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ANTHROPOGENICAL EFFECTS ON THE PROCESSES IN THE GÖKSU DELTA, MERSİN-TURKEY

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ABSTRACT.- The Göksu Delta, located on the Mediterranean coast in the South Anatolia, is the most significant wetland both in Turkey and Eastern Mediterranean region. The delta environments present suitable reproduction and living conditions for large numbers of continental migratory birds and aquatic species under protection. The eastern shoreline of the delta has been retreating for the last fifty years, whereas recent mouth of the delta progrades toward the gorge of the lagoon. In addition, the lagoons are filled by deposits of crevasse splay, dune and barrier islands deposits by aeolian effects. Dynamic processes in the delta environment were investigated in detail, to explain the causes of retrograding and prograding of the shoreline of the delta and to find possible solutions. According to the data obtained, the natural fluvial system, the shoreline dynamics, and the aeolian processes in the delta have been changed by the anthropogenic effects. The persistence of the variation of the shoreline will cause significant ecological disruption of the delta.

Key words: Göksu delta (Turkey), retreating shoreline, prograding shoreline, delta dynamics, geomorphological units.

INTRODUCTION

The delta environments are indispensable fertile wetlands for reproducing and existing of many fauna and flora. Therefore, the conservation of natural balance at delta environments is crucial, being natural surroundings and wild living areas (Maltby, 1991; Erdem, 1995).

The Göksu delta having a promontory shape is the most significant wetland in the Eastern Mediterranean region (Figure 1). The coastal and lagoonal environments of delta are provided reproduction and development for large numbers of flora and fauna with suitable living conditions. 450 bird species were recorded in the Göksu Delta while 352 of them are included in Ramsar list. 12 of these bird species in the Ramsar list are prone-to-extinction. 140 of these have national and 106 of them have international significance. Marine animals such as *Collinactus papidus, Caretta caretta, Cheloniamydos monchos monchos* and *Epinephelus aneus* living in the delta are under protection. In addition, 441 plant species exist in the delta. 8 of these are endemic and 32 of these are rare (Gülkal 1992; Uslu 1993).

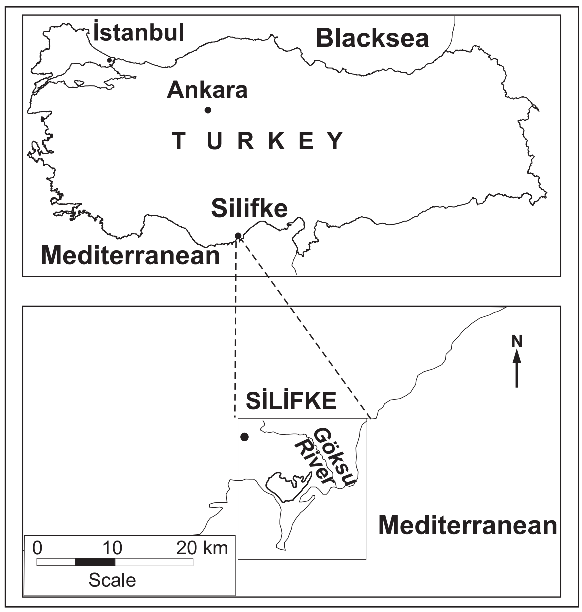

Figure 1- Location of the study area.

The Göksu delta covering an area of 165 km^2 presents a trapezoidal shape. The lithological units in the delta and its close vicinity are Devonian, Cretaceous, Oligocene and Miocene

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clastics and carbonates (Schmidt 1961; Gökten 1976; Gedik at al., 1979; MTA, 2002). Quaternary deposits unconformably overlie these units. Large Pliocene denudational and exhumation surfaces are distinguished as main geomorphological units on the basement lithologies. During Quaternary, some fluvial incisions and slopes have been developed on the former geomorphological units in the hinterland (Keçer, 2001).

The effects of the relative sea level changes on the evolution of the delta, the changes of shoreline, the Quaternary stratigraphy along the shoreline and the isobaths of shoreline are some of the examples of the studies carried out in the Göksu Delta (Çetin at al., 1999; Ediger at al., 1993; Erinç, 1978; Erol, 1991; 1993). The formation of the Göksu delta has started 5,000 yr BP and shaped in seven stages as stated by Erol (1993). It has started forming its first stage 3,000 yr BP and acquired its most recent shape during the mid-twentieth century (Erol, 1993; Çetin at al., 1999). Okyar and Ediger (1998) investigated Quaternary units using seismic method and prepared isobaths near the delta shoreline.

