Recent Rapid Evolution of the Guadiana Estuary Mouth (Southwestern Iberian Peninsula)

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ABSTRACT


A series of interventions in the Guadiana River Basin (dam construction, increase in mining, deforestation, construction of jetties) have resulted in a reduction of average river volume, an increase of sediment load in the river, and ultimately a large scale change of the coastline and margins of the Guadiana Estuary. A series of maps and vertical aerial photographs were interpreted with the help of GIS in order to better understand and quantify the morpho-sedimentary evolution of the Guadiana Estuary mouth in the course of the 20th century.

The results show an average progradation of the western estuary margin by about 950 m since 1870, accumulating an estimated 4.6 x 10⁶ m³ of sediments. About 20-25% of this accumulation was caused by the construction of the jetties, leading to the trapping of the entire littoral drift (estimated 180’000 m³/year) between 1974 and 1980. On the eastern estuary margin, a large marsh system protected by a long spit developed. Although the coastline showed average erosion at a rate of about 3 m/year, the total area of the eastern estuary margin increased because of the progradation of the system into the main river channel.

With the conclusion of the Alqueva dam project in the near future, a further significant reduction in average river volume is expected. Sediments originating from littoral drift will begin to bypass the western jetty, as the area west of it is infilled. Furthermore, as waves and tidal currents will dominate against a much reduced river flow, a further accumulation of sediments in the estuary mouth can be expected.

ADDITIONAL INDEX WORDS: Coastline evolution, GIS, estuary, geomorphology, jetties, dams, tidal inlet, sand banks, Guadiana, Portugal

INTRODUCTION

Changes on coastlines and nearby shelves caused by anthropogenic modifications of solid and liquid river discharges in river basins have been the topic of research for at least four decades. Amongst the first publications on this subject the paper of Norris (1964) stands out, relating changes in the evolution and behaviour of Southern Californian beaches to the interruptions in river basins by the construction of dams. Other examples on the influence of dam construction on rivers, estuaries, and adjacent coasts are the papers by Bowen and Inman (1966), Browly and Brown (1978), Collins and Evans (1986), Hart and Long (1990), Rubin et al., 1994, and Carriquiry and Sánchez (1999).

One of the better-known case studies is the Nile Delta, deeply affected by the construction of the Aswan dams and irrigation systems in the delta (e.g. Frihy, 1988; Stanley et al. 1998). The dramatic reduction in solid discharges (e.g. Carter, 1988) has not only strongly influenced the sediment transport to the coastline, which has since the construction of the dams been receding at an average rate of about 30 m/year, but also the sedimentation patterns on the adjacent shelf and upper shelf slope (Sharaf el din, 1977; Summerhayes et al., 1978).

This type of anthropogenic alterations of coastal systems in general and estuaries in particular is in many cases increased by additional human interventions in the system, such as the construction of jetties and harbours, and dredging activities.

A complex set of problems affects the Guadiana River Basin and its adjacent coastline in the southwestern Iberian Peninsula (Figure 1). These problems are mainly a consequence of the high variability in its flow regime, its transnational character, and increased pressure from anthropogenic activities, particularly since the 1950’s.

The hinterland of the Guadiana River Basin is extremely dry, especially during the summer. A series of large barrages and dams have been built to alleviate shortages in irrigation, and to provide water and electricity for Spanish and Portuguese cities. In 1990, about 70 % of the drainage basin of the Guadiana was regulated by some kind of barrage (Morales, 1995). The result was a dramatic reduction of flow volume in the lower Guadiana River during droughts and winters (when most water is retained in dam lakes). As a consequence the annual flash floods, which usually occurred in winter, have strongly diminished in magnitude in recent years.
The nearly finished Alqueva barrage complex will cover an area of ca. 250 km$^2$ to create the largest artificial lake in western Europe, retaining a maximum capacity of 4'150x10$^6$ m$^3$, and expected normal volumes of 3'150x10$^6$ m$^3$. The interruption of the river flow to fill the dam lake is planned for 2001. The Alqueva dam will almost double the volume of water retained in dam lakes in the river basin (Figure 2). This project is likely to further accentuate existing problems in the estuary, drastically altering the flow regime and associated sediment transport, with direct effects on the estuary and coastal morphology.

