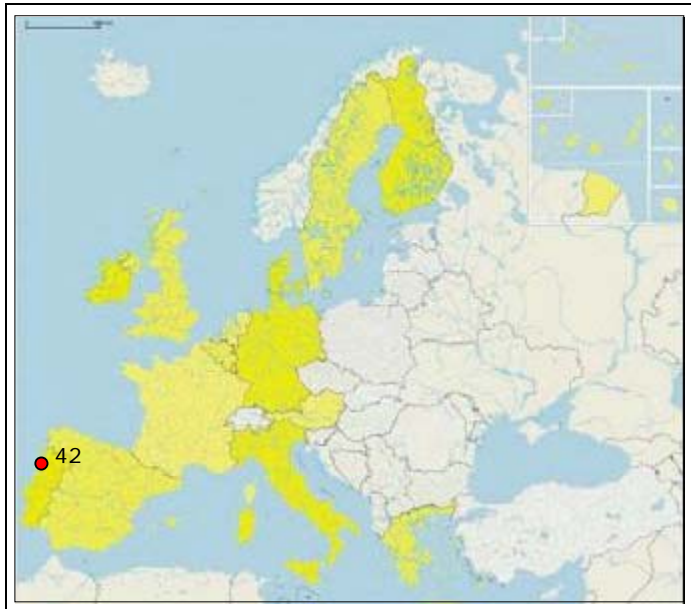


VAGUEIRA - MIRA (PORTUGAL)



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1. GENERAL DESCRIPTION OF THE AREA

The pilot study area is located on the Northwest coast of Portugal. The area is limited to the north by the Douro river inlet and to the south by Cape Mondego (see Figure 1).

1.1 Physical process level

1.1.1 Classification

- General: low sandy coast , beaches
- CORINE: beaches
- Coastal guide: coastal plain

The area has a linear extension of 110km. The stretch between Douro River mouth and Cape Mondego, excepting the first fifteen kilometres is basically consisted of extensive sandy beaches. It is interrupted by the inlet of Aveiro lagoon. In the first fifteen kilometres, instead, the coastal zone is highly exposed to the sea action, with rocky outbreaks in sandy beaches.

1.1.2 Geology

The sediment facies of the littoral zone are mainly composed of deposits from the Holocene and the Quaternary. The coastal area is occupied by sandy dunes that form, in the zone of Maceda and Cortegaça, small elevations. The sediment characteristics for the stretch between Douro inlet and Espinho consisted of medium and coarse sand mainly composed by quartz, feldspars and calcium fragments.

