Application of a Hydrodynamic HEC-RAS Model For Shatt Al-Arab River

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ABSTRACT

Shatt Al-Arab river suffer from high values of Total Dissolved Solid (TDS), these come from two sources the first is from Euphrates river and the second is from Arabian Gulf. Therefore, In this paper one dimension and unsteady case was applied to study hydrodynamic and TDS simulation of the river water by using HEC-RAS in Shatt Al-Arab river and associated rivers was done. HEC-RAS model is produced by US Army for analyzing river system. This model could simulate steady and unsteady open channel flow. The data of discharge, stage and TDS was taken daily for the year of 2014 at different sections along Shatt Al-Arab river and Tigris-Euphrates confluence. Some of these gauges was taken as boundary conditions and the others was taken for verification of the model. Calibration and verification of the Model using these data were done. Model results were compared with the observed data in these real rivers. The result show that a very good agreement between observed and simulated data with minimum correlation (R) was equal to 0.825.

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تطبيق نموذج HEC-RAS الهيدروديناميكي على نهر شط العرب

الخلاصة

نهر شط العرب يعاني قيم عالية من إجمالي المواد الطلبة المذابة (TDS) ، وهذه تأتي من مصدرين الأول هو من نهر الفرات، والثاني هو من الخليج العربي. لذلك في هذا البحث تم الأخذ بنظر الاعتبار حالة الجريان غير المستقر في بعد واحد وتم تطبيقها لدراسة تمثيل الهيدروديناميكية والمواد الصلبة الذائبة الكلية في مياه النهر باستخدام HEC-RAS في نهر شط العرب والأنهار المرتبطة به. نموذج HEC-RAS أنتج من قبل الجيش الأمريكي لتحليل نظام النهر. هذا النموذج يمكن محاكاة تدفق قناة مفتوحة ثابتة وغير مستقرة.

تم جمع بيانات يومية حول التصريف ومستوى الماء وقيم المواد الصلبة الذائبة الكلية لسنة 2014 في مقاطع مختلفة على طول نهر شط العرب ومنطقة ملتقي نهري دجلة والفرات ، وقد تم اعتبار بعض هذه البيانات كشروط حدودية للنموذج وأما الباقي استخدمت للتحقق من تشغيل النموذج. وقد تم أجراء معايرة النموذج والتحقق من صحته باستخدام هذه البيانات. وتمت مقارنة نتائج النموذج مع البيانات المرصودة في هذه الأنهار الحقيقية. النتيجة تظهر أن هناك تقارب جيد جدا بين البيانات المرصودة والمحاكاة بحيث كان أقل قيمة لمعامل الارتباط (R) يساوي 0.825 .

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Introduction

Shatt Al Arab river is formed from a confluence of Tigris and Euphrates rivers in Qurna district, north of Basrah city, the river where pouring in the Arabian Gulf, the length of the river is about 200 Km from Qurna to the estuary as shown in Fig. 1, shallow well-mixed estuary which flows into the Gulf and therefore influenced by tidal action.

The Gulf is a shallow sea, with an average depth of 50 meters and with water depths near the Iraqi coast usually only a few meters deep. Tides in the Gulf are semidiurnal, and its influence is significant up to Qurna and more upstream.

Tigris River which is originality from Turkey enters the large agricultural plain developed around the city of Ammara, where, in correspondence of Ammara barrage it splits in several branches feeding the marshlands system (Central Marsh and Huweizah Marsh). Downstream of Ammara the Tigris receives the water flowing from Huwaizeh Marsh via Kassara outlet, before joining the Euphrates at Qurna.

Euphrates River which is originality from Turkey and flow through Syria, then enters Iraq, the Euphrates ends up creating a complicated micro water system in itself, characterized by a dense network of canals crisscrossing the entire region downstream Nasiriyah. Some of the canals are manmade others are natural. While the main reach flows in the eastern direction in the marshes area towards the Tigris, some other reaches feed Hammar Marsh.

Several scientific studies were conducted to examine by setting up a mathematical model based on de-saint-venant equations to predict the hydraulic conditions of the Shatt Al-Arab river channel, Al-Mahmoud et. al. [1] studied one dimensional model for hydrodynamics properties for north part of Shatt Al Arab River by using Mike 11 software, the study include the part of Shatt Al Arab river which has 64 Km length starts from Qurna confluence (upstream river) toward Basrah city at Al Maqal port(center of Basrah), Mike 11 which performed an implicit finite difference computation of unsteady flow in rivers based on the saint Venant equations, the study include an Input of constant value of discharge at upstream which equals 300 m^3/s, and the time series file of water level of Shatt Al Arab river downstream was created with 30 days period, which started 01/03/2009 to 31/03/2009, Al-Fartusi, A. et. al. [2], studied a hydrodynamic simulation model of the Shatt al-Arab river 30.5 N, the model used to stimulate the amount of fresh water inlet and discharge from Shatt al-Arab river in Basra city 30.50 N south of Iraq, the data for this model are based on local measurement during the period 1/10/2012 to 31/12/2012, and by using a computer program called Mike 11, the result of paper shows a good agreement between the mathematical model and the local measurement data, Shahidi et.al. [3]

construct numerical modeling for prediction of the salinity in the estuary into the Shatt al-Arab river.

The aims of the present study is to developing the mathematical model to simulate the flow and to find the TDS along Shatt Al- Arab river, Tigris and Euphrates, by using HEC-RAS software, where it can be shown from the previous studies that HEC-RAS is better than Mike 11 in modeling [4], as well as to provide physical and hydrological conditions of the mathematical model for the numerical simulation which match to the reality. The result shows a good agreement between the mathematical model and the local measurement data.

Study Area

The study area were divided into (3) reaches, which include Tigris river downstream of Qalat Saleh barrage which about 54.45 km to the Qurnah, (the confluence point), Euphrates river from Al Medainah district which about 27.13 km to Qurnah and part of Shatt Al Arab river from Qurna city to Abu Al Khaseeb District (about 30°27'5.25" North and 47°59'17.64" East) with a length of 90 km [5], as shown in Fig. 1.

HEC-RAS Model

The Hydrologic Engineering Center River Analysis System (HEC-RAS) model was developed by the U.S. Army Corps of Engineers. This software is a professional engineering software package which allows to perform one-dimensional steady flow and unsteady flow simulation, in this study the unsteady flow based on a one-dimensional form of the Saint-Venant equations, by formulating a discrete form using the implicit finite difference scheme, then solving using the Newton-Raphson iteration procedure and the modified Gaussian elimination technique [6].

Geometric Data

In present study, the geometric data includes; draw river and its reaches, cross section data at rivers sections is entered which includes the cross section of river at Tigris which were 63 cross sections, Euphrates which were 26 cross sections and Shatt Al Arab river which were 90 cross sections, the distance between cross section were about 1000m [5]. The data to be entered is from upstream to downstream direction of the river in geometric data editor of HEC-RAS as shown in Fig. 2. The cross-section data represent the geometric boundary of the stream, the required information for a cross-section consists of the river reach, the river station identifiers (station and elevation points) as well as lengths of sub reach and main channel bank station [5]. The information required is displayed on the cross-section data editor as shown in Fig. 2.

