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Physiographic study of Shatt Al-Arab Delta South of Iraq by Application of Remote Sensing Technique

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Abstract - The Shatt Al-Arab River is formed by the confluence of the Tigris and Euphrates Rivers near Qurna 75 km, Basrah Governorate, approximately 75 km north of the city of Basrah, southern of Iraq. Satellite images of Landsat 7 ETM$^+$ for years 2000, 2002 and 2006 were processed with ERDAS Imagine 8.4 and ArcGIS 9.3. They were used to interpret the geomorphology of Shatt Al-Arab delta. Shuttle Topographic Radar Mission. Geomorphologic structures, suspended load distribution and lateral movement of the main channel are interpreted and three lobes are distinguished at the formative delta front, confirming lateral channel movement as the prime factor in the delta's formation. A westward deviation in the main channel of the Shatt Al-Arab River could divert into Abdullah Creek within a few years.

Key words: Physiography, Delta, Shatt Al-Arab River, Channel and Iraq.

Introduction

Deltas are considered as important sedimentary environment due to the huge quantity of sediments and a high sedimentation rate in comparison with other sedimentary environments. Climate is another important factor, due to its influence on the hinterland and consequent delivery of a notable quantity of sediments to the delta (Nichols, 1999).

The delta is directly affected by the sea level changes, where the draw down in sea level produces many bottom distributary channels that redistribute the sediments (Marisawa, 1985).

Recently, remote sensing is an essential tool to study in multidisciplinary of applied sciences; it involved in the study of the physiography of the delta and predicts the future geomorphology (Marisawa, 1985). The water in the channels during the ebb or flood period was studied by Bergé-Nguyen and Crétaux (2015). The flood water and inundation of successive years where studied by remote sensing technique to construct maps (Kuenzer *et al*., 2015). Al-Azawi (1996) made many geomorphologic maps of the Iraqi coast. Mobasheri (2008) studied the suspended sediments of Bahmeshir River near Shatt Al-Arab River, whereas, the Shatt Al-Arab River was studied and geomorphological maps classified by Al-Mulla (2005). Geomorphologic features of the surface between the Shatt Al-Arab River and Khor Al-Zubair were presented by multi maps (Al-Assady, 2005). Various maps of land use and land cover for the region were produced by Al-Ali (2007) and Al-Mawla (2014).

The aim of this present study was to make the physiographic maps of Shatt Al-Arab delta and the lateral shifting of its main channel over a 6-year period, from 2000-2006.

Study Area:

a. Hydrologic Settings:

The Shatt Al-Arab Delta is located at the northwestern head of the Arabian Gulf, bracketed by Mossa Creek (Khor Musa) to the east and Abdallah Creek (Khor Abdullah) to the west (Fig. 1). It has formed by the confluence of Tigris and Euphrates Rivers near Qurna, 75 km. to the north of Basrah Governorate. The Tigris and Euphrates Rivers pass through the marshes in the southern part of Mesopotamian plane; these marshes as well as upstream damming and irrigation offtakes act as a filter for sediments, and the sediment load of the river north the Karun River is very low (Abdullah, 1990). The majority of delta sediments budget has been derived from the Karun River, the last tributary of Shatt Al-Arab River, and the continuous erosion of the river bed and river banks (Albadran *et al*., 1995), and the erosion induced by the irrigation outlet branches of Shatt Al-Arab River. The Karun River supplies about 9,500,000 tons per year as suspended load, plus 85,000 tons of bed loads at the confluence of Shatt Al-Arab and Karun Rivers (Al-Manssory, 1996). The Karun River discharges about 52% monthly to the total discharge of the Shatt Al-Arab River into the Gulf. The measured annual quantity of bed load and suspended loads at the Shatt Al-Arab River mouth near Al-Fao is 9.460 and 0.167 million tons, respectively (Al-Manssory *et al*., 1998). The main constituent of sediment is silt of Karun origin; sand deposits in the delta represent periods of large discharge (Albadran *et al*., 1995) plus erosion and deposition during a regression period (Albadran, 1995). The third constituent of sediments is a clay fraction composed of quartz, feldspar, carbonates and clay minerals. The tide regime in the area is a semi-diurnal, affected by a mixed type (Al-Ramadhan and Pastour, 1987). The climate of this area is arid, and the evaporation rate is higher than the precipitation rate (Abdullah, 1990). The temperature in July, August and September reaches more than 48 $^{\circ}$C (Al-Mulla, 2005), and reaches annual lows during December, January and February 18 $^{\circ}$C. Prevailing winds are from north and northwest (Abdullah, 1990), and affect water current velocity, distribution of sediments and tidal range in the area.

