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Potential Implications of Sea-Level Rise for France

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ABSTRACT

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Concern is growing in France about climate change and the related issue of accelerated sea-level rise (ASLR). Although a national vulnerability assessment has not been produced, available information is sufficient to clearly identify the coastal zones which are at risk. On the Mediterranean coast, the most vulnerable area corresponds to the deltaic plain of the Rhône River, chiefly because of human actions (*e.g.,* shortage of sediment supply as a result of dam construction; river embankments). Coastal erosion, lowland flooding, and ground water salinisation are the main impacts expected from ASLR. The Languedoc coastal barriers will move landward faster than at present, thus jeopardising dense tourist facilities. On the Atlantic coast, enhanced erosion of the Aquitaine sandy beaches is expected. Existing salt marshes do not appear threatened because mud sedimentation from soil erosion is active, but reclaimed areas will be at risk of flooding. Moderate salt intrusion is expected into the Loire estuary. The Normandy chalk cliffs may not recede faster than at present. Existing laws and regulations dealing with coastal management are sufficient to address the potential impacts which may affect populations and economic activities in the forthcoming decades as sea level rises.

ADDITIONAL INDEX WORDS: *Coastal erosion, coastal management, coastal vulnerability, Rhône delta, low land flooding, salt intrusion.*

INTRODUCTION

Excluding its overseas territories, France has a coastline which is about 5,500 km long: 3,800 km on the Atlantic and 1,700 km on the Mediterranean, including 850 km on Corsica. About 40% correspond to rocky coasts, 35% to beaches, 10% to salt marshes, 1% to estuaries, and 14% to artificial shores. It is estimated that 24% of the total population of the country (58 million inhabitants) live within a distance of 50 km from the sea. Directly sea-related economic activities represent 1.5% of the gross domestic product, *i.e. a* gross added value of FRF 105 billions in 1997, and provide employment for about 400,000 persons. The tourist sector dominates with 170,000 employees (IFREMER, 1999). It must be stressed that these figures leave out harbour and harbour-linked industrial activities which are significant on production and employment in France. As far as environmental management is concerned, pollution of coastal waters, conservation of sites of special ecological interest as well as beach and cliff protection against marine erosion are the main issues taken into special consideration. Coastal erosion is giving rise to increasing concern. According to the results of the European coastal erosion project (CORINE, 1998), 24% of the French coastline is receding, 45% is stable and 11% is prograding. Half the length of beaches is eroding, which is degrading the primary resource for tourists. Annual expenses for coastal defense amount to FRF 100 to 120 millions. Local authorities bear most of this cost, but a financial contribution up to 30% may be provided at a national level. At the end of the 1980s, the state budget line was about FRF 9 millions per year. Following the storm surges which occurred in 1990, an exceptional subsidy of FRF 28 millions was allocated. No funds were given in 1994. However, the financial assistance amounted to FRF 3 millions in 1996 and to FRF 6 millions in 1999. Figures are not yet available for 2000, but it can be logically assumed that, after the heavy coastal damages resulting from the two exceptional storms which hit the Atlantic coast of France in December 1999 (SALOMON, 2001), financial assistance at a governmental level has also been exceptional. About 550 km of coastline are currently protected by some form of defence structure throughout the country, representing a total investment of about FRF 5 billions.

CURRENT STATUS OF KNOWLEDGE

Potential impacts related to accelerated sea-level rise (ASLR) and associated increase in storminess have been addressed in France during the last decade mainly at a governmental level. Ten years ago, at the request of the Ministry of Environment, a consulting agency produced a report dealing with climate change and ASLR in France, focusing on the assessment of the involved socio-economic impacts (MINISTERE DE L'ENVIRONNEMENT, 1991). The report includes a coloured map at a 1:1 250 000 scale, illustrating the vulnerability of coastal areas to flooding, erosion, and salt intrusion assuming a 50 cm ASLR, as well as a table summarising the costs derived from such an ASLR on beaches, marshes, reclaimed areas, and harbours. The report also analyses the

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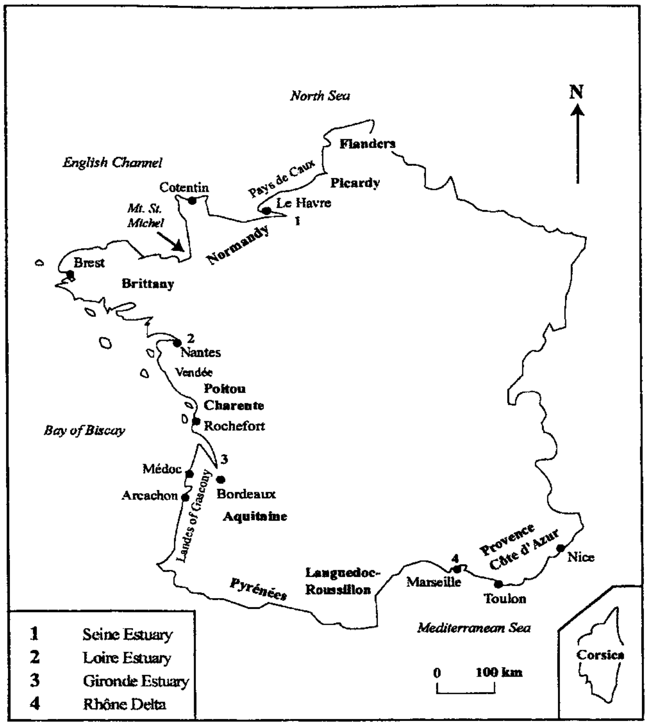

Figure 1. Location map.

detailed case study of the Rochefort area, located on the central part of the Atlantic coast of France. Here extensive marshy lowlands, largely reclaimed in the past centuries, are prone to flooding when low frequency, high magnitude storm surges occur (Figure 1).