Entering Initial and the Boundary Conditions
● **Flow Data Initial and the Boundary Conditions**

The type of flow data entered depends upon the type of analysis to be performed in the project. In present paper, the unsteady flow analysis was performed, the data of

discharge and the stage were taken for the period from 1 January 2014 to 31 December 2014 in different locations [7], point of section 63 in Tigris river, point of section 28 in Euphrates river (stage only), and point of 1 beside Abu Al Khaseeb district, these points were taken as a boundary condition to the model (as shown in Figures 3, 4, 5, 6 and 7), another point which was beside of Basrah center at section number 20 and 35 were taken for calibration of the model. The initial conditions are the discharge (Q) and stage (h) in gauges stations of Shatt Al Arab river and there reaches.

The maximum flow for Shatt Al Arab river at section 1, was 99.30 m^3/s which was measured at 25 March 2014 and minimum flow was 25.50 m^3/s which was measured at 30 October 2014.

In this unsteady flow simulation model, the values of Manning's roughness coefficient (n) for Shatt Al Arab river was 0.033 and 0.06 for banks [8]. The result of HEC-RAS model show that the values of (n) give closest agreement between simulated and observed computed hydrograph, the range of n coefficient was taken from table 1 [9]

• TDS Initial and the Boundary Conditions

TDS was performed In the present study, the data of TDS were collected for the period from 1 January 2014 to 31 December 2014 [7] in different locations, point of section 63 in Tigris river, point of section 28 in Euphrates river and point of 1 beside Abu Al Khaseeb district, these points were taken as a boundary condition to the model, another point which was taken for calibration the model which were section number 20 (about 20 km up stream of Abu Al Khaseeb district), and section number 35 (about 35 km up stream of Abu Al Khaseeb district), as shown in Fig. 8, the initial conditions were taken along Shatt Al Arab river and there reaches.

The Predictive Model

The dispersion coefficient is not a physical parameter that can be measured directly. It represents the mixing of saline water and freshwater, and can be defined as the spreading of a solute along an estuary induced by density gradient and tidal movement. Knowing the river discharge is crucial for determining a dispersion coefficient [10, 11]. However. In this study, the river discharge data on the days of the measurements were used from the gauging station located at the most downstream part of the river network.

Water quality model was performed after it was coupled with hydraulic model. Accordingly, different values of dispersion coefficient (D) were computed using advection-dispersion equation with first-order decay [12, 13] :-

$$\frac{\partial C}{\partial t} = -U \frac{\partial C}{\partial x} + D \frac{\partial^2 C}{\partial x^2} \qquad (1)$$

Where,
C = concentration [ML^{-3}];
t = time [T];
U = flow velocity [LT^{-1}];
x =distance [L];
D =dispersion coefficient [L^2 T^{-1}].

The data of dispersion coefficient of the hydraulic model where found that the ranged value is between 25 to 500 m^2/s [12]. Finally the chosen value was the dispersion coefficient equal to 53 m^2/s which was taken because it give closest agreement between simulated and observed computed TDS graph as shown in Fig. 9.

Results and Discussions

The model begins from upstream at section 63 (for Tigris river), and section 28 for Euphrates river which there confluence at section 90 in Shatt Al Arab river, and it was finish to downstream at section 1 (in Shatt Al Arab river), and during 360 days which was daily recorded the flow rate, stage and TDS in the sections of 63, 28 and 1 above which was taken as boundary condition as well as sections 20 and 35 in Shatt Al Arab river which was taken for calibration the model. As shown in Figures 9 and 10, the result show that a very good agreement between observed and simulated data with minimum correlation (R) was equal to 0.825.

After giving all the input parameters to the software for the computation, the output in terms of graphs was obtained which includes, cross sections along the river, showing water level at any section and at any date for the year of 2014.

The profile for the water level in the case of maximum water level is shown in Fig. 11 for Shatt Al Arab river with Tigris river and Fig. 12 for Shatt Al Arab river with Euphrates river.

By following the profile along Shatt Al Arab river with time along the year, it can be conclude that there was two source of high TDS values, the first was from Euphrates river and the second was due to the effect of saline wedge intrusion from Arabian Gulf in the case of flood tide.

From Fig. 8 it can be shown that the maximum TDS was occur in the month of February and by followed the results of HEC-RAS simulation of TDS in this month it can be shown that the effect of high value of TDS from Arabian Gulf approach to distance of 20 km upstream of Abu Al Khaseeb district i.e. beside Al- Jubailah quarter in center of Basrah, as shown in Fig. 13 for the day of 16 February, but some time of the year the effect of saline wedge intrusion from Arabian Gulf high TDS approach to the point of confluence as occur at 8 September of 2014 (as shown in Fig. 14).

Fig. 15 show the effect of high TDS value of Euphrates river comparative with low value of Tigris river which effect along Shatt Al Arab river.

By following the profile over the year, it can be conclude that for almost time of the year the area of Shatt Al Arab river between section 20 (beside Al Al Jubailah quarter) and section 30 (downstream of Ktiban district), have a good values of TDS and within the acceptable limit of TDS for drinking water, for the year of 2014, and therefore this area is suitable for installing water treatment plant.

Although the minimum discharge was 25.50 m^3/s which was occur in 30 October of 2014, it can be shown a low values of TDS and under 3000 mg/l, that due to low values of TDS in Tigris and Euphrates river even with low discharge in these rivers, as shown in Fig. 16.

Conclusions
Based on the results of this study, the following conclusions can be drawn:

1- Saline wedge from Arabian Gulf effects to a distance of approximately 20 km upstream of Abu Al khaseeb district except some times of the year which effect to a distance approach to the confluence.
2- The Area between section 20 and 30 have a good values of TDS and within the acceptable limit in almost time of the year.
3- Unsteady flow HEC-RAS model is developed for Shatt Al Arab river and its reaches to predict the value of Manning's (n) through calibration procedure. The appropriate value of Manning's (n) is (0.033)for the channel and 0.06 for the banks, since it gives reasonable agreement between computed and observed hydrographs.
4- Applying HEC-RAS model to predict the values of dispersion coefficient which was 53 m^3/s.

Suggestions
1- Cut off Euphrates river and convert its path to marshes to get rid of high values of TDS.
2- It is suggest a good location for installing water treatment plant in Shatt Al Arab river which is downstream of Ktiban district and upstream of Al Jubailah quarter.