b. Geologic Settings:

The size and shape of the Shatt Al-Arab Delta is constrained by its geographic situation, bracketed by Bahmasher Canal and Musa Creek in the east, and Abdallah Creek in the west, in addition to the gulf bottom trenches of Al-Khafga, Al-Umaya and Al-Rocka (Albadran, 2004). Another factor plays a role in the distribution of delta sediments is the anti-clockwise long-shore current (Al-Sharhan and Kendall, 2003). Albadran (2004) classified the Shatt Al-Arab Delta as a tide dominated delta with little influence of waves. Reker *et al.* (2006) stated that the surface area of this delta is 20,000 km^{2}, the coastal gradient is 0.14° and the annual subsidence was 2mm. The rate of delta development at Ras Al-Bisha was 3,000 m. between 1986 and 2004 (Al-Mahmood, 2006). The tectonism plays a role in the shape and size of the delta; which is located above the unstable shelf of Mesopotamian zone created by the collision of the Arabian and Euroasian plates during the Permian to Triassic, ending with the regression of Tethys Sea during the Oligocene and Early Miocene (Buday and Jassim, 1987). The Early Holocene period was characterized by rising of sea level of the deglaciation period. The effect of tectonism is marked in the area from the deviation of river courses (Al-Sakini, 1993). Kassler (1973) stated three major tectonic movements occurred from Pliocene to Recent.

Methods and Data

This study deals with the delta Shatt Al-Arab, situated in the southeast of Iraq (Fig. 1). The coordinates are between 29° 71′ to 30° 5′ N and 48° 27′ to 48° 46′ E. Satellite images of Landsat 7 ETM+ for years 2000, 2002 and 2006 were processed by ERDAS Imagine 8.4, including geometric correction, band combinations, spatial enhancement, radiometric enhancement, spectral enhancement, topographic analysis, and supervised and unsupervised classifications.

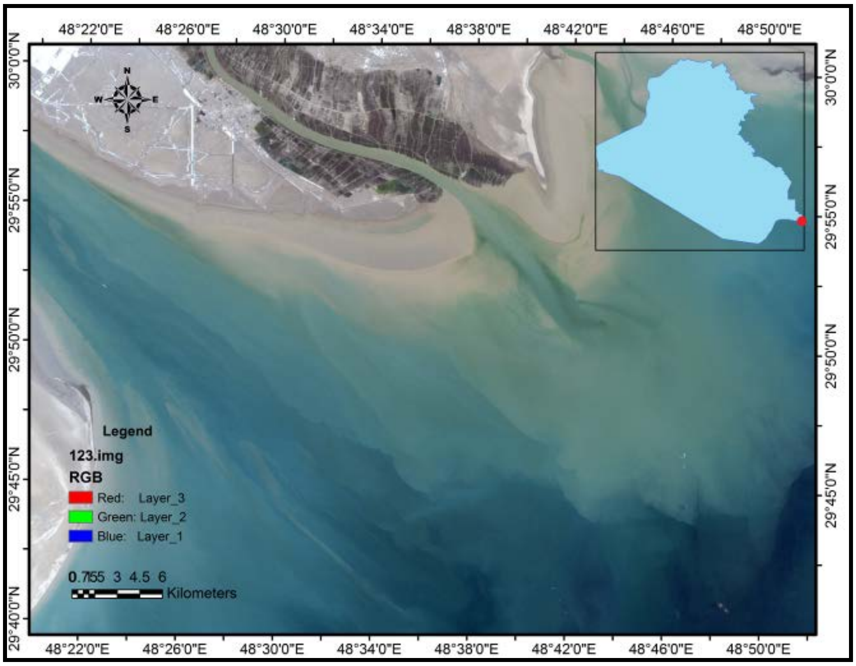

Figure 1. Location of study area.

