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A quantitative analysis of transverse river profiles and its applications for morphotectonics: A case studying Shatt Al-Arab River, Southern Iraq

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Abstract - The present study discussed the quantitative analysis of Transverse River Profile (TRP) on Shatt Al-Arab channel, by deriving several TRP parameters that can be easily quantifiable and comparable. These parameters are useful to detect the morphotectonic indicators of Shatt Al-Arab basin. Five cross sectional profiles were considered from the previous bathymetrical surveys of Shatt Al-Arab channel starting from Qurna (upstream) at the confluence of Tigris and Euphrates rivers towards Fao (downstream). The results illustrated the main rate of controlling the tectonic activity along the river channel by forming of islands bar at the middle of main river course and increasing in its meanders. The applied analytical technique also efficient in detecting the neotectonic activities for subsurface structures and their effects on deflecting and meanders of the river basin.

Keywords: Morphotectonic, Transverse River Profile, Quantitative analysis, Tectonic activity.

Introduction

Shatt Al-Arab is formed by confluence of twin rivers Tigris and Euphrates at Qurna town northern Basra Governorate. It is considered as part of Mesopotamian basin. It extends for 120 km within Iraqi lands and 84 km within Iraqi-Iranian boundaries, before running into the Arabian Gulf (Figure 1). Tectonically, Shatt Al-Arab basin is located at unstable shelf, particularly in the Mesopotamian zone, according to the tectonic division of Buday and Jassim (1987). This part is characterized by a very thick sedimentary cover and the subsurface structures are not reflected to the surface. (Less and Falcon, 1952; Buday and Jassim, 1987). Shatt Al-Arab displays different river patterns such as (straight, meandering, and braided). Particularly, meandering and braided patterns specifically appear at its southern part from its course (Al-Azzawi, 1996; Mulla, 2005; Al-Whaely, 2009). The meandering Phenomena were discussed by many geological studies dealing with the subject of fluvial geomorphology. (Richards, 1982; Morisawa, 1985; Knighton, 1998). These studies discussed the causes and factors that led to its presence meandering. The important causes can be summarized as follows; changing in its erosion state from vertical to lateral, differentiation of river banks in erodebility and changes of the gradient of river valley floor due to the tectonics activity.

This study aims to assess the possibility of quantitative analysis method for isolating tectonic factors from the hydrological factors and determine the factors controlling the meandering and braided pattern in Shatt Al-Arab River.

