Regione Emilia-Romagna
Assessorato alla Sicurezza Territoriale
Difesa del Suolo e della Costa
Protezione Civile

New tools for coastal management in Emilia-Romagna

SICELL
the littoral cells management system

COASTANCE

this project is co-funded by
the European Regional Development Fund

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New tools for coastal management in Emilia-Romagna

edit by

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The Emilia-Romagna coast is a complex system in which various factors, natural and anthropogenic dynamics interact. The Emilia-Romagna Regional Government has decided to include the coastal defense and management system among its main priorities. This decision has been made in the light of the precious natural and historical assets and the presence of several economic activities, including tourism, which is one of the most important sectors at a national and European level.

For this reason, over the years, the Emilia-Romagna region has carried out several studies and research works, and it has developed and refined coastal defense management policies and strategies, which have placed it at the forefront both in Italy and in Europe. These activities, especially in the last decade, could also benefit from EU funds through the participation in several European projects. Among those recently concluded (CoastView, Cadsealand, Beachmed-e, PlanCoast, Micore) or still under way (CoastBest, Maremed, Coastance, Shape), have developed synergies and guidelines related to various themes: risk assessment, study and monitoring of coastal dynamics, sediment management, integrated coastal zone management (ICZM), maritime spatial planning.

The Coastance project, aimed at the development of tools for predicting the risk of flooding, erosion control and the formulation of coastal defense and management plans, was designed and developed from the experiences and results achieved by previous European projects. It provides continuity with the "EUROSION" project, promoted by the Directorate-General for the Environment of the European Commission, which has highlighted the state of erosion of coastal areas in Europe and the actions needed to curb this trend.

This publication, which I am pleased to introduce, does not only take stock of the state of the art in knowledge, critical coastal management practices and regional policies, but it is also intended to illustrate a new coastal and sediment management support tool - called SICELL -. This tool has been developed under the Coastance project and based on the breakdown of the regional coast into 118 management cells.

This is the result of a fruitful collaboration between the regional departments engaged in coastal defense (Soil and Coast Defense and Reclamation Service, Geological, Seismic and Soil Survey, the Coastal and Po di Volano River Basin Regional Technical Service, the Romagna River Basin Regional Technical Service, Arpa Emilia-Romagna - Specialized Sea-Coast Unit). This instrument also benefits from the integration of the most advanced knowledge and experience of the sector in a GIS-based management database, shared by the various regional departments involved. As already illustrated, in its advanced stage of development, at the "COASTANCE" conference, held in Bologna in February 2011, the system, now completed for the 2000-2010 period, also includes detailed data on the 118 coastal cells and it will be continuously updated thanks to a specific collaboration initiated between the regional departments.

Together with monographic data-sheets on coastal cells, a data analysis providing an overview on the state of the coast, the definition of coastal and submarine sand resources available for beach nourishment purposes, this publication also illustrates the beach sediment management practices promoted and implemented by the Regional authority, with the aim of standardizing all the different practices at best, being currently put in place by local actors in different coastal areas.

The SICELL database also provides useful information for sediment movement management, which makes the object of a specific regional regulation, in compliance with Art. 109 of Legislative Decree 152/2006, to reorder the authorisation procedures for the implementation of dredging and beach nourishment actions.

The system is already used by Coastal Technical Services and by Central Services. It has thus already proved to be a valuable tool to support coastal management activities and it provides a basis of useful elements for the drafting of sediment management plans and for the planning and design of coastal defense interventions.

The flourishing of studies, monitoring activities, development of management practices, thematic analysis, proves the importance of a far-sighted coastal management vision, supported by robust scientific and experience-based evidence, which has been adopted by the Regional Emilia-Romagna Government.

This is key to understand the great importance attached to synergy and ongoing co-operation between the various regional departments operating for the building of coastal management, defense practices and knowledge base. Hence, let me acknowledge and congratulate all the working group, and in particular the Soil and Coast Defense and Reclamation Service of the Emilia-Romagna Region, on their commitment in promoting and coordinating the activities and achieving the expected results through their valuable and admirable efforts. The following pages will undoubtedly provide a clear evidence of it.

Finally I would like to conclude with the hope that this successful cooperation will continue and further flourish along the path that has already been set.

Paola Gazzolo
Councilor for Spatial Security,
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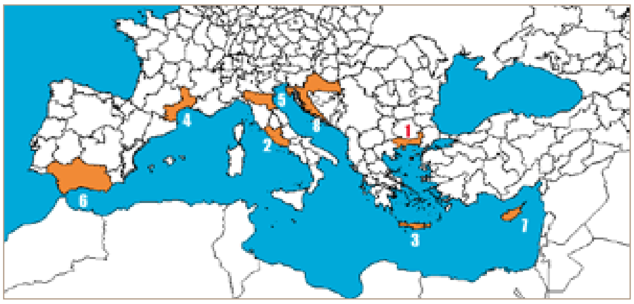
INTRODUCTION

The COASTANCE project and the Littoral Cells Management System (SICELL)

The European project COASTANCE (MED Programme), "Regional action strategies for coastal zone adaptation to climate change for a sustainable coastal planning in the Mediterranean basin", stems from experiences and results deriving from previous European projects focusing on coastal management and defence issues, including BEACHMED (INTERREG 3B Medocc) and BEACHMED-e (INTERREG 3C -South) for the Mediterranean area and SAFECOAST (INTERREG 3B North Sea). The project also refers to the EUROSION (2004) initiative, DG Environment of the European Commission, which highlights the state, impacts and trends of coastal erosion in Europe. The project has a budget of €1,812,775.33, for the 2009-2012 period and it is aimed at the development of tools for the forecast of flooding risks and for the drafting of coastal management and defence and erosion control plans.

The Emilia-Romagna Region has developed a coastal defence and management information system based on the subdivision of land into coastal cells (SICELL), in the framework of the COASTANCE project, in co-operation with the Mediterranean project partner regions. This tool is also designed to optimize coastal sediment management and the exploitation of sediment deposits outside the coastal system. It has been developed on the basis of previous experiences, studies, proposals and management plans (1981 Coastal Plan, 1996 Draft Plan, 2002 and 2008 State of Coast Report), in liaison with the regional offices dealing with research, monitoring, management, planning and implementation of coastal defence actions: Soil and Coast Defence and Reclamation Service, Regional River Basin Technical Services (Regional Po di Volano River Basin and Coastal Technical Services STB, Romagna STB), the Geological, Seismic and Soil Service, ARPA Technical Management - Sea and Coast Specialized Unit.

This publication reports the results of data and information restructuring the coastal physical system designed to build SICELL, along with the current regional policy framework, intervention strategies, best practices already in use or to be introduced for a proper regional coastal management system. It also contains tables and monographic data sheets of 118 littoral management cells for the 2000-2006 period.



COASTANCE partnership: 1. Region of East Macedonia and Thrace (GR), Lead Partner; 2. Lazio Region; 3. Creete (GR); 4. Département de l'Hérault (FR); 5. Emilia-Romagna Region; 6. Junta de Andalucia (SP); 7. Ministry of communicationand works of Cyprus (CY); 8. Dubrovnik Neretva County Development Agency (CR).

A response to erosion and marine ingression risks

Coastal areas, especially low and sandy shores, are naturally subject to erosion generated by the action of waves and sea level changes. These natural processes are amplified during storm surges that are often responsible for marine ingression events in coastal areas and towns. As emerged from the sea storm analyses of the last 50 years, carried out in the framework of the MICORE project (Seventh Framework Programme), in the northern Adriatic sea, an increase in the frequency of surge episodes (inland penetrating storm waves) has been recorded, but not a significant change in frequency and intensity of storm surge phenomena (Ciavola *et al.* 2009; Ciavola *et al.* 2011).

Different environmental factors (water, wind, climate, river sediment transport, etc.) contribute to the development of the coastal environment, which normally keep the system in a dynamic equilibrium. These natural factors are increasingly more influenced and modified by human activity.

In fact, a heavy impact is exerted on the coastal environment by urbanization and intensive use of land for economic purposes, including the construction of works blocking the transit of natural sediments along the coast (jetties, docks, etc..). These are the factors that further amplify localized erosion and marine ingression risks.
Coastal defence strategies have traditionally relied on the construction of hard coastal defence structures (breakwaters, groins, etc.). On the one hand, they have protected coastal areas, but on the other hand, they have simply shifted the coastal erosion problem closer to the works themselves, thus creating a domino effect, such as in the case of the Emilia-Romagna region, where about 60 km long hard defence structures have been built along the coastline over the past 70 years by national authorities.
In recent years this "hard" coastal defence approach has been slowly replaced by a "soft" approach, by means of the adoption of low environmental impact defence systems, such as sand nourishment, using sand coming from littoral or underwater deposits.
The climate change effects (increased frequency of surge episodes during storm events, rising sea levels, etc..) have a greater impact on low, sandy shores, which, besides being more exposed to marine weather events, often occur in correspondence with more intensively urbanized areas.
Some scientific studies also predict that global warming will have a lasting impact on the Mediterranean basin, thus leading to more intense extreme weather events and a rise in temperature of at least 1° C by 2025. The Mediterranean basin has, in fact, been identified by the International Panel on Climate Change (IPCC) as a "hot spot" area "at risk of marine ingression, coastal erosion and land deterioration" (Communication from the Commission to the Council and the European Parliament - Towards an Integrated Maritime Policy for better governance in the Mediterranean -COM (2009) 466 - 11/09/2009).
Hence, it seems clear that in order to fight coastal erosion and risk of flooding a broad approach is to be adopted in relation to expected medium to long-term climate change, with a view to developing adequate coastal defence strategies that are likely to manage shorelines and sediments in a sustainable way, by paying special attention to the environmental impact that human intervention may have on the coast.
To reach these objectives COASTANCE project is subdivided in 5 components. The first component is about the management and coordination of activities, the second one the dissemination of obtained results and there're three technical components:

- **COMPONENT 3** Coastal risks: erosion and sommersion (Responsible: Departement de l'Herault);
- **COMPONENT 4** Territorial action plans for coastal protection and management (Responsible: Emilia-Romagna Region);
- **COMPONENT 5** Guidelines for Environmental Impacts focused on coastal protection works and plans (Responsible: Lazio Region).

The project is developed by two main themes:

1. **Capitalization of knowledge and resources already acquired in the field of coastal protection:**
   a. 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;
   b. 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/ICZMMED Subprojects, Plancoast, Cadseland, Micore projects;
   c. environmental Impact Assessments of the new technologies (dredging activities, nourishment work etc.) and Strategic Environmental Assessment on coastal plans based on Beachmed, Beachmed-e/EU-DREP/POSIDUNE Subprojects.
2. **Mid to long term planning actions for climate change effects adaptation of coastal zones in line with the EU Directive 2007/60/EC:**
   d. 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 thedevelopment of Coastal Protection ManagementPlans based on previous EU projects findings(eg. Safecoast, Comrisk and Messina);

e. 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);

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

SICELL as a support tool for coastal management

As already mentioned, the hard defence structures (breakwaters, groins, etc.) built in the past few years have often simply moved erosion away to adjacent stretches of the coastline that were supposed to be protected. Over time, then, new defence strategies were introduced, based on “soft” systems, such as artificial beach nourishment. Although being a temporary remedial action that requires regular maintenance, with further sand feeding, it appears to be the most suitable coast protection method, while maintaining the natural environmental dynamics.

In this context it is essential to work out a new defence strategy, not based on specific ad hoc actions to remedy emergency situations, but on a sustainable coastal and sediment management strategy based on two main pillars:

1. **beach nourishment by means of sediments coming from outside the system** (i.e. underwater sand, building excavations, etc.) **or from within the coastal system itself** (accumulation of beach sediment, harbour mouths, etc.) and, wherever and whenever possible, from river sediment transport (natural beach nourishment);
2. **the reduction of leakages from the system,** through effective beach sediment management practices of (in situ cleaning, windbreak barriers, winter defence dikes, etc..) or actions to reduce the anthropogenic component of subsidence (reduced extraction of water and hydrocarbons from the underground).

Apart from the restoration of river sediment transport and subsidence reduction, which undoubtedly are key strategic actions, yet, in the long term, further spatial and economic policies are required in addition to those already introduced by the Regional authorities over the past few decades. In the short term, it is essential to resort to possible sediment sources to implement the best practices in a view of a sustainable use and proper management of beach sediments.

The Littoral Cell Management System (SICELL) is a database designed to support coastal management along stretches of coastline under the jurisdiction of Coastal Technical Services. At the same time, it provides an overview of the actions put in place to secure the protection and health status of the regional coastline, through continual upgrades. The SICELL System has been developed in the framework of the COASTANCE project, under Component 4, by integrating and reorganizing the source data used in other regional databases (DB nourishment, DB hard defence works), the available knowledge on the physical Coastal System (Sea and Coast Coastal Information System, IDROSER and ARPA data), on the beach sediment and littoral deposit management practices, on river sediment transport, subsidence rates in different coastal areas, and on the interventions made during the 2000 - 2006 and 2007-2010 periods.

The choice of periods is linked to the timing of subsidence monitoring surveys and of bathymetric campaigns carried out by ARPA. The fifth subsidence control and bathymetric campaign is currently under way (2011-2012); then the second reporting period will extend to the end of 2012, although data updated to 2010 has already been processed and analyzed in this research work.

The SICELL is already used by the Technical Services and by the Land Reclamation & Coastal

Protection Service. It is a useful support tool to regional coastal management and provides a data base for the drafting of sediment management plans and interventions designed to fight erosion.

The COASTANCE project and the SICELL system have now become an integral part of a more than thirty-year-long regional coastal protection experience.

figure 1a

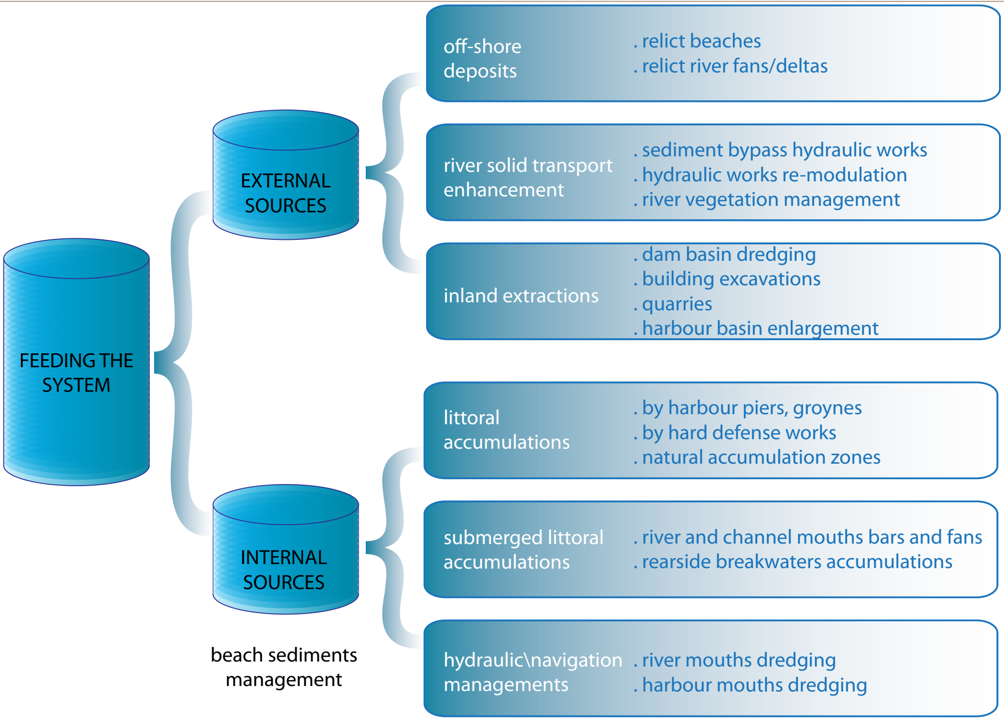


figure 1b

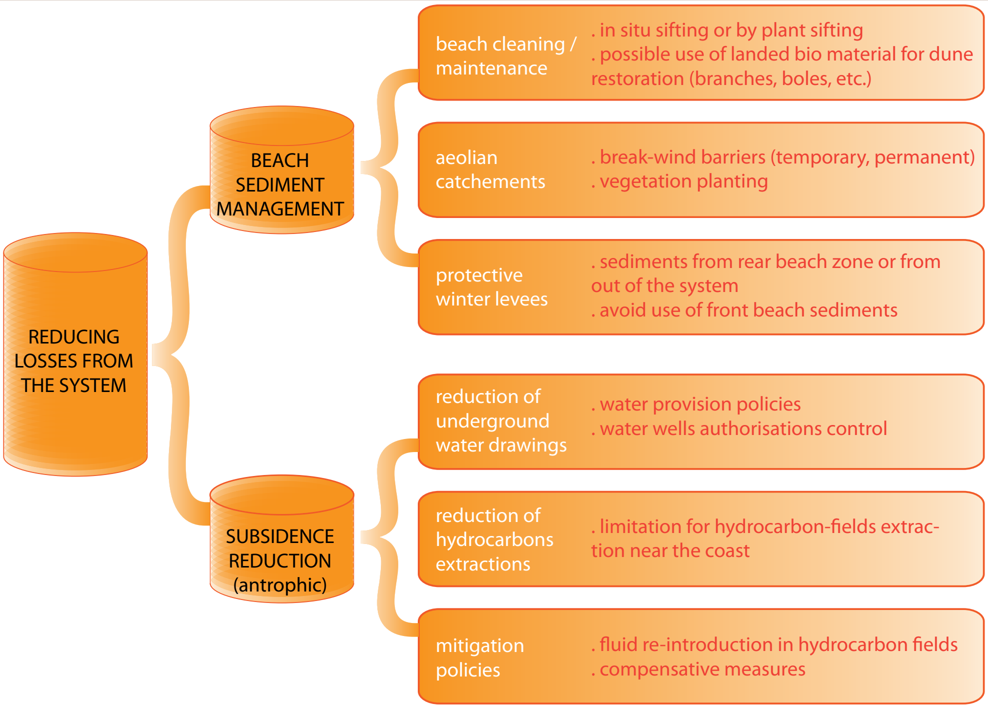


figure 1 The sustainable littoral management is based on two main pillars: feeding the littoral system with internal or external sources (a) and reducing losses from the system (b).

