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Estimating of Sediment Transport Rates for Euphrates River in Al- Hindiya City Using HEC-RAS Model

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Abstract

A Hydraulic analysis was performed to estimate sediment transport rates for the Euphrates River at a specified reach in (Al- Hindiya city). Information presented in this study includes surveyed channel cross sections, discharge, stages, and measurements of bed material characteristics. The study reach was between station (Km 625+200) upstream and station (Km 639+200) downstream with a length of (14) km. This reach includes (20) cross sections. HEC-RAS (4.1) package was used and applied for modeling and calculating the sediment transport by (Ackers-white, Engelund-Hansen, Laursen, Toffaleti, and Yang) formulas. Hydraulic computations existing in HEC-RAS4 were used to compute a series of steady flow profiles (13 profiles).These profiles used to develop hydro-dynamic parameters for sediment transport and calibrated to the hydraulic conditions of the reach. A stable solution for sediment transport rates was obtained under specified conditions. The modeling formulas were compared with the field results and the closest formula to the field results was (Laursen), while (Ackers-White) formula was the poor one while the other samples give lower results than the field values with a bit of convergence in some of these results which had been obtained through statistical method. The average annual sediment transport has been predicted by (Laursen) formula using HEC-RAS (4.1) model to be (3376) tons.

Keywords: Sediment, transport, One-dimensional model, HEC-RAS, River

1- Introduction

The hydraulics of flow in a river and its sediment transport characteristics are the two basic phenomena that determine its geometric and plan form shape. There are many variables that affect the hydraulics of flow and the nature of sediment transport in a natural stream. Many research programs have been devoted to the study of the sediment transport in channels. Extension can be found by Vanoni (1984), Yallin (1972) developed a bed load equation incorporating reasoning similar to Einstein (1942, 1950). One of the most extensive field and laboratory studies of sediment transport is that by Van Rijn (1984). He has presented a method which enables the computation of the bed load transport as the product of the saltation height, the particle velocity and the bed load concentration. More recently, Hassanzadeh (2007) based on the dimensional analysis and the Buckingham Π-theorem in reasoning and discussion of bed load phenomenon has presented a dimensionless semi-empirical equation on the bed load. Today, new developments in computer science and modeling are capable of solving any complicated equations. The need for time consuming, costly physical models are over. The application of a proper computer model to any specific region and its calibration is uniquely important [Jaafarzadeh, 1992].Literature mentions a group of systematically developed models from the families: HEC-RAS [HEC-RAS,2009], MIKE11 [Havn et al.,1995], CCHE2D [Zhang,2005], CCHE1D Model [Vieira,2002], BRI-Stars [Molinas,2000] and Fluvial-12, [Chang,1985], which simulate sediment transport in an open channel with changeable bed. These tools are used to estimate changes in channel geometry during floods, useful in river training, to describe the silting-up of river channels and reservoirs, contaminant transport, etc. The two primary modes of sediment transport are bed load and suspended load. Bed load is sediment that is moving on or near the bed by rolling, bouncing or sliding. Movement can be either continuous or intermittent but is generally much slower than the mean velocity of the stream. The suspended load include sediments moving above bed layer and their specific weight is carried by water flow and are suspended for a long time. The suspended load and bed load or bed material discharge and washed-load discharge together are called total sediment. In the Euphrates river watershed, bed load consists primarily of coarse sands [K.W.R.D, 2012]. Suspended sediment is supported by the turbulent motion in the stream flow and is transported at a rate approaching the mean velocity of flow. In the Euphrates river watershed, suspended sediment consists primarily of fine sands, silts and clays. The boundary between bed load and suspended load can change between low flows and high flows as material that was being transported as bed load at low flows becomes suspended when velocities and turbulence increase sufficiently during high flows.(Nama, 2012) studied on Tigris River about transporting the sediment within Al- Musol city constituting islands within this reach of the river because decreasing the discharge of Tigris River A steady one dimensional mathematical model for simulating the flow and estimating the sediment transport potential of the studied reach was implemented and run by using the HEC-RAS (Version 3.1.3) software and making use of recorded field measurements for running and carrying out the calibration and verification processes. (Haghiabi et al, 2012) studied in (2012) Karun River in Iran and primarily focused upon identifying critical erodible points and areas with potential sediment aggregation along this river. The latest version of HEC-RAS model, called HEC-RAS (4), is utilized in this paper; the obtained results from simulations of river bed were compared to those models reported in the literature.

2- Description of HEC-RAS 4 Model

A computer experiment consisting in modeling water flow in an open channel and allowing for sediment transport phenomenon was conducted by means of HEC-RAS4 model. HEC-RAS 4 is a widely tested model developed by the US Corps of Engineers –Hydraulic Engineering Centre. It is used as a tool for reproducing steady and unsteady flows in almost any hydraulically possible cases .The first step in the general operation algorithm was defining hydraulic flow conditions in the watercourse; then it was possible to start sediment transport calculations. HEC-RAS4 is a one-dimensional, movable boundary, open channel flow model developed to simulate streambed profile changes resulting from varying river flow and tail water conditions. The model is based on one-dimensional, gradually varied flow hydraulics and sediment transport theory and is capable of calculating sedimentation in dendritic, closed loop and distributary networks of river systems. [Brunner, 1995]

2-1 Transport Calculations

Six different transport functions are currently available in HEC-RAS4 including Ackers and White (1973), England-Hansen (1967), Lauren (1958), Myer-Peter-Muller (1948), Toffaleti (1968), and Yang (1972). Total transport capacity is calculated by invoking the similarity hypothesis (Armanini, 1992 and Vanoni1975after Einstein, 1950) by dividing the sediment gradation curve into discretesize classes, independently computing a transport potential for each size class and then weighted by the relative abundance in the active layer.

To present the possibilities offered by HECRAS software. With this aim, the following elements of the experiment were adopted:

– Initial channel geometry,
– River engineering works in the channel,
– Channel bed structure,
– Discharge hydrographs,
– Water temperature.

The above elements determined the choice of computational methods available in HEC-RAS package. The first step in the general operation algorithm was defining hydraulic flow conditions in the watercourse; then it was possible to start sediment transport calculations. [MARKOWSKA, 2012]

3- Modeling of the case study

Euphrates River at (Al-Hindyia city); (Fig. 1) has been used as a practical case study for the research purposes. This reach of the Euphrates River from Km (625+200) to Km (639+200), its field data and information are accessible. According to [K.W.R.D., 2013], the reach discharges, the depths of flow, and the cross sections of the reach were obtained. (20) Cross sections all of which introduced into the model. (Fig. 2) shows the general schematic of the study reach. [Fig.3] shows the cross section

Fig. 1: Euphrates River at (Al-Hindyia city), [After: KWRD, 2011]

