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Hydraulic Model Investigation of the Babil Stream under Concrete Lined Condition

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Abstract –The Babil Stream is used to irrigate agricultural lands and supply water treatment stations for about 36 km from the head regulator at Shatt Al Hillah then heading east to the Main Outfall Drain. Plans were made to develop the Babil Stream and increase its discharge capacity from its current capacity of 10.5 m^3/s to 15m^3/s to serve more added agricultural land and lining its whole length by concrete. The main objective of this paper is to analyze the current and modified conditions of the flow along Babil Stream by developing a steady state one dimensional hydraulic model utilizing HEC-RAS version 5.0.7 Software. Cross section data for unlined and concrete lined of Babil Stream, water elevation at head regulator, and the flow outlets, 170 outlet and 11 water treatment stations, along it length were provided by the Center of Studies and Engineering Designs of the Ministry of Water Resources. The result showed that the total required discharge of the irrigation outlets and the water treatment stations along Babil Stream is equal to 16.74 m^3/s, which is higher than the design discharge capacity under unlined and concrete lined conditions. The Babil Stream simulation under unlined condition, with Manning n 0.03, and concrete lined condition with Manning n 0.015, showed that the stream can accommodate the discharge of 15 m^3/s with a minimum free board of 0.95 m. A sensitivity analysis to Manning n for unlined and concrete lined conditions showed that the water level at the head regulator is increased by just 0.07 m and 0.1 m, respectively, at a discharge of 15 m^3/s. This increase is not significantly affecting the capacity and the safety of the stream.

Keywords –Babil Stream, HEC-RAS software, unlined conditions, concrete lined conditions.

1. Introduction

The Babil Stream is one of the important irrigation projects in Babil Governorate, Iraq. Babil Stream is used to irrigate the agricultural lands on its sides at a discharge capacity of 10.5m^3/s. Due to adding more irrigation projects along the Babil Stream, this discharge capacity is not sufficient to irrigate all agricultural lands, especially at the end of the Stream. It is intended to develop Babil Stream by increase its capacity to 15 m^3/s to serve more added agricultural land and lining the whole length of the stream by concrete. This study aimed at investigating the hydraulic performance of Babil Stream under unlined and lined and conditions at a discharge of 15m^3/s by the aid of the HEC-RAS software.

