Modeling of Sediment Transport Upstream of Al-yaa'o regulator in Al-Najaf city

Prof. Dr. Saleh I. Khassaf
Mohammed jaber Abbass
Kufa University-Faculty of Engineering

Abstract

In this research it was studied and modeling the sediment transport in the channel regulator of Al-Yaa'o in the southern city of Najaf.The reason of choosing the study area is to control water releases of the channel regulator because of the large agricultural areas on both banks of the river that make use of the channel regulator for the purpose of agriculture, as well as constituting of some islands in the river because of the low rates water discharges. A mathematical model of one-dimensional simulation flow was run and performed; the amount of sediment load in this part of the river was calculated by using the program of HEC-RAS version (4.1) in which field measurement were taken by the ADCP device to calculate the discharge and areas of cross-sections.The research requires choosing seventeen cross-sections along the study reach which is (5 km).

It has been shown by comparison with field results that the Toffaleti formula from this model was the closest to the results of the field, and sediment transport load annually through this formula ranges from (11023) tons to(248419) tons by the lowest and highest discharge respectively.

Keywords

sediment transport, modeling, regulator, HEC-RAS

1- Introduction

Sediment transport is a major problem in the control and utilization of the surface waters of the earth. Sedimentology is the branch of science dealing with the properties of solid particles considered singly or as a mixture. Mixtures may be composed of different kinds of particles varying in size, gradation and specific weight.The cause for selecting this site of this study due to the composition of these islands and the increase of the sediment deposition in the river reach and to control water releases of the channel regulator.The decrease in the discharge of Euphrates

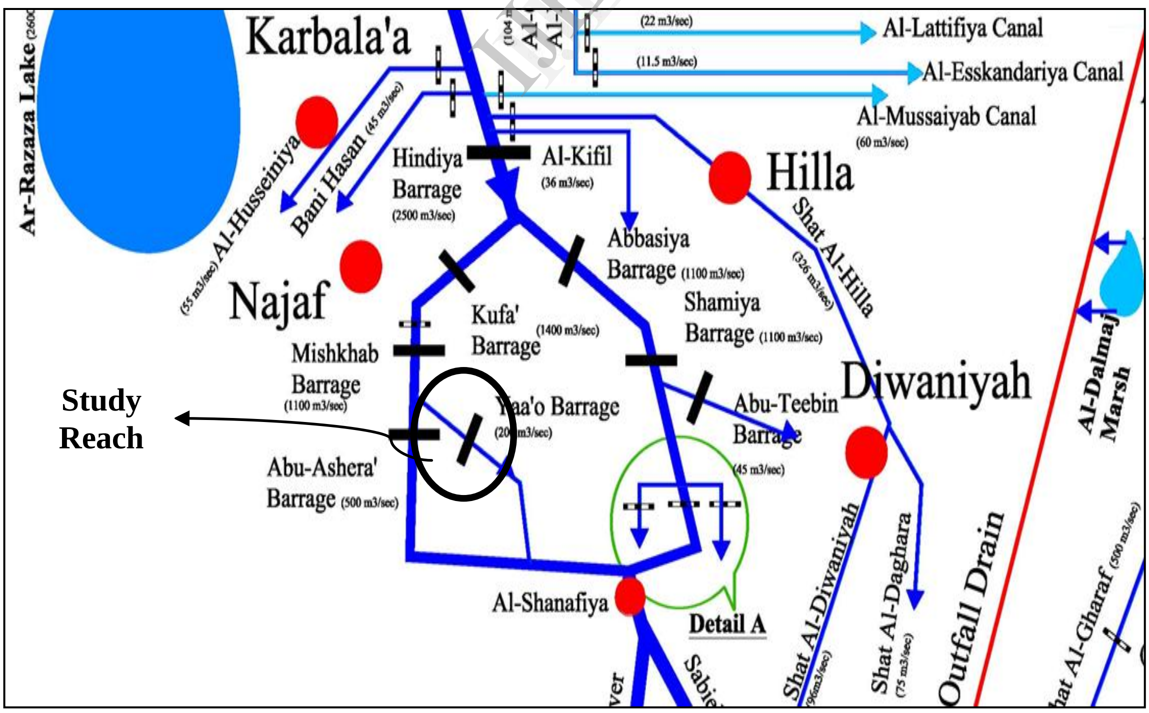
River because of the decrease in the water resources causes decrease in flow velocity, constituting of islands and changing the morphological characteristics of this reach.

In this research, the model of (HEC-RAS)(4.1) is a software program that permits to perform one-dimensional steady flow and bed modeling,and perform a mobile bed sediment transport analysis computations.

2- Description of Study Reach

Al-Yaa'o channel regulator is an important project of irrigation in the south of Al-Najaf governorate in the middle of Euphrates region within (50) km southeast of Al-najaf city in the region of Al-Qadissya, a branch of the lift side of Al-Meshkhab river, and downstream of it, on the Euphrates river. It was constructed on Kifil-Shenafiyah branch.

