RÉMIRE-MONTJOLY
ILLE DE CAYENNE
FRENCH GUYANA
(FRANCE)

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1. GENERAL DESCRIPTION OF THE AREA

Because of its geographical position, Guiana is under the influence of the inter-tropical convergence zone (ICZ), which moves its latitude depending on the season of the year between the tropic of Cancer and the equator. It is not affected by cyclone phenomena, but it can suffer heavy swell caused by cyclone trajectories passing 1000km from the coasts of the department. Wind speeds on the Ile-de-Cayenne remain rather moderate: an annual average of less than 4m/s at Rochambeau (Matoury) reaching 20m/s, with a maximum instantaneous wind speed of 23m/s in February 1977.

The coastal fringe of the study sector, as well as the whole Guiana coast, is an area with a very active sedimentary dynamic, marked by the alternation of rapid phases of sedimentation and erosion linked to a drift towards the northwest, under the influence of the Guianas current, of a trail of silt coming from the Amazon arranged in the form of banks tens of kilometres long.

1.1 Physical processes

The speed of movement of the banks of silt is of the order of between one and two kilometres per year. They are separated from one another by inter-bank spaces through which an intensive phase of coastal erosion is produced, manifested in the destruction of muddy areas of foreshore colonised by mangroves and then a direct attack by the sea on the strips of sandy beach situated behind them. The result is a coast with a changing appearance, periodically subject to progradation and natural regression to which man is limited to adapting himself. These advances and retreats amount to several hundred metres.

1.1.1. Coastal type

The coast of the Ile-de-Cayenne, the only rocky outcrop of an ancient shelf along 2000km between the Amazon and Orinoco deltas, varies in nature and morphology. Its exposure to the currents, of which the main one is the Guiana current, to swell and to the tides, as well as the periodic movement of silt banks originating from the Amazon, make this coast one of unceasing evolution, which is sometimes very rapid.

On the Rémire coast, behind the banks of silt, (away from the rocky stretches of coast) a set of sandy strips is found marking the different variations in sea level throughout the Holocene period. The current strip (the one nearest to the sea) is witness to the most recent incursion by the sea and represents the furthest advance of the sea in the current conditions of sedimentation and sea level. This is the limit of the spring tide High Water Mark (HWM) which has been defined as being the “coastline” in the PPR project Coastal Risks on the Ile-de-Cayenne (report BRGM 2001 n° RP-50475-FR).

The coast is made up of a succession of low sandy stretches (when the mud and the mangroves are absent) and rocky cliffs (insular shelf, magma rocks…). In the estuaries, the rivers are always edged by mangroves.

1.1.2 Geology and morphology

Sandy coasts

The sandy coasts lie between rocky outcrops from St-François Point to the southern edge of the Mahury. They are all sensitive to sea erosion, but they develop differently depending on their position, their size and their morphology:

- The largest beaches (> 1km), Montabo Cove (1.6km), Bourda-Montjoly Cove (3.5km), Rémire Cove – Gosselin beach (about 3km), are made up of a succession of strips of sand and depressions that lie a long the coast, becoming older as they go further away from the current shoreline and corresponding to ancient shorelines (sometimes as far as 300m from the current shore). Four of these structures can be seen.

- The small beaches (< 1km: Mahury coast) have a simpler structure with smaller volumes sometimes resting directly on the rock platform. These beaches are very sensitive to erosion, as they do not have a large stock of material. In some cases, there is a steep bank behind the beach and this is also susceptible to erosion.

Rocky coasts

The rocky coasts correspond to the relief of the platform (age paleoproterozoic, -2200 to –2150 million years). From west to east, they are the coastal part of Cayenne, the Montabo, Montjoyeux and Bourda hills (all formed from high grade metamorphic rock), then Montravel and the large Mahury massif (dioritic magma rock). The relief of these hard rocks is varied, with rounded or slightly raised platform shapes (less than 10 metres), while some hills show steep escarpments in cliff areas.

These rocky coasts, unique on the South American coast between the Amazon and the Orinoco, form the anchorage points to which the low, sandy coasts of the Ile-de-Cayenne are attached.

