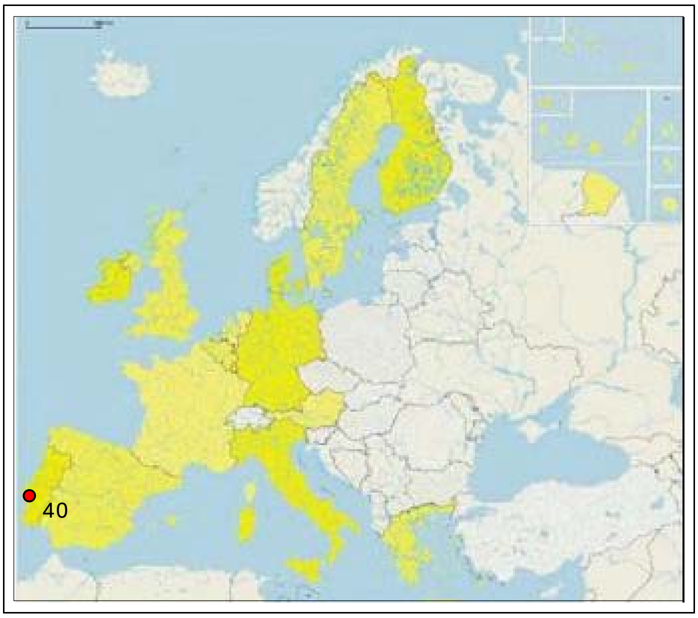
COVA DO VAPOR
COSTA DA CAPARICA
(PORTUGAL)



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1. GENERAL DESCRIPTION OF THE AREA

The area is located in the South region of the Tagus river mouth and to the north of Setúbal Peninsula. This coastal zone is distinguished by a great fluvial morphodinamic influence in the river inlet area. The area of study starts in the Cova do Vapor and ends at south of Costa da Caparica village (figure 1).

Fig. 1: Location of the groyne field maintenance with artificial sand nourishment study area.

Millions of people use Costa da Caparica beach during summer and the urban seafront requalification is included in a major national programme for urban areas requalification called POLIS programme.

1.1 Physical process level

1.1.1 Classification

- General: sandy beach and fossil cliffs
- CORINE: beaches
- Coastal guide: coastal plain, cliffs

1.1.2 Geology

Geologically, the area is characterized by an alluvium deposing related with the interaction effects phenomenon of waves/tides/river flow, with refraction/diffraction patterns that provoke a local alluvium transport from south to north, creating a small sand spit, in our days, near to the NATO harbour (figure 1). In the past, this sand spit had significant dimensions, projected in to the Bugio lighthouse direction (figure 5). This way, it was created an extensive alluvium on south side of Tagus river (Cova do Vapor – Espichel Cape and Bugio bar). In south of Costa da Caparica village we can find a fossil cliff that extends in the direction of Albufeira lagoon. This cliff has 70 m of maximum high, and suffered some changes through the geological times (Quaternary period) and due to erosive processes that have given those particular characteristics, this cliff become unique in Portugal. In 1984 this area was defined as a protected area (DL 168/84 of 22 of May) (figures 2, 3 and 4).

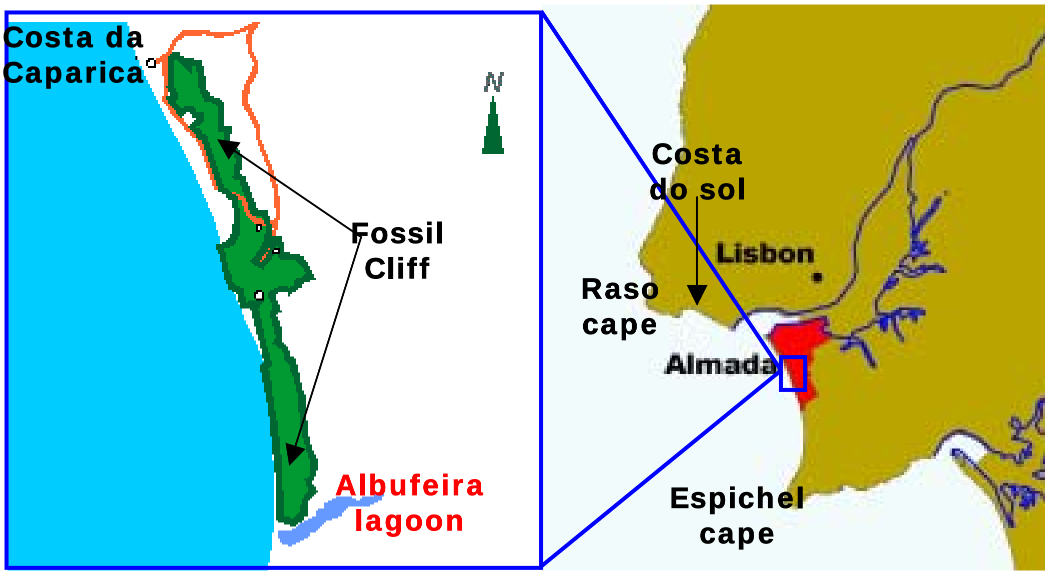

Fig. 2: Fossil cliff location.

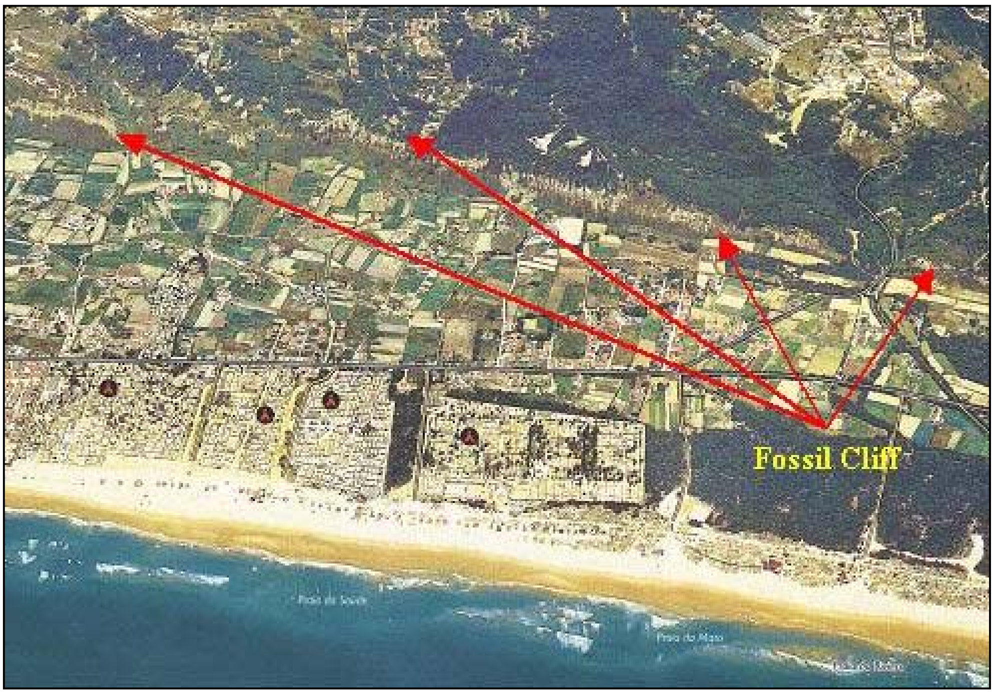

Fig. 3: Aerial view of fossil cliff (littoral aerial guide, 2sd edition, Dom Quixote).

