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THE CHALLENGES TO OVERCOME THE PROBLEMS OF NW COASTAL ZONE OF PORTUGAL

F. Veloso Gomes

Director of the Instituto de Hidráulica e Recursos Hídricos
Faculdade Engenharia Universidade do Porto

Rua dos Bragas, 4099, Porto Codex Portugal

Fax 351-2-310870 / -318787 / -319280

Abstract

The main objectives to be achieved by the Regional Plan of Territorial Management (Plano Regional de Ordenamento do Território - P.R.O.T) of the portuguese Center Littoral are pointed out. This paper describes some aspects directly related with a more delimited area of dynamic interface between land and sea, the "Center Region Coastal Zone", but on a territorial view of P.R.O.T. littoral objectives. The anthropogenic impacts on that coastal zone have become severe along the past few decades and both spatial and time scales of such impacts tend to increase. There is a generalized erosion situation on the "shoreline" and the causes of the present situation have been identified as a response to several forcing factors. The urban expansion has induced environmental problems that must be controlled in order to avoid the global degradation of the functions and values. As a coastal zone management plan must consider the potential conflicting uses and interests of several nature, typical of an heterogeneous, opened, dynamic and strongly polarizing system some elucidative examples are illustrated. A simulation of alternative sceneries of urban expansion near the shoreline with different technical, economical, social and political implications is presented. The option for one of the urban expansion sceneries must be assumed with all the implications and responsibility. The local urban plans will consider the specific situations.

1. Introduction

1.1 The Regional Plan of Territorial Management (Plano Regional de Ordenamento do Território - P.R.O.T) of the portuguese Center Littoral (Fig.1) includes twenty five Municipalities, grouped in the Territorial Units of the Low River Vouga, Low River Mondego and Littoral Pine-Woodland, with an area of 5 600 km² and about 950 000 habitants (161 hab/km²). The Comissão de Coordenação da Região

