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Seabed Morphological Changes Related to the Expansion Works of the Alexandroupolis Harbour (NE Aegean Sea)

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ABSTRACT

The aim of this study is to examine the bathymetric changes of the coastal zone surrounding the harbour of Alexandroupolis, in relation to its successive expansions between 1960 and 2004. Qualitative and quantitative assessments of the bottom relief changes have been based upon the comparison, with the use of GIS, of the hydrographic charts published in 1960, 1973, 1987 and 2004 by the Hellenic Navy Hydrographic Service. Sampling and analyses of the surficial bottom sediments were used to study the sedimentological properties of the nearshore bottom. The results show that the area is characterised mainly by fine-grained sediments, originating from the River Evros, whose active delta area is located 15 km to the east of the harbour, and secondarily by sediments transported by the wave action and the nearshore patterns of water circulation. Bathymetric changes (accretion and/or erosion), ranging from -70cm to +40cm, are associated with the expansion of harbour breakwaters and the reduction of sediment supply by the Evros River.

Keywords: Alexandroupolis, harbour, bathymetry, sediments.

ΠΕΡΙΛΗΨΗ

Σκοπός της παρούσας μελέτης είναι η εξέταση των γεωμορφολογικών και βυθομετρικών αλλαγών της παράκτιας ζώνης γύρω από το λιμάνι της Αλεξανδρούπολης, σε σχέση με τα στάδια επέκτάσης του, από το 1960 μέχρι το 2004. Η ποιοτική και ποσοτική εκτίμηση των μεταβολών του υποθαλασσίου αναγλύφου έχει βασιστεί στη σύγκριση, με τη χρήση του GIS, των χαρτών της υδρογραφικής Υπηρεσίας του πολεμικού Ναυτικού των ετών 1960, 1973, 1987 και 2004. Για τη μελέτη των ιζηματολογικών ιδιοτήτων έλαβε χώρα δειγματοληψία και ανάλυση των επιφανειακών ιζημάτων του πυθμένα. Σύμφωνα με τα αποτελέσματα η περιοχή χαρακτηρίζεται από λεπτόκοκκα ιζήματα, προερχόμενα κυρίως από τον Έβρο ποταμό, του οποίου το ενεργό δέλτα τοποθετείται 15km ανατολικά του λιμανιού και δευτερευόντως από τη κινητοποίηση ιζημάτων λόγω της κυματικής δράσης και της παράκτιας κυκλοφορίας. Οι βυθομετρικές αλλαγές (απόθεση ή διάβρωση) σχετίζονται αφενός με την επέκταση των λιμενοβραχιόνων και αφετέρου με τη μείωση της παροχής υλικού από τον ποταμό Έβρο.

Λέξεις κλειδιά: Αλεξανδρούπολη, λιμάνι, βυθομετρία, ιζήματα.

1. INTRODUCTION

In 1870 the present harbour of Alexandroupolis was a small piscatorial shelter. Since the 1950s it has been developed further, due to its national and international socio-economic significance, with the aim of becoming the principal commercial harbour in the NE Aegean Sea, serving not only NE Greece but also the surrounding Balkan countries.

However, the construction of ports and harbours in sandy coast zones has often proved to

SEABED MORPHOLOGICAL CHANGES RELATED TO THE EXPANSION WORKS OF THE ALEXANDROUPOLIS HARBOUR (NE AEGEAN SEA)

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be problematic. As early as 1934, E.R. Matthews stated that: "The construction of harbours upon a sandy coast is always risky, resulting in no end of trouble and expense... The interference with the natural sand-travel upon a coast cannot but be injurious; the breaking of any of Nature's laws has a detrimental effect" (Komar, 1983). Well known examples of such problems come from the Madras harbour, at the east coast of India and from Santa Barbara, in California (Komar, 1983), whilst a more recent example is that of the New Damietta harbour at the Nile Delta, in Egypt (Asmar & White, 2002).

The scope of the present investigation is to assess qualitatively and quantitatively the coastal and seabed morphological changes caused by the successive seaward extensions of the harbour breakwaters of the port of Alexandroupolis between 1960 and 2004.