This coastal zone is a plain coast with an arc shape that represents the most important fossil cliff in Portugal. The cliff is protected, from the sea by a considerable extension of sand. It is constituted by sub-horizontal layers of sedimentary rocks, with ages that varies between medium Miocenic period to our days.

Fig. 4: View of fossil cliff ('Paisagem Protegida da Arriba Fossil da Costa da Caparica').

1.1.3 Morphology of the coast

Topography and Bathymetry

The topography of the study area has a simple characterization, it is a circle arc coast, and presents an orientation SSE-NNW. This coastal zone is an extensive plain near the coast line, until the fossil cliff that reach the 70 m high (figure 3).

The sea bathymetry is very smooth, with bathymetric lines almost parallel to the coast line and with a very small slope. Near the area, there are two sand banks parallel to the navigation channel of Tagus estuary inlet, the north Cabeça do Pato (or north Cachopo) and the south Bugio bar (or south Cachopo), which has suffered very significant morphologic changes along last decades. According to Mota Oliveira, (1993), between 1939 and 1985 the Bugio bar moved 700 m to the north and suffered an accentuated erosion process (figure 5).

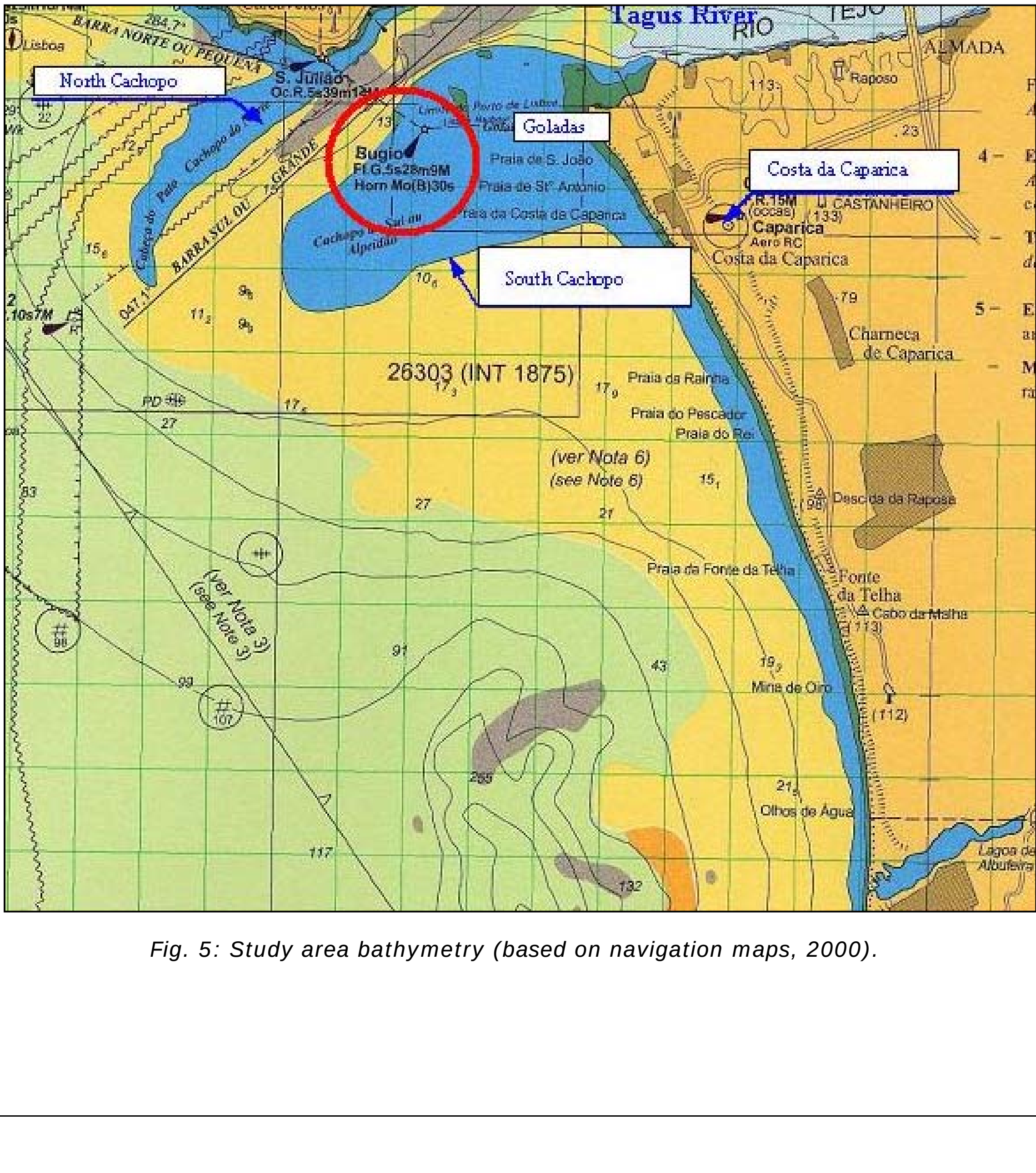

Fig. 5: Study area bathymetry (based on navigation maps, 2000).

1.1.4 Physical processes

Wave Climate

The monthly average regime, calculated for the neighbourhood of Bugio lighthouse, is characterized by medium periods between 5 and 9 s, with an spectral direction between WSW and WNW, Oliveira (1999). The significant average wave height and the maximum wave height vary between 0.7 m and 2.6 m, and 1.2 m and 4.1 m respectively.

The general regime observed in this area, according to this author, is characterized "by periods of zeros up-crossing, T_z, between 3 s and 16 s, that are associated to local medium spectral directions between S-20-W and WNW, respectively. Significant wave heights near Bugio are limited by breaking and they are smaller than 8.4 m. Finally, the most frequent local wave directions are between 260º and 290º, almost associated to wave heights between 0.5 m and 2.5 m. Most frequent period varies between 5 and 8 s".

Tidal Regime

The astronomic tides are semidiurnal type, with tidal cycles of approximately 12h 25 m and propagating from South to North. The maximum spring tide reach in Cascais tide gauge was 3.83 m and to neap tide was 0.27 m. In meteorological tides and when occur low pressures and wind persistent the waves can reach 5 m.

Near Shore Currents

According to results of a bidimentional finite elements model the velocities of tidal currents in the Tagus estuary are strong although with low heights. In spring tide, they exceed the 2.0 m/s during the flood and 1.8 m/s during the ebb. The correspondent medium values are respectively1.5 m/s and 1.4 m/s.

In the Costa da Caparica waterfront, near the river inlet, the residual tidal currents have a smaller intensity due to the velocities that occur in inlet, appearing represented in the model results with values smaller then 0.2 m/s and with directions from south to north in front of the Costa da Caparica beach. This current from south to north results from a close circuit.

According to Abecassis (1997), a great part of the sea regime reaches the stretch Cova do Vapor - South of Caparica rotated to Southwest, due the diffraction phenomenon effect (around the Cape Raso, for the coming sea conditions of the quadrants North and West) and refraction (due the area complex bathymetry), inducing a net alluvium transport from South to North. The ebb tide currents conjugated with action on the bar, in Golada zone (figure 5), reinforce the sand movement capacity in the same direction, depositing finally in the north face of the bar slope, contributing this way for its progression in the same direction. During the ebb, strong currents that are verified in the natural channel promote sand transport into the external side of the bar, depositing them as its intensity decreases, contributing to the depth reduction that is verified. In sequence, it is the incident sea action, in particular the one that comes from the North quadrant, that induces the transport process into the coast, along the slope turned to South, closing an alluvium movement circuit (figure 6).

