Public document

Response of the Coastline to Climate change

Specific Report for the RESPONSE Project LIFE-Environment programm: Evolution of coastal risk (erosion and marine flooding) for the Aquitaine and Languedoc-Roussillon pilot regions

Final report

BRGM/RP-54718-FR
September, 2006

Geoscience for a sustainable Earth

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Study conducted as part of research projects
2003-2006 RISCOTE18/PC3

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Synopsis

As stated in the project specification document, the RESPONSE project aims "*to develop sustainable strategies for management natural hazards in coastal areas taking account of the impact of climate change".*

The RESPONSE project received funding from the European LIFE–Environment program. BRGM's participation in the project was ensured jointly by European funding and a research endowment to BRGM from the Ministry for Research.

The purpose of this report is to define BRGM's role in the RESPONSE project and to explain the results obtained for the two French pilot regions, Aquitaine and Languedoc-Roussillon. This document will be appended to the final report submitted by the RESPONSE project's coordinator. It also aims to be comprehensive so as to further dissemination of the methodology.

The first chapter describes the mapping methodology, starting with the existing data on through to the risk map, underlining adaptations that were made of the method initially proposed, that was based on experimental studies conducted for south-eastern counties in England (Hosking *et al.,* 2002; Cooper *et al.,* 2002). For each step of the mapping process, an analysis of the results for the considered regions is provided.

The first phase was to map "coastal behaviour systems" that are thought to respond in a coherent manner to the impact of climate change. This was conducted using existing data on geomorphology, coastal processes, historical hazard events as well as existing defence works. The result of this mapping process underlines an existing vulnerability of the coastline in both regions with respect to erosion and marine flooding on most of the low-lying sandy Languedoc coast, and also on parts of the Aquitaine sandy coast where the dune system is cut by coastal river outlets. The efficiency of existing defences on these coastlines is questionable in some places. The cliff-lined coast of Aquitaine, made of weathered sedimentary rocks, is subject to ground movement hazard, while the hard Cambrian rocks on the Roussillon coast proved to be more stable.

The second phase was to propose a regional adaptation of the modelling of global climate change impacts. To answer to the end-users' demands and to obtain a wider scope of the likely future critical conditions, the most pessimistic scenario is chosen for the potential rise in sea level, which is added to the maximum present-day sea level at high tide and to the known storm surge specific to each considered region.

The third phase was to evaluate the change in the erosion and marine flooding hazards, judged by a panel of experts called on to assess the impacts of the regional climate change scenarios upon the coastal systems described above. Both regions exhibit an increased level of the hazards considered, to degrees ranging between significant and drastic. However, due to the sedimentary stock present in dune systems, the sandy Aquitaine coast displays a better capacity for adaptation to change than the Languedoc-Roussillon lidos. Existing hazards persist and new segments would join the list of those endangered, such as small pocket beaches, where little sedimentary stock is found.

The fourth phase was to evaluate which assets would be placed at risk by an increase in the coastal erosion and marine flooding hazard. In Aquitaine, mainly urbanized and tourist assets concentrated around the outlets of coastal rivers on the sandy coast and on the cliff-lined coast of Pays Basque will be endangered, in addition to industrial assets that in spots could be flooded in the hinterland. Due to widespread development of the Languedoc-Roussillon coastline, urban, tourist, industrial and agricultural assets would be placed at risk, more specifically those inland from the systems of lidos.

Throughout this procedure, “hotspots” defined as areas requiring highest priority for attention, were identified, first as existing and studied hotspots (SMNLR, 2003),then as spots or streches of coast where the hazards are likely to increase drastically, and lastely as spots (or streches of coast lines) where drastically increasing hazrds would put assets as risk (this last step answering the RESPONSE methodology definition “as sectors classified at higher risk on the basis of present or future hazard maps”. Individual statement files of some of those hotspots is given in Appendix 4.

The second chapter presents the estimates obtained for the present and future costs of managing coastal risks, although this task (Task 2) has proven difficult to accomplish according to the terms of the project submitted to LIFE–Environment.

Accompanying this report are appendixes relative to the report content, and also ones presenting complementary information gathered during that project such as the status of research on climate change and coastal environments in France, and the assessment of dissemination efforts for the RESPONSE project.

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1. Presentation of the RESPONSE Project

1.1. CONTEXT

1.1.1. The coastal zone at the beginning of the 21st century

An interface between the continental and marine environments, the coastal zone is a fragile domain where a multitude of ecological and human constraints are interacting. It is subject to a certain number of physical hazards that render it fragile and unstable. Shoreline retreat due to erosion is observed over nearly 20% of Europe's coastlines (Eurosion, 2004). Furthermore, a substantial proportion of the coastline is composed of low-lying sandy coast that afford very low-elevation inland regions with unreliable protection against marine flooding. Lastly, the effects of meteoric water, hydrogeology and the sea destabilize cliff-lined coasts by favouring landslides and collapses.

The coast likewise constitutes an area associated with high socio-economic and environmental stakes: dense population and harbour, industrial and tourist activities for the former, wetlands and biodiversity for the latter.

Over past decades, because of the importance of these stakes, coasts have been "protected against" the sea ("*hold-the-line*") through more or less rigid methods ("hard" and "soft" engineering). The effectiveness of these defences is often open to debate, for they were constructed to solve a local problem whilst disregarding effects potentially incurred by neighbouring coasts.

More recently, the notion of integrated management of the coastal zone has emerged. This concept, as stated by the European recommandation (30th may 2002) has modified defence strategy for coastal zones by obliging coastal risk management projects to integrate the entire sedimentary cell at very least. Alternatives to "hard-engineering" solutions are being proposed, such as strategic retreat and recourse to "soft-engineering" techniques, "beach nourishment" among them.

1.1.2. Global warming

Climate change and variations in sea level are natural phenomena that have been occurring throughout geological times. Following the end of the last ice-age, during the Holocene period, sea level rose rapidly, then stabilized for several thousand years near its current level.

Measurements and observations made over recent decades reveal that sea level was not only rising, but that this rise was actually accelerating (12 cm in one century, measured on tide gages of the SHOM - Service Hydrographique et Océanographique de la Marine) in Marseille and Brest. A connection has been made between this situation and global warming caused by human activities.

According to IPCC 2001 models (Intergovernmental Panel on Climate Change), sea level can be expected to rise at an increasing rate during the century to come. Indeed, as dealt with in greater detail in section 2.5, whatever social and economic hypothesis are referred to, scenarios relying on greenhouse gas emission models systematically predict global warming, albeit to varying degrees. How much the sea level rises will depend on temperature increase. The models are predicting a 13 to 88 cm rise depending mainly on the hypotheses taken into account. The most commonly accepted hypothesis, which presupposes an economic scenario favouring technological advances and the progressive replacement of fossil fuels by renewable forms of energy (the Rio and Kyoto conferences), predicts a 35 to 40 cm rise. This higher sea level would be accompanied by an increased frequency and strength of storms and by possible changes in ocean currents.

Although these models and scenarios are hypothetical for the time being, they nevertheless need to be taken into consideration in order to gain an idea of the impact global warming would have, notably on the coastal environment.

1.1.3. The impact of global warming on the coastal zone

Global warming will have a major impact on the coastline and on coastal processes more specifically by the effect of a sea level rise and increased intensity and frequency of storms events.

A certain number of projects have enabled the present-day coastal erosion phenomenon to be assessed on both a European scale (CORINE coastal erosion,1987 and Eurosion 2004) and a local scale (P.L.A.G.E. in NPC, the Aquitaine coastal observatory-OLA-, many coastal prevention plans (Plans de Prévention des Risques) – cliffs, etc.). Other projects have addressed the risk of marine flooding (INTERREGG/ SAFECoast and others preventions plans for marine flooding).

Many coastal risk management plans have been or are in the process of being prepared. Although the probable impact of global warming on the coastline is, in principle, generally recognized, it is rarely integrated into these management plans.

1.2. THE RESPONSE PROJECT: OBJECTIVE AND APPROACH

1.2.1. The objective

As stated in the project specification document submitted to DG XII in the framework of the European LIFE–Environment program, the RESPONSE Project's objective is "*to develop sustainable strategies for management of natural hazards in coastal areas taking account of the impact of climate change*". The goal set is accordingly to develop a tool that will afford a good understanding of the effects of climate change on coastal risks, so that this concept will be integrated into management and development planning. To do so, one must:

- determine the probable impact of climate change upon the shoreline by assessing changes in hazards and risks as of 2100 in terms of erosion, marine flooding and landslide;
- estimate present and future coastal defence costs;
- analyze the strategies currently implemented and propose decision-support tools and good practice guidelines;
- transfer this methodology to the decision-makers.

1.2.2. Project organization

The project structure and coordination were ensured by the Isle of Wight Coastal Centre for Environment (IWCCE).

The project team includes scientists from France (BRGM), Italy (IRPI/CNR[1]) and Great Britain (Halcrow, Ltd., under contract from IWCEE). It also integrates end-users affiliated with the Marche region and the Pesaro i Urbino province, in Italy, with the county of Scarborough North-East Coast) and SCOPAC (Standing Conference on Problems Associated with the Coastline, Southern England), in the U.K., with the Maritime Bureau of Gnydia, in Poland. In France, data and advices were collected from SMN Gironde and DDE Landes in Aquitaine, and from SMNLR and EIDMéditerranée, in Languedoc-Roussillon).

Five pilot regions (Figure 1) were selected to help in developing the project methodology.

The project is broken down into six main tasks:

- Task 1: coordination;
- Task 2: estimating present and future coastal risk management costs;
- Task 3: assessing changes in coastal hazards and risks in regards to climate change:
  - · compiling existing data (coastal processes, known coastal hazards, geomorphology and existing defences). Defining Coastal Behaviour Systems (CBS) *i.e.*; geomorphological units that behave uniformly with regard to climate change,
  - · adapting climate change hypotheses to regional contexts,
  - · assessing changes in hazard and risk.

[1] Accronyms used in this report are explained in Table 1, at the end of this chapter.

Organisms	BRGM	Bureau de recherches géologiques et minières
	CELRL	Conservatoire des espaces littoraux et des rivages lacustres
	CETMEF	Centre d'études techniques maritimes et fluviales
	CNR/IRPI	Consiglio nazionale delle ricerche/Istituto di Ricerca per la Protezione Idrogeologi
	DDE	Direction départementale de l'Équipement
	DIREN	Direction Régionale de l'Environnement
	EIDMéditerannée	Entente interdépartementale pour la Démoustication - Méditerranée
	IFREMER	Institut Français de Recherche pour l'Exploitation de la MER
	INSEE	Institut national de la statistique et des études économiques
	IPCC	Intergovernemental panel for Climate change
	IWCCE	Isle of Wight Center for Coastal Environment
	MEDD	Ministère de l'Écologie et du développement durable
	MIACA	Mission Interministérielle pour l'aménagement de la Côte aquitaine
	MIAL LR	Mission interministérielle de l'aménagement du littoral du Languedoc Roussillon
	MIES	Mission Interministérielle sur l'effet de serre
	Munich Re	Reinsurrance company
	OLA	Observatoire du littoral aquitain
	ONERC	Observatoire national sur les effets du réchauffement climatique
	ONF	Office national des forêts
	SCOPAC	Standing Conference on Problems Associated with the Coastline
	Service des domaines	Service fiscal des espaces publics
	SMN	Service maritime et de la navigation
	SMNLR	Service maritime et de la navigation en Languedoc-Roussillon
Data bases	CORINE land cover 1990	Base de données issues du programme de CoORdination de l'InformationN sur L'Environnement
	Eurosion	Projet européen financé par Direction Générale Environnement-DGXII sur l'érosion côtière actuelle
	IPLI	Inventaire permanent du littoral
Divers	DPM	Domaine public maritime
	GIS	Geographic Information system
	NGF	Nivellement général de la France
	PPR	Plan de prévention des risques
	ZICO	Zones importantes pour la conservation des oiseaux
	ZNIEFF 2	Zones naturelles d'intérêt écologique pour la faune et la flore (priorité 2)
	ZNIEFF1	Zones naturelles d'intérêt écologique pour la faune et la flore (priorité 1)

Table 1 - List of accronyms quoted in the report.

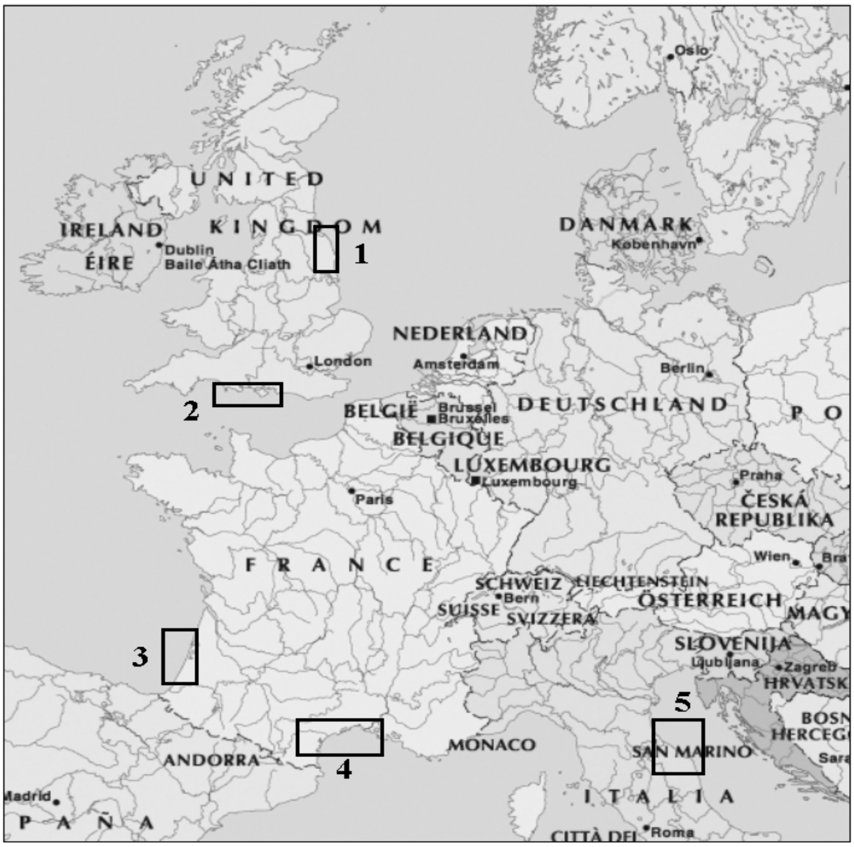


Figure 1 - Location of the pilot regions in Europe (© European Community, 2006): Scarborough County (1), the Isle of Wight and counties in southern England (SCPAC, Dorset and Kent) (2), the Aquitaine region (3), the Languedoc-Roussillon region (4) and the Marche region (5).

A preliminary methodology for accomplishing this task was proposed by IWCCE on the basis of work already conducted on the south coast of England by SCOPAC. This methodology has been adapted to take into account various regional characteristics and so it could be transposed subsequently to the scale of the coasts of Europe.

- Task 4: a comparison of coastal risk management policies within the European Union. Preparing guidelines in methodology and good practice to help methodology transfer to other regions;
- Task 5: oversight and adjustment of the project's objectives by the end-users' working group as it is being conducted in order best to satisfy the needs of coastal risk managers;
- Task 6: disseminating knowledge gained during the RESPONSE project to local authorities and stakeholders involved in coastal zone management and in anticipating climate change.

BRGM's contribution to the project has mainly concerned Tasks 2, 3 and 6, and Task 4 in part for the two French pilot regions.

1.2.3. The choice of French pilot regions

The two French regions were chosen in contrast to Southern England and Region of Marche, as representative of a predominantly sandy coast line coexisting with a part that is lined with cliffs.

Both are known to have suffered from coastal hazards and to have benefited from defences built “against the sea”, mainly in the 20th century. In both regions the efficiency of this management is questioned, leading to management planning in the years to come. However, this planning is conducted at a local, township, scale and does not often take into account the impact of climate change. Two case studies of such projects (Cap Breton in Aquitaine, Lido of Sète in the Languedoc-Roussillon region) are given in Appendix 1.

Also, during the 20th century, both regions have experienced a sharp increase in population density in the coastal zone and a strong tourist-orientated development. This development is expected to continue growing in the coming decades (www.INSEE.fr, diagnostic du littoral aquitain, 2005, Diagnostic du littoral languedocien, 2000).

Many stakeholders ranging from local authorities ones to a national level are concerned by the coastal risk problem and in the recent years they have engaged in joint efforts aimed at a sustainable and integrated management of the coastal environment:

- in Aquitaine, the “Observatoire du littoral aquitain” is the result of concerted action on the part of state local authorities and of other institutions such as BRGM, IFREMER, and the *Office National des Forêts* with the objective of gaining a better knowledge of the coastal environment as a tool for an integrated management;
- in the Languedoc-Roussillon region, MIAL (the *Mission Interministérielle de l’Aménagement du littoral*) was created in 2001. One of its objectives was to achieve a proper balance between development and the preservation of the environment. It brings together partners from local authorities, state representatives as well as economic and environment actors.

Nevertheless, although both regions will have to seriously take into account the impact of climate change, each region displays specific characteristics with respect to its geomorphology, coastal processes and development.

The following section gives a short presentation of both pilot regions. Most details and illustrations will be provided in the coming chapters as a result of the mapping process and in the companion maps (CD-Rom).

a) The Aquitaine region

Figure 2 is taken from the geological map of France at 1:1,000,000 scale (Copyright BRGM): it shows the geology of Aquitaine with a long Quaternary sandy coast from the Pointe de Grave to Anglet, and a Cretaceous and Tertiary rocky coast from Anglet to the Spanish border. The Gironde estuary, as an atypical case, has not been dealt with in this study.

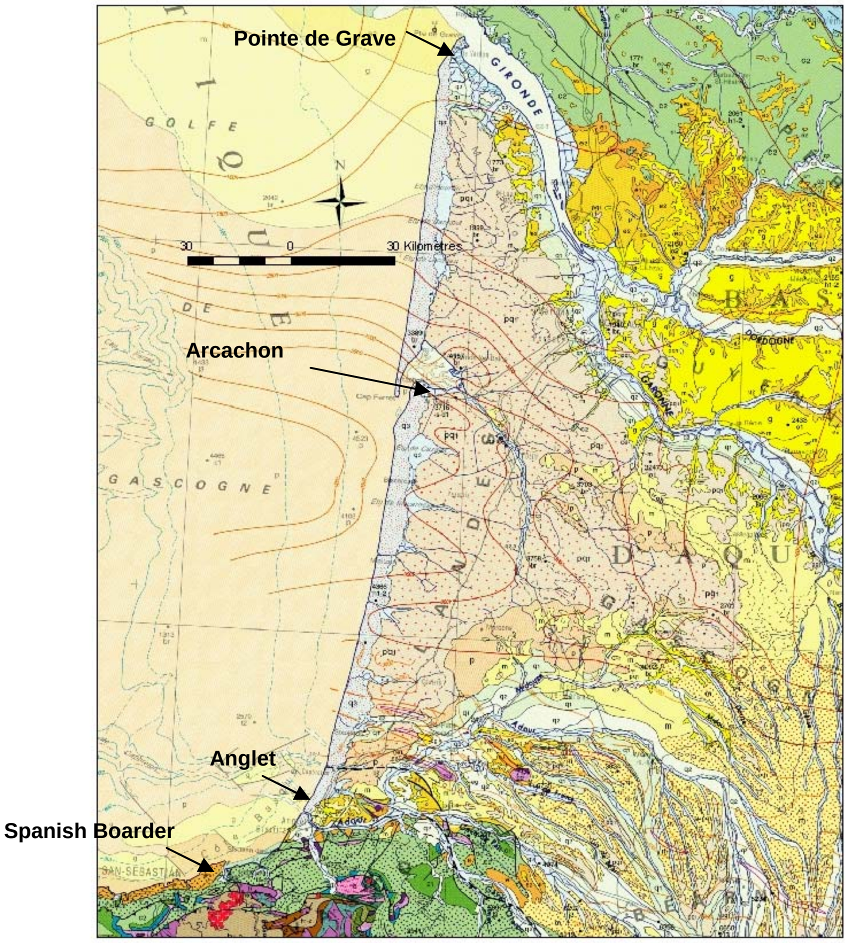


Figure 2 - The geology of the Aquitaine region derived from the geological map of France.

- **The sandy coast**

The sandy Aquitaine coast is 200 km long and extends along two administrative units, the Gironde Department (from the Gironde estuary to the Arcachon Bay) and the Landes (from the Arcachon Bay to the Adour estuary). From the Gironde river mouth to Anglet (the Adour river mouth), this coastline is composed of dune systems; it is interrupted by the Arcachon semi-enclosed bay and small outlets of coastal rivers.

The sandy coast is composed of sandy ridge-and-runnel beaches systems, longshore sediment drift related, backed by dune systems that are large (several kilometres) and high (over 20 m high). Those dune systems are cut by coastal rivers outlets.

Development planning for the Aquitaine region (MIACA, 1967) provided for development behind existing urban spots, perpendicular to the coastline, which preserved long stretches of the sandy coastline from urbanization. However its focus was primarily on urbanization, and it somehow disregarded coastal risks.

Apart from the Arcachon Bay, which contains a high density of urban, tourist and agricultural assets, human occupation of the sandy coast is concentrated in several towns of tourist attraction, most of them situated near the outlets of coastal rivers and in some instances linked to harbour infrastructures in the hinterland.

While the northern part of this system, from the Pointe de Grave to Soulac, is heavily protected by a continuous breakwater system, shielding the dune system from breaching and that has been in place since the 19th century. From Soulac to Anglet, defense works are concerned with preserving urbanised spots and consist mainly of groynes, often composed of wooden pilings and rocks. River outlets are protected by jetties. Urbanised shorelines are often protected by seawalls, used as a base for communication and tourism infrastructures.

In view of the high cost of maintenance and reinforcing of these works, and questions over their efficiency, new projects involving “soft” methods and integrated management principles have been elaborated, which try to accommodate the urban and tourist use of the coastline. The Cape Breton project, described in Appendix 1, intends to partially restore the longshore sedimentary transit by building an hydraulic by-pass system that should bring sand to the eroded beach south of the transversal works.

- **The cliff-lined coast**

The Pyrénées-Atlantiques Department (French Basque coast) extends from the Adour river mouth to the Spanish boarder. The coastline consists of tertiary and cretaceous cliffs and hills, drawing rocky points and sandy coves where beaches are narrow, often overlie bedrock and possess little sedimentary stock. The cliff system is interrupted by several bays (Hendaye, Saint-Jean-de-Luz…).

Most of the cliff-lined coast is urbanized and has been involved in traditional tourism since the 19th century. Many industrial assets are linked to this urbanization, mainly concentrated along the course of the Adour river.

Many instances of ground movement (Mallet *et al.,* 2005) have been occurring on those cliffs, due to their lithology (weathered and aquiferous sedimentary rocks), their geometry (alternating hard and soft rocks, dipping seaward) and hydrodynamic context. Anthropic pressures have in some spots been an aggravating circumstance.

Over the past two centuries, many protective structures have been installed to combat that cliff movement hazard. Cliff engineering (involving base abutments, palings, seawalls, shotcrete...) has been conducted (Alexandre *et al.*, 2003). Most of the cliffs are concerned by such works, which now have to be maintained.

Recent approaches underline the major role played by groundwater in cliff movements, and drainage methodology is a useful method for decreasing if not preventing cliff movements.

Narrow foot-cliff or pocket beaches, lying on bedrock, here little to no sedimentary stock, other than weathering products of the cliff.

b) The Languedoc-Roussillon region

Figure 3 is taken from the geological map of France at 1:1,000,000 (copyright BRGM) scale and shows the geology of the Languedoc-Roussillon region with a long Quaternary sandy coast extending from Grau-du-Roi to Argeles, and a Paleozoic rocky coast from Collioure to the Spanish border.

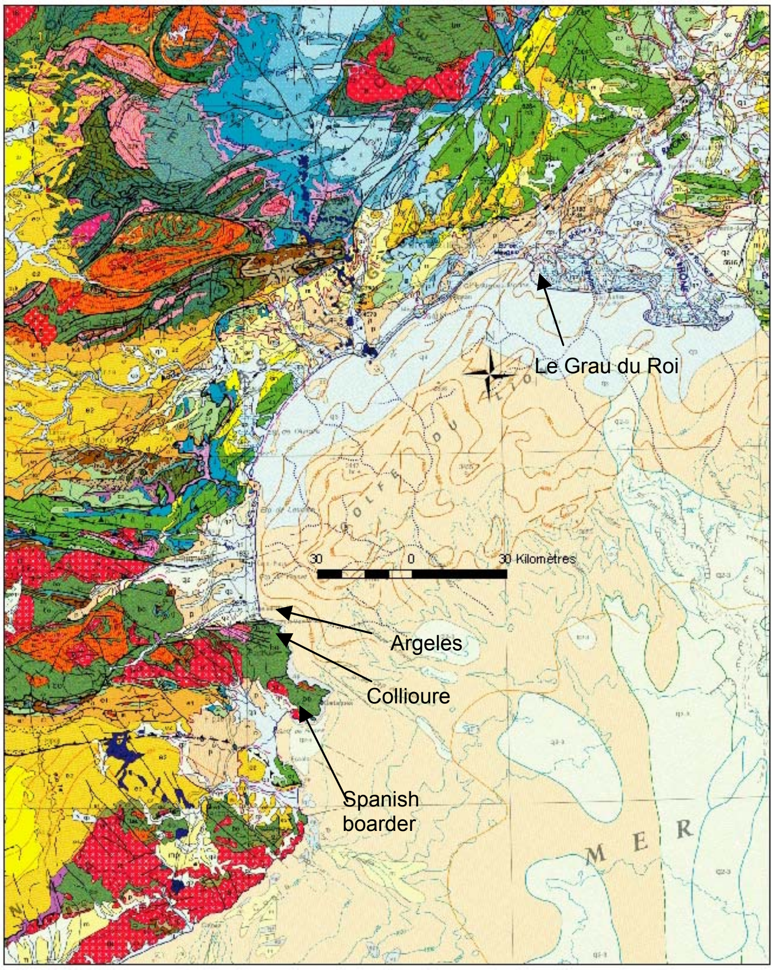


Figure 3 - The geology of the Languedoc-Rousillon region derived from the geological map of France.

- **The sandy coast**

From the west of the Rhône delta (Grau-du-Roi) to Argelès (including the Gard, Hérault, Aude and part of the Pyrénées-Orientales Departments), the Languedoc-Roussillon coast is composed of a narrow and often steep beach, fringing low-lying

(~5 m high) and narrow dune systems called "lidos" limited landward by salt lagoons or marshes and linked to the sea by narrow and initially divagating inlets called "graus".

Several rocky points (Sète, Agde…) mark the limit of the main sedimentary cells. Sedimentary drift is linked to the dominant winds and can be longshore or crossshore; and may be modified by landward transport in case of storms.

During the same period as for Aquitaine coastline (1963-1983), the development planning of the Languedoc-Roussillon coast (Mission Racine) aimed to protect existing urbanization and settle new resorts such as la Grande-Motte, whilst preserving nature zones such as backshore lagoons. However, coastal risk once again was disregarded in this planning.

This narrow, low-lying coastline is fragile, and erosion is known to be taking place in a number of spots. Storm events have also been responsible for storm surge and marine flooding. Urban development contributes to aggravating these hazards.

Urbanization and tourism are developed extensively all along the coastline, whereas industrial and agricultural assets are located in the hinterland, in association with the backshore salt lagoons.

In the second half of the 20th century, the importance of the assets at stake prompted an ambitious building and maintenance program (groynes and breakwaters). However, the siting of these defence works was often decided in answer to local problems and these have in many cases generated problems in adjoining areas by impeding longshore drift. Heavy urbanization also has trapped most of the sedimentary stock that would have lent adaptive capacity to the system.

Recently completed or forthcoming projects do take in account the concept of integrated management and tend to seek a balance between maintaining existing works and using "soft" strategy, such as partial retreat. An example is given in Appendix 1, for the restoration of the Lido of Sète.

- **The cliff-lined coast**

The cliff-lined coast stretches from Collioure to the Spanish boarder (the southern part of the Pyrénées-Orientales Department. Cliffs are composed of Cambrian metamorphic rocks, dipping steeply into the sea, drawing points and coves with little or no beach. Beaches are limited to a few sheltered bays.

Little is known in terms of catastrophic events linked to erosion, ground movement and flooding, probably due to the hard lithology of the cliffs, poorly aquiferous and less prone to weathering.

Urban and tourist development of this part of the coast is concentrated around the sandy bays (Collioure, Port-Vendres and Cerbère) since most of the coastline is composed of agricultural land and areas of environmental interest.

Unlike the Basque coast, little work has been undertaken to protect this coast, apart from harbour infrastuctures. It should nevertheless be emphasized that sandy pocket beaches have little or no sedimentary stock.

1.3. OBJECT OF THIS REPORT

The object of this report is to inform on the results of BRGM participation in the project and the results obtained. It is to be appended to the final report submitted by the RESPONSE project's coordinator. Thus, the document is organized into two main chapters describing the process of mapping and the results for the two French "pilot regions", and the results of investigation for present and future cost of coastal risk management.

Description and results of the mapping process is also to be disseminated, for further application and improvement of the approach. Therefore this chapter was extensively developed.

Appendices 2 and 3 refers to other and complementary tasks of the project:

- Appendix 2 gives an overview of French research in the coastal environment and climate-change fields and of the policies implemented in these two areas on national and regional scales;
- Appendix 3 gives the current situation regarding dissemination of RESPONSE results by BRGM attached to the report, a CD-ROM of the maps is provided as well as appendix giving

The mapping methodology has also been detailed in this report in order to be a guide for further applications.

Different organizations, projects, or databanks will be further quoted by their acronym, in reference to the following Table 1.

Maps 1 through 7 resulting from the mapping process are provided in digital form on a CD-ROM accompanying the report, as referred to in Appendix 4.

The Geographical Information System that allowed these maps to be established will remain the property of BRGM, and its communication could be envisaged subject to terms to be agreed upon with the applicants under a data-exchange agreement.

2. The mapping process

2.1. PRESENTATION OF THE METHOD

Mapping the evolution of climate-change-related hazards and risks consisted of four phases:

- the mapping Coastal Behaviour Systems (CBS);
- a choice of climate change scenario and regional adaptation;
- application of the climate scenarios to the CBS and assessment of changes in hazards;
- a cross-comparison of the map of the issues at stake with that of changes in hazard; risk analysis.

In the first phase (Figure 4), Coastal Behaviour Systems were defined. These systems are a result of the compilation, mapping and cross-comparison of data characterizing the coast (geomorphology, coastal processes, hazards, protection works and defences - Maps 1 to 3, Appendix 4).

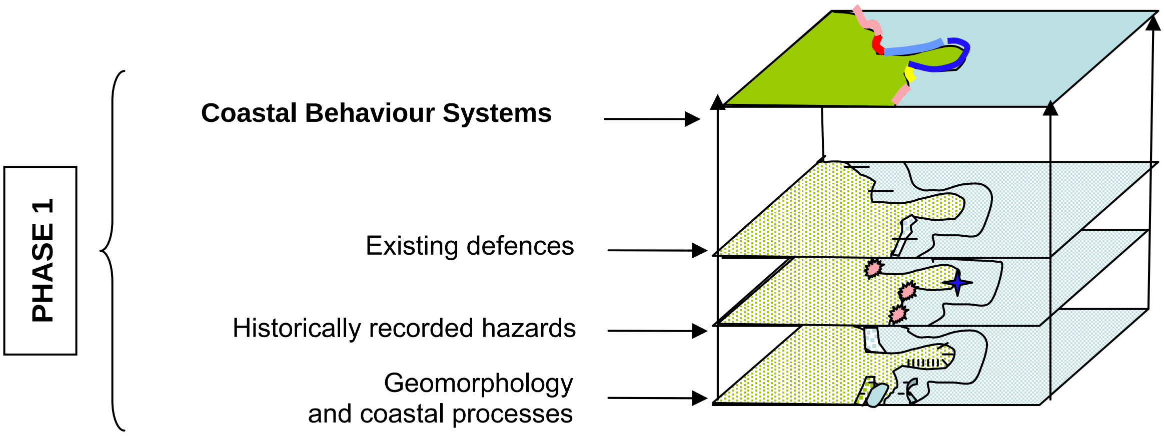


Figure 4 - Diagram illustrating the method used to define Coastal Behavour Systems (CBS).

In the second phase (Figure 5), several climate-change scenarios were discussed, and one of these was selected on the basis of climate models proposed by the Intergovernmental Panel on Climate Change (IPCC, 2001) and regional meteorological and hydrodynamic characteristics.

The purpose of the third phase (Figure 5) was to apply this scenario to each of the previously defined coastal systems to foresee their evolution in terms of hazard changes (Map 5). The hazards considered are erosion, marine flooding and cliff instability. This approach was validated by a panel of experts on coastal issues.

Lastly, the map of assets (Map 4) was merged with the hazard change map so as to identify the sectors and assets affected by increased risk (Figure 5).

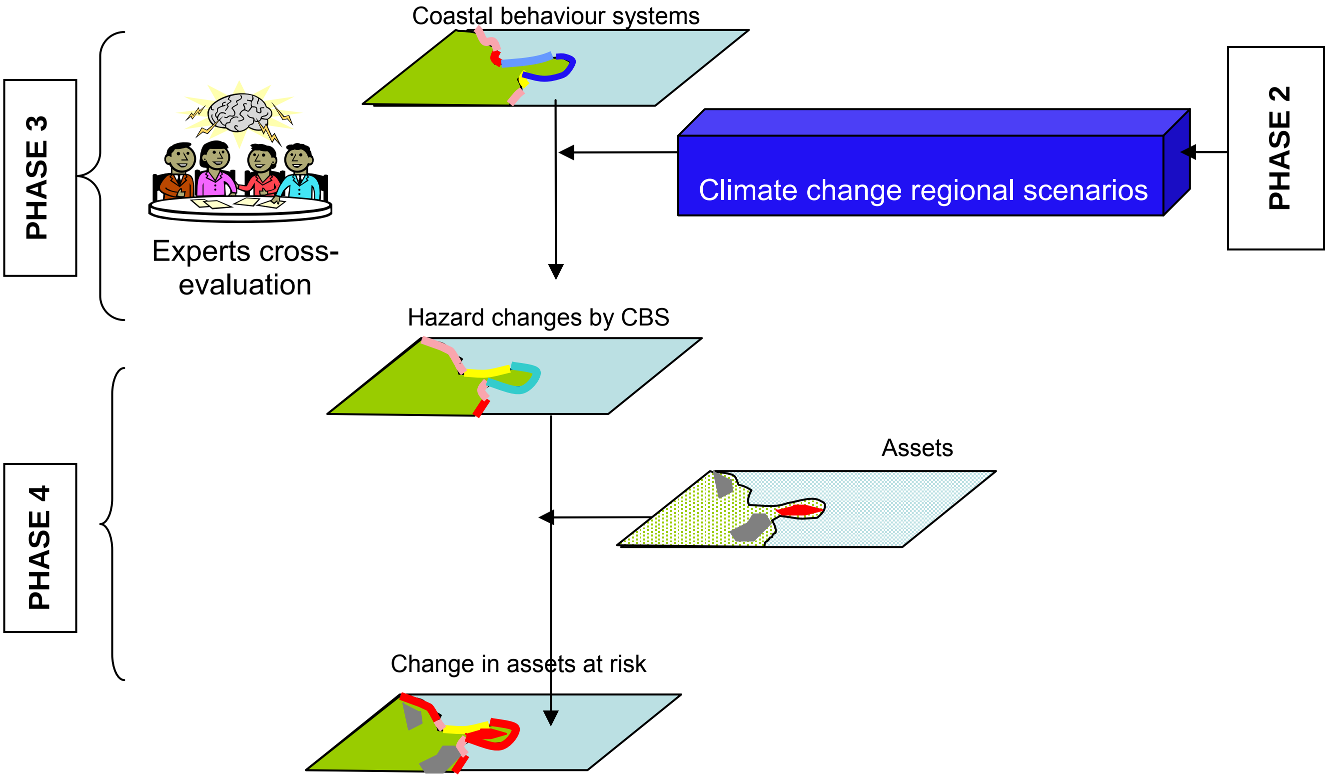


Figure 5 - Diagram for phases 2 to 4.