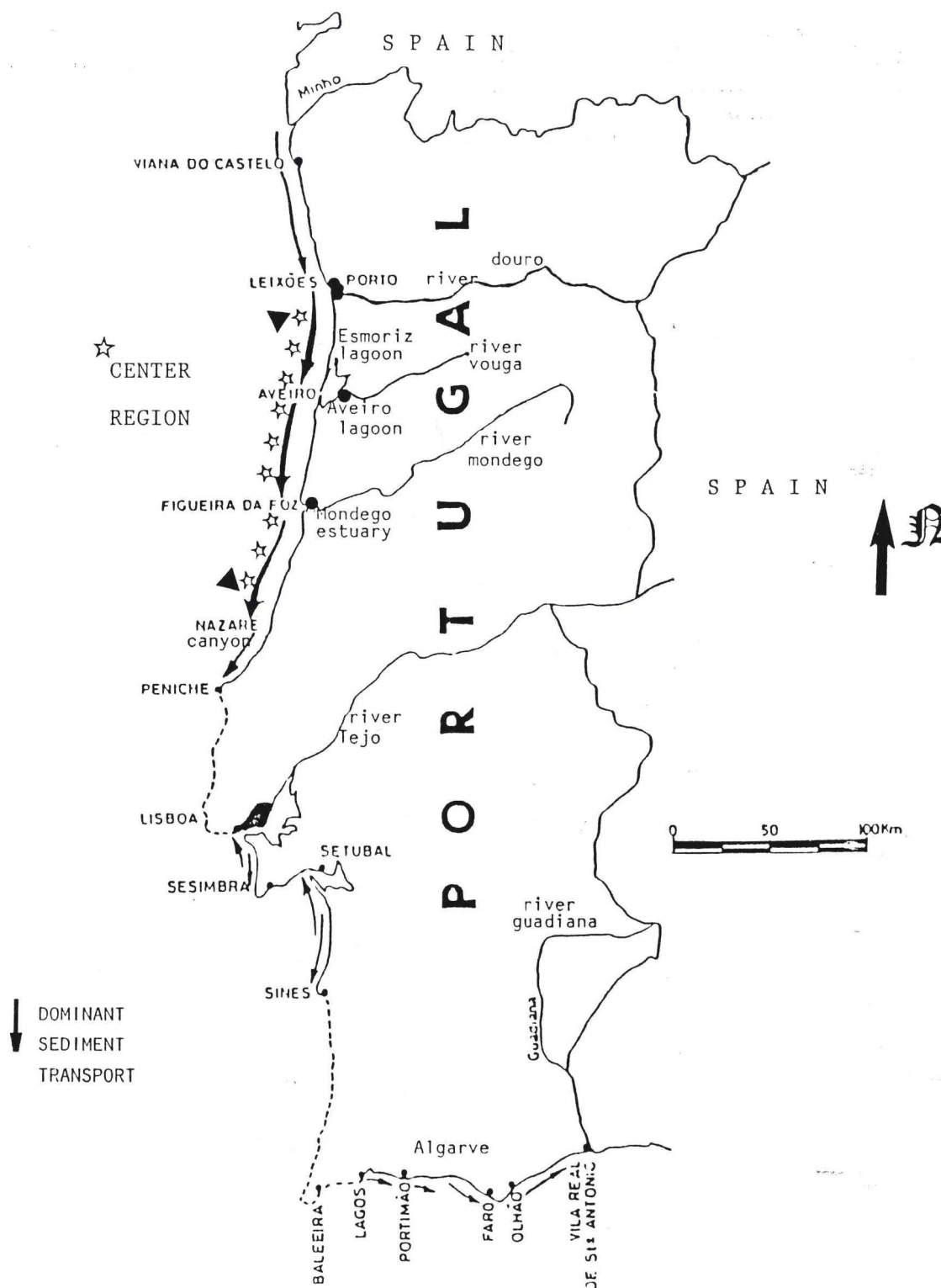


FIG. 1 THE COASTAL ZONE OF THE PORTUGUESE CENTER REGION

Centro (C.C.R.C.) is the governmental institution leading the P.R.O.T. Some of the main objectives to be achieved, considering that they must be integrated and connected are:

- the global compatibility of the economic and demographic growing, as well as the urban expansion, with the correct use of the natural resources and the cultural patrimony;
- the contribution to the improvement of the life quality conditions of the populations;
- the promotion of infrastructures and equipment, particularly those who have a structural role;
- to assure the compatibility on the territory between the planing actions and social-economic development at a regional and national level, with the territorial management actions at a local and municipal level;
- to elaborate general land use regulations towards a correct coastal zone planning integrating the diversity of the territory.

1.2 In the scope of these studies (in progress) and considering the spacial and temporal scales proper of these studies, C.C.R.C. has appointed the Instituto de Hidráulica e Recursos Hídricos da Universidade do Porto (I.H.R.H.) to detail and to deepen some aspects more directly related with a more delimited area, but on a territorial view of P.R.O.T. littoral objectives.

That area is referred by "Center Region Coastal Zone". It is the interface between land and sea, assuming particular importance by the intense and interactive dynamic aspects, by the high biological productivity, by its diversity, sensibility and weakness, by its generalized importance in terms of natural, human, landscape and climatic resources, creating a special and strong capacity, inside the P.R.O.T. area, for its occupation, use e transformation.

Inside this area:

- the beaches have high recreational and high coastal protection value;
- there are well preserved beaches and dune fields;
- there is a strong urban pressure for construction near the shoreline;
- there is a generalized coastal erosion process;
- municipal management plans are now at a final stage preparation;
- the Reserva Ecológica (Ecological Reserve) delimitation is being prepared;
- local urban plans will be developed.

Other P.R.O.T. studies are running in parallel. They are related with natural resources, climate, demography, urban areas, forest resources, tourism, socioeconomic activities, sewer and water systems, transportation infrastructures, natural areas...

A regional coastal G.I.S. database is being implemented.

1.3 Eleven Center Region municipalities have maritime fronts: Ovar, Murtosa, Aveiro, Ílhavo, Vagos, Mira, Cantanhede, Figueira da Foz, Pombal, Leiria and Marinha Grande. The length of the "shoreline", without taking in account the perimeter of the lagoons and estuaries) is about 140 Km.

On the synthesis report of the Corine project (1988) the main natural morpho sedimentological facies indicated are:

C.121 e C.122 (North sector): deposits from the Holocene and Quaternary;

C.122 (South sector): rocks from the Jurassic, Cretacic, Quaternary and Holocene;

C.123: rocks from the Jurassic, do Quaternary and Holocene.

With the exception of a 8 km length coastal sector on the Mondego Cape all the remaining extension is an exposed sandy coast with few outcrops. The wave climate is severe. Significant wave heights can reach 6m and tide range is 2.5 to 4.0 m.

On the Center Region Costal Zone, we can specify with a sequence from North to South, the following littoral geological environments:

lagoon (Barrinha of Esmoriz), beach and dunes (from Ovar), littoral bars (lagoon of Aveiro), beach and dunes (Gândara / Mira-Quiaios), littoral carbonated Mesozoic and Cenozoic (Hills of Boa Viagem), estuary (Mondego river) and beach and 7 km wide dune field (Pin-Woods of Lavos, Leirosa, Urso and Leiria).