In addition, a large sand bank (‘Banco do O’Bril’) dominated the mouth of the estuary in historic times (Figure 1). The highly dynamic character of this bank frequently led to extensive problems for the shipping traffic (WEINHOLTZ, 1978). In an attempt to control the migration of the bank and avoid further infilling of the main estuary channel two large jetties were built between 1972 and 1974, marking the sides of the main river channel (Figure 1) (DIAS, 1988).

This paper discusses, using the Guadiana Estuary as an example, the consequences of anthropogenic interventions in river basins on river mouths and their adjacent coast. Furthermore, in the specific case of the Guadiana Estuary it is of particular importance to establish a database of the status quo of the estuary. The determination of the existing sedimentary regime will allow a future evaluation of the impact of the Alqueva barrage complex in the future.

**STUDY AREA**

The Guadiana Estuary is situated in the SW of the Iberian Peninsula, forming part of the river basin of the Guadiana River. The River is 810 km long, and its basin is 66'960 km$^2$, the fourth in size of the Iberian Peninsula. Of this area, 55'260 km$^2$ (83%) are Spanish, and 11'700 km$^2$ (17%) Portuguese.

The main river channel delineates the border between Spain and Portugal in the last 40 km of its course. Most of its bed is relatively narrow and delimited by the rocky formations outcropping in this area.

The river only crosses an open coastal plain in its last 7 km. This coastal plain is part of an old deltaic plain, dominated by marsh systems formed by the river (MORALES, 1997). The mouth of the estuary is a highly dynamic area, with considerable movement of sediments and associated morphological changes. The coastline only reached a position close to the present one about 200 years ago (MORALES, 1997).

The coast adjacent to the estuary is semidiurnal mesotidal, with average tidal amplitudes of around 2 m, reaching 3.4 m at spring tides. Tidal currents at the river mouth are about 0.6 m/s (direction 340°) during peak flood tide, and 1.2 m/s (direction 140°) during peak ebb tide (INSTITUTO HIDROGRÁFICO, 1998). At high tide, saline coastal waters penetrate about 40 km upriver.

The offshore coastal wave regime is primarily dominated by waves from W and SW (approximately 50% of occurrences). SE waves also have a significant influence with ca. 25% of occurrences. Average offshore significant wave height is about 0.9 m, with an average period of 4.6 s, and peak average periods of 8 s (Costa, 1994). The net annual littoral drift is from W to E.

The Guadiana River flow volume is marked by large seasonal changes, as well as changes associated with dry and wet years (LOUREIRO et al., 1986). The regional climate is classified as semi-arid, with the exception of July and August (arid) and November to January (temperate-humid) (MORALES, 1995).

![Figure 1. Overview of the Guadiana Estuary (after MORALES, 1995).](image-url)
Recent evolution of the Guadiana Estuary

At the hydrometric station of Pulo do Lobo, the minimum measured flow volume was 6 m$^3$/s, and the maximum 2492 m$^3$/s, both in 1963. The wettest year in recent times was 1963/64 with an mean annual flow of 436 m$^3$/s, and the driest 1980/81, with an mean annual flow of 8 m$^3$/s. Between 1946/47 and 1968/69, the mean flow rate was 163 m$^3$/s and the average yearly drainage $5.2 \times 10^6$ m$^3$, but ranged between $0.3 \times 10^6$ m$^3$ and $14 \times 10^6$ m$^3$ in any one year (a maximum/minimum ration of 46). In comparison, the same ratio for the Tejo River is 17 and for the Douro River 6 (both rivers are on the Iberian Peninsula).

Furthermore, the Guadiana River Basin is characterised by recurring yearly floods. Since the year 680 a total of 128 historically registered floods were considered to be catastrophic (ORTEGA AND GARZÓN, 1997).