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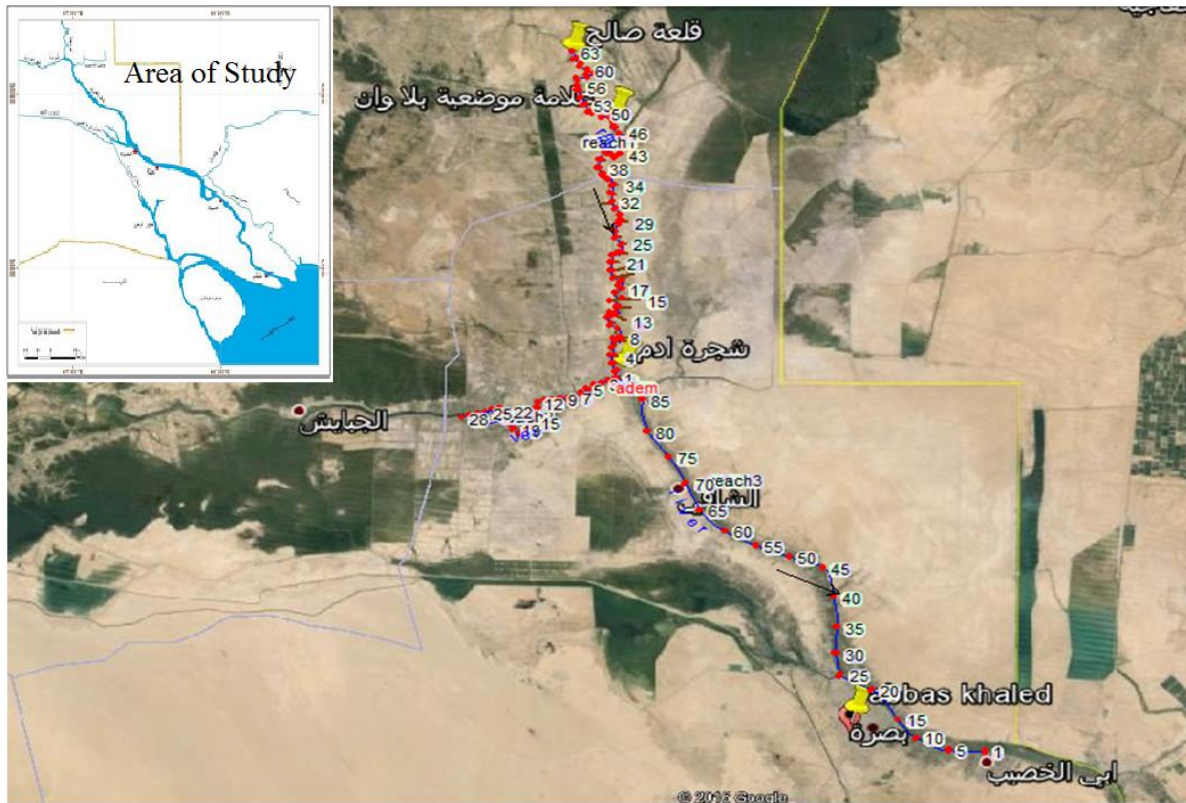
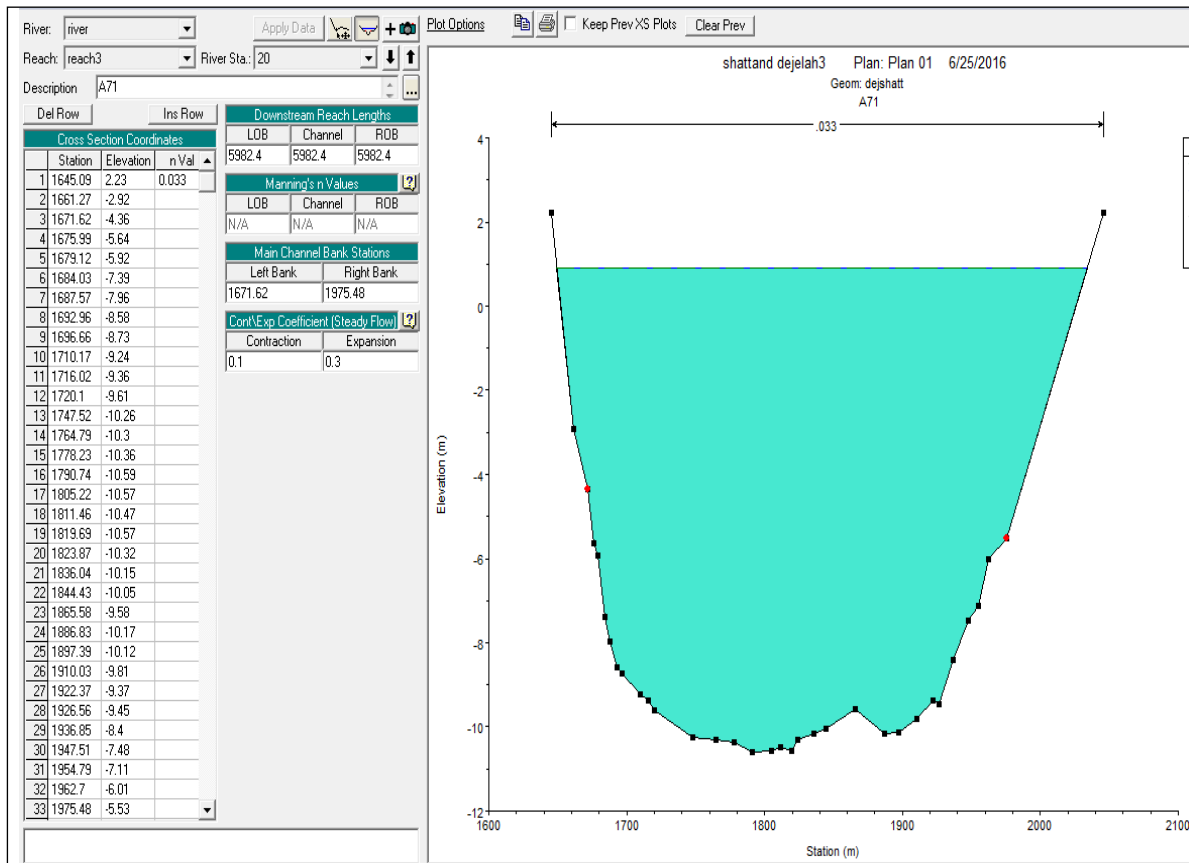**Figure 1. Schematic diagram of the study area**.

Figure 2. Cross-Section of Shatt Al-Arab river beside Al Jubailah quarter about 20 km up stream of Abu Al- Khaseeb district.

Table 1. Roughness Coefficients n-values for Manning's Equation (Channels, Flood Plains and Excavated Channels) [9]

