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Managing the Flood Waves from Hemrin Dam

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ABSTRACT

Diyala Governorate was exposed recently to high flood waves discharged from Hemrin Dam to Diyala River when the dam reached its full capacity. The recently recorded discharge capacity of Diyala River was reduced to just $750 \text{m}^3/s$. This exposes cities and villages along the Diyala River to flood risk when discharging the flood waves, which may reach 3000 m^3/s. It is important to manage, suggest, and design flood escapes to discharge the flood waves from Hemrin Dam away from Diyala River. This escape branches from Hemrin Lake towards Ashweicha Marsh. One dimensional hydraulic model was developed to simulate the flow within the escape by using HEC-RAS software. Eighty-two cross-sections were extracted from the digital elevation model for the escape and used as geometric data.

Moreover, thirty cross-sections for the Diyala River were utilized from the Strategic Study for Water and Land Resources in Iraq. Since the escape passes through two regions of different geological formations, two roughness coefficients of 0.035and0.028were used. Two discharge cases were applied$3000 m^3/s$, which is the 500 years return period extreme hydrograph of Hemrin Dam, and 4000 m^3/s, which is the design discharge of Hemrin Dam spillway. A spillway was proposed at the escape entrance with crest level 105$m.a.m.s.l.$, followed by a drop structure with eighteen rectangular steps

Keywords: Flood, Flood Escape, Spillway, HEC-RAS

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ادارة موجة الفيضانات من سد حمرين

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الخلاصة

تعرضت محافظة ديالى في الآونة الأخيرة لموجات فيضانية عالية تم اطلاقها من سد حمرين إلى نهر ديالى عندما بلغ السد طاقته الخزنية الكاملة اثناء الفيضان, كما ان احدث سعة مسجلة لنهر ديالى مؤخراً كانت اقل لغاية 750 م^3 / ث فقط. مما يعرض المدن والقرى الواقعة على طول نهر ديالى لمخاطر الفيضانات عند تصريف موجات الفيضان التي قد تصل إلى 3000 م ^{3}/ث. من

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المهم ادارة, اقتراح و تصميم مهرب فيضاني من سد حمرين بعيداً عن نهر ديالى. يتفرع المهرب مباشرة من بحيرة حمرين بأتجاه هور الشويجة. تم تطوير نموذج هيدروليكي أحادي البعد للمهرب بأستخدام برنامج HEC-RAS لنمذجة جريان الماء في المهرب؛ تم أخذ 82 مقطعًا عرضيًا من نموذج الارتفاع الرقمي للمهرب ، وتم استخدام ثلاثين مقطعًا عرضيًا لنهر ديالى من الدراسة الإستراتيجية لموارد المياه والأراضي في العراق. نظرًا لأن المهرب يمر ضمن منطقتين مختلفتين بالتكوين الجيولوجي ، فقد تم استخدام قيمتين لمعامل الخشونة 0.035 و 0.028. تم تطبيق حالتين للتصريف وهما 3000 م³/ ث (مخطط هيدروغرافي للتصريف المطلق من سد حمرين مع فترة عودة 500 عام) و 4000 م³/ ث (التصريف التصميمي لمسيل سد حمرين). تم اقتراح مسيل مائي عند مدخل المهرب بمستوى قمة 105، متبوعًا شلالة بمنشأ يتكون من ثمانية عشر تدرج بمقطع مستطيل.

الكلمات الرئيسية: فيضان, مهرب فيضاني, مسيل مائي

1. INTRODUCTION

Hemrin dam lies on the Diyala River, Diyala governorate, 120 km northeast of Baghdad, and 10 km upstream Diyala Weir. The purposes of its construction are: preventing the flood of Diyala River by controlling the amount of discharge downstream Hemrin Dam, Providing irrigation water for agricultural lands of Diyala River basin, and Electric power generation.

