Empirical Formula for Estimation the Sediment Load in Shat AL-Gharaf River

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***Abstract*-In this research ,the sediment load in Shat Al-Gharaf River , lies in the south of Iraq ,has been studied . Two empirical formulas those have been presented by ; Bagnold and Van Rijin were adopted as a deterministic equations for computing the sediment discharge in selected reaches of river . The application of these equations requires to do different hydraulic , sediment , and geometric measurements for the selected reaches . Accordingly , thirteen sections along the river within a study area have been adopted . After analyzing the available data , a new formula for estimating the suspended sediment load in Shat Al-Gharaf was developed , depending on the data for ten sections of this river and by using SPSS program , the determination coefficient of the new formula was (R^2=0.94) . The validity of the established formula has been verified using some well related (i.e., nearly the same hydraulics and geometrical circumstances) of field data over the world was selected from published literatures [8] these are : Colorado river data of the U.S.B.R.(1958) ,River data from Leopold (1969) , and India canal data of Chaudry et.al.(1970). As well as ,those observed in the remaining three sections of present river , the verification shows a good agreement .**

The results of the adopted two formulas and the new formula were compared with field measurements using Discrepancy Ratio (bais) method . The suggested new formula gave the best results where 50% of data located within a discrepancy ratio close to one and 30% of data located within an error ±20% , that is refer to suitability adoption this formula as a deterministic equation to estimate the sediment load in Shat Al-Garaf river within a study reach .

Index Terms- deterministic equation , fall particle velocity , sediment transport , suspended sediment

I.INTRODUCTION

Several sediment transport formulas have been developed using data derived from laboratory and from field measurements , yet there is no a universal formula that can be considered suitable to be used to estimate a sediment transport for all rivers. The derived formulas perform best only for rivers under study. These are due to the differences in environmental configuration and morphology of river as well as the hydraulic aspects and its measuring tools . Thus, a new sediment formula is required to be used for a specified reach undertaken. In the present work the transportation of sediment, its kind, quantity and the rate in specified reach of Shat Al-Gharaf have been studied and then according to field measurements for fluid , hydraulic and sediment properties , the related formula was extracted to be as a predictive formula of sediment transport for that reach of river. This study was restricted for a specified reach of Shat Al-Gharaf that located between Al –Naser city and Al-Shatra regulator (Al-Badaa) . The river begin from Al-Kut barrage towards Dhi-Qar governorate .Several cross regulators are located along the river in order to facilitate a suitable head needs for irrigation projects . The sediment transport and deposition phenomena were studied, and the evaluation of results have been presented at different feature , to be used just for a study reach (14 Km) located between Al-Naser city and Al-Badaa regulator **.** Due to unavailable direct studies for this region , the present work included study the nature of sediment which transported with flow and estimated the amount of it. Thirteen sections have been chosen by using Google earth program (see Fig.1) , the coordinate of the sections were recorded and by using the GPS in site the sections marked by flags on their shoulders .However the Acostic Dopler Current Profiler , ADCP , was used for surveying the selected section to obtain all necessary hydraulic and geometric data the results of the ADCP data and the sections coordinate are listed in Table.1. This device was used with the help of "marsh center rehabilitation / Dhi-Qar". Field work for this study has been conducted from March to June 2012.

II. SUSPENDED BED SAMPLING

The purpose of suspended sediment sampling is to determine the instantaneous mean discharge-weighted suspended sediment concentration over a stream cross section. The measured suspended-sediment discharge was then computed with the combination of the measured concentration and flow discharge .Using homemade sampler , the suspended samples were taken from the selected reaches after dividing the river width into four quarters and taking measures in the 1/4, 1/2 and 3/4 the top width of stream cross-section as shown in Fig.2 . Also samples from the river bed were taken in order to specify the type , size distribution , and the gradation for recognizing the uniformity or non-uniformity of river bed material. The samples of bed material have been taken from each subsection of suspended load sampling , then mixed to describe the bed material for the entire section undertaken. Laboratory Measurements of the bed material samples (sieve analysis and hydrometer test) and the suspension sediment concentration for each sections are carried out in the laboratory of Al-Shatra Technical Institute. The result of the laboratory tests for the study reaches are listed in Table.2

III. DEVELOPMENT OF A NEW FORMULA

The suspended sediment within the adopted reach of Shat Al-Gharaf is occur due to the influence of different parameters which contribute to this part of sediment transport .From well-known background knowledge related to sediment transport in rivers the parameter having a direct influences are those related to flow and fluid, sediment material , and geometrical variables .Accordingly the following functional relationship can be expressed:

$$f(V, h, b, \rho, g, \upsilon, q_s, \rho_s, w_s, c_g, d_{50}) \quad \text{-- (1)}$$

Where:
V = current average velocity (m/sec)
h = current average depth(m)
b = top width of the channel (m)
ρ = water density(kg/m^3)
υ= water kinematics viscosity(m^2/sec)
g = acceleration of gravity (m/sec^2)
q_s = volumetric suspended sediment transport rate (m^3/s/m)
ρ_s = sediment density (kg/m^3)
w_s = fall particle velocity (m/s)
c_g =weight concentration (mass of suspension of sediment transported in a unit volume ,(kg/m^3)
d_{50}=median diameter (m).