Sea Level Rise

In terms of sea level changes, there is not so much information concerning the future trends in the Portuguese coast. However, it is likely that if the sea level rises it will have negative effects mostly on the wave climate, level and propagation of tides, coastal erosion, flooding and sediment balance. In the study area of Cova do Vapor – Costa da Caparica those effects could be aggravated by the fact that this is a coast constituted by alluviums and fossil cliffs that have a limited resistance to the sea action.

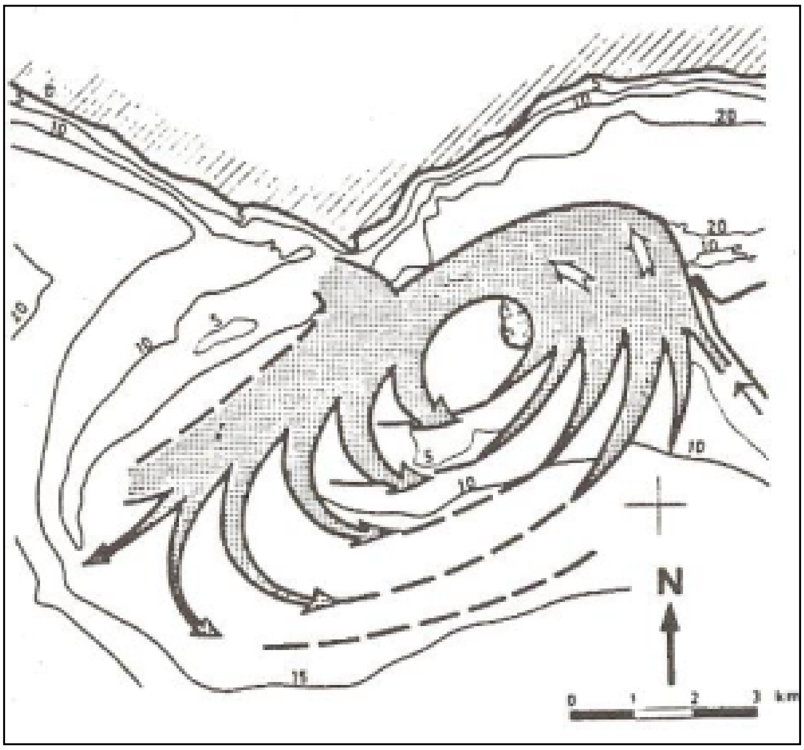

Fig. 6: Plan of circuit waves and sediment movement in Tagus inlet (Mota Oliveira, 1973).

Sediment transport

Data of Inputs and Outputs of Sediments

This area depends exclusively on Tagus river and its estuary inputs. According to the National Water Plan, 2001, the amount of sediments received by the estuary is mainly dependent of storms and flooding and it was estimated in 1 to 77x10^6 ton/year. In dry years, the total estuary discharges in the sea are estimated on 0.4 to 1x10^6 ton of sediments. The medium rates of sedimentation, calculated between 1983 and 1984, points to values between 1.1 to 1.5 cm/year. Between 1928 and 1986, 65% of the sediments could stayed in the system. In our days, it has been observed an intense silting up in the estuary upstream area, due to the loss of capacity of the fluvial system and due to the fact that is a preferential retention area of sediments. According to SNPRCN (1989) the regularization works made in the Tagus river basin, from the 20's to the 50's had a great impact on the amount of sediments carried out from the river. In this period, the coast line retreat was enormous. In littoral area huge amounts of sediments were dredged to works that occurred in other places, including artificial sand nourishment of Costa do Sol beaches.

Direction and Taxes of Transport

The main sediment transport direction in this area is South-North (figure 5), due to the existent littoral drift currents. This fact can be easily demonstrated by the sand spit on the south side of the Tagus river inlet. Sedimentary transport taxes are not available or do not exist. In order to give an idea of the sea capacity transport, some references indicate that it is around 1 000 000 m^3/year.

Coastline Variation

In this area news of erosion on south of Cova do Vapor are know since 1947, reaching particularly the village of Costa da Caparica in 1958. It has been verified that since 1870 an important physiographic transformation and retreat in the coastal line of the area occurred. The sand spit disappearance and the retreat of the coast line are evident (figure 7). The sand spit moved under the wave action up to the NATO harbour. This process was reduced by the construction of defence works (groin field).

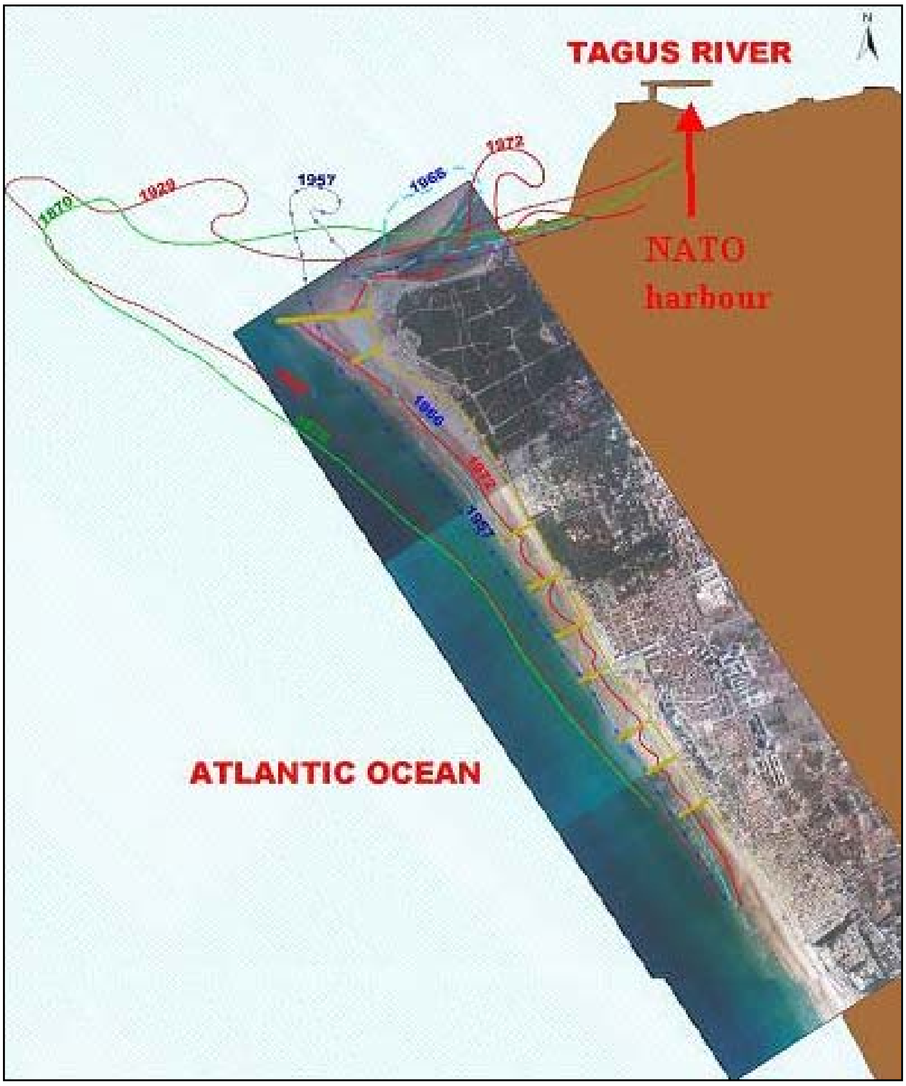

Fig. 7: Coast line evolution between 1870 and 1972.