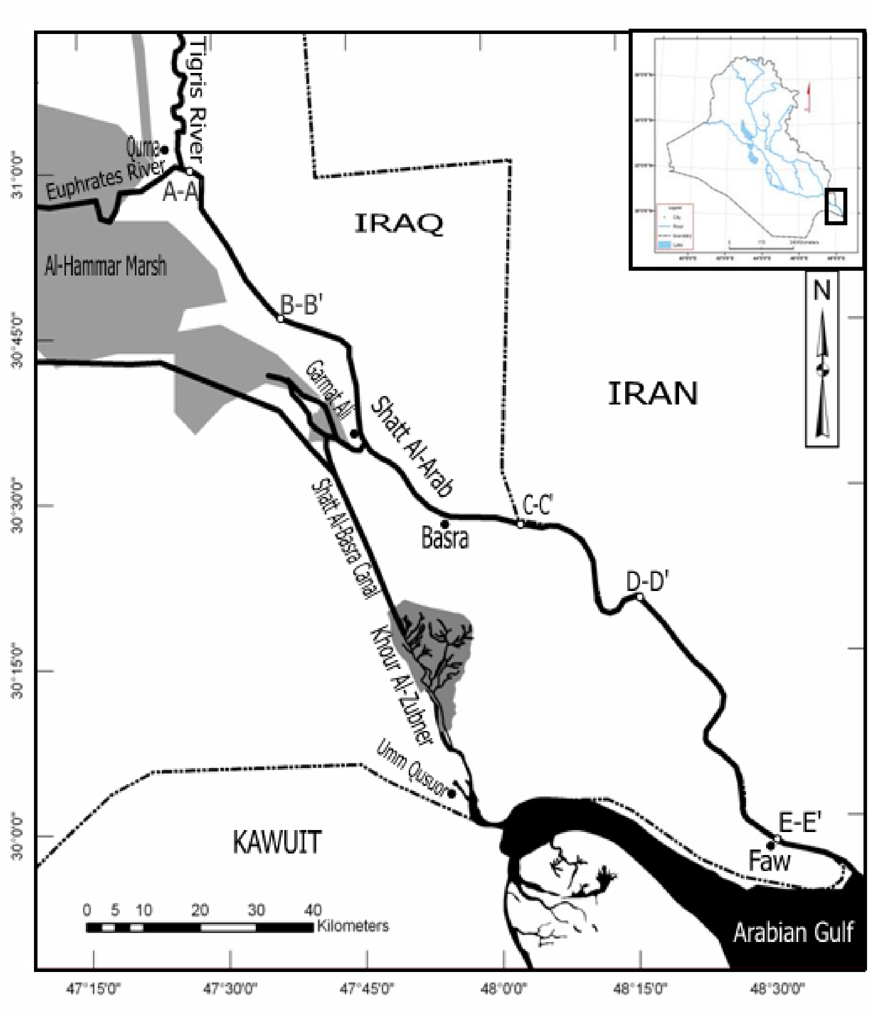

Figure 1. Location map of the study area, by using satellite image ETM+ Global Land Cover Facility.
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Methods

The present study derived data of cross-sectional profiles from various of previous bathymetric surveys of Shatt Al-Arab channel, which was carried out by the marine Science Center (MSC) during 2005. Beside, another cross-sectional profile was taken by Al-Manssory (1996). The study focused on comprises the analysis of five cross sectional profiles, which covers Shatt Al-Arab channel from Qurna to Fao city (Figure 2). These cross sections were selected depending on their close relation to changes of the river pattern (Figure 1).

