

Morphological evolution and management proposals in the Authie Estuary, northern France

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Abstract

The Authie is a small macrotidal estuary largely infilled by marine sand and affected by flood dominant tides and waves. The shallow estuary mouth exhibits a relatively large intertidal zone of about 2.2km² with saltmarshes and on the south bank a massive sand spit platform. It confines the main Authie channel towards the north bank, threatening the dune barrier and the health and seaside-resort of Berck. The localized erosion and the generalized sedimentation have been focussed for a long time. It poses a number of severe management problems, notably estuarine shoreline protection, and call into question the very survival of the estuary itself. The Regional authority have been aware of these problems and undertook a study on estuary restoration. The first stage consisted in understanding the morphological changes within the estuary. They were deduced from analyses of historical documents, bathymetric charts and from the analysis of successive series of scale-rectified aerial photographs covering the last five decades. The main hydrodynamic processes and transport trends involved in these changes are analysed from observations and measurements of currents and waves. The results show that the width of the estuary mouth has decreased over the centuries. Moreover, the trends observed suggest that morphological changes have been linked to empoldering and the progressive construction of defence structures. The aim of the second stage is to develop predictive scenarios on future evolution of the estuary. Therefore, engineering models have been computed in order to simulate sediment dynamics and several defence schemes and a relocation of the sand platform are proposed. They were also complemented by biological studies on potential impacts of the operation on fauna and flora. The long term objective of the Regional authority is to define the best strategy, fighting the north bank erosion and the generalized sedimentation. But the heightened awareness of the socio-economic and the environmental values of intertidal zone give rise to recommendations on an integrated management of the Authie, notably the interaction between the environment and the shellfish farming ecosystems.

Keywords: Macrotidal estuary; Erosion; Sedimentation; Management proposals.

Introduction

Estuarine coastlines make up a significant part of coasts, and at the same time, estuaries are important for many human activities such as provision of sheltered sites for harbours, navigation and nature conservation. Often these interests are conflicting, and managers frequently have to attempt compromises that entail economic constraints.

Infilling in macrotidal estuaries may be favoured by flood-dominant tidal currents. The wave input may occur through recycling of sand drifting alongshore into the estuary mouth, often derived from dune reworking. Understanding these patterns of estuarine development is important to a variety of management issues such as conservation, shoreline protection and embanking. Good examples of macrotidal estuaries exposed to significant storm-wave activity are found on the dune-bound coast of northern France. One of these estuaries is the Authie, an estuary that embodies the paradox of significant overall accretion but severe erosion of its north bank (Fig. 1). Moreover, the evolution of the Authie Estuary morphology results from changes in sediment transport patterns determined by several factors operating at various temporal and spatial scales, as result of morphodynamic adjustments (Anthony and Dobroniak, 2000).

The aim of the present paper is to describe the morphological change that has occurred from the analysis of successive series of aerial photographs covering the last five decades. The main hydrodynamic processes and transport trends involved in these changes are briefly analysed from observations and measurements of currents and waves. In a second time, some predictive scenarios on future evolution of the estuary are developed by the Regional authority to define the best strategy for the estuary sustainable development.

General description of the estuary

The Authie Estuary is located on a low-lying dune coast in northern France (Fig. 1). It forms the terminus of a 98 km-long and straight coastal river that drains a low-gradient Mesozoic limestone plateau catchment covering an area of 989 km². However, the mouth of this estuary exhibits a relatively large intertidal zone of about 2.2 km². Another 2km² of former tidal lands have been transformed into polders (Fig. 1). Large portions of the south bank and parts of the inner estuary have been empoldered since the 12th century and this empoldering accelerated in the 18th century.

River discharge data are relatively sparse but show regular flow, characteristic of a small temperate catchment. The mean liquid discharge of the Authie is moderate (10m³.s⁻¹) and is relatively constant throughout the year, fluctuating between 4m³.s⁻¹ (August) and 13m³.s⁻¹ (March) (Service Hydrologique, 1992). Catchment erosion provides the only sediment brought down to the sea by the Authie. This is exclusively fine-grained suspension load. The mean spring and mean neap tidal ranges at the mouth of the estuary are respectively 8.54m and 4.89m. These ranges decrease to around 4m and 1.8m, respectively, 7km up the estuary. The spring tidal influence on water level goes up to 16km inland. This large tidal range causes rapid tidal currents of up to 1m.s⁻¹ at the mouth (Dobroniak, 2000).