In figure 8 it is possible to see the cross section evolution in Costa da Caparica, between 1957 and 1964, before the construction of defence works. In this time, the disappearance of sand spit facilitated the sand transport to north; this way the Caparica beach entered in a erosive process very accentuated. It is possible to observe the evolution of the lowering of dunes crowning heights (from +14.0 m to +8.0 m HZ), and the retreat of submerges areas.

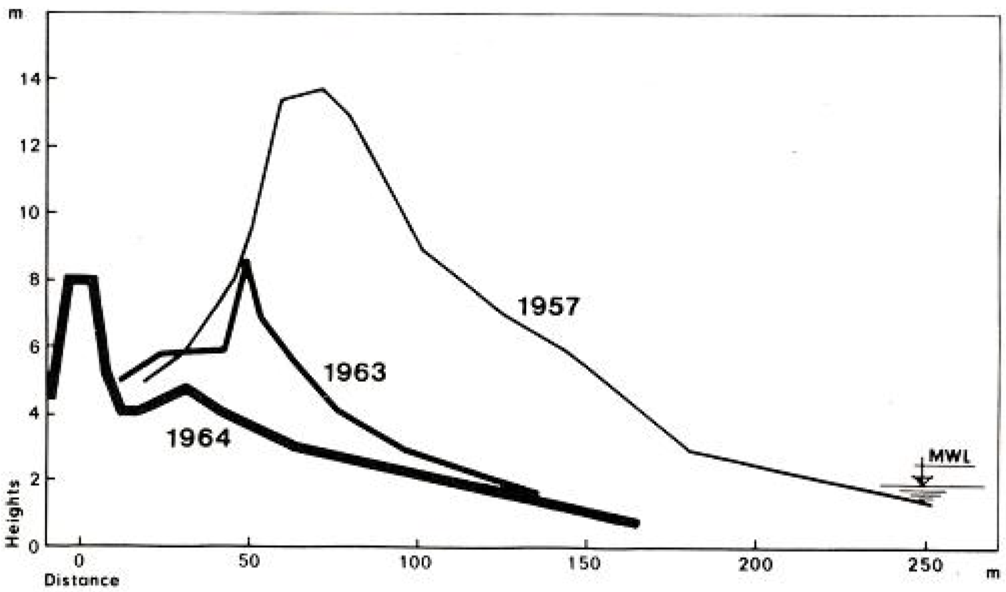

Fig. 8: Evolution of cross profiles between 1957 and 1964 (Barceló, 1971).

It is important to refer that the +4.0 m HZ curve retreated 150 m, and the +2.0 m retreated about 100 m in seven years. On south of Caparica, the waves are almost perpendicular to the beaches and the coast stay dynamically stable.

1.1.4 Erosion Rates and Trends

To establish trends in this area, several documents were analysed. After the analysis, it was possible to identify the vulnerability degree and some possibilities of evolution, presented in the table 1.

Table 1: The shoreline trend evolution.

Location	**Classification in terms of erosion problems**[1]	**Future Evolution**
Cova do Vapor	Vulnerable	With the sand beach disappearance, the sea actions will be stronger and near the waterfronts witch implicates an increase of danger, vulnerability and risk in urban areas.
Costa da Caparica	Vulnerable	The shoreline evolution depends on the maintenance works of the defence structures (groyne field) and artificial sand nourishment that could be accomplished.

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

According to the Water National Plan (2001), on Tagus river inlet in the period between 1939 and 1985 the Bugio sand banc or South Cachopo advanced about 700 m to the north suffering generalized erosion and the North Cachopo or Bico de Pato moved about 800 m to southeast. According with figure 6 the coast line retreat is evident, enormous and preoccupating. Between 1870 and 1966 the sand spit disappeared, with a period of great erosion.

1.1 Socio-economic aspects

The Portuguese coast has in general a high concentration of population in relation to the rest of the territory. In Almada municipality, happens the same and has one of the most height demographic denseness in all country. Besides, is located near the Portuguese capital, Lisbon that have 3 000 000 people and is included on Lisbon Metropolitan Area. The Costa da Caparica is a very important beach area and is used by millions of people during the summer, many of them are from the neighborhoods such as Lisbon and other municipalities of Metropolitan Area.

The urbanistic pressure and the erosion problems lead to a certain difficulty on the area management. Despite the need for studies on these types of impacts and on assessment of capital at risk, in Portugal special attention has not yet been taken into account on this important subject.

1.2.1 Population rate

In Portugal, there is an uneven distribution of population between the littoral area and the rest of the country. This uneven distribution is expected to be furthermore significant as the growing rate population in the littoral municipalities is higher than that one observed on the Portuguese territory (Table 2). According to the table 2, between 1991 and 2001, Almada population has increased at rates near the average of littoral municipalities. It is important to refer that this municipality has one of the highest population density in the country.

Table 2: Recent evolution, density and rate of change, for Almada municipality.

Municipality	**Total Area (km^2)**	**Resident Population (Inhab)**			**Density (Inhab/km^2)**	**Rate of Change 1991/2001 (%)**
		1981[2]	1991[2,3]	2001[3]		
Almada	70.2	147690	151783	160826	2289.9	5.6
Total Littoral Municipalities	15999.7	3698109	3677623	3907117	244.2	5.9
Portugal	92151.8	9830140	9867147	10355824	112.4	4.7

[2] Estudo de Avaliação da Capacidade de Recepção das Águas e Zonas Costeiras em Portugal, IHRH.
[3] National Statistic Institute (INE), preliminary results of the 2001 Census.

1.2.2 Major functions of the coastal area

In the Setúbal Peninsula employment structure where this area is included, the 1st sector has an important reduction when compared with the country average, table 3 and figure 9. Nevertheless, the population belongs mostly to the 3rd sector.

Table 3: Population per sector.

Municipality	Population (%)		
	1st Sector	2nd Sector	3rd Sector
Almada[4]	1.0	23.2	75.9
Península de Setúbal[4]	2.2	28.6	69.1
Portugal[5]	13.0	35.3	51.7

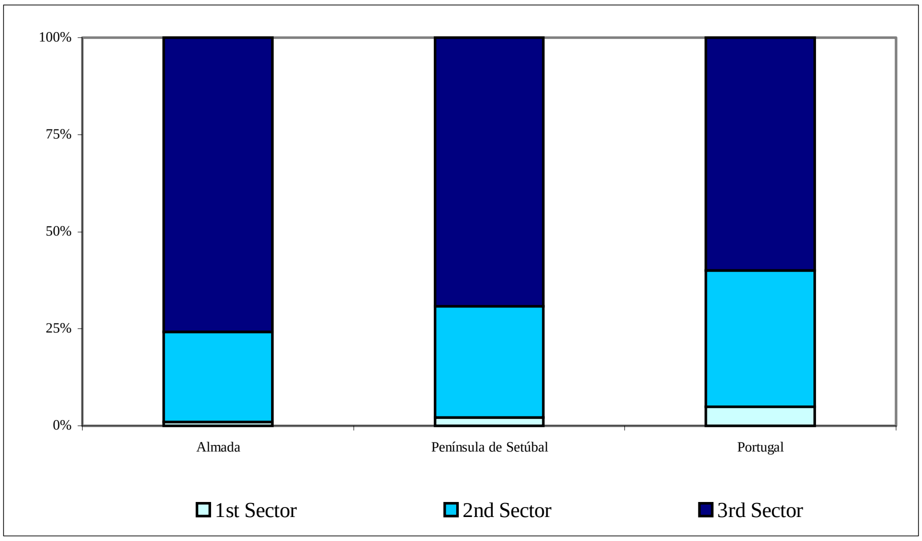

Fig. 9: Population percentage per sector.