The areas of natural interest near the coast are (from North to South C.C.R.C.):

- Lagoon (Barrinha) of Esmoriz
- Dunes of S.Jacinto Natural Reserve (Protected Area, D.L.41.79, 666 ha)
- Aveiro Estuary (Corine Biotope)
- Mira-Quiaios Coast (Corine Biotope)
- Mountain of Boa Viagem (Corine Biotope)
- Mondego Estuary
- National Pin-Wood of Urso (Corine Biotope)
- Ervideira Lagoon (Corine Biotope)
- Leiria Pin-Wood (Corine Biotope)

2. Anthropogenic Effects on the Shoreline

2.1 To manage a coastal zone properly, it is necessary to understand the relevant physical processes and the anthropogenic effects in order to prepare short and long term prognoses for shoreline changes and risk analysis. The anthropogenic impacts on the portuguese coastal zone have become severe along the past few decades and both spatial and time scales of such impacts tend to increase.

2.2 Face to the published data, coming from several sources and to the knowledge that we can obtain "in loco" from the problems, we can state that there is a generalized erosion situation on the Portuguese Center Region "shoreline", situation that is also verified in great extensions of the Portuguese coast and at a world level. Some examples are presented illustrating these statement.

The "shoreline" should be understood as the hydrodynamic interaction zone between sea and land. The quantification of those erosions must be considered with some cautions since it is made difficult by several factors. But there is no doubt that the rates of erosion have been increasing during the last decades (up to a mean retreat of 8m/ year) and the phenomenon has reached new coastal extensions where there were no records of past problems.

The extrapolation of erosion data to forecast land loss in next decades or centuries, have to be faced with caution, due to the complexity and non linearity of the involved physical phenomena and the possibility to be achieved an unforeseeable and uncontrollable situation.

Several coastal works have been built on the Portuguese Center Region beaches like long breakwaters, groynes and seawalls. A database with its location, number, type,

building date, reformulations and the extension of the updrift and downdrift effects has been prepared.

2.3 The causes of the present situation of generalized coastal erosion process have been identified as a response to:

- the mean sea-level rise;
- the weakening of the river sediment sources and river flow transport;
- the human occupation;
- the groynes and adherent works construction;
- other causes.

2.4 After a period of time in which part of the scientific community claimed that the main cause of recent erosion was a response to the sea-level rise, it seems now there is a global consensus that on the Portuguese Center Region Coastal beaches, the erosion phenomena are mainly the result of the weakening of the river sediment sources in recent decades.

Much less sediment is supplied to the strong longshore current as a result of the construction of a large number of big dams in rivers of Portugal and Spain (hydrodynamic changes), as a result of dredging works for navigation purposes and civil construction industries and due to land use changes. The sandy coast erodes because potential transport capacity of the waves (between 1 000 000 and 2 000 000 m³/year) is greater than the annual sediment volume supplied by the rivers ($\approx$ 200 000 m³/year).

The construction of several harbour breakwaters (Aveiro lagoon inlet, river Mondego mouth) and dredged navigation channels, long enough to intercept the littoral transport has induced erosion problems in the adjacent shorelines.

2.5 A 1.5 mm/year sea level rise in Portugal (global eustatic effects associated with climate changes, regional climate effects, coastal subsidence) is commonly accepted as another erosion cause. We need a lot of scientific research on that subject. It is a matter of international concern the prognoses of the evolution of the sea-level rates and the long-term effects associated with the increase of the frequency and severity of storms on the shoreline world-wide. A sea level rise of 1.5 mm/year cannot explain recent visible changes in portuguese coastal morphology. The shoreline response to such phenomenon is locally dependent and may be much more complicated than predicted by Bruun Rule. The long term environmental implications are uncertain.

2.6 Residential development along waterfronts during the last three decades, sometimes over the beaches and dunes (buildings, streets) contributed also, at least locally, to change morphological conditions and to increase the risk of damage. There are 16 km of urban construction along the 140 km of the shoreline and about 20 popular beaches. After emergency situations, groynes and seawalls have been built to protect waterfront constructions (33 structures over 10 km of the shoreline length). These works induced other erosion problems southwards.

A Master Coastal Defence Plan for the portuguese Northwest Coast developed by a private consultant contracted by the coastal authorities, considers more than 160 groynes (lengths between 100m and 200m) and some small amount of artificial beach nourishment as a complimenter technical protection. The past experience has shown that construction of such structures in order to solve critical situations has started

without the necessary stages in project realization, without a controlled feedback to design consideration and criteria and without a global coastal management plan. They have induced extended negative effects southwards and an artificial scenery along some coastal stretches. There are claims towards the complete stop of the construction of groynes and seawalls but alternative measures must be found.