Image Processing:

The international system of classification ITC oriented to obtain the morphometry through using different colors Land Use and Land Cover, Anderson USGS Classification was applied.

a. Supervised and Unsupervised Classification:

Supervised classification, isodata by ERDAS Imagine 8.4 software was applied to differentiate geomorphologic features of the delta. Sedimentologic spits in the southern entrance of Abdullah Creek, migrated channels, delta lobes, and suspended matter are clarified after mixing the blue, green and red bands (Fig. 2). The Shatt Al-Arab channel penetrates the Gulf with different suspended load concentrations, and supervised classification helps to differentiate these geomorphologic aspects. It also shows their future status, as indicated by appearance of new sedimentologic units. Unsupervised classification of visible bands of satellite image of 2006 (Fig. 3) highlights geomorphologic and sedimentologic changes.

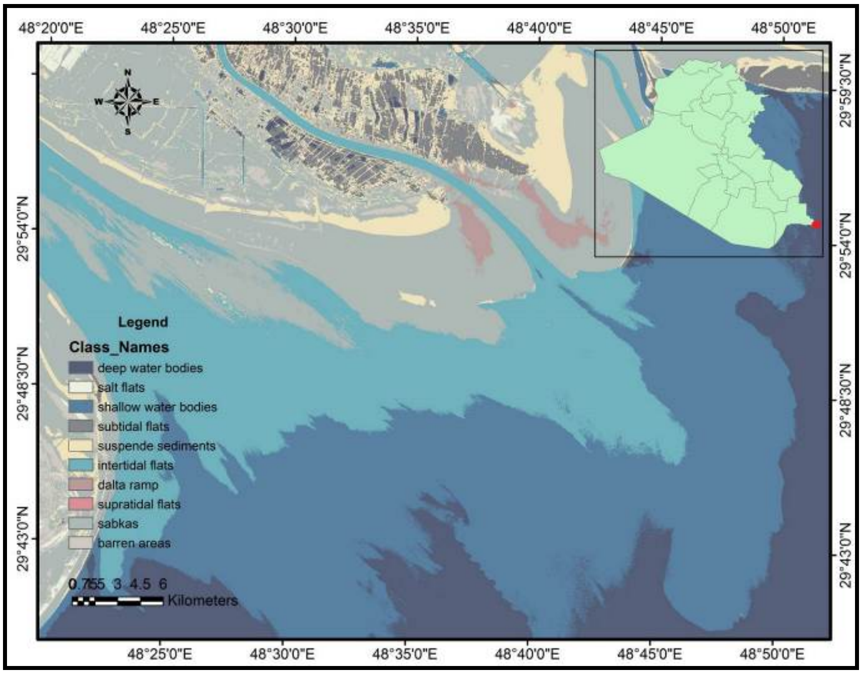

Figure 2. Supervised classification of delta landforms (Landsat 7 ETM+, 2002).