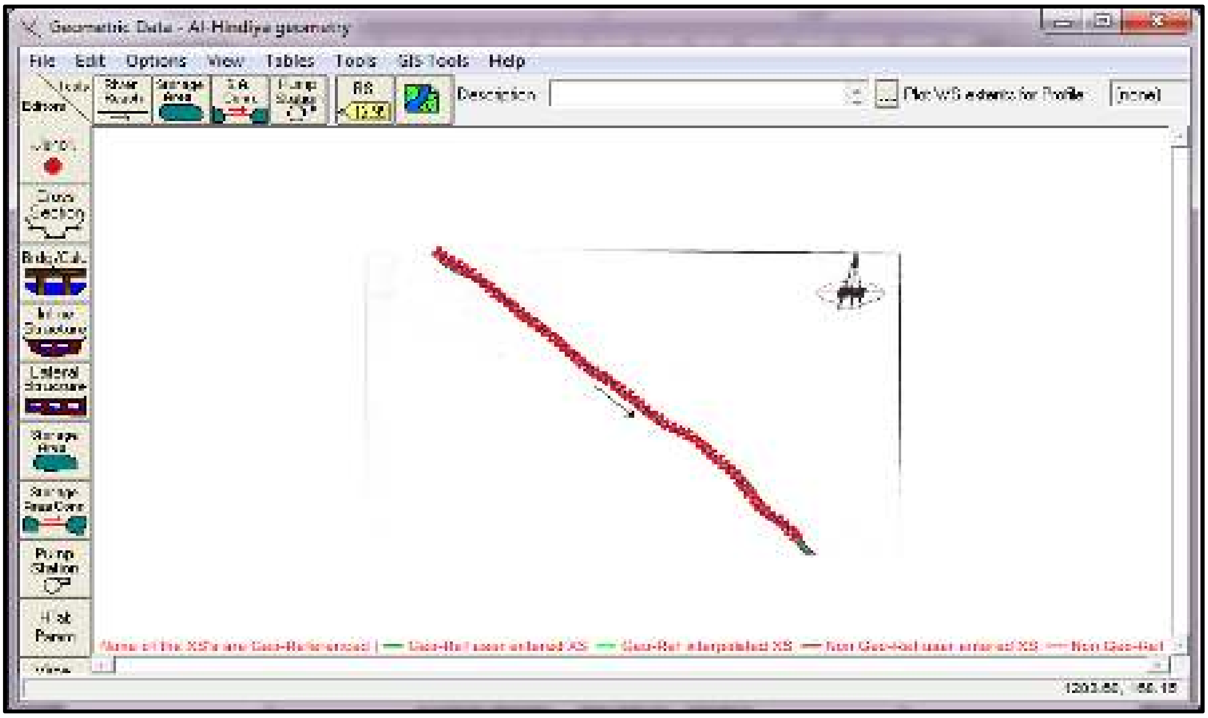


Fig. 2: General schematic plan of the study reach

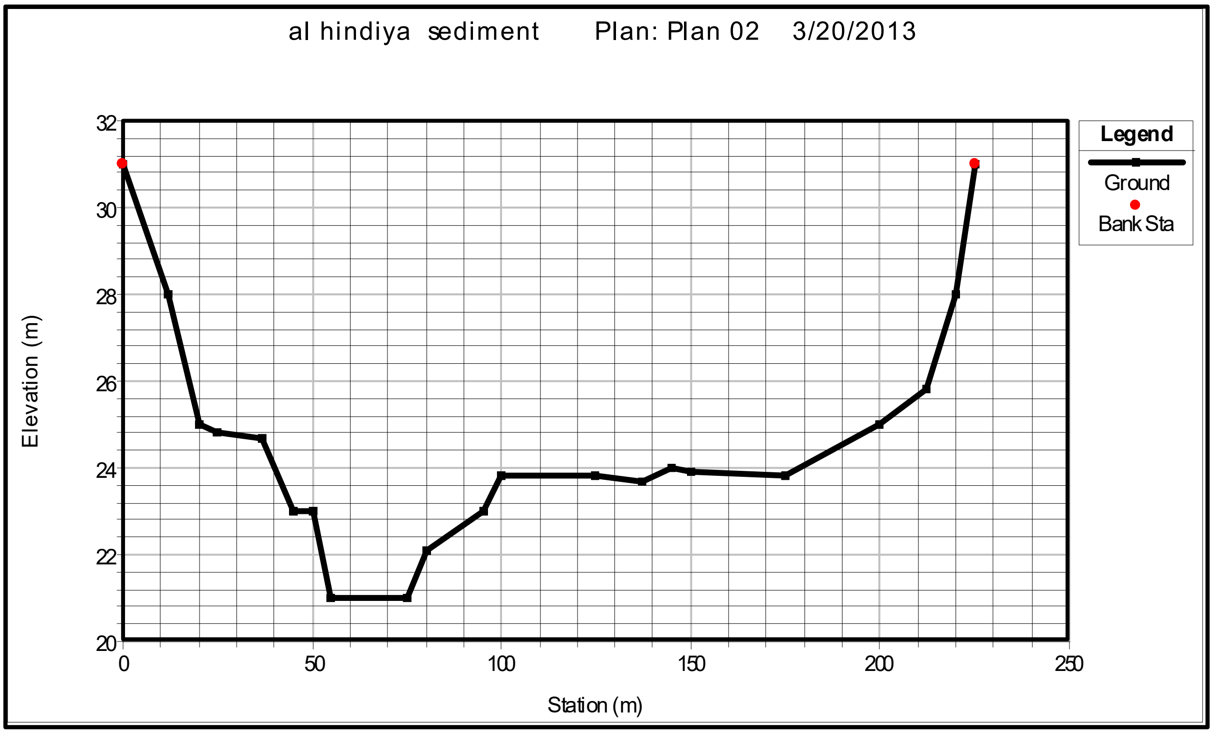


Fig. 3: cross section at (Km 625+200)

3-1 Sediment Data

In this research, ten samples (from right, main, and left of cross sections) were taken to represent the bed material. Bed material samples were collected throughout the study reach during a field reconnaissance in April 2013. Samples were collected by boat from the channel Thalweg (the lowest-elevation point of each cross section) the grain-size distribution curve for the bed material is shown in **Fig. (3)**.

