

ONE DIMENSIONAL HYDRODYNAMICS MODEL FOR KHOR AL-ZUBAIR  
CHANNEL, SOUTH WEST OF IRAQ

ALI A. LAFTA<sup>1</sup>  
SAMER A. AL-TAEI<sup>2</sup>  
ADIL J. AL-FARTUSI<sup>3</sup>

<sup>1,2,3</sup> Marine Science Center, University of Basrah, Basrah, Iraq

**ABSTRACT**

The study of hydrodynamics behavior of Khor Al-Zubair channel was performed using one dimensional model “Mike11 computer program”. The model was run for two months with time step ( $\Delta t$ ) =100 sec and distance step ( $\Delta x$ ) =1000m. Model calibration and verification was done in two site along the channel, A1(Khor Al-Zubair port) and A2(south of Umm Qasar port), respectively. The results of the model have an acceptable agreement with the observation values. Thus the model can be used to investigate the different physical characteristics of the channel such as sediment transport, water quality or salinity distribution.

**KEYWORDS:** Khor Al-Zubair, Hydrodynamics Model, Numerical Modeling.

**INTRODUCTION**

There is a significant increase in economic, especially close to lagoons and estuaries. The most of industrial facilities such as factories and ports has been established close to these water bodies. A study of hydrodynamics behavior of lagoons and estuaries are essential to know the pollution movement and the ability of lagoon or estuary to inflow pollutant from industrial facilities and ships movement to the open sea. One of the most important tools to study the hydrodynamics properties of lagoons, estuaries, channel and rivers is computer modeling. These models are used in a wide range around the world in the field of water management like hydrological studies, salinity intrusion, oil spill, water quality, fate of pollution and sediment transport (Lafta et al., 2013).

Khor Al-Zubair, south west of Basrah city, is located within two of the most important Iraqi ports, Umm Qasar port and Khor Al-Zubair port. An additional to these ports there are four industrial plants: the petrochemical, steel, Umm Qaser cement, and fertilizer plant are located close to study area.

There are a few literatures investigated the hydrodynamics of Khor Al-Zubair that used numerical modeling. Al-Syab (1990) was developed one dimensional model for Khor Al-Zubair to study the effect of changing bathymetry on currents, it was assumed that Khor Al-Zubair has rectangular cross sections of constant width (1000m) and depth(10m). The 2-D numerical model had been developed by Baker et al.(1996) to compute the tidal elevation and vertical distribution of current and salinity along Khor Al-Zubair, and also rectangular cross section was assumed in this study. A 2-D mathematical model had been developed by Kudair (1997) to simulate pollutants in Shatt Al-Basrah canal and Khor Al-Zubair estuarine lagoon. The model investigated the hydrodynamic and water quality characteristics that influence the transportation, decay and biochemical transformations of the discharged pollutants. Al-Taei et al. (2012) use MIKE12 HD package to track the movement and fate of oil pollutants in Khor Al-Zubair. The aim of this study is to simulate hydrodynamics behavior of Khor Al-Zubair using Mike 11 hydrodynamic (HD) modeling program.

### **Study Area**

Khor Al-Zubair is an extension of the Arabian Gulf waters lays between 47°30′-47°55′North and 31°10′-30°30′ East. The lower boundary of Khor Al-Zubair is close to Warba Island about 8 km south east of Umm Qasar (figure1).

The total length of the channel is about 40km. The depth of the navigational channel ranges between 10 and 20 m. At high spring tide, the area that covered by water is approximately 60 km<sup>2</sup> (Al-Ramdhan, 1988). The tidal regime of Khor Al-Zubair is a mixture of the semi-diurnal and diurnal types, but the semi-diurnal type is dominant, hence two high waters and two low waters occur daily with inequalities in heights and time of occurrence (Al-Ramdhan, 1988).

In 1983, an artificial canal (Shatt A-Basrah canal) was opened in order to connect the Euphrates river (in Qarmat Ali), after it emerges from Al-Hammar marsh, with Khor Al-Zubair, changing the environment of Khor Al-Zubair from a hypersaline lagoon to an estuarine (Hussain and Ahmed,1999). In 1993, Shatt Al-Basrah canal connection with Qarmat Ali river was closed, and new connection made with MOD (Main Outfall Drain) at about 10 km from a head of the canal (MOD, 2008). To prevent the sea water from Khor Al-Zubair to Shatt Al-Basrah canal during the flood tide, the flow in the canal was controlled by a barrage (Al-Basrah Barrage) located at about 22 km from canal upstream.