| Natural Streams			
	Minimum	**Normal**	**Maximum**
Main Channels:			
• Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
• Same as above, but more stones and weeds	0.030	0.035	0.040
• Clean, winding, some pools and shoals	0.033	0.040	0.045
• Same as above, but some weeds and stones	0.035	0.045	0.050
• Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
• Clean, winding, some pools and shoals, some weeds and many stones	0.045	0.050	0.060
• Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
• Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages:			
• Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
• Bottom: cobbles with large boulders	0.040	0.050	0.070
Floodplains			
Pasture, no brush:			
• Short grass	0.025	0.030	0.035
• High grass	0.030	0.035	0.050
Cultivated areas:			
• No crop	0.020	0.030	0.040
• Mature row crops	0.025	0.035	0.045
• Mature field crops	0.030	0.040	0.050
Brush:			
• Scattered brush, heavy weeds	0.035	0.050	0.070
• Light brush and trees, in winter	0.035	0.050	0.060
• Light brush and trees, in summer	0.040	0.060	0.080
• Medium to dense brush, in winter	0.045	0.070	0.110
• Medium to dense brush, in summer	0.070	0.100	0.160
Trees:			
• Dense willows, summer, straight	0.110	0.150	0.200
• Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
• Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
• Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
• Same as above, but with flood stage reaching branches	0.100	0.120	0.160
Excavated or Dredged Channels			
Earth, straight and uniform			
• Clean, recently completed	0.016	0.018	0.020
• Clean, after weathering	0.018	0.022	0.025
• Gravel, uniform section, clean	0.022	0.025	0.030
• With short grasses, few weeds	0.022	0.027	0.033
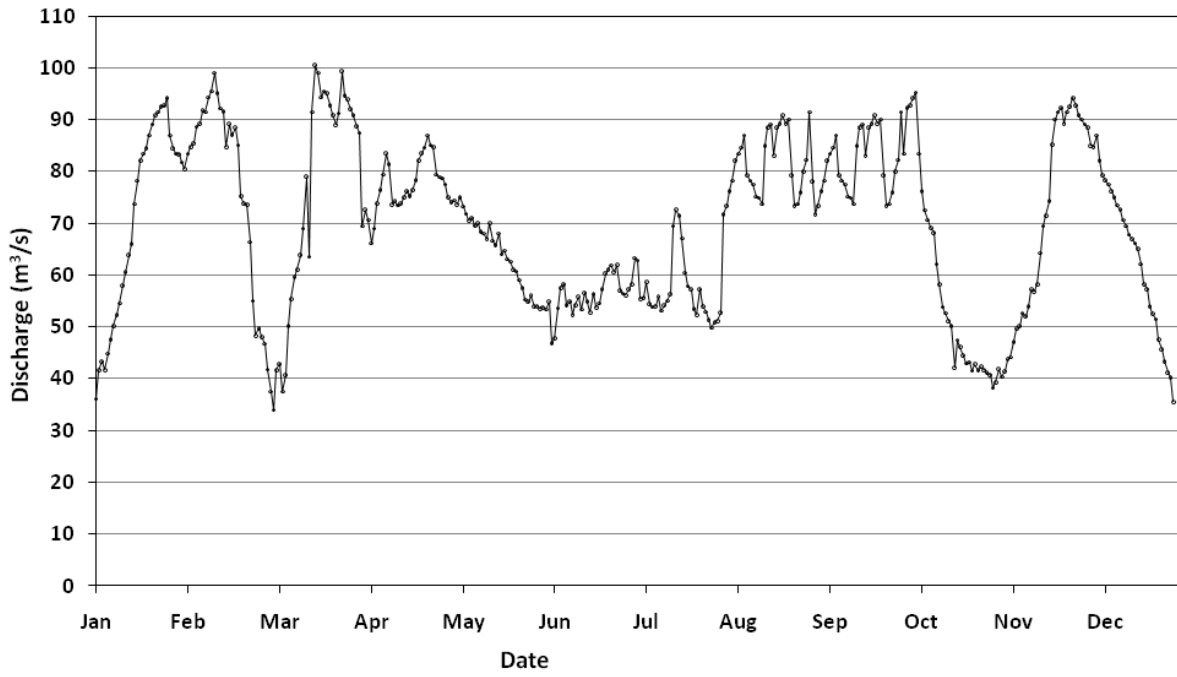
Figure 3. Observed discharge hydrograph at station (63) for Tigris river
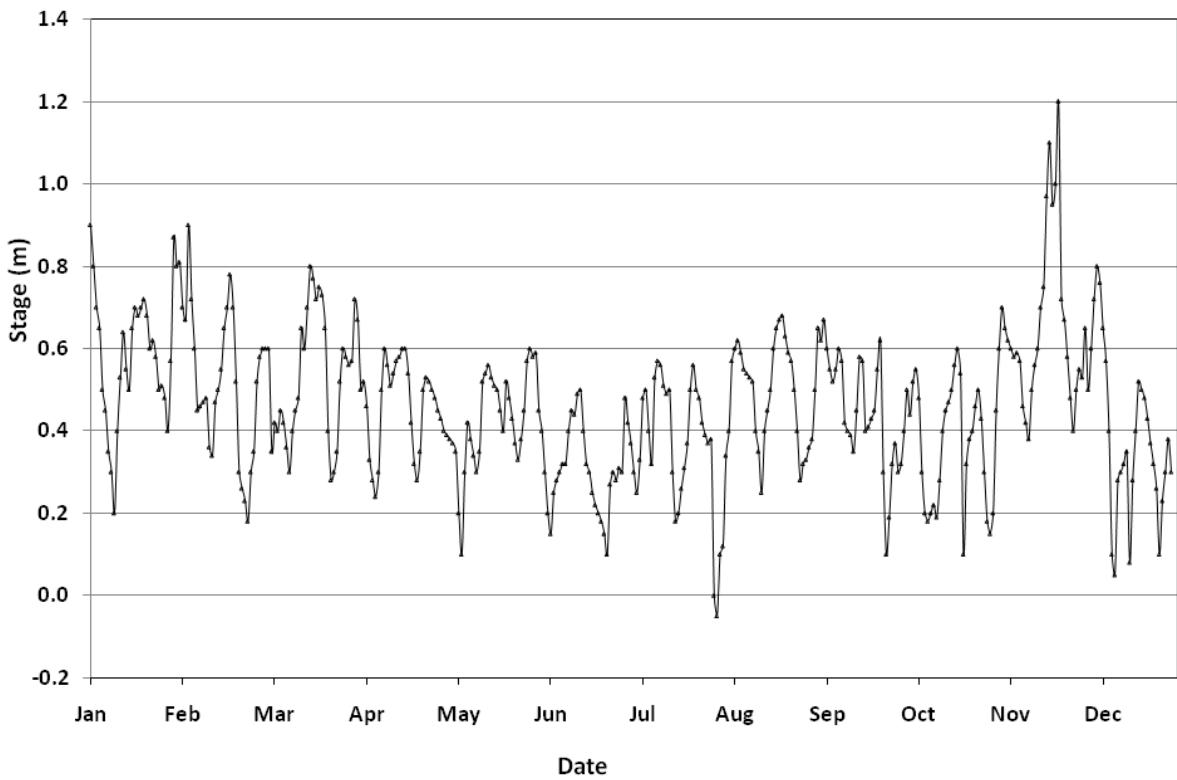
Figure 4. Observed Stage hydrograph at station (63) for Tigris river
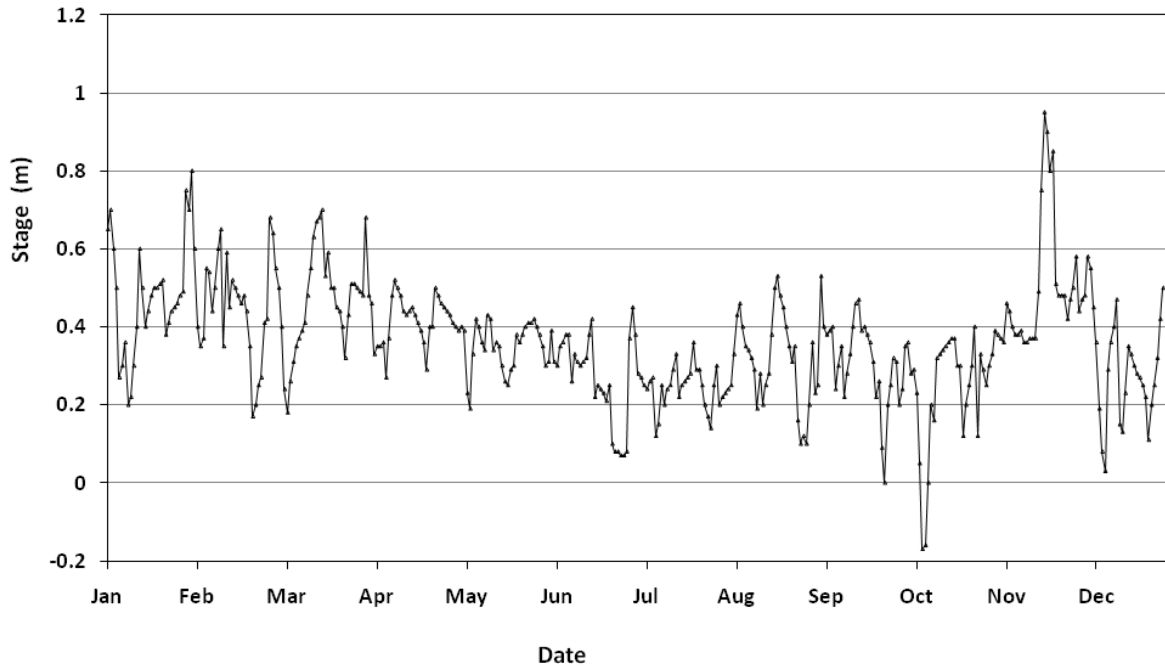
Figure 5. Observed stage at station (28) for Euphrates river
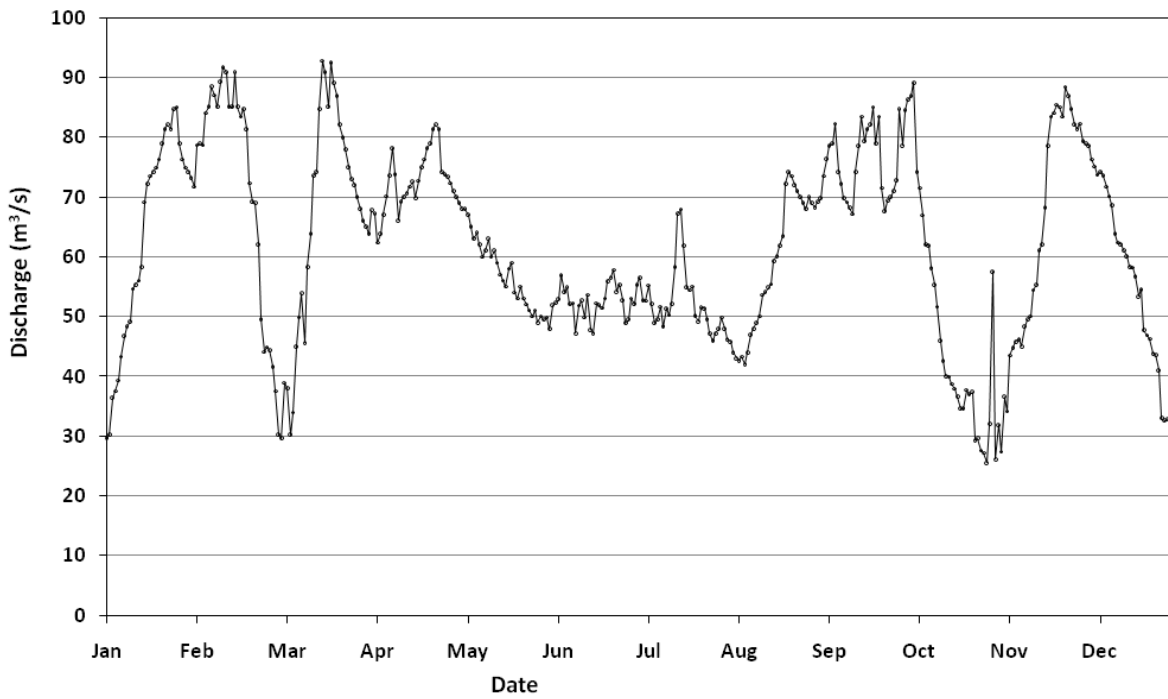
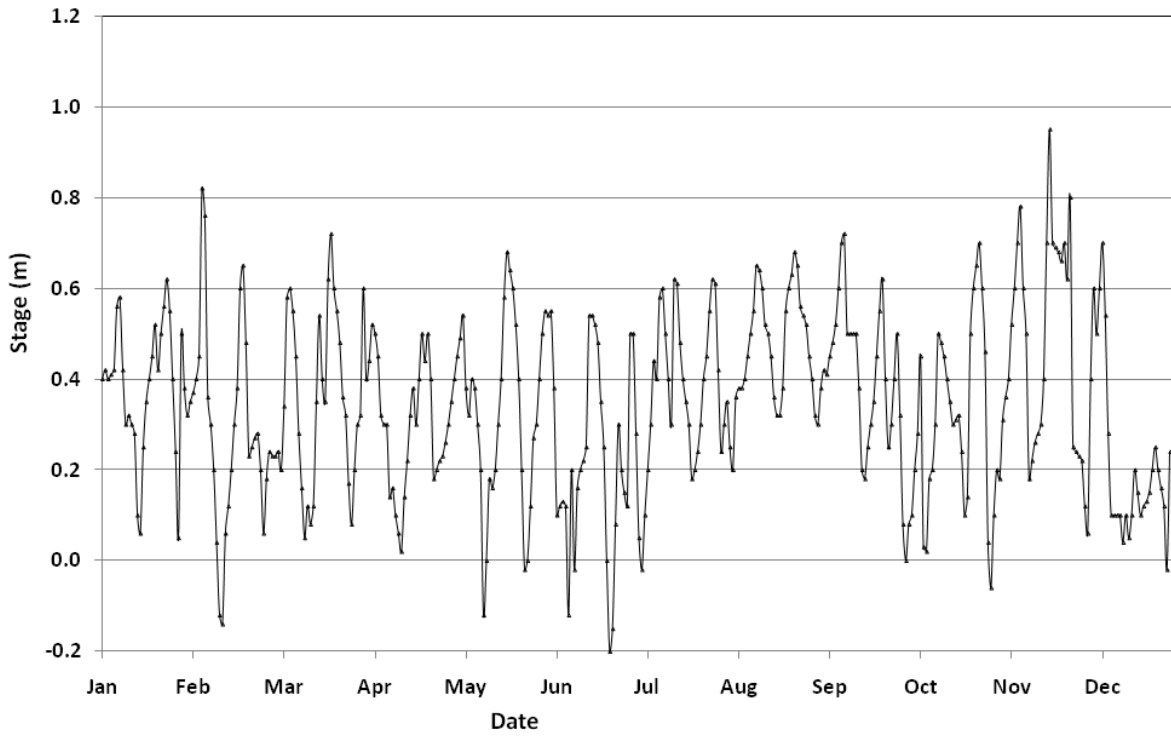Figure 6. Observed discharge hydrograph at station (90) for Shatt Al-Arab river.