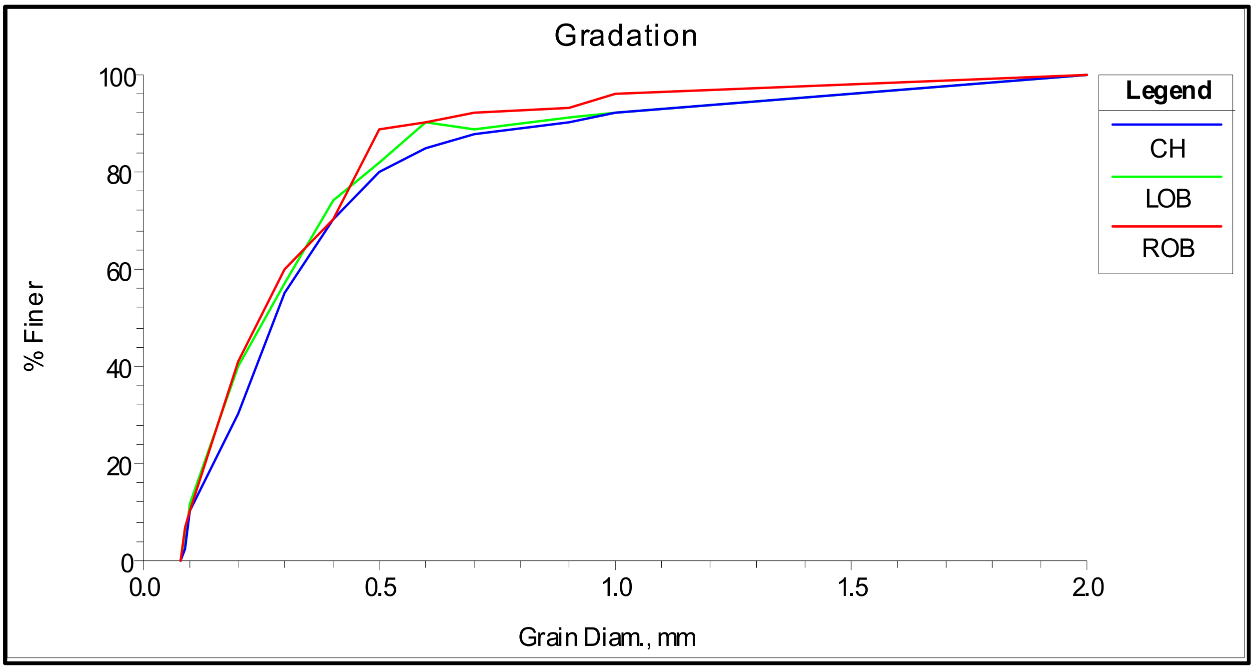


Fig.3: Grain size distribution of the taken samples

Historical flows measured by [K.W.R.D.,2013] at the reach gauge near Al-Hindiya Bridge (Km 625+200) were used as upstream boundary condition while discharge-surface levels (rating curve) of Station at Km (639+200) was used as the downstream boundary condition into the model.

3-3 Model Calibration

Model reliability depends upon its calibration and verification of results as important steps before put the model in use. Literature review showed that the correct determination of erosion and sedimentation at a cross-section of a river depends upon the selection of the sediment transport equation and Manning roughness coefficient [Haghiabi et. al. 2012]. The hydraulic calculations in (HEC-RAS4) were compared with field observations of flow at the study reach [**Fig 4 and Fig. 5**]. The calibrated Manning roughness values for reach from upstream to downstream be (0.03). During model calibration, the model was run repetitively and by changing Manning roughness coefficient (n) at intended stations at Km (625+200) and Km (639+200) and the Manning values were calculated by comparing the predicted water levels with those measured at Km (631+00) as selected as the observation station.

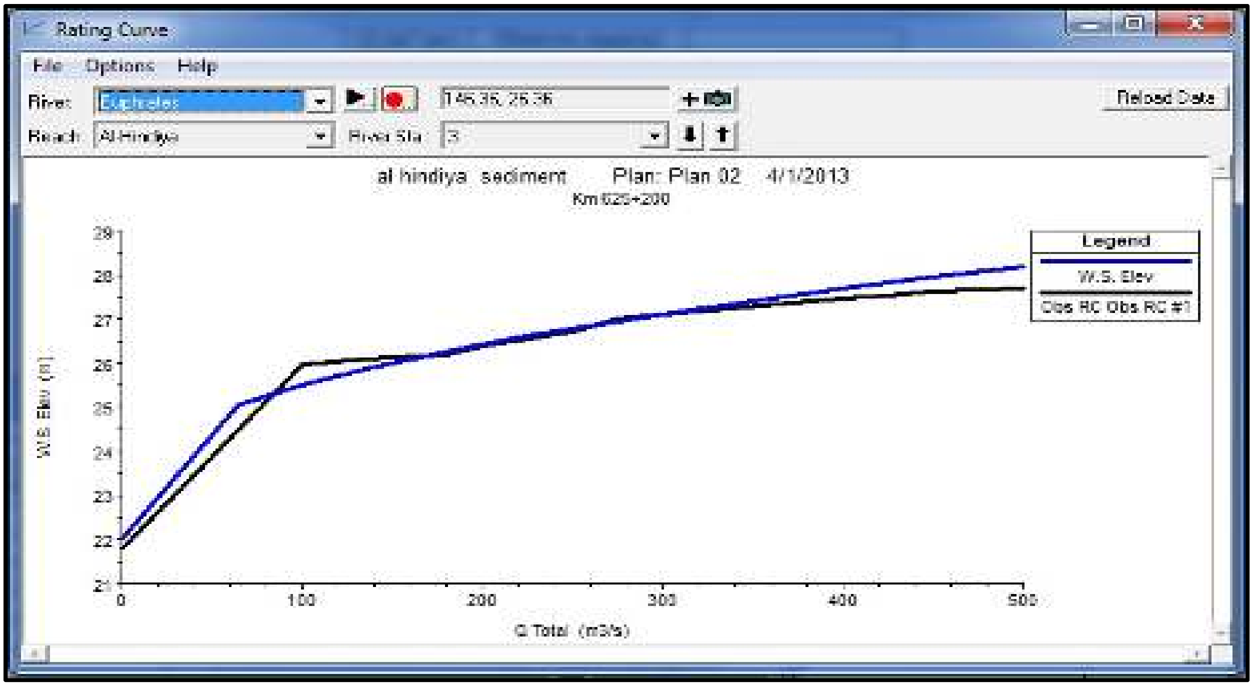

River: Euphrates
Reach: Al-Hindiya
River Sta: 3
146.36, 25.36

Fig. 4: Comparison of computed and field discharges at Al-Hindiya Bridge (Km 625+200)