2. STUDY AREA

The study area extends 5 km on either side of the harbour of Alexandroupolis from the shoreline to the bathymetric contour of 15 m (Figure 1). The Gulf of Alexandroupolis is located on the inner continental shelf of the NE Aegean (Samothraki Plateau). The seabed relief is smooth with very low gradients (<1%) extending several kilometres offshore.

The seabed consists of fine-grained sediments, showing a zonal distribution parallel to the coastline and fining seawards (from sand to clay). The shore zone consists primarily of sandy material whilst in places east to the harbour includes low-relief sandy bodies. Relict sand deposits cover the largest part of the outer continental shelf (Pehlivanoglou, 1995 and Pehlivanoglou et al., 2000). The harbour area is at a distance of 15 km west of the mouth of the River Evros, which transports annually some 3.2×10^6 tonnes of sediment (Pehlivanoglou, 1989), functioning as the main source of fine-grained sediment for the area. The gulf of Alexandroupolis is exposed to waves caused predominantly by S and SW winds, whilst the dominant direction of coastal sediment transport is E to W, especially for the region to the east of the harbour (Pehlivanoglou, 1989).

Wave heights induced by average wind speeds (4-5 B) are in the order of 1.3 m, reaching 5 m during storms (Athanasoulis & Skarsoulis, 1992); these waves are expected to break in water depths of about 2.5 m and 6.5 m, respectively, being also capable to resuspend the surficial bottom sediments (Karditsa, 2006). Offshore circulation is controlled by the Samothraki anticyclone.

3. METHODOLOGY

The study of the bathymetric changes of the gulf of Alexandroupolis, focusing on the area surrounding the harbour, was based on the comparison of bathymetric charts of scale 1:10,000, which were produced and published by the Hellenic Navy Hydrographic Service (HNHS) in 1960, 1973, 1987 and 2004. The charts were digitised and imported into a GIS (ArcMap 8.3) and a digital elevation model (DEM) of the sea bottom was constructed for each chart. Successive charts were compared to each other, by subtracting each DEM from the previous one, with the use of the GIS function named "cut and fill" and three differential surfaces were computed, representing the bathymetric changes in the vicinity of the harbour. The total error, due to digitisation, registration and surface fitting, was estimated to be less than ±10-15cm for any point of the differential surfaces. It is assumed that the original bathymetric charts are of similar accuracy and free of any systematic errors, so that no additional errors are induced in the computation of the differential surfaces. This is a reasonable assumption, taking into account that all charts are of the same scale, produced by the same organization and depict a harbour area and its vicinities, where extra care is taken in the preparation of bathymetric maps. Consequently, bathymetric changes in excess of ± 15cm are considered significant in this study.

The morphodynamic study includes topographic cross-sections in combination with sediment sampling and geomorphologic observations in the coastal areas on either side of the harbour. Grain size analyses have been carried out at the Laboratory of Physical Geography and the results are presented according to Folk's (1974) methodology.

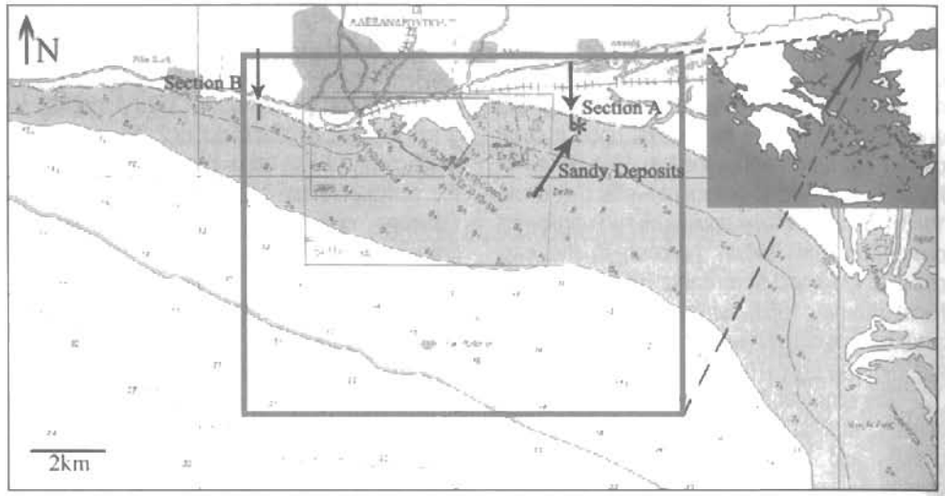

Figure 1: Exerpt of the hydrographic chart XEE 64 (3221) (HNHS, 2003) showing the study area (boxed) and the locations of cross sections A and B of the sandy deposits (described in the text).

