SICELL

The littoral cell management system
2006-2012 update

RegioneEmilia-Romagna
Assessorato Difesa del Suolo e della Costa
Protezione Civile e Politiche Ambientali
e della Montagna

RegioneEmilia-Romagna
Assessorato Difesa del Suolo e della Costa
Protezione Civile e Politiche Ambientali e
della Montagna

The littoral cells management system SICELL

2006-2012 updating

edit by

Roberto Montanari, Christian Marasmi

Texts, pictures, cartographic and informatic processings

Carlo Albertazzi, Ambra Bonazzi, Monica Guida, Christian Marasmi, Roberto Montanari
Soil and Coast Protection and Land Reclamation Service

Margherita Aguzzi, Rosalia Costantino, Maurizio Morelli, Nunzio De Nigris, Tiziana Paccagnella, Silvia Unguendoli
Arpa SIMC

Flavio Bonsignore
Arpa Technical Directorate

Lorenzo Calabrese, Paolo Luciani, Luisa Perini
Geological, Seismic and Soil survey Service

with the contribution of

Maurizio Farina, Christian Morolli
Coast and Po Basin Technical Service

Mauro Corbelli, Andrea Foschi, Fabia Foschi, Ennio Malavolta, Sanzio Sammarini
Romagna Basin Technical Service

Graphic and design
Christian Marasmi

English translation
Mariapia Falcone

In the cover picture of Antonio Trogu

This English version is made for the FINAL JOINT CAPITALISATION EVENT, held in Bruxelles the 24-25 March 2015

INDEX

Paola Gazzolo
Regional Minister for Soil and Coast Protection, Civil Protection
Environmental and Mountain Policies.
Emilia-Romagna Region

The Emilia-Romagna coast is a complex system in which various natural and anthropogenic factors interact with different dynamics and often a difficult balance. It is a valuable natural and historical heritage characterized by a widespread presence of economic activities and a tourism system of national relevance. Yet, at the same time, coastal system management and protection is one the priority areas for the Emilia-Romagna Regional Government.
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 defence management policies and strategies, which have placed it at the forefront both in Italy and in Europe.
Also due to dwindling national funding sources, these activities could also benefit from EU funds, through the participation in several EU Territorial Cooperation projects, thus creating synergies and each time capitalizing the experiences and results achieved by individual projects (i.e. (CoastView, Cadsealand, Beachmed-e, PlanCoast, Micore, CoastBest, Maremed, Coastance, Shape, Coastgap).
SICELL, the Littoral Cells Management System, which makes the object of this presentation, is a demonstration of continuity and capitalization. SICELL was launched within the framework of the Coastance project, then further developed and updated by the Coastgap project, with implementation to the Emilia-Romagna regional coastal area and further capitalization by other Mediterranean partner regions. SICELL has thus proved to be a versatile and customizable management tool, applicable to other coastal contexts as well.
This is the result of a fruitful collaboration between various regional departments engaged in coastal defence (Regional Soil and Coast Defence and Land Reclamation Service, Geological, Seismic and Soil Survey, Regional Coast and Po di Volano River Basin Technical Service, Romagna River Basin Technical Service, Arpa Emilia-Romagna - Hydrometeorological Service).
This tool 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. The 2014 review, based on data processing of the last topo-bathymetric, sedimentological and subsidence control campaign, provides an update about the state of the art of coastal areas and of the coastal erosion phenomenon, in comparison with the last reporting period and especially based on the most recent review on coastal sediment management and coastal erosion mitigation measures.

Coastal erosion has become an increasingly more urgent matter brought to the attention of the Italian Ministry of the Environment and Protection of Land and Sea. A national panel for joint action with the various Regional authorities has recently been set up, to pool together technical and scientific knowledge to address the coastal erosion problem. It has been estimated that a 10-hectare beach is worth 3 million Euros a year, on average, with reference to the seaside tourism revenues, without considering the environmental, social and ecosystem implications, which therefore gives a clearer idea of the extent of the problem.

The coastal sediment management optimization provided by the SICELL system, in compliance with 2004 Eurosion Recommendations, meets the goal of a sustainable use of natural and economic resources. The Emilia-Romagna Region is fully committed to pursuing this important goal, in addition to other objectives, while coping with dwindling financial resources and balancing the need for a more effective administration and management action.

In the 2010 – 2014 period a total amount of 9.3 million euros has been allocated for coastal protection actions (of which 5.6 million euros from the Programme Agreement and 3.7 million euros from other regional funds). It accounts for less than one third of the funds that had been allocated in the previous 2005-2009 period (32 million). To secure a high level of protection along coastal areas, great efforts had to be made by the regional and local authorities and by all the stakeholders involved. Even greater efforts shall have to be secured also in the future, in order to achieve a more efficient, integrated and participatory system, which will be able to further enhance the coastal management and protection best practices that have already been developed over the past few years.

The regional strategy has been designed in full compliance with the ICZM Guidelines, with reference to the "soft option" of beach nourishment. It has so far proven to be effective, in spite of limited available funds, through a comprehensive approach focusing on coastal areas and sediments as strategic resources and on the use of state-of-the-art knowledge and tools, such as SICELL, for a systematic action.

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

Effective policies for coastal area adaptation to climate change are required to achieve a further reduction of the anthropogenic component of subsidence, and the river solid sediment transport recovery. New coastal and marine spatial planning policies (also in pursuance of the ICZM Protocol of the Barcelona Convention and of the new Directive 2014/89 / EU on Maritime Spatial Planning) will be necessary in the long term to reach an adequate level of security in coastal areas, thus increasingly reducing the need for finite, non-renewable resources, such as off-shore sand deposits.

The combination of short and medium-term strategies and actions to combat coastal erosion and subsidence, and of the longer-term maritime spatial policies, will lead to a more sustainable use of resources and to a more efficient management, greater safety and well-being along the regional coastal areas.

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, to preserve such a valuable common heritage which is our coastline. 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, defence practices and knowledge base, also with reference to this particular project.

Hence, let me invite all of you to read this report carefully and let me acknowledge and congratulate all the working group, and in particular the Soil and Coast Defence 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.

INTRODUCTION

picture of davideoneclick

Foreword

In 2010 the Emilia-Romagna Region developed a coastal defence and management information system, known as the **Littoral Cells Management System (SICELL)**, in the framework of the European COASTANCE project, (MED Programme). This information tool is designed to support coastal management and protection. It has been developed on the basis of previous studies, databases and information constantly updated by the regional information system.

The SICELL System has been designed by the Emilia-Romagna Region to serve as a database providing the necessary knowledge about coastal sediments and their evolutionary trend to optimize coastal sediment management to maintain the regional coastal system balance.

Low sandy shores are more exposed to sea and weather events and to erosion and marine ingression. Different environmental factors interact in a coastal environment (sea action, wind, climate, river intake, sediment transport along the coast) and affect the dynamic balance of the beach. Interaction between anthropic and natural factors can determine the coastal environment imbalance: such as the construction of hard defence works (piers, docks, etc.) blocking the natural sediment transport along the coast and the intensive urbanization which determines and increases the risks of erosion and marine ingression.

Building coastal defence works might also further disturb this sensitive balance. This is the reason why, over the years, there has been a gradual shift from "hard" coastal defence works (shore-parallel emerged breakwaters, cross-shore groynes etc.), mostly built by national authorities, before the transfer of powers to the regional authorities in the late 1990s, to a "soft" approach, based on beach nourishment with sand coming from different sources.

A thorough knowledge of the evolutionary trend of the coast and its current status is therefore essential to support action policies that are technically more cost-effective in terms of coastal defence, landscape and environmental protection and support of seaside tourism industry.

The sharp reduction of river solid sediment transport over the past decades and the very few nourishment actions with submarine sands (only 2 in the last twelve years, due to lack of funds), have not allowed and adequate natural or artificial nourishment of the regional coastal system. The situation is made even more serious also by coastal erosion and subsidence.

In this framework, in order to manage the most critical coastal stretches, it is therefore absolutely necessary to ensure an optimal beach sediments management, a source diversification (excavation sites, port and river dredging, littoral accumulations as well as any other means to mitigate erosion) and an optimization of dredging and nourishment practices depending on the distance between the donor and target sites. The SICELL system and the subdivision of coastal areas into littoral cells is functional to these optimization needs.

This publication reports data updating and processing on the status of littoral cells in the 2006-2012 period, based on data from the last topo-bathymetric and sedimentological campaign (2012), since the last subsidence survey (2011-2012) along the coast, and data on actions, beach nourishment and withdrawals, carried out during the reporting period. Compared to the previous database, further information is provided on sedimentology, the identification of "significant stretches of coastline" for management purposes and subdivision of river and port cells into two sub-units, i.e. a seaward sub-unit and an inland sub-unit. These new elements have been introduced in view of a forthcoming regulation on littoral sediment handling permissions by the Regional authority.

The regional coastal zone management and protection strategy

In the late 70s, RL 7/1979 was the first regional law on coastal protection, which led to the first coastal defence project, called 1981 Coastal Plan. It provided for artificial beach nourishment as "soft" defence action alternative to "hard" coastal works (breakwaters), with a high impact on landscape and environment. In 2005, the ICZM Guidelines for integrated coastal zone management were approved, which reconfirmed beach nourishment as the optimal coastal defence solution as an alternative to "hard" defence works, which had often shown a limited effectiveness and a few drawbacks.

The Regional Law and ICZM Guidelines have had a significant impact. Over the years, the creation of new hard coastal defence works has substantially been reduced and in parallel the number of beach nourishment actions and the quantity of sand used to feed eroding beaches have grown steadily.

To give a better idea of the evolution of this trend before the adoption of the 1981 Coastal Plan and of the ICZM Guidelines, in the 1950-1980 period various types of hard defence works were built by the central government authorities to protect about 55 km long stretches of the shoreline (1.8 km / year) in the ER region, while between 1980 and 2006, further 10 km long hard defence works were built (0.4 km / year), while in the 2006 – 2012 period, no new hard defence works were built, apart from a lot of maintenance on existing works. Figure 1 shows the various types of works, and the length of the protected shoreline. Several stretches of coastline are protected by more than one type of work. The defence works census has been carried out starting from the 2011 AGEA aerial survey. Sea-inlet di Goro defence works stretch over a 10 km long shoreline, with a double row of embankments: a seaward seawall, consisting of a boulder embankment and a landward embankment made of compacted earth.

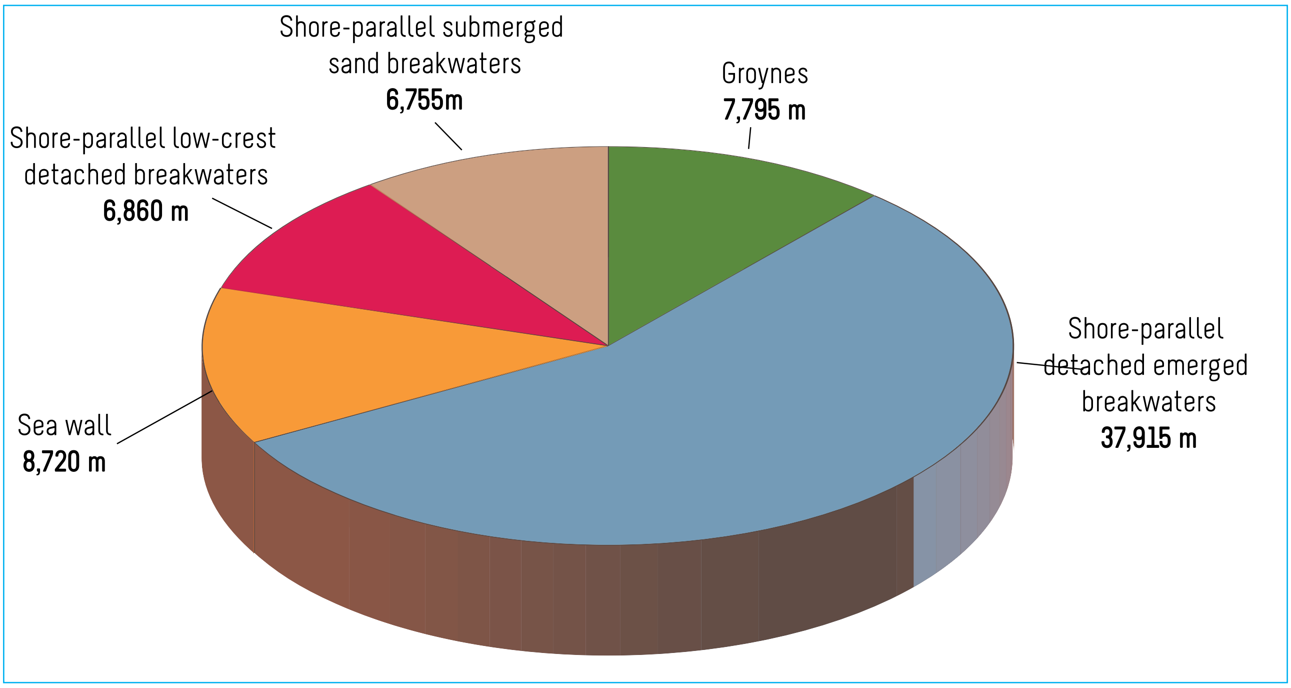


Figure 1 Hard protection works on regional coast in 2011, the value represent the total length of coastline protected, in meters. This does not include the 10 km of attached protection inside the Sacca di Goro for the defense of the territory of Goro.

Between 1983 (when the first major beach nourishment project was implemented by the Region) and 2000, just over 3 million m³ of sand, amounting approximately to 185,000 m³ / year, have been used for the nourishment of beaches under erosion, mainly using sand from inland quarries; while in the 2000-2006 and 2006-2012 periods about 3.5 million m³ (575,000 m³/ year) and 2.8 million m³ (470,000 m³/ year) of sand were respectively harvested (Figure 2, Figure 3, Figure 4). An important evolution of the "soft" strategy was the diversification of sand harvesting sites towards those with lower environmental impact.
Between 1983 and 2000, 85% of sandy material came from inland quarries, and only 14% from littoral accumulations. Between 2000 and 2006, the use of material from inland quarries dramatically decreased (19%), with an increase of coastal sand deposits (36%). This reduction was also due to the use of new sand sources, such as offshore underwater sand deposits (23%) and material from excavations for the construction of buildings, underground car parks and docks (22%). This strategy also continued in the last period (2006-2012), in fact, only 7% of sand used for beach nourishment purposes came from land quarries (just over 200,000 m³) while 48% from coastal sources (more than 1.3 million m³), 29% from underwater deposits (800,000 m³) and the remaining 16% from port excavation or sites (about 400,000 m³).
Since the last survey on the regional shoreline status, drafted by Arpa in 2013, it has been shown that in the 2006-2012 period the action against erosion was less effective than in the 2000-2006 period. This is due to a general state of coastal sedimentary deficit, to adverse weather and sea conditions, but also to a lower overall quantity of sand used for nourishment purposes (Figure 3 and 4).
In the 2006-2012 period the accumulation of sediments along the sandy bar (Scanno) was estimated to amount to over 2.2 million m³, of which 1.2 million m³ collected and deposited in the sea-inlet (Sacca). Given the large quantities of sand available and the appropriate particle size

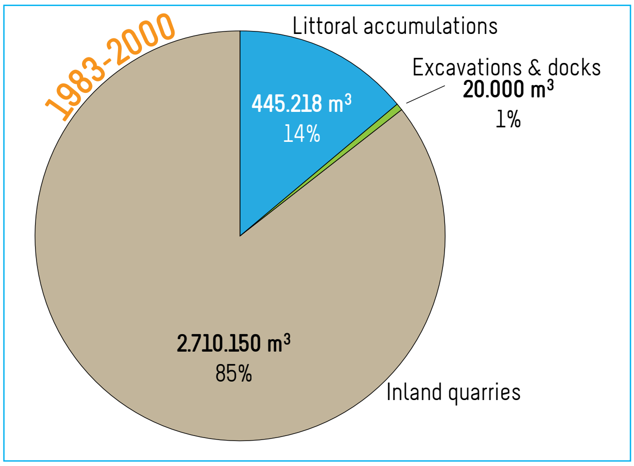


Figure 2 Volume of sand nourished on beaches under erosion from 1983 to 2000 and sources.

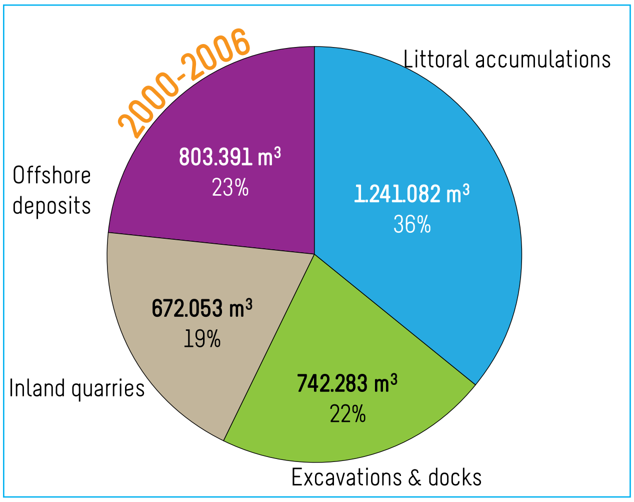


Figure 3 Volume of sand nourished on beaches under erosion from 2000 to 2006 and sources.

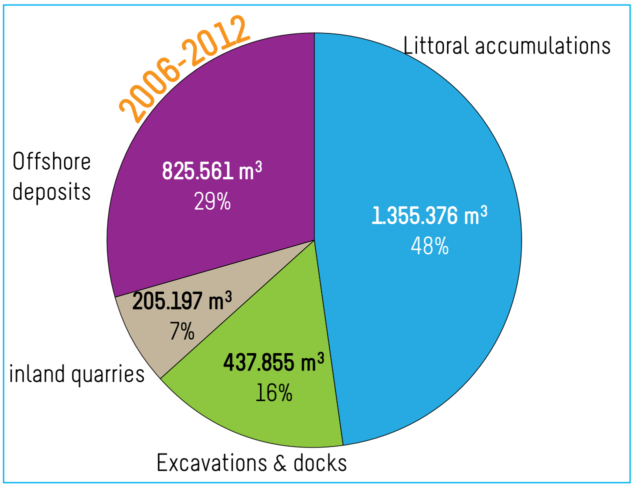


Figure 4 Volume of sand nourished on beaches under erosion from 2006 to 2012 and sources.