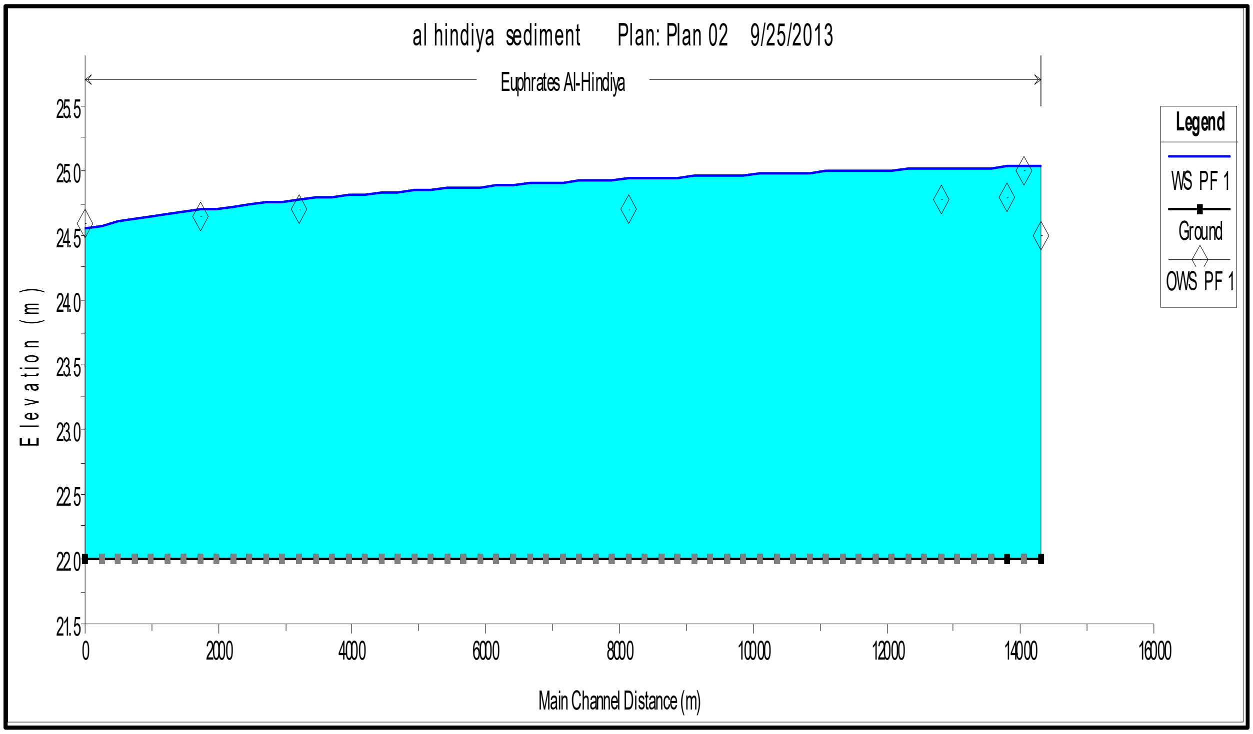
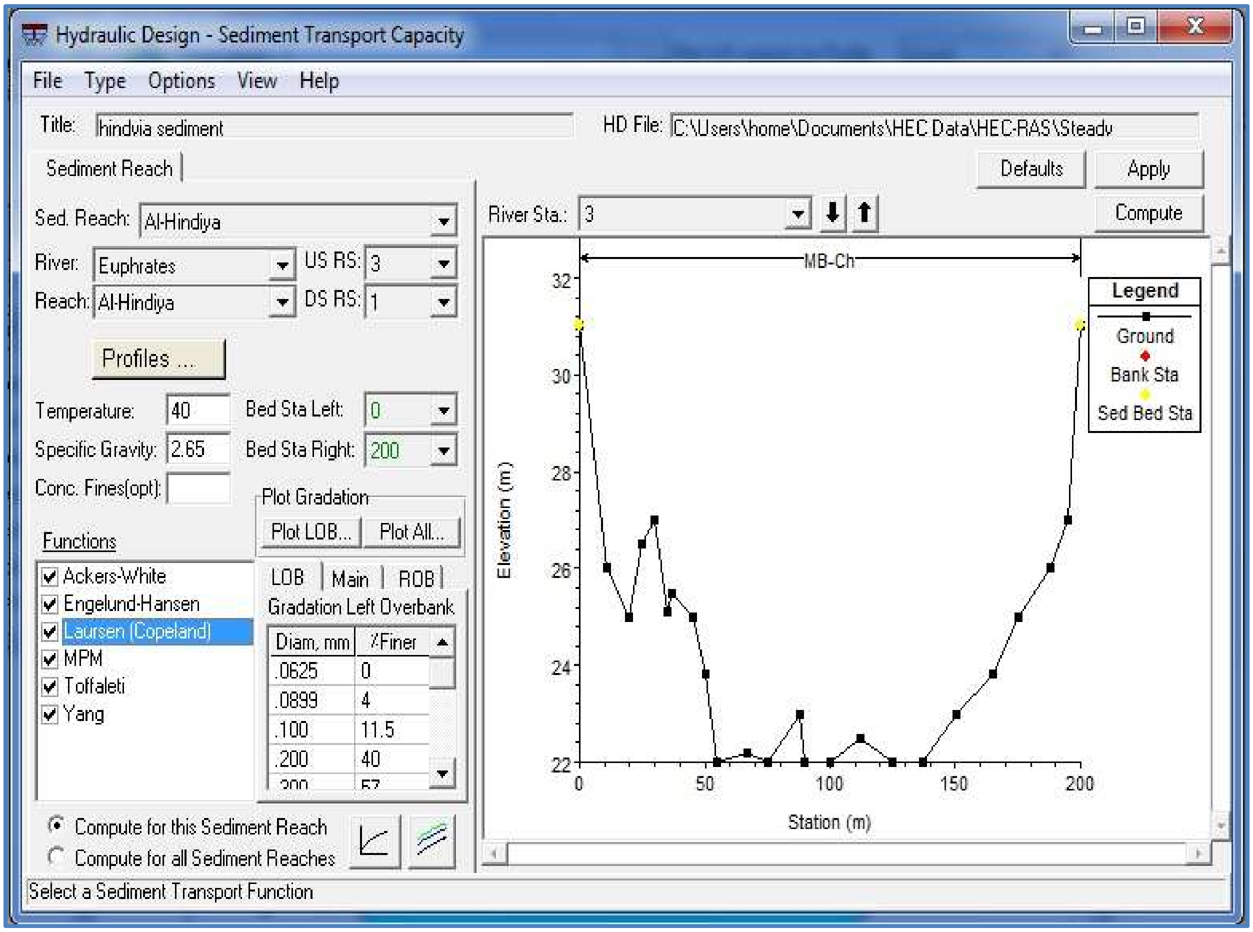


Fig. 5: Comparison of computed water surface profile with observed water level at specified locations

3-4 Sediment Transport Calculations

In all HEC-RAS models, geometry is modeled by cross sections and hydraulic roughness is assigned by either a Manning's n value or a Chezy coefficient. A flow hydrograph is segmented into a series of steady flow events of variable duration (quasi-steady). For each flow sequence, the one-dimensional conservation of energy equation is solved to determine the water surface profile and pertinent hydraulic parameters such as energy slope, velocity, depth, at each cross section. Sedimentation processes (erosion, transportation, deposition and compaction of sediment particles) are computed at each cross section by solving the sediment continuity equation and a user-selected sediment transport function. [Fig. 6] Shows the software menu displaying sediment data. Input data range for a user-selected sediment transport function to calculate sediment load in (HEC-RAS4) which are listed in Table (1).



Title: hindvia sediment
HD File: C:\Users\home\Documents\HEC Data\HEC-RAS\Steadv
Sed. Reach: Al-Hindiya
River: Euphrates
Reach: Al-Hindiya
US RS: 3
DS RS: 1
River Sta.: 3
Temperature: 40
Specific Gravity: 2.65
Conc. Fines(opt):
Bed Sta Left: 0
Bed Sta Right: 200

Functions
☑ Ackers-White
☑ Engelund-Hansen
☑ Laursen (Copeland)
☑ MPM
☑ Toffaleti
☑ Yang

Gradation Left Overbank

Diam, mm	%Finer
.0625	0
.0899	4
.100	11.5
.200	40
.300	57

● Compute for this Sediment Reach
○ Compute for all Sediment Reaches

Select a Sediment Transport Function

Fig. 6: A view of software menu displaying sediment data

Table (1): Input data range to calculate sediment rate in HEC-RAS4

Function	Parameters
	Ackers-White (flume):
	1.2 < V < 9.4 fps 0.03 < D < 3.9 ft.