In the last years there is a reduction in flow rates from MOD to Shatt Al-Basrah canal and then to Khor Al-Zubair. The current flow of the MOD to shatt Al-Basrah canal is less than  $15 \text{ m}^3/\text{sec}$  and reduces to  $0 \text{ m}^3/\text{sec}$  in some seasons ( Marine Science Centre, 2013). Umm Qasar River<sup>1</sup> is an artificial canal was constructed to expand and develop Umm Qasar port in west side of Khor Al-Zubair and it contains many emptying berths for ships. The canal length is about 4 km with average depth between 7m and 12 m. On the other hand, the climate is affecting the hydrodynamics of Khor Al-Zubair, an arid desert where the hot season which runs from May until October, is characterized by high wind speed and evaporation (Al-Taei etal, 2012). There are two types of prevailing winds in the region, northwest winds (65%), which causes dust storms in the summer, and southeast winds (35%) mostly during autumn and winter(Al-Mahdi and Mahmood, 2010).

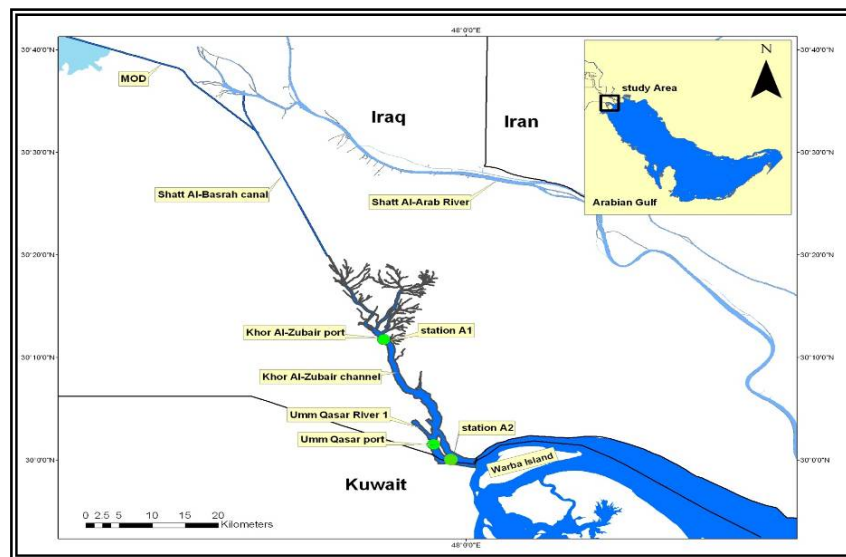


Figure (1): Location map of study area shows the stations of calibration and verification of the model(A1 and A2).

### Model Description

Mike 11 is a one- dimensional modeling system developed by Danish Hydrologic Institute, which is capable of simulating the hydrodynamics properties, water quality and sediment transport in rivers, estuaries and channels (DHI, 2007). It's performed an implicit finite difference computation of unsteady flow based on the saint Venant equations described below:

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} \left( \frac{Q^2}{A} \right) + \frac{\partial}{\partial x} \left( \frac{Q^3}{A^2} \right) = -gA \frac{\partial h}{\partial x} - \frac{Q}{A} \frac{\partial A}{\partial x} \quad (1)$$

(1)

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

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

### Model Application

The geometry of study area has created in one dimension in network file (network 11). It deals with actual data grid (Eastern and Northern points of study area). Satellite image at the 38 zone of southern Iraq was used to obtain the actual coordinates grid of network file. The networking process was began from Shatt Al-Basrah canal (south of the Al-Basrah barrage) at geographical position 30°23'57.65" N and 47°46'48.92" E and finished at Warba Island about 8 km south east of Umm Qasar at geographical position 29°59'49.74"N and 47°59'42.14"E, and then Umm Qasar River 1 branch was connected to Khor Al-Zubair branch (Figure 2).

The bathymetry model was set up using 51 cross sections along the channel of Khor Al-Zubair and 4 to Umm Qasar River 1. The cross sections that used in this study were obtained from a survey done by the Marine Science Centre, the University of Basrah (Marine Science Centre, 2006). It's necessary data to modeling and simulate morphological setting of channel and then estimate hydraulic parameters for each 1000 m. The accuracy of bathymetric data is directly reflected on the hydrodynamic model accuracy. The boundary of the upstream and downstream is an open type. At upstream (chainage 0.0 m) the discharge value was used is constant and equal to 0 m<sup>3</sup>/sec. A time series file for downstream water level (chainage 51166.0 m) was created using data from May and June 2012 (Figure 3).