Simulteanously, the Ministry of Environment launched a research project, co-ordinated by a working group composed of scientists, engineers, and economists, on measurements, impacts, and responses to ASLR on French coastal areas, assuming a rise of about 60 cm at the end of 21st century (EZUS, 1996). The following main topics were selected: (1) assessment of ASLR at a regional scale from tide gauge and land survey data; (2) statistical study of sea surges; (3) effects of ASLR on beaches; and (4) salt intrusion into estuaries.

In 2000, the French Interministerial Mission for the Greenhouse Effect (MIES), a governmental body in charge of a national programme addressing climate change, organised a Euro-Mediterranean symposium in Arles (southeastern France), the topic of which was climate change and coastal areas, ASLR, risks and responses, with special emphasis on the Rhône delta (PASKOFF, 2001b).

French universities and the National Center for Scientific Research (CNRS) have also been directly involved in the sea level rise problem, producing a number of publications. In particular, a special issue of the *Annales de Géographie* was devoted to sea-level variations and their human consequences, with a special emphasis on France (PASKOFF and PIRAZZOLI, 1998). PIRAZZOLI (1986), in a general article on secular trends of relative sea level changes, provided data which showed that almost everywhere in France relative sea level has been steadily rising during the last decades (Table 1). In a synthesis paper, PASKOFF (2000b) reviewed the impacts to be expected from the projected ASLR in continental France and in its overseas territories.

Table 1. *Long-term trend (in mm/yr) of changes in relative sea level in France, from Pirazzoli (1986).*

Locality	Latitude	Longitude	Time	Trend
Atlantic				
Cherbourg	49°39′ N	01°37′ W	1860–1884 1975–1981	+1.7
Cherbourg	49°39′N	01°37′ W	1891–1958	+0.4
Brest	48°23′N	04°30′ W	1807–1981	+0.8
Brest	48°23′N	04°30′ W	1807–1890	+0.3
Brest	48°23′N	04°30′ W	1890–1981	+1.2
Les Sables d' Olonne	46°30′ N	01°47′ W	1892–1956	+2.3
La Pallice	46°10′ N	01°13′ W	1891–1951	+3.1
Biarritz	43°29′ N	01°34′ W	1885–1950	+0.4
St. Jean-de-Luz	43°24′ N	01°41′ W	1890–1963	+1.4
Mediterranean				
Port Vendres	42°31′ N	03°07′ E	1888–1958	+0.9
Sete	42°24′ N	03°42′ E	1888–1961	+0.3
Port de Bouc	43°24′ N	04°59′ E	1894–1951	+2.6
Martigues	43°24′ N	05°03′ E	1894–1956	−0.3
Marseille	43°18′ N	05°21′ E	1885–1978	+1.3
La Ciotat	43°10′ N	05°37′ E	1893–1951	+2.1
Villefranche	43°42′ N	07°20′ E	1913–1957	+0.9

VULNERABILITY ASSESSEMENT: CASE STUDIES

In continental France (Figure 1), from the above mentioned publications, coastal areas appear to be more or less vulnerable to the ASLR scenarios which may occur in the 21st century. Since it is not possible to give an exhaustive vulnerability assessment concerning the whole country within the framework of an article, selected case studies are presented and discussed below. These are: (1) the deltaic plain of the Rhône river; (2) the sand barriers and lagoons of the Languedoc coast; (3) the beaches of the Aquitaine coast; (4) the reclaimed areas on the Atlantic coast; (5) the Loire estuary; (6) and the chalk cliffs of Normandy.

The Deltaic Plain of the Rhône River

On the Mediterranean coast, the deltaic plain of the Rhône River (1,700 km²)—the so-called Camargue—is actually the hot spot number one as far as impacts of ASRL are concerned in France (Figure 2). The coastal margin between the two distribuaries of the Rhône River—the Grand Rhône and the Petit Rhône—displays a sequence of former barriers, associated with abandoned river mouths, and lagoons. Because of the natural subsidence of the area, the rate of the relative sea level rise is presently about 2.1 mm/yr, instead of 1.3 mm/yr at Marseille, located east of the delta (SUANEZ *et al.*, 1997). As in many other deltas of the world, the subsidence is no longer compensated by sediments brought down by the river since this supply has been drastically reduced as a result of the building of several dams upstream. It is estimated that the fluvial sediment yield is now only 20% of what it was in the last century (PONT, 1997). Shingles and sands are im-

