rate is 0.20, the no of floors 3 and the building height 13.10 meters, whereas for tourist villages/tourist installations the building coefficient is 0.25, the cover rate is 0.20, the no of floors 2 and the building height 8.30 meters;
- agriculture zone: the building coefficient and cover rate is 0.10 no of floors 2 and building height 8.30 meters.

Therefore it is expected that in the following years more hotels and tourist resorts will be developed in this coastal zone. Due to the rapid erosion, coastal property owners will demand for coastal protection works or they will build private coastal works. In this context the pilot site project will facilitate the future tourist development of the area and serve as an example for other areas with similar problems.

Illustration of policy options assumed in relation to site specific characteristics

Taking in consideration the recent data on the rate of erosion and the socio-economic stakes, it has been decided to choose the policy option 5: Limited intervention.
This policy will have four axes:

- beach nourishment in order to protect the total length of the pilot site (1,600 m). The beach nourishment will create at least a 10m wide beach which will function as a "buffer" zone for the wave energy and will stop the erosion of the elevated terraces (earth cliffs). The numerical modelling showed that the new beach sediment should coarser than the existing sand sediment (D_{50}=0.12 mm). Beach stability can be accomplished with sediment of D_{50}>40 mm. Experience from other projects in Cyprus showed that beach nourishment with mixed material sand + pebbles offers better beach stability. As the local sediment from Alaminos resort is not enough to cover the whole pilot site, other sources of sediment (sand and pebbles) should be found;
- beach protection works coupled with beach nourishment. The quality and volume of the sand necessary for beach nourishment in combination with the strong wave action in the area, makes simple beach nourishment projects non viable. Beach nourishment project, in many cases, have to be coupled with other coastal protection works as groynes and submerged breakwaters;
- combined monitoring by orthophotomaps and satellite images processing and in situ Topographic surveys. The annual monitoring of the pilot area in an annual basis can show how the beach nourishment site is retreating and which volumes of sand is lost every year. It can also show if other beaches in the area are affected from the project or other reasons;
- long term management of the coastal area based on erosion rates and the cost of coastal protection works. Beach nourishment and beach stabilisation works are rather expensive for protecting the whole area. Individual private works will fragment the beach aesthetically and will create inaccessible "private" beaches. A local midterm to long-term "Coastal Zone Management Plan" is necessary for the Kiti-Zigi area in order to define which zones will be protected and how these zones will serve for the promotion of tourism in the greater area. This "Coastal Zone Management Plan" should include information on:

1. which zones they will be protected and at which cost (initial investment cost and annual maintenance cost);
2. the source and the cost of the necessary sediment;
3. relocation where necessary of the coastal road, so as to be protected from future erosion and future creation of parking lots and vertical pedestrian path-ways for easy access to the protected beach;
4. possible creation of pedestrian path-ways along the beach;
5. definition of zones where private or public "bathers facilities" could be created (showers, WC, beach bars etc.);
6. definition of zones with high erosion risk,

and no coastal works, where no building and infrastructure should be build;

7. possible “beach rent” to be paid by the property owners who will benefit from the coastal protection works.

This policy of limited intervention coupled with a long term “Coastal Zone Management Plan” will prevent the need of a more costly and environmentally brutal policy of “Hold the line” in the future.

Objectives for coastal stretches geometry arrangement

Erosion rate depends on many parameters:

- long term sediment starvation because of river sediment yield decrease;
- long term sediment starvation because of updrift barriers (ports, groynes, etc.);
- long term erosion because of long shore sediment transport (frequent storm events);
- long term erosion because of rip currents (frequent storm events);
- rapid erosion during extreme storm events.

The calculation of this erosion rate is possible by simulating long time series of wave climate on detailed mathematical or physical models of the coastline.

Figure 74. Aspect of the Coastance pilot site. Photo taken towards the east. The picture shows the erosion of the elevated “terraces” and the eroding earth cliffs.

Another way of estimating the erosion rate is by observation of the multiannual erosion. In the case of our pilot site during the time period 1973-2003 a 23m maximum erosion was documented.

The pilot site is constituted of elevated terraces (fig. 74). These earth cliffs are eroding, leaving behind a very narrow pebbly beach. This narrow beach width varies from 20 m (near the outlets of a local stream) to 5 m in the summer and during winter storm events the waves reach the horizontal cliffs (fig. 75). If no auxiliary wave protection works are foreseeing, at least a 10 m wide beach is necessary for the protection of the elevated terraces.

The protected areas, in the lee of coastal works, accumulate a fine sand of approximately D_{50}=0.12 mm. The beach nourishment will be partly done with this material. Numerical modeling shown that

Figure 75. Aspect of the Coastance pilot site. Photo taken towards the west from a narrow pebbly beach strip. The picture shows the erosion of the elevated “terraces” and the eroding earth cliffs which also contain pebbles. The fine sandy material is absent.

a coarser sediment with D_{50}> 40 mm is necessary in order to create a stable beach profile.

Program of interventions, including priorities, with project preliminary indications

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.
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 m³ per year.

Figure 76. 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.

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.
For the creation of a stable profile 10m wide, with D_{50} > 40 mm approximately 65 m³/m will be necessary. In total, 104,000 m³ for the nourishment of 1,600 m of beach. This volume will be partly constituted by the fine sediment of Alaminos resort (D_{50}=0.12 mm, approximately 3,600 m³ per year) and in greater part form coarser material from other sources.
Further studies are necessary in order to locate sufficient and compatible inland or off shore sediment deposits.
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.
Other, "opportunistic" sources of sediment can be used as well: sediment accumulation from other coastal works, sediment extraction from new coastal works (groynes and port construction) etc.
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 used for beach nourishment in the critical coastal stretch.
After the first beach nourishment campaign, monitoring will be necessary so as to measure the erosion rate.
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.

Estimation of economic resources needed

The cost of the beach nourishment project is estimated between 7-20 Euros/m³, total cost of 728,000 to 2,080,000 Euros (for 104,000 m³). The final price of the project depends greatly on the availability of a suitable machinery in the vicinity of the project, be-

cause it is a very small beach nourishment project. The lower price reflects the solution of sediment extraction by mechanical means of the nearby beach of Alaminos Hotel resort. The higher price reflects to dredging with a dredger boat from Alaminos hotel or off-shore deposits by a dredger that will come from another area.
Addition, annual re-nourishment projects of 3,600 m^3 will cost 25,200 to 72,000 Euros.
The use of off-shore deposits will necessitate an exploration campaign with a cost in the order of approximately 50,000 Euros. The exploration campaign can be useful for other projects of beach nourishment.
An additional study is necessary, in order to determine the most appropriate beach stabilization works and have an estimation of their cost. The cost of the stabilization works will have to be added to the total cost of the project.

	Alaminos Hotel Resort Accumulation	Off-shore deposit
Study + EIA	60,000	60,000
Exploration campaign		50,000
Sand Nourishment (1st)	25,200-72,000 (for 3,600 m^3)	728,000 – 2,080,000 (for 104,000 m^3)
Sand Nourishment (annual)	25,200-72,000 (for 3,600 m^3)	25,200-72,000 (for 3,600 m^3)
Stabilization works	-	-
Annual Monitoring	2,000	2,000

Table 4: Overall cost of the beach nourishment and stabilization project

The experience from this project will be used for the protection of other Cyprus critical coastal stretches. Off-shore deposits will be necessary for the larger scale projects.
A long-term coastal protection plan including beach nourishment of several coastal stretches can reduce the costs as the appropriate dredger will be used in Cyprus for several sites.
Possible financing sources:

- EU funds;
- National funds;
- Regional funds (Districts);
- Municipal funds.

Coastal projects in Cyprus are typically funded 50% by the local municipality or District and 50% by National funds.

Indications on sustainable exploitation of sediments stocks

As analysed in section previously the sand that can be removed from Alaminos Hotel Resort on annual basis is about 4,500 m^3. Alaminos Hotel Resort is a renewable sand deposit. This volume is insufficient for large scale beach nourishment projects.
Off-shore deposits should be located in order to able to plan a mid to long term beach nourishment plan for the pilot site (1,600 m coastal stretch) and other sites with erosion problems.
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 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.
State Legislation clearly stipulates which projects require Environmental Impact study, according to the type of the works and the importance of the works.
The Coastance pilot site is not included in the Natura 2000 protected zones.

The excavated sediment from Alaminos Hotel Resort will not demand any treatment. The local wave climate will induce a natural selection of the appropriate sediment side. The sand deposit has sand of similar characteristics to the beach nourishment site.
The littoral sand excavation will be accomplished with traditional excavation machinery:

- Front shovels;
- Hydraulic excavators;
- Long Reach Excavation Loaders;
- Track loaders;
- Compact Track Loaders.

The transportation of the sand will be done by trucks.
The off-shore sand excavation will be accomplished by dredgers.
Small types of the below dredging ships will be adequate:

- Trailing suction hopper dredger;
- Cutter suction and suction dredger;

In both cases, for the profiling of the of the sand nourishment site 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.
Environmental restraints and methods of excavation do not influence the available volume of sand to be extracted.

Indications for possible upgrading of policies and interventions for river solid transport enhancement and subsidence mitigation

Important irrigation works, supplied by dams and desalination works have reduced the rate of pumping from the aquifer.
Cyprus government stopped the excavation of sand and gravel from river beds in 1970, in order to stop the erosion. The material removed from rivers was used in the construction industry.
In the study, “SUSTAINABLE MANAGEMENT OF SEDIMENTS TRANSPORTED BY STORM WATER AND TRAPPED IN DAMS IN CYPRUS”) research project realized by Koronida Research and Development Centre Ltd, funded by the Cyprus Research Promotion Foundation in 2007, the problem of sediment starvation of the beaches was studied in detail. The PWD Coastal Unit participated in this project
Because of the water scarcity and uneven rainfall distribution (long dry periods) the water policy of Cyprus, from the 60’ was “No drop of water to be lost at sea”. This policy led to the construction of a total of 108 dams (56 of them of them more than 15 m high) with a total of 331,933,000 m^3 of storage capacity.
The majority of the large dams are located close to the river deltas in order to maximize the size of the catchment area and hence maximize the potential quantity of stored water and in the same time they minimize the sediment transport towards the sea.
The trapping of sediments in the reservoirs reduces the storage capacity of the dam and arrests the sediment supply to the river mouth/delta. This starvation of sediment supply to the coastal environment results in the termination of the development of the river delta. Depending on the coastal hydrodynamics, recess of the delta and erosion of the coastline is initiated. This problem is acute in Cyprus, where almost all rivers have been dammed and erosion of the beaches is experienced in numerous areas.
During the Koronida project measurements were taken in important Cyprus dams so as to determine the volumes of trapped sediments. Data were also collected of specific catchment areas and the downstream coastline, showing the erosion effects after the construction of dams.
Some of the results of this project are the following:

- Cyprus dams are over dimensioned. Dams dimensioning was based on long series of historic rainfall data (prior to 1980) and recent rainfall (after the 90ies) is more scarce. The result is that water demand has not been met and large part of the “usefull volume” of the dams remains empty all year;
- in some catchment areas more than one dams have been build and in most cases no water

(and no sediment) practically reaches sea;
- most of the water of the dams (around 80%) is used for agriculture;
- the sediment volume trapped in dams does not reach the coast, causing beach erosion;
- because of Cyprus dams operational patern (practically no outflow), it is not feasible to practice “flushing” techniques for sediment removal.

Because of Cyprus morphology, it is very expensive to build small sediment traps or check dams.

The project proposed pre-reservoirs for the capture of sediment up-stream the dams and use of this sediment for beach nourishment.

A proposal has been developed in this research program which addresses holistically the problems of sediment management and water quality. This proposal is, in summary, a small dam, called pre-reservoir with the following characteristics (fig. 77):
- it is constructed in the entrance of the existing dam reservoir (no land reclamation is necessary);
- storm water is temporarily stored;
- the water quality is checked after the storm:
    1. if the quality is acceptable, then the water is allowed to enter the reservoir through a pipeline
    2. if it is not acceptable, then the appropriate measures are taken (e.g. collection and treatment, diversion downstream)
- The sediments are collected and their quality is tested:
    1. if their quality is acceptable, sieving takes place and suitable material is transported and deposited at the river mouth/ beach.
    2. if their quality is not acceptable, then suitable measures are taken (e.g. treatment, burial etc).

The cost of this proposal is very low compared to the benefit achieved. In particular, the design of a pre-reservoir as a pilot project for the Evretou Dam was carried out:
- the initial/ capital cost is estimated to be of the order of 450,000 Euros (very small percentage of the cost of the dam);
- the annual cost of evacuating the sediment is 5 Euros/m^3 (small amount compared to the evacuation using dredging);
- the annual cost of selection of sediments and transportation to the beach is 10 Euros/m^3 (reasonable cost/no alternative source);
- the cost of mitigating of accidents depends on the pollutants.

At policy level it is proposed:
- to replace the existing policy of “No drop of water to be lost at sea” with “No drop of water to be lost”;
- to adopt the policy of taking measures to:
    1. ensure that water of acceptable quality enters the reservoirs;
    2. collect, select and transport suitable sediments from the reservoirs to the beach;
    3. maintain the storage capacity of the reservoirs.

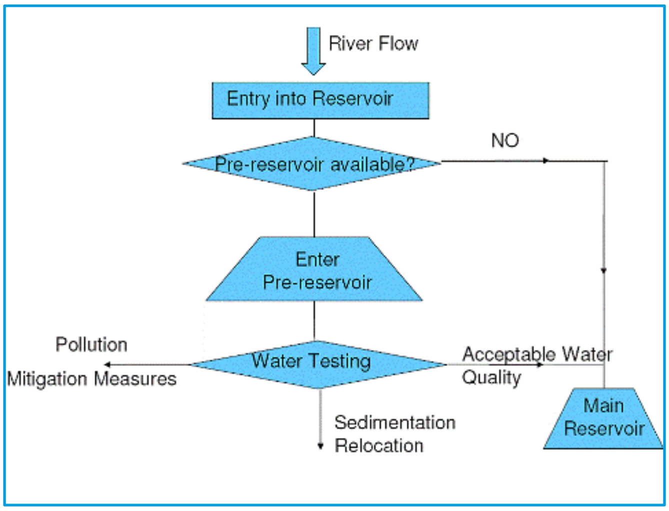


Figure 77. Schematic of a Pre-reservoir constructed up-stream a dam for trapping heavy sediments

Formulation of Coastal Protection and Management Plans: Département de l'Hérault

Actual state-of-the-art of coastal zone and critical stretches

The Languedoc-Roussillon coastline is 200 Km long and extends from the western side of the Rhone Delta up to the border with Spain. The coast is mainly sandy. This coastline is subdivided into sections by a sequence of rocky promontories such as the Mount Saint-Clair a Sète, the Cap d'Agde, the Cap Leucate and the Vermeille Coast, in southern Roussillon.
The Languedoc- Roussillon coast is composed of river deposits from the orogenic process which took place in the Pyrenees during the Tertiary Era. The formation process then continued into the Cenozoic Era with the latest glaciations and the rise in sea level which generated the transport and deposit of sedimentary material from the continental shelf. This evolution created the littoral bar (lido), which currently separates the sea from a number of saltwater lagoons and wetlands covering the higher land within the coastal valley.
Up until 1950 the Languedoc-Roussillon coastline was mainly left to its natural state. Construction work was mainly limited to hunting grounds and small fishing villages which were often built inland. With the exception of the city of Sète the coast was therefore in a very natural state. As a consequence of the Racine Mission in the 60s the main centre of human activity for the Hérault department moved to the coast from its previous location inland. It has become a trade, production and innovation centre whose development requires continuous focus, especially with regards to urban planning, tourist trade, environmental protection and social services. It also requires a balanced approach which can, over time, ensure that any changes made do not affect the local habitat.
A number of port structures were built in order to accommodate the leisure boat sector which had been included by the Racine mission as part of the coastal development plan. This infrastructure caused the coast to be divided into relatively independent sections, i.e. sedimentary cells. These works heavily affect longitudinal sand drift and cause severe erosion at a local level. Additionally the planning of sandbars (e.g. La Grande Motte) has deprived the system of considerable volumes of sand. At the same time the decrease in river sedimentation has intensified. Coastal erosion currently negatively affects the entire Gulf of Lion and is due to a number of negative factors.
A methodological study was carried out at a regional level to define Coastal Management Strategic Guidelines. In June 2003 the Department of Hérault approved the general guidelines contained in the Sustainable Development Charter and has committed, as proposed by the Interministerial Mission for the Planning of the Languedoc-Roussillon coastline, to take part in the implementation of the Plan for the Sustainable Development of the Coastline. This plan, based on the Guidelines mentioned above, forms a baseline for research into coastal protective and developmental measures. The objective is to set the groundwork for future coastal management practices by creating a development plan.
The aim of this strategic research project in Languedoc- Roussillon has been to look at managing issues at a global level and no longer at a local one. These studies have basically analysed the way coastline erosion is managed. However the project also focused on other factors (socio-economic, landscape, environment) in order to gain an accurate picture of the effect of natural threats and quantify the issues that need to be resolved. This is the only way in which coastal management can be implemented effectively, that is by following an integrated coastal zone management approach.
The heavy structures built along the flat and sandy Gulf of Lion coastline can no longer protect the beaches and fight natural phenomena, such as erosion and flooding, alone.
Several experts believe that the solution for the 21st Century is to make use of "artificial sand nou-

rishment" procedures in order to wait the possibility to organize a global strategic retreat of the human influence on the coast and the socio-economical stakes.

Illustration of policy options assumed in relation to site specific characteristics

In the long term, an approach which favours strategic withdrawal coupled with restoring the natural transport of sediments is the only durable solution that can be envisaged. As of now, this is the goal we need to strive for, even if it is true that it will not be achieved for several decades.
As a transitional initiative, until these approaches are put into action, it is necessary to ensure that the economic activity linked to beaches is maintained via the 'soft' management of sediments; beach nourishment and reinforcement and protection of dune belts. This means methods which have indirect advantages or zero effect on the environment and the coastline transporting sediments downstream.
The transitional phase concerning the management of erosion via soft methods can only be envisaged as part of a well thought-out and structured global process for the development of the coastline on the scale of the Gulf of Lion. The notion of sustainable financing of action taken is key to the success of the new coastal order.
During the transitional phase, the value of coastal socio-economic issues should not be increased. This would make strategic withdrawal even more difficult. Investments of this kind should therefore be stopped or completely depreciated when the plan for withdrawal is implemented. The same goes for the regulatory frameworks relating to flooding and PAPI-type (Programme d'Action pour la Prévention des Inondations, French flood prevention programme) flooding, which should be extended to take into consideration the risk of erosion.
Finally, the position and promotion of the environment and natural processes should be better integrated into the study and should be monetised in order to have a common interest with anthropogenic developments.

Positioning of the sediments management plan as a policy option used for Herault sedimentary cells.