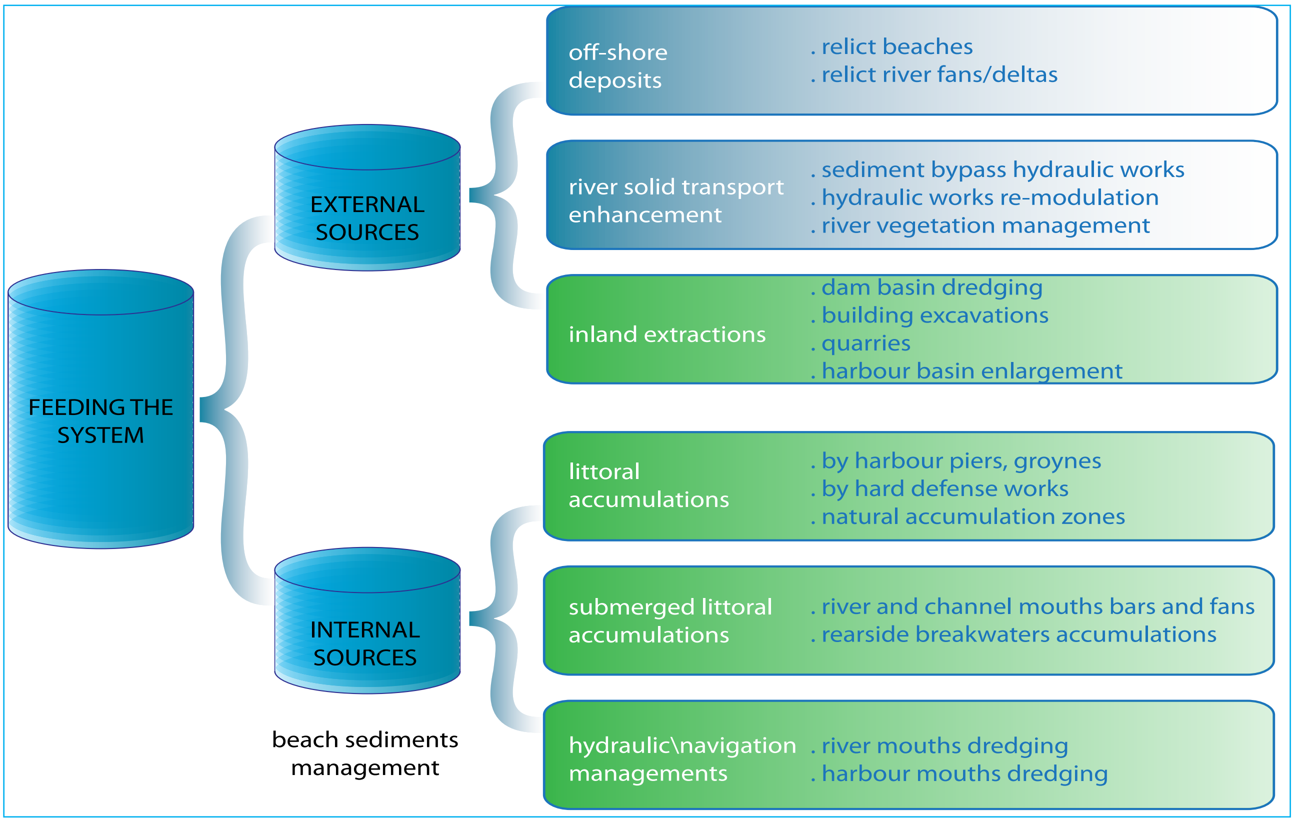


Figure 5a With green fields of application of SICELL according to the regional strategy for the management of coastal sediments

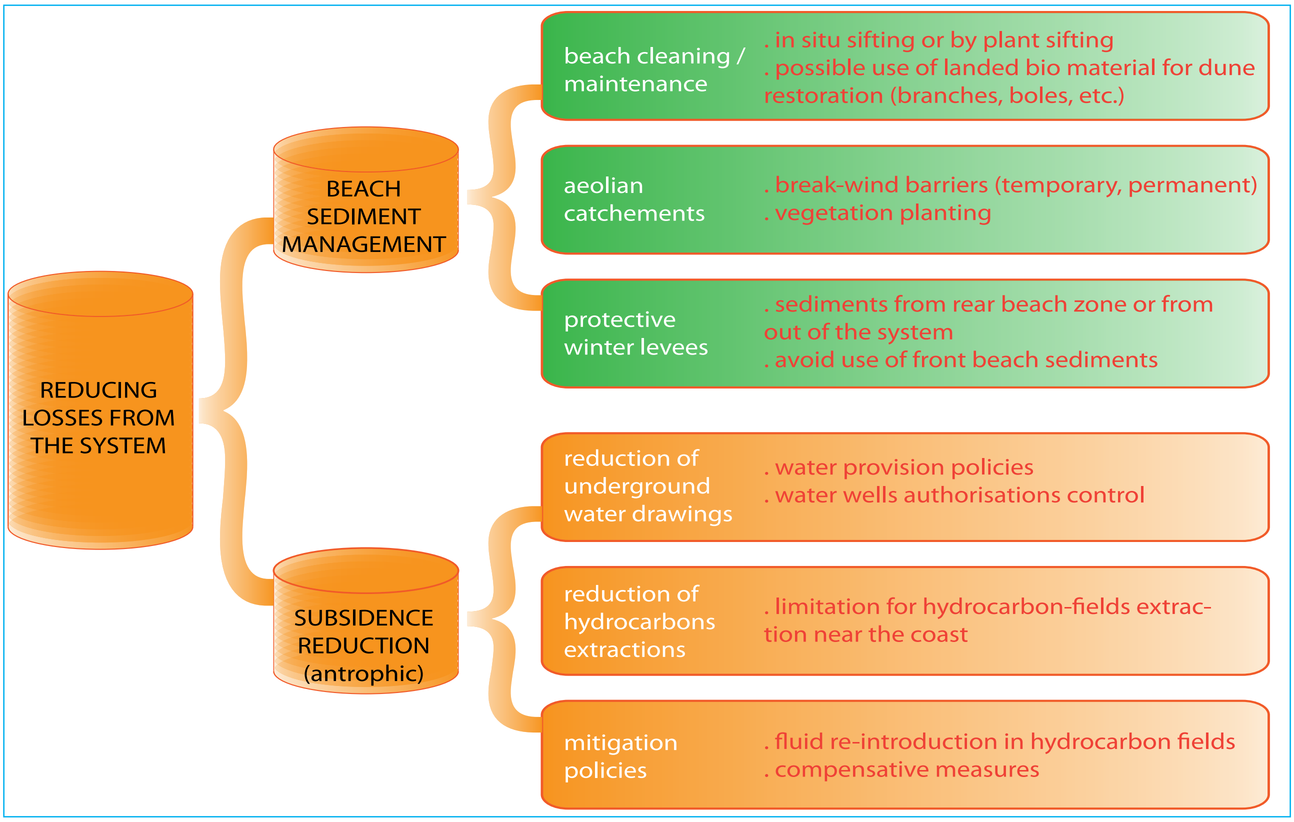


Figura 5b With green fields of application of SICELL according to the regional strategy for the management of coastal sediments

(average diameter 0.35-0.125), this sand proved to be optimal for the nourishment of eroding beaches in the Lido di Volano North area.

Proper littoral accumulation management has therefore become a determining factor over the years to optimize resources and to protect the coast from the erosion and ingression risk in a sustainable and integrated way. SICELL is therefore designed as a suitable tool to meet these needs, thanks to the definition of littoral cells as coastal spatial units and to the availability of a set of data and information from different existing regional databases (nourishment, hard defence works, subsidence, shoreline, etc.). Hence, it is possible to carry out an analysis on the shoreline state at different spatial scales (cell, group of cells, significant stretches of the coastline etc.) and at different time scales.

SICELL also serves as a comprehensive and integrated approach developed by the Region considering sediments as a strategic resource, based on two pillars: nourishing the coastal system and reducing losses from the system (Figure 5). As far as the first pillar is concerned, specific policies are implemented to promote the restoration of river solid sediment transport, the use of external sources of sediments (offshore underwater sand deposits, materials from excavation sites and from port basin extension works), and of internal sources (sand accumulations at the pier and harbour mouths, estuaries and river mouth bars, hard defence works, etc.) for the maintenance of the most critical coastal stretches. The second pillar features a whole set of actions, including a proper beach sediment management (proper execution of the winter defence levees, use of wind traps, proper cleaning of beaches with on-site screening), and policies aimed at reducing subsidence (reduction of groundwater and hydrocarbons withdrawal, and at fostering mitigation measures, such as the re-introduction of fluids into the underground or other compensatory measures).

In order to achieve an effective coastal management, to counter erosion and reduce risk factors, the Regional authority is engaged in drafting specific regulations on coastal sediment handling and management procedures, on the basis of the above-mentioned strategic guidelines. The set of strategies and actions here briefly illustrated, pursued with the involvement of regional and local authorities and local stakeholders, is expected to lead to an increasingly more efficient management system capable of ensuring an adequate level of safety and security of coastal areas.

The SICELL system is updated by the Emilia-Romagna Regional authority at five-year intervals, through topo-bathymetric campaigns, while beach nourishment, coastal sediment handling and defence works maintenance operations are scheduled annually, in collaboration with the Regional River Basin Technical Services operating in the coastal area.


picture of Jessamyn West

SICELL UPDATE FOR THE 2006-2012 PERIOD

picture of Dave Gunn

SICELL update for the 2006-2012 period

SICELL was updated on the basis of data collected during the 5th topo-bathymetric campaign and 2nd sedimentological campaign, carried out in 2012 for the fifth General Study of the Regional Coast commissioned to ARPA Emilia-Romagna. The study referred to the previous survey campaigns on regional monitoring networks:

- topo-bathymetric campaigns: 1984, 1993, 2000, 2006;
- shoreline 1983, 1991, 1998, 2006;
- subsidence 1984, 1987, 1993, 1999, 2005;
- sedimentology 1993.

In the framework of this latest regional campaign, data analysis and processing were performed according to both a traditional approach, similarly to the latest report on the 2007 state of the shoreline, and to coastal state indicators (DPSIR model, Aguzzi et al., 2012) using littoral cells as elementary spatial units.
ASPE is one of these indicators and is an integral part of SICELL.
Compared to previous campaigns and then to the preliminary version of the SICELL database for the 2000-2006 period, a few new features and improvements have been introduced:

- **areal cells:** during the sediment balance and ASPE indicator calculation phase, the cell is always defined as an area laterally limited by its borders with other cells, seaward by the -3m bathymetric depth (with reference to the geographical position of the -3 bathymetric line identified during the first 1984 campaign) and landward by the edge of the beach establishments or the foot of the dunes. The novelty consists in the shift from the linear to the areal representation both on the cells forms and on GIS;
- **Subdivision of harbour, river and lagoon cells into relevant stretches:** in view of the adoption of the forthcoming regional regulation on sediment dredging and handling, the canal, river and port mouth areal cells have been respectively subdivided into various portions: Marine Relevance (PM); Port Relevance (PP); River Relevance (PL) and Lagoon Relevance (PL). This subdivision is related to the need to launch two sediment sampling campaigns with different in-depth analysis for the two relevant areas;
- **Significant stretches of coast (TLS) for management purposes:** these stretches bring together a certain number of cells as a function of periodic management operations, in view of the new Regulation, with the possibility of simplification of the licensing procedure applied to sediment handling;
- **Sedimentology:** a specification has been introduced related to the prevailing average particle size class of the samples analyzed within the Cell or in neighboring Cells, identified thanks to the sedimentological campaign.

For the new calculation of the ASPE indicator, referred to the 2006-2012 period, the following SICELL database fields have been updated, for individual coastal cells, thanks to the monitoring and activities campaigns:

5th 2012 topo-bathymetric campaign (ARPA ISCM)

- volumes accumulated or eroded in the 2006-2012 period;
- shoreline trend in the 2006-2012 period;

2nd 2012 interferometric analysis (ARPA, Technical Management Unit)

- subsidence rate in the January 2006 - May 2011 period;

Update of annual nourishment and works database (STB Po di Volano, STB of Romagna)

- works built between 2006 and 2012;
- works maintenance carried out between 2006 and 2012;
- nourishment volumes between 2006 and 2012;
- volumes collected between 2006 and

CLASS	DESCRIPTION
accumulation	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
precarious 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

Table 1 ASPE classes: are considered significatn accumulation or losses > 30 m^3/m.

2012;

Integrated analysis and calculation (ARPA ISCM)

- unitary volume variation for ASPE analysis;
- analysis and calculation according to ASPE classification.

The ASPE classification, in addition to providing information about the condition of the single Cell, is an assessment tool providing a quick overview the overall criticality state of the regional coastal area. It is an indicator that defines the evolutionary trend of beaches in terms of accumulation, erosion, or stability, over a given period of time, excluding the effects of works or actions. Excluding the effects of defence works, this indicator highlights the real evolutionary trend of the cell, identifying the most or least critical stretches of coast and the ones in good condition.

The ASPE classification is based on an integrated analysis of the various elements listed below:

1. **Changes in sand volume of backshore and shoreface:**

- losses/accumulations resulting from the comparison between topo-bathymetric surveys;
- losses due to subsidence;
- accumulations due to nourishment;
- losses resulting from sand harvesting to be used for nourishment of eroded beaches;

2. **Shoreline changes:**

- retreating/advancing shoreline due to sea dynamics or to human intervention;

3. **Defence works conditions:**

- presence or absence of hard coastal defence works;
- construction of new works in the period under review;
- maintenance of new works in the period under review;
- accomplishment of nourishment operations in the period under review.

The four ASPE classes are reported in Table 1 and Figure 5

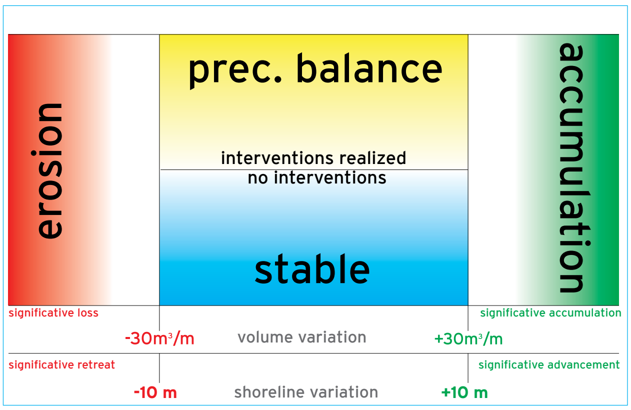


Figure 5 Scheme of ASPE subdivision in 4 classes.

SUBSIDENCE ALONG THE COAST

foto di Jorden Esser

Subsidence along the coast

Until 2005, subsidence along the Emilia-Romagna coast was measured by means of a geodetic network established by Idroser in 1983 and detected by means of the high precision geometric leveling method in 1984, 1987, 1993, 1999 and 2005. Over time the initial network geometry has undergone several changes, aimed, above all, at minimising the propagation of errors deriving from the long connecting lines to the target landmark, namely the reference point whose altitude, established by IGM upon the measurement of the national network in the 1950s, could be considered unchanged over time. For the first three coastal network surveys, the landmark was located in the upper valley of Marecchia, near Pennabilli and in the first two surveys (1984 and 1987), the landmark was in turn connected to another presumably stable landmark, situated in the Bologna Apennines (Castel de 'Britti). In 1993, due to saving reasons, the connection to the Castel de' Britti landmark was avoided, relying solely on the Pennabilli landmark, which proved to be less effective than the previous ones. In 1999 the coastal network was measured at the same time with the regional network established by Arpa. Hence, the same landmark of the regional network itself was used, namely an IGM landmark located near Sasso Marconi (Bologna Apennines), whose altitude (1950s) was consistent with the Pennabilli and Castel de' Britti landmarks

Interferometric Analysis

In 2005, for the first time, subsidence was detected at a regional scale, primarily using the radar satellite data interferometric analysis method, supported by the measurement of a subset of the regional leveling network also including the coastal network, using the same altitude landmark used in 1999. In 2011 the subsidence survey was carried out on a regional scale by means of the radar satellite data interferometric analysis method, supported by the processing of 17 permanent GPS stations. The coastal leveling network, for the first time, was not directly measured: thanks to progress made in remote sensing techniques, the lowering of the soil can now be more precisely measured, both in terms of accuracy and data diffusion through radar measurements. In particular, an interferometric analysis was carried out using the SqueeSAR™ technique of satellite radar data acquired over the entire plain of the region, by identifying the present landmarks, their average annual speed and displacement time series in the 2006-2011 period. At the same time, data acquired from 17 permanent GPS stations have been processed, in order to calibrate and assess interferometric analysis data, through vertical movement speed values. Thus, for the first time, the survey of subsidence in Emilia-Romagna was carried out, going beyond the concept of the absolute landmark within a geodetic network, historically considered as fixed and unchanging over time, on the basis of considerations of general stability of the structural geological context of the area. In essence, every single GPS station becomes by itself a landmark, not by virtue of a presumed absolute stability, but based on the precise knowledge of its movements measured over time.

Subsequently, in order to attribute, however, an altitude on the average sea level to those leveling landmarks used to support the topo-bathymetric network, the altitudes of these landmarks measured in 2005, have indirectly been updated, i.e. a lowering speed has been attributed to each landmark, in the 2005-2012 period, derived from an appropriate processing of the lowering speed of scattered points located in a particular point around the landmark itself.