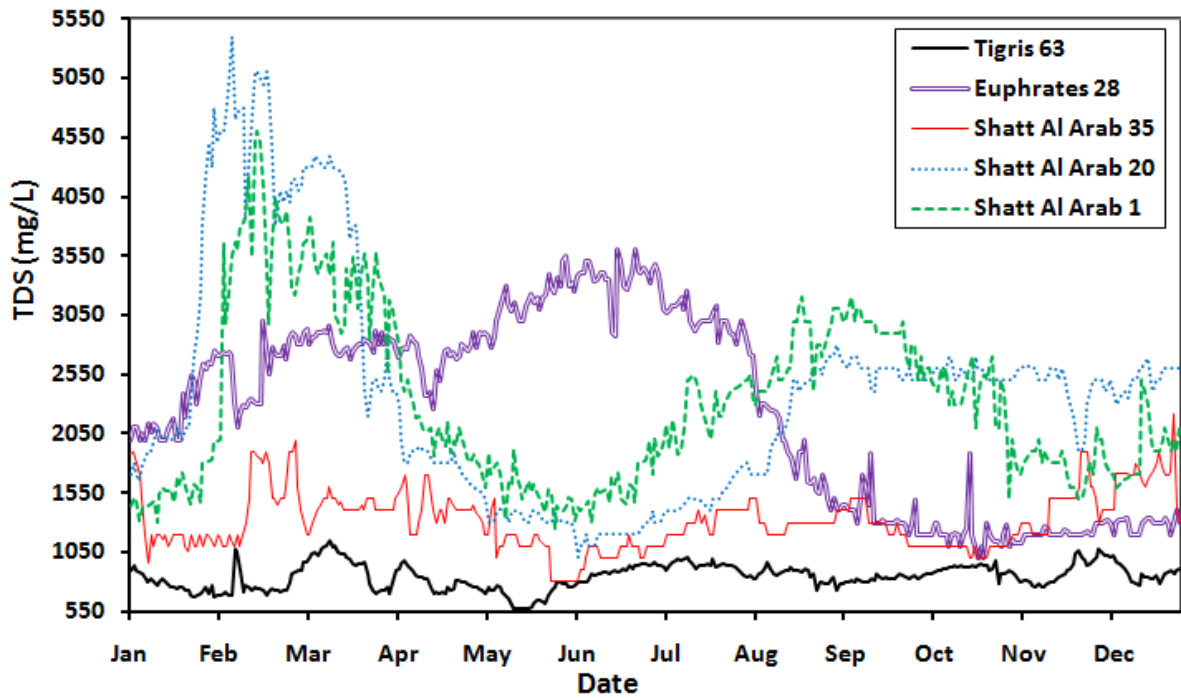**Figure 7. Observed stage at station (90) for Shatt Al-Arab river.**