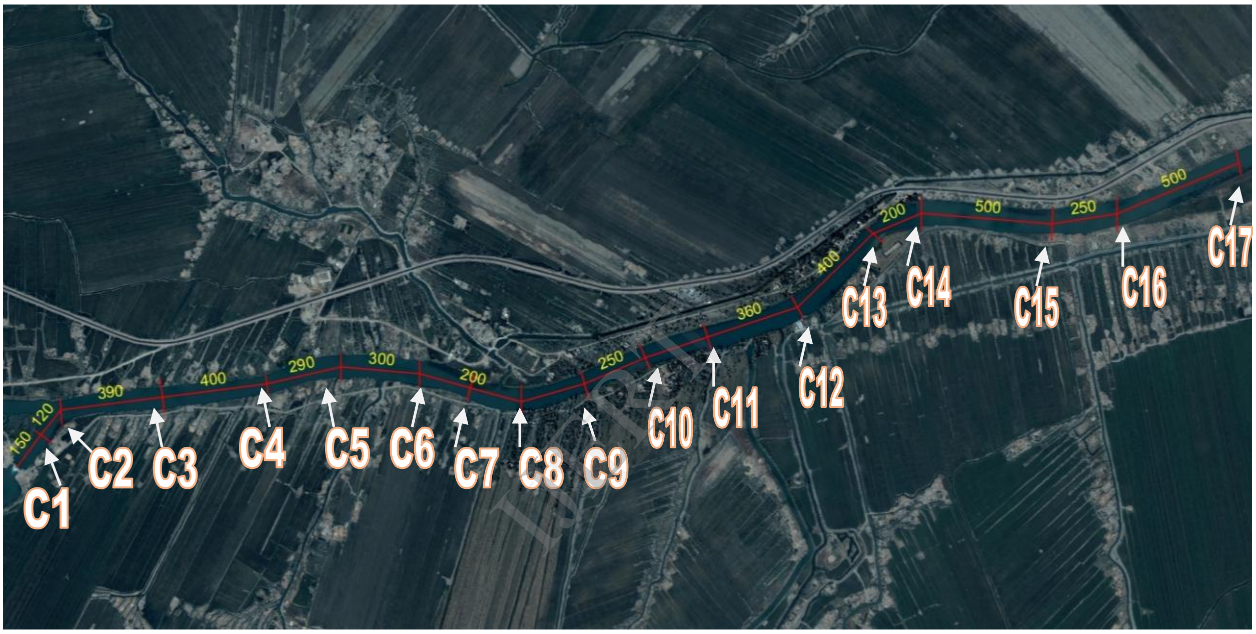
The designed flood discharge of the channel regulator is(400) $m^3. s^{-1}$,and the operational discharge range (150) $m^3. s^{-1}$with an operational water level as mentioned in the upstream is(17.75)m above sea level. The study region is located between Y 35°08'244.8" to Y 35°12'349.65" and X 45°11'87.47" to X 45°36' 53.40".Figure(1) explain the location of Al-Yaa'o channel regulator **[2,3].**



Figure(1): Schematic diagram for reach-study location[3].

3- Field Data

Seventeen cross sections are specified in the upstream of the channel regulator which were selected at **(150, 120, 390, 400, 290, 300, 200, 200, 250, 250, 250, 360, 400, 200, 500, 250, and 500) meter** intervals. These distances were chosen due to a hydraulic changes in these sections which expanded from AL-Yaa'o channel regulator against the water flow direction, as shown in figure (2). The duration of the field work was done for the period from (3/ January / 2013) to (17 /April /2013). The (ADCP) device used to measured the Hydraulic properties as shown in figure(3).



Figure(2): Reach-study location by Google Earth.

Figure(3): ADCP device.

The observed cross sections, discharges, , mean velocities, and specific gravities for the study reach resulting from (ADCP) device are tabulated in table (1) below:

Table (1):The hydraulic properties of the study reach(cross section area, discharge, mean velocity, and Specific gravity) for each section.

Section No.	Cross section area (m^2)	Discharge ($m^3.s^{-1}$)	Mean velocity ($m.s^{-1}$)	Specific gravity (Gs)
1	172.10	37.33	0.217	2.68
2	205.30	22.97	0.112	2.70
3	244.90	25.99	0.106	2.67
4	161.40	40.62	0.252	2.68
5	149.80	25.18	0.168	2.67
6	189.60	39.43	0.208	2.68
7	171.70	42.33	0.247	2.69
8	182.80	44.54	0.244	2.70
9	177.60	60.51	0.341	2.66
10	170.00	53.25	0.313	2.70
11	150.20	41.76	0.278	2.66
12	166.10	42.97	0.259	2.68
13	189.60	38.74	0.204	2.67
14	154.50	41.93	0.271	2.69
15	174.70	38.59	0.221	2.70
16	187.10	22.03	0.118	2.66
17	199.50	21.09	0.106	2.70

4- Flow Routing Model

A steady one dimensional flow mathematical model was used to simulate the flow in this reach in order to obtain the water surface elevation, flow velocity and sediment transport load along the reach under a set of steady flow conditions. The HEC-RAS software Version (4.1),figure(4) was used to perform this target**[8]**.

