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Riverbed Scour Due to Accumulation of Floating Debris on Al-Msharah Bridge Piers

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Abstract

This paper aims to implementing and run a study hydraulic simulation model by using the HEC-RAS software to simulate the flow in AL-Msharah River and studying the effect of floating debris accumulation on Al-Msharah Bridge piers on the flow conditions upstream the bridges and estimating the scour development according to this effect.

All the required geometric, hydrological and riverbed material data were provided by Ministry of Water Resources, Iraq. These data were adopted for implementing the hydraulic simulation model. The effects of debris accumulation at the bridge piers were studied according to the present state of the river through considering six inflow discharge 5, 10, 15, 20, 25, and 30 m^3/sec each with a range of floating debris dimensions (width, m × depth, m) up to (2m×2m).

Results of applying the implemented hydraulic model showed that accumulation of debris on the bridge piers for more than 1m×1m increase the water surface elevation upstream the bridge to about 1m with the case of maximum discharge of 30m^3/sec and debris of 2m×2m and increase the flow velocity and changing the flow velocity distribution within the bridge cross-section by about 15 to 20%.

The total main channel scour depth increase from 0.77 m for the case of no debris with minimum discharge, 5 m^3/sec, to 1.9 m for the case of 2m×2m debris with maximum discharge, 30 m^3/sec.

According to these results it is recommended that accumulated debris on AL Msharah Bridge piers must be carefully monitoring when its dimensions became more than 1m×1m and it must be removed from the bridge piers when its dimensions become more than 2m×2m because the resulted scour damage the bridge.

Keywords: Scour, Floating Debris, Accumulation and Al-Msharah Bridge

Introduction

Al-Msharah River extends from the center of Al-Am'arah city to the center of Al-Msharah city, Iraq, Fig. 1, about 32.5 km, and from the center of Al-Msharah city toward Al-Huwayza Marsh, about 16.5 km, the latter part is about 15 km long called Al-Malah River and discharges in AsSanna'f Marsh close to AsSodda bridge at AsSanna'f Marsh outfall to Al-Huwayza Marsh, New Eden group (2005).

Al-Msharah River feeds fifteen irrigation channels along its length. All these channels are located on the right side of the river.

The flow cross sectional area of last part of Al-Msharah River, Al-Abbter River, is narrow and very shallow. Currently, the water at the end of Al-Msharah River is diverted to re-flood an area located to the right of its end

Al-Msharah Bridge, locally named, Al-Handasy, is a steel bridge constructed at 1982 for a military proposes, Fig. 2, and then continued to use for serving the residents of the area.

Floating twigs of trees, reeds and papyrus accumulated on the bridge piers especially with the high flow, Fig. 2. This may increase the river bed scour and damages or destroying the bridge.

This paper aims to study the effect of floating debris accumulation at Al-Msharah Bridge piers on the flow conditions upstream the bridges and estimate the scour development according to this effect. This can be achieved through implementing and run a study hydraulic simulation model by using the HEC-RAS (Version 4.0.0) software, (HEC, 2008), to simulate the flow in AL-Msharah River.

Flow Routing Hydraulic Models

A steady one dimensional flow hydraulic model, using the HEC-RAS, was used to simulate the flow in Al-Msharah River and to study the effect of accumulating floating debris at Al-Msharah Bridge piers on the flow conditions upstream the bridges and estimating the scour development according to this effect.

Theoretical Concepts

The water surface profiles are computed from one cross section to the next by solving the energy equation with an alternative procedure called the standard step method. The energy equation is written as follows:

$$y_1 + \frac{\alpha_1 v_1^2}{2g} + z_1 = y_2 + \frac{\alpha_2 v_2^2}{2g} + z_2 + h_e \quad \text{….. (1)}$$

Where:
α_1, α_2: kinetic energy correction factor
y_1, y_2:depth of water at cross-section, m.
z_1,z_2: elevation of the main channel inverts, m.
v_1, v_2: Averaged velocity at the section, m/sec.
g: gravitational acceleration, m/sec^2.
he: head loss, m.

The head loss in a reach of length *L* may be calculated as:

$$h_e = L * \bar{S}_f + C\left[\frac{\alpha_1 v_1^2}{2g} + \frac{\alpha_2 v_2^2}{2g}\right] \quad \text{….. (2)}$$

Where:

$\bar{S}_f$: Representative friction slope between the two sections.
C: Expansion or contraction loss coefficient.