2.2. DATA AND METADATA SOURCES

2.2.1. Metadata

Table 1 in Appendix 5 provides the sources of the data used; all data were converted to ESRI format (*shape files*). Some were integrated in their original form. Others were modified, computed or digitized to meet RESPONSE Project needs.

The original data sets were drawn from:

- the EUROSION database (http://dataservice.eea.eu.int/dataservice/metadetails.asp id=738);
- the SMNLR GIS;
- the IPLI (permanent coastal inventory) database (http://siglittoral.3ct.com/);
- IFREMER or CNEXO data (http://www.ifremer.fr/anglais/);
- SHOM (http://www.shom.fr/) (the naval hydrographic and oceanographic bureau);

- ONF (national forestry bureau) (http://www.onf.fr/);
- the Aquitaine coastal observatory (http://littoral.aquitaine.fr/);
- IGN (http://www.ign.fr/) (National Geographical Institute);
- the Corine Land Cover database (http://www.ifen.fr/donIndic/Donnees/corine/produits.htm);
- the GIS of the Aquitaine and Languedoc-Roussillon of DIREN (http://www.ecologie.gouv.fr/article.php3?id_article=1294);
- administrative data contained in MapInfo;
- administrative data made available by ESRI;
- data from diverse studies quoted in the bibliography (Durand P., 1999; Mallet *et al*., 2005; Alexandre *et al.*, 2003; Oliveros *et al.,* 2004; etc.).

The metadata are subdivided into two main directories, *i.e.*, general and coastal-specific data, under which a number of secondary categories were defined. The data sets that were used to prepare the maps are organized in the GIS according to these two directories. Each data set is identified by name, description and source, as well as by whether or not it was modified for the purpose of inclusion in the maps.

2.2.2. Data

Table 2 in Appendix 5 lists the fields derived from these 48 data sets in order to build the Aquitaine/Languedoc-Roussillon RESPONSE GIS that would enable the RESPONSE maps to be prepared. Most of the data were integrated into the GIS using as a reference, the coastline from the EUROSION database plotted on a WGS84 projection system so it could be mapped at 1:100,000 scale, the one chosen for the final map.

2.2.3. Data ownership

All the data used in the RESPONSE project are either available to the public, obtained directly from the holder of the data, and used in compliance of conventions between data owners and BRGM. Their sources are listed in Table 1 (Appendix 5) and, as needed, in following sections describing the mapping process.

2.3. COMPILING AND MAPPING EXISTING DATA

2.3.1. Geomorphology and coastal processes maps (Maps 1a and 1b)

The geomorphology map (Appendix 4, Map 1a) and the map of coastal processes (Appendix 4, Map 1b) were prepared in accordance with the methodology defined in the RESPONSE Project and presented in the March 2005 interim report.

a) Principle

Figure 6 presents the four divisions and their corresponding features used to describe coastal geomorphology. The classifications in italics are ones that have been modified or added, as compared with the listing proposed by the initial RESPONSE methodology, in order to account for certain features specific to the French pilot regions.

A subsequent recombination of the geomorphological features of each coastal segment will enable Coastal Behaviour Systems (CBS) to be defined.

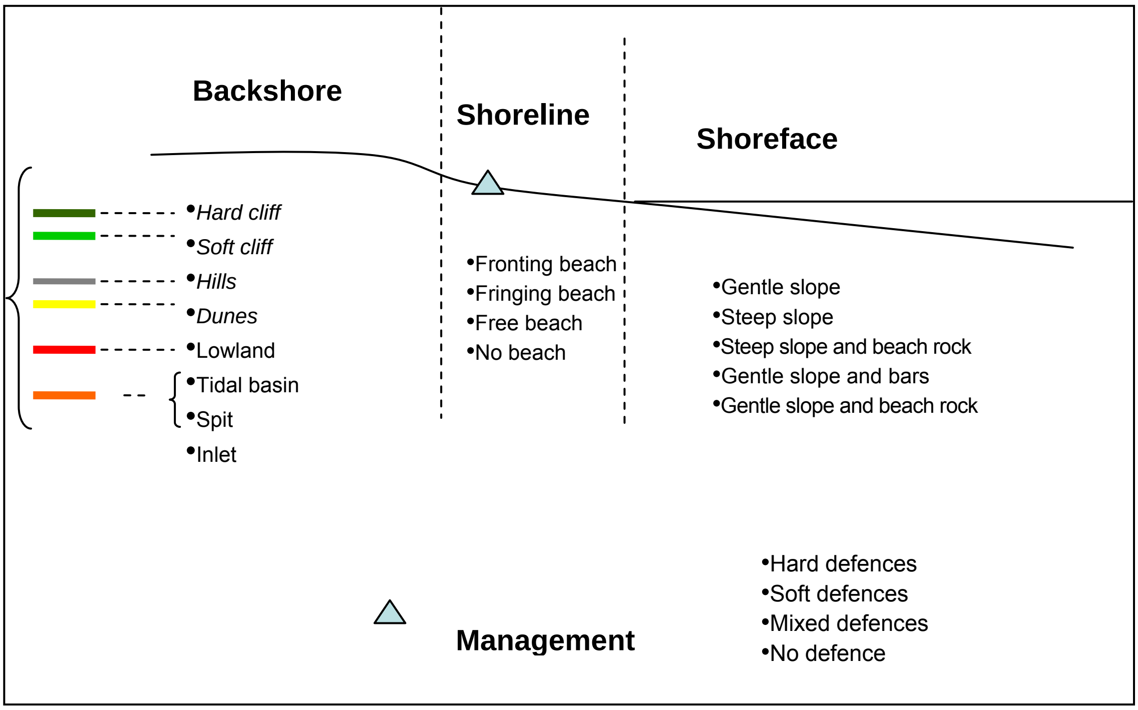


Figure 6 - The various divisions and features describing coastal geomorphology.

b) Regional adaptation of the classifications

- **Cliffs**

Initially, cliffs were described according to a lithologic criterion (hard rock/soft rock cliff). It will be recalled that these notions actually derive from EUROSION classifications A/AC and B. We felt it was more appropriate to take into account the resistance to degradation processes (erosion, collapse, etc.). In actuality, hard (eruptive or effusive) rocks that are weathered or fractured are fully as prone to erosion as soft (sedimentary) ones are. We have accordingly chosen to retain two categories of cliff: *hard* and *soft*. A cliff will be classified as “hard”, or resistant to erosion, if the segment of cliff in question has undergone less than one instance of ground movement per kilometer over a ten-year period. Conversely, a cliff will be classified as “soft”, or subject to erosion, if it is composed of rock that is either soft or weathered or fractured and has undergone degradation processes of at least one ground movement per kilometer over a ten-year period.

- **Hills**

This is a new category under the backshore division corresponding to a sector unaffected by ground movements but that is liable to undergo continental or marine erosion. The category is associated with a moderately sloping backshore (a gradient of at least 5 m per 600 m, or 0.8%, inland).

- **Dunes**

This category was added to describe the coastal dune systems in the Aquitaine region, together with a certain number of segments in the Languedoc-Roussillon region. This category indicates the presence of an accumulation of wind-deposited sandy sediment from the backshore and is characterized by a gradient slope of at least 5 m per 300 m.

- **Sandbars and bedrock**

Describing the shoreface revealed the need to complete the notion of slope, proposed in the original methodology, with an indication of the presence of sandbars or bedrock. The presence or absence of one or the other of these two elements plays an important role in the evolutionary process of the coastline.

- **Sandy spits**

The boundary of the sandy spits were traced manually, adopting as a limit the change in bars morphology, underlining where the direction of the spits' progradation inverses.

- **No beach**

This situation is observed on a certain number of segments where the sea is constantly in contact with the foot of the cliffs, with no intervening beach.

- **Defences**

The description of defences as proposed in the original RESPONSE method does not differentiate between whether the work is designed to protect the beach and/or the cliff or backbeach. However, in neither of the French regions was there an instance where the defences protected the shore and the backshore simultaneously. This classification was accordingly not modified.

c) Mapping

- **Shoreface**

The -10 m, -20 m, -50 m and -100 m depth contours were drawn on Map 1 so as to visualize the shoreface slope.

- **Shoreline**

The position of the shoreline was derived from the EUROSION database (2004) as were the fields describing beach type. Map 1a (Appendix 5) proposes a beach description based on its morphology and composition.

- **Backshore**

Data on the backshore were likewise derived from the EUROSION database.

- **Sediment transport**

The sediment transport was digitized from an IFREMER document (CNEXO, date unknown) published on the Internet.

Three parameters were mapped:

- the direction resulting from sediment transport;
- the boundaries of the sedimentary cells;
- the boundaries of the sedimentary sub-cells.

For the Languedoc-Roussillon region, a second, more recent, data source was made available by SMNLR. It contains redrawn boundaries for the sedimentary sub-cells that differ somewhat from the ones in the aforementioned IFREMER document. This information, although included in the GIS, was not plotted on Map 1b.

- **Wave energy on the coast**

On the Aquitaine coast, the wave energy on the coast was assessed by expert judgment according to the angle of the coast with respect to the predominating direction of the local swell. We have distinguished four energy categories, namely high, moderate, weak and undetermined. This parameter is symbolized on the map by a coloured line parallel to the shoreline.

The data is not available for Languedoc-Roussillon coast.

- **Erosion**

Information concerning coastal erosion comes from the EUROSION database.

- **Tidal amplitude**

Tidal amplitude was digitized off maps prepared by SHOM. The value mapped is that of a mean spring tide.

2.3.2. Map of works and defence means against the sea (Map 2, Appendix 4 – CD-ROM)

The fields used to describe the data concerning works and means of defence are the result of merging heterogeneous data from diverse sources.

A certain number of fields were taken from BD EUROSION (Table 2 in Appendix 5). For the Aquitaine region, data was also procured from databases at the Aquitaine Coast Observatory (IFREMER, ONF, BRGM). For the Languedoc-Roussillon region, some are issued from SMNLR data.

For each segment of coastline in the two pilot regions, the presence or absence (binary field) of the different types of works mentioned has been indicated. The listed works are shown in the first column of Table 2.

<table>
<tr><th>Original type (Fr/UK)</th><th>Type in TCote_Schematique (Fr/UK)</th><th>Type in RESPONSE</th><th>Overall type in RESPONSE</th></tr>
<tr><td>Block</td><td>Block</td><td></td><td></td></tr>
<tr><td>Cliff reinforcement</td><td>Cliff reinforcement</td><td>Cliff engineering</td><td rowspan="7">Hard engineering</td></tr>
<tr><td>Base abutment</td><td>Base abutment</td><td rowspan="2">Cliff remedial</td></tr>
<tr><td>Seawall</td><td>Seawall</td></tr>
<tr><td>Breakwater</td><td>Breakwater</td><td rowspan="6">Control structure</td></tr>
<tr><td>Dike</td><td>Dike</td></tr>
<tr><td>Riprap protection</td><td>Riprap protection</td></tr>
<tr><td>Groynes</td><td>Groynes</td></tr>
<tr><td>Wood paling</td><td>Wood paling</td><td rowspan="2">Soft engineering</td></tr>
<tr><td>Palissade, pilings</td><td>Palissade</td></tr>
<tr><td>Wharf, slip, Jetty,</td><td>Port structure</td><td>Harbour structure</td><td>Hard engineering</td></tr>
<tr><td>Distributary, weir,</td><td>Distributary</td><td>Harbour structure</td><td>Hard engineering</td></tr>
</table>

Table 2 - Typology of coastal protection works.

These fields were subsequently processed as described to allow simplified mapping into four typological levels characterizing the type of structure following the initially proposed RESPONSE terminology, *i.e.*, cliff engineering, cliff remedial, control structure and harbour structure. Human interventions on the different segments of coast were then classified according to approach: hard engineering, soft engineering or a combination of the two.

Map 2 (Appendix 4) gives details on the types of these constructions, mentioning whether they correspond to control structures and/or are intended to stabilize the cliff.

The “beach nourishment” field, supplied sporadically, was filled in manually.

Data on defence maintenance were not included in the mapping, considered as complex and likely not complete. Collected data are included in Appendix 8.

2.3.3. Map of historical and present-day hazards (Map 3, Appendix 4 – CD-ROM)

a) Coastal evolution

Coastal evolution is mapped using:

- EUROSION data (the “aggradation”, “erosion” and “unchanged” fields);
- for the Languedoc-Roussillon region, erosion rates were digitized from P. Durand (1999). These data result from a diachronic mapping of different periods (1962-1997 in the Roussillon region, 1968-1997 in the Narbonne region, 1968-1996 between Saint-Pierre and Cap d’Agde and 1966-1996 between Cap d'Agde and Sète). From those data, the mean retreat rate value was derived for each segment and plotted on the map.

b) Historical events

Historical events were mapped using material from various sources:

- for the Aquitaine region, data was collected by the Aquitaine coastal observatory and completed with those from MétéoFrance’s historical data base. The events, numbered sequentially on the descriptive table of events (Appendix 6, Table 1, Table 3), are identified thus on the map 3 (Appendix 4);
- for the Languedoc-Roussillon region, historical data in the Golfe du Lion, up to the end of the 19th century, were integrated (Oliveros C. *et al.*, 2004). For more recent data (since 1963), specific research was conducted using archives (theses, the press, etc.), in the www.prim.net base and in Météo-France’s historical base (Appendix 5, Table 2).

Since these events are generally associated with one or more municipalities, their location was attributed to the centroid of the municipality or locality. On Map 3 of the Aquitaine region, all the storm events were voluntarily located off shore from the coastal municipalities mentioned to improve readability.

c) Zones currently exposed to marine flooding

As a supplement to data on the Coastal Behaviour Systems, defined in terms of geomorphology, outlines of marine flooding phenomena were mapped on Map 5. These outlines were obtained using two approaches:

- transposing to the map marine flooding events that have already occurred (SMNLR data for the Languedoc-Roussillon region);
- estimating the maximum local storm surge (the highest known tide increased by the maximum known storm surge).

  - **In the Languedoc-Roussillon region**

- the tide is semidiurnal and presents diurnal inequality. The tidal amplitude is 0.4 m at spring tide, varying between 0.2 and 0.6 m above the hydrographic chart datum

(SOGREAH 1995), this being 0.343 m under NGF datum. The highest tide sea level is 0.26 m above IGN datum (NGF);

- the highest storm surge is 1.5 m;
- the potential marine flooding level is therefore 1.76 m (rounded up to 1.8 m for mapping purposes) above IGN zero.

- **In the Aquitaine region**

- the highest tide level is 2.92 m above IGN datum;
- the highest storm surge is 2 m;
- the present potential marine flooding level is 4.92 m above IGN datum, rounded down to 4.9 m.

The zones currently liable to flooding are mapped using the specific values for each of these regions, such zones being any connected to the shoreline and lying lower than the calculated levels. These include, notably in the Languedoc-Roussillon region, zones that are already flooded (coastal lagoons) but that would be subject to changes in size and salinity due to a rise in sea level.

2.4. PHASE 1: DEFINING GEOMORPHOLOGICAL COASTAL BEHAVIOUR SYSTEMS AFFECTED BY CLIMATE CHANGE

2.4.1. Defining coastal behaviour systems by combining geomorphological elements

a) Principle

The principle is to subdivide the coast into cross-shore segments for which the hypothesis can be made that, because of their morphology, they will present a uniform response to the impact of climate change.

To be recall, three landform divisions are used to describe the coastal zone following a perpendicular profile (Figure 7): the shoreface, offshore from the shoreline, the shoreline itself and the backshore (or hinterland). Superimposed on these landform elements are coastal protection works, or defences “against the sea.”

For each of these elements, a certain number of landforms are encountered (Table 3). Some landform characteristics specific to the French pilot regions (dunes, hills, bars and bedrock) have been added.

b) Mapping (Map 5, Appendix 4)

The coastal behaviour systems (CBS) were defined by combining the values of the ArcGIS table fields used to prepare the preceding maps. The calculated results (ArcGIS) yield 47 possible combinations to describe the CBS in the two pilot regions (Appendix 7).

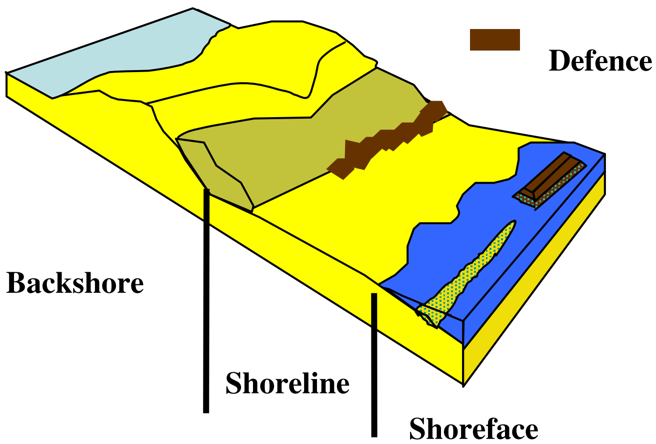


Figure 7 - Delineation of the landform divisions describing the coastal zone.

Coastal Behaviour System							
		Hard Cliff	**Soft Cliff**	**Lowlands**	**Spits, Inlets, Tidal Deltas, Tidal Bassin**	**Dunes**	**Hills**
Landform elements used to described detailed CBS	Shoreface slope	-Steep slope -Gentle slope -Bedrock gentle slope	-Steep slope -Gentle slope -Bedrock /slope gentle slope	-Steep slope -Gentle slope	-Gentle slope -Bars/gentle slope	-Gentle -Bars, gentle	-Gentle -Steep -Bars, gentle -Bedrock, gentle
	Shoreline	-Fringing beach -No beach	-Fringing beach -No beach	-Free Beach -Infrastructure -Harbour -No beach	-Tidal Flat -Free inlet -Fronting Inlet -Fronting Spit	-Fronting Beach	-Fronting beach -Fringing beach -Free Beach -Infrastructure -Harbour -No beach
	Hinter-land	-Hard cliff	-Soft cliff	-Lowland	-Lowland -Hills -Dune	-Dune	-Hills
	Mana-gement	-Hard -Mixed (hard and soft) -No management					

Table 3 - Detail of the different landforms encountered in french pilot regions for each of the coastal divisions.

Some data were processed as described below.

- **The shoreface**

The shoreface slope was calculated using the ArcGIS *Spatial Analyst* and taking into account the distance to the -20 m contour. The boundary between gentle and steep slope is arbitrarily set at 2%.

- **The backshore**

The backshore is considered to be of a hill type if the slope is steeper than 0.8% over 600 m and there is no cliff. This slope is calculated from the IGN DTM (50m step) using the ArcGIS *Spatial Analyst* and taking into account the distance between the shoreline and an elevation of +5 m with respect to the highest tide level (*i.e.,* 7.92 m IGN for the Aquitaine region and 5,26 m IGN for the Languedoc-Roussillon region).

2.4.2. Validation

Each coastal segment defined in Map 1 was assigned to coastal behaviour system. This coding was subsequently validated on the strength of expert judgment (Regional Aquitaine and Languedoc-Roussillon geological surveys) and of a certain number of available documents (printed matter or Internet). Thus the following were consulted:

- MNT IGN with a sampling rate of 50 m;
- scanned 1:25,000 scale maps from the IGN;
- geological maps at 1:50,000 or 1:80,000 scale;
- oblic photographic survey done by EIDMéditerrannée on the Languedoc-Roussillon coast in August 2005;
- the orthophotoplans: “ortholittoral 2000 ©”;
- the “France vue sur mer” internet site;
- the GoogleEarth site (satellite image).

In certain instances, this validation has called, for certain systems, to be manually redefined, landform elements (sandbars and bedrock) to be completed and new types of CBS to be defined.

Appendix 7 gives the definitive list of possible combinations for the detailed coastal behaviour systems.

2.4.3. The aggregation of the coastal behaviour systems

In order to facilitate the mapping of the CBS at 1:100,000 scale on Map 5 in Appendix 4, the detailed CBS were merged in consideration of the backshore.

The final version of Map 5 displays the six classes of CBS arising from the aggregation of the detailed systems legended as in the Figure 8. The descriptions of the detailed CBS can still be consulted in the GIS under ArcGIS.

Hard Cliff	Soft Cliff	Lowlands	Spits, Inlets, Tidal Deltas, Tidal Bassin	Dunes	Hills

Figure 8 - Global CBS resulting of merging detailed CBS via backshore features.

2.4.4. Present-day marine flooding hazard

The zones currently considered vulnerable to flooding on the basis either of a maximum flooding height or of observations (SMNLR, Languedoc-Roussillon) have been plotted on this map.

2.4.5. Summary of results: the main characteristics of the two pilot regions

The different landform features of each coastal transect collated with the presence or absence of defences has made it possible to define 47 different coastal systems (Appendix 7) for the two pilot regions including the Arcachon Basin, which will not be considered in the further step. Some combinations, however, were seen to reappear frequently in each of the two regions and are characteristic of them. Details on the CBS have been conserved in the GIS used to prepare in .pdf format maps in the report's companion CD (Appendix 4).

a) Aquitaine

The coastline of the Aquitaine region is morphologically uniform throughout, from the Gironde estuary to the Adour river. This coast is characterized by the presence of high, wide dunes that supply the beach with a substantial sedimentary stock and by wide ridge-and-runnel beaches. The longitudinal coastal sediment transport is substantial. The inter-tidal zone generally slopes gently, and sandbars frequently occur on the shoreface.

The tourism-oriented towns are mainly situated at the outlets of small rivers. Defences, some of which were built at the end of the 19th century, are concentrated around these assets; these consist essentially of jetties, transversal groynes and dikes in urbanized zones. These structures afford access to watercourses, to ports constructed behind the dunes, or aimed to protect beaches. In a number of spots, they have altered the longshore sediment transport and generated erosion phenomena downdrift.

Furthermore, defences were set up more than a century ago from the Pointe de Grave to Soulac to limit the brechification of the dune ridge, which was quite pronounced at the end of the 19th century.

Only one segment was described as a sandy spit, attesting a high-energy process: the ocean coast of Cap Ferret.

The CBS in the Arcachon Bay were also described in this chapter, and reveal an energy process that differs markedly from the Gironde and Landes ocean coasts, associated with a tidal flat and channel configuration. The mechanism causes the for-end of the bay to tend to fill up whereas the tidal channels, at the baymouth exhibit high mobility, which erodes the bay-orientated side of the Cap Ferret. In view of this atypical mechanism, driven by parameters quite different from those at work on the coastline, the decision was taken to omit the Arcachon Bay from the remainder of the study, since the proposed approach was unsuited to this specific context.

The Basque Coast (Pyrénées-Atlantiques department) southwards from the Adour river is structured differently from the Gironde and Landes coasts in that it consists of alternating stretches of cliffs, sandy bays or pocket beaches. The cliffs are composed of sedimentary rock, Cretaceous in age (Pyrenean foreland), folded, moderately altered, bordered on by beaches that are narrow, steeply inclined in spots, frequently rocky, and possessing a limited stock of sand other than that produced by weathering. In several places, there is no beach left. The sandy bays, rimmed with hills, are more or less protected behind rocky points and operate with a particular mechanism linked to the bay morphology.

The defences installed on the Basque coast target cliff instability. There are indeed quite a number of such events on record (Map 3, Appendix 4 – events connected with coastal risks). The defences take the form of abutments at the foot of the cliff and of retaining walls that frequently double as scenic footpaths or coastal roads. Local drainage techniques are also used to mintigate groundwater action in cliff instability.

It should be noted that very few floods have been recorded for the Aquitaine coast (Map 3, Appendix 4) and that these do not appear to be necessarily storm surge-related. The outline for potential flooding situates this risk at watercourse outlets (the Basque coast or the sandy coast), which is in agreement with known historical events.

b) The Languedoc-Roussillon region

A major part of the Languedoc-Roussillon coast is composed of low sandy shores interspersed with occasional rocky promontories at Sète and the Cap d'Agde. Only its south-western end is made up of cliffs and small beaches protected by rocky points or bays.

Sandy shores account for 90% of the coastline and are associated with low-elevation dunes (5 m or less) known as "lidos" with, inland from them, salt marshes or lagoons that connect with the shoreline, via "graus" or inlets, more or less stabilized. The low dunes lie along narrow beaches. The shoreface slopes more or less sharply, and sandbars are present at times.

Sediment transport, linked to dominant winds, is composite according to the disposition of the coast. It may be either longshore or crosshore and can be modified by storms.

These coasts, which have experienced a population boom in the 20th century, are highly vulnerable. This vulnerability and the increasing economic assets at stake have motivated the massive installation of defences composed of groynes, breakwaters and, more locally, of riprap and dikes at the foot of the dunes. These latter structures are used in a number of spots as supports for roads and building protection purpose.

The inlets “graus” are resulting of the lagune closure by a prograding spit, and they show a natural unstability which is reflected in their lateral shift. However, most of them are channelized, or even reconverted into port facilities. At present, they allow communication between the Mediterranean Sea and the coastal lagoons in the hinterland.

It should be noted that these are the sectors where marine flooding due to storm surge has occurred and that the outline of the potential flood zone on the basis of MNT encompasses the lagoons and their fringes.

The cliff sector extends from the Spanish border to Collioure. It is composed of Cambrian rock that makes up the western end of the Pyrenean axial zone. These formations, not prone to erosion, alternate with small, narrow sand, gravel or pebble beaches that are more or less sheltered by the pattern of the coastline and often remodelled into harbour installations. This sector has relatively few defences against the sea.

c) A comparison

Already it can be stated that the topography, the existence of a stock of sand and the prevalence of sediment transport are all factors that determine the vulnerability of the coastline both to erosion and to flooding. The existence of a more plentiful stock of sand, of dune of greater height and of wide beaches despite a strong longitudinal transport render the Gironde and Landes coasts **relatively** less liable to erosion and marine flooding than the low shores of the Languedoc-Roussillon region, whose flat topography and narrow beaches gives a poor protection to erosion and marine flooding.

The liability to erosion of cliff-lined coasts is strongly influenced by their lithology, their geometry and the degree of weathering. Thus, for the Basque coast, historical record attests to a large number ground movements connected with cliff instability whereas, for the coast of the Pyrénées-Orientales Department, is reported. Rock fall have, thus, been observed East of Cap d’Agde and at the Sète Corniche.

2.4.6. A preliminary identification of present-day hotspots in the French pilot regions

a) In terms of present-day erosion

The criteria gathered in order to map the geomorphological units makes it possible to identify some hotspots with regard to current risks.

In earlier works, hotspots were defined in terms of the erosion criterion alone: these are sectors where erosion is more severe than in the areas to either side, continues to be severe despite preservative measures (Dean *et al.,* 1999) or present a deficiency in sedimentary stock (Kraus et Galgano, 2001). The latter authors suggest ranking the hotspots thus defined with regard to the duration of the erosion phenomenon, its lateral extent, the erosion process, the dominant erosion mechanism, like longshore or crosshore sediment transport, and the potential for predicting and/or mitigating the phenomenon.

These criteria correspond to CBS where:

- the beach is narrow and the backshore low-lying, supplying no sedimentary stock (fringing beach/lowland, fringing beach/hill);
- the cliff is susceptible to erosion and poorly protected (fringing beach or no beach/ soft cliff);
- development has destabilized the sedimentary balance (inlets/lowland/hard).

Some of the spots have been picked out in the two pilot regions who correspond to this type of coast. However, they were also selected by factoring in the notion of assets endangered by the existence of the hazard (the strategic objectives of SMNLR, 2003), as well as the existence, for some of them, of risk-management projects (Appendix 8).

- **In the Aquitaine region**

The sites currently listed are those described in unpublished reports cited in the bibliography, that were communicated to us by the administrations responsible for managing them (Direction de l'Equipement des Landes, Service Maritime de Gironde). The localities identified as being at risk on the rocky Pyrenees-Atlantiques department coast are drawn from BRGM data on cliffs (Alexandre *et al.*, 2003; Nedellec *et al.*, 2003). They are described in Table 4 and plotted on Figure 9.

- **In the Languedoc-Roussillon region**

The sites viewed as critical with respect to erosion at the present listed in Table 5 and plotted on Figure 10. Their priority was assigned by SMNLR (2003) in terms of the urgency of taking action.

b) In terms of present-day marine flooding

If a parallel is drawn with the definition of hotspots in terms of erosion, segments selected will be ones that are more flood-prone than those adjacent or for which marine flooding phenomena have already been identified.

This parameter is encountered in low zones, and more particularly in existing channels between the coastline and the backshore. To a lesser degree, low narrow dunes may be flooded or breached by the effects of storm surge, particularly near existing inlets when these have not been remodelled and stabilized.

This corresponds to CBS's of the "inlet/lowland type" and, to a lesser extent, to sectors featuring "lidos", described as "fringing beach/lowland" in the CBS database.

Sectors that can currently be considered hotspots in terms of marine flooding correspond to zones that are currently liable to flood, identified on Map 5.

- **In the Aquitaine region**

The potentially floodable sectors indicated on Map 5 are relatively small in size in the Aquitaine region and also correspond for the most part to actual marine flooding events. They are accordingly to be considered hotspots.

- **In the Languedoc-Roussillon region**

In the Languedoc-Roussillon region, the area liable to marine flooding is extensive. In order to prioritize this information and identify spots where the risk is exceptionally critical, we accordingly propose to retain as hotspots in the context of this project only CBS's for which there is information concerning at least two known flooding events (Figure 10 and Appendix 7). The spot is drawn inland for readability, backward from the concerned township.

Although this approach does enable hotspots to be identified on a regional scale, within the demonstration objective of the RESPONSE Project, the definition of hotspots in terms of vulnerability to marine flooding admittedly lacks precision; a more rigorous definition for marine flooding would be recommended, notably one where the actual impact of a storm surge would be modelled with the corresponding estimated return period.

c) List of present-day hot-spots

- **In the Aquitaine region**

Selected hotspots, following the above described method, are listed and situated in Table 4 and Figure 9.

Township or locality	Present hotspot (current known risk)
Soulac	Erosion
L'Amélie	Erosion
Lacanau	Erosion
Biscarosse	Erosion
Mimizan	Erosion
Capbreton	Erosion
Pointe Saint Martin (Anglet/Biarritz)	Ground movement
Côte des Basques (Biarritz)	Ground movement
Guéthary	Ground movement
Sud baie d'Eromardie(Saint-Jean-de-Luz)	Ground movement
Pointe Ste Barbe (Saint-Jean-de-Luz	Ground movement
Baie de Saint-Jean-de-Luz	Marine Flooding
Pointe de Socoa (Urrugne)	Ground Movement
Hendaye	Erosion and Marine Flooding

Table 4 - List of nowadays known hotspots in Aquitaine.

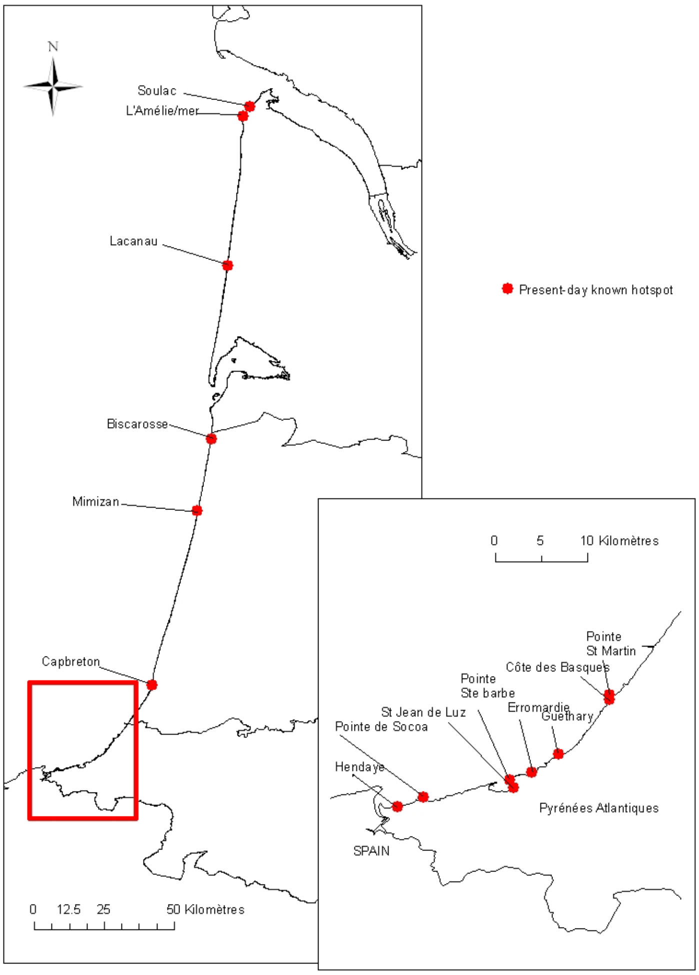


Figure 9 - Position of nowadays known hotspots in the Aquitaine region in terms of erosion and marine flooding hazards.

- **In Languedoc-Roussillon**

The hotspots to be retained with respect to flood are listed on Table 5 and located on Figure 10.

Township or locality	Present hotspot (current known risk)
Petite Camargue	Erosion
Grau du Roi	Erosion/Marine Flooding
La Grande-Motte	Marine Flooding
Petit Travers	Erosion
Maguelone	Erosion
Arresquiers	Erosion
Frontignan	Marine Flooding
East of the Lido from Sète to Marseillan	Erosion/Marine Flooding
La Tamarissière	Erosion
Portiragne	Erosion
Valras	Erosion/ Marine Flooding
Vendres	Marine Flooding
les cabanes de Fleury	Erosion/marine Flooding
Narbonne-Plage	Marine Flooding
Gruissan	Marine Flooding
Port La Nouvelle	Marine Flooding
Port Barcares	Erosion
Toreilles	Marine Flooding
Ste Marie plage	Erosion/Marine Flooding
Canet	Erosion/Marine Flooding
Saint Cyprien N	Erosion
Saint Cyprien S	Erosion
Argelès	Marine Flooding
Collioures	Marine Flooding

Table 5 - List of nowadays known hotspots in Languedoc-Roussillon.