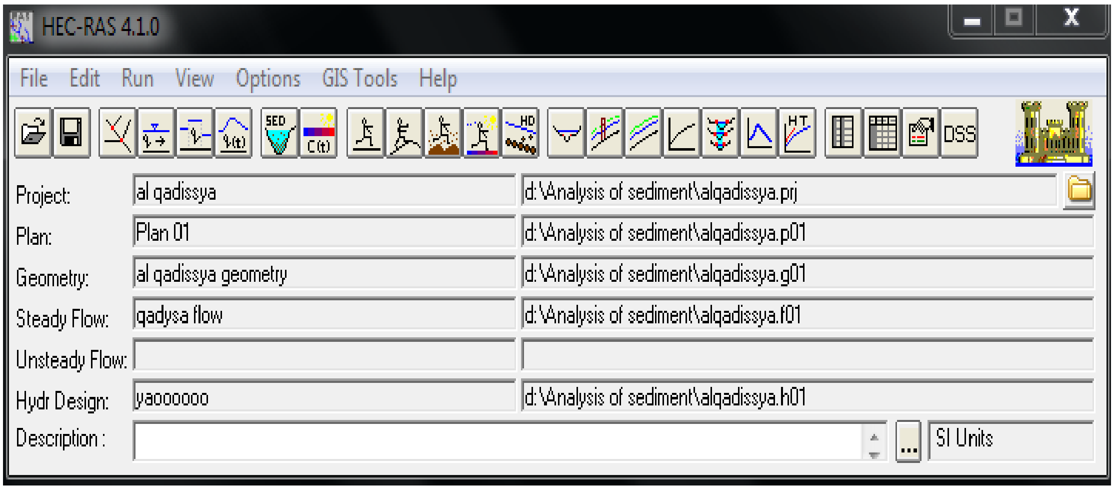


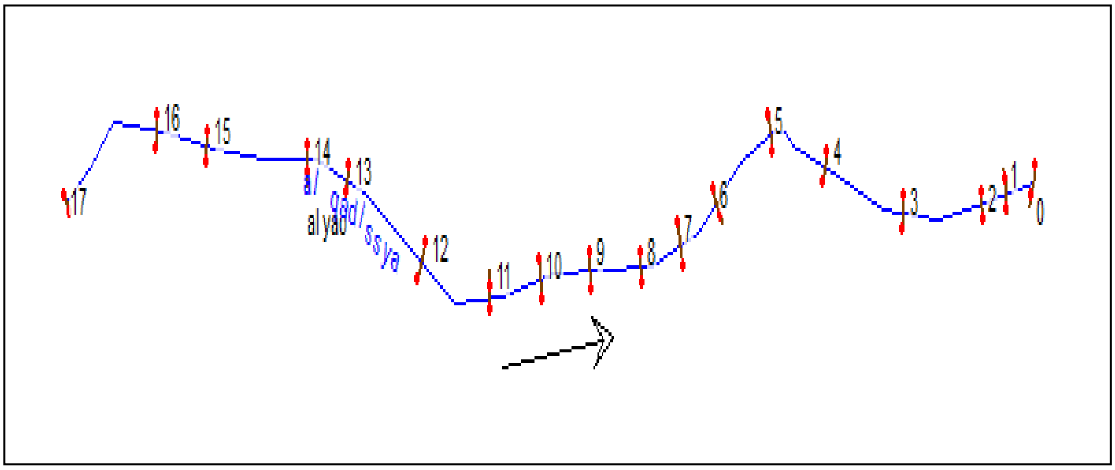
Figure (4): Main menu of HEC-RAS(4.1.0) model [7].

4-1 Geometrical Data

The surveyed river cross sections,left and right banks, downstream reach length, proposed initial Manning's roughness coefficient, n, of the main channel, information were the geometrical data required to run the model. These data were input to the model through the menu of cross section geometrical data.

All sections are drawn from upstream to downstream (in the flow direction) because the HEC-RAS(4.1) model assumes this to be true, as shown in figure(5).

After the river schematic system was drawn. The next step is to input the essential geometric data which consist of connectivity information for the stream system such as cross section data that represent the geometric boundary of the stream as the model is about the seventeen cross sections (x,y) coordinates (station and elevation points).It is needed at representative locations along the stream and at locations where changes occurs in discharge and slope.as shown in figure(6)and(7)**[8]**.



Figure(5): General schematic plan of the study reach by HEC-RAS(4.1).

