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Total dissolved solids modeling in the Shatt Al-Basrah canal, using Mike 11

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Abstract - The application of one dimensional model is presented to simulate the distribution of total dissolved solids in the Shatt Al-Basrah canal using Mike11. The model was being run for 22 days with time step Δt=60 sec and Δx=200m. The hydrodynamic behavior and TDS distribution were studied for two time periods, the first period was represented the high flow period due to drying of the marshes and the second period was the period after opening the Nasiriyah drainage pump station in Dhi-Qar province. The model was calibrated in two site of the canal, the first locate before Al-Basrah high way bridge and the second locate near Al-Zubair bridge. The result of the model was in a good agreement with the field data of water level and TDS distribution.

Keywords: Mike 11, Total Dissolved Solids, Modeling.

Introduction

Shatt Al-Basrah canal was operated in 1983 to convert the flood water from the Euphrates river through Hammar marshes during the flood periods, then to drain it to Khor Al-Zubair channel, toward to the Arabian Gulf. For the period between (1983-1993), the canal was started from Qurmat Ali river to Khor Al-Zubair channel.

The flow in the canal was controlled by barrage to prevent the upstream movement of brackish water from Khor Al-Zubair. This barrageis located about 22 km from the upstream of the canal, and the inflow of the canal varied over a range of 200-500 m^3/sec.

In 1993, main outfall drain (MOD) was connected to this canal at about 10 km from the canal head and the connection with Qurmat Ali river was closed. This caused an increase in the flow rates which varied between 100-200 m^3/s.

Shatt Al-Basrah canalwas used in the nineties of the last century in the processes of drying the marshes by draining water across it to the Arabian Gulf. The water of canal in this period was with an average TDS does not exceed 3000 mg/l in the upstream of the canal (Karim, 1998). In 2008 the Nasiriyah drainage pump station was opened which it is a land drainage pumping station in Iraq located about 10km southeast of Nasiriyah city in the province of Dhi-Qar. The station pumps farm run-off is collected by the Main Outfall Drain (MOD) north of the Euphrates river in Dhi-Qar and Muthanna provinces to a siphon under the Euphrates river where it is then returned to the MOD and eventually discharged in the Arabian Gulf through the Shatt Al-Basrah canal.

The MOD canal which is the water of the drained regions of the Euphrates basin is agricultural water drainage (more particular and harmful elements of TDS are chemicals, pesticides, and herbicide used in agriculture which come with surface runoff) are only supplier of water to the Shatt Al-Basrah canal in the present time (MOD, 2008).

An important tool in assessing the hydrodynamic properties and water quality in rivers, streams, channels, lakes and estuaries is the computer models. These models are currently used on a wide range globally to help in the process of water management as well as in the process of forecasting future changes in water quality by assuming possible effects of exposure, such as lack of water resources or pollution faced by water sources. These models are used widely in water management like hydrological studies, salinity intrusion, sediment transport and water quality modeling such as total dissolved solids (Malakahmed, 2008).

Total dissolved solids (often abbreviated TDS) are a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular or ionized suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve the size of two micrometer (DeZuane John, 1997).

A 1-D Hydrodynamic model in Shatt Al-Basrah canal had been developed by Golder and Associates (1981) to simulate the optimum operation conditions for the gates of Shatt Al-Basrah barrage.

The 2-D mathematical model (labeled FESTSHD & WQ) had been developed by Kudair to simulate pollutants in Shatt Al-Basrah canal and Khor Al-Zubair estuary. The model is characterized by two components: (1) hydrodynamic (HD) model, (2) water quality (WQ) model that describes the transport, decay and biochemical transformations of the discharged pollutants. The continuity, momentum and transport equations are solved by the finite element method using Calerkin Weighted Residuals (CWR). The calibration and verification of this model were done, based on data that related to physical and chemical characteristics of water of the study area.

The hydrodynamic properties in Shatt Al-Basrah canal had been studied by Al-Aesawi (2010) by apply one dimensional model using Mike11 software. This work aims to simulate the variations of the hydrodynamics conditions and TDS distribution in the Shatt Al-Basrah canal in two different time periods by using one dimensional hydrodynamic model.