2.5. PHASE 2: BUILDING REGIONAL CLIMATE CHANGE SCENARIOS

2.5.1. Hypotheses and models from IPCC 2001

a) Socio-economic scenarios

Models applying to the impacts of climate change are built upon a certain number of scenarios of socio-economic development that would affect the level of greenhouse gas emissions and how it would be expected to evolve.

Socio-economic development could follow four possible global or regional orientations (global economy or economic independence), favouring either economic development or the protection of the environment (Figure 11). The scenarios in IPCC 2001 draw upon and refine the ones proposed in 1992 (IS92a to IS92f).

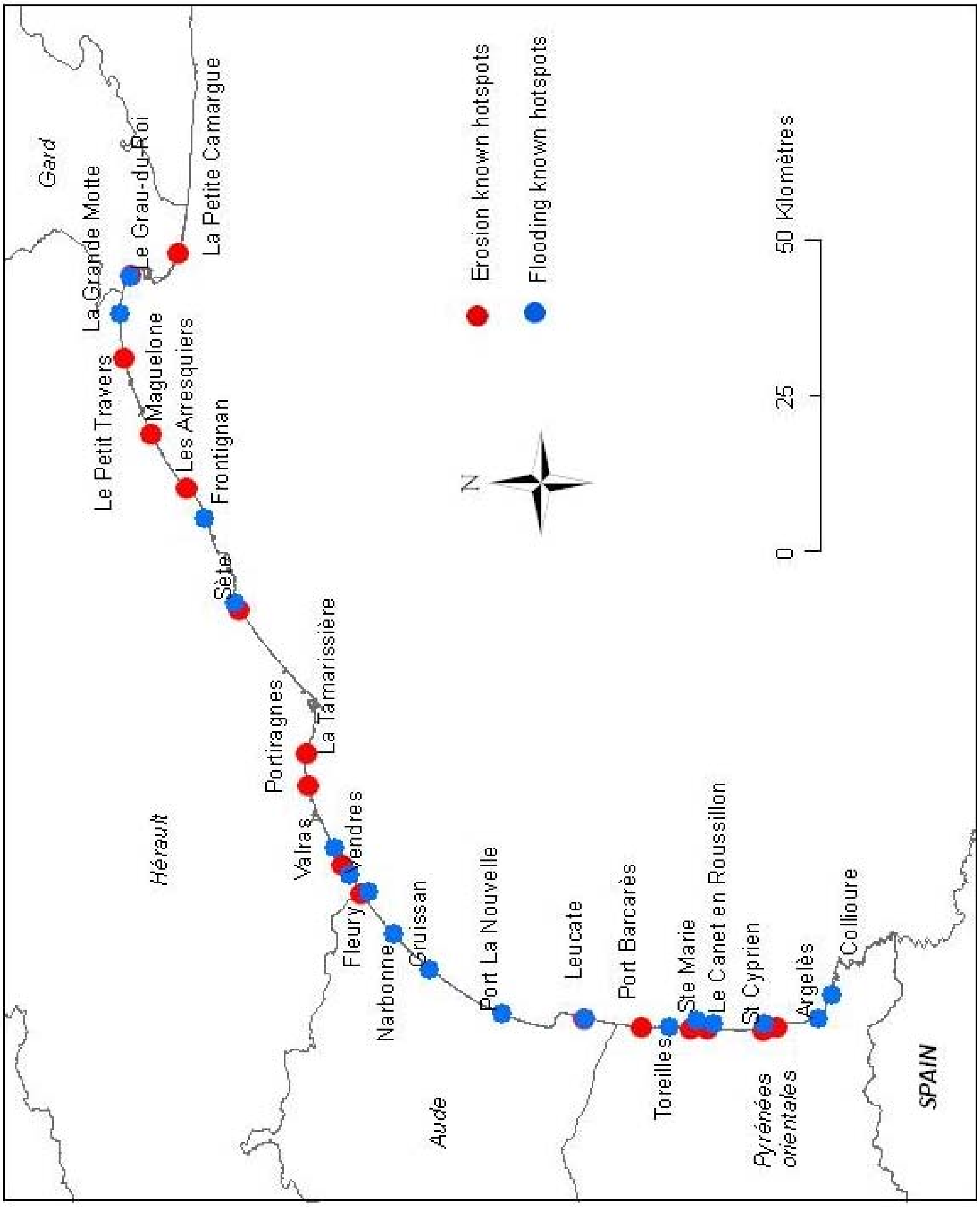


Figure 10 - Position of nowadays known hotspots in the Languedoc-Roussillon region in terms of erosion and marine flooding hazards.

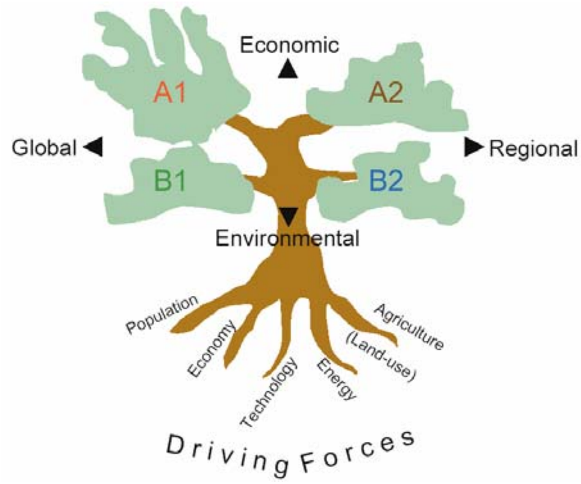


Figure 11 - The four IPCC SRES scenario storylines (after Nakicenovic et al., *2000).*

Scenario **A1** would correspond to a global context characterized by high economic growth in conjunction with a population that would continue to increase until mid-century, after which it would regress. This overall scenario is broken down into three sub-scenarios that reflect whether or not fossil fuels are used and whether they are phased out in the mid-term to be replaced by sustainable sources of energy.

Scenario **A1b** corresponds more specifically to a society that had succeeded in progressively balancing its energy sources and technological development. This hypothesis would result in increasing greenhouse gas emissions until the 2060's, after which they would begin to decrease. This would correspond to the objectives set by the conferences of Rio (1992) and Kyoto (1997) for participating nations.

Scenario **A2** corresponds to a more heterogeneous world, encouraging the preservation of local identities and national autonomy. This would imply a steady growth in population and slow technological development.

Scenario **B1** corresponds to an accelerated transition towards a global and technology-based society and the swift replacement of fossil fuels by sustainable forms of energy. Population would increase during the first part of the 21st century, but subsequently would decrease.

Lastly, scenario **B2** corresponds to a world where development would be locally controlled. Population levels would increase continuously

b) Greenhouse gas emission models and potential impacts

Figure 12 depicts the models for greenhouse gas evolution under the above scenarios (IPCC2001). The impact of these greenhouse gas emissions can notably be expected to be reflected by higher temperatures, changes in rainfall patterns (volume and distribution), a rise in sea level, an increase in the frequency and severity of extreme weather events like storms and by the hydrodynamic modifications these would cause.

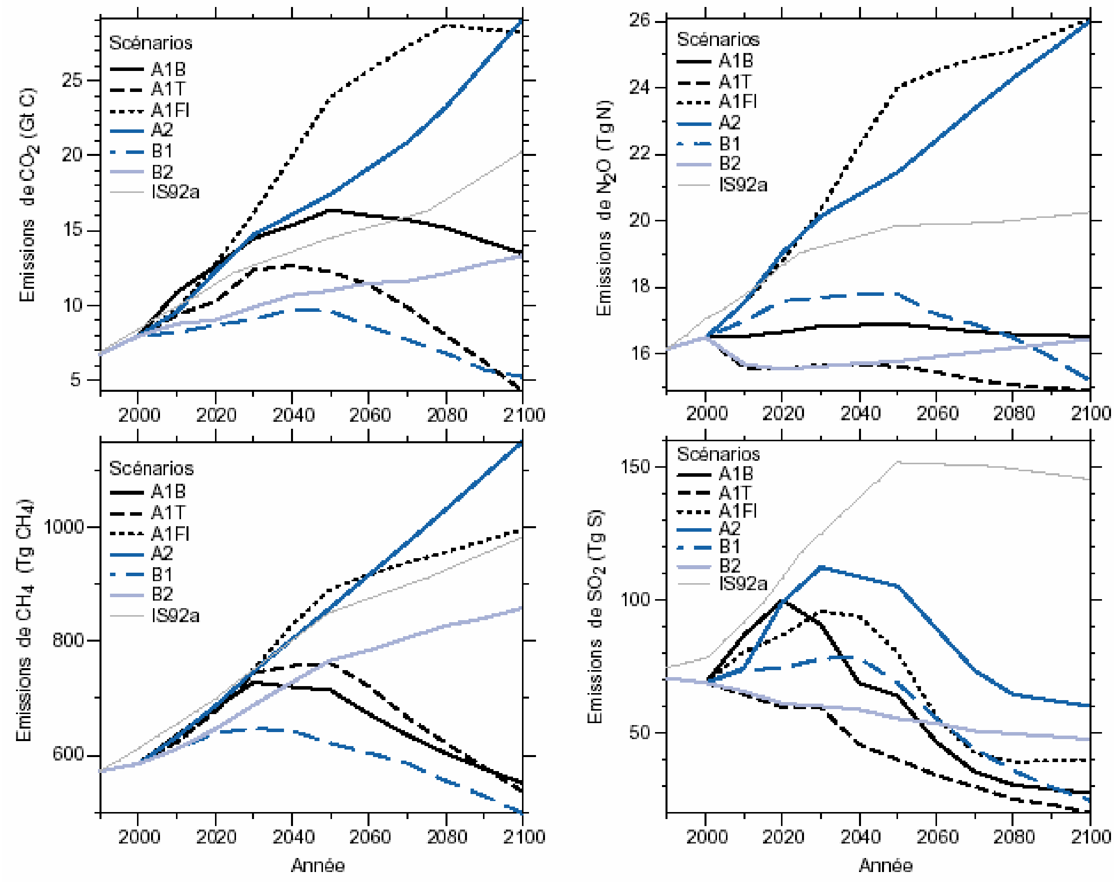


Figure 12 - Models for greenhouse gas evolution under the different scenarios (IPCC, 2001).

2.5.2. Comparisons between models in order to define regional scenarios

So as to adapt global or European scenarios to the scale of the pilot regions, a comparison was made between the various climate models applied at a European scale (ACACIA, TYNDALL), also used by the British team and on a national scale (Météo-France).

This comparison was possible for temperatures and precipitation levels. It was considered unnecessary for the IPCC hypotheses on rise in sea level, which are already the result of a synthesis of several models.

a) Evolutionary trends for temperature and rainfall

- **Météo-France**

Météo-France's digital models (Figure 13) are built on the hypothesis of a doubling of CO_2 emissions between 1990 and 2060. These models estimate probable changes in temperature and rainfall on a local scale throughout France and according to season.

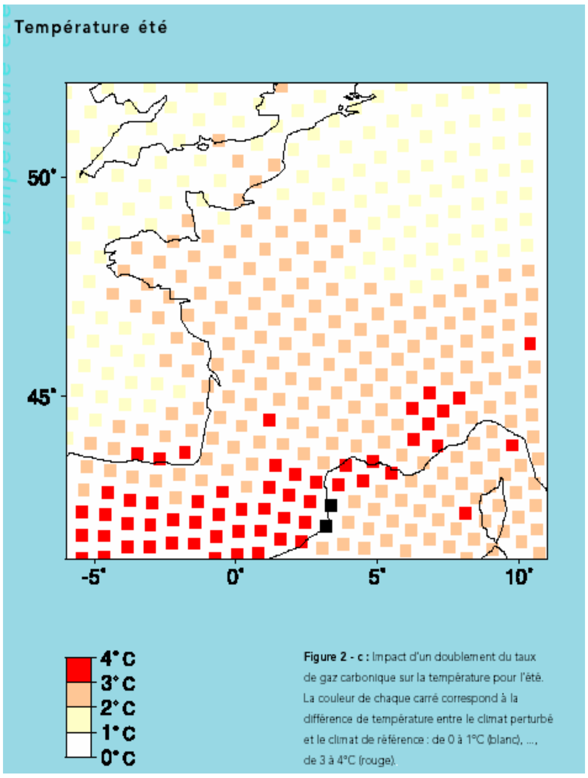


Figure 13 - Example of temperature change throughout France in summer based on the hypothesis of doubled carbon dioxide concentrations (Méteo-France).

Annual rainfall in France tends to be on the rise since 1900, albeit with decreased rainfall in summer (Figure 14).

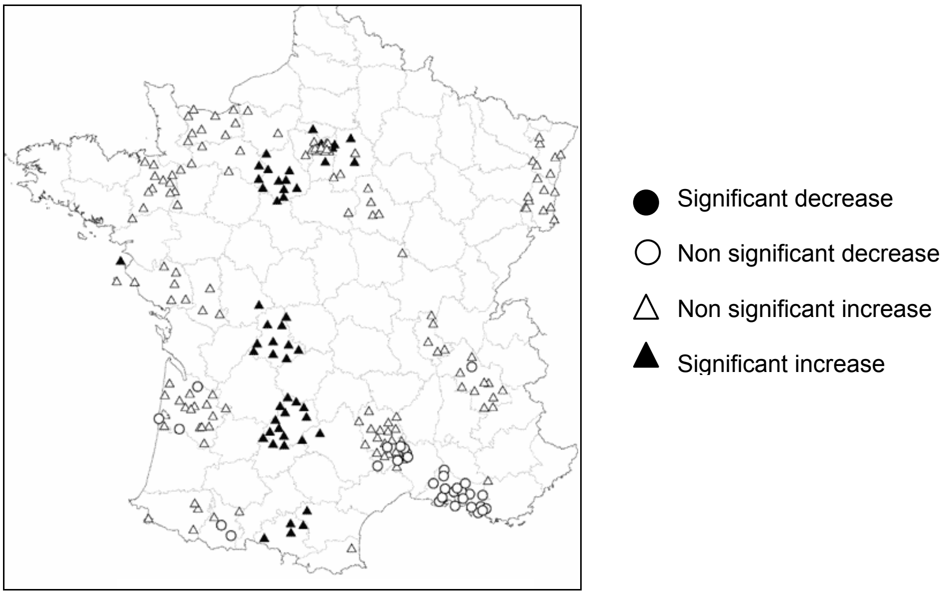


Figure 14 - Annual rainfall trends throughout France since 1900.

For the two regions considered, changes would be as follows in 2060 (Table 8):

Aquitaine							
Temperature Changes (°C)				Rainfall Changes (mm/d)			
Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
+1 to +2	+1 to +3	+2 to +3	+2 to +3	+1 to +2	-0.2 to +0.6	-0.2 to +0.2	-0.2 to -0.6
Languedoc-Roussillon							
Temperature Changes (°C)				Rainfall Changes (mm/d)			
Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
+2 to +4	+2 to +3	+2 to +3	+2 to +4	+0.2 to +0.6	-0.6 to +0.0	-0.2 to +0.2	-0.6 to +0,6

Table 6 - Temperature and rainfall changes for the case of doubled carbon dioxide concentrations.

- **Comparison with other models**

The mean annual temperature increase according to Météo-France would range between 1.5 and 2.74 °C for the Aquitaine region and between 2 and 3.5 °C for the Languedoc-Roussillon region. The predictions proposed by Météo-France for temperature and precipitation levels were compared with the European ACACIA model, the TYN CY 3.0 model (Tyndall) and with global models used by IPCC (2001).

IPCC's global models (Figure 15) give a temperature range of 1.4 to 2.7 °C that is coherent with Météo-France's predictions.

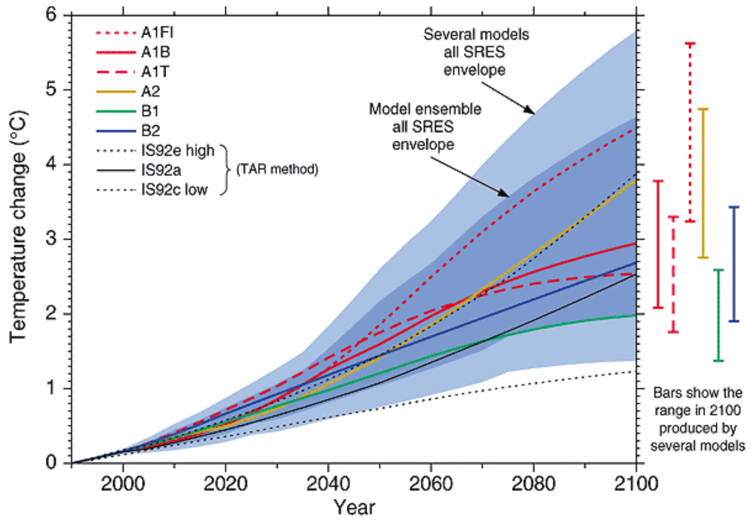


Figure 15 - Temperature increases between 1990 and 2100 according to different economic scenarios.

The ACACIA model proposes differences in temperature and precipitation levels for 2020, 2050 and 2080 by reference to known data for the 1961-1990 period (inter-yearly mean). The cells considered are regional in size (one cell for each of the regions studied, season by season) and take into account the different socio-economic scenarios.

Model TYN CY 3.0 represents France by a single cell and hypothesizes trends between 2071 and 2100, extrapolating from existing data between 1961 and 1990 (inter-yearly mean). The tendencies are expresses by month or season in degrees of temperature and millimetres of precipitation.

In order to be able to compare the predictions, the values proposed for each of the two cells in the ACACIA model, representing the concerned regions for 2020, 2050 and 2080, are interpolated so as to obtain a value for 2060. In like manner for the Tyndall data, an interpolation between the 1960-1990 and the 2071-2100 intervals allows values to be estimated for 2060.

Precipitation data are recalculated in mm/d, and temperature data in °C. Comparisons of results from different models are shown for the four seasons in reference to the year 2060 as compared with the year 1990.

- for the Aquitaine region, Table 9

	Temperature Changes (°C)				Rainfall Changes (mm/d)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
TYN CY 3.0	+1 to +3.07	+0.85 to +3.07	+0.85 to +6.07	+1.15 to +4.38	+0.16 to +0.8	-0.23 to +0.36	-1.09 to +0.02	-0.25 to 0.13
ACACIA			+1.17 to 4		>0		-26.7 to +6.7	
Météo-France	+1 to +2	+1 to +3	+2 to +3	+2 to +3	+1 to + 2	-0.2 to +0.6	-0.2 to + 0.2	-2.0 to -0.6

Table 7 - Temperature and rainfall changes in 2060 for the Aquitaine region based on TYN CY 3.0 and ACACIA data relative to 1961-1990, and on the Météo-France model (considering a doubling in carbon dioxide concentrations).

- for the Languedoc Roussillon region, Table 10:

	Temperature Changes (°C)				Rainfall Changes (mm/d)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
TYN CY 3.0	+1 to +3.07	+0.85 to +3.07	+0.85 to +6.07	+1.15 to +4.38	+0.16 to +0.8	-0.23 to +0.36	-1.09 to +0.02	-0.25 to 0.13
ACACIA			+ 1,7 to +3,9		>0		-26.7 to -6.7	
Météo-France	+2 to +4	+2 to +3	+2 to +3	+2 to +4	+0.2 to +0.6	-0.6 to +0.0	-0.2 to + 0.2	-0.6 to +0.6

Table 8 - Temperature and rainfall changes in 2060 for the Languedoc-Roussillon region based on TYN CY 3.0 and ACACIA data relative to 1961-1990, and on the Météo-France model (considering a doubling in carbon dioxide concentrations).

The following is observed:

- a relative uniformity in the overall ranges of temperatures increase for the different models, excepting the Tyndall model's higher values in summer and fall;
- sharply decreased precipitation in summer proposed by ACACIA, whereas the other models yield a more uniform range of values, on the order of 1 mm/day, positive in winter (increased precipitation), more pronounced according to the Tyndall model, and negative during the other seasons (decreased precipitation).

It therefore appears justified to use Météo-France data for temperature increases over the century to come.

Change in precipitation distribution will lead to an increased watertable fluctuation in a range that can be different from one model to the other. For coherence, Meteo-France value will be considered.

- **The tendency in sea-level change**

The measurements available for the 20th century indicate a mean rise in sea level of 0.7 mm per year, which would amount to 70 cm in a hundred years' time (D. Violeau, 1999).

The different atmosphere-ocean global coupling models integrate thermal expansion and the melting of continental icecaps, as well as changes in permafrost, sedimentary drift and eustatic fluctuations. Applied to the different socio-economic scenarios in IPCC 2001, they result in hypotheses for sea-level rise (Figure 16) ranging from 0.1 to 0.88 m between now and 2100.

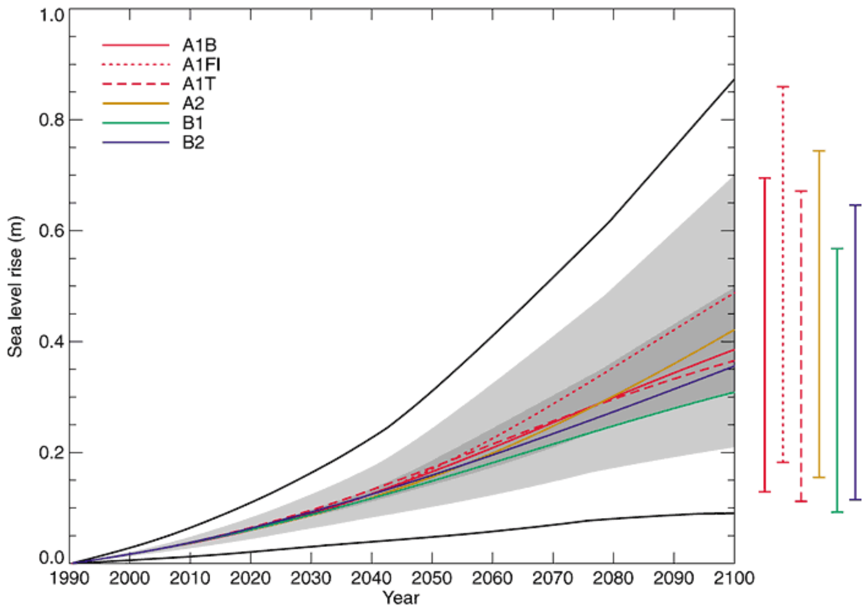


Figure 16 - The mean global rise in sea level between 1990 and 2100 for various socio-economic scenarios computed using the seven coupled air/ocean models (IPCC, 2001). Uncertainties in the results of each scenario are indicated to the right of the graph.

The values proposed in the different scenarios predict a rise in sea level of between 0.25 and 0.45 m, with a high level of uncertainty. The most pessimistic hypothesis (the pessimistic A1F1 scenario plus the upper limit of uncertainty) calls for a 0.30 m rise by 2050 and 0.88 m in 2100. “Regional” variations on a European scale ranging from 0.13 to 0.68 in 2050 are proposed in the site http://www.grida.no/climate/ipcc_tar/wg2/495.htm.

- **Tendencies in the evolution of storms, wave heights and storm surges in France**

Existing data since 1950, both regional and global (Météo-France, IPCC 2001), do not indicate significant changes in wind speed during storms (It should be borne in mind, however, that instrument technology evolved significantly in the 1970’s, thereby older measurements are considered as less liable). However, there is too little regional data and no global or regional models are currently available to allow these tendencies to be extrapolated to figure what to expect in the future.

Nevertheless, wave height measurement during storms are known over the same period to have increased of around 1% per year (this corresponds to a 2 to 3 cm increase of the annual average wave height).

It is plausible that increased wave heights and rising sea levels will influence storm surges particularly in estuaries. It’s commonly accepted today is that storms will increase in frequency and severity. In this project, storm effects are also integrated into the notion of maximum known storm surge used to map potential marine flooding.

2.5.3. The choice of a climate scenario for the two French pilot regions

a) Changes in temperature and precipitation

The figures for temperature and precipitation change to be used in this project are those provided by Météo-France (Table 8). It should be emphasized, nevertheless, that although temperature change is one of the major parameters inducing the rise in sea level, it does not have a direct impact on coastal hazards (erosion and marine flooding). It is likely, however, that increased temperatures would bring about changes in the assets at stake in terms of population and the tourist trade.

Changes in precipitation, and especially in its distribution, which will influence the value of effective rainfall, can on the contrary be expected to have a strong hydrological impact, on the water table fluctuation, and, accordingly, a role in cliff erosion phenomena (triggering collapse and landslide). The impact of rainfall change on soil erosion and river sediment output can only be anticipated but not quantified.

b) Sea level rise

For the two French regions, it thus was decided that the global hypotheses for sea-level rise could be used.

It first was proposed that two scenarios should be applied:

- a “more probable” or “more acceptable” scenario corresponding to the hypothesis of a society with global economy that would foster technological advances and the progressive replacing of fossil by sustainable forms of energy. The rise in sea level associated with this scenario is estimated at 0.35 m by 2100;
- a “pessimistic” scenario that adopts the maximum hypothesis of a 0.88 m rise in sea level by 2100.

However, it was decided to apply only the most pessimistic scenario in line with the project’s objective which is to stress, for the benefit of local authorities, the sectors liable to become critical, and upon request from the group of end-users (the steering committee, on September 19 and 20, 2005).

To assess potential marine flooding, this sea-level value will be added to the combination of that of the highest tide level and known values of the highest known storm surge as proposed in section 2.3.3.

- **In the Aquitaine region**

- The highest tide sea level added to the highest storm surge is 4.92 m.
- Accordingly, the potential marine flooding in 2100 is 5.80 m above IGN datum.

- **In the Languedoc Roussillon region**

- - The highest tide sea level added to the highest storm surge is 1.76 m.
- - Accordingly, the potential marine flooding in 2100 is 2.64 m above IGN datum.

c) Storms, wave heights and storm surges

In view of the uncertainty as to the evolution of storm patterns during the coming century, the empirical assumption would be made that storms, more severe and frequent in future, will constitute an aggravating factor for coastal hazards. It will be recalled that the storm surge height is taken into account in the estimation of potential marine flooding level.

2.6. PHASE 3: EVALUATING AND MAPPING EVOLUTION OF COASTAL HAZARD

2.6.1. Method

Hazard change was assessed (Figure 17) by a panel of nine experts for each of the previously defined CBS’s, taking into account the climate scenario selected in the preceding section. Thus the panel assigned a grading to each segment of coast that expresses the potential change in hazard induced by climate change according to the scenario proposed in section 2.5. The coastal hazard evolution map presents the results of this rating process.

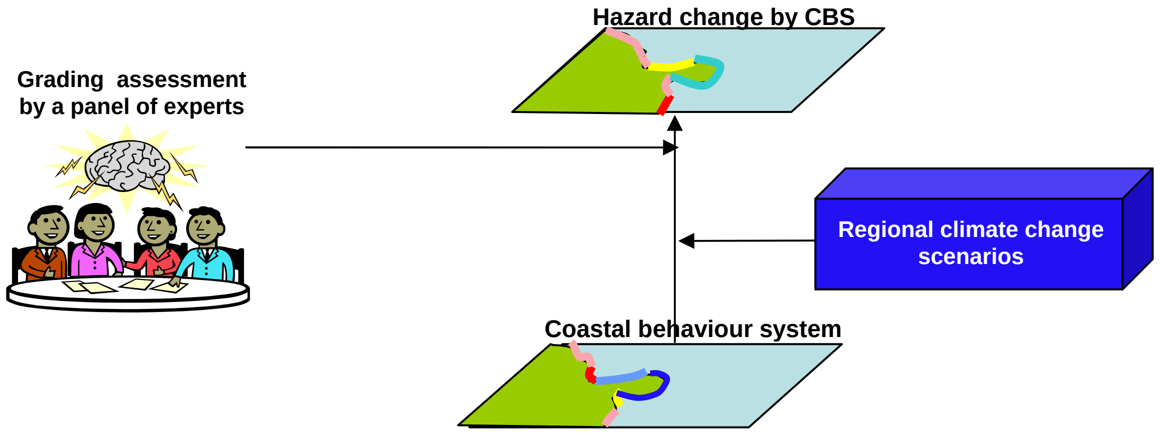


Figure 17 - Method for assessing hazard change.

2.6.2. Grading hazard change

The objective is to evaluate future evolution, by 2100, of coastal hazards in the two regions considered. The process uses the map of the CBS's defined in section 2.4 and the proposed climate scenario. For each detailed CBS, consultation amongst a panel of nine experts (BRGM) on coastal environments made it possible to grade:

- the probability of change in marine flooding hazard;
- the rate of beach erosion, integrating the notion of the sedimentary stock constituted by the backshore;
- the rate of erosion by ground movement.

This grading system was conceived on a scale of -2 to +2 defined as follows:

- a drastic decrease in the hazard (-2);
- a significant decrease in the hazard (-1);
- hazard unchanged (0);
- a significant increase in the hazard (+1);
- a drastic increase in the hazard (+2).

Ratings of -2 and -1 were never assigned to the two French regions: under no circumstances could climate change lead to a decreased hazard.

An extreme increase in hazard is capable of rearranging the characteristics of a CBS, thereby actually changing its type. The situations that were encountered are:

- the disappearance of the beach;
- the disappearance of the sandbars.

Each expert consulted independently proposed its grading, then the panel as a whole met to debate these choices and reach a consensus over a definitive rating. A certain number of conventions and common hypotheses were agreed upon:

- Hypotheses on future defence structures are disregarded.
- Existing defence structures are considered as they are adaptations that might be made in them by future society are not considered. This implies that the presence of "hard" defences can be considered insufficient at the least, if not useless, since their design does not integrate the hypothesis of climate change.
- The effect of hydrodynamic changes on sandbars in the shoreface due to climate change has not been proven to date, but the hypothesis of their disappearance is made, in which case the coastline would be rendered more vulnerable to erosion.
- The availability of sediment stocks in the dune systems of the backshore is taken into consideration as a potential adaptation factor to erosion.

Finally, the grading were aggregated as follows: the two ratings concerning erosion, broadly speaking, *i.e.*, beach erosion and erosion through ground movement were first combined by adopting the higher of the two. Next, the resultant erosion value and the marine flooding value in the database were merged similarly, the higher of the two grading being retained.

2.6.3. Mapping

The complete map for the two French regions studied is included with the report in the Appendix 4 CD-ROM.

a) The current tendency for the "coastal erosion" hazard

For the sake of comparison, existing data on coastal hazard (erosion) were plotted along the coastline of the map. This information is derived from the EUROSION database (2004), completed for the Languedoc-Roussillon region with SMNLR data.

The current evolution of the coastline, when known, is represented on the coastline with the following legend:

- erosion (solid red line);
- gradation (solid green line);
- stability (solid grey line);
- unknown (blue line).

b) Hazard change

The definitive grading obtained for hazard change were mapped parallel to the coastline with:

- solid lines for erosion;

- dotted lines for marine flooding;

and using the following colour-coding:

- red for a drastic increase;
- orange for a significant increase;
- grey if unchanged;
- blue if the information was not estimated (Arcachon Bay).

Morphological changes liable to alter CBS typology are indicated back of the coastline. Three situations are encountered:

- disappearance of the beach (red stars);
- disappearance of sandbars (yellow stars);
- disappearance of sandbars and subsequently of the beach (blue stars).

c) Potential marine flooding zone in 2100

To avoid overcrowding the map, the present marine flooding hazard that was furnished on the CBS map was not shown on this map: only the potential 2100 hazard is indicated. Floods other than marine floods (rivers flood or groundwater flood) are not considered here, even though these phenomena will very probably be impacted by climate change.

This map uses the values for the highest present sea level (section 2.3.3.c) increased by the pessimistic hypothesis for sea-level rise of 0.88 m in 2100. The maximum level, that may be reached by the sea, in 2100 is thus potentially 5.8 m above IGN datum for the Aquitaine region and 2.7 m above IGN datum for the Languedoc-Roussillon region.

2.6.4. Analysis of results

a) Limitations

The limitations of the method applied should be given before we proceed to analyze the results:

- CBS definition was also subject to the limits of existing data. These units are based essentially on geomorphology criteria and the existence of defences. Since the project scale is regional, data are accordingly dependent on the knowledge available: CBS definition does not integrate the role of coastal hydrodynamics and notably of sediment transport.
- To assess the future evolution of coastal hazards, hypotheses rely on socio-economic scenarios. The models for greenhouse gas emissions were built according to these hypotheses as well their expected impacts on climate and sea level change. Such models are built on a global scale, and had to be adapted to a regional one within the limits of current knowledge.

- The grading proposed here are the result of judgment by a panel of experts, on the basis of conventions linked with an understanding of the context, in order to ensure a measure of uniformity and reproducibility in the grading. Those conventions can be discussed and stregthenned. In the event of a change in scale, and for use concerning individual localities, they will need to be adjusted by integrating a better understanding of hydrodynamics and of sediment budget, on the basis of additional measurements and more precise modelling.

Thus, the interpretations proposed here must necessarily be considered on a regional scale and be understood as representing tendencies liable to evolve.

b) Results

It is clearly established that in no instance, in both considered regions, will climate change cause erosion and marine flooding hazards to decrease. On the contrary, not only a majority of the sectors recognized to-day as critical will see their hazard increase, but also a certain number of new segments not presently marked as exposed to a coastal hazard will enter this category under the hypothesis of global change.

A significant or drastic increase would affect 98% of the coastline in the Aquitaine region and 89% of that in the Languedoc-Roussillon region distributed as follows (Table 9).