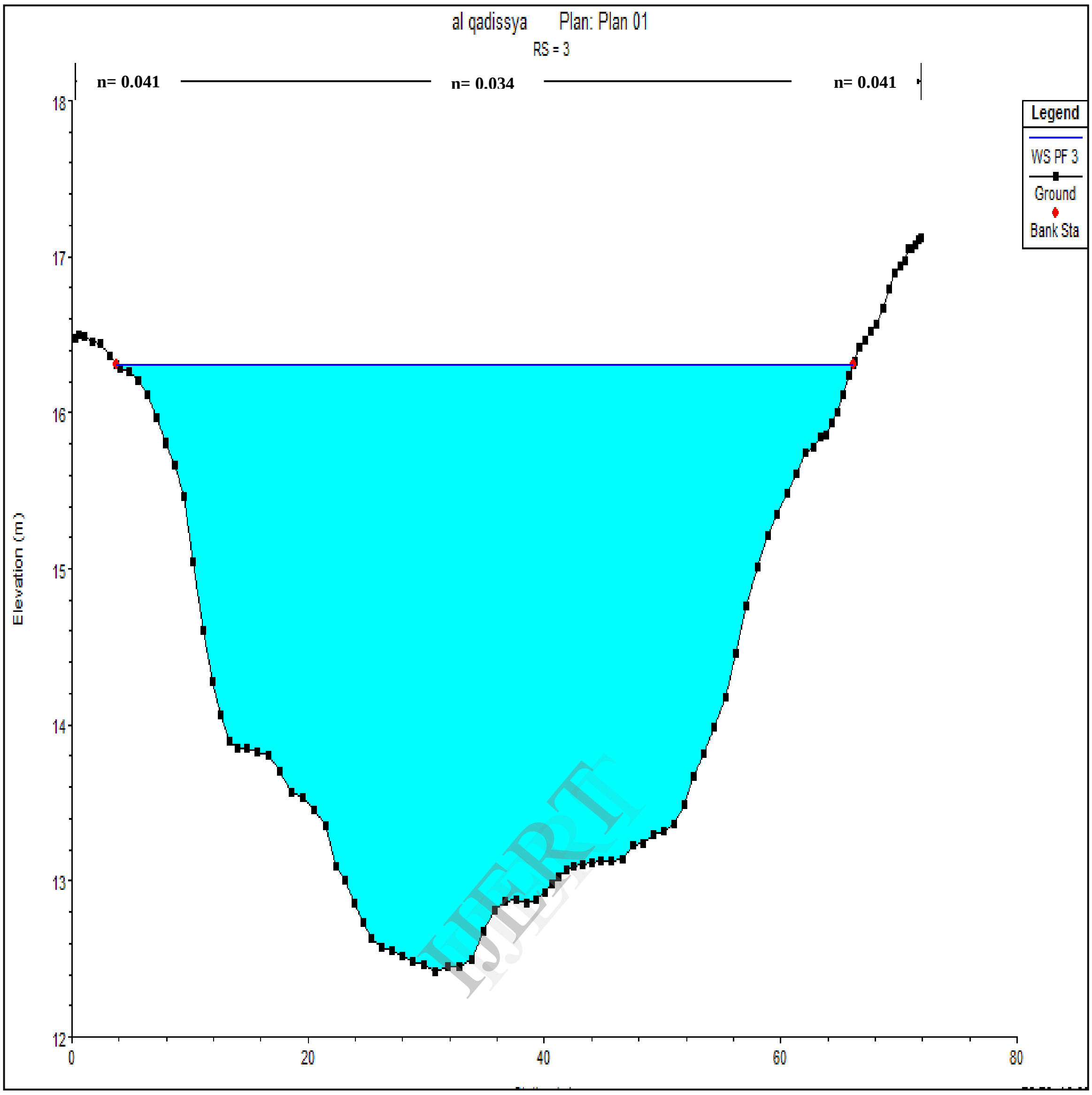


Figure (6): Data of the study reach (cross section).

4-2 Steady Flow Data

The HEC-RAS(4.1) model deals with the boundary conditions depending on the flow regime. In a subcritical flow regime, which is the flow regime in the river under consideration, boundary conditions are only necessary at the D/S ends of the river system and deals with its data in a separated window. The measured discharges from ADCP device for seventeen cross sections are were inputted,and adopted as the upstream boundary required to run the model using the steady flow data menu. The adopted normal flow slope was(0.0001) as shown in figure(8),and(9).

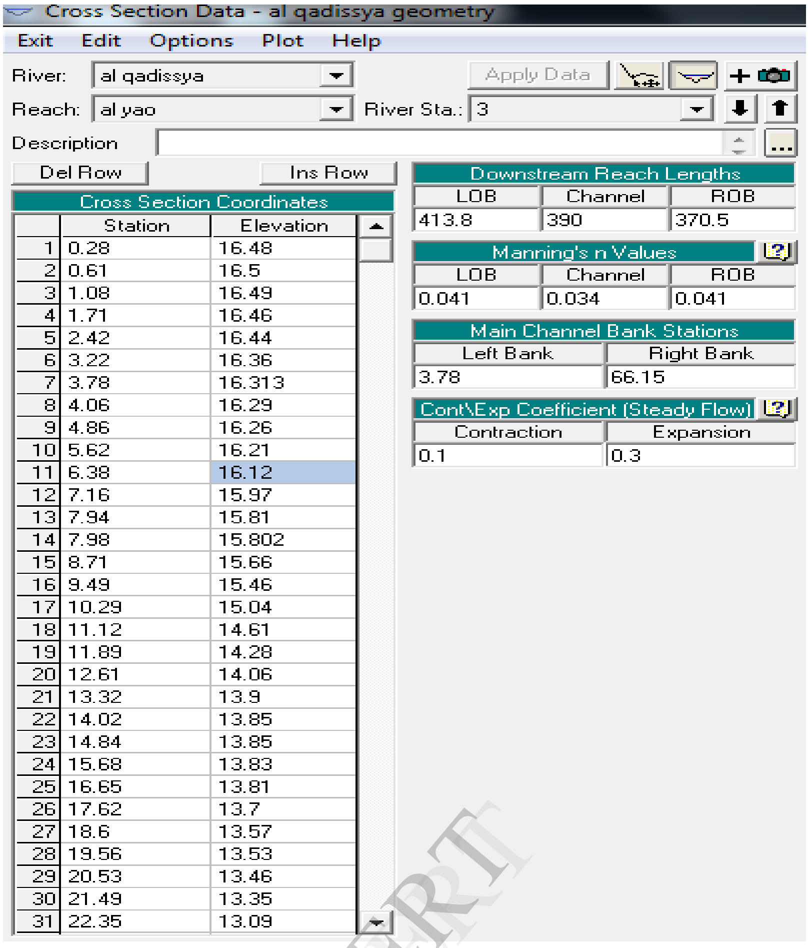


Figure (7): Data of Cross-section.