Study Area:

The long of Shatt Al-Basrah canal is about 36 km that extends from coordinate position (Upstream) (47°41'48.791"E 30°35'37.792"N) in Qurmat Ali river at north west Basrah city to coordinate point Downstream (47°49'58.242"E, 30°17'38.76"N) at the head of Khor Al-Zubair channel located south east of Basrah (MOD, 2008) as shown in Figure (1). Shatt Al-Basrah canal is affected by tidal phenomena because of its link with Khor Al-Zubiar channel.

The tidal regime in Khor Al-Zubiar is same as that in north west of the Arabian Gulf that it is characterized by predominantly semi-diurnal types (Al-Ramadhan, 1986). Occasionally, tidal ranges exceed 4.00 meter during spring tide in Khor Al-Zubair (Al-Mahdi *et al.*, 2009).

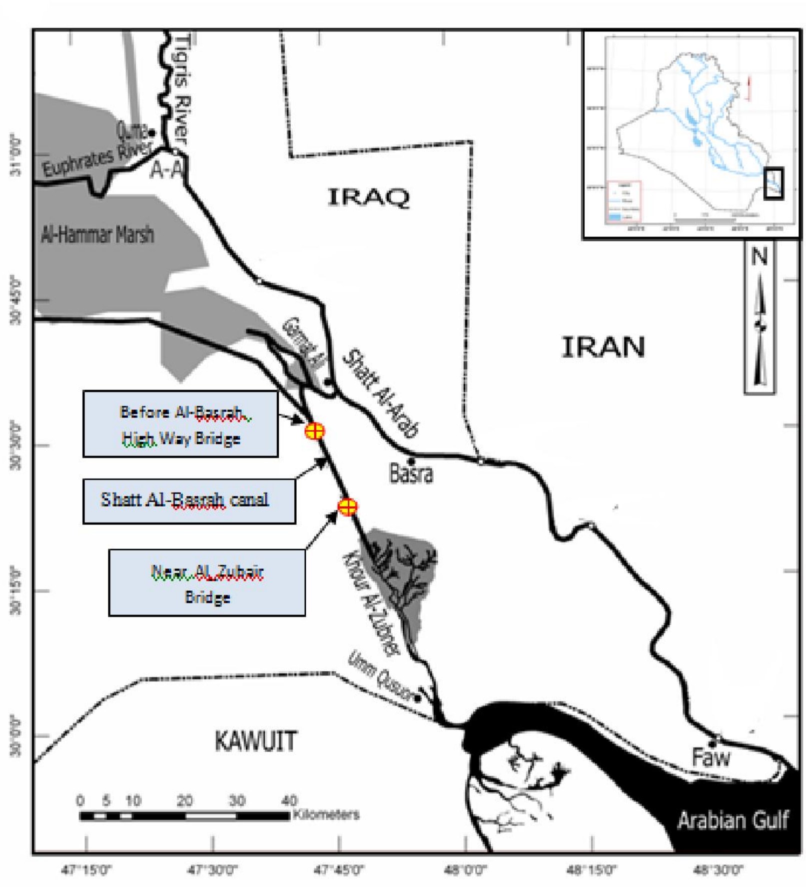

Figure 1. Location map of study area, show the two sites of model calibration.

Models Description

MIKE11 is commercial software for simulating flow and water level, water quality and sediment transport in rivers, estuaries, irrigation canals, reservoirs and other inland water bodies. It is a comprehensive engineering tool with a wealth of capabilities provided in a modular framework (Andersen *et al.*, 2006).

In the hydrodynamics module, Mike-11 solves the following one-dimensional equations of continuity and momentum, known as the Saint-Venant equations (DHI, 2007):

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q \qquad (1)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial\left(\alpha\frac{Q^2}{A}\right)}{\partial x}+gA\frac{\partial h}{\partial x}+g\frac{n^2Q|Q|}{AR^{4/3}}=0 \qquad (2)$$

Where, Q = discharge, A = cross-sectional area, h = water surface elevation above an arbitrary horizontal datum, n = Manning's coefficient of roughness, R = hydraulic radius, g = gravity acceleration, α = kinetic energy coefficient, x = distance along the watercourse and t = time.

