FLOW SIMULATION OF SHATT AL-ARAB RIVER BY HEC-RAS 5.0.3

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Abstract - Shatt Al-Arab River is an important water body in the Basrah Governorate for human, agricultural and animal uses. The river is flow from Qurna district to Abu Flus district within Iraqi country, then the river becomes common borders with Iran until its outlet to the Arabian Gulf at Al-Faw district. The most important tributaries of the river within Iraqi country are the Tigris, Euphrates and Garmat Ali River. Therefore, this study aims to simulate the flow in Shatt Al-Arab River and parts of its tributaries using the latest version of Hec-Ras model (v5.0.3). The calibration and verification of model were showed that the final Manning's roughness coefficients (n) of the main channels for Tigris, Euphrates, Shatt Al-Arab River, and Garmat Ali River were 0.028, 0.029, 0.033 and 0.033, respectively. Whereas, the Manning's roughness coefficients (n) of the banks for the reaches river were 0.06. The Results were illustrated that a very good agreement between the simulated and measured stages, where the correlation coefficient (R^2) was 0.88 (as average), so the maximum water velocity in the main channel was not exceeds 0.8 m/s and ranged up to this rate up to Qurna confluence and start to decrease behind it due to expanded the width of the river and increase the depths.

Keywords - Hec-Ras, Shatt Al-Arab River, hydrodynamic, simulation

I. INTRODUCTION

The Shatt Al-Arab river area is situated in the lower Mesopotamian delta in southern of Iraq and extends from the confluence of the Euphrates and Tigris rivers at Al- Qurna City, north of Al-Basra Governorate (31° 00'17"N and 47° 26'29"E), to the Arabian Gulf [1], the hydrological regime of the Shatt Al-Arab River is affected by several factors, especially the discharge of Tigris river and the tides from the Arabian Gulf. The Shatt Al-Arab River has a length of about 200 km, a width range between 250 m and up to more than 2 km at the estuary and a depth between 8-17 m, considering tides. [2].

Arabian Gulf is a shallow sea, with an average depth of 50 meters and with water depths near the Iraqi coast usually only a few meters deep. Tides in the Gulf are semidiurnal, and its influence is significant up to Al-Qurna city and more upstream [3]

In recent years it is noticed a lack of the fresh water that reached to Shatt Al-Arab River each year, this lead to increasing salinity in Shatt Al-Arab River [4].

Several scientific studies were conducted to examine by setting up a mathematical model based on de-saint-venant equations to predict the hydraulic conditions of the Shatt Al-Arab River channel, Al-Mahmoud et. al. [5] studied one dimensional model for hydrodynamics properties for north part of Shatt Al-Arab River by using Mike 11 software, the study include the part of Shatt Al-Arab river which has 64 Km length starts from Qurna confluence (upstream river) toward Basrah city at Al Maqal port(center of Basrah), Mike 11 which performed an implicit finite difference computation of unsteady flow in rivers based on the saint Venant equations, the study include an Input of constant value of discharge at upstream which equals 300 m^3 /s, and the time series file of water level of Shatt Al-Arab river downstream was created with 30 days period, which started 01/03/2009 to 31/03/2009, Al-Fartusi, A. et. al. [6], studied a hydrodynamic simulation model of the Shatt Al-Arab River 30.5 N, the model used to stimulate the amount of fresh water inlet and discharge from Shatt Al-Arab River in Basra city 30.50 N south of Iraq, the data for this model are based on local measurement during the period 1/10/2012 to 31/12/2012, and by using a computer program called Mike 11, the result of paper shows a good agreement between the mathematical model and the local measurement data, Ahmed Hamdan, A. [1] has been studied the hydrodynamic simulations of river water by controlling gates in Shatt Al-Arab river. Three different sluice gates opening cases simulate the water surface level using Hec-Ras in Shatt Al-Arab River. His study also deals with six cases of flow rates in upstream of Shatt Al-Arab River.

The aim of this study was to simulate the flow and water level in Shatt Al-Arab River. So, Hec-Ras 5.0.3 model was applied on Shatt Al-Arab River, including part of Tigris, Euphrates and Garmat Ali Rivers. The study area was extended from Qal'at Saleh regulator downstream of Maysan province up to Abu-Flus region which its length is approximately180 km.