The coasts with blocks and cones of fallen rock

A peculiarity of certain parts of the Montravel coast and above all Mahury, is that they are made up of large rounded blocks, piled one on top of the other to depths that are apparently large but unknown. The exact origin of these accumulations has not been precisely established, although their morphology on the ground (eastern and southern slopes of Mont Mahury) evokes vast cones of rubble put in place during periods of meteoric climatic disturbance and ancient erosion of the reliefs involved, probably during the Quaternary glacial periods. This type of coast can in certain cases be destabilised by the action of swell and currents, which can loosen some of the blocks, especially those smaller than $1m^3$ in size.

The swampy coasts

The sections of the coastal strip of the Ile-de-Cayenne that are currently made up of low, swampy coast are almost entirely situated in estuary areas and, because of this, under a particular, regular dynamic, less aggressive than the marine dynamic (flood and ebb tide currents of up to 1.25m/s). Locally, the presence of small strips of sand of continental origin can contribute towards overall stabilisation. It remains like this unless:

- Certain parts of the marshy coasts of estuaries may be exposed to the effects of swell, notably between the Crique Fouillée canal and the port of Larivot on the Cayenne River and between Mahury Point and Dégrad des Cannes on the Mahury.
- During the last few years a net regression of the mangroves has been observed in these very sectors, accentuated by the various developments that has been carried out on and around the shore.
- The mangrove on the left bank of the Mahury downstream of the port of Dégrad des Cannes has been almost entirely destroyed, giving way to a sandy shore.

Fig. 1: View of Anse de Rémire, from Mahury Mount.

1.1.3 Physical processes

The morphology and nature of the large strips behind the main beaches make them sensitive to coastal phenomena. In natural conditions, these areas can be considered to be stabilised beyond the second strip, but they are currently considerably modified by development (deforestation, roads, construction, concreting, drainage, watercourses) and therefore made fragile by the occupation and activity of humans.

The dynamic of the current sandy beach formations is not well known. The finer sand is the more mobile it is. The detailed granulometry of these formations is not known (fine and medium dominant). While it is probable that contributions from the land are small (weak local river dynamic) and moreover reduced by urbanisation and recent developments, it can be stated that, in the short term, at least on the longer beaches (> 1km) the overall stock of material is maintained and there is currently a transfer of sediment (observed in 2000) from the western part (under erosion) to the eastern part (under expansion) of these beaches. In the two cases in the diagram, the sand lies on clay, which can in its turn be exposed and eroded. This is the case with the Bourda sector on Montjoly beach.

Transport agents

The local factors in the coastal dynamic are particularly complex and currently remain very little studied and little known. They are linked to overall regional hydrodynamics and vary depending on the phases of installation, development, then destruction and disappearance of the bank of silt until its eventual absence before the arrival of the next bank.

These hydrodynamic agents are:

- **The currents**, of which the greatest is the Guiana current, an extension of the north Brazilian current, with a SSE-NNW direction, an intensity of 1 to 5 knots, a greater intensity during the first quarter of each year, and which partially turns back on itself along Guiana to feed the north equatorial counter-current during the second half of the year. This coastal flow is largely fed by waters of Amazonian origin. There is no precise diagram of circulation along the continental shelf, but alternating currents appear near the coast, opposite to the surface currents, as well as offshore currents during the ebb tide.

- **The impact of the local rivers** (Mahury and Cayenne River), especially concerning the morphology of estuaries, where river and sea waves meet. During spring tides, deposited elements go into suspension and then are deposited during the neap tide period.

- **The swell**, whose regime is little studied, going from northeast to east, with an amplitude of between 2 and 2.5m on depths of 10m and of 0.5 and 0.7m near the shore. North/northeast swells become dominant from December to February, particularly in January.

- **The tide,** of twice daily type, with a tidal range of 2.90m (spring tide) to 0.80m (neap tide), which generates a transversal flow with respect to the continental shelf with maximum intensity near the coasts or around river mouths and estuaries, where it plays an important role in configuration, with reversals of flow able to generate a 10m difference in the depth of silt at the meeting point between sea and river water. At the tide gauge at Dégrad des Cannes, the level can reach 3.50 to 3.60m due to the large spring tides.