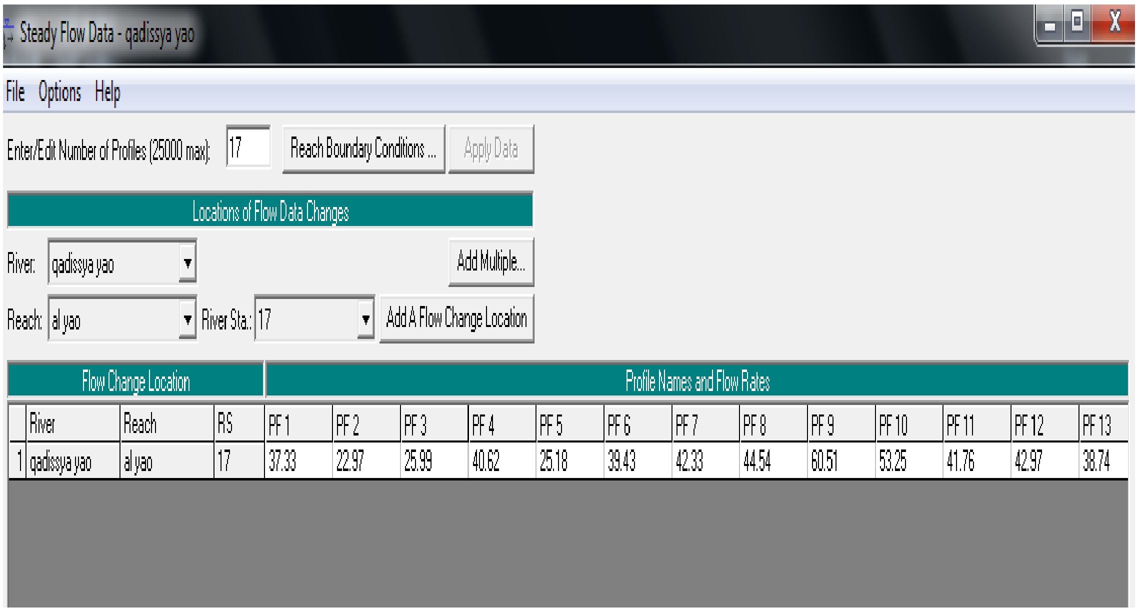


Figure (8): Data of the study reach (discharges of cross-sections).

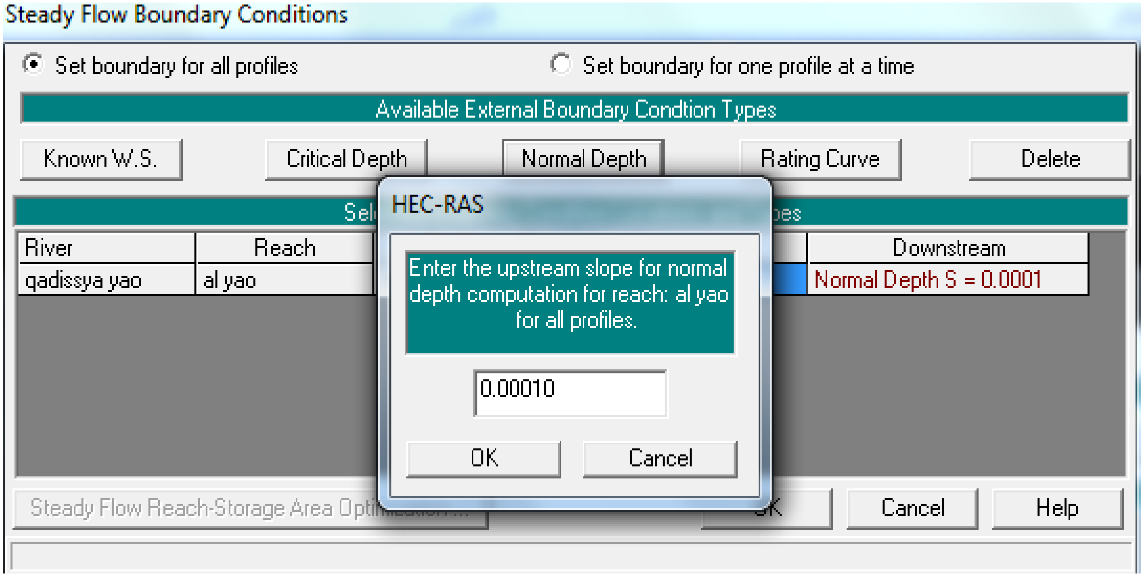


Figure (9): Data of the study reach (slope of the study reach).

4-3 Model Calibration

A calibration process was carried out using stage measurements along the reach,**[4]** The calibrated Manning's n values along the main channel and its left and right banks are(0.034) and(0.041),respectively. An acceptable agreement was achieved between the estimated stage values using the calibrated data and the measured values.

4-4 Sediment Transport Functions

The sediment transport capacity computations can only be run once, steady or unsteady flow computations have been run.The sediment transport capacity for any cross section can be computed using any of the following sediment transport functions **[7,8]**.

1) Ackers-white.

2) Enguland-Hansen.

3) Laursen (Copeland)..

4) Toffaleti.

5) Yang.

The morphological characteristics of the studied reach are compatible with the criteria of Toffaleti, sediment transport function which is:**[9]**

Toffaleti (field):

$0.062 < d < 4$ mm $\quad$ $0.095 < dm < 0.76$ mm

$0.021 < R < 17.18$ m $\quad 40 < T < 93$ degrees F

$0.000002 < S < 0.0011 \quad 19.1 < W < 1103.03$ m

Four zones are used to define the sediment distribution. They are the upper zone, the middle zone, the lower zone and the bed zone. Sediment transport is calculated independently for each zone and the summed to arrive at total sediment transport. This method was developed using an exhaustive collection of both flume and field data.The sediment transport was estimated for the measured discharges.