II. STUDY AREA

The study area was divided into four reaches with a total length was 180.6 km as shown in Fig. 1. The first reach was about 88.5 km long, which represents the lower part of Tigris River extending from Qal'at Saleh Barrage to Al-Qurna city (the point of confluence with Euphrates River). The second reach was about 27.6 km long, which represents the lower part of the Euphrates River from Al-Medina city to Al-Qurna city. The third reach was 15 km long,

which represents the Garmat Ali river, (which lies about 2.5 km north of Basrah), The fourth reach was about 92.1 km long, which represents the Shatt Al-Arab from Al-Qurna city to Abu Flus district (30 ° 27'26.54 "north and 48 ° 01'24.03" east).
The flow along the Shatt Al-Arab river is now coming only from the Tigris, also considering that Garmat Ali river currently can’t discharge water from the Hammar marsh because blocked by embankment dam; the flow contribution from the Karun river is very small [7].

III. FIELD WORK

The cross sections of the Shatt Al-Arab and its tributaries (Tigris, Euphrates and Garmat Ali) were measured during the period from December 2016 to February 2017.

The total number of cross sections that measured for the four reaches of the study area was 254 cross sections as shown in Fig. 2. The number of cross sections measured for the first (the lower part of Tigris River), second (the lower part of the Euphrates River), third (the Garmat Ali river) and fourth reach (the Shatt Al-Arab River up to Abu Flus region) were 88, 54, 6 and 96 cross section, respectively.

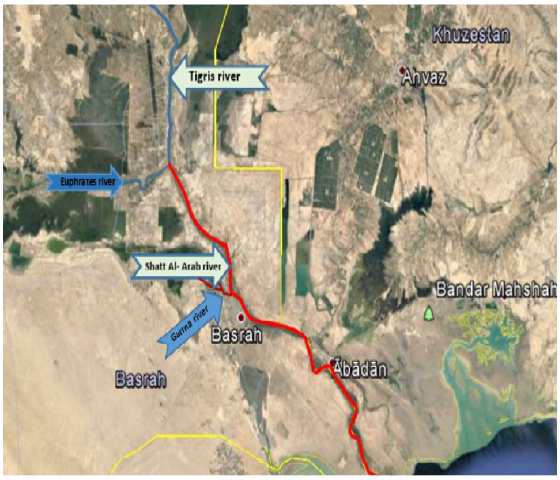

Fig. 1: Shatt Al- Arab river and its tributaries

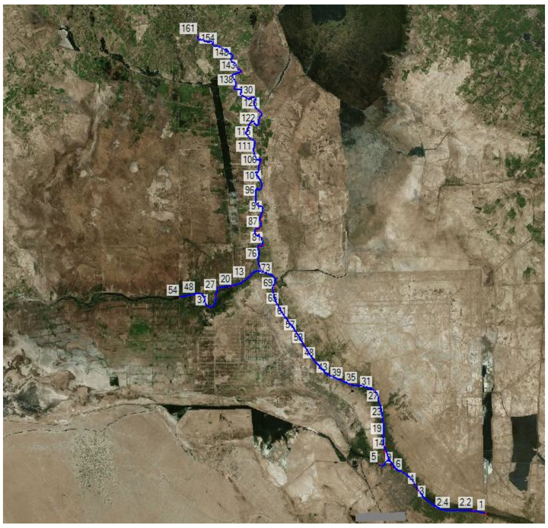

Fig.2: Schematic diagram of the study area

IV. HEC-RAS MODEL

Hec-Ras is a computer program which was developed by the US Department of Defense, Army Corps of Engineers (USACE), the program can models the hydraulics of water flow through natural rivers.
The flow was simulated using the new Hec-Ras-v5.0.3 model developed by the USACE, the new Hec-Ras- v5.03 solves either the full Saint Venant equations or the diffusive wave equations, initially, and the present study considered both options the full Saint Venant equations and the diffusive wave. Both methods provided the same results, but simulation solving the diffusive wave equations was faster than the other, Fig. 3 Shows the main menu of Hec-Ras 5.0.3 model [8].
Hec-Ras software allows the user to view cross sections, water surface profiles, detailed tabular output at a single location, and summary tabular output at many cross sections.