Sediment transport

The migration towards the northwest of the banks of silt coming from the Amazon, in the heart of the great atmospheric and oceanic circulation systems of the tropical Atlantic, is a regional phenomenon described, on the scale of the Guiana coast, in various studies (Gibbs, 1976, Eisma 1971) and synthesised in a review of knowledge of the coastal area of French Guiana (Frouin, with the co-operation of Pujos and Watremez, 1997).

It concerns three spatial scales, with the overall movement of material (macrosystem), the movement of the banks and inter-banks (mesosystem) and the movements of the inter-tidal coastal mud towards the open sea (Pujos et al, 1989). The banks form oblique extensions of the shore and can reach tens of kilometres in size and several metres in thickness. Their movement is irregular (a few hundred metres to 1-2km per year) and more active from January to May than from June to December according to the intensity of the Guiana current.

The processes of silting and de-silting are governed by internal factors (mineralogical and physico-chemical properties of the sediments) and external factors (tides, swell, currents, salinity), changing over periods of several years (more than ten – 18-30 years according to various authors), but irregular and unstable. This is one of the main causes of the phases of erosion and sedimentation (also changing over several years) and therefore of the development of the coast of the Ile-de-Cayenne.

The transport of sandy sediment has not been specifically studied in the case of the Ile-de-Cayenne. It is certain that there is contribution from the River Mahury because the sand there is exploited by dredging upstream of Dégrad des Cannes and the stock seems to be partly renewed. In the same way, dredging the commercial port access channel moves a quantity of sandy silt that is hardly negligible. This contribution could be the origin of the stock of sand that can be seen on the coast south and east of Mahury, from where some may be moved by the currents towards Rémire Cove. The east-west movement between the coves that follow each rocky promontory has not been quantified, but seems to be weak or non-existent, at least for large particles.

1.2 Socio-economic aspects

1.2.1 Population rate

The study sector forms part of what is locally called the Ile-de-Cayenne, an area bordered in the east and the west by two estuaries and in the south by a canal (Crique Fouillée Canal).
The Ile-de-Cayenne, made up of the three communities of Cayenne, Rémire-Montjoly and Matoury, forms by far the main economic and human pole of attraction in the département of French Guiana. At the last census in 1999, Cayenne had 50,594 inhabitants, Rémire-Montjoly 15,555 inhabitants and Matoury 18,032 inhabitants. Together this represents 54% of the population of the *département* (157,274 inhabitants in 1999).

The annual rate of population growth in the L'Ile-de-Cayenne was 3.4% between the 1990 and 1999 censuses. Moreover, l'Ile-de-Cayenne contains 69% of the establishments with more than 50 employees in the *département*.

Table 1: Development of the population of L'Ile-de-Cayenne.

Community	**1999**	**1990**	**Annual rate of growth in the period 1990-99**
Cayenne	*50 594*	*41 067*	*+2,4%*
Matoury	*18 032*	*10 152*	*+6,6%*
Rémire-Montjoly	***15 555***	***11 701***	***+3,2%***
Ile-de-Cayenne (total)	84 181	62 920	+3,4 %

1.2.2 Major functions of the coastal area

The coast corresponding to this sector is essentially devoted to recreational and tourist uses. From the time when the beaches are "de-silted" (inter-bank period) and the mangrove has been destroyed, they show the required characteristics (sand, swell) for swimming or sporting uses (windsurfing, dinghies…). Around the Mahury mountain there are some precariously built houses on some small beaches occupied by Brazilian families living off traditional fishing.

Above the beaches, the area behind them is strongly urbanised, with individual houses or estates. In the south (Rémire cove), there are facilities intended for the public situated above the beaches (restaurants) or on the beaches themselves (café-restaurants, sailing centre).