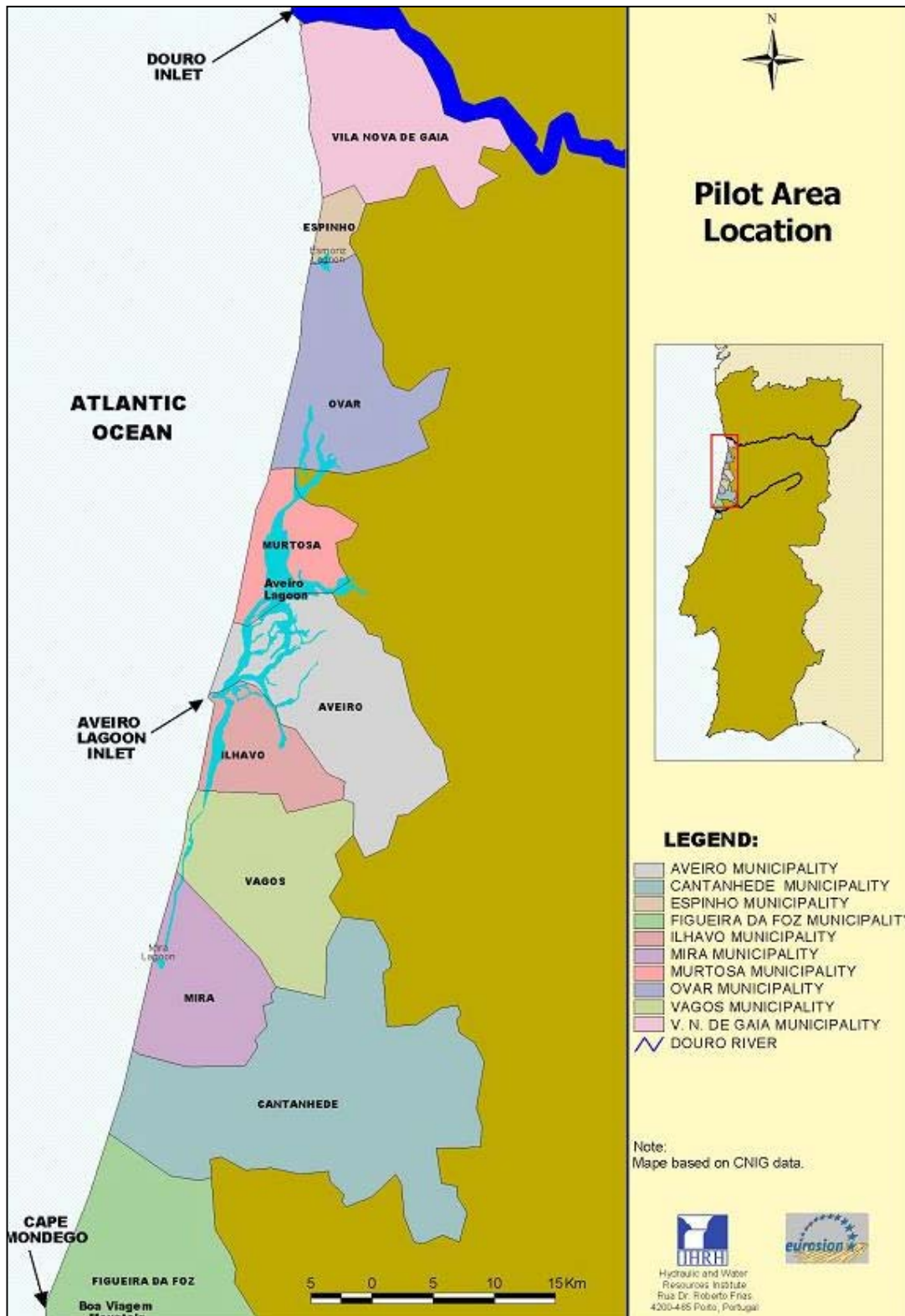


Fig 1: Location map of the Aveiro coast.

In the study area there is an estuary and a lagoon, connected with two important rivers (Douro river and Vouga river), of great importance to the equilibrium of this area. The coast presents two distinct orientations - NNW-SSE from the mouth of Douro River to Espinho and NNE-SSW from Espinho to Cape Mondego.

It is only a low sandy coast, practically linear, with exception of the fifteen first kilometres, where there are some rocky outbreaks with reduced elevation. The most important elevation is located in the middle zone. In Maceda and Cortegaça area, there are small elevations that have been formed secondly. The most important relief is Boa Viagem Mountain, located in the south of the study area and it is 257m high. Besides this elevation, all the area can be considered belonging to the coastal plain with a uniform elevation topography.

Relatively to the sea bathymetry, it is very smooth, with bathymetric lines almost parallel to the cost line and with a very small slope (Figure 2).