The sediments management plan should be viewed as a technical tool designed to aid coastal development.
Coastal development itself will only be able to feel the benefits of a global strategy after several years. This strategy should allow for the development of a complete diagnosis of the coast, should take into account a number of issues and constraints, like the rising sea level, and should carry out a complex prospective exercise that will lead to the creation of a plan of action with multiple phases.One of these will no doubt be a new sediments management plan.
Between now and then, it has been suggested that developments be made without waiting for an initial sediments management plan, in accordance with the methodology proposed in the phase 2 report.
The development of an integrated coastal management strategy could either lead to modifying the sediments management plan or lead to a second sediments management plan, which would therefore lead on from the first plan, applying the shared vision established by the coastal strategy

Objectives for coastal stretches geometry arrangement

It is necessary for a GIZC strategy, including coastline management, be introduced along the whole of the Golfe du Lion. The proposals made here are inspired by procedures that have already been implemented, notably in the Languedoc-Roussillon region, and are inspired by the coastline management practices recently published by MEEDDM. But before we go any further, we will recap the main points to be considered to define a coastline management strategy.
First of all, the strategy that we will outline must enable us to manage the consequences of several phenomena: the reduction of sedimentary input along our coastline, the interruption of sedimentary transit by port and protection openings, the

reduction in sand stocks due to urbanisation and the abusive use of the dune layout and, finally, the consequences of climate change, including the rise in sea level which increase vulnerability to marine flooding.
But in taking the conclusions of the EUROSION project, our strategy will consider that our coastline, which remains a living one, possesses the inherent ability to adapt to the changes caused by the rise in sea level, by extreme events any by the occasional human-related impacts, while still keeping its functions for the long term.
This is what we call coastal resilience, a concept which is particularly important in light of the phenomena we have just mentioned. In this context, we must consider the possible modes for managing the coastline which are commonly accepted in literature.
The first one is active defence, which involves maintaining the coastline while acting on sedimentary transit by installing or modifying defence works. This is the centuries-old way of combating the sea. It is well accepted by coastal communities as it provides a reassuring response to local problems and consumes few private spaces as the installations are most often installed on public-domain maritime land. However, as this does not attack the roots of the problem, it requires often heavy maintenance and has numerous harmful effects downstream of the sedimentary drift.
This is why this management mode must be reserved for zones with high stakes that cannot be moved, such as dense urban zones or activity zones that require closeness to the sea.
The second is non active management that involves the restoration or maintenance of natural operation. This involves either following the natural evolution of the coastline or accompanying it through soft techniques such as stabilisation of the dune belt, adding sand to beaches and by-passing works. Its main advantage is that it is sustainable and has no negative effects downstream, since it is based on natural mechanisms and also guarantees high environmental quality for the protected sites.
But as it is less visible and consumes space, it is less reassuring for communities. Finally, it requires regular monitoring over the long term.
This management mode must therefore be reserved for zones with sensitive natural asset stakes.
The third management mode is strategic fallback. It involves moving the stakes behind a new defence line, natural or created, then restoring the coastline to achieve a new balance quickly.
In objective terms, this is the most sustainable management mode, as it notably reduces vulnerability, restores the natural operation and does not require any maintenance. But it supposes that we can have the space necessary for the fallback and that its socio-economic and asset consequences are acceptable to the communities concerned. It therefore supposes a profound change in mentality by these communities.
The only example where a strategic fallback has been implemented along our coastline is the one at Lido de Sète in Marseillan where the element to be moved was a road that was regularly destroyed by storms.
Finally there is the lack of any management which in fact is what happens in the main along the coastline. This management mode involves considering that the stakes threatened by erosion may be destroyed or abandoned as they do not justify the investment required for their protection. However, it has no impact since it accepts the natural process.

Program of interventions, including priorities, with project preliminary indications

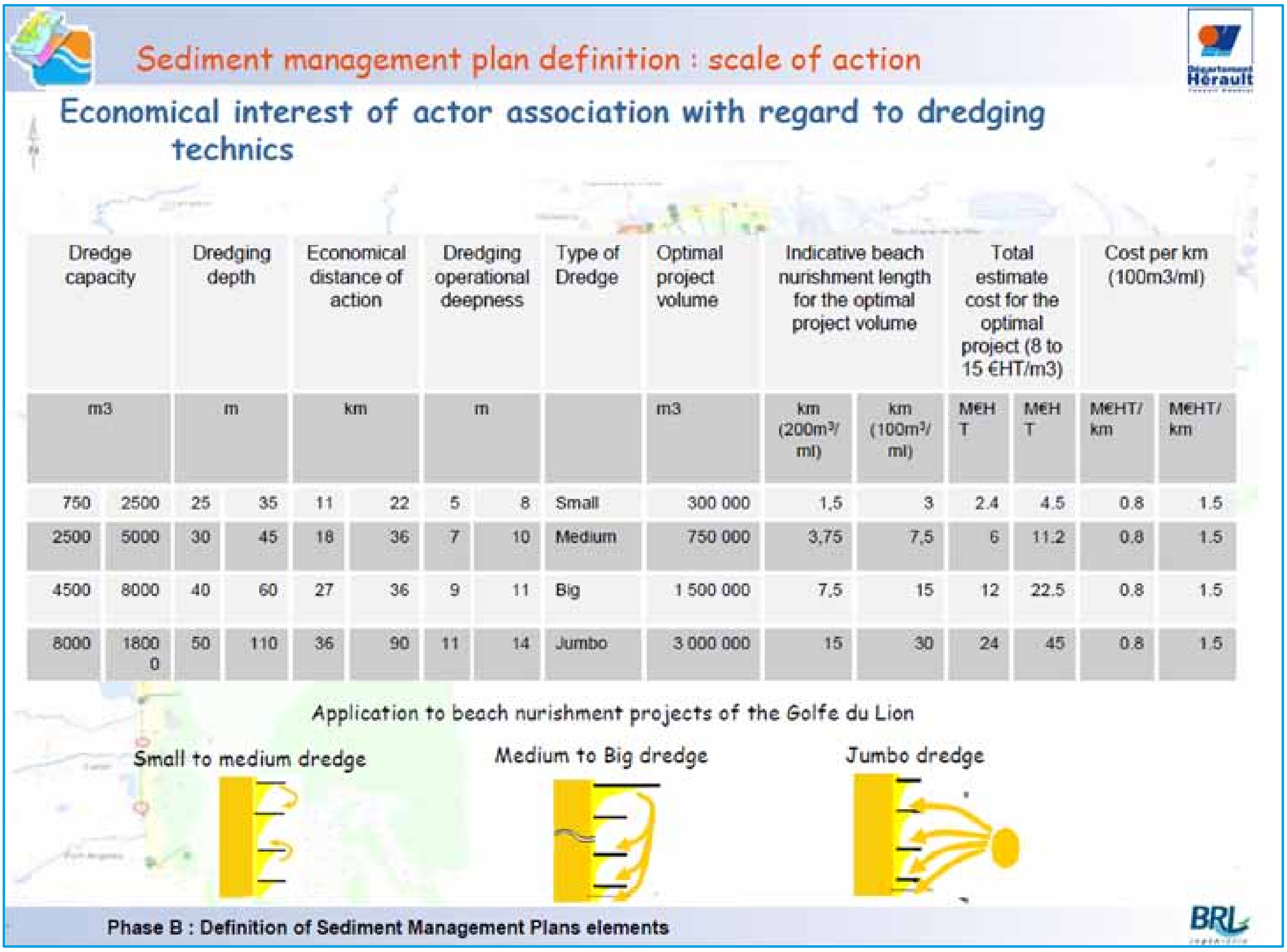
The strategic fallback includes the ten orientations established by the MIAL for the LR coastline in 2003. It involves pushing the stakes back to leave the coastline a free zone so that erosion does not present any risks (mobility zone). This method is socially and technically difficult as uses must be pushed back over large distances for the mobility zone to be large enough.
The strategic fallback cannot therefore be programmed as such immediately, except in specific cases. First of all, we must study its feasibility sector by sector in the context of a global approach to coastline development. This is an action which must be integrated into the management plan.

Also, we must deal with erosion while waiting for the stakes to move back. To do so, topping up the beach is a very interesting method. In fact, it is one of the "soft" coastline management techniques. It enables a sufficient beach width to be recreated for the sedimentary dynamic to establish itself. In addition, the sedimentary transit is not interrupted, which avoids worsening erosion problems downstream.

Technical progress in locating and characterising deposits (micro-seismic) and estimating and monitoring requirements (Lidar) on the one hand and the probable legal availability of large offshore deposits on the other constitute strong opportunities for the deployment of topping-up operations on the scale of whole sedimentary cells.

Particular attention must be paid to the co-ordination between those involved in territorial development and communication to the public to enable effective and efficient implementation for good social acceptance.

Estimation of economic resources needed



Dredge capacity		Dredging depth		Economical distance of action		Dredging operational deepness		Type of Dredge	Optimal project volume	Indicative beach nurishment length for the optimal project volume		Total estimate cost for the optimal project (8 to 15 €HT/m3)		Cost per km (100m3/ml)	
m3		m		km		m			m3	km (200m³/ml)	km (100m³/ml)	M€HT	M€HT	M€HT/km	M€HT/km
750	2500	25	35	11	22	5	8	Small	300 000	1,5	3	2.4	4.5	0.8	1.5
2500	5000	30	45	18	36	7	10	Medium	750 000	3,75	7,5	6	11.2	0.8	1.5
4500	8000	40	60	27	36	9	11	Big	1 500 000	7,5	15	12	22.5	0.8	1.5
8000	18000	50	110	36	90	11	14	Jumbo	3 000 000	15	30	24	45	0.8	1.5

Figure 78. Scheme of economic interest of actor association in relation to the dredging technics

Indications on sustainable exploitation of sediments stocks

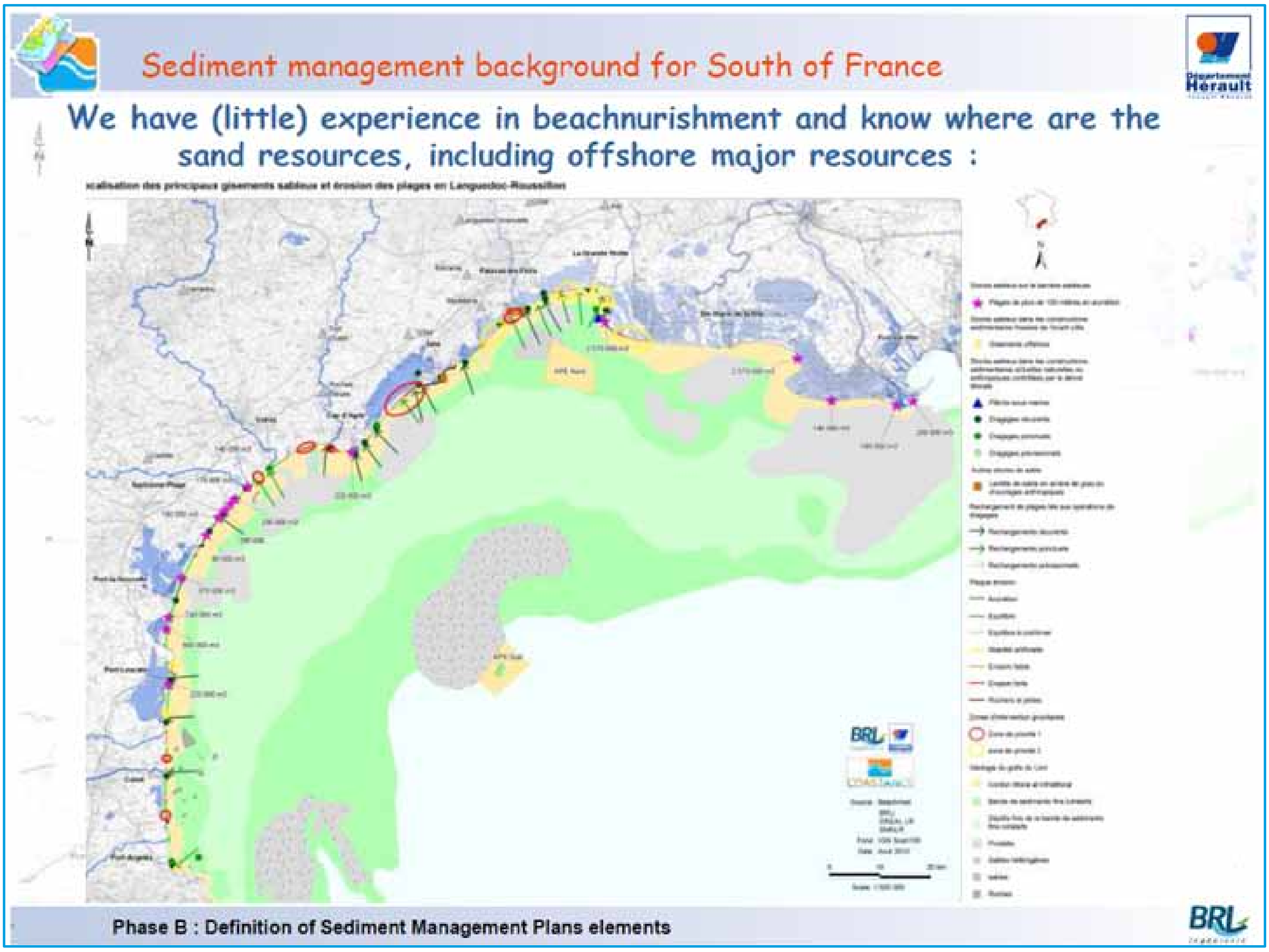


Figure 79. Scheme of different sand sources avaiable for nourishment

The thesis of this management plan is to assume that the long term objective (50 years?) is to re-establish a coastal system in which we will no longer need to keep adding sediment, either through strategic fallback or by re-establishing a stable and balanced natural or neo-natural operation.
It will take time to achieve this result and in the short to medium term we will have to adopt alternative solutions that resolve the problems at least temporarily, without having any negative effects.
The strengthening or restoration of the natural operation is a balanced solution whose potential we suggest exploiting here. To do so, topping up the coastal sand system appears to be the best method possible over the coming years for the Golfe du Lion, especially with the opportunity of exploiting the major off-shore deposits called "Beachmed Sud".

Good practices for beach sediments sustainable management

In keeping with the Inter-Ministerial Mission MIAL 2003, which recommended "managing coastal erosion in an integral way and on an adapted scale" and in keeping with the "action principles shared by all coastal actors", the following distribution of tasks and competences may be recommended:

1)Co-ordination structure(s):

- definition of a main management plan (overall strategy, based on common principles and general organisation) and overall co-ordination;
- co-ordinated management of common off-shore sediment stock;
- development of knowledge, general monitoring of the coastline at the scale of the Golfe du Lion and common capitalisation on experience, linked to the Observatoire du littoral;
- implementation of the general aspects of the communication plan (notably the effective mobilisation of the known stocks);
- monitoring-assessment of the management plan: definition of the framework and organisation of monitoring and contracting of external evaluations every five years.

2) Execution structures:

- contribution to the definition of the management plan;
- definition of the operational plans, applying the strategy and common principles;
- execution of the operational plans: contracting and monitoring of operations and work, including communication and local deliberations;
- local implementation of the knowledge development programme and contribution to the Observatoire du littoral (data acquisition and local enhancement of feedback);
- input into monitoring-evaluation through real-time information transfer, regular formal reporting and involvement in the external evaluation phases.

Management plan organisation

We recommend structuring the management plan traditionally, for example, using the following plan:

Descriptive and analytical approach

Geographical presentation of the study zone

Inventory and diagnostic

- Status of coastal sand erosion
- Socio-economic stakes and actors related to coastal erosion
- Characterisation of the Golfe du Lion's sedimentary resources
- Estimation of theoretical sand requirements by sedimentary cell
- Characterisation of the ecological stakes of the sediment sampling and deposit zones during topping-up
- Documentary resources, current monitoring and available data

Analysis of the potential sediment management methods and management plan axes

- Strategic analysis of the management plan
- Analysis of the management plan's themes (technical, knowledge, communication, governance)

Prospective and strategic approach

40-year vision, objectives and indicators

20-year management plan strategy

- Intervention strategy and logic (specific objective, expected results, main activities, space conditioning)
- Organisational strategy (organisation chart, timetable, monitoring-evaluation, financing strategy)

Operational approach

- Organisation of piloting and implementation
- Activities
- Detailed organisation of the monitoring-evaluation system
- Indicative budget and areas for financing
- Timetable

Strategic approach

As indicated in the phase B report, it is important that local stakeholders remain active during the transitional phase in order to facilitate the development of the sediments management plan (by collecting as much information and data and as many analyses as possible required for its creation), and to demonstrate, through their pro-activeness, that its implementation will be relayed locally and that it is indeed one of the area's fundamental concerns.

global objective: to launch the development of the sediments management plan in the Gulf of Lion in collaboration with all of the actors concerned, under the guidance of the State.

specific objective: to facilitate the launch of the development of a joint management plan under the guidance of the State.

expected results:

- a network of actors, including the State, is created, working on a project which aims to form a sediments management plan in the Gulf of Lion;
- the main sediment sites identified are made accessible; global systems for the conservation of sediments are implemented;
- those actions which can be carried out without deadlines will be, foreshadowing the future management plan;
- the value of the assets subject to risks of erosion and flooding will not have increased (risk therefore not increased).

Plan of action

1) Action carried out in the field foreshadowing the management plan:

  - completion and evaluation of current operations and achievement of overall capitalisation on these;
  - carrying out local action which can be undertaken in the short term with no major legal constraints or availability problems in terms of sediments (intracellular and intercellular transfers between adjoining cells);

2) Communication:

  - Raising awareness among contracting authorities concerning the grouping of orders;
  - Communication associated with the work to be carried out (targets: local elected representatives, the general public, socio-professionals);
  - Political communication:
    - Contributing to preparing the creation of a structure which would be in charge of developing the management plan and then coordinating its implementation and requesting collectively the involvement of the State;
    - Lobbying in favour of the legal accessibility of the sediment resources identified: Beachmed Sud and the intercellular transfer of sediments between non-adjoining cells;
    - Lobbying in favour of an integrated study into long-term investments in coastal zones that lead to an increase in the value of socio-economic issues and could therefore potentially have negative effects on strategic withdrawal.

3) Further action to be taken in preparation for the sediments management plan:

  - Creation of a network of actors;
  - Research of durable financial solutions for operations in the field;
  - Acting in advance in order to encourage the conservation of backfill:
    - By setting up a regional aggregate market (sale of excavated material and backfill) and by putting in place constraints regarding re-use by construction companies;
    - By reserving land for storing backfill and by putting in place a suitable legal framework.

Operational approach

Organisation of piloting and implementation

This transitional plan of action is being proposed to the Service travaux d'aménagements portuaires et protection du littoral (Department of Hérault Council which deals with port developments and coastal protection) in preparation for the future sediments management plan. It nevertheless remains necessary to make its structure clear internally by explaining its piloting and implementation, by clarifying the specifications of each section, and by ensuring that the subsequent workloads are compatible with the job descriptions and workloads of the individual agents concerned. Once this has been clarified, this structure can remain flexible and adaptable, and not overly formal.

Activities:

1) Communication:

Raising awareness among contracting authorities concerning the grouping of orders

The grouping of orders enables the price of sediments per m^3 to be reduced, along with the number of regulatory studies and administrative processes to be carried out. Raising awareness among contracting authorities of these grouped orders, by specifying limits in terms of the volumes concerned and the targeted sources of sediments, is therefore a measure which will facilitate the effective implementation of nourishment actions.

Additionally, grouping orders can also lead to contracting authorities pooling means set aside for any eventual compensation. This could help make them more consistent and more efficient, all the while once again making aspects of management simpler.

One or several consultation meetings should be organised for this, and should be structured as follows:

- quick evaluation: theme of the meeting, positioning in relation to past events and short, medium and long-term perspectives;
- technical presentation: type of nourishment according to sediment sampling sectors and link with the technical means to be called upon, the regulatory procedures and the cost of operations;
- discussion time: listen to the opinions of participants and do not judge them, especially in the event of disagreement: every point of view is taken on board, despite whether or not they go down the envisaged route, or whether or not they are justified and well put forward. It can be requested that a party rephrase a concern, in case of confusion or unexpected points, in order to ensure that the point of view has been heard and is understood correctly;
- negotiation time: answers are given to any questions actors may have; a quick summary of all of the comments is given;
- conclusion: possible arrival at a consensus or compromise which seems acceptable, produced during the meeting; the announcement of the schedule and what is to come; particular involvement of CG 34 and reformulation of any possible commitments of other stakeholders.

Communication associated with the work to be carried out (targets: local elected representatives, the general public, socio-professionals, other departments of CG 34)

As mentioned previously, the first feedback acquired from nourishment actions, including those in Aigues Mortes, tends to confirm the central role of communication, as this ensures that any technical success when it comes to operations will also effectively mean success in terms of general opinion and economic agents.

Any action that will be undertaken within the framework of the current plan of action will therefore need to be accompanied by suitable communication plans.

An evaluation/capitalisation of the communications carried out in the past and an analysis of all of this, carried out by an agency specialising in this domain, should therefore increase significantly the effectiveness of this communication.

The first action to be taken in this sense will therefore be to call upon a communication agency to establish a plan and generic communication tools for a nourishment operation, which CG 34 and its partners will then be able to present and use during each operation.

The specific evaluation of this communication will be extremely useful in developing the sediments management plan.

Political communication

- Contributing to preparing the creation of a structure which would be in charge of developing the management plan and then coordinating its implementation and requesting collectively the involvement of the State

The creation of a suitable governance structure designed to be responsible for the development of the management plan and then coordinate its implementation should be prepared in advance in order to speed up the process.

This action will consist in informal and formal meetings between local actors and State departments which will enable them to share their perceptions of requirements and will help formulate a solution which will create a consensus.