The estuaries, notably and above all that of the River Mahury in the southeast, have an important economic function, including the presence of fishing ports (River Cayenne) or commercial ports (River Mahury) sheltered at the back of the estuary. The navigability of the estuaries is a permanent concern for the maritime and port authorities. The sedimentary dynamic (silt, the development of silt banks, the silting of access channels to the ports), leads to maintenance of particular areas of the bottom in the channels and therefore to frequent dredging. Permanent access to the ports – the only links for supplies and exports - must be ensured.

2. PROBLEMS OF EROSION

The large beaches in the eastern part of L'Ile-de-Cayenne are all of considerable length – several kilometres – and they are all generally oriented towards the northeast sector, with a more or less pronounced concave shape. Bourda-Montjoly beach shows concave-convex-concave morphology, with the centre of the beach advanced towards the sea. The development of the coastline may be characterised by two main phenomena:

- Development translated into a retreat, sometimes very fast, of the sandy limit of the supra-tidal zone, with destruction and loss of the first coastal strip and/or a lowering of the level of the beaches by sand loss or transfer. This is the case with Bourda beach (where several cadastral sections have disappeared) and the northwest part of Rémire cove.

- An oscillation in the direction of sedimentary transport to the beaches, which leads both to an advance in the coastline at the eastern ends of beaches (retreat at the western end) and to a reverse development.

Montjoly beach – Anse de Bourda

Bourda cove and Montjoly beach were subject to considerable development between 1945 and 1998:

- At the southern end, an advance of 80m between 1945 and 1998.
- In the centre, a maximum retreat of 50m between 1945 and 1968; a retreat of about forty metres between 1968 and 1998, relatively stable around 1987-92-98.
- In the north (on almost a third of the length of the beach), extreme alternative developments: +150 m (1946-1968), -120 m (1968-1987), +60 m (1987-1992) and finally, between 1992 and 1998, a retreat of -100 m.

In 1968, the beach showed a peculiar and original morphology compared to the situations in 1945, 1987, 1992 and 1998: it was practically rectilinear between Montravel and Mont Bourda. In the other years, the northern and southern ends were more or less concave, although the central part was convex. The "oscillation" of the beach (advance of the coastline at one end of the beach and retreat at the other) is noticeable between one cartographical snapshot and another (between 1987 and 1992, then between 1992 and 1998). This phenomenon is characteristic of the sensitivity of the beach, oriented perfectly northeast, to the swell regime attacking it during a sufficiently long period before the date the aerial photographs were taken: a swell regime coming from the E-NE sector will have a tendency to cause sediment transport towards the west, and therefore an advance in the coastline at the western end of the beach; a N-NE regime will have a reverse effect.

One characteristic of this beach is the presence in its central area of a large depression occupied by the wetland of Montjoly Lake, cut from the sea by the current coastal strip. The waters of the lake flow into the sea through an opening in this strip. The stock of sediment naturally available for beach-strip exchanges is limited here.

The putting in place of two large series of rock piles at the northern end of the beach, which were started in 1998 as makeshift developments, has today led to the advance of enormous promontories in the sea. All the same, erosion does not stop happening on the beach, where an ancient strip (the second) is disappearing: with a tide level at 3.30m and a low level of

agitation, the waves hit the 2-3m high mini-cliff, made up of movable silt-clay material and in places lying on clay. This is retreating with serious collapses.