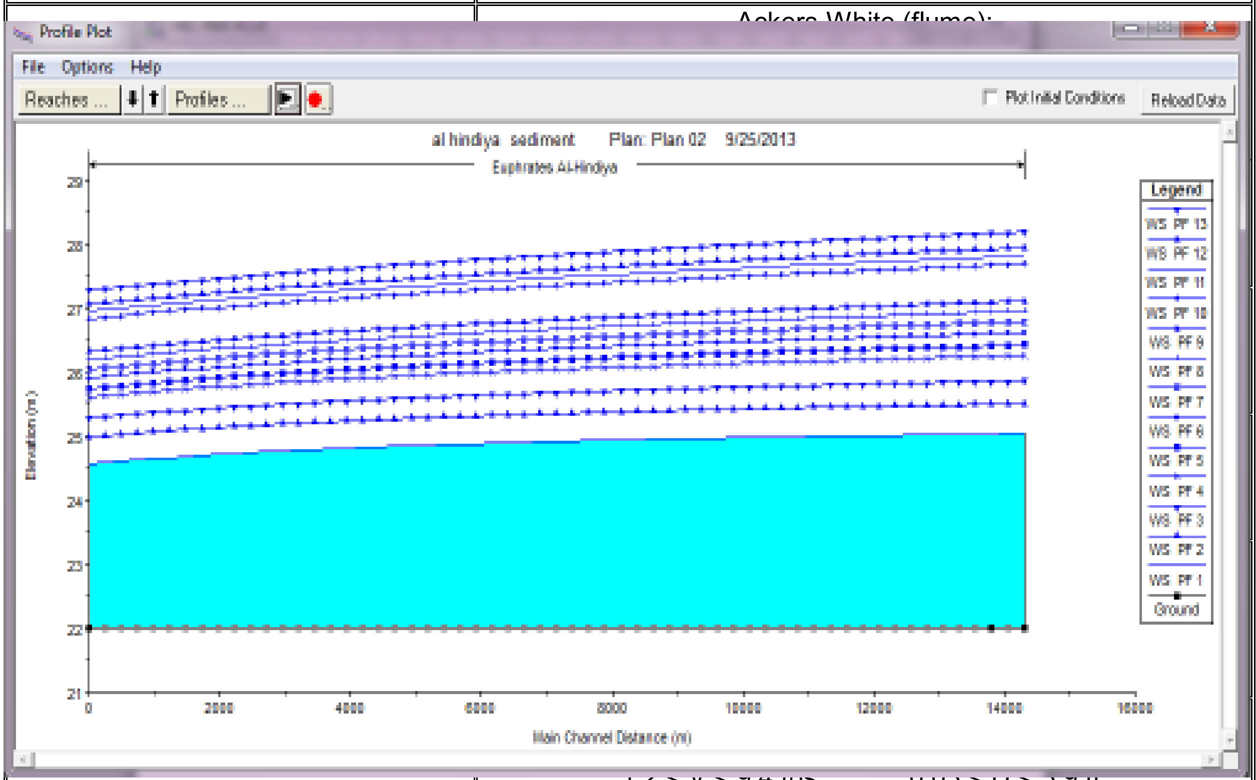
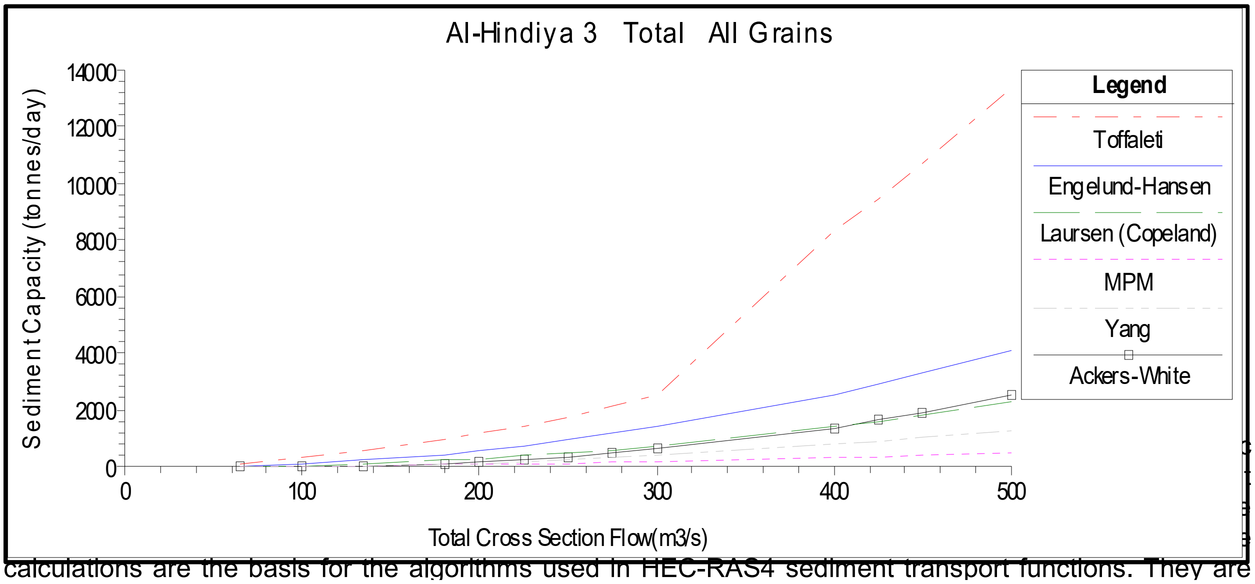


Fig. 7: water surface profile corresponding to used discharges



calculations are the basis for the algorithms used in HEC-RAS4 sediment transport functions. They are cc st

Fig. 8: Sediment rating curves at station (3) with different discharges and sediment functions