The bridge routines in HEC-RAS allow the modeler to analyze a bridge with several different methods without changing the bridge geometry.

There are four methods available for computing losses through the bridge when the flow going through the bridge opening is open channel flow and the water surface through the bridge is completely subcritical, (Yarnell, 1991):

- Energy equation (standard step method)
- Momentum balance
- Yarnell equation
- FHWA WSPRO method

Computation of scour at the bridges within the HEC-RAS is based upon the methods outlined in Hydraulic Engineering Circular No. 18 (HEC No. 18, FHWA, 1995). This publication recommends using a modified version of Laursen's (Laursen, 1960) live-bed scour equation, Eq. (3), for estimating the live-bed contraction scour.

$$y_2 = y_1 (Q_2/Q_1)^{6/7} (W_1/W_2)^{k1} \quad \text{….. (3)}$$

Where:
y_s= Average depth of contraction scour in (m).
y_2= Average depth after scour in the contracted section, (m).
y_1= Average depth in the main channel or floodplain at the approach section (m).
y_0= Average depth in the main channel or floodplain at contracted section before scour , (m).
Q_1= Flow the main channel of floodplain at the approach section which is transporting sediment, (m^3/s).
Q_1= Flow the main channel of floodplain at the approach section which is transporting sediment (m^3/s).
W_1= Bottom width in the main channel or floodplain at the approach section, (m).
W_2= Bottom width in the main channel or floodplain at the contracted section, (m).
k_1 = Exponent for mode of bed material transport.

A local pier scour equation developed by David Froehlich , Eq. (4), (Froehlich, 1991), has been used for computing the pier scour.

$$y_s = 0.32\ \varphi(a)^{0.62}\ y_1^{0.47}\ Fr_1^{0.22}\ D_{50}^{-0.09} + a \quad \text{….. (4)}$$

Where
ϕ= Correction factor for pier nose shape: ϕ = 1.3 for square nose piers; ϕ = 1.0 for rounded nose piers; and ϕ = 0.7 for sharp nose (triangular) piers.
a= Projected pier width with respect to the direction of the flow, (m).

According to the flow and embankment characteristics the Hire equation, Eq. (5)**,** (Richardson, 1990)**,** was used for computing local scour at abutments.

$$y_s = 4\ y_1\ (K_1/0.55) K_2\ Fr_1^{0.33} \quad \text{….. (5)}$$

Where:
y_s = Scour depth in (m).
y_1= Depth of flow at the toe of the abutment on the overbank or in the main channel, (m), taken at the cross section just upstream of the bridge.
K_1= correction factor of abutment shape.
K_2 = correction factor for angle of attack (θ) of flow with abutment.
θ=90 when abutment are perpendicular to flow, θ < 90 if embankment points downstream, and θ> 90 if embankment point upstream. K_2=(θ/90)0.13.
Fr_1 = Froude number based on velocity and depth adjacent and just upstream of the abutment toe.

Geometrical Data

CRIM, 2006, conducted a topography cross sectional survey for the river up to A1-Huwayza Marsh at 24 stations. Al Msharah Bridge geometry was as shown in Fig. 3. All the hydraulic structures and obstacles were taken in consideration.

The values of Manning's roughness were taken as estimated, results of calibration and verification process, by Al-Khafaji, 2008. These values ranged between 0.25 to 0.05 for the main channel and the overfill banks at the upstream end to 0.060 for the overfill banks at downstream end of the river.

The grain size distribution of the riverbed material at the bridge is as shown in Fig. 4, (Ministry of Water Resources, 2012). About 55% of the material is clay, 40% is silt and only 5% is fine sand. The median size of this material d_{50} is equal to 0.0035 mm. and d_{95} is 0.075mm.

Seventeen cases of debris dimensions, Table 1, were studied according to the expected accumulation of the floating twigs of trees, reeds and papyrus.

Upstream Boundary Condition

The HEC-RAS model deals with the boundary conditions depending on the flow regime. In a subcritical flow regime, which is the flow regime in the river under consideration, boundary conditions are only necessary at the downstream ends of the river system and deal with its data in a separated window.

Six inflow discharge (5, 10, 15, 20, 25, and 30 m^3/sec) were taken in consideration for studying the effect of debris on the contraction and bridge scour. These discharge covering must of the flow conditions in the river. All the discharges of the branched irrigation canals were taken equal to zero to consider the worst flow case.

