

Analyzing the Impact of Climate Change on the Hydraulic Performance of the Al-Diwaniya River via Mathematical Modeling

Saraa M. Ali ^{1,*}, Zaid Abed Al-Ridah^{2, a}, Mohammed S. Shamkhi^{3, b}

¹ College of Engineering, Al-Qasim Green University, Babylon 51013, Iraq

² Civil Engineering Department, College of Engineering, Al-Qasim Green University, Babylon 51013, Iraq

³ Department of Structures and Water Resources, Faculty of Engineering, University of Kufa, Najaf Al-Ashraf, Iraq

³ College of Engineering, University of Warith Al-Anbiyaa, Karbala, Iraq

* saraa.m213017@wrec.uoqasim.edu.iq, ^a zaidalmnsory@wrec.uoqasim.edu.iq, ^b mohammeds.alfahdy@uokufa.edu.iq

Abstract

Iraq's arid sector is characterised by way of a unique hydrological machine. The Tigris River and the Euphrates are the cornerstones of Mesopotamian civilization and are celebrated at some point in the area. The Al-Diwaniya River, one of the Euphrates' tributaries, irrigates a giant expanse of cultivable land and regulates water purity inside the downstream region. We simulated the Al-Diwaniya River's drift pattern using the hydrological version (HEC-RAS). The hydrological version turned into calibrated by comparing its performance with the utilization of Manning's roughness coefficients, which have a final calibration range of (0.016–0.024) and a mean of 0.022 in the preponderance of the areas under investigation. The root-mean-rectangular blunders (RMSE) values were nearly 1, indicating immoderate consistency among the simulated and discovered data. The hydrodynamic version that was built with HEC-RAS is broadly diagnosed. And is closely correlated with the determined glide discharge, as tested with the validation results. This discovery could be a beneficial tool for estimating the release at ungagged places alongside the river. There aren't any comprehensive studies on using HEC-RAS to remedy hydraulic issues in the Al-Diwaniya River.

Keywords: HEC-RAS 6.4.1; Euphrates River; Al-Diwaniya River: Mathematical Modeling.

1. Introduction

One vital prerequisite for society's development, sustainability, and enhancement is the supply of enough cost-effective water sources; therefore, water protection is paramount. Evaluating canal float conditions is critical for identifying water usage throughout the seasons, awaiting average demand, and decreasing the risk of droughts and floods. The majority of studies focusing on the replication of canal flow characteristics have employed both physical and numerical models [1]. Many people consider rivers to be the primary sources of freshwater, and they contribute substantially to the advancement of society. Additionally, safeguarding is intricately linked to sufficient water reservoirs and enhancing ecological conditions and public well-being [2]. The layout and operation of hydraulic structures on the Euphrates River and Tigris Rivers in Iraq are considerably impeded by the absence of hydraulic and hydrologic records [3]. Designing and overseeing the use of water sources necessitates a comprehensive, extended examination of hydrological and hydraulic components, which remain

underexplored in these regions. The current analysis may also require the development of a technical method to measure this phenomenon [4]. River simulation assists stakeholders in figuring out the ideal approach for mitigating and forecasting flood occurrences (flood evaluation), drought periods, and the design and control of hydraulic infrastructure located alongside river structures [5]. The identification of documents on river hydrology and hydraulic behavior is facilitated by computer modeling techniques, which are more beneficial to engineers [6]. One of the strategies used in hydraulic modeling is the analysis of one-dimensional (1-D) consistent country flows, evaluated at diverse factors in time [3, 7]. Many researchers utilize hydraulic modeling in conjunction with HEC-RAS to capture unique features. In one look, researchers evolved a 2D version of HEC-RAS to research hydrologic conditions and manual ecological layout [8]. A different examiner employed the HEC-RAS to conduct an investigation. The hydraulic model estimates the diffusion profundity and velocities of irrigation and discharge channels during moderate rainfall [9]. A one-dimensional version of HEC-RAS simulated the Tigris River's float pattern, demonstrating that The simulated and determined data showed a higher level of compliance [10]. We also use HEC-RAS to evaluate the size of culverts on roads in wooded regions, determining their capacity to empty maximum discharges [11].