4-5 Sediment Transport Data File

All the data about the sediment transport for the reach of study that includes the temperature (Av. T=64.4) and average specific gravity(Av. Gs=2.68) was entered. The sieve analysis (for lift over bank, right over bank, and main length) indicates the five formulas of model for total sediment transport; then, it indicates all the needed discharges to count the sediment transport for it as shown in figure (10), (11), (12), and(13)**[8]**.

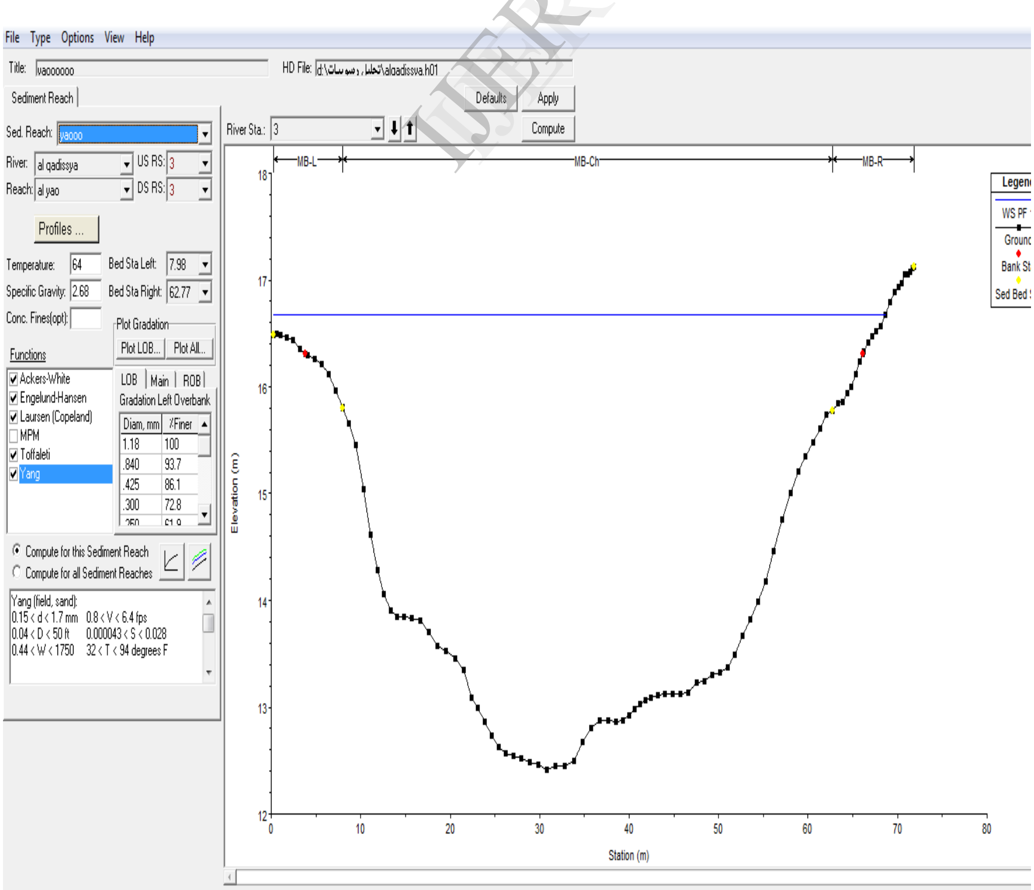


Figure (10): Menu of Sediment transport capacity(Data of the study reach).

4-6 Modeling Results

The predicted values of sediment transport formulas HEC-RAS(4.1) and observed values, are listed in table (2) below:

Table (2) :Predicted values from the formulas of model HEC-RAS (4.1) for sediment discharge and observed values in (kg. sec^{-1}).

Sec. No.	Ackers-white	Enguland-Hansen	Laursen (Copeland)	Toffaleti	Yang	Observed
1	1.505	2.997	1.240	4.530	1.244	3.420
2	0.008	0.064	0.014	0.350	0.0031	1.170
3	0.0035	0.032	0.0032	1.188	0.003	1.210
4	3.571	5.655	3.285	7.880	2.90	5.620
5	0.135	0.606	0.164	1.360	0.133	1.380
6	0.052	0.392	0.157	1.500	0.074	2.290
7	0.157	0.727	0.210	1.345	0.164	3.050
8	0.370	1.136	0.457	2.260	0.331	3.220
9	2.086	3.885	2.250	6.794	1.690	7.130
10	2.918	5.104	2.560	7.448	2.390	6.910
11	2.083	3.606	1.649	5.584	1.593	5.170
12	1.130	2.512	1.144	3.039	0.993	4.080
13	0.005	0.129	0.028	0.878	0.010	1.960
14	2.946	5.027	2.147	7.022	2.337	5.420
15	0.383	1.155	0.435	2.087	0.339	2.370
16	0.009	0.158	0.038	0.834	0.016	1.110
17	0.0025	0.012	0.001	0.358	0.0012	1.020