This paper, as dissimilar to previous researches, intends to explain the cause of the retrograding and prograding that has reached an important grade along the shoreline of the Göksu delta. For this purpose, the amounts of shoreline variation on the Göksu delta were determined from the topographical maps produced in different times and scales. The dynamic processes existing in the recent delta environments were investigated to clarify the reason why the variation of shoreline took place. The geomorphological units were first mapped in detail to recognize the processes. Then, the relations of the geomorphological units with fluvial, marine and aeolian processes were established in the delta environments. Finally, the reasons for the retrogradation and progradation along the shoreline of the Göksu delta were evaluated based on the findings. Also, the issue how could the wetlands, which are crucial for the fauna and flora living at the delta environments, be affected by the variations of the shoreline was shed light on.

METHODS

The studies were realized in four main stages such as: (1) determining the amount of the variations along the shoreline using maps produced at different dates; (2) aerial photo (1/35 000 scale) analyses for mapping the sedimentary environments; (3) field examination of different sedimentary environments determined by aerial photographs and; (4) evaluation of the data collected.

Vertical black-and-white aerial photographs of medium scale (1/35 000) were interpreted to identify recent geomorphological units. The topographical maps at 1/25 000 scale prepared in between 1961-1995 were used to determine the variations of the shoreline of the delta. For this purpose, the maps were digitized using the on-screen methods for shoreline data input by Arc/Info geographic information system (GIS). The maps were scanned with the resolution of 350 dpi and georeferenced to the UTM coordinate system. The total root mean square (RMSE) errors were kept less than 0.005 in (=0.127 mm) which is equivalent to 3.175 m ground resolution at 1/25,000 scale. Besides, the 1/5 000 scale cadastral maps produced by local municipality were used to verify the variations along the shoreline of the eastern part of the delta. On the other hand, 1/250,000 scale topographic maps prepared in between 1945 and 1927 were utilized to locate the watercourse of the Göksu River before 1945.

RECENT VARIATIONS ALONG THE SHORELINE OF THE DELTA

The variations of shoreline of the Göksu delta in the 20th century were investigated by Çetin et al. (1999), using aerial photographs and satellite images. The researchers drafted and measured the variations amount along the shoreline around recent mouth and İnceburun. However, they only mentioned the variation of the eastern shoreline of the delta. According to these researchers, the progradation around the recent mouth of the delta occurred maximum 700 m long and covering approximately an area of 0.4 km^2 between 1951 and 1995.

In this paper, the dimensions of the retrogradation along the eastern shoreline of the delta were determined to evaluate changes of shoreline of the whole delta. According to 1/25,000 topographic maps prepared in 1961-1995, the eastern shoreline was retrograded in nearly 13 km long section under the control of the marine dynamics (Figure 2). The measured maximum retrogradation is 380 m long in this area. The spatial distribution is of 0.77 km^2 as well. At the same time, the changes along the eastern shoreline of the delta were investigated by means of the maps which were prepared at different times at 1/5,000 scale by the Municipality of Altınkum and İller Bankası. According to these cadastral maps, on 17 September 1969, 16 August 1983, 08 December 1991 and 28 August 1999, the shoreline was retrograded 170 m, 70 m and 74 m respectively and in total 314 m (Figure 3).

Using the same method, the progradation and retrogradation were re-measured for the years 1961-1995 around the former and recent mouth of the Göksu River using 1/25, 000 scale topographic maps. The whole prograded area which is