REGIONAL POLICIES FOR COASTAL MANAGEMENT

Foreword

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 (Fig.2), different valleys have been reclaimed, wasteland and woodland have substantially shrunk.

transferred from the Italian central Government to the Regional authorities only in 2001. The Emilia-Romagna Regional authority had already started addressing the issues related to coastal protection already since the early 1970s, following the establishment of Regional authorities: from the enactment of the first regional law on this is-

figure 2 Riccione beach in the early XX century (left picture) and in the 1990 (right picture). In 100 years all the dunes have been destroyed.

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.
A coast protection plan had already been launched by the central Government since the 1930s, with a few limited projects - such as the construction of the first shore-parallel emerged breakwaters in Porto Garibaldi. It has been massively resumed with the development of beach tourism in the early decades after World War II. It should be underlined that coastal defence powers were

sue (RL 7/79) to the following plans and studies (that are further illustrated in the following paragraphs) to the most recent report published by ARPA on "The state of the Emilia-Romagna coast in 2007 and the ten-year management plan" (Preti *et al.*, 2008). In this study, as in previous ones, critical stretches along the regional coastline were identified, requiring beach nourishment actions during the following decade in order to regenerate or at least rebalance them. Since the year 2000, a Regional Sea and Coast information system (SIC) has been developed in an ArcGIS environment in compliance with national (RNDT) and European (INSPIRE) guidelines, now also available in the WebGis version, on the basis of which further analyses and publications were developed, such as the latest "The Emilia-Romagna Sea and Coast System" (Perini and Calabrese, 2010).

The weaknesses of the Emilia-Romagna coast

The critical stretches along the regional coastline are those in which beach erosion or deterioration pose a threat to the assets and activities along the coast and inland (residential and tourist infrastructures, farmland, valuable natural environment).

It is worth noting that up to a total of 140 km long stretches of the coast are affected by erosion or are in precarious balance, related to the Cell system length, while 117 km-long cells including beaches (except for river mouths, port mouths, dock fronts and stretches of the coast protected

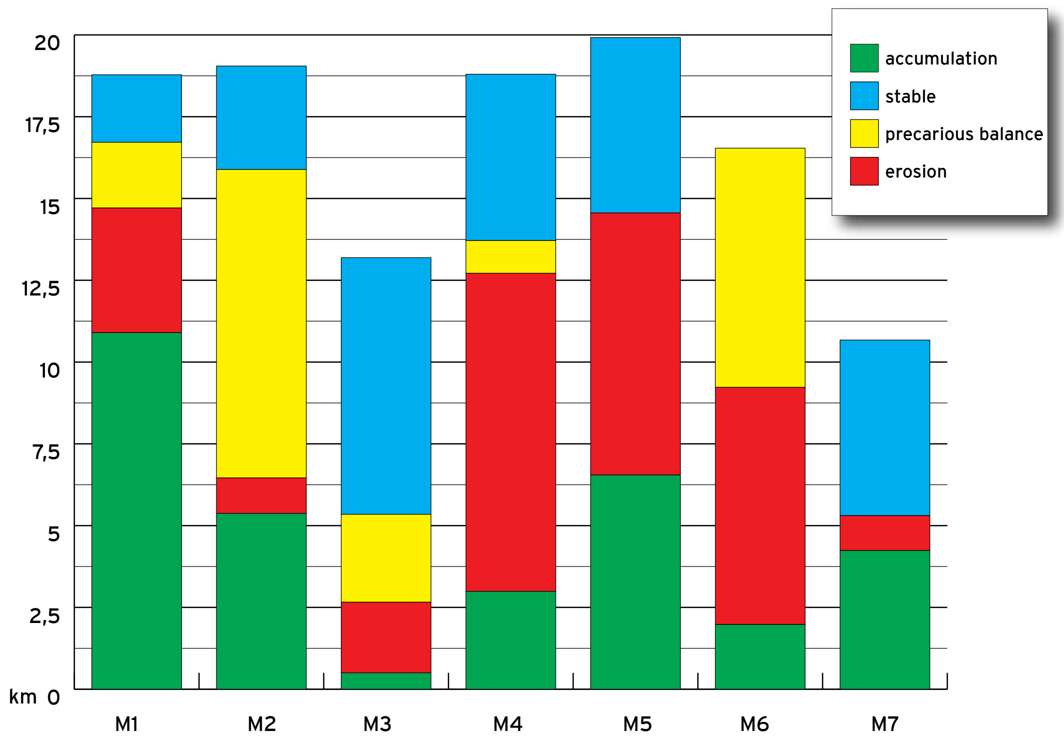


figure 3 A.S.P.E. classification (accumulation, stable, precariuos balance and eroded stretches) of the 7 Macrocells (see chapter 3) which is subdivided the Emilia-Romagna coastal zone.

by shore-parallel emerged breakwaters) have been identified.

A review and update of the regional critical stretches of the coastline has been conducted since the last published works (Preti *et al.*, 2008; Perini and Calabrese, 2010), on the basis of direct experience in the field by the Regional River Basin Technical Services and of the analysis of coastal cells already put forward by the study carried out by Preti *et al* in 2008. Based on the SICELL data and on the ASPE classification (See Chapter 5), about 55 km long stretches along the regional coastline show some criticalities, of which 32.9 km (23.5%) featuring a more or less severe erosion and 22.7 km (16%) being in a precarious balance (Fig. 3).

The stretches of the coastline, which have been classified under precarious conditions, have often undergone beach nourishment interventions or maintenance of existing works. This points out their "precarious" balance and need for maintenance, through various types of interventions.

Among the coastline stretches, which have been classified as being affected by erosion, not less than 26 km long coastline has already been equipped with hard defence structures, while about 21 km long beaches in precarious balance are protected by hard defences. This is an element to be taken into consideration. As a matter of fact, approximately 3,500,000 m^3 of sand has been transported to these areas for beach nourishment purposes during the 2000-2006 period, along about 45 km long coastline (33% of the total coastal cells), whereas 3,000,000 m^3 of sand has been used for beach nourishment purposes along stretches of coastline that were already protected by hard defence structures (Fig. 4).

of adjacent coastline stretches.

According to the 2008 ARPA study, Reno river mouth, Fiumi Uniti river mouth 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

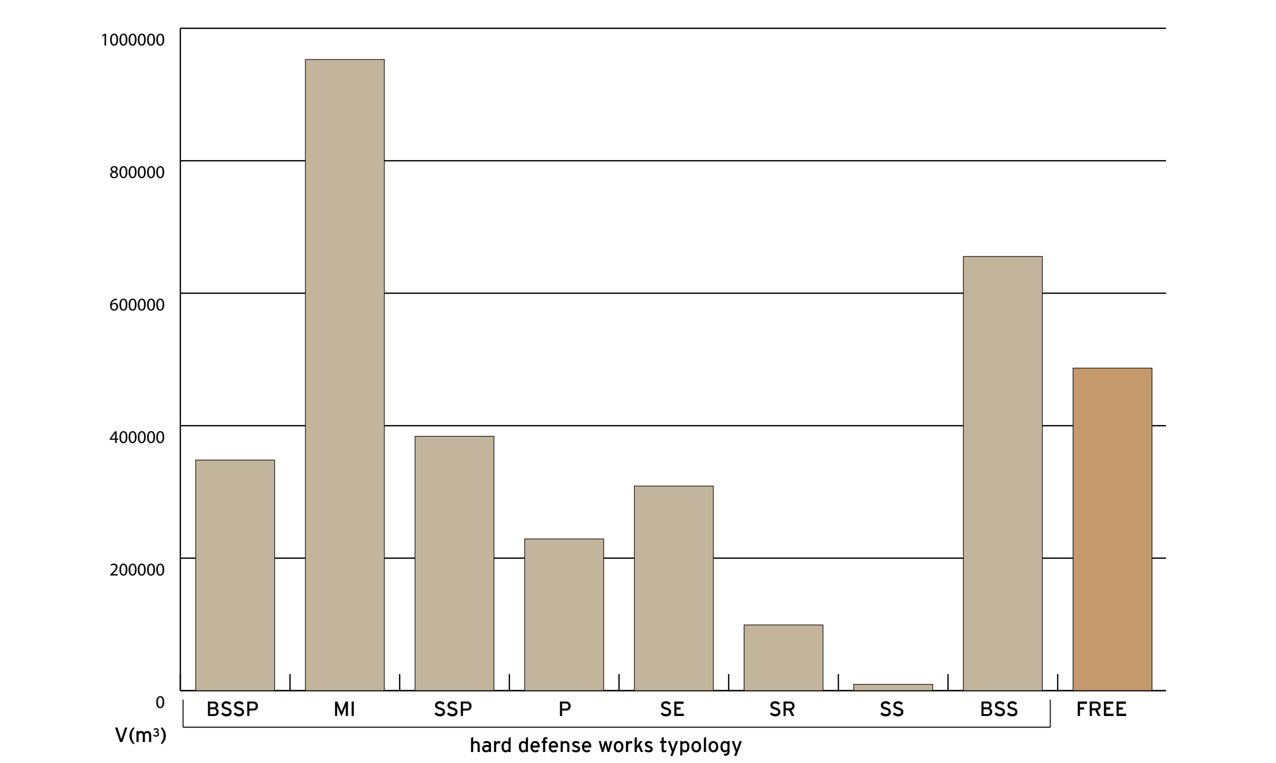


figure 4 Nourishment sand volumes on beaches protected by hard defense works (**BSSP** submerged sand barriers and groins, **MI** mixed, **SSP** low-crested breakwaters and groins, **P** groins, **SE** emerged breakwaters, **SR** seawall, **SS** low-crested breakwaters **BSS** submerged sand barriers) and on beaches not defended (data for the period 2000-2006).

The unprotected critical coastline stretches are generally downdrift beaches as against hard defence works, which are severely eroded because they are undernourished in terms of sand feeding. This condition had already been pointed out in the studies carried out for the first Coastal Plan (1981) and confirmed by subsequent studies. The study conducted by Preti *et al* in 2008, highlights that many of these stretches of coastline, protected by hard defence works, are strategically important because they can serve as sand feeding points along several kilometres of downdrift beaches. Based on the analysis of the cell database it is estimated that about 11 km of coastline can be used as recharging points for beach nourishment

km long stretch between the river mouth and the first Lido di Spina bathing establishments. During the 80s, the area South of 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 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 Fiumi Uniti river mouth 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.

Coastal defence strategies: from hard defence works to beach nourishment

RL 7/1979 was the first regional law on coastal protection, which led to the first 1981 Coastal Plan (later approved in 1983), followed by a second draft plan in 1996, and finally to a series of reports on the status of coastal zones with reference to the years 2000 and 2007 (M. Preti, 2002; Preti *et al.* 2008). Since the early '80s, it has also led to the implementation of three monitoring networks: topobathymetric, subsidence and shoreline (years of greater subsidence 1984, 1987, 1993, 1999 and 2005, years of relevant bathymetry and shoreline 1984, 1993, 2000, 2006 and 2011).

In the 1950-1980 period hard defence works were built by the central government authorities to protect about 54 km long stretches of the shoreline in the ER region, while between 1980 and 2006, further 12 km long hard defence works were built (Fig. 5).

This reversal of the trend started in the 1980s and continued over the following years, in compliance with the indications emerging from the 1981 Coastal Plan. The beach nourishment strategy for coastal protection was thus launched, despite a few considerable difficulties. In 1983-84, the E-R Region implemented a major beach nourishment project mainly using quarry sand, a true première for Italy.

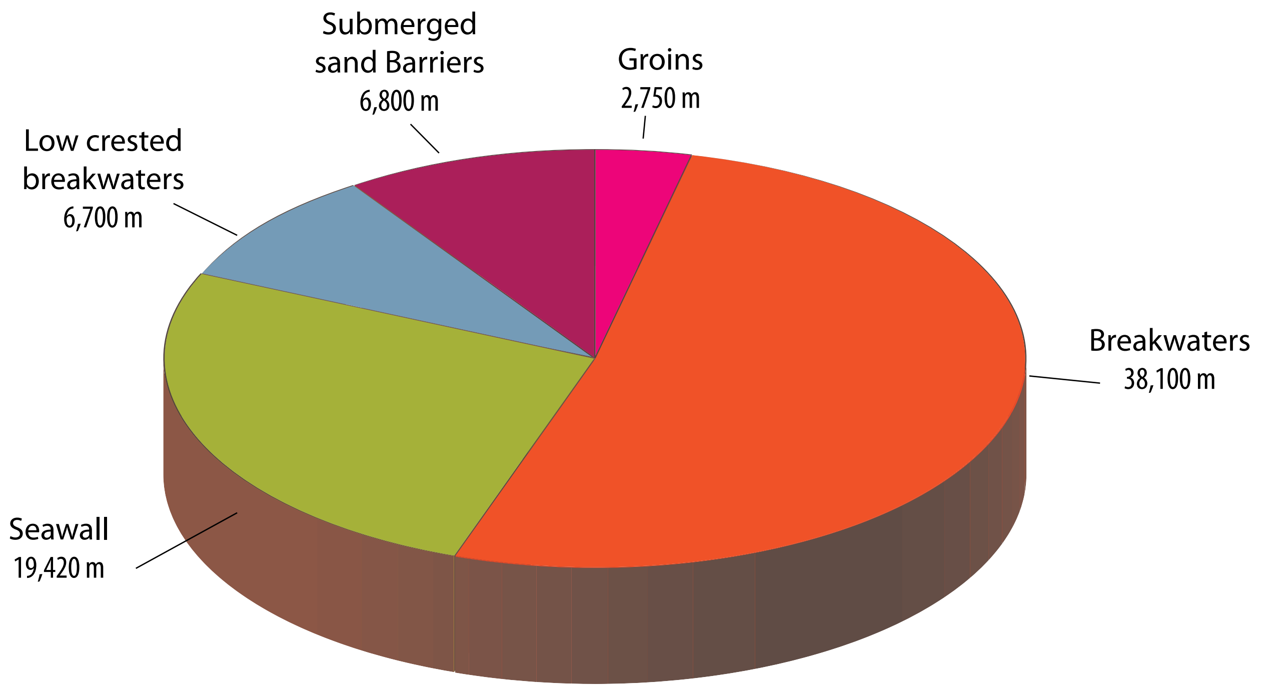
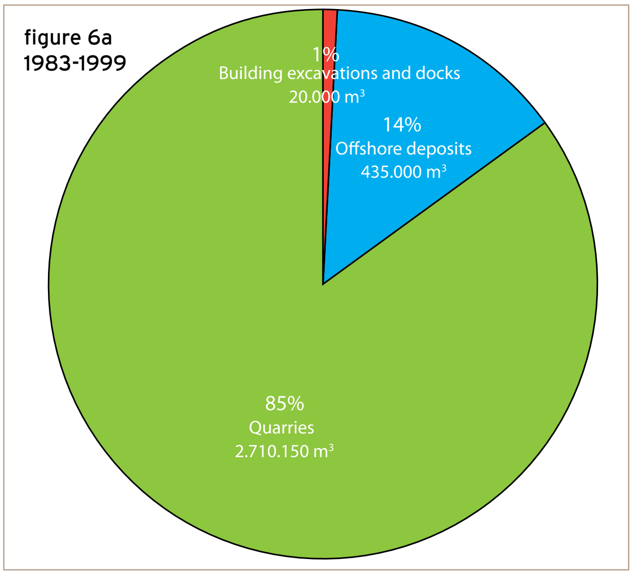


figure 5 Hard defense works built on regional until 2007 (Preti et al., 2008; ARPA 2009).