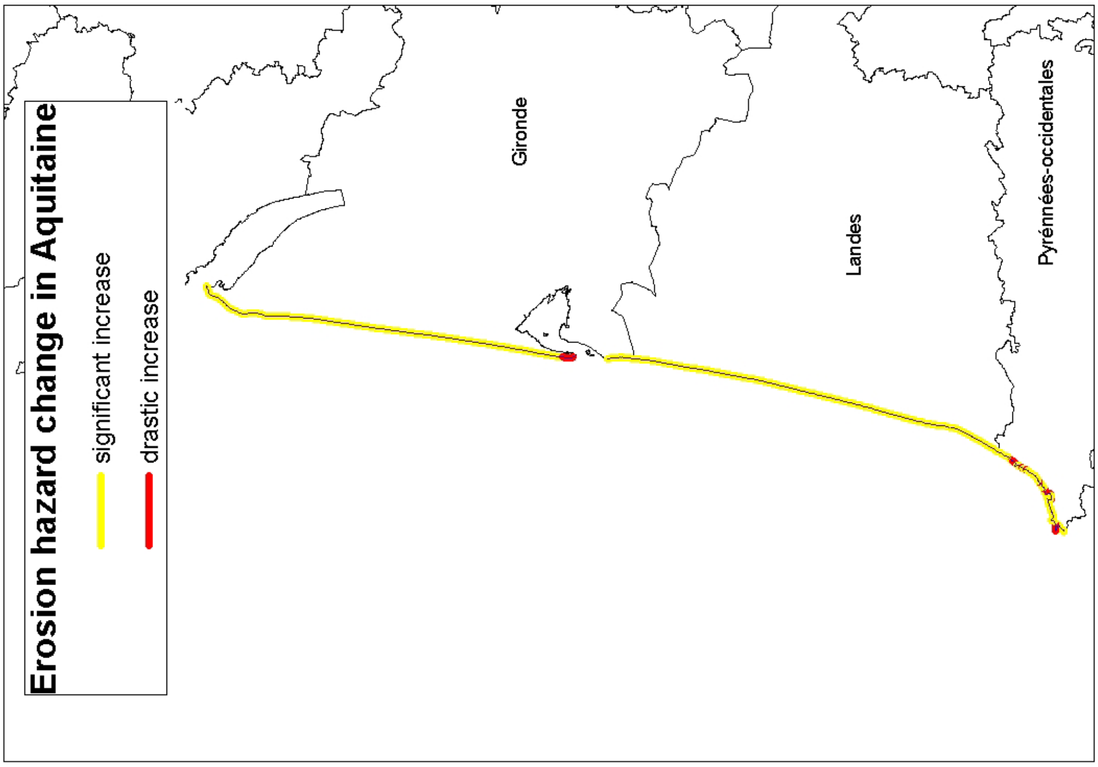
	Significant hazard increase (km of coastline)	Drastic hazard increase (km of coast line)	Significant hazard increase (% of total coastline)	Drastic hazard increase (% of total coastline)	Total hazard increase
Coastline subject to increased hazard	**AQUITAINE REGION**				
	251 km	12 km	94%	4%	98%
	LANGUEDOC-ROUSSILLON REGION				
	57 km	131 km	26%	61%	87%

Table 9 - Length of coastline concerned by an increase in coastal hazards (calculated from Map 6).

The proposed ratings strongly reflect the geomorphology of the two concerned regions.

- **In the Aquitaine region**

The various systems composing the Aquitaine region coast respond differently to climate change (Figure 18):



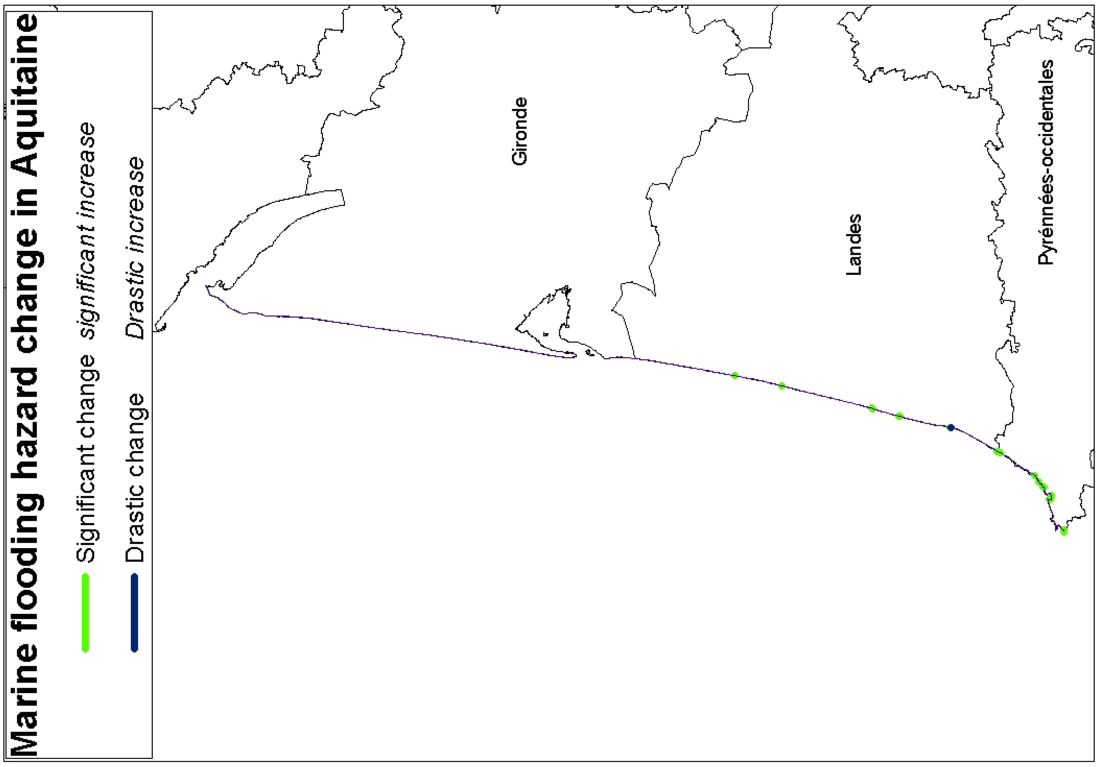


Figure 18 - Rating results for erosion and marine flooding hazard changes in the Aquitaine region. Derived from Map 6.

- In the sandy coast (Gironde and Landes):
  - · The rise in sea level and increase in the frequency and severity of storms will cause an increase in erosion hazard both on the beach and at the base of the dunes. However, the backshore of the sandy coast is composed of high, wide dunes, and these can be considered to contain a substantial sedimentary stock which would confer on the coast a certain capacity for resilience versus climate change.
  - · Also, the hypothesis is made that the sandbars present offshore, that account for part of this stock, are not sustainable and are destined to disappear, and, with them, the protective role they play. However, this hypothesis would need to be supported by a hydrodynamic model. The CBS's comprising backshore dunes thus display a significant increase in erosion (a +1 grading).
  - · Certain segments of the sandy coast, however, have been considered less capable of adapting to climate change in terms of erosion and were accordingly rated +2 (a drastic increase in erosion). This rating takes into account their present hydrodynamic instability (the sandy spit at Cap-Ferret) or the apparent deficiency of coastal defences if they remain in their present condition (rivers outlet of Aquitaine currents, lower or urbanized dunes).
  - · The elevation of the dunes, about 20 m, is obviously a protective element against marine flooding (the potential flood level in the Aquitaine region being 5.8 m). The sectors concerned by this hazard are the rivers outlets that gives ways to the flooding of the backshore, which is generally low-lying.
- The cliff-lined coast (Pyrénées-Atlantiques department):
  - · The rise in sea level will have little effect on cliff-type systems. On the contrary, the increased severity and frequency of storms and changes in the hydrogeolocial context (increase of the watertable fluctuations will be likely to trigger ground movements on soft cliffs, vulnerable to erosion due to their sedimentary nature and weathering. The cliff segments are accordingly judged liable to a significant change in erosion hazard.
  - · Systems with a backshore made up of cliffs or hills are naturally not exposed to a present day marine flooding hazard, nor are they liable to the appearance of this hazard with climate change.
  - · Beaches at the foot of these cliffs or in the bays between cliffs are narrow (fringing beaches) and frequently lie on bedrock; the backshore consists of cliffs or rocky hills. These beaches represent a small volume of sediment and are accordingly liable to incur a considerable hazard change, or even to disappear altogether. For this reason, they have been rated +2 (drastic increase).
  - · the exposure of the cliff-lined coast to marine flood is limited to the mouths of rivers and coastal watercourses.

- **In the Languedoc-Roussillon region**

The sandy coast of the Languedoc-Roussillon region (the Gard, Hérault, and Aude Departments) would likewise react differently to climate change than the cliff-type coast of the Pyrénées-Orientales Department (Figure 19):

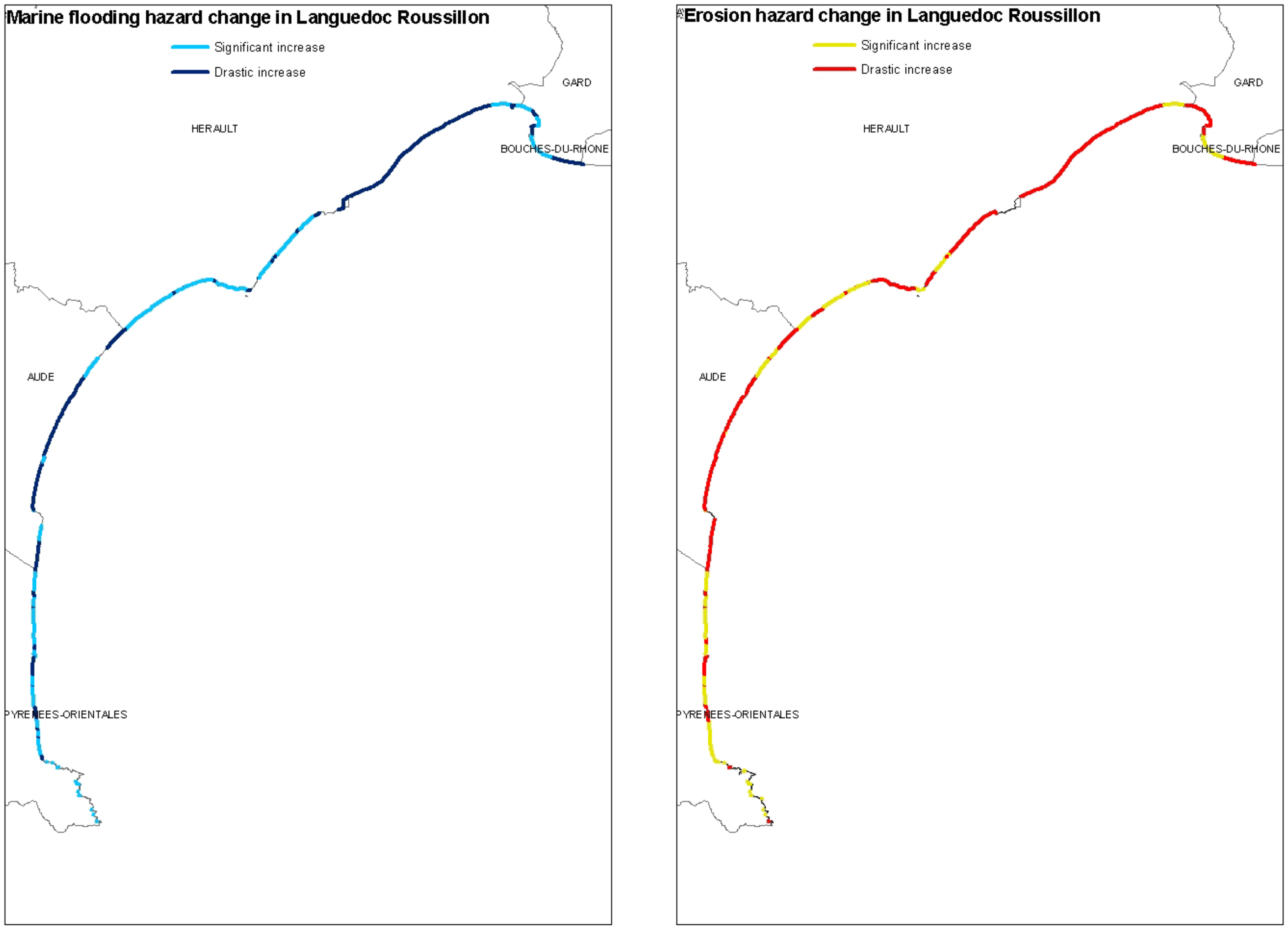


Figure 19 - Rating results for erosion and marine flooding hazard changes in the Languedoc-Roussillon region. Derived from Map 6.

- The sandy coast:
  - Unlike along the Aquitaine coast, dunes that make up the backshore of this straight coast are narrow and low. On their inland side, they are in contact with low, marshy or drowned zones. Furthermore, the presence of urban development and transport network (infrastructures) decreases the availability of the sediment stock they would represent to counteract the erosion of beaches and bases of dunes. They are frequently protected by hard defences (groynes and breakwaters) that will quite probably be ineffective if they are not adapted in future. These types of CBS were accordingly graded+2 (a drastic increase) with respect to erosion hazard, except for a few sectors where dunes were higher and their sediment stock available.
  - These dunes are liable to be breached in the event of severe storm, as shown by inlets that tend to be laterally unstable (unless they have been stabilized) and that already allow the hinterland to be flooded. The increase in marine flooding hazard under the hypothesis of storm surges that might reach 2.7 m above IGN datum is rated either significant (+1) or drastic (+2) according to the density (occurrence?) of inlets and the height of the dunes.

    It is to be noted that the notion of marine flooding as applied to coastal lagoons requires explanation: although these zones are already under water, marine flooding phenomena would increase both their size and salinity. Thus their impact should not be disregarded.
- The cliff-lined coast (Pyrénées-Orientales department):
  - The cliffs consist of hard rock. They have undergone little weathering and are not currently subject to erosion. Beaches are absent. The results of climate change would modify this situation little if at all.
  - On the other hand, the beaches enclosed in bays are narrow, their volume is small, and they would be extremely vulnerable to a rise in sea level and an increase in storm activity for lack of sediment stock. They have been rated as liable to a drastic increase in hazard (+2) or may even disappear altogether.
  - A few small sectors of this cliff-lined coast situated at the mouths of coastal rivers, will be subject to a flooding hazard if we take into account a potential flood level of 2.67 m above IGN datum in 2100. However, only a small area of land is involved.

c) Hazard-related hotspots under the hypothesis of climate change

On the basis of the definition of Coastal Behaviour Systems and a knowledge of current erosion and flooding hazards, attention was drawn to a certain number of present hotspots in section 2.4.6.

An analysis of the results presented on Map 6, depicting the change in coastal hazards in relation to climate change, leads one to realize that while today's hotspots will for the most part continue to be a source for concern, new segments of the coast also will achieve critical status during the coming century.

- **In the Aquitaine region**

Figure 18 shows that the spots currently identified on the sandy coast, such as Soulac and Cap-Breton, as being vulnerable to erosion will continue to be a source for concern if existing defences remain as they are today.

It should further be noted that the entire sandy coast will be subject to a significant increase in erosion hazard although the sediment stock represented by the dunes should help to a certain extent in adapting to this change.

The probable increase in hazard at the spit of Cape Ferret stands out as particularly drastic. This hypothesis does, however, require validation by integrating modelling of the sector’s hydrodynamic evolution.

On the cliff-lined coast, the current level of erosion is viewed as critical. An increase in this hazard will be significant for all the cliffs and drastic on the beach segments, which sediment stock is only provided by cliff weathering. These beaches would be at danger of disappearing despite the fact that they are not all currently considered as critical, cliff weathering product being presently considered as sufficient (Mallet *et al.,* 2005).

In terms of potential marine flooding, the segments classified as vulnerable now will be even more so in the event of a rise in sea level. However, no new segments are identified as being exposed to flood.

These new hotspots are described in detail in Table 10 and have been plotted on Figure 20. A selection of better known sites are described in Appendix 8.

Township or locality	Present hotspot (current known risk)	Hazard evolution Type of hazard	
		Maintained	*Increased*
Soulac	Erosion	Erosion	
L'Amélie	Erosion	Erosion	
Lacanau	Erosion	Erosion	
Cap Ferret (seaward)			Erosion
Biscarosse	Erosion	Erosion	
Mimizan	Erosion	Erosion	
Cap Breton	Erosion	Erosion	
Pointe Saint Martin (Anglet/Biarritz)	Ground movement		Ground Movement
Côte des Basques (Biarritz)	Ground movement	Ground movements	
Plage de Milady (Biarritz)			Erosion (beach)
N Plage du Pavillon Royal (Chaya ?)			Erosion (beach)
Guéthary	Ground movement	Ground movements	
Plage de Cenitz (Guéthary)			Erosion (beach)
N Plage de Lafitenia			Erosion (beach)
N plage d'Eromardie			Ground movements
Plage dEromardie			Erosion (beach)
Sud baie d'Eromardie (Saint Jean de Luz)	Ground movement	Ground movements	
Pointe Ste Barbe (Saint Jean de Luz)	Ground movement	Ground movements	
Haize Rota			Erosion (beach)
Baie de Saint Jean de Luz	Marine Flooding	Marine Fooding?	Erosion (beach)
Baie de Socoa			Erosion (beach)
Pointe de Socoa (Urrugne)	Ground Movement	Ground movements	
Hendaye	Erosion and Marine Flooding		Erosion (beach)

Table 10 - List of hotspots to be considered in regard to increased or maintained coastal hazards, in Aquitaine.

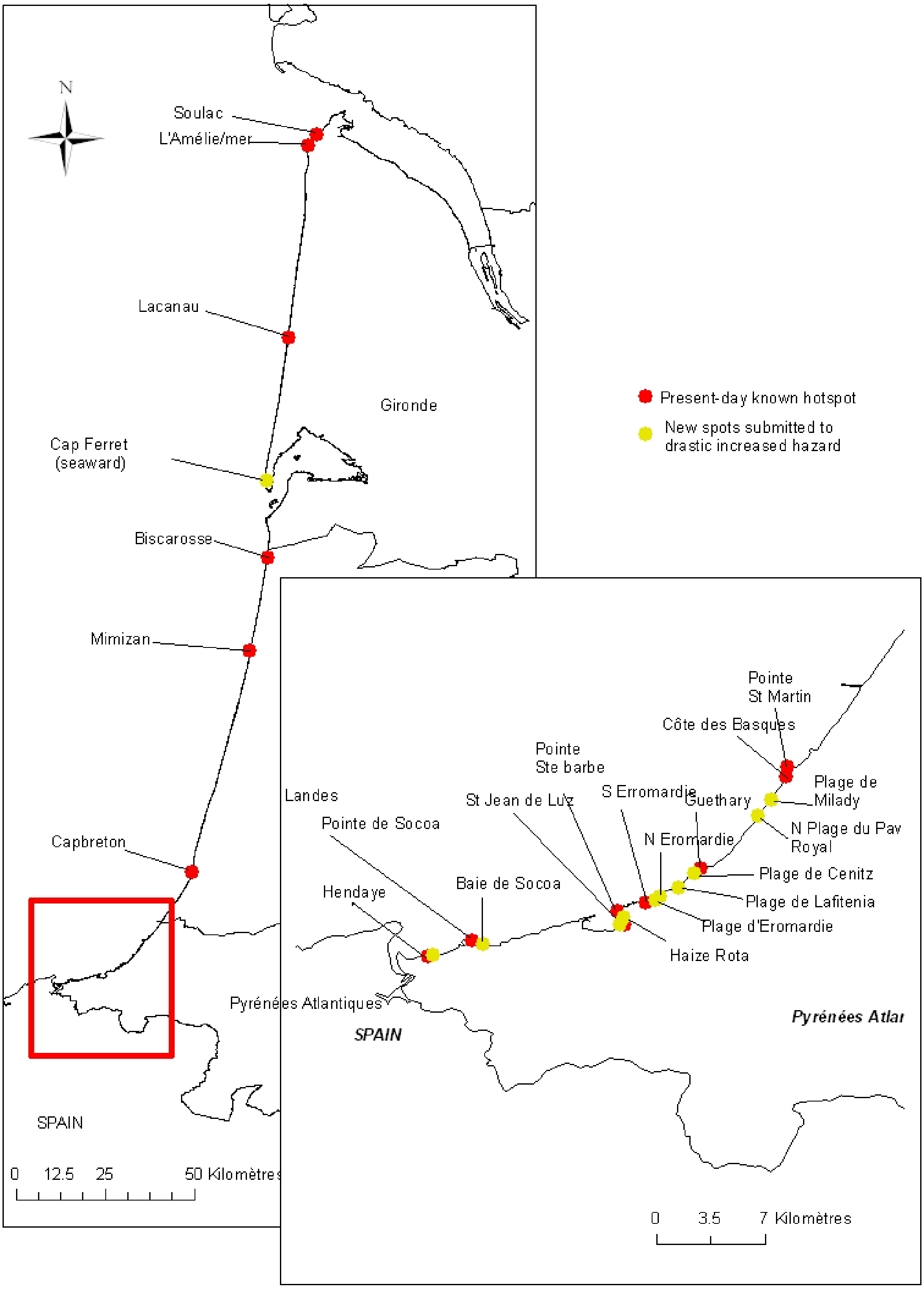


Figure 20 - The position of hotspots with respect to hazard change in the Aquitaine region.

- **In the Languedoc-Roussillon region**

Following the RESPONSE approach, the spots currently considered to be vulnerable to erosion on the sandy beach, mentioned in section 2.4.6, can expect to be subjected to a drastic increase in erosion hazard, and the segment of coast concerned will be more extensive. In any case, the increase in erosion hazard affecting the whole sandy coast will be at the very least significant, if not drastic.

Regarding marine flooding, it was decided in section 2.4.6 to retain as hotspots only those that had already actually been flooded. The estimation of the increase in this hazard considerably extends this notion, notably in the vicinity of inlets and to most lido systems.

At this stage of the mapping process, for erosion as well as marine flood hazard, the result is not discriminatory enough on the sandy coast to be able to pinpoint new hotspots other than those already identified with the current state of knowledge. Nevertheless, the implied coastline length will need to be extended laterally in the future, to the sedimentary call scale.

On the cliff-lined coast of the Pyrénées-Orientales department, the beaches, which are narrow and contain no stock of sediment to remediate erosion, emerge as new spots deserving concern.

These new hotspots for Languedoc-Roussillon region are listed in Table 11 and have been plotted on Figure 21. It is to be underlined that present-day hotspots are included in coastline segments to be considered as hotspots in regards to an increased coastal risk. This approach emphasizes the fact that not only spots but wider systems, linked to sedimentary cells are to be considered in a future management of the risk.

Township or locality	Present hotspot (current known risk)	Hazard evolution	
		Type of hazard	
		Maintained	***Increased***
E petite Camargue	Erosion		Erosion/ Marine Flooding
Port Camargue			Erosion
Grau du Roi	Erosion/Marine Flooding		Erosion/ marine Flooding
Lido from Grau du Roi to la Grande Motte			Erosion/ Marine Flooding(locally-graus)
La Grande-Motte	Marine Flooding	Marine flooding	
Lido from Grand Travers to Palavas	including Petit Travers		Erosion/ Marine Flooding
Lido from Palavas to Sète	including Maguelone, Arresquiers and Frontignan		Erosion/ Marine Flooding
Port de Sète			Marine Flooding
Lido from Sète to Marseillan	including E lido		Erosion/ locally (graus) Marine Flooding
Port d'Ambonne			Erosion/Marine Flooding
Cap d'Agde			Marine flooding
E plage Richelieu			Erosion
La Guirandette			Erosion
La Tamarissière	Erosion	Erosion	Marine Flooding
Farinette			Erosion
Portiragne	Erosion	Erosion	
Ancien Grau du Libron			Marine Flooding
Grau de Sérignan			Marine Flooding
Sérignan/Valras-plage	including Valras	Marine Flooding	Erosion
Vendres	Marine Flooding	Marine Flooding	
Lido from Fleury to Pissevaches	Including "les cabanes de Fleury"		Erosion/Marine Flooding
Narbonne-Plage	Marine Flooding		Erosion
Lido from "côte rose" to Gruissan			Erosion/Marine Flooding
Gruissan	Marine Flooding		Erosion/Marine Flooding
lido de Gruissan à Port la Nouvelle			Erosion/ Marine flooding
Port La Nouvelle	Marine Flooding	Marine flooding	Erosion
Lido de Port la Nouvelle à La Franqui			Erosion/Marine Flooding
Leucate Plage to Port Barcares N			Erosion
Port Barcares	Erosion		Erosion
L'Agly outlet			Erosion/ Marine flooding
Toreilles	Marine Flooding	Marine Flooding	
Sainte Marie plage	Erosion/Marine Flooding	Marine Flooding	Erosion
From Canet -plage to camping Mar Estang	Erosion/Marine Flooding		Erosion/Marine Flooding(locally-graus)
Lido de l'étang de canet (including Saint Cyprien N)	Erosion	Erosion	
Lido of Saint Cyprien	Erosion	Erosion	
Le Tech outlet			Marine flooding
Grau de la Riberta			Marine Flooding
Argelès	Marine Flooding		Marine Flooding
Collioures	Marine Flooding	Marine Flooding	

Table 11 - List of hotspots to be considered in regards to increased or maintained coastal hazards.

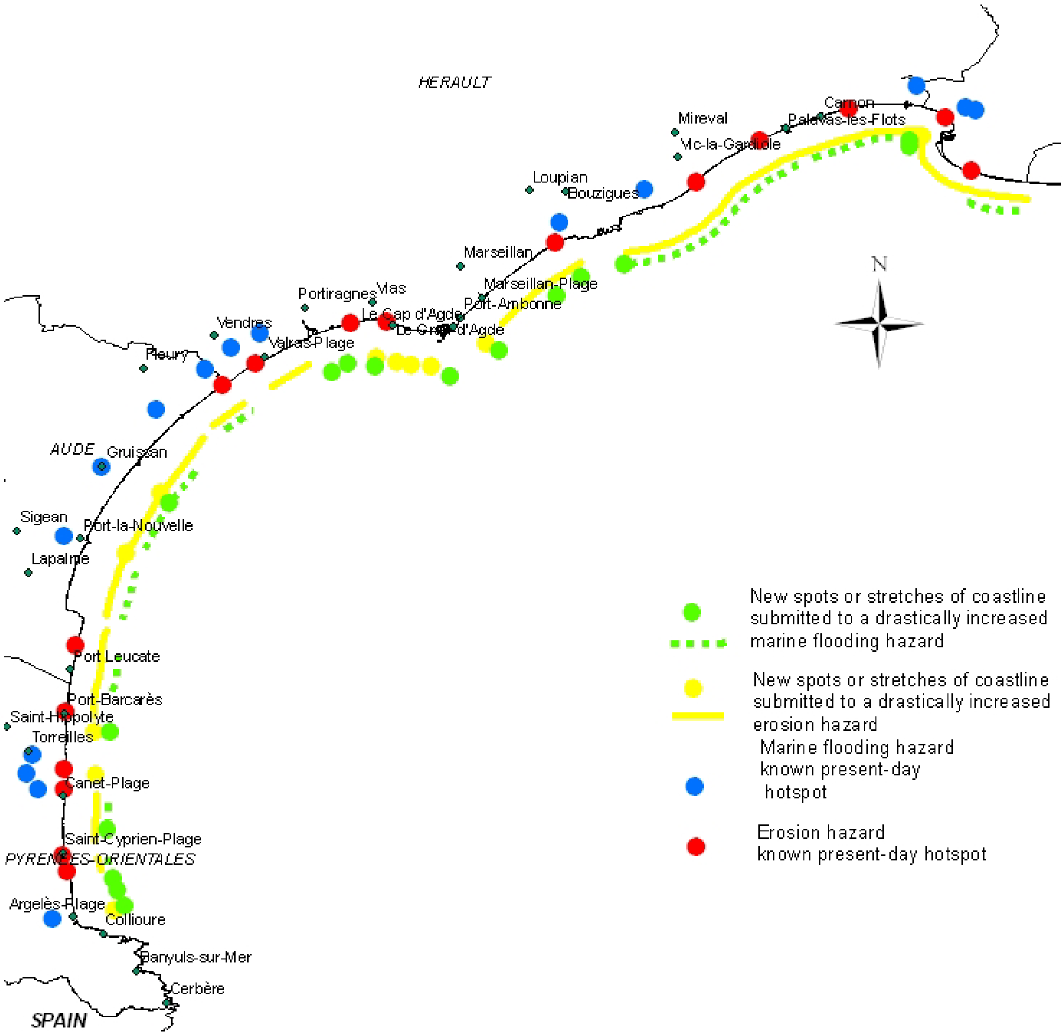


Figure 21 - The position of hotspots with respect to hazard change in the Languedoc-Roussillon region.

2.7. PHASE 4: EVALUATION OF THE ASSETS PLACED AT RISK DUE TO HAZARD CHANGE

2.7.1. Method

This phase is designed to assess the change in coastal risk (Figure 22). At this juncture, the concept of specific assets at stake must be integrated and merged with the map obtained after assessing hazard change, so as to target the assets at greater risk.

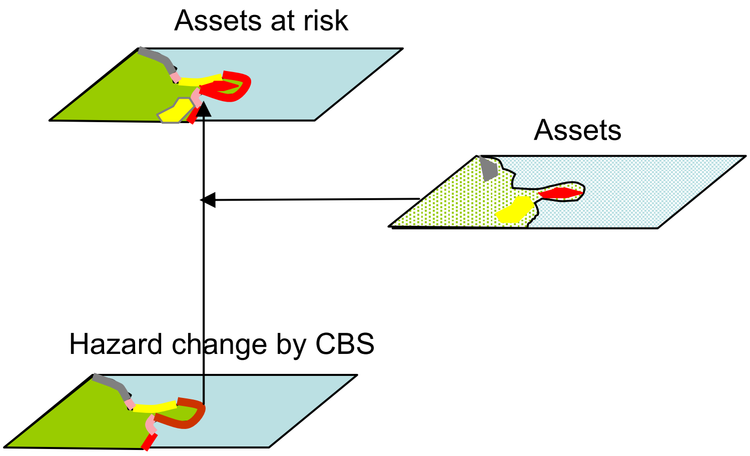


Figure 22 - Method for estimating changes in risk.

2.7.2. Mapping assets

The assets placed at risk by the existence of a coastal hazard are economic, societal and environmental. Human "assets" are in direct relation with the presence of population and to its evolution. The various assets of a societal, economic or environmental nature were derived from the databases described hereinafter.

a) Population

The data on urban population were drawn from the MapInfo tables. They are mapped with symbols proportional in size to the number of inhabitants.

The various territorial analyses published by INSEE on the Internet reckon on a probable population growth of about 10 to 20% during coming decades and in the coastal zones of the two regions considered. This growth is not factored into this project, but it will in all likelihood contribute to raising the stakes for the assets concerned.

b) Economic and societal assets at stake

Economic and societal assets, associated with the presence of population, were provided by the CORINE Land Cover database. The version chosen was that of 1990 to respect coherence with the time interval considered for climate change, *i.e.*, 1990–2100. These assets are identified in the CORINE base as urban, industrial or agricultural: the different land-use categories were combined into assets of urban, industrial, agricultural or tourist types. It should be borne in mind that the probable evolution of assets (the appearance of new ones or spatial modification) was not taken into account in this project.

Lastly, structural assets such as railways, the road networks, etc., were also taken from CORINE Land Cover, 1990.

c) Environmental assets

The data concerning zones protected for environmental purpose came from the GIS of the Regional Directorates for the Environment (DIREN) of the corresponding regions. They include maps of ZNIEFF, ZICO, Natura 2000, nature reserves and of sectors protected under the European Habitats Directive.

2.7.3. Mapping the change in coastal risk

a) The risk today

- **Erosion risk**

In order to obtain elements of comparison with the future evolution of erosion risks, it was decided to plot on this map the present-day coastal erosion risk when known. This information was derived from EUROSION data by retaining the segment of coast thought currently to be undergoing erosion collated with the presence of assets at distances not exceeding 300 m from the coast line. This 300-meter distance is the one proposed in the initial RESPONSE methodology in the definition of backshore as equivalent to potential coastal retreat in 100 years' time (Interim RESPONSE report, March 2005).

This parameter is noted with a solid line drawn off shore from the segment considered.

- **Marine flooding risk**

To ensure readibility of the final map, the outline of the current marine flooding has not been indicated, although it remains available in the GIS and on Maps 3 and 5 (Appendix 4).

b) Evolution of the risk in the future

- **Erosion risk**

The group of assets believed to be subject to a growing risk is determined by selecting all those situated within a 300-meter zone inland from the sectors considered subject to a growing erosion or marine flooding hazard (whether significant or drastic), on the same argument than above quoted.

In the background of the map, all the assets not selected on the basis of this criterion are shaded in grey, for they may at present be subject to a coastal risk.

- **Marine flooding risk**

The assets that lay within the potential extent of marine flooding for 2100 as it was calculated in preparing the hazard change map were selected. In the background of the map, all the assets not selected according to this criterion are shaded in grey, for they may at present be subject to a coastal risk.

2.7.4. Analysis of results

a) Limitations of the method

Map 7 concerning changes in risk integrates the notion of assets endangered by an increase in hazard. For this reason, mapping assets at risk also suffers from the limitations of the method used to map hazard evolution (Map 6, Appendix 4).

Mapping these assets was performed using the existing mapped data: it notably was decided to use the data from CORINE Land Cover 1990 to respect coherence with the time interval considered for climate change (section 2.5, Figure 15). It does not consider the evolution between 1990 and the present, not the future evolution of the assets themselves, highly probable in the perspective of population growth in coastal areas (INSEE, 1999).

The maps obtained by merging the assets with the coastlines concerned by a probable increased erosion and/or flooding hazard only highlights the assets located near the coastline. Moreover, only those assets that would be materially affected by a hazard were dealt with. Nor does this map indicate the subsidiary effects that might be induced on economic or societal assets farther inland from the coastline.

Finally, the assets are represented in this mapping process according to a binary approach, *i.e.*, presence or absence. No difference in weight is assigned to one type of asset compared with another in this map, and the adaptive potential of the assets is not assessed. Thus at this stage, the results obtained do not correspond to a risk assessment or a change in risk *strictly speaking*, but rather merely represent a map of assets endangered by a hazard change under the hypothesis of climate change according to the scenario described in section 2.5.

b) Results

Establishing the map of changes in risk does, however, make it possible to weight the results of the hazard change map, reflecting the importance of land-use development policy in coastal areas to risk distribution.

The total length of coastline that should be considered in terms of increased risk appears to be smaller than what is concerned by an increase in the coastal hazard in question: according to the spatial distribution of assets and coastal development policy, certain sectors, although exposed to a hazard, would not be at risk insofar as they have no associated assets.

- **In the Aquitaine region**

Table 12 summarizes the possible evolution of risk for each type of asset.

The ranges of values given in Table 12 were calculated as follows:

- the lower figure takes into account the coastline subject to increased hazard that is strictly perpendicular to the asset in question;

- the upper figure includes a 300-meter zone of influence It should be noted that two assets may be superimposed;
- the meaning of these figures is relative, but they do emphasize the fact that the assets placed at risk by the potential increase in hazard are essentially of an urban and tourist nature.

	Significant risk increase (km of coastline)	Drastic risk increase (km of coast line)	Significant risk increase (% of total coastline)	Drastic risk increase (% of total coastline)	Total risk increase per asset (% of coastline)
Agricultural	1 to 3	0 to 1	0.3 to 1%	0 to 0.3%	0.3 to 1.3%
Industrial	1 to 3	0 to 0.5	0.4 to 1%	0 to 0.1%	0.4 to 1.1%
Tourist	2 to 9	0.5 to 3	0.7 to 3%	0.3 to 1%	1 to 4%
Urban	10 to 38	3 to 7	3 to 13%	1 to 2 %	4 to 15%

Table 12 - Length of coastline in the Aquitaine region concerned by assets exposed to risk due to an increase in coastal hazard.