2006-2011 Survey Ratings

Considering the coast as a whole (Figure 7), the last survey (2006-11 period), highlights a prevai-

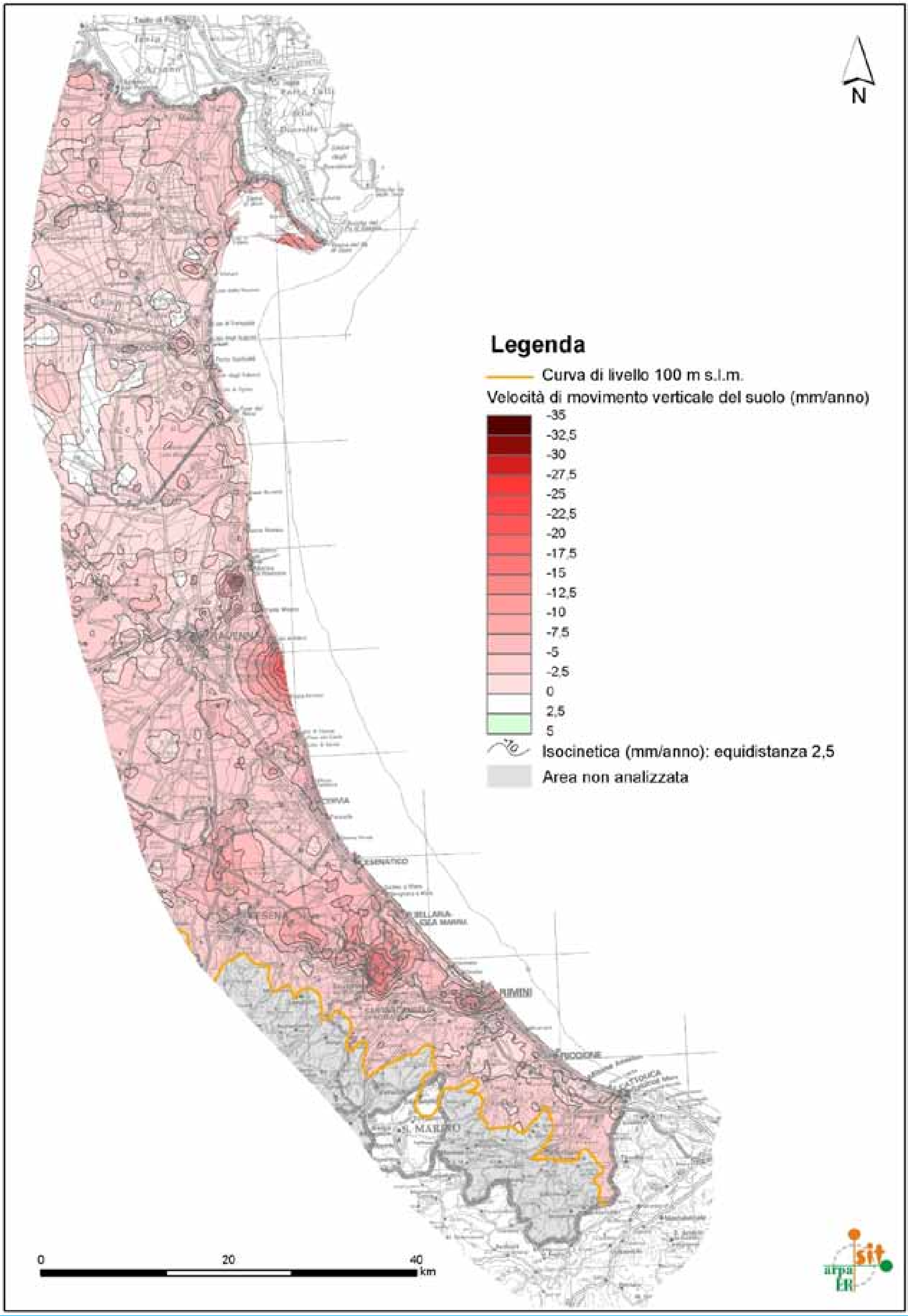


Figure 7 Map showing the rate of vertical movement of the soil in the period 2006-2001 along the regional coast.

ling reduction in the subsidence trend, compared to the previous one (2002-2006). This is in part true for the coastline of Ferrara and Ravenna, at least up to Marina di Ravenna, with a general lowering of few mm/year.
About 5 mm/year lowering can be observed at Porto Corsini - Marina di Ravenna, where lowering has almost been halved compared to the previous period. Even the area of Dosso degli Angeli - Foce Reno, which is historically affected res a subsidence reduction with current values around 5 mm/year, which is confirmed further south between Cesenatico and Bellaria. Subsidence is further reduced from Bellaria to Rimini, up to 2-3 mm/year. The Rimini coastline, south of the pier, features maximum values up to 8-9 mm/year for about 1 km long stretch, which rapidly drop to some mm/year along the entire coast up to Cattolica, roughly in line with the previous period.

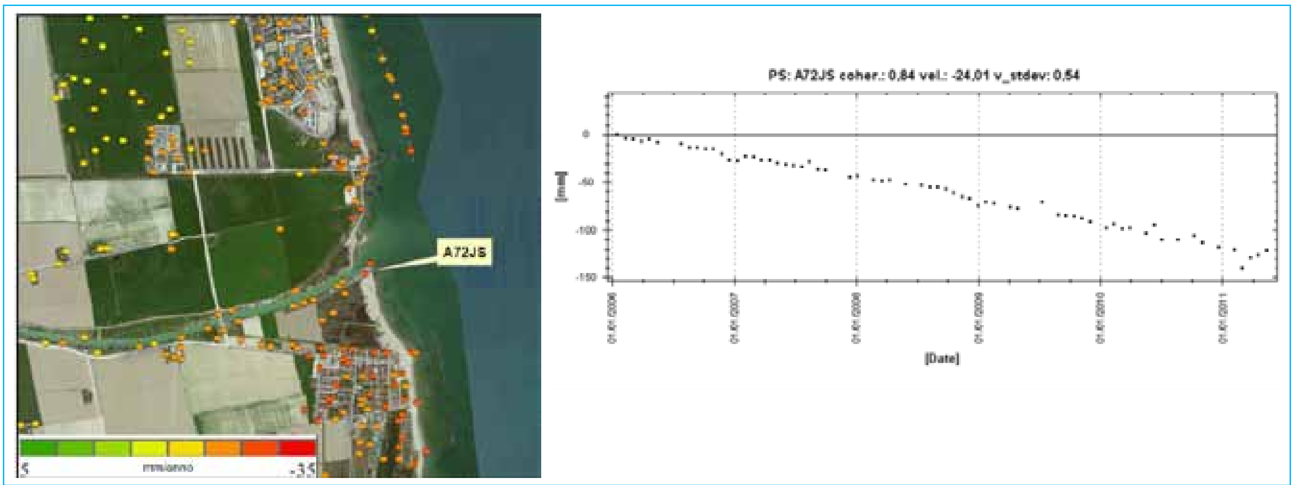


Figure 8 Area of Fiumi Uniti mouth showing the PS / DS analyzed (left) and the time series of point A72JS (right) with a speed of 1.24 mm / year.

by subsidence, features the same trend. Further south, however, a large area of subsidence still remains, affecting the coastal area from Lido Adriano to over Bocca del T. Bevano, with a maximum level of over 20 mm/year at the Fiumi Uniti river mouth with a maximum inland extension of about 5 km: the area features subsident values with some slight increase compared to the previous survey but it now appears to be more clearly defined thanks to the greater amount of data made available by the new algorithm used for the interferometric analysis (Figure 8).
The remaining coastline of Ravenna featu-

As for overall subsidence, between 1984 and 2011, Lido di Dante appeared to be the most subsiding area (45 cm) along with the neighbouring Lido Adriano (40 cm), followed by Dosso degli Angeli (Reno river mouth) and Porto Corsini with 38 cm, Goro (37 cm), Cesenatico (36 cm), Milano Marittima (33 cm), and Rimini (25 cm).
In the 2006-11 period, the shoreline in its entirety showed a mean subsidence by about 4 mm/year, related to a 5 km-long inland strip, which was essentially halved compared to the previous period.

SEA STORMS IMPACT ALONG THE EMILIA-ROMAGNA COAST

foto di Rose Chell

Introduction

The term sea storm refers to a medium-high intensity sea-weather storm event, having significant impact on the coast: flooding, coastal erosion and damage to works and facilities.
Two factors contribute to generate sea storms along the Emilia-Romagna coast: wave energy, generated by wind, responsible for the mobilization of large amounts of sediments, and high water, due to the combination of astronomical tide and meteorological " storm surge", giving rise to a tidal wave.
The Wave Climate that characterizes the Emilia-Romagna coastline is a low energy Wave Climate, with a wave height of greater frequency of ≤ 1 m (which has a 65% recurrence) and a maximum tidal range of about 90 cm. Storm waves, reaching a significant 3.3 m height for 1 year return periods, mainly come from East / North East (associated with Bora winds), while in the event of Scirocco sea storms, wave height is generally lower due to the protection effect produced by the Conero promontory. Sea storms, associated with strong winds from southeast (Scirocco), however, are more likely to generate high water, because they force the accumulation of water towards the northern part of the Adriatic basin, preventing the natural flow of currents in the opposite direction.

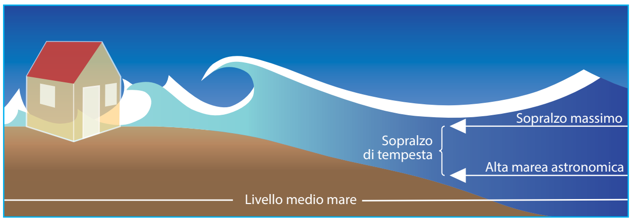


Figure 9 When a storm is in phase with an high water (due to high tide and atmospheric effect) may occur flood.

In this context it should be underlined that impact due to sea storms is all the more relevant as spatial exploitation becomes more intense. As a matter of fact, the Emilia-Romagna coastline is in a morphologically vulnerable environment due to the presence of large inland areas situated immediately behind the beach, below the sea level, and also to a natural century-old retreat of the shoreline. These areas are characterized by an extremely high urbanization rate - among the highest at the national scale - which, combined with the destruction or fragmentation of coastal dunes and construction of seaside infrastructures along the beaches, greatly increases the level of risk.
The publication "Sea storms and impact on the coast in Emilia-Romagna (1946-2010)" provides a thorough overview of these phenomena and of the characteristics of the impact of sea storms on the regional coastline, which might be referred to for further information.
Since 2011 the Emilia-Romagna Regional Authority (SGSS), with the support of ARPA-SIMC and the Regional River Basin Technical Services, have developed a new information system, called in_Storm, dedicated to the collection, organization and analysis of all the data concerning extreme sea-weather events with an impact on the local coastal zones. This tool allows to keep information on the most critical areas up to date, and constantly improve the knowledge of the phenomena, refining the threshold levels used for coastal early warning systems for civil protection purposes.
The beach critical status is updated with the help of the Regional River Basin Technical Services, through post-event inspections, and thanks to the systematic GPS network survey for monitoring of sea storms, which was established by SGSS starting from 2010.

The impact due to the historical sea storm

The analysis of historical sea storms has been conducted by the Geological, Seismic and Soil Survey, ARPA-SIMC and by the University of Ferrara in the framework of Micore European project (2008-2011), which has produced relevant and useful results for coastal risk management and prevention. These results allow to define the most critical areas to be further analysed, to develop a coastal early warning system to be used by the Civil Protection Unit.
First of all, the analysis of all data collected in the sea-weather catalog has allowed to define the characteristics of the phenomena generating the most significant impacts and, through the comparison of these data with the field observation, impact thresholds for natural and built areas have thus been established.
It has been pointed out that the sea storms that generate the most frequent impacts on the coast are associated with the concomitant combination of winds of the first quadrant (from the North and North East) with the high water phenomenon, even though the latter is often triggered off by a previous Scirocco wind. Such a combination of factors causes not only beach erosion but also marine ingression phenomena, thus affecting bathing facilities and, more rarely, the urban centres. In the event of heavy sea storms, waves move significant volumes of beach sand towards the backshore (overwash phenomenon), thus causing severe sediment losses for the beach system.
Wave motion by itself, when persistent, can also cause significant damage to bathing facilities, because of the gradual erosion of the beach, of artificial embankments and of the dune system, in the few stretches of natural coastline.
During the research work, it has also been pointed out that, with high water exceeding 0.8 m, even under moderate swell, rather severe flooding and damage can be recorded.
The frequency at which these severe events occur might be even more important. As a matter of fact, when a sea-weather event occurs a few days after a previous sea storm, it can cause a significant impact even though the characteristics of the event are below the minimum threshold values.
This observation thus emphasizes the importance of a coastal criticality recording tool, which provides an update of the coastal vulnerability level on a daily basis, allowing the appropriate adaptation of civil protection measures.
The analysis of all the data contained in the ca-

Figure 10 Erosion of a beach during a storm event.

talog has also allowed to identify the 32 most frequently affected locations, and the most recurrent damage types, i.e.: beach and dune erosion, backshore flooding, damages to bathing facilities and to offshore defence works and channel overflow.
The most frequently affected period is late autumn, especially during the months of November and December. The month of May also seems to be particularly critical.
The most extreme events, in terms of extent of damage and severity, occurred in: November 1966, also due to the combination with a severe flood that affected most of the country, December 1979, February 1986, December 1992, December 1996, November 1999, September 2004, December 2008, April 2009 and March 2010.
Casualties were fortunately recorded only in two cases, due to inappropriate behavior, i.e. stopping in hazardous areas, such as harbour piers and along the waterfront.

Sea storms in the 2011-2014 period

From January 2011 until mid-November 2014, 27 heavy sea storms were recorded causing the most severe impacts on the coastal area of the Emilia-Romagna Region, mostly concentrated in the months of November and February (Figure 11). The high frequency of extreme events in February, comparable to the month of November, deviates from the long-term trend (1946-2010), with only two sea storms with a major impact recorded
in the same month.
In the 2011-2014 period, 24 sea storms exceeding the impact thresholds, in terms of wave height or tide level or the combination of both parameters (Figure 12) were recorded.
In 16 cases the 0.8 m tide threshold level was exceeded. On two occasions, the 1.10 m height a.s.l. with a maximum 1.15 m tide level a.s.l. was reached with the most severe impact reached during the 31 October to 1 November 2012 storm surge. This sea storm was characterized by a combination of two factors, with over 2 m high wave height and over 1 meter high water, over a period of more than 10 consecutive hours. To make things even worse, this sea storm occurred only two weeks after a previous extreme event, which had already badly affected the shoreline.
It caused more than 4.5 million euro damages i.e.:

- **Marine ingression** (Figure 13) with massive sand transfer to the backshore up to urban

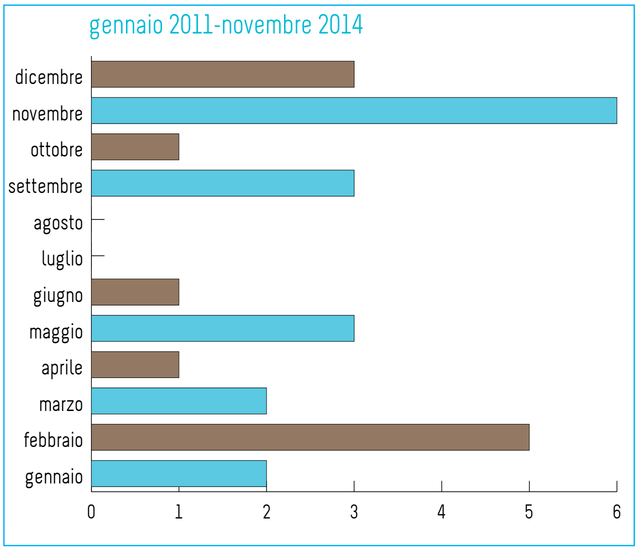


Figure 11 Number of storms per month from January 2011 until mid November 2014 which have produced effects on Emilia-Romagna coast.

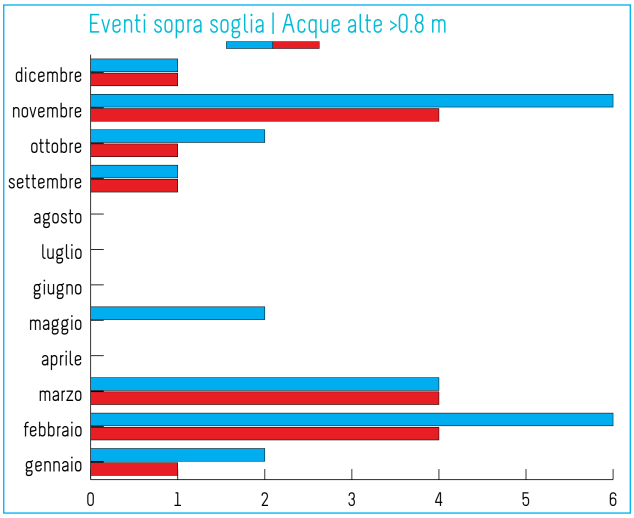


Figure 12 Sea storms characterized by exceeding the thresholds of impact from January 2011 to November 2014.

areas (overwash phenomenon). In many sites, where surveys were carried out, a significant sand transport was recorded, which caused great inconvenience not only for tourist seaside resorts along the coast, but also to the road network, to the sewerage system and civilian homes;

- **Coastal erosion (**Figure 14) along the entire regional coastline; over one meter lowering of the beach floor was recorded, with a major retreat of the sand dune system, if any;
- **Damage to coastal defence works** (Figure 15); in different areas low-crested coastal defence works were undermined, seriously endangering the inland areas;
- **serious damage** to tourism facilities (Figure 16).

Figure 13 Marine ingression.

Figure 14 Effects of the 'Halloween' sea storm in Misano Adriatico.

Figure 15 Seawall eroded near the Volano nord pinewood.

Figure 16 Lido di Spina sud, Jamaica bath establishment.

Concluding remarks

The study of sea storms affecting the Emilia-Romagna coast, has allowed us to draw some important and useful conclusions aimed at improving spatial planning tools and making coast defence strategies more effective.

From a quantitative point of view, a limited number of sea storms occurs every year with a heavy impact on regional coasts. Yet, every time a sea storm occurs, it causes severe economic damages to local inhabitants and businesses and it also determines a substantial loss of beaches and ecosystems. It can be pointed out that:

- hazard is mainly due to the high degree of exposure of assets. In fact, many urban settlements were built on the edge of the beach, often dismantling the only natural defence represented by the dune system itself. In some cases, to reduce the risk, it would be useful to reduce assets exposure, such as planning an "urban boundary" retreat and preventing new construction on the waterfront;
- Several tourist seaside resort facilities located on the beaches are extremely vulnerable and exposed to hazards. Since they are located at a height only slightly above the sea level, they are often flooded and are not

structurally equipped to cope up with these hazards, even when resorting to temporary self-protection measures. Removable or fence facilities should instead be preferred. Even temporary winter protections, bulkheads and sand levees should be put in place according to efficiency enhancing criteria;

- the massive beach losses often exacerbate these problems and negatively affect the seaside tourism industry. It has become increasingly more evident that the massive loss of sand suffered by beaches during severe events, cannot be easily recovered. Hence, to offset this sedimentary deficit, large quantities of sand from outside sources are needed and (both inland and seaward) loss reduction practices have to be implemented to encourage the river solid sediment transport.

Hence, in such a fragile and vulnerable environment, it is important to secure an effective spatial management, through the sea storm impact monitoring network and the further improvement of the use of operational tools, such as in_Storm.

It is also essential to enhance the whole early warning and prevention system used by the Civil Protection, by strengthening the real-time observation tools and coastal early warning system based on a dedicated application developed by SGSS-ARPA ISCM and by the University of Ferrara, which is already operational and is going through the testing phase.


picture of Carl Milner

LITTORAL STATE ANALYSIS

picture of potomo

The new ASPE classification

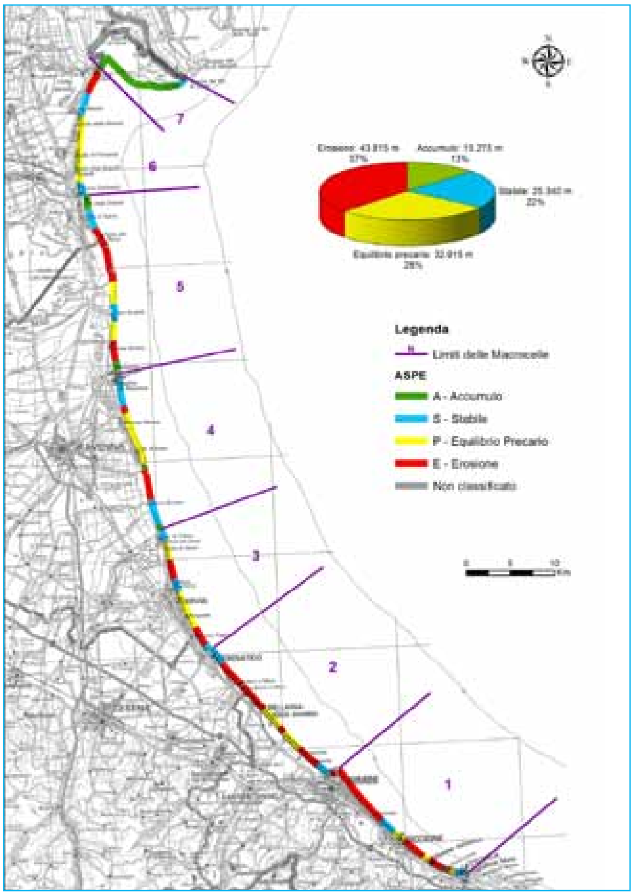


Figure 17 Results of the 2006-2012 ASPE classification on the Emilia-Romagna. A: accumulation; S: stable; P: precarious balance; E: erosion.