The 1981 Coastal Plan already pointed out the option of "soft" defence strategies, i.e. beach nourishment, as the best way to combat erosion and flooding, compared to the building of new hard defence works, which already proved to have a heavy impact on landscape and on water quality, and a limited effectiveness, as a whole, in solving the problem of erosion and risk of marine ingression.

During the initial 15 year-long period, artificial beach nourishment projects were carried out mainly using sand from inland quarries, a practice that proved to be not very environmentally and economically sustainable. Later, starting from the late '90s, sediments coming from coastal deposits were used. At the beginning of 2000, offshore underwater sand deposits were used. They had already been detected in 1984 (Idroser 1985) and thoroughly studied by Idroser and CNR (National Research Centre) also through further offshore research campaigns (1987-88, 1994, 2000, 2007-08). Two beach nourishment projects with sand coming from underwater deposits were carried out in 2002 and 2007, by the Regional authority, up to a total of over 1.6 million m^3 of sand harvested and used for the nourishment of beaches under erosion (Fig. 6).



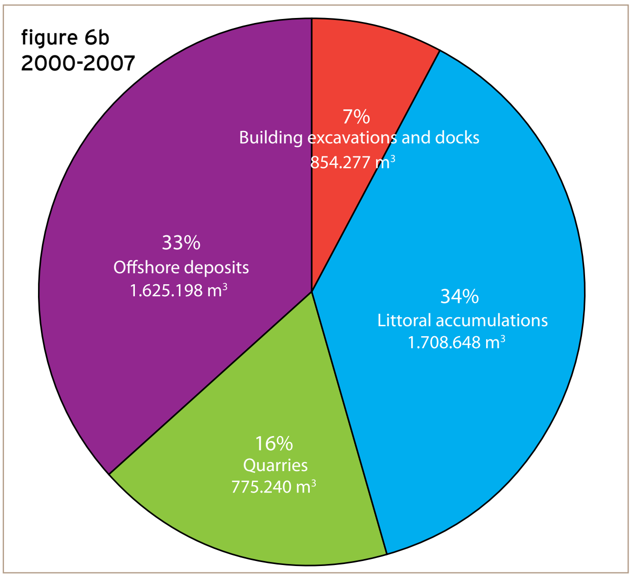


figure 6 Nourishment campaigns carried out along the Emilia-Romagna coast during the 1983-1999 (a) and 2000-2007 (b) periods and sand sources (Preti et al., 2008; ARPA 2009).

According to calculations performed by the latest study by Preti *et al* (2008), the total volume of sand (harvested from various sources of origin) used for the nourishment of the Emilia-Romagna beaches under erosion from 1983 to 2007 amounted to approximately 8.1 million m^3 (Fig. 6).

In the framework of the programme agreement (pursuant to art. 2, paragraph 240, of Law 191/2009), signed by the Minister for the Environment, Land and Sea and by the President of the Regional Government of Emilia-Romagna on November 3rd , 2010, the Regional authority has initiated a series of coastal protection actions under the "General Comprehensive Beach Nourishment Project", to be implemented in the 2011-2012 period. Under this programme, several nourishment projects have been envisaged up to a total of about 648,000 m^3 of sand mainly coming from coastal deposits - about 505,000 m^3 - and secondly, from building excavations, beach cleaning deposits, quarries – up to a total of approximately 143,000 m^3.

Furthermore, in order to better regulate dredging and beach nourishment issues, the Regional authority has drafted a specific Regulation, pursuant to Article .109 of Decree No. 152/2006, for the preliminary quality investigation, assessment and compatibility of sediments and issuance of authorizations, for the handling of sediment and for the implementation of beach nourishment projects in the backshore and foreshore along the regional coastline.

Policies encouraging river solid transport

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

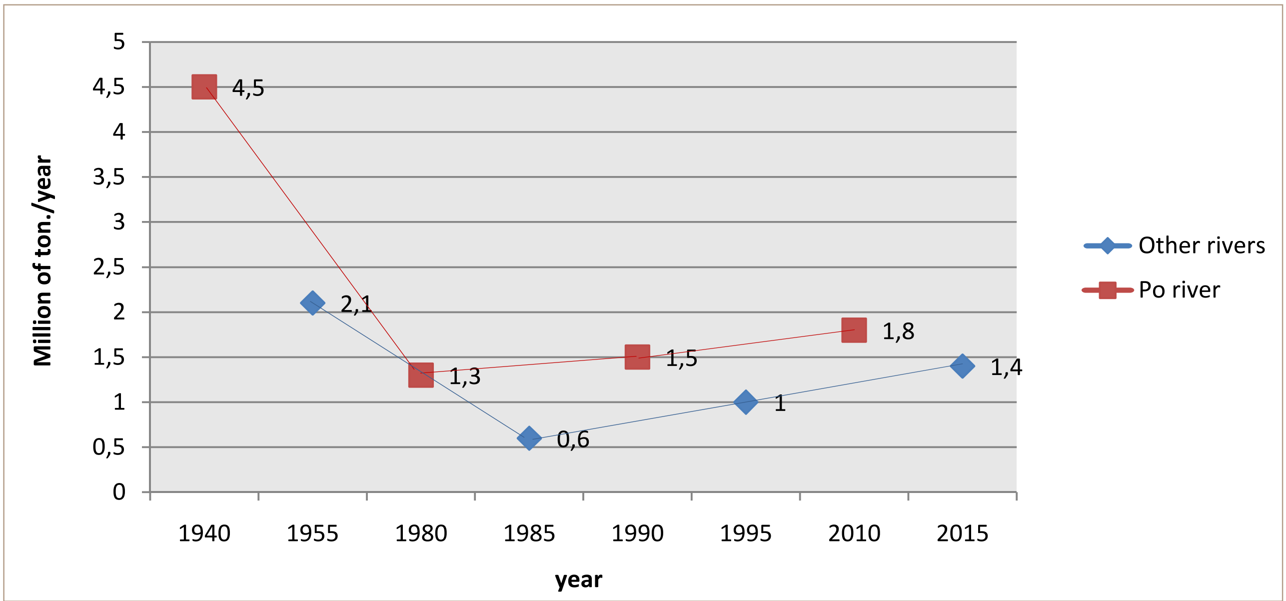


figure 7 **Quali/quantitative extimation of rivers solid transport on Emilia-Romagna coast.**

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.

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 beds 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 for the anthropogenic subsidence 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 Emilia-Romagna Region 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).

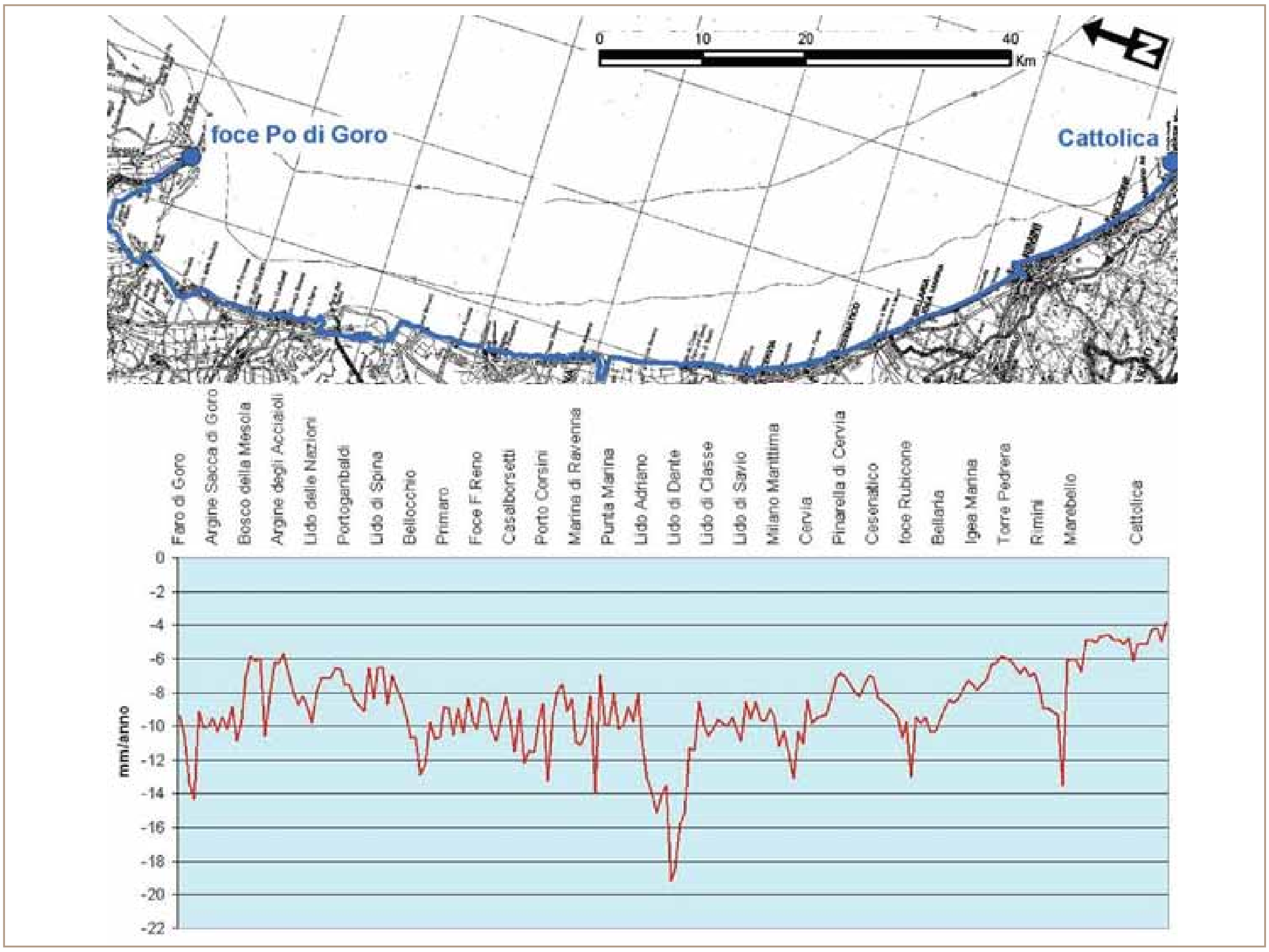


figure 8 On top is blu underlined the regional coastal subsidence network. Below are reported the subsidence rates from 1999 to 2005 from Cattolica (South) to Po di Goro (North) (Preti et al., 2008; ARPA 2009).

The Integrated coastal zone management (GIZC) in the EU framework

The regional framework for the protection of coastal zone, included the ones alredy described, (beach nourishment, subsidence reduction, rivers solid transport enhancement) is defined in the Regional Council Deliberation n. 645/2005, that approve the Integrated Coastal Zone Management Guidelines. The base concept, represented by the idea of "integration", is the importance of opening up to a full-fledged recognition of the unitary system of the coastal setting, although in the full awareness of the difficulty in construing the singularity provided by the coast as a territorial body. The management of coastal areas focussed on sustainability can be successful only by adopting a complete set of juridical, economic tools, agreements, information delivery, technological solutions, research, education and training. The ICZM theme has been developed concretely by EU from more than one decade. An EU ICZM Demonstration Program, designed around a series of 35 demonstration projects and 6 thematic studies, was operated by European Commission from 1996 to 1999. This operation gave relevant feedback on ICZM policies implementation that were included in the subsequent official EU documents in this sector: the Communication from the Commission to the Council and the European Parliament on "Integrated Coastal Zone Management: a strategy for Europe" (COM/00/547 of 17th September 2000), and the European Parliament and Council Recommendation concerning the implementation of Integrated Coastal Zone Management in Europe (adopted on 30th May 2002). More recently, a survey on the ICZM implementation was commissioned, and the results published in 2006, by the European Union in order to point out the state of art around Europe: Evaluation of Integrated Coastal Zone Management in Europe (18th August 2006). Recently, in 2008 in Madrid, was signed the ICZM Protocol for Mediterraean, previously ratified by European Union and other Mediterranean countries (2010/631/UE, 13th of September 2010).

The ICZM in Emilia-Romagna

The experience carried out by Emilia-Romagna Region has fostered an exchange of views between inevitably tied sectors in order to have an effect on the ecological healthy state and urban functionality in the coastal area.

The base concept, represented by the idea of "integration", is the importance of opening up to a full-fledged recognition of the unitary system of the coastal setting, although in the full awareness of the difficulty in construing the singularity provided by the coast as a territorial body. It should also be remarked that the coast, although somehow emerging imposingly as a unitary object within the framework of different land use plans at provincial level, would be broken up into other territorial contexts, due to its dimensional prevalence – within individual provinces.

The methodological and content framework for

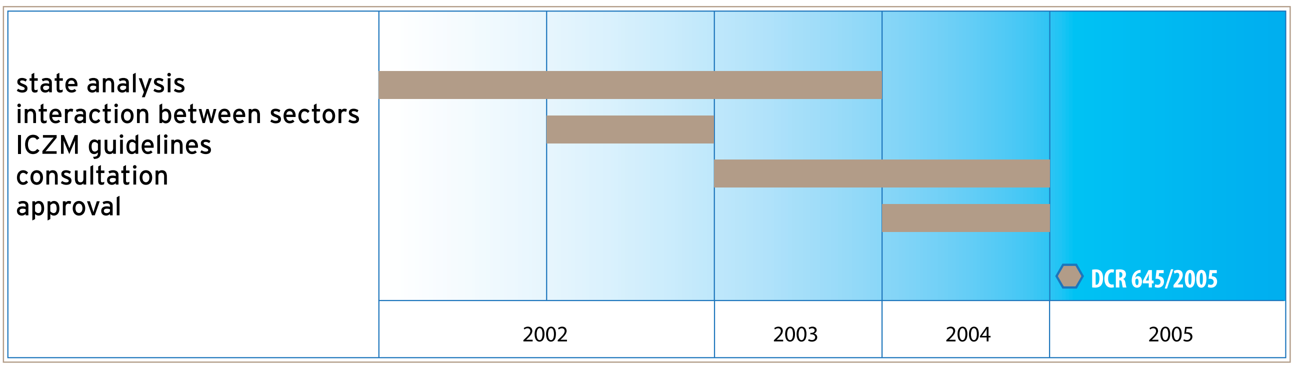


figure 9 ICZM timeline process in Emilia-Romagna

regional action on integrated management of coastal areas is the Regional Environmental Protection Program 2001 (Regional Council resolution No. 250 of September 26, 2001), called "Environmental Action Plan for a Sustainable Future", containing also references to the EU environmental programmatic context and to the deliberation of Regional Government n. 2794 of 10/12/2001 that approves the ICZM framework and gives the start up of the ICZM process in Emilia-Romagna.
This process stated operatively in 2002, following different steps as indicated in the scheme represented in figure 9.
The state of art analysis (SOA) phase, and the interaction analysis phase, concerned the different sectors having direct influences and impacts on coastal zone, organized in the following 9 themes plus 1, transversal activity, concerning communication and training directed to the wider public and local administrators.