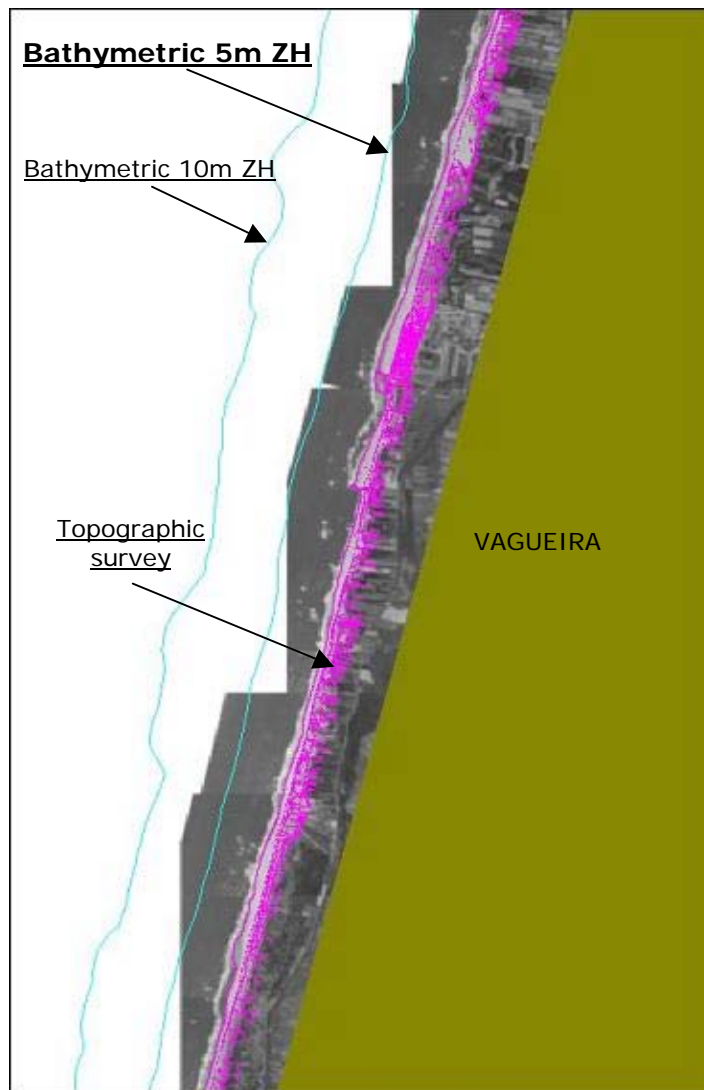


Fig. 2: Example of bathymetry in Vagueira coast (based in risk maps-1999).



1.1.4 Physical processes

Wind

The local wind climate generates currents and small waves with intensities and directions, which can be related to the velocity, persistence and direction of the wind that has originated them. Wind from SW and W occur with a maximum frequency in March, and in winter to summer. The main storms reaching the North-western coast of Portugal come from the North Atlantic, particularly between October and March.

Waves

The wave regime is the most energetic in this area, and its main modelling agent. The wave climate has medium significant heights from 2 to 3m, with periods ranging from 8 to 12s. The local wave conditions are different from the offshore ones due to the effects of bathymetry and local phenomena such as refraction, diffraction and shoaling.

Currents

The littoral drift currents act mainly in the North-South direction although some singular events of South east currents can be found. Another exception occur downdrift tidal inlets and river mouths, where a reverse on the dominant direction of the littoral drift can happen as a consequence of specific hydrodynamic processes. Littoral drift currents have a great importance in the littoral sediment transport process in the study area. Currents with a parallel component to the coast can reach significant intensities between the breaking zone and the beach.

Tides

Tides are of the semidiurnal type, reaching a range of 2 to 4m for spring tides. The average range of spring tides varies between 1.27m in Aveiro Harbour and 3.7m in Figueira da Foz. Meteorological tides are not significant outside enclosed waterbodies. Nowadays Douro river only contributes with a small amount of sediments, because of the dam's construction that reduced the erosion power of the river bed and margins, the flow velocity and consequently, the amount of transported sediments.

1.1.5 Erosion

Erosion type

As a consequence of the littoral drift currents, accretion occurs in the north (updrift) areas of obstacles (e.g. groins), and erosion in the south (downdrift). Before the beginning of dam's construction in 1930, the total littoral sediment transport was near an amount of 2×10^6 m³/yr, with the Douro river guaranteeing itself 90% of this value. Nowadays Douro river only contributes with 250,000m³/yr.

Erosion cause

Erosion problems are mainly due to human activities and settlement, damming and harbour works, and tends to aggravate further and further in the future with the need for new

defence systems of new sea waterfronts and the consequent unbalances in the physical dynamics that cause constraints and increase in the vulnerability of some areas. Besides this, there is an important amount of sand extraction for construction, dredging river bed in several places and in quantities beyond the sustainable.