V. GEOMETRIC DATA

The first step after starting a new project was enter geometric data, which consist of a background map layer, connectivity information for the stream system (River System Schematic), and cross-section data. The required information had been displayed on the cross-section data editor as shown in Fig. 4.

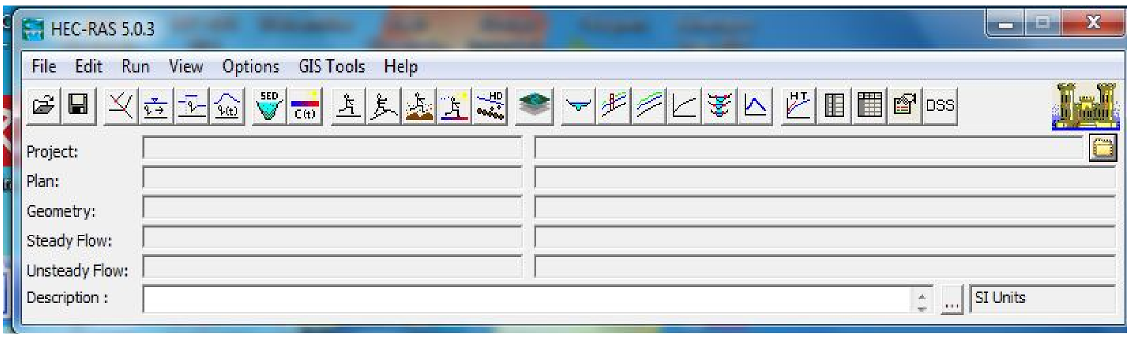

Fig.3: Main menu of Hec-Ras 5.0.3 model

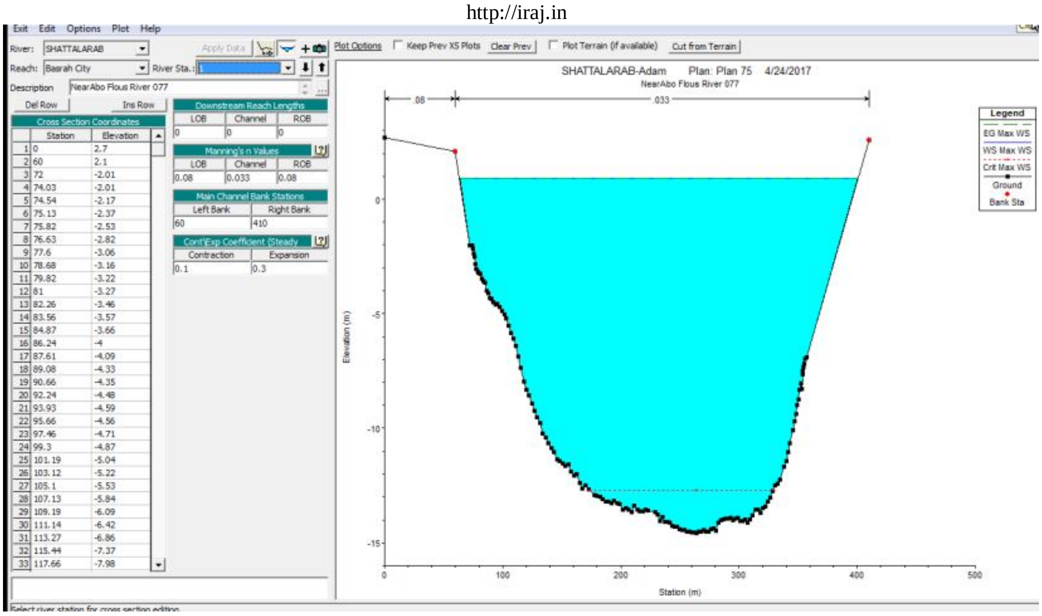

Fig.4: Cross-section data editor (section number1)

VI. RIVER REACHES

The modeler can develop the geometric data in Hec-Ras by first drawing in the river system schematic. This is accomplished, on a reach-by-reach basis, by pressing the River Reach button and then drawing in a reach from upstream to downstream (in the positive flow direction), as shown in Fig. 2.