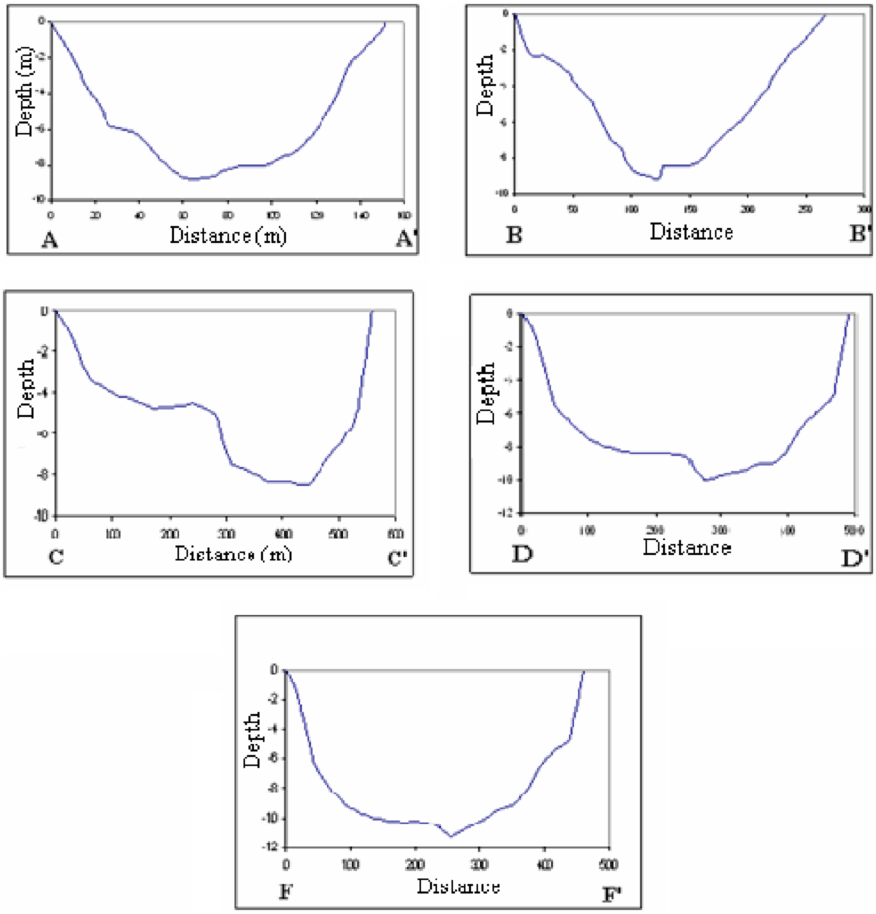

Figure 2. Transverse River Profiles (TRPs) of Shatt Al-Arab River (A-A'): Qurna Section, (B-B'): Nahr Umr Section, (D-D'): Umm Al-Rusas Section, (E-E'): Sihan Section, after MSC, 2005 and (F-F'): Fao Section, after Al-Manssory, 1996.

TRPs analysis of Shatt Al-Arab River has been performed and applied according to the study of Sinha-Roy (2001) which provides a new approach of analysis of TRPs using several TRP parameters that are quantifiable and comparable. The procedure has been tested in case study of Shatt Al-Arab channel. In order to obtain the quantified and comparable parameters and hypothetical analysis to each cross-section would be performed. The conceptual normalized steps of TRPs can describe as follows:

1- Performing a simple modification of a given cross-section by making its values varies between (0 to 1), representing the high and low values in the TRP curve as shown in Figure (3).

  a- The X ordinate represents the ratio Li/L, when L is the profile length and Li is the distance of the individual data point (breaks in slops) from the channel one end of the profile.

b- The Y coordinate represents the ratio ΔHi/ΔH, where ΔH is the difference between the maximum and the minimum elevations of the profile, ΔH is the difference in elevation between the individual data points.

c- The area (Ea) between the profile curve and the H1-H2 Line joining the two opposite sides of the channel bank was defined as the total valley erosion in the given TRP. It is expressed as percent of the area ABH2H1, is an approximate two dimension measure of the total channel erosion in the given TRP (Figure 3).

2- In order to assess the incision at each channel site the following procedure would be made:

a- Smoothening of TRP curve (Figure 4).

b- The Thalweg (Th) of the main river being located at the minimum height in the TRP where the ΔHi/ΔH is equal to zero, would plot by line to join M at the line H1-H2, to define (Ch) i.e.; the maximum vertical incision at the current channel sit (Figure 4).

c- The point M on H1-H2 line is joined with the point A, the line intersects the TRP curve at the point. The point P joins N on H1-H2 line to define the normalized expression of average valley-side incision (Eh). Each TRP has two values of Eh; one for the left bank [Eh (LB)] and the other for the right [Eh (RB)].

3- In order to obtain the channel symmetry (Bs) and valley symmetry (Va), and the channel side slopes (Vs), several modifications in TRP would be made (Figure 5).

a- The channel symmetry can be given by AT-0.5, where the AT is normalized distance of the Thalweg from one end of the profile, 0.5 is the central TRP on Li/L axis which is the central point of the drainage basin on the profile. Bs values would vary from +0.5 to -0.5 with zero value indicating perfectly symmetric basin.

b- In order to obtain a more realistic measure of the channel side slope (Vs) from TRP curves, and from surfaces of TRP new curves are obtained by joining the maximum deflection points on the concave and convex sides of the profile curve for each bank with the Thalweg T Broken lines in (Figure 5). The form surface angles for both LB and RB curves are bisected. The angles between the bisectors and the line TM will give the Vs value. It is noteworthy that the channel side slops (Vs) thus computed does not give the actual channel-side slope angle.

c- The difference in the channel side slopes values for the left and right bank is a measure of the valley symmetry (Va).

4- The most important parameter in this study is the parameter Eh*Ln where the (Ln) is the normalized profile length derived from the ratio Lp/Lmax, where Lp is the length of the individual TRP i.e.... the valley width at each TRP location.

Lmax is the maximum valley width of the study TRPs, while Eh* is the mean Eh value of the given TRP. Such parameter is important for expressing valley incision on two counts. First, it is a two dimensional parameter and secondly, it incorporates an element of linkage throw (Ln) between all the study TRPs of the basin.

