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ESTABLISHMENT OF DISCHARGE-SUSPENDED SEDIMENT LOAD RATING CURVE IN TIGRIS RIVER DOWNSTREAM OF AL-AMARAH BARRAGE, SOUTH OF IRAQ

ABAAS J. ISMAEEL*, SARMAD A. ABBAS, WISAM S. AL-REKABI

Civil Engineering Department, College of Engineering, University of Basrah, Basrah, Iraq
*Corresponding Author: jabbaas@yahoo.com

Abstract

In recent years, problems related to water supply have elicited the need for comprehensive studies, based on the potential policies created. One such analysis entails the estimation of the suspended load of sediments in rivers. Specifically, a suspended sediment concentration and suspended sediment discharge rating curve was developed in this research for the Tigris river section located downstream of Al-Amarah Barrage, Maysan Province, South Iraq. The sediment rating curve is the best way for estimating concentrations of suspended sediments (*SSC*) and the load of suspended sediments (*Qs*). In a portion of the river, twenty-nine observations were made whereby each observation involves taking several water samples, after which each sample was filtered to collect data about the *SSC*, water level and river discharge (*Q*). These data are reported at each observation using the (*ADCP*) technology. Rating curves were formed to estimate the *SSC* and *Qs*, based on the experimental results. Finally, the power relation was established for each rating curve. Depending on the value of the correlation coefficient (R^2), a good agreement was reached between the observed data and the power relation.

Keywords: Al-Amarah barrage, Sediment rating curves, Suspended sediment concentration, Suspended sediment load, Tigris river.

1. Introduction

In the design and management of water supply projects, it is crucial to estimate the suspended sediment loads for the quantity of water supplies and quality transported in the river for long distances [1]. It cannot settle in the bed but stays suspended in water and does not form part of the bedload [2]. Sediment is transported mostly as a suspended sediment load (*SSL*) in most rivers [3].

Bedload can be defined as part of the sediment load within the bed layer and can be transferred by sliding, rolling, or salting, while the suspended load can be defined as part of the sediment load that remains suspended in the water for long periods as a result of turbulent water currents being affected. A load of suspended sediments is considered the dominant part of the sediment load and can be viewed as an indicator of soil erosion in the catchment of the river [4].

One of the methods used to measure the load of suspended sediments is the sediment rating curves, which defines the relationship between water discharge and the suspended sediments (concentration or discharge); the reason for using these curves is because the process of calculating the concentration of sediments in rivers and waterways is costly and takes long periods [5-11]. The regression analysis approach is used to find these curves, and the formula of the sediment rating curves is typically a power-law type equation.

The sediment transport curves are classified based on i) a time base of the curve data, or ii) a form of sediment discharge which also constitutes the curve. The sediment curves can be classified as instantaneous, daily, monthly, yearly, or flood period curves through this classification [12].

The purpose of this research is to establish curves for both the concentration of suspended sediments and the discharge of suspended sediments at the downstream Al-Amarah barrage located in Maysan governorate, southern Iraq. This is driven by the lack of data available on the concentration of suspended sediments in this study area.

2. Study Area Description

The study area is situated in the downstream of the Al-Amarah barrage. This dam is considered to be one of Iraq's latest irrigation projects and is specifically located in the Mayan governorate. The study of hydraulic works for the Al-Amarah barrage project began in 1979 and the final designs for the project were completed in 1982. The project was also postponed until 2000, initiated by workers of the Iraqi Ministry of Water Resources on 1/4/2000, and opened on 30/5/2005. The construction of this barrage was to control the discharge of water by raising the water level upstream of the barrage which in turn increases the water levels for the Al-Bterah, Al-Kahlaa, and Al-Msharah irrigation projects as shown in Fig. 1.

3. Methodology

The data used to build the rating curve were collected from section No. 1 located downstream of the Al-Amarah barrage at a distance of approximately (175 m) from the barrage and to the right (0703201E, 3525695N) and left (0703325E, 3525731N) as shown in Fig. 2. Data included a recording of suspended sediment samples at each point of the area, water discharge, water level, and calculation of suspended sediment discharge.