Various options are analysed in this sense and presented in the phase 2 report, with no conclusion at this stage, regarding a subject which exceeds the scope of Coastance. During the first analysis, we noted the following points:

- If possible without negatively affecting the efficiency of management, partnering up with one or several existing structures can present significant advantages;
- Comparatively, it would seem a reasonable aspiration to take advantage of learning from similar models, such as the French national institutional framework for water management, and then to proceed with simplifying the subject as much as possible. In this respect, the deployment of the Plan Rhône can indeed serve as an example.

Another point to note is that in the interest of simplification and as a pragmatic approach, Languedoc Roussillon Region, competent in land development, could legitimately take on the role or leader or itself act as the coordinating structure, under two conditions: it must guarantee the involvement of the State, notably financially, and an arrangement must be made with PACA region and Bouches du Rhône County for the sandy section of coast situated outside of Languedoc Roussillon.

- Lobbying in favour of the legal accessibility of the sediment resources identified: Beachmed Sud and the intercellular transfer of sediments between non-adjoining cells.

It is necessary that the Beachmed Sud site be liberated from the current legal constraints blocking its usage, as this site is key to the envisaged strategy. Indeed, this favours nourishment as an intermediate solution for strategic withdrawal on a large scale, and therefore relies on the accessibility of Beachmed Sud.

For this, we recommend that the organisations and individuals concerned and currently the most involved in this domain, starting with Herault County Council and Mr. Roland Chassain, the Mayor of Saintes-Maries-de-la-Mer, join and work together to carry out active lobbying regarding these subjects with the national authorities.

In order to support their discussions, they can notably make use of the report written by Mr. Chassain in August 2010 and the reports written by Herault County Council as part of the Coastance European Project. The conclusions of these reports led to making this offshore site key to the strategy to be deployed to remedy coastal erosion while waiting to be able to activate the strategic withdrawal strategy on a large scale.

- Lobbying in favour of an integrated study into long-term investments in coastal zones that lead to an increase in the value of socio-economic issues and could therefore potentially have negative effects on strategic withdrawal.

It is difficult to act immediately in terms of strategic withdrawal, but it seems important not to jeopardise the future by making this option more difficult than it already is.

From this point of view, it would therefore be appropriate to make the effort to not increase significantly the value of coastal assets. Declaring a moratorium on the heaviest and most long-term investments (amortisation that goes beyond 2030-2040, for example) could be one option.

<u>2) Further action to be taken in preparation for the sediments management plan</u>

Creation of a network of actors

One of the essential topics within the current plan of action is the preparation of the sediments management plan. It therefore seems necessary to include within this the actions aiming to motivate and

bring together the various actors, notably including the State and the Region.
Fundamentally, this network already exists since numerous consultations have already taken place. However, the most recent structured consultations were several years ago and although the institutions have undoubtedly changed very little, it is often not the same people who are in charge of them.
It therefore seems necessary to re-establish the network of actors, and in order to do this, to begin to update the list of stakeholders, being sure to include all of those whose involvement is necessary in defining the strategy, its implementation, and its follow-up and evaluation.
In particular, we recommend bringing together all of the local actors, which includes communes (communauté de communes – community of communes, a federation of municipalities in France, and communautés d'agglomérations – agglomeration community, in France more integrated than a community of communes, whichever the case may be), and the local socio-economic actors, whether this refer to beach managers, tourism companies along the coastal strip, managers of protected natural environments in the (coastal or marine) area, organisations protecting the natural environment, and local citizens' initiative associations.
The scale of the commune is in keeping with socio-economic interests which justify nourishment with the help of sediments. It is therefore when considering this scale that we come across the "beneficiaries" of the management plan.
During the development of the management plan, beneficiaries should be given the opportunity to express their needs, even if these have already been recognised previously. Indeed, it is always necessary to check that the need actually exists and to consider the manner in which it is expressed. In this case, this involves predicting conflicts that will take place during or at the end of the project if the beneficiaries believe that the project does not turn out as they had hoped. This kind of dissatisfaction can arise if the real needs of beneficiaries have not been understood correctly during the development phase or if the project has not made the scope of its action clear and indicated from the beginning that all requirements cannot be met.
What is more, it is normal and common that the beneficiaries of an action contribute to it, in one way or another. This contribution, whether it be financial and/or in terms of nature and/or time dedicated to the project, can only be obtained if it is negotiated and agreed upon at the beginning of the project, when the beneficiaries are in a position to make compromises to get the action started.
CG 34 can already identify and bring together actors within the County to present its vision for the sediments management plan and gather their opinions and positions through discussion, on the condition that the initial scope of the project is made clear ("we are not currently creating the management plan; there will be no overall decision made pursuant to this local meeting; we are here to consult with each other and attempt to move on to the development process of the management plan with ideas that have already been shared, have already matured, or have even been tried out").
This will enable all parties to be involved in the official process of developing the sediments management plan, having already made progress and already discussed the topic, constituting a significant source of proposals. This could also lead to a local consensus for locally implementing actions which foreshadow the future sediments management plan (by-pass, withdrawal, etc.).

Research of durable financial solutions for operations in the field

Financial support, for nourishment operations in particular, requires considerable means. Recently, we have been able to observe 15-year loans for operations which are planned to last around a decade but will probably in fact last for a shorter amount of time. This poses a problem.
Moreover, no tax system or other solution of this nature establishes a link between the priority beneficiaries of operations (owners of sea-front buildings, economic agents linked to the existence of beaches, etc.) and spending.
It therefore seems relevant to begin researching, and then maybe put into place, durable financial solutions for operations in the field. One way to go

about this would be to:

- Attempt to determine one or several direct and indirect advantages brought about by these operations for certain categories of actors, and to make a sampling;
- Identify and compare the various possible sampling solutions, with the help of a tax system or other tools, in order to finance operations in the field;
- To identify and compare the various financial arrangements that would enable a balance to be maintained between lengths of amortisation and the dates of possible financial operations.

In the preparation phase of the sediments management plan, CG 34 may choose to take these actions as a first initiative, and may then launch a pilot action as an experiment, to be analysed and promoted within the sediments management plan.

This action would consist in a study calling upon economic, taxation and financial competencies. It would initially set about doing the groundwork on the subject by analysing the current situation and solutions adopted elsewhere and through an initial exploration of possible avenues for further investigation.

Acting in advance in order to encourage the conservation of backfill

This action is justified by the long-term objective of the natural or neo-natural nourishment of sediment transportation. This is a very practical and relatively simple action for which experiments have already been carried out, and with success. It will result in a decrease in the global sediment demand, and therefore a decrease in sampling. Even though these are not carried out in the watercourses themselves, this could contribute to reviving the natural production of sediments.

In practice, this would mean:

- setting up a regional aggregate market (sale of excavated material and backfill) and putting in place constraints regarding re-use by construction companies;
- reserving land for storing backfill and by putting in place a suitable legal framework.

Propositions for the sediments management plan of the Gulf of Lion

Expertise and consultation

The phase B report provides details of the reasons why intense consultations seem essential to developing the management plan. It also suggests a concrete timetable for organising these consultations, while making the most of the work and consultations already carried out.

When it comes to technical expertise, these are required to provide the consultation with observations and objective and neutral analyses, and remain directly essential for decision making.

Despite this, the decision as a whole regarding the prospective and strategic approach remains entirely political. It involves defining long-term objectives which will have significant impacts on the general public, the region and public funds. Nothing obliges the policy to follow the results of expertise or the consultation to a tee. Only the public authority, elected as part of a clear institutional framework, is legally allowed to make a choice regarding the various weightings of current issues.

The expertise is therefore legitimate grounds for supplying propositions, including in terms of strategy, which will then be subject to discussion during the consultation. This subsequently enables the public authority to make its decision.

We are therefore putting forward a proposition regarding the content of the sediments management plan. This proposition could serve as a basis for discussions during consultations concerning the prospective and strategic approach of the management plan.

This proposition was formed from bibliographic and technical analyses. It largely emanates from the 2004 Mission Interministérielle d'Aménagement du Littoral (Interministerial mission for coastal development), and is enriched by feedback and analyses (see phase 2 report).

Its formulation, by a research department, does not intend to take into account all political, institutional, economical, financial, social, geographic and environmental issues, among others. It cannot reflect the plurality of legitimately expressed points of view and therefore takes place prior to these processes.

Proposition of a strategic approach for the sediments management plan – logic of intervention

Global objectives

- To contribute to maintaining coastal socio-economic activity;
- To contribute to developing a long-term coastal vision;
- To contribute to preparing in the field the future strategic withdrawal on a large scale and the revival of the natural transportation of sediments (or, at least, not to complicate it by contributing to increasing the risks of erosion/flooding by increasing the value of the threatened assets);
- To contribute to preparing the global coastal management plan on an institutional level (governance structure and Coastal observatory).

Specific objective

While awaiting strategic withdrawal and the revival of the natural transportation of sediments, to ensure that the coast's beaches are maintained using soft techniques (without increasing risks) and to contribute to raising awareness.

Expected results

- The condition of the beaches is maintained via soft techniques
- The existing work underway in terms of coastal protection is maintained and the threats are decreased
- Awareness is raised and knowledge is made more accessible and is used in a better manner

Plan of action

- Soft protective measures as of Beachmed Sud; beach nourishment and protection of dune belts;
- Hard protective measures limited to a strict minimum; protective actions maintained when involving significant socio-economic risks.
- Strategic withdrawal from the most easily-changeable issues;
- Research and implementation of durable financial solutions for operations in the field;
- Communication plan to accompany actions in the field and in favour of the future plan for the integrated management of the coast;
- Set-up and management of a Coastal observatory.

Operational approach to the sediments management plan

Organisation of piloting and implementation

The creation of a suitable governance structure designed to be responsible for the development of the management plan and then coordinate its implementation is an action which should be carried out prior to the creation of the sediments management plan.
The best approach in this case is a functional one: this means studying all of the duties that must be assumed and identifying in terms of each of them on what scale they should be dealt with. The study regarding the structures to be involved or created should be carried out afterwards (without a priori)

Activities

<u>Soft protective measures as of Beachmed Sud; beach nourishment and protection of dune belts</u>

This action is at the heart of the sediments management plan. It will take place while awaiting an integrated coastal management plan and other conditions which will enable strategic withdrawal on a large scale.
It is the integrated coastal management plan which will formulate the long-term vision for the coast and the global plan of action to reach the desired future situation. The desired future situation will not be ideal but it will constitute the best socio-economic and environmental compromise for combating the coastal risks which are worsening.

<u>Hard protective measures limited to a strict minimum; protective actions maintained when involving significant socio-economic risks</u>

In order to ensure that strategic withdrawal will still be possible in the future, it seems essential not

to increase the value of the assets subject to erosion and flooding risks – as this would also cause the risk of erosion and flooding to be increased.
Moreover, it is becoming increasingly clear that progress is slowly being made in terms of knowledge, and we are now equipped with feedback collected over significant time periods. Furthermore, it is becoming increasingly obvious that hard protection measures, which reduce the natural functioning of the sedimentary system, have more negative effects than positive effects in the long term.
Consequently, construction work involving the use of hard techniques on protective structures will be limited to a strict minimum, and therefore to the routine maintenance of dams protecting urban areas.

<u>Strategic withdrawal from the most easily-changeable issues</u>
When it becomes possible, this action will consist in carrying out strategic withdrawal as a pilot experiment. The feedback from these experiments will be helpful in the development of the integrated coastal management plan. Moreover, this action will lead to a decrease in the risk of erosion and flooding, by reducing the issues subject to vagaries.

<u>Research and implementation of durable financial solutions for operations in the field</u>
Financial support, for nourishment operations in particular, requires considerable means. Recently, we have been able to observe 15-year loans for operations which are planned to last around a decade but will probably in fact last for a shorter amount of time. This poses a problem.
Moreover, no tax system or other solution of this nature establishes a link between the priority beneficiaries of operations (owners of sea-front buildings, economic agents linked to the existence of beaches, etc.) and spending.
It therefore seems relevant to begin researching, and then maybe put into place, durable financial solutions for operations in the field. One way to go about this would be to:

- Attempt to determine one or several direct and indirect advantages brought about by these operations for certain categories of actors, and to make a sampling;
- Identify and compare the various possible sampling solutions, with the help of a tax system or other tools, in order to finance operations in the field;
- To identify and compare the various financial arrangements that would enable a balance to be maintained between lengths of amortisation and the dates of possible financial operations.

<u>Communication plan to accompany actions in the field and in favour of the future plan for the integrated management of the coast</u>
The first feedback acquired from nourishment actions, including those in Aigues Mortes, tends to confirm the central role of communication, as this ensures that any technical success when it comes to operations will also effectively mean success in terms of general opinion and economic agents.
Genuine, coherent plans for the communication between them and benefiting from economies of scale should therefore be put into place for each operation, targeting the various categories of actors: elected representatives, civil society, economic officials, etc.
In addition, overall communication is desirable. The functional analysis of the governance of the sediments management plan highlights the spatial scales on which the various tasks should be coordinated and managed:

- On the scale of the Gulf of Lion, coordination structure: implementation of general constituents of the global communication plan;
- On a local scale, implementation structures: local implementation of the communication plan in connection with the operations led locally.

<u>Set-up and management of a Coastal observatory</u>
The sediments management plan should be accompanied with the setting up of a Coastal observatory, from clearly set-out objectives and with the appropriate means. Without taking into account the preparation that may be carried out in advance, the creation of the Observatory should take place parallel to that of the sediments management plan, as

these two tools are inseparable.
Two axes could be developed within the Observatory or in connection with it: follow-up and research. This results in two main actions:

- Through the gathering of expertise and time set aside for consultation, a synopsis of the coast will be developed, composed of the smallest possible set of performance indicators relevant and necessary to pilot sediment management, with detailed information for each of them: necessary data, origin of this data, the techniques and means collected, collection dates, appointment of a manager who will be in charge of this collection, plan to use and promote the indicator, initial evaluation of the indicator (zero state);
- ·Definition of the areas of research to be developed according to the precise medium-term needs which will enable the effective management of sediments in the Gulf of Lion, in collaboration with research actors, management actors and with the management beneficiaries (socio-economic managers of the coastline).

The Observatory is solely envisaged for sediment management, but it will be able to subsequently grow and progress to take into consideration all of the elements necessary for the set-up and piloting of the coastal management plan in its entirety.

Detailed organisation of the follow-up and evaluation system of the management plan

A follow-up and evaluation system is generally perceived to be important in any strategy, but often treated as an element of secondary importance, at the end of a process, or even after the implementation of a plan has begun. These are the kind of errors which lead to the belief that the follow-up and evaluation of a plan are very difficult to carry out and impossible to manage right throughout its implementation.
This is, in fact, not at all true. Experiments show that a well-established follow-up and evaluation system has every chance of being successful right throughout the implementation of an associated plan and that this proves very useful in its piloting.

A “well-established” system is created in cooperation with future users and with those who will be responsible for managing it; it consists of:

- Performance indicators (the synopsis mentioned in relation to the Coastal observatory);
- Means indicators, to monitor the implementation of the management plan and to know in real time whether or not the means envisaged are deployed or used. This data is important for evaluative analyses and, in particular, in evaluating the relevance and efficiency of the plan. Equally effective in fact, whether they are good or bad, the conclusions differ according to whether the means envisaged were called upon or not.
- For each indicator, the cost of acquiring data and the constitution of the indicator should be verified, along with its relevance to the issue for which the indicator provides information;
- For each indicator: precise identification of the necessary data, its origin, the techniques and means of collecting it, the dates on which it was collected, appointment of a manager who will be in charge of this collection, people concerned, their respective responsibilities and the consideration of these additional tasks alongside their job title and within their work schedule; definition of the plan for using and promoting the indicator; initial evaluation of the indicator (zero state);
- Schedule and specifications for each key stage of the follow-up and evaluation process: continuous follow-up, frequency of stages (annually, for example), mid-term evaluation, final evaluation, etc.; and method of using associated deliverables: presentation in a follow-up committee, piloting committee, etc.; people involved in each task (aggregation and use of indicators, presentations during piloting, consideration of follow-up and evaluation reports, modifications made to the strategy or plan of action, etc.).

For logical and practical reasons, the follow-up and evaluation system for the management plan should a priori be constructed and implemented by the secretariat (or equivalent authority) of the Coastal observatory when this has been created.

Formulation of Coastal Protection and Management Plans: Emilia-Romagna Region

Coastal setup and management policies

During the 20th century, the Emilia-Romagna coastal system has undergone deep anthropic changes, which have led to the disappearance of most original landscape-environmental features: dunes have mostly been leveled, different valleys have been reclaimed, wasteland and woodland have substantially shrunk.

The early erosion phenomena emerged already during the early 20th century close to a few cuspate rivers and in the beaches to the North of Rimini and Porto Garibaldi jetties, after their extension. Yet, it was especially in the second post-war period that the environmental deterioration (beach erosion and eutrophication of inshore waters) became extremely serious and exacerbated to the point of risking jeopardising what had by now become the European leading marine tourism industry during the Seventies.

Coastal erosion management policies had already been implemented by the central government since the Thirties, with the early construction of longshore breakwaters in Porto Garibaldi.

Massive beach protection technical and economic efforts were resumed in 1947 and then continued during the following decades. During the 1950-1980 period, hard defence infrastructures were built along a 54 km long stretch of the coastline, whereas between 1980 and 2006 a further 12 km long stretch was protected (fig. 80)

This reversal of the trend in the defence strategy occurred following the issuing of the 1981 Coastal Plan guidelines. They highlighted the heavy landscape-environmental impact deriving from these works and for the first time in Italy it suggested beach nourishment as an alternative.

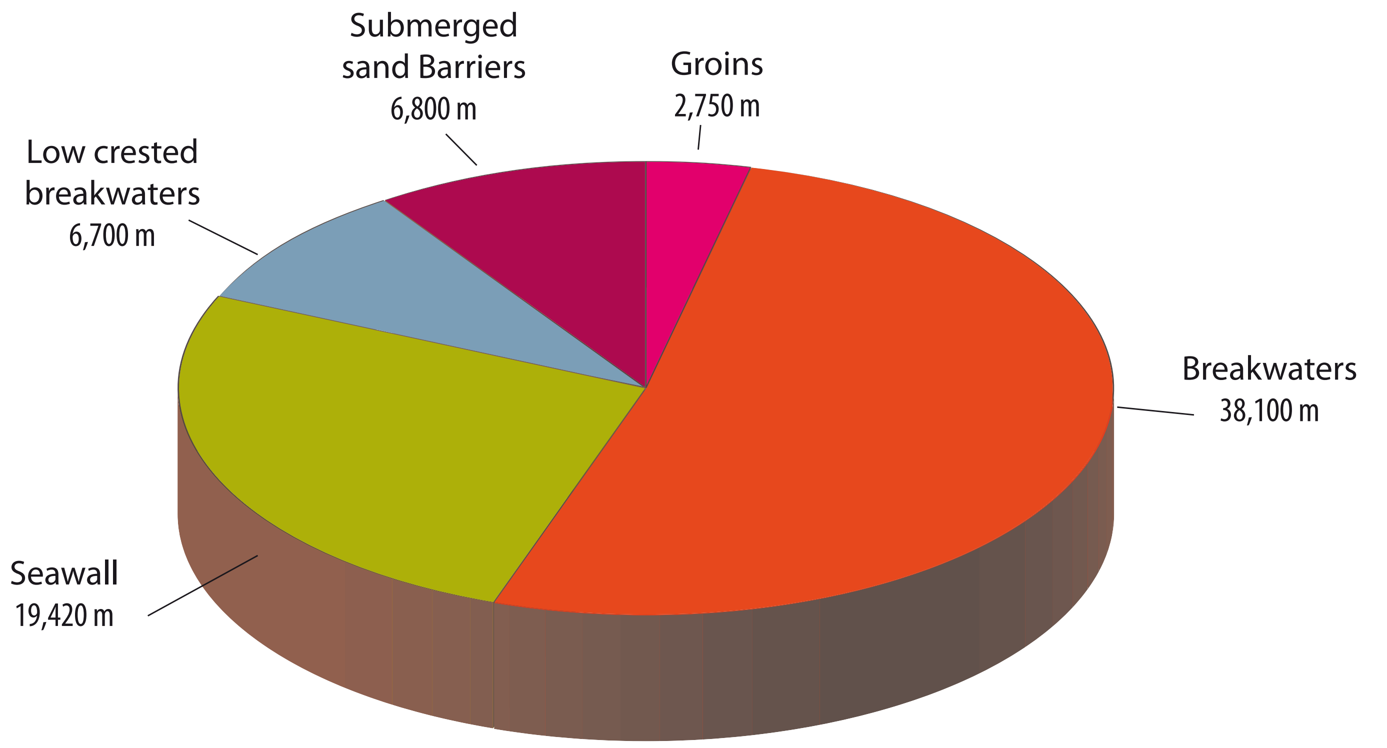


Figure 80 - coastal defense works built along the regional coast in 2007 (ARPA, 2008; Annual Publication, 2009).

