SUGGESTED MODEL TO ESTIMATE SEDIMENTS TRANSPORT IN Al- DIWANIYAHH RIVER BASED ON FIELD AND LABORATORY INVESTIGATIONS

Dr. Thulfikar Razzak Al- Husseini
Department of Civil Engineering,
College of Engineering,
University of Al- Qadisiyah.

Dr. Haider Ali Al- Mussawy
Department of Environment Engineering
College of Engineering,
University of Al- Mustansiriyah

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ABSTRACT

In this paper an experimental (field and laboratory) study was conducted on measuring the amount of suspended sediment transport in Al- Diwaniyah River and introducing a new formula to estimate sediments transport in this river. The application of this study required the selection of 25 sections along the river and its branches and the hydraulic parameters of these sections as well as the slope of bed were measured, and many samples from the river were taken to the laboratory. Samples of suspended sediment in water were taken at each section in the river and analyzed in the laboratory. A new formula was introduced using the dimensional analysis and DataFit 9.1 software corresponding to the field and laboratory measurements in this study. The results were compared with other formulas such as Engelund – Hansen, Laursen, and Einstein formulas and indicate a good exception.

Keywords: Suspended sediment, Sediment transport.

اقتراح موديل لتخمين انتقال الرسوبيات في نهر الديوانية بالاعتماد تحريات حقلية ومختبرية

د. ذوالفقار رزاق عبد المهدي الحسيني
قسم الهندسة المدنية, كلية الهندسة , جامعة القادسية

د. حيدر علي مهدي الموسوي
قسم الهندسة البيئية, كلية الهندسة , الجامعة المستنصرية

الخلاصة

في هذا البحث تم عمل دراسة عملية (حقلية ومختبرية) لقياس كمية حمل الرسوبيات العالقة في نهر الديوانية وتم اقتراح معادلة جديدة لتمثيل انتقال الرسوبيات بذلك النهر . ان تطبيق هذه الدراسة تطلب اختيار 25 مقطع موزعة على النهر وتفرعاته حيث تم قياس المتغيرات الهيدروليكية لهذه المقاطع بالاضافة الى انحدار قاع النهر ومن ثم تم اخذ عينات للمختبر لغرض قياس تركيز الرسوبيات. تم اخذ عينات ماء حاوية على الرسوبيات العالقة بكل مقطع من النهر وتم تحليلها مختبريا. تم تقديم معادلة جديدة باستخدام التحليل البعدي والبرنامج DataFit 9.1 بالاعتماد على البيانات الحقلية والمختبرية في هذه الدراسة لنهر الديوانية وتم مقارنة النتائج مع معادلات اخرى مثل (Engelund – Hansen, Laursen, and Einstein).

1- INTRODUCTION

Sediments play an important role in elemental cycling in the aquatic environment. For the purposes of aquatic monitoring, sediment can be classified as deposited or suspended. Deposited sediment is that found on the bed of a river or lake. Suspended sediment is that found in the water column where it is being transported by water movements. Suspended sediment is also referred to as suspended matter, particulate matter or suspended solids. Generally, the term suspended solids refers to mineral plus organic solids, whereas suspended sediment should be restricted to the mineral fraction of the suspended solids load. The study of river suspended sediments is becoming more important, nationally and internationally, as the need to assess fluxes of nutrients and contaminants to lakes and oceans, or across international boundaries, increases. One of the most serious environmental problems is erosion and the consequent loss of topsoil. Camenen and Larson developed a bed load transport formula for non-cohesive sediment based on the bed – shear concept of Meyer- Peter and Muller and validated for steady flows, oscillatory flows, and combined steady and oscillatory flows **[1].** Al- Kizwini et. al. studied the total sediment transport in Kirkuk irrigation channel by selecting 24 sections along this channel and samples of the laden water taken from each section and then present a formula to estimate the total load in this irrigation channel **[2].** Mizuyama et al measured the suspended load and wash load in mountain torrents using tubidometry and / or direct sampling **[3].** Alkseevskiy et. al. analysed in his paper the interrelation between erosion, sediment transportation and accumulation proposed by N. I. Makkaveyev (1908–1983) and its further development in modern studies of river channel processes in Russia **[4].**

Diplas et. al. explained the methods of sediment transport measurements in rivers **[5].** Kisi proposed in his paper the application of evolutionary fuzzy models (EFMs) for suspended sediment concentration estimation. The EFMs are improved by the combination of two methods, fuzzy logic and differential evolution. The accuracy of EFMs is compared with those of the adaptive neuro-fuzzy, neural networks and rating curve models. The daily stream flow and suspended sediment data belonging to two stations, Quebrada Blanca Station and Rio Valenciano Station, operated by the US Geological Survey (USGS) are used as case studies. The mean square errors and determination coefficient statistics are used for evaluating the accuracy of the models. Based on the comparison of the results, it is found that the EFMs give better estimates than the other techniques **[6].** Esteves et. al. undertake a Field measurements of longshore sediment transport (LST) on barred and non-barred beaches composed of fine, medium and coarse sands in Brazil, Denmark and Portugal. Measurements and predictions of vertical suspended sediment concentration profiles (C-Profiles) and cross-shore hydrodynamic parameters were then combined in a new semi-empirical model for prediction of LST (LTMOD). Instantaneous LST predictions from LT-MOD and well-known bulk LST formulae were compared. Tests using LT-MOD to simulate measured changes in shoreline position in southern Brazil for periods of c. two years showed that LT-MOD gave more accurate predictions than existing bulk LST formulae. Results indicate that LT-MOD may have practical utility at sites where access to equipment is limited and where reliable estimates of LST are required over extended periods**[7].** Tarazon et. al. introduced a paper and examined the relations between rainfall, runoff and suspended sediment transport in the Isábena basin during a quasi-average hydrological year. The Isábena is a Mesoscale river basin that drains a mountainous area comprising patches of highly erodible materials (badlands). The paper includes an analysis of the different hydrological and sedimentary responses of the catchment to a similar rainfall **[8].**