In this study, nine samples of suspended sediment were collected at each time and three samples were distributed for each column of water where the width of the cross-section surface was divided into three columns at (1/4,1/2,3/4). In each of these columns, three samples were distributed at different depths at (0.2d,0.6d,0.8d) where *d* represents the depth of the water in that column measured from the surface of the water. These samples depend on the depth of the water in that column as shown in Fig. 3. For this reason, a home-made sampling system was used which operates a point-integrating sampling method as shown in Fig. 4.; it is used if the vertical distribution of the suspended sediment load is desirable.

The individual stage samples used to obtain these samples were made of plastic material with a capacity of one litter. Two holes were drilled in the cap of each container, the first using aluminium tubes with a diameter of (5 mm), and the second using a diameter of (8 mm) (air exhaust pipe and intake tube). A sealing material was used to seal the area around the tubes to prevent water from escaping into the container and to avoid it from slipping in and out of the bottle cap.

The discharge was measured using the Acoustic Doppler Current Profilers (*ADCP*) technique, developed specifically to calculate river discharge based on the Doppler theory. This technique was developed about 25 years ago and is now commonly used in river applications; bathymetry, depths, and water velocity can be measured and the discharge is determined based on cross-sectional area and average velocity [13]. This system moves by connecting it across the river transect by a moving boat as shown in Figs. 5 and 6.

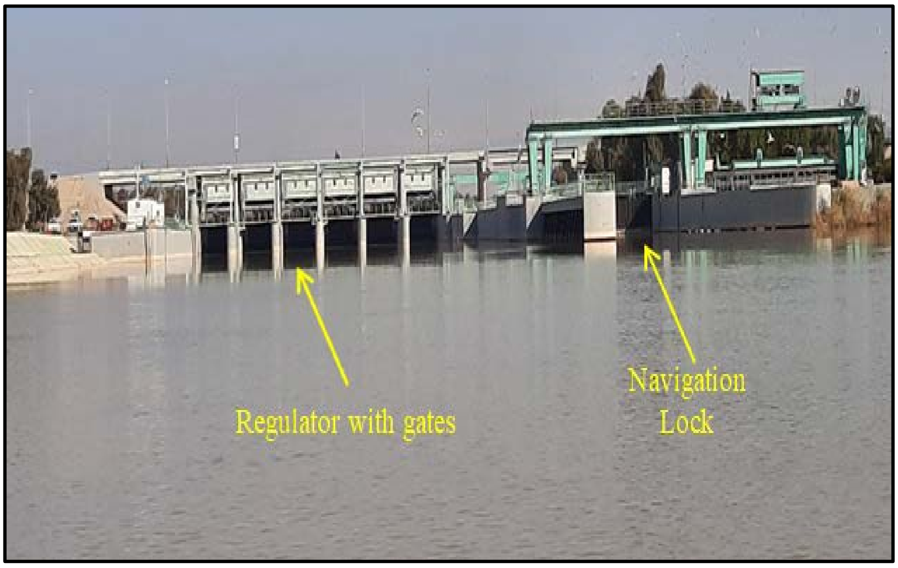

Fig. 1. Components of the downstream Al-Amarah barrage.

Fig. 2. Location of section No.1 for data collection.

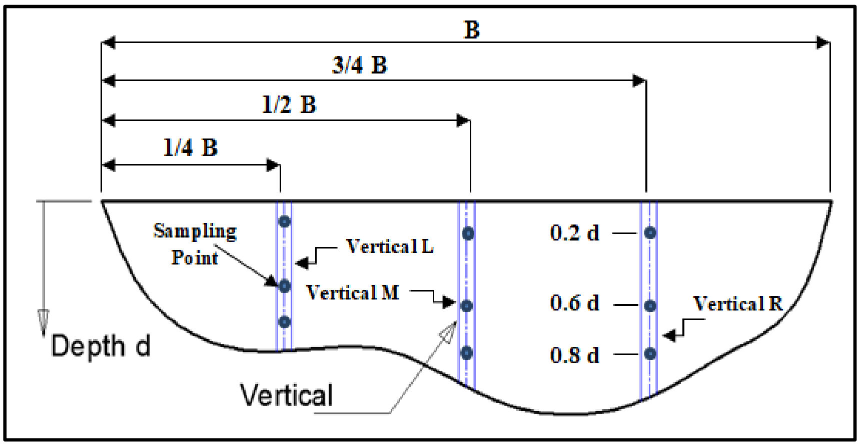

Fig. 3. Selection of sampling.