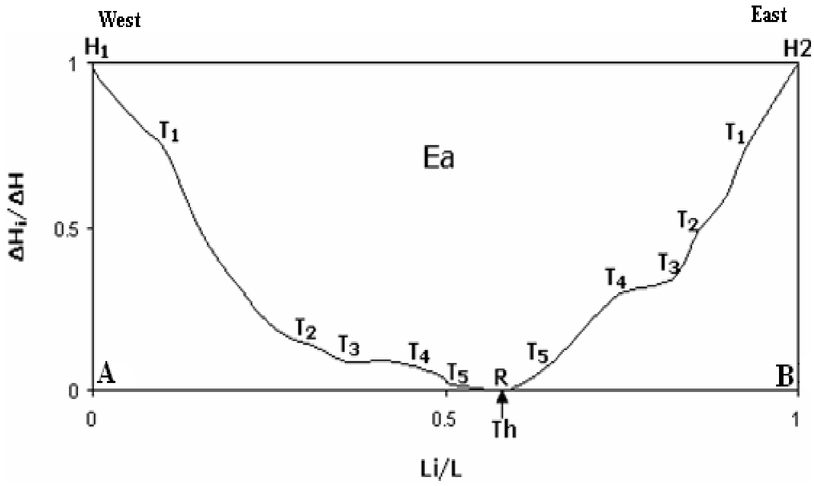

Figure 3. Normalized transverse river channel profile (TRP) across hypothetical river channel profile ΔHi/ΔH is the individual height data (H1) normalized against the maximum and the minimum height differential (ΔH); Li/L is the individual data-point distance (Li) from one end of TRP normalized against total TRP length (L). Thalweg of the main river Th., T1- T5, Terrace position; H1, H2, channel top on the left and right banks, respectively; Ea, measure of channel erosion. For explanation see the text.

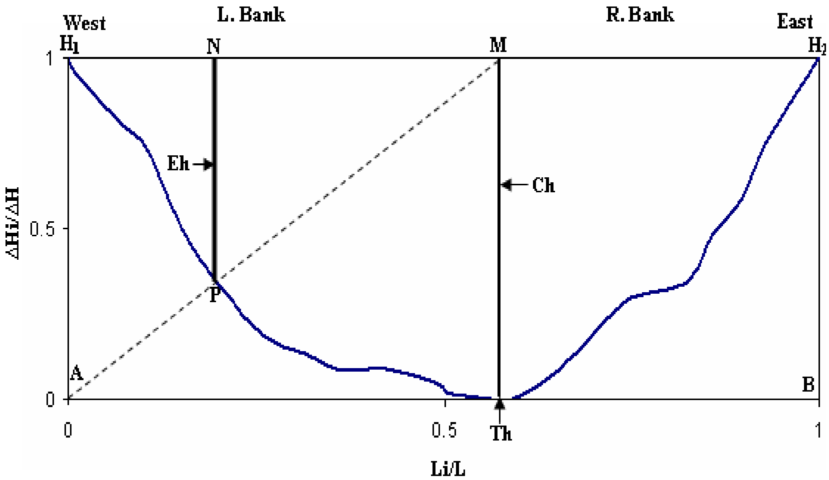

Figure 4. Smoothened hypothetical TRP curve from which Eh and Ch are extracted from one channel side. Thalweg Th. of the main river. For explanation see the text.