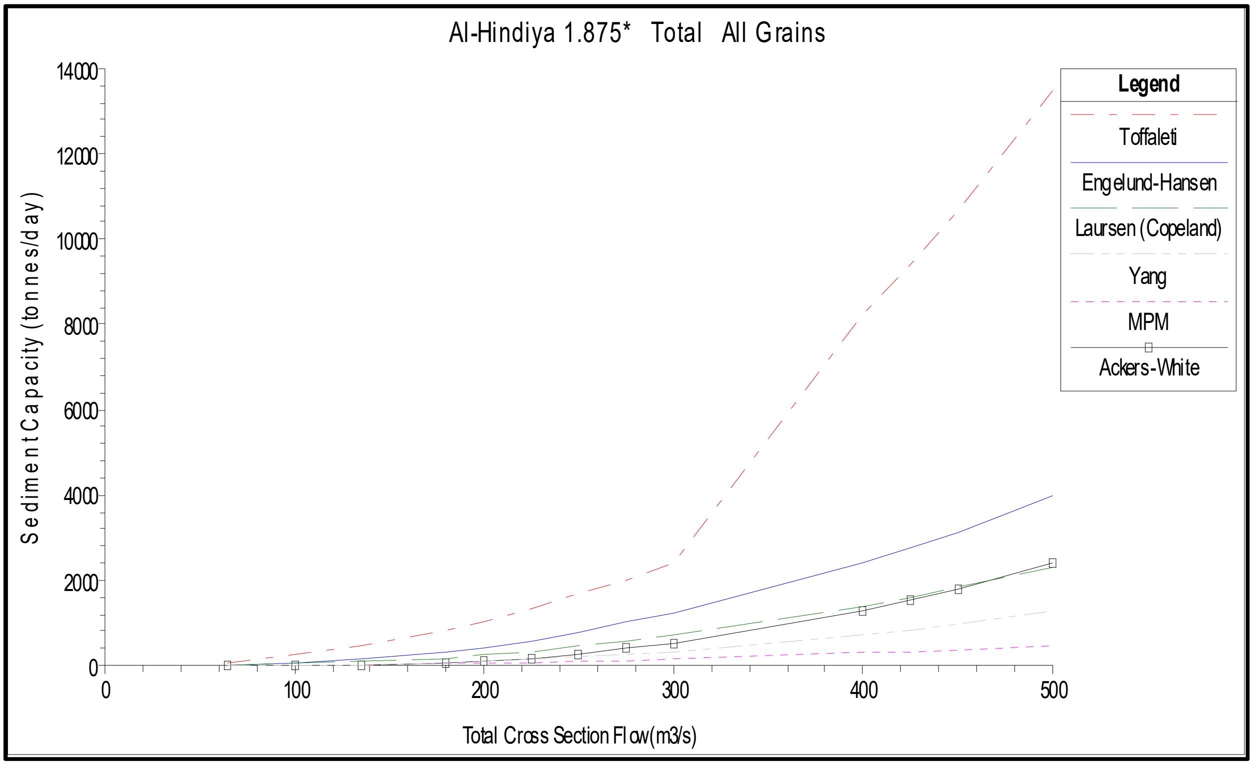


Fig. 9: Sediment rating curves at station (10) with different discharges and sediment

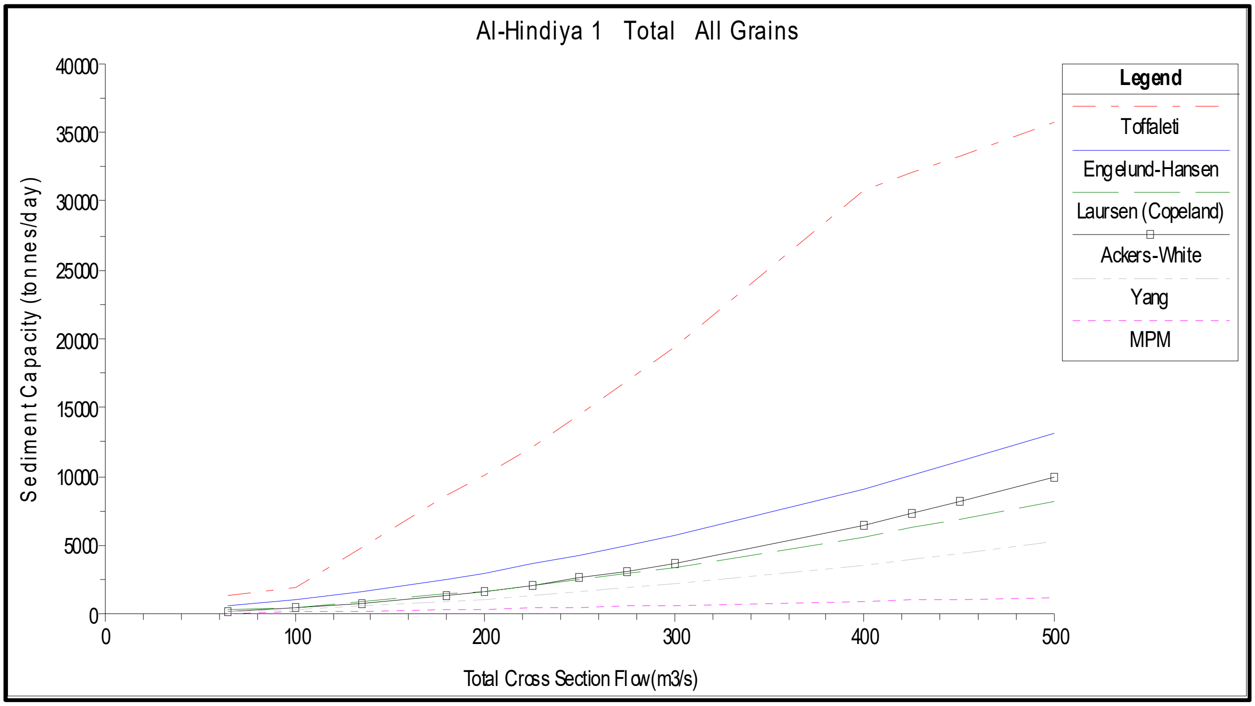


Fig. 10: Sediment rating curves at station (20) with different discharges and sediment functions

