Application of HEC-RAS Model to Predict Sediment Transport for Euphrates River from Haditha to Heet 2016

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Abstract:

The aim of this study is to evaluate the sediment transport and to assess the quality of water for a reach of Euphrates River with a length of (124.4 km), begins from downstream of Haditha dam which represents the upstream of study, and ends at Heet station in Heet city which represents the downstream. There are 196 cross-sections which were distributed along the study area by using the model of one-dimensional HEC-RAS version 4.1. Calibration and Verification processes from(01-Sep-2013) to (30-Nov2013) and (01-DEC-2013) to (28-FEB-2014) respectively, show that the optimal Manning Roughness Coefficient (n) is equal to (0.033) which gives the less error ratio between the observed and calculated water surface elevations. By comparing the results of sediment transport "mass accumulated" for this study which equal to (237.38ton/day) was larger than the value of the previous study which equal to (165ton/day, measured in 2010). But the value of sediment load of this study at Heet station was equal to (551.76 ton/day) which was less than the value of previous study (189.041×10^3 ton/day, measured in 1988), due to increasing in the rates of discharge that was arrived the reach of study area.

Keywords: HEC-RAS model, sediment transport, total load, Euphrates River.

1. Introduction

There are thousands of tons of sediment carried by the various rivers annually, various sizes and types of materials of deposits, including coarse, soft, stone, sand, clay and silt and each one has its characteristics, and the size and quantity these deposits depends on hydraulic factors such as the velocity of water, the flow, the depth of water, and other properties of controls in determining the ability of the river to transport these deposits.

The Euphrates River is one of the big rivers in the world and a large part of its course passes in Iraq, its transporting great amounts of sediment. Large rivers like the Euphrates River such as Fraser River in British Columbia transport significant amounts of sediment. In the distal sand-bedded portion, These sediments range in size from clay and silt to fine and coarse sands. ***[Maureen 2012].***

HEC-RAS model was used in this study. The US Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HECRAS) Version 4.1 released January 2010 was had chosen to aid in this analysis. The study used both hydraulic and sediment transport modules within this software. The basic requirements for hydraulic calculations in HEC-RAS are channel cross sections geometry, values of Manning's n- for the cross sections, riverbank locations, distances between the cross sections, flow information, and flow boundary information. Additional information is required to model bridges and weirs. The HEC-RAS sediment transport model calculate transport capacity for non-cohesive and cohesive soils using hydraulic variables (velocity, flow depth, and shear stress) and sediment properties.

The field determine of roughness coefficient (n) in several channels is a difficult. [**Chow 1959]** was presented several factors affecting the values of roughness coefficients. Thus, the slope of friction is very important parameter, which shall be very carefully selected. Unsteady flow simulation conditions may need special treatment of the slope of friction , majority works in this field find the use of equation of Manning for steady uniform flow agreeable in this case, **[Al-Fahdawi 2009]**.

[Al-Fahdawi 2009] used the HEC-RAS model to apply unsteady flow model for a reach in Euphrates River between Haditha dam and Heet city, (124.4 km length) and analysis flood impact in flood prone areas on roads, land use and strategic projects. The numerical model was applied to the reach to make a sensitivity analysis of the effect of meandering on the following parameters: the river peak discharge, peak water level, lag time of peak discharge, and lag time of peak water level along the river reach under study for various values of Manning roughness coefficient of the floodplain.

[Hameed and Ali 2012] choose the suitable value of Manning's roughness coefficient (n) by the calibration; i.e., the value which re-produces observed data to an agreeable accuracy. For Hilla River, the HEC-RAS model, unsteady flow, is applied to expect the value of Manning's coefficient by perform the calibration for the period from 20 Aug 2008 to 12 Sept 2008. This period were divided into two groups; the first group is for calibration, and the second is for verification which is the process of checking the HEC-RAS model with real data to proof its expected accuracy. the result is found that a good agreement value of Manning's roughness coefficient (n) between observed and calculated hydrographs is (0.027).

The sediment transport in rivers are occur due to water flow, and the relationship between, materials volume which transported and flow factors (depth and velocity) is a very important but complex phenomenon, and it has many necessary engineering aspects such erosion around facilities, dredged refilling channels or reservoirs, erosion below a dam, changes of morphological in rivers, [**Khayyun and Mustafa, 2013**].

2. Study area

The Euphrates River is the longest river in the Middle East. Euphrates River is one of the most important rivers in Iraq. Nine cross-sections were chosen as a major stations from 196 cross-sections which is located along the reach. No tributaries contributes water into the river within the reach which beginning from Hadithah city and ending at Heet city. The river supplies a number of small canals for irrigation purposes, FIG(1).