The Hydrologic Engineering Center, HEC, of the United States developed HEC-RAS to do one-dimensional hydraulic computations for a whole network of natural and artificial channels. The latest version of the HEC-RAS system can calculate steady and unsteady flow, sediment transport, and water surface profiles. It may generate a report for the user that includes data from the river system as well as the computation results in the form of charts and or tables. Several studies were conducted related to the evaluation of hydraulic performance and water control in rivers and streams in Iraq by using this software. Asaad and Abed, 2020 [1], studied the flow characteristics of the Tigris River within Baghdad City during drought. The studied reach is of about 49km staring from north of the Baghdad City at Al-Muthana Bridge to the confluence of Tigris River with the Diyala River south of Baghdad. Steady one dimensional hydraulic model was used by the aid of HEC-RAS software to analyze the flow within and trying to raise water levels within this reach during drought periods. The results showed that Manning n coefficient of 0.032 for the main river bed and 0.040 for flood banks of the river gave the best results with minimum RMSE of 0.076. Inflatable weirs were suggested as a proper solution to maintain the required water levels that ensure continuous operation of water supply project. Al- Kazwini, et al., 2008 [2], evaluated the discharge capacity of Al Husa'chi River, which is one of the three main branches of Al Ka'hla River in Maissan Governorate. A steady one dimensional hydraulic model was prepared to simulate the flow in this river by using the HEC-RAS software. The obtained maximum allowable discharge of this river for the present conditions is ranged from 20 m^3/sec to 35 m^3/sec for the water surface elevation of the marsh from 7.0 to 2.8 m.a.m.s.l, respectively, and the first flood section is located at 23.5 km downstream of the river inlet. Hamdan, 2016 [3], amid to control the surface water of Shatt Al Arab River by using sluice gates. Three cases of different sluice gates opening and different flow rates was simulated by using HEC-RAS to obtain the water level in Shatt al Arab River, the study also deals with six cases of flow rates in upstream of Shatt Al Arab river. The result show closing the sluice gates leads to the rise of water level to approximately 3 m, that leads to feeding the branches which irrigate the agricultural lands. Installing the dam leads to the rise of water level to 1 m when all gates are opened to their full extent as compared to the case of river without a dam and installing the dam prevents saline wedge coming from the sea water from being mixed with river water The suggested location of the gate allows the passage of ships to Abu Floos port and it also irrigates the agricultural lands in Abu Al Khaseeb and Basrah center up to Qurna region. Awad, 2015 [4], estimated hydraulic model development using HEC-RAS and determination of Manning roughness value for Shatt Al-Rumaith. The Manning n coefficient was calibrated and verified by comparing the computed water surface profiles with observed one. A good agreement between the computed and observed water surface profiles was achieved when the Manning's roughness coefficient was set to 0.023 and 0.04 for main channel and floodplain, respectively. Al. Khuzaie, et al., 2018 [5], estimated by using a hydraulic model developed by using HEC-RAS software to identify friction coefficient for Euphrates River within Al Muthanna Governorate, Iraq. The study showed that value is at a value of Manning's n of 0.04, a best agreement was achieved between the observed and the model result. Daham and Abed, 2020 [6], studied by using one and two-dimensional hydraulic simulation of a Reach in Al-Gharraf River. The reach in the present study is 58200 m long and lies between Kut and Hai Cities. Both numerical models were simulated using HEC-RAS software, 5.0.4, with flow rates ranging from 100 to 350 m^3/s. While the openings of Al-Gharraf Head Regulator were ranged between 60cm to fully opened. The suitable Manning roughness for the unsteady state was 0.025. The obtained results showed that the average velocities for the one dimensional model were ranged between 0.36 and 0.5 m/s, and the average water surface elevations range between 15.14 m and 17.84 m. While these values ranged between 0.25 and 0.44 m/s and 14.125 and 18.82 m, respectively for the two-dimensional model. The simulation results of the two-dimensional model were more accurate than their corresponding one-dimensional model, due to more agreement of these values with measured values. Ghali and Azzubaidi, 2021 [7], evaluated flood management of Diyala River. Thus, the study's objective is to design a flood escape out of the Diyala River, to discharge the flood wave through it. The flood escape simulation was done by using HEC- RAS software. Two hundred twenty-three cross sections for the escape and 30 cross-sections of the Diyala River were used as geometric data. An outflow downstream Hemrin Dam varies from 1100 m^3/s to 1800 m^3/s was applied as boundary condition upstream Diyala River. One dimensional hydraulic model was developed for the escape and the river, the results showed that aside weir could be constructed at the escape entrance with crest level 67 m.a.m.s.l. and 800 m width, followed by drop structure of four rectangular steps, this case provides safe discharge to Diyala River if flood wave of 1500 m^3/s released from Hemrin Dam. Al Mansoury and Azzubaidi, 2022 [8], conducted a hydraulic model investigation of the Babil Stream. The main objective of this study was to analyze the flow under unlined condition along this stream by utilizing HEC-RAS version 5.0.7 Software. The study showed that the sum of the provided discharge of irrigation outlets and water treatment stations equals to 16.74 m^3/s that is higher than the current capacity of the Babil Stream of 10.5 m^3/s. The Babil Stream can accommodate the design discharge of 10.5 m^3/s and the discharge that meets the actual water demand of 16.74 m^3/s. The study showed that the water levels when combining the outlets as a single outlet at each 2.5 km along the stream are close to that when using the actual outlets locations so that the number of discharge outlets is reduced from 181 outlets to just 14 outlets, which reduces the simulation required data. Sensitivity analysis to Manning n for Babil Stream showed the water level at head regulator increased by just 0.06 m and 0.07 m, when applying the discharges of 10.5 m^3/s and 16.74 m^3/s, respectively. This increase is not significantly affecting the capacity of the stream.