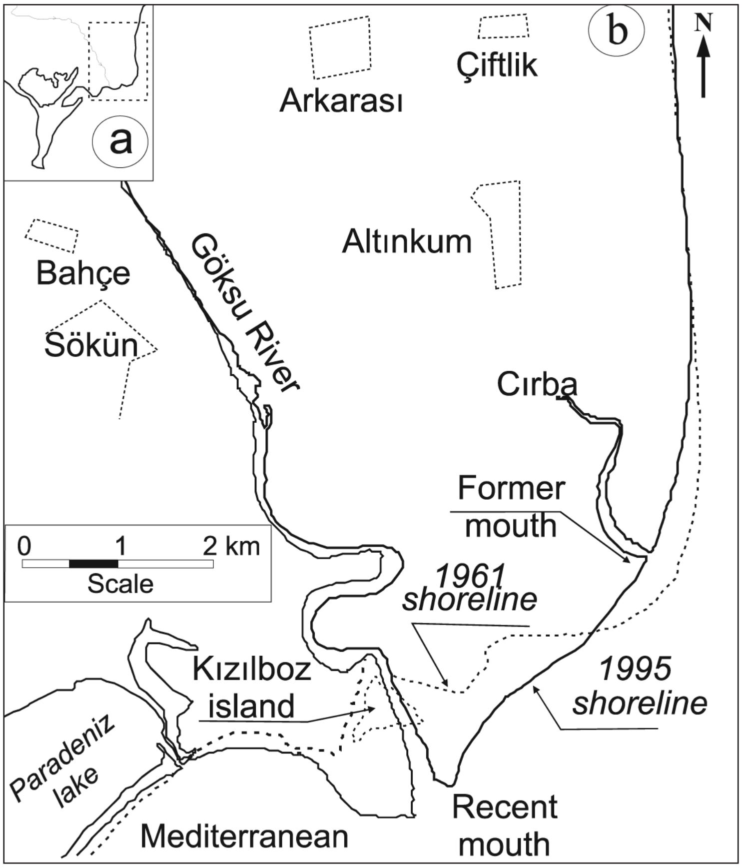

Figure 2- The variations of the shoreline in the Göksu delta. (a) The Göksu delta. (b) Progradation and retrogradation in the delta. The dotted and simple lines represent 1961 and 1995 shorelines, respectively.

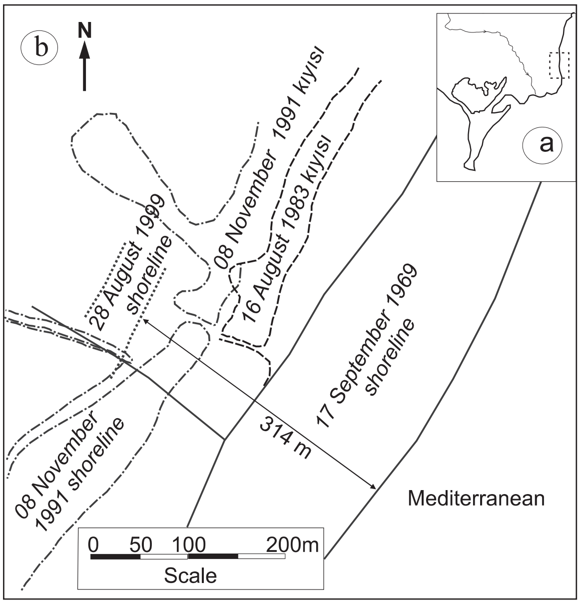

Figure 3- (a) The Göksu delta. (b) Retrogradation along eastern shoreline in the delta. The shoreline retrograding defined using 1/5 000 cadastral maps along eastern shore of the delta between 1961 and 991

effective in an area of 2.24 km^2 in the delta was identified (Figure 2). The progradation and retrogradation, which occurred during last fifty years, are found around the recent mouth and eastern shoreline of the delta. Therefore, to explain the causes of progradation and retrogradation along the shoreline of the delta, recent geomorphological formations and dynamic processes were investigated.

GEOMORPHOLOGICAL UNITS

In order to understand the recent processes in the delta, the geomorphological units present in the delta area were mapped in detail (Figure 4). These units were differentiated as five groups as fan, fluvial, aeolian, lagoonal and marine deposits. The fan deposits, which were derived from hinterland and carried by the tributary creeks to the delta, consist of semi-rounded block, pebble, sand, silt and rarely clay. The fluvial deposits formed by the Göksu River are differentiated as terrace deposits (QFt), levee deposits (QFl), flood plain deposits (QFfp), back march deposits (QFbm), ox-bow lake and cut meander deposits (QFo) and channel deposits (QFc). The aeolian deposits are dunes, which are transported from beach and former costal barrier deposits. Lagoonal and marine deposits are quite complicated at the Göksu delta. The main units of these are coastal plain deposits (QMcf), marine beach deposits (QMb), former coastal barrier deposits (QMfcb), lagoonal coastal plain deposits (QMlc), lagoonal swamp deposits (QMlm) and former lagoon deposits (QMfl).