According to the Engineering Studies and Design Center's data, **Ministry of Water Resources,** the dam is high- zoned earth embankment with a clay core, a height of 40 m, and a length of 3360 m. Also, it is supplied with five radial gates spillway, the gates are 70 m total width and 12.5 m height, the maximum discharge of the spillway is 6800 m³/s at maximum reservoir level, which is 107.5 *m.a.m.s.l.*, and the operational water level of the dam is 104 *m.a.m.s.l.* with discharge 4000 m³/s. The full storage capacity of the dam is 3.76 billion cubic meters. Also, the dam is equipped with four irrigation outlets of 250 m³/s and a powerhouse that generates 50 MW with a total design flow rate of 200 m³/s. **Fig.1** shows different storage capacities against different water levels
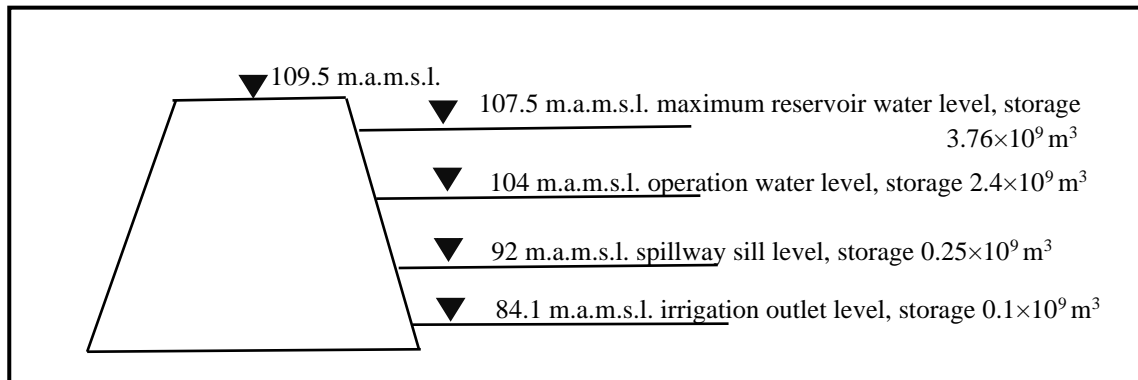

▼109.5 m.a.m.s.l.

▼ 107.5 m.a.m.s.l. maximum reservoir water level, storage
3.76×10⁹ m³

▼ 104 m.a.m.s.l. operation water level, storage 2.4×10⁹ m³

▼ 92 m.a.m.s.l. spillway sill level, storage 0.25×10⁹ m³

▼ 84.1 m.a.m.s.l. irrigation outlet level, storage 0.1×10⁹ m³

Figure 1. Different Storage Capacities vs. Different Water Levels of Hemrin Dam.

Regarding Diyala River originates in the Zagros Mountains in Iran, joins the Tigris 15 km south of Baghdad. It consists of three reaches, upper reach that lies upstream Hemrin dam, middle reach, which is sited between Hemrin dam and Diyala Weir, and lower reach extending from downstream Diyala Weir to the confluence of Diyala River and Tigris river.

At 10 km downstream of Hemrin Dam, Diyala Weir is located. Firstly, the objectives of its construction are raising the water level upstream the weir and regulating the water distribution to the tributaries on both sides of the upstream Diyala Weir and secondly, discharging the flood wave to the lower part of the Diyala River. The maximum water level upstream of the weir is 69 *m.a.m.s.l.* at which the discharge is 2660 m³/s, while the design water level is 67.5 *m.a.m.s.l.*, this data is according to the **Directorate of Diyala Water Resources (DDWR).**

Hemrin Dam and Diyala Weir form an integrated hydraulic system to make use of Diyala River, which plays a vital role in two aspects, firstly, disposing of the flood wave. Secondly, thriving the cities and agricultural lands situated on both sides of the river.

Recently, Diyala Governorate has been at the real risk of high floods because Hemrin Dam reached its full capacity during the flood period, and the flood waves have to be discharged to Diyala River. Because of the lack of regular maintenance of Diyala River cross sections, the capacity of the river was reduced to 750 m³/s (**DDWR, Flood Report of 2019),** in addition to overtaking along the banks of Diyala River, therefore, overtopping these banks during the flood period resulted in flooding large areas along Diyala River. The Directorate of Diyala Water Resources prepared a detailed report about the floods that occurred in 1988 and 2019. In 1988 and 2019, Hemrin Dam water levels were 105.7*m.a.m.s.l.* and 105.3*m.a.m.s.l.,* respectively, while the dam's normal water level is 104*m.a.m.s.l.* Also, the water levels of Diyala River were 44*m.a.m.s.l.* and 42.43*m.a.m.s.l.* in 1988 and 2019, in turn, as compared to the banks level, which is 41*m.a.m.s.l.* in Ba'quba City. After the flood of 1988, a flood escape was constructed from Diyala River, at 500*m* upstream Diyala Weir and toward Ashweicha Marsh, which was known as Salahdin Escape. This escape was constructed as a precautionary action after the flood, and it was not needed to be used until the flood of 2019. The lands along a part of the escape were illegally used for residential purposes and the establishment of villages. Consequently, during the flood of 2019, it was not possible to use Salahdin Escape as a flood escape or modify it under the current condition.