The new ASPE classification of the regional coast (Figure 17) is based on the comparison of the last 2006 and 2012 (topo-bathymetric, subsidence and shoreline) monitoring campaigns data combined with the reading of the annual data related to nourishment actions on hard defence works. According to this indicator, in 2012 the regional coast featured 15 km long beaches with an overall accumulation (13%), about 25 km long beaches in stable conditions without the need for any interventions (22%), while about 77 km long beaches showing various degrees of critical conditions (65%). Among the most critical stretches, about 33 km long beaches featured a precarious balance (whose balance has been maintained through nourishment operations), and about 44 km long eroding beaches as a whole. The former did not feature any significant sand loss in the reference period simply because they have been kept in balance through defence actions (nourishment, new coastal defence works or maintenance of existing ones); as for the latter, significant sand losses were instead observed during the same period (more than 30 m^3/m losses). It should also pointed out that the eroded beaches included stretches with varying degrees of criticality. Among them, for example, beaches such as Rimini-centre, which for the first time in 2012 featured a sand loss limited to the shoreface but without any evidence on the shoreline and backshore, or other stretches, such as the Bellocchio coastline (to the north of the Reno river mouth), which for decades had featured a 9-10 m/year retreat rate.

The Macrocell-based analysis of the shoreline features a rather complex situation (Figure 18).

The stretches of regional coastline between Cattolica and Cesenatico (Macrocells 1 and 2) and between Porto Corsini and Porto Garibaldi (Macrocell 5) feature the largest number of beaches under erosion or in precarious balance. Macrocell 2 includes 16 km long beaches in critical conditions, whereas Macrocell 5 includes 13 km long beaches in critical conditions. These coastline stretches are mainly characterized by erosion rather than precarious balance.

In each one of the three Macrocells corresponding to the stretches between Cesenatico and Porto Corsini (Macrocells 3 and 4) and between Porto Garibaldi and the Po di Volano River mouth (Macrocell 6) about 10.5 km long beaches are in critical conditions. Most of them, however, are not affected by significant losses during the period under question, thanks to regular maintenance.

Beaches under accretion were detected in the four Macrocells included between the Savio River and the Po di Goro mouths (Macrocells 4, 5, 6 e 7), whereas stable stretches have been

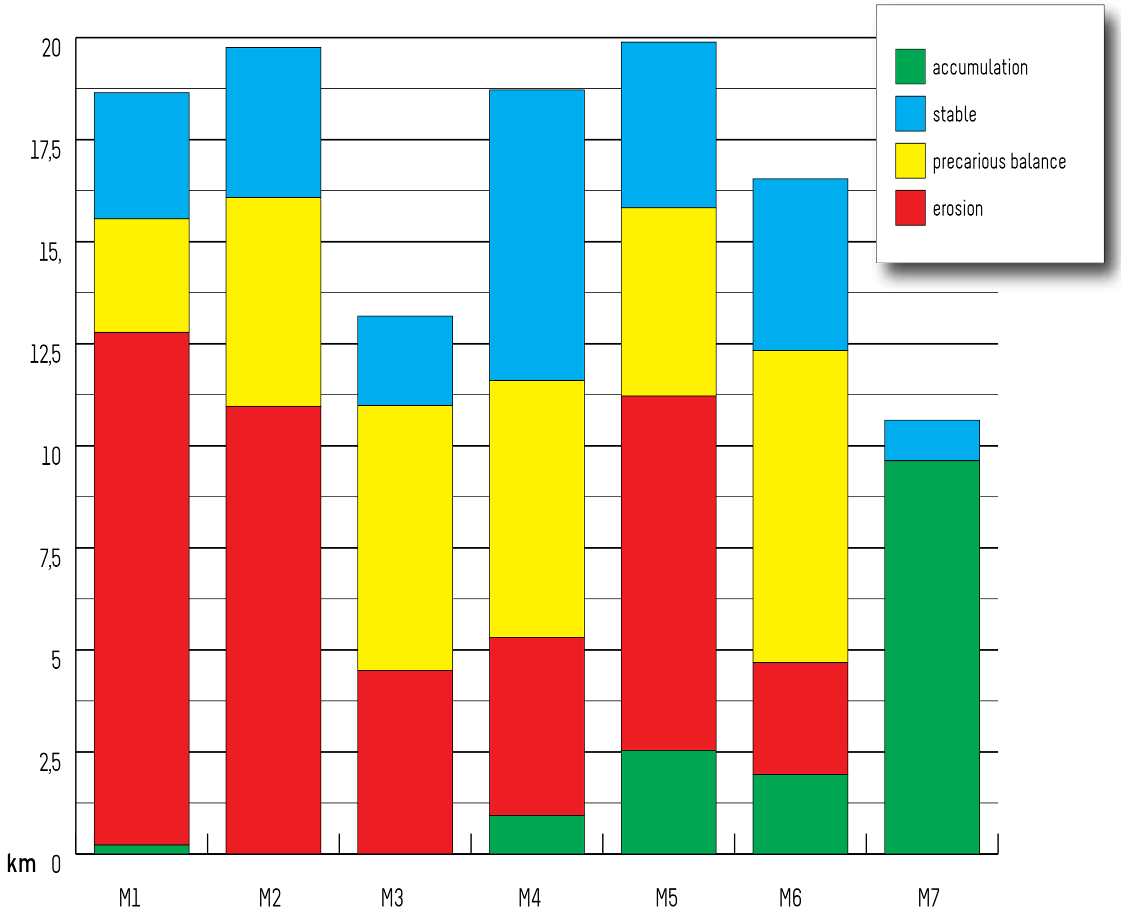


Figure 18 Classification results of ASPE 2006-2012 for each of the seven Macrocells A: accumulation; S: stable; P: precarious balance; E: erosion.

identified along the whole coast, but especially in Macrocell 4, between the Savio River mouth and Porto Corsini.
Other assessments can be made within each individual Macrocell, always with reference to the diagram of Figure 18.

Macrocell 1

12.5 km-long beaches between Cattolica and Rimini are under erosion, with special reference to the critical stretches of Misano and Riccione South. These sites, which have already been nourished in the past, would require continuous and significant nourishment actions as well as a refurbishment of the defence works system (Misano groynes and breakwaters).
The situation of other beaches is less serious, such as those between Cattolica-north and Porto Verde, where erosion is manageable with 'just a few' periodic nourishment operations. Finally, a few stretches have been identified within this Macrocell that, despite having a rather stable shoreline and wide beach, during the period under review have suffered major sand losses along the shoreface, without any evidence on the backshore. These sites, corresponding to the Riccione-centre beaches and those between Miramare and Rimini-centre, are to be constantly monitored.

Macrocell 2

Eroding beaches between Rimini and Cesenatico cover a total 11 km-long area. With regard to this stretch, various types of beaches have been identified either requiring periodic nourishment, or already protected by breakwaters, such as the ones between Viserba di Rimini and Valverde di Cesenatico.

Macrocell 3

In the coastal area between Cesenatico and Savio, the extension of eroded beaches is much smaller (4.5 km) than the one observed in the two southernmost Macrocells. A few especially critical stretches of this coastline have been identified between Cesenatico and Tagliata, and along the beach north of Milano Marittima, where, in addition to continuous nourishment, the existing defence works require maintenance. Furthermore, sand losses have been recorded along the Cervia beach shoreface. Although no repercussions have been recorded on the backshore, this stretch should also be strictly monitored.

Macrocell 4

Around a 4.3 km long eroding stretch of the coastline extends from the Savio river mouth to the south jetty of the Port of Ravenna.This stretch includes the most critical beaches located north of Torrente Bevano, as well as the beaches between Lido di Dante and Fiumi Uniti and Punta Marina north beach. The beaches protected by breakwaters and groynes between Lido Adriano and Punta Marina are kept in balance through periodic nourishment. A more than 7 km-long stretch of the coastline south of Bevano and Marina di Ravenna, near the south pier of the Port of Ravenna is in rather good stable conditions.

Macrocell 5

Between the Port of Ravenna and the south pier of Porto Garibaldi, an approximately 8.7 km-long stretch is sharply eroded, out of a total 13.3 km-long stretch of the coastline under critical conditions.
The stretches requiring a radical overhaul of coastal defence systems include Marina Romea beach, the long stretch of Poligono Militare di Foce Reno protected only by low-crested breakwaters and Bellocchio beach, up to Lido di Spina.
This Macrocell also includes stable or accretion beaches due to their favorable position in relation to the longshore sediment transport direction: Porto Corsini, Lido di Spina and Lido degli Estensi.
A slowdown in the accretion of these beaches has, however, been recorded on the two accretion beaches of Porto Corsini and Lido degli Estensi, which is a further evidence of the decline of sand volumes circulating in the system. Finally, the Casalborsetti beach is stable, partially protected by shore-parallel emerged breakwaters and partially by low-crested breakwaters and rock groynes.

Macrocell 6

Along the stretch of the coastline between Porto Garibaldi and Po di Volano river mouth, the large majority of beaches are in a critical situation, whose balance is maintained through regular nourishment actions along 10 out of 17 km-long stretch within the Macrocell.

Macrocell 7

The area around the lagoon mouth and Scanno di Goro is mainly in accretion.
The Scanno di Goro tip, Porto Corsini and Lido degli Estensi cell are identified as strategic cells from the management point of view, since they have been and still are the harvesting coastal sites used for the maintenance and nourishment of eroded beaches along various stretches of the regional coastline.

Comparison between the 2006-2012 and the 2000-2006 trend

The comparison between the 2006-2012 and the previous 2000-2006 ASPE analysis has highlighted a worsening of the situation in 2012. In 2006, 54 km-long beaches proved to be in critical conditions (undergoing erosion or in a precarious balance), compared to 2000; while in 2012, 77 km-long beaches proved to be in critical conditions, compared to 2006, (Figure 19).
The following changes can be observed by analyzing each specific Macrocell, (Figure 20).
Except for the fourth, sixth and seventh Macrocells (Foce Savio-Porto Corsini and Porto Gari-

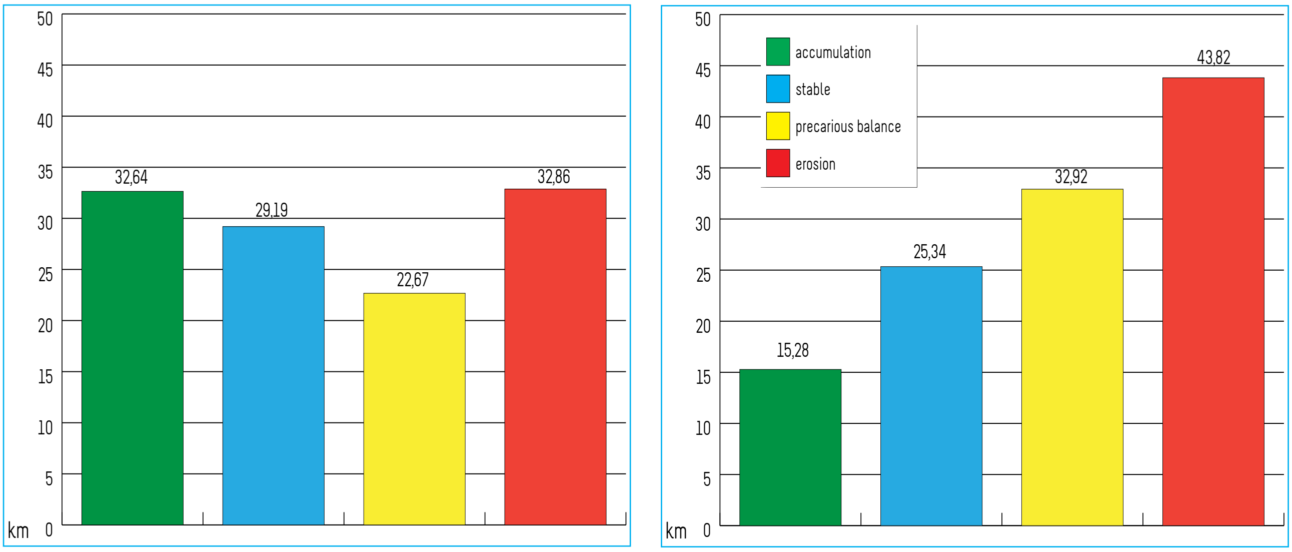


Figure 19 Comparing the results obtained with the analysis ASPE 2006-2012 and the one for the previous period 2000-2006 along the entire coastal zone. A: accumulation; S: stable; P: precarious balance; E: erosion.

baldi - Po di Goro) since 2006, in the other four Macrocells, an increase of coastal stretches under critical conditions (undergoing erosion or in a precarious balance) has been detected, with an almost total disappearance of accretion beaches.

The most serious deterioration has been recorded in the three southernmost Macrocells (between Cattolica and Foce Savio). After 2006, the number of critical beaches has doubled, with an increasing trend towards the disappearance of accretion beaches and with a significant decline in stable stretches.

A different situation can be observed in the area north of the Savio river mouth limited by Porto Corsini (Macrocell 4): on the one hand, the number of critical beaches has remained constant, whereas on the other hand, a declining erosion trend has been recorded. In 2012, compared to 2006, 4.4 km-long stretches of the coastline underwent erosion as against the previous 8.9 km-long stretches in 2006 compared to 2000.

The two northernmost Macrocells (Porto Garibaldi at the Po river mouth) are in sharp contrast, with a significant shoreline improvement trend observed in 2012. In addition to a remarkable reduction of eroding stretches, an increase in the number of stretches in good condition can be recorded within Macrocell 6. An accretion trend in almost every stretch could be observed in Macrocell 7, not only at the lagoon mouth, but also at Scanno di Goro. In this case, this trend might be a potential challenge connected with the closure of the lagoon mouth, with obvious negative

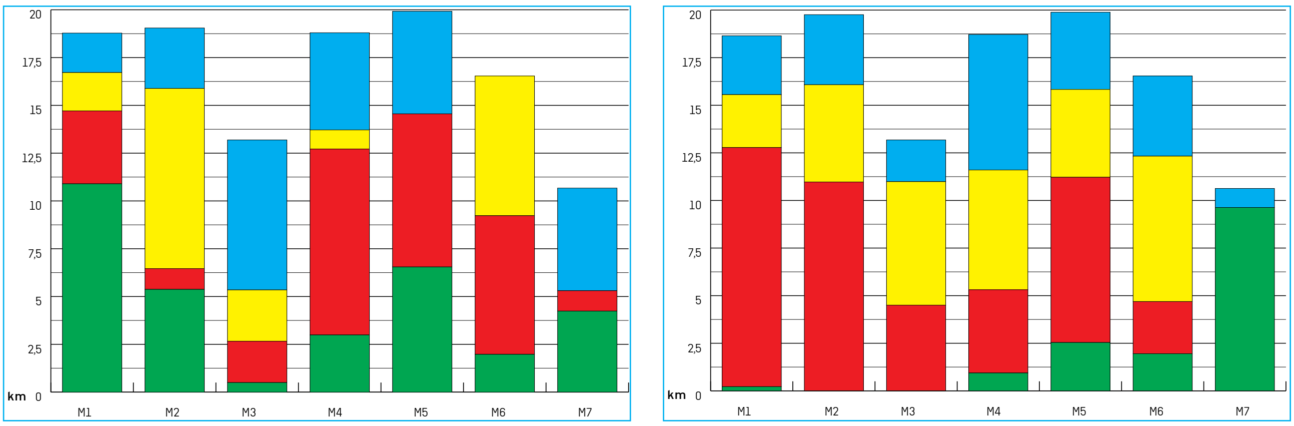


Figure 20 Comparing the results obtained with the analysis ASPE 2006-2012 and the one for the previous period 2000-2006 for each Macrocell. A: accumulation; S: stable; P: precarious balance; E: erosion.

consequences on the whole Sacca di Goro sea-inlet and its shellfish-farming activities. Sand harvesting for the nourishment of the Ferrara beaches and a proper sediment management of Scanno di Goro beach provide a two-fold benefit to the whole coastal area environmental conditions and safety, on the one hand, and to local economic activity, on the other hand.
The comparison shows that, in general, the regional coastline is increasingly more affected by erosion. The ongoing erosion process should not be underestimated because it is clear that, with the exception of the Po di Goro river, due to a reduced river solid sediment transport.
The dynamic balance of the coastal system can be maintained in the regional strategic plan, through an ongoing coastal sediment management, through regular massive sediment nourishment from external sources, approximately every 5 years, also taking into account the action by the sea, subsidence and the low river sediment transport capacity. It should be clearly underlined that no major off-shore underwater sand nourishment operations have taken place, during the period under review, due to the lack of adequate funds, as instead expected during the 2012 winter-spring period. This action could have been useful to counter the ongoing erosion affecting the entire regional coastline, by using new sand harvesting sites .
On balance, during the 2006-2012 period, about 640,000 m^3 of sand less than the previous year was harvested for beach nourishment purposes (2.82 million m^3 in the 2006 -2012 period, as against 3.46 million m^3 in the 2000-2006 period).
The coastal defence policies, which have so far been conducted by the Regional and Local Authorities, have proven to be successful. Yet, it is far too clear that in the future an increasingly larger number of nourishment actions will be required and, in particular, it will be necessary to exploit coastal sources more wisely and strategically, and also to make a greater use of external sources (eg. Off-shore underwater deposits).


US Army Corps of Engineers - Long Beach Island

Beach nourishment and coastal protection works

In the 2006-2012 period, the Emilia-Romagna Region has carried out a total of 2.82 million m³ sand nourishment operations (Table 2), of which just under 1.47 million m³ from external sources (excavation sites, inland quarries and off-shore underwater deposits) and just over 1.35 million m³ from internal coastal sources (eg. Accretion Beaches).

In the 2000-2006 period, about 3.46 million m³ of sand were used for beach nourishment purposes, hence 640,000 m³ more than the subsequent period (Table 2).