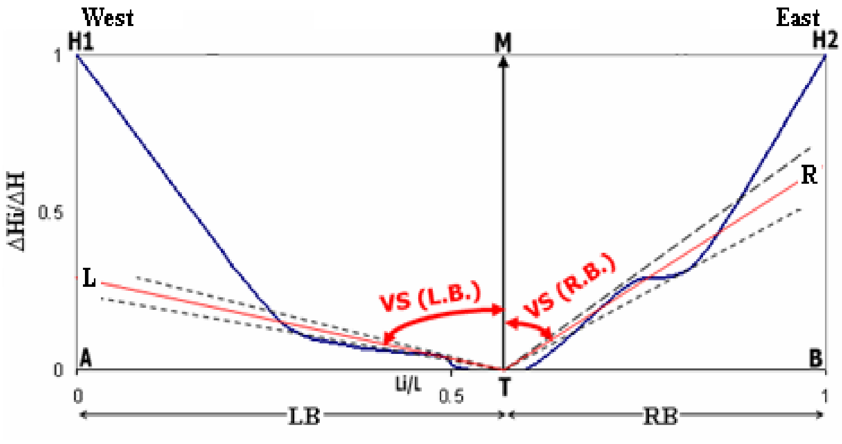

Figure 5. Method of computation of basin symmetry (Bs) and valley (channel) symmetry (Va). Dotted lines are form surfaces of profile curves origination from T (Thalweg of the main river). The angles between the bisectors of the from surface angles at T and the line TM give the actual gradient but ‹LTM-‹RTM gives the valley symmetry (Va) and AT-0.5 gives the basin symmetry (Bs). LB = Left bank; RB = Right bank.

Results and Discussion

The selected sections were studied analyzed several parameters for the interpretation of the tectonic effectiveness on the morphological setting of the Shatt Al-Arab River were (Table 1) obtained. The quantitative parameter of the analyzed TRPs is evaluated in the light of known tectonic features and possible tectonic influence on the river planform was assessed.

Table 1. Computed parameters of the TRPs across Shatt Al-Arab River.

Profile	Ea (%)	Eh (L_B)	Eh (R_B)	Eh (L_B)/ Ch	Eh(R_B)/ Ch	Eh^*	Eh^*·Ln	Bs =Th-0.5	Vs		V_a Degree
									L_B	R_B	
A-A'	65.8	0.68	0.62	0.68	0.62	0.65	0.176	0.57-0.5 = 0.07	78	59	19
B-B'	57.5	0.55	0.60	0.55	0.60	0.58	0.261	0.27-0.5 =-0.23	40	65	25
C-C'	63.6	0.68	0.54	0.68	0.54	0.61	0.610	0.2-0.5 =-0.3	45	65.5	20.5
D-D'	67.4	0.7	0.6	0.7	0.6	0.65	0.638	0.27-0.5 =-0.23	59	64,5	5.5
E-E'	73.2	0.62	0.74	0.62	0.74	0.68	0.303	0.44-0.5 =-0.06	70	77.5	7.5

1- Qurna Section (A-A'):

Table (1) shows that the variable (Eh/Ch) is slightly similar at both banks which reaches up to (0.68 and 0.62). These values indicated that there is an increase in the bank erosion because of decreasing of the incision caused by the decreasing of river energy. The channel symmetry (Bs) reaches 0.07. This value is very low and approaching zero because of the influence of the Tigris and Euphrates tributaries. The variable high and low values for the parameters Ea, Eh, and Eh*Ln (65 %, 0.65, 0.176 respectively) in this section indicating high channel incision. This might due to the tributary influence more than neotectonic activity.

2-Nahr Umr Section (B-B'):

This section revealed considerable an increase in the neotectonic index Eh*Ln (0.261) as well as the Channel symmetry (Bs= -0.23) than the former section. While the parameters Ea and Eh (60, 0.58) tend to decrease through this section. The Thalweg line migrates laterally away from the center of channel toward the right bank. This interpreted an increase in Bs value. Although the value of Eh is small, revealing that west bank is more eroded than the east bank, this section coincides with the subsurface structure recognized by previous authors (Al-Sakini, 1995; Alumtury, 2007).

3-Umm Al-Rusas Section (D-D'):

In this section, the neotectonic index (Eh*Ln=0.61) is clearly visible more than Nahr Umr section, as well as, the values of Ea and Eh (63.6, 0.61 respectively), and the channel symmetry (BS=-0.3). This value is more than all the other analyzed sections. The high values of the Eh*Ln, Bs, Ea, and Eh reflect the involvement of several factors regarding the change of river plan form. The neotectonic effect are high through the values of (Eh*Ln, and Bs), this agreed with other the geological studies such as (Karim, 1991; Al-Sakini, 1993; Jassim and Goff, 2006). In addition to that there are visible effects of the tributary and the mass wasting process through the value of (Eh), as emphasized by the geological studies (Mahmood *et. al.*, 1999; Al-Badran *et al.*, 2002; Al-Whaely, 2009, Sedkhan, 2009).