4. RESULTS AND DISCUSSION

The eastern coastal zone is almost horizontal, characterised by very low gradients (0.3%) as shown in Figure 2. The nearshore bottom along section A consists of sand, whilst the subaerial part of the beach, as well as the trough landwards of the breaking zone (water depths about 1.5 m) consist of coarser material ((g)S-gS). In addition, extensive (>150 m long, 2-5 m wide) shore-parallel sandy deposits are present within the swash zone, in the form of emergent longitudinal bars, incipient barrier islands and spits (Figure 3). Their formation is most likely the combined result of the westward transport of sediments supplied by the River Evros, the on-offshore transport due to heavily refracted waves and the fluctuation of sea level due to astronomic and meteorological tides.

On the western side of the harbour, the overall bottom morphology appears to be much steeper and irregular (see section B, in Figure 4) in comparison to the shore zone to the east of the harbour. Here, gradients are about 2-3% with the characteristic presence of two long-shore bars at water depths of 0.5-1 m and 1.5 m and at a distance of 40m and 190m from the shoreline, respectively, separated by a trough where water depth exceeds 2m. The subaerial part of the shore zone consists of gravely sands, whilst the nearshore zone consists of gravely and slightly gravely sand. At distances greater than 200 m from the shoreline sand-sized sediments are the dominant seabed material.

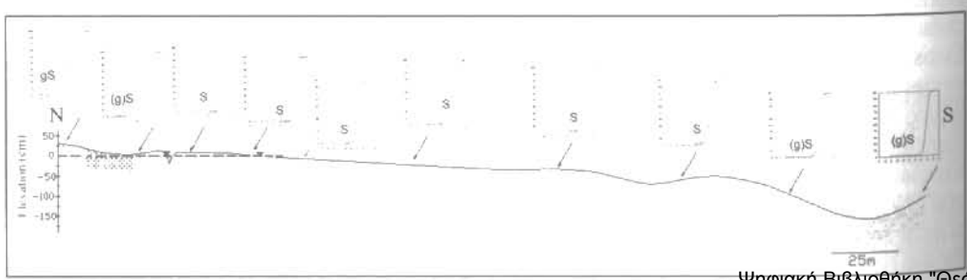

Figure 2: Beach and nearshore bottom morphology and grain size characterisation according to Folk (1974) along section A, to the East of the harbour (for location see Fig 1) (s stands for sand, g for gravel).

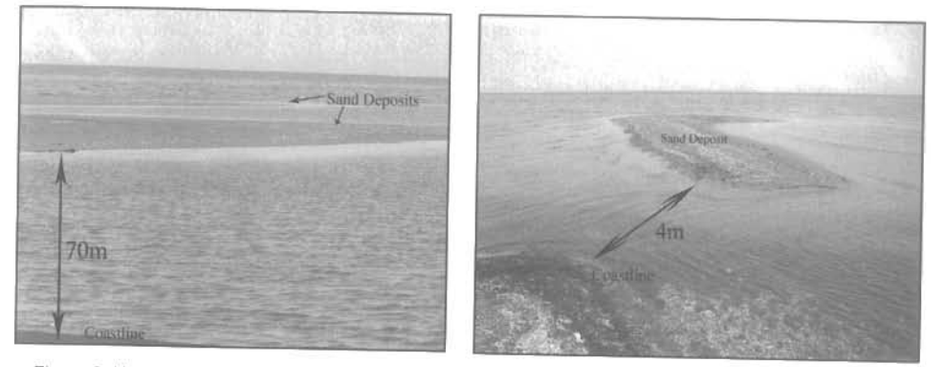

Figure 3: Nearshore sandy deposits, to the east of the harbour (for location see Fig.1).

The increased bed gradients, comparatively to the east side, together with the reduced presence of fine-grained sediment close to the shoreline, indicate the presence of erosional processes at the west side of the harbour.

The above observations and results are in agreement with the study of Xeidakis et al. (2006), according to which the coastal zone to the west of the harbour of Alexandroupolis is under erosion, whilst the east side is under accretion with almost horizontal nearshore bottom.