In any case, the sequence they were built to attend the successive "emergency" situations, the insufficient data and the limited financial resources did not produce solutions that technically could be repeated in the future.

It continues a matter of research the hydrodynamic and hydromorphological behaviour of a groyne or a groyne field. In fact, the acceptance of the technical solution "groyne" implies that after the beach saturation updrift, some years after the construction, there will occur a sand transposition, and the littoral transport will be replaced as before the construction. If this hypothesis is not verified on the field, because the littoral drift current affected by the "groyne barrier" takes the sediment to depths that the waves cannot move them again to the beach, then everything will have to be discussed again, since the effects of erosion downdrift will be permanent.

Nevertheless it is an almost impossible task to predict which would be the actual erosion rates, the situation of the shoreline and of those waterfront constructions if defence works have not been built. And we must recognize there is a strong public pressure from the and local authorities claims to built coastal defence structures in spite of the consequences over longshore distances of several kilometres and over many years.

2.7 Of course the urban expansion in coastal areas of the portuguese Center Region has induced other kinds of environmental problems that must be controlled in order to avoid the global degradation of the functions and values.

In several situations such development has introduced landscape alterations without any quality criterium in terms of volume, colour and envelop treatment. The clandestine secondary houses built in dunes has assumed alarming proportions in some of the coastal municipalities but recent efforts were able to correct most situations by demolition and planning control. Through aerial photography it is possible to identify several coastal places with longitudinal and transversal path ways on the dunes lines. Fortunately the majority of field dunes remain preserved.

Quality problems in some of the coastal water stretches and lagoons have been introduced by leakage of sewage industrial and urban treatment plants (now under construction).

There are alarming indicia and objective cases of loss of vegetation cover and forestal destruction (mainly by fires, criminal and accidental causes) on the littoral zone, when all the region was traditionally "consolidated" on such woodland.

2.8 We must consider other possible causes of the generalized coastal erosion. As an hypothesis, meteorological changes occurred on the last decades inducing wind directional spectra changes (and consequently wave directional spectra changes) could explain the increasing erosion rates also. A small angular mean deviation of winds and waves towards North would mean an increase of the erosion action.

Erosion phenomena already verified on the last Century or in the first half of the present Century cannot be attributed to the dam construction or to harbour works

or even to great urban pressures. The causes may be associated to the other referred factors.

Near the North limit of the Center Region, in Espinho, there are indications of erosion in 1869, 1871, 1874, 1885, 1889, with a mean retreat of 8m /year. The first frontal defense works have been made in 1909 (and destroyed by a storm in 1911). Between 1880 and 1911, the high-water line moved near about 225 m towards the shore.

Natural highly dynamic shorelines (Fig.2) that in the past did not raised any intervention (and existing know-how was not able to do it) are actually opposed by the actual land and navigation uses.

We can provide a typical example in this region. As result of the hydromorphological evolution of an extensive and pronounced bay that developed from Espinho until near the Cape Mondego, on the common estuary of rivers Vouga, Águeda and Cértima, the shoreline, the barrier, the inlet and the lagoon configuration have suffered deep changes. Particularly documented since the X century until now, it is possible to notice a progressive sedimentation of the lagoon and a bar migration to the south. The inlet was artificially fixed in 1808.

The Aveiro harbour breakwaters were built on the 50's decade, with a length of 700 m, relatively to the primitive water level. The North breakwater has been extended 500 m between 1983 and 1987. The littoral transport to south was seriously affected. The sedimentary retention on the north beaches and on the submerged bank external to the bar has reached 20 millions of m³ on the decades of 50 and 70.

The 4700 ha lagoon is submitted to complex natural and human induced phenomena of sedimentation and eutrophication. The sandy littoral barrier rooted at the south, is very narrow and sensitive to the erosion phenomena. The urban expansion there (Costa Nova / Vagueira) destroyed almost all the dunes. A strong urban and tourism pressure for construction still remains.

2.9 It is necessary to continue research on many aspects of coastal dynamics in order to achieve a better assessment and understanding of erosion and sedimentation problems, predictions of shoreline positions for several sceneries and timescales of climate variability and direct human influence, vulnerability of beaches to storms and other extreme events, impact of coastal structures, ecological changes.

3. Potential Conflicting Uses and Interests

3.1 A coastal zone management plan must consider the potential conflicting uses and interests of several nature, typical of an heterogeneous, opened, dynamic and strongly polarizing system. It involves aspects of economical, social, technical and political nature.