The mouth of the Guadiana Estuary can be split into three main morphological elements (Figure 1): The western margin, the O’Bril sand bank, and the western margin. Significant anthropogenic elements are the jetty on the western margin, with a length of 2'040 m, a 900 m long submerged jetty on the eastern margin, and a groin with a length of 150 m about 1.7 km west of the western jetty (Figure 1; WEINHOLTZ, 1978; DIAS, 1988).

METHODS

Analysis of aerial photographs

The evolution of the Guadiana Estuary mouth was studied mainly using aerial photographs and maps. Key morphologic and anthropogenic elements were groundtruthed during field visits.

A number of aerial photographs only show either the western, Portuguese side (marked with an *), or the eastern, Spanish side (marked with a +) of the estuary. Photographs from the following years were used: 194? (*, date uncertain, most likely 1945), 1956 (+), 1958 (*), 1969, 1972 (*), 1977, 1980, 1985, 1986, 1991, 1994, 1999. From this set only the pictures of 1999 are in colour. The scale of the photographs varies between 1:8'000, and 1:30’000.

The study of the evolution of the O’Bril sand bank, and the morpho-sedimentary evolution of the estuary margins before 1940 was based on bathymetric maps from 1870, 1915, 1938, 1964, and 1978.

All aerial photographs and maps were scanned at 300 pixels/inch. The photographs and maps were geo-referenced with ERMapper 6.0 using a series of geographic tiepoints. The projection used is UTM (Datum Lisbon, Castelo de S. Jorge). Comparisons between photos showed that the maximum overlap error between known points is generally below 5 m, and occasionally up to 9 m for some photographs on the eastern margin (where only one accurate tie point exists). This is well below the error given by DOLAN et al. (1991) for the overlap of aerial photographs.

The scanned photographs were interpreted with the GIS based program MapInfo. A series of geomorphological elements could be identified and mapped on all photographs. The criteria for distinction of the areas were shape, shade of grey (or colour where available), texture, and context. The photographs were interpreted beginning with the most recent one. The created map was subsequently used as a mapping help for the next older one, and so on. The distinguished areas, forming roughly three logical groups, were:

a) Non vegetated sandy areas; Dunes with sparse vegetation; Well vegetated dunes; Dunes with trees;

b) Sandy marshes; Marshes; Channels; Areas associated with channels;

c) Paths; Roads; Urban areas (all constructions and buildings, including jetties);

The smallest mapped objects have a diameter in the range of 3-6 m, depending on the quality of the photograph. Exceptions were made where smaller objects are well visible on the photos and are of diagnostic significance, for instance some tidal channels.

The studied area was equal for all photographs. The area of investigation was delimited in the following way:

1) To the north by older dune belts, that show little variation over time;
2) To the west by the small groin on the western margin;
3) To the south the high water mark, well visible on most photographs;
4) To the east, about halfway across the extension of the marsh and barrier island system of the eastern margin, corresponding to a distance of about 2 km from the mouth of the estuary.

For the purposes of this study, these limits were considered far enough from the estuary to include all areas affected significantly by it, as well as areas outside the influence of the estuary on both sides.
Figure 3. Landcover maps of the Guadiana Estuary mouth for 1956/58, and 1994; The cross locates the same geographic position on both maps.
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The only mapped intertidal areas are the intertidal bank and the river terrace of the eastern margin because of their importance as a link between the margin and the Guadiana River. Although the limit of the river terrace can be clearly seen on most photographs, the limits of bank and terrace towards the river were estimated. For an example of the created maps see Figure 3.

Analysis of coastline trends

The analysis of coastline trends was done using methods described in Foster and Savage (1989), Dolan et al. (1991) and Gorman et al. (1998). Transects perpendicular to the coastline with a spacing of 50 m were drawn along all mapped shorelines to measure rates of shoreline change. While it was possible to estimate 11 rates of change for the western margin, it was only possible to calculate 6 on the eastern margin, because on this side of the estuary accurate measurements were only possible on the basis of the aerial photographs. Analysed statistical values included the average of rates, and the standard deviation of the rates. Both values were computed for averaged along-the-shore rates, as well as for all values on both sides of the estuary for each year, in order to determine locations and periods associated with the most significant changes.