Chegini Pender explored a laboratory study to determine the influence of current uniform flow conditions on bed load of different small size sediment particle beds and its bed formations. The influence of uniform flow and its related near bed turbulent flow conditions on bed load sediment transport and its related bed form in relatively low, mild and steep slopes channel has been experimentally investigated. Four sediment particle sizes were evaluated in the experimental study: (1) fine sand (0.2 mm), coarse sand (1.6 mm), very coarse sand (2.8 mm), and fine grain (4.4 mm). A traditional experimental technique was developed to enable accurate performance for sediment particle transport measurement. The technique of estimating the transport rate of sediment particles is based on the trap measuring device **[9].** Xue et. al. used a Coupled Wave–Ocean–Sediment Transport Model to Hindcast coastal circulation and fine sediment transport on the Mekong shelf in southeastern Asian in 2005. Comparisons with limited observations showed that the model simulation captured the regional patterns and temporal variability of surface wave, sea level, and suspended sediment concentration reasonably well **[10].** Claudi et. al. used three methods to estimate river bed load discharges were compared in a large sand–gravel bed river. The unit and total bed load transport rates estimated by sediment sampling, dune tracking method and the equations of Van Rijn and Meyer-Peter and Müller were compared. The analysis was based on a large data set obtained from field surveys that combined sediment sampling, acoustic Doppler profiler (ADP) measurements, and multi-beam echo soundings of the middle reach of the River Loire (France) for contrasting flow conditions ranging from low flows to 2 year floods. For transport stages between 2 and 6 (i.e. between the annual mean discharge and the discharge for a 2-year flood), the tested equations predicted fairly well the unit and total bed load discharges and roughly estimated the temporal variability of the bed load during floods. For these transport conditions, the best agreement with the sediment sampling measurements was observed with the Van Rijn formula. For lower flow conditions, the tested formulas provide lower estimates than those sampled **[11].** Khanchoul et al. introduced a methodology to predict sediment loads in the Kebir drainage basin (681 km^2). The methodology is developed by a conventional sediment rating curve and a multiple regression model. The former method is investigated with the mean discharge classes derived from the recorded instantaneous suspended sediment concentrations and water discharges for the Kebir basin, prior to the Mexa reservoir construction. The latter is based on rock type erodibility, mean annual runoff and basin area variables, and which is applied for the ungauged Mexa reservoir basin located upstream of the Kebir gauging station (651 km^2) **[12].**

Sibetheros et. al. presented a study of sediment transport in a complex Mediterranean watershed consisting of temporary flow tributaries and karstic springs. Both daily data and monthly sediment concentration data were used to calibrate the modified Soil and Water Assessment Tool (SWAT) model, designed to simulate the hydrology, sediment yield, and water quality of ungagged watershed **[13].** Armijos et. al. measured the suspended sediment transport in the Amazon river of Peru and studied the crust evolution **[14].** Haddadchi et. al. conducted a Field experiments on total load transport in the Chelichay River Basin, a mountainous catchment (1,400 km^2) located in north eastern of Iran, to evaluate total load formulas including four gravel bed rivers and a sand bed river (Qaresoo River). Gravel bed rivers in Chelichay River Basin can be grouped into two types; steep slope rivers with high shear values (Chehelchay River and Khormaloo River) and mild slope rivers with low shear values (Narmab River and Soosara River). Two depth integrating suspended load samplers (DH-48 and D-49), and two bed load samplers (Helley-Smith and BLSH) were used to measure total load **[15].** Termini applied in his work a 1-D numerical model, which includes a new expression of the so-called “adaptation coefficient”, to test its capability to simulate the transient bed profiles. Specifically, the model has been applied to predict bed level changes due to sediment overloading and sediment cut-off. The model’s application to literature study cases (used by other researchers to assess coupled models) has shown that it gives reasonable results and, thus, it appears suitable for practical applications **[16].** Mouri et. al. showed through the field measurements revealed that suspended sediment behavior and fluxes decreased along the mainstream Sukhaya Elizovskaya River from inflows from a tributary catchment located in the volcanicmountain range. In his laboratory experiments, water samples collected from tributaries were mixed with those from the mainstream flow of the Sukhaya Elizovskaya River to examine the cause of debris flow and characteristics of suspended sediment in the mainstream. The experimental results were up scaled and verified using field measurements. His results indicate that the characteristics of suspended sediment and river discharge in the Sukhaya Elizovskaya River can be attributed primarily to the beginning of snowmelt in volcanic tributaries of the lahar valley, suggesting a significant hydrological contribution of volcanic catchments to in stream suspended sediment transport **[17].** Wilkinson et.al. developed a time – stepping sediment budget model for assessing land use impacts in large river basins **[18].**

The aim of this study is to measure the sediments transport through measuring the hydraulic parameters in Al- Dewaniya River and introducing a new formula to estimate that sediments in this river.

2- TYPES OF SEDIMENTS TRANSPORT

Sediment transport is a direct function of water movement. During transport in a water body, sediment particles become separated into three categories: suspended material which includes silt + clay + sand; the coarser, relatively inactive bed load and the saltation load.

Suspended load comprises sand + silt + clay-sized particles that are held in suspension because of the turbulence of the water. The suspended load is further divided into the wash load which is generally considered to be the silt + clay-sized material (< 62 µm in particle diameter) and is often referred to as “fine-grained sediment”. The wash load is mainly controlled by the supply of this material (usually by means of erosion) to the river. The amount of sand (> 62 µm in particle size) in the suspended load is directly proportional to the turbulence and mainly originates from erosion of the bed and banks of the river. In many rivers, suspended sediment (i.e. the mineral fraction) forms most of the transported load **[19] .**

Bed load is stony material, such as gravel and cobbles, which moves by rolling along the bed of a river because it is too heavy to be lifted into suspension by the current of the river. Bed load is especially important during periods of extremely high discharge and in landscapes of large topographical relief, where the river gradient is steep (such as in mountains). It is rarely important in low-lying areas **[19].**

Measurement of bed load is extremely difficult. Most bed load movement occurs during periods of high discharge on steep gradients when the water level is high and the flow is extremely turbulent. Such conditions also cause problems when making field measurements. Despite many years experimentation, sediment-monitoring agencies have so far been unable to devise a standard sampler that can be used without elaborate field calibration or that can be used under a wide range of bed load conditions. Even with calibration, the measurement error can be very large because of the inherent hydraulic characteristics of the samplers and the immense difficulty with representative sampling of the range of sizes of particles in transit as bed load in many rivers. Unless bed load is likely to be a major engineering concern (as in the filling of reservoirs), agencies should not attempt to measure it as part of a routine sediment-monitoring programed. Where engineering works demand knowledge of bed load, agencies must acquire the specialized expertise that is essential to develop realistic field programs and to understand the errors associated with bed load measurement. Due to these reasons the bed load for Al- Diwaniyah river can be ignored since have not a high extremely discharges, have not a steep slope, and not in a mountain area.