VII. BOUNDARY CONDITIONS

In this study, the upstream boundary condition were the daily flow discharges from the Tigris river behind Qal'at Saleh regulator (section 161), as depicted in Fig. 5. whereas, the flow from other tributaries (Euphrates and Garmat Ali River) had been considered zero discharge. On the other hand, the downstream boundary condition were the hourly stages at the section 1 of Shatt Al-Arab River near to Abu Flus district, as depicted in Fig. 6. The upstream and downstream conditions had been taken for ten months from 01 February 2014 to 30 November 2014.

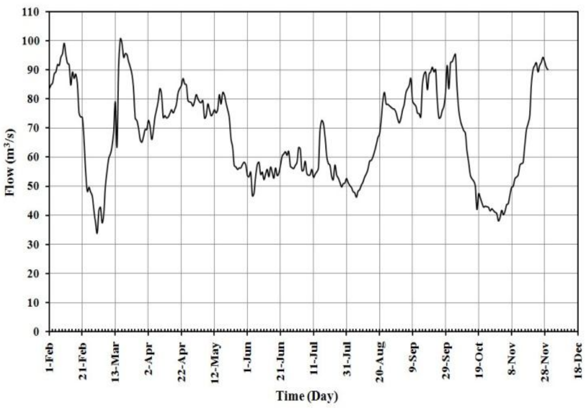

Fig. 5: Tigris discharge during 1Feburuary to 30 November 2014

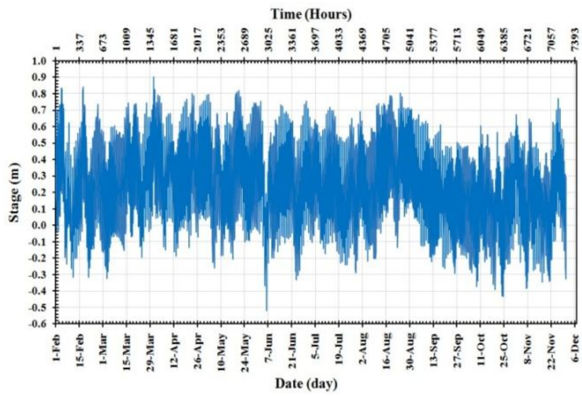

Fig. 6: Tidal's variation during 1Feburuary to 30 November 2014

VIII. MODEL CALIBRATION AND VERIFICATION

Model Calibration is determine the right values of the model parameters by iterative process of changing the values of model parameters and comparing the model results with real system then improve the model until the accuracy is judged to be acceptable.

Manning's roughness coefficient (n) was considered as calibration parameter for the hydraulic models. Manning's roughness coefficient (n) is values to describe the resistance to flow due to channel roughness caused by sand or gravel bed, bank vegetation and other obstructions, as shown in Table 1.

In this study, the initial Manning's roughness (n) values for all the reaches was 0.025 for the channel sections and 0.06 for the bank stations. Then, these initial values were modified during the calibration process until a good simulation have been occurs between the simulated stage levels and the measured stages levels at the sections of Shatt Al-Arab River(sections 3.2 and 55) for the period from

February 2014 to September 2014. Thereafter, the verification of model was carried out on the same sections (sections 3.2 and 55) for measurements of water levels during period from October 2014 to December 2014.

Table 1: Manning's roughness for natural streams [9]

Type of Channel and Description	Minimum	Normal	Maximum
1- Main Channels			
Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
Same as above, but more stones and weeds	0.030	0.035	0.040
Clean, winding, some pools and shoals	0.033	0.040	0.045
Same as above, but some weeds and stones	0.035	0.045	0.050
Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
Clean, winding, some pools and shoals, some weeds and many stones	0.045	0.050	0.060
Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2- Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070

IX. RESULTS AND DISCUSSION

In this study, Manning's roughness coefficient (n) was consider as a model parameter to do the calibration process of the model. Therefore, a wide range of Manning's roughness coefficients values for both the main rivers and its banks were investigated to calibrate the model under unsteady flow condition. According to Table 1, these values of Manning's roughness coefficient (n) were ranged from 0.020 to 0.033 for the main channel of Tigris, Euphrates, Garmat Ali and Shatt Al-Arab River. Whereas, the values of Manning's roughness coefficient (n) for the banks of the all reaches was taken as 0.06. For each iteration of the model calibration, a set values of Manning's roughness coefficient (n) were selected (within the limits mentioned above) for all river reaches, then running the model and then its results (simulated stages) were compared with the measured stages of the Shatt Al-Arab River in sections 3.2 and 55 for six months from 01 February 2014 to 31 July 2014. The correlation coefficient (R^2) was used to judge the accuracy of agreement between the simulated and measured stages.

