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Investigate the Suitability of Suspended Sediment Transport Formulas in the Main Outfall Drain

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Abstract

Main Outfall Drain (MOD) is important project established in 1950 in Iraq. MOD suffers from the sedimentation. Six developed formulas in previous studies were used to estimate the sedimentary load in MOD at Al Nasiriya City. An evaluation of six current formulas were presented to estimate the suspended sediment load, two of these formulas are global and four of them are local, based on field data obtained at sections in Main Outfall Drain at Al Nasiriya, which are characterized with silt, clay and sand particles are formed deposition that are traveled through MOD. Although there are deviations in the results for some formulas between the measured and calculated values, a limited number of formulas gave reasonably acceptable values. It was found according to graphical and statistical comparison that are more suitable than other adopted formulas to represent the suspended load in MOD in Al Nasiriya City.

Keywords: Suspended sediment, transport formulas, Main Outfall Drain, Al Nasiriya City,Clay.

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1 Introduction

There are three main rivers in Iraq, Tigris and Euphrates, the third one is important project established in 1950, it's known as MOD (Main Outfall Drain).The MOD intersects with the Euphrates River at Al Nasiriya City by pumping system with a syphon to ensure discharged the water freely below the Euphrates River.Carried out the study on one of the Asian rivers as a result of its great effect by climate change. One of the objectives of the study is to identify and describe the flow of suspended sediments in main reach of river in the short term as well as through the construction of dams. The study proved and through daily simulations and in presence of dams where the sediments were 106.9 million tons in the outlets of the main tributaries. As for the climate change in the case of dams, it decreased to 84.5 tons. prepared a study in southeast Ireland for two low-level dams, it was included the investigation of the discharge of the suspended load under and over two dams .It was used to find out the storage of sediments from the balance of those sediments. The results also showed that 68% of the sediments in that region occur in high discharges and it is possible to control the movement of those sediments that occur at the end of the reach which depend on the sediments of upstream of it.

Since most of the proposed formulas for sediment discharge were chosen based on data developed and collected in laboratories or depended of limited data, that’s why little is known on performance in reference with measured flow and sediment data in rivers[1-9].

The current load is divided into two movement, bed load and suspended load. There is a lot of sediment transport formulas that’s available, the performance of the existing formulas in reference with measured flow and sediment data in natural rivers is un known. Hence, the use of field data is very important in making more real estimation and selection of sediment transport formulas for a specific river condition. Suspended sediment discharge formulas are investigated in this paper depending on field data collected from the Main Outfall Drain (MOD) southern Iraq as shown in Figure1.

2 Description of Study Area

Study area extends from the area which is located at Latitude:31°2′12.86″N, Longitude: 46°19′17.66″E (East of the AL Nasiriya City) to the upstream of pumping station which is located at Latitude: 30°58′29.09″N, Longitude: 46°20′3.82″E.Then,the path of study area continues to extend to 30°53'23.09"N, 46°21'34.65"E at station 150.

Data collected from the field survey are the most important elements of any flow channel analysis. A field survey was conducted along the study area of 20000 m in the flow channel, and eight stations were chosen, starting from section 167 north of Nasiriya towards section 150 south of Al Nasiriya city. It includes the measurement of suspended load in MOD at upstream and downstream of the pump station as shown in (Table 1) and Figure 2.area.

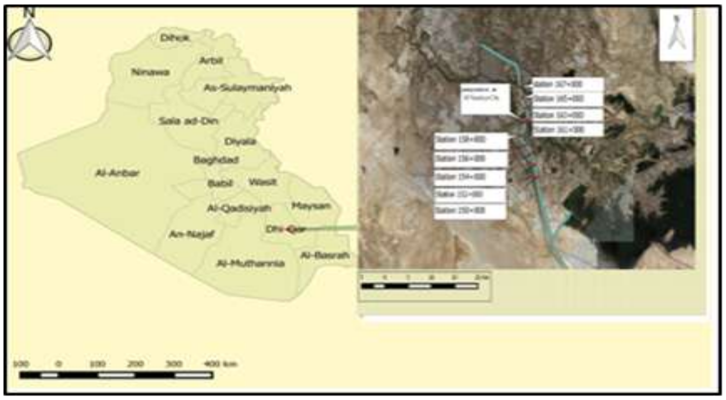

Figure 1 Location of the study site.

Table 1 Locations of the suspended load sampling in the present study.