The geomorphological units mapped in the delta have been formed as a result of the fluvial, marine and aeolian processes. The active processes that continue on the delta can be transformed to ineffective processes. In this situation, the dynamic processes are exchanged for another and the environments were transmitted to effect of a new dynamic process. So, main erosional and depositional processes of fluvial, marine aeolian, which have significance effects at the delta, are explained below.

Fluvial depositional and erosional processes

The Göksu River is the main factor for the formations in the delta environments. The river performs its basic functions (depositional elements) between levees located on both flanks of the river. The flat-lying levees parallel to the river are asymmetric natural levees. Except for the times of flood, the Göksu River maintains its erosional and depositional processes between the natural levees. From Silifke to the shoreline, the levees with abandoned beds and ox-bows in between are situated (Figures 4 and 5). These relicts of the former beds are observed between the two levees of the Göksu River, getting wider toward the Mediterranean Sea (Figure 4). During the floods, the Göksu River tears the natural levees and transports fine material to the flood plain,

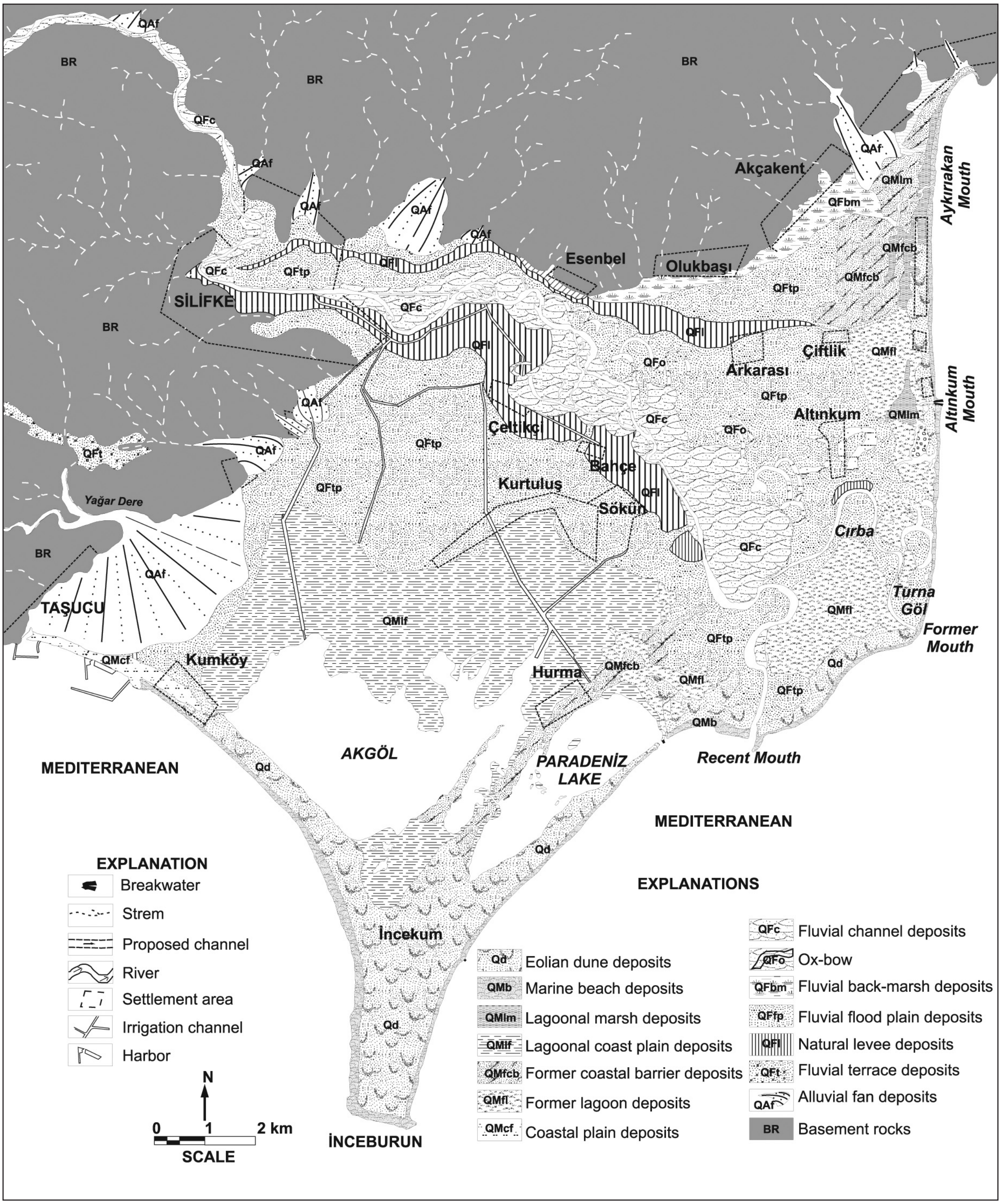

Figure 4- The map of the Quaternary deposits in the Göksu delta

lagoonal costal barrier, former and recent lagoons by the crevasse splay. Small size deposit fans with a smooth morphology were formed as a result of this process. The dendritic pattern drainage such as gully is observed on these fans.

Marine depositional and erosional processes

The fluvial material carried by the Göksu River was transported and deposited by the marine activities from both flanks of the mouth as the depositional marine units. Frontal-coast barriers or barrier islands and mouth barrier deposition units lying parallel to the shore were formed as a result of this process. There are two diverse barrier islands that belong to recent and former sea level at the delta.

The old ones have formed depending on former sea level rising and drowning. The most evident barrier island was divided into three parts by two inlets at Çiftlik region (Figure 4). The other barrier island of the same period was situated between Paradeniz and Akgöl lagoons, like a coastal cord. This barrier island lies parallel to the coast between the Göksu River and İncekum and is separated by an inlet, at the northeast of Paradeniz. Another old barrier island having a concave shape and lying between Kumköy and İncekum formed as a result of the transportation of the material by Yağar Stream in SE direction. The younger barrier island was formed by the current sea level as a continuation of the beach. It is flat and leans against the former barrier island. It is discriminated from the former ones by having coastal dunes.