The aims of this study are to manage, suggest and design flood escape directly from Hemrin Lake and away from Diyala River to discharge the flood wave through it.

2. LAYOUT OF THE SUGGESTED FLOOD ESCAPE

By using Arc GIS software, the map shown in **Fig.2** was generated for the study area. It was found that there is an area that lies between Hemrin Dam and Ashweicha Marsh that can be used for passing the escape route. **Fig.2** shows a general layout of the proposed flood escape with a total length of 107.2 km. The escape intake was set at the left side of Hemrin Dam and passed to the south direction of Diyala Governorate towards Ashweicha Marsh. It joins the path of Salahdin Escape at location 37+000 km. Then, the escape ends at Ashweicha Marsh. The elevation map shown in **Fig.3** was extracted from the digital elevation model map through Arc GIS software. It shows the elevation range of the area that the escape passes through. It was used to identify the best flood escape route. The criteria of selecting the best route are to make the escape passes through geological areas that follow the ground levels and keep the cut and fill works as minimum as possible. Based on **Fig.3,** part of the escape length from the upstream side passes through an area with an elevation range from (95 to 120) *m.a.m.s.l.,* which is considered as relatively high elevations; besides, it is a rocky region (part of Hemrin mountains). Therefore, it is beneficial in terms of implementation to make the escape length passing through this zone as short as possible. Accordingly, only the first 15*km* of the flood escape passes through the area with an elevation range (95-120) *m.a.m.s.l.* The following 22 km passes through a lower elevation range of (41-62) m.a.m.s.l., an alluvial plain, the remaining part of the escape joins Salahdin Escape at 37+000 km. According to the Ministry of Water Resources, this remaining part of Salahdin Escape lies within the non- inhibited area. Therefore, it was utilized as a part of the suggested Hemrin Flood Escape.
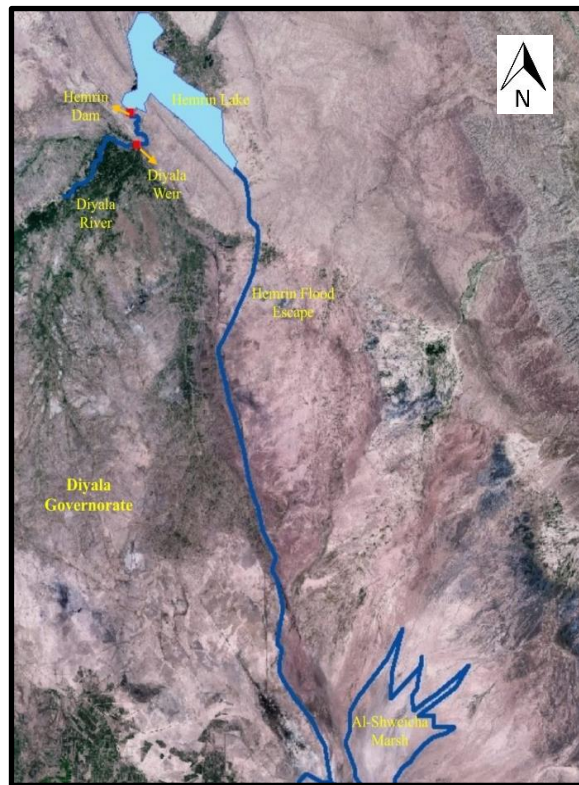
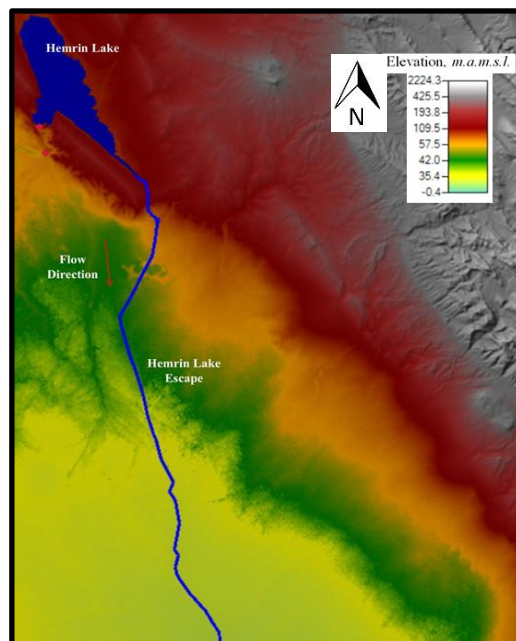**Figure 2.** General Layout of the Flood Escape, by Arc GIS 10.7.1, ESRI.