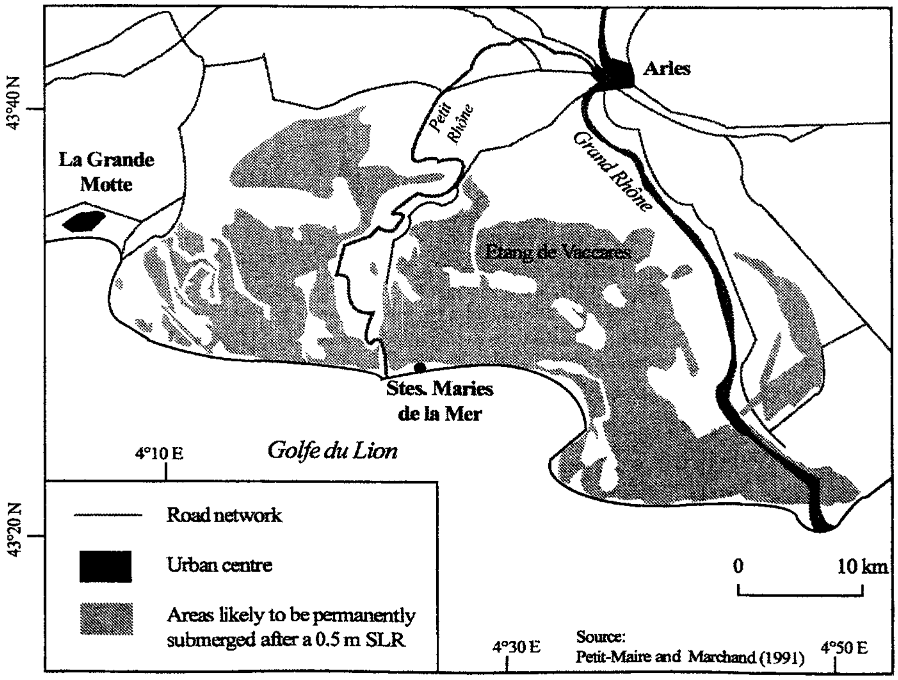

Figure 2. The deltaic plain of the Rhone River.

pounded in reservoirs, and only fine sediments—silts and clays—can reach the sea. The delta was normally built by frequent flooding and shifts in the position of the distributary river mouths. The two branches of the Rhône are now firmly embanked and neither flooding of the plain nor changing positions of the distributaries are longer permitted. Moreover, the water flow of the Rhône has been significantly reduced because of an increasing irrigation demand upstream. Rapid erosion of the shoreline, where abandoned sub-delta lobes are located, added to the above mentioned subsidence explains the threat of submergence over large areas of the Rhône deltaic plain with an ASLR. Among the most threatened areas are those of Faraman, west of the Grand Rhône mouth, and the Petite Camargue, west of the Petit Rhône mouth. Recession rates of more than 10m/year were observed before the building of defensive structures of sea wall and groyne types. As a counterpart of such an erosion, the Beauduc and Espiguette spits are rapidly prograding (SUANEZ and SABATIER, 1999).

From a socio-economic point of view, the Camargue is not densely populated (8,000 inhabitants). To the east, sheltered by La Gracieuse sandy spit, Fos serves as an harbour and an industrial extension of Marseille. Part of the area corresponds to a nature reserve (85,000 ha) of particular importance for migratory birds. There is only one small urban center, Les Saintes-Maries-de-la-Mer, with 2,000 permanent inhabitants, which is already threatened by the sea. Nowadays, declining farming activities mainly based on rice production and extensive traditional cattle breeding characterise the Rhône deltaic plain. Tourism and salt production represent two other economic activities in the deltaic plain. There are privately-owned salt pans, over about 22,000 ha in the Faraman and the Aigues-Mortes areas. However, salt production could be discontinued in the near future since the salt pans are threatened by submergence. Hence, the activity is less and less economically competitive, particularly because of the cost of sea defence, which is the responsability of the land owner. In spite of a vast array of defensive structures, the salt pans are still at risk. The most serious recent flooding occurred in December 1997, during a storm estimated to occur on average once every twenty years, and characterised by a surge of 1.6 m and waves reaching a maximum height of 10 m. In places, dikes were overtopped and destroyed (Figure 3), and the salt pans were flooded.

The present evolutionary trend of the Rhône delta allows a predictive view of the impacts of the ASLR projected for the 21st century (L'HOMER, 1992; SUANEZ and PROVANSAL, 1998). Stretches of shore which are already affected by erosion and submergence will show a stronger regressive trend. La Gracieuse spit may thin and become detached, so reducing its protective role for the docks and industrial facilities of the Fos harbour. The same fate is in store for the Beauduc and Espiguette spits. If salt production is not discontinued, the situation will become critical, especially in the Faraman area. Here coastal defences would have to be firmly strengthened to resist high water levels since ASLR will induce a decrease of the return period of water levels associated with storm surges, even without considering any possible variation in storminess. Les Saintes-Maries-de-la-Mer will continue to protrude into the sea since it is more than likely that relocation of the buildings threatened by marine erosion will not be considered by the inhabitants who scoff at the notion of

Figure 3. Overtopping of a sea wall in Petite Camargue during the storm surge of December 1997.