Nourishment (m³)		
	2000-2006	2006-2012
no works	416.613	872.002
BSS	826.464	564.873
MI	375.750	29.884
PBSS	348.068	262.579
PL	349.200	237.086
SE	365.783	362.404
SEP	192.600	74.265
SR	51.450	0
SS	9.482	12.475
SSP	516.970	408.433
total	**3.452.380**	**2.824.001**

Table 2 Volumes of sand brought to nourishment. No works: stretches without defense works; BSS; underwater sandbags barriers; MI: mixed works; PBSS: groins and breakwater in sandbags; PL: wooden groins; SE: emerged breakwaters; emerged breakwaters and groins; SR: attached breakwaters; SS: low-crested breakwaters; SSP: low-crested breakwaters and groins.

During both periods, the majority of beach nourishment operations were performed in stretches protected by other types of defence works (Table 2, Figure 21, Figure 22). These nourishment actions have especially concerned those beaches protected by shore-parallel submerged detached breakwaters using bags filled with sand and beaches protected by submerged breakwaters and groynes (BSS and SSP respectively, Table 2, Figure 21, Figure 22).

In the 2006-2012 period, the quantity of sand used for the nourishment of beaches not protected by any type of defence works has more than doubled (Table 2, Figure 22).

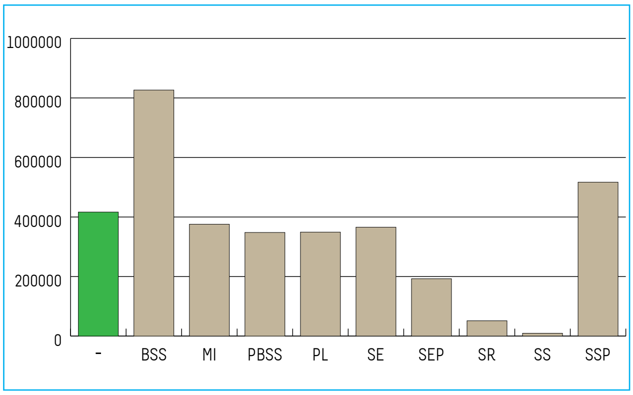


Figura 21 Volumes of sand brought to nourishment from **2000 to 2006**. with green: stretches without defense works; BSS; underwater sandbags barriers; MI: mixed works; PBSS: groins and breakwater in sandbags; PL: wooden groins; SE: emerged breakwaters; emerged breakwaters and groins; SR: attached breakwaters; SS: low-crested breakwaters; SSP: low-crested breakwaters and groins.

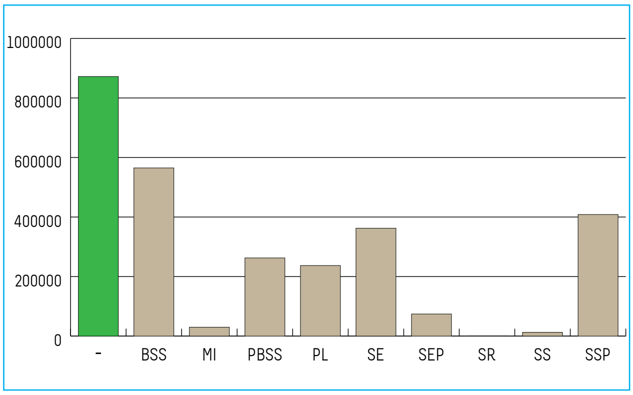


Figure 22 Volumes of sand brought to nourishment from **2006 to 2012**. with green: stretches without defense works; BSS; underwater sandbags barriers; MI: mixed works; PBSS: groins and breakwater in sandbags; PL: wooden groins; SE: emerged breakwaters; emerged breakwaters and groins; SR: attached breakwaters; SS: low-crested breakwaters; SSP: low-crested breakwaters and groins.

Sand harvesting

Between 2006 and 2012, 1 million m^3 sand more than in 2000-2006 has been harvested along the Emilia-Romagna coast (Figure 23).
Sand harvesting operations have mainly been conducted at the Port of Ravenna and at the lagoon mouth (M7). Unlike the previous period, sandy material dredged from the Porto Garibaldi port (M6) and Cattolica (M1 - Mouth Tavollo) (Figure 24, Figure 25) has been used for nourishment purposes.
No major differences were recorded in sediment harvested along the sandy stretches of coastline (Figure 24). It should be noted, however, that in the 2006-2012 period sand harvesting from the Lido degli Estensi beach has been reduced (Figure 26).

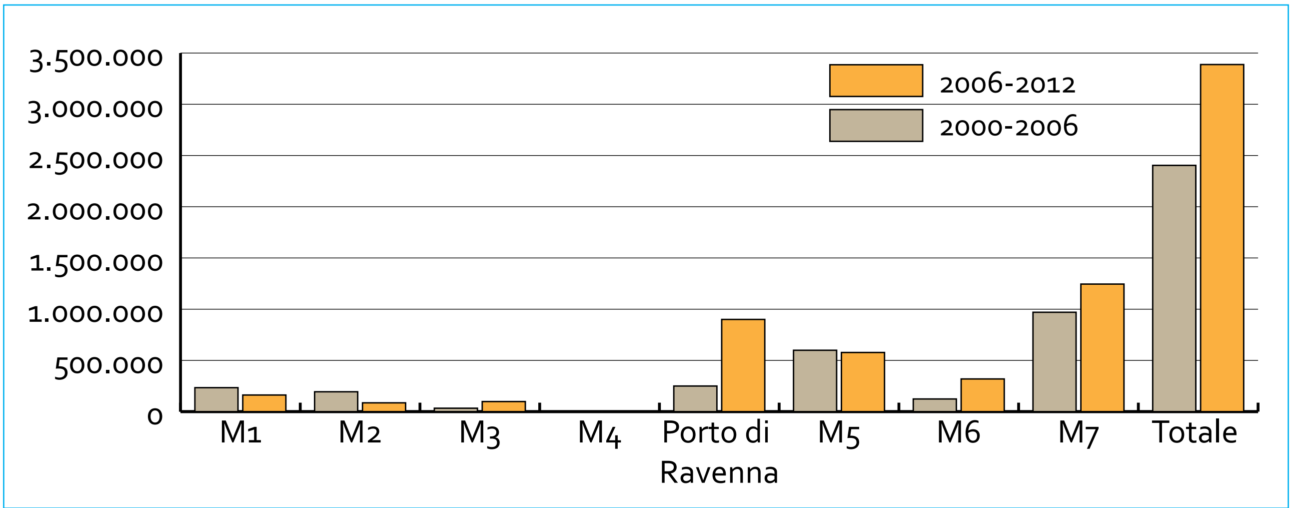


Figure 23 Volume of sand harvested along the regional cost in 2000-2006 and in 2006-2012 by Macrocell.

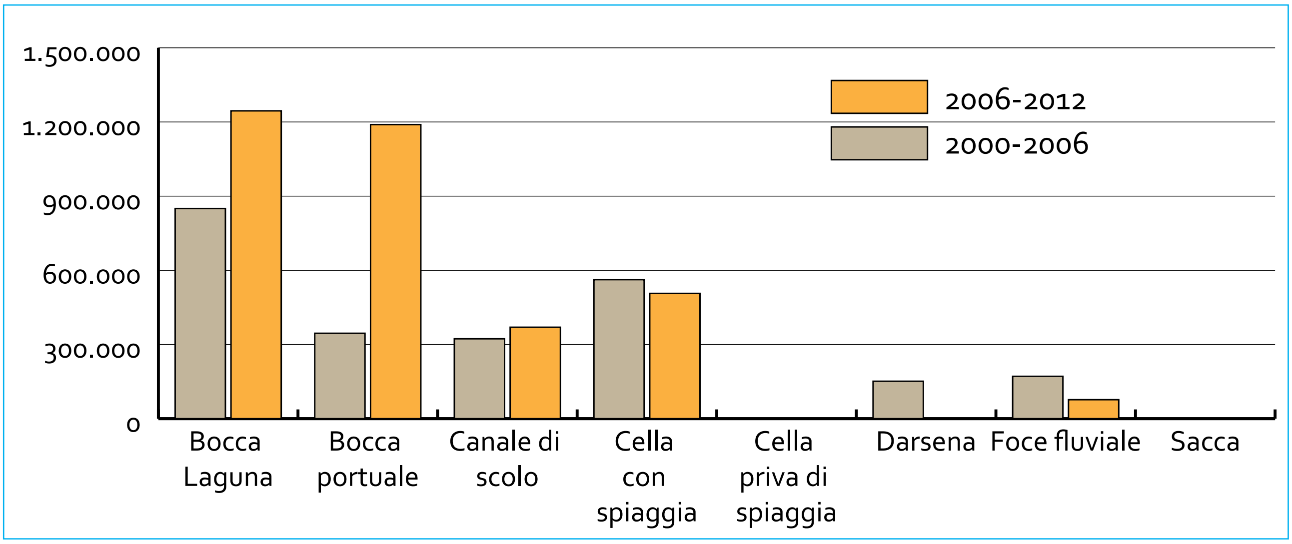


Figure 24 Volume of sand harvested along the regional cost in 2000-2006 and in 2006-2012 by cell typology

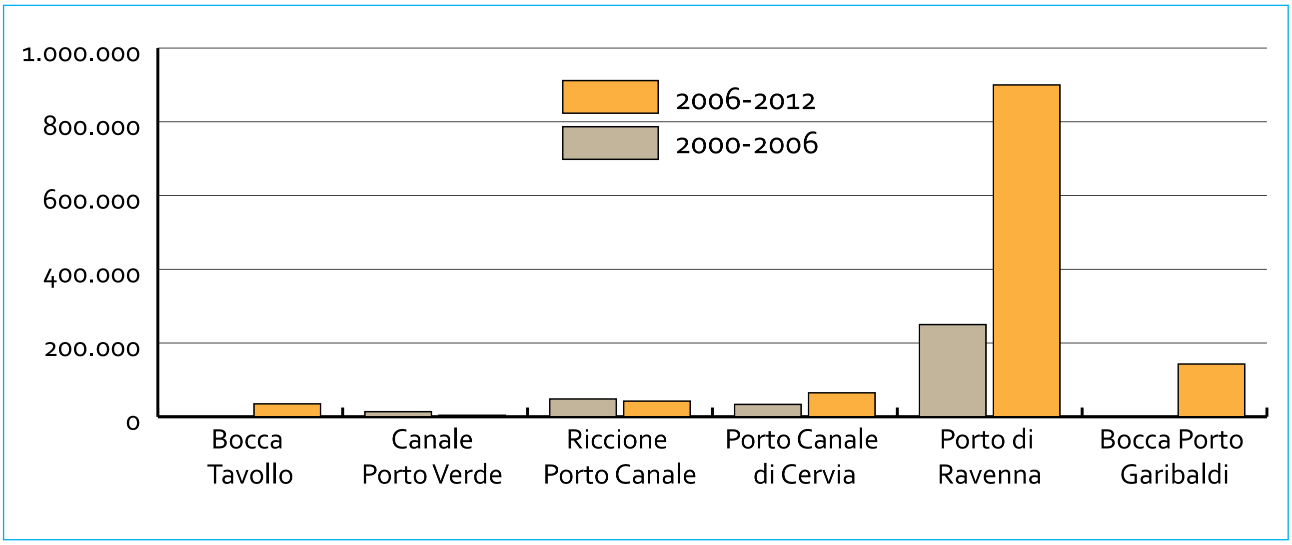


Figure 25 Volume of sediment dredged inside the regional port in 2000-2006 and in 2006-2012.

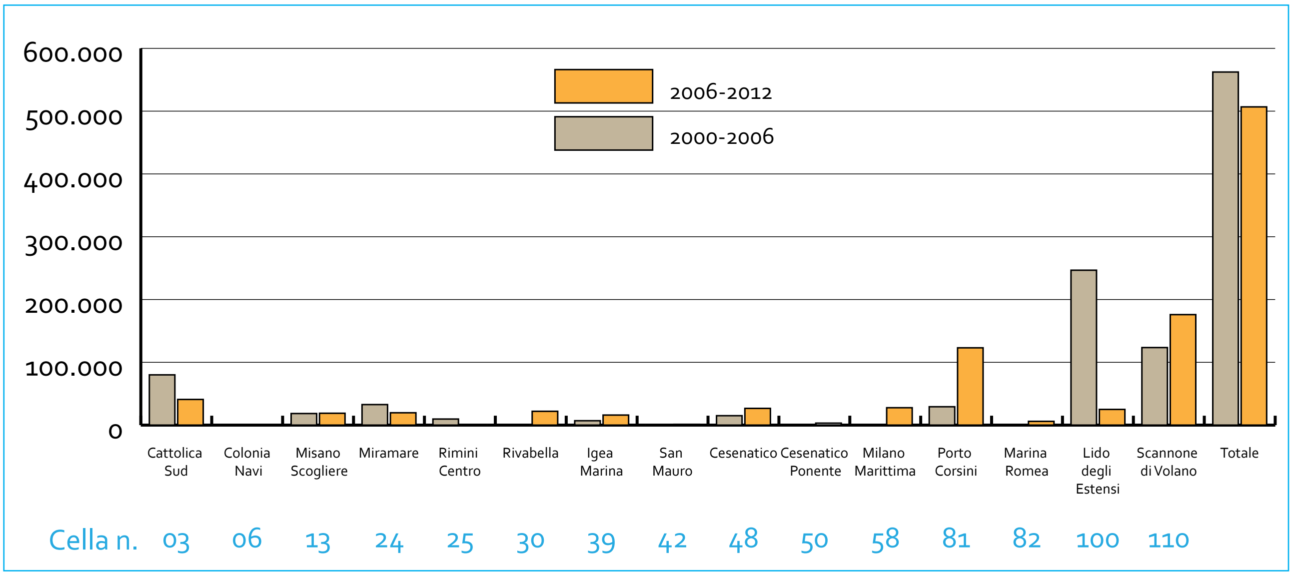


Figura 26 Coastlines caracheterized by emerged beach where were harvested sands in the periods 2000-2006 and 2006-2012.

Sand harvesting from river mouths has also declined. After 2006 no more dredging has been performed at the Ventena and Conca river mouths and at the Po di Goro river mouth. 150,000 m^3 of sand more than in 2000-2006 was harvested only at Logonovo.

Sedimentology

Sedimentological data is critical in the evaluation of the physical and hydrodynamic characteristics of coastal systems and of sediment transport mechanisms in the study of coastal dynamics. For this reason, in 2012 a supplemental sedimentological campaign was carried out along the entire coast. Three sedimentological campaigns have been conducted along the Emilia-Romagna coast, involving the coastline as a whole, in addition to a host of regional and local studies, which have been performed in the framework of monitoring projects concerning already existing defence works and new coastal facilities. A first regional detailed sampling campaign (over 300 samples collected every 2 km) was carried out in 1971 and 1972 by the University of Ferrara. About 20 years later, in 1993, a further sampling campaign was commissioned by Idroser when drafting the 1996 Regional Coastal Plan, which coincided with the 2nd topo-bathymetric network survey, commissioned by the E-R Regional authority. Similarly to the campaign conducted in the 1970's, this campaign concerned the entire Emilia-Romagna coast, but with a smaller number of samples (156), distributed across the regional topo-bathymetric network profiles spaced between 2 and 8 km. Samples were harvested at the same depth as during the previous campaign conducted by the University of Ferrara, which also supervised the particle size analysis, the sedimentological study and the comparison with the 1971-1972 campaign data.

Finally in 2006, Arpa Emilia-Romagna led an additional sampling campaign along the entire regional coast as part of the "Research program for the management and reuse of coastal sediments - ENI CIPE Project" according to a sampling plan with a different purpose of study: the physical-chemical characterization of the beach sediments for the standardisation of sediment quality assessment criteria. In 2012, a further sedimentological campaign was carried out along the entire regional coast to define the sedimentological characteristics of the coastline in conjunction with the fifth topo-bathymetric campaign. Over 300 sediment samples were harvested at the backshore and shoreface, from Cattolica to the Po di Goro river mouth. Samplings were made across the regional topo-bathymetric network profiles.

Samples were classified according to the Udden-Wentworth particle size scale, as summarised by the following Table:

phi	micron	Udden and Wentworth	Sigle
		Gravel	G
-1	2000		
		Very coarse sand	SMG
0	1000		
		Coarse sand	SG
1	500		
		Medium-sized sand	SM
2	250		
		Fine sand	SF
3	125		
		Very fine sand	SMF
4	63		
		Silt	SILT
9	2		
		Clay	A

Among the various indicators calculated to define the average sample grain, as part of the 2012 SICELL update, the average diameter was chosen as the most significant data.

Samplings were conducted on regional topo-bathymetric network profiles spaced at 2-3 km at various depths; consequently there is no one-to-one sample-cell match: more samples fall within a few cells, while none in others.

For this reason, assigning an average diameter value to each SICELL cell was carried out by referring to the 2012 average diameter map.