Figure 8. TDS boundary condition at river reaches of Tigris at section 63, Euphrates at section 28 , and Shatt Al-Arab river at sections 1, 20 and 35.
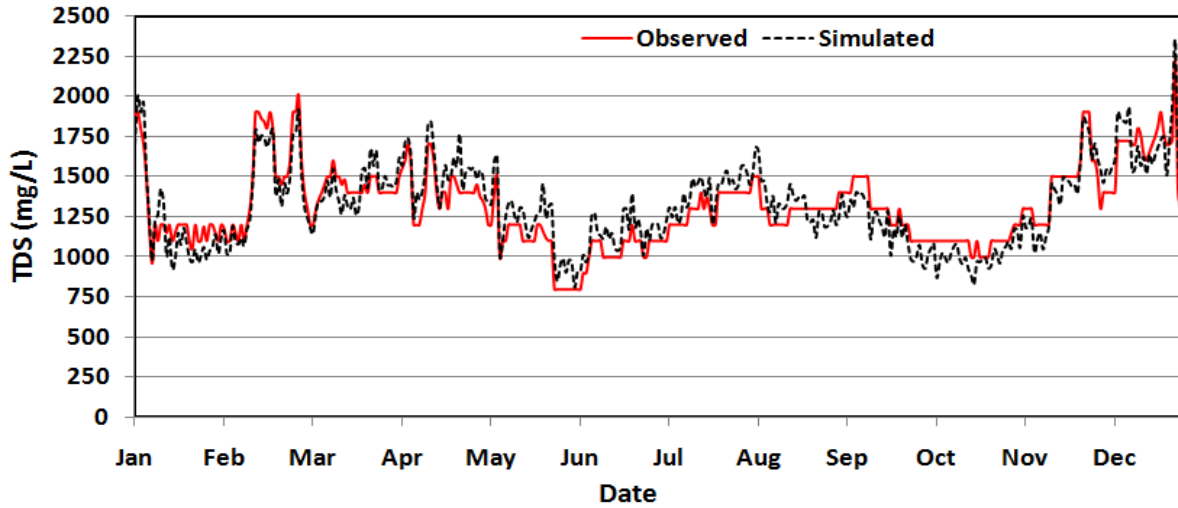
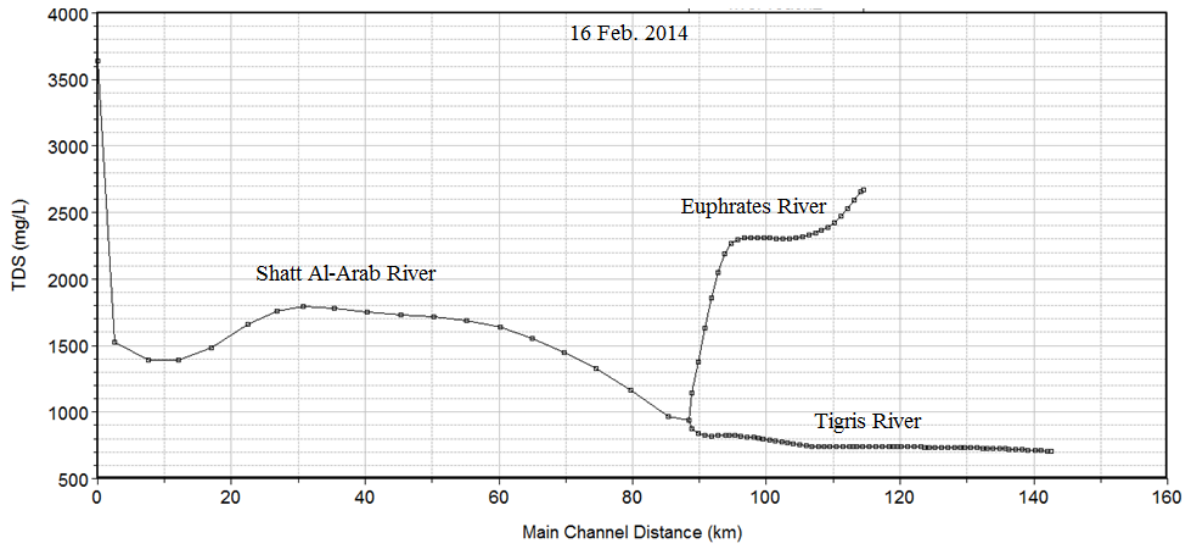**Figure 9. Compassion between simulated and observed TDS at station number 35 in Shatt Al Arab river**
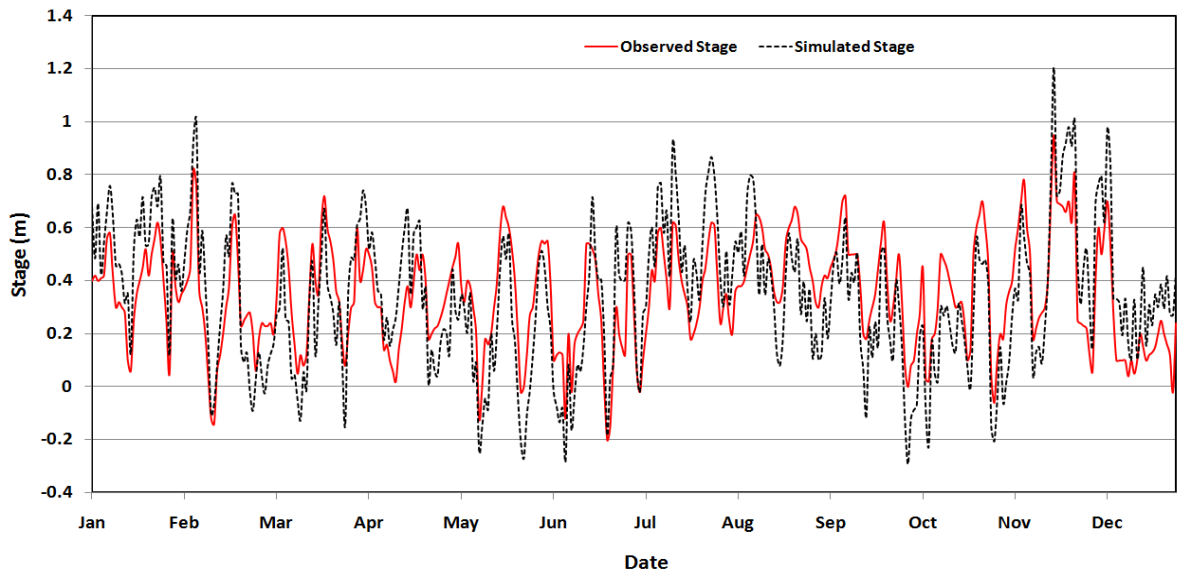
Figure 10. Compassion between simulated and observed stage at station number 35 in Shatt Al Arab river
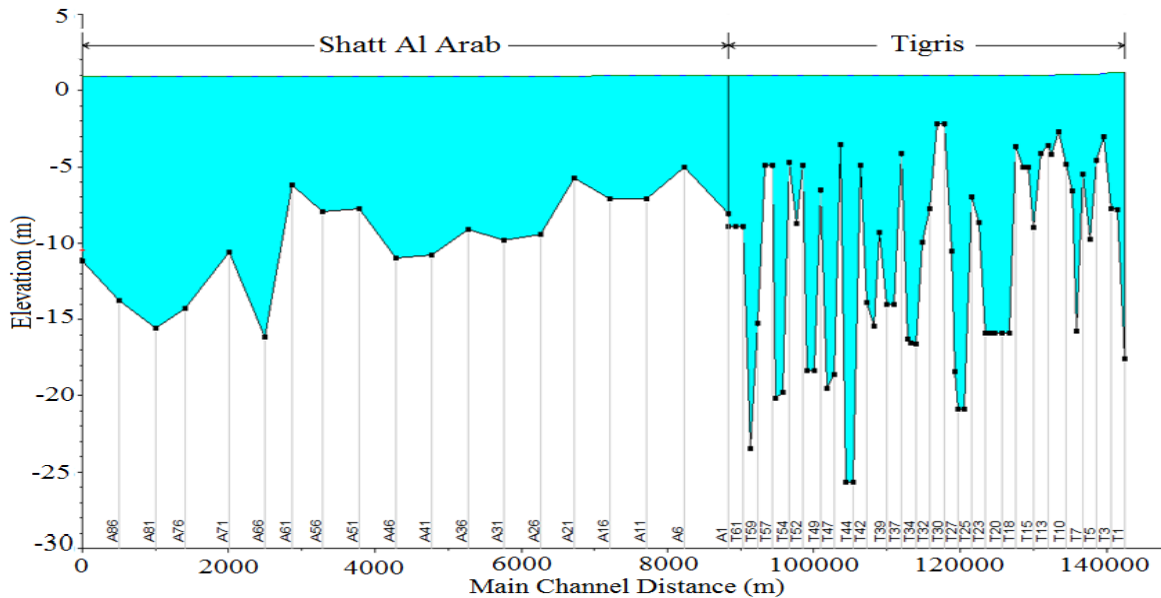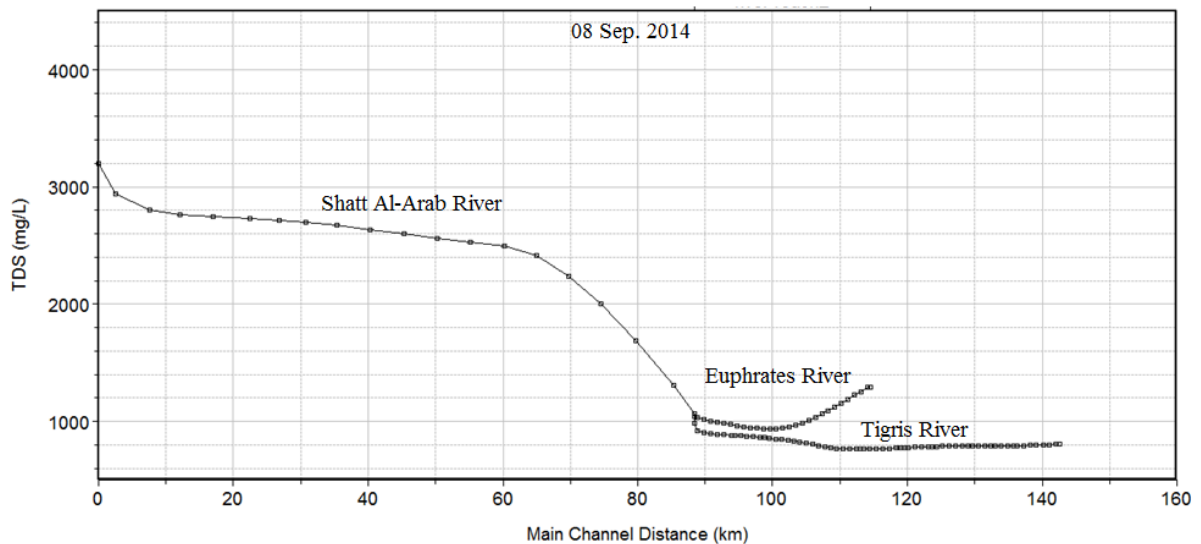
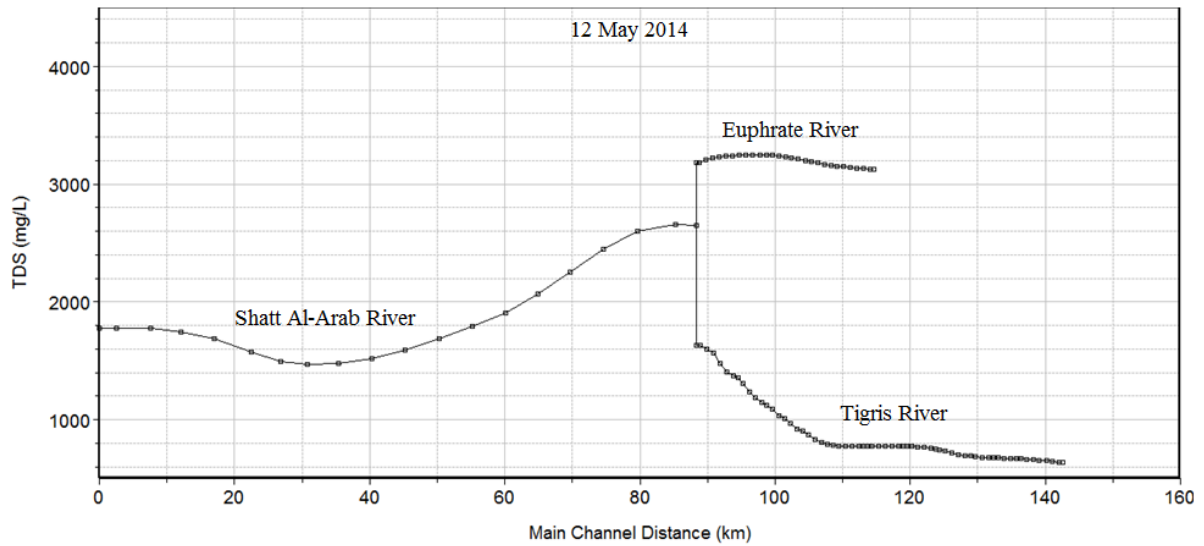**Figure 11. Shatt Al-Arab river with Tigris river profile.**
