University of Baghdad
College of Engineering

Journal of Engineering

journal homepage: www.joe.uobaghdad.edu.iq

Volume 29 Number 8 August 2023

Simulation of the Entrance to the Escape of the Flood Branching from the Diyala River

Zahraa Muslim Hadi[1,*], Hayder Q. Majeed[2]

Department of Water Resources, College of Engineering, University of Baghdad, Baghdad, Iraq
zahraa.almamoori2010m@coeng.uobaghdad.edu.iq[1], hmajeed@coeng.uobaghdad.edu.iq[2]

ABSTRACT

The Diyala River is considered the third most important river in Iraq. However, in the recent period, Diyala Governorate has been subject to several floods. This study aims to simulate an efficient labyrinth weir at the flood escape entrance branching from the Diyala River to reach the best entrance through which the flood waves can pass safely. The discharge coefficient was calculated laboratory for five types of trapezoidal side labyrinth weirs with different sidewall angles. Results showed that the coefficient discharge for the trapezoidal labyrinth side weir with an angle of the sidewall is 75° and has a discharge coefficient greater than the rest of the labyrinth side weirs. The second part of this study is validating the laboratory work using the CFD technique, where the same laboratory channel was simulated with the weirs of the side trapezoidal labyrinth using the Ansys-Fluent program. The numerical study gave very close results compared with the experimental results with MSE, where the error percentage error was from 3.3% to 10%. The last part of the work is numerically simulating the trapezoidal labyrinth side weir with an angle of the sidewall of 75° at the flood escape entrance branching from the Diyala River. The results showed that the side labyrinth weir has a larger discharge capacity of 4.8% than the rest of the traditional weirs and is more effective in flood treatment.

Keywords: Labyrinth Side Weir, Flood Escape, Flood, CFD.

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2023.08.10

Article received: 06/10/2022
Article accepted: 21/11/2022
Article published: 01/08/2023

محاكاة مهرب الفيضان المتفرع من نهر ديالى

زهراء مسلم هادي[1]،*،حيدر قيس مجيد[2]

قسم هندسة الموارد المائية، كلية الهندسة، جامعة بغداد، بغداد، العراق

الخلاصة

يعتبر نهر ديالى ثالث أهم نهر في العراق ويقع ضمن محافظة ديالى. لكن في الفترة الأخيرة تعرضت محافظة ديالى لعدة فيضانات. تهدف هذه الدراسة إلى محاكاة مهرب السيول المتفرع من نهر ديالى للوصول إلى أفضل مدخل يمكن لموجات الفيضان أن تمر من خلاله بأمان. تم حساب معامل التصريف مختبريا لخمسة أنواع من الهدارات الجانبية شبه المنحرفة بزوايا جدار جانبية مختلفة. اظهرت النتائج المختبرية ان هدار المتاهة الجانبي شبة المنحرف بزاوية جدار جانبية 75° له معامل تصريف اكبر من بقية الهدرات المستخدمة في هذا الدراسة . وقد تم التحقق من صحة العمل المختبري باستخدام *تقنية* CFD، حيث تمت محاكاة نفس القناة المختبرية بهدارات المتاهة الجانبية شبه المنحرفة باستخدام برنامج Ansys–Fluent. أعطت الدراسة العددية نتائج قريبة جدًا مقارنة بالنتائج التجريبية باستخدام MSE حيث تتراوح نسبة الخطأ *من* 3.3٪ *الى* 10٪. بعد استخراج أفضل هدار متاهة جانبي شبه منحرف تجريبياً وعددياً تم الأنتقال الى الجزء الأخير من العمل وهو محاكاة هدار المتاهة الجانبي شبه المنحرف بزاوية جدار جانبية 75° عدديا عند مدخل المهرب الفيضاني المتفرع من نهر ديالى. أظهرت نتائج هذه المحاكاة أن هدار المتاهة الجانبي له قدرة تصريف أكبر بنسبة 4.8٪ من بقية الهدارات التقليدية وله دور أكثر فاعلية في معالجة الفيضانات.

الكلمات الرئيسية: سد المتاهة الجانبي, الفيضان, مدخل هروب الفيضان.