The environmental asset that encompasses the different protected areas listed in the GIS of the Aquitaine DIREN covers the entire Aquitaine coast; it may accordingly be assumed that wherever hazard increases drastically, this asset is placed at risk.

On the other hand, amongst the socio-economic assets, the ones most affected are urban and tourist-related ones. Industrial and agricultural assets are infrequently placed at risk. The industrial assets mapped are mainly located on the Basque coast. Most often they are sited inland from the coastline in the vicinity of rivers and would tend more be placed at risk by an increase in marine flooding hazard.

Figure 23, drawn from Map 7 (Appendix 4), shows that although the Basque coast presents a higher concentration of urban and tourist assets at risk, restraint development on the sandy coast has limited risk to urban and tourist assets, at risk clustered around coastal outlets.

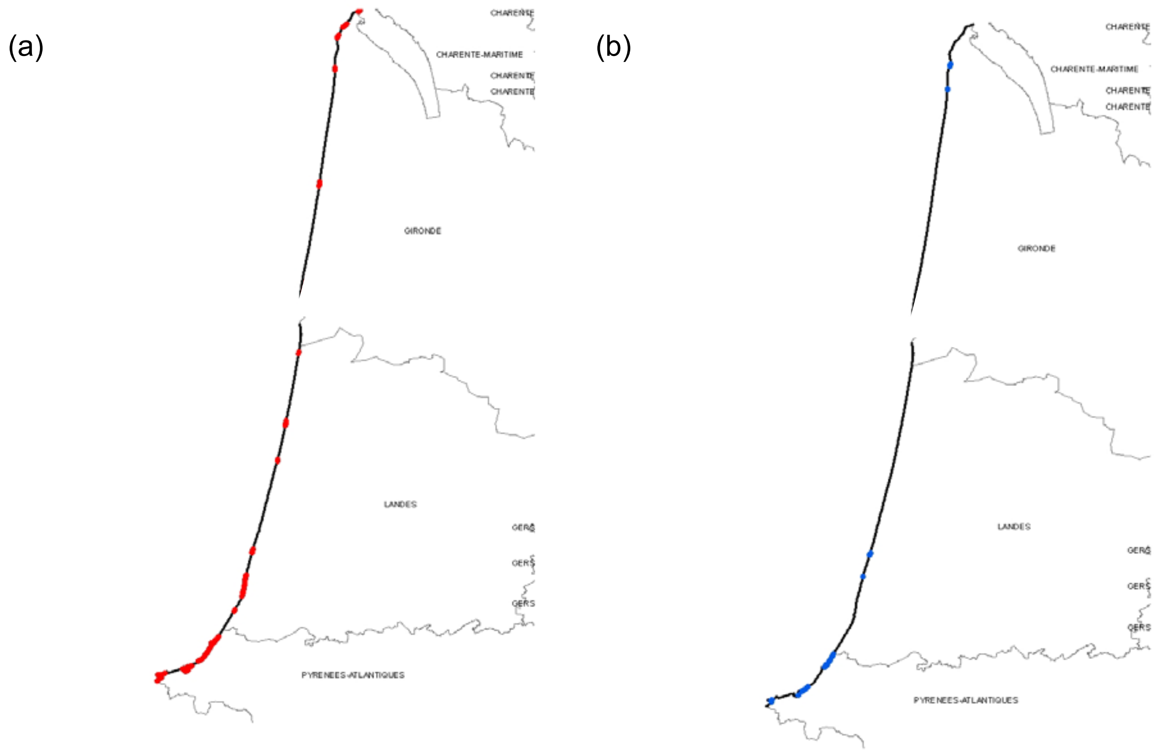


Figure 23 - Drawn from Map 7 situating the urban (a) and tourist (b) assets that would be placed at risk by an increase in coastal hazards in the Aquitaine region.

- **In the Languedoc-Roussilon region**

Unlike the Aquitaine region, the Languedoc-Roussillon region's population grew massively during the latter decades of the 20th century, creating important socio-economic assets in the coastal area. Table 13 gives the ranges of values for length of coastline that places the different types of asset at risk (calculated using the same principle as in Table 12). Figures 24 and 25 show their geographical distribution.

	Significant risk increase (km of coastline)	Drastic risk increase (km of coast line)	Significant risk increase (% of total coastline)	Drastic risk increase (% of total coastline)	Total risk increase per asset (% of coastline)
Agricultural	1 to 13	5 to 24	0.4 to 6%	2.1 to 11%	2.5 to 17%
Industrial	2 to 5	5 to 18	0.8 to 2%	2.7 to 9%	3.3 to 11%
Tourist	1 to 11	2 to 13	0.5 to 5%	0.8 to 6%	1.3 to 11%
Urban	4 to 18	15 to 44	1.9 to 9%	6.8 to 20%	8.7 to 29%
Environmental	15 to 48	49 to 100	7.1 to 22%	23 to 47%	30 to 69%

Table 13 - Length of coastline in the Languedoc-Roussillon region concerned by assets exposed to risk due to an increase in coastal hazard.

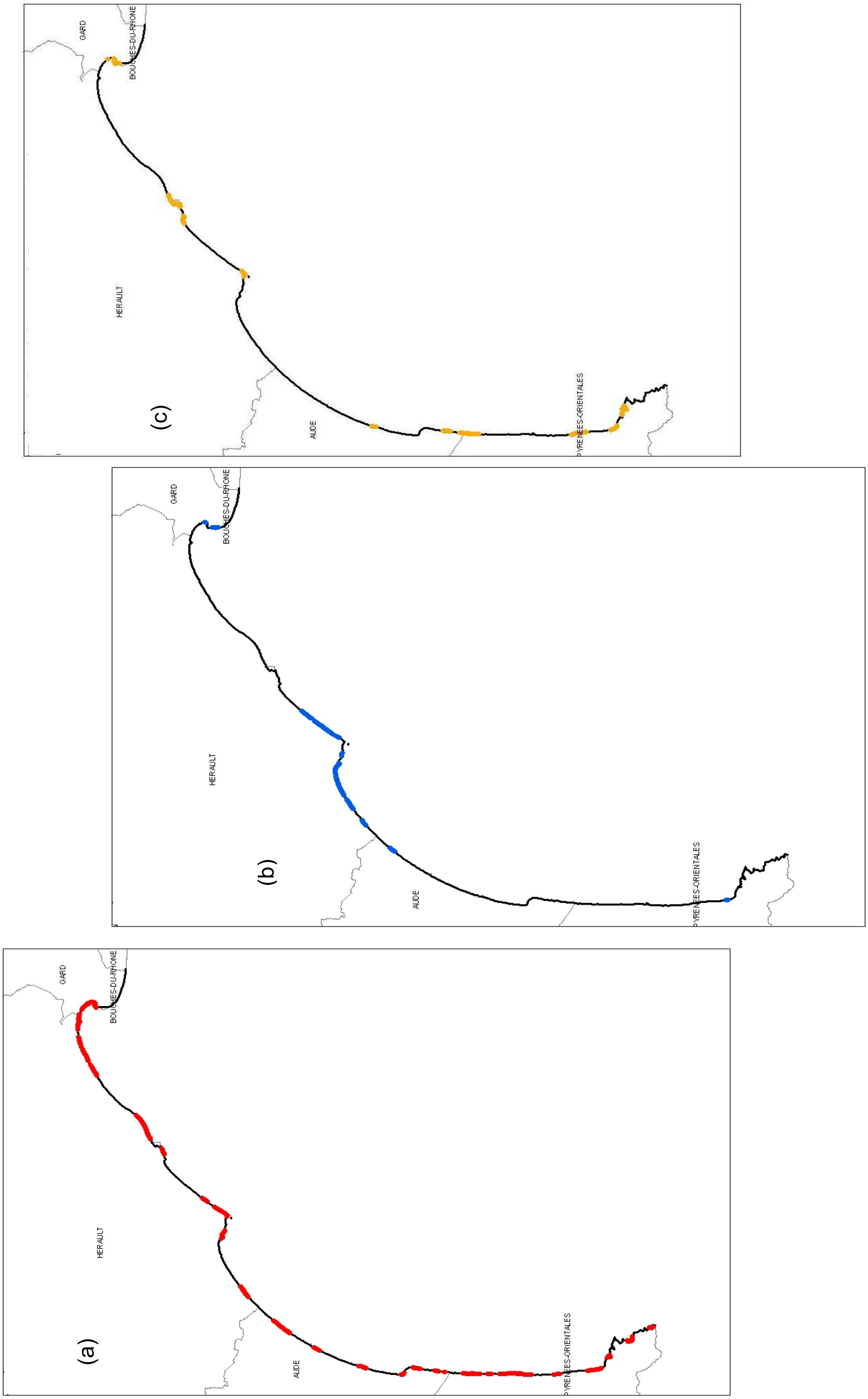


Figure 24 - Drawn from Map 7, situating the assets in the Languedoc-Roussillon region placed at risk by an increase in coastal hazard according to type: a) urban; b) tourist and c) industrial.

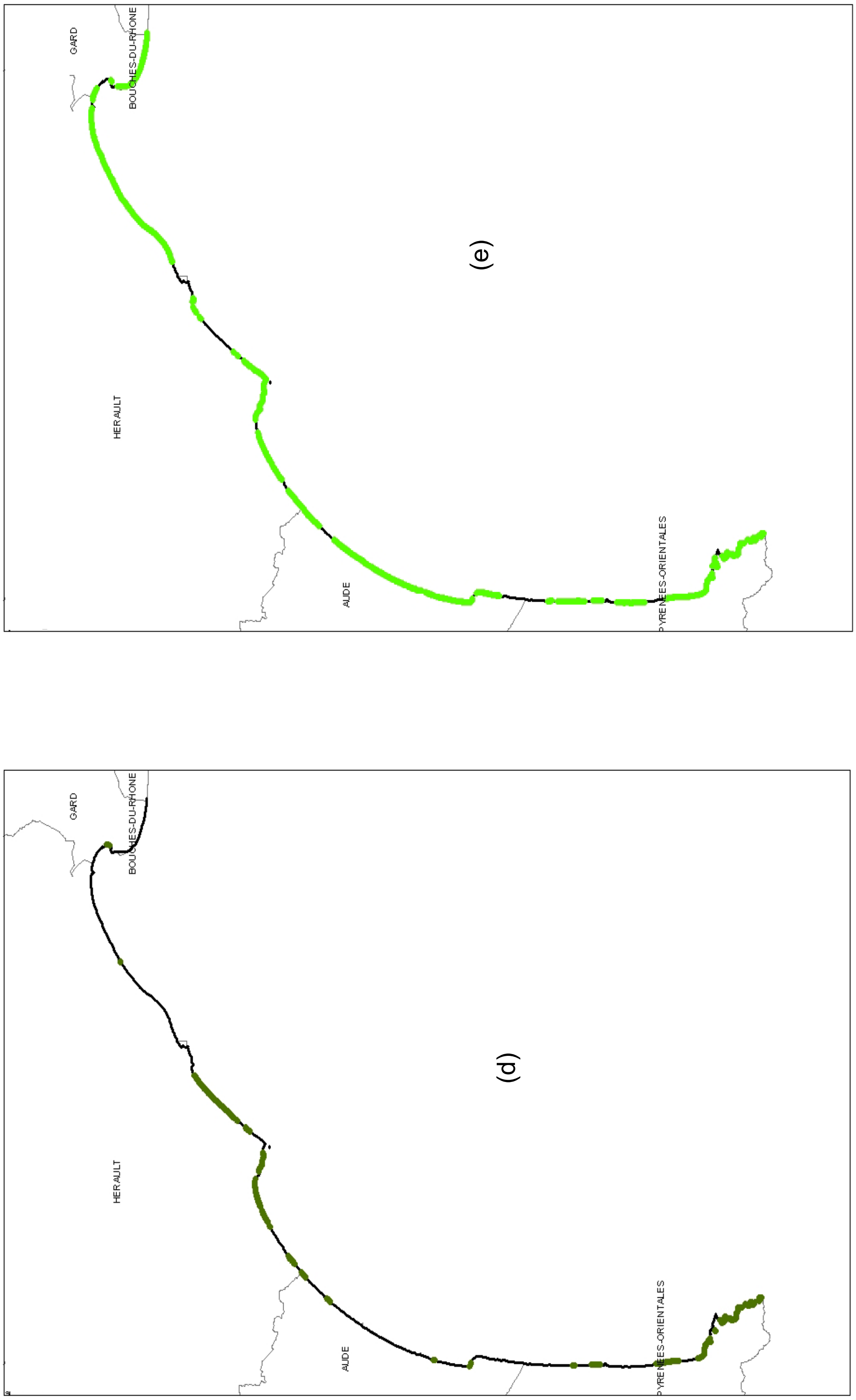


Figure 25 - Drawn from Map 7, situating the assets in the Languedoc-Roussillon region placed at risk by an increase in coastal hazard according to type: d) agricultural and e) environmental.

Here, even more than for the Aquitaine region, one notes the extent of the coastline where urban assets will be placed at risk by an increase in coastal hazard. Moreover, the extent of coastline that places other types of asset at risk is not to be disregarded: industrial assets being distributed by spots, tourist assets completing or superimposed on urban assets, agricultural assets often connected with shellfish farming activities inland form the lidos. These assets are endangered to the same extent by a potential increase in erosion hazard and by an increase in marine flooding hazard.

A very large proportion of the Languedoc coast is listed under a variety of directives on European, national or regional scales as requiring protection, notably the backshore coastal lagoons exclusive of urban zones and a few agricultural sectors. Many of these protected sectors are subject to a probable increase in coastal hazards.

c) Risle evolution related hotspots

Hotspots were identified in preceding sections:

- as present day hotspots, according to definitions found in the literature (Dean *et al.*, 1999; Bodge *et al.*, 1999 and Kraus & Calcgano, 2001), that is, coast segments where the hazards (erosion or marine flooding) have already been recognized as exceeding those to either side of them;
- this notion was refined on the strength of the results of hazard mapping: a certain number of hotspots, some of them already known to present a high level of hazard will, under the hypothesis of climate change, experience a drastic increase in this same hazard. Moreover, new spots of concern from a hazard standpoint were recognized.

The definition proposed in the context of the RESPONSE Project is as follows: a "hotspot," or critical location, is an identified sector that is classified as at higher risk on the basis of maps of present or future hazards. The issue is to then determine whether the hotspots, defined in the section 2.4.6 and 2.6.4(c) in terms of hazard change, endanger socio-economic or environmental assets. Each new spot considered previously is thence associated with information concerning the assets placed at risk. If there are none, the location will no longer be classed as a hotspot.

It will be to be kept in mind that a location marked as a hotspot, in terms of hazard, will need to be considered as such in future, if development is projected that would create assets potentially exposed to risk.

For each of the regions in question, a synthetic table is given (Tables 15 and 16) that is built according to the following principle (Table 14), specifying the stage of the RESPONSE approach at which the location was recognized as a hotspot and whether it should continue to be viewed as such in future in terms of coastal risk. In appendix 8, statements are given for a choice of spots, on the base of the best existing informations. Data on incoming management project are however often not complete. Further recommendations on future management are common to all spots: integrate in management planning the likely impact of climate change, make sitologic studies (measurement, processes modelling).

Township	Present hotspot (current known risk)	Hotspot in terms of hazard change	Hotspot in terms of assets exposed to risk
Township or locality A	Erosion and/or marine flooding	Current hazard maintained or increased	Future risk maintained or increased
Township or locality B	*No hazard and/or risk currently known*	Drastic increase in hazard *Type of hazard*	Asset(s) placed at risk *Type(s) of asset*
Township or locality D	*No hazard and/or risk currently known*	Drastic increase in hazard *Type of hazard*	No known assets

Table 14 - Evolution of the notion of hotspot to define those to be considered on the basis of higher risk under the hypothesis of climate change.

- **In the Aquitaine region**

Townships on the sandy coast with tourist based economies, already considered as hotspots at present, will experience a significant increase in erosion hazard, but not a drastic one, in view of the fact that existing defences are inadequate. According to the above definition, these townships are not classified as hotspots in the context of the RESPONSE Project insofar as they are already a subject of concern and are targeted by projects (*i.e.,* Cap-Breton). On the other hand, the Pointe Cap-Ferret is stands out as a location where the increase in hazard could be drastic and would place at risk a urbanized and touristic sector.

It should be noted that the probable increase in marine flooding hazard places at risk of some urban and industrial assets, inland from the coastal rivers outlets.

On the cliff-lined coast of the Aquitaine region (Basque coast), the cliffs are already being eroded and measures to preserve them have been implemented or are projected; the hazard should increase significantly but not drastically. Only the beach segments are judged liable to undergo a drastic increase in hazard. This increase would place a certain number of urban assets at risk.

Unless environmental assets are more effectively ranked, it does not seem feasible to designate hotspots relative to this asset, insofar as the entire Aquitaine coast is concerned.

Finally, for the Aquitaine region, we construct the Table 17 making use of the method proposed above. Coming out of this analysis grid, 23 hotspots are retained that should be granted attention. These spots are plotted on the map in Figure 26. Convergence of the position of urban and touristic development with the lower spots of the sandy coast, on the outlets of coastal rivers lead to keep all the spots where coastal hazards are likely to be maintained or drastically increased.

Township or locality	Present hotspot (current known risk)	Hazard evolution – Type of hazard – Maintained	Hazard evolution – Type of hazard – Increased	Asset at Risk
Soulac	Erosion	Erosion		Urban/touristic
L'Amélie	Erosion	Erosion		Urban/touristic
Lacanau	Erosion	Erosion		Urban/touristic
Cap Ferret (seaward)			Erosion	Urban/touristic
Biscarosse	Erosion	Erosion		Urban/touristic
Mimizan	Erosion	Erosion		Urban/touristic
Capbreton	Erosion	Erosion		Urban/touristic
Pointe St Martin (Anglet/Biarritz)	Ground movement		Ground Movement	Urban/touristic
Côte des Basques (Biarritz)	Ground movement	Ground movements		Urban/touristic
Plage de Milady (Biarritz)			Erosion (beach)	Urban/touristic
N Plage du Pavillon Royal (Chaya ?)			Erosion (beach)	Urban/touristic
Guéthary	Ground movement	Ground movements		Urban/touristic
Plage de Cenitz (Guéthary)			Erosion (beach)	Urban/touristic
N Plage de Lafitenia			Erosion (beach)	Urban/touristic
N plage d'Eromardie			Ground movements	Urban/touristic
Plage d"Eromardie			Erosion (beach)	Urban/touristic
Sud baie d'Eromardie (Saint Jean de Luz)	Ground movement	Ground movements		Urban/touristic
Pointe Sainte Barbe (Saint jean de Luz)	Ground movement	Ground movements		Urban/touristic
Haize Rota			Erosion (beach)	Urban/touristic
Baie de Saint Jean de Luz	Marine Flooding	Marine Fooding?	Erosion (beach)	Urban/touristic
Baie de Socoa			Erosion (beach)	Urban/touristic
Pointe de Socoa (Urrugne)	Ground Movement	Ground movements		Urban/touristic
Hendaye	Erosion and Marine Flooding		Erosion (beach)	Urban/touristic

Table 15 - List of hotspots in Aquitaine where coastal hazard is likely to be maintained or drastically increased, and which would place assets at risk.

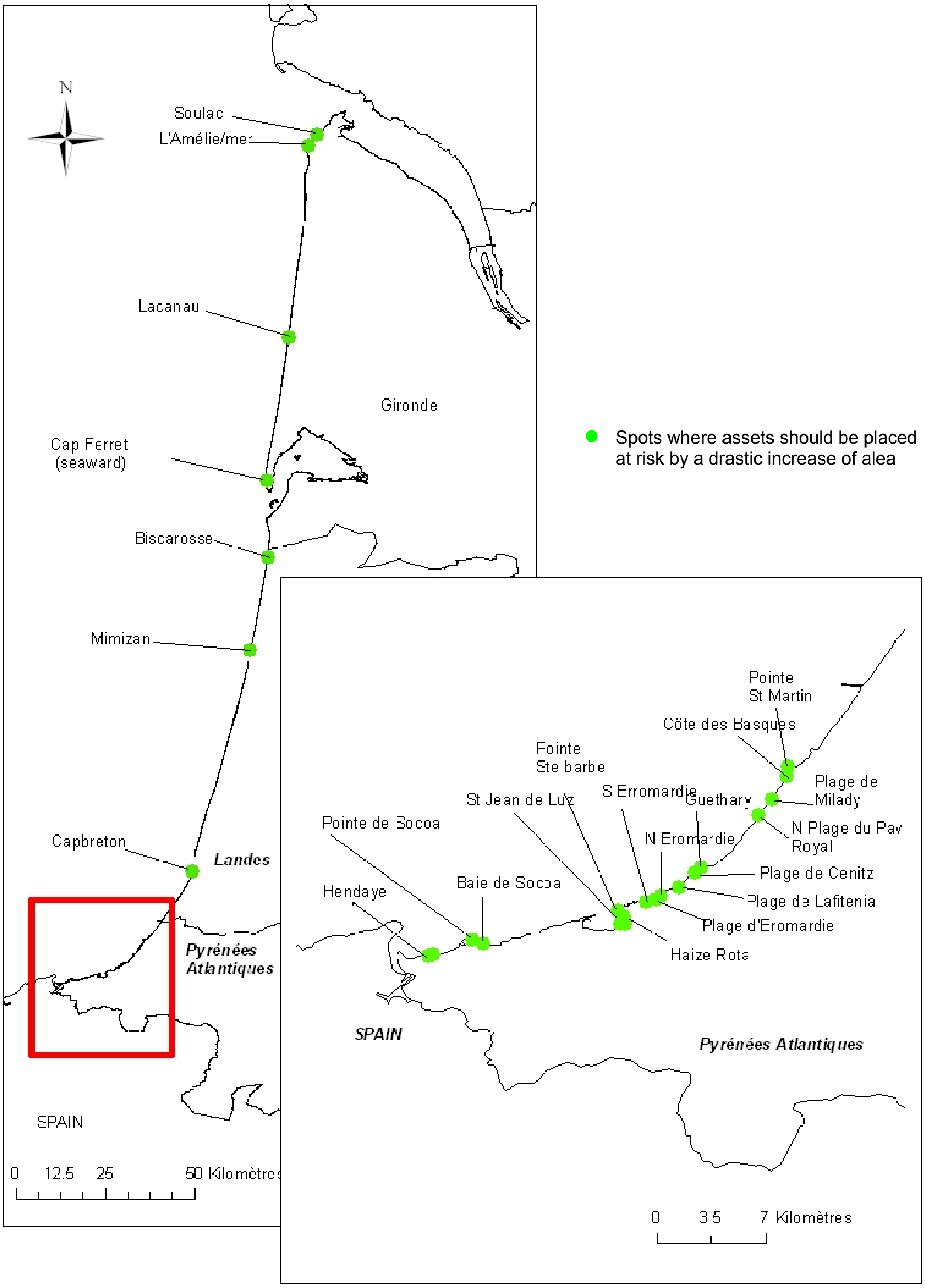


Figure 26 - Hotspots in the Aquitaine region defined in terms of assets placed at risk by drastically increased erosion or marine flooding hazard.

- **In the Languedoc-Roussillon region**

The increase of erosion and marine flooding hazards in the Languedoc-Roussillon region was rated as significant to drastic over most of the sandy coast, and notably at the lidos. The locations currently identified as hotspots belong to this coastline.

Although the distribution of assets perpendicular to these endangered coastlines is more irregular, it continues to be difficult to distinguish what spots are of greater concern than others, insofar as, on the basis of current understanding, the assets are not assigned varying values. All the lidos should be regarded as hotspots, and managed in an integrated policy.

On the cliff-lined Pyrénées-Orientales coast, the small sandy beaches have appeared, after assessing hazard change, as particularly vulnerable insofar as they do not have a stock of sand to help withstand beach erosion. However, a certain number of these spots classed as critical do not endanger assets other than the environment, about which we saw above that it needed to be associated with a range of values.

Finally, for the Languedoc-Roussillon region, was constructed the Table 18 which defines up to 33 hotspots to be considered by the fact that they are drasticly submitted to a present and/or future coastal hazard and that this hazard put some assets at risk. The considered positions are plotted on the map in Figure 27. In most cases, on the sandy coast, it should rather be question of stretchs of coastline, including the lido system than “spots”.

Township or locality	Present hotspot (current known risk)	Hazard evolution		Asset at Risk
		Type of hazard		
		Maintained	***Increased***	
E petite Camargue	Erosion		Erosion/ Marine Flooding	Agriculture(salt basin)
Port Camargue			Erosion	Tourism/Urbanization/infrastructures
Grau du Roi	Erosion/Marine Flooding		Erosion/ marine Flooding	Urbanization/Tourism/Industry
Lido from Grau du Roi to la Grande Motte			Erosion/ Marine Flooding(locally-graus)	Partially urbanized (Grau du Roi, La Grande Motte)
La Grande-Motte	Marine Flooding	Marine flooding		Urbanization/Tourism
Lido from Grand Travers to Palavas	including Petit Travers		Erosion/ Marine Flooding	Partially urbanized (Carnon, Palavas)
Lido from Palavas to Sète	including Maguelone, Arresquiers and Frontignan		Erosion/ Marine Flooding	Partially urbanized (Palavas,Frontignan,Sète)/vineyards
Port de Sète			Marine Flooding	Infrastructure
Lido from Sète to Marseillan	including E lido		Erosion/ locally (graus) Marine Flooding	urbanization, tourism, infrastructures and agriculture
Port d'Ambonne			Erosion/Marine Flooding	Urbanization/Tourism
Cap d'Agde			Marine flooding	Urbanization/tourism
E plage Richelieu			Erosion	Partially urbanized and agricultural
La Guirandette			Erosion	Partially urbanized
La Tamarissière	Erosion	Erosion	Marine Flooding	Tourism
Farinette			Erosion	Tourism
Ste Geneviève - Portiragne	Erosion	Erosion		Tourism
Ancien Grau du Libron			Marine Flooding	Tourism
Grau de Sérignan			Marine Flooding	Agricultural
Sérignan/Valras-plage	including Valras	Marine Flooding	Erosion	Partially urban and tourism
Vendres	Marine Flooding	Marine Flooding		
Lido from Fleury to Pissevaches	Including "les cabanes de Fleury"		Erosion/Marine Flooding	
Narbonne-Plage	Marine Flooding		Erosion	Urban
Lido from "côte rose" to Gruissan			Erosion/Marine Flooding	tourism
Gruissan	Marine Flooding		Erosion/Marine Flooding	urban/tourism
lido de Gruissan à Port la Nouvelle			Erosion/ Marine flooding	
Port La Nouvelle	Marine Flooding	Marine flooding	Erosion	Urban/industrial
Lido de Port la Nouvelle à La Franqui			Erosion/Marine Flooding	
Leucate Plage to Port Barcares N			Erosion	Urban/tourism/industrial
Port Barcares	Erosion		Erosion	industrial/urban/tourism
L'Agly outlet			Erosion/ Marine flooding	
Toreilles	Marine Flooding	Marine Flooding		Urban

Table 16 - List of hotspots in the Languedoc-Roussillon region where coastal hazard is likely to be maintained or drastically increased, and which would place assets at risk.

Township or locality	Present hotspot (current known risk)	Hazard evolution *Type of hazard*		Asset at Risk
		Maintained	***Increased***	
Sainte Marie plage	Erosion/Marine Flooding	Marine Flooding	Erosion	Urban
Canet -plage to camping Mar Estang	Erosion/Marine Flooding		Erosion/Marine Flooding (locally-graus)	Urban
Lido de l'étang de Canet (including Saint Cyprien N)	Erosion	Erosion		
Lido of St Cyprien	Erosion	Erosion		Industries/infrastructures/Urbanization
Le Tech outlet			Marine flooding	
Grau de la Riberta			Marine Flooding	partially urbanized
Argelès	Marine Flooding		Marine Flooding	urban
Collioures	Marine Flooding	Marine Flooding		Urban

Table 16 - List of hotspots in the Languedoc-Roussillon region where coastal hazard is likely to be maintained or drastically increased, and which would place assets at risk (suite).

No present day known risk — present day spots included in wider stretch of coast

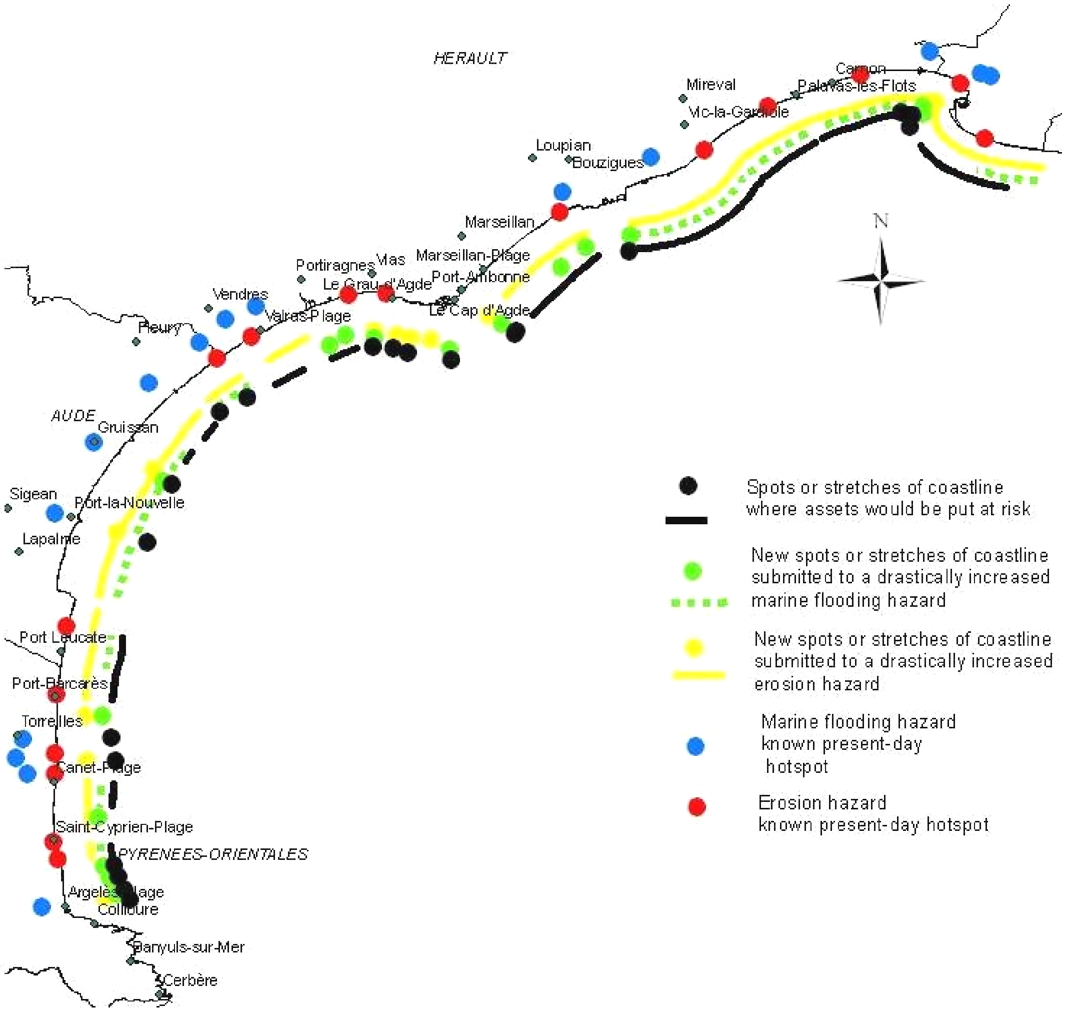


Figure 27 - Hotspots in the Languedoc-Rousillon region defined in terms of assets placed at risk.

3. Assessing the present and future costs of coastal risk management

3.1. A WARNING REMARK

In the previous section dealing with existing assets at risk from hazard increase due to potential climate change, it was stressed that the mapped data on assets did not specify their value endangered or give any indication as to the nature of the damage incurred.

In the context of the RESPONSE project, the task was intended to be taken a step further in asset definition by assessing the present and future costs of coastal risk management. Following the cost typology described in the scoping report on coastal risk costs, included in the interim report of March 2005, different cost references have been sought so as to evaluate the present and future cost of coastal risk management.

Data collected on the present cost of coastal risk management have yielded very heterogeneous results, both for different types and within a single type of cost, largely due to the variety of stake holders and projects and the very different scopes of the costs involved.

The decision was made to quote these figures for **indicative** purposes, but to take care to consider them as a cost range. Furthermore, no attempt is being made to predict future costs in view not only of this heterogeneity of the available data but also because it is not known which strategy will be applied.

Factors affecting choices made for coastal management will naturally include political considerations, but will also take into consideration cost-effectiveness ratios, including a complete scope of implied costs. Such ratios cannot be calculated on a regional scale, and will have to be applied to specific management projects. In this chapter, elements are provided on the assets concerned by increased risk, to gain a regional view of which strategy, if not which cost, might be entailed.

3.2. PRESENT-DAY COASTAL RISK MANAGEMENT COSTS

3.2.1. Data sources

The data were derived from the following documents and from oral communication on behalf of several organisms.

Hard or soft management data were obtained from several case studies given by the maritime service (SMNLR[2] in the Languedoc-Roussillon region and SMN Gironde and DDE Landes in the Aquitaine region) giving the global cost of projects, and from a study conducted by CETMEF giving the linear (meters of works) cost of work, calculated in updated costs from data supplied by maritime services.

Data on environmental assets has been drawn from a SMNLR study regarding management strategy for erosion (2003); it furnishes a relative indexed value of natural assets.

Additional information was made available by CELRL, the Service des domaines (the economic value of natural land) and ONF (dune management costs).

Data on natural disasters came from Munich-Re, a reinsurance company. However, the figures provided do not distinguish coastal damage from other types of damages occurred on coastal communities. No data was able to be obtained from other reinsurance companies.

3.2.2. Results

a) Economic costs

- **Mitigation costs**

Table 17 provides a synthesis of the collected data in terms of economic cost referring to the cost of mitigating or attenuating the effects of natural hazards. It was prepared in order to show the known costs involved in the different possible management choices. Directly linked with the value of the assets involved, the choices will be:

- maintaining and upgrading defence works;
- restoring natural processes;
- retreat, implying loss of land and expropriation. This cost is reflected in land value.

This review is not exhaustive. Data sources are indicated in the table, with figures referring to specific projects (data collected from DDE, SM, ONF, CELRL…) or from the synthesis concerning the cost of hard defences made by the CETMEF (unpublished). The figures must be construed as a range of values, to be discussed and improved on in the event new data are obtained. Besides, it refers to different units: costs are expressed in euros per linear metric reference for hard and soft defence works, euros per area for land value and euros per cubic meter for sand nourishment The economic value of natural land when included in the DPM is cited for the sake of comparison. However, such land is legally inalienable; its natural value is estimated on the basis of a relative index proposed by SMNLR and given in Table 18.