3- SAMPLING FOR SUSPENDED SEDIMENTS

The methods and equipment used for sampling suspended sediment are different from those used for deposited sediments. Also sampling methods for measurements of the quantity of sediment in transport are different than for measurement of sediment quality. The reason for these differences reflects the fact that sediment quantity must include the sand-size fractions which are unequally distributed in depth, whereas sediment quality focuses on the silt plus clay fraction which is not depth-dependent.

For bottom sediments it may be necessary to collect deposited sediments with minimum disturbance in order not to lose the fine material on the sediment surface, or because the vertical distribution of the sediment components is important (such as during establishment of historical records or depositional rates). In deep waters this necessitates the use of grabs or corers (see also section 11.2.2), but in shallow water a scoop or spatula may be used. Further discussion of the relative merits of different sampling techniques is available in Water Quality Assessments and other relevant publications.

There are four main types of samplers for suspended sediments **[19]:**

1-Depth- Integrated samplers: this sampler traverses the complete depth of the stream and back at a uniform and collected a sample which has a concentration equal to the average concentration in the vertical.

2- Point- Integrated samplers: it contains a sample at a desired point where it remains for a certain time.

3- Pumping samplers: by pumping, water can be withdrawn from a stream at a pre-determined depth. During each sampling, one liter is pumped from the stream and stored in bottle for laboratory analysis.

4- Continuous monitoring: this device consists of a light- emitting source and a photocell located opposite to it. The intensity of light received by the cell is affected by the presence of the suspended solid particles, which decreases the transparency of the water.

The concentration of the coarser fractions of suspended sediment increases towards the bottom of the river channel. This segregation of material by particle size requires that, for the purposes of measuring quantity of suspended sediment, a depth-integrating sampling technique is used to obtain a sample that accounts for different sediment concentrations throughout the vertical profile of a water body. Many types of sampler have been designed for depth-integrated sampling of suspended sediment. Some are available commercially but are rather expensive. All of them have a number of features in common **[19]:**

1- Each has a water inlet nozzle and an air outlet. As the water and suspended sediment enter, air is displaced through the air outlet.

2- Each permits isokinetic sampling. That is, water velocity through the inlet nozzle is equal to the water velocity at the depth of the sampler. This is important for larger particles, such as sand, because the sampler would otherwise tend to over- or under-estimate the amount of suspended sediment. Errors caused by lack of isokinetic sampling are minimal for small particles (< 62 μm) and for practical purposes can be ignored.

3- Each has a metal body (for weight) that encloses a glass or plastic bottle for retaining the sample. The bottle is changed after each sample is taken.

4- The diameter of the water inlet can be selected (or changed) so that the sampler will fill more or less quickly, depending on the depth of the river.

In practice, depth-integrating samplers are lowered to the river bottom, then immediately raised to the surface; lowering and rising should be done at the same rate. The objective is to fill the sampler to about 90 per cent capacity; if the sampler is completely full when it emerges from the wate,r the sample will be biased because the apparatus will have stopped sampling at the point at which it filled up **[19].**

Large, heavy samplers are usually only necessary when samples must be obtained from a bridge, boat or similar situation. In shallow streams, where all points can be reached by wading, a bucket (if nothing else is available) or a small sampler attached to a metal rod can be used. It is possible to make a simple depth-integrating sampler for use in shallow streams, using a wide-mouth, 1-litre bottle, a rubber stopper and short pieces of rigid tubing. The tubing forms the water inlet and air outlet. The lengths and diameters of the tubes may require experimentation but, in general, the air outlet tube should be of a smaller diameter than the water inlet. The bottle is secured to a metal rod or wooden pole, then lowered and raised as outlined above. An example of a home-made sampler is shown in **Figure (1).** The sample must be taken facing upstream so as to avoid sampling bottom sediment that was re-suspended by the operator's feet **[19].**

The home – made suspended sediment sampler was designed as the specification in **Figure (1)** and manufactured locally to measure the suspended load as an integrated sampler in Al- Diwaniyah river as shown in **Figure (2).**

4- MEASURING SUSPENDED SEDIMENT

Particle size distribution and concentration not only vary in the vertical section, but may also vary considerably across a river section. Therefore, measuring suspended sediment concentration must take into account these variations. This becomes especially important when suspended sediment concentration is being measured for the purpose of calculating sediment load in a river. There are two generally accepted methods for measuring suspended sediment concentration for load determination as described below **[19].**

4.1- Equal Discharge Increment method.

This method requires first that a complete flow measurement be carried out across the cross section of the river. Using the results, the cross-section is divided into five (more on large or complex rivers) increments (i.e. vertical sections) having equal discharge. The number n of increments is based on experience. Depth integrated suspended sediment sampling is carried out at one vertical within each of the equal-discharge-increments, usually at a location most closely representing the centroid of flow for that increment. The sediment concentration for each equal-discharge-increment is measured as will be indicate in section 5. The mean discharge-weighted suspended sediment concentration (SSC) is obtained by taking the average of the concentration values C obtained for each interval i **[19].**

$$\text{SSC} = \frac{\sum_{i=1}^{n} Ci}{n} \qquad (1)$$

The discharge-weighted suspended sediment load (SSL), in tons per day, for the river cross-section is obtained by multiplying the concentration, C, in ppm (mg / ℓ) by the discharge, Q, in m^3/s of each equal-discharge- increment, i, and summing for all increments. This method is very time-consuming, but is that most used by sediment agencies **[19].**

$$\text{SSL} = \sum_{i=1}^{n}(Ci * Qi) * 0.0864 \qquad (2)$$

4.2- Equal Width Increment method.

