Journal of Coastal Conservation 10: 43-52, 2004

Erosion risk levels at the NW Portuguese coast: The Douro mouth - Cape Mondego stretch

Veloso-Gomes, F.[1*]; Taveira-Pinto, F.[1,2]; das Neves, Luciana[1,3]; Pais Barbosa, Joaquim[1,4] & Coelho, Carlos[5]

[1]*Faculty of Engineering, University of Porto, Rua do Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal;*
[2]*E-mail fpinto@fe.up.pt;* [3]*E-mail lpneves@fe.up.pt;* [4]*E-mail jlpb@fe.up.pt;*
[5]*University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal; E-mail ccoelho@civil.ua.pt;*
[*]*Corresponding author; vgomes@fe.up.pt*

Abstract. The entire northwestern coast of Portugal is undergoing severe erosion and there are several areas at high risk of erosion. Commonly considered as a problem – because it jeopardizes human development along the coast – erosion is indeed a natural process of sediment redistribution. This paper presents a brief analysis of erosion driving forces and the subsequent state of vulnerability that coastal segments between the mouth of the River Douro and Cape Mondego are facing. The paper also discusses erosion risk levels, low or high, and the subsequent questions whether there are populations, economical assets or natural habitats at risk and/or areas prone to coastal flooding. Main challenges and future trends along the study area are identified in the light of understanding the underlying causes of conflicts and what realistically can be achieved given the morphodynamics and hydrodynamic processes, human development established along this coastal segment and the existing policies.

Keywords: Erosion, Hydrodynamics; Littoral drift; Morphodynamics; Risk analysis; Shoreline development.

Abbreviations: ICZM = Integrated Coastal Zone Management; POOC = Plano de Ordenamento da Orla Costeira (Coastal Zone Management Plan).

General characterization

The coastal area described in this paper is located on the Portuguese Northwest coast, facing the North Atlantic Ocean. This area is limited to the North by the mouth of the Douro and to the South by Cape Mondego (Fig. 1). It has a linear extension of ca. 110 km and a general orientation NNE-SSE.

Coastal scenery includes two important environmental features: the lagoon of Aveiro, classified as a special protection zone by the *Birds and Habitats* Directive, and a small residual lagoon, the Barrinha de Esmoriz. The dune system of São Jacinto situated in this area is a Natural Reserve as classified by Portuguese Law.

From a geomorphologic point of view, this segment is mostly a sandy and low lying coast composed of alluvium sands and dune systems.

Coastal morphodynamics is mainly shaped through wave action. Waves are indeed the dominant force, driving the littoral processes on this coast. Although the wave climate changes seasonally, it can be characterized by medium significant wave heights from 2 to 3 m, with periods ranging from 8 to 12 seconds (Anon. 1993, 2003).

Seasonal storms, particularly between October and March can produce significant storm surges when they coincide with astronomical tides. Waves can reach heights of more than 8 m, with periods reaching 16 to 18 seconds (Anon. 1993, 2003). The tide amplitude from low to high water can range between 2 and 4 m at spring tides, twice a day due to the semidiurnal characteristics of the tide. Furthermore, local wave phenomena, especially refraction, diffraction, shoaling and also the bathymetry can influence tremendously local wave conditions. More detailed information on the characteristics of the wave regime in the area in analysis can be found in Pires Silva (1988) where also additional references can be found.

Meteorological tides have little influence on water levels outside semi-enclosed, protected water bodies,

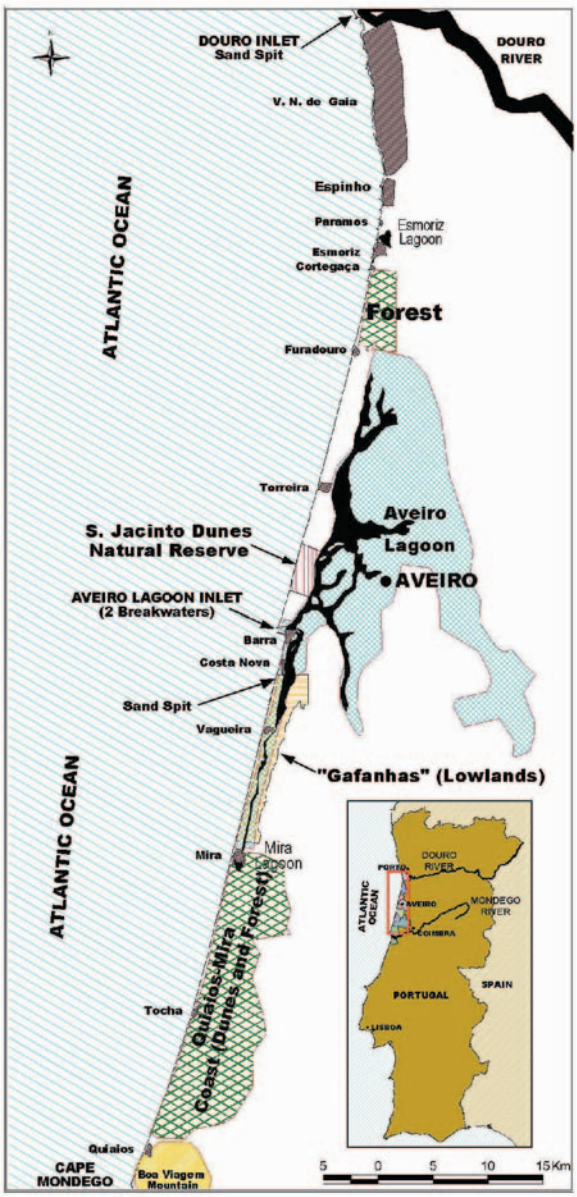

Fig. 1. Study area between the mouth of the River Douro and Cape Mondego.

but they can increase the risk of flooding when simultaneously occurring with astronomical spring tides or severe storms. In the same way, tidal currents are only important in the areas surrounding the river mouth of the Douro and the Ria de Aveiro.