1. INTRODUCTION

One of the governorates in Iraq is frequently subject to floods from the Hamrin Dam flowing into the Diyala River is the Diyala governorate, particularly when the dam is at capacity. On the Diyala River, the Hemrin Dam is 100 kilometers northeast of Baghdad, Iraq. This river, which originates at the meeting of the Sirwan and Tangro rivers in Darbandikhan Lake in the Sulaymaniyah Governorate in northern Iraq, is regarded as the fifth tributary of the Tigris River. The river is 445 kilometers long and flows through Iran and Iraq. The river rises in the Zagros Mountains and empties into the Tigris River south of Baghdad, the country's capital. The dam's primary functions are flood control, irrigation, and hydroelectric power generation. Its power station has a capacity of 50 MW. The dam and powerhouse were constructed between 1976 and 1981. The Diyala Weir, also known as the Diyala Barrage, is a diversion dam located 90 kilometers northeast of Baghdad, Iraq, on the Diyala River. It was built from 1966 to 1969. The dam's principal purpose is to transfer flows from the Diyala River's Hemrin Dam to the Khalis and Sadr Al-Mushtarak canals for agriculture. Hemrin Dam and Diyala Weir are part of an integrated hydraulic system that uses the Diyala River, which is important in two ways. The first is that it helps to dispose of flood waves. On both sides of the river, the second are prosperous cities and agricultural plains.The capacity of the Diyala River has recently decreased due to poor management in several parts, increasing the risk of floods. One of the most significant floods that the Diyala River was exposed to is the flood of 1988 and the last in 2019, where the waters of the Hamrin Dam reached 105.7 in 1988 and 107.3 in 2019. The Salah-Din Escape was established in 1988, branching from the Diyala River. It was not used due to the construction of neighboring villages, and therefore its use leads to losses of Humans and materials. As a result, the Flood Escape, situated on the Diyala River, had to be created as a substitute for Salah-Din Escape. **(Ghali and Azzubaidi, 2021b)** during which it was proposed to design the flood escape branching from the Hamrin Dam so that it is far from the Diyala River, and this escape branches off from Hamrin Lake and heads towards Mar Al Shuwaija. This one-dimensional hydraulic model of the escape was developed using the HEC-RAS program. **(Ghali and Azzubaidi, 2021a)** during this research, some solutions were found to prevent flooding in the Diyala River, as happened in 1988 and 2019. The hydraulic model was produced using the one-dimensional HEC-RAS program to escape the flood, and this escape branches from the Diyala River and has a length of 94.3 km and passes south of Diyala to Hawr Ashisheh. Located of the flood escape from the Diyala River is 1.6 km upstream of the Diyala Weir. Some modifications have been applied to the escape, including a side barrier at the entrance and a four-step landing structure. A levee was erected to elevate the bank level and accommodate the flood wave. Testing an outflow range between 1100 m^3/s and 1800 m^3/s downstream of Hemrin Dam was done in addition to researching a width range between 200m and 800m to maintain the weir's breadth. The outcome demonstrated that the best side weir width is 800m, lined with an outflow of 1500 m^3/s downstream of Hemrin Dam. In this case, a safe discharge of 750 m3/s to the Diyala River through the Diyala Weir, with a height of 67.88m, is ensured. Side weirs are usually used as an entrance to the flood escape, which diverts the overflow water from the original river to the flood escape.**(Coşar and Agaccioglu, 2004**) conducted 1735 experiments to calculate the discharge coefficient of a sharp-crested triangular side weir located in a straight channel and a bend. **(Emiroglu et al., 2010)** during this research, 2830 laboratory tests were examined to find out the study coefficient of the discharge for different types of labyrinth side weirs and the effect of some weir parameters on this coefficient. The findings revealed that the labyrinth side weirs give a higher discharge coefficient of 1.5-4.5 than the traditional rectangular side weirs. **(Haun et al., 2011)** calculated the water flow over a trapezoidal broad-crested weir using two computational fluid dynamics (CFD) programs**.** **(Aydin and Emiroglu, 2013)** during this research, several computational fluid dynamics (CFD) models were used with experimental models for several types of side labyrinth weirs located in the side wall of a rectangular channel. The discharge capacity can be calculated for these weirs. The results showed a good convergence between laboratory and numerical results.**(Zachoval et al., 2014)** conducted 360 tests on a labyrinth weir in three cycles, 2, 1, and 4, to determine the discharge coefficient for various modes, and the influence of deformation and an increase in the cycle number on the flow hydraulics were explored in this study. **(Khalili and Honar, 2017)** a laboratory study was conducted on a semicircular side labyrinth weir to determine the effect of some engineering parameters on the dam's discharge capacity. **(Wsoo and Rasul, 2017)** tested the subcritical flow system of types of side weirs in a rectangular channel using five different types of side weirs, and the results revealed that the labyrinth side weirs had a greater discharge coefficient than rectangular weirs, at 1.27. **(Kardan et al., 2017)** explained how to optimize the geometry of trapezoidal labyrinths. The volume of the weir is the criterion for determining success. Different weir factors, such as the overall width, the upstream apex width, and the actual length of the side leg, are included as design variables. **(Saleh et al., 2019)** examined experiments to determine the ideal weir's crest shape to boost head loss, lower the level of the upstream bank, and achieve the most economically sound structure. **(Karimi et al., 2019)** studied 12 models of symmetric and asymmetric triangular side labyrinth weirs and two linear side weirs that underwent 227 laboratory tests. **(Bagherifar et al., 2020)** This research simulates a circular channel with a side weir in its side wall using FLOW-3D and the RNG k–turbulence model. **(Ghaderi et al., 2020)** studied through experimentation and numerical analysis how geometric factors of triangular-trapezoidal labyrinth side weir affected the downstream system, the discharge coefficient, and the energy dissipation. Based on the Volume Of Fluid a (VOF) technique, and the (RNK-k-ϖ) turbulence model, the free flow was simulated using the FLOW-3D software. **(Mattos-Villarroel et al., 2021)** investigated the hydraulic performance of a labyrinth-type weir by modeling various apex and crest shapes using computational Fluid Dynamics (CFD).