1. the physical system, risk factors and defence strategies;
2. integrated water management at basin scale;
3. port, transport, navigation related risks and management;
4. natural habitats and biodiversity;
5. sustainable tourism;
6. fishing and aquaculture;
7. sustainable agriculture;
8. energy policy;
9. urbanisation and transport;
10. education and dissemination.

The process has been governed by the following boards:

- ***Institutional Committee***, the political level (6 Regional Councillorships, 4 Provinces Presidents, 14 Municipalities Mayors).
- ***Intersectoral Committee***, the integration level, Board of the Directorates General involved (DG Environment, Soil, Industry, Tourism, Spatial Planning, Agriculture).
- ***10 Working Groups***, one on each ICZM theme (almost 200 experts, scientists and stakeholders), the operative level.

The SOA analysis phase individuated specific problems and criticalities related to the different themes through the collection and updating of data and studies carried out in the different sectors by regional, local administrations, boards and institutions offices.
The Sector interaction phase was directed to analyze influences and pressures between the different sectors and to individuate possible mitigations and policy integration areas between sectors in order to overcome conflicts generated by sector specific policies for the coastal area.

figure 10 example of projects financed by ICZM.
on top: monitoring station in the Valley of Fattibello (Ferrara).
below: rehabilitation of public bulding near Punta Marina (Ravenna)

The third phase saw the first formulation of Guidelines, for each theme profile, aimed to activate or to enforce integrated management processes for the coastal area, with a particular emphasis on their sustainability in the future, together with the definition of lines of intervention: structural actions, support actions (assistance, education, training, dissemination), study and monitoring actions.
The Consultation phase, constituted by several

public and technical meetings during the whole year 2004, gave relevant feedback and drove to the tuning up of the ICZM Guidelines in the form finally approved by the Regional council at the beginning of year 2005.
A first implementation of ICZM Guidelines was launched by the Region in the period 2006-2008 with about 8 Million Euro funds (5M by the Regional Administration and 3M by Local Administrations) for the development of pilot projects in the different sectors (Fig. 10).
All the coastal provinces (Ravenna, Forlì-Cesena, Rimini, Ferrara) and the 14 Municipalities have adopted the Guidelines at local level within their spatial and urban planning tools. Today ICZM Guidelines represent the tool to address all coastal activities towards economic, social and environmental sustainability, in compliance with EU Recommendation 30 May 2002.

Beach sediment management

The reduction of sediment losses from the coastal system is a very important factor in the framework of the regional coastal defence strategy. In addition to huge losses caused by subsidence - as already mentioned - a special emphasis is laid on losses, resulting from incorrect routine beach maintenance operations or from the lack of measures to be implemented in view of the winter season. Losses are estimated to amount to approximately 120 to 140,000 m^3/year . Given the critical regional coastal sediment system, reducing losses through proper beach management has become an increasingly more important need over the years. it is necessary to secure the cleaning of beaches, the construction of levees to protect the bathing facilities during winter and the construction of windbreaks.
Public beach management in the Emilia-Romagna Region is regulated by Regional Law 9/2002, on “the exercise of administrative functions relating to marine state property and territorial sea areas “, and following amendments, by the Resolution of the Regional Council No. 468/2003 on “Guidelines for the exercise of administrative functions relating to marine state property and territorial sea areas in accordance with Art. 2 paragraph 2 of L.R. 9/02 “and by an annual decree of the Regional Tourism Board (in charge of Trade, Tourism and Quality of tourist areas).

Beach Cleaning

During the bathing season, Municipalities are responsible for the cleaning of public beaches, while privately managed licensed beach resorts are under the responsibility of the individual bathing establishment managers.
Outside the bathing season, the beach cleaning service is to be secured by municipalities both on public and on licensed beaches. The coastal municipal authorities have signed special arrangements with specialised companies in charge of environmental management services (AREA, HERA, GESTURIST, etc.), which in turn, either supply the service themselves or subcontract it to third parties. The waste collection, transport and disposal service deriving from beach cleaning operations and the frequency of the cleaning service are set out by Technical Regulations issued by the Local Authority in charge (ATO), within the provincial jurisdiction, in the framework of the Agreement for the management of Municipal Solid Waste Services signed between the Local Agency and the Area Managing authority, pursuant to the provisions of R.L. No. 25/99 and by R.L. No. 10/08.

figure 11 Example of selective cleaning: during the winter trunks are left on the beach to protect from sea-storms

Reducing the amount of sand that is removed together with waste is a priority action. As a matter of fact, sand accounts for 50-70% of the waste volume removed.
To this end, the Regional authority has undertaken several actions:

- direct agreements with the Municipalities or the Management Companies for the recovery of sand to be reused for nourishment purposes;
- selective cleaning, such as leaving the trunks during winter to protect beaches from storm and as natural windbreaks barriers (Fig.11);

- regional regulation for the characterization of sediments derived from beach cleaning for the purpose of environmental and health compliance and transport on the beach.

figure 12 Screening the storage area

A good practice scheme has also been put in place in view of reducing losses due to beach cleaning, which shall be directly integrated into the technical specifications of the Solid Municipal Waste management service designed by ATO (Ambito Territoria Ottimario, Optimal Territorial Area) providing for the following items:
- direct sand screening on the beach during waste collection in the autumn - winter season (Fig. 12);
- 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.

Winter defence embankments

The embankments built for protection from winter sea storms are often created by using sand from the foreshore (Fig. 13a). This operation can create adverse effects on coastal dynamics, since it increases the beach slope, while decreasing its resistance to storm surges.
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

figure 13a

figure 13b

figure 13 A: not properly built winter defence enbankments, by removing sand from the foreshore. B: properly built winter defence enbankments, with sand coming from other sources

addressed to municipalities, to improve the quality of these temporary defence works and to reduce sediment loss due to an incorrect action management, which suggested to prevent the construction of embankments with sand from the foreshore and to use instead (Fig. 13b):

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

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

Creation of windbreaks

Given a loss of sand from the backshore due to wind erosion amounting to 60,000 m^3/year along the regional coastline, and given the lack of legislation enabling the public authorities to require

figure 14a

figure 14b

figure 14 A: negative effects caused by the absence of windbreaks B: a windbreaks properly built

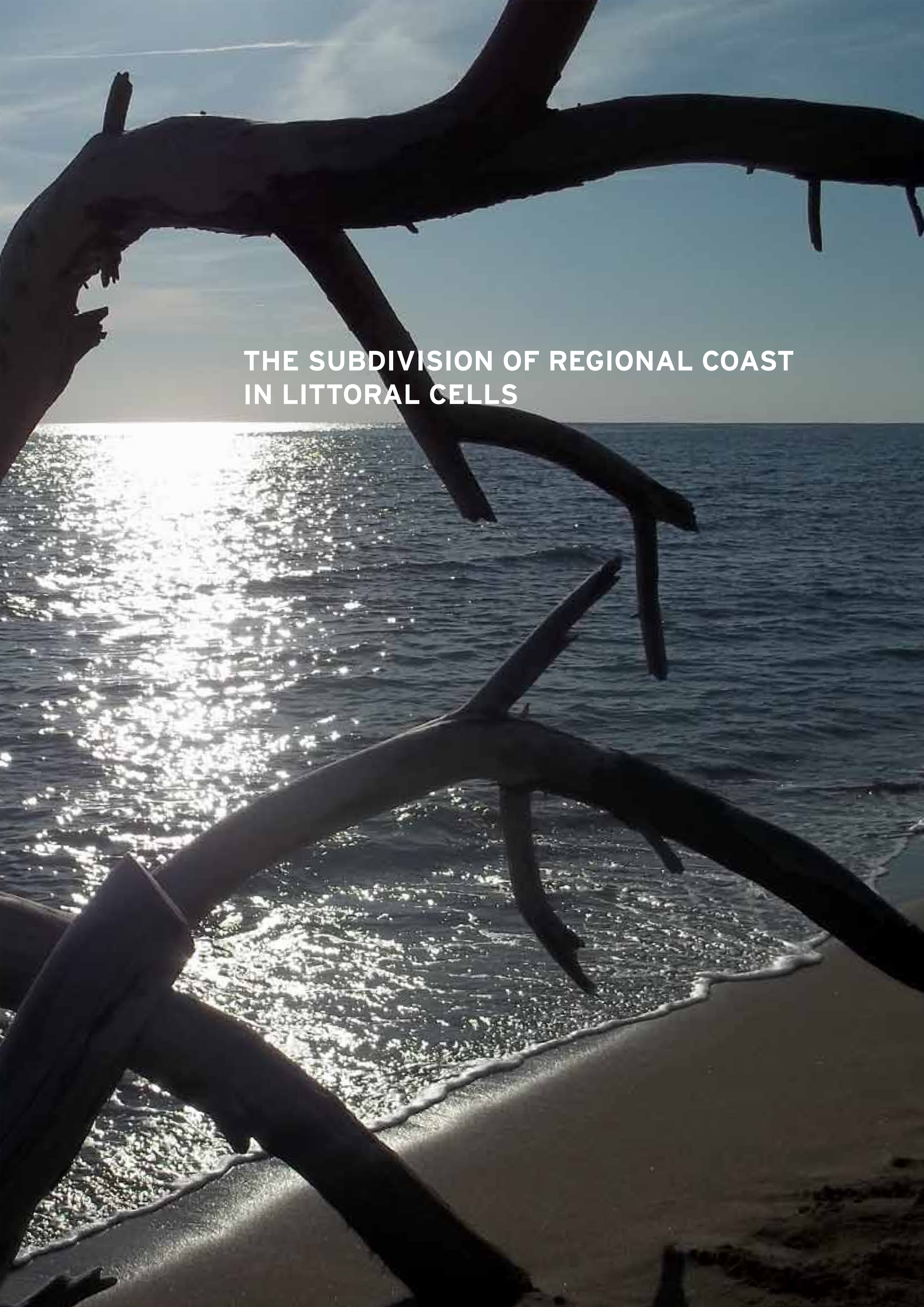
the installation of barriers, in 2006 the Region put forward a technical directive on windbreak barriers to municipalities.
It is a valid alternative to the winter embankments used for the protection of bathing establishments and to minimize loss of sand from beaches. Fur-

thermore, it should also be pointed out that sand is blown by the wind and it piles up also in backyards and along the streets (Fig. 14a), thus running down into the sewage system, with consequently higher disposal costs.

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

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

THE SUBDIVISION OF REGIONAL COAST IN LITTORAL CELLS



Foreword

Following the need to define a shared database for the management of coastal defence measures and for the future implementation of sediment management plans, regional services in charge of coastal management and defence (Po di Volano River Basin and Coastal Regional Technical Service, River Basin Technical Service of Romagna, Geological, Seismic and Soil Survey, ARPA Technical Management, coordinated by the Land Reclamation & Coastal Protection Service, have initiated a review process of the coastal area, through its subdivision into sedimentary cells for management purposes, whose findings are presented in the study carried out by ARPA in 2008.

During the first phase of the COASTANCE project, knowledge and direct experiences made by the different regional departments, through studies, research works, monitoring, programming, planning and implementing activities, were analyzed and systematized. Such knowledge, as well as the wealth of experience in the development of sediment management and interventions, make reference to the Sea and Coast Information System and to recently published studies and reports (Preti *et al.*, 2008; Perini and Calabrese, 2010; ARPA, 2009).

The starting point was therefore the subdivision of the coastline into Cells and Macrocells defined by the study by Preti *et al* in 2008 and its subdivision into geomorphologic units and sub-units, as defined by the Perini and Calabrese study, in 2010 (fig. 15).

While the subdivision into geomorphologic units corresponds to a structural coastal zone management and to geological processes, the spatial subdivision of the coastline for management purposes was kept almost unchanged except for a few specific adjustments. The latter also takes into account the current anthropogenic and natural processes taking place in the coastal dynamics, and it has been thoroughly reviewed by the working group. This analysis led to the initial subdivision of the coastline into 7 Macrocells and 80 Cells (as suggested by the study by Preti *et al.*, 2008) and then to the current subdivision into 118 coastal cells, thus keeping the same number and position of Macrocells generally outlined by jetties.

The increase in the number of cells, due to a further breakdown and to the inclusion of new types of cells, such as river, channel, port mouths and dock fronts, is intended to meet the actual requirements stemming from a direct experience in the field and from the management practices already in place (sampling from specific areas, handling methods, regular sand harvesting sites, etc.) and the management requirements set out by Technical Coastal Services.

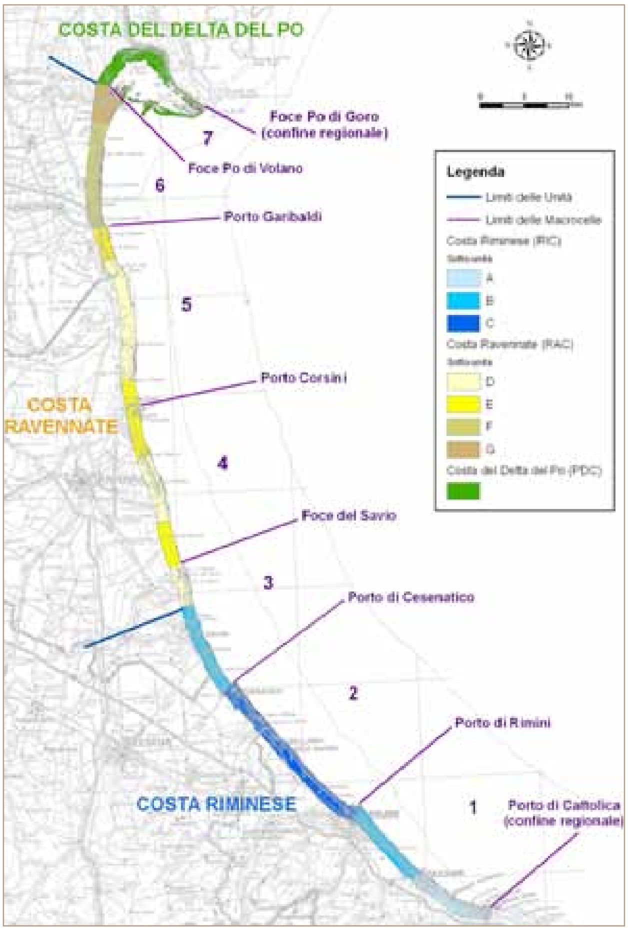


figure 15 Littoral subdivision in 7 Macrocells and in Geomorphological Unit (RIC, RAC and PDC) and Sub-unit (A, B, C, D, E, F, G) proposed by SGSS (2009). *Po di Volano mouth and Fiume Savio mouth are respectively a convergence point and a divergence one of the longshore transport

The coastal cell framework

The following table provides the complete framework of the 118 cells in which the regional coastline has been divided into, along with the information set provided under the "General" section of the associated database. The following Chapter 5 provides a detailed description of the contents of other database sections.