Furthermore, HEC-RAS collaborated with the Water Quality Analysis Simulation Program (WASP) to enlarge a comprehensive water-satisfactory version of the Shatt Al Arab River, effectively with the flow records and calibrates Popular; HEC-RAS is a somewhat appeared instrument for hydraulic modeling in a lot of programs [12]. The model was transformed to calibrated and demonstrated, enabling the correct determination of Manning's roughness coefficient. The Al-Diwaniya River is the Hilla, Diwaniyaha, and Daghara Rivers, produced from the most essential and colossal irrigation systems on the banks of the Euphrates. The Al-Diwaniya River is a stream of the Euphrates River that comes from the left side, specifically within the United States Hindiyah Barrage. It originates from the Al-Hilla River. Sediment deposition and inadequate primary flow maintenance resulted in a decrease in the Al-Diwaniya River's discharge capacity. Additionally, these issues prevented the river from accumulating the critical water levels required to irrigate rural lands and the intake of water stations in the communities of Diwaniya and Rumaitha [13].

In mild of the scarcity of modern hydraulic studies inside the area under investigation, it's vital that we put into effect a focused investigation to assess the hydraulic conditions of the Al-Diwaniya River. This could be executed with the aid of cultivating a one-dimensional hydraulic model. The model will replicate the flow underlying contemporary circumstances in many scenarios.

2. Study Area Description

The division of the Al-Diwaniya River, a tributary of the Al-Hilla River, is believed to begin at the precise geographic location of 481925 meters Easting and 3566651 meters Northing, as indicated by the UTM coordinate device. This bifurcation is approximately 112 kilometers., reaching the Al-Rumaitha region within the Al-Diwaniya Governorate of Iraq. The river commences to divide into smaller tributaries that distribute themselves for the duration of the vicinity upon accomplishing the Al-Rumaitha sector. Shatt Al-Diwaniya's primary function in supplying potable water and preserving irrigation systems for both home and commercial purposes inside the Al-Diwaniya and Al-Muthanna governorates underscores its importance [14]. Moreover, the river's proximity to diverse settlements guarantees this water supply meets their desires adequately. Overall, the Al-Diwaniya River is vital in sustaining the vicinity's water wishes and helping agricultural activities, emphasizing its significance within the local environment. We selected an eight-kilometer river look-ahead section inside the middle of the metropolis, a place densely populated. This location is undoubtedly one of The provinces that deems the groundwater fallacious for intake, making this place a dry place wherein the river serves as each the town's lifeblood and its number one water supply. Numerous pollution, which include sewage, circle of relatives refuse, and agricultural land contamination, infiltrate the river on all sides. These pollutants, which consist of acids, alkalis, dyes, poisonous salts, fat, and microorganisms, have the potential to contaminate the water [15,16]. Studying and handling its hydraulic overall performance has a helpful effect on river overall performance through mitigating the outcomes of pollution, as proven in Fig.1.



Fig.1. study area Map in Google Earth.

3. Fieldwork and Data Collection

We employed worker gauges at the sites to record water levels, and we modified the Acoustic Doppler Current Profiler (ADCP) device to measure the flow of river head regulators. We have chosen monitoring sites that are located at the discharge site, taking into account the presence of degree measuring team members' devices, the accessibility of a measuring boat, and the proximity of a walkway that is convenient in size. This is because fieldwork is crucial for collecting vital statistics used to examine the machine and organize the hydraulic device to take a look at the region. We utilize the information to calibrate the Al-Diwaniya River using the HEC-RAS software program, confirm it, and create the hydraulic version. The water level is measured at five stations alongside the Al-Diwaniy River, and seventy-seven discharges are conducted.

4. Developing the hydraulic model

Using Manning's roughness coefficient (T) fee to set the price of many water resource projects related to the glide of canals is a good concept. These initiatives include designing hydraulic systems and bridges, handling erosion and sediment, and stabilizing the banks. Calculating the roughness coefficient is crucial for figuring out flow charges, water tiers, and the canal's velocity on the glide subject. This study aims to estimate Manning's

roughness coefficient beneath consistent situations and examine the canal's load-wearing ability in character pass sections using the canal evaluation gadget furnished via the Hydrological Engineering Centre (HEC-RAS) [1,17]. The interactive software program HEC-RAS is one of the maximum broadly used for simulating numerous hydraulic structures, including rivers, floodplains, culverts, dams, and flow flows. Numerous hydraulic approaches, such as sediment transport, great water go with the flow, steady waft, and unsteady flow, can be simulated using this device in single or extra dimensions. The one-dimensional version effectively replicates the flow in the primary channel of a nicely combined river, ensuring that stratification no longer appears alongside the profile [18,19]. Derivations for the equations above are fantastic.

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} - q_i = 0 \quad (1)$$

$$\frac{1}{A} \times \frac{\partial Q}{\partial t} + \frac{1}{A} \times \frac{\partial}{\partial x} \left(\frac{Q^2}{A} \right) + g \times \frac{\partial y}{\partial x} - g(S_o - S_f) = 0 \quad (2)$$

Wherein x denotes the gap, y the glide depth, t the duration, Q the release, and qi the lateral inflow. We constitute gravity acceleration via g, bed slope by So, and electricity grade slope through Sf. We have theoretically solved it. We use a four-factor implicit box partial differential schema in Equations (1) (2) for the 1 D-unsteady float [18, 20]. The Al-Diwaniya River's mainstream includes records from 77 move-sections. The boundary situation is the steady discharge and water degree upstream and the regular intensity downstream.