In 1983, the Regional authority launched the first major nourishment campaign ever developed in Italy by mainly using sand from off-shore and inland quarries.
Despite some difficulties and a certain discontinuity, this technique has been implemented over the following few decades by using off-shore and inland sources (fig. 81), until 2002 and 2007. Two major interventions were carried out by harvesting sand from off-shore underwater sand deposits in 1984 (Idroser 1985), with further detailed analyses in the framework of sea research campaigns (1990, 2001, 2009).

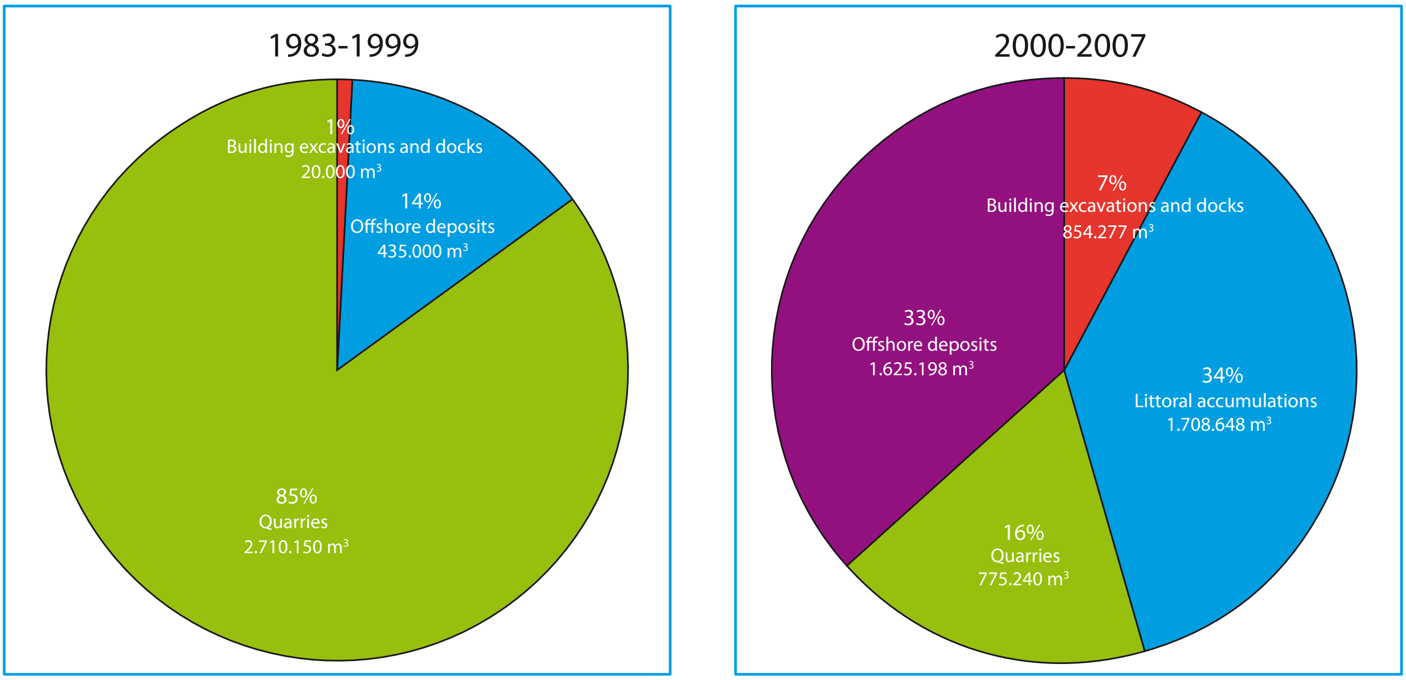


Figure 81 - Nourishment campaigns carried out along the Emilia-Romagna coast during the 1983-1999 and 2000-2007 periods and sand sources (ARPA, 2008; Annual Publication, 2009).

As shown by the calculations made in the framework of the most recent study by ARPA (2008), the total volume of sandy material used for nourishment purposes (deriving from different sources) along the Emilia-Romagna beaches from 1984 to 2007 amounts to about 8.1 million m^3.
The 1981 Coastal Plan and the following studies (1996, 2000, 2007) have given rise to the first major initiatives aimed at identifying and addressing the other major cause for coastal erosion: subsidence.
Subsidence is a phenomenon involving sinking of the earth's surface that might be due to natural causes (tectonics, Isostasy, Sediment compaction) as well as anthropic causes (e.g. pumping off underground fluids, reclamations etc.).
Subsidence along the Emilia-Romagna coastal area is due to natural causes, with a lowering of a few millimetres a year, whereas anthropic subsidence has reached a peak velocity of 50 mm/year during the 1940-1980 period. The main causes are underground water and natural gas pumping.
During the 80s-90s in order to reduce subsidence, major aqueduct works were carried out to bring surface water to the coast and thus limit pumping off underground water.
At present, the regional coast sinks by 10 mm a year on average; lowering velocity peaks are detected at Lido di Dante (19 mm/year) and between Pineta di Classe and Lido Adriano (15 mm/year) (Fig. 3). It has been estimated that about 100 million m^3 of material have been rescued from subsidence along the coast, between 1950 and 2005, and over the past 1999-2005 period a quantity amounting to a bit less than 1 million m^3 has been saved on an annual basis (ARPA, 2008).

Beach sediment management

Beach cleaning service (both during the winter and summer seasons)

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.

Figure 82 - Piles of waste on the beach (mostly lumber) awaiting transport to storage

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

- direct agreements with the Municipalities or the Management Company 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 (fig. 82);
- 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 providing for the following items:

- direct sand screening on the beach during waste collection in the autumn - winter season;
- 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 83. Left: not properly built winter defence enbankment, by removing the sand from the foreshore. Right: properly built winter defence enbankement, with sand coming from outher sources and with the right shape

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.
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. 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:

- 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 (fig. 83).

Creation of windbreaks

Given a loss of sand from the backshore due to wind erosion amounting to 60,000 m^3 a 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.
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 (fig. 84).
On low narrow beaches, it might be useful to position them on top of embankments. An effective

Figure 84 - negative effects caused by absence of the windbreaks

Figure 85 - permanent windbreak barrier 2 years after its construction (Porto Garibaldi beach). Please note the formation of a stable dune on the left side

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 (fig. 85). 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.

Sediment sources

The offshore sources

Six underwater sand deposits (A, A1, B, C1, C2, C3, Figure 86), 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 prac-

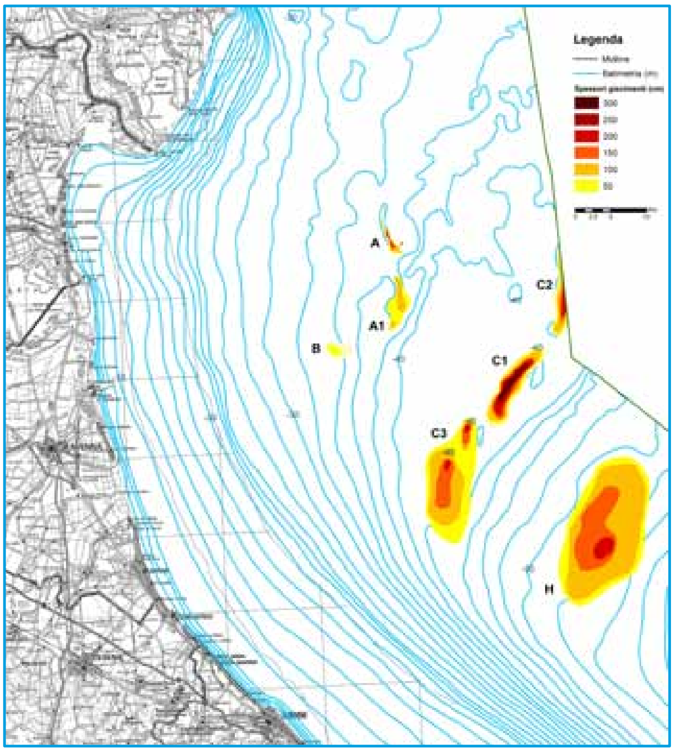


Figure 86. Six underwater sand deposits (A, A1, B, C1, C2, C3)

tical 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 million 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.

The two underwater sand nourishment projects

In 2000 and 2006, respectively, two major emergency safety actions were carried out along critical stretches of the Emilia-Romagna coast, through

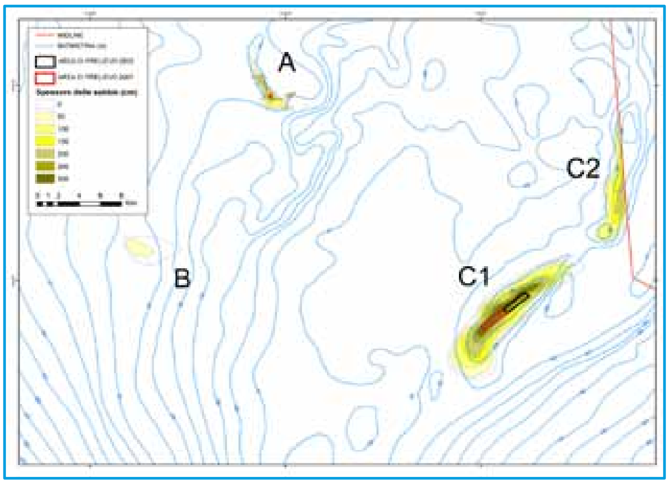


Figure 87. Sand harvesting sites for beach nourishment: 2002 and 2007 operations

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. 87). 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

Figure 88. Ham 316 during dredging operations

C1 site, and in 2007, further 815,000 m^3 were harvested in part from A and in part from C1 sites (fig. 86).
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).

On-shore sources away from the coastal system

On-shore 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.

Figure 89 - Area south of Ravenna along the Adriatic road: in black the areas used as sand quarries

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. 89);
- 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 made only by means of trucks, thereby causing a strong impact and serious traffic problems along the road network (fig. 90).

Figure 90 - Beach nourishment by means of sand from land-based quarries undoubtedly is the solution with the heaviest environmental impact

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
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.
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 m^3 (Fig. 91).

Figure 91 - South of Riccione: sand coming from the building excavation before nourishment by means of underwater sand in spring 2007.

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.

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. 91).
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. 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). The material was collected and deposited by means of a dredger.

Figure 92 - San Giuliano Beach, before and after the construction of new marina near the pier north of the port canal.

The port canal of Cattolica is located in the final

Figure 93 - Cattolica: At the top the “fishing harbour““(2005), at the bottom, the new dock built behind the existing one (2009)

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. 93).
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).

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. 94, 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.

Figure 94 - Bellaria-Igea Marina (May 12, 2009): section of the offshore reef perimeter of the new dock built in Spring 2009

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. 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 located 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 m^3 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.
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.

cell	name	w/drawal m^3 2000-2006	w/drawal m^3 2006-2010
80	Port of Ravenna	250.000	900.000

table 1. Port of Ravenna withdrawals

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 selective 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.

On-shore sand sources

Beaches under 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.
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.
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. 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 7km 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).
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 18 cells shown in table 2, as stretches of coastline that could be potentially used for sand harvesting purposes.

cell	name	w/drawal m³ 2000-2006	w/drawal m³ 2006-2010
3	Cattolica sud	80,050	17,400
13	Misano Scogliere	18,450	10,620
23	Fogliano Marina	0	0
24	Miramare	32,700	19,665
25	Rimini Centro	9,650	0
30	Rivabella	0	5,000
31	Viserba Zona Sud Sortie	0	0
34	Viserba Nord	0	0
39	Igea Marina	7,000	14,000
42	San Mauro	0	1,250
48	Cesenatico	15,000	18,890
58	Milano Marittima	0	6,000
79	Marina di Ravenna	0	0
81	Porto Corsini	29,255	112,200
100	Lido degli Estensi	246,800	25,000
110	Scannone di Volano	123,500	141,295
117	Scanno di Goro Centro	0	0
118	Bocca laguna	0	0
	total volume	562,405	371,410

Table 2 - 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 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 (fig. 95).
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.
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 m³ of sand were collected in Lido degli Estensi (fig. 95).

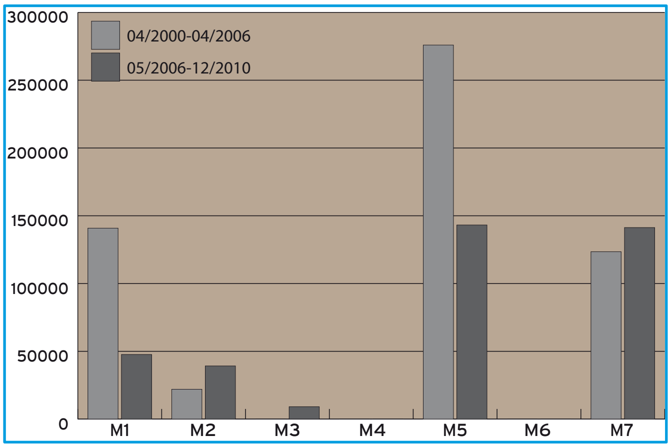


Figure 95 - volume of sand harvested from the 1, 2, 5 and 7 macrocell, in the 2000-2006 and 2006-2010 period

Most of the selected cells are characterized by a 50 - 100 m wide backshore with an inshore 1 - 2 m closure (fig. 95 and 96). 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).

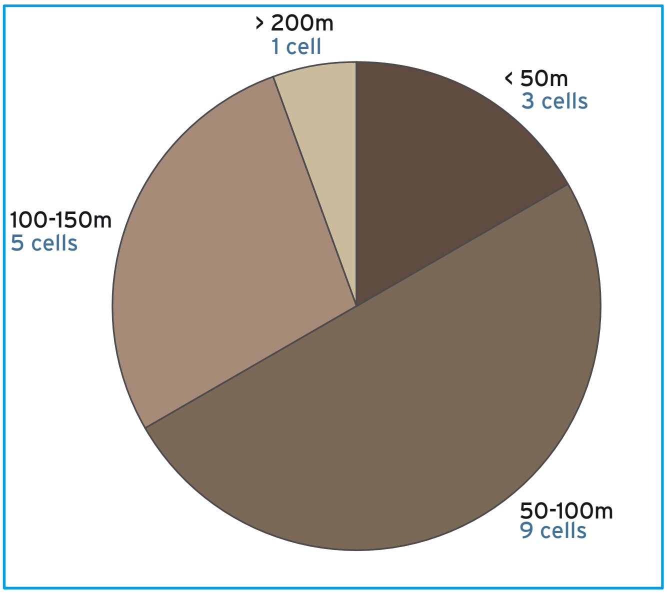


Figure 96 - Average backshore width of the 18 cells that are potentially suitable for sand harvesting

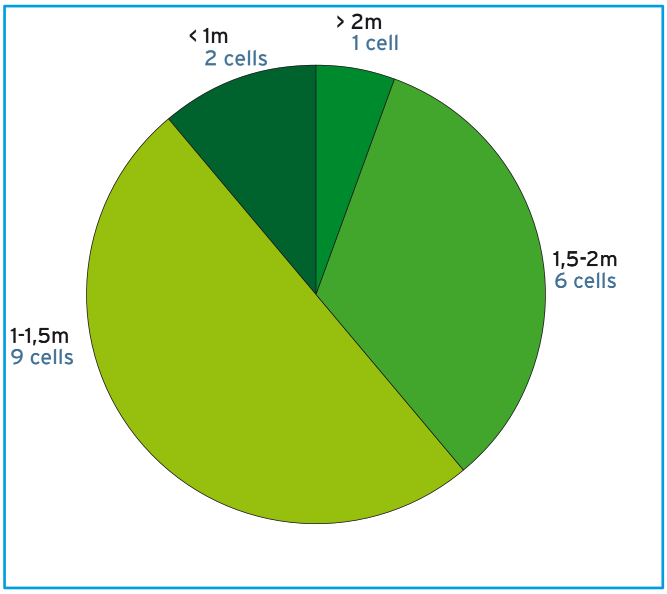


Figure 97 - the average inshore closure depth of the beach of the 18 cells that are potentially suitable for sand harvesting

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

Figure 97 - Port of Cesenatico

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:

- Cell n.1 Port of Cattolica
- Cell n.9 Porto Verde (private) in Misano A.
- Cell n.18 Port of Riccione;
- Cell n.26 Port of Rimini;
- Cell n.49 Port of Cesenatico (fig. 97);
- Cell n.57 Port of Cervia;
- Cell n.101 port of Porto Garibaldi;

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.

cell	name	w/drawal m^3 2000-2006	w/drawal m^3 2006-2010
1	Bocca Tavolo (Porto Cattolica)	0	35,000
9	Port Canal of Porto Verde	16,000	4,000
18	Port Canal of Riccione	48,200	42,400
26	Port Canal of Rimini	0	0
49	Port Canal of Cesenatico	0	0
57	Port Canal of Cervia	33,500	64,950
101	Entrance of Porto Garibaldi	0	133,000
	Total volume	97,700	279,350

Table 3 - port mouth suitable for sand withdrawals to use for nourishment and volumes of sand dredged from 2000 to 2006 and from 2006 to 2010.

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.

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, fig. 99);
- 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.

Figure 99 - Logonovo river mouth

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 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 below).
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 from these 6 other cells 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.

cell	name	w/drawal m^3 2000-2006	w/drawal m^3 2006-2010
5	Ventena river mouth	16,800	900
7	Conca river mouth	14,150	0
22	Marano river mouth	0	0
29	Deviatore Marecchia	0	0
40	Uso river mouth	20,400	15,500
44	Rubicone river mouth	33,500	3,050
53	Tagliata canal	0	2,600
59	Canalino delle Saline	0	0
62	Via Cupa Canal	0	0
64	Savio river mouth	0	0
74	Fiumi Uniti river mouth	0	0
84	Lamone river mouth	0	56,000
87	Destra Reno Canal	0	0
95	Gobbino river mouth	57,000	61,020
99	Logonovo river mouth	247,800	170,444
111	Po di Volano river mouth	0	0
115	Po di Goro river mouth	120,000	0
	Total volume	476,150	309,514

Table 4 - Mouths and bars of rivers and canals suitable for sand withdrawals to use for nourishment and volumes of sand dredged from 2000 to 2006 and from 2006 to 2010.

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

Figure 100 - a tombolo behind a emerged breakwater

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" (fig. 100).
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.

River solid transport

The Emilia-Romagna Region coastal system is mainly fed by sand carried to the sea by several rivers and torrents, whose deltas are located along the coast at a distance of 10-15 km from one another. This arch shaped coastline stretches from the Gabicce mount to the South and the cuspate delta of the Po River to the North, along with the coastal current action from the South and from the North, allows the regional coastal system to receive even limited sedimentary contributions both from the Marche coastline (the Gabicce cliff) and from the Veneto coast (Southern branches of the Po River delta).
In the past, a small quantity of sand produced by the erosion of the cliff foot stretching from Pesaro to Gabicce has fed the Southern beaches of the regional coastline, yet over the past few years. This

source is actually exhausted since the cliff has been protected by breakwaters in several sections.
The Emilia-Romagna beach feeding closely depends on the transport of inert materials from rivers that flow into the Adriatic Sea, whereas the contribution provided by the Po River mainly concerns Scanno di Goro and Volano beach.
The progressive reduction of river sediment transport has been and still in the main cause of erosion of the Emilia-Romagna beaches. This problem has been thoroughly studied and quantified for the first time during the drafting of the "1981 Coastal Plan". In the late 70s the study recorded a reduction of river sediment transport by 3-4 times as against the conditions existing in the 40s, when river basins have not yet been heavily affected by the anthropic impact of the following decades (waterways management, slope erosion control, changes in land, river bed excavations, etc.).
Based on this evidence, the Emilia-Romagna Region issued a piece of legislation that would ban the extraction of sediments from river beds (deliberation of the Regional Council no. 1300, 24 June 1982) which was gradually applied to regional rivers over the following years, until the issuing of an excavation and also to the national Po river basin, through a specific resolution by the Po River authority, in 1990.
An in-depth survey was carried out on all the regional rivers and based on this evidence in 1981 the Coastal Plan pointed out the widespread presence of river works, which stopped most residual sediment transport as well as land use characterised by the abandonment of arable crops towards less erodible crops such woods and meadows.
The effectiveness analysis of the measures that were undertaken and the assessment of previously made considerations made the object of the new 1981 Coastal Plan, which was completed in 1996.
The "1996 Coastal Plan Project" developed to specific research lines on the issue of sediment transport river: the first one was aimed at assessing the state of the art of the regional catchment areas along the Adriatic coast, after about 15 since their early characterization occurred during the 1981 Coastal Plan, and the second one was aimed at the implementation of an innovative procedure for the assessment of sediment transport useful for beach maintenance.
In order to build the sedimentary budget along the coast, when drafting the Coastal Plan in 1980 experts tried to extrapolate the volume of material useful for beach nourishment, by means of "weighed estimates". The National Hydrographic Service as well as literature data was used as source of reference.