The maximum height of the grand surface level is (227 m.a.s.l.) at the northeastern part of Haditha Reservoir, and the minimum height is (50 m.a.s.l.) at the Heet city. The region is characterized by a flat strip which runs parallel to the Euphrates River, and used for agriculture purposes. Several undulations surround the flat land, and turn to hills, Fig(2). [***Al-paruany 2005].***

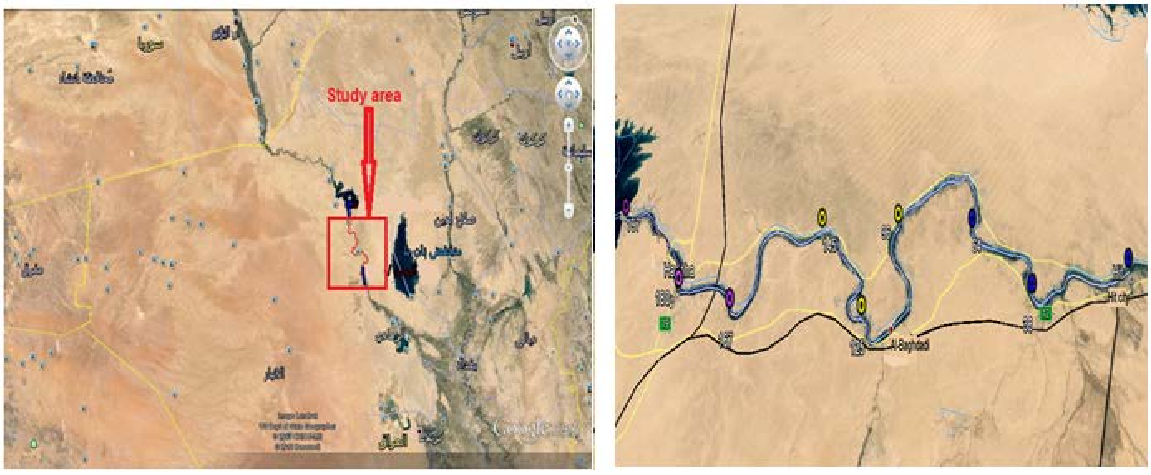

Figure (1): Euphrates River in Iraq, Reach of Study Area

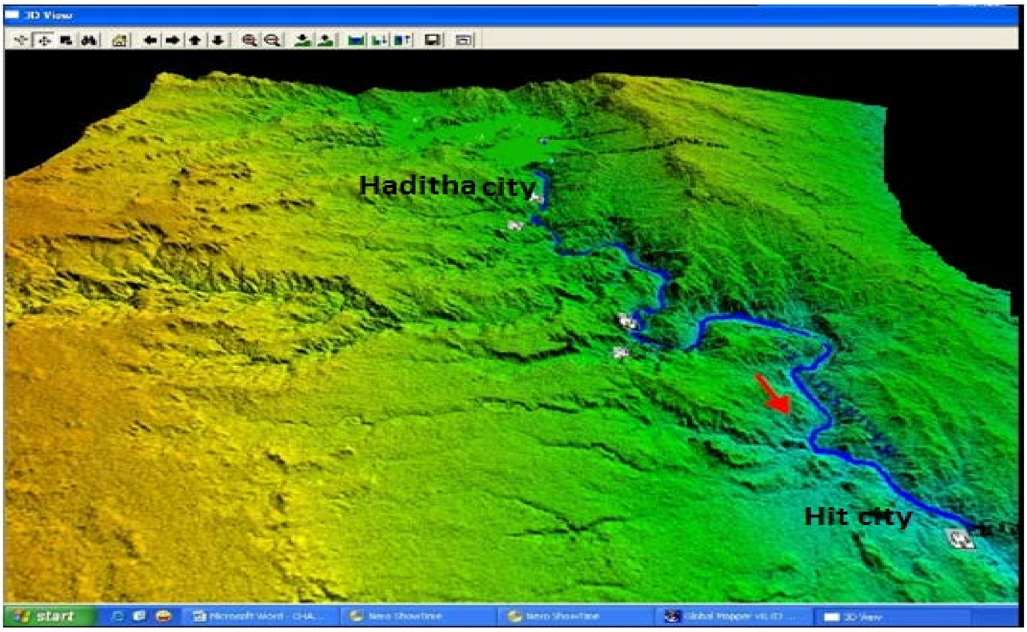

Figure (2): geological characterized of study area.

3. Theoretical Basis of Model

In this study, the model which used for the simulation, was (HEC-RAS) model, which proposed by "US army Corps of Engineers River Analysis System". The mentioned software is able to simulate the steady flow, gradually varied flow, water quality, and sediment transport. The sedimentation simulation ability has been added to its newest versions. This model has an advanced graphic having a lot of abilities to display the software outputs. The sediment load part of this model has been developed to simulate the one dimensional deposition of sedimentation and erosion of the rivers, [***Brunner,2010a***].