The marine erosional units are gorges between barrier islands, escarpments on the shoreline, erosions along the beach of the storm waves, and the destructive effect of marine currents on the breakwater roots.

Aeolian depositional and erosional processes

The sands, which belong of the former and younger barrier islands and beach in the delta, have formed the coastal dunes by moving in two directions with aeolian effects. The movement direction of the dune between the Cırba Mouth and Kumköy is from southwest to northeast while the other is from northeast to southwest (Figure 4). This area extends from Aykırıakan to the abandoned beds located around the east of Altınkum. The source for coastal dunes is former coastal barriers and current beach sands. The costal dunes in the direction of the recent lagoon, former lagoon and back-marsh have steep slopes, but toward the sea they have gentler slopes. Some of these dunes are active, while the other ones are fossilized.

ANTHROPOGENIC EFFECTS ON THE NATURAL DYNAMICS

Corresponding to the abandoned beds and ox-bows, the Göksu River flowed between Çiftlik and Cırba, and drained into Mediterranean Sea from the eastern shore of the delta. However, the recent mouth of the Göksu River is located around Paradeniz Lake in the south. The variations of the Göksu River mouth occurred about 1950s have been determined from the topographic maps printed between 1927 and 1995 by the General Headquarter for Mapping of the Turkish Army (HGK). The Göksu River drained into the Mediterranean Sea from Cırba (former) mouth based on the 1/250 000 scale topographic maps printed in 1927 and 1945. But, according to the 1/25 000 scale maps printed from 1961 on and aerial photographs taken from 1956 on the Göksu River drains its waters into the Mediterranean Sea from the new mouth close to the Paradeniz Lake.

According to the geomorphological units that were investigated in detail and by recent dynamics processes, the changes of the river mouth did not occur naturally. In the delta, the Göksu River flowed between the levees located its either two side, which is obvious from the abandoned channel and ox-bow lakes. There is no other geomorphological data showing that the Göksu River flowed outside of the natural levees.

Although the date is not definitely known the Göksu River was artificially diverted to the new mouth from the its former mouth (Cırba). According to the local people, this diversion of the Göksu River mouth was made in 1952. Another possibility for this diversion might be that when the river was forced to flow out of its original bed and forced to flowed linearly by human activity from the northeast of Sökün in 1955 (Figure 4).