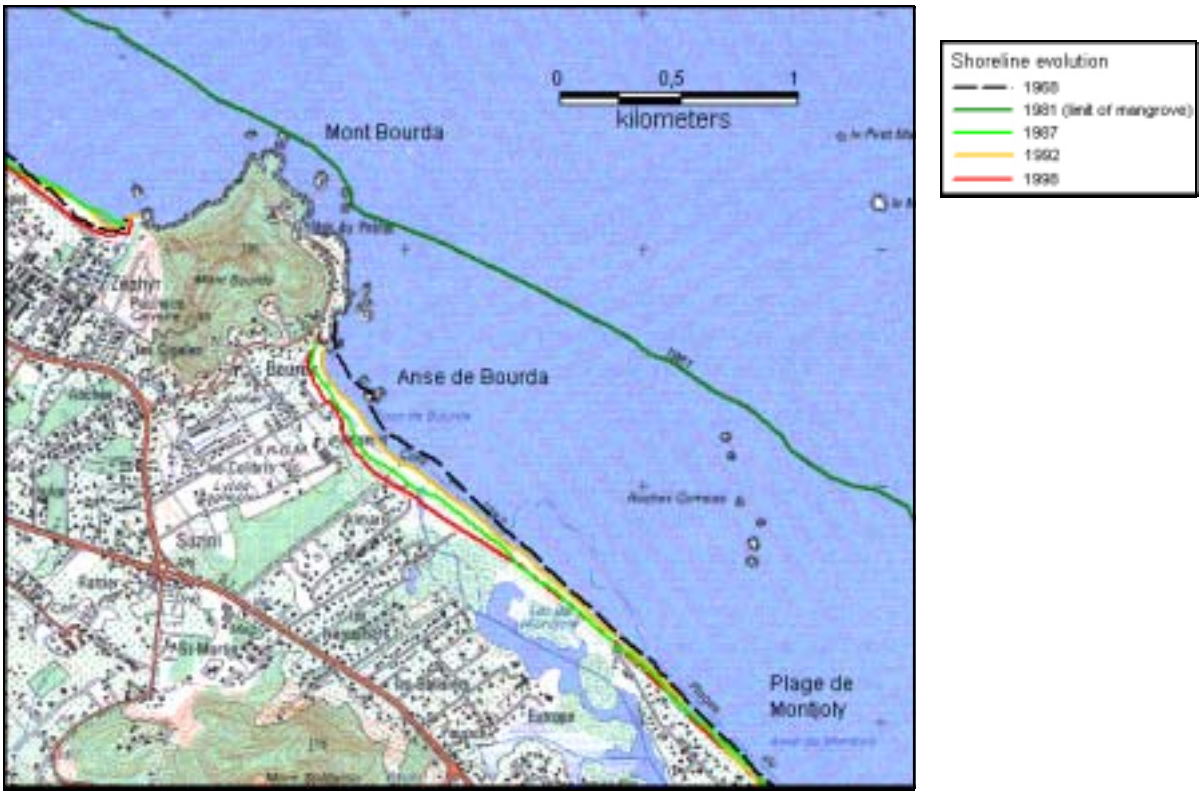

Fig. 2: Shoreline development at Anse de Bourda.

Fig. 3: Erosion of the beach in the north part of Anse de Bourda (June 2001).

Today, it is noticeable that erosion is continuing in “protected” areas. Structures have introduced such a discontinuity in the beach that it is impossible to predict the development of the sector in the short term. It is not known whether the structures themselves can be maintained without repeated contributions of piles of rock. It can be concluded that the artificialisation of the coastline has the effect of concentrating and accentuating erosion in unprotected sectors – the western end of Bourda Cove – where the retreat has been between 30 and 50m since July (date the aerial views were taken).

Gosselin Beach – Anse de Rémire

The cove has shown considerable development between 1945 and 1998:

- In the east, a retreat of 80m between 1987 and 1998.
- In the centre, stable around 1987-92-98, but a retreat of 60m between 1945 (or ‘68, with a very similar situation) and 1987.
- In the west, the beach has been stable overall around 1968-98-92-98 after a considerable advance of about forty metres after 1945.