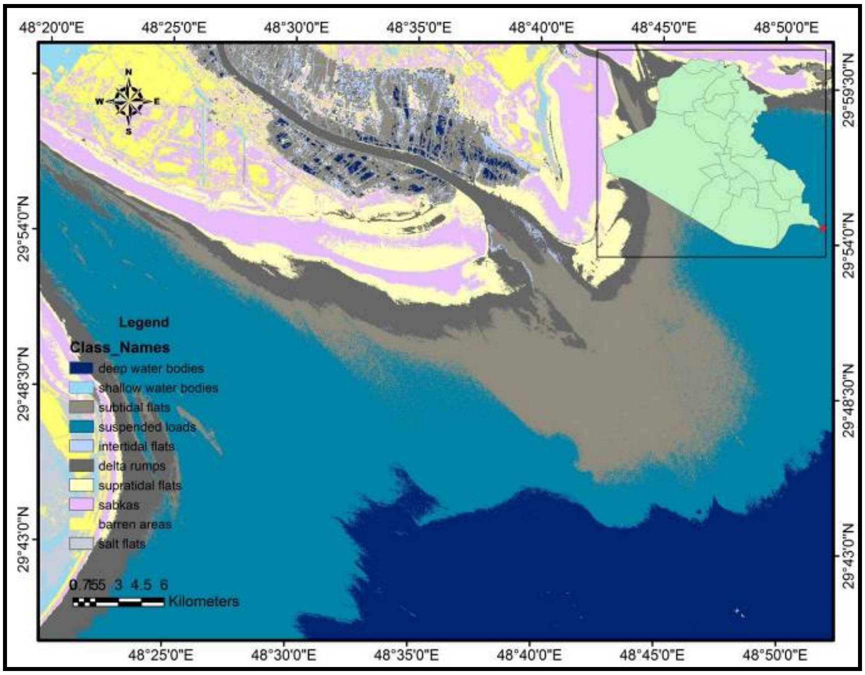

Figure 3. Supervised classification of delta landforms (Landsat ETM+, 2006).

b. Digital Enhancement:

The distribution pattern of suspended load around the mouth and southern entrance of Abdullah Creek appears in multi-layers of movement and deposition. Digital enhancement such as spectral and radiometric enhancements, besides making several band compositions shows the different of spectral signatures.

c. Band Combinations:

The application of supervised and unsupervised classifications of the satellite images of this study produce the same results (the same color ramps showing in both images). A good example is the band compositions of visible and infrared bands (2, 4 and 7) (Fig. 4), showing the distribution of the suspended load at the mouth of Shatt Al-Arab River. The coastal Sabkha is clear in the satellite images, which clarity is heightened after mixing the green band and infrared bands (Fig. 5).

Results and Discussion

The image should be during the ebb period at which the limits of the tidal flats are clear. These intertidal flats also appear in the satellite image by mixing visible bands with colors near to natural colors. Intertidal flats appear on both sides of Shatt Al-Arab River, and the topographic slope of sub-aqueous gullies was distinguished in the short infrared band (Fig. 6). These parallel gullies run approximately perpendicular on the shoreline. It also appears in the subtidal zone, a result of interaction of many factors of the sedimentation process (Reading, 1987). The gullies are longitudinal along the trend of the channel, and continue to Abdullah Creek and the front of the delta. The lithology of the sub-tidal flats could be clayey where the gullies are clear. These physiographic features are clearer after the merge of topographic profile image of the near infrared band with visible bands (Fig. 6).

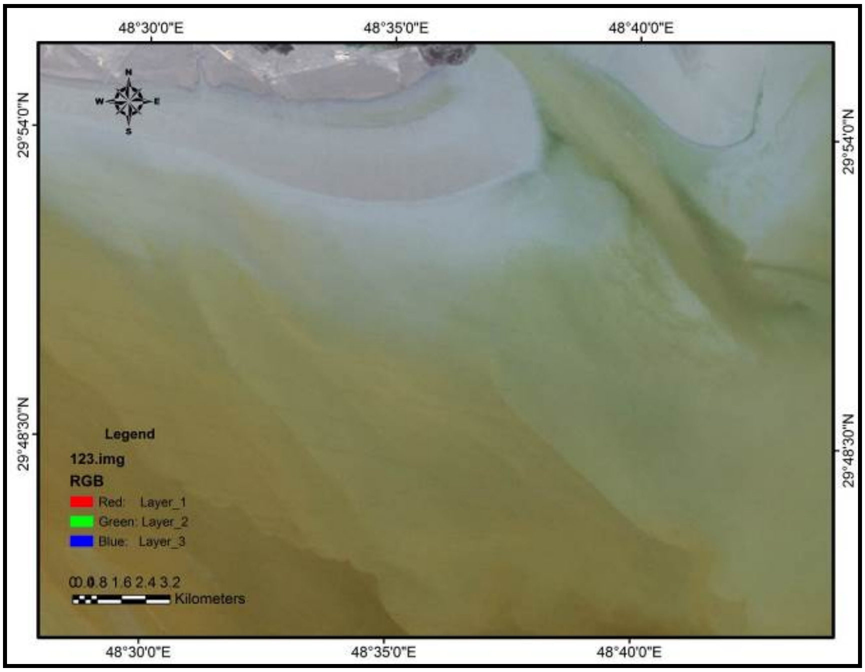

Figure 4. Suspended loads in the delta area (Landsat 7 ETM+, 2006).