The main objective of this study is to find the best labyrinth side weir in terms of discharge capacity, ease of construction, and hydraulic performance in the laboratory and validate the laboratory work by using the CFD technique, where the same laboratory channel was simulated with the weirs of the side trapezoidal labyrinth using the Ansys-Fluent program, and Simulate the most efficient design geometry of the labyrinth the side weir in the Diyala river flood escape entrance using CFD software, to study the effect of this weir in this region.

2. EXPERIMENTAL WORK

This experiment was carried out in Iraq's University of Baghdad's hydraulic laboratory. The investigation included a rectangular channel with a length of 5.8 meters, a width of 0.6 meters, and 2.9 meters. The channel is divided into two parts. Each component is a rectangular conduit with a width of 0.3 m and a length of 2 m shown in **Fig. 1**.

Figure1. Laboratory channel to simulate side weir.

The first part represents the main channel, and the second is the side channel. The side weirs are placed in the main channel's sidewall to divert part of the water in the main channel to the side channel shown in **Figs. 2 and 3**. A sharp-crested weir is installed upstream of the main channel, which calculates the discharge entering the main channel.

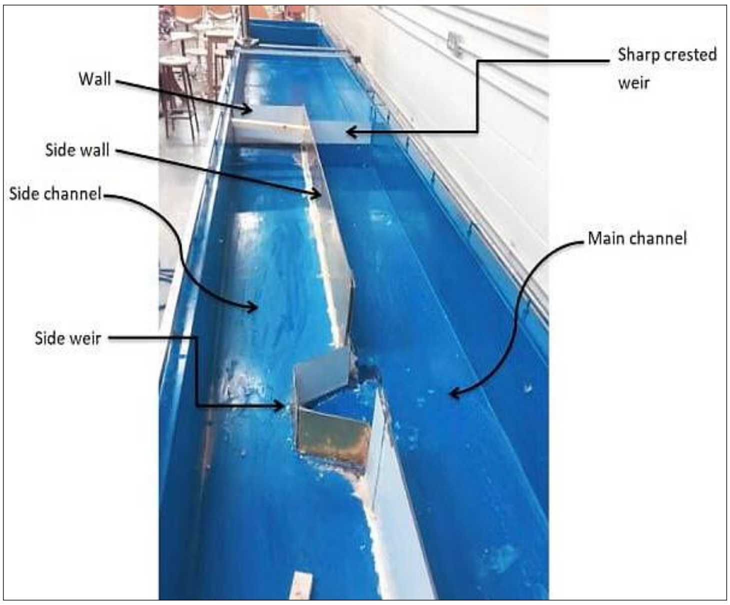
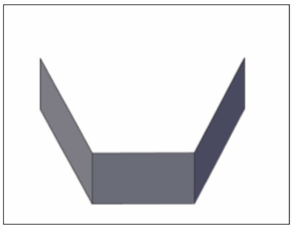
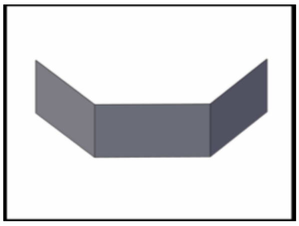