Although significant changes also occurred in the main Guadiana Estuary channel limits, only seaward shoreline trends are discussed here. The main reason is the lack of a reliable outward visual limit of the intertidal bank and eastern margin terrace towards the estuarine channel, necessary to plot shoreline changes.

RESULTS

O’Bril sand bank

The O’Bril sand bank has been in existence at least since 1648, as can be seen on a map of the Algarve of this date. It shows a cyclic behaviour, described in Weinholtz (1978) and Morales (1997):

The bank grows over the course of a few decades on the western margin of the Guadiana Estuary, rotating east to the distal part of the bank, thus partially blocking the mouth of the estuary. Subsequently a new river channel usually forms close to the western margin splitting the bank into two (or more) segments. This new channel widens in time, initiating a migration of the bank towards the eastern estuary margin. Eventually the sand bank will attach itself onto the eastern, Spanish shoreline. From here, the remnants of the sandbank slowly erode. The sand is either transported downdrift eastwards, or amalgamated to the coastline. This cycle has occurred several times over the past few hundred years.

In 1876 the O’Bril sand bank was probably at the end of such a cycle. The largest flood of the Guadiana River in historic times occurred that year raising the river level to 50 m above the low-tide level at Pomarão (approximately 50 km up-river), and destroying large parts of the O’Bril bank (Figure 4). The bank had at this time an area of 0.8 km\(^2\) on the Portuguese side, and a total of 2.7 km\(^2\) including the sand bars on the Spanish side (Figure 5).

In 1915, the bank had reconstituted itself, with an area of 3.7 km\(^2\) on the Portuguese side, and 5.9 km\(^2\) as a whole (Figures 4, 5). Subsequently, the size of the O’Bril bank decreased, losing approximately 48 m\(^2\)/year in area. Simultaneously, it began rotating northwards (Figure 4). This process was slightly accelerated after the construction of the jetties in 1972-1974. On the map of 1978 the O’Bril sand bank is smaller than after the great flood of 1876, with a size of 0.6 km\(^2\) on the Portuguese side, respectively 1.3 km\(^2\) including the Spanish side (Figure 5).
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The speed of northward rotation of the bank was found to be irregular. It was quickest between 1915 and 1938 with 65 m/year, slowed down to 19 m/year between 1938 and 1964, and increased slightly to 22 m/year between 1964 and 1978. Causes for this could be the wave climate, and the occurrence (or not) of annual floods in the river basin.
Western Estuary Margin

The evolution of the western estuary margin has been characterised by a strong progradation in the last 140 years. The map of 1876 shows the coastline following the limits of an older dune belt (Figure 6). The maps of 1915 and 1938 show that by this time the coastline had begun to prograde southward. These coastline limits can be identified on the aerial photograph of ca. 1945. An analysis of morpho-sedimentary features shows that the coastline grew from west to east by accreting swash bars (Figure 6).

Between 1938 and the time when the aerial photograph of the 1940’s was taken a large spit grew eastwards, enclosing a small low energy area. The total growth of supratidal area was of 170’000 m², corresponding to an accretion of approximately 24’000 m²/year (Figure 7).

Until 1958 this spit grew eastwards and then northwards as the point grew closer to the main Guadiana Estuary channel (Figure 6). Simultaneously, the main coastline quickly prograded southwards. Marshland developed in the back of this area, otherwise predominantly consisting of dunes.

Figure 8. Evolution of the eastern Guadiana Estuary margin since 1956.
This trend of growth and progradation of the western margin continued throughout the sixties (Figures 6, 7). From 1972-1974 a large jetty was built on the western margin of the Guadiana Estuary. Additionally, a 300 m long groin was placed approximately 1.7 km to the west, to prevent a quick infilling of the area west of the jetty (DIAS, 1988). The result was, however, the quick accumulation of a large sand wedge with an area of approximately 125'000 m² against the jetty between 1974-1980. Sand continued to accumulate rapidly in the vicinity of the jetty until 1986. As the area against the jetty was infilled sands were deposited westward on the adjacent coast, leading to a progradation of the coastline (Figure 6).