The analysis of data collected in the sedimentological campaign confirm that the Emilia-Romagna coast is mainly composed of sands and, to a lesser extent, of silty sands and silt, only on

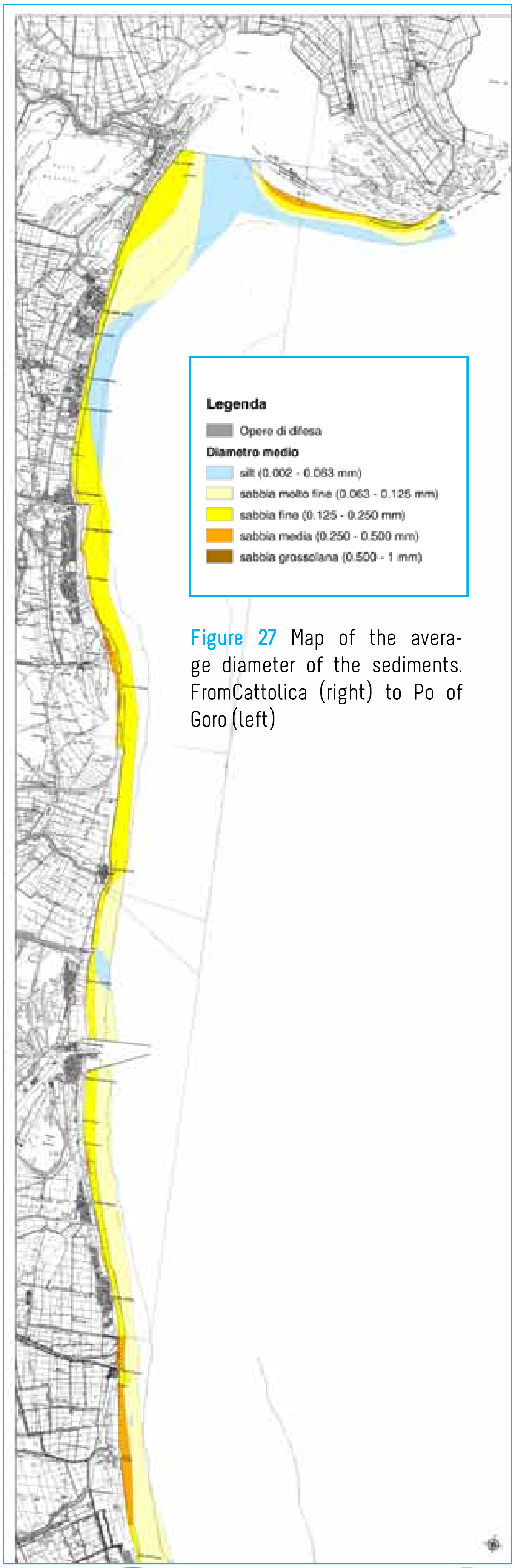


Figure 27 Map of the average diameter of the sediments. FromCattolica (right) to Po of Goro (left)

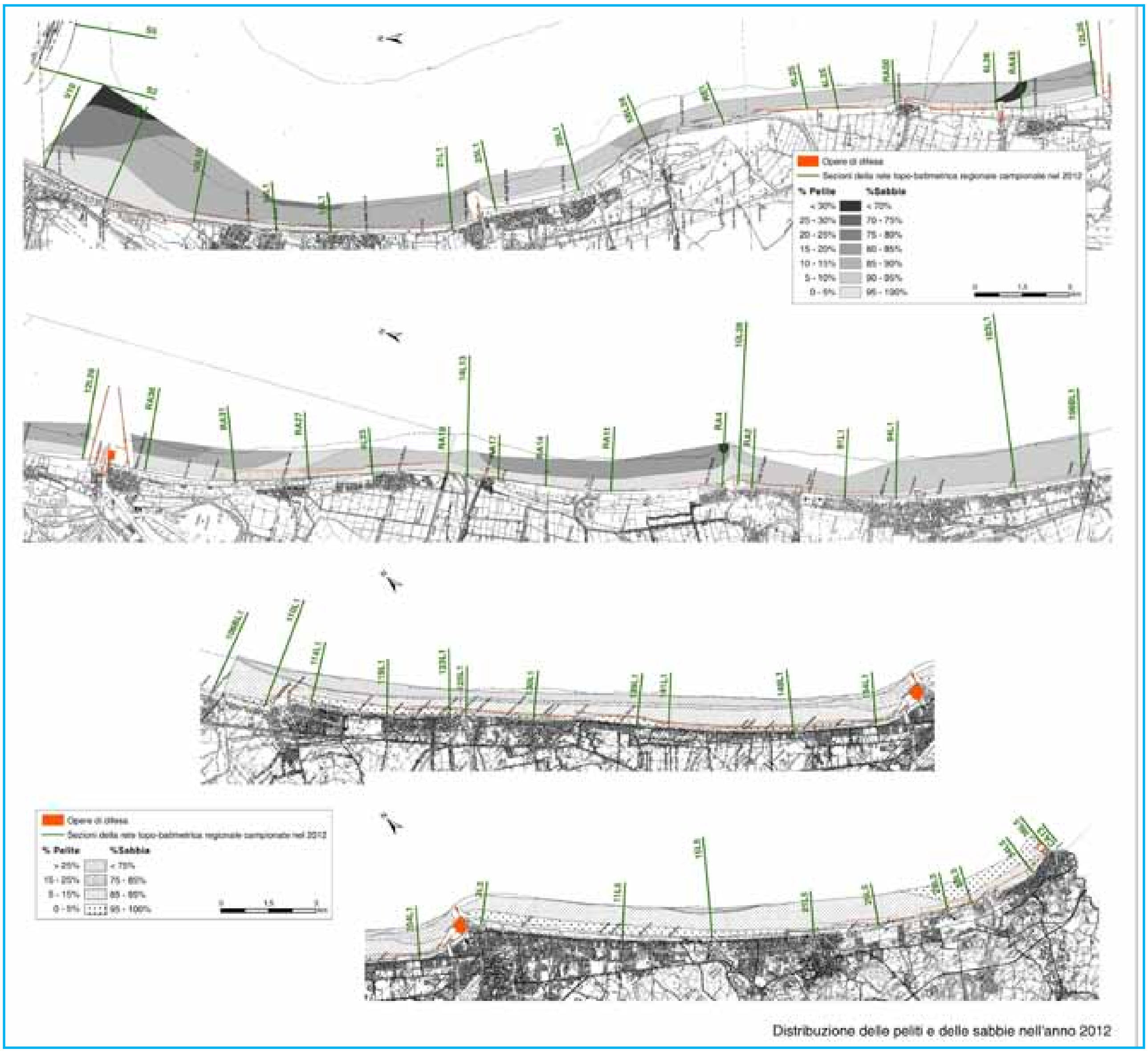


Figure 28 Distribution map of clay and sand.

the shoreface.
Among the various indicators calculated to define the average sample grain, as part of the 2012 SICELL update, the average diameter was chosen as the most significant data.
Samplings were conducted on regional topo-bathymetric network profiles spaced at 2-3 km at various depths; consequently there is no one-to-one sample-cell match: more samples fall in a few cells, while none in others.
For this reason, assigning an average diameter value to each SICELL cell was carried out by referring to the 2012 average diameter map.
The analysis of data collected during the sedimentological campaign has confirmed that the Emilia-Romagna coast is mainly a sandy coast and, to a lesser extent, of silty sands and silt, only on the shoreface.
The analysis of the average diameter of sediments (Figure 27) showed that 56% of samples is made up of the fine sand class (0.25-0.125 mm), 21% from of very fine sand (0125-0063 mm), 12% of medium-sized sand (0.5-0.25 mm) and 10% of the silt class of (0063-0002 mm).
As regards the sediment sorting degree in the analyzed samples, in most cases it tends to worsen with depth. Instead, in several cases it was noted that in correspondence of beaches near

river mouths and protected by defence works (eg. Savio river mouth), sediments next to the shoreline are less sorted than the deeper ones. Sediments are moderately sorted and in some cases well sorted on the backshore and near seabed, whereas, offshore samples are scarcely sorted.
Along the regional coastline, on the backshore and nearshore (up to -3 m) sediments mainly have an average diameter, typical of fine sand class.
However, a few coastal stretches are characterized by coarser deposits whose grain average size falls in the medium-sized sand class: i.e. beaches near Bevano, the area close to Fiumi Uniti, the beach north of Punta Marina south of the Ruvido groyne, the stretch between Marina Romea at Lido degli Estensi and Scanno di Goro (Figure 1). With the exception of the last two beaches listed above, all other are stretches are affected by severe erosion.
The average diameter on the seabed, between 3 and 7 meter depth, varies substantially from zone to zone.
Coarser deposits, whose average grain size falls in the fine sand class, have been identified in the stretches between Cattolica and Rimini and between Casal Borsetti and Porto Garibaldi. Sediments with an average diameter typical of very fine sands were identified up to 6-7 m depth along the coast between Cesenatico and Casal Borsetti and between Lido delle Nazioni and Volano.
On the seabed between Rimini and Cesenatico and along the Scanno di Goro Scanno di Goro a seaward decrease in the average grain size was recorded during the migration from very fine sands (down to about 5 m) to silt.
Finally, in the seabed in front of the Lamone and between Lido degli Scacchi and Lido delle Nazioni, silt is already present at a 3-4 meter depth.
As regards the pelitic fraction (Figure 28), the following observations were made. The lowest percentages of pelite, generally less than 15%, were found in stretches of coast between Cattolica and Rimini, between Cesenatico and Lido di Savio, including Lido di Dante and Punta Marina, between Casal Borsetti and Lido degli Estensi (annexed pelite and sands map).
Pelite reaches 20% maximum in Marina Romea, Marina di Ravenna, between Porto Garibaldi and Lido degli Estensi. Whereas, pelite reaches 25% between Rimini and Cesenatico, from Lido di Classe to Lido di Dante, Lido di Pomposa and Lido di Volano,.
In Lido di Volano, mud reaches 90% with 10% of clay. A high amount of pelite (40%) was also found at the Lamone river mouth and in front of the Savio river mouth (90%).

The updated framework of coastal cells

The following Table provides the full picture of the 118 regional cells that make up the ASPE classification of the shoreline. In addition to the general information about the cells, the ASPE classification is applied to the 2000-2006 and to the 2006-2012 period as well.

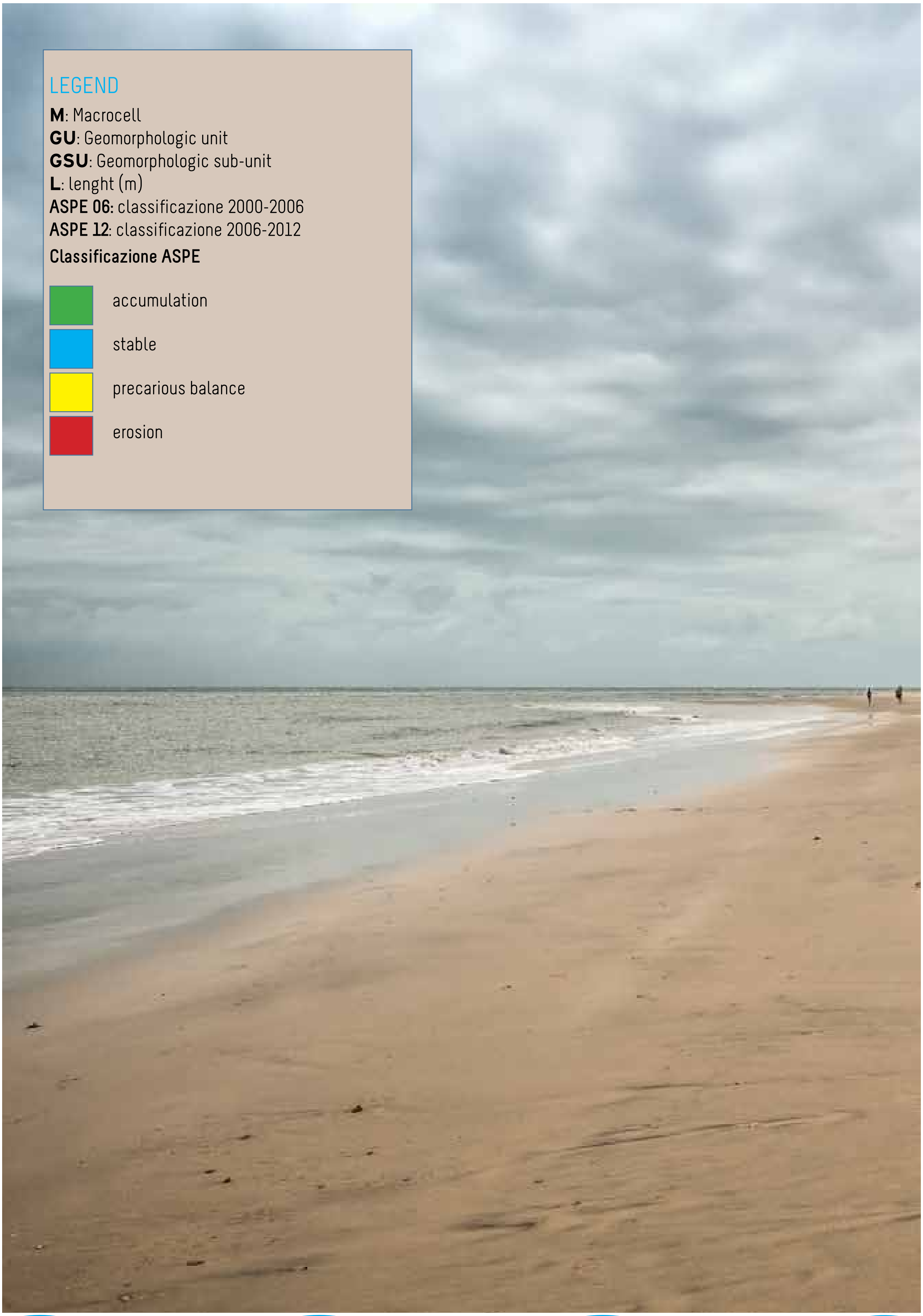
n	name	typology	physical delimitation	Municipal.	Prov.	M	GU	GSU	L	ASPE 06	ASPE 12
1	Bocca Tavollo	Harbour entrance	coastal stretch between south pier and Cattolica dock	Cattolica	RN	M1	RIC	A	55		
2	Darsena di Cattolica	Dock	coastal stretch of Cattolica dock	Cattolica	RN	M1	RIC	A	250		
3	Cattolica Sud	Cell with beach	coastal stretch between Cattolica dock and the ninth breakwater	Cattolica	RN	M1	RIC	A	1.230	S	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	P
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	E
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	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	E
11	Porto Verde Scogliera Radente	Cell with beach	coastal stretch relative to Porto Verde seawall	Misano Adriatico	RN	M1	RIC	A	220	E	A
12	Misano Pennelli	Cell with beach	coastal stretch relative to 26 groins	Misano Adriatico	RN	M1	RIC	A	1.680	E	E
13	Misano Scogliere	Cell with beach	coastal stretch defended by 7 emerged breakwaters	Misano Adriatico	RN	M1	RIC	A	755	A	P
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	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	E
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	P
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	P
21	Riccione Alba Nord	Cell with beach	coastal stretch between piazzale Azzarita and Marano river mouth	Riccione	RN	M1	RIC	B	1.250	A	S

n	denominazione	tipologia	delimitazione fisica	comune	prov.	M	UG	SUG	L	ASPE 06	ASPE 12
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	S
24	Miramare	Cell with beach	coastal stretch between Rimini/ Riccione municipality boundary and Ausa	Rimini	RN	M1	RIC	B	6.190	A	E
25	Rimini Centro	Cell with beach	coastal stretch between Ausa and Rimin harbour	Rimini	RN	M1	RIC	B	1.350	A	E
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	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	S
31	Viserba Zona Sud Sortie	Cell with beach	coastal stretch between the 13th and the 16th breakwater	Rimini	RN	M2	RIC	C	630	A	E
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	E
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	E
35	Viserbella	Cell with beach	coastal stretch between the 4th breakwater and Fossa Brancona	Rimini	RN	M2	RIC	C	1.200	S	E
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	P
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	P
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	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	P
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	E
42	San Mauro	Cell with beach	coastal stretch between of San Mauro a Pascoli municipality	San Mauro Pascoli	FC	M2	RIC	C	700	P	E
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	E

n	denominazione	tipologia	delimitazione fisica	comune	prov.	M	UG	SUG	L	ASPE 06	ASPE 12
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	E
46	Villamarina	Cell with beach	coastal stretch between the 7th breakwater and the first Valverde groin	Cesenatico	FC	M2	RIC	C	880	P	E
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	E
48	Cesenatico	Cell with beach	coastal stretch between Colonia Agip groins and Cesenatico southern pier	Cesenatico	FC	M2	RIC	C	2.015	A	S
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	S
51	Cesenatico Colonie	Cell with beach	coastal stretch 800 m long starting from the big groin	Cesenatico	FC	M3	RIC	B	775	E	E
52	Cesenatico Campeggio Zadina	Cell with beach	coastal stretch 500 m long southern of Tagliata channel	Cesenatico	FC	M3	RIC	B	500	A	E
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	E
55	Cervia	Cell with beach	coastal stretch 4400 m long southern of Cervia dock	Cervia	RA	M3	RIC	B	4.420	S	P
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	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	E
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	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	P
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	S
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	A
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	S
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	S

n	denominazione	tipologia	delimitazione fisica	comune	prov.	M	UG	SUG	L	ASPE 06	ASPE 12
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	E
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	E
72	Lido di Dante	Cell with beach	coastal stretch between the first and the last groin	Ravenna	RA	M4	RAC	D	605	E	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	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	A
76	Lido Adriano	Cell with beach	coastal stretch defended by 19 emerged breakwaters	Ravenna	RA	M4	RAC	D	2.560	E	P
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	P
78	Punta Marina Nord	Cell with beach	coastal stretch between the 11th and the Bagno Ruvido groin	Ravenna	RA	M4	RAC	E	865	S	E
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	S
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	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	E
83	Marina Romea Nord	Cell with beach	coastal stretch 950 m long southern Lamone river mouth	Ravenna	RA	M5	RAC	D	945	E	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	P
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	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	S
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	S
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	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	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	E

n	denominazione	tipologia	delimitazione fisica	comune	prov.	M	UG	SUG	L	ASPE 06	ASPE 12
94	Foce Gobbino Sud	Cell with beach	coastal stretch 850 m long southern Gobbino channel mouth	Ravenna	RA	M5	RAC	D	860	E	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	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	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	S
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	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	S
103	Lido degli Scacchi	Cell with beach	coastal stretch between the 16th and the 34th breakwater	Comacchio	FE	M6	RAC	F	2.500	P	P
104	Lido di Pomposa	Cell with beach	coastal stretch between the 35th and 52nd breakwater	Comacchio	FE	M6	RAC	F	2.240	E	P
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	P
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	S
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	S
108	Volano Zona Pennelli	Cell with beach	coastal stretch between the first and the last groin	Comacchio	FE	M6	RAC	G	990	E	E
109	Volano	Cell with beach	coastal stretch 1750 m long starting from the last groin	Comacchio	FE	M6	RAC	G	1.750	P	E
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	A
111	Foce Po di Volano	River mouth	coastal stretch of Po di Volano	Comacchio / Codigono	FE	M7	RAC	G	1.880		
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	S
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	A
118	Bocca Laguna	Lagoon mouth	coastal stretch of lagoon mouth	Goro	FE	M7	PDC		4.625	A	A



LEGEND

M: Macrocell
GU: Geomorphologic unit
GSU: Geomorphologic sub-unit
L: lenght (m)
ASPE 06: classificazione 2000-2006
ASPE 12: classificazione 2006-2012

Classificazione ASPE

- accumulation
- stable
- precarious balance
- erosion

INNOVATIVE INTERVENTIONS FOR THE PROTECTION OF THE COAST

As already mentioned, a proper management of coastal sediments is critical to optimize the available (financial and natural) resources and to plan a sustainable and integrated coastal defence plan. In November 2010, the Regional authority signed a programme agreement with the Ministry of Environment, allocating 5.6 Million Euro for coastal defence, in addition to other funds for soil conservation. The funds allocated by the Programme Agreement were not sufficient to serve as a "critical mass" to start an offshore underwater sand based nourishment project (which would have been the third one in the regional programmes, expected for 2012). However, this fund allocation has allowed the drafting of a Comprehensive Nourishment Plan using coastal sands, over a multiyear period. From 2011 to 2014, 10 nourishment campaigns funded by the programme were implemented, along with 9 further actions funded by other regional schemes, up to a total amount of about 3.6 million. By implementing SICELL in the regional decision-making system, it has thus been possible to design the best sustainable and integrated coastal defence action plan. As part of the Agreement, in addition to extraordinary maintenance works of a few critical stretches along the coast, two further projects based on a particularly innovative, technical and implementation approach were also carried out: the permanent sand pipeline of Riccione and the nourishment of Lido di Volano beach.

The permanent sand pipeline of Riccione is a highly innovative work, co-funded by the Region of Emilia-Romagna and by the Ministry of Environment, including 1 million euro funded under the Programme, aiming at optimizing the management of sand resulting from periodic ordinary dredging operations (Figure 29) at the Riccione (RN) canal harbour mouth.