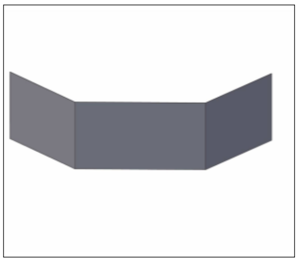
Figure 2. Experimental arrangement and boundary conditions



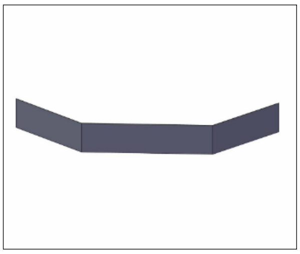
(a) Trapezoidal labyrinth side weir(θ=15°)



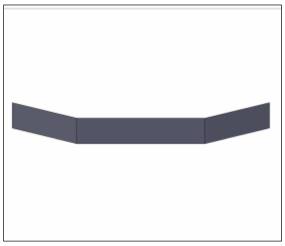
(b) Trapezoidal labyrinth side weir(θ=30°)



(c) θ=45°



(d) θ=60°



(e) θ=75°

Figure 3. Trapezoidal labyrinth side weir with various side wall angles

The flow of water that is transferred from the sump to the main channel through the connecting tubes is controlled by a valve. The discharge coefficient of five types of trapezoidal labyrinth lateral weirs with different sidewall angles of 15°, 30°, 45°, 60°, and 75° were tested, and the discharge coefficient was determined as shown in **Figs. 4 and 5**.

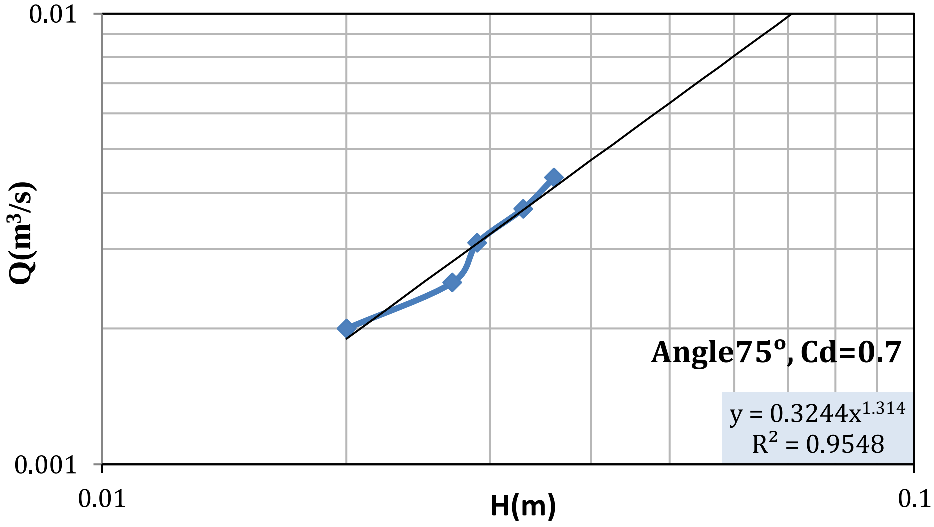


Figure 4. Discharge vs. head over labyrinth side weir with θ=75°.