Location of sampling	Description of location
Group one	This location is starting from (sec167) towards (sec161)
Group two	This location is starting from (sec 156) towards (sec 150)

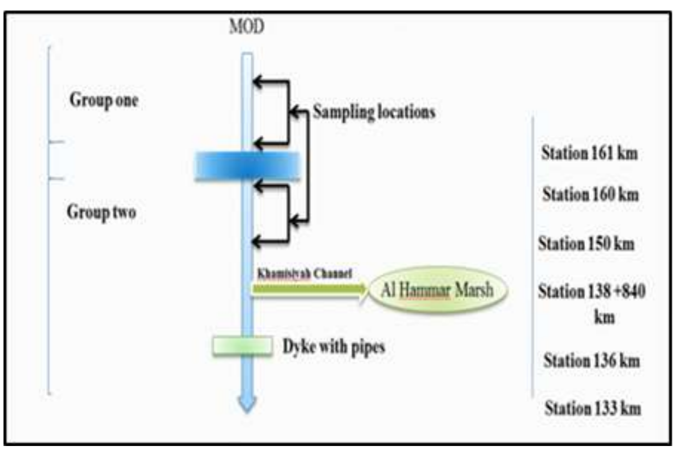

Figure 2 Scheme of sampling locations in the study area.

3 Bed Materials and Suspended Sediment Data

The field work was done to collect all necessary data and information relevant to the aims of this study along the MOD which contains: the geometry of each selected section included top width and flow depth, water discharge and velocity at all determined sections using ADCP (AcousticDopplerCurrent profile), representative samples of the bed material taken by (grape devise) from the river bed and Integrated samples of the suspended sediment at 3 places in each station (1/4,1/2,3/4) of the MOD width. A detailed analysis was performed of the samples taken for the suspended sediment, the surface layer material of the river bed. This analysis showed that the surface material consist of silty clay soil as shown in (Table 2). With median size of 0.04mm to 0.0517 mm over the reach. In addition to the bed and suspended sediment samples water discharge, the channel area, channel width and average concentration in each station were measured as presented in (Table 3, 4)and Figure 3. All the mentioned data were used to estimate the suspended sediment discharge. Also, the results will be used to compare the measurements with the available formulas.

Table 2 Percentage of sand, clay and silt and and specific gravity of the bed material in MOD within the study area

Station	Coarse soil (%)	Fine soil (%)		Specific gravity
(km)	sand	clay	silt	
167	11.4	30.6	58	2.66
165	3.9	43.1	53	2.65
163	5.2	43.8	51	2.68
161	6.4	42.7	50.9	2.6
156	4.8	43.2	52	2.66
154	9.7	34.9	55.4	2.65
152	8.9	35.1	56	2.68
150	10.1	39.1	50.8	2.66

Table 3 Bed material characteristics over the MOD reach

Station	d_{35}	d_{50}	d_{65}	d_{90}
(Km)	(mm)	(mm)	(mm)	(mm)
167	0.005	0.0481	0.058	0.0711
165	0.014	0.0519	0.06	0.1028
163	0.005	0.0489	0.064	0.0976
161	0.015	0.0517	0.063	0.0976
156	0.009	0.045	0.056	0.078

154	0.01	0.04	0.055	0.075
152	0.0065	0.042	0.055	0.07
150	0.011	0.043	0.065	0.08

Table 4 Concentration of suspended sediment and flow characteristics over the MOD reach.

Station	Date of sampling	Average C	Q	Rh	Area	V
(Km)		(ppm)	(m^3/s)	(m)	(m^2)	(m/sec)
167	12/12/2018	334	58	2.76	234	0.203
165	12/12/2018	325	50	2.8	246	0.201
163	13/12/2018	314	60	2.58	298	0.152
161	16/12/2018	324	52	4.2	341	0.287
156	16/12/2018	374	59	2.34	192	0.123
154	2/1/2019	302	25	2.7	203	0.168
152	4/1/2019	314	33	2.69	197	0.204
150	10/1/2019	332	39	2.3	191	0.204

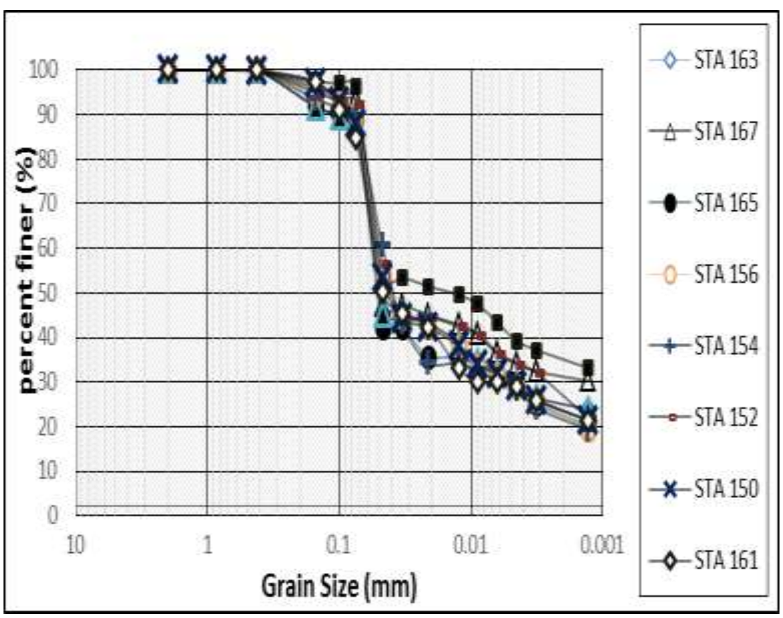

Figure 3 Grain size Distribution of the study reach stations.