Some of the following assumptions are involved in analytical that used in this version of the model:

1. Flow is steady, gradually varied. (Except at hydraulic structures).
2. Flow is one dimensional (i.e., velocity components in directions other than the direction of flow are not accounted for).
3. River channels have "small" slopes, say less than 1:10.
4. Neglecting the impact of meandering along the river and treated as a straight.
5. Neglecting the value of wash load because it is a very small value.

A sediment model requires a several data, a geometry data, a quasi-unsteady flow data, a sediment data, and a sediment analysis plan. The modeling of sediment transport is difficult noticeably. The data which was used to expect the bed change is basically not sure and the theory employed is empirical and very sensitive to a wide collection of physical variables. But, with well data, a skilled of model designer can used a calibrated sediment model to expect regional, trends in the long-term that can tell decisions of planning and can be used to assess alternatives of project. HEC-RAS now contains the framework with which to accomplish mobile boundary, modeling of sediment transport, can be performed, [***Brunner,2010a***]**.** The researcher must select the suitable method that the model software will deal with equations of formula., [***Brunner,2010b***]. In this study the adopted formula that adopted is "Toffaleti".

[Toffaleti's] method (1968) is a modified-Einstein total load function that breaks the suspended load distribution into vertical zones and replicating a two-dimensional sediment movement. Toffaleti were used four zones to define the distribution of sediment, Fig(3). These zones are: the upper zone, the middle zone, the lower zone and the bed zone. Sediment transport is computed separately for every zone, and the singular sediment transport summation for every zone was found. This method was developed using an exhaustive collection of both flume and field data. Experiments of the flume are used grains of sediment with average diameters between 0.3 to 0.93 mm, but successful applications of the Toffaleti method are propose that the average grain diameters less than 0.095mm are agreeable, [***Brunner,2010b***].

The general equations of transport for the function of Toffaleti for a single grain size are represented by: [***Brunner,2010a***]

For ($lower\ zone$):

$$g_{ssL} = M\frac{\left(\frac{R}{11.24}\right)^{1+n_v-0.756z} - (2d_m)^{1+n_v-0.756z}}{1+n_v-0.756z} \quad (Eq.1)$$

For ($middle\ zone$):

$$g_{ssM} = M\frac{\left(\frac{R}{11.24}\right)^{0.244z}\left[\left(\frac{R}{2.5}\right)^{1+n_v-z} - \left(\frac{R}{11.24}\right)^{1+n_v-z}\right]}{1+n_v-z} \quad (Eq.2)$$

For ($upper\ zone$):

$$g_{ssu} = M\frac{\left(\frac{R}{11.24}\right)^{0.244z}\left(\frac{R}{2.5}\right)^{0.5z}\left[R^{1+n_v-1.5z} - \left(\frac{R}{2.5}\right)^{1+n_v-1.5z}\right]}{1+n_v-1.5z} \quad (Eq.3)$$

$$g_{sb} = M(2d_m)^{1+n_v-0.756z} \ (bed\ zone) \quad (Eq.4)$$

$$M = 43.2C_L(1+n_v)VR^{0.756z-n_v} \quad (Eq.5)$$

$$g_s = g_{ssL} + g_{ssM} + g_{ssU} + g_{sb} \quad (Eq-6)$$

Where: g_{ssL} = Suspended sediment transport in the lower zone, in tons/day/ft

g_{ssM} = Suspended sediment transport in the middle zone, in tons/day/ft

g_{ssU} = Suspended sediment transport in the upper zone, in tons/day/ft

g_{sb} = Bed load sediment transport in tons/day/ft ; g_s=Total sediment transport in tons/day/ft

M = Sediment concentration parameter ; C_L=Sediment concentration in the lower zone

R = Hydraulic radius ; d_m= Median particle diameter; n_v= Temperature exponent,

z = Exponent describing the relationship between the sediment and hydraulic characteristics

Many methods are available for calculating fall velocity and the researcher must be choose the most suitable algorithm. In HEC-RAS, there are four methods in fall velocity editor. In this study the Ruby formula was adopted. Rubey(1933) Prepared an analytical relationship between the sediment properties, fluid, and the fall velocity is depend on the combination of "Stokes law" (for fine particles subject only to resistance of viscous) and an impact formula (for big particles out of scope the Stokes area), [***Brunner,2010a***].