The hydrodynamics module contains an implicit finite difference computation of unsteady flows in rivers and estuaries. The formulations can be applied to branched and looped river networks. The computational scheme is applicable to vertically homogeneous flow conditions ranging from steep river flows to tidally influenced estuaries. Both subcritical and supercritical flows can be described by means of a numerical scheme that adapts according to local flow conditions.

In the advection-dispersion module, the basic equation is the one-dimensional advection-dispersion (DHI, 2007):

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) = -A\lambda C + C_2 \qquad (3)$$

Where, C = concentration, D = dispersion coefficient, λ = linear decay coefficient and C2 = source/sink concentration.

This module requires an output from the hydrodynamics module in terms of discharge, water level, cross-sectional area and hydraulic radius. The advection-dispersion equation is solved using a fully time and space centered implicit finite difference scheme which is unconditionally stable and has negligible artificial dispersion.

Model Application

The model began from upstream at chainage 0.00 m (Qurmat Ali) and finished to downstream at chainage 36191 m (The head of Khor Al-Zubair channel).

Boundary Conditions:

Two types of boundary conditions were used in the model, constant inflow (discharge) for upstream and time series of tidal fluctuations at downstream of the canal. The model was run with time step Δt=60 sec and Δx=200m and during 22 days from time series of water level readings for two different periods (Table 1) to simulate the hydrodynamic conditions of the canal. The water level fluctuations are influenced by the semi-diurnal tide (Al-Ramadhan, 1988). The barrage of Al-Basrah was considered to be opened in the study. The present study was divided into two time periods which are:

Table 1. Input parameters for the model simulations.

Item	Value
Time step Δt	60 sec
Distance Δx	200 m
Simulation periods	1-from 1/7/1997 to 22/7/1997 2-from 1/3/2009 to 22/3/2009
Resistance	Manning number, Coefficient 0.025
Boundary condition	Upstream: (inflow)discharge
	Downstream: Water Level

1. The period of high flow:

This period represented high inflow in Shatt Al-Basrah canal because of the drying of marshes. The constant value for discharge was used in the upstream of the canal which equaled to 110 m^3/sec (Kudair, 1999). The downstream tidal data was obtained from Total Tide software technique (UKHO, 2003), which transferred from Um Qassar port to Khor Al-Zubiar port with different time (Δt=28.5 minute), as shown in Figure (2).

By depending on the field observation, the TDS value in the upstream was considered to be 3000 mg/l (Karim, 1998). The TDS value at the downstream is the same at the Khor Al-Zubiar channel equal to 35000 mg/l.

2. The period after 2008:

The inflow rate in the upstream of the canal in this period was about 60 m^3/sec. The downstream tidal data for this period can be shown in Figure (3) (Al-Aesawi, 2010).

By depending on the field observation, the TDS value in the upstream was 5000 mg/l (Al-Aesawi, 2010). The TDS at the downstream was 35000 mg/l.

Calibration the model:

The accuracy of the model can be assessed by the Root Mean Square Errors (RMSEs) between the simulated and measured values of water levels and TDS.

$$\text{Root Mean Square Error (RMSE)} = \sqrt{\frac{\sum_{i=1}^{N}(Mi - Ci)2}{N}}$$

Where *Mi* is the measured (observed) value, *Ci* is the calculated (simulated) value, *N* is the number of observation.

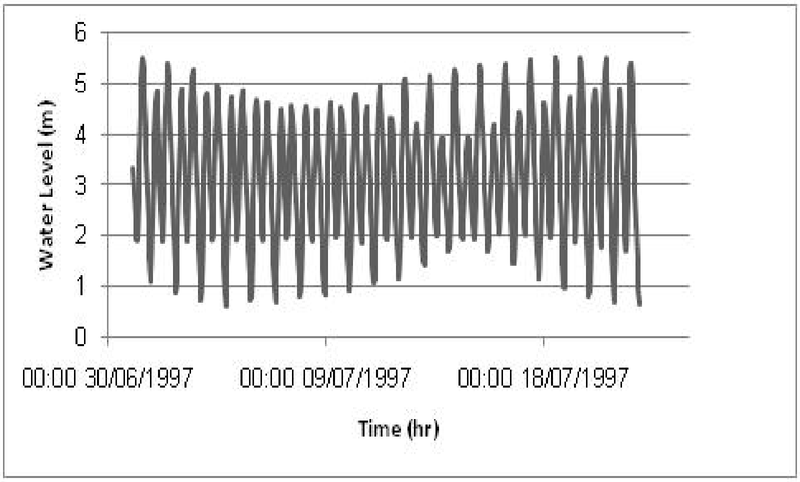

Figure 2. Water Level Fluctuations for 22 days in Khor Al-Zubiar port for first simulation period (UKHO, 2003).