Figure 3. Elevation Range of the Study Area, by Arc GIS 10.7.1, ESRI.

3. ONE DIMENSIONAL HYDRAULIC MODEL

One dimensional hydraulic model was developed with the aid of HEC-RAS 5.0.7 software. HEC-RAS is software designed by the US Corporation Engineers, Hydraulic Engineering Centre, in order to simulate and analyze steady and unsteady flow in rivers. The software solves the fundamental equations of flow in open channels, including energy equation, momentum equation, and 1D Saint Venant Equation by using an iterative solution method.

One dimensional hydraulic model was carried out using geometric data and hydrological data; the geometric data includes Eighty -two cross-sections were extracted from the digital elevation model for the escape simulation. Besides, thirty cross-sections for the middle reach of the Diyala River were obtained from **the Study of Strategy for Water and Land Resources in Iraq, SWLRI, 2014**.

With the lack of available data about the area under study, the calibration and verification of the value of the Manning coefficient were not possible. Therefore, the roughness coefficient was evaluated as follows; the first value is 0.035 **(Chaudhry, 2008),** which was applied for the first 15*km* of the flood escape, a rocky area. Since the rest of the escape is located within the Diyala River basin, the second value was used by depending on the roughness coefficient of the Diyala River that was determined in (**SWLRI, 2014**), which is 0.028.

The hydrological data consists of two cases of discharge that were utilized as a boundary condition upstream of the flood escape. Firstly, extreme hydrograph of Hemrin Dam outflows with 500 years return period, which is 3000*m³/s,* according to **(SWLRI, 2014)**. Secondly, the design discharge of the Hemrin Dam spillway is 4000 m³/s. Since the recorded capacity of the Diyala River is 750 m³/s *(DDWR, flood report of 2019)*, this amount would be discharged into Diyala River through the Hemrin Dam spillway. Thus, the applied net flood discharge cases were 2250 m³/s and 3250 m³/s, in turn.

At the downstream side of the river and the escape, a normal depth was adopted as a boundary condition and computed with a slope of 0.00077 and 0.0003, respectively. These values were calculated from the longitudinal profile of the river and the downstream part of the escape.

To carry out the one- dimensional steady-state flow computation within the suggested escape, the following data were defined by using HEC-RAS 5.0.7 software:

- Schematic layout of Hemrin Lake, the flood escape, and the Diyala River was sketched. The escape and the river were sketched in the positive direction of flow. The river sketch started from downstream Hemrin Dam at the upstream side of Diyala River reach under study, and to the upstream of Diyala Weir downstream of Diyala River reached under study. In contrast, the escape was sketched from the upstream at Hemrin Lake towards the downstream direction, until Ashweicha Marsh, as shown in **Fig.2.**

- Cross section data: eighty-two cross sections for the escape were extracted from the digital elevation model of the study area that was generated with the aid of Arc GIS 10.7.1 software, and by using the feature of HEC- GeoRAS, the extracted cross sections data exported to HEC-RAS. The data of cross-sections include station along with the cross-section and elevation data, in addition to downstream reach lengths. On the other hand, 30 cross section data of Diyala River reach were located, and their data were defined. The data of these cross-sections include station and cross-section and elevation data, banks, and lengths of downstream reach. In addition to the two values of Manning coefficient 0.035 and 0.028

The boundary conditions used for running the model are: two values of flood wave 2250m³/s and 3250m³ /s were applied upstream the escape in two separate runs, with a normal depth as a boundary condition at the downstream that computed with slope 0.0003. Regarding Diyala River, 750 m³ /s was used as a boundary condition at the upstream and normal depth downstream with slope 0.00077.