Figure 5. Coastal sabkha in the northern delta area (Landsat ETM+, 2006).

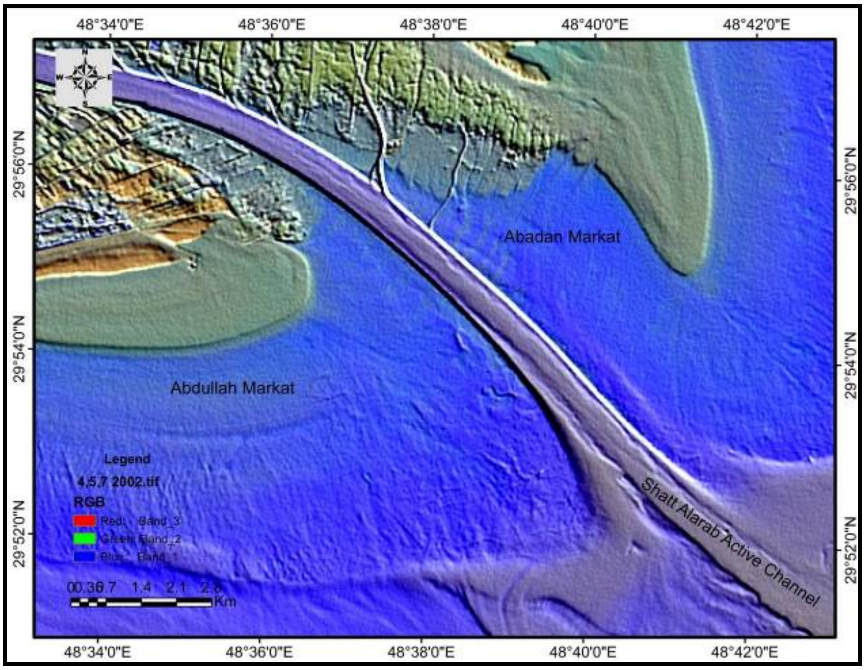

Figure 6. Subaqueous gullies (Landsat ETM+, 2006).

The sub-aqueous channel of Shatt Al-Arab River continues to the Gulf, and appears clearly in some suitable band composition most notably (infrared band) with merging of bands 1, 2 and 3 of LANDSAT 7, and 2, 4 and 7 of the same satellite (Fig. 7). This channel was responsible of transport of sediment loads of the river. Channel bed deviation, due to the continuous alteration between erosion and deposition processes, is clear in this channel. Many longitudinal sediment bars, deposited from the river loads (Albadran, 2004), obstruct water flow, which consequently deviate the channel course. These bars are sharp-ended upstream, and broad-ended downstream. The existence of subaqueous gullies near the mouth of the Shatt Al-Arab; Khor Al-Kafka, Khor Al-Umaya and Khor Al-Roka, act as suctional funnels, take the sediments to the deeper part of the Gulf (Fig. 8).