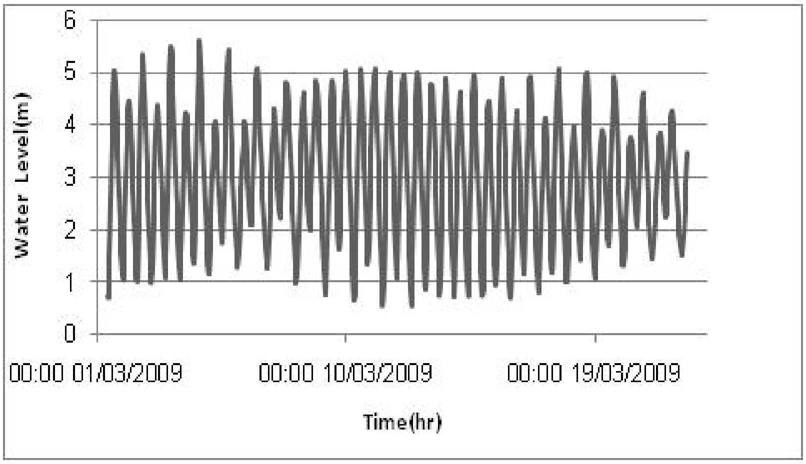

Figure 3. Water level fluctuations for 22 days in Khor Al-Zubiar port for second simumlation period (Al-Aesawi, 2010).

1. The period of high flow:

To calibrate the hydrodynamics model, available data measurement of July 1997, including water level at chainage 20000 m (near Al-Zubiar bridge at coordinate position 47° 46' 2.845" E, 30° 25' 37.557" N) were used. The Manning coefficient was determined by minimizing the differences between the measured and simulated water levels at chainage 20000 m.

In this way, the Manning coefficient of 0.025 (This value lies within the range of manning number (0.02-0.03) of the flood plain regions (DHI, 2007) was obtained with a RMSE of 0.21 m between the measured and simulated values of water levels which is an acceptable range. Figure (4) shows a comparison between the model results and measured water levels at the mentioned station.

In the case of advection-dispersion (TDS calibration), the model was calibrated using available data measurement of TDS for July month from year 1997 (Kudiar, 1999) at chainage 20000 m (near Al-Zubair bridge). The surface temperature used in the model was 28°C. The dispersion coefficient was determined by minimizing the differences between measured and simulated TDS along the canal.

The dispersion coefficient of 1100 m^2/sec was obtained between measured and simulated TDS distribution. Figure (5) shows the comparison between measured and simulated TDS at the mentioned station with RMSE equal to 530.5 mg/l.

2. The period after 2008:

To calibrate the hydrodynamics model, available data measurement including water level at chainage 4800 m (before Al-Basrah high way brige at coordinate position 47° 43' 4.257" E, 30° 31' 38.628" N) (Al-Aesawi, 2010) were used. Figure (6) shows the comparison between model results and measured water levels with RMSE equal to 0.19 m at the mentioned station.

For TDS calibration, the model was calibrated using the available data measurement taken in March 2009 at chainage 4800 m. The surface temperature used in the model was 20°C. Figure (7) shows the comparison between measured and simulated TDS with RMSE equal to 17.8 mg/l.