2. The Area of the Study

The Babil Stream is located in the Babil Governorate, Iraq, as shown in Figure 1. The Babil Stream branches at a distance of 31.350 km from the left side of Shatt Al Hillah, The Babil Stream extends for a distance of 36 km from the head regulator at Shatt Al Hillah to Main Outfall Drain east of the Babil Governorate. The design discharge capacity under unlined condition at the upstream end of the stream is 10.5 m^3/. The number of outlets located along of the Babil Stream 170 outlets and 11 water treatment stations. The Ministry of Water Resources is planning to develop the Babil Stream to serve more added agricultural lands and future irrigation projects and lining the whole length of the stream by concrete. The development includes increase the supplied discharge to 15 m^3/s. Generally, the lining sections of the Babil Stream were designed by Studies and Design Center with a discharge of 15 m^3/s. The Babil Stream contains a head regulator at its upstream end of the stream as shown in Figure 2. The regulator have four gates having a dimension of 2*2 m with a top level of 30.00 m.a.m.s.l and bed level equal 26.5 m.a.m.s.l. The maximum discharge capacity of the regulator is 15 m^3\s at a water level of 28.35 m.a.m.s.l at upstream side of the regulator.

Figure 1: The Babil Stream layout

Figure 2: The head regulator of the Babil Stream.

3. Numerical modeling

The simulation of the hydraulic model of Babil Stream was conducted by using HEC-RAS software version 5.0.7, under unlined conditions, with a discharge of 15 m^3/s and Manning n coefficient 0.03 according to Chow, 1959, and lined conditions, with discharge 15 m^3/s and Manning n coefficient 0.015. Sensitivity analysis for Manning n was performed for the lined case and the unlined case for the Babil Stream. Figure 3 show geometric data of Babil Stream by HEC-RAS. Figure 5 show the cross sections data of the Babil Stream unlined of the HEC-RAS Software. Figure 4 show the cross sections data of the Babil Stream concrete lined of the HEC-RAS Software.

The 170 outlet and 11 water treatment stations along Babil Stream were combined as a single outlet at each 2.5 km along the stream, which was shown by Al Mansoury and Azzubaidi, 2022, to be close to that when using the actual outlets locations.

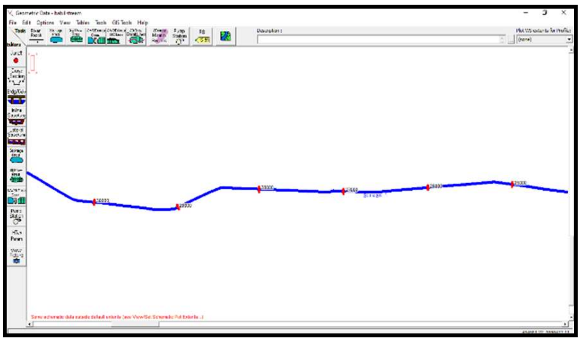

Figure 3: Geometric data of Babil Stream by HEC-RAS.

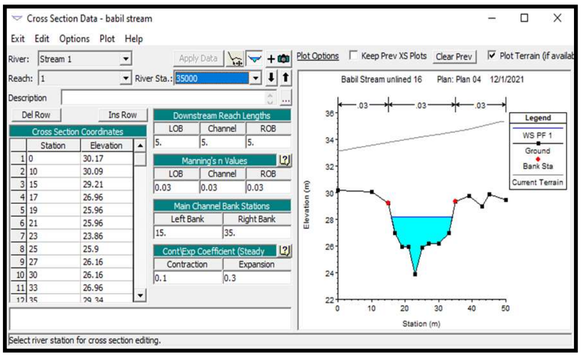

Figure 4: A cross section data of Babil Stream under unlined conditions.