In Almada municipality the 3rd sector is the most important one, as it happens in Portugal and in the Península of Setúbal.

- **Tourism** is an important sector of the national economy and an important industry in Almada municipality, due natural to the resources existents in this area. In table 4, there are included some values related to the tourism sector in the year of 2001 in the area and in Portugal.

[4] National Statistic Institute (INE), final results of the 2001Census.
[5] Regional Directorate of Statistic, 2001.

Table 4: Tourism indicators.

Municipality	Capacity of Hotel Facilities (No. of places)	Nights Lodging (No.)	Guests in Hotel Facilities (No.)	Occupation Rate (%)	Average Stay (nights)
Almada[6]	1 306	144 451	45 700	38,1	3,2
Portugal[7]	222 958	33 795 123	9 515 615	42,1	3,6

In 2000, the annual occupation rate for Portugal was 42% and the average stay was 3,6 nights. From the analysis of the previous table we can conclude that the annual occupation rate of hotels in Almada municipality is lower than national rate, approximately 38%, happening the same relatively to the average stay in hotels (3,2 nights). This indicates that even though these areas have good tourism potentialities and great facilities are associated to great natural resources such as, great sand beaches, beautiful landscape and unique geological resources (fossil cliff). Nevertheless, many of the tourists don't appear in this numbers, because they are from Lisbon and other areas of the Metropolitan Area. This tourist it only stays during the day to sunbath and bathing purpose.

The main energy source in Portugal is the oil derived products as well as electricity. In Table 5 there are included some values of energy consumption in the area of the municipality of Almada.

Table 5: Energy consumption in Almada.

Municipality	Diesel (ton)	Fuel-oil (ton)	Domestic Consumption of Electricity (Thousands of kwh per consumer)	Domestic Consumption of Electricity (Thousands of kw/h)	Industrial Consumption of Electricity (Thousands of kwh per consumer)	Industrial Consumption of Electricity (Thousands of kw/h)
Almada[8]	-	-	1,8	174 160	76.3	75 968

1.2.3 Land use

The land use in the area is mainly related with the urbanism, some reduced forested areas. It's also to refer the importance of the estuary Tagus river in the way that it influences the surrounding area including the coastal zone. Most of these urban areas are to much close to the shore line, witch leads to an important number of coastal defences that could be seen on the sandy stretch of Cova do Vapor – Costa da Caparica. In figure 10 (dated from 1996, the last survey) is possible to verify the great increase of the urban area between 1972 and 1996. This aerial view shows the different uses and their interconnection, which gives an image of potential conflicts.

[6] National Statistic Institute (INE).
[7] Anuário estatístico de Lisboa e Vale do Tejo (2001).
[8] National Statistic Institute (INE).

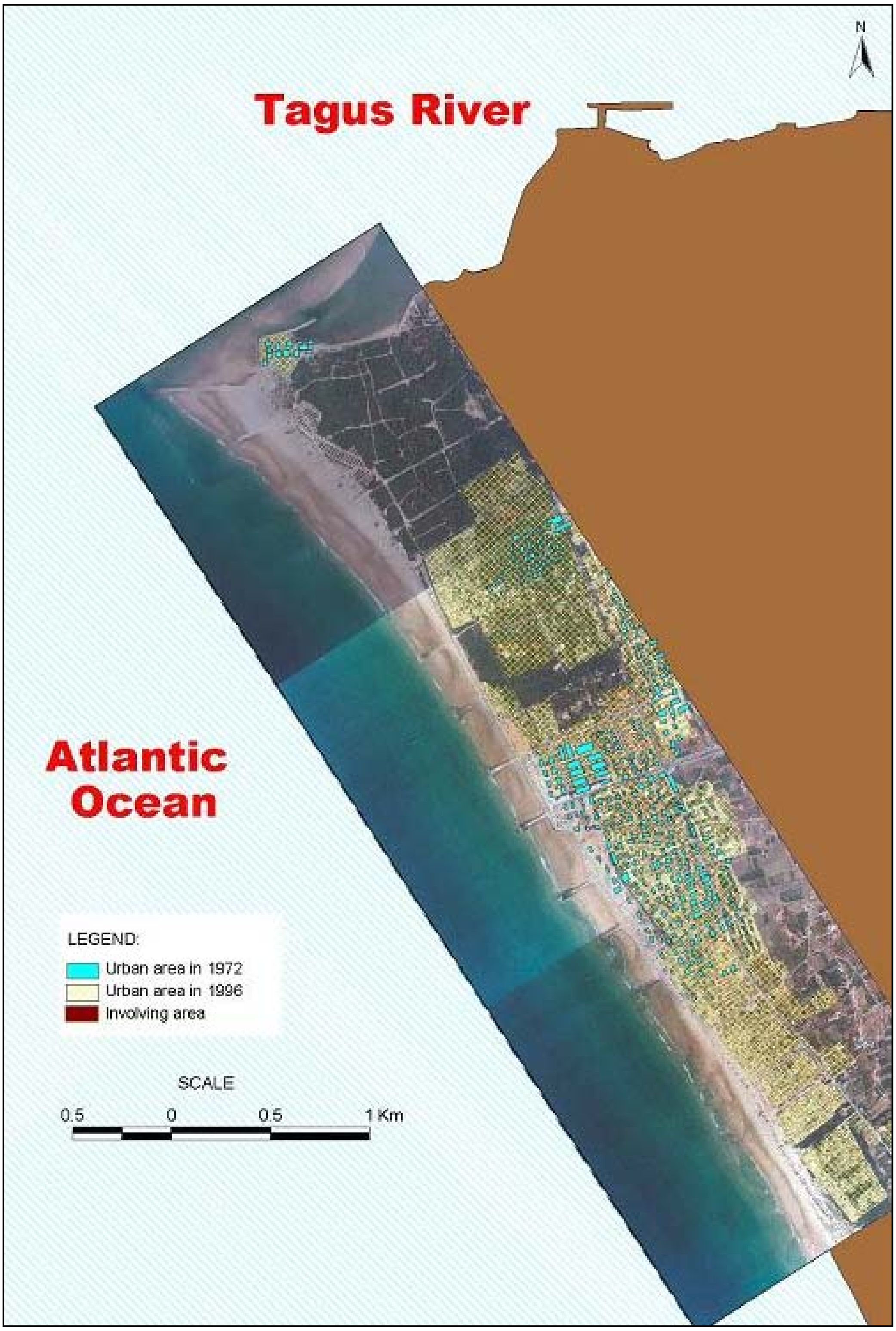

Fig. 10: Evolution of the urban area.

1.2.4 Assessment of Capital at Risk

Has happens in the other cases of wp 4, in Portugal special attention has not yet been taken into account on this important subject, with the exception of the first version of the Risk Maps, but does not give any information about that. The uncertainties and the low scientific capability to forecast extreme coastal forcing events (storms, sea level, tsunamis), 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 capital at risk.