4 Methodology

4.1 Investigating the suitability of the available suspended sediment transport formulas

Most of the existing formulas were developed depending on laboratory data or on data from specific rivers. Hence, these formulas may give a good matching with observations in some reaches and poor in other.

4.2 Comparisons using Statistical Methods.

In order to evaluate the accuracy of the six mentioned formulas three methods are used by comparing the

Observed suspended sediment discharge with the computed by the adopted formulas.

- Comparison using Percentage of Error

  Percentage of error or Percent error shows the difference between an approximate value and an exact or known value as a percentage. It is used in science to report the difference between a measured value and exact value. It’s a good way to gauge how close a measured value is to an exact value.

  $$Percentage\ of\ error = \frac{observed\ Qs - computed\ Qs}{Observed\ Qs} \times 100 \quad \ldots.\ (1)$$

- Comparison using Mean normalized error.

  Mean normalized error or mean square error were used in order to choose the best formula

  $$MNE = \frac{100}{j}\ \Sigma_{j=1}^{j} |Observed\ Qs - computed\ Qs/Observed\ Qs| \ldots\ (2)$$

  In which J = no. of data used

- Discrepancy Ratio:

  The discrepancy ratio was used to evaluate the difference between the Observed and the Computed values, it is defined as:

  $$Discrepancy\ Ratio\ = \frac{computed\ Qs}{Observed\ Qs} \quad \ldots\ (3)$$

  The computed value will be identical to the observed if the discrepancy ratio closes to one. The computed value will be overestimated if the discrepancy ratio is over one, and the computed value will be underestimated if the Discrepancy ratio is smaller than one.

4.3 Graphical Comparison

Comparison of the rating curves of predicted sediment discharge versus water discharge, and the predicted sediment discharge versus with the observed values are made.

5 Results

The predicted suspended sediment load for the Six developed formulas in previous studies[1][2][3][4][6][7] are presented in (Table 5).

Table 5 Observed and computed suspended sediment discharges (kg/sec) in all the selected stations.

Stations	Observed	Bagnold	Van Rijin	Jasem	Khassaf	Al-Kizwini	Maatooq
		1966	1984b	2012	2005	2007	2016
167	20.04	0.00002	0.48	40.16	104.42	24.73	19.8
165	19.5	0.00002	0.26	33.99	84.58	26.15	18.3
163	18.84	0.00003	0.26	35.57	87.02	28.55	19.67
161	19.44	0.00003	0.04	17.51	90.93	31.72	17.38
156	22.44	0.00001	1.11	63.29	130.15	18.11	19.53
154	19.14	0.00001	0.01	59.65	177.85	21.49	9.28
152	18.84	0.00002	0.05	56.49	155.54	21.24	12.19
150	19.92	0.00001	0.14	68.58	142	17.86	16.64

Table 6 Summary of the percentage of error to the six formulas

Formula	%10	%20	%30	%40	%50	%60	%70	%80	%90	%100
Bagnold 1966	-	-	-	-	-	-	-	-	-	%100
Van Rijin 1984 b	-	-	-	-	-	-	-	-	-	%100
Khassaf 2005	-	-	-	-	-	-	-	-	-	-
Al-Kizwini 2007	%10	%30	%60	%60	%60	%80	%90	%90	%100	%100
Jasem 2012	%10	%10	%10	%10	%10	%10	%10	%20	%30	%30
Maatooq 2016	%40	%80	%100	%100	%100	%100	%100	%100	%100	%100

Percent error is an indicator of how the possible values may deviate from the "exact" value the use of a value with a specific percent error in measurement is the judgment of the user. The result of the comparisons is shown in (Table 6).

To choose the best formula to predicted sediment discharge, the comparison is listed in (Table 7).