This diversion that is made in 1950s caused a number of changes in the delta environments. The river tears the natural levees in the flood seasons because of the thalweg of the river increased due to the forcing to linear flow of the river for a 4.5 km distance to southwest from former mouth. At the new progradation point, a new asymmetric delta lobe formation began with the sediments that are transported by increased energy and a higher flow rate of the river in the SW direction (Figure 5). The geometry of the lobe is also obvious on the bathymetric chart (Okyar and Ediger, 1998) of the delta area. During these processes, Kızılboz Island existing near the recent mouth was connected to the coast and a new coastal barrier has been formed at the shore.

In the event that persistence of the lobe formation will cause a risk to close of the mouth of the Paradeniz lagoon. If this lobe formation maintains, the inlet of the Akgöl located more to northeast, as a former lagoon and temporary lake, will be either closed or displaced as well. This situation will cause significant ecological degradations and decreasing the effect of the sea on the Paradeniz lagoon and Akgöl.

The coastline is being changed by SW trending marine erosion, which become predominant by ceasing the fluvial transportation at the former progradation area (Cırba mouth, Turna Lake, Aliağa Lake, and the coast to the breakwater at North). In this area, under the control of marine dynamics, the shoreline has retrograded in the last three decades along approximately 13 km part of the shore. In the event that preventative measures are not taken, the progradation will reach 1.2 km close to Altınkum and up to the linear line where is from the 2 m altitude point located eastern side of the river mouth to Ayıkıran.

On the other hand, the vegetation of the barrier islands and dunes has been destroyed by human activity and by excavations for taking aggregates. Because of these, the barrier islands, which have very important role in forming and keeping position of the lagoons, have been damaged by aeolian erosion. The materials moving with aeolian effects from the barrier islands and dunes have been deposited in the former lagoons. In case of flood of the Göksu River forced to linear flow, the conduit crevasse has been transported the materials to the former lagoons. The wetlands are being filled by these materials transported and transformed into terrestrial area.

The beaches are protected by means of the barrier islands. Destructions of the barrier islands by aeolian effects result in damage of beach sand by the waves. In addition, the draining channels constructed during the reformation in the delta flow into Akgöl and Paradeniz Lagoon. The sediments and chemical waste derived from agricultural areas are transported by the draining channels to these lakes.

DISCUSSION AND CONCLUSION

The effective directions of the marine current are different at the shore of the Göksu Delta (Okyar and Ediger, 1998). The dominant marine currents are clockwise at the eastern shore of İnceburun, while they are counterclockwise at the