n	name	typology	physical delimitation	municipal.	prov.	M	GU	GSU	L	ASPE
1	Bocca Tavollo	Harbour entrance	coastal stretch between south pier and Cattolica dock	Cattolica	RN	M1	RIC	A	55	
2	Darsena di Cattolica	Dock	coastal stretch of Cattolica dock	Cattolica	RN	M1	RIC	A	250	
3	Cattolica Sud	Cell with beach	coastal stretch between Cattolica dock and the ninth breakwater	Cattolica	RN	M1	RIC	A	1.230	S
4	Cattolica Nord	Cell with beach	coastal stretch from the tenth breakwater and the pier of Ventena mouth	Cattolica	RN	M1	RIC	A	615	A
5	Foce Ventena	River mouth	coastal stretch between piers of Ventena mouth	Cattolica	RN	M1	RIC	A	40	
6	Colonia Navi	Cell with beach	coastal stretch between Ventena northern pier and the south groin of Conca river mouth	Cattolica	RN	M1	RIC	A	260	P
7	Foce Conca	River mouth	coastal stretch between the Conca river groins	Misano Adriatico	RN	M1	RIC	A	175	A
8	Porto Verde Sud	Cell with beach	coastal stretch between the northern groin of Conca river mouth and the southern pier of Porto Verde	Misano Adriatico	RN	M1	RIC	A	65	E
9	Canale Porto Verde	Harbour entrance	coastal stretch between Porto Verde piers	Misano Adriatico	RN	M1	RIC	A	40	
10	Porto Verde Nord	Cell with beach	coastal stretch between Porto Verde pier and a groin	Misano Adriatico	RN	M1	RIC	A	165	P
11	Porto Verde Scogliera Radente	Cell with beach	coastal stretch relative to Porto Verde seawall	Misano Adriatico	RN	M1	RIC	A	220	E
12	Misano Pennelli	Cell with beach	coastal stretch relative to 26 groins	Misano Adriatico	RN	M1	RIC	A	1.680	E
13	Misano Scogliere	Cell with beach	coastal stretch defended by 7 emerged breakwaters	Misano Adriatico	RN	M1	RIC	A	755	A
14	Riccione Sud	Cell with beach	coastal stretch 1 km long defended by submerged sand barriers starting from Misano A. breakwaters	Misano / Riccione	RN	M1	RIC	A	1.000	E
15	Riccione Centro	Cell with beach	coastal stretch 1850 m long defended by submerged sand barriers	Riccione	RN	M1	RIC	A	1.850	P
16	Riccione Porto	Cell with beach	coastal stretch beetween the end of submerged sand barriers and Riccione docks	Riccione	RN	M1	RIC	A	570	A
17	Darsena di Riccione Sud	Dock	coastal stretch of Riccione southern dock	Riccione	RN	M1	RIC	A	50	
18	Riccione Porto Canale	Harbour entrance	coastal stretch between Riccione harbour	Riccione	RN	M1	RIC	A - B	25	
19	Darsena di Riccione Nord	Dock	coastal stretch of Riccione northern dock	Riccione	RN	M1	RIC	B	60	
20	Riccione Alba Sud	Cell with beach	coastal stretch between the Riccione northern dock and piazzale Azzarita	Riccione	RN	M1	RIC	B	840	E

n	name	typology	physical delimitation	municipal.	prov.	M	GU	GSU	L	ASPE
21	Riccione Alba Nord	Cell with beach	coastal stretch between piazzale Azzarita and Marano river mouth	Riccione	RN	M1	RIC	B	1.250	A
22	Foce Marano	River mouth	coastal stretch of Marano river mouth	Riccione	RN	M1	RIC	B	45	
23	Fogliano Marina	Cell with beach	coastal stretch between Marano river mouth and Rimini/Riccione municipality boundary	Riccione	RN	M1	RIC	B	610	S
24	Miramare	Cell with beach	coastal stretch between Rimini/ Riccione municipality boundary and Ausa	Rimini	RN	M1	RIC	B	6.190	A
25	Rimini Centro	Cell with beach	coastal stretch between Ausa and Rimin harbour	Rimini	RN	M1	RIC	B	1.350	A
26	Rimini Porto Canale	Harbour entrance	coastal stretch of Rimini habour	Rimini	RN	M2	RIC	B	70	
27	Darsena di Rimini	Dock	coastal stretch of Rimini dock	Rimini	RN	M2	RIC	C	425	
28	San Giuliano	Cell with beach	coastal stretch between Rimini dock and southern pier of Marecchia drainage channel	Rimini	RN	M2	RIC	C	450	E
29	Deviatore Marecchia	River mouth	coastal stretch of Marecchia draining channel	Rimini	RN	M2	RIC	C	150	
30	Rivabella	Cell with beach	coastal stretch defended by 12 breakwaters starting from Marecchia draining channel	Rimini	RN	M2	RIC	C	1.660	A
31	Viserba Zona Sud Sortie	Cell with beach	coastal stretch between the 13th and the 16th breakwater	Rimini	RN	M2	RIC	C	630	A
32	Viserba Sud	Cell with beach	coastal stretch between the 17th breakwater and the southern pier of Mulini channel	Rimini	RN	M2	RIC	C	520	A
33	Canale dei Mulini	Draining channel	coastal stretch between the two piers of Mulini channel	Rimini	RN	M2	RIC	C	30	
34	Viserba Nord	Cell with beach	coastal stretch defended by 3 breakwaters starting from Mulini channel	Rimini	RN	M2	RIC	C	465	A
35	Viserbella	Cell with beach	coastal stretch between the 4th breakwater and Fossa Brancona	Rimini	RN	M2	RIC	C	1.200	S
36	Torre Pedrera	Cell with beach	coastal stretch between Fossa Brancona and Rimini/Bellaria-Igea Marina municipality boundary	Rimini	RN	M2	RIC	C	1.960	S
37	Igea Marina Sud	Cell with beach	coastal stretch between Rimini/ Bellaria-Igea Marina municipality boundary and a groin	Bellaria Igea Marina	RN	M2	RIC	C	515	E
38	Igea Marina Zona Sperimentale	Cell with beach	coastal stretch defended by a low-crested breakwater delimited by two groins	Bellaria Igea Marina	RN	M2	RIC	C	825	E
39	Igea Marina	Cell with beach	coastal stretch between the groin and the southern pier of Uso river mouth	Bellaria Igea Marina	RN	M2	RIC	C	2.630	S
40	Foce Uso	River mouth	coastal stretch of Uso river mouth	Bellaria Igea Marina	RN	M2	RIC	C	40	
41	Bellaria	Cell with beach	coastal stretch between Uso river mouth and Bellaria-Igea Marina/San Mauro a Pascoli municipality boundary	Bellaria Igea Marina	RN	M2	RIC	C	2.690	P

n	name	typology	physical delimitation	municipal.	prov.	M	GU	GSU	L	ASPE
42	San Mauro	Cell with beach	coastal stretch between of San Mauro a Pascoli municipality	San Mauro Pascoli	FC	M2	RIC	C	700	P
43	Savignano	Cell with beach	coastal stretch between San Mauro a Pascoli municipality boundary and and the southern pier fo Rubicone mouth	Savignano	FC	M2	RIC	C	155	P
44	Foce Rubicone	River mouth	coastal stretch of Rubicone river mouth	Savignao / Gatteo	FC	M2	RIC	C	160	
45	Gatteo a Mare	Cell with beach	coastal stretch between northern pier of Rubicone river mouth and the 6th breakwater	Gatteo a Mare	FC	M2	RIC	C	700	P
46	Villamarina	Cell with beach	coastal stretch between the 7th breakwater and the first Valverde groin	Cesenatico	FC	M2	RIC	C	880	P
47	Valverde	Cell with beach	coastal stretch between the first Valverde groin and the Colonia Agip groins	Cesenatico	FC	M2	RIC	C	1.750	P
48	Cesenatico	Cell with beach	coastal stretch between Colonia Agip groins and Cesenatico southern pier	Cesenatico	FC	M2	RIC	C	2.015	A
49	Porto Canale Cesenatico	Harbour entrance	coastal stretch of Cesenatico harbour	Cesenatico	FC	M3	RIC	C	55	
50	Cesenatico Ponente	Cell with beach	coastal stretch between the Cesenatico northern pier and the big groin	Cesenatico	FC	M3	RIC	B	825	E
51	Cesenatico Colonie	Cell with beach	coastal stretch 800 m long starting from the big groin	Cesenatico	FC	M3	RIC	B	775	E
52	Cesenatico Campeggio Zadina	Cell with beach	coastal stretch 500 m long southern of Tagliata channel	Cesenatico	FC	M3	RIC	B	500	A
53	Canale Tagliata	Draining channel	coastal stretch of Tagliata channel	Cesenatico	FC	M3	RIC	B	10	
54	Zadina Tagliata	Cell with beach	coastal stretch 1 km long starting from Tagliata channel	Cesenatico / Cervia	FC / RA	M3	RIC	B	1.000	P
55	Cervia	Cell with beach	coastal stretch 4400 m long southern of Cervia dock	Cervia	RA	M3	RIC	B	4.420	S
56	Darsena di Cervia	Dock	coastal stretch of Cervia dock	Cervia	RA	M3	RIC	B	165	
57	Porto Canale di Cervia	Harbour entrance	coastal stretch of Cervia harbour	Cervia	RA	M3	RIC	B	40	
58	Milano Marittima	Cell with beach	coastal stretch between northern pier of Cervia harbour and southern pier of Canalino delle Saline	Cervia	RA	M3	RIC	B	1.365	S
59	Canalino delle Saline	Draining channel	coastal stretch of Canalino delle Saline	Cervia	RA	M3	RIC	B	30	
60	Milano Marittima Nord	Cell with beach	coastal stretch between northern pier of Canalino delle Saline and the first groin	Cervia	RA	M3	RAC	D	1.685	P
61	Milano Marittima Colonie	Cell with beach	coastal stretch between the first groin and southern pier of Cupa drainage channel	Cervia	RA	M3	RAC	D	540	E
62	Canale di Via Cupa	Draining channel	coastal stretch of Cupa drainage channel	Cervia	RA	M3	RAC	D	20	
63	Lido di Savio	Cell with beach	coastal stretch between the northern pier of Cupa and southern groin of Savio river mouth	Ravenna	RA	M3	RAC	D	2.070	S
64	Foce Savio	River mouth	coastal stretch of Savio river mouth	Ravenna	RA	M3	RAC	D	265	
65	Lido di Classe	Cell with beach	coastal stretch between the northern groin of Savio and the first groin of Lido di Classe Nord	Ravenna	RA	M4	RAC	D	1.220	S

n	name	typology	physical delimitation	municipal.	prov.	M	GU	GSU	L	ASPE
66	Lido di Classe Nord	Cell with beach	coastal stretch between the first and the last groin of di Lido di Classe Nord	Ravenna	RA	M4	RAC	E	580	S
67	Bevano Sud	Cell with beach	coastal stretch 1 km long starting from the last groin of Lido di Classe nord	Ravenna	RA	M4	RAC	E	1.000	P
68	Bevano Centro Sud	Cell with beach	coastal stretch between 1900 m long southern Bevano river mouth	Ravenna	RA	M4	RAC	E	1.900	S
69	Foce Bevano	River mouth	coastal stretch of Bevano river mouth	Ravenna	RA	M4	RAC	E	110	
70	Bevano Centro Nord	Cell with beach	coastal stretch 1300 m long from Bevano river mouth	Ravenna	RA	M4	RAC	E	1.300	S
71	Bevano Nord	Cell with beach	coastal stretch 1 km long southern of the first groin of Lido di Dante	Ravenna	RA	M4	RAC	D	1.000	E
72	Lido di Dante	Cell with beach	coastal stretch between the first and the last groin	Ravenna	RA	M4	RAC	D	605	E
73	Sud Foce Fiumi Uniti	Cell with beach	coastal stretch between the last groin of Lido di Dante and the Fiumi Uniti river mouth	Ravenna	RA	M4	RAC	D	600	E
74	Foce Fiumi Uniti	River mouth	coastal stretch of Fiumi Uniti river mouth	Ravenna	RA	M4	RAC	D	270	
75	Nord Foce Fiumi Uniti	Cell without beach	coastal stretch between Fiumi Uniti mouth and the first breakwater of Lido Adriano	Ravenna	RA	M4	RAC	D	360	E
76	Lido Adriano	Cell with beach	coastal stretch defended by 19 emerged breakwaters	Ravenna	RA	M4	RAC	D	2.560	E
77	Punta Marina	Cell with beach	coastal stretch between the first and the 11th groins defended by a low-crested breakwater	Ravenna	RA	M4	RAC	D	3.730	E
78	Punta Marina Nord	Cell with beach	coastal stretch between the 11th and the Bagno Ruvido groin	Ravenna	RA	M4	RAC	E	865	S
79	Marina di Ravenna	Cell with beach	coastal stretch between Bagno Ruvido groin and southern pier of Ravenna harbour	Ravenna	RA	M4	RAC	E	3.000	A
80	Porto di Ravenna	Harbour entrance	coastal stretch of Ravenna harbour mouth	Ravenna	RA	_	RAC	E	1.230	
81	Porto Corsini	Cell with beach	coastal stretch 1 km long starting from Ravenna harbour	Ravenna	RA	M5	RAC	E	1.000	A
82	Marina Romea	Cell with beach	coastal stretch between 1 km and 2,3 km from Ravenna harbour	Ravenna	RA	M5	RAC	E	1.300	A
83	Marina Romea Nord	Cell with beach	coastal stretch 950 m long southern Lamone river mouth	Ravenna	RA	M5	RAC	D	945	E
84	Foce Lamone	River mouth	coastal stretch Lamone river mouth	Ravenna	RA	M5	RAC	D	140	
85	Foce Lamone-Casal Borsetti	Cell with beach	coastal stretch between northern pier of Lamone mouth and the first breakwater of Casal Borsetti	Ravenna	RA	M5	RAC	D	2.110	E
86	Casal Borsetti Sud	Cell with beach	coastal stretch between the first breakwater of Casal Borsetti and the right channel of Reno river	Ravenna	RA	M5	RAC	D	835	S
87	Canale Destra Reno	Draining channel	coastal stretch of right channel of Reno river	Ravenna	RA	M5	RAC	D	30	
88	Casal Borsetti Nord	Cell with beach	coastal stretch defended by 4 emerged breakwaters starting from the right channel of Reno river	Ravenna	RA	M5	RAC	D	520	E

n	name	typology	physical delimitation	municipal.	prov.	M	GU	GSU	L	ASPE
89	Casal Borsetti Fio 82	Cell with beach	coastal stretch between the 4th breakwaters and the 2nd groin of Casal Borsetti	Ravenna	RA	M5	RAC	D	630	A
90	Poligono Militare	Cell without beach	coastal stretch 2,5 km long starting from the 2nd groin of Casal Borsetti	Ravenna	RA	M5	RAC	D	2.500	P
91	Poligono Militare Nord	Cell with beach	coastal stretch 1,1 km long southern Reno river mouth	Ravenna	RA	M5	RAC	D	1.100	E
92	Foce Reno	River mouth	coastal stretch of Reno river mouth	Ravenna	RA	M5	RAC	D	235	
93	Nord Foce Reno	Cell with beach	coastal stretch 2 km long starting from Reno river mouth	Ravenna	RA	M5	RAC	D	2.000	S
94	Foce Gobbino Sud	Cell with beach	coastal stretch 850 m long southern Gobbino channel mouth	Ravenna	RA	M5	RAC	D	860	E
95	Foce Gobbino	Draining channel	coastal stretch of Gobbino channel mouth	Ravenna	RA	M5	RAC	D	100	A
96	Foce Gobbino - Bagno Giamaica	Cell with beach	coastal stretch between Gobbino river mouth and Giamaica establishment	Ravenna / Comacchio	RA / FE	M5	RAC	D	1.575	E
97	Lido di Spina Sud	Cell with beach	coastal stretch 900 m long starting from Giamaica establishment	Comacchio	FE	M5	RAC	D	900	E
98	Lido di Spina Nord	Cell with beach	coastal stretch 2 km long southern of Logonovo channel mouth	Comacchio	FE	M5	RAC	E	2.070	A
99	Foce Logonovo	Draining channel	coastal stretch of Logonovo channel mouth	Comacchio	FE	M5	RAC	E	200	
100	Lido degli Estensi	Cell with beach	coastal stretch between Logonovo muth and southern pier of Porto Garibaldi	Comacchio	FE	M5	RAC	E	1.540	A
101	Bocca Porto Garibaldi	Harbour entrance	coastal stretch of Porto Garibaldi harbour	Comacchio	FE	M6	RAC	F	110	
102	Porto Garibaldi	Cell with beach	coastal stretch between northern pier of Porto Garibladi and the 15th breakwater	Comacchio	FE	M6	RAC	F	1.480	P
103	Lido degli Scacchi	Cell with beach	coastal stretch between the 16th and the 34th breakwater	Comacchio	FE	M6	RAC	F	2.500	P
104	Lido di Pomposa	Cell with beach	coastal stretch between the 35th and 52nd breakwater	Comacchio	FE	M6	RAC	F	2.240	E
105	Lido delle Nazioni	Cell with beach	coastal stretch between the 53rd breakwater and the groin closing the breakwater	Comacchio	FE	M6	RAC	F	2.910	E
106	Bocche del Bianco	Cell with beach	coastal stretch, defended by a seawall, 1,1 km long starting from the groin	Comacchio	FE	M6	RAC	F	1.130	E
107	Pineta di Volano	Cell without beach	coastal stretch, defended by a seawall, 1,6 km long southern of the first groin	Comacchio	FE	M6	RAC	F	1.600	P
108	Volano Zona Pennelli	Cell with beach	coastal stretch between the first and the last groin	Comacchio	FE	M6	RAC	G	990	E
109	Volano	Cell with beach	coastal stretch 1750 m long starting from the last groin	Comacchio	FE	M6	RAC	G	1.750	P
110	Scannone di Volano	Cell with beach	coastal stretch 1950 m long southern of Po di Volano river mouth	Comacchio	FE	M7	RAC	G	1.949	A
111	Foce Po di Volano	River mouth	coastal stretch of Po di Volano	Comacchio / Codigono	FE	M7	RAC	G	1.880	

n	name	typology	physical delimitation	municipal.	prov.	M	GU	GSU	L	ASPE
112	Po di Volano Area Naturale	Sacca	coastal stretch 750 m long starting from Po di Volano river mouth	Codigoro / Goro	FE	M7	PDC		750	
113	Territorio del Comune di Goro	Sacca	coastal stretch 10 km long defended by seawall	Goro	FE	M7	PDC		10.000	
114	Po di Goro	Sacca	last stretch of Po di Goro river	Goro	FE	M7	PDC		5.260	
115	Foce Po di Goro	River mouth	coastal stretch of Po di Goro river mouth	Goro	FE	M7	PDC		140	
116	Faro di Goro	Cell with beach	coastal stretch 1 km long southern of the groin of Po di Goro	Goro	FE	M7	PDC		1.000	E
117	Scanno di Goro centro	Cell with beach	coastal stretch between the 1st and the 6th km westward Po di Goro mouth	Goro	FE	M7	PDC		5.000	S
118	Bocca Laguna	Lagoon mouth	coastal stretch of lagoon mouth	Goro	FE	M7	PDC		4.625	A