Downstream Boundary Conditions

A known water surface elevation boundary condition type was adopted in all runs of the model. The downstream boundary conditions of a known water surface elevation are listed in Table 2.

Selection of these values was based on recorded hydrological data, (CRIM, 2007).

Results And Discusion

The results of running the implemented hydraulic model shows that the water surface elevations and flow velocity along the river for the considered inflow discharge cases (5, 10, 15, 20, 25, and 30 m^3/sec) without debris**,** were as shown in Figures 5 and 6, respectively.

Results of running the model for the same cases of inflow discharges with the considered cases of debris accumulation, show that the flow characteristics, velocity and water surface elevation, did not affected by the accumulated debris for the cases of 0.5m×0.5m and 0.5m×1.0m. The water surface elevation and flow velocity along the river for the cases 1.0m×1.0m and 2.0m×2.0m were as shown in Figures 7 to 10.

These figures show that accumulation of debris on the bridge piers for more than 1.0m×1.0m increase the water surface elevation upstream the bridge to about 1m in the case of maximum discharge of 30m^3/sec and debris of 2.0m×2.0m.

Effect of accumulated debris on the flow velocity distribution at the bridge cross-section for the cases of inflow discharge 30m^3/sec without debris and with accumulated debris of 1.0m×1.0m and 2.0m×2.0m, are shown in Figures 11 to 13, respectively. These figures show that accumulation of debris on bridge piers for more than 1.0m×1.0m increase the flow velocity and changing the flow velocity distribution within the bridge cross-section by about 15 to 20% in the case of maximum discharge of 30m^3/sec and debris of 2.0m×2.0m.

The estimated total scour at the bridge for the considered cases of inflow discharge without debris and with the considered cases of debris accumulation were as shown in Fig. 14.

These results show that the total main channel scour depth increase from 0.77 for the case of no debris with minimum discharge, 5 m^3/sec, to 1.99 for the case of 2.0m×2.0m debris with maximum discharge, 30 m^3/sec as shown in Figures 15 and 16.

Conclusions

Debris substantially affects bridge scour in several ways. A build-up of material reduces the size of the waterway under a bridge causing contraction scour in the channel. A build-up of debris on the abutment increases the obstruction area and increase local scour. Debris deflects the water flow, changing the angle of attack, increasing local scour. Debris might also shift the entire channel around the bridge causing increased water flow and scour in another location.

The results of applying the implemented hydraulic model showed that accumulation of debris on the bridge piers for more than 1.0m×1.0m increase the water surface elevation upstream the bridge to about 1m with the case of maximum discharge of 30m^3/sec and debris of 2.0m×2.0m and increase the flow velocity and changing the flow velocity distribution within the bridge cross-section by about 15 to 20%.

The total main channel scour depth increase from 0.77 for the case of no debris with minimum discharge, 5 m^3/sec, to 1.99m for the case of 2.0m×2.0m debris with maximum discharge, 30 m^3/sec. Accordingly, it is recommended that accumulated debris on Al-Msharah Bridge piers must be carefully monitoring when its dimensions became more than 1.0m×1.0m and it must be removed from the bridge piers when its dimensions become more than 2.0m×2.0m because the resulted scour damage and may be destroyed the bridge.

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Table 1: Dimensions of the accumulated debris.

Case	Debris width (meter)	Debris height (meter)
1	0.0	0.0
2	0.5	0.5
3	0.5	1.0
4	0.5	1.5
5	0.5	2.0
6	1.0	0.5
7	1.0	1.0
8	1.0	1.5
9	1.0	2.0
10	1.5	0.5
11	1.5	1.0
12	1.5	1.5
13	1.5	2.0
14	2.0	0.5
15	2.0	1.0
16	2.0	1.5
17	2.0	2.0

Table 2: Downstream boundary conditions, River stage, [CRIM, 2007].

