Mathematical Model for Evaluating of Sediment Transport (Case Study: Karkheh River in Iran)

Farhang Azarang*, Abdol Rasoul Telvari2, Hossein Sedghi1 and Mahmoud Shafai Bajestan3

1Department of Water Science and Engineering, Science and Research Branch, Islamic Azad University, Tehran - 1477893855, Iran; farhang.azg@gmail.com, hsedgh@yahoo.com
2Department of Civil Engineering, Faculty of Engineering, Islamic Azad University, Ahwaz, Iran; telvari@gmail.com
3Department of Water Science and Engineering, Shahid Chamran University, Ahwaz, Iran; m_shafai@yahoo.com

Abstract
Reservoir dams are the most important hydraulic structures built on rivers and have a great impact on the river conditions. In this study, MIKE 11 mathematical model in Karkheh river is used in Iran. Karkheh River is one of the most important rivers of Iran on which Karkheh Reservoir Dam is built. MIKE 11 Model is used for simulation of flow and sediment in rivers. The studied river flow downstream of Karkheh Reservoir Dam and encompasses geometric, hydraulic and sediments information of Karkheh River in Abdolkhan and Hamidiyeh hydrometric stations. Manning’s roughness coefficient 0.025 was considered for Karkheh River and computational results were compared and evaluated with observational data. Cross sectional geometrical changes of Karkheh River upstream (Abdolkhan hydrometric station) were calculated and the best ways to predict changes were introduced. Engelund-Hansen and Ackers-White equations offered better predictions of changes in the Karkheh River shape. Longitudinal bed level changes of Karkheh River was estimated from upstream to downstream. Elevation changes of Karkheh river bed was obtained at the hydrometric stations of Abdolkhan (upstream) and Hamidieh (downstream) using MIKE 11 Model. According to the results of the study, it can be understood that Karkheh River has changed changes in its river bed shape and MIKE 11 Model can be an appropriate software for predicting sediment conditions of the rivers in Iran.

Keywords: Karkheh River, MIKE 11, Sediment Transport, Total Sediment Load

1. Introduction
Rivers are the most important water supplies and studying their hydraulic and sediment conditions are great matter. One of the most important studies in this field is erosion and sediment transport. Estimating of sediment transport capacity in rivers is very important component in planning and designing of soil conservation and watershed treatment, river training, flood control and hydraulic structures. In fluvial rivers and open channels, stream channel confluences produce significant changes in flow regime, sediment transport and water quality. The study of river bed changes is the issues which has attracted river engineers. Attention to investigate the rate of scour and sedimentation is significant in studies of rivers and channels. With construction of reservoir dams, a large amount of sediment are accumulated behind them. Therefore, water released from reservoir dam is so clear and possesses high sediment transport capacity, which causes the river erosion at downstream the dam. The use of hydraulic and sediment simulation models in rivers can be very important for planning and studies of the watershed. Karkheh Basin is one of the most important watersheds of Iran which belongs to Karkheh River (the third biggest river of Iran). Karkheh river is very important for Khuzestan province, because various agricultural projects is designed in this province. Our aims in this study have evaluated the sediment conditions of Karkheh River downstream Karkheh Reservoir Dam and to predict changes in the geometry of the river.

Keskin et al. simulated by MIKE 11 in Yuvacik Dam Basin, simulation period in between the years 2001 and 2006, they calibrated the MIKE 11 Model with snowmelt and rain on snow events and verified with the daily event2.
Neary et al. studied the sediment transport process of Napa River using MIKE 11 Model. They used hydrodynamics and sediment transport parts of the model and studied the river bed elevation changes between 1989 and 1997. Shvidchenko et al. carried out the simulation of flood and sediment transport in Coachella Valley using MIKE 21 model and evaluated sediment transport specifications of the river. Timbadiya et al. have used MIKE 11 Model for Tapi Basin in 2003 to 2006, they calibrated the MIKE 11 Model for Tapi River and computed hydraulic parameters, also, they believed the simulation results based on the hydrodynamics modeling can be improved by using a two-dimensional model.

2. Material and Methods

2.1 Karkheh Catchment

Iran is located in Southwest of Asia and Karkheh catchment area is located in south-western of Iran. Downstream of Karkheh River Catchment is located in Khuzestan Province and it has an area of about 50 thousand square kilometers. The average annual rainfall of the Karkheh Catchment is 500 mm and rainfall and precipitation is in autumn, winter and spring. Figure 1 shows the study area.