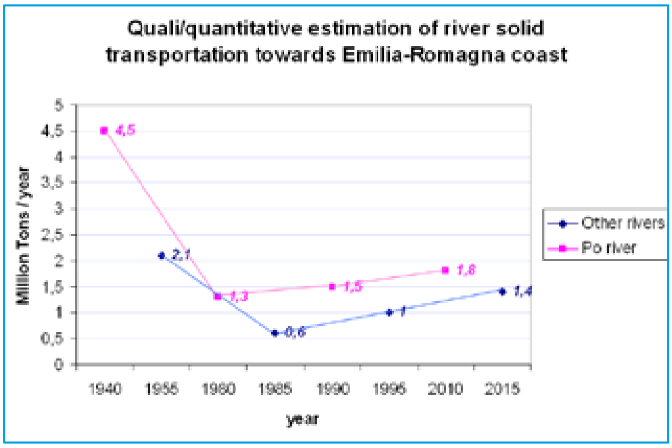


Figure 101. Quantitative estimation of river solid transportation towards Emilia-Romagna coast (from 1940 to 2015)

Thanks to the analysis carried out on the river basins and along the river courses, a systematic description has been provided concerning the present conditions of the whole geological system, morphological variations of waterways, the different land uses ranging between the early 80s and the mid 90s, the state of the art and development of drainage systems and especially the consequences of the mining activity ban.
The analysis of collected information is allowed to identify, although in a qualitative way, the possible evolution trends in the sand river transport.
The effects and early signs of recovery of river sediment transport towards the sea can be clearly observed the along the Cattolica beaches, to the North of the Secchia river mouth, and along the Scanno di Goro.
As far as other rivers are concerned, such as Savio and Fiumi Uniti, the analysis that has been carried out has highlighted no recovery in the resumption

of sand contribution to nearby beaches also due to the thick vegetation grown within the riverbeds and not removed for a very long, 25-30 year-old period, and to subsidence loss.
The study has allowed to estimate the phenomenon evolution overtime (fig. 101):

- regional waterways directly flowing into the Adriatic sea, except for the Po river, during the first half of the 50s transported 2.1 million t/year of sandy material useful for the replenishment of beaches;
- this quantity progressively reduced until it reached the minimum value of 0.6 million t/year in 1985;
- after this date, after the ban of inert material extraction from river beds, sediment contributions increate up to an average value of slightly less than 1 million t/year in 1995;
- for the future, the model that has been implemented indicates that in the regional river system an upward trend in the sand transport can be identified, which will translate into a total value of slightly less than 1.4 million t/year in the medium-term, mainly in 2015.

As for the contribution by the Po river, the methodology that has been adopted mainly refers to available turbidity measures, information on the past and most recent evolution of the river Delta, the data related to the river bed morphological characteristics. This analysis has allowed us to calculate the amount of sand transported to the sea, which was estimated to be around 4.5 million t/year in 1940, and 1.3 million t/year in 1980. Based on the same calculation model, in this case as well, it has been estimated that the control action and the following extraction ban introduced by the Po River authority have led to a gradual increase of the sand transported to the sea, from 1.5 million t/year in 1990 two 1.8 million t/year in 2010.
The river beds excavation ban, cleaning and management operations, carried out during the 80s and 90s, have proved to be very important. Unfortunately, the expected effectiveness of these measures has not yet fully emerged, due to different causes, such as:

- the progressive spreading of wasteland, and woodland along the mountain slopes;
- supra-alluvial formations upstream several cross dredging works along the river beds;
- the different and produced rainfall system;
- inert material excavation authorised by the competent offices for hydraulic safety reasons;
- offsetting land sinking due to subsidence.

Although experimental sediment transport measures have been carried out, a bottom transport close to zero has been recorded, according to the comparison of topo-bathymetric network surveys, which confirm a few, although modest positive elements, is already pointed out by the 2000 Coastal State Report.
It refers to the advancement of the shoreline behind the Cattolica rock barrier, to the North of the Secchia river mouth until Viserba (Southern sector of the regional coast) and to the North of the Savio river mouth (central sector).
No evidence is provided for the Fiumi Uniti river mouth (central sector), since the limited sand recovery is stultified by high subsidence rates in the area, and at the Lamone River mouth (central-Northern sector), where of the past few years, to nourishment operations had been carried out in the severely eroding beach to the South.
No significant improvement has been now achieved in front of the Sacca di Goro (Northern sector) and in a few points the situation has even further deteriorated.
Since the river plays the most important role in maintaining the natural balance of beaches, it is not sufficient to confine oneself to measuring the scope of the problem, but indeed urgent actions should be undertaken to restore the beach balance.
With reference to the above-mentioned causes, said it is not possible to influence the rainfall system, due to climate change under way, the possible alternative solutions are the implementation of policies aiming at the extension of arable land (to the detriment of wasteland), the removal of works that have already accomplished the aims for which they had been built, moving downstream the materials excavated from the river bed for hydraulic safety reasons (by preventing them from being sold on the construction inert material market), the further

reduction of the anthropic component of subsidence deriving from pumping off underground fluids (water and natural gas).

Knowledge reorganisation for the development of shared management tools: SICELL

In the last decades, sediments management became a fundamental aspect in the coastal protection and management programmes of Emilia-Romagna Region.

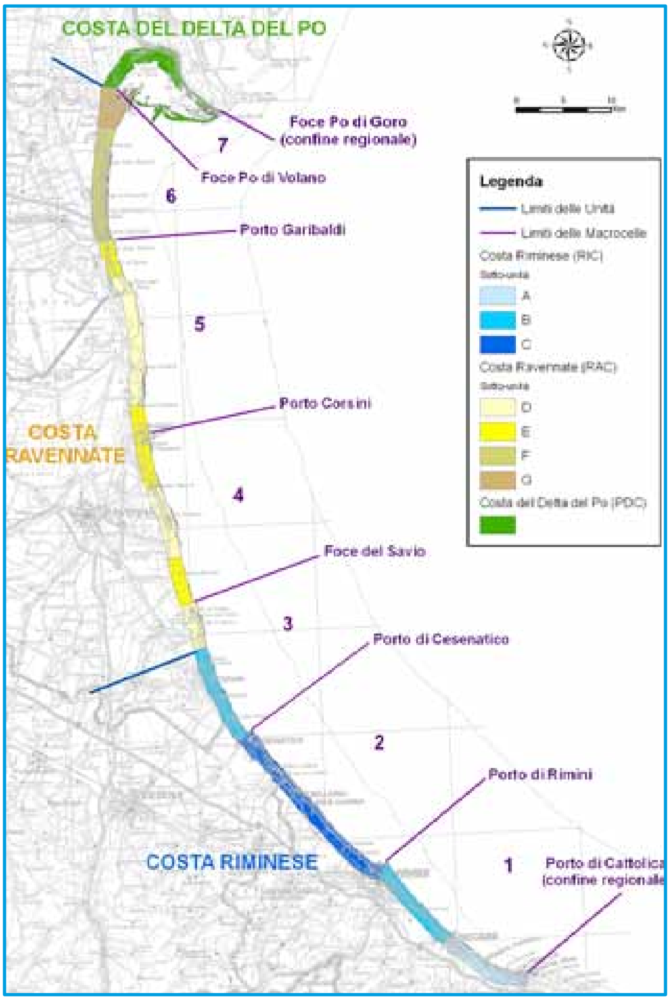


Figure 102. Coast subdivision into 7 macrocells, illustrated in the ARPA publication (2008) limited by long piers or "zero" points of the sediment transport* and in the 3 Units (RIC, RAC and PDC) and 7 Sub-units (A, B, C, D, E, F, G) suggested by the SGSS study (2009). *Close to the Po di Volano and Savio River delta a convergence and divergence point of the coastal sediment transport are present respectively.

In parallel, it raised the need for a support tool able to optimised the use of littoral sediments and the sustainable exploitation of sediment resources coming for out of the coastal system (off-shore/inland provenience).
In order to give a response to this need, Emilia-Romagna Region developed a specific information system for coast management and protection based on the subdivision of the coastal belt in littoral cells (SICELL).
The tool has been developed, in the cooperation framework with other Mediterrnean partner regions, by a regional work group comprising several structures having specific competences in study, monitoring, programming, managing and interventions realisation on the Emilia-Romagna coastal zone: the Soil and Coast Defense and Land Reclamantion Service, the two coastal Basin Technical Services, the Geological Seismic and Soils Service, the regional agency ARPA Coast and Sea Special Unit.
Basing on several previous studies, direct experiences and specific knwoledge, the 130 km of regional coastal belt have been subdivided in 118 littoral cells and 7 macrocells according with coastal dynamics, sedimentary balance, structures and defence assets, beaches assets and geomorphology (fig. 102). Moreover, according with last decades intervention practices, 14 "significant coastal stretches" (grouping cells within a macrocell) have been defined for management purposes.
The SICELL dataset, on a GIS basis, also integrates data coming from other regional databases (Coast and Sea Information System, nourishments and hard defence works DBs, subsidence rates, topo-bathymetry) re-elaborated and specifically reorganised according with the specific aim of the tool. The period covered by the SICELL dataset goes from year 2000 to year 2011, with updating every six months. Next updating, by the end of 2012, will include data from the now ongoing 5th regional topo-bathymetric and subsidence surveys and the comparative analysis with the previous surveys (4th campaign) dated 2006.

Applications of the littoral cells management systems

A littoral cell is defined as a coastal stretch characterised by specific and uniform morphologic and evolution conditions of emerged and submerged beach that distinguish it in respect of nearby stretches. To define its evolution trend in terms of sedimentary balance, a specific indicator named ASPE (Accumulation, Stable, Precarious, Erosion) has been created considering a 6 years cycle observation period.
The SICELL is organised in 4 data sections by each littoral cell:

- framework information: cell typology, coordinates, location, extension, description, macrocell belonging, ASPE class belonging.;
- evolution state information (useful for ASPE classification): realised interventions, nourishments, sand draws, new hard defence works or maintenance of existing ones, coastline trend, sedimentary balance (topo-bathymetric campaigns comparison);
- Morphology, dynamics, beach asset information: alongshore drift direction, subsidence rate, emerged and submerged beach morphology, beach and back-beach uses;
- Management information: interventions needs highlighting, presence of constraints (natural protected areas, particular infrastructures, military zone, etc.), suitability as sand withdrawal zone, suitability as nourishments strategic recharge point for down drift stretches (interventions optimisation).

The section of the sheet concerning the information (category 2) useful for the definition of the evolutionary state of the cell in terms of the tendency to erosion, stability and accumulation, is the fundamental element for the definition of the state of individual cells.
For the implementation of this information, a state indicator has been taken into account and adjusted to the new needs. The “state of the coast indicator” has been specifically covered by a specific article on coastal erosion of the regional Annual Publication on 2009 environmental data.

The workgroup that has been involved in this project has reviewed the data set up and analysis criteria applied with for the definition of the indicator that introducing a few changes.
An analysis methodology on the state of regional beaches has been agreed upon and share by all the factors involved, consisting in the distinction into four types of coastal sections (ASPE classification):

- Accumulation stretches,
- Stable stretches,
- precarious balance stretches,
- eroding stretches.

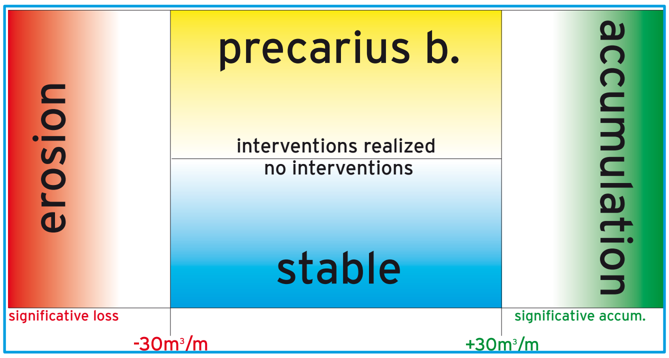


Figure 103. The 4 ASPE classes

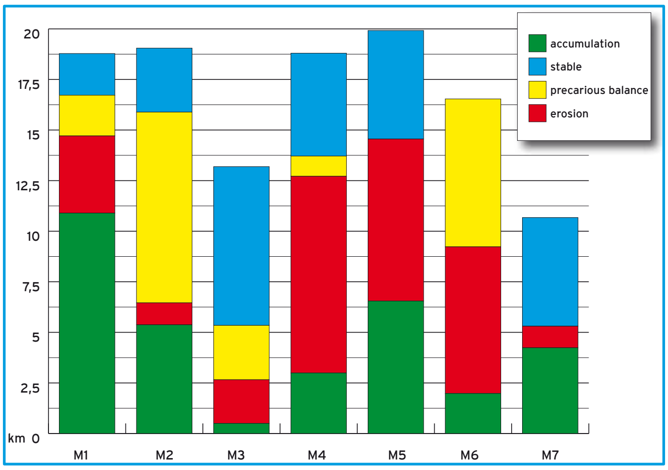
ASPE provides four classes (fig.103) starting from a sand volume variation threshold of 30 m^3/m referred to six years (the period between the last two available regional coastal surveys of 2000 and 2006) and is
based on the integrated analysis of a whole set of information:

- Volume variation related to the backshore and shoreface
- volume losses related to the subsidence,
- nourishment interventions,
- sand harvesting,
- works progress and maintenance status,
- the quality enhancement trend of the shoreline.

This set of data is fundamental for various reasons. A volume loss can be linked to erosion, but also to land sinking due to subsidence or to sand artificial harvesting. At the same time, an accumulation can result either from natural processes or from artificial nourishment. The presence of hard coastal defense works in the plea changes the enemy can morphological beach features. Information related to the progress of works in terms of effectiveness and maintenance needed is absolutely necessary for proper analysis. Finally, the shoreline, which has always been a fundamental parameter in the study of the coast evolution trends, is affected by interventions taking place on the coast that modify its profile.

Basing on the SICELL dataset a number of analysis are possible at different scales: local (cells), wide area (macrocell), whole coastal system.

The chart in figure below highlights that about 55 km of coastal stretches are in critical conditions, of which 32,9 km in erosion (23,5%) and 22,7 in precarious balance (16%). Percentages are calculated on the total extension of littoral cells system (140 km). In the 2000-2006 period, 3 million up to total 3,5 millions of m^3 of sand were brought for nourishment on 45 km of littoral extension, stretches protected by hard defense works (data of the 2007-2011 period confirms this trend).



ASPE classification of the 7 macrocells based on the classification of the 118 cells

Other possible kinds of analysis refers to volumes withdrawn by each cell, grouping by cell typology and helps in identifying further cells potentially suitable for sand withdrawals. Thus, 18 cells with accreting beaches, of which 12 already used and 6 potentially suitable for sand withdrawal have been identified, with estimated volumes.

As well as 7 cells corresponding to harbour mouths, 5 already used and 2 potentially suitable, and 17 cells corresponding to river and channel mouths, 9 already used and 8 potentially suitable. It must be underlined that the potential suitability of cells is an indication not sufficient by itself to start the exploitation. Specific assesments shall be carried out considering the several aspects of local conditions.

The SICELL finds applications in:

- Littoral accumulations management plans;
- Sediments management of harbour mouths;
- Coastal protection plans and intervention programs;
- Sea storm damages recording (volumes eroded from the beaches, damages to the existing structures).

The SICELL construction operation has meant the capitalization of knowledge and experiences ripened by several regional structures and the reorganization of existent data with the specific aim of littorals and sediments management.

It supports the systematisation and optimisation of coastal protection interventions, coastal management and littoral sediments dredging and managing programmes and operations.

By its characteristics the SICELL is a tool:

- multi scale, that allows to rapidly switch analyses from local level (Cells), to sector level (Macrocells) and to the whole littoral system
- shared by regional Structures operating within knowledge development, planning, programming, managing, interventions implementation, in coastal protection field
- easy usable by other local stakeholders operating on the coast (Municipalities, Port Authorities, local operators)
- transferable, as a model, in other territorial context, national and European coastal regions.

Significative stretches and maps of relations between inetrventions and sources

For the purpose of a Regional Regulation (under formulation) on dredging and beach nourishment, “significant stretches” have been identified, which represents a merge of the cells identified within the SICELL, aimed at the management/movement of littoral sediments.

Once have been identified the cells and the significant stretches it was possible to define the elements that will compose the sediment management plan. The first part of the activities, now completed, concern the management of coastal sediments; have been identified the cells of 'normal' withdrawals, the target and the annual quantity of sediment moved (or ideally move if having the necessary funding), summarized in the following table.

Significative stretch 1

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
1	Bocca Tavollo	Harbour entrance	55			5,000
2	Dock di Cattolica	Dock	250			
3	Cattolica Sud	Cell with beach	1,230	S		8,000
4	Cattolica Nord	Cell with beach	615	A		
5	Foce Ventena	River mouth	40			
6	Colonia Navi	Cell with beach	260	P	3,000	
7	Foce Conca	River mouth	175	A		2,000
8	Porto Verde Sud	Cell with beach	65	E	2,000	
9	Canale Porto Verde	Harbour entrance	40			
10	Porto Verde Nord	Cell with beach	165	P	2,000	
11	Porto Verde Scogliera Radente	Cell with beach	220	E	5,000	
12	Misano Pennelli	Cell with beach	1,680	E	15,000	
13	Misano Scogliere	Cell with beach	755	A		8,000
			5,550		**27,000**	**23,000**

Needs: 27,000 m^3/year
For the alimentation of cells 6, 8, 10, 11, 12

Available withdrawals m^3/year from:
Cell 1: 5,000 m^3/year
Cell 3: 8,000 m^3/year
Cell 7: 2,000 m^3/year
Cell 13: 8,000 m^3/year
tot 23,000 m^3/year

Significative stretch 2

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
14	Riccione Sud	Cell with beach	1,000	E	10 - 15,000	
15	Riccione Centro	Cell with beach	1,850	P	10 - 15,000	
16	Riccione Porto	Cell with beach	570	A		
17	Dock di Riccione Sud	Dock	50			
18	Riccione Porto Canale	Harbour entrance	25			
19	Dock di Riccione Nord	Dock	60			
20	Riccione Alba Sud	Cell with beach	840	E	10,000	20,000
21	Riccione Alba Nord	Cell with beach	1,250	A		
			5,645		**30-40,000**	**20,000**

Needs: 30,000-40,000 m^3/year
10,000 mc/year for the alimentation of cell 20
20,000-30,000 mc/year for the alimentation of cells 14 and 15

Available withdrawals m^3/year from:
Cell 18: 20,000 m^3/year

Significative stretch 3

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
22	Foce Marano	River mouth	45			
23	Fogliano Marina	Cell with beach	610	S		
24	Miramare	Cell with beach	6,190	A		8,000
25	Rimini Centro	Cell with beach	1,350	A		
26	Rimini Porto Canale	Harbour entrance	70			
			8,265			

Available withdrawals m^3/year from:
Cell 24: 8,000 m^3/year (from beach clearing)

Significative stretch 4

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
27	Dock di Rimini	Dock	425			
28	San Giuliano	Cell with beach	450	E		
29	Deviatore Marecchia	River mouth	150			
30	Rivabella	Cell with beach	1,660	A		10,000
31	Viserba Zona Sud Sortie	Cell with beach	630	A		
32	Viserba Sud	Cell with beach	520	A	5,000 ?	
33	Canale dei Mulini	Draining channel	30			
34	Viserba Nord	Cell with beach	465	A	5,000 ?	
35	Viserbella	Cell with beach	1,200	S		
36	Torre Pedrera	Cell with beach	1,960	S	3,000 ?	
37	Igea Marina Sud	Cell with beach	515	E	7,000	
38	Igea Marina Zona Sperimentale	Cell with beach	825	E		
39	Igea Marina	Cell with beach	2,630	S	30,000	8,000
			11,460			