This method is used without making flow measurements and is usually used in small to medium rivers and especially rivers that are shallow enough for wading. The operator marks off 10-20 equal intervals across the river cross-section. At the deepest point, the operator takes a depth-integrated sample, noting the transit rate of the sampler (i.e. the uniform speed at which the sampler is lowered, then raised to the surface). Using that same transit rate, a suspended sediment sample is taken at each of the intervals. Because each vertical will have a different depth and velocity, the sample volume will vary with each vertical sampled. Note that the bottle must never be over-filled. All samples are composited into a single container which is then agitated and sub-sampled, usually two or three times, and analyzed for suspended sediment concentration. The average of these analyses is the mean cross sectional suspended sediment concentration. In this method, the results are corrected for differences in discharge at each section by virtue of using the same transit rate (and the same nozzle diameter) at all sections - i.e. a shallow section with less discharge will produce a proportionally smaller suspended sediment sample than a deep section having greater discharge **[19].**

In this paper the equal width increment method is used for sampling the suspended sediment in Al-Diwaniyah River. **Figure (3)** shows the suspended sediment sampling from Al- Diwaniyah River and its branches.

5- HYDRAULIC PARAMETERS FOR Al- DIWANIYAHH RIVER AND ITS BRANCHES

The range of the hydraulic parameters which were measured for Al- Diwaniyah River and its branches was shown in **Table (1).** The velocities were measured for each section using M-9 device **[20]** which shown in **Figure (4)**, the depths of water for each section and slopes between sections were measured using the level device, and the specific gravity diameters of particles were measured using sieve analysis in the laboratory. Seven parameters were selected according to notifying many formulas that used to estimate suspended sediment load which are depth of flow h, specific gravity S.g, Slope S, d_{65}, d_{35}, density of flow ρw, and discharge Q.

6- LABORATORY PROCEDURES FOR MEASURING SEDIMENT CONCENTRATION

The sample is wet-sieved, i.e. distilled water is used to rinse the sample through the sieve. All of the water that passes through the sieve (original sample plus rinse water) is collected and filtered through a membrane filter of 0.45 μm pore size and of known weight. The sand collected on the sieve is dried and weighed [W_{sand} (g)] and the silt and clay collected on the filter paper is dried and weighed [$W_{clay+silt}$ (g)]. The results can be expressed as follows **[19]:**

$$\text{Concentration of sand (mg / ℓ)} = (W_{sand} / V_{sample}) \times 10^6 \quad (3)$$

$$\text{Concentration of clay + silt (mg / ℓ)} = (W_{clay+silt} / V_{sample}) \times 10^6 \quad (4)$$

$$\text{Total suspended load (mg / ℓ)} = [(W_{sand} + W_{clay+silt}) / V_{sample}] \times 10^6 \quad (5)$$

If sand concentration is not required separately, then filter a known volume of raw water through a pre-weighed 0.45 μm pore diameter filter paper. The suspended sediment concentration is then the dry weight (in grams) of the filter paper + retained sediment, minus the original weight of the filter paper, all divided by the volume (ml) of the sample, as in equation (5) **[19]**:

The sampling of suspended sediments for Al- Diwaniyah River and its branches were analyzed in the laboratory and the data were obtained depending on the procedure described in paragraph 6. The following paragraph represents the dimensional analysis and generation a new formula for this river.

7- DIMENSIONAL ANALYSIS

A dimensional analysis for the selected eight parameters which effect on suspended sediment transport was done according to the flowing:

$$f_1(\text{ h (m), S.g (-),Q } (m^3/s)\text{, S (-), } d_{65}\text{ (mm), } d_{35}\text{ (mm), } Q_s\text{ (Kg/s), } \rho w\ (\frac{Kg}{m3})) = 0 \quad (6)$$

$$Qs = f_2\,(h, S.g, S, d_{65}, d_{35}, \rho w, Q) = 0 \quad (7)$$

$$f_3\,(\frac{Q^3 Qs}{h^4\,\rho w}, \frac{h}{d_{65}}, \frac{d_{65}}{d_{35}}, S.g, S) = 0 \quad (8)$$

$$Q_s = \frac{h^4.\rho w}{Q^3}\ f_4\,(\frac{h}{d_{65}}, \frac{d_{65}}{d_{35}}, S.g, S) \quad (9)$$

Where:

Q_s: suspended sediment (Kg/s)
h: depth of water in the river (m)
S.g: specific gravity of the bed river (dimensionless)
S: slop of river bed (dimensionless)
d_{65}, d_{35}: the size for which 65 % and 35 % of the bed material is finer, respectively (mm).
ρw : density of water ($\frac{Kg}{m3}$)
Q : discharge of water in the river (m^3/s).

8- DataFit 9.1 SOFTWARE

After the dimensional analysis for the selecting parameters a DataFit 9.1 software is used to predict a new formula (equation 10) - by trial and error of changing its formation in DataFit 9.1 until obtaining a maximum correlation coefficient (R^2)- for estimating suspended load for Al- Diwaniyah river (R^2 = 95 %) . **Figures (5) through (7)** show the application of DataFit 9.1 for measured data of suspended load. Equation 10 can be used as a formula to estimate suspended load as well as total load since the bed load is very small compared with suspended load.

$$Q_s = A.Q.\rho w.S + B.\,(\frac{h}{d_{65}})^{(C.S.h)} + D.\,(\frac{h}{d_{35}})^{(E.S.h)} + \frac{F}{(S.g-1)^N} + M.\frac{h}{d_{65}}.S \quad (10)$$

Where:-
A = 1.187196
B = 432.138
C = -20147.21
D = $-3.413*10^{(-4)}$
E = 11050.75
F = 10925.2
M = 1092.81
N = 17.73
The limits of formula (10) are illustrated in **Table (1).**

9- COMPARISON BETWEEN NEW FORMULA AND OTHER FORMULAS

The new formula was compared with other formulas such as Engelund – Hansen, Laursen, and Einstein as shown below **[21].**

1- Einstein Formula (1950):

$$Qs = 11.6 * b * U_* * a * [2.303 \log (\frac{30.2}{\Delta}) I_1 + I_2] \qquad (11)$$

Where:
Qs : suspended load (kg/sec);
U_*: Shear velocity due to grain roughness = $\sqrt{g.R.S.}$ (m/sec) ;
b: river width;
Δ: Correction factor = apparent roughness of the bed surface = $\frac{d_{65}}{X}$; d_{65}: Particle diameter in which 65 percent finer.
The values of I_1 and I_2 were indicated in **Figures (8) and (9)** in terms of fall velocity ($\boldsymbol{\omega}$) and shear velocity ($\boldsymbol{U'} *$) due to grain roughness