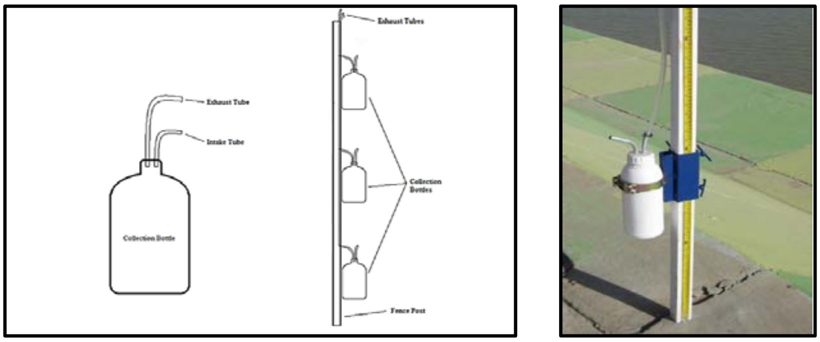

Fig. 4. Suspended sediment sampler.

Fig. 5. (*ADCP*) SonTek river surveyor.

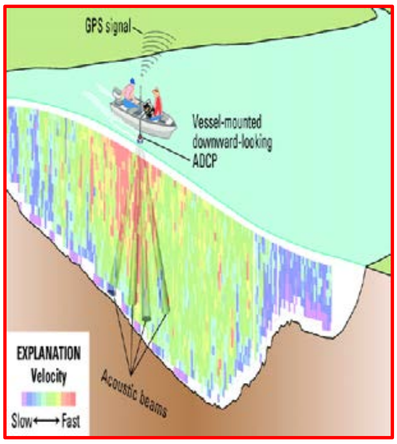

Fig. 6. Usng *ADCP* to measure streamflow.

3.1. Measurement of sediment concentration

The concentration of suspended sediment was established in the laboratory by using the method of filtration on the samples collected at the specified field locations. This process included the filtering of a litter of water for each sample using appropriate filter paper which was pre-dried at a temperature of (105°C) inside an oven for (30-60) minutes. The weight of the filter paper was determined before filtering and after drying, and a graduated cylinder with a capacity of one litter determined the volume of water used. For filtering purposes, these used samples must be well mixed. After the filtering process, the filter paper is put with the sediments inside the oven for a full 24 hours at a temperature of (105°C) to extract the water from the sediment. The filtration paper was then removed from the oven and the dry sediment was taken. The sediment weight was detected by the difference of two weights i.e. the weight of the filter paper with the sediment minus the weight of the pre-dried filter paper. The weight of this sample, as measured in Fig. 7, is based on the volume of water that contains the suspended sediments and was used to calculate the sediment [14]. Sediment concentrate was measured using the Eq. (1).

$$SSC = \frac{W_2 - W_1}{V} \tag{1}$$

where *SSC* is the suspended sediment concentration, W_1 is the weight of dry filter paper, W_2 is the weight of dry filter paper + suspended sediment, and *V* volume of sample.

3.2. Calculate of suspended sediment discharge

By multiplying the concentration of sediments in suspension during water discharge using the Eq. (2) [14], the suspended sediment rate can be determined:

$$Qs = C \times Q \times 0.001 \tag{2}$$

where *Qs* is the suspended sediments discharge, *Q* is the water discharge, and *C* is the suspended sediment concentration.

Table 1 shows all the data that were used to construct the suspended sediment rating curves for this study area.