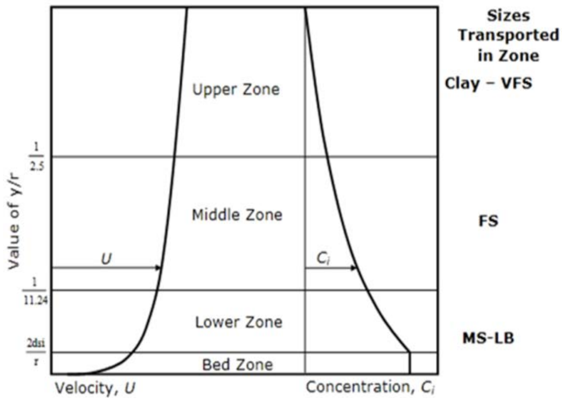

Figure (3): Toffaleti's zones for computing transport [Vanoni, 1954]

$$\omega = F_1\sqrt{(s-1)gd_s} \qquad (Eq.7)$$

In which:

$$F_1 = \sqrt{\frac{2}{3}+\frac{36v^2}{gd^3(s-1)}} - \sqrt{\frac{36v^2}{gd^3(s-1)}} \qquad (Eq.8)$$

Where:ω=particle fall velocity; v=kinematic viscosity; s=specific gravity of particles; d=particle diameter; g=gravitational constant; and F_1=Froude Number.

4. Boundary Conditions:

Boundary conditions of sediment were chosen by selecting the grid cell related with the interest site. Boundary conditions buttons of different sediment will be available depending on the given site properties: *Equilibrium Load; Sediment Load Series; and Rating Curve*.

4-1 Quasi-Unsteady Flow

The River Hydraulic must be known, to be able to calculate the sediment transport by HEC-RAS. HEC-RAS characterized by used a hydrodynamic simplification, a common approach used by various models of sediment transport. Each separate profile of steady flow is divided, and more of subdivided, into shorter time blocks for calculations of sediment transport, HEC-RAS uses three various time steps, every a subdivision of another. [***Brunner,2010a,b***] For an *upstream* external boundary a *Flow Series* must be chosen, which was based on a *Computational Increment* in (hours); *Flow Duration* in (hours); and *Flow* in (m3/s); Fig(4).

Each downstream boundary can be either: Stage Time Series, Rating Curve, or Normal Depth. In this study a "Rating Curve" was selected for downstream boundary condition.

A rating curve can be specified as the boundary condition of downstream . The Rating Curve (Flow-Stage curve) for downstream cross section can be created by using model of HEC-RAS, Fig(5).

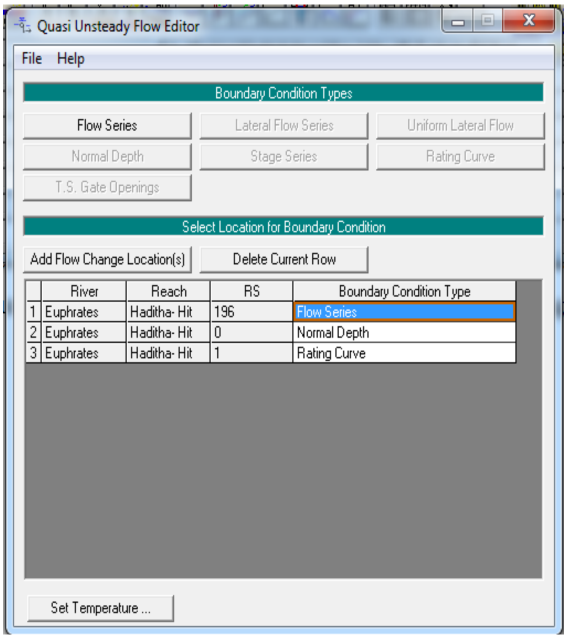

Figure (4): Quasi-Unsteady Flow window

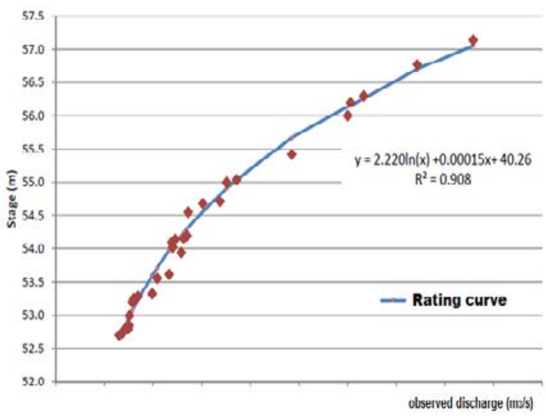

Figure (5): Rating curve at Heet station.

5. Data Requirement and Sampling

There are nine cross-sections were chosen as a major stations from the 196 cross-sections, which was taken by Al-Fahdawi (2009), (Table-1). The distance between the cross-sections depends on the geographical nature, geometric change in the river, and the presence of rivers meandering and other factors. The study reach was passing through several cities and villages.