The bathymetric changes of the whole study area, related to harbour works, are shown schematically in Figures 5, 6 and 7. In all figures, the harbour area has been excluded from the calculations so that changes related to harbour works, such as breakwater expansions and dredging, will not be taken into account. Thus, by comparing the bathymetric charts of 1960 and 1973 (Fig. 5) it is evident that the area to the west of the harbour is characterised, mainly, by deposition (40cm), with some erosion present very close to the shoreline. In contrast, on the east side of the harbour a zone of erosion is observed, extending up to a water depth of 7m; most probably, this has been caused by the reduction of sediment fluxes of the River Evros, following dam constructions in the 1950s and 1960s. According to our calculations, the water depths in the nearshore zone have increased by 20-70 cm, whilst some deposition (up to 40 cm) has occurred further offshore and adjacent to the east breakwater of the harbour.

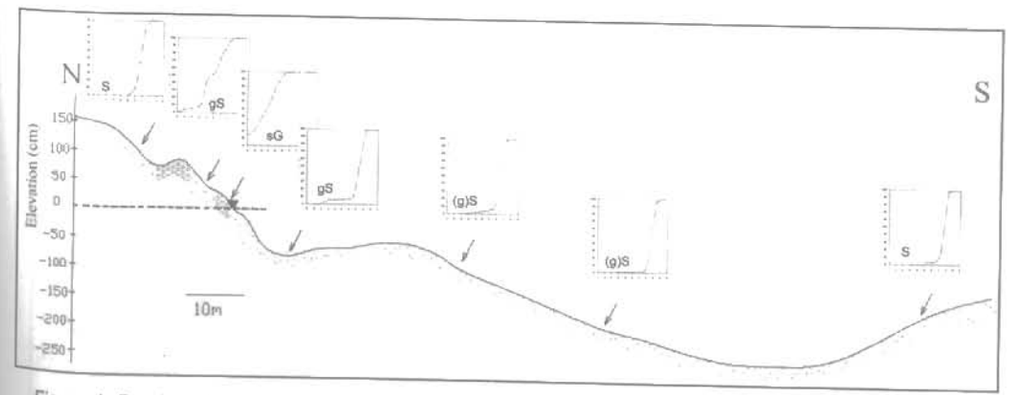

Figure 4: Beach and nearshore bottom morphology and grain size characterisation according to Folk (1974) along section B, to the west of the harbour (for location see Fig. 1) (s stands for sand, g for gravel).

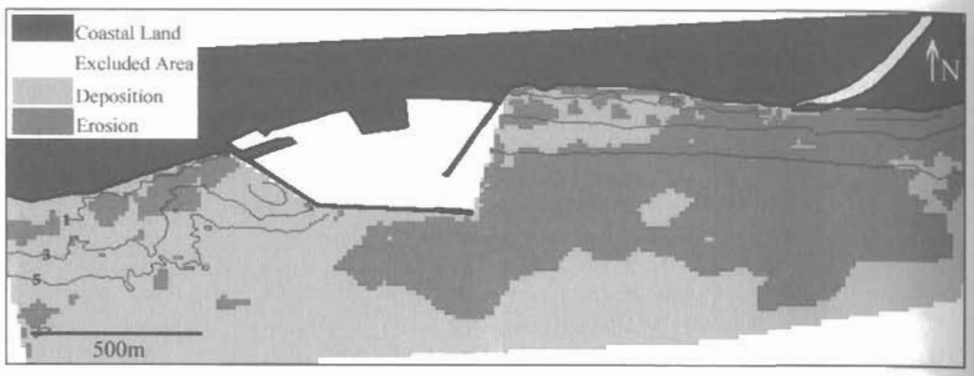

Figure 5: Bathymetnc changes obtained by comparison of the hydrographic charts of 1960 and 1973.

The comparison of the bathymetric charts of 1973 and 1987 (Fig. 6), shows that there are no extreme bathymetric changes in the study area during this period, which is characterised by further (but less intensive) erosion, as water depths have generally increased by approximately 10-20 cm, whilst the sporadic patches of deposition (decreased depths) are of the order of a few mm and, therefore, considered to be negligible.