From the functional relationship Eq.(1) , it can be adopted some convenient dimensionless parameter related to the problem, these are ;transport rate parameter ϕ_s , this reflect the rate of suspended sediment within a study reach ; particle mobility parameter , D_* , this reflect the influence of gravity , density and viscosity on sediment transport; and particle mobility parameter for initiation of suspension , θ_{cr} ,which is a ratio of fall particle velocity and submerged particle weight (presented by Shields). The use of the above dimension less parameters because their form contains most the influencing of Eq.(1) , as well as simplifies the form of a deterministic formula . Wherease , the aim of any presented empirical formula is to decrease the requirements needs in field measurements , thus the measurements restricted to river width , flow depth , average current velocity , and the median particle size of bed material . The regression analysis resulted the following deterministic equation with R^2 =0.94

$$\phi s = 1316 \left[\frac{V}{w_s}\right]^{0.797} \frac{[\theta_{cr}]^{0.697}}{[D_*]^{1.822}} * \frac{1}{[\frac{b}{h}]^{0.922}} \quad \text{---(2)}$$

Where:
h = average depth (m)
b = width of the channel (m)
V = average current velocity (m/sec)
w_s = fall velocity (m/sec).

$\phi s = \frac{q_s}{((\frac{\rho_s}{\rho}-1)g)^{0.5} * d_{50}{}^{1.5}}$. it is a rate of suspended sediment (dimensionless term) .

$D_* = d_{50}[\frac{(\frac{\rho_s}{\rho}-1)g}{\nu^2}]^{1/3}$, it is a particle parameter (dimensionless term) .

$\theta_{cr} = \frac{w_s{}^2}{(\frac{\rho_s}{\rho}-1)gd_{50}}$, it is a critical shields mobility parameter (initiation of suspension ,dimensionless term)

It should be noticed that the fall velocity , w_s is calculated by using a relevant equation according to median particle size . For d_{50} less than 100μ , the following relationship can be used ;

$$w_s = \frac{(\frac{\rho_s}{\rho}-1)gd^2}{18\nu} \quad \text{---- (3)}$$

The predicted suspended sediment discharge "q_s" by using Eq.(2) and the observed values have been listed in Table(3) . Fig.3 illustrate the scattering between them. However , some of field data over the world are selected from published literatures (**William R. Brownlie ,1981**) as well as ,those observed in three sections of present reach, were adopted in order to verify the proposed formula (i.e.,Eq.(2)) , these data are from : Colorado river of the U.S.B.R.(1958) , Leopold (1969) (river) , and Chaudry et.al.(1970) (data extracted from different irrigation canals in India) . These data have been used beside to provide a verification of the present formula , it also reflect its ability for use with other reaches having nearly same flow and boundary conditions if the predicted results nearly approached to measured with acceptable bais (i.e., Discrepancy Ratio=1) . The observed (measured) and computed (by using Eq.(2)) sediment discharge of a three cross-sections of Shat Al-Gharaf and the other reaches is scheduled in Table(4). The comparison between the observed sediment discharges and the computed values are also illustrated in Fig.4 . As can be seen the most scattering data induced to be near the perfect line , it refer that the functional parameters those formulated the Eq.(2) has a good correlations . Accordingly this equation can be used as a predicative formula of sediment rate in Shat Al-Gharaf and other river reaches having the same flow and boundary conditions .

IV. EVALUATION OF SEDIMENT DISCHARGE FORMULA

In order to test the reliability of some well known universal deterministic formulas if used to predict the sediment discharge in Shat Al Gharaf , the study focused on two formulas related to suspended sediment transport in rivers , these are Bagnold(1966) and Van Rijin(1984b) , (for more details about these formulas , refer to [3] and [7]. The discrepancy ratio method were applied to evaluate these formulas . This ratio used to test the accuracy of the computed and measured values.
[Hassanzadeh, et.al. (2011)] , where :

$$\text{Discrepancy Ratio(DR)} = \frac{computed\ qs}{measured\ qs} \quad \text{----(4)}$$

The comparison is shown in Table (5) .This table represents the discrepancy ratio in the range (0 - 8) . When the value of Eq.(4) is closer to one that indicate more accurate formula as a deterministic equation for suspended sediment in the study reach . As can be seen from table no formula has a reliable results . As a Bagnold used , just 30% of results has DR approached to just 0.3, it still far to considered a reliable formula. While with Van Rijin applications 20% of results approached to DR=0.5 beside 60% of results considered highly over predict compared with the measured values of suspension sediment . However , a new formula showed a good agreement with the observed sediment discharge , where 50% of results has DR close to one , and 30% of results baised from measured just nearly ±20% , that is give an agreement confidence for the present formula .