LEGEND

M: Macrocell
GU: Geomorphologic unit
GSU: Geomorphologic sub-unit
L: lenght (m)

ASPE classification

- accumulation
- stable
- precarious balance
- erosion

THE SEDIMENT SOURCES USEFUL FOR BEACH NOURISHMENT

Foreword

The sediment sources useful for beach nourishment can be broken down into two main categories: internal sources and external sources.
Internal sources include sediment accumulation subject to internal dynamics within the coastal system: backshore and foreshore up to its closure (including offshore breakwaters), and sediment accumulation close to the port, river and canal mouths.
External sources include those sediment deposits, or other sediments coming from outside the current coastal system dynamics, which are introduced into the system only as a result of their artificial or natural transfer (human intervention or river transport). They also include off-shore sand deposits (Middle Adriatic relict beaches), inland sand quarries, various sand harvesting sites, such as those associated to construction or infrastructure projects, the construction of new marinas or expansion of ports and finally the existing sediment transport to the sea by the Po River and by other watercourses from the Apennines, which are, much less now than in the past, the natural feeding of the Emilia-Romagna coastal system.

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.
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.

figure 16 Picture of Po di Goro mouth and Scanno e dello Scanno extends westward

Over the past 50 years, the Scanno di Goro (Fig. 16) 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.

M	n	name	w/drawal m^3 00-06	w/drawal m^3 06-10
1	3	Cattolica Sud	80.050	17.400
1	13	Misano Scogliere	18.450	10.620
1	23	Fogliano Marina	0	0
1	24	Miramare	32.700	19.665
1	25	Rimini Centro	9.650	0
2	30	Rivabella	0	5.000
2	31	Viserba Zona Sud Sortie	0	0
2	34	Viserba Nord	0	0
2	39	Igea Marina	7.000	14.000
2	42	San Mauro	0	1.250
2	48	Cesenatico	15.000	18.980
3	58	Milano Marittima	0	6.000
4	79	Marina di Ravenna	0	0
5	81	Porto Corsini	29.255	112.200
5	100	Lido degli Estensi	246.800	25.000
7	110	Scannone di Volano	123.500	141.295
7	117	Scanno di Goro Centro	0	0
7	118	Bocca laguna	0	0
		total volumes	562.405	371.410

table 1 Littoral cells with beach in accumulation suitable for sand withdrawal to be used for beach nourishment purposes of beach under erosion, related macrocells and volumes of sand withdrawals in the 04/2000-04/2006 and 05/2006-12/2010 periods

As a result of various human interventions in the following years, this bar of sand was interrupted at about 7 km from its root and in a few years a 20 m gap turned into 700 m opening under the tide pressure. Later, the relict beach stretch further west, which was no longer fed, became almost completely eroded, while the materials coming from the mouths have accumulated to the east of the opening. 800,000 m^3 of sand were harvested here in 2002 and over one million m^3 of material was collected in 2009 and then redistributed within the Sacca area to revitalize its bottom and increase the growth of shellfish (a project funded by the shellfish producers' cooperatives).

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 1, as stretches of coastline that could be potentially used for sand harvesting purposes.
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. 17).
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.

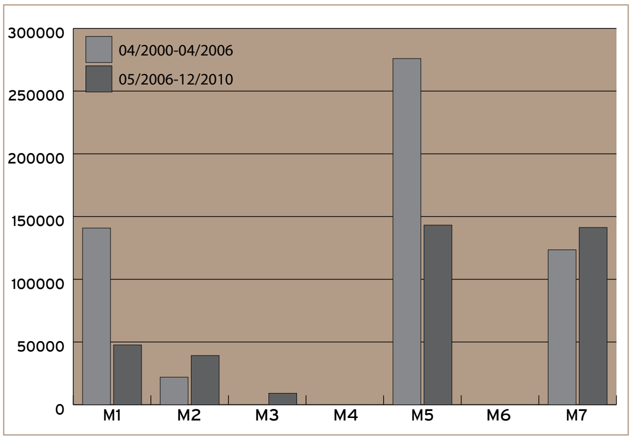


figure 17 Volumes of sand harvested from the 1st, 2nd, 5th, and 7th macrocell, from 04/2000 to 12/2010.

In 2000-2006, M5 (Corsini Porto - Porto Garibaldi) was the most exploited macrocell: approximately 250,000 m^3 of sand were collected in Lido degli Estensi.
Most of the selected cells are characterized by a 50 - 100 m wide backshore with an inshore 1 - 2 m closure (Fig. 18 and 19). 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).

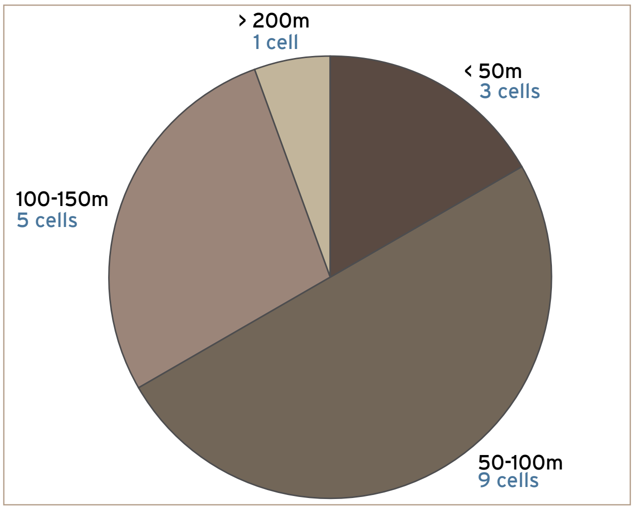


figure 18 Average backshore width of the 18 cells in table 1

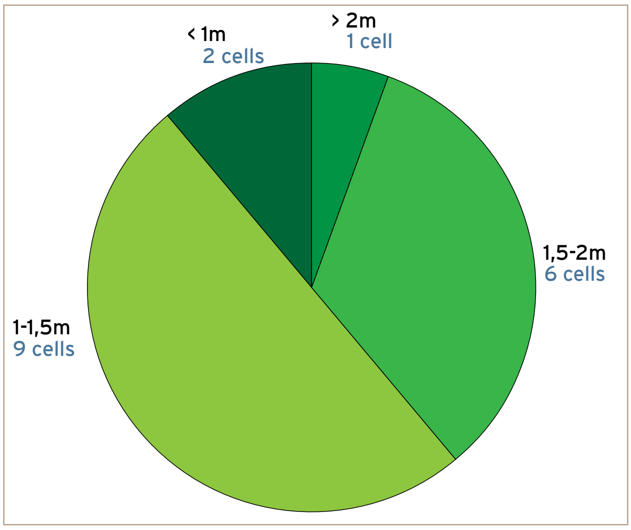


figure 19 The average inshore closure depth of the beach in the 18 cells of table 1

Port dredging

Several ports are located along the 130 km long coast of the Emilia-Romagna Region. They have often been built either using the river mouths or by building an artificial canal cutting through the backshore and shoreface.
This was the only way to link the inner basin, serving as shelter or mooring for boats, to the open sea. For these reasons, all the Emilia-Romagna ports fall in the category of port-canals (i.e. harbour entrances with parallel jetties).
All port-canals are subject to silting up, depending on their location, the length of the piers and direction of coastal solid sediment transport.
The materials silting up in the vicinity of the port-canal entrances are mostly made up of beach sand drifting along the coast transported by coastal currents.
In a coastline, such as that of Emilia-Romagna, the opening of an underwater canal to facilitate access of vessels to the port translates into a change in the morphology of the seabed, which inevitably is short-lived, since the wave motion lifts and drifts the underwater sand, thus silting up the canal and restoring the initial sea bottom situation.
The best way to dispose of sand silting up the canal is to use it for the nourishment of eroding beaches not far from the port entrance, provided that it is not polluted. Yet, until 1996, the sand dredged at the port entrance was transported and discharged into the sea a few miles offshore.
The law regulating the dredging and dumping of material in the coastal area has been updated by the Ministry of Environment Decree dated 24 January 1996, which provides for severe technical and legal procedures to be applied to any handling activity.

figure 20 Cesenatico harbour.

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-Roma-

gna 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. 20);
- 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.
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.

n	name	w/drawal m^3 00-06	w/drawal m^3 06-10
1	Bocca Tavollo (Porto di Cattolica)	0	35.000
9	Canale Porto Verde	16.000	4.000
18	Riccione Porto Canale	48.200	42.400
26	Rimini Porto Canale	0	0
49	Porto Canale di Cesenatico	0	0
57	Porto Canale di Cervia	33.500	64.950
101	Bocca Porto Garibaldi	0	133.000
	total volumes	97.700	279.350

table 2 port mouth suitable for sand withdrawals to be used for nourishment and volumes of sand dredged from 04/2000 to 04/2006 and from 05/2006 to 12/2010.

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. 21);
- Po di Goro River mouth.

In the case of the Marano River mouth, the material was harvested from the beach on either side, rather than inside the area within the river mouth. About 4-5000 m^3 every 4-5 years are harvested, by means of mechanical shovels and transported to the eroding beaches in Riccione by truck.
The Logonovo Canal mouth separates Lido di Spina from Lido degli Estensi and therefore it is located within a very wide beach under constant accretion.
The Logonovo Canal connects the Valli di Comacchio with the open sea. Keeping its mouth clear of sediments is therefore a necessity.
Towards the late 1980s, ERSA (Regional Agency for Rural Development) of Ferrara identified this site as the most suitable one for harvesting sand to be used to rebuild dunes eroded by the sea in the south of Lido di Spina.
After a few years, large quantities of sand from Logonovo, amounting to 20 to 40,000 m^3 every 4-5 years, were repeatedly harvested by the Po di Volano Basin Technical Service.
Another interesting case is the harvesting of sand from the Po di Goro river mouth bar.

figure 21 Logonovo channel mouth.

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 di-

scharging 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 3).

n	name	w/drawal m^3 00-06	w/drawal m^3 06-10
5	Foce Ventena	16.800	900
7	Foce Conca	14.150	0
22	Foce Marano	0	0
29	Deviatore Marecchia	0	0
40	Foce Uso	20.400	15.500
44	Foce Rubicone	0	3.050
53	Canale Tagliata	0	2.600
59	Canalino delle Saline	0	0
62	Canale di Via Cupa	0	0
64	Foce Savio	0	0
74	Foce Fiumi Uniti	0	0
84	Foce Lamone	0	56.000
87	Canale Destra Reno	0	0
95	Foce canale Gobbino	57.000	61.020
99	Foce canale Logonovo	247.800	170.444
111	Foce Po di Volano	0	0
115	Foce Po di Goro	120.000	0
	total volumes	476.150	309.514

table 3 Mouths and bars of rivers and canals suitable for sand withdrawals to be used for nourishment and volumes of sand dredged from 04/2000 to 04/2006 and from 05/2006 to 12/2010.

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.

Tomboli behind the breakwaters

Between 1947 and 1980, several emerged longshore breakwaters were built, for a total of 40 km in length, to protect many stretches of beach under erosion.

The longest barrier is the one built between the port of Rimini and the port of Cesenatico piers, 20 km apart from each other.
The emerged longshore breakwaters are able to stop and dampen more than 80% of the wave motion energy, thus reducing the sea energy within the basin enclosed between the breakwaters and the shoreline. As a result even the material sedimentation process is significantly altered in favour of finer particles.
The area where the energy is most dampened is that behind the main body of the work. In this area the largest sedimentation takes place. Hence, in many cases, if the breakwaters have been built at a short distance from the shoreline and there is enough flow of material, the beach gets connected with the offshore reef and it takes on the characteristic shape of a "tombolo" (Fig. 22).
If the offshore breakwaters are distant and/or there is a small quantity of material, submerged deposits pile up close to the reefs.

figure 22 Tombolo behind breakwaters

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.

Sand sources away from the system

Off-shore sand sources

Six underwater sand deposits (A, A1, B, C1, C2, C3, Figure 23), and an extensive silty-sandy body (H) (Idroser, 1985, 1990, 1996, ARPA, 2001; Correggiari *et al.*, in press; Beachmed-e, 2006-2008) have been identified to date on the northern Adriatic continental shelf, off the coast of Emilia-Romagna.
These offshore sand sources are a finite non-renewable resource, which should be used according to a sustainable management model.
Overall, the presence of about 195 million m^3 of sand has been estimated in the first 6 deposits and further 195 million m^3 of sandy silt has recently been discovered in the H deposit. Yet, a portion of material should be subtracted from these overall figures, since it cannot be used for the reasons that are described here below.
Indeed, a layer of sand must be left at the base of the deposit, so as to prevent the removal of the underlying pelites, both for environmental and practical issues, related to the fact that the discharge of clays on the beach might entail not negligible economic damage. Although the debate among technicians is still going on regarding the proper sand layer thickness, they have agreed on leaving at least a 50 cm thick layer in place. According to this reference limit, the volume of available sand amounts to about 120 million m^3 and silt to about 100 million m^3.

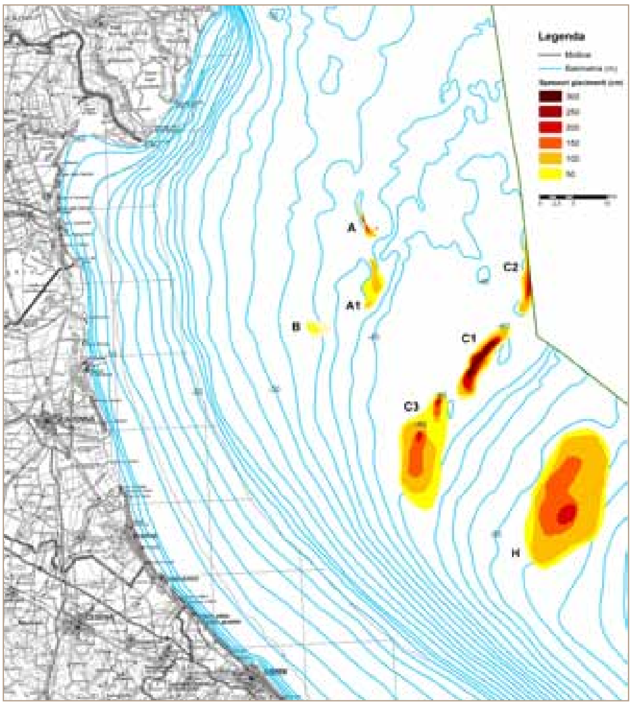


figure 23 Six off-shore sand deposits

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 off-shore 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 nourishment by means of off-shore 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 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).

figura 24 Pipeline working during the second off-shore sand nourishment in 2002.