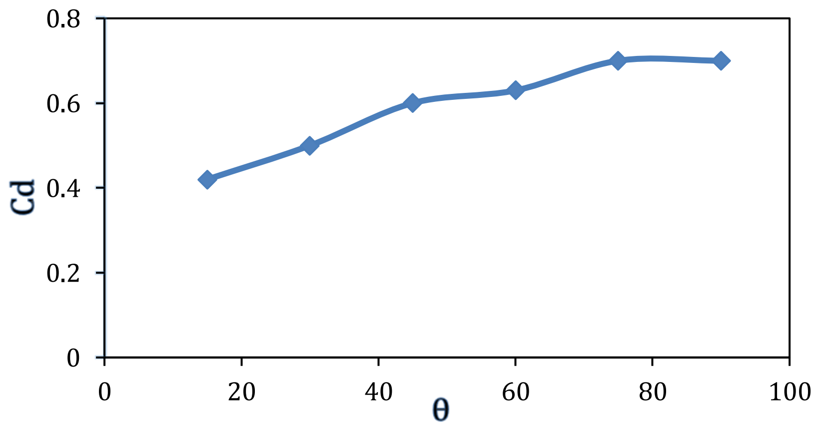


Figure 5. Variation of discharge coefficient (Cd) with different angles labyrinth side weirs (θ).

3. CFD OUTCOMES AND COMPARISON WITH EXPERIMENTAL OUTCOMES

Results from using computational fluid dynamics (CFD) based on experimental data using the software (ANYSAS-FLUENT) are shown in **Table 1.**

Table 1. Comparing the estimated Cd from CFD software to the experimental Cd value.

Angle (0)	Cd(EXP)	Cd(CFD)	% Error
15	0.42	0.45	7.1
30	0.5	0.55	10
45	0.6	0.62	3.3
60	0.63	0.67	6.3
75	0.7	0.74	5.7
90	0.7	0.74	5.7

The proposed equations between the experimental data and the results acquired from CFD are used to derive the correlations between the calculated values and the discharge coefficient. The determination coefficient for the two shapes utilized in the present study is (R^2=0.9919), which is an excellent indicator. The CFD and experiment results are substantially near to one another. Additionally, the values from the drawn line with a 45° angle are symmetrical and convergent, making this a perfect index. Additionally, the range of error percentage values used to assess the similarity between experimental and CFD findings was (3.3% - 10%). The output of the ANSYS FLUENT program is shown in **Fig. 6.**

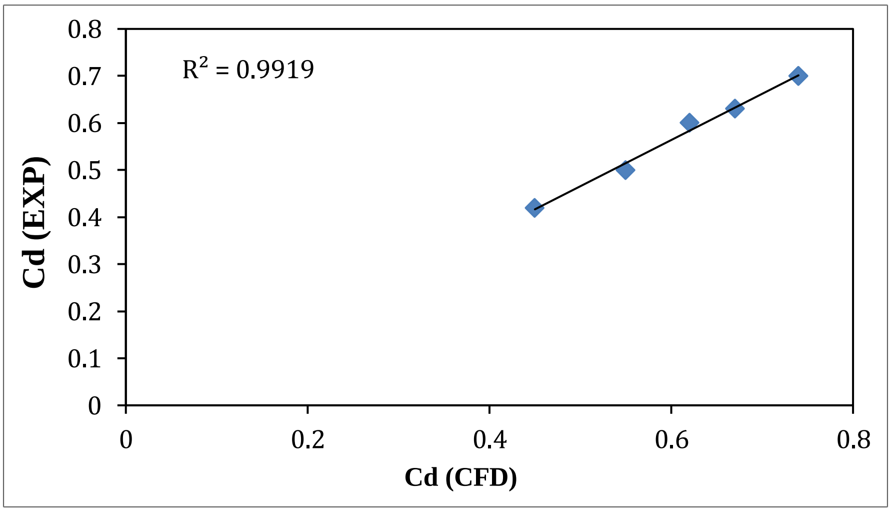


Figure 6. Comparison coefficient of the discharge values of side weirs.

The Mean Standard Error can be used to compare (MSE) can be used to compare the experimental and CFD results. The MSE used in determining the degree of agreement between the experimental and the CFD findings is presented as follows:

$$MSE=\frac{100}{N} * \sum_{n=1}^{N} \left|\frac{Cd(Exp)-Cd(CFD)}{Cd(Exp)}\right| \quad (1)$$

where MSE: Mean the Standard Error, N: The number of expected values to be obtained. The outcome of the mean, standard error (MSE) for this approach is (6.35%)