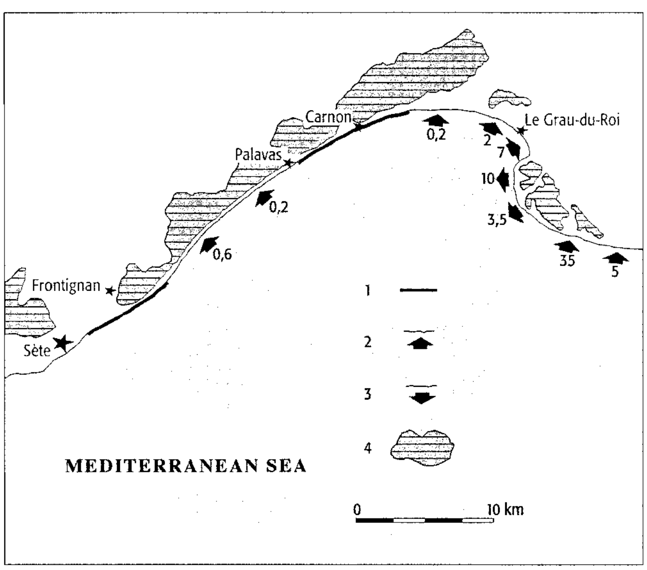

Figure 4. Coastal barriers and lagoons on the Languedoc coast, from Rueda (1985). 1—Shoreline protected by defensive structures. 2—Shoreline erosion (in m/yr). 3—Shoreline progradation (in m/yr). 4—Lagoons.

planned retreat. This implies the construction of stronger defensive structures. Lagoons will tend to widen, to deepen, and to become more salty as a result of coastal barrier breaching, permanent sea water inundation, and rising water tables (Petit-Maire and Marchand, 1991). As a result, lagoonal islands which provide nesting and breeding sites for birds, especially pink flamingoes, may disappear. As far as agriculture in the deltaic plain is concerned, more fresh-water taken from the two Rhône branches will be needed to compensate salt-water intrusion, and some adaptation of the large irrigation and drainage network will have to be made.

Sand Barriers and Lagoons of the Languedoc Coast

In southeastern France, coastal barriers isolating lagoons on the Languedoc coast are already migrating landward and thinning because of the present sea-level rise and a deficit in sediment supply (Figure 4). Barrier rollover is related to overwash processes which are particularly effective during storm surges of high magnitude. This combination occurred in 1982 and 1997 when onshore migration of several metres was observed. Sand was stripped from the beach and passed over the dune crest onto the back slope. Such an evolution will continue and accelerate with the projected ASLR. Inlets will enlarge and new ones will appear. Lagoons will tend to widen and deepen since the sediment supply of continental origin is rather limited. There will be accompanying ecological changes on the lagoonal shores, which are likely to affect

Figure 5. Near Arcachon (Aquitaine coast), blockhouses of the Atlantic Wall, dating back to World War II, originally built up on the foredune and nowadays toppled over the beach.

fields under cultivation, especially vineyards, because saline environments will extend farther inland (Corre, 1992). Conversely, increased marine influence upon the lagoons will favour aquaculture which is already an important economic activity. Tourism, another important activity, faces significant problems as ASLR threatens associated buildings, facilities, and equipments. Since the 1960's resorts and pleasure harbours have developed on the barriers which are now extensively urbanised. Hard engineering structures have been used to control erosion and to hold the coastline. If such a policy is continued, the beaches will disappear. Beaches may be maintained by artificial nourishment as sea-level rises, but the cost will increase with time. Urban areas, which also developed on wetlands around the lagoons, will be at risk of flooding as the water table rises. Thus the Languedoc coast is at risk in a situation of ASLR.

Beaches of the Aquitaine Coast

The most impressive case of erosion affecting sandy shores in the country is found on the straight 230 km long mesotidal coast of Aquitaine, in southwestern France. This is backed by extensive dune fields which were artificially afforested during the 19th century. Erosion started at the beginning of the Christian era and, in the northern part, the shore retreat since then amounts to more than 10 km (Figure 5). In places, the average annual retreat rate has been as high as 1.5 m during the last hundred years (Figure 6). Such a rapid recession is primarily explained by a natural factor: a negative sediment balance. There are neither river mouths nor eroding cliffs along the entire coast. Only fine suspended material, unable to nourish the beaches, is expelled from the Gironde estuary. Erosion started when the sand brought to the nearby sea shore by the postglacial transgression was depleted (Paskoff, 2000a). The Bruun rule, which appears to be valid only when beaches have attained an equilibrium profile, cannot be used here to estimate the shoreline retreat and its position at the end of the 21st century because the system has been out of balance for a long time and the southward longshore drifting of sediments is active, being more than 500,000 m^3/yr. However, an accelerated erosion can be predicted since, with a higher sea level, deeper water will decrease wave refraction. So, waves will get closer to the shore before dissipating their energy by breaking and act further up on the beach profile.