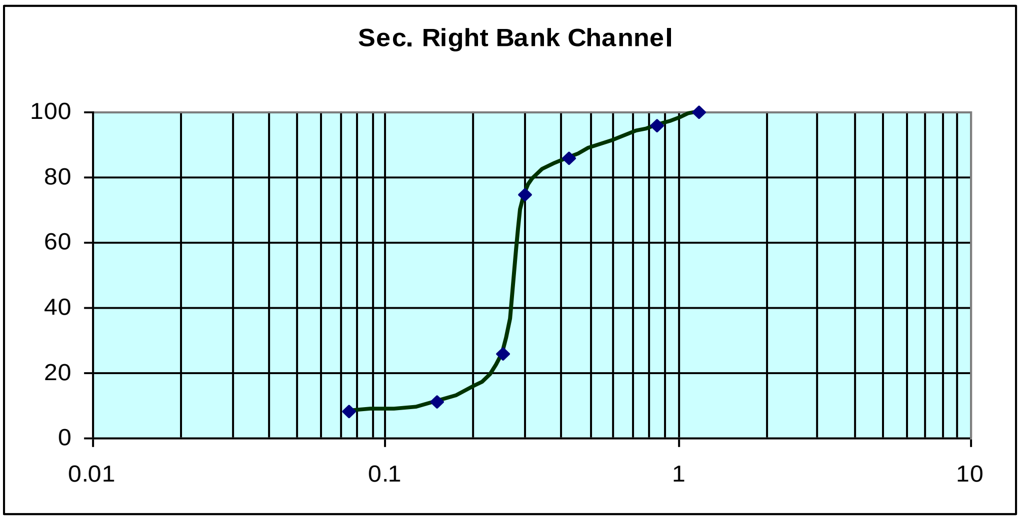


Figure (11): Grain size distribution curve for right bank of the reach study.

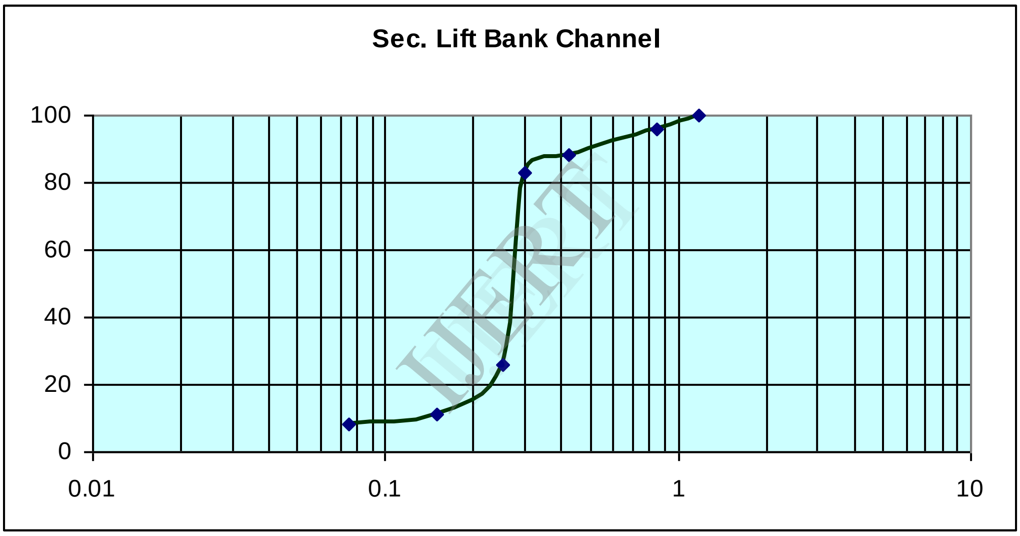


Figure (12): Grain size distribution curve for lift bank of the reach study.

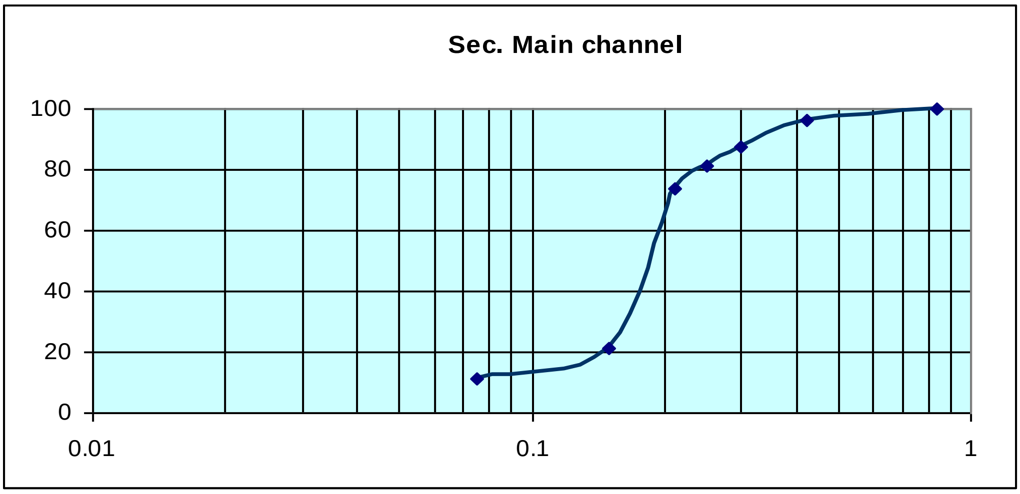


Figure (13): Grain size distribution curve for main channel of the reach study.

5- Testing Adequacy of Model HEC-RAS(4.1)

In order to determine the adequacy of the model ,the predicted sediment rates of these formulas from the model were compared with measured amounts using statistics methods.

5-1 Comparison Using Statistics Relations

Among many statistics method, two methods are used in this research to evaluate the performance of each formula through giving the extents of error with respect to measured values.