4. NUMERICALLY SIMULATION OF THE FLOOD ESCAPE ENTRANCE DIYALA RIVER

During this study, the flood escape entrance of the Diyala River was numerically simulated using a three-dimensional CFD program. The length of this escape is 94.3 km, about 1.6 km upstream of the Diyala weir. Numerically simulated based on the experimental results, where five types of labyrinth side weirs were used in the side wall of a main rectangular channel that diverts the surplus water from the main channel to the side channel. The side weirs include five trapezoidal labyrinth side weirs with different sidewall angles (15°, 30°, 45°, 60°, and 75°). The hydraulic performance of these types of weirs was examined, and the best side labyrinth weir was selected in terms of discharge capacity and ease of construction to be applied as an entrance to the flood escape branching from the Diyala River. The labyrinth side weir with a side wall angle of 75° is considered one of the best types of side weirs used in this experiment, as it gives the largest value for the discharge coefficient of 0.7, so this weir will be chosen for its application at the entrance to the flood escape of the Diyala river. The information required to conduct the simulation process was entered, which includes the water level that was obtained by taking the average water in the sections of the Diyala River and the value of the velocity that was calculated from the discharges in this study **(Ghali and Azzubaidi, 2021a)** and because the results of the previous research indicated that the best discharge is 1500 m^3/s with a width of 800 m, the value of this discharge has been relied upon. The velocity was calculated for it, as shown in **Table 2**. **Fig. 7** shows the geometry and boundary condition of the Diyala River and escape entrance junction using Ansys Workbench.

Table 2. Simulation process for the entrance flood escape branching from the Diyala River

Side weir type	Side wall angle (°)	Width (m)	Discharge of Hemrin Dam (m^3/s)	Discharge of side weir (m^3/s)	Discharge of side weir (m^3/s) (previous study)	Side weir discharge %	Side weir discharge % (previous study)	The difference between the value of the two discharges
Trapezoidal labyrinth side weir	75	800	1500	822	750	54.8	50	4.8

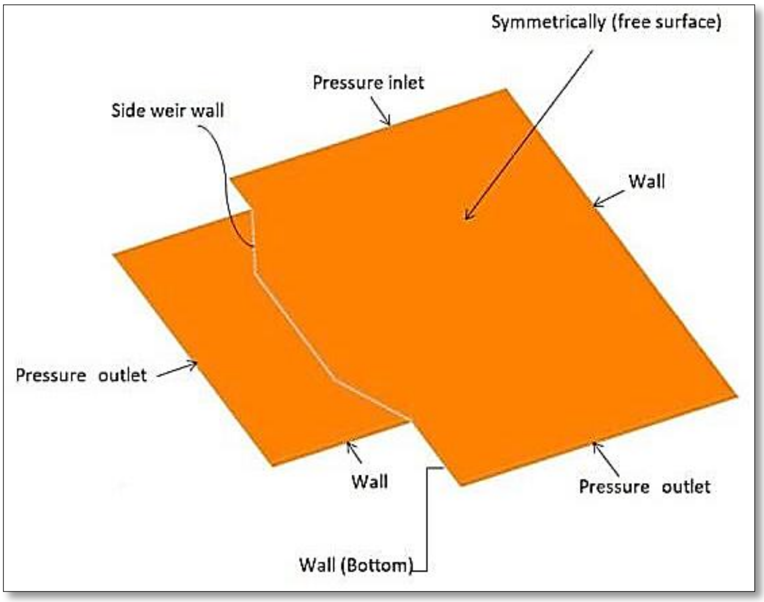


Figure 7. Boundary conditions for the Diyala River section

After knowing the discharge of the side trapezoidal labyrinth weir, the amount of residual release in Diyala River after the side weir was compared with the amount of residual discharge for the previous study. The amount of remaining discharge of the Diyala River is 555 m^3/s, and in the last research, 750 m^3/s, and this indicates that the trapezoidal labyrinth side weir is more effective when flooding occurs in the Diyala River. This confirms one of the advantages of trapezoidal side labyrinth weirs, which states that when using this type of weirs, a larger discharge can be obtained compared to traditional dams of the same width.