Table 7 Comparison between the measured and computed suspended load by using Mean normalized error

Formula	Bagnold 1966	Van Rijin 1984 b	Khassaf 2005	Al-Kizwini 2007	Jasem 2012	Maatooq 2016
MNE	%99.90	%96.80	9%809.1	%%62.8	%224.30	%11.70

Three intervals are used to represent the discrepancy ratio in a schedule (0.75-1.25), (0.5-1.5), and (0.25-1.75). The results demonstrate that Maatooq 2016 formulae having a discrepancy ratio of 1.0 which mean that it is the best formulae to predict sediment load of MOD as shown in (Table 8). The comparison of the suitability of the selected six formulas with the measurements of sediment discharge in MOD within the study area showed that the results were a fairly good agreement with the observed values for [7][4] with discripency ratio of 1.0 and 0.7 respectivily. Also, The comparison showed that the results were overestimated for [3][6], while [2][1] formulas shows under estimated values, this fluctuation in predicted value could be attributed to the variance in the properties of the study area for the derived formulas such velocity and particle size.

In [3][6]made the study to their area with higher d_{50} than that in MOD, while [2][1]derived their formulas depending on higher velocities than that in the MOD.

Table 8 Comparison using discrepancy ratio

Formula	0.75-1.25	0.5-1.5	0.25-1.75
Bagnold 1966	-	-	-
Van Rijin 1984 b	-	-	-
Khassaf 2005	-	-	-
Al-Kizwini 2007	60%	70%	90%

Jasem2012	%10	%10	%10
Maatooq 2016	100%	100%	100%

Figure 4 were made to clarify the variation in value for each six developed formulas [1][2][3][4][6][7]comparing with the observed value while the Figure 5 and Figure 6 were made to clarify how close is the predicted value to the observed.

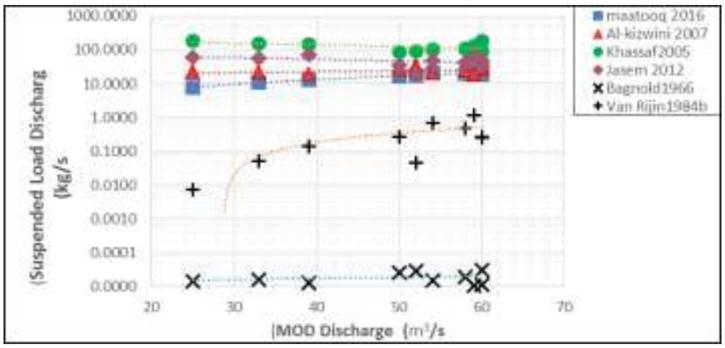

Figure 4 Suspended sediment discharges against water discharge in MOD by using the the six equations

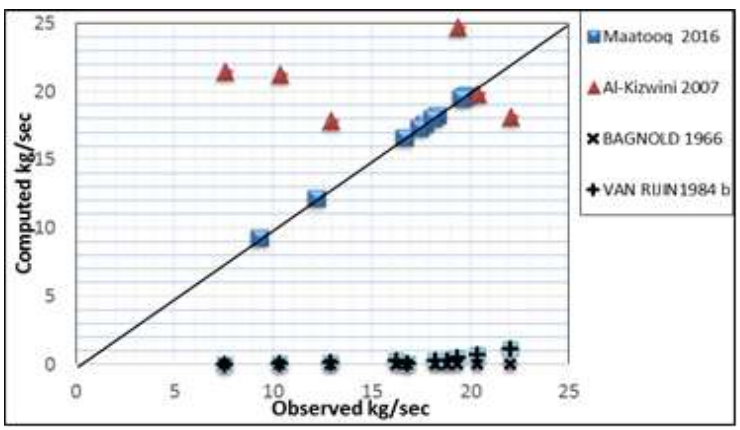

Figure 5 Predicted sediment discharges plotted against observed sediment discharges in MOD for [1][2][4][7] formulas.

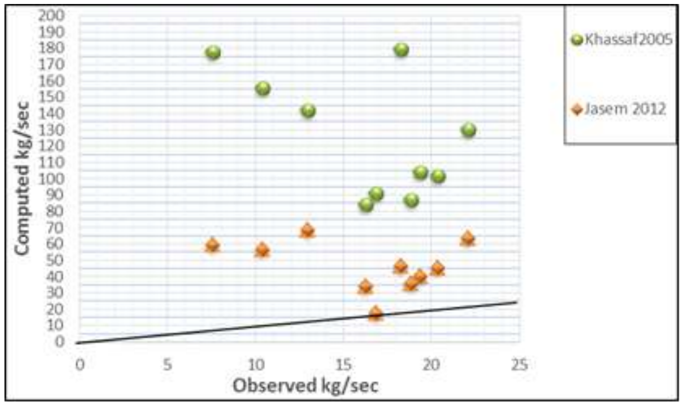

Figure 6 Predicted sediment discharges plotted against observed sediment discharges in MOD for [3][6]

6 Conclusion

The suspended sediment discharge of MOD in study area can be predicted with reasonable amount by[7] gives a clear convergence to the measured values in MOD.

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