2- Laursen Formula (1958):

$$Qs = Q * \gamma * 0.01 * \sum_i Pi \left(\frac{d_{si}}{D}\right)^{7/6} \left(\frac{\tau'_o}{\tau_{ci}} - 1\right) f\left(\frac{U_*}{Wi}\right) \qquad (12)$$

Where:
$\tau'_o = \frac{p\,V^2}{58}\left(\frac{d_{50}}{D}\right)^{1/3}$
Values of $f\left(\frac{U_*}{Wi}\right)$:-

1- For $\left(\frac{U_*}{Wi}\right) \leq 0.3$, then $f\left(\frac{U_*}{Wi}\right) = 10.5\left(\frac{U_*}{Wi}\right)^{0.24}$; where the movement is bed load
2- For $0.3 < \frac{U_*}{Wi} \leq 2.1$, then $f\left(\frac{U_*}{Wi}\right) = 3.12565\left(\frac{U_*}{Wi}\right)^2 + 5.7426\left(\frac{U_*}{Wi}\right) + 6.0776$ where the movement is suspended and bed load
3- For $2.1 < \frac{U_*}{Wi} < 29$, then $f\left(\frac{U_*}{Wi}\right) = 6\, f\left(\frac{U_*}{Wi}\right)^{2.1951}$
4- For $29 \leq \frac{U_*}{Wi} \leq 160$, then $f\left(\frac{U_*}{Wi}\right) = 35223.76 \log\left(\frac{U_*}{Wi}\right) - 42974.526$
5- For $\frac{U_*}{Wi} > 160$, then $f\left(\frac{U_*}{Wi}\right) = 9713\, f\left(\frac{U_*}{Wi}\right)^{0.2516}$; where the movement is predominantly suspended load.

3- Engelund – Hanson Formula (1967):

$$Qs = 0.05 .b. \rho s. V^2. \sqrt{\frac{d_{50}}{g(S.g-1)}} \left[\frac{\tau_0}{(\gamma s - \gamma) d_{50}}\right]^{3/2} \qquad (13)$$

Figures (8) and (9) show the comparisons between the new formula for Al- Diwaniyah river with other formulas.

From **Figures (8) and (9)** the new formula gave best results for measured data compared with the other formulas.

10 – CONCLUSIONS

In this study a new attempt was made to measure the sediment load that transport in Al- Diwaniyah River and suggest a new formula based on field and laboratory investigations which were measured through this study. Many samples were collected from the river and analyzed in the laboratory. From the measured data a new formula was introduced to estimate the sediment transport in that river since there is no any previous study.

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Table (1): The range of the measured hydraulic parameters for Al- Diwaniyah River and its branches.

Parameters	The range
Depth of water h (m)	1.02- 2.57
Specific Gravity S.g	2.69 – 2.72
Slope S	0.0001 – 0.0002
d_{65} (mm)	0.12 – 0.39
D_{35} (mm)	0.085 – 0.16
Discharge Q (m^3/sec)	21.2- 33.0
Velocity V (m/sec)	0.32- 0.93

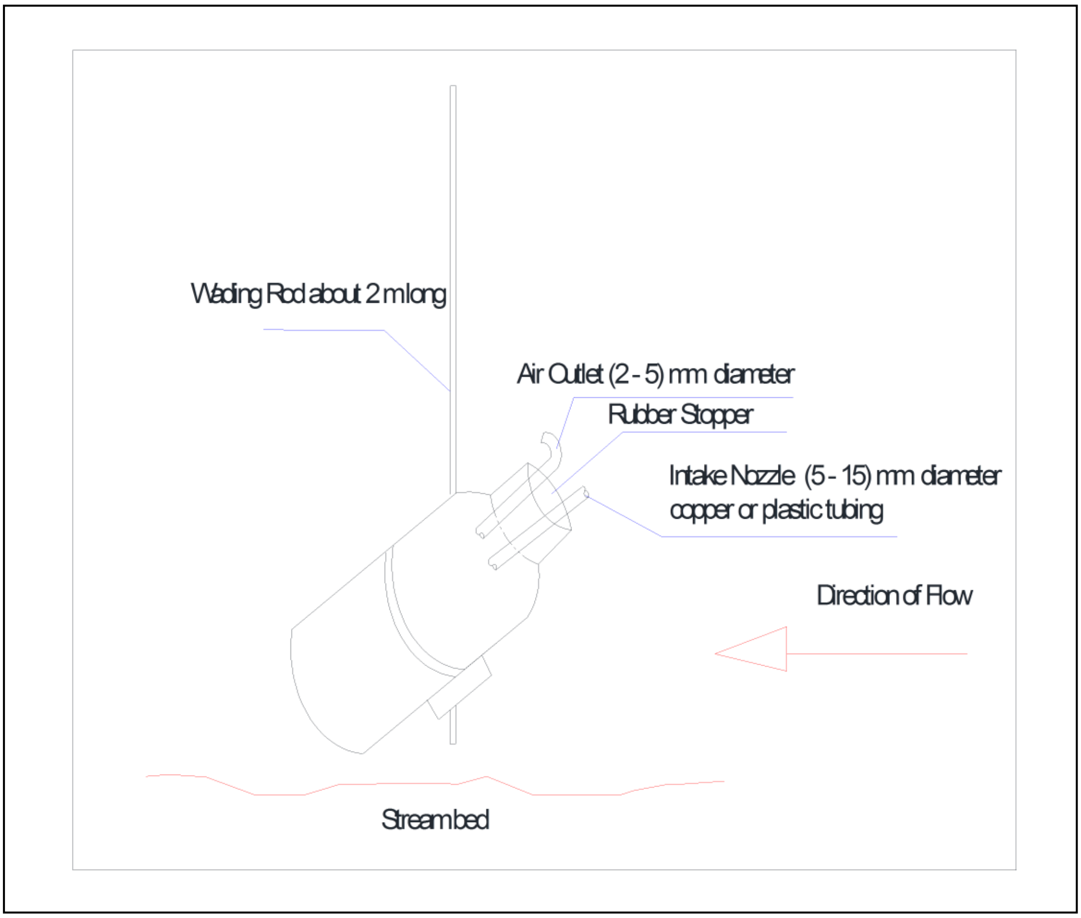

Figure (1): Home – made suspended sediment sampler [19].

Figure (2): Home – made suspended sediment sampler locally manufactured.

Figure (3): Suspended sediment sampling in Al- Diwaniyah River and its branches.