The sediment are always in constant touch with the river bed and carried forward by rolling, sliding, or hopping, [***Brunner 2010a].*** In this study, there are two types of sampling:

- **Sampling of Suspended Load:** for this test, there are 40 samples which were taken of the cross sections in Table (1). Five samples for each cross section, which distributed at a distances (w/6) from beginning of cross section, (***W*** is the River width). Sampling by immersing the sampler bottle to specific distances, (0.25, 0.5, and 0.75) of the depth of river water, were measured from the water surface. Fig(6A) shows the suspended Sampler device.

- **Sampling of Bed Load:** For this test, there are (24) samples of the bed sediment were taken from the same nine previous river cross-sections for the study area and by three samples of each section. The samples were taken by using a device (Bed Sedimentation Sample), Fig(6B). Then measured sediment movement for a period of (30 minute) at each measurement sample, conducted laboratory needed for the distribution of particleboard volumetric samples.

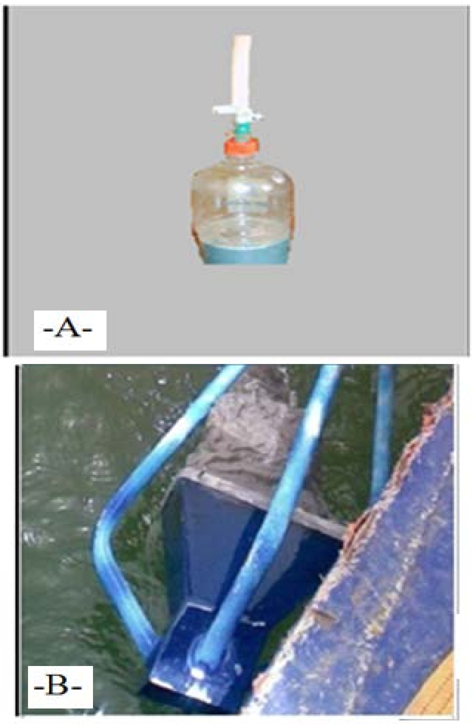

Figure (6): The device which used to take the samples

Table (1): Main nine cross-sections

No. of Cross-Section	City	Distance from Upstream (m)	Coordinate at Center	Width -W- (m)
196	Haditha	0	N 34 12 13.47 E 42 21 35.66	384
180	Haditha	14900	N 34 05 14.65 E 42 22 19.96	471.8
167	Haditha	23850	N 34 01 18.64 E 42 24 38.69	515
145	Baghdadi	42550	N 33 58 48.92 E 42 33 41.09	220.1
125	Baghdadi	56900	N 33 53 13.77 E 42 32 05.11	339
96	Baghdadi	75200	N 33 54 03.34 E 42 38 45.86	391.9
73	Heet	90300	N 33 50 20.04 E 42 45 40.36	192.5
38	Heet	107900	N 33 43 39.55 E 42 43 14.02	300.2
1	Heet	124400	N 33 38 17.36 E 42 50 34.89	220.2

Each cross section must have an bed gradation. Rates of sediment transport are calculated for the specified hydraulic and parameters of sediment for each representative grain size. In this study, the diameter for each type of particles sieve No. is shown in Table (2).

Table (2): Diameter of each Sieve No. type of grains

Sieve No.	Sieve Dia.(mm)	Grain Material type
5	4	Fine Gravel
8	2.36	V. Fine Gravel

16	1.18	V. Coarse Sand
35	0.5	Coarse Sand
50	0.3	Medium Sand
100	0.15	Fine Sand
200	0.075	V. Fine Sand
pan	0	Clay

6. Results and Discussions

6-1 Calibration and Verification For Model:

Reliability of model is based on the calibration and verification of results as important procedures before placing the model in use. Review of literature showed that the perfect determination of erosion and deposition at a cross-section of a river is based upon the chosen of the sediment transport formula and Manning roughness coefficient, [***Haghiabi and Zaredehdasht 2012].*** In this study, the data were taken for the period from 01-Sep-2013 to 28-Feb-2014.