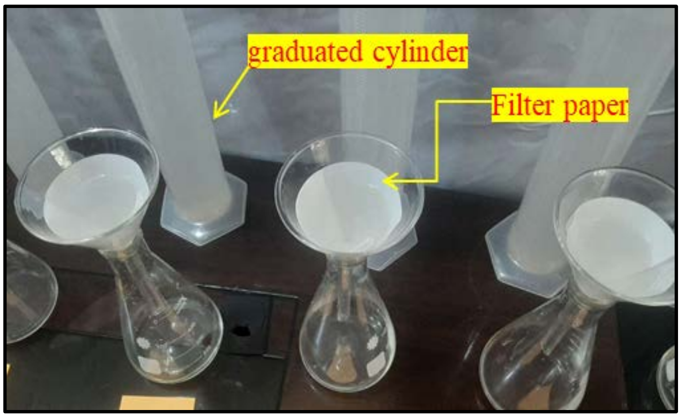

Fig. 7. Filtration method.

Table 1. Suspended sediment rating curve data.

Record No.	Water Level (m)	Water Discharge (m^3/s)	Average sediment concentration (ppm)	Sediment discharge (kg/s)
1	7.0	143	180	25.74
2	7.08	146	200	29.20
3	6.85	133	160	21.28
4	6.5	117	125	14.63
5	6.6	114	110	12.54
6	6.55	108	90	9.72
7	6.41	110	92	10.12
8	6.55	104	81.1	8.43
9	6.63	113	94.5	10.68
10	6.87	122	107	13.05
11	6.83	125	104	13.0
12	6.73	122	110	13.42
13	6.72	115	122	14.03
14	6.68	112	106.7	11.95
15	6.65	116	101	11.72
16	6.63	114	116	13.22
17	6.7	118	108.9	12.85
18	6.65	120	124.5	14.94
19	6.64	118	126	14.87
20	6.6	115	117.8	13.55
21	6.64	116	123	14.27
22	6.6	113	105.6	11.93
23	6.5	113	100	11.30
24	6.57	120	123.3	14.80
25	6.65	114	128	14.59
26	6.72	116	117.8	13.66
27	6.7	114	107	12.20
28	6.57	112	110	12.32
29	6.7	120	118.9	14.27

4. Suspended Sediment Rating Curve

Rating curves are the correlation between the river and other variables of the river, where discharge is typically used for any other variables, such as water level or concentration of sediments, etc. The curve describes the relationship between the discharge (*Q*) and (*SSC*) or (*Qs*) in the suspended sediment rating curve. The aim of these curves is usually to produce a series of sediment levels or discharges, etc. [15].

Figure 8 shows the relationship between the suspended sediment concentration (*SSC*) and the water discharge (*Q*) and the number of records for the study period, while Fig. 9 shows the relationship between the water level (*WL*) and the number of records for the same study period.

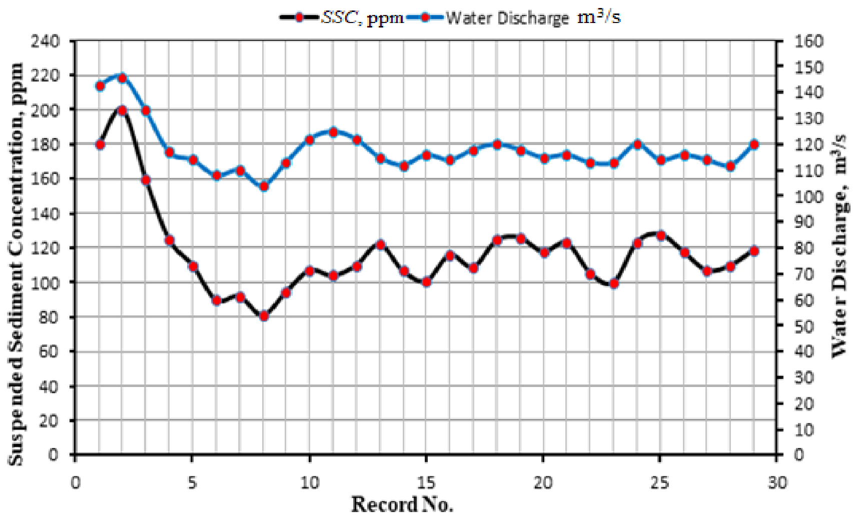

Fig. 8. Relationship between *SSC*, *Q*, and record number.