5.

Methods

The boundary situations upstream and the geometry of the river segment downstream should be taken into consideration at the same time as enforcing drift modeling with HEC-RAS. The ranges of each of the 77 sections of the Shatt al-Diwaniyah, as tested in Fig.2, had been determined by gathering engineering and hydraulic information on the usage of an ADCP device to diploma The pass-sectional vicinity, water float, and release river are the variables which might be being assessed. The size approach was facilitated by providing a measuring boat or a nearby bridge and a diploma measurement team of staff instruments. Fieldwork is critical because it gathers the essential facts for tool assessment and research of the hydraulic machine to look at the area, as illustrated in Fig. Three(a and B). Fig. 4 illustrates the employment of the Total Station (TS) gadget to degree the water tiers at every river segment, watching the change in water ranges due to the flowing discharge.

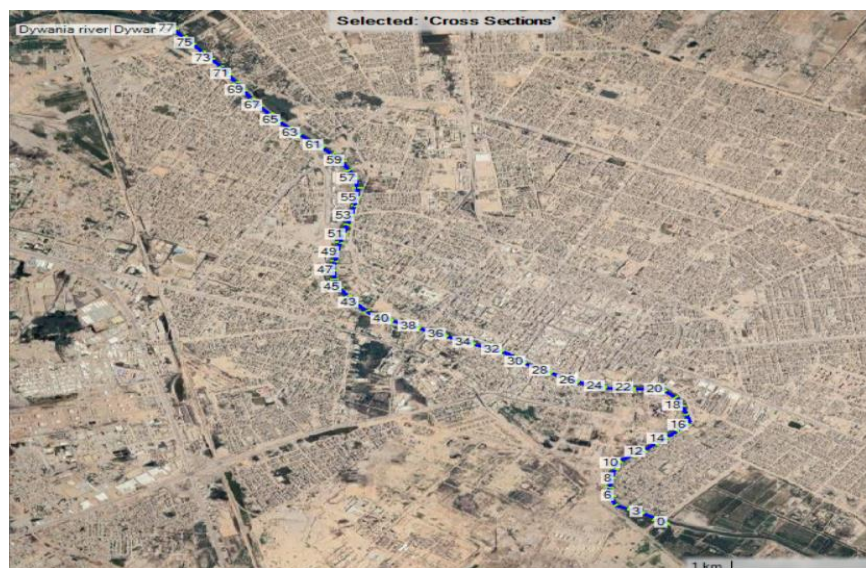


Fig.2. The upper reach of Shatt al-Diwaniyah is depicted in the satellite image on Google Earth.



(a)



(b)

Fig.3. Snapshots showing the sphere works (a) ADCP Device Monitoring of discharge on ShattAl-Diwaniya ; (b) Survey paintings using a degree tool.



Fig.4. Survey paintings with the usage of a stage tool.

The US Army Corps of Engineers had been influential in developing the Hydrologic Engineer Centre Rivers Analytic Systems (the HEC-RA)[8]. In addition, preliminary mathematical calculations are performed by the HEC-RAS program. A typical application of this software program is the simulation of one-dimensional river flow [11]. HEC-RAS is essential for hydrological calculations and hydraulic modeling due to its reliability and simplicity in a single dimension. This method frequently estimates one-dimensional Water floor profiles in each consistent and aberrant float regime. Additionally, it incorporates additives for numerical simulations of 1D water great evaluation simulation [15].

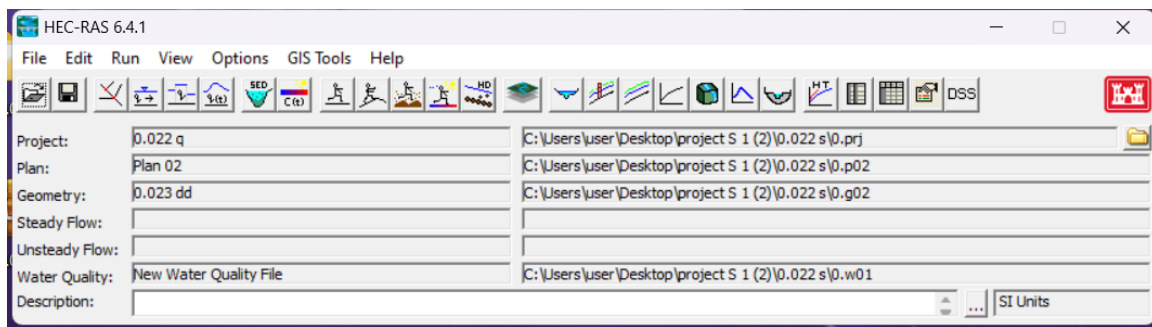


Fig.4.Main Menu of HEC-RAS model.