The fixed system consists of two pipelines inserted in the heads of the piers of the canal harbour buried underground along a 550 meter

Figure 29 Joint of the dredge with Riccione sand pipeline

Figure 30 Joint plug of the Riccione sand pipeline

Figura 31 Nourishment with the sand-water mixture coming from the Riccion port dredging.

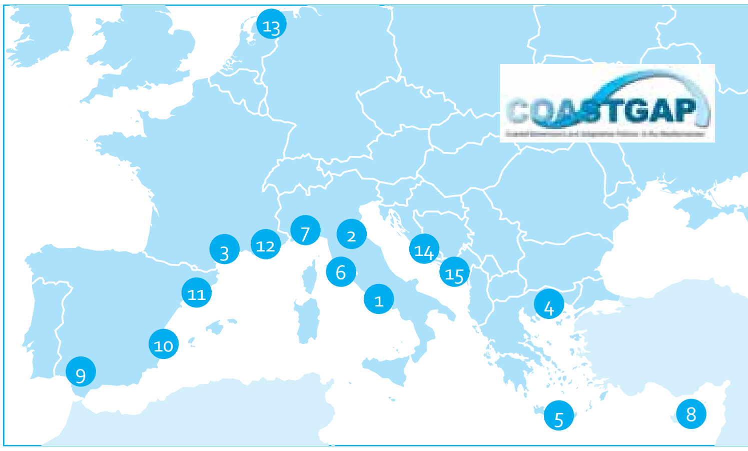
long stretch of the beach North of the port and a 3,300 meters long stretch to the South, since both coastal stretches are subject to severe erosion (Figure 30). The two sand feeding pipeslines, thanks to 25 underground wells (22 along the south pipeline, and three in the North), allow the nourishment of specific areas of the beach (Figure 31) through the reflux pipe coupling of the dredger during the dredging of the port of Riccione. The system allows to optimize the management of sandy material resulting from dredging, to largely reduce set-up times and the building site size, to improve the use of means of transport and thus to significantly reduce unit costs of sand used for beach nourishment purposes. The system was completed in autumn 2013, with the official opening scheduled in November 15. It has already started its full operation in winter-spring 2013 – 2014, with excellent results. The "Riccione II" dredger owned by the Municipality of Riccione is an integral part of the system and it is used for the dredging of the canal harbour. The municipal authority of Riccione was already using sand dredged from the canal harbour entrance for nourishment purposes but the system adopted so far envisaged the use of collecting tanks, loading and transport systems by trucks and sand distribution by means of mechanical shovels. The new facility has allowed to enhance the efficiency of the operation and to reduce its environmental impact, thanks to the underground direct sand replenishment pipeline, which benefits from a constant inflow of sediments from the harbour mouth, with an estimated amount of approximately 10-15,000 m^3 of sand a year. The second operation was also carried out in the framework of the Comprehensive Nourishment Plan. It envisaged the nourishment of Lido di Volano with sand coming from Scanno di Goro. In this case, sand was transferred by means of an approximately 4 km-long temporary sea pipeline, with sand coming from Scanno di Goro, a site undergoing massive accretion, to the Lido di Volano beach (Figure 32). The total volume of 124,000 m^3 of sand was distributed along a nearly 2.5 km long stretch of eroded beach, at a maximum distance of about 8 kilometers from the harvesting site. This is the first operation of this kind implemented using sand coming from Scanno di Goro. This transfer system allows to reduce the time and cost of transport compared to transport by boat, and also to reduce the unit cost of sand used for nourishment operations. The building of the system was contracted out in late 2013, due to environmental constraints and tourist seasonal requirements. The underwater pipeline laying operations were conducted in October 2014. The project is expected to be completed in March 2015.

Figure 32 Temporary Sand pipeline of Goro. In red the area of the dredging, the purple line represent the sand pipeline that will be connected to land pipeline (in red).

Figure 33 Dredge working on Scanno di Goro.

SICELL CAPITALIZATION IN THE COASTGAP EUROPEAN PROJECT

SICELL capitalization in the COASTGAP European project



PARTNERSHIP

1. Regione Lazio (IT)
2. Regione Emilia-Romagna (IT)
3. Department of Hérault (FR)
4. Region of East Macedonia and Thrace (GR)
5. Decentralized Administration of Crete (GR)
6. Regione Toscana (IT)
7. Regione Liguria (IT)
8. Ministry of Communications & Works of Cyprus (CY)
9. Universidad Pablo de Olavide of Seville UPO (ES)
10. FEPORTS (ES)
11. University Autonomous of Barcelona (ES)
12. CEREMA (FR)
13. Christian-Albrechts University in Kiel (DE)
14. RERASD Split-Dalmatia County (HR)
15. DUNEA Dubrovnik Neretva County (HR)

The European project COASTGAP "Coastal Governance and Adaptation Policies in the Mediterranean" (Governance and adaptation policies in the Mediterranean coastal areas), whose lead partner is the Region of Lazio, involves 15 partners with a total 1.36 million euro budget. The project aims at the capitalization of 12 best practices from nine different European projects in order to develop governance tools and adaptation policies to reduce hazards along the coastal areas and to promote their sustainable development. Furthermore, the COASTGAP project, starting from the objectives defined in the Bologna Charter (Charter of the European Regions for the promotion of a strategic action framework for the protection and sustainable development of the Mediterranean coasts), aims at defining a Joint Action Plan for coastal adaptation to climate change and the promotion of a European Interregional Observatory for Mediterranean Coastal Defence.

The Emilia-Romagna Region is the promoter of the SICELL littoral cells management system within the framework of this project, among further best practices.

In its capacity as project promoter, the role played by the Emilia-Romagna Region consists in providing guidance and support to partners interested in the capitalization and implementation of good practices in their own territories. In the case of SICELL, the capitalization process was driven by the Regional authority through a series of technical meetings addressed to partners involved focusing on the possibility of adapting the tool to the specific spatial characteristics.

Seven European institutions and regions have shown interest in the SICELL capitalization:

- Regione Lazio;
- Regione Toscana;
- CEREMA;
- Montenegro;
- Department de l'Herault;
- Cyprus;
- Region of East Macedonia & Thrace (GR).

Every institution has pursued a different level of SICELL capitalization, based on the different coastal facilities, the availability of databases and the level of development and implementation of coastal monitoring networks.

The collaboration between the Emilia-Romagna Region and the other partners has led to different systems based on the SICELL approach, with the obvious adaptation to the local needs of each partner, but pursuing the same basic goal, namely the creation of a tool able to support coastal defence through a sustainable and integrated management of coastal sediments.

SICELL capitalization followed three main phases.

1. In the first phase of the project, the Emilia-Romagna Region provided partners with the technical information about SICELL spe-

cifications, scope of application and adaptation to each region.
2. In the second phase, in response to specific questionnaires, partners defined SICELL feasible capitalization level to be achieved by the end of the project;
3. In the third and final phase, partners developed and tested their customized SICELL pilot versions on specific coastal stretches, with the supported of Emilia-Romagna technicians.

The capitalization process has led to significant results for each partner.
A customized SICELL pilot version has been developed and then tested on a pilot area by the Lazio Region and Cyprus.
The Lazio region has subdivided the coast into 170 littoral cells, numbered from 10 to 1700,from North to South. For the ASPE classification definition the Lazio Region has based the volumetric change calculation on areal variations between the shoreline, considering a value of ±10 m^3/m per year, as a significant sand accumulation/loss limit, different from the value taken by the Emilia-Romagna Region. Finally the Cell data sheets have been drafted only for the Montalto di Castro pilot area.
In the case of Cyprus, the coast has been divided into 12 macrocells, in turn subdivided into sub-areas. Each sub-area has been divided into littoral cells. SICELL has been tested on the Paphos pilot area and 4 Cell data sheets have been produced (Figure 34).
The Region of Tuscany has since long developed a monitoring system for the coastal evolution assessment, which consists in the subdivision of about 200 km-long beaches in the regional area into physiographic units; a number of sectors has been identified for each unit, where linear and areal changes of the beach are periodically monitored. These areas will then be merged into macrocells, which will serve as basis for the calculation of sedimentary budgets in order to optimize the locally available resources.
The Region of East Macedonia and Thrace (GR) (REMTH) is testing the SICELL pilot version on the Kariani area, which has already been divided into five littoral cells. The capitalization results will become an integral part of the new REMTH coastal defence and monitoring plan to be developed in the coming years.
The Department de l'Hérault and CEREMA Partners, in addition to the French translation of the operating guidelines and SICELL implementation, have assessed the applicability and comparability of this tool as against the current system based on physiographic units in use in the Languedoc Roussillon Region.
At the conclusion of the capitalization process, it can be stated that SICELL has proved to be a flexible and adaptable tool to different coastal areas. In order to make the necessary customizations to the management system for its adaptation to the specific knowledge and spatial base, the partners involved have been able to work on both the database and cell data sheet structure, in a user-friendly and intuitive way.

Figura 34 Cell of Phaphos, Ciprus.

CONCLUSIONS

picture of Roberto Ferrari

Conclusions

The updating of SICELL along with annual coastal maintenance operations and the implementation of innovative solutions, such as the ones implemented in Riccione and in Lido di Volano, are major steps forward towards the optimization of natural and financial resources and coastal sediment management. SICELL capitalization and application in other Mediterranean and European regions has confirmed its validity as an effective management tool.
The Emilia-Romagna Region is committed to pursuing the goal of optimizing the use of natural and economic resources, also due to an increasingly more limited availability of funds.
The total 9.3 million euro funding (5.6 million euros from the Programme Agreement and 3.7 million euros from other regional funds) made available for coastal defence in the 2010 - 2014 period accounts for less than one third of funds allocated in the previous 2005-2009 period (32 million euros).
In this framework, in order to maintain a high level of safety and security in coastal areas, great efforts have to be made by the Regional and local authorities, as well as by all the stakeholders involved, and it will be even more so, if an even more efficient, integrated and participatory system is to be achieved in the future, which is able to develop and enhance coastal management and defence good practices that have been developed over the past few years.
The policies initiated by the Region in the 1980's and 90's aimed at the reduction of the anthropogenic component of subsidence (limitation and regulation of water and natural gas extraction from underground, construction of the Ridracoli dam and of the Romagna aqueduct) are today showing their positive effects along the coastline, with a significant reduction in subsidence rates along almost the entire coast. In the 2006-11 period, the coastline, as a whole, featured an average subsidence rate of about 4 mm / year along a 5 km-long inland strip, which has essentially halved compared to the previous period.
The restoration of the river solid sediment transport at sea, which is a further goal pursued by the 1980's Regional policies (excavation ban in river beds), does not feature similar positive findings, due to the fact that, because of the different hydraulic regulation works carried out on river courses, sediments present in river beds, although protected by the law, reach the sea only to a very limited extent and mainly with reference to the finest fraction.
The regional strategy, which has been adopted for some decades and codified by the ICZM Guidelines, has proved to be effective in terms of spatial management, even with limited funds, through a comprehensive approach focusing on coastal areas and sediments as strategic resources, which allows the optimization of financial resources in climate change coastal adaptation actions.
The 2006-2012 ASPE classification of coastal cells, and the comparison with the previous period (2000-2006), reported a significant increase in the number of coastal stretches in critical conditions. This increase is mainly due to a significant reduction of funds available in the region for coastal defence.
The effectiveness of the regional action is proven by the fact that, over the last period, the stretches under critical conditions have increased slightly less than 1/5 compared to the previous period, given a reduction of allocated funds by 2/3 compared to the same period.
In 2012, along the regional coast, about 15 km-long beaches (13%) are in a total accumulation and around 25 km-long beaches (22%) prove to be in a stable condition without any need for action, while about 77 km -long beaches (65%) feature different critical conditions. Among the most critical stretches, about 33 km-long beaches (28%) are in precarious balance (i.e. kept in balance through continuous actions) and about 44 km km-long beaches (37%) overall were shar-

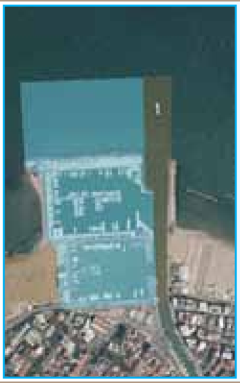
ply eroded.
In this situation, some areas of the regional coast with wide beaches and seemingly stable shorelines (macrocells M1 and M3) showed significant losses of sand from the shoreface, with no particular evidence that emerged. Such zones, corresponding to the cells 15, 24, 25, 55, should be strictly monitored and fed into the submerged parts with adequate volumes of sediments, directly or indirectly or through updrift charging zones.
Further accumulation/reservation areas, in particular also in the shoreface, are included in Cells 72 (M4) and from 90 to 94 (M5).
The largest accumulation/reservation areas including sediments deriving from nourishment actions are the ones corresponding to the lagoon mouth in Punta Scanno (C118), Lido Estensi (C100) and Porto Corsini (C81). While, C100 and C81 Cells feature an accumulation declining trend as against the past, due to a decline in the inflow of sediments deriving from an increasingly poorer river solid sediment supply, which has not been offset since the expected third largest offshore sand nourishment action has not taken place.
To compensate for this lack of action, in 2006-2012 a further harvesting of coastal sands amounting to about 1 million cubic meters, as against the 2000-2006 period, which was aimed at the management of critical stretches. Yet, it should be pointed out that his kind of action could be envisaged only in the short run, to avoid further exacerbating the ongoing subsidence phenomenon - even though it has halved compared to the previous period – thus causing a further lowering of the coastline as against the average sea level, which in turn tends to rise due to the effect of climate change. Hence, the only way to regain altitude is feeding new sediments from external sources to the coastal system.
It is therefore necessary to continue to consider sediment as a strategic resource (EUROSION 2004 Recommendations), which is based on two main lines: nourishment and sand loss reduction from the coastal system.
Yet, in the long term, in addition to nourishment and to the "ordinary" maintenance system through coastal sands and "extraordinary" external sediment, it is also important to promote local policies to improve spatial resilience, i.e. the inherent ability of the system to adapt to climate change, sea level rise, sea storms and floods, and to maintain its balance substantially unchanged in the long term.
More effective policies are required in furtherance of coastal area adaptation to climate change, further reduction of the anthropogenic component of subsidence, restoration of river solid sediment transport and new coastal spatial management policies (also in pursuance of the ICZM Protocol for the Mediterranean sea and the new Directive 2014/89 /EU on Maritime Spatial Planning), in order to achieve an adequate safety level along the coast in the long term, by increasingly reducing the need for finite, non-renewable resources, such as offshore underwater sands deposits.
The combination of short and medium-term strategies and actions aimed at combating subsidence and erosion, and of longer-term spatial policies will lead to a more sustainable use of resources and to a more efficient coastal management, to secure an adequate and sustainable level of wellbeing, safety and security in the entire regional coastal area.

THE MONOGRAPHIC SHEET

picture of Paolo Lottini

General information

M1	COSTA RIMINESE				A
Denominazione	Bocca Tavollo				1 TLS01
Tipologia della cella	Bocca portuale				
Delimitazione fisica	Tratto compreso fra il molo sud e la darsena di Cattolica				
Coordinate I	Lon	43,97201186	Lat	12,75143229	
Coordinate F	Lon	43,97198115	Lat	12,75211586	
Lunghezza cella (m)	55				
Comune/i	Cattolica				
Provincia	Rimini				



A	S	P	E		A	S	P	E	

Aerial photo of the cell

The area of the cell used as a reference for the ASPE index calculations is highlighted in blue or brown in the picture.
If the cell is a river, lagoon or port mouth, it is subdivided into the Marine Relevance area (PM) and, respectively, into the Port Relevance area (PP), River Relevance area (PL) and Lagoon Relevance area (PL).

Cell name

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

Cell type

Cell with beach	characterized by the presence of backshore
Cell without beach	characterized by the absence of backshore
River mouth	corresponding to the river mouth bounded by banks
Port mouth	corresponding to ta Port mouth, bounded by piers
Dock	corresponding to the sea front dock
Drainage channel	corresponding to the Drainage channel mouth
Sea-inlet	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.

Significant coastal stretch (TLS)

Starting from the south, significant coastal stretches (TLS) of are numbered from 1 to 14. TLS is a grouping of cells for management purposes, in view of the new regional rules for sediment dredging and movement, towards a simplification of licensing procedures.

Macrocell (M1-M7)

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-Foce Savio	From the port of Cesenatico (excluded) to the Savio river mouth (included)	13.765
M4	Foce Savio – Porto Corsini	From the Savio river mouth (excluded) to the Port of Ravenna (excluded)	19.100
-	The 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 – Foce Po di Volano	From Porto Garibaldi (included) to Po di Volano river mouth (excluded)	16.650
M7	Foce Po di Volano-Foce Po di Goro	From the Po di Volano river mouth (included) to the regional border with the Veneto Region.	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.

Geomorphologic units and subunits

Units	Sub-unit	stretches
RIC	A	Cattolica-Riccione
	A	Cattolica-Riccione
	B	Riccione-molo Rimini; Cesenatico north - Lido di Savio
	C	Rimini north - Cesenatico pier
	RAC	Aree di inter-cuspide (Bocca Bevano, Porto Corsini, Lido degli Estensi)
	F	Porto Garibaldi-Lido delle Nazioni
	D	Delta cusps(Foce Reno-Casal Borsetti, Foce Savio e Fiumi Uniti-Punta Marina)
	E	Inter-cusp Areas (Bocca Bevano, 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 and 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 subunits 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.

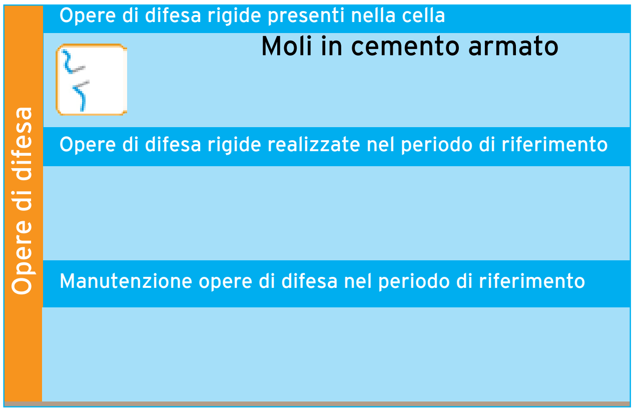
ASPE classification

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.

class	definition
accumulation	Stretch of coastline showing significant
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
precarious 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

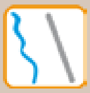
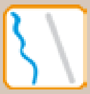
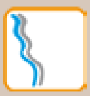
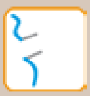
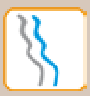
It has been decided to maintain the landward and seaward cell borders unchanged over time, in order to calculate the volumetric changes and to make the analyses and comparisons between the measurements performed over the years as comparable and homogeneous as possible. Volume change calculations were 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.
The new cell datasheet features two ASPE classifications, one corresponding to the 2000-2006 period and the other one, covering the 2006-2012 period.