4- Sihan Section (E-E'):

The tectonic factor in this section is more clear than all these analyzed sections, with a value of (Eh*Ln =0.638). The high values of the factor of (Eh*Ln) needs more explanation. Al-Mulla (2005) pointed out that the presence of Mehela Island bar at the eastern part of Shatt Al-Arab (Iranian side) is belonging to the tectonic effect by Seba subsurface structure. However, Seba structure is located far from this section as compared with Umm Al-Rusas section. Accordingly the increasing in tectonic factors expressed by the value above suggests the presence of another morphostructural element than Seba structure. The present study revealed that the tectonic effect generated from Eastern side of Shatt Al-Arab (Iranian side). The value of Eh also is high, especially in Iraqi side than the opposite side. The present finding agreed with other studies such as Mahmood *et al.* (1999) and Al-Badran *et al.* (2002). They mentioned that the Iraqi side is marked domains of deposition. This is a reasonable point of view on the basis of the presence of the point bar near the analyzed section, however, Al-Whaely, 2009 mentioned that the eastern banks are reinforced by the Iranian government and thus lading to the erosion processes in the opposite bank.

5- Fao Section (F-F'):

The parameter Eh*Ln=0.303 referred to a considerably ongoing of tectonic activity. While the parameter Eh= 0.68 revealed a greater value than all the studied sections. This means that the banks subjected to erosion than the incision in the river bed.

This disagrees with the study of Al-Badran, *et al.* (2002). They mentioned that the sedimentation rate is high in two river sides, so the banks became gentler, with a decrease in river depth. In addition the change of river course from one place to another was accompanied with the formation of many of river meanders. The present study attributes the existence of these meanders to the tectonic factor and not to the sedimentation factor. But these factors need farther subsurface geological studies to detect the type and position of these morphostructures.

It appeared in all studied sections these some parameters such (Vs, Va) are difficult to use to compare different TRPs across the same drainage basin. Lack of detailed geological data about the studied drainage basin was noticed.

Conclusion

Due the study result we can concluded the following:

- Predominance of tectonic factors as compared with hydrological factors, especially in the middle and southern parts of Shatt Al-Arab River that led to the forming of the meandering and braided patterns.
- The quantitative analysis was efficient in detecting the neotectonic activities for subsurface structures and their effects on Shatt Al-Arab River form.

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التحليل الكمي لمقاطع النهر العرضية وتطبيقاتها في المورفوتكتونكس: دراسة في شط العرب، جنوبي العراق

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المستخلص - إجري تحليل كمي للمقاطع العرضية لقناة شط العرب- جنوبي العراق، بإشتقاق عدة معاملات يمكن حسابها من المقطع العرضي، ومقارنتها كمياً داخل المقطع الواحد، أو بين مقطع وأخر لحوض نهري واحد

أو لعدة أحواض نهرية، والتي تفيد في الكشف عن دلائل مورفوتكتونية للأحواض النهرية. استخدمت الدراسة الحالية خمس مقاطع عرضية على قناة شط العرب ابتداءاً من أعالي النهر في نقطة التقاء نهري دجلة والفرات في مدينة القرنة إلى أسفل النهر في مصب شط العرب بالخليج العربي في مدينة الفاو، وأخذت هذه المقاطع من المسوحات السابقة لأعماق شط العرب. خلصت الدراسة الحالية إلى سيادة العامل التكتوني على العامل الهيدرولوجي للنهر في الجزئين الوسط والجنوب من شط العرب خاصة، مما أدى إلى انحراف وتغير مجرى القناة، وانتشار عدد من الجزر، فضلاً عن نجاح طريقة التحليل الكمي للمقاطع العرضية في الكشف عن التنشيط التكتوني الحديث للتراكيب تحت السطحية وتأثيرها على إنحراف وتغير مجاري الأنهار.