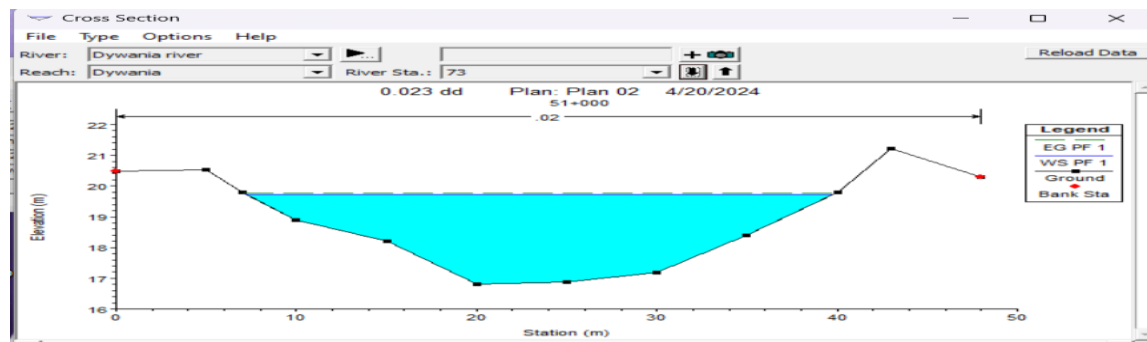


Fig.5. cross sections data editor

Fig. 4 illustrates the middle list of the HEC-RAS version. The HEC-RAS version's principal listing is displayed. To estimate the average cost of the Manning coefficient n , a hydraulic standard pattern was implemented on the Shatt al-Diwaniyah over a 77 km distance using HEC-RAS. The cross-phase records window was validated in Figure 5.

6. Results and evaluation

This segment will compare and analyze the consequences of drift capability on the Al-Diwaniya River site, which has been simulated using an HEC-RAS version. The assessment encompasses both the attainment's contemporary or updated discharge capacity and Manning's calibration and verification.

6.1. Calibration and Verification of HEC-RAS model

We calibrate a model by adjusting its parameters within acceptable bounds until the simulated results closely resemble the observed values. Ensuring a calibrated model can replicate a set of data or predict future circumstances without requiring any extra parameter modifications is the process of validation [21,22]. We constantly perform the calibration process to make essential changes to the model's algorithms and parameters, enhancing the precision and dependability of the simulation version's overall performance. This Manning's n coefficient is of tremendous significance when calculating the channel's open waft, so it can't be disregarded during the calibration of the model in those studies. Any modification to this single coefficient significantly impacts the estimates of waft, depth, and velocity [23,24]. We must examine the accuracy of findings during model calibration and validation to guarantee the accurate depiction of hydraulic characteristics. We recommend using the model evaluation parameters to assess a model's performance. We evaluated and compared the simulated and located water degrees using the foundation-suggested square blunders (RMSE).

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (S_i - O_i)^2}$$

N: a variety of statistics

S_i : simulated water level

O_i : observed water level

Using HEC-RAS, we have to calculate the average Manning coefficient n for a distance of 8 km at the Al-Diwaniya River. We evaluated the Manning coefficient at ten different values, ranging from 0.016 to 0.024. With a roughness coefficient (n) of 0.022, the actual and predicted water levels can be reasonably balanced. Figure 7 compares the simulated and actual water surface elevation along the study route, with $n = 0.022$. We obtained the results from the model calibration over six months.