[2] A list of acronyms used in this text is provided in Table 1 of the report.

Strategic option	Details		Languedoc-Roussillon: present value	Aquitaine: present value	Data for other regions	Data sources
Retreat: land loss	urban zones		≥2.5 M€/ha			SMNLR
	natural zones (DPM)		5,000 €/ha	1,500 to 3,500 €		DPM, CERLM
	industrial and commercial zones		>0.5 M €/ha			SMNLR
	touristic and leisure zones		1 M €/ha			SMNLR
	agricultural land (including salt marshes)		5,000 to 10,000 €/ha			SMNLR
	forest land			1,000 to 6,000 €		ONF
	public infrastructures		3 M€ /ha			SMNLR
	infrastructures		0.3 to 5 M€/ha			SMNLR
Reconstruction of natural processes	preliminary study					
	dune management			3,000 €/km-yr		ONF
	by-passing and maintenance			1,450,000 €		SM33
	beach nourishment		6 to 50 €/m^3	9 €/m^3		CETMEF
Construction, maintenance or upgrading of hard defences	groynes	New	330 to 4,800 €/mlw	290 €/m²w		CETMEF
		Upgrading		500 €/m²w		CETMEF
		Concrete groynes			570 €/m²w	CETMEF
		Steel sheet groynes			4,000 €/m²w	CETMEF
	breakwaters	New	4,600 €/mlw			CETMEF
		Upgrading	60 €/mlw			CETMEF
		Wooden Bw			270 €/m²w	CETMEF
	upper beach rock walls	New		1,800 €/m²w		CETMEF
		Upgrading		290 €/m²w		CETMEF
	cliff engineering	Concrete coating		no data		
		Thread		12 €/m²w		CETMEF
		injection				
Soft defences		Wooden piles groynes			185 €/m²w	CETMEF
		Wooden paling		28 €/m		CETMEF
		screen		12 €/m^2		CETMEF
Emergency	population at risk		218 h/km^2	91 ha/km^2		INSEE

Table 17 - Data collected on different types of defences in the Languedoc-Roussillon and Aquitaine regions.

It is seen that the average cost of defence works can vary widely according to composition (concrete, wooden piles, rock fill) and size, but also to the distance to the sources of fill materials. The table also shows that the cost range for soft defences is lower.

The cost review on restoring natural processes is far from complete. Costs of beach nourishment are given, as well as an example of a hydraulic by-pass project.

In the Aquitaine region, information on specific projects was contributed by the Landes DDE and SMN Gironde (Appendix 9, Table 1). No cost data could be obtained from the Pyrénées-Occidentales department. The same range of cost is obtained when cumulating works per township since the 1950's (from 100 K€ to 4,000 €). These ranges cover cost data for all types of hard and soft defences, when present, some being projected (*i.e.,* Cap Breton). The information is likely not to be exhaustive either.

In the Languedoc-Roussillon region, information on specific projects was given by SMNLR (Appendix 9, Table 2). It shows that the budget for reinforcing a sedimentary cell varied on an order of 100 to 3,000 K€[3] between 1948 and 2003 to protect the coasts of urbanized and touristic shorelines. The cost ranges cover hard defences (groynes, seawalls and breakwaters) and beach nourishment from existing data, but this cannot be considered exhaustive.

Generally speaking those figures, whatever solution is chosen underlines the fact that the choice of defence strategy is to be closely compared to the value of the assets involved and backed up by a cost-effectiveness ratio study.

- **The economic costs of catastrophic events**

Data on catastrophic events are shown in Table 20. Supplied by only one reinsurance company, they are not exhaustive and do not give information on the impact of the events on the coastal zone concerned. The table expresses the costs of the events in terms of insured and economic loss, as well as the population involved. Nevertheless, it displays a high cost range in terms of economic value ranging from a tenth to a hundredth of a million US dollars and/or euros.

- **Environmental costs**

Table 19 gave the total value of natural land for the two regions, calculated on the basis of a value per square meter of 0.5 to 1 € provided by the Service des Domaines (state property department) for the DPM (maritime state property). This land is supposed to be inalienable, but can be illegally occupied. A ruling in a law case concerning the expropriation of occupied public coastal land in the Languedoc-Roussillon region cited a higher estimate.

[3] Those figures indicated have not been updated for price increases.

Event	Starting date	Ending date	Sector ?	Region	Description	Deaths	Economic Losses US M$	Insured losses US M$	Injured	Missing	Evacuated
Winter storm Nana	11 Feb. 1990	12 Feb. 1990	N, S, W,	Brittany, Pays de Loire, Lower Normandy, **Biarritz**	Wind speeds up to 160 km/h, hail. Houses and cars damaged. Numerous trains delayed. Roads blocked by downed trees and traffic signs. 75-meter-high crane overturned, tanker drifted from mooring in port of Brest. **Promenade of Biarritz** flooded. Also affected: the United Kingdom and Ireland.	0	60	30	0	0	0
Severe storm	13 Aug.1990	13 Aug.1990	SW	**Garonne area**, Agen, Damazan	Violent storm accompanied by torrential rain, lightning and hail. Cars and houses damaged in Agen and Damazan (80% of roofs), vineyards and crops damaged/destroyed.	1	50	31	0	0	1300
Winter storm	25 Dec.1990	27 Dec. 1990	W,	**Aquitaine**	Strong gusts. Power supply disrupted. **Ship capsized.**	0	0.1		0	0	0
Severe storm	8 Aug.1992	9 Aug. 1992	SW,	**Bayonne**	Thunderstorm, high wind speeds, heavy rain, hail. Houses (roofs) and caravans damaged. Trees downed, 30 wildfires. Vineyards (Margaux, **Médoc, Haut-Médoc**) damaged.	1	25	10	0	0	0
Flash flood	11 May 1993	11 May 1993	SW,	**Aquitaine,** Bergerac	Tempest, heavy rain, hail. Vineyards damaged.	0	1		0	0	0
Severe storm	11 Sep. 1993	12 Sep. 1993	NW,	West coast, **Arcachon**	Wind speeds up to 130 km/h, **high waves**. Houses damaged (roofs, cellars flooded), trees downed, roads blocked. Power lines interrupted. **Vessels damaged**. Missing: 5	0	5		0	5	0
Windstorm	7 Feb. 1996	9 Feb. 1996	SW,	**Atlantic coast.** Spain, N, Bilbao	Wind speeds up to 160 km/h. Torrential rain, mudslides, snow drifts up to 6 metres. Riverbanks burst. Houses, roads, bridges**, boats damaged. Ferry traffic affected**. High tension insulators damaged, power failure (230,000 without electricity).	5	3		24	1	0
Flash floods	8 Dec. 1996	8 Dec. 1996	SW,	**Languedoc-Roussillon, esp. Béziers**	Heavy rain, thunderstorms. Flooding along numerous rivers. City of Béziers submerged. Dozens of houses, railway lines and roads flooded. Traffic affected.	0	150	100	0	1	100
Windstorm	16 Apr. 1998	17 Apr. 1998	W,	west coast, esp. Bayonne	Wind gusts 120 km/h**. Port affected**, crane damaged. Traffic disrupted.	0	0.1		1	0	0
Severe storm	7 Aug. 1999	8 Aug. 1999	SW,	**Gironde, Bordeaux, Montpellier**	Gusts up to 140 km/h, thunderstorms, lightning, heavy rain. Numerous buildings damaged, camp grounds affected, cars damaged. Roads, railway lines blocked. Trees and power lines downed. Losses to agriculture. .	5	1		2	0	2
Winter storm Martin	27 Dec. 1999	27 Dec. 1999	W, SW,	Charente Maritime, La Rochelle, **Landes, Bordeaux**, Lot-et-Garonne	Wind speeds up to 150 km/h, gusts up to 198 km/h (Ile d'Orlons). Benedictine abbey Mont Saint-Michel damaged. Versailles: >10,000 trees uprooted (2 times more than in1990), damage to the castle est. US$ 9.5 m. Valmy (Eastern France): historic wind mill destroyed. Paris: Circus tents destroyed, Seine embankments damaged, Orsay museum damaged. Houses, businesses damaged, road, railway and air traffic disrupted, airports closed, roads, bridges closed. Power failure: > 1 million houses without electricity.	8	4000	2450	0	0	0

Table 18 - Data on catastrophic events provided by Munich-Re (Nat cat Service - 1990 to 2004) W and SW Europe.

While a value in euros can indeed be assigned to urbanized coastal land, an appraisal of public maritime zone does not allow the environmental value of land to be evaluated. Table 19 summarizes these values: it is based on an evaluation made by SMNLR in 2003 that assigns a relative value to natural assets using a scale from 0, the lowest, to 5, the highest relative value. It needs further discussion in terms of sustainable development and cost-effectiveness ratio.

Evaluation of natural zones (Languedoc-Roussillon)	SMNLR index
Zones covered by legislation	2
Zones in scientific inventories	2
Zones designated under International directives	2
CELRL-owned land	2
CELRL-managed land	2
Forest (except coniferous)	3
Coniferous forest	4
Lawns, pastures, moors, scrub	3
Dunes and beaches	4
Marshes	4
Schorres	3
Salt lagoons	4
Landscapes	0 to 1
Historical and archeological heritage zones	5

Table 19 - Indexed evaluation on a scale of 0 to 5 of natural assets (from SMNLR).

This indexation was designed to provide a relative valuation for natural assets in the Languedoc-Roussillon region. It could be extrapolated to the Aquitaine region, in the framework and for the purposes of this project, apart perhaps from the coniferous forests there, which are often agro-economic in nature.

- **Social costs**

The costs of catastrophic events. Social costs are indicated in Table 18. Again, this does not allow the impact on the specific coastal area to be discriminated, but does show that deaths, and missing and injured persons can be involved, more specifically in storm events.

Costs of mitigation. Mitigation of social costs is difficult to estimate: The best approach is to examine what expropriation of landowners or defence would cost. No figures can be given here.

Data on population in coastal areas are derived from territorial diagnostics coordinated in both regions by INSEE on the basis of the 1999 census. Coastal communities of Aquitaine region townships have a relatively low population density (80 inhabitants per square kilometre, increasing to 91 inhabitants per square kilometre, in coastal localities). This density, however, is unequally distributed along the coast, with a very high density in the Pays Basque (501 inhabitants per square kilometre) and in the vicinity of the Arcachon Basin, while the northern Landes and Medoc areas average 20 and 27 inhabitants per square kilometre, respectively.

Languedoc-Roussillon figures show a high density of population in coastal Languedoc-Roussillon townships, with 218 inhabitants per square kilometre, *i.e.,* 349,000 inhabitants, expected to rise to 440,000 over the next ten years. This density is fairly equally distributed over coastal localities except for some towns in the Aude department, near Narbonne, where the density is lower.

3.3. THE EVOLUTION OF RISK MANAGEMENT COSTS OVER THE 21ST CENTURY

3.3.1. Hypothesis on the choice of strategies

Coastal risk management in the coming century will need to consider the impact of climate change on the coastal system, *i.e.,* a sea-level rise hypothesis of 25 to 88 cm and an increased frequency and intensity of storms. Maps 6 prepared a gradation of possible impacts on the studied area ranging from an insignificant change in erosion and/or flooding hazard to significant or dramatic changes.

It should be recalled that “no change” does not imply “no hazard”. The hazard may already exist and be maintained at least at its present level throughout the coming century.

In addition to the likely increase in catastrophic events and associated costs, estimating cost evolution for coastal risk prevention is strongly dependent on the strategic choices made for managing this risk. Choices will be made as to:

- the increase in hazard;
- the value of the assets involved.

Increased frequency and intensity of storms are liable to induce more frequent catastrophic events. **Emergency management and remediation** is already calculated in tens to hundreds of millions of dollars or euros, and the catastrophies are responsible for human loss of life or injuries (Table 18). Logically, the consequences will be multiplied by the number of such events unless measures are taken to adapt to the risk. Also, it is to be remembered that population in coastal communities is expected to increase in the coming century.

Maintaining and upgrading hard defences is likely to be the choice in areas where increased risk is predicted to be drastic and where the value of assets is very high (urban assets, expected to increase in the coming century, as well as tourist and industrial assets). Hard defence is nevertheless an expensive strategy, both to build and to maintain. Adaptation to risk change should therefore call for preliminary studies, to propose a cost-effectiveness scheme as part of integrated management of the sedimentary cell involved. Also, the return periods for catastrophic events must be evaluated so as to be integrated into upgrading defences to a condition compatible with an acceptable level of risk.

Restoring natural processes also implies preliminary studies to improve knowledge of those processes in the context of each sedimentary cell. This strategy is more likely to be chosen when such restoration will decrease or eliminate the erosion hazard. It will have little effect on flooding hazard. Settling for such a process appears, in terms of present cost, cheaper than maintaining hard defences. It is, however, conditional upon the sustainability of beach nourishment or bypass structures. It may also entail the destruction of ineffective defence works.

Retreat strategy is more likely to be chosen in situations where asset values are low (agricultural or natural assets). This also implies a cost-effectiveness study. The cost of such a strategy is evaluated from the economic value of the land loss. Long-term societal costs must also be taken into consideration, but these are difficult to evaluate.

3.3.2. Application to French pilot regions

Results presented in earlier chapters showed which assets were exposed to greatest risk by increased hazard due to potential climate change. It was underlined that differences in the style of development and the evolution of assets in the two regions considered lead to different figures relative to coastline placed at risk.

The present population of the **Aquitaine coastline** is 420,000, with a very high concentration in the Pays Basque area. Coastal population is expected to reach 530,000 in 2020 (INSEE).

On the basis of the present study, the coastline submitted to increased hazard amounts to around 90%, only some 5% of this being drastic. Over around 40% of this total length, assets are placed at risk by this hazard, with the change likely to be drastic in 8% of instances. The risk is mainly linked to erosion.

Urban and tourist assets subject to increased risk are mainly located, in connection with population density, behind the cliffs of the Pays Basque area, considered less erosive, and in several towns such as Cap-Breton, Soort-Hossegor or Soulac characterized by dune morphology considered vulnerable to erosion.

The reader should recall that the very heavily urbanized Arcachon Basin, behaving as a semi-enclosed bay, was not considered in this study.

Few industrial assets are implicated, again located mostly in the Pays Basque area, or in the low-lying lands near coastal river beds.

Environmental assets cover the whole Aquitaine coastline.

According to the CORINE land-cover and IPLI databases, more than half the Aquitaine coastline considered has few to no assets at the present time.

Where assets are few and the cost of land low (natural land - DPM), a retreat strategy should be considered, whilst a combination of soft and hard defences is likely to be the preferred strategy in the Pays Basque area and the touristic towns mentioned above

The **Languedoc-Roussillon** coastline presents a high and uniform density of population, with 349,000 inhabitants in coastal communities and an expected increase to 440,000 inhabitants in the next ten years (INSEE).

Judging by RESPONSE calculation and mapping, around 38% of the calculated coastline length for the Languedoc-Roussillon region submits its assets to a change in risk, 3/4 of this being expected to experience a drastic change. Both erosion and marine flooding are involved. The assets at risk are varied in nature and can cumulate behind the same coastline segment.

The Languedoc-Roussillon region displays intensive urbanization and tourist development (due to a likely concomitance of the two assets, tourism may not have been well distinguished from urbanization and therefore under-evaluated in the data used to map assets.

It should be emphasized that the Languedoc-Roussillon region, despite its degree of urbanization, also has many classified environmental habitats. The values of industrial and agricultural assets also are far from insignificant.

In view of the importance of assets in the Languedoc-Roussillon region, a strategy of defence rather than retreat is clearly appropriate, just considering the present value of urban land (Table 17). The case study (Appendix 1) of the Lido de Sète project (51 M€), however, does underline the fact that although local authorities today are prepared to invest in managing coastal risk, they also try to work out a strategy that will achieve some sort of balance between retreat and defence, and will opt for soft defence when possible.

3.4. CONCLUSIONS ON EVALUATING THE COSTS OF COASTAL RISKS AND COASTAL RISK CHANGES

Comparisons of results between the Languedoc-Roussillon and Aquitaine coastal zones show that:

- The weight of assets and population involved in the Languedoc-Roussillon region in conjunction with a widespread drastic increase of coastal hazard will imply a high-cost impact of climate change, likely to prompt a combination of different defence strategies, in line with the best cost-effectiveness ratio.
  An awareness of this situation already exists in the Languedoc-Roussillon region, where a strategy has already been elaborated for the coming decades, to which any management project must refer.
- The disparity of assets on Aquitaine coastline and a hazard increase that is for the most part significant rather than drastic should allow retreat to be envisaged and planned in areas where no assets are implicated. Attention will need to focus on the Pays Basque coastline, where most of the assets are concentrated, as well as on the coastal towns of the Landes and Gironde areas, which are subject to a drastic change in hazard. On these segments, cost-effectiveness studies should have to be conducted to inform the best strategic choice.

Up to now, the Aquitaine region has mainly developed pre-existing resorts dating from the mid-sixties to 1970 (MIACA), but no strategy has yet been built at a regional scale

A comparison between those two regions and, beyond that, with other pilot regions in the study clearly shows that no estimates of future costs engendered by coastal risks can be given. These will be closely related to the strategies chosen. The choices will have to take into account asset values, predicted damage and the strategy's cost-effectiveness on a long-term basis.

Strategic choices in the coming century will of course have to factor in other criteria than knowledge of a range of hazards and asset values. Nevertheless, the purpose behind the effort made in this study to collect and exploit data is to inform coastal management and development at a regional scale, and it is important that they should be used in support of strategic choices with which our societies will be confronted in future.

At the core of this study is an effort to anticipate hazard change and its associated effects. Evolution in assets is also to be considered, including a predicted increase in coastal populations, and must be borne in mind when making strategic choices.

4. Conclusion

The objective of the RESPONSE Project is to assess, on a regional scale, the impact of possible climate change on coastal risks by 2100 in order to provide decision-makers with elements for managing this risk so that it may be factored into development planning for coastal areas.

In the two French regions examined (Aquitaine and Languedoc-Roussillon), **coastal risk is a reality today**. Erosion (low coasts and cliffs) and marine flooding events have been inventoried. Also, a selection of present-day hotspots have already been identified in each of these two regions and analyzed in terms of hazard and risk.

In the Aquitaine region, vulnerable coastline is nowadays tourist-oriented towns on the sandy coast where existing defences are relatively inefficient; and cliffs on the Basque coast that are subject to ground movement, and certain beaches wedged between the cliffs. In the Languedoc-Roussillon region, most of the lidos, narrow and densely built up are endangered. Some specific spots are more specifically studied.

This project has produced mapped elements making it possible to determine **changes in coastal hazards** under the hypothesis of climate change; it can be expected to increase, either significantly or drastically, under the hypothesis of climate change

Erosion hazard would either significantly or drastically increase on low coasts in both the regions in question. Most of the sandy coast of Aquitaine would be submitted to significant increase, including nowadays identified alarming spots. Low coasts of Languedoc Roussillon show an extension of erosion hazard from segments to the whole sedimentary cells (lidos).

The probability emerges, in both regions, that small pocket beaches in rocky coves of the Pyrenees could disappear.

The marine flooding hazard would increase fairly locally in the Aquitaine region at the mouths of rivers, whereas it concerns an extensive stretch of coastline in the Languedoc-Roussillon region corresponding to low lidos and to spots in these cut by inlets.

The **assets that would be put at risk by the impact of climate change** were assessed in the project on the basis of maps of existing assets, merging this information with the hazard change assessment. This mapping effort underlines the importance of development planning policy for coastal zones. This is a necessity for the sandy coastline in the Languedoc-Roussillon region, where the erosion and marine flooding hazards will increase globally. Assets in the Aquitaine region concentrate particularly in the Pyrénées-Atlantiques department and, more locally, on the sandy coast.

By establishing a hierarchy for hazard change, it is possible to highlight the sectors that will become a source of concern in regards to coastal hazard over the coming century. By collating these “hazard hotspots” with the existence of assets exposed to risk, we are then able to **propose hotspots according to RESPONSE Project terms, that is, spots characterized by a highest risk in the event of climate change.**

It should be noted that what are classed as hotspots in the present days will under no circumstances experience a decrease in coastal risk and thus are retained as “hotspots”.

The limitations of this approach must be borne in mind:

- The approach assumes a uniform behaviour for the coastal systems (CBS) defined along a profile, and does not take into account any interactions between the systems. Nor does the regional scale allow the role of coastal hydrodynamics to be taken into account in erosion and/or flooding phenomena.
- The climate scenario selected builds upon socio-economic scenarios and global models that introduce a high level of uncertainty. The regional adaptation of the climate hypotheses and notably the rise in sea level tends to oversimplify.
- The characterization of assets needs to be developed, notably by seeking to assign a value to the asset at risk in order to prioritize the risk more aptly. It should also be remembered that these assets will evolve over the century to come.

Despite these reservations, the results of this study do allow **guidelines to be established for the future management of the coastline,** confirming that coastal risk would increase in the two regions under the hypothesis of climate change and that future development planning for the coastal zone and strategic defence strategies will need to be conducted in the light of this knowledge, notably as concerns the spots identified as particularly “hot”.

On those peculiar spots, impact of climate change is to be considered in further management planning, and hypothesis validated by further measurement and local processes modelling.

5. Bibliography

The references are being presented hereinafter according to theme. A large number of them are not scientific publications but rather reports on work projects and/or unpublished material, or again have been downloaded from websites, with the address indicated where possible. Sources of the data used to prepare maps have also been listed.

5.1. SOURCES OF MAP-RELATED DATA

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http://www.ifremer.fr/anglais/

http://www.shom.fr/ (Service Hydrographique et Océanographique de la Marine)

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Appendix 1

Case studies in the Languedoc-Roussillon and Aquitaine regions

1. CASE STUDY OF A PARTIAL: LE LIDO DE SÈTE. RETREAT STRATEGY

The Sète Lido (Languedoc-Roussillon) project can be cited as an example of partial retreat strategy (Gomboa *et al.*, 2004).

The Lido is a barrier spit of sand, with a dune morphology (elevation between 1 and 4 meters), separating the lagoon of Thau from the sea. Longshore submerged sediment bars act as a natural protection for the entire lido. Erosion processes are determined by south-eastern storm waves and seaward winds actions, leading to a resultant NE-SW longshore drift of sediments, accumulating N-E of the tranversal groynes. Tidal impact is negligible.

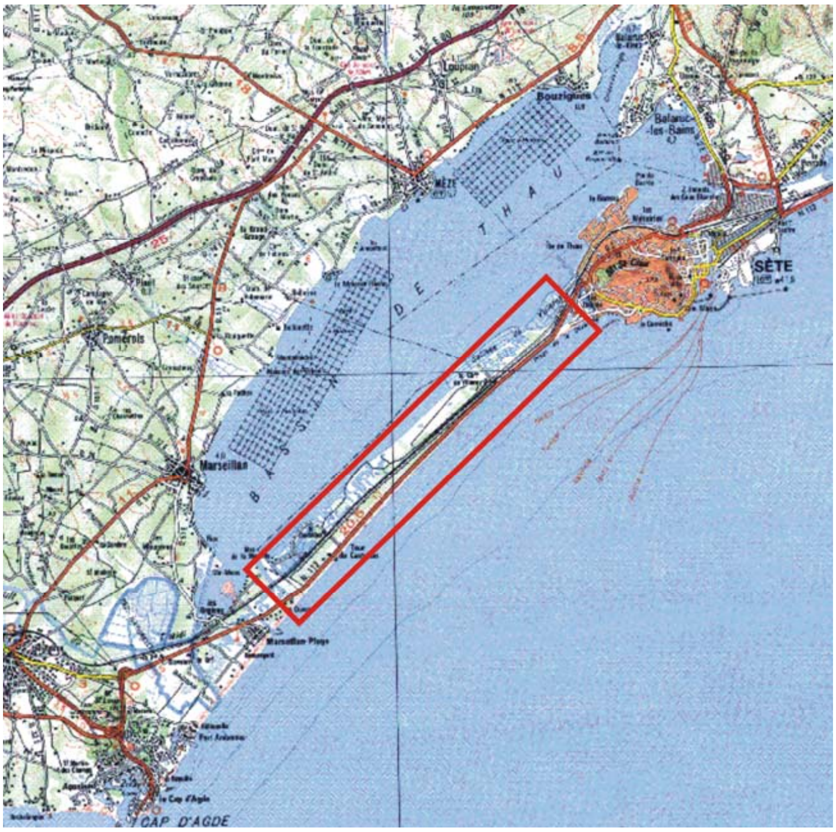

Figure 1 - Location of the case study "Lido de Sète".

Beach erosion has been evaluated at a loss of 45 ha for the period between 1953 and 2000 (Barusseau, 1996; Certain, 2002; and BCEOM, 2000 in Gomboa, 2004). Erosion acts discontinuously, in the northern part of the lido near Sète, and north of Marseillan.

Land-use of the Lido has an economic and touristic impact (salt mines, vineyards, shellfish farming and camping). A coastal road built at the beginning of the 20th century runs along the shore. Inland from the dune is a railway.

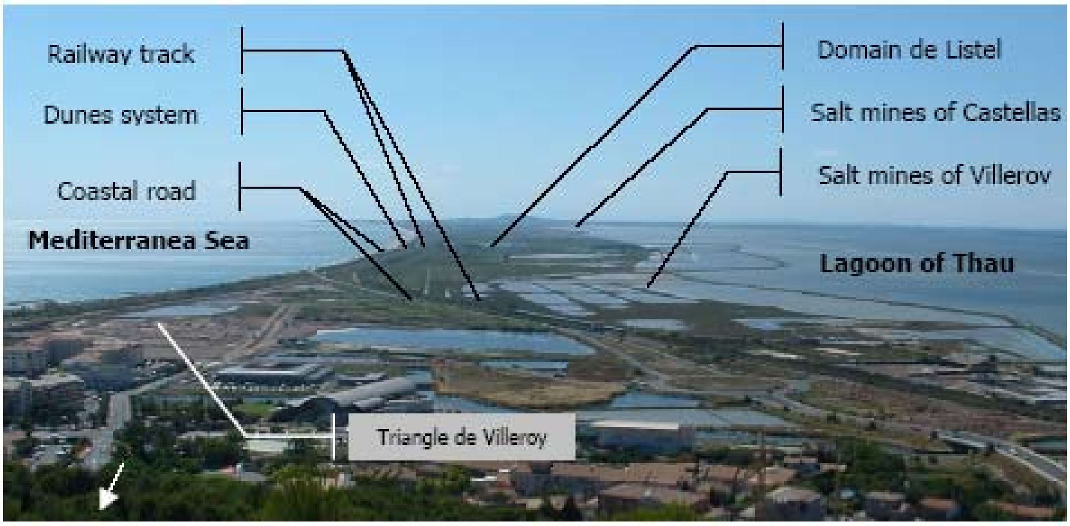

Figure 2 - Configuration of the Lido of Sète and implied assets (from Gomboa et al.*, 2004).*

Hard defence works have been installed to combat erosion: groynes were built in 1953 at the southern end of the Lido (Le Castellas campsite), and another groyne was added in 1954 on the Lazaret Beach (middle part of the Lido). Damage to the coastal road has been mitigated by rock revetment along the upper beach on several occasions.

Breakwaters were built between 1987 and 1993 in the northern part of the Lido. Local soft defences such as wooden stakes and sediment refill have also been experimented. Although groynes and breakwaters do indeed help locally to accumulate sand, they tend to increase erosion on adjacent coasts.

Figure 3 - Hard defence works: the groyne at the Castellas campsite, a rock seawall reinforcing the coastal road (from Gomboa et al.*, 2004).*

Despite these coastal defences, erosion still threatens the road and beach. The cost of maintenance to date is evaluated at 250,000 €/yr, mainly for the road restoration.

Following pre-operational diagnostics and scenarios prepared by BCEOM to set project guidelines (URBANIS, 2004), backed by a multi-criteria approach of the European

Interreg IIIc/MESSINA project (Gomboa *et al.*, 2004), a strategy of moving backward the infrastructures" is, to be carried out, coordinated by the Communauté d'Agglomération du bassin de Thau and in partnership with departmental, regional and national authorities. The project includes:

- relocating of the coastal road further inland, near the railway;
- beach nourishment;
- dune restoration to 3 meters high and the restoration of footpaths;
- and marine defences still under discussion: soft (geotextile tube) versus hard defences (building up the breakwaters).

The total cost of the project is estimated at 51 M€, 35% of which are directly involved in coastal protection works. This cost does not include preliminary studies by BCEOM and URBANIS.

The management project will probably be phased, due to required financial resources. The relocation of the road is to start in 2006, followed by dune rehabilitation, while management works on the beach should begin in 2008.

2. CASE STUDY OF A PARTIAL RESTORATION OF NATURAL PROCESSES: SOORT-HOSSEGOR AND CAP-BRETON

The coastal towns of Soort-Hossegor and Cap-Breton in Aquitaine tell a long and costly story of defences against beach erosion and protection of the resorts. This shoreline is backed by an urban and touristic land-use area, with an active marina. The census gave a figure of 9,951 permanent residents in 1999, but it should be added that the towns also count up to 7,827 vacation homes (INSEE, 1999), which leads to a three- to fivefold increase in this population figure in summer.

Built on a former dune, breeched by the outlet of Boucaut, this resort faces a gentle to steep beach. Behind the dune, the inlet leads to a low-lying hinterland. Submitted to a coastal drift from north to south, the beach system undergoes strong accumulation and erosion process despite the existing defences.

The edges of the inlet (Passe du Boucaut) have been consolidated by a pier since the 19th century and reinforced between 1958 and 1993. Between 1953 and 1990, five groynes were built (two rows of wooden piles with rock fill in between) and regularly restored. Seawalls were built and restored between 1950 and 1999.

Since the last restoration of groynes in the 1980s, the northern groynes facing Hossegor have been buried in sand, and sand has accumulated ahead of the northern pier. The southernmost groyne of Cap-breton has progressively been destroyed. The most recent work was done on a part of the seawall destroyed by the 1999 storm.

Maintenance of the Boucaut channel consists in dredging the channel and transporting sand by lorry transport to the southern beaches. From the beginning, the management of defence works has been shared between communal, departmental and harbour authorities.

A partial restoration project of the natural system is planned to prevent accumulation of sand north of the Boucaut pier and erosion of the southern beach, by hydraulic sand by-passing from the north to the south of the inlet. Furthermore, restoration of two southern groynes is planned.

Where the dune is not built on, soft management is planned (geotextile, limited access to the dunes…). The costs of existing (non-exhaustive) as well as projected works for this site are summarized in Table 1 (based on DDE40 data). The future project, for which partnership and funding is still under discussion, should start in 2007-2008 and last three years.

Cap-Breton/Hossegor	
Costs to date (building and restoration)	up to (€)
groynes	550000
seawalls	756 000
piers	1 330 000
Total	2 636 000
Future projects	
by-passing, including maintenance	1 459 000
dune management	420 000
groyne restoration and construction	839 000
Total	2 718 000

Table 1 - Costs of existing and projected defence works in the towns of Cap-Breton and Soort-Hossegor.

Figure 4 - Orthophoto of the coastal town of Soort-Hossegor and Cap-Breton (copyright ORTHOLITTORALE2000).

Appendix 2

Status of research on the littoral environment and climate change in France and policies implemented to fight global warming

This note gives a brief review of actions and research in France in regards to climate change, advances in modelling and, more specifically, to the impact of climate change on coastal environment. Most research programs are in progress. Besides research, the French government has expressed its firm intent to fight against greenhouse effect, now to be devolved to local authorities.

Currently, local authorities in charge of coastal environment mainly deal with short-term changes, but they show a strong interest in developing tools for anticipating climate change in the longer term.

1. NATIONAL ACTION AND RESEARCH REGARDING CLIMATE CHANGE

The response of French public authorities to climate change prediction has taken the form of actions seeking to reduce greenhouse gas emissions and to promote research aimed at improving our understanding of the phenomena involved.

1.1. Government implication (Table 1)

An awareness concerning probable greenhouse-gas induced climate change led in 1992 to the establishment of an inter-ministerial delegation on greenhouse effect (Mission Interministèrielle sur l'Effet de Serre, *i.e.*, MIES) renewed in 1998. This delegation is a division of the Ministry in charge of the environment (Ministère de l'Ecologie et du Développement Durable *i.e.,* MEDD). MIES's duties include reporting to international and European institutions, taking part in expert meetings in order to define policies and applying policies.

One of its main achievements has been the creation of the national plan to act against climate change (Plan Climat 2000). This plan contains recommendations and policies to reduce greenhouse gas emissions by 2010 to their 1990 levels through communication on adaptation to climate change, fossil energy conservation, developing sustainable sources of energy, sustainable transport, energy-efficient construction, CO_2 emission quotas and exchanges, CO_2 emission reduction, etc. The results of this plan are to be reported to the United Nations framework convention on climate change.

Governmental agency		Objectives	Action
Mission Interministérielle contre l'Effet de Serre	MIES (MEDD)	"Climat" Plan	
		Coordination of Research programs	Research programs (§ 1.2): GICC -1 (1998) GICC-2 (2005)
Office National sur les effets du réchauffement climatique	ONERC (prime minister)	Liaison with local communities	Conferences (adaptation strategy 2004, extreme events 2003)
		Coordination of pilot studies on climate change	The impact of climate change on overseas French coastal environments

Table 1 - Governmental implication regarding climate change.

The year 2001 witnessed the creation of ONERC (national observatory of the effects of climate change) under the direct authority of the prime minister; its aim is to be the link between policy-makers, local authorities and scientific experts. National conferences such as the conference on adaptation strategies for local authorities with respect to climate change (30 September 2004) or extreme climate events (2003) number among its actions.

1.2. Implication of the Scientific community

The Ministry in charge of the environment (MEDD) and the MIES have implemented a research program on the management and impact of climate change (GICC - Gestion et Impact du Changement Climatique), in order to promote research on the processes and impact of climate change, building methods and tools for preventing and adaptating to climatic change. This program is currently in its second phase. One of its projects deals with coastal evolution in connection with climate change in the Camargue region.

Program		Objective	Coordinator	Involved organizations
Programme Gestion et impact du changement climatique (Management and impact of climate change program)	GICC-1 and 2	Scenarios on climate change evolution Climate/economy/society interaction Carbon sequestration in forest and agricultural lands Greenhouse gas inventories Impact on the biosphere Impact on the hydrosphere Impact on health Impact on biodiversity Relations between national and international actions	MIES/ MEDD	Méteo-France (CNRM), INRA, CIRAD, IRD, CNRS and associated laboratories (IPSL, IFRI, CEREGE, CETMEF, CIRED…) Universities, Commissariat au plan, ARMINES…
Pilot studies on climate change effects on overseas coastal zones		Improve knowledge about the impact of climate change on coastal zone	ONERC	Call for tenders in process
Site study concerning the impact of climate change on coastal zones		Evaluation of future land gain and loss, on Conservatory-owned land	Conservatoire de l'environnement littoral et des rivages lacustres (CELRL) Procter and Gamble Fondation	Organizations associated with CELRL

Table 2 - Research programmes coordinated by governmental administrations.