3.2 Some elucidative examples of the difficulty to rise equilibriums, to get compromises, to take decisions and to implement such decisions have been illustrated. Concerning the Coastal Zone of the Portuguese Center Region, such examples cover the following issues:

- interests at short timescales in the use and occupation of coastal zones versus very variable natural phenomena timescales evolution and extreme events: millions of years, thousands of years, decades, seasonal, days (storms), hours (tides), seconds (waves).

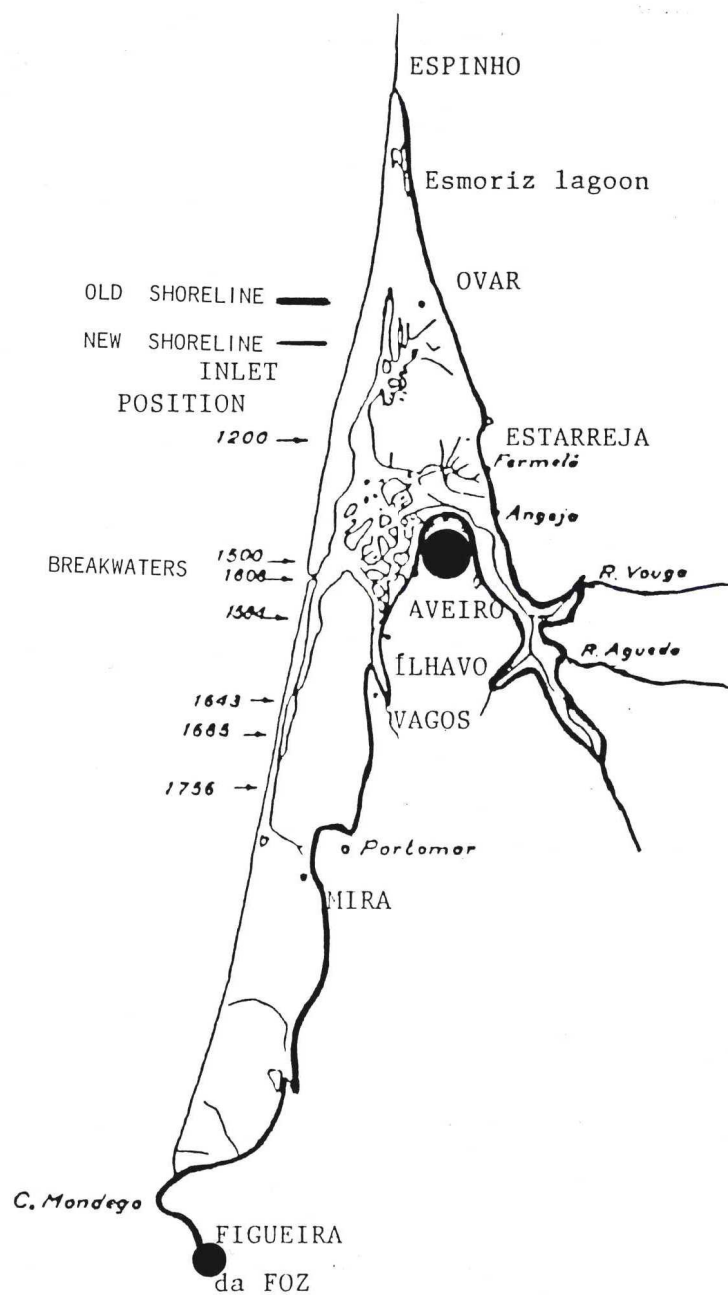


FIG. 2 EVOLUTION OF THE SHORELINE AND AVEIRO LAGOON INLET

- interest on river energy production versus interest to avoid damming the rivers.
- interest to avoid desertification of catchment river basins by forestation and agriculture versus interest to have available sediment sources on those catchment areas that could be transported to the sea by river flows.
- interest on harbour works construction, namely breakwaters, jetties and dredging navigation channels, essential for safety and operational shipping conditions versus interest to avoid the interception of the longshore sediment transport.
- interests of the construction industry to extract sand from beaches and estuaries, essential to house and infrastructures building versus interest to reduce or to avoid such extraction in order to minimize erosion and ecological problems.
- interests of populations on the usufruct of coastal weather amenity and amenity versus interest to reduce the seasonal fluxes and the colonization of the coastal zone to preserve and protect the cultural heritage, the natural values and to avoid a regional disequilibrium.
- interests of populations to build on the beaches and dunes, versus interest to avoid changes on those ecosystems and to avoid to "fortify" the coastline trying to reduce the risk of population exposition to storm events and erosion but inducing aesthetics problems and downdrift erosion.
- interests of the populations to spend their holidays on a populated resort in a transformed scenery versus interest of populations to spend that period in calm and natural environment.
- interests of communities to rise their economical income with increasing activity on industry, fishing, commerce, mass tourism and urban construction (with special appetite by the coastal zone) versus the need to balance such economic pressures in order to achieve a long term sustainability.
- interest to develop suitable road and sanitary infrastructures in the existing small communities versus interest to avoid an uncontrolled pressure over those communities by the attraction of new inhabitants and visitors.
- interests in mass production and uniformization versus the interest to maintain or to increase the biological, cultural, landscape and economic diversity.
- interests to act in an integrated and dynamic way in the planning, management and implementation versus interest of some groups and individuals to avoid an efficient decision-making system, taking advantage of a complex administrative structure, disconnected decision-making centres, diluted responsibilities and lack of financial resources.
- interest to inform, to sensitize, to educate and training the public, the technicians and the politicians on (coastal) environmental protection on a interdisciplinary approach versus some indifference on the acquisition of that information, sensitization and education.