Figure (2): Network file of study area

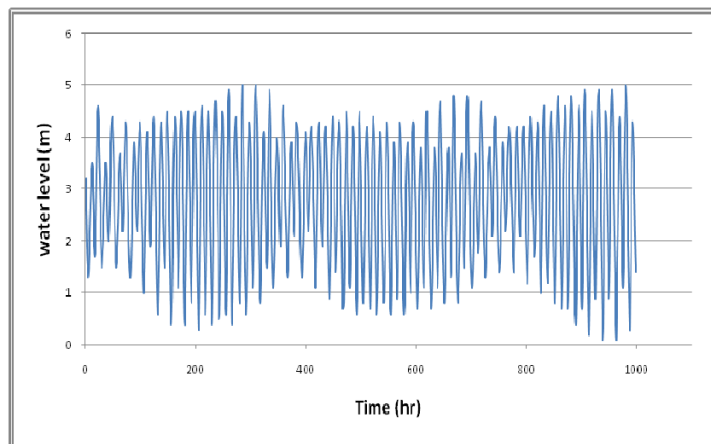


Figure (3): Water level fluctuations in downstream of Khor Al-Zubair (UKHO, 2003).

### Results and Discussions

The model was run with time step ( $\Delta t=100$  sec and  $\Delta x=1000$ m) and during two months from time series of water level readings (UKHO, 2003) to simulate the hydrodynamics conditions of Khor Al-Zubair channel. Calibration is the process by which adjusted the parameters that selected from the model to make the output result match real measurements. Calibration purpose in this study is to obtain a reasonable set of parameters in order to be used in simulation. In the Hydrodynamic model, Manning number  $n$  is so- called calibration parameter. The accuracy of the model can be assessed by the Relative Errors (RE) between the simulated and measured values of water discharge.

$$RE = \sum_{i=1}^N \frac{|M_i - C_i|}{M_i} \times 100\% \quad (3)$$

Where  $M_i$  is the measured (observed) value,  $C_i$  is the calculated (simulated) value,  $N$  is the number of observations.

One of the most important parameters in developing hydrodynamic models is bed roughness coefficient. Although such coefficient is linked to physical properties of the modeled river reach, their values have to be determined through a calibration process. By adjusting the Manning number  $n$ , the simulated discharge become fit with the observed values. The Manning number  $n$  value must be 0.04 to obtained best matching between measured and simulated values.

The measurements of discharge in station A1 (Khor Al-Zubair port) in figure (1) at the geographical position  $30^{\circ}11'52.67''\text{N}$  and  $47^{\circ}53'5.58''\text{E}$  on 27<sup>th</sup> June 2012 was used in the calibration of the model as shown in figure (4), with RE 7% between the measured and simulated values of discharge. The verification of the model was done using measurements of discharge in station A2 (Umm Qasr port) at the geographical position  $30^{\circ}0'2.49''\text{N}$  and  $47^{\circ}58'43.37''\text{E}$  on 29<sup>th</sup> June 2012 as shown in figure (5). The field measurements of discharge was done by specialist team from the Marine Science centre, the University of Basrah, using Acoustic Doppler Current Profile model kHz 1200 Rio Grand.

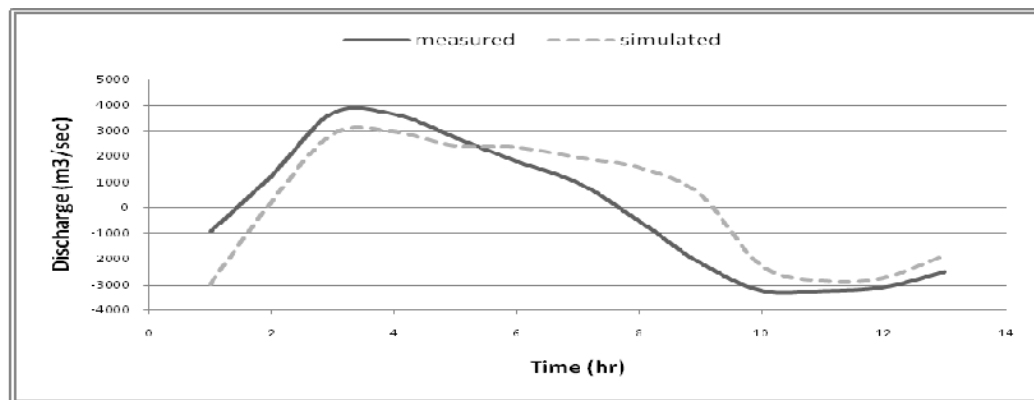


Figure 4. Comparison between simulated and measured discharge at station A1.