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The model's output is shown in Fig. 4, a longitudinal profile of the flood escape with natural ground level without modification. Obviously, there is a rapid drop in ground level from 117.43*m.a.m.s.l.* to 67.57*m.a.m.s.l.* within 4.9*km*, the slope of this part is 0.01. Then, there was a sudden rise in the ground level to 78.39*m.a.m.s.l.,* after that, the level decrease to 43.25*m.a.m.s.l.* within 10.1 km. Consequently, this part of the escape needs special treatment to avoid any flow instability problems. So then, the ground level falls gradually, reaching the lowest point of 20.44*m.a.m.s.l.* at Ashweicha Marsh.
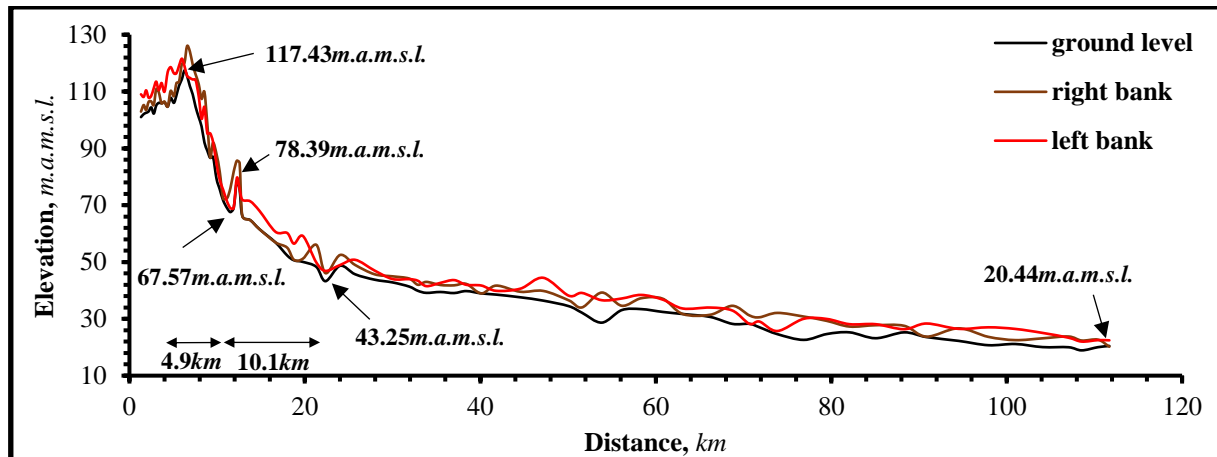

Figure 4. Longitudinal Profile of the Flood Escape Without Modification.

4. RESULTS AND DISCUSSION

The natural ground level was modified. This modification includes lowering the elevations of 117.43*m.a.m.s.l.* and 78.39*m.a.m.s.l.* shown in **Fig. 4**. In addition, a control structure is required upstream of the flood escape in order to control the desired discharge from Hemrin Lake through the escape at a specific water level. Moreover, a drop structure is carried out to prevent extreme erosion due to the steep slope, started from 3+053*km* until 21+300*km* of the escape layout. **Fig.5**. shows the longitudinal profile of the escape after modification.
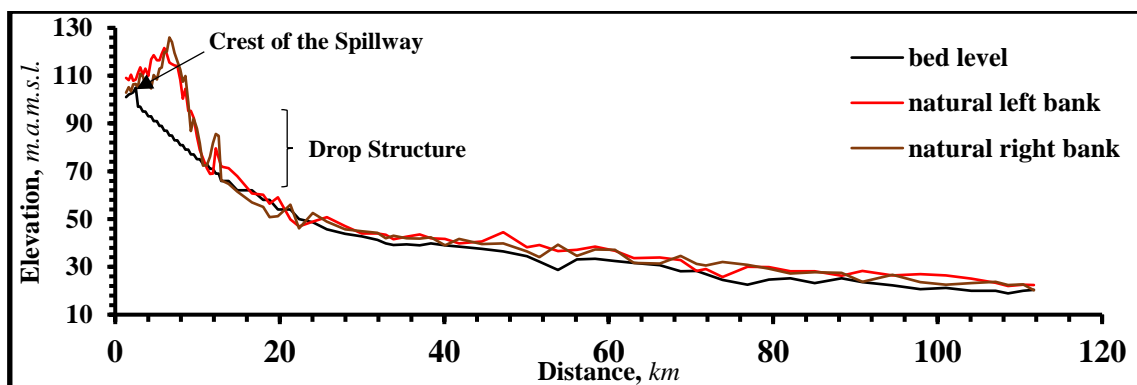

Figure 5. Longitudinal Profile of the Flood Escape After Modification.