Another important process is the littoral drift currents. Along the northwestern Portuguese coast, these currents have a dominant North-South direction, except local deviations due to specific hydrodynamic processes (e.g. near river mouths).

The dominant direction of the littoral drift can be directly shown by the sediment accretion to the North updrift of obstacles (e.g. groynes) and by the erosion to

Fig. 2. Groyne effect; updrift accretion on Vagueira beach (source: CCDR-Centro; Anon. 2001).

the southern downdrift (Fig. 2). Indirectly, this can also be demonstrated through the analysis of the wave direction frequencies reaching the Portuguese West coast, which exhibits the higher frequencies and intensities in the north/west quadrant.

The wind climate also affects coastal morphodynamics. Beyond its indirect influence on waves and currents – local wind climate generates currents and small waves with intensities and directions that can be related to the velocity, persistence and direction of the wind which caused them – it has also a direct effect on the formation of dunes. Sea currents end up having negligible importance when compared to the other actions involved.

Another characteristic of this coastal area is its high vulnerability to erosion. Indeed, a major part of the shore is undergoing significant erosion, which jeopardizes human development. Driving forces, present conditions and future trends will be analysed within their principle aspects.

A more in-depth review of what is happening in the coastal segment from the mouth of the Douro to Cape Mondego can be found in Anon. (2003) – a report developed within the framework of the European project EUrosion – and also in the large amount of papers published about the area in analysis, such as Mota Oliveira et al. (1982), Ângelo (1991), Ferreira (1993), Veloso Gomes & Taveira Pinto (1994), Mota Oliveira (1997), Vidinha et al. (1997), *i.a.* including also associated references.