Like all the other estuaries on this coast between the Somme (Fig. 1) and Belgium, the Authie is a shallow estuary that shows advanced sandy infill. The shallow estuary mouth exhibits a massive sand deposit covered only during high spring tide stages (Fig. 1), comprising a spit platform. The tip of the platform exhibits a massive dune barrier that extends northwards up the coast. The platform stretches across the shallow estuary

mouth, confining the main Authie channel towards the north bank. Mudflats and salt marshes occur in the inner estuary.

Historical reconstructions of estuarine evolution over the last three centuries show significant northward extension of the south bank dunes, and concomitant erosion of the north bank dunes (Briquet, 1930; Dallery, 1955). By progressively prograding across the shallow estuary mouth, the south bank confines the main Authie channel towards the north bank, threatening the dune barrier and the health and seaside-resort of Berck (Fig. 1) which developed in the 18th century. To keep the Authie channel from moving and eroding, several groynes and major embankments were constructed from the beginning of the 19th century to the early 1960^s (Dobroniak, 2000).



Fig. 1. The Authie Estuary, northern France. Aerial photograph is from the French Geographic Institute, the "Institut Géographique National" (IGN), carried out in 1991.

Morphological trends

Bathymetric charts show a clear pattern of erosion and sedimentation at the estuary mouth. These documents highlight systematic erosional and depositional trends, respectively of the north and south banks of the estuary. The superposition of shorelines on these documents shows that the width of the estuary mouth has decreased over the centuries. Dallery (1955) showed that the width between the Pointe de Routhiauville and

the Bec du Perroquet, decreased from an initial 3.5km in 1671 to 1.8km in 1953. It suggests that the progradation rate of the south bank is superior to the rate of erosion of the north bank, the ultimate fate of this rapidly accreting is complete silting up.

On the north bank, scale-rectified aerial photographs covering the last five decades show marked changes (Fig. 2). Their analysis documents progressive dune erosion and the migration of this erosional sector towards the inner estuary. The superposition of the photographs highlights important spatial and temporal variability with successive zones of erosion and accretion, the positions of which change in time. It has been linked to the progressively construction of defence structures (Dobroniak, 2004). The shoreline retreat from 1947 to 2000 has not been constant (Fig. 2). It has been estimated at 395m northward (about $7.5\text{m}\cdot\text{y}^{-1}$) and 230m inwards (about $4.5\text{m}\cdot\text{y}^{-1}$), reducing the width of the dune barrier and threatening the human constructions on the Pointe du Haut Banc. In contrast, the shoreline has been accreting further south (about $11\text{m}\cdot\text{y}^{-1}$), leading to the formation of the inner estuarine spit of Bec du Perroquet (Fig. 2). This accretional zone is characterised by successive longitudinal dune ridges that highlight progressive extension of this inner estuarine shoreline.

The trends observed from the aerial photographs are corroborated by topographic survey (profile and DEMs). It shows the importance of human defence structure to limit wave attack of the dune cliff face (Dobroniak and Anthony, 2002).