There are several factors have affect the chosen of the Manning's Coefficient **(n)** value, many of the more important factors are the type, materials size that compose the channel's bed and channel's banks, and the channel shape, [***Chow, 1959].*** The values of Manning's coefficients (0.024, 0.027, 0.030, 0.033, and 0.039) were used by the many researchers for the calibration process. The observed and calculated of Water Surface Elevations (WSEl) were compared to get a suitable value of Manning coefficient. Data which entered into model discharge, WSEl, water temperature, and etc. was obtained from Ministry of Water Resources. There are many studies which applied this type of calibration of model for sediment transport, such as [***Al-Fahdawi 2002], [Haghiabi and Zaredehdasht 2012], [Ross Doherty 2010], [Chapokpour and Daneshfaraz 2013], [Ayoub 1999], [AL-Ani 2001], [Doherty R. 2010], [Hameed L. K. and Ali S. T. 2012], [Ali A. A. 2013].***

The data pertaining to Sediment transport for period from (01-Sep-2013 to 30-Nov2013) has been used for calibration. The records from Heet gauge station were used as an observed data in the calibration process. After selecting the nearest three results of Manning's coefficients (0.24, 0.33, and 0.39) to be applied in a model, results of water stages were plotted as in Fig(7) at Heet station for each Manning's coefficients. This Figure shows that the best agreement value between the calculated and observed data of Manning's coefficients at n=0.033 for the Euphrates River in the study area.

The verification of model was applied to observed sediment values which matches to WSEl and optimal Manning coefficient (n). The calculated sediment value at Al-Anbar Electrical Thermal Station by model must be equal to or nearest equal to available observed sediment which equaled to(60×10^{3}ton/year) i.e. equal to (165 ton/day), which measured by Consultative official of College of Engineering of University of Anbar. The nearest calculated sediment value of verification model was equaled to (167.23 ton/day) when optimal Manning coefficient (n) is equal to (0.033).

For this study the period is equal to (181 days) for six months from (01-SEP-2013 until 28-FEB-2014). The amount of sediment load "Mass Cumulative (ton)/ period of study(day)" was obtained from the table output of model, the value of total load at Heet station is equal to (551.76 ton/day), and the amount of total load at Al-Anbar Electrical Thermal Station was increases to become equal to (237.38 ton/day), which was the larger than the value of Al-Anbar university study in 2010.

By comparing the current results of this study with the previous study for sediment transport it is review that the value of this study (237.38 ton/day) is larger than the value of previous study which measured in 2010 at Al-Anbar Electrical Thermal Station that equal to (165 ton/day) because of the low rate of discharge that arrived at the study area for the rates that existed in the previous years, due to reducing in velocity and obvious change in the forms of cross-sections because of the continuing occurrence of erosion and sedimentation process.

The form of each cross-section after deposition or erosion can be noted through selection the (Sediment XS Changes) from View of main window of HEC-RAS. Deposition is based on settling velocity and Erosion which is based on "Characteristic Flow Length".

There are many main factors which affected either erosion or deposition, these are flow velocity, channel slope, channel's bed roughness, and cross-section channel shape and etc. All these factors can; either transporting more materials and making them settle down in any cross section, or work to erosion amount of materials from the bed of cross-section, then transported to other cross sections or converting to suspended materials. (Table-3) and Fig (8) illustrate the model output of total load results for main cross-sections and showed which was the cross-section have an erosion or deposition.

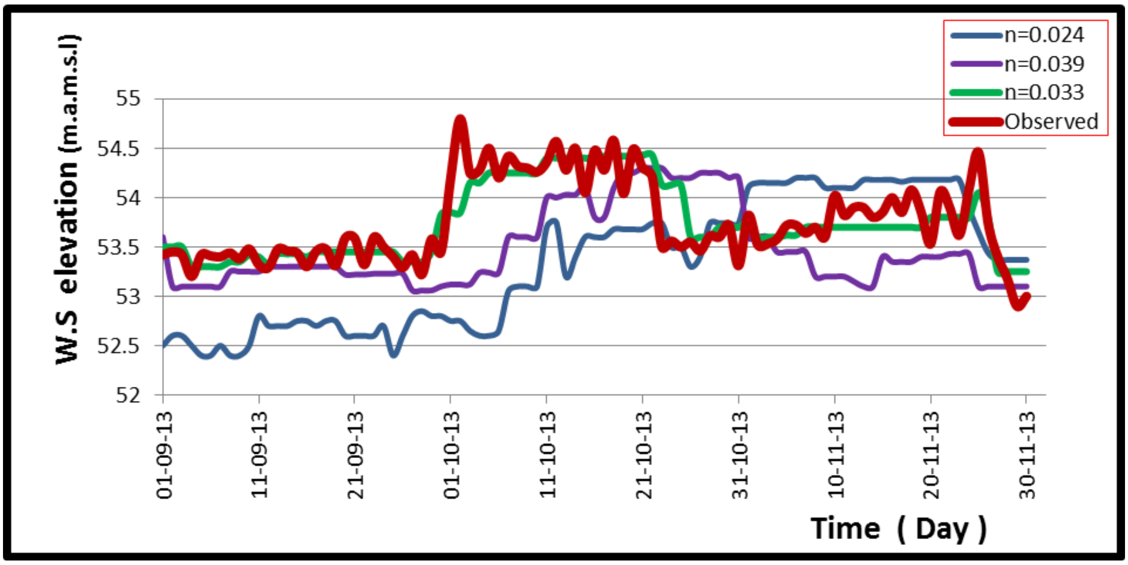

Figure (7): Calculated and Observed Water Surface Elevation at Heet Station for different values of Manning's (n)