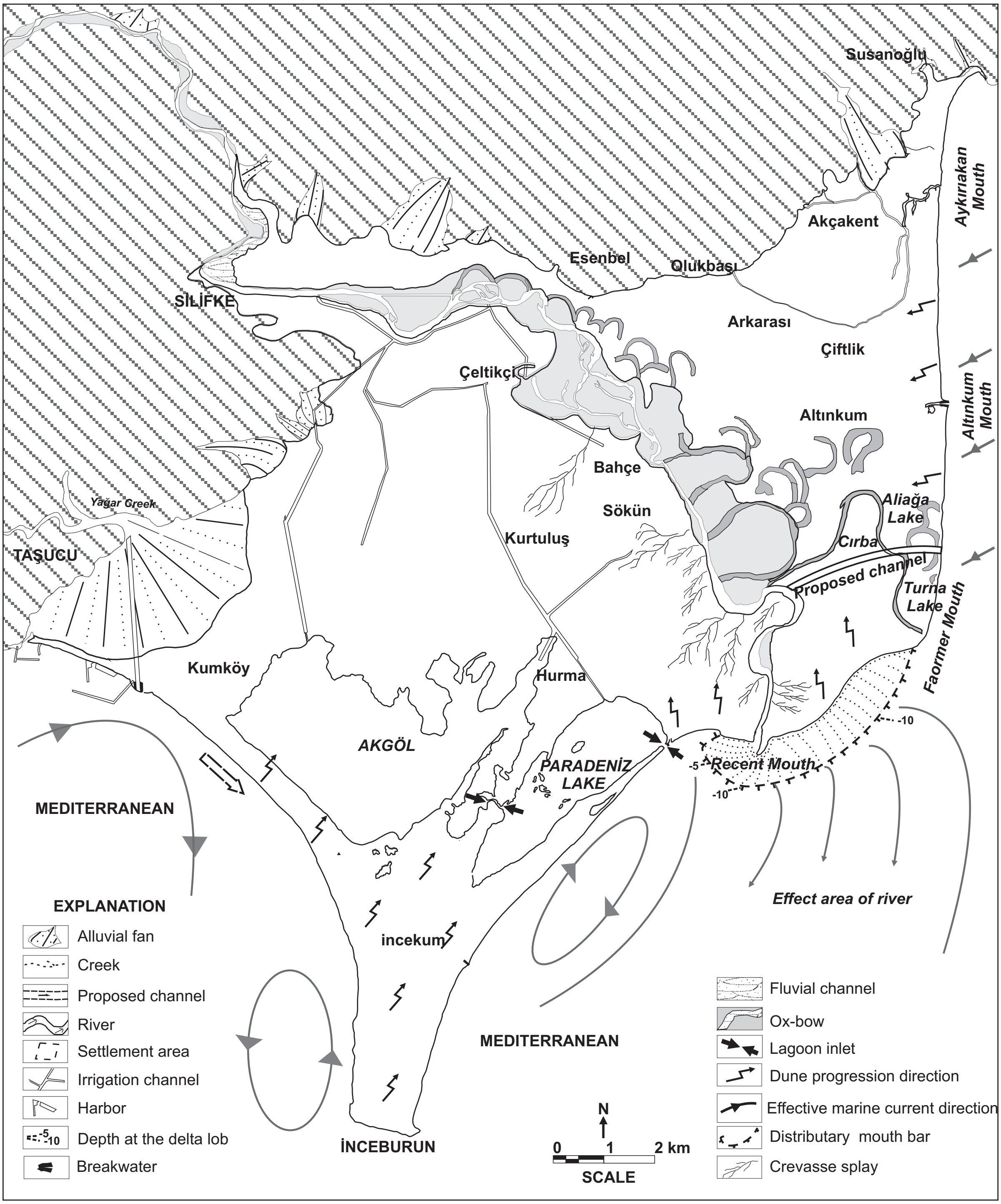

Figure 5- The natural dynamics processes in the Göksu delta. Marine currents directions from Okyar and Ediger (1998)

western shore of the delta (Figure 5). The dominant currents at the eastern and southern shore are toward southwest and clockwise parallel to the shore, respectively. The Göksu River is the source of the dynamics of the fluvial erosion and deposition in the delta environments. The river continues its activity within the bed fan-shaped widening towards southeast at the delta (Figure 4).

The Göksu River and the currents of shore have basic agents for developing unique shape and natural balance of the Göksu Delta. The Göksu River was flowed within the levees towards southeast during its natural process. This is also evident on traces left by the river flowed between natural levees (Figure 4). The river transported the sediments to the eastern shore of the delta during its natural process. These transported sediments were processed by southwest marine currents and formed barrier islands. The barrier islands that formed in different times were played significant role to shape and form both Paradeniz Lake and İnceburun. The reverse currents each side of the İnceburun was simultaneously assisted to gain the special feature of the delta as well. This system has been destroyed due to anthropogenic interference to the natural processes of the Göksu River bed. The eastern shoreline of the delta has been retreated more then 350 m while the shoreline has been propagated about 700 m around recent mouth of the river. The persisting of the propagation 15 m/year in average will be resulted in a risk to close the inlet of the Paradeniz lagoon.

It is now accepted that the delta environments is crucial for many fauna and flora. In this context, taking into consideration of protecting the shore, marshy areas and agricultural places, land use planning studies have been carried out by local government. The status of first-degree natural preservation of the delta area was declared.

Besides the protecting and planning studies of the delta, the rebuilding of the natural equilibrium at the delta is indispensable condition. For this reason, the natural dynamics processes of the delta should be again provided. For this purpose, the Göksu River should be taken on an artificial channel starting from Cırba segregation and reaching to the sea at Aliaga Lake region and flowing towards the former delta progradation of the river should be again provided (Figure 4). So, this region of the delta becomes from retrogradation into progradation in character by its natural processes. Therefore, recent mouth can be prevented because of the deposition at the current mouth. Also, the formation of the lobe will be ended, developing close the mouth of the Paradeniz Lagoon. In addition, transportations of the materials to the lagoons by crevasse splays will be reduced and filling of the lagoons by these deposits will be ended.

The bed of the Göksu River, which will be abandoned southern from starting point of the artificial cannel, can be transformed into wetlands being the water of river under the control and can be used as a 4 km-length fish trap. Bringing to a stop of taking aggregate material from the beaches and barrier islands and growing plants suitable for the ecosystem on the dunes can be also provided stability.

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