2.2 Karkheh River

Karkheh River is one of the largest river in Iran that originated of the Zagros Mountains and in the downstream of Karkheh basin falls into Hooralazim. Main branches of Karkheh river in upstream of Karkheh Catchment is: Gamsariab, Gharehsoo, Seymareh and Kashkan.

2.3 Karkheh Reservoir Dam

Karkheh Reservoir Dam is the biggest earth dam on the Middle East and has influenced positively on its district in terms of plantation area and in addition has controlled devastating floods. The dam was built at 2000. Figure 2 show Karkheh Reservoir Dam.

2.4 Studied River Reach of Karkheh

This study focused on the downstream of Karkheh Reservoir Dam; the length of Karkheh River is approximately 100 kilometers between the Abdolkhan hydrometric station and Hamidiyeh hydrometric station. The study period of this research is exactly ten years, between 2001 and 2010.

2.5 Mathematical Model used in Research

MIKE 11 Model is a professional, one-dimensional and dynamic engineering software of the DHI (Danish Hydraulic Institute) produced in 1992. This software is used to simulate flow regime, sediment transport and water quality in rivers and channel networks of catchments, as well as the management of rivers and the irrigation and drainage networks. MIKE 11 Model simulates the flow and sediment transport of rivers and channels in one-dimensional condition. This software is now widely used in
the world. The following abbreviations of module names are used:

- Hydrodynamic.
- Advection-Dispersion.
- Sediment Transport.
- Rainfall-Runoff.
- Flood Forecast.
- Data Assimilation.
- River Ice Modelling.

In this research, Hydrodynamic and Sediment Transport of MIKE 11 Model are used for simulating of Karkheh River. The following information of river is required in order to simulate by MIKE 11 software:

- Geometry Data of River.
- Hydraulic Data of River.
- Sediment Data of River.

MIKE 11 software uses of the equations of dynamic wave model to routing the flow regime in the rivers. Equation of continuity and momentum in this method is known as Sant Venant equation, which includes:

\[
\frac{\partial Q}{\partial t} + \frac{\partial (\alpha Q^2 / A)}{\partial x} + \left( gA \frac{\partial h}{\partial x} + \frac{gQ|Q|}{C2AR} \right) = 0 \tag{1}
\]

\[
\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \tag{2}
\]

Where,

- \( Q \) = Discharge.
- \( A \) = Area of Cross Section.
- \( C \) = Chezy Coefficient.
- \( R \) = Hydraulic Radius.
- \( h \) = Water Level.
- \( q \) = Lateral Discharge.
- \( \alpha \) = Momentum Correction Factor.

Also, the MIKE 11 Model uses nine equations to calculate total sediment load of the river. These equations include:

- Ackers and White.
- Ashida and Michiue Ashida.
- Takahashi and Mizuyama.
- Engelund and Fredsoe.
- Lane and Kalinske.
- Meyer-Peter and Muller.
- Kikkawa and Ashida.
- Smart and Jaeggi.
- Van Rijn.

The following Figure 3 shows a view of the MIKE 11 Model.

The length of Karkheh River which this research has been is located in downstream of Karkheh Reservoir Dam. This river reach is approximately 100km starts from Abdolkhan hydrometric station at upsteram to the Hamidiyeh hydrometric station at downstream. In this research, the information has been gathered from two different hydrometric stations, named Abdolkhan and Hamidiyeh. The location of the Abdolkhan and Hamidiyeh stations on MIKE 11 Model is showed at Figure 4.

3. Results and Discussion

3.1 Hydrodynamic Model

The hydrodynamic model of the MIKE 11 Model is the basis of all this model equations including diffusion, transmit, water quality, sediment transport and etc.

Figure 3. Views of MIKE 11 Model.

Figure 4. Plan of Karkheh River at the interval distance of study on MIKE 11 Model.
3.2 Cross-Section Data

In this research, approximately 200 cross sections with an average distance of about 500 meter from each other along the Karkheh River (From Abdolkhan station to Hamidiyeh station) were used. Figure 5 shows an example of a cross-section in MIKE 11 Model.

3.3 Boundary and Initial Conditions

The numerical method was used at MIKE 11 software, requires determination of the initial quantities of water level and flow discharge of river at all computing nodes to start the computations. For determining the upstream and downstream boundary conditions of river to the hydrodynamic model, the time series of daily flow discharge of the river at Abdolkhan station (at upstream) and the water level - discharge curve of Hamidiyeh station (at downstream) were used, respectively (Figure 6).