Sand mounds C1 and A were selected as harvesting sites (Fig. 23). The C1 sand site has been mined both during the 2002 and 2007 campaigns, while site A only during the 2007 campaign (Correggiari *et al*., In press).
In 2002, 800,000 m^3 of sand were harvested from C1 site, and in 2007, further 815,000 m^3 were harvested in part from A and in part from C1 sites (Fig. 23).
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 off-shore sand. (ARPA, 2009; Preti *et al*., In press b).

Inland quarries

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

Substantial evidence is at the basis of this conclusion:
land-based quarries have an extensive and heavy landscape and environmental impact, thus scarring the flat land with "big" holes;

1. a large amount of sand is taken away from the construction aggregates market;
2. the unit price of sand, which is already very high, increases substantially (about 20 Euro/m^3);
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. 25).

figure 25 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.

figure 26 South of Riccione: sand coming from the building excavation before nourishment by means of off-shore sand in spring 2007

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. 26).
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. 27).

figure 27 Rmini new docks was built near the main pier of Rimini port

figure 28 San Giuliano beach (Rimini) two years after nourishment with sand coming from the costruction of Rimini dock.

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 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 (Fig. 28);
- 51,450 m^3 of material made of 1/3 of lime, 1/3 sand and 1/3 of gravel used for beach nourishment purposes of the shoreface in front of the rock armour of Porto Verde (Misano Adriatico). The material was collected and deposited by means of a dredger.

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

In 2006, the new offshore sea defence works of the yachting marina of Cattolica were built in front of the old " fishing harbour" (Fig. 29).

figure 29 Cattolica: at the top the "fishing harbour"(2005), at the bottom, the new dock built in front of the existing one (2009)

figure 30 Bellaria-Igea Marina: section of the off-shore reef perimeter of the new dock built in Spring 2009.

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

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

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

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. 30, ARPA 2010b). In the design phase, in view of the building of this work, several thousand cubic meters of sand were to be dredged and used as beach nourishment material for the adjacent beaches.
The use of the dredged material used to build the docks for beach nourishment purposes has two advantages, an environmental and an economic one. As a matter of fact, on the one hand, this operation allows to recover material that would presumably be dumped away and, on the other hand, the price charged to the community is equal to zero, since the material dredging, transport and storage operations are at the dock owner's charge.

Dredging of the Port of Ravenna

figure 31 Port of Ravenna.

The port of Ravenna (Fig. 31) 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 Lamone river mouth.

n	name	w/drawal m³ 00-06	w/drawal m³ 06-10
80	Porto di Ravenna	250.000	900.000

table 4 From 2000 to 2010 the total sand withdrawals from Ravenna port were 1,15 milioni fo m³

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 m³ of material partly deriving from the deepening of the seabed and partly from extensions.

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.
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.
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 sy-

stem, 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 Marecchia 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:

- 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.

figure 32 Marecchia river alluvial bed

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 Marecchia 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).

THE CELLS MANAGEMEMENT SYSTEM DATABASE

Foreword

The monographic data sheets and tables reported here below, referred to the 118 coastal cells, provide the information of the associated database. Although the database was updated in late 2010 (with a further update started in 2011, which is still in progress) the data reported in the data sheets concern the 2000-2006 period. This is due to the fact that the ASPE cell classification uses, as a fundamental benchmark, the topobathymetric profiles to evaluate volume changes of the foreshore and backshore (net of contributions or withdrawals from deposits and considering the lowering due to subsidence). To update the ASPE classification it is therefore necessary to await the results of the topo-bathymetric and of the subsidence monitoring campaigns, which are still under way (2011-2012). Yet, it seemed relevant to come up with this first classification and database, which give an account of the information reorganization and systematization work being done and serving as reference for a further updating at the end of 2012.

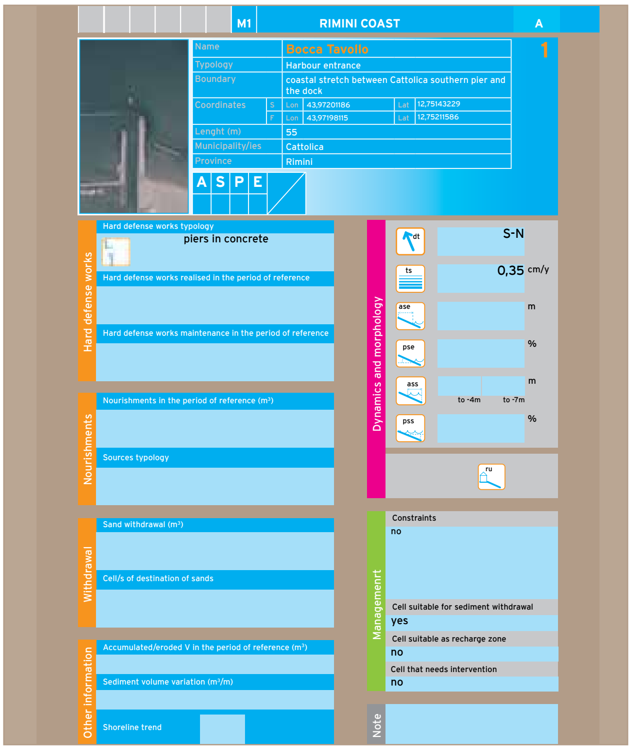


figure 33 Monographic sheet of the 1st cell, Bocca del Torrente Tavollo

The Cell monographic data sheets: description of the parameters

A littoral cell refers to a stretch of the coastline characterized by morphological conditions and uniform evolutions of the foreshore and backshore, which distinguish it from adjacent coastline stretches.

The monographic data sheet is the "identity card" of a coastal cell, and summarizes the main morphodynamics and management aspects. As already pointed out, the monographic data sheet refers to the 2000-2006 time period and it is broken down into 4 main information categories (fig.33).

1. **General information** that determine the location, length, type (e.g. beach, river mouth, dock, etc.), the macrocell, the geomorphologic Unit and Sub-unit and ASPE class of the cell;
2. **Information on the evolutionary state of the cell** contributing to the ASPE classification: various interventions, beach nourishment, harvesting, new defence works or maintenance works of existing hard defence structures, sediment balance (accumulated or eroded volumes), the shoreline trend;
3. **Information on the morphology and dynamics of the cell:** the morphology of the beach, the rate of subsidence and the direction of the longshore drift; information relating to the use of the shore and backshore;
4. **Operational information:** the presence of constraints, suitability of the cell to be used as harvesting area or as a strategic recharging point and finally the need for defence measures within the cell.

In order to achieve the classification of the evolutionary status of individual cells (Chapter 2) a status indicator was taken into account and adjusted to the management needs, called "State of the shoreline indicator", defined by the ARPA Specialised Sea and Coast Unit in the chapter de-

voted to coastal erosion of the 2009 Regional Environmental Data Yearbook .
As part of the review process of coastal cells, the new analysis method, introduced by the abovementioned indicator, has been revised and agreed upon by the COASTANCE working group, thus becoming a support tool to be applied to coastal management, for the ASPE classification, which identifies the 4 following classes:

- accumulation (A)
- stable (S)
- precarious balance (P)
- erosion (E)

The allocation of coastal stretches to the various classes is based on an integrated analysis of a set of information:

- Change in volume of the foreshore and backshore (compared to the topobathymetric profiles of two following campaigns);
- Volume losses related to subsidence;
- Beach nourishment projects;
- Sand withdrawal;
- Presence and maintenance of defence works;
- Shoreline trend.

The integration of these parameters is essential for various reasons. A volume loss can be linked to erosion, but also to subsidence or to artificial sand harvesting. At the same time, an accumulation can be caused by natural processes, but it can also be linked to nourishment being carried out in the same stretch or in contiguous areas. The presence of hard defence works also heavily affects the beach dynamic and morphological characteristics. The situation of defence works in terms of efficiency and maintenance requirements cannot be ignored when performing a thorough analysis. Finally, the shoreline has always been considered to be essential in the study of the evolutionary trend of the coastline. A qualitative analysis is also necessary, bearing in mind that this parameter is closely dependent on the continuous interventions that are carried out along the coast. For classification purposes, the work team has deemed as significant an accumulation or loss of sand greater than 30 m^3/m (fig.34).
According to this parameter, considering the other above mentioned parameters, an accumulation in a cell occurs when there is a significant accumulation of sand (> of 30m^3/m) in the period under consideration (in this case 2000-2006). A cell is considered to be stable if it has not suffered any significant losses or accumulations of sand and if no nourishment and/or construction or maintenance of hard defence works have been made in the period under consideration. A cell is considered to be in a precarious balance if a strategic accumulation or "significant" loss has been recorded in that particular stretch of the coastline, but where nourishment and/or construction or maintenance of hard defence works have been made in the period under consideration. Finally, a cell is considered to be under erosion if a sand loss greater than 30m^3/m is recorded.
The ASPE cell classification is an integral part of

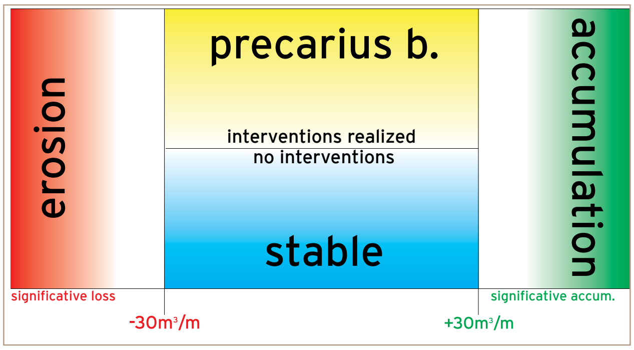


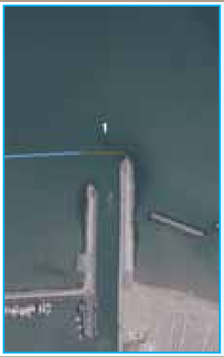
figure 34 ASPE classification scheme

the information system, developed in the 2000-2006 period, and further updated in late 2010, based on the data related to the new beach nourishment and hard defence work maintenance projects carried out in the 2007-2010 period, with further updates envisaged in the following years.
The ASPE cell classification will be upgraded at the end of 2012, by integrating the bathymetric and subsidence survey data, whose 2011 – 2012 campaign is still under way. A second publication will be issued to provide a comparative analysis between the first and the second observation and management period.

The detailed monographic data sheet

General information

						M1	RIMINI COAST	A



Name			Bocca Tavollo			1
Typology			Harbour entrance			
Boundary			coastal stretch between Cattolica southern pier and the dock			
Coordinates	S	Lon	43,97201186	Lat	12,75143229	
	F	Lon	43,97198115	Lat	12,75211586	
Lenght (m)			55			
Municipality/ies			Cattolica			
Province			Rimini			

A	S	P	E

Cell name
The cell name is attributed based on localization and distinctive spatial elements.

Cell type

Cel with beach	characterized by the presence of backshore
Cell without beach	characterized by the absence of backshore
River moth	corresponding to a river mouth, bounded by banks
Port mouth	corresponding to a Port mouth bounded by piers
Dock	corresponding to the sea front dock
Drainage channel	corresponding to the drainage channel mouth
Sacca	corresponding to a stretch of the internal shore of the Sea-inlet/Lagoon
Lagoon mouth	corresponding to the Lagoon mouth

Boundary
Brief description of the physical limits of the cell, clearly identifiable also through the geographical coordinates.

Cell length
The length of the cell is expressed in linear meters.

Municipality and Province
The Municipality/ies Province/s where the cell is located.

Cell number
Cells are numbered from 1 to 118 starting from the south.

Macrocell
The macrocell is a stretch of the coastline characterized by reduced sediment exchange with the adjacent coastal areas due to the presence of points of convergence of solid transport or long piers hindering the transport of sediments along the coastline.
The 7 Macrocells are illustrated in the following table:

n	name	Physical delimitation	L (m)
M1	Cattolica - Rimini	From the regional border with the Marche region to the port of Rimini (excluded)	19.390
M2	Rimini - Cesenatico	From the port of Rimini (included) to the port of Cesenatico (excluded)	20.620
M3	Cesenatico - Savio river mouth	From the port of Cesenatico (excluded) to the Savio river mouth	13.765

M4	Savio river mouth - Porto Corsini	From the Savio river mouth (excluded) to the port of Ravenna (excluded)	19.100
-	Port of Ravenna	From the southern outer breakwater to the northern outer breakwater of the Port of Ravenna	1.230
M5	Porto Corsini - Porto Garibaldi	From the port of Ravenna (excluded) to Porto Garibaldi (excluded)	20.590
M6	Porto Garibaldi - Po di Volano river mouth	From Porto Garibaldi (included) to the Po di Volano river mouth (excluded)	16.650
M7	Po di Volano river mouth - Po di Goro river mouth	From the Po di Volano river mouth (included) to the regional border with Veneto.	28.655
		total	140 km

This classification, proposed by ARPA in the 1996 Coastal Plan, breaks down the regional coastline into littoral cells depending on the morphological changes, direction of coastal sediment transport, presence of hard defence works and above all of breakwaters. The Macrocells are bounded by long piers or "zero" points (convergence and divergence points) of sediment transport along the coast, whose length varies between 10 and 20 km. Macro-cells are characterized by their own sediment balance and are regarded as key spatial reference points for the large-scale analysis of sand losses in the backshore and foreshore.

Geomorphologic units and subunits

Units	Sub-Units	Stretches of coast
RIC	A	Cattolica-Riccione
	B	Riccione- pier Rimini; Cesenatico north - Lido di Savio
	C	Rimini north - Cesenatico pier
RAC	D	Delta cusps (Reno river mouth-Casal Borsetti, Savio river mouth & Fiumi Uniti-Punta Marina)
	E	Inter-cusp Areas (Bevano river mouth, Porto Corsini, Lido degli Estensi)
	F	Porto Garibaldi-Lido delle Nazioni
	G	Volano river mouth
PDC		Po Delta

It is an evolutionary and geomorphologic classification of the coastal region based on the geological system, the evolutionary history and coastal land use, developed by the Geological, Seismic and Soil Service of Emilia-Romagna Region.
The classification stems from the integration of findings of specific studies related to the physical conformation, spatial geological balance and evolutionary history of the different time scales. The parameters used for classification have been grouped together into three main classes:

- **morphology and geology:** characteristics of depositional systems of the coastal plain; coastal dynamics, beach and dune development; shoreface morphology;
- **physical evolution:** a tendency to the 1,000, 100 and 10 years scale; main sedimentary processes;
- **land use:** main land use and ports.

On the basis of these main factors, the Emilia-Romagna coastline can be subdivided into three main units: the Rimini Coast (RIC): including the coastline of the Province of Rimini and Forlì-Cesena and, marginally, of Ravenna; the Ravenna Coast (RAC): including the coastal provinces of Ravenna and Ferrara, and the Po Delta coast (PDC) including the coastline of the Province of Ferrara. According to the variability of some physical characteristics, it has been possible to recognize a further subdivision of the Rimini and Ravenna Coast; as a consequence, seven sub-units have been identified, which are distinguished on the basis of the following parameters:

- coastal defences and / or complex sand bars;
- typology of coastal defence works;
- shoreface sedimentary structures.

This subdivision into sub-morphological units differs from the SICELL cell subdivision, created for management purposes, since it refers to homogeneous stretches of the coastline in terms of evolutionary behaviour, depending both on natural dynamics and on anthropogenic action.