An analysis of the landcover areas shows that the amount of sandy areas peaked during periods of rapid accretion (1938-45, 1977-86). The areas of sparsely vegetated dunes remain relatively constant throughout the period of the analysis, and can be considered a transitional type of landcover. The fastest growth was observed in well-vegetated dunes, which grew by an average area of approximately 7'000 m²/year between ca. 1945 and 1999. This type of landcover at present dominates the dune belt. Significant growth in area could also be observed by marsh and channel, which grew by approximately 4'500 m²/year.

**Eastern Estuary Margin**

The Eastern Margin of the Guadiana Estuary differs strongly from its western counterpart. Early maps are mostly sketch-like, making an accurate evaluation of landcover development of the eastern Guadiana Estuary margin impossible for the time before 1956. An interpretation of the evolution of this area can be found in MORALES (1997).

Until approximately 1920-1930 the eastern estuary margin consisted of marshland, merging into sandy tidal flats to the south. A dendritic system of tidal channels drained southward. The southern border of the tidal flat was protected towards the sea in the east by a system of barrier islands. Between 1915 and 1938 the easternmost spit of this system, called *Punta de la Espada* (‘Sword’s tip’), grew westwards and became wider.

The aerial photograph from 1956 showed only very little or no vegetation on the spit. At this time the former southward draining tidal channel system drained westward into the Guadiana Estuary (Figure 8a). Additionally, a new thin spit is visible pointing W along the coast and NW on the margin of the estuary (Figure 8a).

In 1969 the *Punta de la Espada* has rotated northward and grown towards the Guadiana Estuary (Figure 8a). The older spit shows strong erosion at the front. Much of its remnant area shows a growth in density of vegetation, and thus also a stabilisation. The area between the spits was infilled, developing a sandy marsh. The tidal channel system prograded outwards into the main estuary channel. The newly visible intertidal bank forms a linear limit with the main estuary channel.

The aerial photograph of 1977 is the first one taken after the construction of the submerged jetty (Figure 8b). The effect of the jetty on the eastern margin is not nearly as drastic as the one seen on the western part of the estuary. This contrasts with the coastline further east, where coastal erosion is a known problem, and which might be connected to the construction of the jetties and subsequent sand starvation (GONZALEZ et al., 2000).

From 1977 on, the following trends for the eastern margin of the estuary can be observed:
- The coastline stabilises in 1977, only showing slight shifts;
- The outer spit of the *Punta de la Espada* slowly grows into the main estuary channel, at a rate of approximately 10 m/year (Figure 8 c,d);
- This growth of the barrier island is accompanied by an outward growth of the intertidal bank, leading to an increase of marshland, which grows at a rate of approximately 3'500 m²/year between 1977 and 1994;
- The area in the vicinity of the intertidal bank and the channel system grew outwards between 1977 and 1985, bulging into the main Guadiana Estuary channel. The growth of this area peaked in 1985. Although it continued to grow afterwards, this happened at a much slower pace (Figure 8).
- The area covered by channels, sand marsh, and related areas slowly decrease on the whole eastern margin in favour of marsh, as channels are infilled and the system matures (Figure 9).

Globally, the eastern margin of the Guadiana Estuary shows a slight increase in area between 1977 and 1994, mainly caused by the westward growth of the marsh, and to a lesser extent the barrier island.
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Coastline trends

While the western margin shows a continuous trend of accretion along the shoreline, most of the eastern side is subjected to erosion (Figure 10a). Local accretion on the eastern margin is associated with areas in the vicinity of the submerged jetty.

Average accretion on the western margin is in the range of 7-10 m/year, with exception of the area close to the estuary margin, respectively the western jetty after 1974. Here, the accretion rates peak at around 50 m/year. This area of fast progradation has a western extension of around 450 m, west of which the values drop off quickly. Erosion trends on the eastern margin show relatively moderate values of around –3 m/year. An exception is again the coastline in the 200 m next to the main estuary channel, where the average erosion is of up to -15 m/year (Figure 10a).