Flow , (m^3/sec)	D/S boundary condition, Stage, (m.a.s.l)
5	5.66
10	5.80
15	5.93
20	6.08
25	6.38
30	6.66

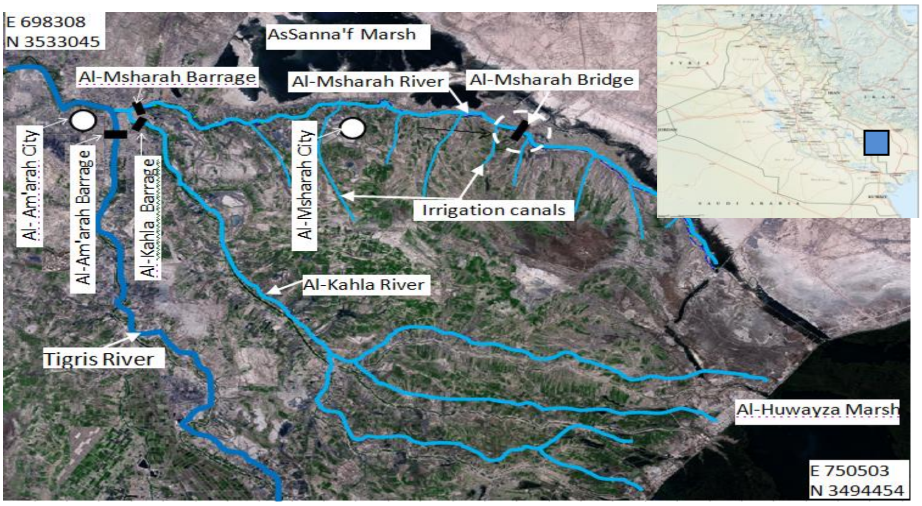


Figure 1: Schematic Layout of Al- Msharah River.

Figure 2: Al- Msharah Bridge

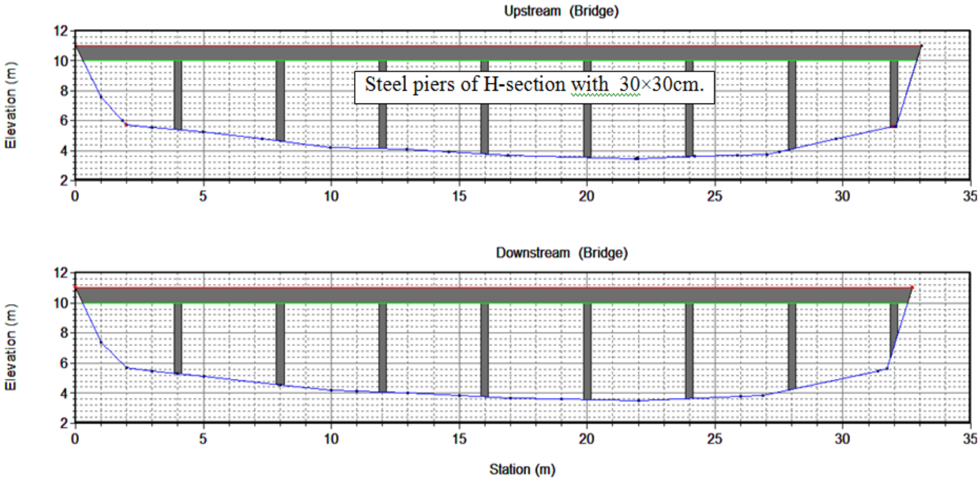


Figure 3: Geometry of Al-Msharah Bridge

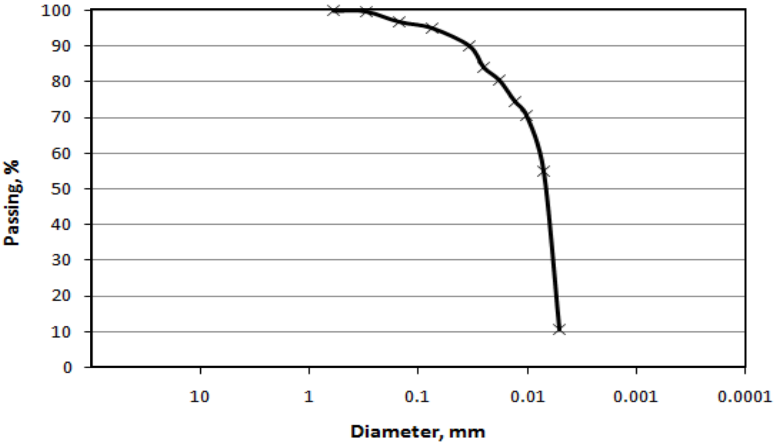


Figure 4: Grain size distribution of the riverbed material at the bridge.