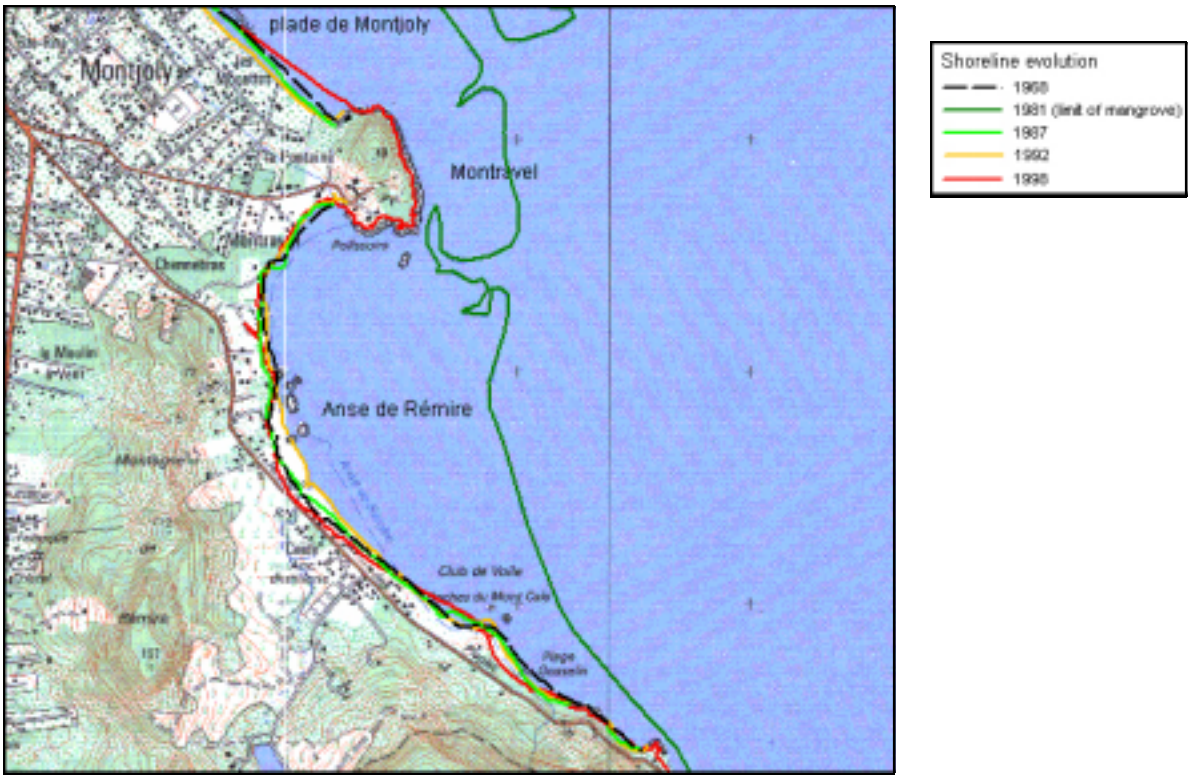

Fig. 4: Shoreline development at Anse de Rémire.

Fig. 5: Erosion of the north part of Anse de Rémire.

3. SOLUTIONS / MEASURES

3.1 Policy options

Considering the general dynamic affecting the coast (movement of silt banks), the causes which seem to have led to the considerable developments noticed in the medium-term past, and the importance of the Guianese coastal strip, the option sustained is to recover - with replenishments of sand - lengths of beach equivalent to those of the past and to protect the sectors currently under threat. The set of measures is meant to lead to creating a coastal space available to everyone and accessible to all, and to end economic disasters (organisation of local services for beach users).

3.2 Coastal defence measures (near future)

With regard to the tendencies observed, protection measures have been put forward depending on various techniques.

In the north of Bourda cove: re-establishment of the 1998 coastline with the integration of the existing defence works (frontal breakwaters) into dune-type arrangement above the beach by replenishing sand, or destruction of the current defences (and the houses situated on them) then replenishment.

In the centre of Bourda cove: maintaining the dune cordon by re-establishing the beach with replenishments, with a gain in the coastline towards the sea. This is a necessary condition for preserving the dune cordon.

In the north of Rémire cove: reinforcement of the current defence works (strong protection); re-establishment of a beach by replenishment with an advance of the coastline towards the sea that will ensure the survival of the works behind.

Coast south of Rémire cove: reinforcement of current defence works (rock fill above the beach) and to their right the re-establishment of a beach by replenishment for an advance in the coastline towards the sea (indirect protection of the works); replenishment to be carried out on Apcat and Gosselin beaches in the case of very severe erosion.

3.3 Financial aspects

Measures are not yet applied.

4. EFFECTS AND LESSONS LEARNT

The protection measures have not been put into practice. It is a scheme that has the advantage of treating the whole of the Rémire-Montjoly coast taking account the effects on the environment and the local economy.

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