Management plans should be based on an adequate understanding of the coastal dynamics. 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 for several scenarios and timescales of climate variability and direct human influence, vulnerability of beaches, dunes and coastal structures to storms and other extreme events, impact of coastal structures and ecological changes.

2. PROBLEM DESCRIPTION

The coastal zone was interventioned being evident a morphologic evolution extremely dynamic. It is evident that after hundreds of years of progress to seaward direction (sand spit) and submarine accumulation (Bugio bar and Bico de Pato bar), waves and sediment dynamic have change. There are notices of erosion in Costa do Vapor since 1947, reaching the Costa da Caparica village particularly in 1958. In figure 11 and 12 is compared the situation before and starting the erosion process.

Fig. 11: Costa da Caparica beach before starting the erosion process (Barceló, 1971).

Fig. 12: Costa da Caparica in nowadays, after starting the erosion process.

These events and the increasing urbanization, near the dangerous area (coast line), and the insufficiency of the coastal management plans, increase the vulnerability and risk and the need for protection against the coast line retreat, overwashes, flooding and infrastructures destruction.

The Coastal Zone Management Plan (POOC – Plano de Ordenamento da Orla Costeira) for Sintra – Sado (that includes the zone Cova do vapor/Costa da Caparica) recognize some danger situations and some guidelines such as:

- The waterfront is on possible risk situation
- The defense, in relation to the urban nucleus, is realized by the seawall
- The small importance of the groins field on reconstruction of the sand beach
- Attribution of this inefficiency to the fact that groins are short and with small distances between them
- The need of sedimentary dynamic studies in the coastal zone
- It is proposed a great artificial nourishment intervention on north extremity of the stretch, to approach the coast configuration to previous configurations.
- It is indicated that such intervention have to be made with Tagus river inlet sediments
- It is possible to expand the beach area and contribute to the beach of Caparica requalification

This area stands more or less in equilibrium after the groins field construction in Costa da Caparica (1972) and three groins expansion in Cova do Vapor (1968/1971). It is important to refer that the great urban expansion that occurred between 1972 and 1996, despite the fact that the coastal stretch is still vulnerable to storms, even though the existence of coastal defence works. This expansion of the waterfront urban area could reach the adjacent area, provoking the worsening and increasing of sea actions and risks.

In the persistent winter of 2000/2001, the destruction of the beach supports located improperly above primary dune in S. João beach, occurred. In this beach it was verified the disappearance of a great amount of sand and dunes suffered an intense erosive process. The beach support must and will be relocated, but the beach and the dunes, according to the historical knowledge and the recent dynamic, difficultly will recover the profiles by natural actions.

3. SOLUTIONS/MEASURES

3.1 Policy Options

Coastal erosion is a very serious problem and probably will increase as a response to the continuous weakening of the river sediment sources, the dredging works, the mean sea-level rise, the waterfront human settlement, the changing of the morphodynamics pattern and other causes.

The actual urban waterfront is defended by coastal structures that need maintenance and reformulation in focus of the groins length and the seawall crest. In such highly exposed areas, probably the "soft" coastal defences are not effective. It is necessary to adopt a “preventive” policy, but also a “curative” one because of the severity of the present problems.

The research into new coastal defence technical solutions and/or the improvement of the current ones should be promoted. However, it is not expectable that more environmental and cost effective solutions will appear in the next years. The adopted policy in this area was to hold the line. This policy and the new intervention for this area, was the proposal to protect the urban area and expand the beach area through artificial sand nourishment.

3.2 Strategy

In this area, Barceló (1971), the erosion begun due to the collapse of the natural protection (sand spit) afforded by the sand formation north of the beaches, which ends at the zone of the Bugio lighthouse (figure 13).

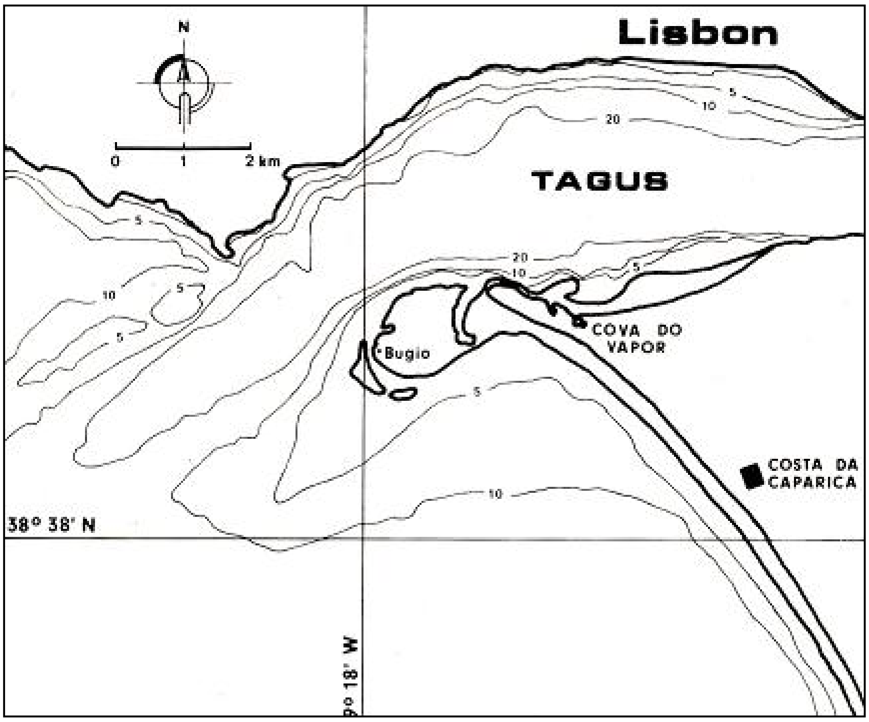

Fig. 13: Costa da Caparica and Cova do Vapor beaches in 1929 (Barceló, 1971).

When this natural protection on the north collapsed, an intense longshore drift begun that formed a spit in the root of the existed formation; this spit was fed in part by the sands carried out northward, the remainder being deposited in the channel of the Tagus estuary, which avoided serious disturbances. This phenomenon has begun to affect Caparica practically in 1960 in the form of the erosion mechanism.

The first defence work was constructed in 1959, namely the groyne named E3. In 1962 was built the groyne E2 and in 1963 was built the groyne E3 as well as the seawall between the groins E2 and E3 (figure 14). These works had as main objective to constitute a hard nucleus to hold the coast line. In 1959 was built a seawall (dike) on the south side (between Cova do Vapor and Costa da Caparica). This seawall had as main objective to avoid the sea flooding during the storms that overwash the existent dunes.