The deposition and erosion processes are closely tied to the seasonal change, in that pluvial period lead to high discharge, and vice versa. Deposition and erosion are responsible for reworking of muddy sediments with small amount of sand (Albadran *et al*., 1995). The mouth of the Shatt Al-Arab River underwent intensive dredging before 1980, when the first Gulf War started. Thereafter, it was abandoned without dredging, so that sedimentation has undergone many interactions between nature processes and urban activities. As stated above, this is a tidal type influenced by wave actions, with tidal currents responsible for reworking of the sediments, and deposition and sedimentation processes reflect this effect (Nichols, 1999; Albadran, 2004). The main channel or active channel of the delta could bifurcate into multiple branches related to the nature of discharge, suspended load and bedloads. Each branch forms a new lobe of sediments, and thereafter the channel migrates laterally (Hudson, 2005). In this area, three lobes could be distinguished in the topographic profile image of panchromatic bands (Fig. 9). These lobes appear on the image in successive forms, related to the migration of the main channel which responsible for their formation. The upper lobe, located to the east of the current position, was the first position of the main channel of Shatt Al-Arab River. The surface area of this lobe is about 48.94 km^2. The central lobe, in front of the main channel, has an active depositional surface area of about 169.83 km^2. To the west lies an area of about 88.62 km^2 where new lobe could be formed within few years, if the channel migrates, westward due to the formation of the second lobe. The surface area of these lobes may reflect the real loads of Shatt Al-Arab River. The older lobe is the smaller one, probably due to the dredging activity of the Iraqi Ports Authority before the first Gulf War of 1980. The second, current lobe is larger due to the huge quantity of sediments subsequently transported directly to the mouth of Shatt Al-Arab River as suspended and bed loads. The third future lobe reflects a reduction in load quantity consequential to the large reduction in water discharged by the Shatt Al-Arab River due to upstream damming, and assuming no dredging works in the area.

The southern entrance of Abdullah Creek manifests many sedimentologic spits on both sides of the channel, probably formed during slack water and deposition of the sediment load in the area between the southern entrance of Abdullah creek and the western side of the Shatt Al-Arab mouth. These spits appeared on the images after processing a topographic profile image of the near infrared band (Fig. 10). The Iraqi coasts have a good chance in comparison with the Kuwait coast. This could be laid to the nature of sediment texture; the texture of the sediments of the Iraqi coast is muddy, making modification and reworking by the tidal current or waves in the area.

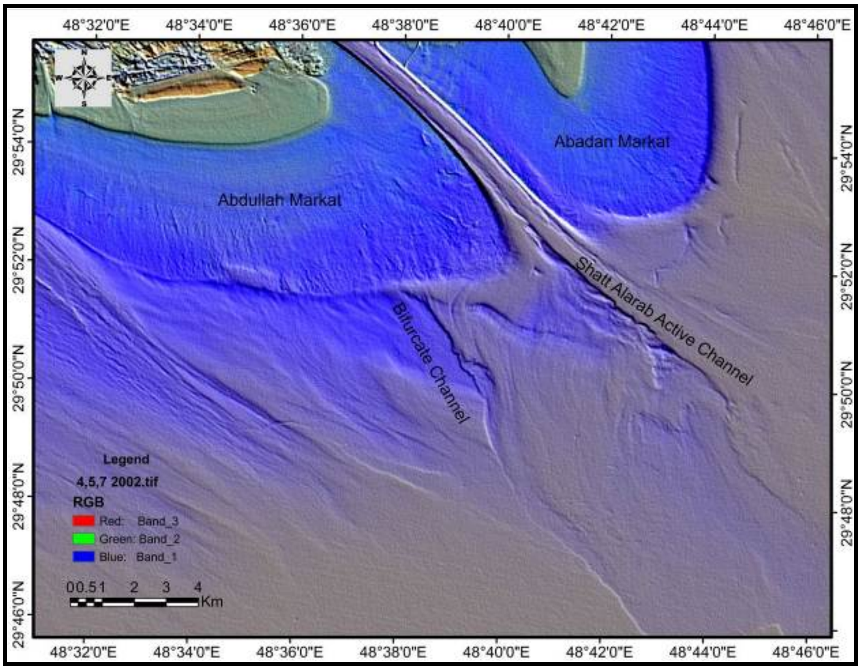

Figure 7. Subaqueous channel of the Shatt Al-Arab River (Landsat ETM+, 2006).