Needs: 50,000 m^3/year
10,000 mc/year for the alimentation of cells 32 e 34
10,000 mc/year for the alimentation of cells 36 and 37
30,000 mc/year for the alimentation of cell 39

Available withdrawals m^3/year from:
Cell 30: 10,000 m^3/year
Cell 39: 8,000 m^3/year
Tot 18,000 m^3/year

Significative stretch 5

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
40	Foce Uso	River mouth	40			
41	Bellaria	Cell with beach	2,690	P	10,000	8,000
42	San Mauro	Cell with beach	700	P		
43	Savignano	Cell with beach	155	P	10,000	
44	Foce Rubicone	River mouth	160			
45	Gatteo a Mare	Cell with beach	700	P	12,000	2,500
46	Villamarina	Cell with beach	880	P	13,000	5,000
47	Valverde	Cell with beach	1,750	P	15,000	2,500
48	Cesenatico	Cell with beach	2,015	A		3,000
49	Porto Canale Cesenatico	Harbour entrance	55			
			9,145		**60,000**	**21,000**

Needs: 60,000 m^3/year
10,000 mc/year for the alimentation of cell 41
10,000 mc/year for the alimentation of cell 43 (from quarry)
40,000 mc/year for the alimentation of cells 45, 46 and 47

Available withdrawals m^3/year from:

Cell 41:	8,000 m^3/year
Cells 45, 46, 47:	10,000 m^3/year (with Scraper, inside the cell)
Cell 48:	3,000 m^3/year
Tot	**21,000 m^3/year**

Significative stretch 6

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
50	Cesenatico Ponente	Cell with beach	825	E	16,000	3,000
51	Cesenatico Colonie	Cell with beach	775	E	20 - 30,000	5,000
52	Cesenatico Campeggio Zadina	Cell with beach	500	A		2,500
53	Canale Tagliata	Draining channel	10			2,500
54	Zadina Tagliata	Cell with beach	1,000	P	5,000	
55	Cervia	Cell with beach	4,420	S		
			7,530		**41 - 51,000**	**13,000**

Needs: 41,000 – 51,000 m^3/year
16,000 m^3/year for the alimentation of cell 50
20,000-30,000 m^3/year for the alimentation of cell 51
5,000 m^3/year for the alimentation of cell 54

Available withdrawals m^3/year from:
Cell 50: 3,000 m^3/year (with Scraper, inside the cell)
Cell 51: 5,000 m^3/year (with Scraper, inside the cell)
Cells 52 and 53: 5,000 m^3/year (with Scraper, inside the cell)
Tot **21,000 m^3/year**

Significative stretch 7

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
56	Dock di Cervia	Dock	165			
57	Porto Canale di Cervia	Harbour entrance	40			10,000
58	Milano Marittima	Cell with beach	1,365	S		15,000
59	Canalino delle Saline	Draining channel	30			
60	Milano Marittima Nord	Cell with beach	1,685	P	10 - 15,000	
61	Milano Marittima Colonie	Cell with beach	540	E	10 - 15,000	
62	Canale di Via Cupa	Draining channel	20			
63	Lido di Savio	Cell with beach	2,070	S	10,000 ?	10,000
64	Foce Savio	River mouth	265			15,000
			6,180		**30 - 40,000**	**50,000**

Needs: 30,000 – 40,000 m^3/year
20,000-30,000 m^3/year for the alimentation of cells 60 and 61
10,000 m^3/year for the alimentation of cell 63

Available withdrawals m^3/year from:
Cell 57: 10,000 m^3/year
Cell 58: 15,000 m^3/year
Cell 63: 10,000 m^3/year (with Scraper, inside the cell)
Cell 64: 15,000 m^3/year
Tot **50,000 m^3/year**

Significative stretch 8

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
65	Lido di Classe	Cell with beach	1,220	S		
66	Lido di Classe Nord	Cell with beach	580	S	20 - 30,000	
67	Bevano Sud	Cell with beach	1,000	P		
68	Bevano Centro Sud	Cell with beach	1,900	S		
69	Foce Bevano	River mouth	110			
70	Bevano Centro Nord	Cell with beach	1,300	S		
71	Bevano Nord	Cell with beach	1,000	E	20 - 30,000	
72	Lido di Dante	Cell with beach	605	E	10,000	
73	Sud Foce Fiumi Uniti	Cell with beach	600	E	10,000	
74	Foce Fiumi Uniti	River mouth	270			10,000
			8,585		**60 - 80,000**	**10,000**

Needs: 60,000 – 80,000 m^3/year
20,000-30,000 m^3/year for the alimentation of cells 66 (recharge point) and 67
40,000-50,000 m^3/year for the alimentation of cells 71, 72 and 73

Available withdrawals m^3/year from:
Cell 74: 10,000 m^3/year
Tot 10,000 m^3/year

Significative stretch 9

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
75	Nord Foce Fiumi Uniti	Cell without beach	360	E	10,000	
76	Lido Adriano	Cell with beach	2,560	E	10,000	
77	Punta Marina	Cell with beach	3,730	E	40,000	4,000
78	Punta Marina Nord	Cell with beach	865	S	20 - 30,000	
79	Marina di Ravenna	Cell with beach	3,000	A		20,000
			10,515		**80-90,000**	**24,000**

Porto di Ravenna

80	Porto di Ravenna	Harbour entrance	1,230			(50,000)

Needs: 80,000 – 90,000 m^3/year
20,000 m^3/year for the alimentation of cells 75 and 76
40,000 m^3/year for the alimentation of cell 77
20,000-30,000 m^3/year for the alimentation of cell 78

Available withdrawals mc/year from:
Cell 77: 4,000 m^3/year (with Scraper, inside the cell)
Cell 79: 20,000 m^3/year
Cell 80: 50,000 m^3/year
Tot 74,000 m^3/year

Significative stretch 10

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
81	Porto Corsini	Cell with beach	1,000	A		20,000
82	Marina Romea	Cell with beach	1,300	A		
83	Marina Romea Nord	Cell with beach	945	E	10 - 20,000	
84	Foce Lamone	River mouth	140			2,000
85	Foce Lamone-Casal Borsetti	Cell with beach	2,110	E	40,000	
86	Casal Borsetti Sud	Cell with beach	835	S		
87	Canale Destra Reno	Draining channel	30			
88	Casal Borsetti Nord	Cell with beach	520	E	10,000	
89	Casal Borsetti Fio 82	Cell with beach	630	A		
90	Poligono Militare	Cell without beach	2,500	P		
			10,010		**60 - 70,000**	**22,000**

Needs: 60,000 – 70,000 m^3/year
10,000-20,000 m^3/year for the alimentation of cell 83
40,000 m^3/year for the alimentation of cell 85
10,000 m^3/year for the alimentation of cell 88

Available withdrawals m^3/year from:
Cell 81: 20,000 m^3/year
Cell 84: 2,000 m^3/year
Tot 22,000 m^3/year

Significative stretch 11

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
91	Poligono Militare Nord	Cell with beach	1,100	E	10,000	
92	Foce Reno	River mouth	235			
93	Nord Foce Reno	Cell with beach	2,000	S		
94	Foce Gobbino Sud	Cell with beach	860	E	10,000	
95	Foce Gobbino	Draining channel	100	A		
96	Foce Gobbino – Bagno Giamaica	Cell with beach	1,575	E	10 - 15,000	
97	Lido di Spina Sud	Cell with beach	900	E	10 - 15,000	
98	Lido di Spina Nord	Cell with beach	2,070	A		
99	Foce Logonovo	Draining channel	200			40,000
100	Lido degli Estensi	Cell with beach	1,540	A		(100,000)
			10,580		**40 - 50,000**	**40,000**

Needs: 40,000 – 50,000 m^3/year
10,000 m^3/year for the alimentation of cel 91
10,000 m^3/year for the alimentation of cell 94
20,000-30,000 m^3/year for the alimentation of cells 96 and 97

Available withdrawals m^3/year from:
Cell 99: 40,000 m^3/year
Cell 101: (100,000 m^3/year)
Tot 40,000 m^3/year

Significative stretch 12

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
101	Bocca Porto Garibaldi	Harbour entrance	110			50,000
102	Porto Garibaldi	Cell with beach	1,480	P	10,000	
103	Lido degli Scacchi	Cell with beach	2,500	P	10,000	
104	Lido di Pomposa	Cell with beach	2,240	E	15,000	
105	Lido delle Nazioni	Cell with beach	2,910	E	15,000	
			9,240		**50,000**	**50,000**

Needs: 50,000 m^3/year
for the alimentation of cells from 102 to 105

Available withdrawals m^3/year from:
Cell 101: 50,000 m^3/year
Tot 40,000 m^3/year

Significative stretch 13

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
106	Bocche del Bianco	Cell with beach	1,130	E		
107	Pineta di Volano	Cell without beach	1,600	P		
108	Volano Zona Pennelli	Cell with beach	990	E	15-20,000	
109	Volano	Cell with beach	1,750	P	15-20,000	
110	Scannone di Volano	Cell with beach	1,949	A		30,000
			7,419		**30-40,000**	**30,000**

Needs: 30- 40,000 m^3/year
for the alimentation of cells from 106 to 109

Available withdrawals m^3/year from:
Cell 110: 30,000 m^3/year
Tot 30,000 m^3/year

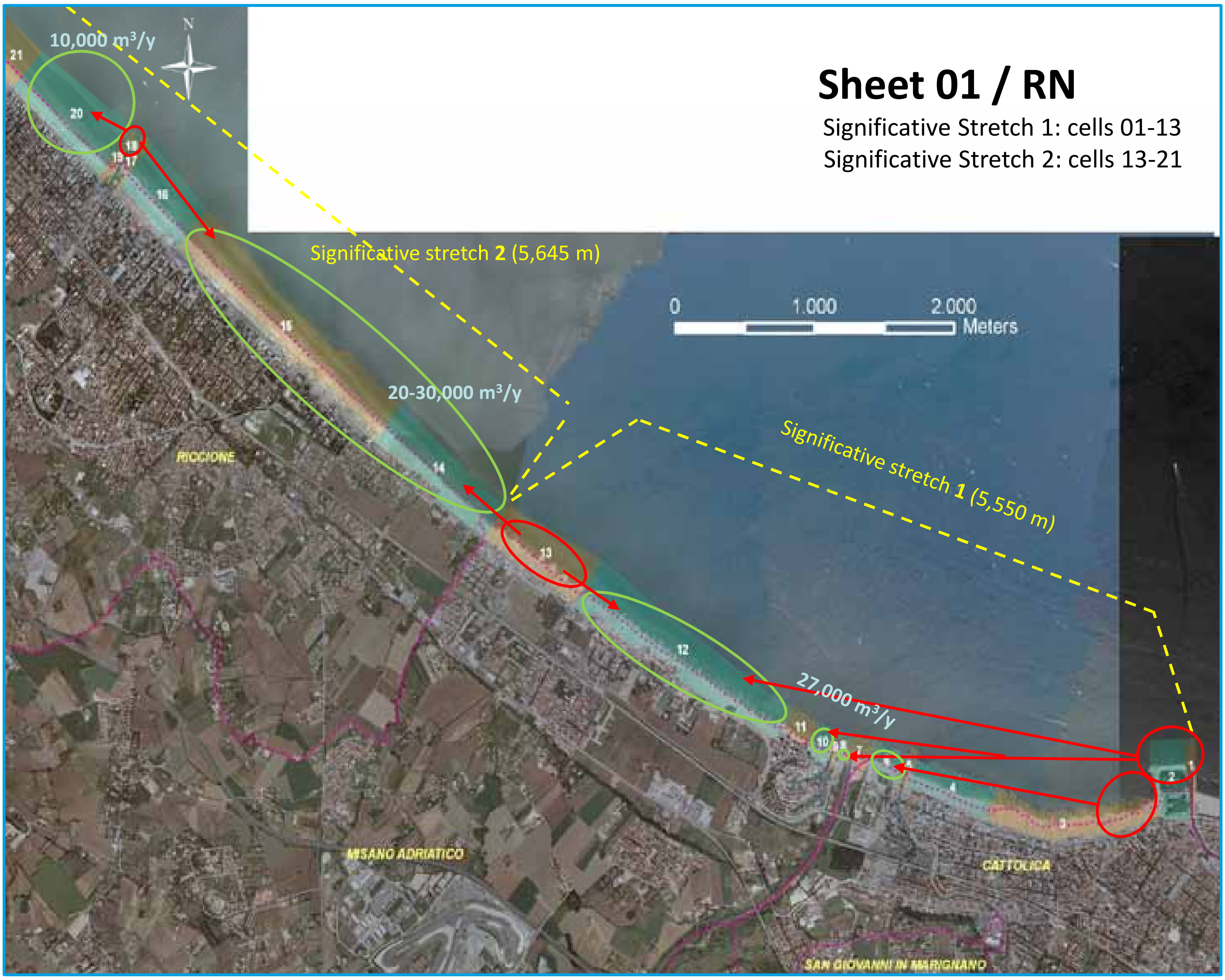
Significative stretch 14

Cell	Name	Tipology	Lenght(m)	ASPE	Sediment needs m^3/year	Sediments availability m^3/year
111	Foce Po di Volano	River mouth	1,880			
112	Po di Volano Area Naturale	Sacca	750			
113	Territorio del Comune di Goro	Sacca	10,000			
114	Po di Goro	Sacca	5,260			
115	Foce Po di Goro	River mouth	140			
116	Faro di Goro	Cell with beach	1,000	E	10-15,000	200,000
117	Scanno di Goro centro	Cell with beach	5,000	S		
118	Bocca Laguna	Lagoon mouth	4,625	A		250,000
			28,655		**10-15,000**	**450,000**

Needs: 10- 15,000 m^3/year
for the alimentation of cell 116

Available withdrawals m^3/year from:

Cell 116: 200,000 m^3/year
Cell 118 250,000 m^3/year
Tot 450,000 m^3/year



Example of a map representing the management of littoral accumulation based on SICELL and significative stretches subdivision of Emilia-Romagna coastal zone. Red circles represent the sources of littoral sediment while the green circles represent the nourishment areas

Program of interventions, including priorities, based on critical zones

The 2008 ARPA study points out the critical regional coast zones, where nourishment will have to take place over the next decade, to maintain their balance or at least to assure their improvement.

ted by erosion or precarious conditions, which jeopardise the assets and the activities present on the coast and the coastal hinterland (residential areas, tourist infrastructures, farmland and valuable natural assets).
The study highlights the critical stretches that are not protected by any hard coastal defense works,

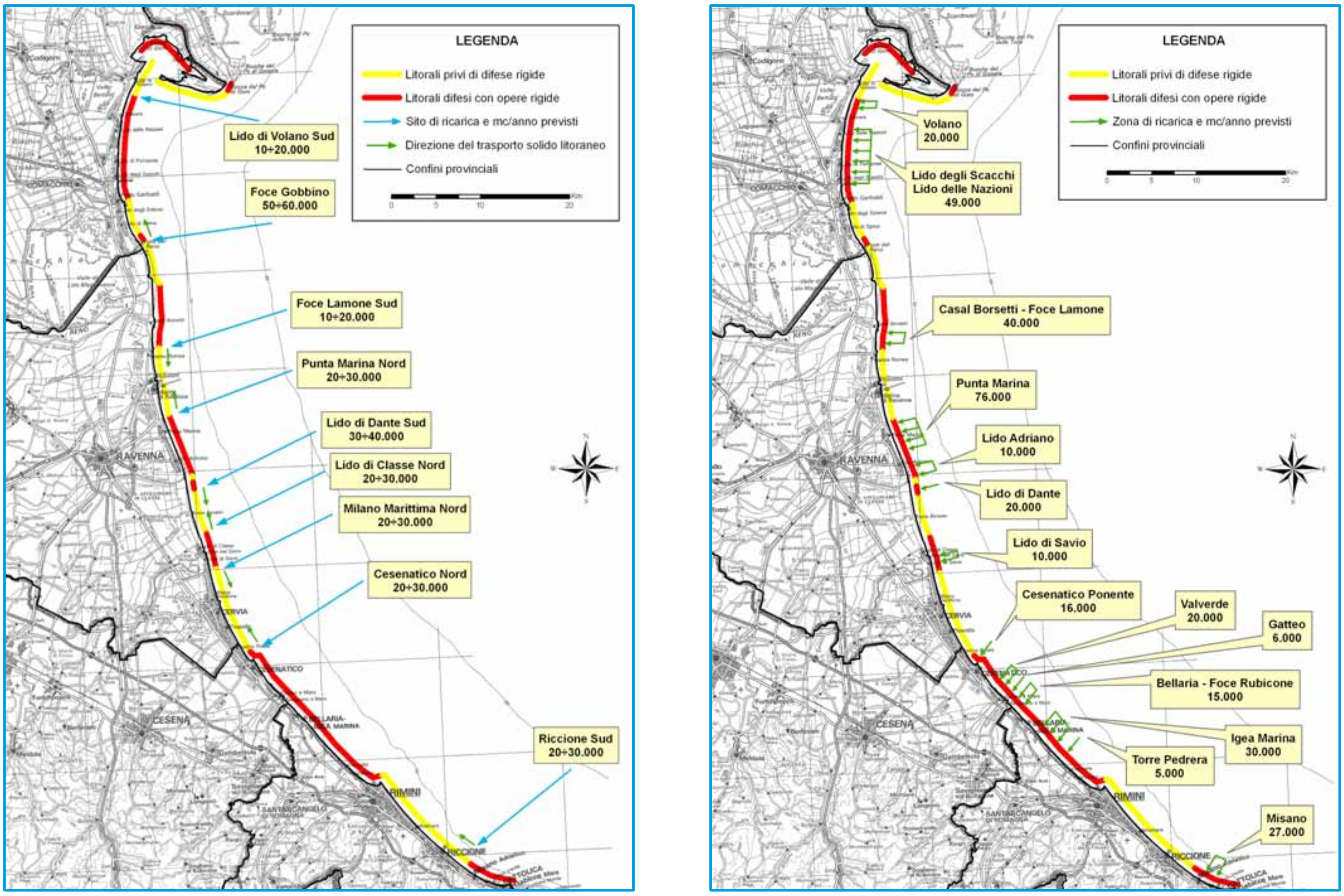


Figure 104 - Location on the critical Emilia-Romagna coastal zones identified by the 2008 ARPA study and estimate of the sand volume necessary to guarantee their balance. To the left, critical stretches without any hard defence structures and to the right critical stretches protected by hard defence structures (ARPA, 2008).

The identification of these beaches results from an in-depth study of the entire coastline and of all the aspects that characterise it, including both physical, economic and social ones. The analysis has been carried out at different detail levels in order to have an overall framework of the coastal system, necessary for an effective action management.
The study defines the critical beach stretches affec-

as against the protected ones and it estimates the volume of sand necessary to guarantee the balance over the next 10 years (Fig.4).
The most critical unprotected beaches generally are those placed downdrift a hard defence infrastructures, thus highly undernourished and vulnerable to erosion. The study identifies that they play a strategically important role, because they are at

the feeding points for long stretches of free down-drift beaches. Due to these natural dynamics, it is believed that for the future coast management it would be sufficient to periodically nourish 9 critical stretches to guarantee the balance of about 40 km long free beaches. The beaches to be taken into account are (fig.104):

- Riccione South
- Cesenatico North
- Milano Marittima North
- Lido di Classe North
- Lido di Dante South
- Punta Marinto North
- Foce Lamone South
- Foce Gobbino
- Lido di Volano.

As for beaches in critical conditions protected by hard defence structures (except for Misano Adriatico that is protected by a groin field and subject to severe erosion processes) the remaining stretches are protected by revetments. Hence, they are less vulnerable than the beaches belonging to the former category. Smaller quantities of sand at lower frequencies are required for these beaches (fig. 104):

- Misano Adriatico
- Torre Pedrera
- Igea Marina
- Bellaria – Foce Rubicone
- Gatteo
- Valverde
- Cesenatico West
- Lido di Savio
- Lido di Dante
- Lido Adriano
- Punta Marina
- Casal Borsetti-Foce Lamone
- Lido degli Scacchi and Lido delle Nazioni
- Volano.

According to the 2008 ARPA study, Reno river mouth, Foce Fiumi Uniti and Misano Adriatico are the most severely affected beaches, which would require nourishment interventions.