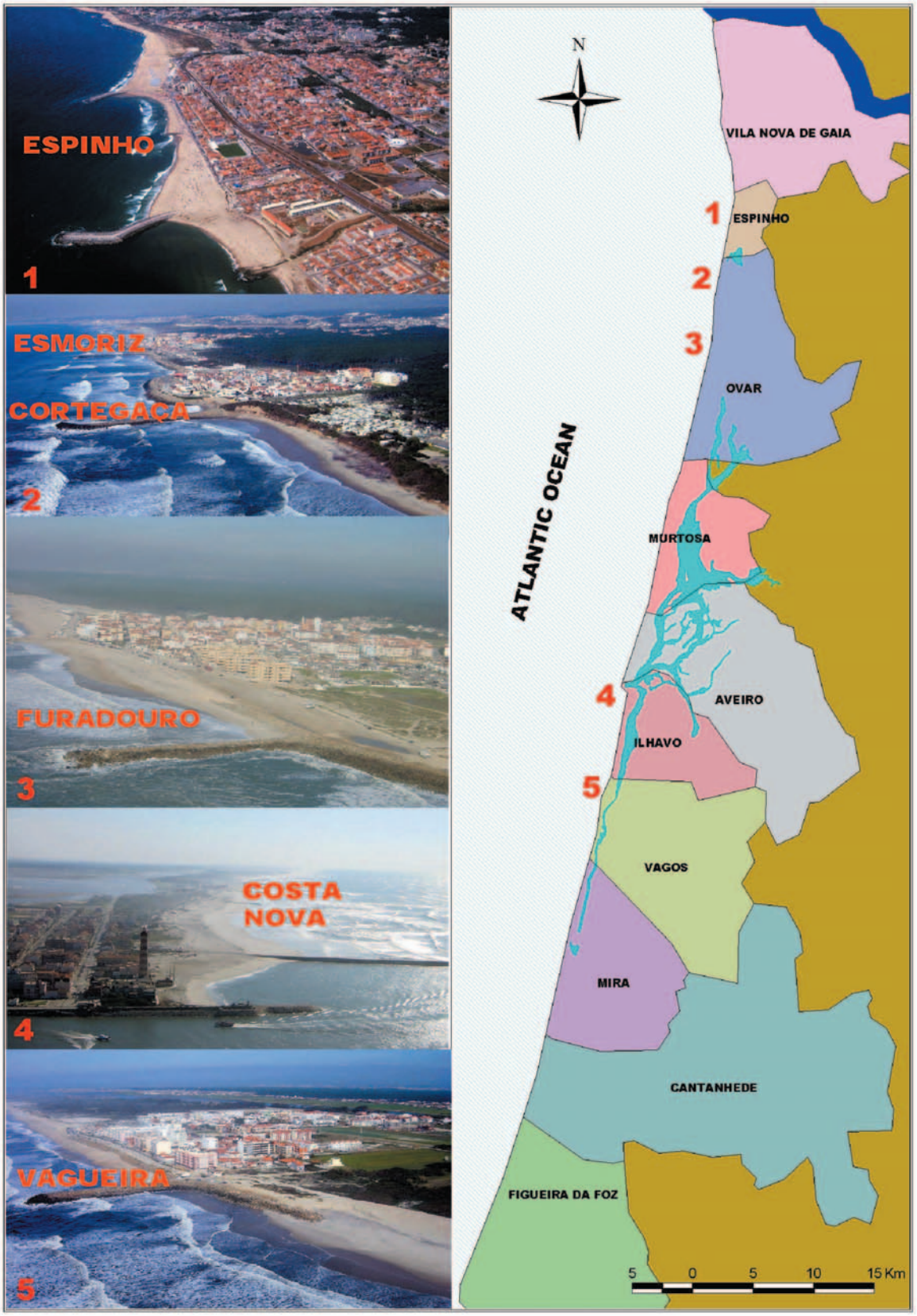

Fig. 3. Examples of coastal segments facing coastal hazards.

Shoreline development: Conditions and driving forces

Introduction

Through various physical processes the shoreline has been eroded and shaped and the landscape modified. Most shoreline changes are natural responses to these processes, either at a time scale of days (e.g. between tides) or of years (e.g. global climate change). These natural dynamics are in some cases incompatible with the increase of human development along the coast.

For many different reasons several areas along the coastal segment under investigation are doomed to undergo severe erosion. Indeed, even with coastal defences, many shore stretches have not yet reached equilibrium with the present littoral processes; thus both populations and economical assets are at risk. The driving forces need to be reviewed, not only to describe what was done in the past but also to understand the critical factors, which are behind the present state of vulnerability, and to try to find solutions to mitigate coastal erosion processes in specific locations.

Several coastal populations are facing high risk situations, for instance at Cortegaça, Vagueira and Espinho (Fig. 3). Indeed, despite the existence of coastal defences the situation continues to be critical. Lessons learnt from the past show that most of the measures taken so far to prevent erosion provide only local solutions which do not address the underlying cause of erosion, i.e. shortage of sediment supply. In fact, in some cases, erosion is accelerated downdrift of the protected areas.

Over the last decades, investment priorities concerned engineering interventions while the importance of developing preventive measures and policies were neglected. Although essential, these interventions have created a misperception of the problem: through the blind reliance on technical structures one forgets that without sediment supply nor natural rock protection, it is just a question of time before erosion starts.

The main driving forces along the northwestern coast of Portugal are related to damming, coastal defences, harbouring and related dredging activities. Other phenomena, such as climate change, including accelerated

Fig. 4. Coastal structures between Espinho and Paramos (Pais Barbosa 2003).

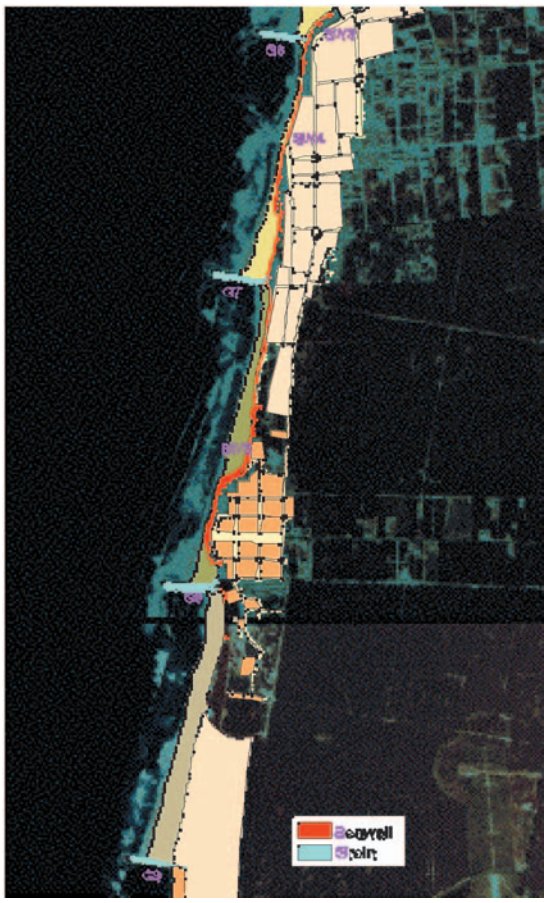

Fig. 5. Coastal structures between Esmoriz and Cortegaça (Pais Barbosa 2003).

sea-level rise and an increased frequency of storm surge occurrence, can have influence in specific cases.

Human development along the coast tends to aggravate the consequences of shortage of sediment supply. The impact of coastal erosion processes is dependent on the activities of the local population, economical assets or natural habitats at risk, and/or areas prone to coastal flooding.