Following the completion of the harbour works in 2004, the dredged harbour basin and the associated navigational channel have water depths between 6m and 7m. The comparison between the charts of 1987 and 2004 (Fig. 7) shows that after the last expansion of the harbour and the seaward extension of the harbour breakwaters (today, the W breakwater, directed to the ESE, has a length of 2 km), the depths outside the harbour have increased by approximately 50cm. This erosion is obviously related to the nearshore hydrodynamics which, after the harbour expansion and the new transport pathways, tend to redistribute sea bed sediments, trying to establish a new hydrodynamic and morphodynamic equilibrium in the area.

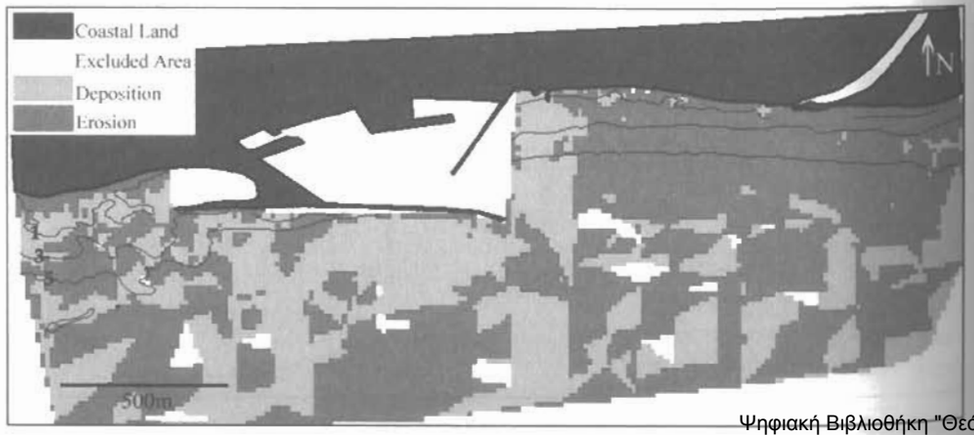

Figure 6: Bathymetric changes obtained by comparison of the hydrographic charts of 1973 and 1987.

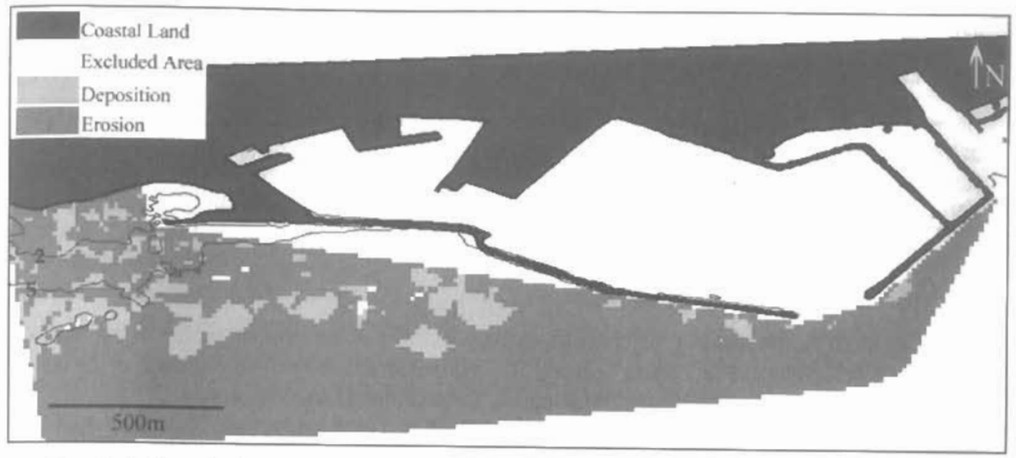

Figure 7: Bathymetric changes obtained by comparison of the hydrographic charts of 1987 and 2004.

5. CONCLUSIONS

The observed bathymetric changes, ranging from -70cm to +40cm, around the Alexandroupolis harbour, are mainly associated with the shallowness of the inner shelf, the proximity to the mouth of the River Evros and the presence of fine-grained sediments that are resuspended and redistributed by the waves and the wave-induced nearshore currents. On the basis of the above, it seems that the position of such a large harbour is rather unsuitable and its operation problematic, at least from a sedimentological and geomorphologic point of view.

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