Salt Marshes and Reclaimed Areas on the Atlantic Coast

A salt marsh could respond to a rising sea-level in three ways: drowning, retreat, or expansion by vertical and lateral accretion if sedimentation rate and plant productivity can increase sufficiently, not only to compensate but even exceed the effects of sea level rise. On the Atlantic and the Channel coasts of France, where tidal marshes are widespread, progradation of the coastline is still in progress in spite of a

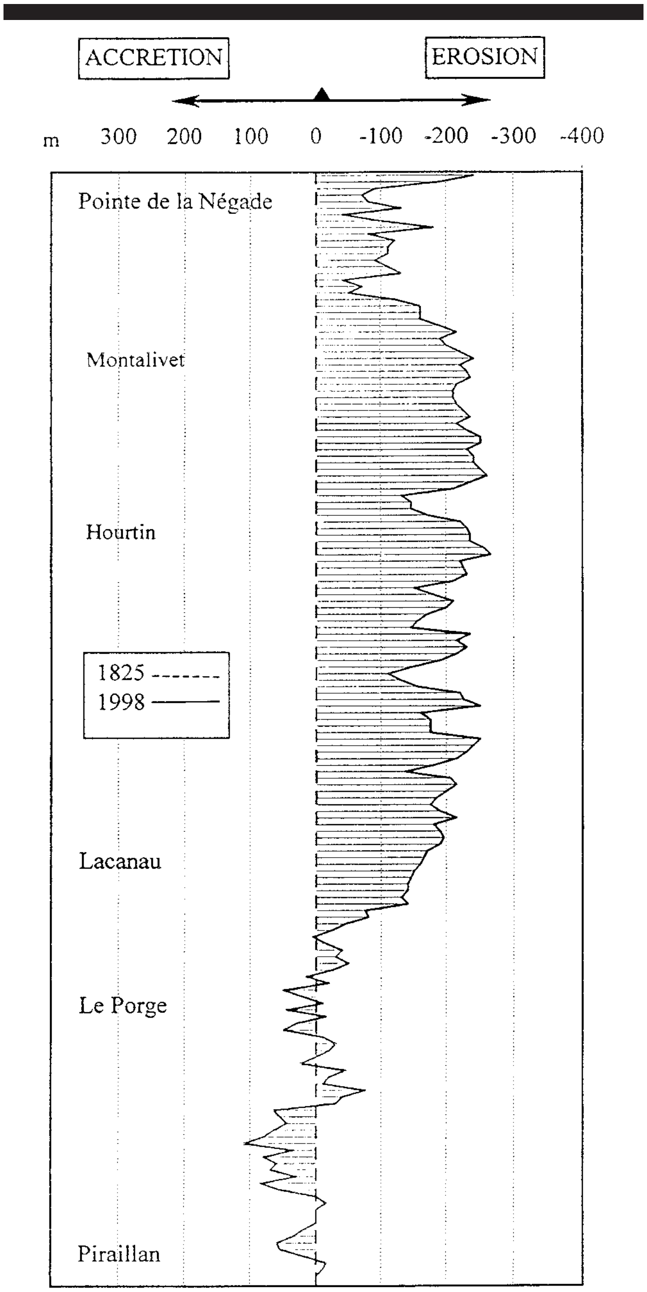

Figure 6. Shoreline evolution along the Médoc coast, Aquitaine, between 1825 and 1998, according to Clus-Auby (2003).

rising sea-level. Along the Charente coast, opposite Oleron island, the marsh front gained 1,100 to 1,700 m from 1700 to 1850 and 200 to 300 m from 1850 to 1974. Between La Rochelle and the mouth of the Charente River, the progradation from 1850 to 1974 reached nearly 600 m on a shoreline 1,700 m long (Regrain, 1980). In Picardy, the tidal flats of the Baie of Somme have been affected by active mud deposition in recent times. Consequently, they have been quickly converted into salt marshes, which is clearly shown by accurate diachronic comparisons between air photographs (Figure 7). Marshes progradation has reached 5.5 ha/year from 1939 to 1947, 2.5 ha/yr from 1947 to 1971, 13.5 ha/yr from 1971 to 1975 (Demarco *et al.* 1979). As a result, water depths are rapidly diminishing in the Baie de Somme. Farther north, on the southern side of the Authie bay, salt marshes have also advanced and gained 300 to 700 m depending on local variations between 1878 to 1955 (Verger, 1968). However, the most impressive example of progradation occurs in the Mont-Saint-Michel bay where the vertical sedimentation reaching a rate of about 2 cm/yr is threatening the insularity of the site and, consequently, the scenic beauty of the famous medieval abbey (Figure 8). Between 1984 and 1994, in spite of the removal of a submerged protective dyke, salt marshes gained ground over more than 150 ha (Bouchard *et al.*, 1995).

However, on the Atlantic and the Channel coasts of France, large areas (about 135 000 ha) of salt marshes and even tidal flats have been reclaimed since the Middle Ages. They have mainly been converted into polders devoted to crops for cattle breeding. These areas are located below the high tide levels, and are protected by defensive walls that have been designed in relation to the present sea-level. At spring high tide, dikes are often directly in contact with sea water, as no marsh buffer zone is left. As a result, these reclaimed areas appear to be vulnerable to the projected ASLR. Even today, they are prone to flooding during storm surge episodes. In December 27 and 28, 1999, the Gironde estuary and the Charente coast were affected, in spite of a rather moderate tide coefficient (77 on a scale of 120), by a 1.30 m surge on the open coast and up to a 2.20 m inside the estuary. 12,000 ha of cultivated land and oyster basins were temporarily submerged. Even more serious was the partial flooding of the Blaye nuclear plant, located on a reclaimed area situated on the northern bank of the Gironde estuary. Fortunately, the reactors were not damaged.