3.3 An extended environmental, social and economic appraisal of such "interests" considering several evolution sceneries would provide a useful tool for the decision-making process demanding an inter-disciplinary approach to evaluation. The uncertainties of extreme events, the "intangible" impacts, the evaluation of environmental impacts and the evaluation of the needs, values and aspirations of communities are some of the limitations of this approach.

4. A Simulation of Alternative Sceneries of Urban Expansion Near the Shoreline

4.1 A simulation of alternative sceneries of urban expansion near the shoreline with different technical, economical, social and political implications has been presented and discussed with the planning and administrative authorities.

The "base situation" (Fig. 3A) was inspired on Furadouro beach but it reflects many other small urban area with coastal waterfronts. Its urban growth has started from a road perpendicular to the shoreline identifying an hierarchy vector with an other urban area or a town without a beach. The number of its floating inhabitants can exceed two or three times the resident population.

There are several streets converging to the beach. The sandy beach is under an erosion process. One or more groynes were built to retain some sand. The groynes have induced downdrift erosions. Sea walls were built to avoid waves overtopping. These works were financed by the Central Administration. The detection of several zones around the urban area without vegetation cover may be an indicative of an attempt to build new residential areas.

4.2 Figures 3 and 4 illustrate some simulations of future evolution of that small town.

Fig. 3B represents a "retreat" option. The beaches defence works will be removed and it will be interdict to build in a zone witch would be related with the erosion rate on a project horizon, for instance 100 years (is it possible to forecast that erosion rate?). Destruction of existing residential and public buildings and permanent property loss will occur

Another limit case is represented on the Fig 3C: the possibility of an expansion along the waterfront as a result of the actual urban pressure for construction near the shoreline. This hypothesis is only possible with the construction of heavy defense works requiring maintenance and progressive reinforcement along the next years with negative implications of several nature.

These two limit sceneries are economically, socially and politically unacceptable but are limit situations to be compared.

Figs. 3D, 3E and 3F represent a complete restrictive option concerning land use for construction purposes. Because the beaches can be overpopulated on Figs 3E and 3F it is considered new controlled accesses to the beach with parking areas and removable support equipment allowing a larger beach extension use.

On Fig. 4A the hypothesis of an urban area expansion towards updrift and landward the dunes accepts that the dunes and the existent groynes would provide a permanent safe defence against erosion.

On Figs. 4B, 4C and 4D, a controlled urban expansion to the inland is considered: a "wedge" expansion, a "rectangular" expansion and an expansion at a certain distance from the waterfront, distance that could be in the order of some hundreds of meters until several kilometres.

4.3 The Figs. 4E and 4F should be considered in parallel with the previous ones. They rise the question of alternative measures to groyne defence works.

The use of artificial sand supply techniques in very exposed seas without any structures is a time to time maintenance job, with a large amount of sand supply which can reach several million m³ per year. The sediment sources are not available unless