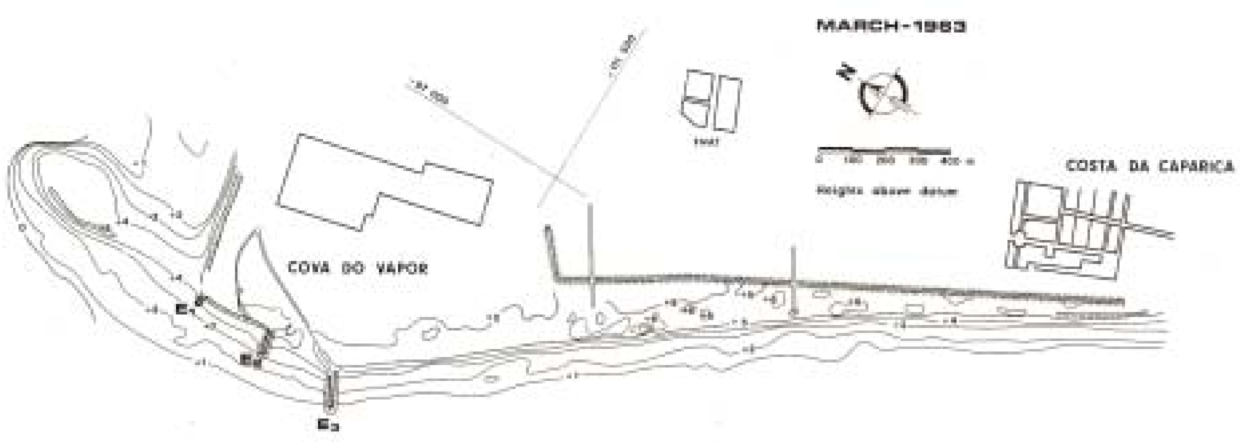

Fig. 14: Costa da Caparica and Cova do Vapor sea defences work plan, 1963 (Barceló, 1971).

The situation became worse in 1964, where the destructions in the central area of Costa da Caparica occurred. The dike was reinforced and a small groyne was constructed. It was evident that the influence of groins built in Cova do Vapor was too small to originate sand accumulation on the southern beach, and reduce/finish the erosive process. Between 1968 and 1971 the three groins of Cova do Vapor were expanded. The bigger one was executed with 600 m length being admitted the necessity to expand even more (figure 15)

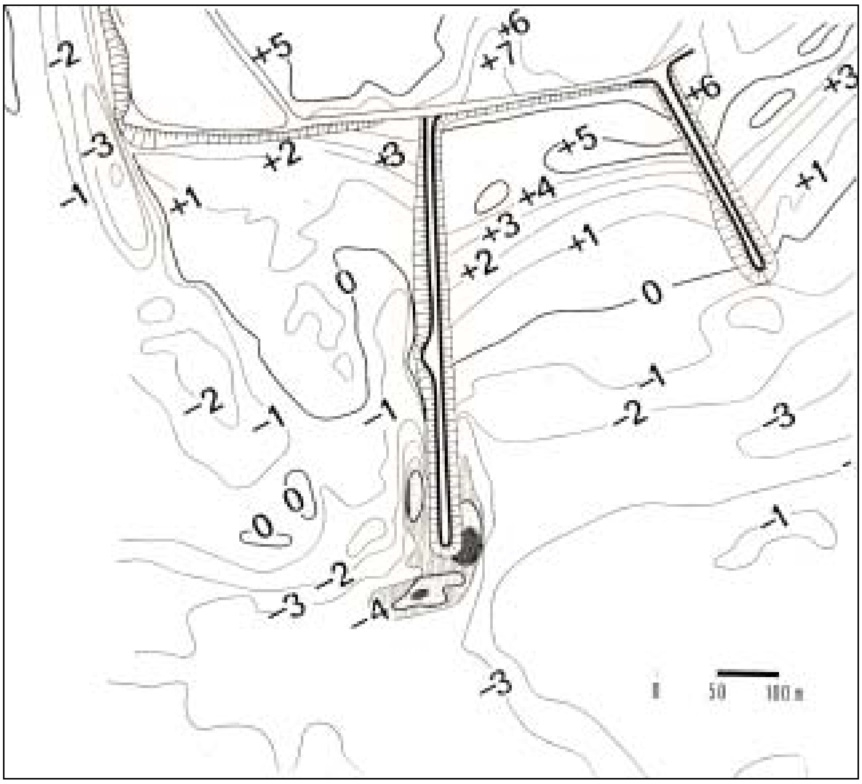

Fig. 15: Cova do Vapor sea defences work plan, 1969 (Barceló, 1971).

With progress of erosion to south, from Cova do Vapor to Costa da Caparica the situation was progressively worsening. Were fixed two defence objectives: protection of urban area against the sea actions and the recreation of beaches. This way the plan included the construction of a seawall with a length about 2500 m and the construction of a groyne field, with seven structures and the foundation on the seawall. The purpose of the groyne field was to catch and fix the small amount of sand that moves on the shore (figure 16).

The groins of this groyne field had in 1973 behaviour considered acceptable but being admitted the review of the groins length. The groins length was around 180 m and the distance between them around 330 m.

Between 1972 and 2000 the coast line was more or less stable. However, with the persistent winter of 2000/2001 was demonstrated that this area is very instable and vulnerable. In Costa da Caparica after the winter 2001/2002, was verified that:

- There is no sand on the beaches, staying partially under water in high tide
- Great part of the sea defences in Costa da Caparica were damaged: generalized groins shortening, destruction of the head and the trunk, lowering and destruction of structures in significant zones

Costa da Caparica beach is used by hundred thousands people during summer and the requalification of its urban seafront and beach is very important. The requalification plan is included on a major national programme for the requalification of urban areas, the POLIS programme.

The proposed solution consists of a commitment intervention to correct the existent solution and the difficulties to forecast the behaviour of the interventions. The experience demonstrates that forecast power is very limited in spite of the significant scientific progresses and the existence of several models in the market. Prudence and good sense are necessary.

On one side, the existent solution of defence can be improved although structurally degraded. This solution worked for 30 years in terms of coastal defence but it didn't provide a beach sufficiently developed for bathing purposes.

Fig. 16: Cova do Vapor and Costa da Caparica sea defences, 1996.

On the other hand, it must be recognized that the extreme hydro morphological phenomenon and the evolutions on a medium and long term are difficult to forecast, face to the actual state of scientific knowledge and the inadequacy of field data.

The medium term (five years) solution in conjunction with the artificial sand nourishment will reduce the length some intermediate groins and will increase the length of the not eliminated ones that will become the structural groins of the defence.

The elimination of some intermediate groins (medium term purpose) will only be realized after monitoring, to demonstrate its inefficiency. The length increasing of the “structural” groins could be then better evaluated. It can also be better evaluated the configuration of that increasing (rectilinear, oblique, in T) or a breakwater highlighted after system monitoring in next years.

The interventions in the defence works with artificial sand nourishment, consist basically in (figure 17):

A) Reshaping of the existent groins:

- Increasing the length of those that will have a “structural” role.
- Reducing the length of the ones that could be, in a medium period, eliminated.
- These operations should be preferentially realized downdrift the structures (north) or updrift (south), in a way to improve the capacity of sand retention.

B) Reshaping of the existent adherent works (seawall) in the urban waterfront:

- Recognizing the vital importance of this structure in terms of defence and the existence of alternatives different than an accentuated retreat of builted waterfront (streets and buildings).
- Walk paths and seaside road rehabilitation.

C) Proceed with artificial sand nourishment:

- With origin off-shore will be transported, sand source already characterized by the Instituto Hidrográfico for this effect, (and/or with origin in dredging works of the harbour administration (APL) for navigation proposes).
- Feeding the beaches updrift (south) the groins field of Costa da Caparica, between the groins of Costa da Caparica and updrift (south) of S. João's beach.
- The several deposit places should always be locate updrift (south) of the areas to nourish, to be modelled by the sea actions, moving sands and to reconfigure the beach. The dunes of S. João's beach will also benefit from this operation.