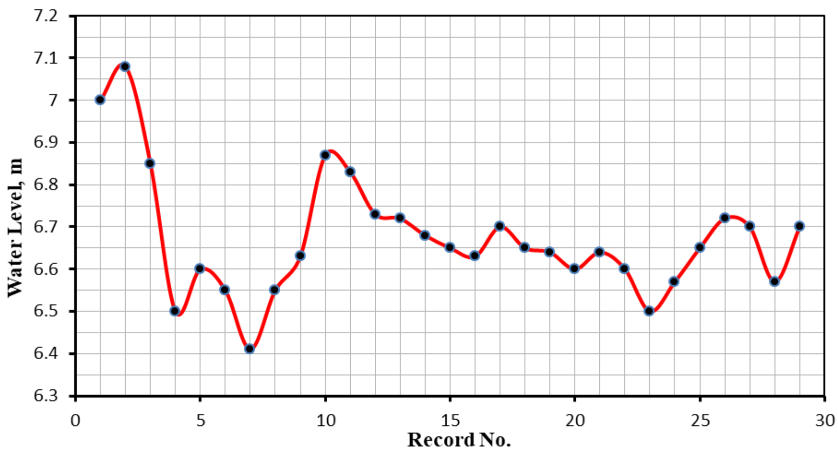

Fig. 9. Relationship between *WL* and record number.

Figure 10 shows the relationship between water level (*WL*) and water discharge (*Q*). This figure shows that there is a close connection between the observed data and the relationship in which the correlation coefficient (R^2=0.7411) and takes the following form as shown in Eq. (3).

$$y = 2.009Q^{0.2517} \quad (3)$$

where *y* is the water level.

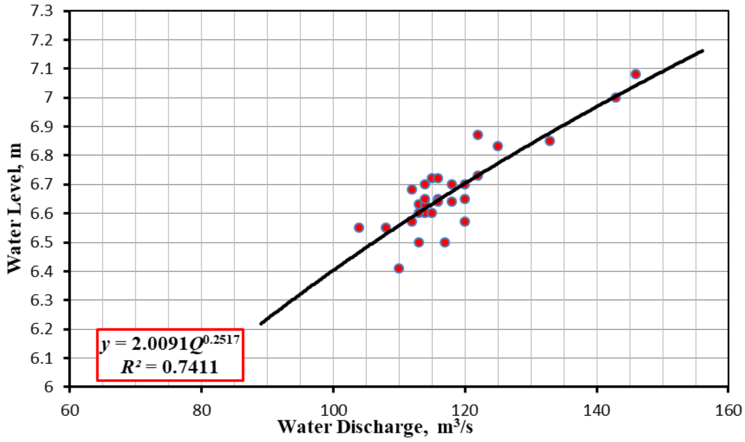

Fig. 10. Relationship between *WL* and water discharge (*Q*).

Figure 11 shows the concentration rating curve observed for the suspended sediment while Fig. 12 shows the load rate curve observed for the suspended sediment. Good consistency was also noted in the sediment concentration curve, where the correlation coefficient was (R^2=0.7665), while the relationship was more consistent with the suspended sediment load curve, where the correlation coefficient was (R^2=0.8717). The sediment rating curve will take its shape as in Eqs. (4) and (5).