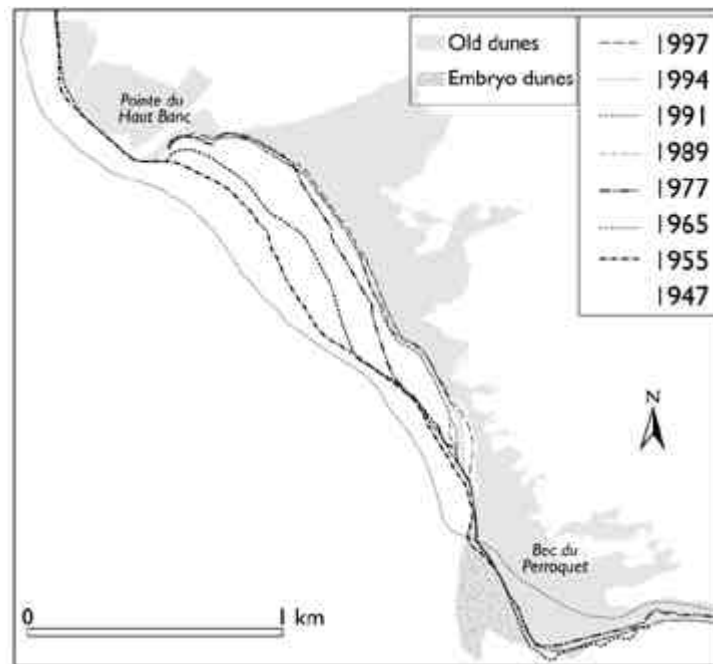


Fig. 2. Changes in the position of the dune-bound northern shore from scale-rectified aerial photographs. Photographs were chosen covering the last fifty years from the French Geographic Institute, the "Institut Géographique National" (IGN).

Sediments transport

Patterns of sedimentation and erosion of the Authie mouth were suggested by currents measurements inner the estuary and offshore. Records highlight a strong northward longshore drift attributed to combined tidal and waves currents. At the mouth of the Authie, a counteractive drift to the south is manifested by sediment movement, confirmed by the orientation of major morphological features, notably dune spits, at the north bank approaches to the estuary, and by preferential entrapment of sand on the northern updrift sides of groynes on the Berck seafront (Fig. 3A). This wave-induced drift is overwhelmed and strongly reinforced by flood tidal currents directed towards the inner estuary (Fig. 3B).

Along the north bank, all currents are parallel to the coast towards the inner estuary, jammed between the massive sand platform and the dune barrier. They confirmed the residual inward transport pattern (Fig. 3C). This hydrodynamic circulation involves both a wave energy gradient from the exposed outer estuary to the more sheltered inner estuary and a residual shore-parallel flood current. Much of the sand released by storm erosion of the dunes is transported alongshore and inwards towards the Bec du Perroquet spit, within this sediment drift cell driven by combined wave and flood-tidal currents. It suggests a southward transfer of sand characterised by an updrift erosional sector that feeds a depositional one further downdrift.

Moreover, Dobroniak and Anthony (2002), by the interpretation of profile survey, highlighted the dominant role of the estuarine beach. The sand is temporarily stored on the intertidal beach by storm-wave erosion of the dunes. Then it is transferred onto longitudinal dune ridges further inside the estuary, by both wave-current reworking and winds, although limited backcycling may occur into dune blowouts. This sand finally ends up its recycle in estuarine deposits, building up mudflats and saltmarsh substrates (Fig. 3D). Dobroniak (2004) points that recycling of this sand, eroded from coastal dunes lining the estuary and transported by tidal drifts into the intertidal inner estuarine sink, transforms the saltmarsh vegetation into embryo dunes vegetation.

This important input of dune sand into the intertidal estuarine sink, and the enhanced mud accumulation and saltmarsh development it causes, accelerate the silting up of this estuary.