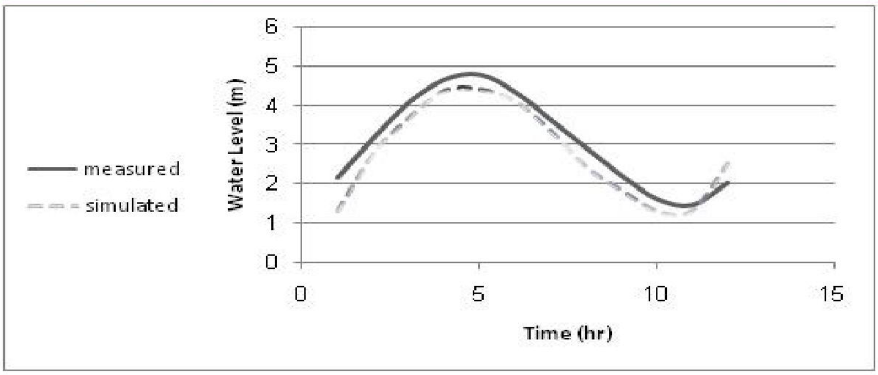

Figure 4. Comparison between simulated and measured water level at chainage 20000 m in 18 July 1997.

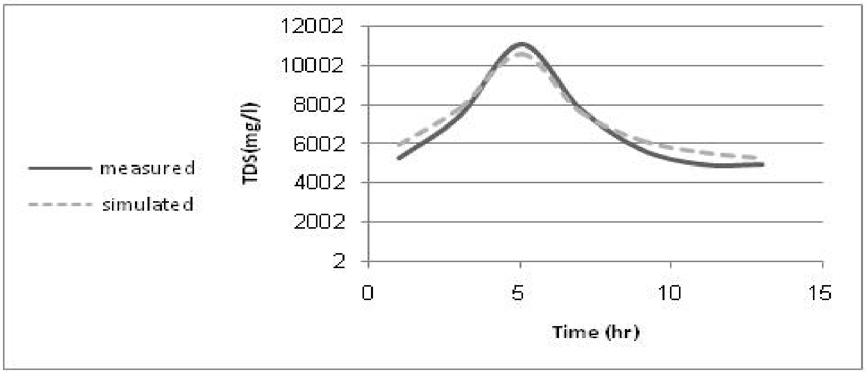

Figure 5. Comparison between measured and simulated TDS at chainage 20000 m in 18 July 1997.

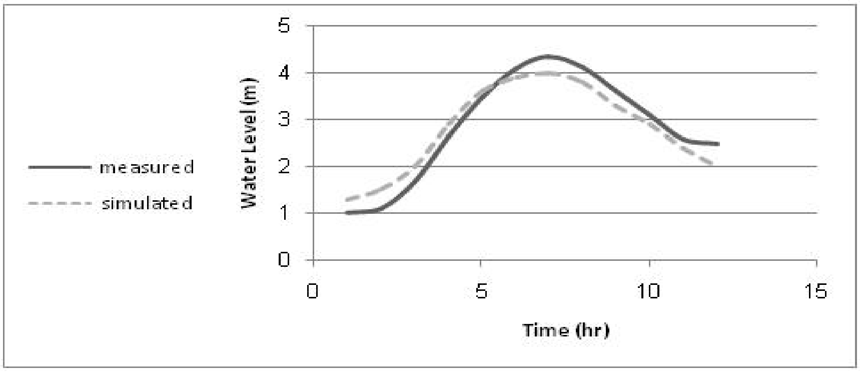

Figure 6. Comparison between simulated and measured water level at chainage 4800 m in 3 March 2009.

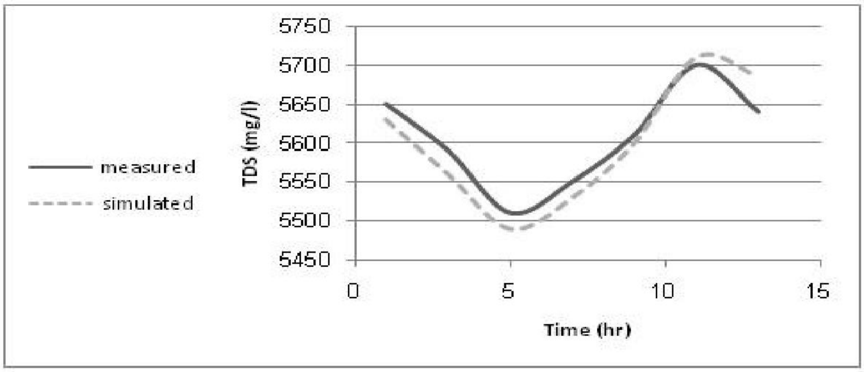

Figure 7. Comparison between measured and simulated TDS at chainage 4800 m in 3 March 2009.