The velocity at the entrance to the Diyala River section is as high as possible and then begins to decrease gradually because of the amount of water transferred by the trapezoidal labyrinth side weir located at the branching escape entrance to the Diyala River, as shown in **Fig. 8.**

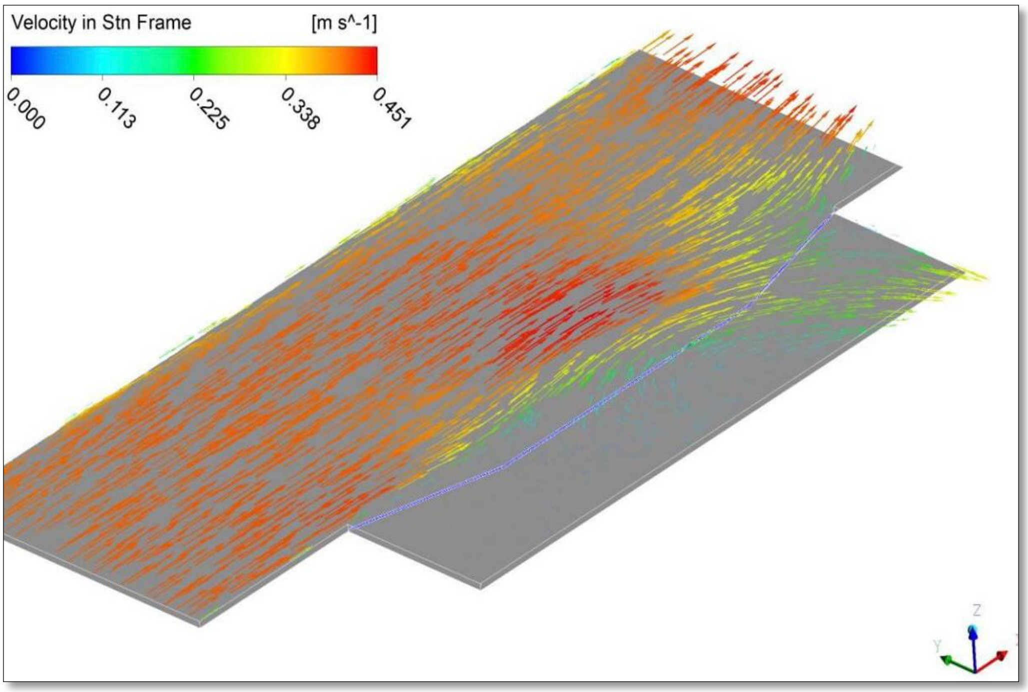


Figure 8. The direction of the velocity and change through the Diyala River section.

5. CONCLUSIONS

Diyala Governorate has recently been subjected to several floods, including in 1988 and 2019. The cause of these floods is the arrival of the Hamrin Dam, located on the Diyala River, to the maximum storage limit. Because of the neglect of the Diyala River, the lack of maintenance of its sections and the overtaking of its banks led to a reduction in the river's discharge capacity, which led to the emptying of flood waves into the cities and lands near it. Since the previous studies proposed a flood escape branching from the Diyala River, this study's entrance to this escape was numerically simulated using the CFD program and based on laboratory results. The most important conclusions reached are:

- Several laboratory experiments were conducted for the side weirs situated in the side wall of a rectangular channel to know the effect of the side wall angle on the discharge capacity. These weirs include a straight weir with a side wall angle of 90° and a labyrinth trapezoidal side weir with different side wall angles (15°, 30°, 45°, 60°, and 75°). Where a discharge coefficient was calculated for each weir through several equations obtained in the laboratory by establishing a relationship between the value of discharge in the main channel, which was calculated by a sharp-crested weir located upstream of the main channel, and the value of the head above each weir as it varies from one weir to another based on side wall angle. The results showed that the discharge coefficient is directly proportional to the angle of the side wall, which means that when the side wall angle of the side weir is increased, the discharge coefficient will increase and vice versa. As a result, the lateral trapezoidal labyrinth weir with a side wall angle of 75° has a larger discharge coefficient than other weirs, and therefore the discharge capacity is larger.

- Computational fluid dynamics models the experimental data using the program (ANYSAS FLUENT). The percentage error between these results is (3.3-10%), and a significant correlation has been discovered between the experimental results and the results derived by (CFD).
- Using CFD software with (K-omega-SST) turbulence model to simulate the flow through the side weir located in a rectangular channel, besides (VOF) scheme simulates. The CFD model accurately forecasted changes in the free surface flow.
- After extracting the best trapezoidal side labyrinth weir laboratory and numerically applying it at the entrance to the flood escape branching from the Diyala River, the results showed that the labyrinth trapezoidal weir has a greater discharge capacity than the side weir used in previous studies. The percentage of side weir discharge used in the last study was 50%, and the percentage of side trapezoidal labyrinth weir discharge used in this study was 54.8%. Therefore, the discharge capacity of the labyrinth weir is higher by 4.8% than the traditional weir.