Figure 10. a) Distribution of total shoreline evolution rates west and east of the main channel of the Guadiana Estuary averaged for all years from 1956/58 until 1999. Note the position of the jetties on both sides of the estuary, as well as the groin, delimiting the area to the west; b) Standard deviation of total averaged rates of coastline change; c) Along-the-shore rates of coastline change averaged by time periods. Note that the period before 1956/58 only applies for the western side.

A large standard deviation of coastline trends is caused by a large variation in coastline shifts. Therefore, the standard deviation of average rates gives an indication for how dynamic the coastline is. The highest standard deviation of 10-20 m is measured to a distance of up to approximately 300 m to the west and 500 m to the east of the main estuarine channel, the values being slightly lower on the eastern side (Figure 10b). While the standard deviation drops off to around 2-3 m on the western margin out of the range of the jetty, it remains high at around 5-10 m on the eastern margin on the whole coastline of the barrier island. The standard deviations are lowest in the vicinity of the submerged jetty, with values around 4-5 m (Figure 10b).

Variations of coastline evolution rates on the western and eastern Guadiana Estuary margin show two periods of rapid coastline change (Figure 11). Shoreline change rates stayed relatively stable for the western margin during most of the
20th century, showing an accretion of 3-5 m/year. A peak of over 20 m/year can be observed during the period of 1938-ca.45, falling back to the base level after that. Accretion rates increase during the sixties, with the notable exception of the period 1969-72, when the tip of the western margin was eroded (cf. Figures 6, 10c). This land loss was so substantial that it shows on Figure 12 as a net average coastal erosion of 10 m/year of the margin, although it was limited to the part of the margin closest to the estuary channel. A large accretion rate of more than 20 m/year can be observed for the period between 1977 and 80, when large amounts of sediment were deposited against the western jetty (Figures 10c, 11). This rate decreases subsequently, finally leading to slight net erosion between 1994 and 99 (Figures 10c, 11).

The data for the eastern margin shows a stable coastline on the eastern margin during most periods, accreting slowly at a rate of around 1 m/year (Figure 11).

Standard deviations averaged for periods of time reflect the change in magnitude of accretion/erosion along the shoreline (Figure 11). The western margin standard deviation of the period from 1938 to ca. 45 is relatively low at around 10 m, compared to up to 50 m after the jetty was built, and to 25 m after the erosion of 1969-72. This reflects the fact that in 1938-45 the entire coastline prograded, while the changes between 1969-72 and 1977-80 affected mostly the areas closest to the estuary.

DISCUSSION

MORALES (1995) estimated, that the average accumulation rate of sediments in the vicinity of the Guadiana Estuary grew considerably since 1876. This growth in sediment availability was (and is) most likely caused by an increase in up-river as well as up-drift anthropic activity. Large areas of woodland in proximity of mines were deforested during the industrial revolution between the mid 19th century and the beginning of this century, as the mining industry needed increasing amounts of wood for the calcination of the ore (GARCIA, 1996). Furthermore, activities associated with mining (construction of railways, improvement of ports) contributed to the availability of sediments.

The results of this study show an additional peak in sedimentation between 1938 and ca. 1945. The reasons for this are not well understood. It is very likely associated with an increase of erosion in connection to the so-called campanha do trigo (‘wheat campaign’), an isolationist attempt for self-support of the country in the thirties. During this ‘wheat campaign’, huge areas in the interior of the Iberian Peninsula were deforested and used for agricultural purposes. The result was a large increase in soil erosion.

The last large period of growth of the (western) Guadiana Estuary margin happened between 1974 and 1980, caused by the construction of the jetties. During this time more than 1'000'000 m³ sand accumulated between the pre-existing margin and the jetty. This corresponds to an accumulation rate of 180'000 m³/year. This estimate only considers supratidal areas and assumes, an average topography of 4 m above mean sea level for the dune system. In reality the average topography is probably higher. Therefore, these values have to be considered as conservative values at the lower end of the range of estimates. The calculated accumulation rate can be used to indirectly estimate the littoral drift in this area during the second half of the seventies. The value is well within the order of magnitude of other regional estimates calculated by CEEPYC (1979), with 300'000 m³/year, D.G.P. (1989), with 150'000 m³/year, CUENA (1991), with 180'000 m³/year, or BETTENCOURT (1994), with 100'000-150'000 m³/year.