The sediment rating curve (discharge of river vs. total sediment load) of Abdolkhan hydrometric station is shown at the Figure 7.

3.4 River Roughness Coefficient Estimation

One of the parameters that should be calibrated in mathematical models of hydrodynamic simulations is the resistance coefficient of river’s bed which defined as Manning roughness coefficient or Chezy coefficient. Experimental methods used to determine the Manning roughness coefficient (Table 1). 0.025 value for the Manning roughness coefficient were considered.

To run the sediment transport model in MIKE 11 software, the grain size distribution curves were considered at the Karkheh River. Also, the specific weight of sediments based on measurements at hydrometric stations was assumed equal to 2.65 ton per cubic meter. Figure show grain size distribution curves of Abdolkhan and Hamidiyeh Stations (Figure 8).

3.5 Hydraulic Results of the River

Table 2 indicates to hydraulic parameters of the Karkheh River at Abdolkhan and Hamidiyeh hydrometric stations.
measurements at hydrometric stations was assumed equal to 2.65 ton per cubic meter.

To run the sediment transport model in MIKE 11 software, the grain size distribution curves were considered. The roughness coefficient (Table 1) was taken as 0.025 value for the Manning roughness coefficient.

Table 2. Hydraulic parameters results

| Hydrometric Station | Discharge of River (m³/s) | Cross Section Area (m²) | Velocity of River (m/s) |
|---------------------|---------------------------|-------------------------|------------------------|
| Abdolkhan           | 100                        | 157                     | 0.44                   |
|                     | 200                        | 398                     | 0.56                   |
|                     | 500                        | 722                     | 0.67                   |
|                     | 1000                       | 1287                    | 0.73                   |
| Hamidiyeh           | 100                        | 205                     | 0.37                   |
|                     | 200                        | 413                     | 0.47                   |
|                     | 500                        | 743                     | 0.56                   |
|                     | 1000                       | 1343                    | 0.63                   |

which calculated on the basis of different water discharges by hydrodynamic part of MIKE 11 Model.

3.6 Morphological Results of the River

In the simulation process, all methods of MIKE 11 Model that was mentioned at model introduction part were used and their results were compared. Refer to this model computation and compared results with the field observations, the methods of Engelund-Hansen and Ackers-White had the most correlation at the morphological model. Predicted changes at the shape of river cross section versus observed data values by the two methods of Engelund-Hansen and Ackers-White at the Abdolkhan Hydrometric Station is shown at Figure 9.

To indicate the longitudinal profile of the river bed assessments the Engelund-Hansen method was used (Figure 10).

The Figure 11 exhibited the Karkheh River bed elevation changes versus time at the Abdolkhan and Hamidiyeh Hydrometric Stations which can be interpreted as follows:

Figure 11(a), which is related to Abdolkhan station, shows a sinusoidal trend is changing. In general, bed...
elevation value is increased due to the sedimentation. Figure 11(b) also represents the variation of the bed elevation at Hamidiyeh station which this value is reduced and erosion occurred during the period of study.

### 3.7 Total Sediment Load Assessment

The total sediment load of the river versus the different river flow discharges is obtained by the MIKE 11 Model. By study of model out puts, it is recommended to use the Engelund-Hansen and Ackers-White methods to simulate the total sediment load of the Karkheh River. Table 3 displays total sediment load assessment using two mentioned methods and the results were compared with the measured values of the field at Abdolkhan and Hamidiyeh Stations.

- Flow velocity of Karkheh River is low so sediment deposits in river.
- The Ackers-White values are usually predicted to be more than Engelund-Hansen values.
- The results show that Karkheh River in Hamidiyeh Station has more sediment transport capacity.
- Karkheh River is an alluvial river and sedimentation area in Khuzestan Province.
- Engelund-Hansen and Ackers-White methods are suitable in Karkheh River Catchment.
- Another methods of sediment transport are not valid for downstream of Karkheh River.

### 4. Conclusion

We studied hydraulic and sediment transport of Karkheh River Downstream in artificial flow.

In this research, MIKE 11 Model is used for hydrodynamic and sedimentary simulations of the river. Processing the out puts of MIKE 11 Model suggests that the Engelund-Hansen and Ackers-White methods are very suitable in downstream of Karkheh Reservoir Dam. Our results can be appropriate research for river engineers.

### 5. References

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