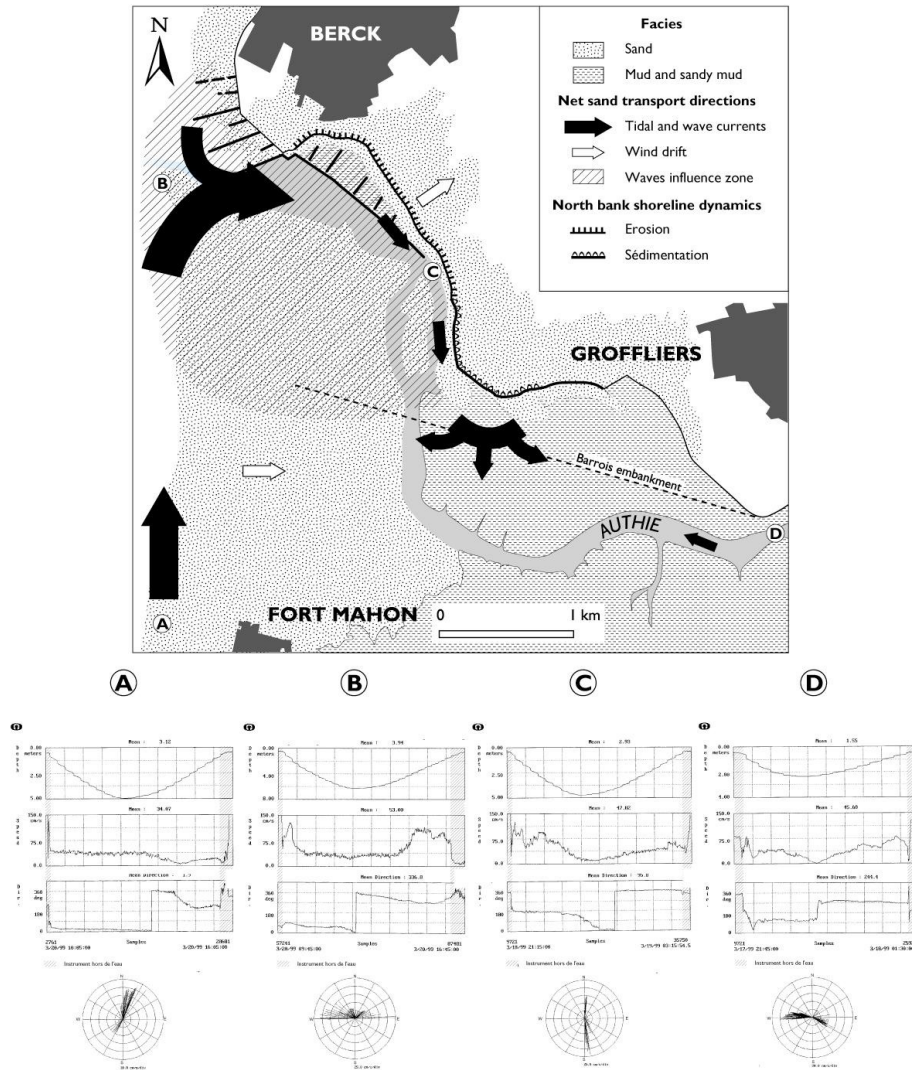


Fig. 3. Tidal current and sand transport patterns in the Authie Estuary. Arrows size indicates relative importance of sand transport.

Management proposals

The localized erosion and the generalized sedimentation of the estuary pose a number of severe management problems, notably estuarine shoreline protection and call into question the very survival of the estuary itself. To oppose these trends, the Regional authority is responsible for the operation and management of the Authie Estuary. The SOGREA H has been appointed to develop predictive scenarios on future evolution of the estuary. Engineering models have been computed in order to simulate sediment

dynamics, using a number of studies about coastal processes, notably those of Coastal Geomorphology and Shoreline Management Unit. Managers bring to propose several defence schemes and a relocation of the sand platform. In the past, they showed a marked preference for using hard structures to protect the north bank. But today, they know the acceleration of erosion and sedimentation patterns are linked to the progressive construction of defence structures along the bank. They prefer to adopt a comprehensive conception of soft management with a long term objective. Proposals are also complemented by biological studies on potential impacts of the operation on fauna and flora. Dynamism and physical characteristics of the landforms and sediments, highlighted by the study, play a relatively greater role in the evolution of the benthos and salt-marshes communities.

As a result the Regional authority prefers to choose a relocation of the sand platform, less harmful than groynes and embankments. Engineering models show the performance of sea defences along the north bank to protect the dunes and the Berck-resort. But they highlight an amplification of accretion inner estuary. On the contrary, the possibility of a relocation of the Authie channel by the excavation of a new channel, removes the threat further the north bank and has less sedimentation effects. But, the location of this new channel induces hydrodynamic changes and disturbs saltmarshes and embryo dunes development (Fig. 4). The heightened awareness of the socio-economic and the environmental values of intertidal zone give rise to recommendations on an integrated management of the Authie, notably the interaction between the environment and the shellfish farming ecosystems. By another way, to keep the estuary in this new configuration, post-relocation maintenance dredging of the new channel is necessary.