The Loire Estuary

In the Loire estuary, a numerical model was used to evaluate the displacement of the salinity front corresponding to 0.5 g of salt per litre, assuming a 60 cm sea-level rise and a river discharge of 150 m^3/s (Dribault and Pelletier, 1996). The result shows a salt water intrusion of only 1 km upstream. This is a small displacement if compared with the 10 km penetration of salt water which has occurred during the last 20 years and which is explained by the artificial deepening of the estuary aimed to improve navigation conditions.

Assuming also a 60 cm ASLR and a river discharge of 150 m^3/s, the tidal turbidy maximum which corresponds to a suspended sediment concentration and also to a pollutant concentration would penetrate about 2 km further upstream (Le Hir and Bassoullet, 1996). This is also a relatively small displacement since, with the present sea-level position, an increase in the river discharge fom 150 to 200 m^3/s would produce a 4 km downstream displacement.

As far as the Loire estuary is concerned, it can be estimated that potential impacts of ASLR will not be significant if compared with those already induced by anthropogenic modifi-

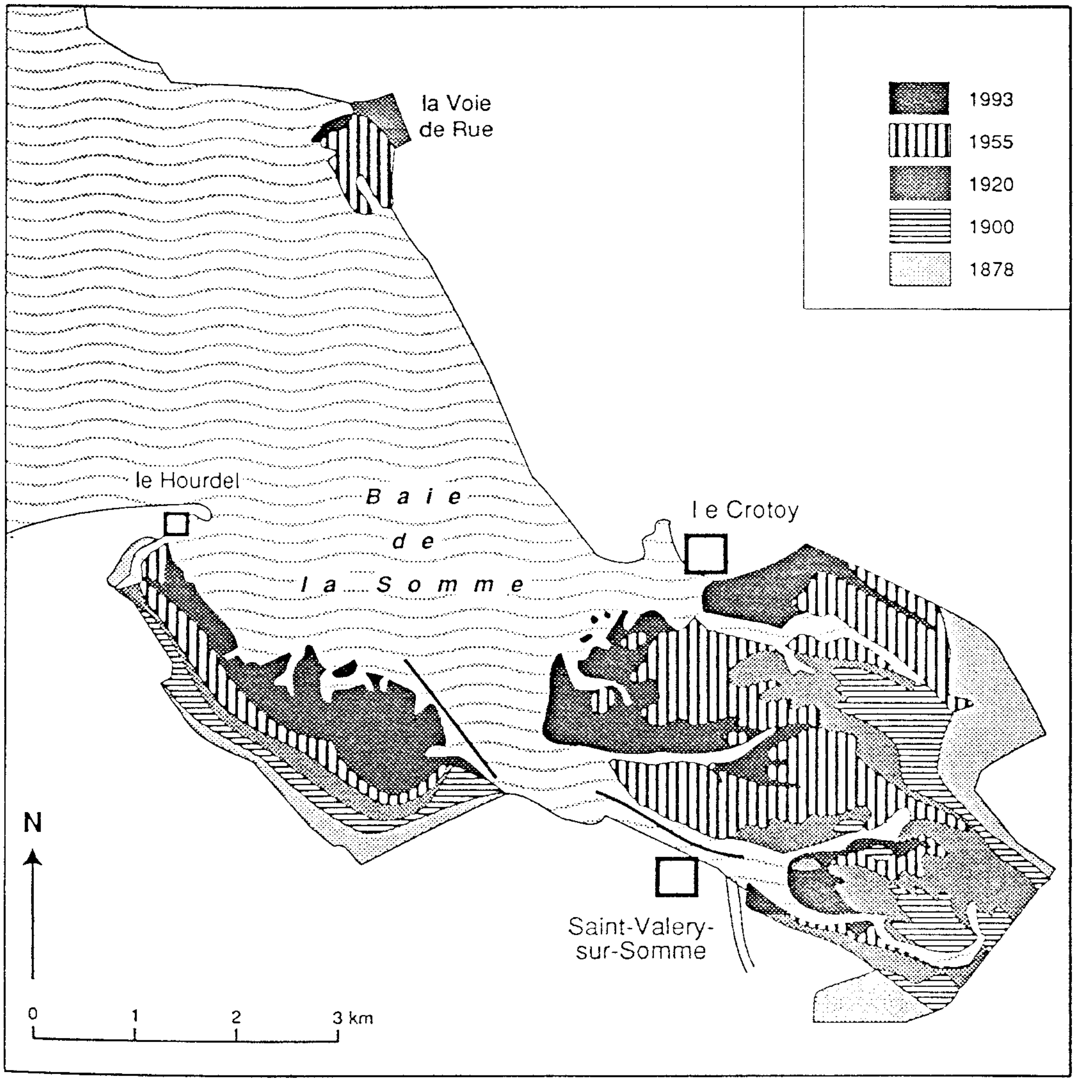

Figure 7. Salt marshes progradation, in Baie de Somme, Picardy, from 1878 to 1993, according to Latteux (1998).

cations of the water body or expected from forthcoming climatic variations in the drainage area of the river.