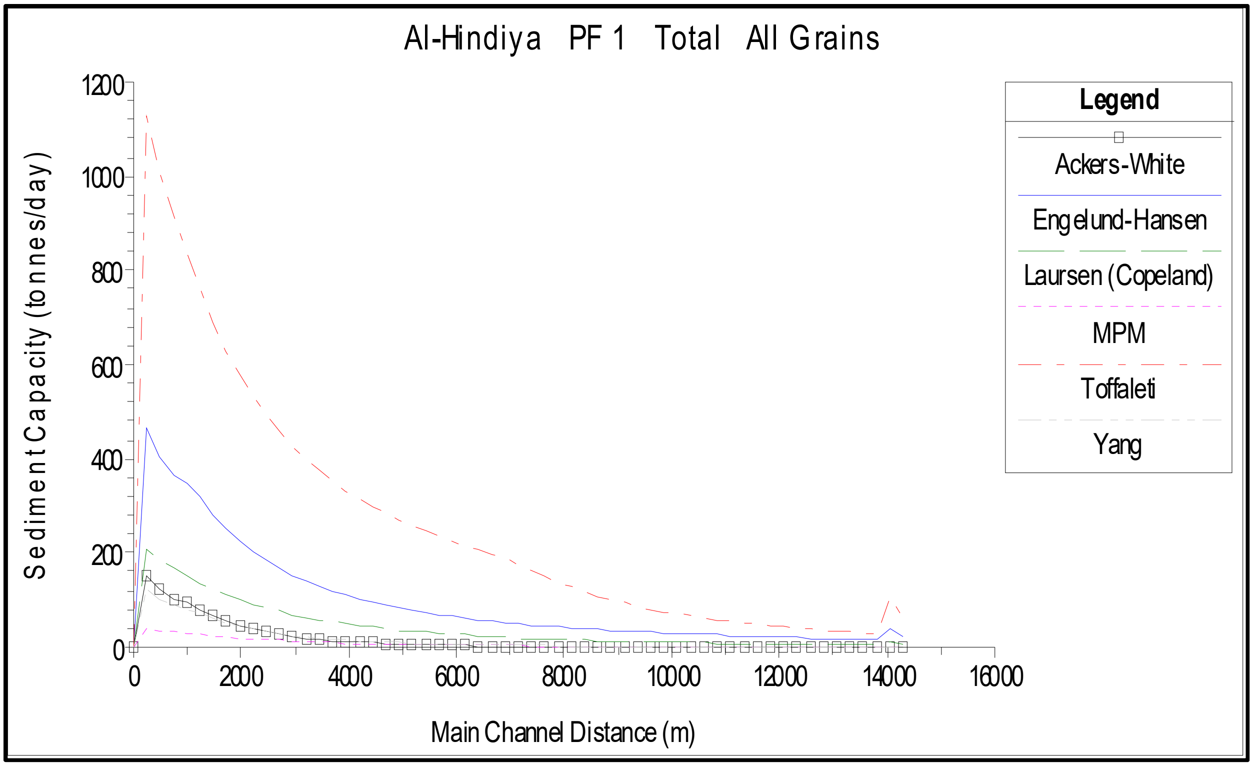


Fig. 11: Sediment potential profile with discharge (Q=65 m3/sec) and different sediment functions

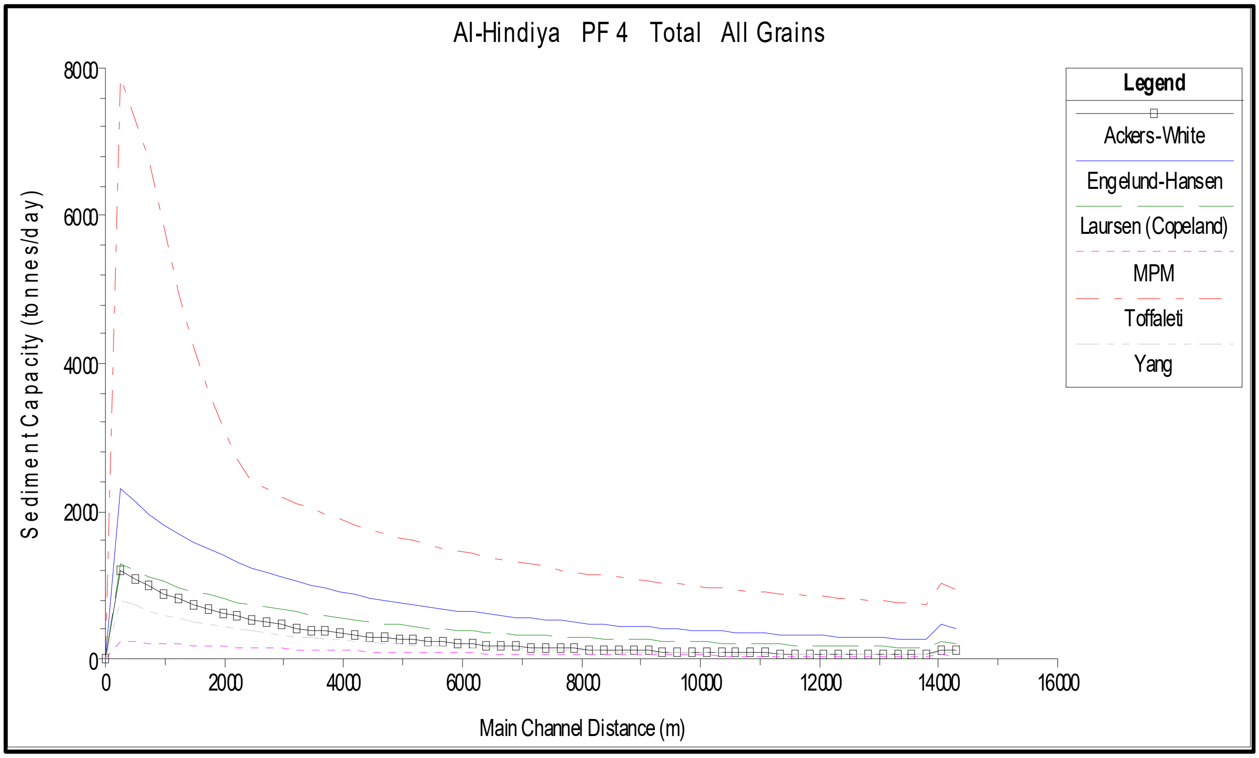


Fig. 12: Sediment potential profile with discharge (Q=180 m3/sec) and different sediment functions

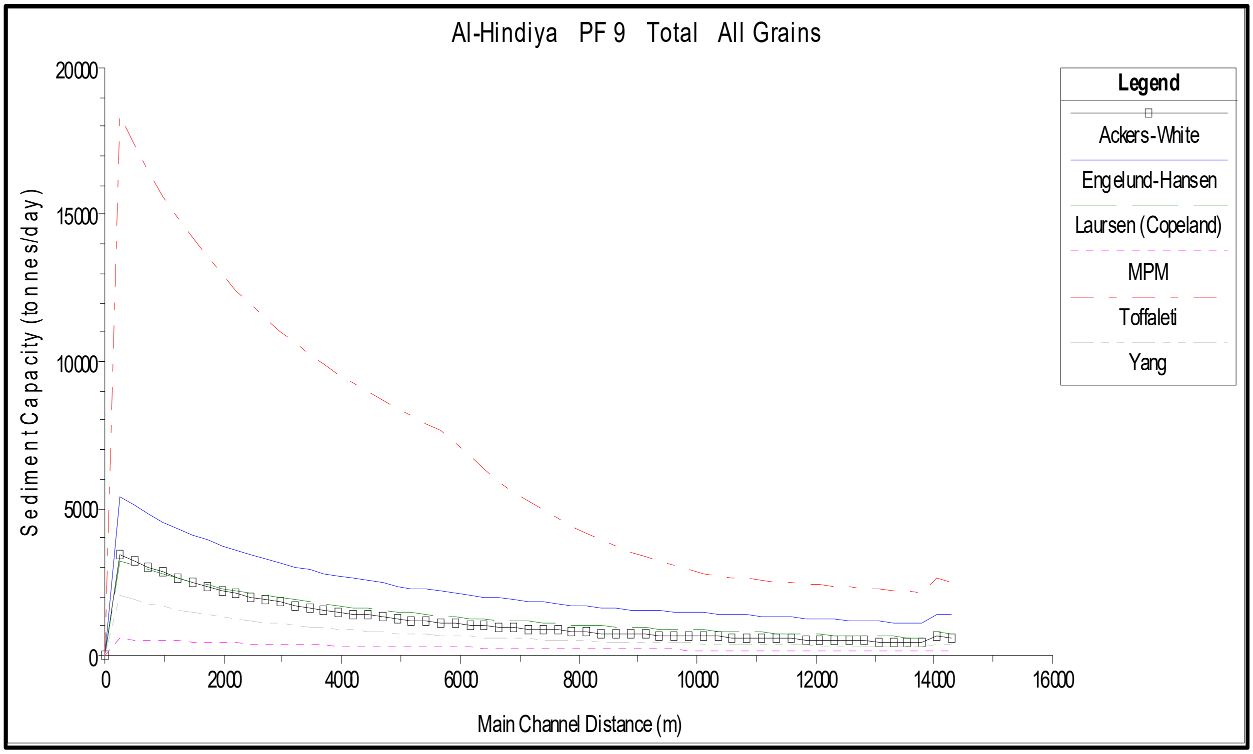


Fig. 13: Sediment potential profile with discharge (Q=300 m3/sec) and different sediment functions