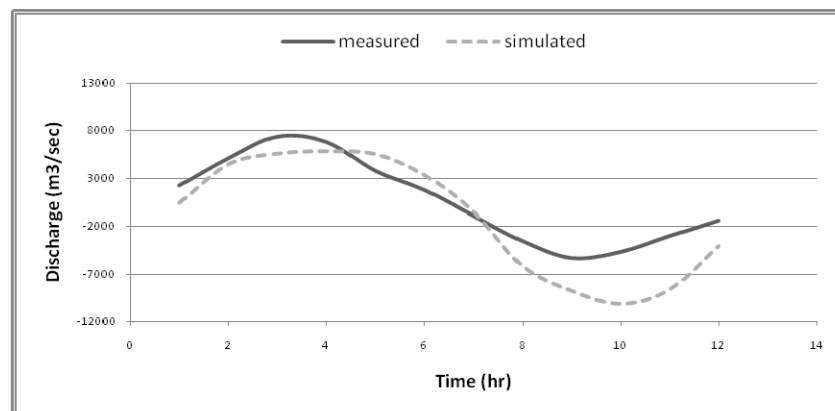


Figure 5. Comparison between simulated and measured discharge at station A2.

After the calibration of the model was used to study hydrodynamics behavior of Khor Al-Zubair Channel. The tidal phenomenon mainly represents the influencing factor in the change of hydrological situations in this area. The flow is strongly affected by the range of water levels and phase of tide in the Channel. It means that the water velocity, water level,

flow direction, and tidal fluctuations could be changed. The hydrodynamic characteristics for any point of the Channel can be explained in the model results. In general, the nature of the tidal for the study areas is a mixed type of diurnal and semidiurnal with semidiurnal is dominant, and this is evident in the results of the model, and water rising in high tide to 5.4 m and 5.2 m in station B1 (Khor Al-zubair port) and station B2 (Umm Qasar ports) respectively. The calculated tidal range was 4m and 3.5m in spring tide and 3.5m and 2.9m in neap phase in station B1 and station B2 respectively. The time period of the ebb phase was longer than of the flood period phase in Khor Al-Zubair. The time period in station B1 for the ebb phase reach up to 8 hours and up to 5 hours for the flood phase. these time periods could be change from one site to the other along the Channel according to tidal effect and section topography.

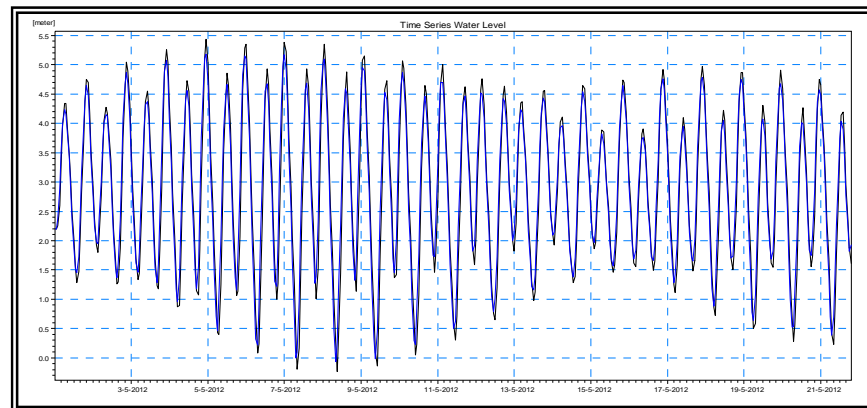


Figure (6): Computed tide heights for Khor Al-Zubair at stations( —B1 and —B2 )

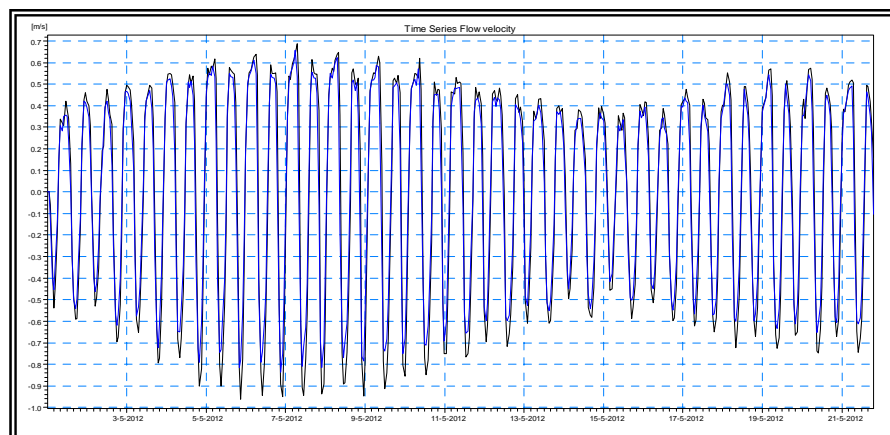


Figure (7): Currents velocity in Khor Al-Zubair at stations ( —B1 and —B2 )