The retreat process of the cuspidate delta of the Reno river is intermittent and century-old. Between 1982 and 2006 75 hectares of land have been lost with a 200 m coastline retreat, close to the 5 km long stretch between the river mouth and the first Lido di Spina bathing establishments. During the 80s, the area South of the Foce del Reno (river mouth) was a protected by revetments. These works are subject to continuous damage, and are often overwashed by the sea, thus flooding the whole surrounding area close to the military firing ground. To the North of the Foce del Reno (river mouth) the only works that have been built are 1800 m long Longard tubes close to the Gobbino canal, dating from the early 90s and excessively swept away by the sea.

The Foce Fiumi Uniti area became subject to erosion starting from the first half of the 20th century, but only during the 70s the phenomenon gave rise to concerns when to the South and to the North the Lido Adriano and Lido di Dante bathing establishments were built. Starting from those years a complex system of hard defence structures and several beach nourishment interventions were carried out. The area is undergoing continuous deterioration since it lacks the river sediments transferred and is subject to a severe subsidence rate (19 mm/year) due to the intense exploitation of a natural gas deposit (Angela-Angelina platform).

The Misano Adriatico beach requires high management costs, because it is subject to a severe erosion of the backshore and shoreface. The Conca river no longer transports coarse sediments to the sea due to the building of a dam, a few kilometres away from the coast. The originally pebbly beach in the first stretch to the South is now sandy also due to tourist operator needs. Over the past few years, this beach has been protected by groins and sand nourishment, but after a short time sand tends to migrate to the sea bottom, between 3 and 4 m depth, and to the North.

Analysis and remodulation proposals for coastal defence works

The first Emilia-Romagna coastal protection structures were built in Viserba in 1914. Yet, no visible traces remain of these transverse groynes.

The first 3 shore-parallel emerged breakwaters da-

ting from the early 1930s are still in place. They were built to protect the first stretch of beach just north of Porto Garibaldi port.
During the second half of the 20th century several types of works were tested and built to combat increasingly more intense erosion phenomena. The shore-parallel emerged breakwaters are the most typical example of artificial reefs stretching along an almost 40 km long coastline.
Since 1995 the Emilia-Romagna Regional Authority has opted for low crest structures at the mean sea level to reduce the high landscape and environmental impact due to these works.
Between 1995 and 2006, 4 significant defense works were built: 3 about 800 m long structures each (Igea Marina, Cesenatico Ponente and Lido di Dante) and one 3,800 m long reef (Punta Marina).
Annual surveys were carried out between 2002 and 2009 by Arpa on all 4 works, and especially in Igea Marina. They pointed out that low crest structures, compared to the shore-parallel emerged breakwaters led to a substantial improvement in the water and seabed quality in the bathing area; whereas, they proved to be much less effective in damping wave motion, especially in conjunction with scirocco storm surges associated with the high water phenomenon, which certainly is the most harmful event (see chap. 9 “State of the shoreline in 2007,” Preti et al).
The environmental impact reduction, underlying the promotion of low-crested cliffs, is nevertheless not always secured in terms of landscape value and water quality when referred to the model applied in a few sites, such as Lido di Dante and Punta Marina. Here transverse partitions were built at 350 m intervals from each other. Starting from the backshore they reach the longitudinal breakwaters, to reduce the transport of sand along the coast. In these cases, the result has been the transformation of the bathing area into pools closed on 3 sides by ripraps. Moreover, in all four cases it was observed that low crest structures do not prevent the downdrift beach erosion, as in the case of shore-parallel breakwaters.
It was therefore evident that hard defense structures, including both low crest and shore-parallel breakwaters, are undoubtedly not the ideal solution to combat erosion. Such an evidence was confirmed by the SICELL data related to the large amount of sediment carried to the beaches directly affected and adjacent to protected stretches of the coast for sand nourishment purposes, over the last ten years. Other determining erosion factors have been identified, such as the limited supply of solid sediments from rivers and severe subsidence along the coastal areas (i.e. sinking of the earth’s surface), against which hard defense works cannot do much. However, hard defense works are still a harsh reality that has to be addressed and managed by finding new solutions (reshaping, changes, selective dismantling of breakwaters, etc..), in order to achieve a more sustainable coast management, along with a reduction of sediment supply needed to stop erosion over time.
In this context and with these objectives in mind a few studies have been performed on some of the most problematic sites along the regional coastline. A few solutions that should be implemented in the short and medium term have been suggested and reported here below.

Misano Adriatico

The 3,200 m long Misano coast is fully protected by 4 different types of works:
- Submerged breakwaters enclosed by 2 side groynes along the 150 m stretch to the south.
- revetments along the 200 m long stretch in front of Portoverde skyscrapers;
- transverse groynes along the 1600 m long stretch in front of the centre of Misano;
- detached shore-parallel emerged breakwaters protecting the 700 metre long stretch along to the border with Riccione.

No serious marine ingression risks have been recorded in Misano, but backshore and seabed erosion as well tourism pressure on the coast are phenomena that should be taken seriously into account.
Furthermore, over the decades, the nature of the beach has changed, at least in the first 1 km long stretch to the south. The beach was originally made up of pebbles, whereas now it is mostly sandy,

especially due to the beach resort managers' needs. Between 1983 and 2007, 876,000 m^3 of sand were carried to the Misano beach, particularly along the 1600 m long stretch protected by groynes (fig. 105). The 2002-2005 monitoring of the first submarine sand nourishment intervention showed that already in the first year, 40% of the nourished sand had drifted away from the backshore towards the seabed, at a depth between 3 and 4 metres.

Figure 105. Misano Adriatico: 1600 m long stretch defended by 26 groynes. Between 1983 and 2007, 876,000 m^3 of sand were carried to this stretch of coast.

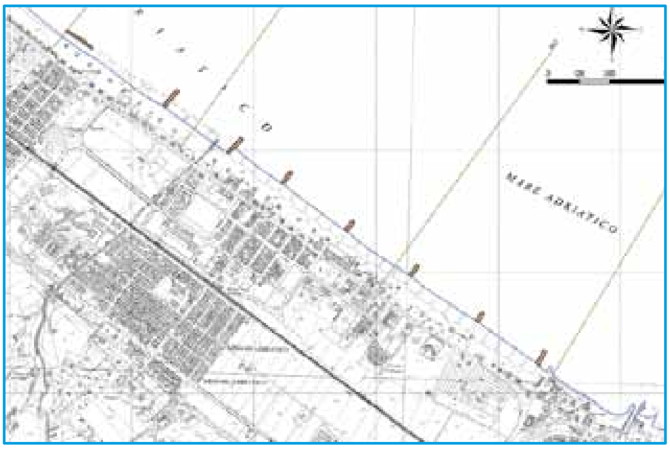


Figure 106. Misano Adriatico remodulation project proposal

In 2006, faced with these problems and with the high shoreline maintenance costs, the Regional Authority entrusted ARPA Ingegneria Ambientale (Environmental Engineering Department) with the task to conduct a thorough study of the Misano and Riccione shores, in order to identify new design solutions that would lead to a reduction in management costs.

According to a study carried out by ARPA, the best solution that was identified was a 35 m extension with 6 groynes, the construction of a seventh groyne close to the breakwater area, accretion through beach nourishment up to the head of the current 19 short groynes, the dismantling of 6 breakwaters and a further 50 m long extension of the northern breakwater. A 5,000,000 euro structural regeneration cost was estimated in Misano, as outlined in figure 106, including the input of 275,000 m^3 of sand at a cost of 13 Euro/m^3. An approximately 45 m shoreline accretion should result from this action.

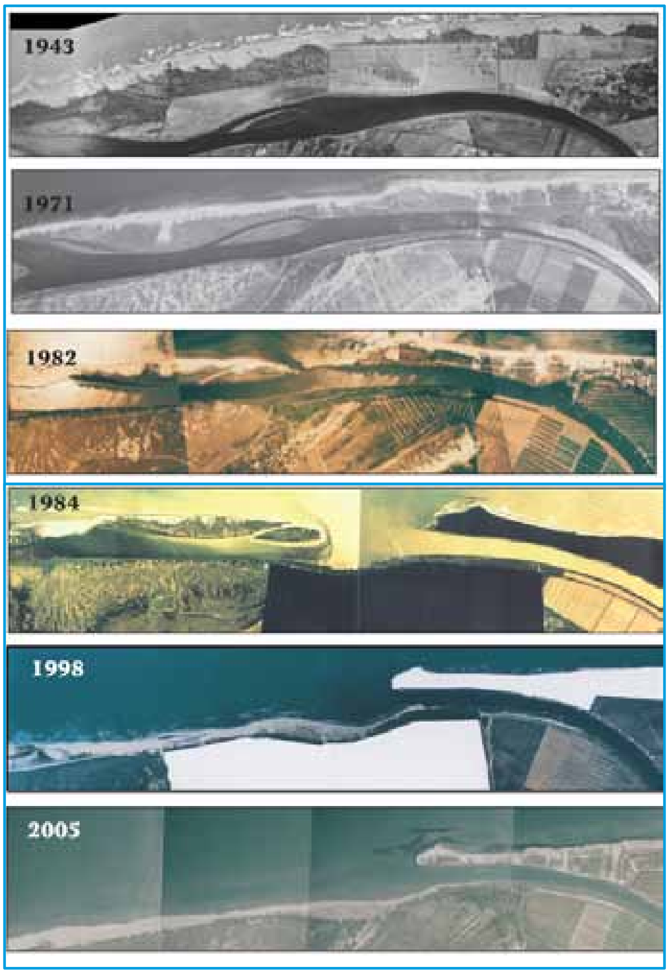


Figure 107 - Evolution of the Reno river mouth between 1943 and 2005. The 1943 photo was taken by the Royal Air Force and it was made available by the Geological, Seismic and Soil Survey.

Reno river mouth

The rapid evolution of the coastal area between 1943 and 2005 immediately stands out by observing the sequence of aerial photographs (fig. 107). The sea accretion south of the new Reno river mouth stopped between 1980 and 1984, following the construction of a 500 m long riprap by the Regional authority in liaison with the State Forestry Department and, further north, of a 4-km long rock armour consisting of an embankment made up of wire mesh armoured bitumen mattresses.

Figure 108. The remains of the defense works destroyed by sea along the first 500 m stretch south of the Reno river mouth.

Figure 109 - The riprap lining close to the military shooting range, along a 3 km long stretch, is subject to continuous collapses due to frequent sea overflows.

Over the past 10 years, the sea has completely dismantled this structure, towards the 500 m area to the north, and it has caused continuing damage in the remaining section shown in the picture (fig. 108 and 109).

The Ministry of Defence, which had fully funded the construction of this work, must now spend a considerable amount of money for its maintenance each year.

Nevertheless, during high intensity sea storms, the sea overflows this riprap and floods the entire shooting range area. As a result, on several occasions it has been necessary to evacuate the whole staff.

The sea water ingression up to the Romea state road, 2 km west, and up to the village of Casal Bor-

Figure 110. The Reno river mouth military shooting range area is located between a sea defense work and the ground embankment. It is therefore shaped like a “bucket” that is flooded every time a severe sea storm occurs.

setti, 2 km south, has so far been prevented by the two internal banks made respectively by the authority in charge of the military shooting range and by the owners of the bordering land (fig. 110).

The competent military authorities have therefore decided to reconstruct the entire riprap lining, this time no longer using bitumen mattresses but loose rocks.

At the same time they have applied for the necessary funding to the Ministry of Defense and have decided to contact the Arpa Sea-Coast Specialized Unit for the provision of technical and scientific support to the preliminary design. The final design will in fact be carried out by the 6th Infrastructure Department of the Army Corps of Engineers based in Bologna.

During 2011, the preliminary surveys were carried

out on land and at sea, while the Ministry of Defense has approved funding.
In 2012 the final design will be completed. Works are expected to start in late 2012 or early 2013.
The active costal area dynamics north of the new Reno river mouth has not been protected by any defense works except for a 1800 m long stretch north of the mouth of Channel Gobbino, whose defense structures are based on sand traps made of Longard tubes, executed in 1990.
These works have now been completely dismantled, and in recent years the sea has “moved” the beach toward the inland lagoons at a speed of 12 m/year. Overall, between 1982 and 2006, a 200 m peak of retreat and a total loss of about 75 ha of land were recorded along the 5 km long stretch between the Reno river mouth and the first beach establishments of Lido di Spina.
The underlying causes of this intense retreat process are the lack of sand input coming from the Reno river and a more than 1 cm/year subsidence. Given the high environmental quality of this area, in the short term an urgent action will be needed to slow down sea accretion, preferably through beach nourishment.

Cesenatico ponente

The Cesenatico coastline is split into 2 sections by the two parallel jetties of the canal harbor. The southern part is fully protected by shore-parallel emerged breakwaters. Hence, no specific actions are envisaged, apart from sand nourishment on the stretch of beach close to Gatteo. To the north, semi-submerged breakwaters were built in Ravenna in 2002 by the Civil Engineering Maritime Works authority to protect the first 800 m long stretch of the beach (fig. 111).
This coastal stretch has been undergoing severe erosion since the early 1970s. In 1978 it was protected by Longard tubes and again in 1983 it was further supplied with sand nourishment and submerged barriers with sand bags. Also in the 1970s, 3 small rock groynes were built 700 m north of the jetty.
Landwards, to the furthest northern end of the protected area, 800 m off the canal harbor, a massive groyne made of boulders extends towards the sea for about 70 m. It is a continuous barrier, with only a lower stretch close to the jetty and it is situated about 250 m from the shoreline, while the berm width is about 12 m. The work was accomplished with approximately 150,000 m^3 of sand and no structural problems were recorded 10 years later, while the beach has been maintained in satisfactory conditions thanks to small sand nourishment interventions.

Figure 111. The semi-submerged breakwaters north of Cesenatico jetty harbour (March 2007).

The most serious problem is instead the severe erosion north of the rock groynes, along a 400 m long stretch of beach. The first 800 m north of the port, in fact, has shifted the point of erosion just north of the defense works.
In 2008 the Municipality asked the Regional Authority to assess the feasibility of the removal of the rock groyne, considered to be the root cause of erosion. The Regional Authority entrusted the Sea and Coast Unit of Arpa with the task to investigate the problem. It concluded, through modeling simulation techniques, that severe erosion processes are not attributable to the presence of groynes, but to the lack of natural sand supply along that stretch of coast.
A south-north longshore current is recorded between Cattolica and Cervia. Furthermore, the 21 km long coastline south of this groyne is characterized by the presence of cliffs and several jetties. Hence,

a very small quantity of sand gets to the west, to Cesenatico ponente.
The area north of the groyne must therefore be periodically fed with artificial sand nourishment. As for the groyne, given its considerable size, it can certainly be shortened or lowered, but its removal will not solve the erosion problem further north.

Igea Marina

The Bellaria-Igea Marina coastline extends for 6.7 km and is fully protected by shore-parallel emerged breakwaters built in the 1960s. A south-north longshore current can be recorded also in this stretch of the coast. Since the 1980s, due to subsidence and to the lack of natural sediments supply from the south, this stretch of coast, although protected by a long series of breakwaters, is severely affected by erosion. In 2000, since the beach along a stretch of over 700 m of the Igea coastline was fully eroded and several inland facilities were flooded during sea storms, beach nourishment using underwater sand was therefore envisaged.

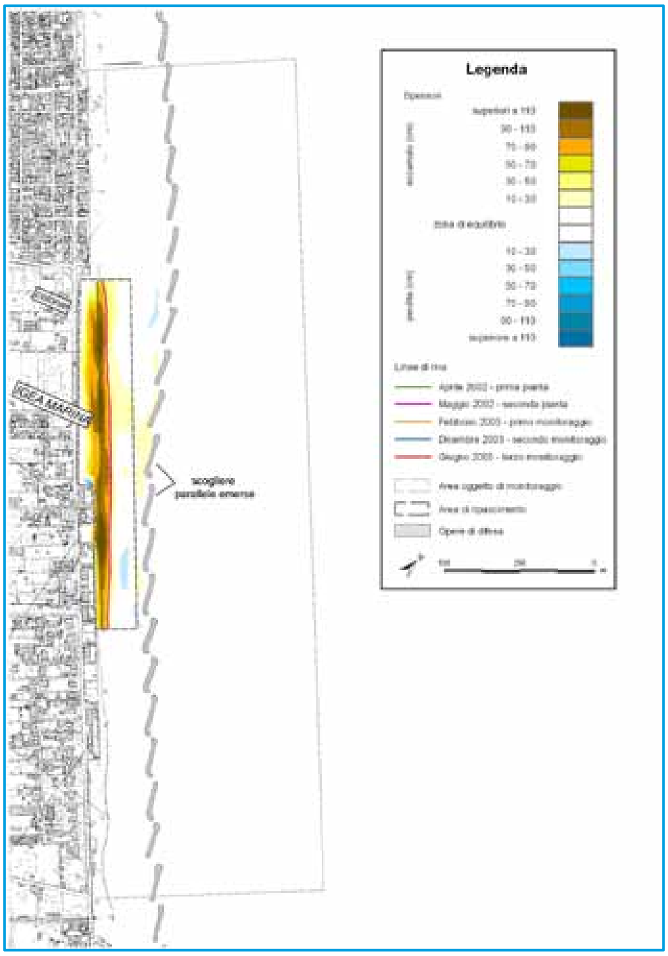


Figure 112. Igea Marina: Map of accumulation and loss of material resulting from the comparison between surveys (April 2002 and May 2002).

In 2002 a beach nourishment intervention with 65,200 m^3 of underwater sand was carried out on a 1,125 m long (58 m^3/m), stretch of beach located between the Colonie (summer camp) and the Rio Pircio area, with a consequent 30-35 m accretion of the coastline (fig. 112).
In 2002, at the time of this intervention, however, a feasibility study had already been started for the implementation of an experimental project in the area aimed at reducing the impact of breakwaters on the seabed and on the bathing water quality.
In 2003 this study led to the transformation of 6 shore-parallel emerged detached breakwaters into a single crest breakwater at mean sea level and to the construction of two partially emerged and partially submerged rock groynes, closing the experimental barrier having a 800 m length.
The Regional Authority entrusted ARPA with the task to follow up the implementation of the project through specific monitoring campaigns, since the landscape and environmental enhancement of several tens of kilometers of beaches protected by detached breakwaters was involved.
The topobathymetric survey began in October 2001 with a first detailed survey. Between 2003 and 2005, again on behalf of the Regional Authority, ARPA Ingegneria Ambientale (the Environmental Engineering Department) conducted 4 major experimental survey campaigns.
In 2005 ARPA Ingegneria Ambientale and DISTART - University of Bologna were entrusted by the Regional Authority with the task to carry out coordinated and complementary monitoring campaigns on the same experimental project in Igea Marina.
It can be stated that the stretch of coastline where the experimental project of Igea Marina is centered can be regarded as a full scale physical model, since between 2001 and 2009 it became the object of as many as 11 topobathymetric survey campaigns and of many other monitoring activities.

Monitoring has allowed to highlight a high success rate of the intervention: the seabed quality has improved and the lower visual impact of barriers has been substantially appreciated by the interviewed tour operators. The water quality proved to be very good both before and after works.
In addition to these favourable aspects, it could be observed that the transformation of emerged barriers into low crest structures, apart from a minor visual impact, provides a lower degree of protection of the beach and thus it theoretically requires a higher maintenance cost linked to a higher annual volume of sand nourishment necessary to ensure the maintenance of the shoreline.
The intervention is anyway considered to be replicable in similar settings.
Based on the results obtained in Igea and given the vulnerability of the coast between Torre Pedrera and Viserbella, 2-3 km further south, where in the first decade of 2000 it was necessary to carry out beach nourishment interventions with the supply of sand from the outside, it was decided to implement a similar project as the one carried out in Igea also along this stretch of coast.