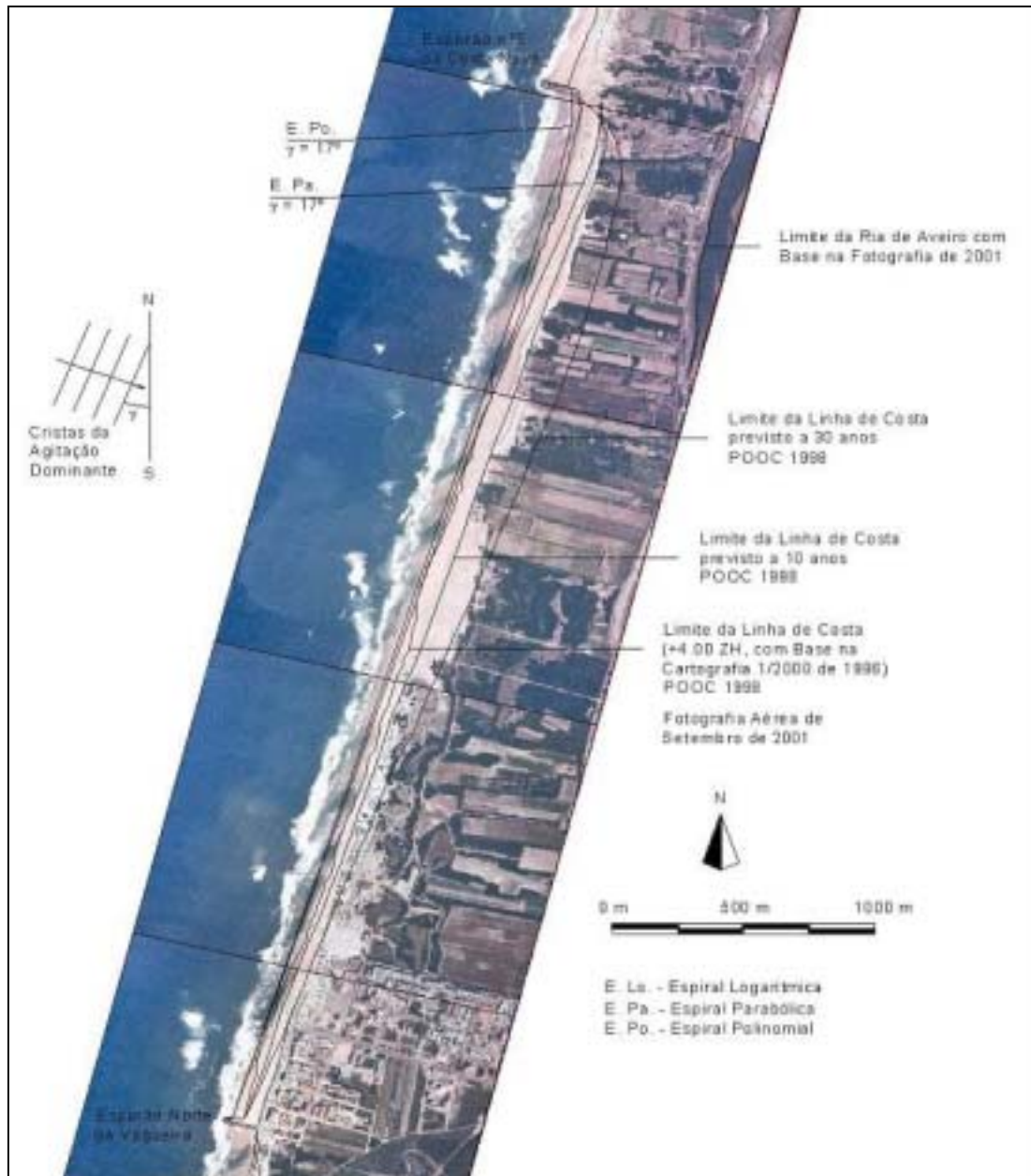


Fig. 3: Sand spit near Vagueira. Theoretical forecast for the coastal line possible new inlets (aerial survey 2001).

In the study area, it is not feasible to estimate the expected erosion, because of the unexpected character of the meteorological conditions are and due to the combination with some hydrodynamic phenomena. Some interventions against the sea actions made by the man, to protect urban areas could increase the erosion near the intervention but could

increase the erosion process in the other side of the intervention or even faraway. Trends in coastal erosion are given in Table 1.

Table 1: Shoreline trend evolution of Aveiro coast (“Plano de Ordenamento da Orla Costeira”).