Conclusion

Authie Estuary provides a good example to highlight the contribution of erosion in the infill of an estuary. It shows also that the sand, released during storm wave attack of the dune on both banks by currents, is recycled successively as beach, dune, and finally, estuarine deposits. As a result, the north bank shoreline transport pathway probably constitutes the major infill pathway of the inner estuary. Erosion of the north bank and estuary-ward recycling of the eroded dune sand is thus largely a reflection of estuarine morphodynamic adjustment to massive sedimentation constraining the tidal flux towards the bank. Understanding such patterns of erosion and sedimentation and their driving mechanisms is important to estuarine management issues such as shoreline protection, estuarine infill and embanking.

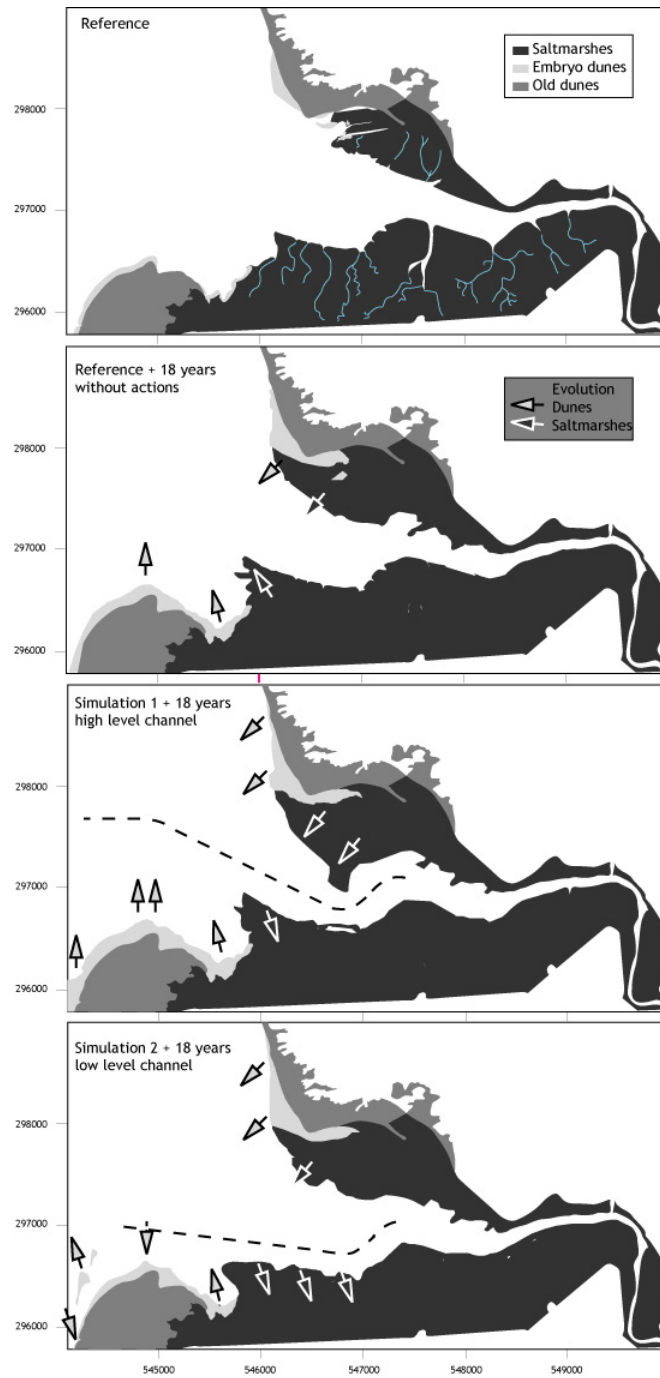


Fig. 4. Dynamics of dunes and salt marshes after predictive models, with (two simulations) and without coastal management. Morphological reference is 1998 data.

In the past, no actions have been taken against accretion. All the actions taken against erosion were hard engineered solutions. Traditionally, action has only ever been taken with regard to erosion, because it is seen as a problem and accretion is not. But, today, Regional authority, knowing sediment processes, prefers soft defences structures and a relocation of the channel. She accepts responsibility of a potential modification of the estuary ecosystem. Finally, the hypothetic modification of the platform will be the focus of considerable debate due to the environmentally sensitive nature of the issues. Studies about human impacts on intertidal ecosystems are essential for the Authie Estuary sustainable development.

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