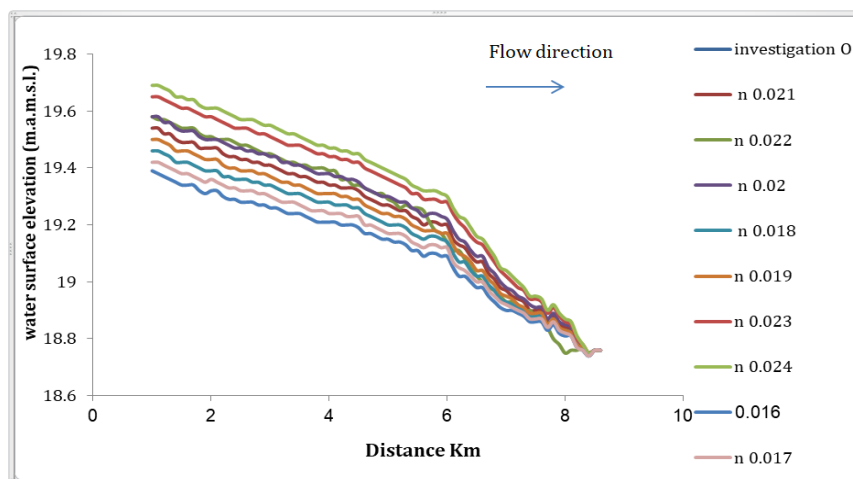


Fig.6. Water surface elevation along the reach of Al-Diwaniya River for various values of meaning coefficient for a discharge of 35.46m³ /s.

The statistical test yields results comparable to the observed values displayed In Fig.7. The root implies the series error was 0.0532 in this case.

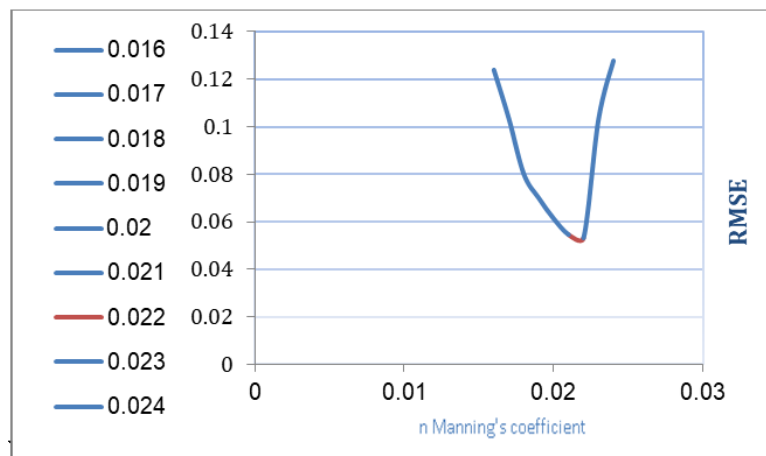


Fig.7. Root mean square for various values of manning coefficient.

Table 1 displays an overview of the findings from the model validation process for the previous six months.

Table 1: Comparison of the discovered and simulated water ranges for the Al-Diwaniya River using the calibrated Manning's coefficients of 0.022.

Q (m ³ /s)	Station (km)	Observed	Simulated n=0.022	RMSE
35.46	51+000	19.59	19.55	0.0532
	52+000	19.49	19.49	
	53+000	19.39	19.42	
	54+000	19.27	19.34	
	55+000	19.15	19.26	
	56+000	19.03	19.05	
	57+000	18.9	18.9	
	58+000	18.78	18.76	

Q (m ³ /s)	Station (km)	Observed	Simulated n=0.022	RMSE
34.58	51+000	19.48	19.54	0.0619
	52+000	19.36	19.47	
	53+000	19.39	19.41	
	54+000	19.29	19.35	
	55+000	19.19	19.25	
	56+000	19.07	19.1	
	57+000	18.91	18.89	
	58+000	18.73	18.7	

Q (m ³ /s)	Station (km)	Observed	Simulated n=0.022	RMSE
45.07	51+000	19.84	19.77	0.121
	52+000	19.73	19.7	
	53+000	19.65	19.63	
	54+000	19.47	19.57	
	55+000	19.26	19.44	
	56+000	19.06	19.26	
	57+000	18.96	18.99	
	58+000	18.8	18.73	

6.2.Current Capacity of Al-Diwaniya River

We assumed the pinnacle regulator's discharge and accelerated it until we attained the layout discharge to estimate the modern discharge ability of the Al-Diwaniya River.

6.2.1. Al-Diwaniya Determination

The Al-Diwaniya River's capacity is currently limited by the use of non-public pumps for irrigation, which are dispersed throughout its reach and are not under the government's jurisdiction. Figure 8 illustrates the integrative water surface profile simulation outcomes for discharges of 35.46 m³/s and 45.07 m³/s. They demonstrate that the river's flow behavior is not consistent. This figure combined the predicted longitudinal water surface elevation profiles for 35.46 m³/s and 45.07 m³/s with the observed hazard level on the river's side banks. The geometry of the model comprises over 77 cross-sections. The station data, the elevation of surfaces, Manning's coefficient (n), lengths between embankments in every move-section, the enlargement and contraction of the canal, and the right and left banks are all blanketed in the go-sections depicted in Fig. 9. The velocities were influenced by the river's topography, which decreased as they moved from upstream to downstream. Figures 10,

11, and 12 are illustrated. It is essential to know river velocities to comprehend eco-hydraulic processes and manage natural resources for various discharges. It facilitates resource management, enhanced ecosystem comprehension, and efficient remote sensing.