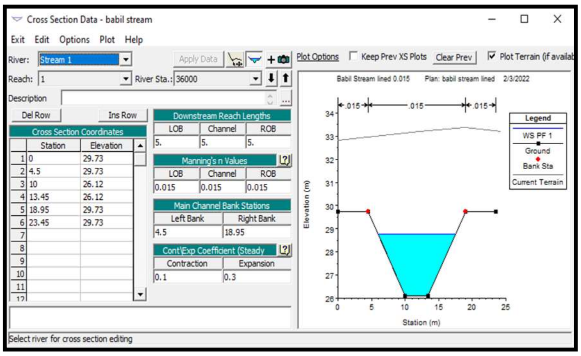

Figure 5: A cross section data of Babil Stream under concrete lined conditions.

The upstream boundary condition at hydraulic models simulation for unlined and concrete lined of the Babil Stream is set at design discharge of 15 m^3/s. When studying the provided discharge required at each outlet and water treatment stations, the total required discharge 16.74 m^3/s. This discharge is greater than the design discharge of the Babil Stream of 15 m^3/s. To meet the design capacity of Babil Stream, the given discharge for each outlet was reduced by the following ratio:

$$Q_R = \frac{Qd}{Qc} * Qo \qquad (1)$$

Whereas:

$Q_{R=}$ reduced discharge, m^3/s

Q_d= Designed discharge, 15 m^3/s.

Q_c= Calculated discharge, 16.74 m^3/s.

Q_o= provided discharge of an outlet, m^3/s.

A normal flow depth was used as a downstream boundary condition.

4. Results and Analysis

Figure 6 and Figure 7 shows simulations output of the discharge and the water level along the Babil Stream, respectively, that was conducted with the unlined conditions with Manning n of 0.03 and a design discharge of 15 m^3/s. The obtained water depth is 1.63 m and a water level of 28.13 m.a.m.s.l at head regulator and minimum free board along the stream is 1.07 m. It is quite clear that Babil Stream can accommodate this design discharge of 15 m^3/s unlined conditions.

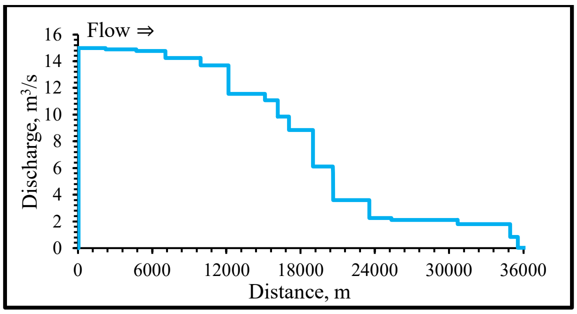

Figure 6: Flow along unlined Babil Stream.

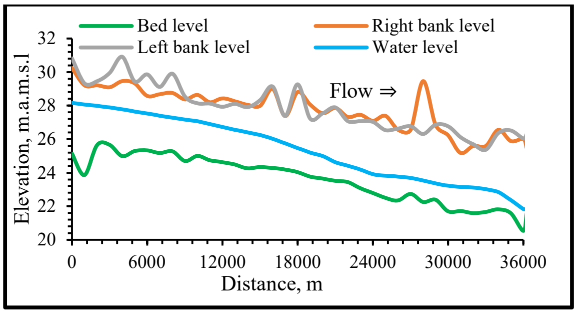

Figure 7: Water level along unlined Babil Stream.

Figure 8 and Figure 9 show mathematical simulation of the concrete lined of Babil Stream was conducted with design discharge 15 m^3/s and Manning n 0.015. The obtained water depth is 1.68 m and the water level is 28.18 m.a.m.s.l at head regulator. The minimum free board is 0.95 m. It can be noticed that the stream within the required design requirements.