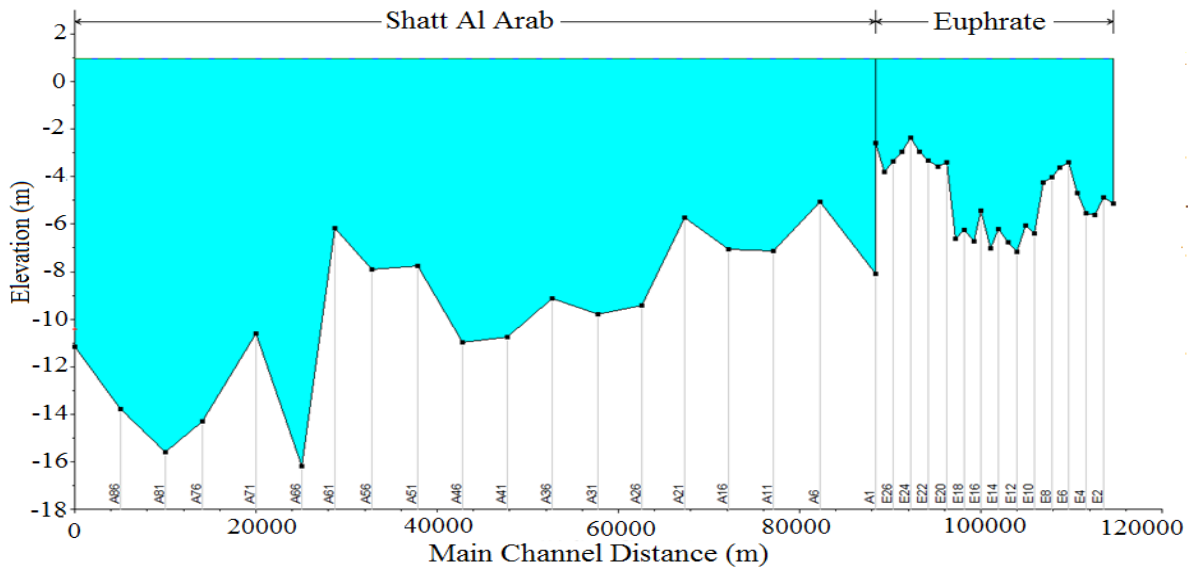
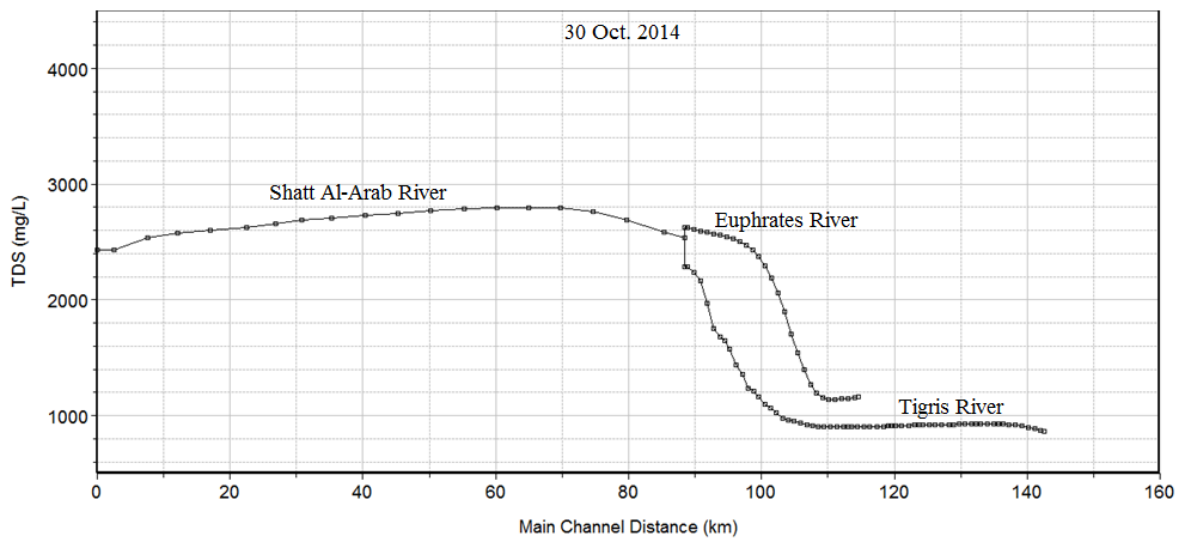**Figure 12. Shatt Al-Arab river with Euphrates river profile.**

Figure 13. Shatt Al-Arab river with Tigris and Euphrates river profile shown the effect of Euphrates high TDS.

Figure 14. Shatt Al-Arab river with Tigris and Euphrates river profile shown the effect of high TDS value from Arabian Gulf to the confluence.

Figure 15. Shatt Al-Arab river with Tigris and Euphrates river profile shown the effect of high TDS value from Euphrates river.

Figure 16. Shatt Al Arab river with Tigris and Euphrates river profile in the date of minimum discharge.