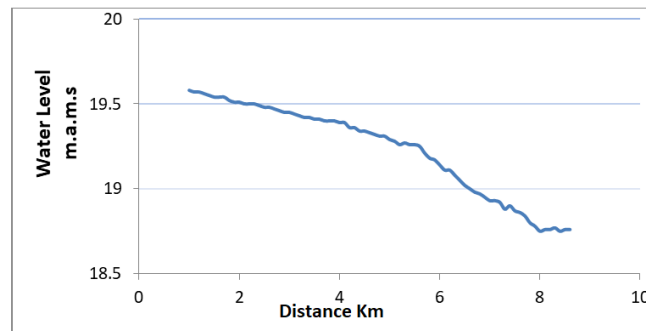


Fig.8. Illustrates the WSE. In addition, a Shatt Al-Diwaniya achievement under current circumstances led to a discharge of 35.46 m³/s for the assumed minimal intake.

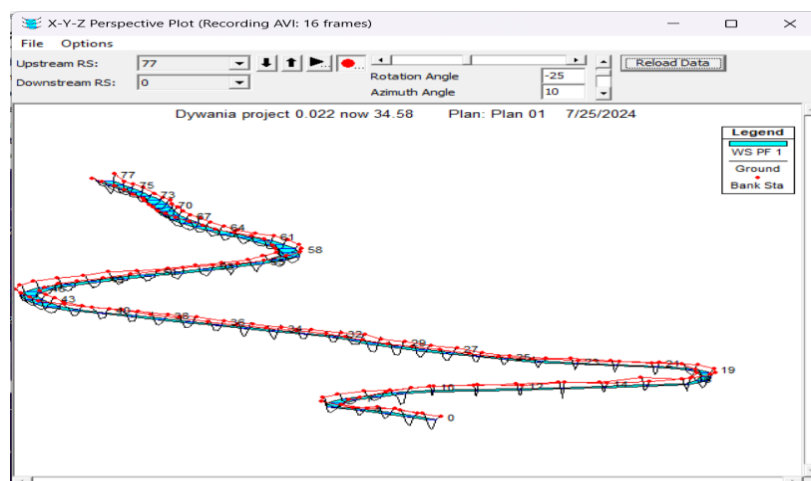


Fig.9. Within the HEC-RAS software window, a 3-D perspective diagram displays the longitudinal and cross-sectional sections of the Al-Diwaniya River.

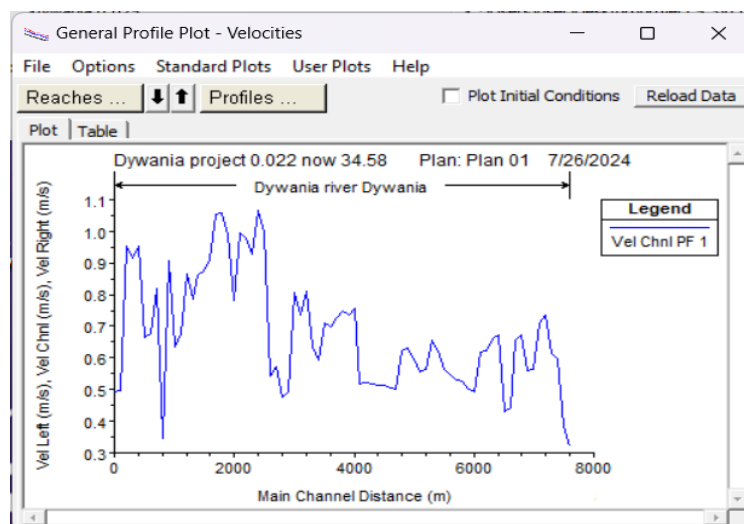


Fig.10. velocities distribution for a discharge of (34.58m³/s)