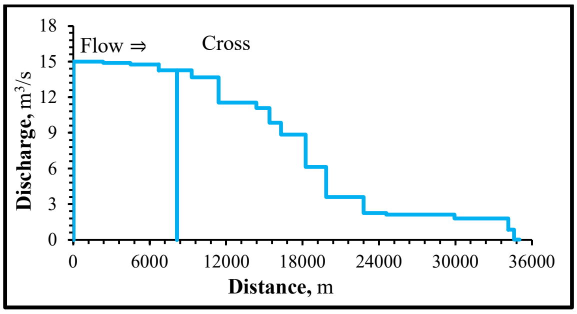

Figure 8: Flow along concrete lined of Babil Stream at discharge 15 m^3/s.

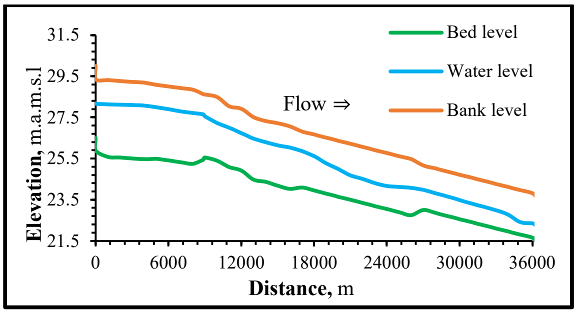

Figure 9: Water level along concrete lined of Babil Stream for a discharge of 15 m^3/s.

Figure 10 shows a comparison between the water levels of the simulated conditions of the designed and the designed with Manning n 0.015. As it can be notices the comparison between the water levels under these conditions are close. The design of the cross-sections of the Babil Stream was based on just seven main outlets and water treatment stations.

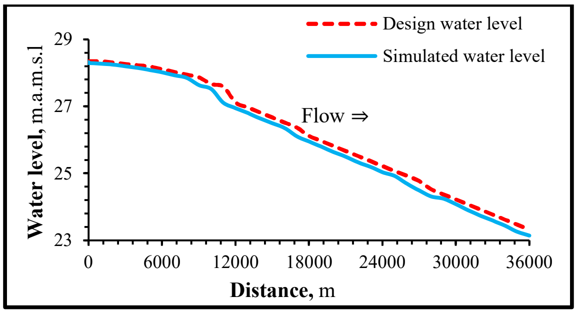

Figure 10: Comparison between the water under different conditions of along the concrete lined of Babil Stream.

The water levels along the Babil Stream were subjected to a sensitivity analysis to the Manning n coefficient. Manning n values of 0.026, 0.028, 0.03 0.032, and 0.034 were selected for sensitivity analysis of unlined of Babil Stream. 0.015, 0.0165, and 0.018 were chosen as Manning n values for sensitivity analysis of concrete lined of Babil Stream. Figure 11 shows variation of water surface elevation according different of Manning n for Babil Stream under unlined conditions, the water surface elevation at head regulator is 27.95 m.a.m.sl for the 0.026 and is increased by about 0.07 for each of 0.028, 0.03, 0.032 and 0.034. When the concrete lined of the Babil Stream, the water surface elevation 28.18 m.a.m.s.l at head regulator for Manning n 0.015 and the water level increases by 0.1 for each of 0.0165, and 0.018 as shown in Figure 12.

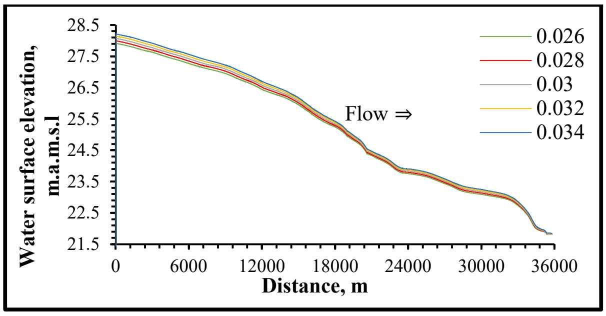

Figure 11: Sensitivity analysis to Manning n for the Babil Stream under unlined conditions.