Present conditions

Coastal zone management

Up to the late 1980s, coastal zone management in Portugal was mostly restricted to 'hard' coastal engineering. For decades many groynes and seawalls were built wherever human development was being threatened by coastal erosion. There are currently 20 groynes, one detached breakwater and some seawalls in the study area. Additionally, there are the two breakwaters protecting the harbour of Aveiro

The spatial distribution of these works is as follows, by segments:

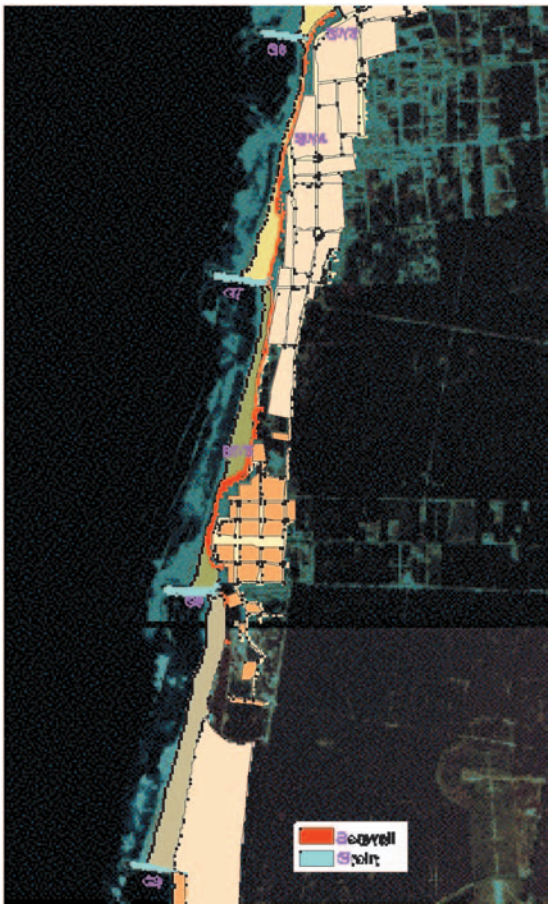

Fig. 6. Coastal structures at Furadouro (Pais Barbosa 2003).

Douro River – Espinho (ca. 14 km length)
- detached breakwater of Aguda (2002)

Espinho – Paramos, ca. 5 km length (Fig. 4)
- Groin 1 – Espinho (1918 / 1981/1983; 350 m)
- Groin 2 – Espinho (1981/1983; 400 m)
- Seawall (400 m)
- Groin 3 – Espinho (1981/1983; 300 m)
- Groin 4 – Paramos (1981/1983; 280 m)
- Seawall (100 m)
- Groin 5 – Paramos (1985; 280 m)

Esmoriz – Furadouro (~11 km length, Figs. 5 and 6)
- Seawall (1978; 140 m)
- Groin 1 – Esmoriz North (1987; 160 m)
- Seawall (before 1977 / 1985; 850 m)
- Groin 2 – Esmoriz South (1987; 180 m)
- Seawall (1990; 1000 m)
- Groin 3 – Cortegaça (before 1972 / 1982; 170 m)
- Groin 4 – Maceda (1989; 150 m)
- Groin 5 – Furadouro North (1986; 100 m)
- Seawall (before1959 / 1970/ 1984; 300 m)
- Groin 6 – Furadouro South (1981; 1997)
- Seawall (1982; 300 m)

Barra – Costa Nova – Vagueira, (~10 km length, Figs. 7 and 8)
- Groin 1 – Barra (1972; 120 m)
- Groin 2 – Costa Nova (1972; 120 m)
- Groin 3 – Costa Nova (1972; 120 m)
- Seawall (before 1981; 750 m)
- Groin 4 – Costa Nova (1972; 120 m)
- Seawall (before 1981; 300 m)
- Groin 5 – Costa Nova (1979; 100 m)
- Groin 6 – Vagueira (before 1984; 130 m)
- Seawall (before 1984; 800 m)
- Groin 7 – Vagueira

An overview of the characteristics of these works can be found, *i.a.*, in Anon. (2003), Pais Barbosa (2003) and Veloso Gomes & Taveira Pinto (1999).

In the last few decades, the option in many of the municipalities along the coast between the mouth of the Douro and Cape Mondego was to consolidate and further increase population density. Relevant physical processes and man-induced effects have been neglected in this process and there was no concern for protecting the natural buffer zones existing in the hinterland areas, notably dune systems.

Social perception of erosion does not go much farther than the experience of recent storms. As a consequence people do not consider implementing simple preventive measures, such as not building too close to vulnerable areas. In many areas the coastline has developed in a haphazard way, causing major social and environmental problems. Therefore, it is crucial to get everyone involved in coastal issues. Without the full participation of all coastal actors sustainable coastal development achievements will never succeed. Good coastal zone planning and management require combining different policies that include co-ordinated approaches at the local, regional and national levels, by the government, local people, non-governmental organizations and socio-economic actors.

The recent approval of the Portuguese Coastal Zone Management Plans – POOC (eight out of nine have already been approved and published for continental Portugal) can lead to important changes in the management of the Portuguese coastline.

Other policies and instruments such as the Water Framework Directive, the EU recommendations on ICZM and the EU sustainable tourism policy, as well as the Portuguese River Basin Plans, will also contribute to sustainable coastal development. This is an ongoing dynamic process, which is still in its infancy. In the future, it should help correct the indirect and cumulative causes and effects of the past, towards sustainable development of coastal zones.