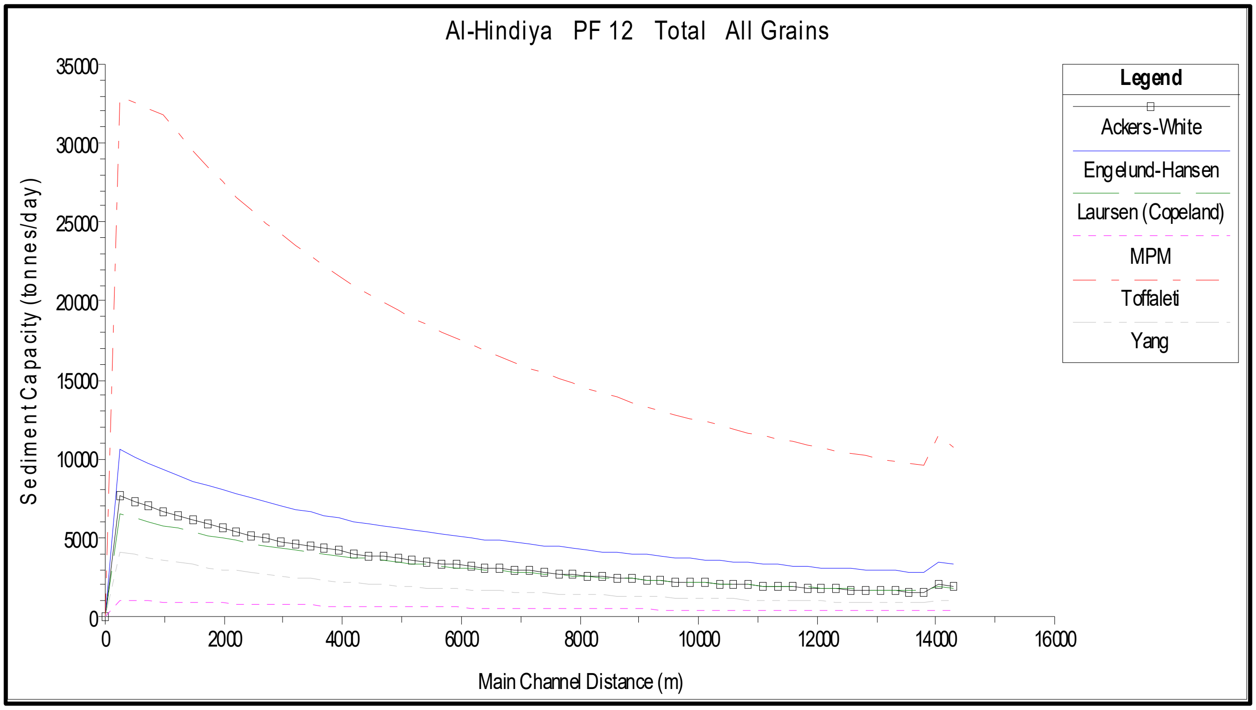


Fig. 14: Sediment potential profile with discharge (Q=450 m3/sec) and different sediment functions

Sediment function	Total Sediment **(tons/day)** (PF1:Q=65 m3/sec	Total Sediment **(tons/day)** (PF4:Q=180 m3/sec	Total Sediment **(tons/day)** (PF9:Q=300) m3/sec	Total Sediment **(tons/day)** (PF12:Q=450 m3/sec
Ackers-White	0.219	103.8	606.7	1885
Engelund-Hansen	22.69	415.5	1396	3281
Laursen	60.15	947.3	2478	10700
MPM	0.853	41.96	156.7	363.1
Toffaleti	7.8	200	722	1805
Yang	0.827	82	369.8	1006
Observed	43	723	1820	8759

Table (2): Sediment Transport Potential (tons/day), River station (3), Specific Gravity of Sediment: 2.65

Sediment function	Total Grains **(tons/day)** (PF1:Q=65 m3/sec	Total Grains **(tons/day)** (PF4:Q=180 m3/sec	Total Grains **(tons/day)** (PF9:Q=300) m3/sec	Total Grains **(tons/day)** (PF12:Q=450 m3/sec
Ackers-White	0.314	88.14	585.9	1841
Engelund-Hansen	17.85	328.3	1288.9	3200.7
Laursen	73.4	882.5	2223.6	10233
MPM	1.5	51.3	144.6	355
Toffaleti	11.2	205	763	1630
Yang	0.9	76.3	300.6	1122
Observed	55	760	1680	9700

Table (3): Sediment Transport Potential (tons/day), River station (10), Specific Gravity of Sediment: 2.65

Sediment function	Total Grains **(tons/day)** (PF1:Q=65 m3/sec	Total Grains **(tons/day)** (PF4:Q=180 m3/sec	Total Grains **(tons/day)** (PF9:Q=300) m3/sec	Total Grains **(tons/day)** (PF12:Q=450 m3/sec
Ackers-White	0.9	78.98	601.7	1849
Engelund-Hansen	14.6	336.4	1199	3250.5
Laursen	77.36	892.3	2314.9	10313
MPM	2.3	60.5	126.4	299
Toffaleti	13.52	299.1	810.4	1644
Yang	2.1	81.3	331	1145
Observed	61	780	2100	11100

Table (4): Sediment Transport Potential (tons/day), River station (20), Specific Gravity of Sediment: 2.65

Tables (2, 3, and 4) explain the computed sediment transport rates according to Sediment functions from table (1). The discharge is one of the most significant factor to raise or reduce sediment transport rate. The statistical analysis of the results; Table (5) shows that Laursen equation provides smaller values of the root-mean-square (R.M.S.). These values of the (∑R.M.S) are the results of the comparison between observed values and the computed ones.

Table (5): Statistical analysis of the results

Sediment function	∑R.M.S.
Ackers-White	4.33
Engelund-Hansen	3.95
Laursen	2.64
MPM	3.11
Toffaleti	2.88
Yang	3.55

5- Conclusions

Both the hydrodynamic and sediment transport model are capable of adequately representing flow and sedimentation characteristics in river reaches containing complex channel geometry. Successful applications of this model to simulating large scale river channel flows and sediment transport problems. The solutions obtained from the simulation indicate that HEC-RAS program is a satisfactory tool for sediment transport intensity calculations where a stable solutions was obtained, which will enable future verification of the quality of model's correspondence to real-life conditions. The analysis of the results from running sediment models indicated that significant sedimentation in Euphrates River within Al-Hindiya reach that agrees with actual situation of the river. lack of regular dredging of the river have caused numerous problems including reduction of river capacity, sudden reduction of river longitudinal slope and the increase of Manning roughness coefficient. Due to high volume of aggregated sediments in the river and lack of proper measures in early stages, such sediments have turned into solid bars and become part of the river section

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