An ungated ogee spillway was proposed at the beginning of the upstream of the flood escape as a control structure. The criteria to select the crest level are as high as possible, resulting in a water level that does not exceed the lake's maximum design water level of 107.5*m.a.m.s.l.* Many runs were conducted with different crest level values, starting with the operational water level of Hemrin Dam of 104*m.a.m.s.l.* and the maximum design water level of the lake of 107.5*m.a.m.s.l.* is not to be exceeded. Based on the ground elevation at the location of the spillway, the height of

the spillway was set. Accordingly, a crest level of 105*m.a.m.s.l.* was selected for both discharge cases of 2250*m³/s* and 3250*m³/s. T*he resulted widths of the spillway for these discharges were 258.7*m* and 373.7*m*, respectively. The base of the spillway at 97*m.a.m.s.l.* for both cases, the resulted water level at the crest is 107*m.a.m.s.l.,* which is less than the maximum water level. **Figs.6** and **7** show the cross section at the location of the spillway for the two discharges, in turn.
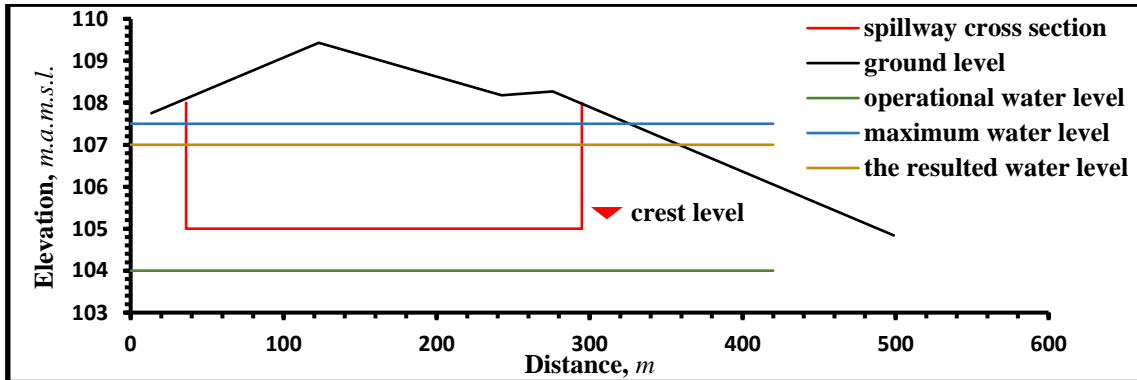
Figure 6. Cross section at the location of the spillway, a width of 258.7 m.
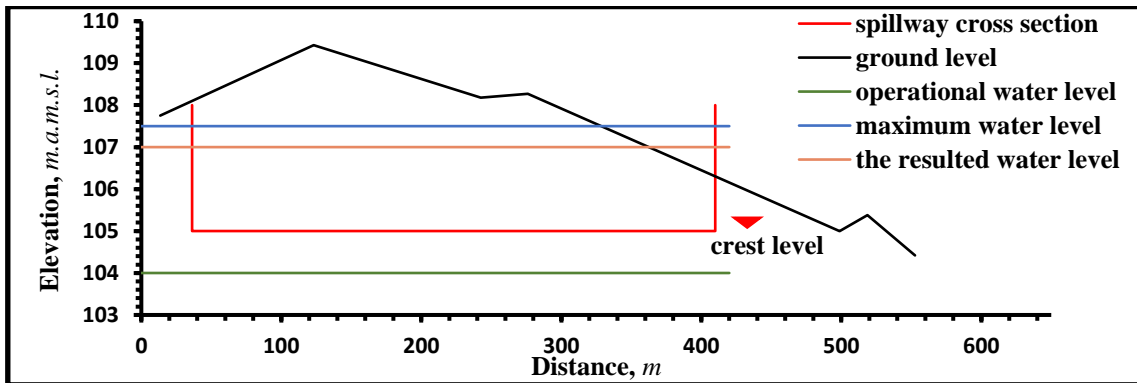
Figure 7. Cross section at the location of the spillway, a width of 373.7 m.