According to MORALES (1997), sedimentation on the western margin is controlled by the littoral drift and wave activity. The waves are mainly responsible for the migration and accretion of swash bars building the accreting margin. In contrast, the sedimentation on the eastern margin is controlled by the combined action of ebb-tidal and river current, and wave refraction. Here, sediment in form of swash bars migrates towards northwest to join the extremity of the Punta de la Espada (MORALES, 1997). Thus, the complete reorganisation of the Punta de la Espada spit in the period from 1956 to 1969 (Figure 8a) is possibly related by the change in flow regime caused by the main construction phase of dams in the mid fifties to mid sixties. During the same time period, the western margin, which is much less controlled by ebb tide and river flow showed considerably less change.
A further component in this system is the channel system of the eastern margin, which in the past 40 years has served as a sediment trap, leading to a quick infilling of the eastern margin marsh and the growth of the intertidal bank. The reduction in dramatic flash floods since the late sixties has allowed the combined bank and barrier island system to grow into the main estuary channel. While the estuary was approximately 1 km wide at the height of the tip of the barrier island in 1956, it was reduced to 470 m in 1969, and 420 m in 1994 (Figure 3). Although the process of estuary infilling is an ongoing trend, the speed of the closure of the main channel, as well as the quick accretion of sands trapped between littoral drift and river current in the estuary mouth can certainly be attributed to anthropogenic causes. A regular, controlled flooding of the lower Guadiana River and estuary is planned after the filing of the Alqueva dam system, simulating natural floods in a similar way as this has been proposed for the Colorado River by RUBIN et al. (1994) where it has been carried out in 1996 (see also USGS home page on the internet for information). However, how far such artificial floods can recreate past natural floods that occurred in the Guadiana Basin is questionable.

It is interesting to note, that in spite of large sediment accumulations on the margins, the O’Bril sand bank has shown a steady decrease in size since 1915. This might be explained by the fact that the whole hydrodynamic and sedimentary setting maintaining the bank in existence changed successively by 1) the growth of a large supratidal area on the western margin, 2) the building of dams, and 3) the building of the jetties.

CONCLUSIONS

The Guadiana Estuary mouth has undergone large changes in its sedimentary dynamics in the past 140 years. These changes were caused mainly by the construction of dams in the hydrographic basin of the river between 1955 and 1965, an increase in soil erosion because of deforestation in the 30’s and 40’s of the 20th century, and the construction of two jetties in estuary mouth in 1974.

As a result of these changes, the area of the O’Bril sand bank was reduced since the beginning of the 20th century from a maximum size of 5.9 km² in 1915 to only 1.3 km² in 1986.

The western estuary margin prograded by an average of 950 m, resulting in an area increase of 1.15 km² between 1870 and 1999. Progradation peaked during the period from 1974 to 1980 following the placement of the jetties, with the deposition of approximately 1’000’000 m³ sand, corresponding to 180’000 m³/year, or the estimated total of the littoral drift.

On the eastern margin a marsh system developed, protected by a barrier island system. Although the coastline of the island eroded slightly until 1969, it has been relatively stable since then. The analysed area of the eastern margin grew by a total of 340’000 m² since 1956, mostly through the growth of the marsh and associated tidal channels into the main estuarine channel. This development was probably only possible because of a continuing regulation of the river flow through barrages and dams since the mid-fifties, leading to an absence of yearly flash floods cleaning the riverbed of accumulating sediment in the past.

Following the construction of the Alqueva barrage system, a further reduction in river flow volume is inevitable. In the future, sea-waves and tidal currents will clearly dominate sedimentation in the mouth of the Guadiana Estuary. An increased clogging of the estuary mouth with sediments is to be expected, along with a possible renewed growth of the O’Bril sand bank. The consequences of this fundamental change in sedimentary regime for the adjacent coast and the continental platform in nearby, down-drift areas are yet unknown.

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