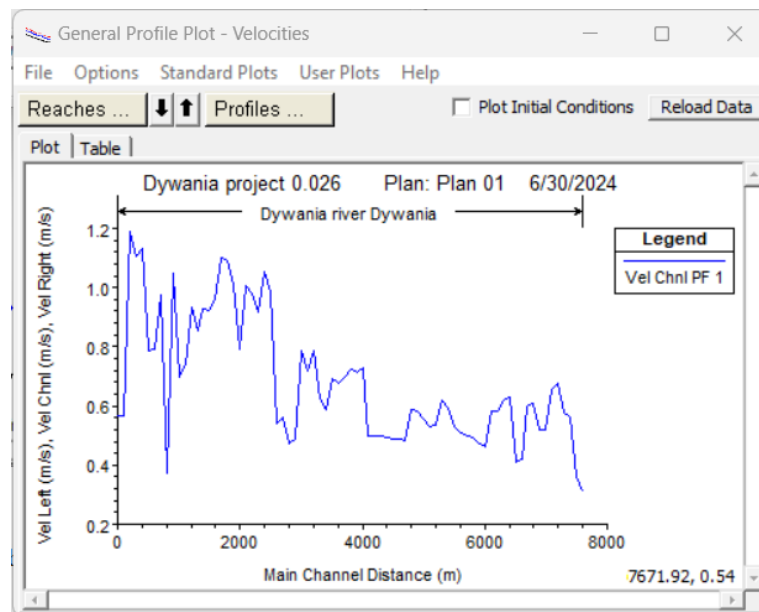


Fig.11. velocities distribution for a discharge of (35.46m³/s)

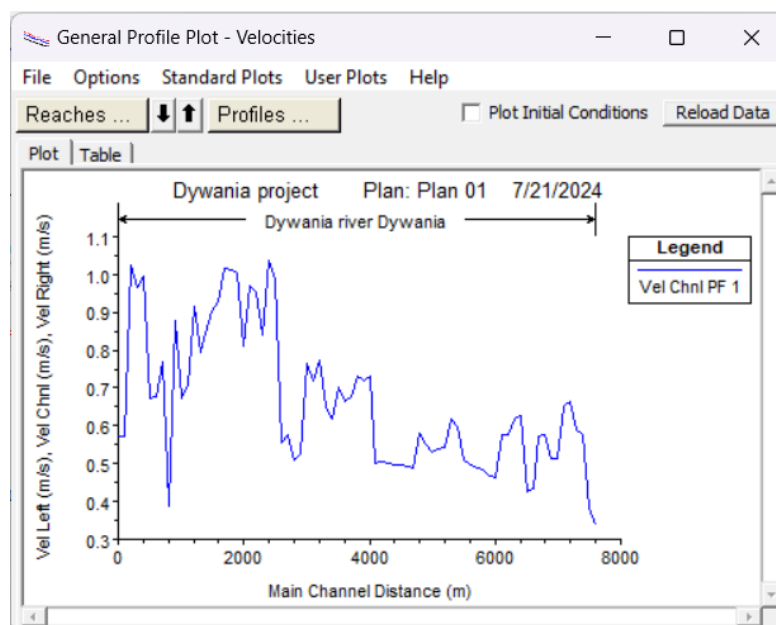


Fig.12. velocities distribution for a discharge of (45.07m³/s)

6. Conclusion

HECRAS's capacity to calculate water surface profiles is evaluated by comparing measured data and model results in this investigation. Consequently, Shatt Al-Diwaniya formulates a constant flow HEC-RAS version to forecast Manning's coefficient fee through a calibration process (0.022) is the appropriate value of Manning's coefficient, as it ensures a reasonable level of Settlement among the computed and found records. In identifying the river's unexplored characteristics, the research has reached a critical juncture that can serve as a foundation for many future studies.

Acknowledgments

The authors thank the Iraqi Ministry for Water Resources (IMWR) and the Directorate of Water Resources in the Diwaniyah Region for providing me with the bathymetric map and flow information, which would have prohibited me from constructing a model.