Coastal segment analysis

The study area can be divided into ten segments, with both similarities and differences. The similarities are intimately linked with coastal erosion and the differences with its on shore consequences. Some patterns will be identified.

From updrift to downdrift, the first segment of ca. 25 km corresponds to the coast between the mouth of the Douro and the city of Espinho. The Douro constitutes the main source of sediments for the area. However in the last few decades the amount of sediment discharged has decreased drastically due to damming and intensive dredging. This decrease causes erosion which affects practically the whole area between the mouths of the rivers Douro and Mondego. The quantitative importance of the process of erosion depends, as it will be seen, on the threats caused to human development.

Up to the city of Espinho erosion is not serious due to the existence of natural rock protections, as well as submerged sand deposits (Mota Oliveira & Martins 1991). Erosion problems are more worrying just south of Espinho, even though some consequences of erosion are becoming visible at Granja beach, immediately north of Espinho.

The first reports of erosion in Espinho go back to the year of 1869 and since the construction of the first coastal defence in 1909, which was destroyed two years later, the

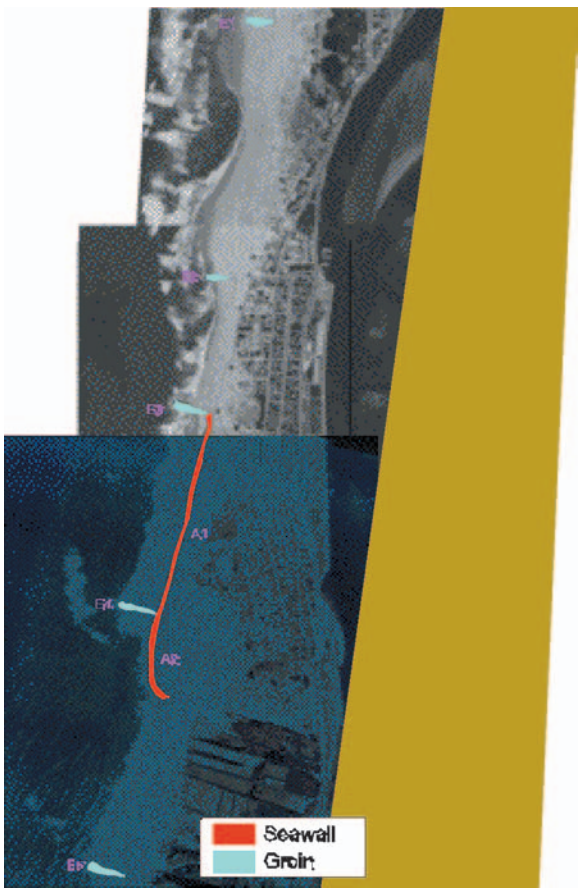

Fig. 7. Coastal structures between Barra and Costa Nova (Pais Barbosa 2003).

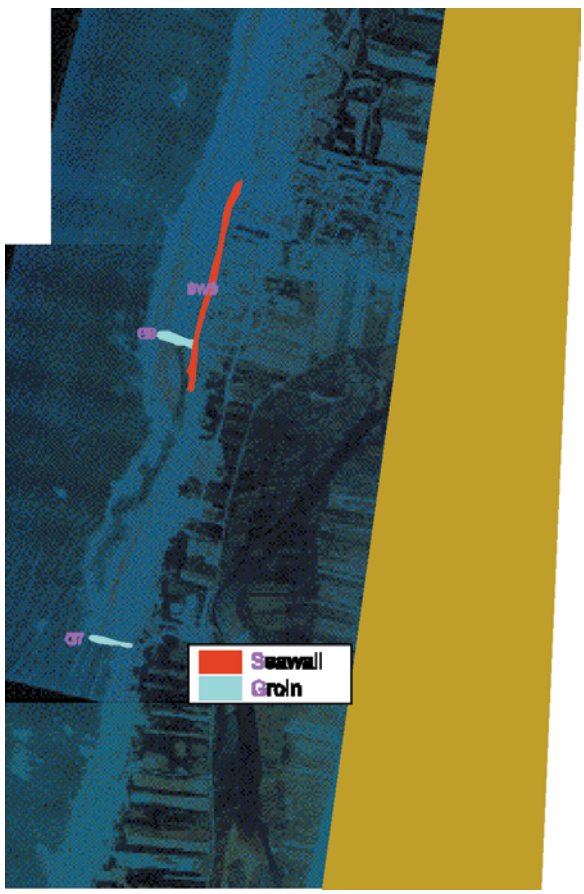

Fig. 8. Coastal structures between Costa Nova and Vagueira (Pais Barbosa 2003).

shoreline has retreated and progressed several m. Today, the urban seafront of Espinho, ca. 3 km long, is protected by two large groynes, one in the North and one in the South and a seawall (Fig. 3 - photo 1) and its situation is considered stable, thanks to the current defences.

The major problems at segment 2, which extends until Esmoriz, start downdrift the southern groyne of Espinho and are especially visible in Paramos, a small fisher village. The erosion problems there are so acute that it is the only case along the northwestern Portuguese coast where a Coastal Management Plan – that for Caminha-Espinho – predicts the re-settlement of the coastal population to the hinterland.