Optimal beach width

The Emilia-Romagna coast extends for 130 km and is entirely made up of low sandy coast.
The loss of dunes, the settlement of bathing establishments, the sinking of the earth's surface due to subsidence, the presence of roads and hotels near the beach and the presence of hard defense works along more than half of the waterfront, have undoubtedly changed the typical features of a low plain environment.
Under these conditions, the idea of rebuilding the beach with characteristics similar to the original ones, runs the risk of being only a purely theoretical exercise.
The fact remains though that a wide beach with dunes at the back is not only the ideal place to develop sea tourism, but it is also the best protection system from sea storms, even more so in Emilia-Romagna, where in the North Central part, more than 170,000 hectares of land in the backshore, are located below sea level.
Taking into account all the aspects mentioned above and the dynamics related to longshore sediment transport, in Chapter 12 of the 1996 Coast Plan, 3 coastal management scenarios have been developed:

1. no program;
2. minimum program;
3. maximum program;

The implementation of the latter was based on the assumption of rebuilding the beach by means of underwater sand.
A 50 m ideal beach width was defined for beaches with no seaside tourism and a 100 m width for seaside resorts. 16,000,0000 m^3 of sand supply requirements were calculated. Operation and maintenance economic costs were envisaged to amount to 15 million euros a year over the first 10 years.
However, considering the limited financial resources available, it can be assumed that a minimum 60-70 m length should be envisaged for seaside resort beaches, also in view of the wave motion damping needs, particularly along beaches without any defense works.
Regarding the inland surface level, the problem is even more complex due to the presence of seaside resort facilities preventing the rise of the sandy shore for tens of kilometers along coastline. The most interesting example in this regard is the Ravenna coast, specifically along the shore 3 km south and 3 km north of the harbour.
The ideal backshore level ranges between 150 and 200 cm above the sea level. As reported by the 1996 Coast Plan, the maximum height that can be reached by the sea during the most severe sea storms is 220 cm.
Yet, even in this case, a distinction should be made between beaches protected by shore-parallel emerged breakwaters and unprotected beaches and their width should also be taken into account.
Tests carried out on a mathematical model applied to the Venice Lido coastline have shown that a 30 m wide beach has a damping effect of the wave motion equal to that of submerged breakwaters. Shore-parallel coastal defence structures have been constructed at a height of more than 3 m above

mean sea level, based on the experience acquired during scirocco storm surges. Shore-parallel revetment breakwaters were built 30 years ago in front of the Pineta di Volano and Goro coastline.
Finally, the beach height is no longer sufficient to contain storm surges due to subsidence. It will be very difficult to find a permanent solution to this problem. So far, the problem has been addressed by building sand embankments in October that are then dismantled in April.

Policies encouraging river solid transport

In the 1980s, the Emilia-Romagna Regional Authority banned the excavation of sand and gravel from river beds (Resolution of the Regional Government n.1300 dated 24 June 1982). The resolution was intended to improve the river sediment transport, which is useful in view of the natural nourishment of beaches, which had severely declined over the previous decades. During the following years the law was gradually applied to the regional rivers, ultimately leading to the banning of excavations also in the national river Po basin, by means of a specific provision issued by the Po river authority in 1990.
The progressive reduction of river sediment transport, along with the progress of subsidence have been and still are the leading cause of beach erosion in the Emilia-Romagna Region. The 1981 Coastal Plan study showed that sediment transport decreased by 3-4 times in the late 1970s compared to the 1940s. At that time, river basins had not yet suffered the heavy human impact that would occur over the subsequent decades (i.e. waterways management, slope erosion control, land-use changes, river bed excavations, etc.).
The study that was performed 15 years later, during the drafting of the 1996 Costal Plan enabled to record the recovery of sediment transport towards the sea by some rivers, with clear evidence to be seen on the Cattolica beach, north of the Marecchia river mouth and along the Scanno di Goro, and to estimate the trend of the phenomenon over time.
The banning of excavations in river beds, river bed cleaning and management operations, during the 1980s and '90s, were the main actions that were undertaken. Their effectiveness has unfortunately not yet emerged as expected, due to several reasons:

- the progression of uncultivated and wooded land along mountain slopes;
- the formation of alluvial mounds upstream of several transverse water drainage works along river beds;
- reduced and different rainfall rates;
- inert material digging authorized by competent authorities for hydraulic security reasons;
- sinking of the land surface in plains along rivers, due to subsidence.

Although solid sediment transport experimental measurements show a sediment transport at the bottom close to zero, the findings deriving from topo-bathymetric surveys confirm a few slightly positive elements, as also highlighted by the 2000 Coastline Report (ARPA 2002).
A few aggradation phenomena have been observed along the coastline behind the Cattolica breakwaters, north of the Marecchia river mouth up to Viserba (southern sector of the regional coastline) and north of the Savio river mouth (central sector). No such phenomena could be recorded at the Fiumi Uniti mouth (central sector), as slight improvements in sand supply are undermined by high subsidence rates in the area, and at the Lamone River mouth (northern-central sector). To the south, the beach, which is severely affected by erosion, has made the object of sand nourishment projects over the last two years.
In relation to the causes listed above, it is not possible to influence rainfall trends due to undergoing climate change. Therefore, a few possible solutions can be found in policies aimed at increasing arable land (at the expense of currently uncultivated and slightly eroded land), at the removal of transverse works that have by now fulfilled the purpose for which they were built, at the downstream movement of material excavated for hydraulic safety reasons in the same river bed (preventing the launch onto the market of construction aggregates) and at the reduction of the anthropogenic component of subsidence resulting from the extraction of underground fluids (water and natural gas).

Actions aimed at the reduction of subsidence

The 1981 Coastal Plan and subsequent studies (1996, 2000, 2007) have also led to initiatives aimed at identifying and addressing the other main cause of coastal erosion: subsidence. Along the Emilia-Romagna coastal area, the degree of subsidence due to natural causes is of the order of a few millimeters per year, while the anthropogenic subsidence reached peak speeds of 50 mm/year in the 1940-1980 period. The established causes are the underground extraction of water and natural gas.
To reduce the subsidence rate and the vulnerability of coastal and inland areas to marine ingression, the Regional Authority has introduced a regulation limiting the extraction of groundwater and natural gas in coastal areas (Regional Council of Resolution no. 72/1983). During the 1980s and 1990s it developed major aqueduct works (Ridracoli Dam and Emilia Romagna Channel) to carry surface water for drinking and irrigation purposes to the coastal area and to limit the extraction of underground water.
Currently the regional coast sinks at a rate of about 10 mm per year on average, with peaks in the sinking rate ranging from 15 to 19 mm/year in some areas of the coast. It can be estimated that about 100 million m^3 of material was "taken away" by subsidence along the coast, from 1950 to 2005. Whereas, about 1 million m^3 of sediments would be required to restore the coastal level sunk due to subsidence recently occurred during the 1999-2005 period (EPA, 2008).
The set of regional strategies for the protection of the coastal territory, including those described above (beach nourishment, subsidence reduction, restoration of river sediment transport), is provided for by the Regional Council Resolution no.645/2005, for the approval of Guidelines for Integrated Coastal Zone Management.
In addition to regional strategies and policies, which have had positive results in combating the subsidence phenomenon, over the past few years, an experimental project was started for the injection of fluids in gas fields. As a matter of fact, by injecting sea water near a field, it is possible to increase pressure in layers by reducing the possible ongoing subsidence. In this regard, a Memorandum of Understanding was recently signed by the Regional Authority, the Provincial Authority and the Municipality of Ravenna, and Eni E&P division, for the implementation of an experimental project that envisages the injection of water into the "Angelina 1" well located in front of the beaches south of Ravenna. The aim is to monitor and maintain pressure of aquifers at production levels.
The Memorandum is the follow up of the agreement signed in 2002 and it aims at ensuring the sustainability of gas extraction by injecting layer and sea water during mining operations, in order to promote repressurization of aquifer levels, from which gas is extracted.
The Memorandum renewal derives from the interesting results obtained since the beginning of the trial -2003- which showed a general increase in underground pressure. So far up to 170 m^3/day of water have been injected into the gas field at a 3000-4000 depth in the course of the activities that have already been conducted.

Conclusions, capitalisation perspectives and networking

The COASTANCE project promotes an integrated vision of the coastal zone and of related erosion problems, submersion risk and adaptation needs to climate change. It implements an integrated approach on different aspects (coastal risk assessment, coastal management and protection, environmental impact assessment) and proposes soft options, as beach nourishment, together with new policies implementation to mitigate coastal risks and to adapt littorals to climate change effects.

Concrete and transferrable results and outputs coming from the project (ending March 2012) are:

1. **a model and tool for forecasting submersion risk** along the coast, based on a number of simple pa-rameters, that is to be made available and usable by a wide public through the web (user friendly web inter-face) – Deliverable Phase B Component 3;
2. **guidelines for developing alternative future scenarios** to assist decision making and planning processes in the Mediterranean coastal areas- Deliverable Phase A Component 3;
3. **a model to formulate coastal protection action plans and sediment management plans**, including ex-amples of plans formulated, during the project, by partner regions, together with a **data model and tool for coastal sediment management based on littoral cells (SICELL)** – present Deliverable Phase C Com-ponent 4;
4. **guidelines for environmental assessment** of coastal protection works, programs and management plans, based on EIA and SEA procedures – Deliverable Phase B Component 5;

The method to realise **risk maps** is based on a tool that allows to calculate in a specific area the sea level elevation under determined conditions considering basic data as sea-land topographic profile, highest land line, atmospheric pressure, wind speed, continental platform extension, depth closure of the beach, wave high and period, off-shore wave angle, tide effect, to be put in a simple and user-friendly interface. Different calculation models integrated in this tool provide each contribution in sea elevation (wave setup, storm surge – wind effect, storm surge – pressure effect, swash and run-up, tide, coastal defences, sea level rise by CC in a mid-long period) to evaluate the total sea level elevation on a specific area in those specific conditions.

The **guidelines for developing alternative future scenarios** are an innovative tool that allows exploring how coastal areas could develop in the future, using an integrative approach that combines quantitative and qualitative methods. This tool takes into consideration coastal hazards and climate change, as well as human interaction, as the process is based on participatory processes involving local stakeholders. The guidelines are composed by a 7-step methodology: compilation of environmental information (bio-physical and socio-economic data); analysis of the current situation and mainstream trends (demographic, economic, political, cultural or physical changes); identification of relevant stakeholders (by social networks' analysis); identification of key drivers (integrating spatial/statistical analysis and participatory methods); selection and construction of possible future scenarios (involving experts groups and stakeholders); creating narrative storylines engaging stakeholders; and extracting recommendations for better management of the coastal area studied. The method has been tested in a pilot site at the local level. Results indicate that scenarios are a powerful and ground-breaking tool for coastal management in the current context of climate change, and also a valuable instrument to create new mechanisms for public participation and governance in the coastal areas.

Concerning point 3) outputs and results, entailing the recommendations and strategic policy options of EUROSION initiative, COASTANCE designed an actions framework for the **protection, management and adaptation of coastal areas** in which alimentation with sediments of the littoral system and reduction of sediments losses from the sy-

stem are the two basic pillars. To support this framework a specific tool based on coastal stretches subdivision in littoral cells has been created (SICELL – littoral cells info and management system). The actions framework considers all the possible sources of sediments out and within the coastal system (off-shore, littoral, inland), good practices for beach sediments maintenance and reduction of sediments losses (by wind effects, beach cleaning operations, protecting winter levees, etc.), measures for subsidence reductions and for river solid transport enhancement. The SICELL geo data set, given known local coastal dynamics, morphology, previous interventions, erosion conditions, provide a list of critical stretch (to be put in a priority scale) in which specific actions and good practices must be undertaken. Moreover the SICELL provide a list of littoral sediments sources (harbour and river mouths, strongly accreting stretches, accumulations by hard defence works, etc.) and integrating volumes eventually needed by other sources (off-shore, inland), thus giving elements for an overall sediment management system.
Concerning point 4) COASTANCE designed specific **guidelines on environmental impacts studies** arrangement and evaluation as a support for EU PAs dealing with coastal works and plans with a special focus on sensitive and/or protected coastal areas. The COASTANCE EIA and SEA Guidelines have been developed according with the specific EU Directives (85/337/EEC and relative modifications in 1997 and 2003, and 2001/42/EC and the Guidelines of EUROSION initiative 2004). Within the COASTANCE guidelines have been developed specific matrixes, on the different environmental aspects, in order to support and drive the evaluation process of specific coastal protection works, programs and management plans.
Nevertheless the **mainstreaming process** started and the high level of transferability of the outputs and results of the project, there are obvious difficulties to obtain the expected returns and implementation within the end of the project itself. It arose clear then to the partners the need of capitalisation activities in order to complete the processes started, to put into value the results and outputs obtained within the project, to transfer it and possibly to give a concrete contribution to the Med regions community.
The willingness of project partners to undertake **capitalisation activities** is in this frame is driven by two main strands.
On one hand, the opportunity to proceed with a follow up of outputs and results in order to complete the mainstreaming process within the respective Administrations, to demonstrate its transferability and to en-hance the territorial cooperation on coastal protection, management and adaptation to climate change in the Med context.
On the other hand, to design a macro-project initiative in this field for the next financing period (2014-2020), together with other projects (Med Program and other Programs) focused on different sectors and aspects concerning the Med coastal zones (coastal protection and management, risk assessment, environment protection, governance, tourism, accessibility, urban development, energy, sustainable use of resources, fishery, navigation and harbour facilities, marine spatial planning) in order to give value not only to COASTANCE but also to other projects results dealing with coastal matters. Thus creating the condition for a strong partnership able to develop a concrete and integrated regional cooperation in the Med area.
With the aim to concretise these intents, the COASTANCE partnership, after a first capitalisation seminar organised by the JTS MED in Rome in June 2011, promoted and started the formation of a project cluster, named **FACECOAST** - "Face the challenge of climate change in the Med coastal zones" www.facecoast.eu - presented officially within the MED Capitalisation Day in Marseille the 30th of November 2011.
Today the cluster is composed, following the signature of a specific Memorandum of Understanding, by 8 projects from different EU programmes, covering quite all the aspects/sectors above mentioned. They are COASTANCE itself, MAREMED, SHIFT (MED programme), RESMAR, PERLA, TEP (CBC IT-F), THESEUS, MICORE (7FP). Other projects, covering other aspects/sectors, have been contacted and are evaluating their adhesion (SHAPE - CBC IPA Adria-

tic, PEGASO – 7FP, BLAST – INTERREG IV C North Sea).

The aim of the Cluster is to design and develop integrated actions at the Mediterranean scale (taking into ac-count the diverse aspects, sectors and policies affecting the coastal areas) inscribed in a wider Macro-project for the 2014-2020 period that will be formulated within a "capitalisation project", following the MED programme capitalisation initiative, in which to integrate and to put into value outputs and results obtained by the adhering projects.

Considering the number of partners being part of the different projects, this will produce a multiplier effect in terms of results transfer capabilities, mainstreaming possibilities and sustainability conditions, and will characterise the initiative with a high potential of innovation in the different fields/ sectors concerning governance, management and protection of the coastal areas.

In June 2011 the Commission adopted a proposal for the next multi-annual financial framework 2014-2020 – COM(2011)500. In this proposal the Commission decided that the cohesion policy should remain an essential element of the next financial package and underlined its pivotal role in delivering the Europe 2020 strategy. The ERDF shall contribute, among others, to the reinforcement of territorial cohesion and cooperation, with a particular focus on networking, cooperation and exchange of experience between regions, towns and relevant social, economic and environmental actors, and one of the investment priorities shall be on climate change adaptation, risk prevention and management.

In this frame, the concrete development of territorial cooperation on this topic in at the Mediterranean scale assumes a particular relevance.

Basing on the multidisciplinary and richness of skills of the adhering projects and partners, the FACECOAST cluster initiative intends to **enhance the territorial cooperation** in the Mediterranean maritime regions in terms of:

- strengthening of the mainstreaming process;
- widening the tools' test and transfer of outputs;
- sharing governance approaches to overcome the territorial fragmentation;
- exchange different approaches to involve policymakers;
- developing synergies between different sectors and different policies (coast and environment protection, eco-innovation, transports, tourism, energy, agriculture, urban development, etc.) for facing coastal adap-tation to CC according to the ICZM principles;
- awareness rising on natural/human coastal risks for the Mediterranean areas at European level;
- designing, on the grounds of past and ongoing projects experiences, an organic and coherent set of ini-tiatives (preparatory, planning, structural and monitoring) able to influence and cope with the issue concerned in the Mediterranean area at a large scale (Macro-project).

During the COASTANCE project a draft of a Macro-project (named BEACHMED-3) was designed and presented in Montpellier during the 2nd COASTANCE Conference (February 2010). This Macro-project was also presented in MEDGovernance project during the final conference in Barcelona (July 2011), and recorded in the conference final acts (www.medgov.net/lazio/documents/regional-strategic-plan-mediterranean-sustainable-development-lazio-region).

The main **specific objectives** of the Macro-Project can be summarised as follows:

1. defining a detailed framework at the regional level of the hazard and risk along the Mediterranean coast for the combined effect of CC, erosion and salt water intrusion and correspondent needs;
2. developing regional balance of the coastal sediments through an adequate knowledge of the inland, coastal and marine resources of sediments in the Mediterranean basin;
3. assessing the optimal ways to manage the sediments under the several concerned aspects (environ-mental, economic, technological, juridical, etc.) along the principles of the coastal and Marine Spatial Planning;
4. finding and promoting actions to get more resilient the Mediterranean coastal zones by the adoption of new and more adaptive approach/ tools in urban water-front concepts, littorali-

zation curbing, sustainable coastal tourism, ports/marinas building and management, eco-energy production, coastal groundwater pumping, etc. along with the principles of the Integrated Coastal Zones Management.

5. launching transferable experiences, really suitable for Mediterranean coastal zones, to achieve adapting solutions to CC, sustainable development and resilience improvements.

The main **activity lines** of the Macro-Project can be summarised as follows:

1. Mediterranean coasts characterization under the profile of their morphological stability (erosion and flood exposition) at a territorial detail to allow a really aware planning of the integrated management of the coastal zones ("EUROSION-MED project");
2. research, characterization and assessment of the coastal and marine resources of sediment in the Mediterranean basin to allow a sustainable recovery of the coastal sediment balance ("RESEARCH");
3. environmental strategic assessment of the plans for the sediment resources exploitation and the sus-tainable coastal protection ("ESA");
4. juridical tool and legal agreements needed for the coastal and marine spatial planning required by the integrated management of the coastal and off-shore resources of sediments ("MSP");
5. reliable and shared elements for Regional Master Plans finalized to the coastal adaptation to CC and erosion contrast and consistent Local Plans for the Integrated Coastal Zones Management of the Medi-terranean ("ICZM PLANS");
6. achievement of protection/adaptation priority works against the natural and human gendered coastal risks consistent with the planning framework ("INTERVENTIONS");
7. survey and monitoring before, during and after the foreseen actions through the institution of a network of Mediterranean Observatories (EURopean Interregional Observatories for the Mediterranean COastal DEfence – "EURIOMCODE").

Being well aware about the difficulties to set up a new structure, the process for creating the Observatory springs up from the realisation of a framework agreement between existing structures (no relevant cost of implementation), being respectful of the different methodologies in use by the involved structures (no initial problem of standard) and projected for a gradual process of harmonisation between them. During the BEACHEMD-e / OBSEMEDI subproject a specific feasibility study individuated, analysed and recorded a number of regional/local structures (observatories). This dataset has been enhanced and updated during the COASTANCE project. The updated database in accessible the www.beachmed.eu home page,

The Observatory proposal was born in 2007 with a first political agreement ("The Bologna Charter" - EUROPEAN REGIONS CHARTER FOR COASTAL AREA PROTECTION AND FOR THE PROMOTION OF A EUROPEAN INTERREGIONAL OBSERVATORY FOR THE DEFENCE OF MEDITERRANEAN COASTS - EURIOMCODE) within the RFO BEACHMED-e (subproject OBSEMEDI) signed by the political representatives of BEACHMED partners and that registered the adhesion of the Arc Latin organism. COASTANCE project has been the first operative step in the direction of concretising the political willingness to create the Med Observatory, on one hand, having defined shared methods and tools for risk assessment and coastal erosion monitoring, best practices, EIA guidelines and plan models for protection and management and, on the other hand, extending the network of contacts and the database on regional/local structures competent for coastal data production and management. The FACECOAST cluster is a step beyond in the direction of the Med Observatory constitution, completing the network at the Mediterranean scale and creating a common data platform.

The FACECOAST Cluster is fed with means/tools (web-site, printed materials, models, dataset, methods guidelines, peer reviews, etc.) freely provided by the participating projects as a contribution consistently with their purposes. All results and experiences of the adhering projects that are relevant in relation to the Cluster's objectives will be capitalised in the Macro-project design and development.

The Cluster will design and launch initiatives with the support of means and resources coming from the participant projects according to their specific mission, objectives and in coherence with the respective project budget lines. Already completed European projects can join the Cluster, sharing their documents and datasets previously issued.
On the FACECOAST web site (www.facecoast.eu) more and updated information on the initiative are available together with the Memorandum of Understanding signed by the adhering projects.

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