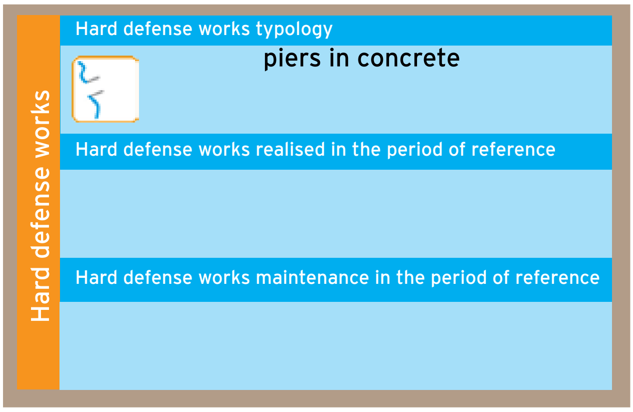
ASPE classification

According to the ASPE classification (Fig. 34) 4 cell classes can be identified (Accumulation, stable, in a precarious balance and undergoing erosion) on the basis of significant changes in volume over the period that has been taken into account. Significant volume changes are regarded as sand losses or accumulations above 30 m^3/m in the period under consideration (in this case the 2000-2006 period).

class	description
accumul.	Stretch of coastline showing significant accumulations of sand in the reference period
stable	Stretch of coastline showing no significant sand losses or accumulations, equipped with no erosion protection measures (beach nourishment or defence works) in the reference period
precar. balance	Stretch of coastline showing no significant sand losses or accumulations, equipped with erosion protection measures (beach nourishment or defence works) in the reference period
erosion	Stretch of coastline showing significant losses of sand during the reference period

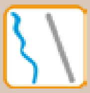
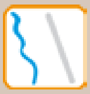
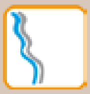
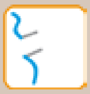
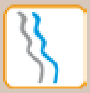
It has been decided to maintain the landward and seaward cell borders unchanged over time, in order to calculate the volumetric changes and to make the analyses and comparisons between the measurements performed over the years as comparable and homogeneous as possible. Volume change calculations were carried out starting from the head of the section to the shore-parallel breakwaters, if present, or to a 2.5 m depth of the first topo-bathymetric survey available in the profile in question.
The ASPE classification also takes into account another data set of hard defence works, beach nourishment, sand harvesting and other information related to each individual cell.

Defense works



Hard defence works present within the cell

A symbol describes the types of defence works present within the cell. The symbol may be followed by a brief description of the works, according to the classification provided by the Regional Geological Service hard defence work database:

Symbol	Defence works description
	Shore-parallel detached emerged breakwaters: reef segments with boulders placed at about a 3 m depth, separated by openings.
	Shore-parallel low-crest detached breakwaters: reef segments with boulders placed at about a 3 m depth, with limited height to reduce the visual impact and with a greater berm width
	Shore-parallel submerged detached breakwaters: alignment of geotextile bags filled with sand
	Shore-parallel emerged groins: groins extending from the backshore to the shoreline
	Shore-parallel submerged groins: synthetic fabric sheaths filled with sand mix
	Shore-parallel low-crest groins: groins extending from the backshore to the shoreline, with a reduced visual impact
	Seawall: consisting of a boulder embankment or by a dune cord
	Reinforced river mouth/docks: river mouth protected by rock embankments, piers.
	Defence against marine ingression: inland defence works

Hard defence works built during the reference period

If the defence works were built during the reference period, the corresponding symbol will appear in the specific line. The creation of new hard defence works is one of the parameters taken into account in the ASPE classification because works profoundly modify the dynamic and morphological characteristics of the beach.

Maintenance of hard defence works carried out during the reference period

If the works present in the cell have undergone maintenance during the reference period a brief description of the intervention will be indicated in the specific line. Changes in the hard defence work structures affects the beach dynamic and morphological characteristics; hence, this aspect is to be taken into account in the ASPE classification.

Beach nourishment

Nourishments	
	Nourishments in the period of reference (m³)
	Sources typology

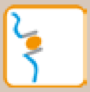
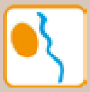
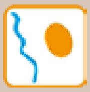
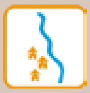
Source data on beach nourishment are provided by the River Basin Technical Services to feed the Regional Geological Service “beach nourishment database”, which is organized differently here for specific SICELL purposes.

Beach nourishment carried out during the reference period

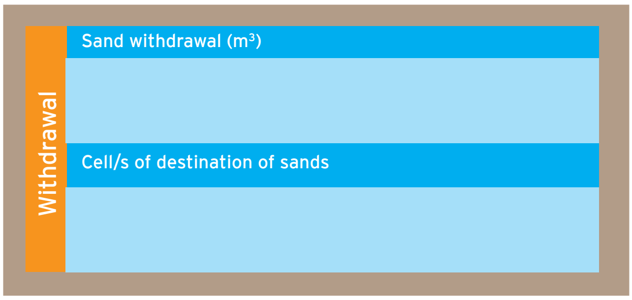
The amount of sand, expressed in m^3, used for nourishment purposes during the reference period, is reported in the specific line. Generally speaking, nourishment is carried out on more adjacent cells. For past interventions the value derived for each single cell is given by the subdivision of the total amount of the material used for nourishment purposes proportionately to the cells concerned. It is possible to accurately define the quantity of sand carried to each cell for nourishment purposes, both with reference to the 2007-2010 period and for the future, thanks to the development of the cell management system.

Cells of origin and sources of sand

The sand used for nourishment purposes can come from other cells (in this case, the line will report the number or numbers of cells where sand comes from) or other sources (in this case the line will report the symbol representing the source where sand comes from). During the reference period, in different years, different sources of material may have been used. For the various action specifications it is necessary to refer to the nourishment database, i.e. an information system developed by the Geological, Seismic and Soil Service in cooperation with the River Basin Technical Services of the Emilia-Romagna Region.
In the Cell data sheet the sources of sand are identified by a symbol as shown in the table below:

Symbol	Description of sand sources
	Dredging harbour, river or canal mouths and excavations for new docks.
	Inland quarries
	Littoral deposits, beach accretion
	Off-shore deposits
	Beach cleaning
	Building excavations

Sand withdrawal



The source data is provided by the Regional River Basin Technical Services. The same data is used to feed the “beach nourishment database” of the Regional Geological Service, here organized differently for specific SICELL purposes.

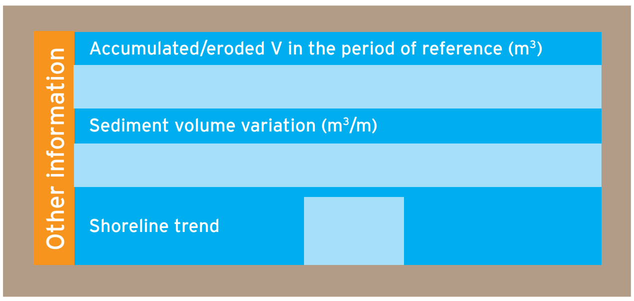
Sand withdrawal

This field reports, if any, the amount (expressed in m^3) of sand that has been harvested during the reference period for the nourishment of other beaches.

Sand target cells

With reference to the cubic meters of sand that have been collected, this field indicates the cell or cells to which the harvested sand has been carried. Similarly the monographic data sheet of the cell where nourishment has taken place reports the cell number from which sand was harvested, under the heading “sources of origin of sand”.

Other information



Accumulated and eroded volumes during the reference period

The m^3 value is calculated based on the comparison between the topo-bathymetric surveys of the 2000 and 2006 campaigns. The value will have a positive sign in case of accretion or a negative one in case of erosion.

Changes in the sediment volume

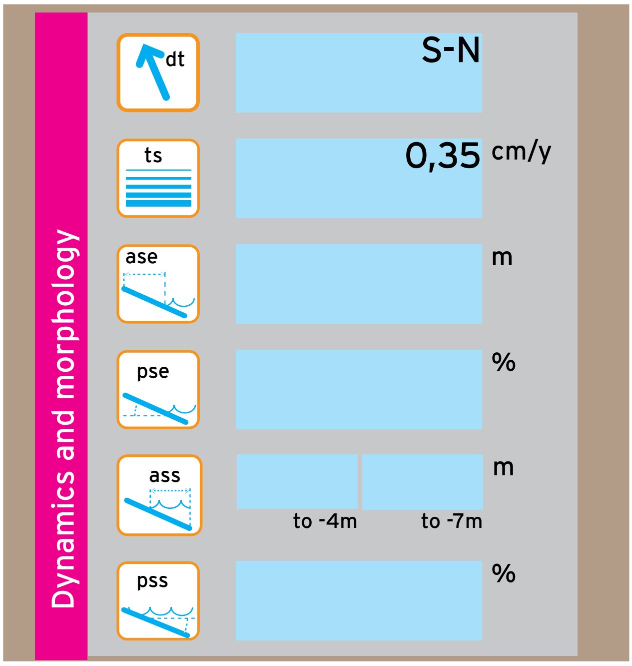
It indicates the sediment volume changes (m^3/m) calculated by detracting the value of accretion and erosion volumes (resulting from the comparison between the topo-bathymetric surveys) from the sand nourishment volume, in the period under review, and/or adding the volumes of harvested sand, related to the same period (accretion and erosion volumes - beach nourishment + sand withdrawal)

The shoreline trend

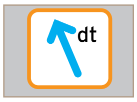
The shoreline trend has been reconstructed on the basis of the comparison between the shoreline of 2000, by means of photo-interpretation, and the shoreline of 2006, directly measured by means of differential GPS.
The shoreline is a further parameter that is taken into account in the ASPE classification, because it describes the evolutionary trend of the coastal area, although it has been severely affected by increasingly frequent sand nourishment and harvesting projects, over the past few decades.
The shoreline trend is represented by a symbol in the cell datasheet as shown in the table here below

Symbol	Description
	**advancing shoreline: advancing shoreline greater than 10 m along at least 100 m long stretches of the coastline**
	**stable shoreline: shoreline changes smaller than 10 m along at least 100 m long stretches of the coastline.**
	**retreating shoreline: retreating shoreline greater than 10 m along at least 100 m long stretches of the coastline**

Dynamics and morphology



Direction of longshore solid sediment transport



When a train of waves approaches a coastline obliquely, two main movement components occur: one perpendicular and another one parallel to the coastline.
The longshore current, which is generated in correspondence with the bathymetric line where wave breaking occurs, determines a longshore transport of sediment particles. The transport of sediment particles can easily be stopped by breakwaters, such as piers, resulting in a downdrift accumulation and an updrift erosion effect.
The longshore current is therefore one of the major factors controlling sedimentation and erosion of low sandy coasts such as the Emilia-Romagna coastline.

Direction	Description
N-S	north - south transport
S-N	south - north transport
E-O	east - west transport
Convergence zone	Solid sediment transport zero point where the longshore current tends to converge
Divergence zone	Solid sediment transport zero point where the longshore current tends to diverge

Subsidence rate

Subsidence is a natural process that determines the compaction of sediments, resulted in lowering the soil, due to the isostatic load of sediments themselves, thus causing the expulsion of fluids that are naturally contained in the sediment pores and therefore crushing pores themselves.
The natural subsidence process is often further aggravated by anthropic subsidence, namely due to human activities, which are likely to accelerate the natural process. They may include the extraction of hydrocarbons or water from the underground and land reclamation.
The coastal subsidence control network was established in 1983 and measurements were carried out in 1984, 1987, 1993, 1999 and 2005. The following measurement was completed in the second half of 2011.
Natural subsidence in the coastal region varies between 0.5 and 3 mm/year in relation to the thickness of geologically recent sediments. The lower values are found south of Rimini and higher values are recorded in the Po river delta area.
The value indicated in this field is an average subsidence rate (cm / y) of soil in the period under study and it is based on subsidence data recorded in 1999 and 2005.

Morphological beach elements

The beach can be subdivided into three main units (Fig. 35): backshore, foreshore and shoreface (alive or mobile) which together constitute a single sedimentary body in which sediments can

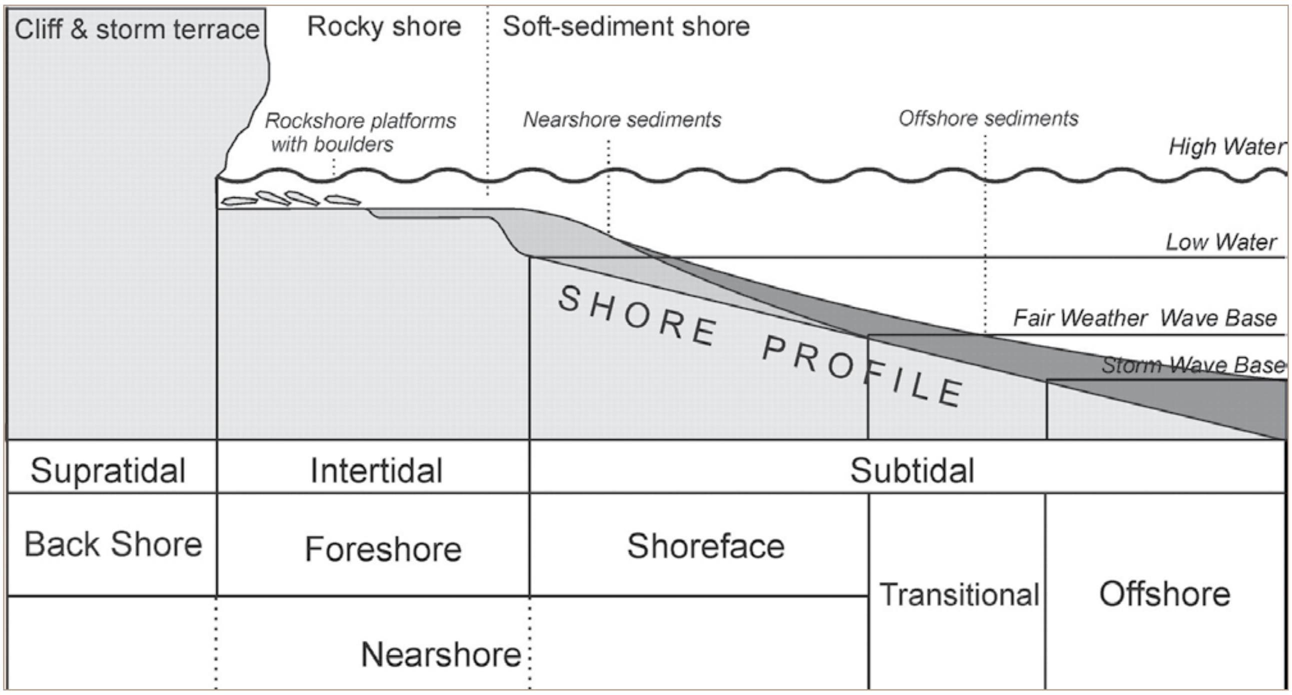


figure 35 A shore profile

move from one section to the other section depending on sea and weather events.
The boundary between the backshore and foreshore corresponds to the mean sea level line.
The lower boundary of the shoreface coincides with the so-called closure depth, within which, depending on slope, grain size and incident waves, sediments undergo further movements.
In Emilia-Romagna it is supposed to range between a 6 - 8 meter depth, except for the presence of breakwaters, artificial reefs or piers. The landward closure depth of the backshore is the line beyond which no effects of the normal marine coastal dynamics occur. This line may correspond to backshore artefacts (i.e. promenade walls, bathing establishment walls, inland defence works or other types of works) or at the foot of the dune, when present. The closure depth line was surveyed by the 2005 Coast flight and the elevation was calculated on the basis of the 2004 LIDAR DTM system. The cell datasheet includes all the main parameters describing the morphology of the beach, as illustrated in the following table.

Symbol	Definition
ase	**Backshore width: it is calculated from the shoreline, derived from the interpretation of aerial photographs taken during the 2005 Coast Flight, to the closing line of the backshore**
pse	**Backshore slope: the average value is calculated on the basis of the closing line level and width of the backshore related to the cell**
ass	**shore width: it is calculated from the shoreline (zero level) to the -4 and -7 m depths, derived from the 2006 topo-bathymetric surveys.**
pss	**shore slope: it is calculated from the 0 depth to the closure point of the beach profile, varying in depth and evaluated on the basis of the 2006 topo-bathymetric surveys.**

Other morphological elements

They are derived from coastal land use maps available in the Sea and Coast Geographical information system. They are represented by symbols in the cell datasheet as shown in the table below

Symbol	Definition

ru	urbanized backshore
sb	presence of bathing establishments
cd	presence of dunes

Management

Constraints

Managemenrt	
Constraints	no
Cell suitable for sediment withdrawal	yes
Cell suitable as recharge zone	no
Cell that needs intervention	no

Presence, description, name of the restricted area in which the coastal cell lies.

Cell suitable for sediment withdrawal

It is a cell from which, sand can be potentially harvested to be used for the nourishment of eroded stretches of the coastal line.

Cell suitable as strategic recharge zone

A cell undergoing erosion or in a precarious balance that can be used as a strategic area where substantial nourishment operations can be made. Thanks to longshore currents, nourishment sand will get redistributed to downdrift adjacent stretches along the coast.

Cell that needs intervention

A cell undergoing erosion or in a precarious balance close to inland areas concerned by intense human activities, infrastructures and economically or environmentally significant natural areas, which require defence actions.

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