The most critical case of erosion is found further downdrift, between the beaches of Esmoriz and Cortegaça (segment 3) and the one of highest concern considering the assets at risk. During the last three decades these two cities have evolved from small fisher villages, to important residential centres, with both secondary and main homes. These two cities are now practically linked into one continuous seafront of ca. 3 km and suffer the same erosion problems.

The shoreline between Esmoriz and Cortegaça has retreated as far as the established urban seafront line of defence and further retreat will implicate loss of the houses built behind those defences. Currently, the two cities appear as small capes protruding from the natural coastline, with the houses on their top being almost directly exposed to sea attack (Fig. 3 – photo 2).

Because of the absence of natural rock protection or buffer zones, in combination with a practically zero sediment budget in the updrift boundary, it will be almost impossible to hold this line of defence for much longer. Moreover, erosion due to wave reflection on the adherent defences further disables the sustainability of this situation due to the increasing instability of the frontal beach, which even tends to disappear. This will result in a steeper sea-bed profile, which subsequently allows larger waves to reach the structure.

The two downdrift segments, Cortegaça/Furadouro (segment 4) and Furadouro/Torreira (segment 5) basically suffer from the same erosion problems, but here there are no economic assets in danger – maybe except the seafront Furadouro, but this is still rather well protected. Shoreline recession in this segment only implies the loss of forest land. However, the shoreline will retreat more and more in the following years.

Segment 6, Torreira/northern breakwater of Aveiro, is limited to the north by the Torreira groyne and to the south by the northern breakwater of Aveiro. It enjoys the input of sediments eroded from updrift and also from the retaining effect of the northern breakwater of Aveiro. This segment is unlikely to expect significant erosion in the near future. The Nature Reserve of São Jacinto is located within this segment.

Segment 7, Barra/Vagueira, ca. 9 km long, extends from the southern breakwater of Aveiro harbour to the northern groyne of Vagueira (Fig. 3 – photo 4). It is strongly influenced by the measures taken in the harbour, especially dredging. Additionally, in contrast to the previous segment, it suffers from sediment trapping at the updrift side of the breakwaters of Aveiro. This segment has one of the highest erosion rates in the study area. Indeed, in the period between 1947 and 1978 an estimated 200 to 300 m of shore was eroded away (Anon. 1998). This high rate of erosion led to the construction of the first groyne field in 1972. Until 1996, erosion progressed over more than 100 m away from the influence zone of the groyne (Anon. 2003). Currently, groynes, seawalls and artificial dunes protect the shoreline, but erosion is still ongoing.

As a consequence of beach erosion, the dune system of Costa Nova/Vagueira, which acts as a buffer zone between lowlands and the sea, is becoming more and more exposed to direct wave attack. The potential consequence of this ongoing erosion is the breaching of new inlets in the Ria de Aveiro and the subsequent flooding of those agricultural lands with coastal waters, meaning the loss or salinization of rich arable lands and several houses. This has not yet occurred due to emergency works which have been carried out frequently over the past few years. There is neither technical nor economical sustainability to continue these emergency works much longer, which has led local and central authorities to launch the study of a more effective solution.

The next segment, no. 8, encompasses the Vagueira/Mira beach. As in the former segment, erosion here has created a new type of conflict, as the retreat of the shoreline jeopardizes the low lying agricultural coastal plains. These plains are protected by a dune system of circa 30 km, which is currently very vulnerable and in need of major intervention.

The two remaining segments correspond to Mira beach/Tocha beach – no. 9 – and Tocha beach/Cape Mondego – no. 10, respectively. The former is apparently in an equilibrium situation, with slight differences in the beach profile and shoreline position. Coastal erosion in this segment does not constitute a threat to urban development, since there is no human settlement along this stretch of coast.

The segment from Tocha beach to cape Mondego does not face any problems of erosion at the moment, since it benefits from updrift sediments trapped near Cape Mondego which act as a natural groin. The equilibrium settled is not expected to be disturbed on a medium to long term (decades).

Future trends and challenges

Coastal erosion processes in the study area have a varied significance as to their threat to human development along the coast. Higher levels of risk are associated with the zones of highest settlement levels, where we also find coastal defences. Erosion risk levels in the NW coastal segment between the mouth of the Douro and Cape Mondego are associated with human development, and with the existence of coastal defence structures.

Driving forces in coastal erosion are obviously also very important in the qualification of risk levels. If we lack a reasonable expectation of the increase in the volume of sediments transported by the littoral drift currents, which is the main direct cause of erosion in this area, the main challenges will be subject to territorial planning and management. This does not only helps to cope with current problems, but also lays a foundation for dealing with future problems.

Coastal Zone Management Plans, River Basin Management Plans and the National Water Plan can play an important role. Hence, it is important to refer to the guidelines established in those plans, in particular those included in the Coastal Zone Management Plans (POOCs).

Since the majority of the study area is included in the POOC for Ovar-Marinha Grande, where the most acute problems occur, this analysis will be focused on it. The following comments for the coast downdrift Aveiro Harbour should be made:

1. The shoreline development trends for the next 10 to 30 years presented in 1998 in the POOC (Fig. 9), are possibly very optimistic, since the actual situation shows that the predicted development (according to several models) is about to be reached. Current trends are particularly concerned with inlet breaching (Fig. 9), establishing new connections between the sea and the lagoon. As mentionedabove , one of the most critical areas in this coastal segment is the dune system of South Costa Nova/South Vagueira. The existing threats were considered within the POOC, which proposed an intervention consisting of the construction of a retreated dune system, but there are still some important issues to be fulfilled.