REFERENCES

Aydin, M. C., and Emiroglu, M. E. 2013. Determination of capacity of labyrinth side weir by CFD. *Flow Measurement and Instrumentation*, 29, pp. 1–8. Doi:10.1016/j.flowmeasinst.2012.09.008

Bagherifar, M., Emdadi, A., Azimi, H., Sanahmadi, B., and Shabanlou, S., 2020. Numerical evaluation of turbulent flow in a circular conduit along a side weir. *Applied Water Science*, 10(1), pp. 1–9. Doi:10.1007/s13201-019-1117-3

Coşar, A., and Agaccioglu, H., 2004. Discharge Coefficient of a Triangular Side-Weir Located on a Curved Channel. *Journal of Irrigation and Drainage Engineering*, 130(5), pp. 410–423. Doi:10.1061/(ASCE)0733-9437(2004)130:5(410)

Emiroglu, M. E., Kaya, N., and Agaccioglu, H., 2010. Discharge Capacity of LabyrinthSide Weir Located on a Straight Channel. *Journal of Irrigation and Drainage Engineering*, 136(1), pp. 37–46. Doi:10.1061/(ASCE)IR.1943-4774.0000112

Ghali, H. M., and Azzubaidi, R. Z., 2021a. Flood Management of Diyala River. *Journal of Engineering*, 27(8), pp. 32–42.Doi:10.31026/j.eng.2021.08.03

Ghali, H. M., and Azzubaidi, R. Z., 2021b. Managing the Flood Waves from Hemrin Dam. *Journal of Engineering*, 27(7), pp. 42–52. Doi:10.31026/j.eng.2021.07.04

Ghaderi, A., Daneshfaraz, R., Dasineh, M., and Di Francesco, S., 2020. Energy dissipation and hydraulics of flow over trapezoidal-triangular labyrinth weirs. Water (Switzerland), 12(7). Doi:10.3390/w12071992

Haun, S., Olsen, N. R. B., and Feurich, R., 2011. Numerical modeling of flow over trapezoidal broad-crested weir. *Engineering Applications of Computational Fluid Mechanics*, 5(3), pp. 397–405. Doi:10.1080/19942060.2011.11015381

Jassam, W. A., and Abed, B. S., 2021. Assessing of the Morphology and Sediment Transport of Diyala

River. *Journal of Engineering*, 27(11), pp. 47–63. Doi:10.31026/j.eng.2021.11.04

Kardan, N., Hassanzadeh, Y., and Shakooei Bonab, B., 2017. Shape Optimization of Trapezoidal Labyrinth Weirs Using Genetic Algorithm. *Arabian Journal for Science and Engineering*, 42(3), pp. 1219–1229. Doi:10.1007/s13369-016-2355-4

Khalili, M., and Honar, T., 2017. Discharge coefficient of semi-circular labyrinth side weir in subcritical flow. *Water SA*, 43(3), pp. 433–441.Doi:10.4314/wsa.v43i3.08

Karimi, M., Jalili Ghazizadeh, M., Saneie, M., and Attari, J., 2019. Flow characteristics over asymmetric triangular labyrinth side weirs. Flow Measurement and Instrumentation, 68(June), P.101574. Doi:10.1016/j.flowmeasinst.2019.101574

Mattos-Villarroel, E., Flores-Velázquez, J., Ojeda-Bustamante, W., Díaz-Delgado, C., and Salinas-Tapia, H., 2021. Influence of crest geometric on discharge coefficient efficiency of labyrinth weirs. *Flow Measurement and Instrumentation*, 81(March). Doi:10.1016/j.flowmeasinst.2021.102031

Saleh, O. K., Elnikhely, E. A., and Ismail, F., 2019. Minimizing the hydraulic side effects of weirs construction by using labyrinth weirs. *Flow Measurement and Instrumentation*, 66, pp. 1–11. Doi:10.1016/j.flowmeasinst.2019.01.016

Zachoval, Z., Knéblová, M., Roušar, L., Rumann, J., and Šulc, J., 2014. Discharge coefficient of a rectangular sharp-edged broad-crested weir. *Journal of Hydrology and Hydromechanics*, *62*(2), pp. 145–149. Doi: 10.2478/johh-2014-0014