The drop structure includes two series of steps depending on the ground level difference, as shown by **Fig.8**. The first series of steps lies between the elevations 97*m.a.m.s.l.* and 69*m.a.m.s.l.,* within a distance of 9.5 km. This difference in elevation of 28 m was divided into fourteen steps with 2 m in height, and a length in the direction of the flow ranges between 290 m to 455 m depending on the ground level difference. This was followed by the second series of steps lies between the elevations 69*m.a.m.s.l.* and 54*m.a.m.s.l.* throughout a distance of 8.74 km. This series includes four steps. Each step has a 3.75 m elevation difference. The length ranges of the steps varied between 760 m and 1800 m. **Table 1** summarizes the details of the steps of the drop structures. The remaining length of escape follows the natural ground level with a mild slope of 0.0003, and it forms a natural stream.
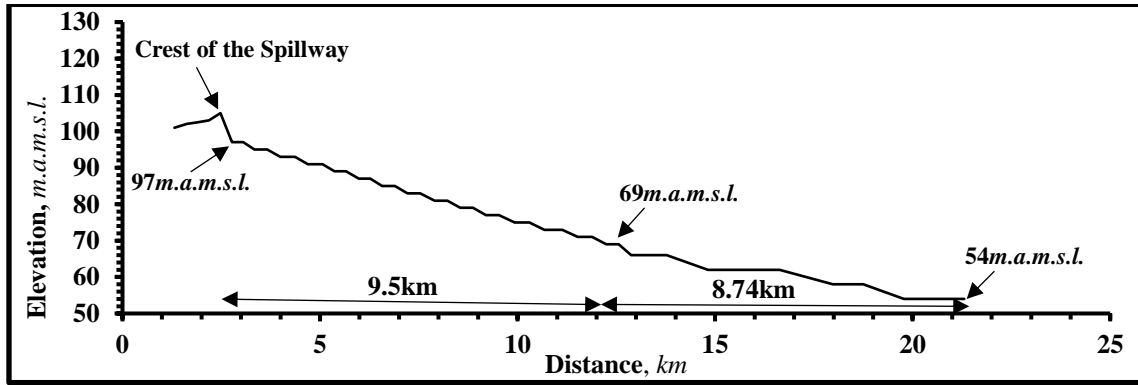
Figure 8. Details of the drop structure.

Table 1. details of the steps of the drop structures

Step series	Width, *m*	Height, *m*	Length, *m*	Number used
First	150	2	319	1
			368	2
			371	3
			291	4
			298	5
			324	6
			327	7
			326	8
			324	9
			328	10
			370	11
			455	12
			364	13
			315	14
Second	150	3.75	900	1
			1800	2
			760	3
			1500	4

Fig.9 presents the water level, natural bank level, and suggested levee level when discharging $2250m^3/s$. The results showed that the water level is higher than the bank level from station 11+500 km until the end of the escape. Hence, the bank level was increased by providing a levee from station 11+500 km until the end of the escape to prevent overflow over the escape banks and keeping a sufficient freeboard. Referring to **Fig. 4**. the bank levels differ in each location along with the escape. However, the resulted levee should be in regular slope, systematic, and uniform profile to provide a practical implementation. Therefore, the levee level values at location 11+500 km and the levee level at the last location of the escape were interpolated to obtain a levee level at each location along with the escape followed to obtain a levee with a regular longitudinal profile. As a result, the rising of the existing banks level ranged from 0.5*m* to 3*m*, giving freeboard value varied from 1*m* to 1.5*m*.

Each levee level was simulated in HEC-RAS as geometry data through the 'levee' feature; this feature allows to rise the bank level with a specified levee value in each cross section of the escape.
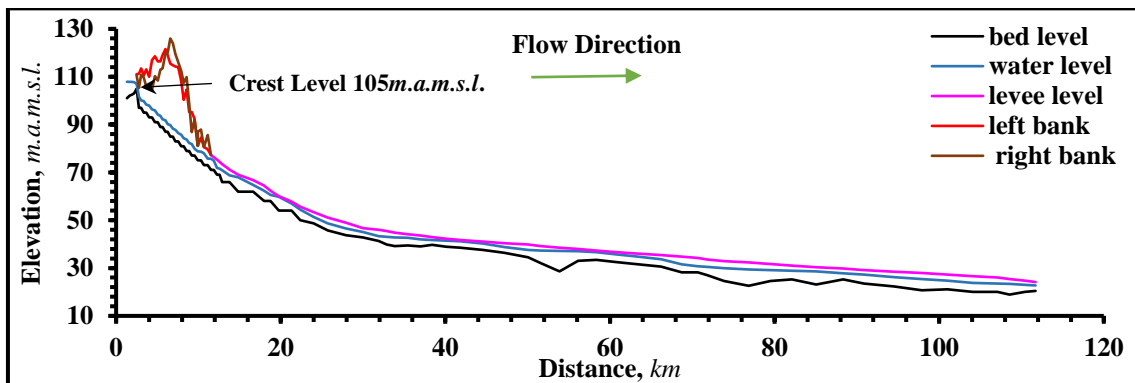