2. The development considered in the POOC does not take into account the existence of critical zones in the dune system, which in the case of breaching would represent a significant aggravation of erosion and land loss by flooding of the low lying coastal plains situated landward.

3. The proposed alignment of the artificial retreated dune ridge (ca. 13 km), corresponds to an equilibrium

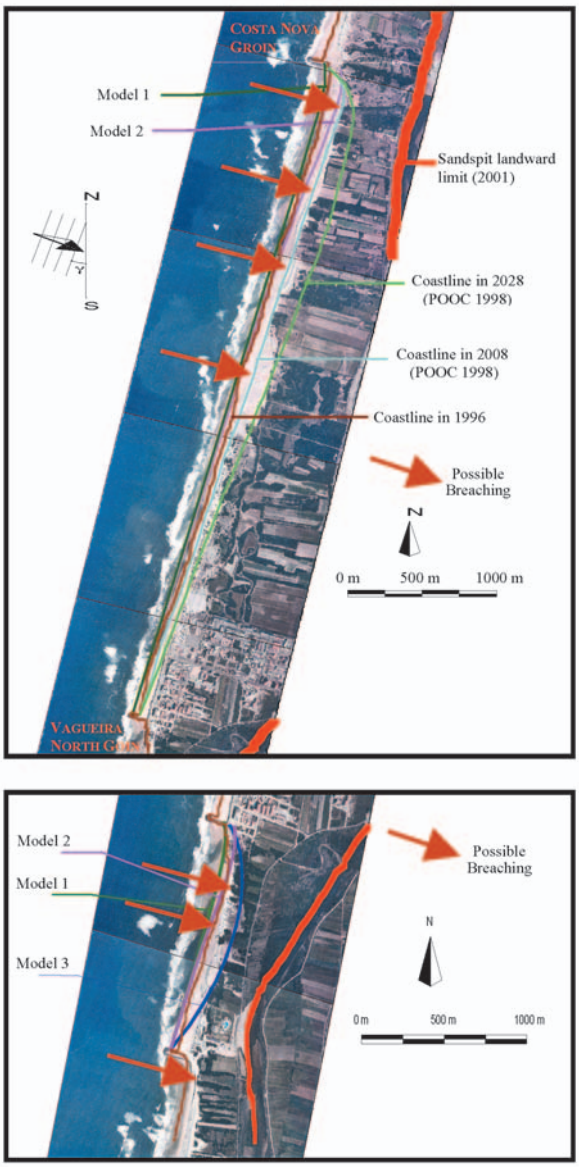

Fig. 9. Sand spit configuration and possible trends near Vagueira. Theoretical forecast of possible breaching of new inlets – Carlos Coelho (2001) in Pais Barbosa (2003), based on the aerial survey in Anon. (2001).

situation for a mean annual wave climate. However, for storm regimes or less frequent directions (e.g. higher waves coming from the southwest) it might not be stable.

4. The artificial reconstruction of the dune system, even for a more retreated position, must be able to face extreme storm situations and therefore should have a resistant core made of rip-rap or other structural components (e.g. sand filled containers made of geotextiles). However, while taking into account erosion levels, beach nourishment must be considered as well.

5. Such retreating artificial dune systems will be

implanted on private lands, some of them agricultural lands, which can rise important juridical questions which must be adequately tackled.

6. The volume of sand needed for the construction of such a retreating dune system is very big, maybe up to one million m^3, disabling the use of locally available sand sources.

7. Dredged sediments - namely from harbour maintenance or offshore - could be used in the former operation. The sediments must be analysed to check if they fit the needs, both quantitatively and qualitatively.

8. The initial profile of the retreated artificial dune system must take into account that it will be naturally modelled (e.g. by wind action).

9. Adequate techniques of re-vegetation must be implemented.

Another important issue concerns the use of sediments dredged from the harbour for the artificial sand nourishment of downdrift beaches, which mitigates the impacts related to harbour activities. It is necessary to collect data on planned dredging operations at the Aveiro Harbour Administration.

Sand bypassing interventions in Aveiro harbour, proposed since 1967, are considered as an interesting alternative despite the important technical constraints. These are clearly identified in the POOC but might not be done in the short term. However, it should be considered as a medium-term alternative.

As to the updrift coast of Aveiro, there are two different situations. On the one hand there are important urban seafronts where the shoreline has already retreated as far as possible and in which re-settlement of populations should be looked at in the medium to long term. On the other hand there are areas where coastal erosion does not imply any associated risks, since there are no human settlements along this stretch of coast.

The main challenges in the coastal segment in analysis can be summed-up in the following four points:

- managed re-alignment, i.e. identifying a new line of defence and re-settlement of the populations in the hinterland;
- cross-sectoral and integrated policies and guidelines linking the objectives and/or targets of the different stakeholders;
- adequate plans for monitoring the existing coastal defence structures, keeping maintenance costs of the structures at a low level;
- artificial sand bypassing and nourishment of dunes and beaches.