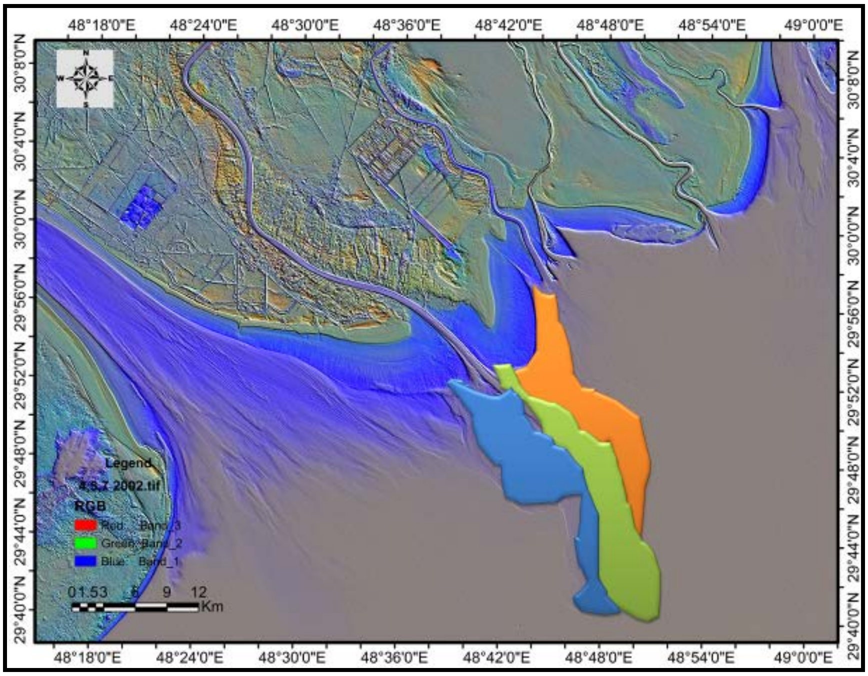

Figure 8. Delta Lobes (Landsat ETM+, 2006).

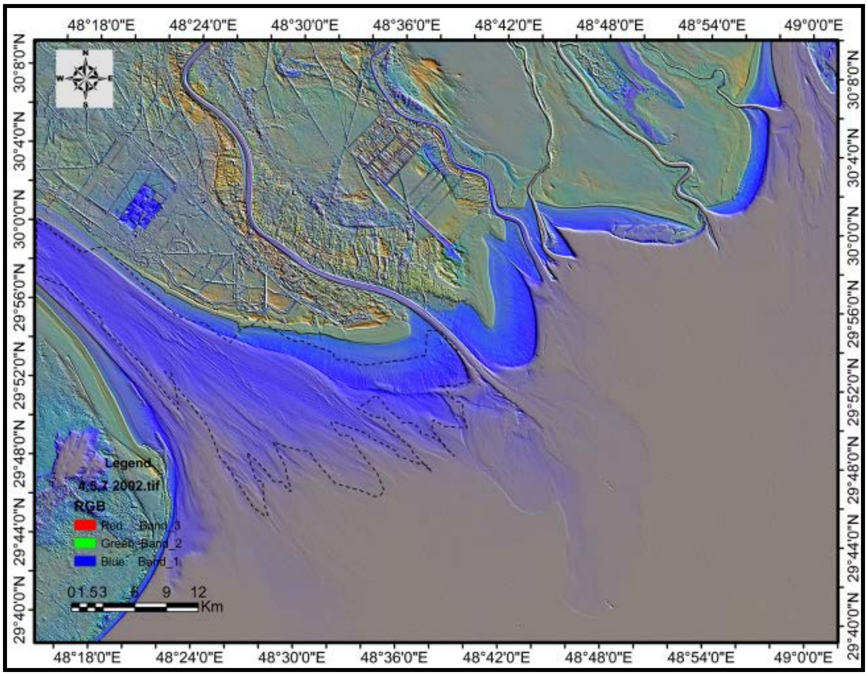

Figure 9. Spits near Delta (Landsat ETM+, 2006).