Stretch	Classification in terms of erosion problems ¹	Future Evolution
Douro - Espinho	Not Vulnerable	The area downdrift the Douro inlet is stable, as it is naturally protected by rocks.
Espinho – Esmoriz	Very Vulnerable	Groyne field. The shoreline tends to be eroded on the downdrift areas of the existent groynes and to stabilize on the updrift ones. The urban seafronts are under important risk exposure.
Esmoriz Cortegaça –	Very vulnerable	Groyne field. The existent beaches are becoming more and more narrowed. The urban seafronts are under important risk exposure.
Maceda Furadouro –	Vulnerable	It is expected that the shoreline will retreat furthermore. Urban seafront high exposed to erosion.
Furadouro Torreira –	Vulnerable	The shoreline will probably retreat in a near future.
Torreira – North breakwater of Aveiro	Not vulnerable	This stretch is stable as it benefits from the sediments provided by the erosion of the updrift beaches and the breakwater barrier effect.
Costa Nova Vagueira –	Very vulnerable	Groyne field. The shoreline evolution depends whether or not a sand bypassing system is implemented. Urban seafronts high exposed to erosion.
Vagueira – Mira beach	Very vulnerable	The shoreline is suffering significantly from erosion and it has been retreating further and further which can implicate the breaking of a new inlet in ria de Aveiro.
Mira beach – Tocha beach	Not vulnerable	The shoreline will probably retreat in the near future. Inexistence of important urban seafronts.
Tocha beach Cape Mondego –	Not vulnerable	The shoreline evolution in this stretch is stable as it benefits from the sediments provided by the erosion of the updrift beaches.

Relatively to erosion state in the pilot study area stretches, in Table 2 is presented a possible classification.

¹ Including the coastal erosion impact on the existent urban seafronts.

Table 2: Erosion state of the coastal zone for the different stretches of the coast.

Stretch	Beach	Kind of erosion
Douro - Espinho		Acute
Espinho – Esmoriz	Espinho waterfront	Acute
	Paramos	Chronic
	Silvalde	Chronic
Esmoriz–Cortegaça	Esmoriz	Chronic
	Cortegaça	Chronic
Maceda–Furadouro	Maceda	Chronic
	Furadouro	Chronic
Furadouro – Torreira	-	Acute
Torreira – Aveiro North breakwater	-	-
Costa Nova-Vagueira	Aveiro	Chronic
	Costa Nova	Chronic
	North Costa Nova / North Vagueira	Chronic
	Vagueira waterfront	Chronic
Vagueira – Mira beach	Labrego	Chronic
	Areão	Acute
Mira beach – Tocha beach	Mira	Acute
	C. Marco	-
Tocha beach – Cape Mondego	Tocha	-
	Costinha	-
	Quiaios	-

1.2 Socio-economic aspects

1.2.1 Population rate

Mean littoral population density: 363.1 inhab/km². Detailed data in Figure 4 below.