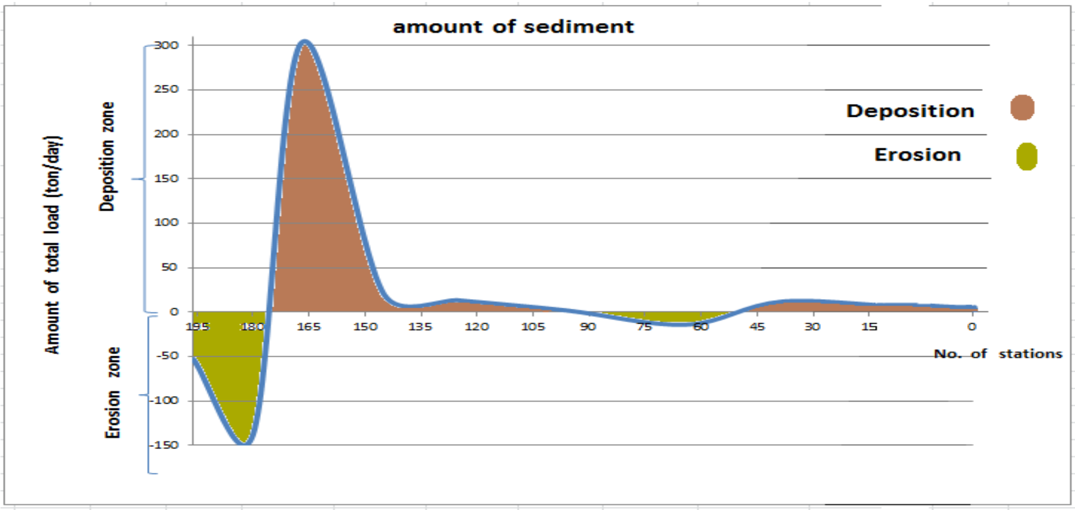

Figure (8): Total load results for main cross-sections, (erosion or deposition)

Table (3): Model output of total load results for main cross-sections

Cross-Section No.	Mass in cumulative (IN) (ton)	Mass out cumulative (OUT) (ton)	IN-OUT= (ton)	TYPE Of Processe
196*	0.00	9547.58	-9547.58	erosion
180	183542.10	208517.40	-24975.30	erosion
167	219668.10	164800.20	54867.90	deposition
145	232440.60	228764.20	3676.40	deposition
125	157943.20	155534.70	2408.50	deposition
96	112557.90	112209.30	348.60	deposition
73	96490.71	99043.84	-2553.13	erosion
38	95716.67	93531.77	2184.90	deposition
1**	99869.16	98781.62	1087.54	deposition
0***	42965.69	38251.09	4714.60	deposition

* Haditha Station
** Heet Station
*** Anbar Thermal Station

7. Conclusion

The conclusions of this study are summarized below:

a) The highly controlled reduced flows of dam and clear water discharge induced major changes to the channel and its flow regime, and reduce of water releases and low flow under the amount design of Haditha Dam has caused to reduction the water surface elevation. This led to emergence the intermediate lands in the study area.

b) The erosion and deposition process were not occurred at Haditha station at cross-section No.(196) due to the rocky nature for bedriver, but this process was occurred at rest cross-sections. Generally, the deposition process were occurred more than the erosion process along the study area.

c) From previous studies, the amount of deposition through the years, and between studies, was varied for the same region, due to the selection of the parameters and depending on the several hydraulic characteristics for river as the flow, the velocity, shape of the cross-sections, the time factor, the water surface elevation, and the period of the study.

d) Total load in the study area were increased when the rainfall increased. This process leads to drift a lot of amounts of sediment transport with runoff water from the valleys to the river, then, transporting between the river cross-sections, which were depending on many factors, including bed slop, the amount of water releases from Haditha Dam, and manning coefficient.

8. References:

[1] Al-Fahdawi S. O. (2009), “Numerical Modeling of Flood Wave Behavior with Meandering Effects (Euphrates River, Haditha-Hit)” Ph.D thesis, University of Technology, Baghdad, Iraq.

[2] Al-Paruany K. B. (2005), “Hydrochemical And Isotopic Study Of Water Resources Between Haditha Dam And Site Of Al-Baghdadi Dam”, Ph.D thesis, College of Science, University of Baghdad.