$$SSC = 0.0022Q^{2.278} \quad (4)$$

$$Qs = 2E - 06Q^{3.2784} \quad (5)$$

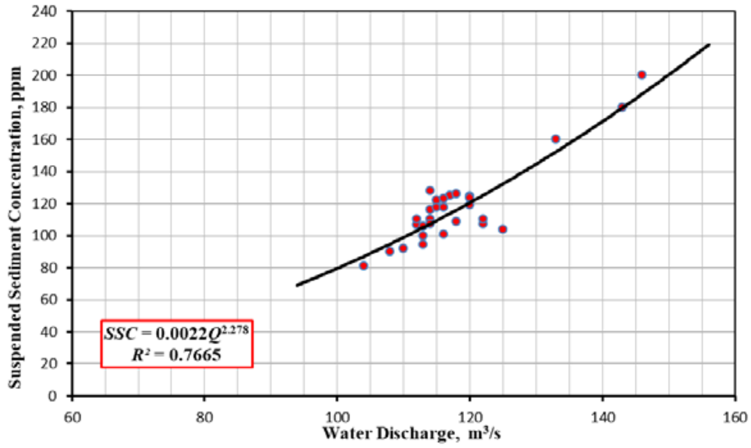

Fig. 11. Observed suspended sediment concentration (*SSC*) rating curve.

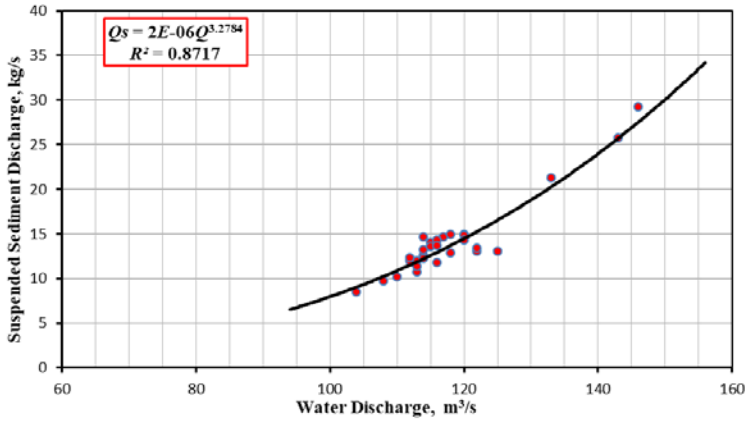

Fig. 12. Observed suspended sediment discharge (*Qs*) rating curve.

Lastly, these relationships match well with the observed data depending on the coefficient of correlation (R^2). The higher the coefficient of correlation, the greater the variance that the independent variable explains.

5. Conclusions

This study shows the fixed *SSC* rating curves and the *Qs* reaching downstream Al-Amarah barrage. The following points are concluded, based on the results:

- There is good agreement between the observed data and their relationship; for both the sediment concentration rating and rating sediment load curves, the correlation coefficients were (0.7665) and (0.8717).
- There is good compatibility between the data observed and the water level and water discharge relationship, where (R^2=0.7411).
- The curve of the suspended sediment load is better for estimating the sediment release in this river area than for estimating their concentration based on the values of (R^2).
- The sediment rating curve's efficiency can be increased by increasing the sampling frequency, including the amount of data available to develop those curves. Furthermore, the efficiency of the sediment rating curve can be increased by taking into account the (bedload) effect i.e. by using the total load for the sediment rating curve.
- Rating curves for sediments can be improved if the data are split on a seasonal, monthly, or annual basis.
- Rainfall plays an important role in the relationship between water discharge and the concentration of suspended sediments as shown in Fig. 11, where the first values are high compared to the remaining values in both *Q* and *SSC* due to the presence of a recorded rain wave.

Finally, the purpose of establishing sediment rating curves is always to predict *SSC* and their discharge over a specific period and for a specific region.

Nomenclatures

B	Top width of river, m

d	Depth of the water, m
Q	Water discharge. m^3/s
Qs	Suspended sediment load, kg/s
R^2	Coefficient of correlation
SSC	Suspended sediment concentration, mg/l
V	Volume of sample, L
W1	Weight of dry filter paper, mg
W2	Weight of dry filter and suspended sediment, mg
WL	Water level, m
y	Water level, m
Abbreviations	
ADCP	Acoustic Doppler Current Profilers

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