Results and Discussion

The application of one dimensional hydrodynamic and water quality model for the Shatt Al-Basrah canal in south of Iraq is presented by this study. It is clear from Figures (4, 5, 6 and 7) that a close match was produced between the simulated and measured water level and TDS distribution for model calibration of the canal. Then, the calibrated model was used to evaluate TDS distribution for two time periods of study at different locations as shown in Figures (8, 9, 10 and 11).

The inverse relationship between the river discharge and TDS distribution, high TDS values are associated with low discharge and vice versa. By comparing Figures (8, 9, 10 and 11), the deterioration in water quality of the canal can be clearly seen.

The TDS concentrations in the chainage 20000 m do not exceed 14000 mg/l in the peak of TDS for first period while in the second period the TDS concentration exceeds 24000 mg/l in the same site of the canal. This deterioration is due to the change in the water quality of canal resources and salinity intrusion from sea towards the canal because of decrease in the upstream inflow.

The effect of tide is very strong in the downstream of the canal and become weaker when moving to the north (toward upstream of the canal). However, increase of inflow leads to decreases in the tidal effect in the upstream of the canal. Also TDS increases, as tidal amplitude increases. The TDS variation about (4000 to 14000) mg/l in spring tide and about (4000 to 10000) mg/l in neap tide as show in Figure (10), and the TDS variation about (9000 to 24000) mg/l in spring tide and about (8000 to 18000) mg/l in neap tide As show in figure 11. As seen in Figures (8, 9, 10 and 11) the phase of tide (spring or neap tide) is affected parameter on TDS distribution.

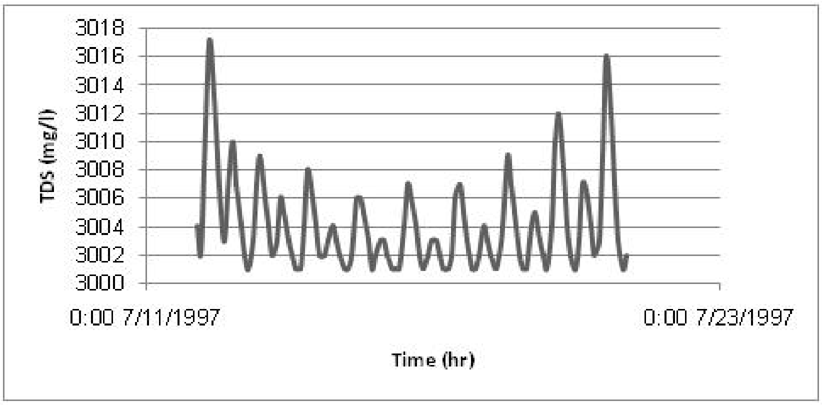

Figure 8. Simulated of TDS at chainage 4800 m in July 1997.

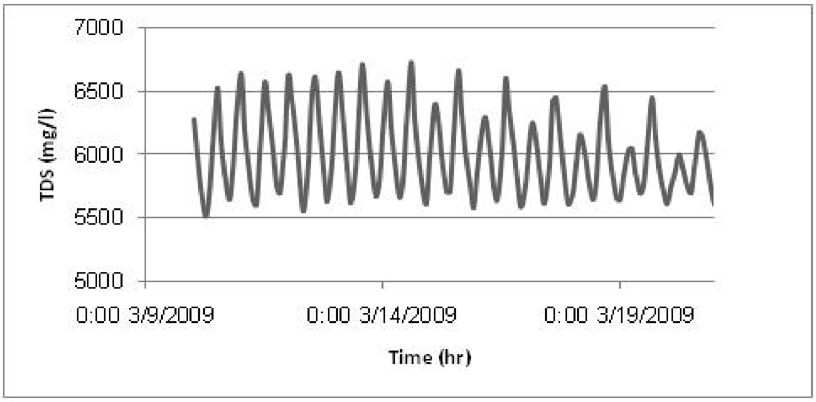

Figure 9. Simulated of TDS at chainage 4800 m in March 2009.