Conclusions

There are no absolute solutions to the problems of coastal erosion affecting the NW Portuguese coast from the mouth of the River Douro mouth to Cape Mondego, given the dynamics of the shoreline and the present conditions of human development. Nevertheless, it is not only possible but also essential to try to mitigate coastal erosion processes at specific locations.

To this end, we identified some of the current challenges that can guide and set the priorities for future interventions along the coast. The main ideas which emerged show that:

- management of the coast has lacked vision and was based on a very limited understanding of coastal processes and dynamics;
- social perception of the erosion problem is mostly based on the effects of recent storms;
- public involvement is mostly connected to economic interests;
- inappropriate and uncoordinated sectoral legislation and policy have often worked in prejudice of the sustainable management of coastal zones.

Consequently, important problems and conflicts have arisen that must be solved if sustainable development is to be achieved along the northwestern Portuguese coast between the mouth of the River Douro and Cape Mondego. Better technical and political approaches are required.

Priority should be given to measures that address the underlying cause of erosion, i.e. shortage of sediment supply through:

- artificial bypassing systems to return sediments trapped updrift in coastal defences and/or at the entrance of the navigation channels, to the littoral drift currents;
- identification of areas where natural coastal protection processes could be stimulated, e.g. dune rehabilitation or periodical artificial beach nourishment with non-contaminated materials collected by dredging;
- control of illegal sand extraction activities and any other human activity which may disturb the natural processes of beach and dune restoration;

In addition, so-called hard coastal defences are indispensable to protect existing settlements; no proposals exist to remove existent groynes, sea walls and other hard defences. It is expected that certain structures will need maintenance works and in some cases changes in their design will be needed.

Regarding the political point of view it is crucial to regulate urban seafront extensions in order to maintain protection costs at a low level. In some cases the policy options of managed re-alignment – i.e. identifying a new line of defence and re-settle the populations in the hinterland – has to be considered.

References

Anon. 1993. *Plano de aproveitamento da zona entre o molhe sul e a ponte-cais No. 3*, Vol. I. Estudos da Agitação Marítima no Porto de Leixões. IHRH Report.

Anon. 2003. *EUrosion Project – Guidelines for developing local information systems*, Vol. I. IHRH Report.

Ângelo, C. 1991. *Taxas de variação do litoral Oeste: uma avaliação temporal e espacial*. In: Conferências e Comunicações, seminário a zona costeira e os problemas ambientais, pp. 109-120. Associação Eurocoast-Portugal,

Ferreira, Ó. 1993. *Caracterização dos principais factores condicionantes do balanço sedimentar e da evolução da linha de costa entre Aveiro e o cabo Mondego*, M.Sc. Thesis. Universidade do Lisboa, Lisboa, PT.

Ferreira, Ó. 1998. *Morfodinâmica de praias expostas: aplicação ao sector costeiro Aveiro – Cabo Mondego*. Ph.D. Thesis Universidade do Algarve, PT.

Mota Oliveira, I. 1997. *Proteger ou não proteger ou sobre a viabilidade de diferentes opções face à erosão da costa oeste Portuguesa*. Colectânea de Ideias sobre a Zona Costeira de Portugal, pp. 205-227. Associação Eurocoast-Portugal.

Mota Oliveira, I. & Martins, L.M.P. 1991. Obras de defesa e de reconstrução das praias de Espinho. *Rev. Recursos Hídricos APRH* 12:71-88.

Mota Oliveira, I., Valle, A. & Miranda, F. 1982. Littoral problems in the Portuguese West Coast. *Coastal Engin*. 3: 1950-1969.

Pais Barbosa, J. 2003. *Aplicação de sistemas de informação geográfica na zona costeira*. M.Sc. Thesis Faculdade de Engenharia da Universidade do Porto, PT.

Pires Silva, A.A. 1988. *Caracterização espectral da agitação marítima na costa oeste Portuguesa*. M.Sc. Thesis Universidade do Técnica de Lisboa, PT.

Veloso Gomes, F. & Taveira Pinto, F. 1994. *Urban expansion in high risk NW Portuguese areas of Portugal*. In: Proceedings of the International Symposium Littoral 94, Vol. II, pp. 981-996. Associação Eurocoast-Portugal,

Veloso Gomes, F. & Taveira Pinto, F. 2003. Portuguese coastal zones and the new coastal management plans. *J. Coastal Conserv*. 9: 25-34

Veloso Gomes, F., Taveira Pinto, F., das Neves, L., Pais Barbosa, J. & Coelho, C. 2002. High Risk in the NW Portuguese Coast: Douro River. In: Veloso Gomes, F. Taveira Pinto, F. & das Neves, L. (eds.) *Cape Mondego, Changing the Coast, Vol. II*, pp. 411-421.

Vidinha, J.M., Andrade, C. & Teixeira, S.B. 1997. *Análise morfológica do cordão dunar entre Espinho e o Cabo Mondego*. In: Colectânea de Ideias sobre a Zona Costeira de Portugal, pp. 391-416. Associação Eurocoast-Portugal,

Received 14 July 2003;
Revision received 31 March 2004;
Accepted 16 June 2004.
Co-ordinating Editor: A.T. Williams.