In the final iteration of the calibration process, we had been get an excellent agreement between the simulated and measured stages at sections 3.2 and 55 where the correlation coefficients (R^2) were 0.921 and 0.904 as shown in Fig. 7 and 8, respectively. The final Manning's roughness coefficients (n) of the main channels for Tigris, Euphrates, Shatt Al-Arab, and Garmat Ali River were 0.028, 0.029, 0.033 and 0.033, respectively. Whereas, the Manning's roughness coefficients (n) of the banks for the reaches river were 0.06.

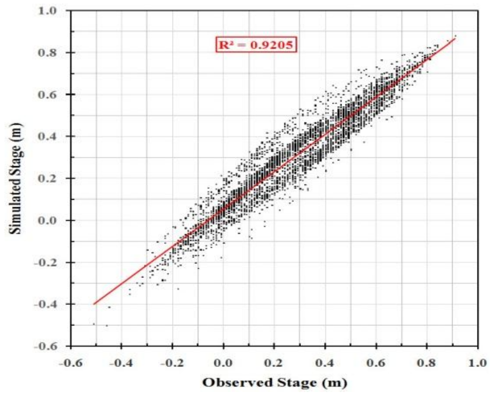

Fig. 7: Comparison between computed and observed in Station number 3.2 for the chosen value of Manning's.

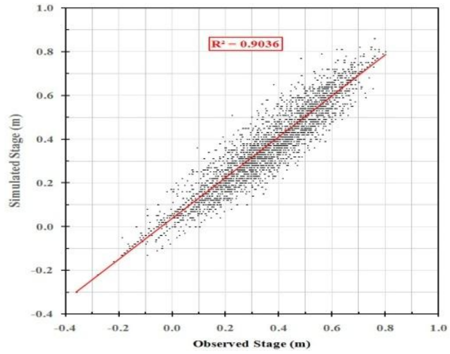

Fig. 8: Comparison between computed and observed in Station number 55 for the chosen value of Manning's.

Model verification has been done to ensure the model and its implementation are correct under the unsteady condition. Therefore, the model was running for other periods (1 August to 30 November 2014) using the final values of Manning's roughness coefficients (n) from the calibration process. Then, the results of model which is simulated stages were compared with measured stages of the Shatt Al-Arab at the sections 3.2 and 55 during the period from August to November 2014. Results of the verification process were showed that a very good agreement between the simulated and measured stages at sections 3.2 and 55 where the correlation coefficients (R^2) were 0.856 and 0.848 as shown in Fig. 9 and 10, respectively.

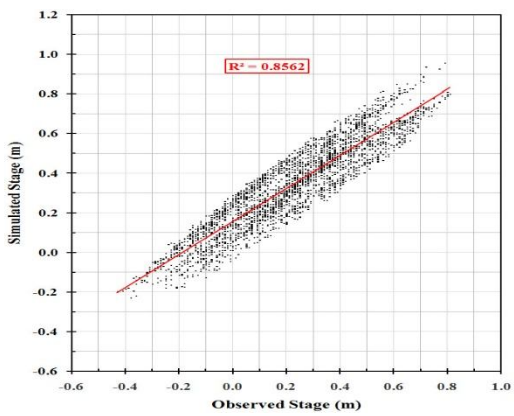

Fig. 9: Comparison between computed and observed in Station number 3.2 for the chosen value of Manning's.