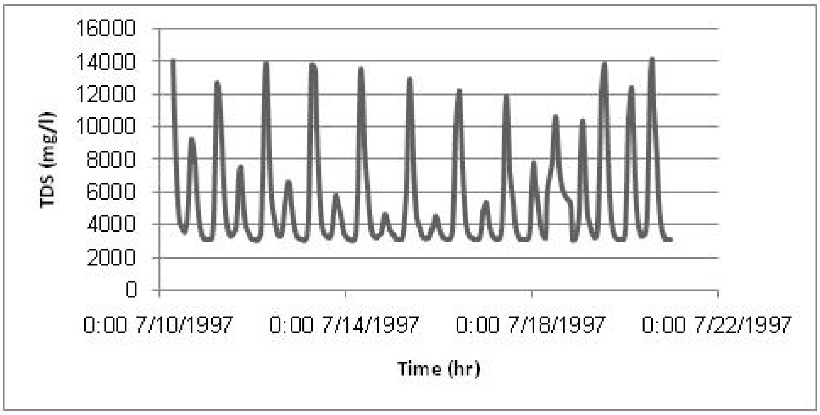

Figure 10. Simulated of TDS at chainage 20000 m in July 1997.

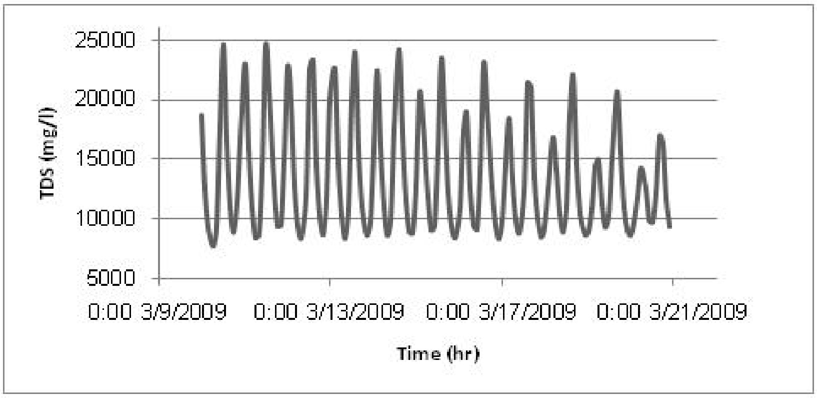

Figure 11. Simulated of TDS at chainage 20000 m in March 2009.

Conclusion

The results of the model have a good agreement with the observed data measurements of water levels and TDS distribution in Shatt Al-Basrah canal, so the model can be considered as a useful tool for assessing water quality along the Shatt Al-Basrah canal in the future if an accurate boundary condition of the model is used. The results of the model indicate that there is a significant deterioration in water quality of the canal because of reduction of inflow and variation in water quality of canal resources.

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نموذج محاكاة المواد الذائبة الكلية في شط البصرة باستخدام برنامج Mike11

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المستخلص - قدمت الدراسة تطبيق نموذج ذو بعد واحد لمحاكاة توزيع المواد الذائبة الكلية في قناة شط البصرة باستخدام برنامج Mike11. تم تشغيل النموذج لمدة 22 يوم وبخطوة زمنية مقدارها 60 ثانية وبخطوة مسافة 200 متر واحدة، تمت محاكاة السلوك الهيدروديناميكي وتوزيع المواد الذائبة الكلية في قناة شط البصرة لفترتين زمنيتين مختلفتين، تمثل الاولى فترة التصاريف العالية والتي تمثلت بفترة تجفيف الاهوار، اما الفترة الأخرى فكانت ما بعد عام 2008 والمتمثلة بافتتاح محطة ضخ المصب العام في محافظة ذي قار. تمت معايرة النموذج في مكانين، يقع المكان الاول قبل جسر الخط السريع والثاني بالقرب من جسر الزبير.كانت نتائج النموذج متطابقة بصورة جيدة مع القياسات الحقلية المتمثلة بارتفاعات المد والجزر وتوزيع المواد الذائبة.