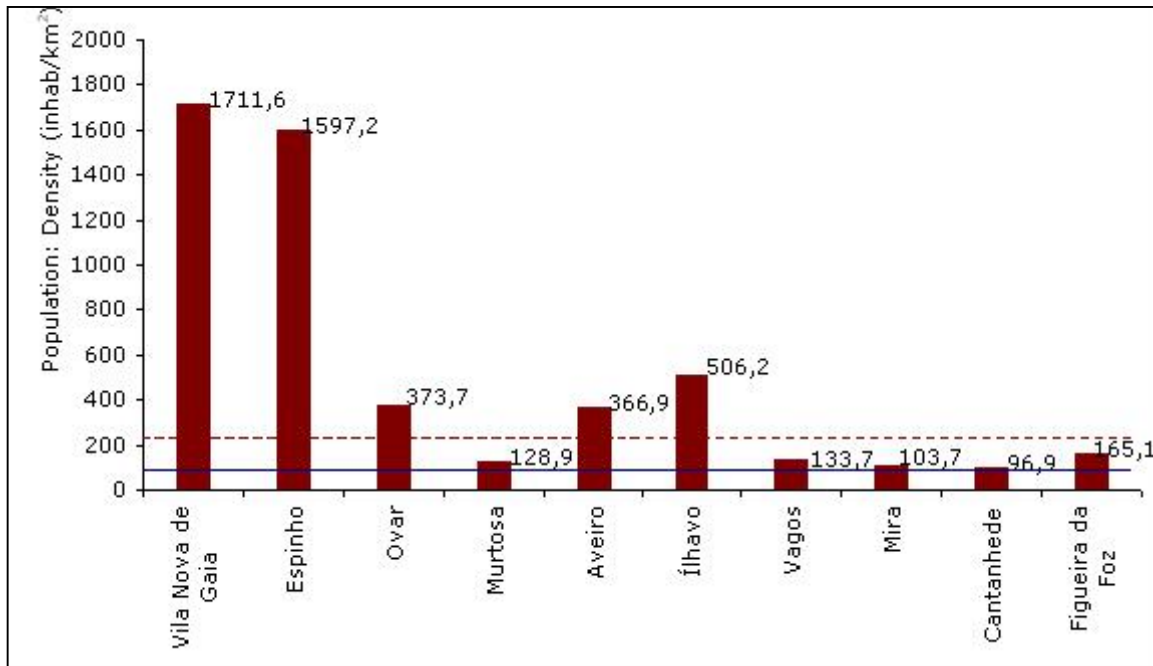


Fig. 4: Population density of the Aveiro coast (by municipalities).

1.2.2 Major functions of the coastal zone

- **Agriculture and forestry:** the study area has a strong potential of the agricultural lands adjacent to Ria de Aveiro and good climatic qualities for horticultural practises. There is a traditional link between agricultural activities and local fisheries. Existence of qualified forestry areas.
- **Fisheries and aquaculture:** Portugal has the largest economical exclusive zone of Europe, with valuable resources which were always been explored. In Aveiro there are important fishery ports with relevance at national context. Aquaculture is becoming more and more important as a complement to satisfy the market demands and to employ fishermen.
- **Urbanization:** it generates the occupation of risk areas with the consequent need for protection causing hydrodynamic unbalance. There is the identification of the areas to protect in the different management instruments, and the existence of objectives and principles of management in the existent instruments that promote the shoreline protection.
- **Tourism and recreation:** it is an important sector of the national economy, absorbing approximately 5% of the employed population.
- **Industry, transport and energy:** the existence of Aveiro harbour is very important for the region as it works as an international link between the local economical activities and the exterior and promotes the settlement of industrial activities in its influence area. Good accessibility trough all shoreline, strategic location on a national context and good quality of the transports frame (roadway, railway and maritime). The main energy source in Portugal is the oil derived products as well as electricity.

1.2.3 Land use

The land use in the area is mainly related with the agricultural activities, some important forested areas and urban areas as well as an important port area. It's also to refer the important area of the Aveiro Lagoon in the way that it influences the surrounding area including the coastal zone.

1.2.4 Assessment of capital at risk

The uncertainties and the low scientific capability to forecast extreme coastal forcing events, the “intangible” and the cumulative environmental evolutions and impacts and the lack of quantification of the needs, values and aspirations of coastal communities are some of the actual limitations to assess at capital at risk.

It is necessary to continue research in many aspects of coastal dynamics in order to achieve a better assessment and understanding of erosion and sedimentation problems, predictions of shoreline positions, vulnerability of beaches, dunes and coastal structures.



Fig. 5: Esmoriz and Cortegaça urban waterfronts - high risk of erosion.



2. PROBLEM DESCRIPTION

2.1 Eroding sites

- **Douro inlet - Espinho:** river basin with several large dams with intense dredging activities. The area is stable and naturally protected by rocks.
- **Espinho – Esmoriz:** the erosion phenomena in Espinho is new since 1869, before dam and harbour constructions. In the period between 1911-1950, the shoreline advanced around 75m. A reduction was achieved due to three groynes that were built between 1911 and 1918. In the South of Espinho, beach was reduced strongly between 1948 and 1977. Since the 1980s two large groins and a sea wall are protecting the seafront of Espinho and the situation is considered to be stable. The most vulnerable area in terms of erosion, in between Espinho and Esmoriz, the small seafront of Paramos. Several large groins protect the area.
- **Esmoriz – Cortegaça:** the stretch between the beaches of Esmoriz and Cortegaça has, in the last three decades, developed into a continuous seafront of approximately 3km. This is considered the most critical stretch not in terms of erosion rates, which is similar to the ones happening in the other stretches, but rather because the shoreline has retreated as far as the urban seafront and further recessions will implicate the loss of urban seafront, some of which is quite recent. The sediment transport that reaches this area tends to be very small. The average retreat in this stretch was in the order of 30 to 40m (1967-1977). It is important to refer, that immediately to south from Cortegaça groin, from 1992 to 1996, the retreat of the coastline achieved almost 40m.
- **Maceda – Furadouro:** significant coastal erosion problems and overwashes. However, the consequences are less expressive because the shoreline recession implies the loss of forestland areas and not urban seafronts. In the following years, it is expected that the shoreline will retreat more and more. In this stretch a small retreat between 1947 and 1958 was observed, increasing between the years of 1958 and 1980. After 1980, erosion reach values even bigger.
- **Furadouro – Torreira:** significant coastal erosion problems and overwashes. However, the consequences are less expressive due to the fact that the shoreline recession implies the loss of forestland areas and not urban seafronts.
- **Torreira – Aveiro North breakwater:** because of its location, benefits greatly with the eroded sediments deriving from updrift coastal stretches and is unlikely to expect significant erosion in the downdrift zone, which is still profiting from the retention effect of the north breakwater of Aveiro. In this stretch there exists the area classified as Natural Reserve of San Jacinto dunes.
- **Costa Nova – Vagueira:** this littoral area has approximately 9km from the south breakwater of Aveiro harbour to the north groin of Vagueira. It is influenced by the interventions made in the Aveiro harbour, especially the dredging channels and the large breakwaters. Several groins, seawalls and artificial dunes protect the shoreline. Between 1947 and 1978 an erosion of 200m up to 300m has been