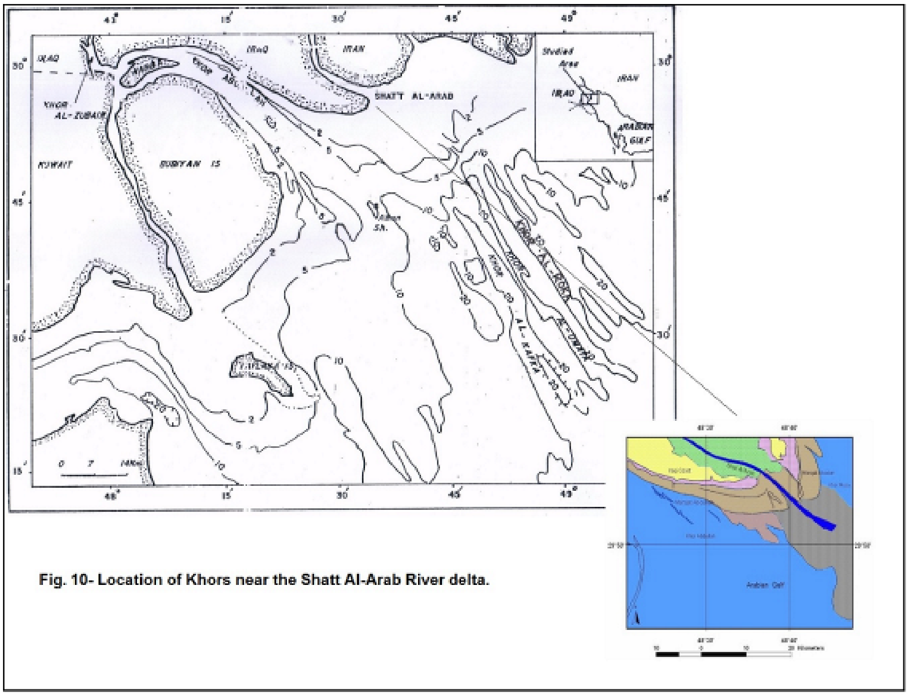

Fig. 10- Location of Khors near the Shatt Al-Arab River delta.

The Shatt Al-Arab River Delta is now facing all of the same issues as the Colorado River Delta. The Colorado River is the most highly regulated river in the world, and its delta is very similar. The delta of Colorado River was modified by the hydrodynamic force and the loss in fresh water; the eroded sediments of the delta are flushed out to the Baja California (Carriquiry and Sanchez, 1999). But for the Shatt Al-Arab River Delta, from time to time, is restored by Karun River water when the Iranian Authority opens it.

Conclusion

The processed images show clearly the physiographic nature of the Shatt Al-Arab mouth. The Abdullah Creek takes a major part of sediment discharge due to the tidal effects and the main circulation of water masses in the Arabian Gulf, which is anti-clockwise. Probably within few years the main channel of Shatt Al-Arab River deviates to the west in the southern entrance of Abdullah Creek. Also, the existence of subaqueous gullies near the mouth of Shatt Al-Arab River; Khor Al-Kafka, Khor Al-Umaya and Khor Al-Roka, act as suctional funnels, take the sediments to the deeper part of the Gulf. All of these factors let Shatt Al-Arab delta to be small delta in comparison with other deltas of the world.

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دراسة فزيوغرافية لدلتا شط العرب جنوب العراق بتطبيق تقنية الاستشعار عن بعد

بدر نعمة البدران[1] و سحر طارق الملا[1] و ميادة محمود عبد القادر[2]

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المستخلص - يتكون شط العرب من التقاء نهري دجلة والفرات قرب القرنة، 75 كم شمـال مدينـة البصرة، جنوب العراق. تمت معالجة المرئيات الفضائية للقمر الصناعي

الامريكي لاندسات +ETM 7 للسنوات 2000 و 2002 و 2006 وبأستخدام برنامج ايرداس 8.4 و ArcGIS 9.3 . أستخدمت لتفسير المظاهر الجيومورفولوجية لدلتا شط العرب والتراكيب الجيومورفولوجية وتوزيع الحمولة العالقة والحركة الجانبية للمجرى الرئيسي للقناة مع تمييز ثلاثة فصوص للدلتا متكونة عند جبهة الدلتا والتي تؤكد الحركة الجانبية كمتغير أساسي في تكون الدلتا. يمكن أن يؤدي الزحف بأتجاه الغرب للقناة الرئيسية لشط العرب إلى إنحرافه وإتصاله بقناة خور عبد الله خلال السنوات المقبلة.