Figure (4): The M- 9 device [20]

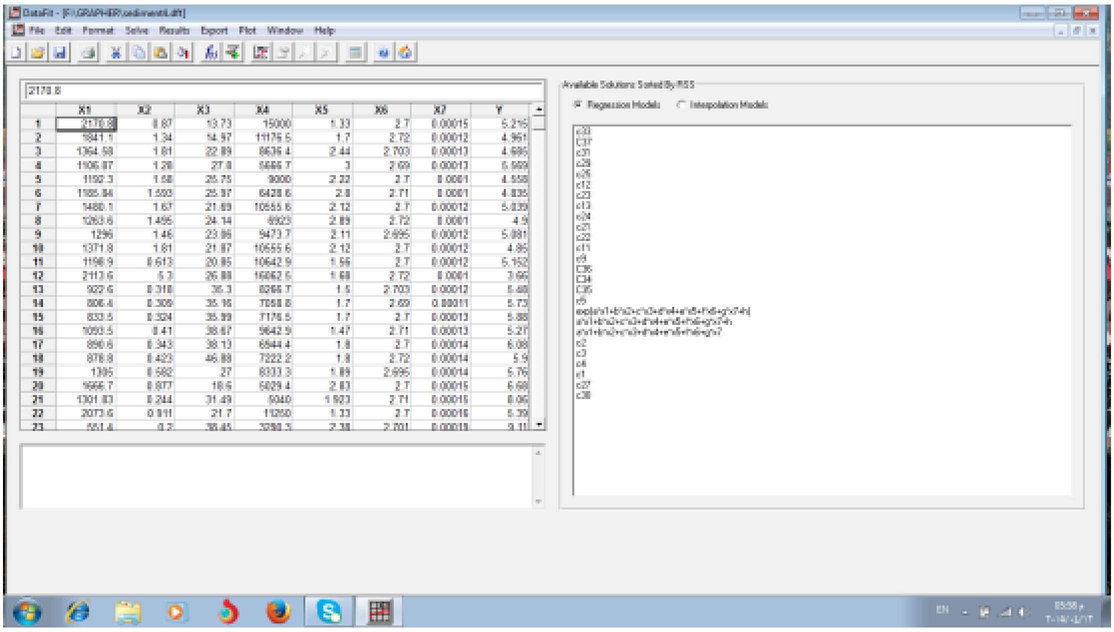

Figure (5): Application of DataFit 9.1 software for Al- Diwaniyah River (step 1).

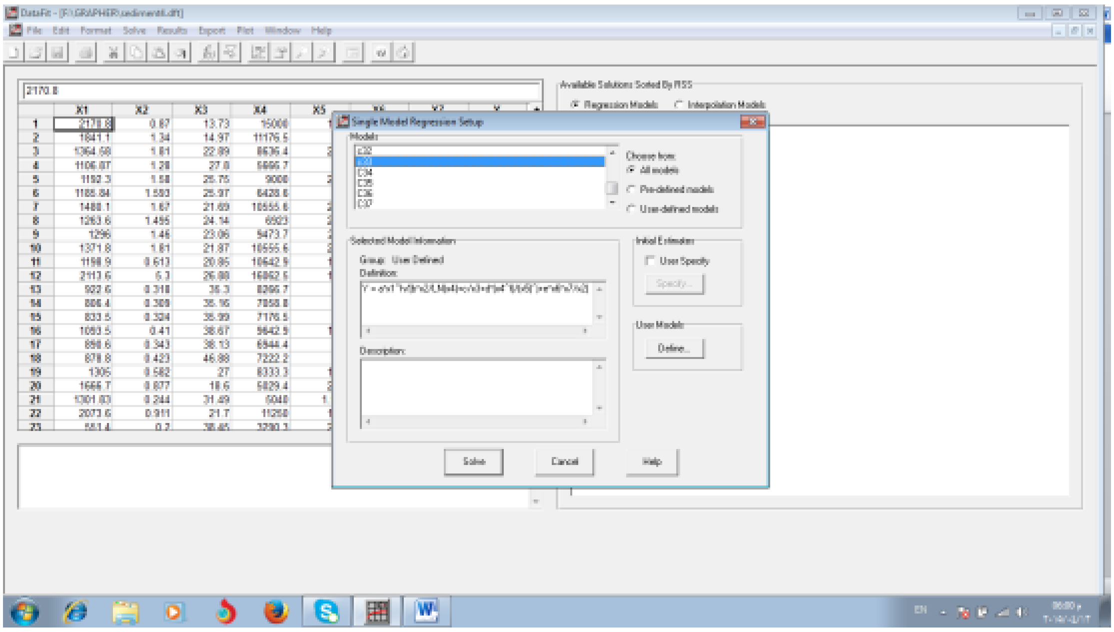

Figure (6): Application of DataFit 9.1 software for Al- Diwaniyah River (step 2).

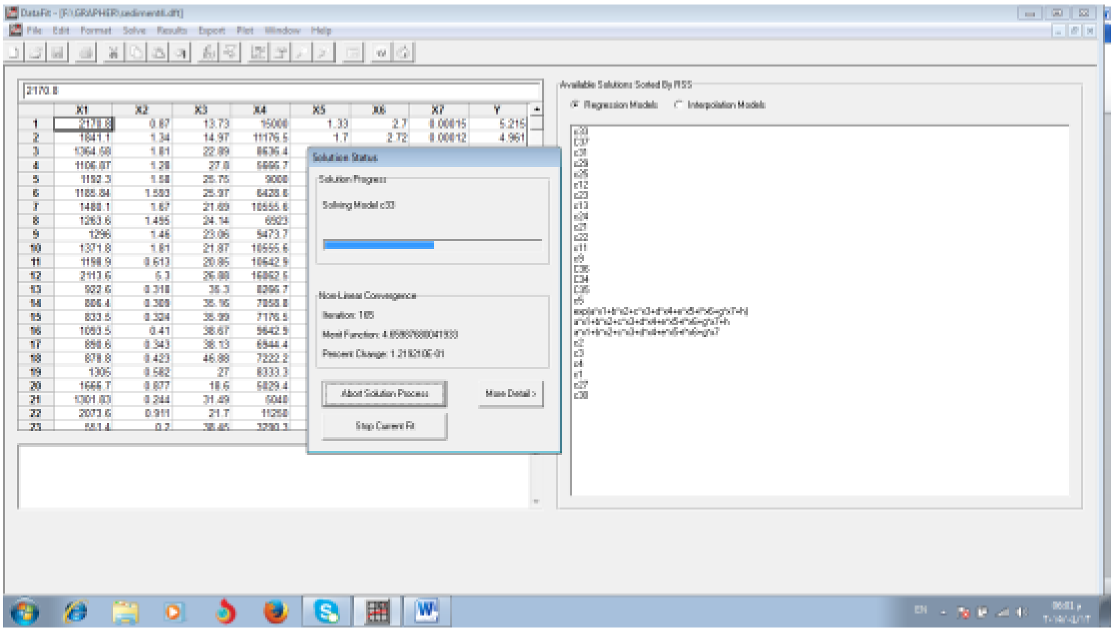

Figure (7): Application of DataFit 9.1 software for Al- Diwaniyah River (step 3).