recorded. The first groin field was built in 1972. Between 1978 and 1996 the erosion outside the groin zone reached 100m.

- **Vagueira – Mira beach:** the erosion phenomena and overwashes are clearly visible along the stretch Vagueira-Mira beach and even though it has not urban seafronts to be preserved, this recession can cause serious problems. It is predictable that the shoreline will retreat to a position that will result in the breaking of a new or more inlets in the Ria de Aveiro. The stretch is protected by a dune system, which is currently very vulnerable and needs to be artificially repaired or reconstructed otherwise the rich agricultural lowland areas (30km²) and several hundred houses behind it will be flooded as they are located in a lower level than the medium level of the beach.
- **Mira beach – Tocha beach:** in this stretch is apparently in a stable situation. Moreover, the retreat of the shoreline in this zone is just significant in terms of loss of land due to the non-existence of important urban seafronts.
- **Tocha beach – Cape Mondego:** the erosion process has not yet reached the stretch Tocha beach-Cape Mondego, since it benefits from the nourishment with sediments from the erosion of the up-drift beaches. In addition, it is located north of a fixed point, Cape Mondego working as a natural groin, and it is likely that the existent dynamic equilibrium is settled for a medium to long period of time.

2.2 Impacts

The retreat of the coastline increases the saltwater intrusion on agricultural lands, which leads to a decrease of this activity. The affected population is forced, due to the unemployed, to search for work in other economical sectors. The guideline approved in the CZMP configure a new "equilibrium position for the shoreline in the future. The capacity to forecast the medium and long-term evolution of beaches, dunes and barrier-islands continues to be very limited due scientific reasons.

3. SOLUTIONS/MEASURES

3.1 Policy options

Hold the line and managed realignment.

3.2 Strategy

Shore protection was understood in terms of the construction of defence structures (groins and longitudinal revetments), and few cases of artificial beach nourishment to control erosion (mainly in Algarve) and to reduce risks of urban exposure to storm actions.

3.3 Technical measures

Historic measures

During the 1970s and 1980s, several coastal defence structures, mainly groins and sea walls, were built in the pilot study zone to protect waterfronts from large storms and to prevent coastal erosion. These works, sometimes built without a clear perspective of global coastal management, have introduced imbalances in the adjacent areas.

V.N. de Gaia-Espinho	Detached breakwater	2002
Espinho-Paramos	5 groins	1918, 1981-1983, 1985
	2 seawalls	
Esmoriz-Furadouro	6 groins	1972, 1981, 1986, 1987, 1989
	5 seawalls	1959, 1970, 1977, 1978, 1982, 1990
Costa Nova- Vagueira	7 groins	1972, 1979, 1984
	3 seawalls	1981, 1984

3.3.1 Technical measures

The groins have symmetric trapezoidal cross sections with an armour layer, under-layer and a core. The groins have linear plant configuration, except the two first groins of Espinho (S-shaped to allow a development of a downdrift diffraction beach). These two groins have 300kN tetrapods armour units, which heads were already destroyed in the past.

3.3.2 Costs

In 1996 and 1997 (Matins, 1997), the amount of investments, for the all country was 19,049,091€ distributed for the following actions: interventions in coastal works, studies and projects, rehabilitation of dune systems and POOC's. In these years, the biggest part of the investment was made in interventions-works (Table 3).