Chalk Cliffs of Normandy

The Normandy coast, in the so-called Pays de Caux, is characterised by active chalk cliffs, several tens of meters high, whose rate of retreat is on average about 0.30 m/yr, but with substantial variations (COSTA, 1997). It is apparently logical to think that erosion will increase in a situation of ASLR. However, since the wave mechanical attack appears not to be the main process of cliff evolution, enhanced erosion may not occur. Notches are not conspicuous at the base of the cliffs. A macrotidal regime as well as a wide wave-cut platform limit the effectiveness of wave action. Rock falls are mainly the product of subaerial processes, essentially rainwater infiltration through the highly cracked and fractured chalk, and subsequent freezing in cold winters. Talus cones thus formed are then gradually reduced by marine corrosion and removed by wave action. With the increased air temperature expected from the climatic change, frost action is likely to be less active and, consequently, cliff retreat could even slow down in spite of a higher sea level. Large uncertainties remain as far as future chalk cliff recession is concerned, and reliable estimates are hampered by the complexity of several factors interacting over variable spatial and temporal scales.

MEASURES FOR TACKLING SEA-LEVEL RISE

It is fortunate that in France, for natural (sea shore hazards and, in the case of the Mediterranean coast, unhealthy conditions related to the malaria problem) and historical (insecurity connected with piracy in the Mediterranean) reasons, large urban centers developed sufficiently far back from the sea in the three areas which appear to be most vulnerable to the expected ASLR, *i.e.* the deltaic plain of the Rhône Riv-

Figure 8. Mont-Saint-Michel Bay; tidal flats and tidal creeks in the foreground; prograding salt marshes and reclaimed areas in the distance.

er, the lagoonal Languedoc coast, and the Aquitaine sandy shoreline. In fact, the tourist infrastructures of the Languedoc region, owing to the narrowness and the low altitude of the sandy barriers on which they were emplaced *ex nihilo* from the 1960's, represent the most important human settlements at stake.

Protection

Different strategies may be proposed to cope with ASLR. Holding the coastline is one option. Hard defensive structures are already used to protect the small town of Les Saintes-Maries-de-la-Mer, in the Rhône delta, and the resorts of the Languedoc coast. Engineering methods are well established, effective, and generally welcome by local authorities and owners whose properties are threatened by the sea. They will require continuous maintenance and adaptation (MIOSSEC, 1998), which means more and more expenses (cost of a sea wall: between 7,000 and 10,000 FRF/m; cost of a detached breakwater: 50,000 FRF/m). They also have severe environmental impacts: on the Languedoc coast, many "protected" beaches have lost most of their sediments and are reduced to narrow ribbons of sand because of the scour effects on sea walls or erosive actions of rip currents generated by groynes. Retreat is not considered here because the value of buildings, roads, and tourist facilities exceed the cost of protecting the existing coastline.

In such a case, the only solution which is less environmentally damaging and more aesthetically pleasing is artificial beach nourishment. Unlike several countries of Europe which have introduced beach nourishment as a means of contributing to the protection of their coastlines from erosion, only a few large schemes of replenishment have been carried out in France up to now. The traditional heavy reliance on hard structural solutions by French engineers largely explain the reluctance to accept this method widely. More than the cost itself entailed by the initial operation, which is estimated to be about 11,500 FRF/m when the offshore borrow source is easily accessible, the question under discussion is the recurrent costs of periodic renourishment operations, required due to the limited durability of replenished beaches (MIOSSEC, 1998). Obviously, in view of ASLR, more extensive nourishment schemes are expected to take place in the densely urbanised beaches of the high-value French Riviera, located on the south-eastern part of the Mediterranean coast (ANTHONY, 1997). These narrow bays and pocket beaches correspond to separate compartments locked by rocky headlands. Sufficiently supplied in the past by sands and pebbles from short and steep coastal rivers, sediment budgets have been altered by mismanagement practices, mainly aggregate extractions and seashore urbanisation (ANTHONY and COHEN, 1995). As a result, beach erosion started, but at a rather slow rate which is likely to increase moderately in the expected situation of ASLR.

Maintaining the coastline where salt marshes have been reclaimed implies higher and wider sea defences. Immediately after the above mentioned flooding of the Blaye nuclear plant, located in a reclaimed area bordering the Gironde estuary, the protective sea walls were raised from 5.20 m to 6.20 above mean sea level. On the Channel and North sea coasts of France, between the 11th and the 13th century, frequent and extended marine floodings occurred. As a result, dykes were systematically raised to protect low lying reclaimed areas (L'HOMER, written communication). In the Rochefort area, located in the Charente region, reclaimed marshes devoted mainly to fodder cultivation and oyster farming cover about 30,000 ha. They are presently vulnerable to flooding. Extensive floodings provoked by storm surges occurred in 1971, 1982, 1985, and particularly in 1999. A 0.5 m of ASLR will considerably increase the frequency of this phenomenon. It is estimated that a protective strategy, which implies raising dykes and building new pumping stations, would approximately cost FFR 700 millions (AUGER, 1992).

Retreat

Retreat is an other response to ASLR which could be used in the less populated areas of the Rhône delta. Taking into account the large space which is still available, here a realignment of the salt pans is a better solution to the risk of inundation, both from an economical and an environmental point of view, than hard stabilisation. After the 1997 catastrophic flooding, the owner was advised to give up some land for more effective protection of the rest of the salt pans. This advice was ignored and a reinforced defensive structure occupies the place where the main breach occurred. At present, the salt pan owner is trying to get financial assistance at a state level for the protection of his land against the sea, with the main argument being the number of jobs at risk. This case is a good example of current coastal practices and conflicts between nature conservation and human activities which are expected to be exacerbated by ASLR in a vulnerable deltaic area whose resilience has been weakened by anthropogenic interference.