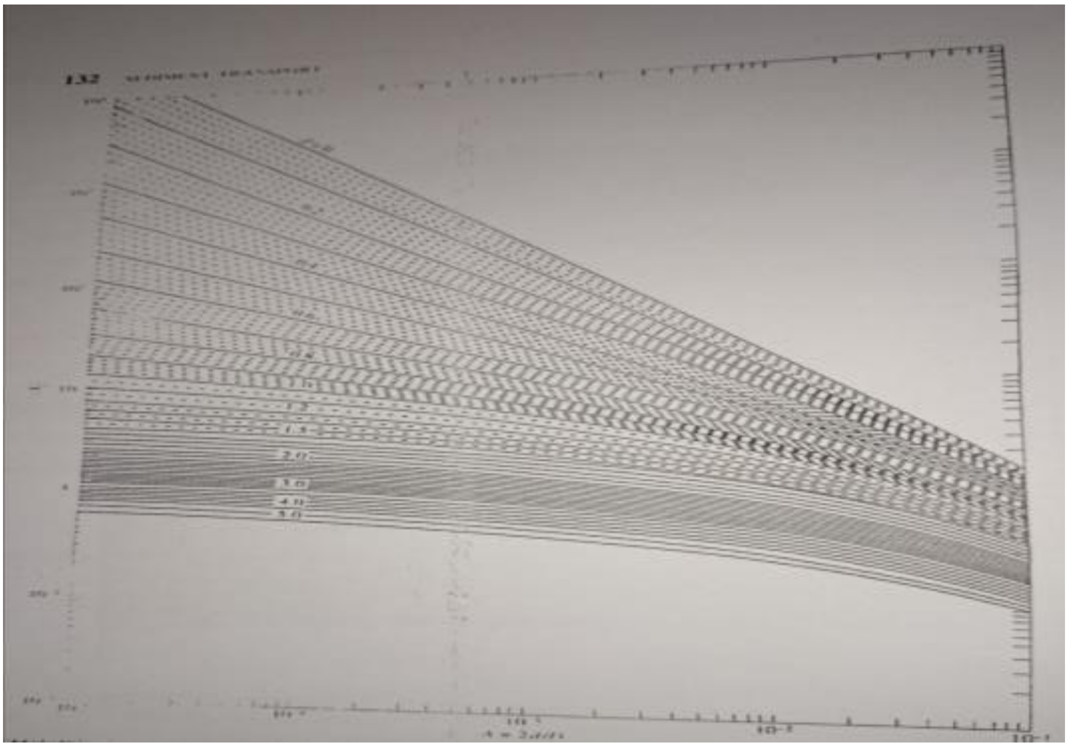

Figure (8): The function I_1 in terms of A (= 2d/D) for different values of Z (Z= $\omega/(0.4.U'*)$ [21].

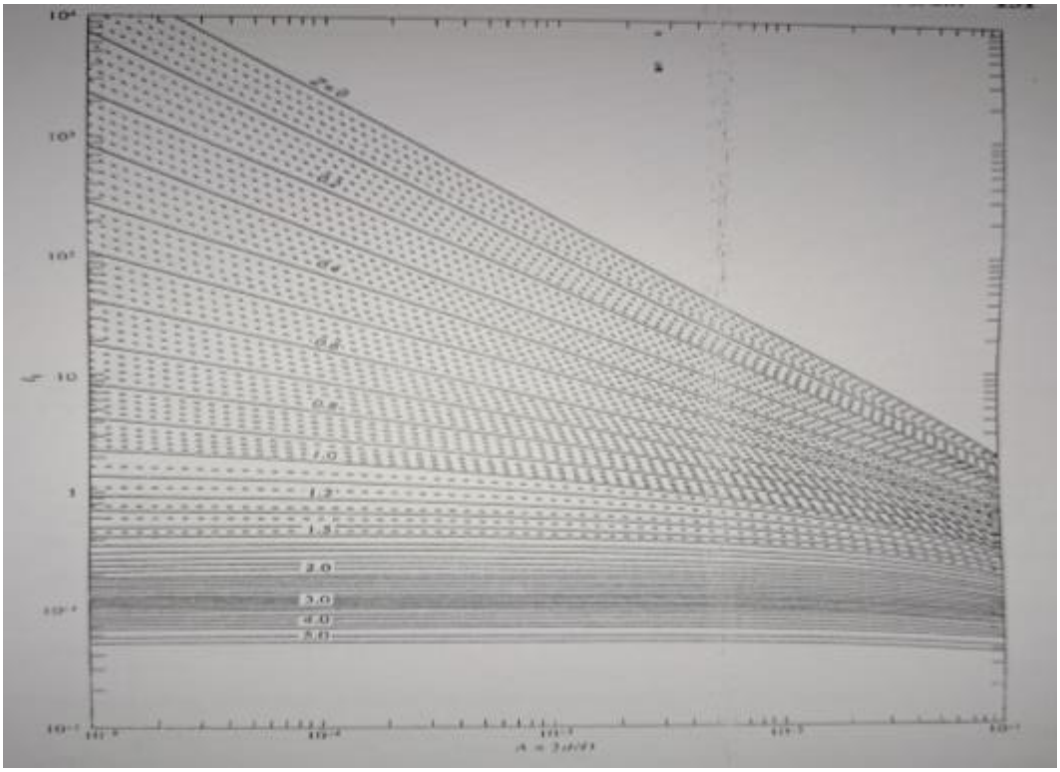

Figure (9): The function I_2 in terms of A (= 2d/D) for different values of Z (Z= $\omega/(0.4.U'*)$ [21].