Besides this national program under the leadership of MEDD and MIES, the PNEDD (Programme National d'Etude de la Dynamique Du climat) conduct climate research implying not less than ten institutions. INSU (Institut National des Sciences de l'Univers) coordinates four research programs within the compass of climate research.

One national programme deals with coastal environment: the PNEC (Programme national d'environnement côtier), also coordinated by INSU and funded by INSU, IFREMER, BRGM, ELF, IRD and CNES.

Program		Objective	Coordinator	Involved organizations
Programme National d'étude sur la dynamique du climat (National program of studies on climate dynamics)	PNEDC	Understanding the climate system, including all its components (atmosphere, ocean, cryosphere, biosphere)	INSU	CEA, Cemagref, CNES, IFREMER, IPV, Meteo-France, IRD - Ministries in charge of the environment and research
Programme ATmosphère et Océan à Moyenne échelle (Program on the atmosphere and ocean on an intermediate scale)	PATOM	Transfer and transformation of energy in oceanic and atmospheric systems, and their interaction with meteorological, oceanological and climate evolution	INSU	INSU-CNRS and associated university research laboratories
Programme Processus biogéochimiques dans l'océan et flux (Program on biogeochemical processes in the ocean and on flux)	PROOF	Physical oceanic forcing influence on ecosystems and biogeochemical cycles in the context of prospective climate change. Development of coupled physics/ biogeochemistry modelling	INSU	INSU-CNRS and associated University research laboratories
Programme national de télédetection spatiale (National Programme on satellite imagery)	PNTS	Transfer of spatial data to oceanographic, meteorological and atmospheric research Studies on carbon sinks	INSU	INSU-CNRS and associated University research laboratories CNES
Programme national de chimie atmosphérique (National Program on atmospheric chemistry)	PNCA	Understanding processes of aerosols, greenhouse gases, etc. in the atmosphere. Coupled modelling, gas chemistry, measurement and monitoring and surveys	INSU	INSU-CNRS and associated university research laboratories
Programme national d'environnement côtier (National Program on the coastal Environment)	PNEC	Thematic research and pilot workshops: biochemical cycles, hydrodynamic and biological cycles, algal blooms, spatial and temporal variability, micro-organ-isms and coastal environment, economic dynamics, sediments dynamics	INSU	IFREMER, CNES, INSU, IRD, BRGM, ELF

Table 3 - National INSU programmes on climate change and/or the coastal environment.

The institutions involved in coastal environment and/or climate change research are listed in Table 4. There are very many institutions involved and programs in progress and the list supplied is likely not to be exhaustive, more specifically for laboratories associated with CNRS. When known, they have been cited as program partners.

Institution		Objectives	Action	National programs participated in
Centre National d'Etudes Spatiales (National centre for space studies)	CNES	Space Science	Research on space use, space data collection and satellite imagery	PNEDC, MERCATOR, CORIOLIS
Service hydrographique et océanographique de la Marine (Naval hydrographic and oceanographic department)	SHOM	Oceanography, data collecting, mapping		PNEDC, CORIOLIS, MERCATOR
Institut français de recherche pour l'exploitation de la mer (French research institute for exploitation of the oceans)	IFREMER	Oceanography, bio-resources	Ocean dynamics, satellite imagery, in-situ measurements	PNEC, PNEDD, CORIOLIS MERCATOR
Institut polaire français Paul Emile Victor (French polar institute)	IPEV	Research on polar and sub-polar environments	Data collecting, oceanography	MERCATOR, CORIOLIS, PNEDC
Institut de recherche pour le développement (Research institute for development)	IRD	Inter-tropical development research in developing countries	Environment, vital resources, health and society	PNEC, PNEDC, CORIOLIS, MERCATOR
Méteo-France / Centre National de Recherche Météorologique (French meteorology institute / National meteorological research centre)	CNRM	Atmospheric research	Climate simulation, modelling weather prediction, atmospheric processes, data collection	CORIOLIS MERCATOR PNEDC
Institut National des Sciences de l'Univers (National universe science institute)	INSU-CNRS* and associated university* laboratories	Ocean/ atmosphere and geosciences	Environmental research, natural risks, earth-related knowledge, data collection, monitoring surveys, …	PNCA, PATOM PROOF, PNTS PNEDC PNEC MERCATOR

Table 4 - National research institutions involved in climate change research.

Other institutions are cited in the different programs such as CEA (Commissariat à l'Energie Atomique), ELF, Cemagref (Institut de recherche pour l'ingénierie de l'agriculture et de l'Environnement), INRA (Institut national pour la recherche agronomique).

Models are a very important aspect of research on climate change: they are the only tool available when attempting to quantify it. Amongst the many worldwide models, two ocean-atmosphere coupled models have been developed in France (CNRS-IPSL associated with the European institute CERFACS). Using the LODYC ocean model and two different atmosphere models (CNRS/LMD and Météo-France), the coupled models allow simulations to be performed based on IPCC (2000) scenarios.

Most of the institutions mentioned are also participants in the CORIOLIS and MERCATOR observatories, to merge the oceanographic and climate data collected by each partner of CORIOLIS or MERCATOR.

As to the impact of climate change on coastal zones, a specific study was published in 2004 concerning lands belonging to CERL. The method is based on historical studies of Conservatory-owned sites, considering a 44-cm rise in sea-level, as "most probable". The evolution of coastal erosion and flooding evolution are estimated in terms of area (lost or gained) for conservatory property including cliffs, dunes, wetlands and polders. Details of this evaluation are given for both studied regions.

2. REGIONAL IMPLICATION IN ACTIONS AND RESEARCH DEVOTED TO CLIMATE CHANGE AND/OR COASTAL HAZARD MANAGEMENT

Most aforementioned programs include participation by regional research institutes (universities, but also regional representation of public or semi-public institutes such as IRD, ONERA and INRA).

Aside from these national programs, several regional and department-level councils of coastal regions, whether associated or not with national regional services (maritime and environmental services) are financing research and actions on coastal management, often with the help of European funding (FEDER, INTERREG). Several regions have established observatories for coastal environment, or are in the process of doing so (Nord - Pas-de-Calais, Picardy, Normandy, Aquitaine…). Their objectives are to gather data on the coastal environment and structure it into databanks, organise research and actions within the scientific community and pass this knowledge on to decision-makers and the public.

A request for proposals was recently launched by DIADT (a delegation under responsibility of the French Prime Minister for territories, land management and regional action), for Integrated coastal zones management cases studies. The 25 selected projects underline concern on the part of local communities to achieve sustainable management of the coastal zone.

Actions undertaken at present at a regional level deal with coastal hazards and risk: the impact of climate change is mainly foreseen for the coming years, in order to frame present-day management of the coastal zone. Nevertheless, the data collected will be valuable for understanding further evolution of coastal risks related to climate change.

Coastal PPR (Risk prevention plans) have been prescribed for coastal communities in several departments and are in different stages of advancement. Where those plans are implemented, the hazard and risk assessments are related to historical evolution. The methodology proposed by the MEDD, refers to an historical base and requires extrapolating the present trend onwards over the next 100 years.

Water management in coastal zones has prompted some coastal departments to create specific plans for water management (SAGE: Schéma d'Aménagement et de Gestion de l'Eau).

The national "Plan Climat", launched by the MIES, is to be applied in a territorial perspective, the regional delegation of ADEME being in charge of communicating on its objectives. Tools are being prepared to involve regional authorities (state representatives and local councils).

Information to regional communities in 2005 already led to a high expectation on what research can contribute to fighting or adapting to climate change. More specifically in coastal regions, the results of projects such as RESPONSE are awaited, and expected to lead to further local studies, to help decision-makers to anticipate on future coastal evolution.

2.1. The Aquitaine region

2.1.1. Research

The University of Bordeaux I, associated with INRA and Nancy University, are conducting research on climate change impact on vegetation, with economic implications for the lumber industry.

2.1.2. Action taken by regional administrations

In the Aquitaine region, the Prefecture, the Regional Council,the ,the Pyrénées-atlantiques departemental council, associated with ONF (Office National des Forêts), IFREMER in the initial phase, and the BRGM have created the Aquitaine Coastal Observatory, in charge of collecting, organizing and disseminating data on the coastal environment and providing expert advice on coastal management (http://littoral.aquitaine.fr).

Departments in charge of coastal management, traditionally responsible for defences and linked to the Minisitry for Equipment, show different levels of involvement:

- The Gironde maritime service has been following several case studies dealing with coastal erosion and defence management (Port de Bordeaux, Dune du Pyla, Amélie-sur-Mer…). Studies conclude about the maintenance or reinforcement of existing defences or, locally, the management of soft defences.
- The Landes DDE (departmental direction for public works) holds earlier data on defences (1970-1990). This competence was transferred to the concerned townships as of 1990.
- Cliff instability has been evaluated for the southern coast of the Aquitaine region (Pays Basque). This work was carried out by BRGM, CG PO, CR, and DRE (2001-2005). Again, the approach does not integrate prospects on climate change impact.

2.2. The Languedoc-Roussillon region

2.2.1. Research on climate change

In the Languedoc-Roussillon region, universities in conjunction with public institutions such as CNRS, INRA, CEMAGREF, and IRD conduct programmes dealing with climate change applied to continental hydrology and forests.

The "Maison de la télédétection" (CEMAGREF, CIRAD, ENGREF and IRD) carries out research using satellite imagery to analyse climate-change effects in space applications. Specific research leading to a PhD thesis was presented in December 2005 on databases for the integrated management of coastal zones.

2.2.2. Action taken by regional administrations

The specificity of the maritime service (SMNLR) whose field of action is the whole region allowed this organization to engage vigorous action to identify coastal hazards and propose a management strategy using choices of defences adapted to different portions of the coast. Maintenance or reinforcement of existing defences are proposed when urban and tourist assets are at issue, while soft defences are considered when the natural environment is concerned. However, this strategy targets the coming decade and does not consider climate-change effect in the long term.

EID-Méditerranée, a public institution in charge of fly extermination, is concerned by the preservation of wetlands and therefore contributes jointly with SMNLR to managing natural zones (dunes and lidos).

Appendix 3

Results achieved by the BRGM team in communicating on the RESPONSE project

Participation in congresses and meetings:

- La Baule (International symposium - Nature and Society Interactions, 3 to 6 may 2006. Contribution accepted for oral presentation)
Vinchon C., Balouin Y., Closset L., Garcin M., Idier D. and Mallet C. (2006) - Evaluation de la réponse géomorphologique du trait de côte au changement climatique, in ATLANTIA - Colloque International Interactions Nature-Société - La Baule - France – 3 au 6/05/2006.

- Barcelona (5th European Congress on Regional Geoscientific Cartography and Information systems) 13-16 june 2006.
Vinchon C., Idier D., Garcin M., Balouin Y., Mallet C., Closset L., McInnes R., Jakeways J. and Fairbank H. (2006) - Mapping the regional impact of climate change on coastal risks; in ECONGEO 2006 - 5th European Congress on Regional Geoscientific Cartography and Information Systems - Barcelona - Spain - 13-16/06/2006.

- Littoral 2006 Gdansk Poland
C. Vinchon, D. Idier, R. McInnes, H. Fairbank, J. Jakeways, A. Cieslak and F. Pontoni (2006) - Geomorphological response of coastline to climate change, Littoral 2006, Gdansk Poland 18-20 /09/06. Poster presentation.

Participatory Planning and working with natural processes on the coast, RIKZ Den Haag – Netherlands. No communication. Leaflet dissemination on 19 January.

In preparation for publication: “Ocean and Coastal Management Journal”: Using geomorphology at a regional scale to anticipate the impact of climate change on coastal risks. Application to Aquitaine and Languedoc-Roussillon (France).

RESPONSE quoted in GEOSCIENCE in the “brèves” – (The review of BRGM for a sustainable earth) national to international dissemination, published at the end of January 2006.

Conception of an internal leaflet following BRGM visual identity guidelines (December, 2005).

Meeting with end-users in both sites (SMNLR, DDE’s, regional geological surveys) PowerPoint slides in French to present the project (November and December 2005).

Information of other BRGM regional surveys, through the internal leaflet, and proposition of visit and presentation of the RESPONSE project to regional actors if interested (started).

e-projet: Intranet space accessible for BRGM project team and interested partners, in order to support project management and promote data exchange (since october 2005).

Presentation of the RESPONSE project to ONERC (01/06/06). ONERC request: Response results on French pilot regions to be linked to the ONERC internet site, and an indicator to be developed through RESPONSE results.

Dissemination of the RESPONSE leaflet:

- through voluntary action / list to be built through coastal networks (Projet ENCORA) (12/07/06).
- according to opportunity: visitors, external meetings, etc.

Appendix 4

Atlas of maps

(CD-Rom attached to this report)

The atlas of maps attached to this report is included in the attached DVD and takes the form of map images in .pdf format at 1:1,000,000 scale covering the concerned regions in their entirety and for each of the seven maps listed in this report. The printout for each of these maps represents two A0 sheets.

Illustrative excerpts have also been furnished for each of the seven maps. These concern the Pays Basque and southern Landes areas for the Aquitaine region and the Lido de Sète for the Languedoc-Roussillon region for each of these maps.

The maps presented are as follows:

- Map 1a: Geomorphology:
  · 1:100,000 Aquitaine (2 A0 portrait),
  · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  · 1:100,000 Lido de Sète excerpt (1 A4 landscape);
- Map 1b: Coastal processes:
  · 1:100,000 Aquitaine (2 A0 portrait),
  · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  · 1:100,000 Lido de Sète excerpt (1 A4 landscape);
- Map 2: Historical catastrophic events:
  · 1:100,000 Aquitaine (2 A0 portrait),
  · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  · 1:100,000 Lido de Sète excerpt (1 A4 landscape);
- Map 3: Coastal defences:
  · 1:100,000 Aquitaine (2 A0 portrait),
  · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  · 1:100,000 Lido de Sète excerpt (1 A4 landscape);
- Map 4: Assets:
  · 1:100,000 Aquitaine (2 A0 portrait),
  · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  · 1:100,000 Lido de Sète excerpt (1 A4 landscape);
- Map 5: Definition of coastal behaviour systems. Mapping of global CBS:
  · 1:100,000 Aquitaine (2 A0 portrait),
  · 1:100,000 Pays Basque excerpt (1 A4 landscape),

  - · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  - · 1:100,000 Lido de Sète excerpt (1 A4 landscape);

- Map 6: Hazard change map by CBS units (detailed units):
  - · 1:100,000 Aquitaine (2 A0 portrait),
  - · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  - · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  - · 1:100,000 Lido de Sète excerpt (1 A4 landscape);
- Map 7: Map of assets exposed to risk by a change in hazard:
  - · 1:100,000 Aquitaine (2 A0 portrait),
  - · 1:100,000 Pays Basque excerpt (1 A4 landscape),
  - · 1:100,000 Languedoc-Roussillon (2 A0 landscape),
  - · 1:100,000 Lido de Sète excerpt (1 A4 landscape).

Appendix 5

Sources of data and metadata

Directory	Sub-directory	Name	Description	Source
Données générales	DonnéesAdministratives	Departements_LRO_AQUI_Cote	Departments delimitation of the Languedoc-Roussillon and the Aquitaine region	IGN, processed
		DepartementsLimitrophes_region	Departments in contact with the the Languedoc-Roussillon and the Aquitaine region	IGN, processed
		FranceEspagne_ESRI	Delimitation of France and Espagne country	ESRI, processed
		F_deptWGS84_region	Department of France	MapInfo
	Environnement	Directive_habitats_transmis_LRWGS84_region	Area concerned by the European Habitat directive, in Languedoc-Roussillon	Europe, processed
		ImportantHabitat_CLC	Habitats obtained from processing of Corine Land Cover database (codes: 421, 422, 521)	CorineLandCover1990, processed
		PNR_Languedoc_RoussillonWGS84_region	Languedoc_Roussillon Natural Regional Park	DIREN, downloaded 2004
		Rn_LRWGS84_region	National Natural Reserve in Languedoc-Roussillon	DIREN, downloaded 2004
		RNV_LRWGS84_region	Regional Natural Reserve	DIREN, downloaded 2004
		Znieff_LRWGS84_region	ZNIEFF(Zones Naturelles d'Intérêt Ecologique Floristique et Faunistique = Natural area of floristic and faunistic ecologic interest)	DIREN, downloaded 2004
	Hydrographie	F_Hydro_LRO_AQUI_Polyline	Rivers in LRO and AQUI	MapInfo, processed
		FHydro_LRO_AQUI_Region	Lagoons and large rivers in LRO and AQUI	MapInfo, processed
		hydro_CoteBasque_polyline	Rivers in Côte Basque	IGN Carthage database
Données générales (suite)	Hydrographie (suite)	hydro_lro_polyline	Rivers in LRO	IGN Carthage database
		Lac_Cote_Basque	Lagoons in Côte Basque	?????
		F_fleuvesWGS84_region	Rivers of France	MapInfo
	OccupationSol	Fvilles_LRO_AQUI	Main cities for AQUI and LRO	MapInfo, processed
		IPLI_Dunes	Dunes area	IPLI Database, processed
		VillesBalnéairesSecondaires	Secondary cities	manually digitalised
		Marais_region	Marsh areas	IGN BD Carto
	OccupationSol/CorineLandCover1990	CorineLandCover_AQUI_LRO_WGS84	CorineLandCover database for	CorineLandCover1990,

Directory	Sub-directory	Name	Description	Source
			Aquitaine and LRO	slightly modified
		FrangeLittoral_CLC_AQUI_LRO_WGS84	CorineLandCover database for Aquitaine and LRO, slightly modified, and extracted within the 30km coastal area	CorineLandCover1990, slightly modified
	Reseaux	FAutoroute_LRO_AQUI	Motorway	MapInfo, processed
		FroutesNationales_LRO_AQUI	National roads	MapInfo, processed
		FvoiesFerrees_LRO_AQUI	Railway	MapInfo, processed
		Routes_lro_polyline	Roads in LRO	IGN, processed
DonnéesLittorales	Bathymétrie	BathyGolfeLion	Bathymetry of Gulf of Lion	CNEXO data digitalised
		IsoBathy100m	100 m iso-bathymetric contour	CNEXO data digitalised
		IsoBathy20m	20 m iso-bathymetric contour	CNEXO data digitalised
	Données Historiques	Evenements_cote_basque_mvt_mto	Ground movement and meteorological events in Cote Basque	Observatoire Côte Aquitaine and BRGM
Données littorales (suite)	Données historiques (suite)	EvenementsHistoriqueLRO_point	Historical hazard events (marine flooding, storms, …) in LRO	Primnet, Météo-France, Midi-Libre, Durand, Bruzzi, Sabatier, processed
		TxErosionTraitCote	Mean velocity of coastline erosion in LRO	Durand Phd Thesis, processed
	Dopnnées Physiques	Beaches	Touristic beaches (from IPLI)	IGN Scan 25 processed
		HighSeaLevelPlus5m	Contour of the 5 m height above the high sea level, in LRO and AQUI	IGN and SHOM, processed
		IsoMarnage_polyline	Iso-value of tidal range in AQUI	SHOM, processed
		LittoralDrift_polyline	Littoral drift, in AQUI and LRO	CNEXO (AQUI) and Durand (LRO), processed
		ResponseRecal_WGS84	Coastline Eurosion file, improved in resolution and position	Eurosion and IGN data, processed
		TcoteSchematiqueRecal_WGS84	Schematic coastline, based on Eurosion coastline, with complementary data	Eurosion, ONF, SMNLR, Observatoire Côte Aquitaine, IFREMER, processed

Directory	Sub-directory	Name	Description	Source
		TcoteSchematiqueRecal_WGS84_complet_051105	Same as TcoteSchematiqueRecal_ WGS84, with supplementary intermediate fields	Eurosion, ONF, SMNLR, Observatoire Côte Aquitaine, IFREMER, processed
		Sea	Sea location	Manually done
	ZonesRisks	IncreasedRiskFloodCLC	Human Assets subject to increased Flood risks	CorineLandCover, Eurosion, IGN, BRGM, processed
		IncreasedRiskFloodHabitat	Habitat subject to increased Flood risks	CorineLandCover, Eurosion, DIREN, IGN, BRGM, processed
Données littorales (suite)	Zones Risk (suite)	Risk_CLC_AQUI_LRO	Human Assets subject to increased erosion and flood risk	CorineLandCover, Eurosion, DIREN, IGN, BRGM, processed
		Risk_Habitat_AQUI_LRO	Habitat subject to increased erosion and flood risk	CorineLandCover, Eurosion, DIREN, IGN, BRGM, processed
		Tcote_Risk_CLC_AQUI_LRO_WGS84	Human Assets subject to increased erosion risk	CorineLandCover, Eurosion, DIREN, BRGM, processed
		Tcote_Risk_Habitat_AQUI_LRO_WGS84	Habitat subject to increased erosion risk	CorineLandCover, Eurosion, DIREN, BRGM, processed
		TcoteSchematiqueRecal_WGS84_RiskActuel	Present day Erosion risk	CorineLandCover, Eurosion, DIREN, BRGM, processed
	ZonesSubmergeables/2100	PotentialFloodAreas_increased_today_2100	New flood area in 2100 (DEM+observation)	IGN, SMNLR, IPCC, processed
		PotentialFloodAreas_MNT_Observed_2100_WGS84_Agrege	Potential marine flood area in 2100 (DEM+observation)	IGN, SMNLR, IPCC, processed
	ZonesSubmergeables/Actual Zones submergeables/actual (suite)	Zones_submergeables_actuelle_mnt_obs	Present day potential marine flood area (DEM+observation)	IGN, SMNLR, processed
		S_SUBM_WGS84_SMNLR	Observation of floods in LRO	SMNLR
		Zones_submergeables_actuelles_WGS84_MNT	Potential marine flood area, obtained using the topographic DEM of IGN	IGN BD Alti, processed

Table 1 - Meta-data for Aquitaine and LRO, within the Response project (Shapefiles).

File	Field	Type	Values	Comments
BathyGolfeLion	BATHY	number		Bathymetry contour lines in Gulf of Lion
Beaches	FID	integer		Touristic beaches (extract from IPLI data base)
CorineLandCover_AQUI_LRO_WGS84	Asset	character	Agricultural lands, tourism, urban area, industry-commercial, important habitat	Field added within Response for Map 4 and 7.
Departements_LRO_AQUI_Cote	FID	Integer	[0..9]	Identity number
	NOM_DEPT	character		Name of departement
DepartementsLimitrophes_region	FID	integer	[0..1]	Identity number
Directive_habitats_transmis_LRWGS84_region	FID	integer		Identity number
Evenements_cote_basque_mvt_mto	Keyword	character	Landslide, storm, …	Historical hazard events in AQUI
EvenementsHistoriqueLRO_point	KEYWORD	character	Earthquake, flood, …	Historical hazard events in LRO
F_deptWGS84_region	FID	integer		Departments of France
F_fleuvesWGS84_region	FID	integer		Rivers of France
F_Hydro_LRO_AQUI_Polyline	FID	integer		Rivers in LRO and AQUI
FAutoroute_LRO_AQUI	FID	integer		Motorway
Fhydro_LRO_AQUI_Region	FID	integer		Lagoons and large rivers in LRO and AQUI
FranceEspagne_ESRI	FID	integer	[0..2]	The 3 countries Andorra, France, Espagne
FrangeLittoral_CLC_AQUI_LRO_WGS84	FID	integer		All CLC assets like : Agricultural lands, tourism, urban area, industry-commercial
FroutesNationales_LRO_AQUI	FID	integer		National road
Fvilles_LRO_AQUI	FID	integer		Locations of all main cities
	NOM	character		Cities name
	POP90	number		Number of inhabitants per city, 1990
FvoiesFerrees_LRO_AQUI	FID	integer		Railway
HighSeaLevelPlus5m	FID	integer		Processed from IGN DEM (+7.92 m in AQUI and +5m in LRO)
hydro_CoteBasque_polyline	FID	integer		Rivers in Côte Basque
hydro_lro_polyline	LARGEUR	integer	[0..3]	Number as large as the river is large
ImportantHabitat_CLC	FID	integer		Identity number
	Asset	character	Important Habitat	Field added within Response for Map 4 and 7.
IPLI_Dunes	FID	integer		Dunes area (from IPLI)
IsoBathy100m	FID	integer		100 m isobatymetric line in AQUI
IsoBathy20m	FID	integer		20 m isobathymetric line in AQUI
IsoMarnage_polyline	MARNAGE	number		Tidal range in cm for spring tide
Lac_Cote_Basque	FID	integer		Lagoons in Basque Country
LittoralDrift_polyline	Type	character	Drift, cell boundary, sub-cell boundary	Digitalised on CNEXO maps
Marais_region	FID	integer		Marsh areas (from IGN)
PNR_Languedoc_RoussillonWGS84_region	FID	integer		Languedoc_Roussillon Natural Regional Park

File	Field	Type	Values	Comments
PotentialFloodAreas_MNT_Observed_2100_WGS84_Agrege	FID	integer		Obtained based on IGN DEM and flood observation
ResponseRecal_WGS84	Shoreline	character	Infrastructure	Eurosion and expert knowledge, processed
Risk_CLC_AQUI_LRO	Asset	character	Agricultural lands, tourism, urban area, industry-commercial	Field added within Response for Map 7, subject to increased erosion and/or flood risk
Risk_Habitat_AQUI_LRO	Asset	character	Important Habitat	Includes Habitat from CLC, but also znieff, habitat directive, …, subject to increased erosion and/or flood risk
Rn_LRWGS84_region	FID	integer		National Natural Reserve in Languedoc-Roussillon
RNV_LRWGS84_region	FID	integer		Regional Natural Reserve
Routes_lro_polyline	FID	integer		Roads in LRO
S_SUBM_WGS84_SMNLR	FID	Integer		Flood observation in LRO
Sea	FID	integer		Sea polygone, only for mapping
TCoteSchematiqueRecal_WGS84	Eshoreline	character	Beach, inlet, …	Nature of the shoreline, from Eurosion processed
	Ebeachcomp	character	Sand, composite, mixed	Beach composition, from Eurosion processed
	Elowland	character	Unconsolidated clastic material, consolidate, unknown	Material of hinterland, from Eurosion processed
	Ecliff	character	HardRock, SoftRock	From Eurosion processed
	EBeachmorf	character	Fringing, fronting, free	Beach morphology, from Eurosion processed
	Barres	character	O	O=Presence of bar
	Shoreface	character		Shoreface morphology (gentle, steep, bedrock, bars)
	QUANTIFERO	number	-20,-10,0,10,20	>0 is accretion, <0 is erosion
	Replenishm	integer	0,1	1: nourishment is done
	Defences	character	Hard, Soft	Obtained processing various defence types
	CliffRemed	Integer	0,1	1: cliff remediation is done
	CliffEngin	integer	0,1	1: cliff engineering is done
	CtrlStruct	integer	0,1	1: Control structure is present
	HarbStruct	integer	0,1	1: Harbour structure is present
TCoteSchematiqueRecal_WGS84 (suite)	CBSglobal	character	CBS1* to CBS6*, Estuary	Global CBS for map 5 of response
	EvolCote	integer	-1,0,1,9	Coast erosion: -1 : erosion | 0 : no significant change | 1 : aggradation | unknown, from Eurosion processed for AQUI, and Durand processed for LRO
	CbsChPes	integer	Nothing, 1,3,4	CBS change: 1: beach loss | 3:bar loss | 4: beahc and bar loss
	FloodPes	integer	-9,0,1,2	Flood risk: -9: Arcachon bay | 0: no signicant | 1:significant increase | 2: drastic increase
	ErosionPes	integer	-9,0,1,2,9	Flood risk: -9: Arcachon bay | 0: no signicant | 1:significant increase | 2: drastic increase | 9: not concerned
	FID	integer		Coastline portion where erosion risk is present (obtained by cross-correlation between erosion hazard area and assets)

File	Field	Type	Values	Comments
TCoteSchematiqueRecal_WGS84_RiskActuel	EvolCote	integer	-1,0,1,9	-1 : erosion | 0 : no significant change | 1 : aggradation | unknown, from Eurosion processed for AQUI, and Durand processed for LRO
TxErosionTraitCote	FID	integer		Locations of all secondary cities
VillesBalnéairesSecondaires	Nom	character		Cities name
	TYPE	integer	1,2	1 : remarkable biological interest 2 : large area rich and lighlty modified, important biological potentialities
Znieff_LRWGS84_region	FID	integer		Obtained based on IGN DEM and flood observation
Zones_submergeables_actuelle_mnt_obs	FID	Integer		Obtained based on IGN DEM
Zones_submergeables_actuelles_WGS84_MNT				

Table 2 - Data used in RESPONSE GIS to draw maps 1 to 7.

Appendix 6

Coastal hasard events in Aquitaine and Languedoc-Roussillon

KEYWORD	COMMUNE	LIEU_DIT	LOCALIZATION	DATE	VOLUME M^3	AMPLITUDE	DEGATS	CAUSE	OBSERVATION
Rock fall	BIARRITZ	Côte des Basques	Faille Dalbarade (tournant du Bld Prince de Galles)	1858		?			Dans les marnes servant de support au chemin de support au chemin de desserte à la plage
Landslide	BIARRITZ	Côte des Basques	Chalet Alexandrine	-/02/1899		?	Sentier conduisant à la petite fontaine emporté	Fortes pluies	
Landslide	BIARRITZ	Côte des Basques	Sea-Cottage, Lou-Bascou et Itxas-Goity	1900-1915		?			
Rock fall	BIARRITZ	Côte des Basques	Etablissement des bains	1922		?			Menace sur la villa Sea-Cottage
Storm	BIARRITZ	Côte des Basques	Etablissement des bains	01/01/1924		?	Parapet emporté et Etablissement des bains endommagé	Raz de marée	Mur de soutènement construit
Landslide	BIARRITZ	Côte des Basques	Perspective Miramar, Villa Alexandrine	14/12/1930		?		Fortes pluies	Menace sur les voies publiques et immeubles riverains
Landslide	BIARRITZ	Côte des Basques	Propriétés Lou-bascou et Argenson	09/01/1939		?			Construction d'un mur drain avec arcatures et contrefort derrière l'Etablissement des bains
Storm	BIARRITZ	Côte des Basques		01/01/1948		?	Partie du quai emportée		Reconstruit avec un encrage plus profond
Rock fall	BIARRITZ	Côte des Basques	Villas Itxas-Goity et Argenson	1954		?			Travaux de réfection des arctures et contreforts
Rock fall	BIARRITZ	Côte des Basques	Villa Belza	-/12/1960	plusieurs m^3	Faible	Chaussée maritime encombrée	Fortes pluies	
Rock fall	BIARRITZ	Côte des Basques	Falaise d'Hélianthe	-/05/1964		?	Domaine public		
Rock fall	BIARRITZ	Côte des Basques	Falaise Lou-Bascou	-/03/1971		?	Etablissement des bains détruit		
Rock fall	BIARRITZ	Côte des Basques	Falaise d'Argenson	-/08/1972 et -/12/1972		?			
Rock fall	BIARRITZ	Côte des Basques	Hôtel Sunset et villa Pereira	-/03/1973		?	Villa Pereira		Evacuation de la villa, consolidations
Landslide	BIARRITZ	Côte des Basques	Sud du Square JB Lassalle (Avenue Notre Dame)	-/01/1982		?			
Storm	BIARRITZ	Côte des Basques	Mur du quai	01/02/1994		?	Affouillement du mur du quai, désagrégation des éléments de l'escalier d'accès à la plage		Ouvrages reconstruits
Rock fall	BIARRITZ	Côte des Basques	Entre la plage Marbella et le CCAS Dordogne	18/07/1994	3 000	Important	Apparition de nombreux surplombs et déstabilisation de paquets de matériaux		L'écroulement concerne un panneau à la surface duquel étaient vraisemblablement plaqués des matériaux glissés provenant d'un écroulement ancien

Table 1 - Table of events in Aquitaine (Archives and orthophotoplan analyzis).

KEYWORD	COMMUNE	LIEU_DIT	LOCALIZATION	DATE	VOLUME M³	AMPLITUDE	DEGATS	CAUSE	OBSERVATION
Landslide	BIARRITZ	Côte des Basques	Propriété Toki-Edera	1996	650	Moyen	Menace à court terme la stabilité de l'immeuble Toki-Edera		La construction peut être encore sauvée (étude ANTEA, 1996)
Landslide	BIARRITZ	Côte des Basques	Jardins sous la Perspective	-/11/1998		?	Des fissures affectent le trottoir de la Perspective en face du restaurant "Les Flots Bleus"		La mauvaise maîtrise des circulations d'eaux superficielles, liée à la vétusté du réseau de collecte et d'évacuation des eaux pluviales a un rôle important dans la stabilité du versant
Landslide	BIARRITZ	Côte des Basques	Villa Montbert	19/07/1999	4 000	Important			Il faut interdire l'accès au pied de falaise (étude ANTEA, 1999)
Rock fall	BIARRITZ	Côte des Basques	Villa Montbert	01/08/1999	12 000	Important	Etalement du cône d'éboulis sur 65 m de large, avançant sur l'estran de 20 m par rapport au pied de falaise avant éboulement		Recul de la crête de falaise de 2,5 à 8 m sur 50 m de long (étude ANTEA, 1999)
Rock fall	BIARRITZ	Côte des Basques	Villa Montbert	14/01/2000	600	Important	Recul de la crête de falaise de quelques mètres en profondeur, sur une 50aine de mètres de front (à 5 m de la villa Montber)		La conservation de la villa Montber n'est plus possible
Rock fall	BIARRITZ	Plateau de l'Atalaye	Entrée des grottes	16/11/1992	240 (500 tonnes)	Moyen			
Rock fall	BIARRITZ	Pointe Saint Martin	En contrebas de la propriété Dassié	1977		?			
Rock fall	BIARRITZ	Pointe Saint Martin	Villa Gulf Stream et fantaisies	1994		?			
Landslide	BIARRITZ	Pointe Saint Martin	Villa Dassié	1997		?			
Storm	ANGLET	Digue nord	Embouchure de l'Adour	01/01/1965		?	Structures bétonnées emportées sur 12 m, affouillement sur 40 m		
Rock fall	ANGLET	Pointe Saint Martin	Sud de la Chambre d'Amour	23/03/1999	12 000	Important			Menace sur la villa "Nuit de Mai"
Rock fall	ANGLET	Pointe Saint Martin	Falaise du VVF	29/07/2002	1 716	Moyen	Surcreusement: ouverture de 22 m, profondeur de 12 m et hauteur de 6/7 m	Fortes pluies	
Rock fall	BIDART	Ilbarritz	Falaise d'Ilbarritz et du Pavillon Royal	-/04/1999		?			Problème de sécurité pour les passants. Le recul de la crête de falaise ne menace pas de bâtiment, mais peut restreindre à terme l'emprise du golf.