Table 3: Coastal zone investments made in 1996 and 1997.

Actions	1996 (€)	1997 (€)	Total (€)
Interventions/Works	328,444,948	920,513,064	1,248,958,012
Studies/Projects	7,221,596	28,887,880	36,109,476
Rehabilitation of Dune Systems	17,200,646	-	17,200,646
Seafront Land-use Management Plans	85,852,097	98,328,528	184,180,625
Preparation Actions for 1997	-	418,491,436	418,491,436
Total (€)	438,719,287	1,466,220,908	1,904,940,195

While for interventions made in 1999 the costs are indicated in the Table 4 below.

Table 4: Investments made in 1999.

Actions	1999 (€)	Municipalities
Dune systems rehabilitation		
Francelos/Miramar/Aguda/Valadares – Accesses management, trails construction.	5,985,575	V. N. Gaia
Francelos/Miramar/Aguda-Norte – Construction of fences in dune areas.	798,077	V. N. Gaia
Silvalde/Paramos – Accesses in dune areas, instalation of fences.	1,197,115	Espinho
Pilot experience on Maceda Dunes	8,978,362	Ovar
Tocha South/Costinha - Automobile circulation contention, reorganization of foot accesses, trails installation	9,975,958	Cantanhede e Figueira da Foz
Total (€)	26,935,087	
Management/Valorization/Environmental Rehabilitation		
Seafront environmental requalification	39,903,832	V. N. Gaia
Seafront environmental requalification	39,903,832	Espinho
Maceda –Accesses definition, management, and automobile circulation contention	9,477,160	Ovar
Total (€)	89,284,824	



Defence Works/Risk zones		
North Paramos groin repair	39,903,832	Espinho
Esmoriz and Cortegaça seawall repair and Maceda groin.	149,639,369	Ovar
Torreira groin repair	49,849,790	Murtosa
Costa Nova groynes repair and seawall	124,699,474	Ílhavo
North Vagueira groin maintenance	12,469,947	Vagos
Total (€)	376,562,412	
Infrastructures of Support to Productive Activities		
Breakwater (fishing facility)	174,579,264	V. N. Gaia
Seawall	12,469,947	V. N. Gaia
Total (€)	187,049,211	

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

The defence works may reduce the risk to the sea actions, but they can eliminate or stop to acceptable levels. The possibility of extreme situations by defence structure rupture and/or by the inexistence of a beach or a small one could occur. The progressive length increase and the reinforcement of these defence structures transform the coastal zones in "fortresses", changing and degrading the landscape, increasing the erosion downdrift and transforming this area in a artificial coast. The original maritime and terrestrial ecosystem in the area could be modified and/or could even disappear.

4.2 Effects related to socio-economic aspects

All these villages are protected by seawalls and groynes, and these structures made possible the normal activities. These structures reduce the risk of urban area destruction, the erosion updrift and preserve some sand on the beaches during summer time. In Aguda these structures are essential for protection and economic activities. The defence work has a double function: protect the urban area from the sea actions, and work as a shelter harbour for the boats.

4.3 Effects in neighbouring regions

The effectiveness of hard sea defences is not total. In this area, the littoral drift currents act mainly in the North-South direction. This can be easily shown directly by the fact that accretion occurs northly of an area of coastal defences (updrift) (e.g. groynes) and there is erosion in the south (downdrift). For this reason the erosion stops or reduce updrift of defences and generally worsening in the south side of the sea defence.

4.4 Relation with ICZM

The main legal requirements are the Coastal Zone Management Plans. These are partial plans, which focus on defining the constraints, vocations and dominant uses, as well as the location of supporting structures for these uses. They also give guidance for specific activities to be developed along the coast, in terms of protecting essential ecosystems and existing resources.

4.5 Conclusions

There is a generalised retreat of the Portuguese coastline, which is of worrying proportions in some areas. Erosion is progressing with great intensity on several known stretches of coast and, despite the existence of seawalls and groins, the situation continues to be critical. Several urban waterfronts (Esmoriz, Cortegaça, Furadouro, Costa Nova, Vagueira,) currently appear as small "capes" that enter the sea, surrounded by coastal defence structures of considerable dimension. There are situations where it has become necessary, or will become so in the medium term, to proceed with the resettlement of the inhabitants living in risk areas.

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