Hard defence 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:

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: groynes extending from the backshore to the shoreline
	Shore-parallel submerged groynes: synthetic fabric sheaths filled with sand mix
	Shore-parallel low-crest groynes: 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

Ripascimenti	Ripascimenti nel p.rif. (m^3)	Celle di provenienza delle s.
	Fonti di provenienza delle sabbie	

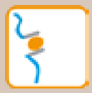
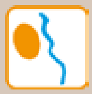
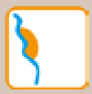
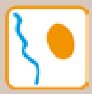
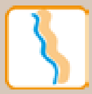
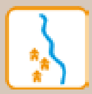
Source data on beach nourishment are provided by the River Basin Technical Services to feed the Regional Geological Service "beach nourishment database" (in-Sand) by the Geological, Seismic and Soil of the Emilia-Romagna Region, which is organized differently here for specific SICELL purposes.

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.

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.
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 underwater deposits
	Beach cleaning
	Building excavations

Sand withdrawal

Prelievi	Prelievi di sabbie (m^3)
	35000
	Cella/e di destinazione sabbie
	12,14

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

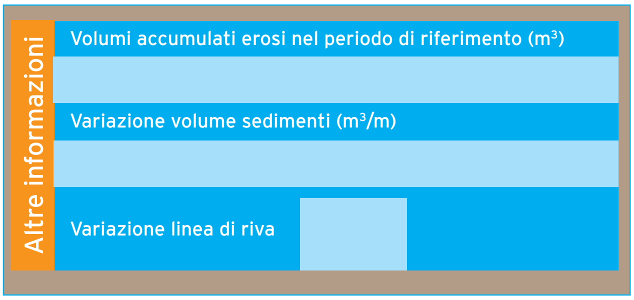
Sand withdrawal

This field reports, if any, the amount (expressed in m³) 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 m³ 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

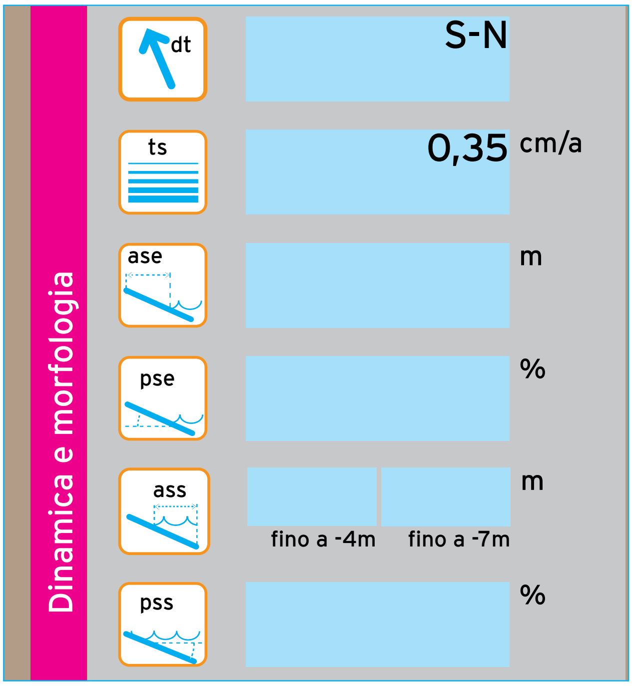
It indicates the sediment volume changes (m³/m) calculated by detracting the value of accretion and erosion volumes (resulting from the comparison between the topo-bathymetric surveys) from the sand nourishment volume, in the period under review, and/or adding the volumes of harvested sand, related to the same period (accretion and erosion volumes - beach nourishment + sand withdrawal)

The shoreline trend

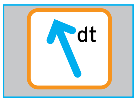
The shoreline trend has been reconstructed on the basis of the comparison between the shoreline
of 2000, by means of photo-interpretation, and the shoreline of 2006, directly measured by means of differential GPS. The shoreline is a further parameter that is taken into account in the ASPE classification, 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	definition
	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

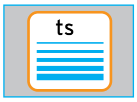


When a train of waves approaches a coastline obliquely, two main movement components occur: one perpendicular and another one parallel to the coastline.
The longshore current, which is generated in correspondence with the bathymetric line where wave breaking occurs, determines a longshore transport of 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.

direzione	descrizione
N-S	Trasporto da nord verso sud
S-N	Trasporto da sud verso nord
E-O	Trasporto da est verso ovest

Zona di convergenza	Punto di zero del trasporto solido in cui la corrente lungo costa tende a convergere
Zona di divergenza	Punto di zero del trasporto solido in cui la corrente lungo costa tende a divergere

Subsidence rate



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 2006 e 2011.

Morphological beach elements

The beach can be subdivided into two main units: backshore, foreshore (alive or mobile) which together constitute a single sedimentary body in which sediments can 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 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	**Shoreface width:** it is calculated from the shoreline (zero level) to the -4 and -7 m depths, derived from the 2006 topo-bathymetric surveys.
pss	**Shoreface 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:

simbolo	definizione
ru	urbanized backshore
sb	presence of bathing establishments
cd	presenza duna

Management

Gestione

Vincoli

no

Cella idonea al prelievo sedimenti

si

Cella idonea alla ricarica

no

Cella con necessità di intervento

no

Constraints

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

Cell potentially 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.

Sedimentology

DM SF

The sedimentological data reported in this new field is related to the average diameter (Folk and Ward, 1957) expressed according to the nomenclature provided by the (modified) Udden and Wentworth grain size reported here below.
A mean diameter was assigned for each cell by referring to the map drawn up for the regional coastal sedimentological campaign conducted in 2012.

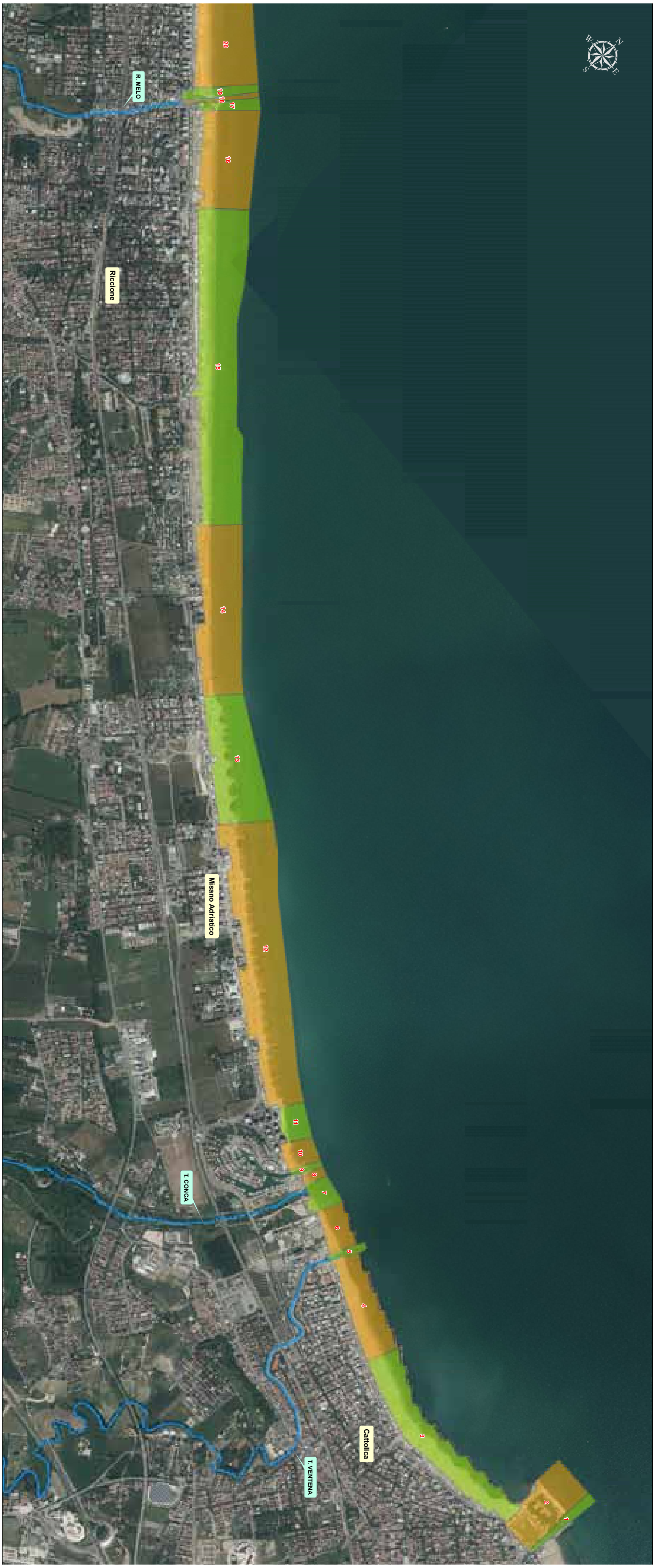
phi	micron	Udden and Wentworth	Sigle
		Gravel	G
-1	2000		
		Very coarse sand	SMG
0	1000		
		Coarse sand	SG
1	500		
		Medium-sized sand	SM
2	250		
		Fine sand	SF
3	125		
		Very fine sand	SMF
4	63		
		Silt	SILT
9	2		
		Clay	A

THE 118 CELLS SHEET

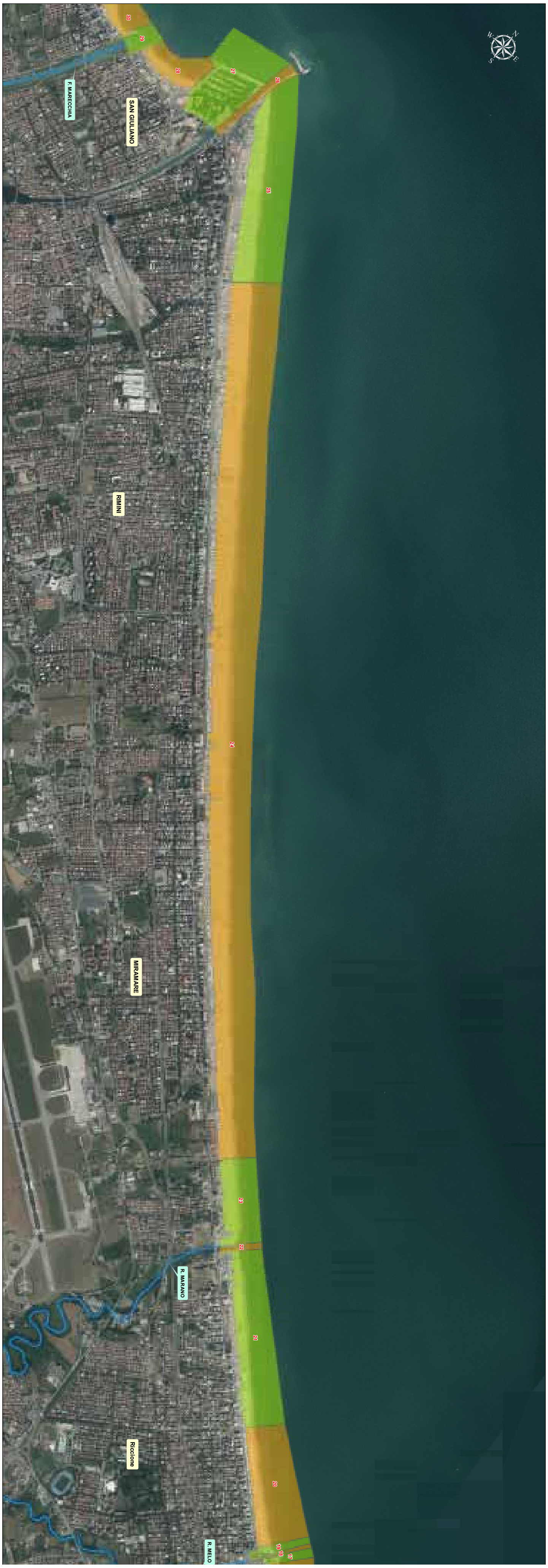
MAPS

MAP 1

RN1


R. MELO
Riccione
Misano Adriatico
T. CONCA
Cattolica
T. VENTENA

MAP 2
RN2


F. MARECCHIA
SAN GIULIANO
RIMINI
MIRAMARE
R. MARANO
Riccione
R. MELO

MAP 3
RN3


F. USO
BELLARIA IGEA MARINA
TORRE PEDRERA
SC. BRANCONA
VISERBELLA
VISERBA
RIMINI
RIVABELLA
F. MARECCHIA
SAN GIULIANO

MAP 4

RN4


PORTO CANALE DI CESENATICO
CESENATICO
VALVERDE
VILLAMARINA
GATTEO
F. RUBICONE
SAVIGNANO SUL RUBICONE
SAN MAURO PASCOLI
BELLARIA IGEA MARINA
F. USO

MAP 5
FC-RA

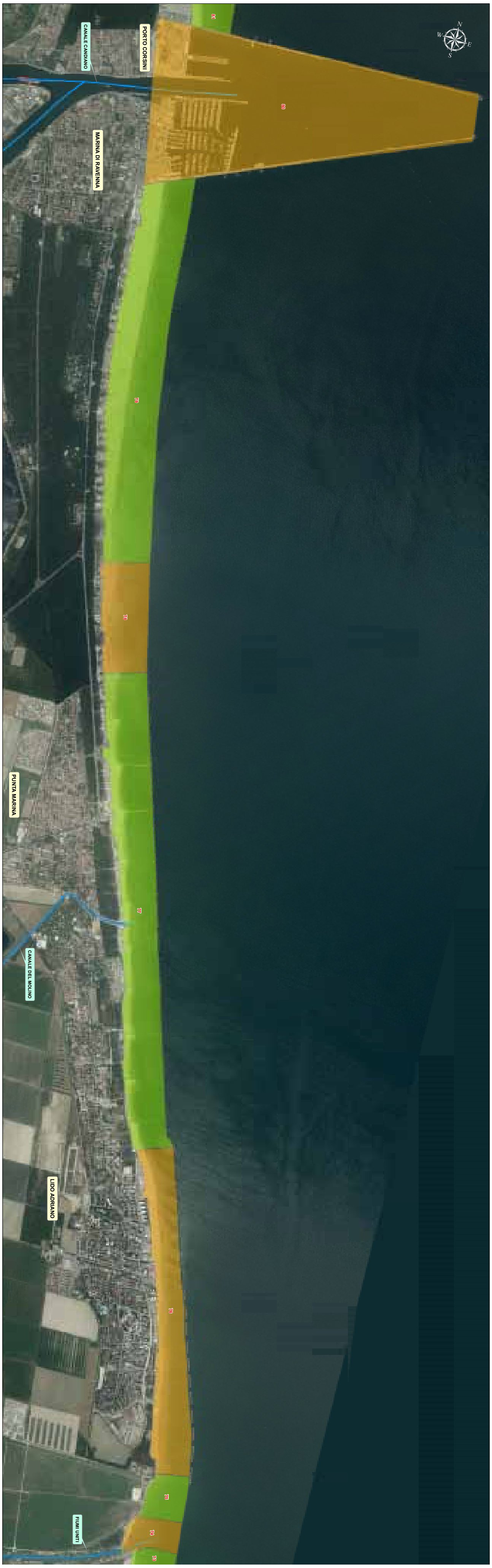

F. SAVIO
LIDO DI SAVIO
MILANO MARITTIMA
SCARICO MADONNA DEL PINO
PORTO CANALE DI CERVIA
CERVIA
PINARELLA
TAGLIATA
SCOLMATORE TAGLIATA
ZADINA
CESENATICO
PORTO CANALE DI CESENATICO

MAP 6

RA1


FIUMI UNITI
LIDO DI DANTE
T. BEVANO
LIDO DI CLASSE
F. SAVIO
LIDO DI SAVIO

MAP 7
RA2



CANALE CANDIANO
PORTO CORSINI
MARINA DI RAVENNA
PUNTA MARINA
CANALE DEL MOLINO
LIDO ADRIANO
FIUMI UNITI

MAP 8
RA3

FOCE F. RENO
F. RENO
Poligono Militare di Foce Reno
CASAL BORSETTI
CANALE DESTRA RENO
F. LAMONE
MARINA ROMEA
PORTO CORSINI
CANALE CANDIANO
MARINA DI RAVENNA

MAP 9
RA-FE

CANALE BURANA NAVIGABILE
LIDO DEGLI ESTENSI
CANALE LONGONOVO
LIDO DI SPINA
CANALE BELLOCCHIO O GOBBINO
FOCE F. RENO
F. RENO

MAP 10
FE1


LIDO DELLE NAZIONI
LIDO DI POMPOSA
LIDO DEGLI SCACCHI
PORTO GARIBALDI
CANALE BURANA NAVIGABILE
102

MAP 11

FE2

F. PO
FOCE PO DI GORO
FARO DI GORO
SCANNO DI GORO
SCANNO DI VOLANO
PO DI VOLANO
LIDO DI VOLANO

BIBLIOGRAPHY

AA.VV. (2012) Formulation of territorial action plans for coastal protection and management . Final report phase C Component 4. Montanari R. e Marasmi C. (a cura di). Territorial action plans for coastal protection and management. Eu progect Coastance.

Aguzzi M., De Nigris N., Preti M., e Mallegni R. (2012) – Nuovi indicatori per lo studio e la gestione della costa emiliano-romagnola. Studi Costieri, 20, pp. 95-109.

Armaroli, C., Ciavola, P., Perini, L., Calabrese, L., Lorito, S., Valentini, A., & Masina, M., 2012. Critical storm thresholds for significant morphological changes and damage along the Emilia-Romagna coastline, Italy. Geomorphology 143-144, 34-51. doi:10.1016/j.geomorph.2011.09.006

Arpa (2008) – Stato del litorale emiliano-romagnolo all'anno 2007 e piano decennale di gestione. I Quaderni di ARPA.

Arpa (2011) – Erosione Costiera. Annuario regionale dei dati ambientali Edizione 2010.

Arpa (2013)-5a Campagna di rilievo della rete topo-batimetrica e analisi dell'evoluzione recente del litorale emiliano-romagnolo. 2a Campagna sedimentologica del litorale emiliano-romagnolo. Relazione finale. – Bologna, Dicembre 2013

Perini, L., Calabrese, L., Deserti, L. M., Valentini, A., Ciavola, P., & Armaroli, C., 2011. Le Mareggiate E Gli Impatti Sulla Costa in Emilia-Romagna, 1946–2010. Bologna: I Quaderni di ARPA – Regione Emilia Romagna.

Montanari R., Marasmi C. (2011) Nuovi Strumenti per la gestione dei litorali in Emilia-Romagna SICELL sistema gestionale delle celle litoranee.

prima edizione
dicembre 2014
Centro Stampa della
Regione Emilia-Romagna

a publication edit by
Servizio Difesa del Suolo
della Costa e Bonifica
viale della Fiera 8
40127 Bologna
Tel. 051 5276811
Fax: 051 5276941
E-mail: difsuolo@regione.emilia-romagna.it