[3] Brunner GW, HEC-RAS 4.1 River Analysis System, Hydraulic Reference Manual (Version 4.1), US Army Corps of Engineers, 2010a.

[4] Brunner GW, HEC-RAS 4.1 River Analysis System, Hydraulic User's Manual (Version 4.1), US Army Corps of Engineers, 2010b.

[5] Chow V. T. (1959), “Open Channel Hydraulics” McGraw-Hill, New York, NY. 680 p.

[6] Haghiabi A. H. and Zaredehdasht E. (2012),"Evaluation of HEC-RAS Ability in Erosion and Sediment Transport Forecasting" World Applied Sciences Journal Vol.17, No11, P1490-1497.

[7] Mustafa A. S. and Khayyun Th. Sh., 2013 “Multiple Linear Regression Model for Suspended Load Transport Rate Prediction and Its Evaluation Using Selected Transport Formulas”, International Journal of Civil & Environmental Engineering IJCEE-IJENS Vol:13 No:06, P28-36.

[8] Maureen E. A., (2012) "Evaluation of a Suspended Sediment Transport Monitoring, Fraser River, British Columbia", M.Sc. Thesis, Faculty of Environment, Simon Fraser University

[9] Ministry of Water Resources, National central for water resources management.

[10] Vanoni V. A. (1975) Sedimentation Engineering, ASCE Manuals and Reports on Engineering Practice-No. 54, 745p.

[11] Hameed L. K. and Ali S. T., (2012), “Estimating of Manning’s Roughness Coefficient for Hilla River through Calibration Using HEC-RAS Model”, Jordan Journal of Civil Engineering, Vol.7, No.1, P44-53.

تطبيق نموذج HEC-RAS للتنبؤ بانتقال الرواسب لنهر الفرات من مدينة حديثة الى مدينة هيت

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الخلاصة

الهدف من هذه الدراسة هو حساب نقل الرواسب وتحديد جودة المياه لمقطع من نهر الفرات بطول حوالي (124,4 كم) يبدأ من مؤخر سد حديثة (مقدم الدراسة) وينتهي عند محطة هيت في مدينة هيت (مؤخر الدراسة), حيث انه تم تحديد (196) مقطع عرضي على طول مقطع النهر الذي يمثل منطقة الدراسة باستخدام نموذج (HEC-RAS) الإصدار 4.1، الذي تم تطويره من قبل فيلق مهندسي الجيش الأمريكي للهندسة، ذا بعد واحد، وحسابات التدفق غير مستقرة. تم اجراء عمليتي المعايرة والتحقيق للموديل للفترة من(1– أيلول – 2013 لغاية 30-تشرين الثاني-2013) ومن الفترة (1-كانون الاول-2013 لغاية 28-شباط-2014) على التوالي، وعند المعايرة تبين أن أفضل قيمة لمعامل ماننك تساوي (0.033) والتي تعطي أقل نسبة خطأ بين منسوب سطح الماء المقاس ومنسوب سطح الماء المحسوب. أما عند التحقيق فكانت نتائج الحمل الكلي المقاس مسبقاً للدراسة الهيدرولوجية والبايولوجية لنهر الفرات لمشروع محطة كهرباء الانبار الحرارية من قبل المكتب الاستشاري لكلية الهندسة في جامعة الانبار في 2010 والذي يساوي (165 طن/يوم) متوافقة مع الحمل الكلي المحسوب في هذا الموديل والذي يساوي (167.23 طن/اليوم).

عند مقارنة نتائج الموديل لهذه الدراسة مع الدراسات السابقة الخاصة بانتقال الرواسب يتبين ان قيمة الحمل الكلي للرواسب في محطة الانبار الحرارية بلغت (237,38 طن/يوم) والتي هي اكبر من قيمة الحمل الكلي لنفس المحطة في 2010 والتي تساوي (165 طن/يوم). أما قيمة الحمل الكلي لمحطة هيت فكان (551,76 طن/يوم) والتي هي أقل من قيمة الدراسة السابقة التي بلغت (189000 طن/يوم) والمقاسة في 1988. يعود سبب هذه الفروقات في كميات الحمل الكلي في محطة الانبار الحرارية الى زيادة معدل جريان ماء النهر التي وصلت الى منطقة الدراسة أكثر من المعدلات التي تم التوصل إليها في السنوات السابقة، ويرجع ذلك إلى زيادة معدل السرعة، والعكس بالعكس لمحطة هيت. إن استمرارية حدوث عملية الترسيب تعمل على تغيير واضح لشكل قاع النهر بسبب استمرار حدوث عمليتي التعرية والترسيب لقاع النهر.