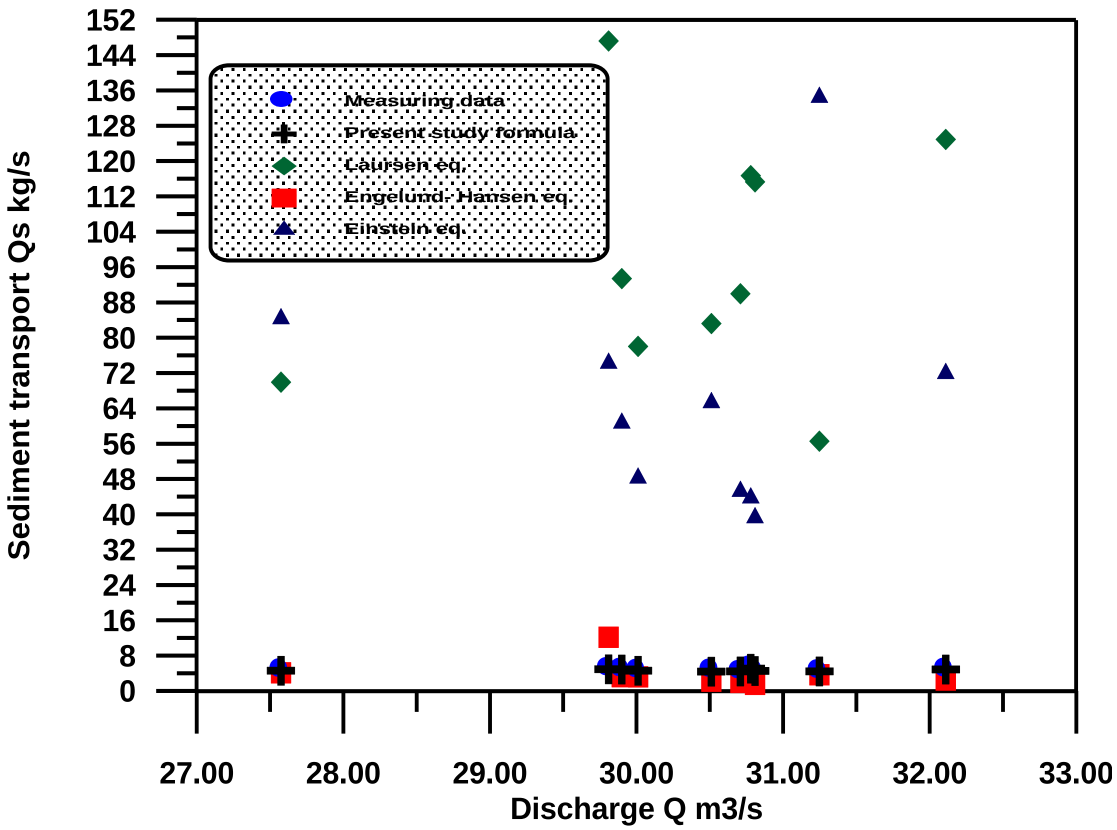

Figure (8): Comparison between the new formula, measured, and other formula.

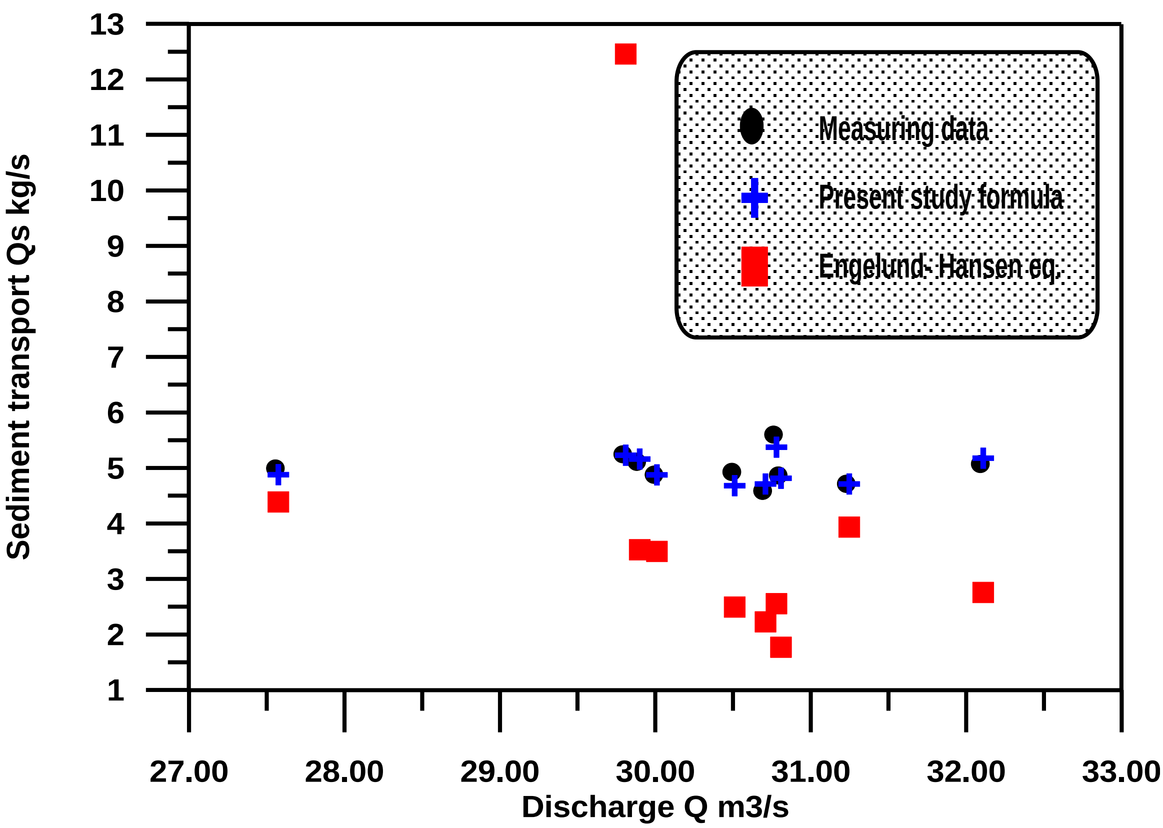

Figure (9): Comparison between the measured, new formula, and Engelund formula.