4. EFFECTS AND LESSONS LEARNT

Coastal erosion is a very serious problem and probably will increase as a response to the continuous weakening of the fluvial sediment sources, dynamic changes, the mean sea-level rise, the waterfront human settlements and other problems.

In this area, as it was described, the erosion problems are very serious and with repercussions in terms of patrimony losses and great socio-economical level impacts. For this reason it is important to defend the area with soft or hard interventions that could reduce the erosion rate. This area has a lack of beach area for the number of users.

This coast line is on evolution, and if nothing is done or planed carefully, it is possible that in the future, important repercussions will occur. The urban area must be restricted to where overwashes and flooding risk are nul. It is not coherent to expand the construction of buildings or beach supports to areas where the risk of destruction is very high, after building sea defences to protect these infrastructures.

Urban expansion along vulnerable coastlines must be stopped. Local authorities and urban planners can not continue to ignore the medium/long term physical dynamic and consequent constraints.

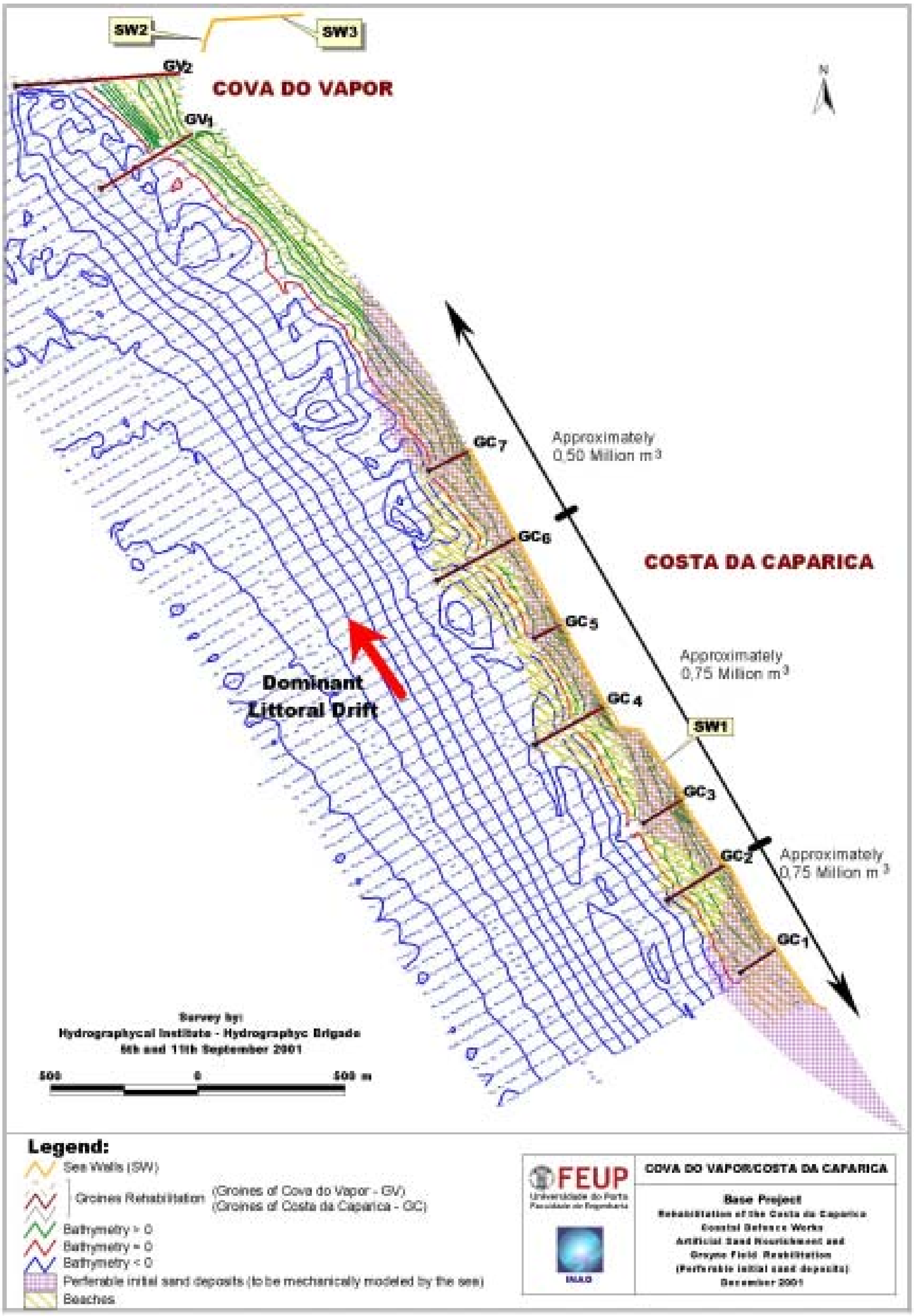

Fig. 17: Costa da Caprica urban seafront requalification.

Between 1972 and 2000, approximately during 30 years and with the help of the groin field and the seawall, the beach and the coast line stayed more or less stable. This is enough time for people forget what happen in the recent past and to build restaurants and beach support in this area.

The sea defences built in 1972 have an in important role in Costa da Caparica defence. The seawall was able to stop Costa da Caparica flooding, but the groin field, actually degraded, was not able to recover the beach configuration. This defence structure has an important role in the understanding and knowledge of the zone dynamics. It can be considered as a field experience that demonstrates that the groyn length was to small for sand retention. This way, these structures were the base for the solution recently presented to the area.

In 2000/2001, persistent sea actions occurred, it was noticed that the area was vulnerable and that there is a possibility of destruction of the sea defences. It is essential to never forget that the area is very instable, with a great probability of change and with a very high physical dynamics.

The capacity to forecast the medium and long-term beaches evolution continues to be very limited due to scientific reasons. Apart from this limitation, the inadequacy of field data (namely, and at least, topo-hydrographic studies) it is an important barrier to the quantification, comprehension and forecasting of the phenomena. It is important to implement a monitoring plan capable to record data and to improve the understanding and comprehension of the dynamics process in the area.

The quantity of sand needed for the artificial sand nourishment is very high (it can reach two million cubic meters) and therefore it is out of question to use just locally available amounts (e.g., using ripping techniques as used in emergency interventions). The sand to be used is located off-shore, or from dredged sediments from harbour maintenance provided that have good quality for this purpose. It is important that sand is similar to the existent on the beach, in terms of size, colour and quality.

5. REFERENCES

Abecasis, F. (1997). *"Caracterização Geral Geomorfológica e Aluvionar da Costa Continental Portuguesa"*, Colectânea de Ideias sobre a Zona Costeira de Portugal, Associação Eurocoast – Portugal, Porto, pp. 9-24.

Aeroguia do Litoral – Portugal (2002). 2ª ediçâo, Publicações Dom Quixote.

Assunção Araújo, M. (2002). "*Relative Sea Level, Diastrophism and Coastal Erosion: the Case of Espinho (Portuguese NW coast)".* Littoral 2002, Faculdade de Engenharia da Universidade do Porto, Porto.

Barceló, J. P. (1971). "*Experimental Study of the Hydraulic Behaviour of Inclined Groyne Systems*" LNEC, Ministério das Obras Públicas, Lisboa.

Universidade do Porto (2001). *Estudo de Reabilitação das obras de defesa Costeira e de Alimentação Artificial na Costa da Caparica*, Projecto Base.