5-1-1 Root Mean Square(RMSE) Method

This method used to test the adequacy of the computed and measured values:**[4]**.

$$RMSE = \sqrt{\frac{\sum_{j=1}^{n}(Observed\ Q_S - Computed\ Q_S)^2}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where n: number of data used.

This equation was used to calculate the percentage of the relative errors of the predicted values with respect to the measured values and to evaluate the performance of existing formulas.

The best equation that is given root mean square approach to **zero**. and table(3) shows the results from the above equation.

Table (3): Comparison using Root Mean Square.

Model	RMSE
Ackers -White	2.538
Enguland-Hansen	1.578
Laursen (Copeland)	2.644
Toffaleti	1.013
Yang	2.766

5-1-2 Discrepancy Ratio Method

The discrepancy ratio or(Difference Ratio) was used to test the adequacy of the computed and measured values ,using the following method : **cited in [1]**.

$$r = \frac{Computed\ Q_s}{Measured\ Q_s} \qquad \text{……………………………..(2)}$$

Where :

r: discrepancy ratio.

The discrepancy ratio is scheduled with the ranges (0.75-1.25), (0.5-1.5), and (0.25-1.75).When the values of discrepancy ratio of a selected formulas are closer to (r =1) this indicates that this model is suitable to be used as a predictive for reach of this study. Table (4) presents values which fall in these three ranges.

Table(4): Comparison using Discrepancy ratio.

	Discrepancy ratio(%)		
Model	**0.75-1.25**	**0.5-1.5**	**0.25-1.75**
Ackers -White	0	11.76	41.18
Enguland-Hansen	17.65	41.18	58.82
Laursen (Copeland)	0	5.88	41.18
Toffaleti	41.18	76.47	100
Yang	0	5.88	29.41

This method emphasizes that Toffaleti formula was the best performance in the study reach and followed by Enguland-Hansen a good result formula.

6- Results and Discussions

The test of five formulas in model HEC-RAS(4.1) showed that all models are over-predicted sediment discharge such as(Ackers-White, Enguland–Hansen, Laursen, Yang).

The comparison of accuracies indicates that Toffaleti formula is more accurate than the other formulas followed by Enguland–Hansen. Very weak performance of calculated results done by(Yang) also can be seen from different comparison methods.

The scattering of points may be attributed to the fact that each formula in this model has a different theoretical basis from the others and each one is sensitive to certain factors more than other factors.

Finally, the hydraulic conditions of each model can affect the performance when they are applied in regions that have different hydraulic conditions .When all these formulas in model HEC-RAS(4.1) predict the total sediment discharge, the measured discharge in this study depends only on suspended sediment concentration according to the conclusion of previous investigators in Iraq, so the missed measured part may a little affects on the final results.

7- Conclusion

Measurements of sediment discharge were performed at seventeen cross sections in Al-Yaa'o channel regulator in Al-Najaf city of Iraq. Based on the analysis of results , the following conclusions are given :

1-The model of HEC-RAS(4.1) as proved its effectiveness in predicting sediment transport to get the required formula that is possible to be used in this study reach in the upstream of Al-Yaa'o channel regulator.

2- The Toffaleti formula from the model of HEC-RAS(4.1) gives best results with observed values that are got from the field. In this formula, Root Mean Square is(1.013).

3- The Engelund-Hansen formula provided closer values to the measured values after Toffaleti formula. But other formulas(Ackers-white, Laursen(Copeland), Yang) gave results faraway with poor performance from the field values and Toffaleti formula.

4-It was concluded that the total sediment load from the model (HEC-RAS)(4.1) (Toffaleti) is (11023) and (248419) tons per year for minimum and maximum values respectively. While the field results is(32167)and(224852) tons per year from minimum and maximum values respectively.

References

1- Hassanzadeh , H.,Faiznia ,S. ,Bajestan ,M.S.,Motamed ,A.," **Estimate of Sediment Transport Rate at Karked River in Iran Using Selected Transport Formula**", World Applied Sciences, Journal 13(2) : 376-384,(2011).

2-Ministry of water resources**, "Statistics of channel regulators in Iraq for the year (2009)**", Republic of Iraq/ Directorate of planning and Follow-up,(in Arabic)(2009).

3-Najaf Water Resources Directorate,(N.W.R.D)."**Report about studying of the barrages at Euphrates River"**.(in Arabic) (2009).

4-Navadi, W., **"Statistics for engineers and scientists"**/second edition/ published by Mc-Graw-Hill, Inc., 1221, NY,(2008).

5-RSS "**River Surveyor System**,**Manual Software Version**" (S5/M9) System Manual, Firmware Version 2.0), 4.3,6837 Nancy Ridge Drive , Suite A , San Diego ,USA,(2010).

6-Simons, D.B, Senturk ,F. ,"**Sediment Transport Technology** " Water Resources Publication , Colorado ,USA ,(1977).

7-US army corps of engineers., **" Hydraulic reference manual** ,**HEC-RAS River analysis system,** "Version (4.1), , hydrological engineering center,(2010).

8-US army corps of engineers, **"Hydraulic Engineering Center River Analysis System"**,(HEC-RAS).User's manual. Version(4.1),/hydrological engineering center, (2010).

9-Yang C.T, "**Sediment Transport**" Mc Graw-Hill Series in Water Resources and environment engineering,(1996).

10- Nama, A.H **"Estimating the Sediment Transport Potential of Tigris River within Al-Mosul City".** University of Baghdad, Baghdad – Iraq,(2012).