Figures (7) represent the water current speed in two positions of the Khor Al-Zubair. It can be seen that the current velocities up to maximum values at 1 m/sec and 0.95 m/sec in



spring tide, and 0.75 m/sec and 0.72 m/sec for neap tide in stations B1 and B2 respectively. The currents speed for flood period was faster than the ebb period along the Channel, this is due to long period of the ebb and the strong tidal effect in the area, this corresponds with the results of Al-Mahdi (1990). The variations of hydraulic radius ( $R_h$ ) of the Channel shown in figure (8). The main factor to this variations is the tide in the Channel. The hydraulic radius values was 10.75m and 14.8m in B1 and B2 respectively, these changes are due to variation in cross sections and the wet perimeter. The changing range in  $R_h$  was 4m in B1, reduced to 3m in B2 because of high tidal energy.

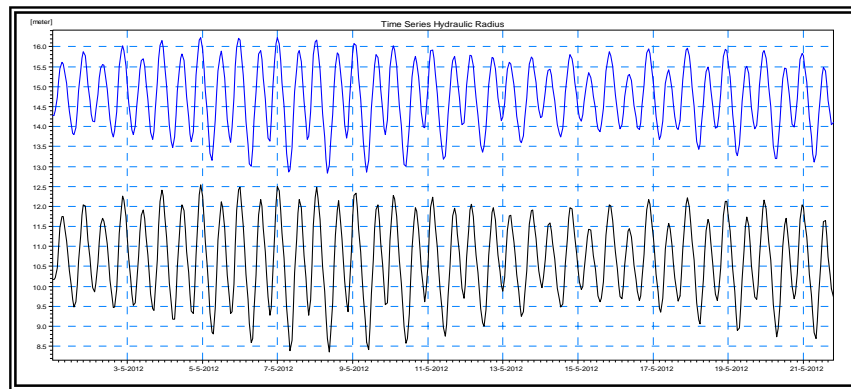


Figure (8): Hydraulic Radius in Khor Al-Zubair stations( —B1 and —B2) .

Figure (9) represent the flow area of Khor Al-Zubair. The flow area in B2 was about 60% greater than in B1 due to the large cross sections depths and width in lower reaches, which is lead to entry the tidal energy smoothly towards the upper reaches of the channel.

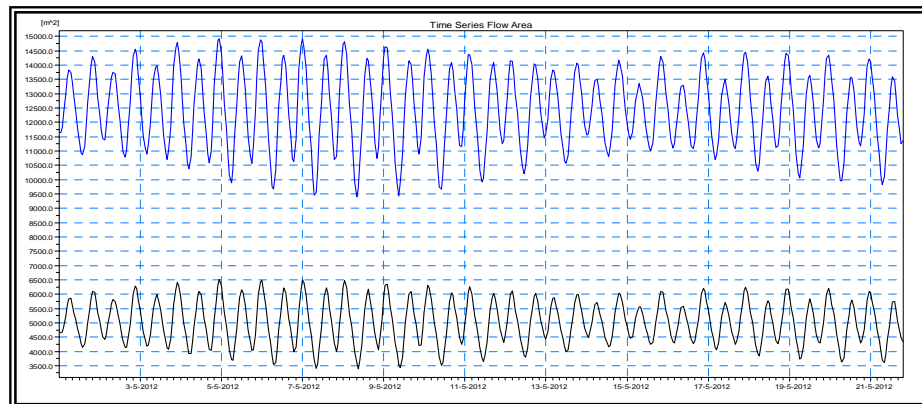


Figure (9): Flow Area of Khor Al-Zubair stations( —B1 and —B2) .



## CONCLUSIONS

The application of one dimensional hydrodynamics model by using Mike11 program has been used to study hydrodynamics behavior of Khor Al-Zubair channel. The result of the model has an acceptable agreement with observations of discharge values. Thus the model can be used to investigate the different physical characteristics of the channel such as sediment transport, water quality or salinity distribution.

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