Figure9. Longitudinal profile of Hemrin Flood Escape at a flood discharge of 2250m^3/s

Fig.10 shows the water level, natural bank level, and suggested levee level when discharging 3250m^3/s. The suggested levee is selected to raise the bank's level from location 11+500 km until the end of the escape by 0.5 m to 3.5 m above the banks to prevent flooding over the escape banks. The levee rise was based on obtaining a longitudinal profile with a uniform slope and keeping an adequate freeboard at the same time. Therefore, the freeboard varied from 1 m to 2 m.
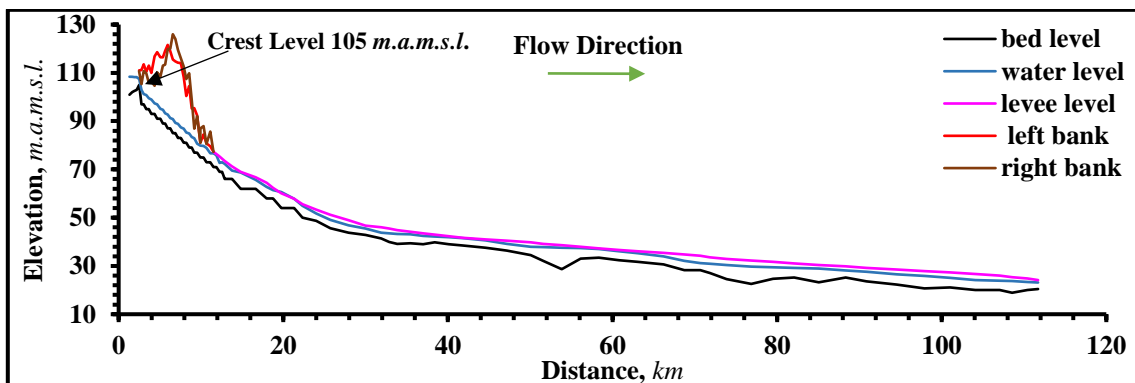

Figure10. Longitudinal Profile of Hemrin Flood Escape at a flood discharge of 3250m^3/s.

5. CONCLUSIONS

The necessity to construct additional flood escapes to discharge flood waves from Hemrin Dam and keep Diyala Governorate safe emerged after the real flood risks in 2019, similar to the flood of 1988. The well-known HEC-RAS 5.0.7 was used to develop one dimensional hydraulic model for the flood escape to discharge the flood wave through it. The escape branched from Hemrin Lake and passes to the south of Diyala Governorate until Ashweicha Marsh. According to the analysis of the results, the following conclusions are made:

- The flood escape could be achieved with length of 107.2 km, it can accommodate the flood wave safely after applying many modifications.

- In the case of adopting an ungated spillway, the best crest level is 105*m.a.m.s.l.,* resulting in a water level of 107*m.a.m.s.l.* over the crest, which is less than the maximum water level of Hemrin Lake by 0.5 m.
- Depending on the flood wave, the width of the spillway would be selected. For example, a spillway width would be 258.7 m for a flood wave of 2250 m^3/s. While for 3250 m^3/s, the width would be 373.7 m.
- The spillway was followed by a drop structure that was suggested to eliminate the steep slope, this drop structure consists of 18 steps.
- For both flood wave cases, the flood escape banks need to be raised by a levee from location 11+500 km until the end of the escape to avoid banks overtopping. The rising height varied from 0.5 m to 3.5 m that giving a freeboard of 1 m to 2 m.
- Since the maximum storage capacity of the dam at 107.5*m.a.m.s.l.,* therefore, constructing a spillway with a crest level of 105*m.a.m.s.l.* will cause a reduction in the dam storage capacity by 1.1×10^9 m^3.

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