References

1. Nenny., Hamzah, Al, Imran. (2019). Sediment Retention Models Right On The Irrigation Channels. 50-53. doi: 10.2991/ICMEME-18.2019.12
2. Chenoweth, J., A re-assessment of indicators of national water scarcity. *Water International*, 2008. 33(1): p. 5-18
3. Kamel, A., Application of a hydrodynamic MIKE 11 model for the Euphrates River in Iraq. *Slovak Journal of Civil Engineering*, 2008. 2(1): p. 1-7
4. Hughes, D., Facing a future water resources management crisis in sub-Saharan Africa. *Journal of Hydrology: Regional Studies*, 2019. 23: p. 100600
5. Gil, Y., et al., Artificial intelligence for modeling complex systems: taming the complexity of expert models to improve decision making. *ACM Transactions on Interactive Intelligent Systems*, 2021. 11(2): p. 1-49
6. Yaseen, Z.M., et al., An enhanced extreme learning machine model for river flow forecasting: State-of-the-art, practical applications in water resource engineering area and future research direction. *Journal of Hydrology*, 2019. 569: p. 387-408
7. Kafle, M.R., and NM. Shakya, Two-Dimensional Hydrodynamic Modelling of Koshi River and Prediction of Inundation Parameters. *Hydrology: Current Research*, 2018. 9: p. 30
8. Iris, Holzer. (2023). Using 2D HEC-RAS Modeling with Vertical Feature Extraction to Inform Ecological Design in the Lower Atchafalaya River Basin, Louisiana. doi: 10.31390/gradschool_theses.5655
9. Budianto, Ontowirjo., Imam, Fathurrahman., M., Zahra., Hendra, Wahyudi. (2023). LiDAR DEM and HEC-RAS On-Grid Rainfall Hydrograph Model for Irrigation System. *IOP conference series*, 1198(1):012023-012023. doi: 10.1088/1755-1315/1198/1/012023
10. Nadia, Nazhat, Sabeeh., Waleed, M., Sh., Alabdraba. (2022). The Hydrodynamic Model using HEC-RAS: The case of Tigris River Downstream of Samarra Barrage (Iraq). *IOP conference series*, 1120(1):012017-012017. doi: 10.1088/1755-1315/1120/1/012017
11. D. V. Kalaba, I. B.Ivanović, D. Čikara and G. O. Milentijević., The initial analysis of the river Ibar temperature downstream of the lake Gazivode. *Thermal Science* 18, 73-80 (2014).
12. Mohammed, J., Mawat., Ahmed, Naseh, Ahmed, Hamdan. (2023). Integration of numerical models to simulate 2D hydrodynamic/water quality model of contaminant concentration in Shatt Al-Arab River with WRDB calibration tools. *Open Engineering*, 13(1) doi: 10.1515/eng-2022-0416
13. Shamkhi, M. S., Hafudh, A., Qa.is, H. and Amer, R., Froude number data analysis and its implications on local scour. *Proceedings - International Conference on Developments in eSystems Engineering, DeSE*, 2019, October-2019, pp. 315–320, 9073025
14. Shan-e-Hyder, Soomro., Caihong, Hu., Muhammad, Munir, Babar., Mairaj, Hyder, Alias, Aamir. (2021). Estimation of Manning's Roughness Coefficient Through Calibration Using HEC-RAS Model: A Case Study of Rohri Canal, Pakistan. *American Journal of Civil Engineering*, 9(1):1-. Doi: 10.11648/J.AJCE.20210901.11
15. Chaurasia, Sadhana., Karan, Raj. (2012). Water Quality and Pollution Load of River Mandakini at Chitrakoot, India.
16. Shamkhi, M.S., Azeez, JMR and Abdul-Sahib, A.A., Morphologic and engineering characteristics of watersheds (a case study: East wasit watersheds that feed the al-Shewicha Trough - Iraq). *IOP Conference Series: Materials Science and Engineering*, 2020, 870(1), 012115

17. Majeed, H.Q., Abed, B.S. and Shamkhi, M.S., CFD simulation for the operation effect of gates openings of al-hay regulator on the local erosion. *Journal of Engineering Science and Technology*, (2021), 16(2), pp. 1098–1109
18. Shamkhi, M. S. and Abbasi R. T., Streamflow simulation using the integrated water resources management model on the lower basin of the Diyala river, Iraq. *AIP Conf. Proc.* 3091, 020014 (2024). <https://doi.org/10.1063/5.0205417>
19. Aldefae, A.H., Al-Khafaji, R.A., Shamkhi, M.S. and Kumar, H.Q., Erosion, Sediments Transport and Riverbank Stability: A Review. *IOP Conference Series: Materials Science and Engineering*, (2020), 901(1), 012014
20. Shamkhi, M.S., Tuama, R.J. and Azeez, MK, Experimental and 3D Numerical Simulations of Flow Over a Rounded Edge-Broad Crested Weir. *AIP Conference Proceedings*, 2023, 2806(1), 040035. <https://doi.org/10.1063/5.0166656>
21. Mohammed, S., Shamkhi. (2022). Assessment of Manning coefficient for Dujila Canal, Wasit/-Iraq. *Open Engineering*, 13(1) doi: 10.1515/eng-2022-0388
22. Vozinaki A-EK, Morianou GG, Alexakis DD, et al. Comparing 1D and combined 1D/2D hydraulic simulations using high-resolution topographic data: A case study of the Koiliaris basin, Greece. *Hydrol Sci J* 2017; 62: 642–656.
23. Lai W, Khan AA. Numerical solution of the Saint-Venant equations by an efficient hybrid finite-volume/finite-difference method. *J Hydrodyn* 2018; 30: 189–202.
24. Shamkhi M. S. and Auad M. H., Improvement of Hydraulic Characteristics for Dujila Canal. *AIP Conference Proceedings* Vol. 2977, Issue 122 (2023). <https://doi.org/10.1063/5.0182187>