V. CONCLUSION

The following conclusions can be drawn within the limitation of the studied case :

- Based on the field data and laboratory results for ten sections , a new formula related to predict a suspended sediment in Shat Al-Gharaf was suggested , it showed a good agreement with the observed sediment discharge , where the discrepancy ratio was in the range close to one , with 50% of data undertaken .This new proposed formula is applicable in the rivers having the same geometrical and flow conditions of Shat Al-Gharaf reach.

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VII. BIOGRAPHIES

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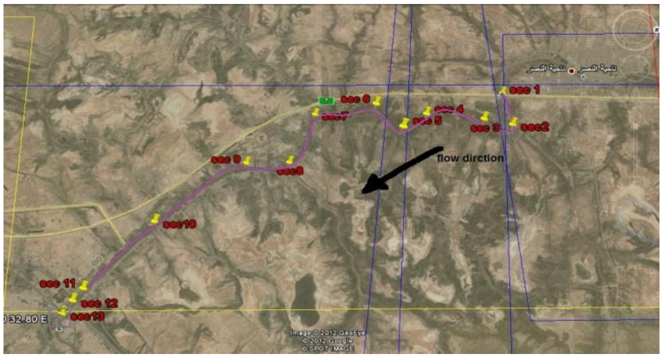

Fig.1: Plan view of the study reach with all thirteen sections selected

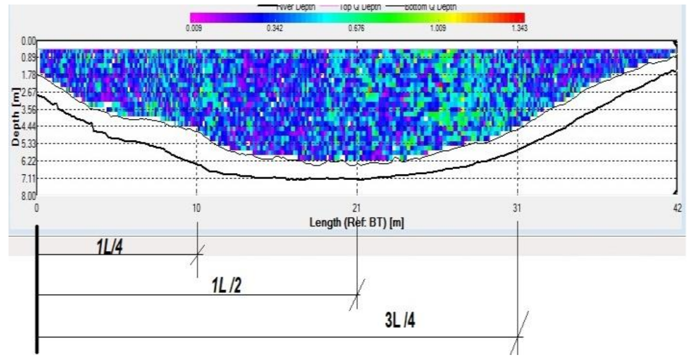

Fig.2: Sampling Locations at Section One

Table.1: The geometric and hydraulic data for sections resulting by using ADCP

Sec No	Section coordinate	Cross- sectional Area. (m^2)	Discharge. (m^3/s)	Flow velocity. (m/s)	Mean flow depth (m)	Top Width (m)
1	31 31 17,9 N 46 07 36,6 E Beside Al-Naser bridge	217.7	45.4	0.209	4.94	44.0
2	31 31 22,7 N 46 08 04,4 E	188.8	44.6	0.236	4.24	44.6
3	31 31 04,9 N 46 07 59,3 E	140.2	47.3	0.337	2.9	48.3
4	31 30 28,5 N 46 07 54,5 E	142.2	45	0.317	2.53	56.3
5	31 30 13,3 N 46 08 05,7 E	144.8	45.9	0.317	3.08	47.0
6	31 29 58 N 46 07 46 E	150.1	45.5	0.303	2.97	50.5
7	31 29 17,8 N 46 07 53,6E	154.5	45.7	0.296	3.12	49.5
8	31 29 01,5 N 46 08 34 E	171.4	43.3	0.253	3.08	55.7
9	31 28 34,5 N 46 08 34,2 E	156.6	44.9	0.287	3.03	51.7
10	31 27 38.56 N 46 09 21.79 E	131.2	35.2	0.268	2.16	60.7
11	31 26 57.18 N 46 10 13.74 E 600 m from Al Badaa regulater	99.3	29.9	0.301	2.06	48.2
12	31 26 51.27 N 46 10 23.01 E 300 m from Al Badaa regulator	155.6	18.7	0.120	1.88	82.8
13	Beside Al Badaa regulator	162.9	27.8	0.171	1.63	100.0

Table.2: The concentration of suspended sediment and median diameter for study reach

Date	Sec No	d_{50} mm	Concentration(mg/l) for each section from left bank			
			1/4	1/2	3/4	average
26/3/2012	1	0.011	414	510	270	397.5
26/3/2012	2	0.01	331.5	409.5	307.5	349.5
5/4/2012	3	0.017	450	510	405	454.5
10/4/2012	4	0.013	345	382.5	330	352.5
17/4/2012	5	0.018	313.5	376.5	289.5	325.5
17/4/2012	6	0.013	255	285	309	282
26/4/2012	7	0.019	306	325.5	273	301.5
26/4/2012	8	0.012	283.5	288	255	274.5
3/5/2012	9	0.01	265.5	276	259.5	267
16/5/2012	10	0.018	253.5	262.5	250.5	255
16/5/2012	11	0.014	234	243	231	235.5
30/5/2012	12	0.01	238.5	229.5	225	231
30/5/201	13	0.013	195	216	208.5	205.5

Table.3:observed and predicted values of sediment discharge

Section No.	Observed values (kg/sec)	Computed values (kg/sec)
1	18.04	16.28
2	15.58	15.90
3	21.49	15.04
4	15.86	12.95
5	14.94	16.24
7	13.77	15.84
9	11.98	13.30
11	7.04	10.22
12	4.31	4.49
13	5.71	5.49