A policy of retreat is even more justified where extended natural areas still exist, without any human settlement or economic activity, as it is the case in parts of the Petite Camargue (PASKOFF, 1998). But coastal communities are generally unhappy with the notion of retreat. Nevertheless, the *Conservatoire du littoral,* a national agency created in 1975, whose vocation is to acquire natural areas on the French coastline to ensure their permanent protection (LEGRAIN, 2000), has already allowed polders to be flooded by the sea again, one in Brittany (100 ha in the Aber de Crozon), the other in Normandy (30 ha in the Baie des Veys). This return of the sea allows formerly reclaimed areas to experience tidal processes, the goal being to restore tidal marshes (VERGER and GOELDNER, 1995). As a general rule, the *Conservatoire du littoral* follows a non-resistance policy to sea erosion and inundation, refusing to undertake heavy defence works in accordance with the goal of conservation of natural sites and ecological equilibrium mentioned in the law which founded the agency (PASKOFF, 1995). The Conservatoire's philosophy concerning environmental management of its land (about 70,000 ha representing about 10% of the coastline length) in a situation of ASLR can be summarized in a sentence: one cannot sustain the fight against the force of nature.

As far as retreat is concerned, it is important to report also that everywhere in the country, relocation, which implies moving buildings back from shores prone to rapid erosion or extensive flooding, has been made possible since 1995, owing to the implementation of a law for the prevention of natural hazards under which owners may be expropriated and compensated, when dwellers are at risk (GRASZK and TOULEMONT, 1996). This is currently the case for several houses built up on the top of a rapidly receeding chalk cliff at Criel-sur-Mer, a resort located on the Normandy coast, which will have to be shortly evacuated and is doomed to be destroyed by erosion (PASKOFF, 2001a).

Anticipatory Actions

Anticipatory actions may also be taken in France according to the Shore Act (*Loi Littoral*) promulgated in January 1986 and basically devoted to the management, development, and preservation of coastal areas (BECET, 1999). Outside areas already urbanised, new roads are no longer permitted along the shoreline and building of houses is strictly prohibited in a strip, at least 100 m wide, landward from the upper limit of the coastal public property in which is included the intertidal zone. For the Aquitaine coast where coastal erosion is rapid and where development is still spatially limited, there is a proposal to extend to 500 m the width of the *non aedificandi* strip. If adopted, this measure, based on the concept of sacrificial areas, will let the sandy shoreline respond naturally to changing conditions related to the forthcoming sea level rise. When sea level is rising, letting nature take its course is undoubtedly the best solution wherever such an option is acceptable.

CONCLUSION

There was not a large debate about coastal issues after the recent huge storms which hit the Mediterranean coast in 1997 and the Atlantic coast in 1999, and taking proactive measures is not yet considered at a national scale. However, concern is growing in France about climate change and the associated ASLR issue. Even without an in-depth national vulnerability assessment, the available studies are sufficient to clearly identify the coastal zones which are most at risk. Contrary to ROTMANS *et al*. (1994) who considered France to be one the most vulnerable countries to ASLR in the European Union, threatened areas are fortunately restricted and, except locally, not heavily developed. ASLR is not considered as such in the long term policy strategies. However, it appears that the existing laws and stringent regulations which concern coastal management provide a good basis to address potential impacts which may affect populations and economic activities in the forthcoming decades. One remaining task, and not the least, is to convince policy-makers, local authorities, and the public in general to change their thinking about coastal issues, and to use the available data and legal tools wisely in shoreline management practices.

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□ RESUME □

On se préoccupe en France du changement climatique et de l'élévation du niveau de la mer qui lui est associée. On ne dispose pas encore d'un rapport détaillé évaluant la vulnérabilité du pays à ces événements, mais il existe assez d'informations pour identifier les espaces côtiers qui peuvent en être affectés. Sur la côte méditerranéenne, le secteur le plus vulnérable correspond à la plaine deltaïque du Rhône, essentiellement à cause d'actions humaines (diminution de la fourniture en sédiments liée à la construction de barrages; endiguement du fleuve). Erosion de la ligne de rivage, submersion des terres basses, salinisation des eaux souterraines sont les phénomènes attendus d'une accélération de l'élévation du niveau de la mer. Les cordons littoraux du Languedoc vont migrer plus rapidement vers la terre, mettant ainsi en danger de nombreuses infrastructures touristiques. Sur la côte aquitaine, on peut prévoir une érosion accrue sur les plages sableuses. Le sort des

marais maritimes de la côte atlantique ne paraît pas en jeu en raison de la sédimentation active dont ils sont le siège, mais les polders gagnés à leurs dépens seront menacés d'inondation. Une avancée modérée du coin salé est prévue dans l'estuaire de la Loire. Il est possible que le recul des falaises de craie de Normandie ne soit pas accéléré. Les lois et les règlements en vigueur qui concernent l'aménagement des côtes semblent suffisants pour faire face aux impacts potentiels, sur les populations riveraines et les activités économiques, attendus d'une accélération de l'élévation du niveau de la mer au cours des prochaines décennies.