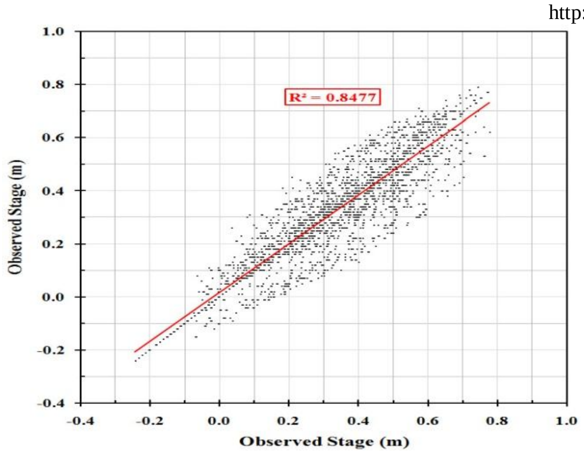

Fig. 10: Comparison between computed and observed in Station number 55 for the chosen value of Manning's.

Fig. 11 was showed the profile of the simulated velocities along the study area for the flow of year 2014. The positive and negative signs indicate the ebb and flood velocity directions, respectively. It's evident from Fig. 11, the flow velocities of the study area were decreased from upstream (Al-Qurna city) to downstream (Abu Flus district). This means that the distribution of velocities along the Shatt Al-Arab River were non-uniform is irregular along the Shatt Al-Arab by the change of the river section because the geometry of river cross sections were non-uniform where its narrow sections in upstream and wide section in downstream of the river. Fig. 12 was showed the water surface profile along the study area for the flow of year 2014 at the maximum flow.

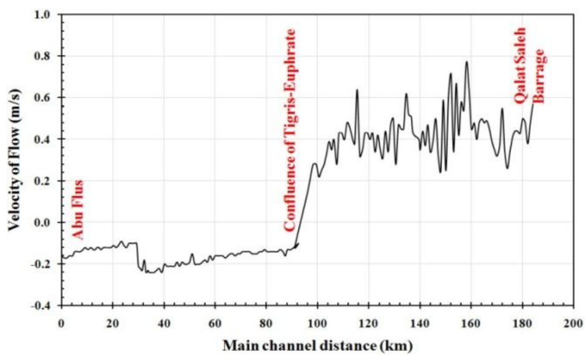

Fig.11: Maximum velocity profile in the main channel in the case of flow of 2014

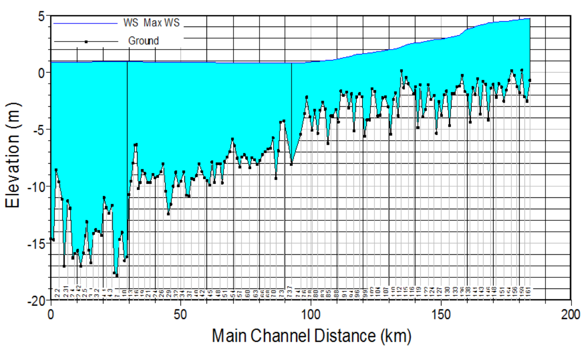

Fig. 12: water level profiles for the year of 2014 in the case of maximum flow

CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn:

- The Hec-Ras 5.0.3 provides the water profile for the case of unsteady flow. This profile will facilitate adopting the appropriate control to insure a reasonable level of water with regarding to the discharge that come behind Qal'at Saleh regulator in the upstream of the river.
- Water surface modeling using Hec-Ras 5.0.3 is an effective tool for hydraulic study and handling of river water management.
- Maximum water velocity in the main channel was not exceeds 0.8 m/s and ranged up to this rate up to Qurna confluence and start to decrease behind it due to expanded the width of the river and increase the depths.
- The final Manning's roughness coefficients (n) of the main channels for Tigris, Euphrates, Shatt Al-Arab, and Garmat Ali River were 0.028, 0.029, 0.033 and 0.033, respectively. Whereas, the Manning's roughness coefficients (n) of the banks for the reaches river were 0.06.
- The results showed that a very good agreement between the simulated and observed stages, where the correlation coefficient (R^2) were 0.88 (as average).

RECOMMENDATION

- Complete the simulation from Abu Flus region to Shatt Al-Arab estuary if the tidal gauge in the estuary and sections along the area behind Abu Flus region are available.
- The simulation under study can be used in future to study the effect of construct barrage in Abu Flus region.
- The simulation under study can be used in future to study the TDS, heat transfer, transport of sediment or pollution along the river.

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