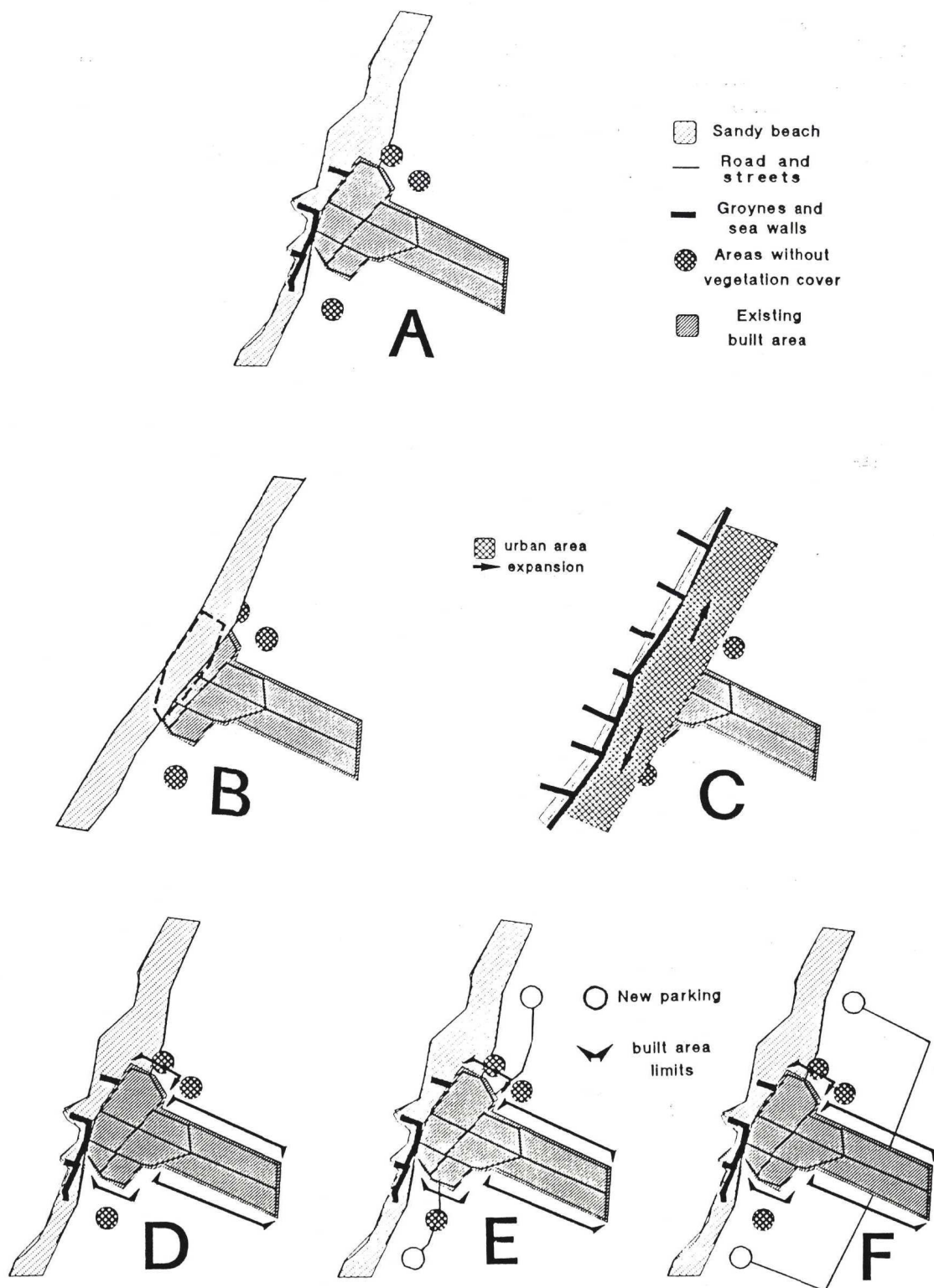


FIG. 3 URBAN EXPANSION SIMULATIONS

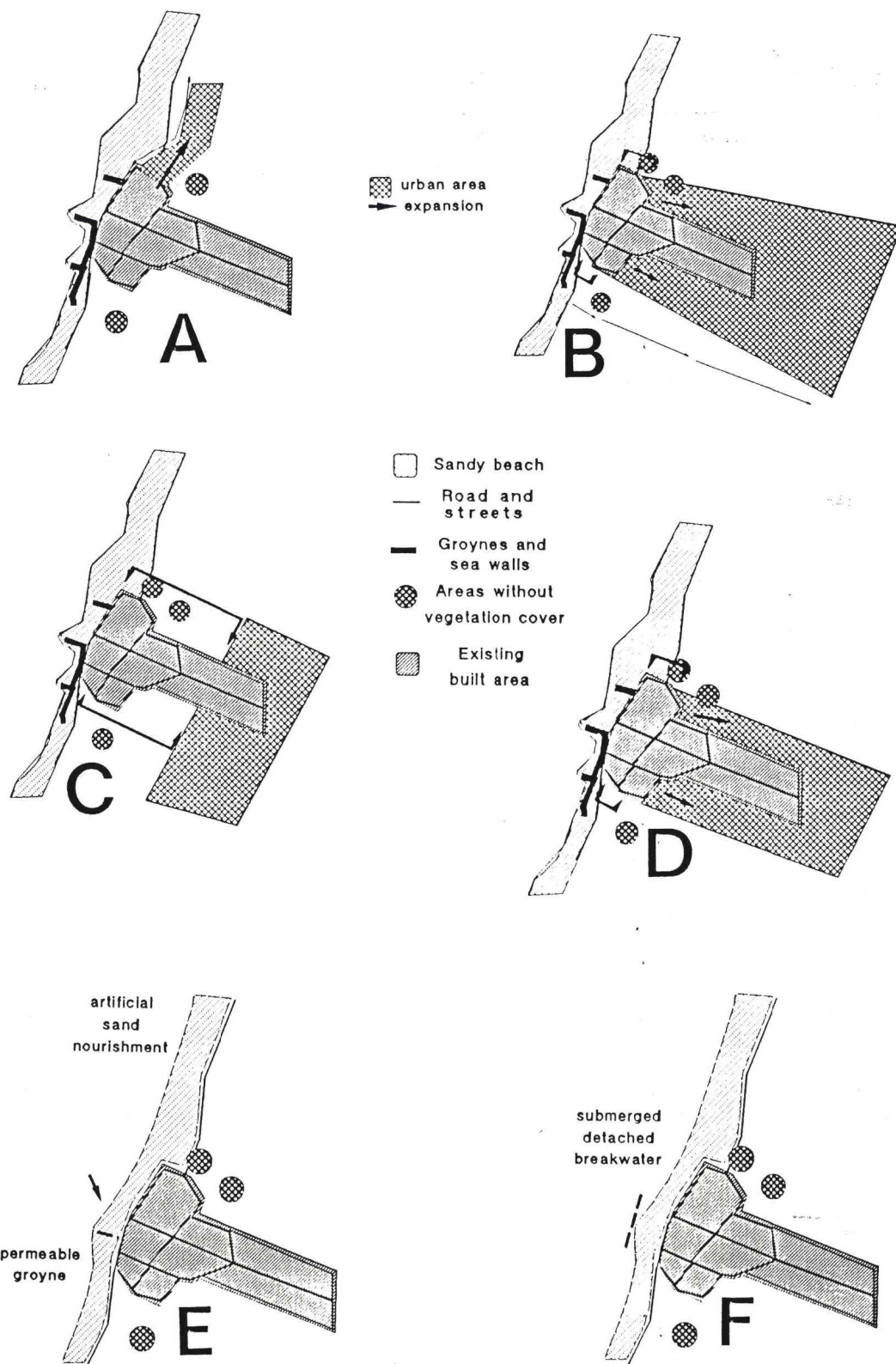


FIG. 4 URBAN EXPANSION SIMULATIONS

at depths greater than 30m at very exposed wave action locations. There are important environment aspects related with borrowing and dumping of sand.

The implementation of bypass-systems and the use of maintenance dredged material for beach nourishment is a strong need, but it has not been done by authorities as a result of the additional costs and Institutional problems between harbour authorities and coastal management authorities. The search for protection structures with less aesthetics and southwards effects, in parallel with artificial sand nourishment is a strong challenge.

4.4 The option for one of the urban expansion sceneries must be assumed with all the implications and responsibility being in mind the next generations. It is unacceptable to assume that the Central Administration will provide technical and financial support to build new emergency defense works against the "sea attack" as a result of a continuous expanding of the new waterfront constructions. In any case we cannot impose a scenery that works as "prescription" to all the coastal urban areas of the portuguese Center Region. The local urban plans will consider the specific situations.

5. Conclusions

It has been possible to assess the main anthropogenic effects on the shoreline of the "Center Region Coastal Zone" but it is necessary to increase research on several aspects of coastal dynamics in order to improve long-term predictions of physical changes.

A regional coastal G.I.S. database is being implemented.

To achieve sustainable levels of development it is necessary to mitigate the identified potential conflicts among user groups, involving aspects of economical, social, technical and political nature. Sound coastal zone management planning including consistent regulation of coastal development and coastal conservation framed by public motivation is being prepared. Its development and implementation will be a challenge.

One of the several aspects to be considered is the strong urban pressure for construction near the shoreline. A simulation of alternative sceneries of urban expansion has been discussed with the planning and administrative authorities. A short presentation is included in this paper.

References

1. P.R.O.T.-C.L.. "Estudos de Caracterização". C.C.R.C. 1992/93.
2. P.R.O.T.-C.L.. "A Evolução Fisiográfica da Faixa Costeira da Região Centro. Que Estratégias de Gestão? I.H.R.H./C.C.R.C. 1992.

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