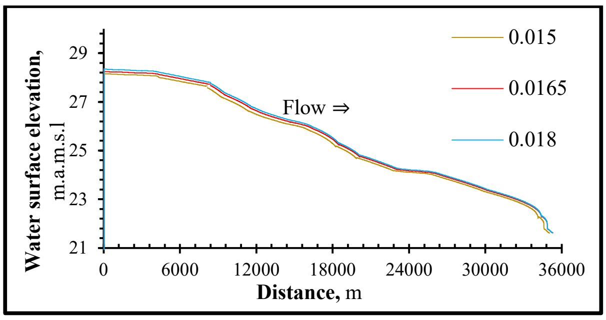

Figure 12: Sensitivity analysis to Manning n for the Babil Stream under concrete lined conditions.

5. Conclusions

The following conclusions may be drawn from this study:

1. Simulation of the Babil Stream by using the HEC-RAS software under unlined with Manning n 0.03 and concrete lined with Manning n 0.015 of discharge of 15 m^3/s, showed that the Stream can accommodate the discharge with a minimum free board of 0.95.

2. The comparison between the water levels of the simulated conditions of the designed and the designed with Manning n 0.015. As it can be notices the comparison between the water levels under these conditions are close.

3. Sensitivity analysis to Manning n for Babil Stream. Manning n values of 0.026, 0.028, 0.03 0.032, and 0.034 for unlined of Babil Stream. 0.015, 0.0165, and 0.018 are Manning n values for concrete lined of Babil Stream, were selected, showed the variation water levels at the head regulator increased by 0.07 m with discharge of 15 m^3/s for unlined and 0.1 m with discharge of 15 m^3/s for concrete lined.

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فحص النموذج الهيدروليكي لجدول بابل تحت الظروف المبطنة بالخرسانة

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نشر في : 30 حزيران 2023

الخلاصة – يستخدم جدول بابل لري الأراضي الزراعية وتزويد المياه لحوالي 36 كم من الناظم الرئيسي في شط الحلة متجهاً شرقاً إلى المصب العام. تم وضع خطط لتطوير وزيادة سعة التصريف جدول بابل من سعته الحالية البالغة 10.5 م 3/ ث إلى 15 م 3/ ث لخدمة المزيد من الأراضي الزراعية المضافة وتبطين طول الجدول بالكامل بالخرسانة. الهدف الرئيسي من هذه الورقة هو تحليل الظروف الحالية والمعدلة للتدفق على طول جدول بابل من خلال تنفيذ تيار ثابت احادي الاتجاه، باستخدام برنامج HEC-RAS الإصدار 5.0.7. تم توفير بيانات المقاطع العرضية المبطنة بالخرسانة وغير المبطنة لجدول بابل، وارتفاع المياه عند الناظم الرئيسي، وتصاريف المنافذ، 170 منفذًا و11 محطة معالجة مياه، على امتداد الجدول من قبل مركز الدراسات والتصاميم الهندسية التابع لوزارة الموارد المائية. أظهرت النتائج أن مجموع التصريف المقدم من منافذ الري ومحطات المعالجة المياه على طول جدول بابل يساوي 16.74 م 3/ ث وهو أعلى من سعة التصريف تحت الظروف غير المبطنة والمبطنة بالخرسانة. أظهرت محاكاة جدول بابل تحت الظروف غير المبطنة، مع معامل الخشونة 0.03، وحالة المبطنة بالخرسانة مع معامل الخشونة 0.015، أن الجدول يمكن أن يستوعب تصريف 15 م 3/ ث مع حد أدنى 0.95 م. أظهر تحليل الحساسية لمعامل الخشونة للظروف غير المبطنة والمبطنة بالخرسانة أن مستوى الماء عند ناظم الرئيسي زاد بمقدار 0.07 م و 0.1 م فقط على التوالي، عند تصريف 15 م 3/ ث. لا تؤثر هذه الزيادة بشكل كبير على سعة الجدول والقيمة المستخدمة البالغة 0.03 التي تمثل متوسط هذه القيم.

الكلمات الرئيسية – جدول بابل، برنامج HEC-RAS، الظروف الغير مبطنة، الظروف المبطنة بالخرسانة.