Table 1 - Table of events in Aquitaine (Archives and orthophotoplan analyzis) (suite).

KEYWORD	COMMUNE	LIEU_DIT	LOCALIZATION	DATE	VOLUME M^3	AMPLITUDE	DEGATS	CAUSE	OBSERVATION
Landslide	BIDART	Plage du Centre	Extrémité sud de la plage du Centre	1997		?			
Landslide	BIDART	Plage du Centre	Extrémité sud de la plage du Centre	1998		?			
Landslide	BIDART	Parlementia	En dessous de la propriété Reinart			?	Menace la propriété Reinart		
Landslide	BIDART	Parlementia	Plage de parlementia	12/11/1997		?		Fortes pluies	Il en résulte 2 types de coulées boueuses : une liquide jouxtant une coulée plus solide
Landslide	GUETHARY	Parlementia	Propriété Landa Berria	1971		?		Mauvais état des canalizations	Des travaux de remise en état des canalizations et de stabilization des glissements de terrain ont été engagés par le propriétaire
Landslide	GUETHARY	Parlementia	Sous la propriété Landa Berria	1978		?	Menace la propriété Landa Berria		Etude géotechnique et travaux de soutènement réalisés
Landslide	GUETHARY	Parlementia	Propriété Landa Berria	20/02/1999		?			Reconnaissance géotechnique et propositions de confortement
Storm	GUETHARY	Arotzen Costa	Plage d'Arotzen Costa	01/01/1965		?	Plage complètement désensablée, plus que des galets. Cabanons emportés. Blocs de ciment arrachés au niveau du port.		
Landslide	SAINT-JEAN-DE-LUZ	Pointe Sainte-Barbe	Chemin de Chaliapine	1963		?		Fortes pluies	Terrain remblayé, drainé et aménagé par les propriétaires
Landslide	SAINT-JEAN-DE-LUZ	Pointe Sainte-Barbe	Chemin de Chaliapine	1971		?		Fortes pluies	
Rock fall	SAINT-JEAN-DE-LUZ	Pointe Sainte-Barbe	Colline de Sainte-Barbe	03/12/2002	7 000	Important	Barrière en bois emportée (pan de paroi d'environ 15 à 20 m de longueur par près de 15 m d'épaisseur éboulé)		Définition d'un périmètre de sécurité, étude de sol prévue
Landslide	SAINT-JEAN-DE-LUZ	Erromardie	Villa Chirimolan	1970-1975		?	Menace la villa Chirimolan		L'affaissement de crête se trouve à 6m de la voie communale qu'il longe sur 30 m. Drainage et mur de soutènement réalisés.
Storm	SAINT-JEAN-DE-LUZ	Baie	Seuil de garantie	16/06/1933		?	Inondation d'une partie de la ville.		
Storm	SAINT-JEAN-DE-LUZ	Baie	Seuil de garantie	01/01/1951		?	Les flots déchainés ont creusé des brèches dans la digue et le parapet s'est effondré.		

Table 1 - Table of events in Aquitaine (Archives and orthophotoplan analyzis) (suite).

KEYWORD	COMMUNE	LIEU_DIT	LOCALIZATION	DATE	VOLUME M^3	AMPLITUDE	DEGATS	CAUSE	OBSERVATION
Storm	SAINT-JEAN-DE-LUZ	Baie	Seuil de garantie	01/10/1961		?	Une 2ème brèche s'est développée dans la partie située en face de l'Avenue Pellot		
Storm	SAINT-JEAN-DE-LUZ	Baie	Seuil de garantie	30/01/1990		?			
Storm	HENDAYE	Plage	Plage	01/01/1951		?	Promenade de la plage endommagée		
Rock fall	SAINT-JEAN-DE-LUZ	Mayarko	Nord de la plage de Mayarko			?			
Landslide	SAINT-JEAN-DE-LUZ	Mayarko	Sud de la plage de Mayarko			?			
Landslide	SAINT-JEAN-DE-LUZ	Lafiténia	Nord de Lafiténia			?			
Landslide	SAINT-JEAN-DE-LUZ	Lafiténia	Nordde Lafiténia			?			
Landslide	SAINT-JEAN-DE-LUZ	Lafiténia	Sud de Lafiténia			?			
Rock fall	SAINT-JEAN-DE-LUZ	Erromardie	Nord d'Erromardie			?			
Landslide	SAINT-JEAN-DE-LUZ	Erromardie	Nord d'Erromardie			?			
Landslide	SAINT-JEAN-DE-LUZ	Erromardie	Nord d'Erromardie			?			
	SAINT-JEAN-DE-LUZ	Erromardie	Sud d'Erromardie			?			
Rock fall	SAINT-JEAN-DE-LUZ	Erromardie	Sud d'Erromardie			?			
Landslide	SAINT-JEAN-DE-LUZ	Erromardie	Sud d'Erromardie			?			
Landslide	SAINT-JEAN-DE-LUZ	Pointe Sainte-Barbe				?			
Rock fall	SAINT-JEAN-DE-LUZ	Pointe Sainte-Barbe				?			
Rock fall	SAINT-JEAN-DE-LUZ	Pointe Sainte-Barbe				?			
Rock fall	URRUGNE	Corniche	Nord de la Corniche			?			
Rock fall	URRUGNE	Corniche	Les Viviers Basques			?			
Landslide	URRUGNE	Corniche	Sud d'Haïzabia			?			
Landslide	URRUGNE	Corniche	Sud d'Haïzabia			?			
Landslide	URRUGNE	Corniche	Sud de la Corniche			?			
Landslide	URRUGNE	Corniche	Sud de la Corniche			?			
Rock fall	URRUGNE	Corniche	Nord de la baie de Loya			?			
Landslide	URRUGNE	Corniche	Nord de la baie de Loya			?			
Rock fall	URRUGNE	Corniche	Baie de Loya			?			
Rock fall	CIBOURE	Socoa	Villa Uhaina	2002		?	" Sentier des douanes " emporté		Mise en péril de l'extrémité de la propriété Uhaina
Rock fall	BIARRITZ	Pointe Saint-Martin	Nord de la plage Miramar	1999					
Landslide	GUETHARY	Arotzen Costa	Maison Roques	1986					Travaux effectués sur la propriété Roques en 1986
Landslide	GUETHARY	Arotzen Costa	Villa Bon-Air	à vérifier			villa emportée ??		

Table 1 - Table of events in Aquitaine (Archives and orthophotoplan analyzis) (suite).

KEYWORD	COMMUNE	LIEU_DIT	LOCALIZATION	DATE	VOLUME M^3	AMPLITUDE	DEGATS	CAUSE	OBSERVATION
Landslide	BIDART	ILBARRITZ	château d'Ilbarritz ou du baron de L'Espée	2003-2004		8 à 10 m	perte de terrain uniquement		Dans une importante couche de marnes
Landslide	GUETHARY	SENIX	Haut de plage du Sénix	2004			aucun bien a subit de dégats		Petits glissement continuent dans un grand glissement
Landslide	SAINT-JEAN-DE-LUZ	SENIX	Bas de la route d'accès à la plage	2004	1	0,5 m	aucun bien a subit de dégats	tempête	Petit effondrement en haut de plage suite sans doute au sappage par la mer
Rock fall	SAINT-JEAN-DE-LUZ	MAIARKO	Nord de la plage de Maiarko				aucun bien a subit de dégats		L'effondrement en bas de falaise a sans doute précédé le glissement des couches meubles sus-jacentes
Rock fall	SAINT-JEAN-DE-LUZ	MAIARKO	Sud de la plage de Maiarko			variable	aucun bien a subit de dégâts	érosion différentielle des marnes met en porte à faux les bancs calcaires	Chute de blocs
Landslide	SAINT-JEAN-DE-LUZ	LAFITENIA	Haut de plage			> 0,5 m	aucun bien a subit de dégâts	infiltration d'eau et océan dégraisse la base	Petits glissements et petites loupes très actives
Landslide	SAINT-JEAN-DE-LUZ	LAFITENIA	Haut de plage			> 0,5 m	aucun bien a subit de dégâts	infiltration d'eau et océan dégraisse la base	Petits glissements et petites loupes très actives
Landslide	BIDART	PARLEMENTIA							Glissements des argiles contenants des blocs de calcaire dont les couches en place semblent pourtant sous les argiles
Landslide	BIDART	PARLEMENTIA					Ancienne conduite cassée		Glissements des argiles contenants des blocs de calcaire dont les couches en place semblent pourtant sous les argiles
Landslide	BIDART	PARLEMENTIA							Glissements des argiles contenants des blocs de calcaire dont les couches en place semblent pourtant sous les argiles
Landslide	BIDART	PARLEMENTIA					Tuyaux cassé et déformé par les glissements		Glissements des argiles contenants des blocs de calcaire dont les couches en place semblent pourtant sous les argiles
Landslide	BIDART	PARLEMENTIA							Glissements des argiles contenants des blocs de calcaire dont les couches en place semblent pourtant sous les argiles
Landslide	HENDAYE	POINTE SAINTE ANNE	Nord de la Pointe		2 m^3	2 à 3 m	Non visible		Pas d'eau d'infiltration visible
Landslide	URRUGNE	SOCOA	Pointe à l'est du Phare				Cloture emportée	Marnes jouent le rôle de couche savon	La couverture argileuse a également glissée
Landslide	URRUGNE	LES VIVIERS BASQUES	Ancienne route		> 1 500	20 m	Une partie de la route est partie	Marnes jouent le rôle de couche savon	Une grande fracture se propage vers l'est et s'élargie
Landslide	URRUGNE	LES VIVIERS BASQUES	Est des Viviers Basques					Sous-cavage	Décollement de dalles calcaires dont l'assise en bas de falaise a déjà disparue
Landslide	URRUGNE	LES VIVIERS BASQUES	Est des Viviers Basques			30 m	Non visible		La roche en bas du glissement est forme des blocs comparables à un éboulement
Rock fall	HENDAYE	HAIZABIA							
Landslide	HENDAYE	HAIZABIA							
Rock fall	HENDAYE	HAIZABIA							
Landslide	HENDAYE	HAIZABIA							
Landslide	HENDAYE	HAIZABIA							
Landslide	HENDAYE	HAIZABIA							
Landslide	HENDAYE	HAIZABIA							
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							Position imprécise
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							Position imprécise
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							Position imprécise
Rock fall	SAINT-JEAN-DE-LUZ	ERROMARDIE							
Landslide	SAINT-JEAN-DE-LUZ	ERROMARDIE							
Landslide	SAINT-JEAN-DE-LUZ	LAFITENIA							
Landslide	GUETARY	Arosten Costa							
Landslide	URRUGNE	LA CORNICHE							
Landslide	URRUGNE	LA CORNICHE							
Landslide	URRUGNE	LA CORNICHE							
Rock fall	URRUGNE	LA CORNICHE							

Table 1 - Table of events in Aquitaine (Archives and orthophotoplan analyzis) (suite).

KEYWORD	COMMUNE	LIEU_DIT	LOCALIZATION	DATE	VOLUME M^3	AMPLITUDE	DEGATS	CAUSE	OBSERVATION
Rock fall	URRUGNE	LA CORNICHE							
Rock fall	URRUGNE	LA CORNICHE							
Rock fall	URRUGNE	LA CORNICHE							
Landslide	GUETARY	Arosten Costa							
Cliff collapse	URRUGNE	LA CORNICHE							
Landslide	URRUGNE	LA CORNICHE							Glissement actuel. Présence d'un mur de soutènement
Landslide	URRUGNE	LA CORNICHE							
Landslide	URRUGNE	ROCHERS DES CRIQUES							
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							
Landslide	SAINT-JEAN-DE-LUZ	ROCHER DAURIA							
Earthquake	ARUDY	OSSAU		29/02/1980					
Storm, flooding	BIARRITZ	BIARRITZ		11/12/1990			houses and car damaged by fallen trees, Biarritz promenade flooded		peak gust speed 160km/h
Storm	LACANAU	LACANAU		17/11/2002					offshore tornado
Storm, flooding	BISCARROSSE	CAZAUX		09/09/2004			one damaged house by fallen broken trees and branches,		rain 24.2 mm, maximum intensity of rain 113 mm/h wind up to 122 km/h
Storm, flooding	ARCACHON	ARCACHON		09/09/2004					numerous fallen branches, wind speed 68 km/h
Storm		AQUITAINE		25/12/1990			power supply disrupted. Ship capsized		
Storm	BAYONNE	BAYONNE		08/08/1992			houses (roofs) and caravan damaged, trees downed, vinyards (Margaux, Médoc, Haut-Médoc) damaged		
Storm	ARCACHON	ARCACHON		11/09/1993			houses (roofs) damaged , trees downed, power lines interrupted, ship damaged, 5 missing		peak gust 130 km/h
Storm	BAYONNE	BAYONNE and N coast of Spain		16/04/1998			port affected, crane damaged, 1 injured, traffic disrupted		peak gust 120 km/h

Table 1 - Table of events in Aquitaine (Archives and orthophotoplan analyzis) (suite).

Year	Month	Date	Location	Impacts	Geo reference	Source	Keyword	Source Location	Event duration	Wind, Wave and tide data
2004	8	16	Marseillan-plage, Tamarissière, Vias	Killed: 4, disappeared: 1		RTL archives	Storm		2	Winds force 7
2003	12	3	Bouches-du-Rhône, Gard, Vaucluse, Pyrénées-Orientales	1,500 cities flooded, Cerbere and Banyuls particularly affected, killed:9, affected: 15000			Flood, mudslide		3	Heavy rains, high winds, wind speed: 147,6 km/g
2002	12	10	Hérault, Gard	Flash flood, weathering, coastal erosion, landslides. deads: 2 (at Aimargues and Fabrègues), 220 people evacuated. Mudslides and flooding at Palavas		catnat	Flash floods, mudslides in urban areas	Base primnet	3	
2002	11	23	Vaucluse	Killed: 1 at Sardan near Sommières (Gard) the 25/11. Flooding of the Rhône and Vidourle		AFP, catnat	Flood	Base primnet	7	
2002	9	8	Gard	Killed: 24, affected: 600,000. Flooding of the Rhône, Vidourle, Gardon, Cèze. Within one day, more than 670 mm on the Cévennes. 330 M € for commerce, artisanat, services and 219,3 M€ for agriculture (60% for vineyards). 25 M € for the roads... "Marshall plan" of 400 m€, local, national and european funds.		AFP	Catastrophic flood	Base primnet	5	
2001	10	6	Gard	Killed :2, flooding of the Vidourle and the Gardon, RN 106 and 110 closed, railway trafic closed between Nîmes and Ales		AFP, Météo-France	Flood	Base primnet	2	More than 300 mm/24 h near Alès and Sommières
2001	10	9	Hérault	From Saint-Martin-de-Londres to Montpellier, homeless families: 50,000, A9 closed		AFP, catnat	Flood	Base primnet	1	
2000			Collioure			ethnographie des tempêtes, Etienne Rogier. Les cahiers d'éole, sept 2003, n8	Storm			
1999	12	27	Western Europe	Languedoc-Roussillon: killed: several, important dammages to roads, houses, telephonic and electric lines		Meteo France			2	Perpignan: up to 140 km/h (wind), Languedoc: up to 180 km/h
1999	11	12	Languedoc-Roussillon	In the Pyrénées-Orientales: killed: 12, disappeared: 7. In the Tarn: killed: 7, Hérault: killed: 1; grounding of the cargo Simba at Port-la- Nouvelle. Flooding of several rivers in the departements: 11, 81, 66, 34 et 12 - important impacts in the Aude (15 bridges affected, 15 breaches of the road)		Midi Libre 14 nov. 1999, ethnographie des tempêtes, Etienne Rogier. Les cahiers d'éole, sept 2003, n° 7	Storm + flooding	Base primnet	3	Big waves from SSE, storm surge > 1 m
1999	8	7	SW, Montpellier	Killed: 5, injured: 2, evacuated: 2, 1 M$ US, Numerous buildings damaged, camp grounds affected, cars damaged. Roads, railway lines blocked. Trees and power lines downed. Losses to agriculture.			Severe storm		2	Gusts up to 140 km/h, thunderstorms, lightning, heavy rain.
1997	11	4	Languedoc-Roussillon			Durand, 2000	Storm		3	
1996	12	8	Languedoc-Roussillon, Béziers	Heavy rain, thunderstorms. Flooding along numerous rivers. City of Béziers submerged. Dozens of houses, railway lines and roads flooded. Traffic affected. Missing: 1, evacuated: 100.			Flash floods	Base primnet	6	

Table 2 - Table of events in Languedoc-Roussillon (Archives and inquiries).

Year	Month	Date	Location	Impacts	Geo reference	Source	Keyword	Source Location	Event duration	Wind, Wave and tide data
1997	12	16	Languedoc-Roussillon	Breaching at Le Gruissan, Narbonne-plage, 15 m breach of the RN112 (Marseillan), breaching and flooding at Aigues-Mortes (Salins du midi). Complete erosion of the beach at: Narbonne-plage, Grau-du-Roi. Flooding of the city front at: Valras, Vias, les Arresquiers, Sète, le Racou, La Grande Motte, Port-la-Nouvelle. Destruction of the city front at Sète, Les Arresquiers, Valras, Vias. Destruction of oyesters parcs at Leucate. telephone and railway lines cut		Farnol & Laval, Midi Libre	Storm + marine submersion		4	Storm surge: 1.06 m NGF (*i.e.* real surge of 0.72 m at Marseillan, 1.45 m at Gruissan andt St-Cyprien). Wind max speed at Sète: 133 km/h, Hs mean: 3.8 m, Tsmean: 7.87 s, Hsmax: 6,98, Hmax: 10.81
1996	1	28	Languedoc-Roussillon, Puisserguier	Flooding of the Orb, mudslide, killed: 4		catnat	Flash floods	Base primnet	2	
1996	1	21	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		3	
1995	12	8	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		2	
1996	1	9	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		2	
1995	12	16	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		2	
1995	11	25	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		2	Storm from SE
1995	11	21	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		3	Wind speed: 55 nodes, SSE
1995	11	10	Golfe du Lion	Beach erosion, no more details	Midi Libre, Durand (2000)		Storm		3	Wind speed: 55 nodes
1994	11	3	Golfe du Lion	Beach erosion, no more details	Durand (2000)		Storm		3	
1993	12		Provence-Alpes-Côte d'Azur	Rhône flood. Killed in Camargue > 10		catnat	Flood	Base primnet		
1992	9	22	Vaison-la-Romaine (Vaucluse)	Flood in the Ouvèze		rapport Bourges	Flash flood	Base primnet	1	
1992	9	26	Aude and Pyrénées-Orientales	Killed at Rennes-les-Bains: several			Flood	Base primnet	2	
1991	3	6	Golfe du Lion	Beach erosion		Durand (2000)			3	
1989	11	16	Languedoc-Roussillon	Marine submersion in the Pyrénées-Orientales (from Perpignan to Argeles, Canet). Gruissan-plage separated from Gruissan-village. Flooding at the river oulets of the Tech, Tet… dead whale on the beach at Le Barcares. Narbonne: boats on the city front.					5	Hs max: 4,82 m, 0,95 m NGF at Sète, wind speed reached 162 km/h, cap Beart: wind at 70 nodes
1989	8	5	Narbonne				Flash floods			234 mm / 3H
1988	10	3	Nîmes (Gard)	Flash flood in Nîmes: 400 mm in 9 h. killed and important impacts	catnat	Ponton Report, Midi Libre	Flash floods, mudslides	Base primnet	1	
1987	10	3	Languedoc-Roussillon	Vermeille Coast (Cerbere, banyuls, collioure): heavy rains, 1,5m water wall in the city of Cerbere. Breaching of the city front. Sète: destruction of the beach restaurants.		Midi Libre	Storm, flash flood, "déluge"		10	Equinox storm, winds from SSE 64 nodes, big waves
1986	10	13	Roussillon	59 cities affected		catnat	Flash floods	Base primnet		
1982	11	6	Languedoc-Roussillon	Sete, Palavas: submersion, total beach erosion (no more beach at La Corniche, Maguelone and Les Arresquiers), breaching, 20 m onshore migration of the barrier, flooding (2 days) of the canal du Rhône a Sete and city canals and port. City front, groin and boats destroyed. Other cities (Balaruc, Mèze, Bouzigues, Poussan, Villeveyrac, Gigean… flooded. from Narbonne to Sete, roads covered by sand and shingle. A part of the RN112 road definitively closed by the préfecture de l'Hérault.		SOGREAH (1984), Midi Libre	Storm, flood		40-60h	Wind speed: 180 km/h; severe swell from East+ storm surge: 0.95-1 m/NGF. The most important event of the last 50 years.

Table 2 - Table of events in Languedoc-Roussillon (Archives and inquiries) (suite).

Year	Month	Date	Location	Impacts	Geo reference	Source	Keyword	Source Location	Event duration	Wind, Wave and tide data
1980	2	29	Ossau, Arudy (Pyrénées-Orientales)			catnat	Seisme	base primnet	1	
1979	1		Marseillan-plage, Tamarissière			Durand (2000)	Storm			
1978	1	10	Languedoc Roussillon	Beach erosion, no more details		Durand (2000)	Storm		3	
1976	9	23	Montpellier			Meteo-France, Midi Libre	Flash floods			Flood of the Lez, and storm surge of 20-40 cm at the river outlet
1970	1	10	Sete	Grounding of the vessel Ioanna		Midi Libre	Storm			Big waves from SSE
1969	7	6	Languedoc-Roussillon			Durand (2000)	Storm			
1968	9		Cevennes	Killed: 35 to 45, damages: milliards of €			Flash floods			
1965	10	9	Roussillon	Dammages: 94,5 Millions of francs		Meteo France	Flash floods		16	
1963	11	5	Nîmes	Killed: 1		Midi Libre	flash floods		6	
1958	9	30	Gard, Hérault	Killed in the Gard: 35. Several cities submerged in the Gard and Hérault		catnat	Floods	Base primnet	1	
1958	9	4	Gard			catnat	Floods	Base primnet	1	
1940	10	16	Pyrénées-Orientales, Catalogne	Important damages, spit breaching at the Tech river oulet		Midi Libre, Catnat	Flash floods	Base primnet	4	
2002	11	14	Drôme	Flooding of the Rhône and others rivers (la Véore, la Drôme, le Bez, le Roubion, le Jabron, l'Herbasse,le Deume, la Cance, Le Doux…), 1 people disappeared in the Var, 250 people evacuated in the Drôme		AFP, catnat	FLOOD	Base primnet	5	

Table 2 - Table of events in Languedoc-Roussillon (Archives and inquiries) (suite).

Appendix 7

List of detailed coastal behaviour systems

Map 5: Coastal Behaviour System

Detailed CBS

- Bars_gentle_FreeBeach_Lowland_Hard
- Bars_gentle_FreeBeach_Lowland_No
- Bars_gentle_FreeInlet_Hills_Hard
- Bars_gentle_FreeInlet_Hills_No
- Bars_gentle_FreeInlet_Lowland_Hard
- Bars_gentle_FreeInlet_Lowland_No
- Bars_gentle_FringingBeach_Hills_Hard
- Bars_gentle_FringingBeach_Hills_No
- Bars_gentle_FringingBeach_Lowland_Hard
- Bars_gentle_FringingBeach_Lowland_No
- Bars_gentle_FringingHarbour_Lowland_Hard
- Bars_gentle_FrontingBeach_Dune_Hard
- Bars_gentle_FrontingBeach_Dune_No
- Bars_gentle_FrontingBeach_Dune_Soft
- Bars_gentle_FrontingBeach_Hills_Hard
- Bars_gentle_FrontingBeach_Hills_No
- Bars_gentle_FrontingBeach_Lowland_Hard
- Bars_gentle_FrontingBeach_Lowland_No
- Bars_gentle_FrontingInlet_Dune_No
- Bars_gentle_FrontingSpit_Dune_No
- Bars_gentle_Inlet_Hills_Hard
- Bars_gentle_Inlet_Lowland_Hard
- Bars_gentle_Inlet_Lowland_No
- Bars_gentle_NB_Lowland_Hard
- Bars_step_FrontingBeach_Lowland_Hard
- gentle_ _Lowland_Hard
- gentle_ _Lowland_No
- gentle_FreeBeach_Hills_Hard
- gentle_FreeBeach_Hills_No
- gentle_FreeBeach_Lowland_Hard
- gentle_FreeBeach_Lowland_No
- gentle_FreeInlet_Hills_Hard
- gentle_FreeInlet_Hills_No
- gentle_FreeInlet_Lowland_Hard
- gentle_FreeInlet_Lowland_No
- gentle_FreeTidal flat_Dune_No
- gentle_FreeTidal flat_Hills_No
- gentle_FreeTidal flat_Lowland_Hard
- gentle_FreeTidal flat_Lowland_No
- gentle_FringingBeach_HardCliff_No
- gentle_FringingBeach_Hills_Hard
- gentle_FringingBeach_Hills_No
- gentle_FringingHarbour_Hills_Hard
- gentle_Fringing_Lowland_Hard
- gentle_FrontingBeach_Dune_Hard
- gentle_FrontingBeach_Dune_No
- gentle_FrontingBeach_Dune_Soft
- gentle_FrontingBeach_Hills_Hard
- gentle_FrontingBeach_Hills_No
- gentle_FrontingBeach_Lowland_Hard
- gentle_FrontingBeach_Lowland_No
- gentle_FrontingInlet_Dune_Hard
- gentle_FrontingInlet_Dune_No
- gentle_FrontingInlet_Hills_No
- gentle_FrontingInlet_Lowland_Hard
- gentle_FrontingInlet_Lowland_No
- gentle_FrontingSpit_Dune_No
- gentle_Harbour_Hills_Hard
- gentle_Inlet_Lowland_Hard
- gentle_NB_Harbour_Dune_No
- gentle_NB_Harbour_Hills_Hard
- gentle_NB_Harbour_Hills_No
- gentle_NB_Harbour_Lowland_Hard
- gentle_NB_Harbour_Lowland_No
- gentle_NB_HardCliff_Hard
- gentle_NB_HardCliff_No
- gentle_NB_Infrastructure_Hills_Hard
- gentle_NB_Infrastructure_Lowland_Hard
- gentle_NB_SoftCliff_Hard
- gentle_NB_SoftCliff_No
- step_ Inlet_Hills_Hard
- step_FringingBeach_SoftCliff_No
- step_FringingHarbour_Hills_Hard
- step_FrontingBeach_Lowland_Hard
- step_FrontingBeach_Lowland_No
- step_NB_HardCliff_No
- step_NB_SoftCliff_Hard
- step_NB_SoftCliff_No

CBS

- CBS1: Hard Cliff
- CBS2: Soft Cliff
- CBS3: Lowlands
- CBS4: Spits, Inlets, Tidal Basin
- CBS5: Dunes
- CBS6: Hills
- Estuary

Present Day Marine Flood Are

- Observed Marine Flood Area
- Digital Elevation Model

High Tidal Sea Level + 5m

- High Tidal Sea Level + 5m

Transport Links

- National Road
- Motorway
- Railway
- Road

Appendix 8

Hotspots statements

METHOD

In each pilot region, the RESPONSE methodology calls for defining “hotspots” as segments of coastline that will, under the hypothesis of climate change, be subject to drastically increased risk.

The steps entailed in defining these were:

- listing and mapping the segments of coastline which are currently considered to be hotspots (Figures 9 and 10 and Tables 6 and 7 in the main report);
- defining which new segment would be considered as submitted to a drastic increase of coastal hazard (Figures 19 and 20 and Tables 12 and 13);
- determining whether those drastically endangered segments put assets at risk (Figures 26 and 27 and Tables 17 and 18). For the sandy coast, in the Languedoc-Roussillon region, the term of “spot” should be construed as a stretch of coastline, including the whole lido system, referring to a basic sedimentary cell.

The result of this process yields a large number of spots or stretches of coastline. In this report, a selection of statement files is provided. The spots chosen were those for which the available information was the most complete.

However, data on incoming of future projects are, in most cases, not completely documented. Recommendations on future action are at this day, limited to an advice to integrate data on climate change impact in further management planning, and validate evolution hypothesis by local measurements and process modelling.

The statement files enclosed in the joint DVD are:

- for **Aquitaine**, from North to South: Soulac, L’Amélie-les-Bains, Lacanau, Biscarosse, Mimizan, Cap Breton, Pointe-Saint-Martin, Côte des Basques, Guéthary, Erromardie, Saint-Jean-de-Luz, Hendaye;
- for **Languedoc-Roussillon**, from East to West: La Petite-Camargue, Maguelone-les-Arresquiers, Le lido de Sète, Sainte-Geneviève - Portiragnes, Valras, Les Baraques de Fleury, Port la Nouvelle, Port Leucate, Sainte-Marie, Saint-Cyprien.

Appendix 9

Projects and works costs tables

Township/locality	Year	Breakwater		Groynes			seawall		wooden pile groyne	beach nourishment	reprofilage	geotextile	management	total €, > ou =	total per communes
		Building	Conforting	Building	Conforting	destruction/ down grading	Building	Conforting							
La Claire/ St Nicolas	1840	■		■											
Les Huttes	1930-34		■												
	2003		■		■									60,000	60,000
Les Arros (Soulac)	1840	■		■											
	1930-34		■		■										
	2004		■											800,000	
Soulac Plage Centrale	1930														
	1994									■	■				
	2001	■								■	■	■	■	*1,026,000*	
Soulac Crossa	2001								■		■	■		158,000	
L'Amélie-sur-Mer (Soulac)	1961 à 2000			■	■				■	■		■			
	2004				■								■	2,000,000	3,984,000
Plage du Gurp (Gr et l'H)	2001			■							■	■	■	198,000	
Plage du Depé	1990			■											
	2001				■						■	■	■	231,000	429,000
Montalivet	1979			■			■			■					
	1994														
	1996				■										
	1998				■						■				
	2001			■							■		■	109,000	109,000
Plage du Pin sec	2001						■				■		■	231,000	231,000
Le Pyla/mer	2005			■						■				2,200,000	2,220,000
	1961			■										52,000	
	1966			■										42,000	
Mimizan	19° century			■											
	1958				■									45,000	
	1967				■									33,000	
	1968			■	■									133,000	
	1974				■									6,000	
	1987				■									28,000	
	2001-2004					■									339,000
Contis	1958-1968			■										193,000	
	1968 to 1989				■									223,000	
	2000				■										416,000
Vieux Boucau	1958-1979			■										313,000	
	1964 to 1987				■									232,000	
	2001				■										545,000
Seignosse	?			■											
	1974 to 1979				■									282,000	
	1999					■									282,000
Hossegor	1953-1975			■			■							24,000	
	1961						■							161,000	
	2005					■									185,000
Cap Breton	1950 to 1980			■			■							1,292,000	
	1968 to 1980				■			■						1,095,000	
	From 2006 on				■					■		■	■	2,719,000	5,106,000
Ondres	1979			■											
	1999					■									

Table 1 - Available data on projects and global investments for defenses and coast line protection in Gironde and Landes departements (data SM33 and DD40).

Township		Cost in € euros	Beach nourishment	Type of works	Investment by sedimentary cell
LE GRAU-DU-ROI	1975	**51,833**		5 groynes	**10,07,993**
	1977	**65,553**		5 groynes	
	1981	**152,449**		4 groynes	
	1982	**91,469**		4 groynes	
	1983	**182,939**		16 groynes	
	1985			Rhone channelization. 3 groynes on former river mouth. Comforting of groynes	
	1989	**151,229**		7 grioynes.	
	1993	**129,582**		5 groynes.	
	1997	**182,939**		5 groynes on l'Espiguette beach. In 1999, comforting	
	1977	**60,980**		comforting	**60,980**
	1972	**182,939**	Grau du Roi beach totally nourrished: 180,000 m^3 .to be continued.		**426,857**
	1986	**152,449**		groynes	
	1990	**91,469**		comforting	
	1984			Building and comforting groynes, as protection of outlet	**90,1279**
	1987	**769,868**	50,000 m^3 sand from l'Espiguette ,.	Buiding and comforting of breakwaters	
	1990	**93,299**			
	1993	**38,112**		Groyne comforting	
	1999	**?**		Groyne comforting.	
LA GRANDE-MOTTE	1981	**60,980**		Breakwaters and groynes	**487,837**
	1969	**289,653**			
	1983	**106,714**			
	1971	**30,490**			
PALAVAS-LES-FLOTS	1976	**27,441**		Groynes building and comforting	**99,397**
	1969	**18,294**			
	1962	**36,588**			
	1957	**10,671**			
	1951	**6,403**			
	1992	**381,123**	25,000 m^3	groynes	**949,148**
	1994	**304,898**		Jetties	
	1996	**70,127**			
	1998	**193,000**		Breakwater and groynes	
FRONTIGNAN	1985	**137,204**			**137,204**
	1948	**6,098**		3 groynes	**268,310**
	1964	**3,049**		Groynes comforting.	
	1970	**45,735**			
	1976	**137,204**		Groynes comforting	
	1977	**15,245**			
	1978	**60,980**			
	1964	**76,225**		Channel comforting	**76,225**
SETE	1981	**304,898**	17,000 m^3 .	breakwater	**1,205,872**
	1983	**579,306**			
	1987	**213,429**	20,000 m^3 (from seaward)	2 breakwaters.	
	1988	**343,010**	20,000 m^3 (from land)		
	1993	**70,127**		breakwater	

Township		Cost in € euros	Beach nourishment	Type of works	Investment by sedimentary cell
AGDE	1977	**15,245**		groynes	**277,457**
	1989	**262,212**	Sand input for infrastructures	Groynes? .	
	1985	**335,388**	400,000 F	Plage Richelieu (Pointe de Roche longue), 5 groynes 4 transformed in breakwaters	**2,651,112**
	1992	**957380**		Transformation of 4 groynes into breakwater, 3 breakwaters	
	1994	**414,661**		2 breakwaters	
	1996	**411,612**		2 breakwaters	
	1998	**196,775**			
	2001	**335,295**		Access to breakwater and breakwater	
	2002			2 breakwaters	
	2003			1 breakwater	
	1995	**243,918**	17,000 m^3	3 groynes	
	1996	**107,477**			
	1998			Groyne: digue des Allemands	
VIAS	1982	**243,918**		groynes	**1,267,967**
	1990	**30,490**		groynes	
	2000	**642,164**		3 breakwaters and dune restoration	
VALRAS-PLAGE	1985	**27,441**		breakwater	**1,322,960**
	1992	**381,123**	50,000 m^3	3 breakwaters	
	1995	**259,163**	22,500 m^3		
	1999	**655,234**	60,553 m^3		

Table 2 - Available cost data for defense works and coast protection for Languedoc-Roussillon (from SMNLR).

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