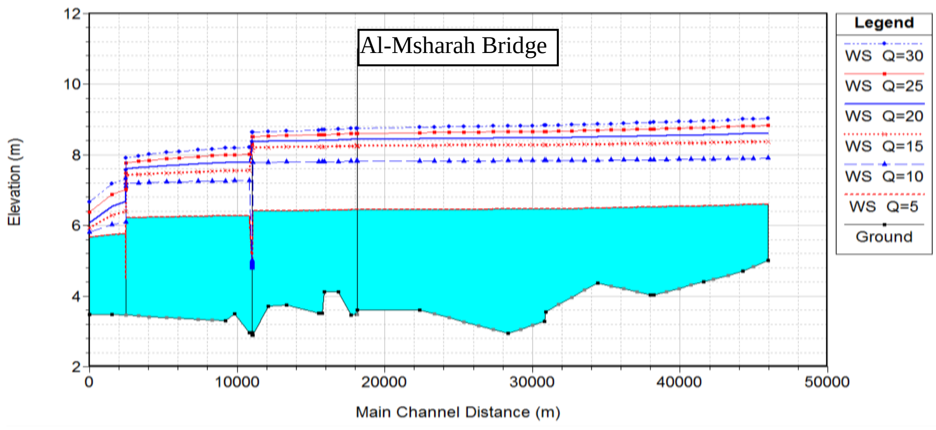


Figure 5: Water surface profiles for the considered inflow discharge cases without debris.

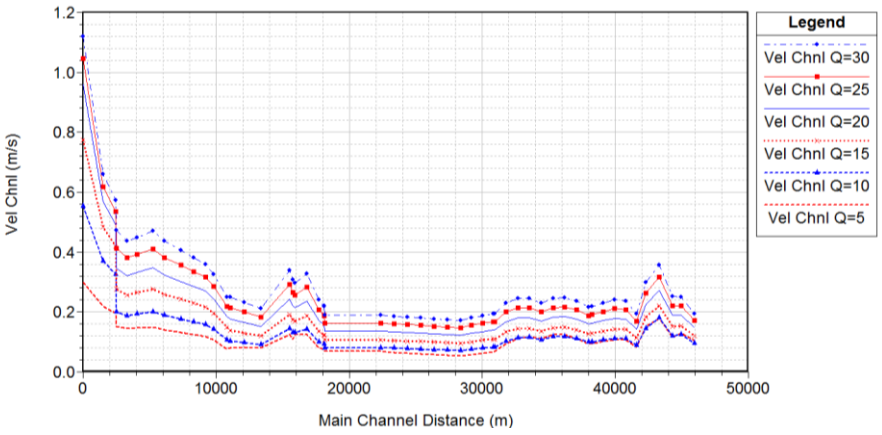


Figure 6: Flow velocity profiles for the considered inflow discharge cases without debris.

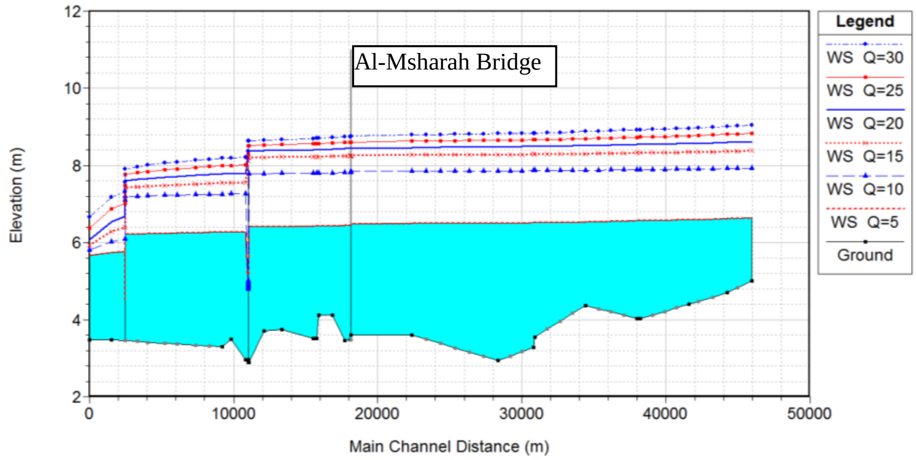


Figure 7: Water surface profiles for the considered inflow discharge cases with 1m×1m debris.

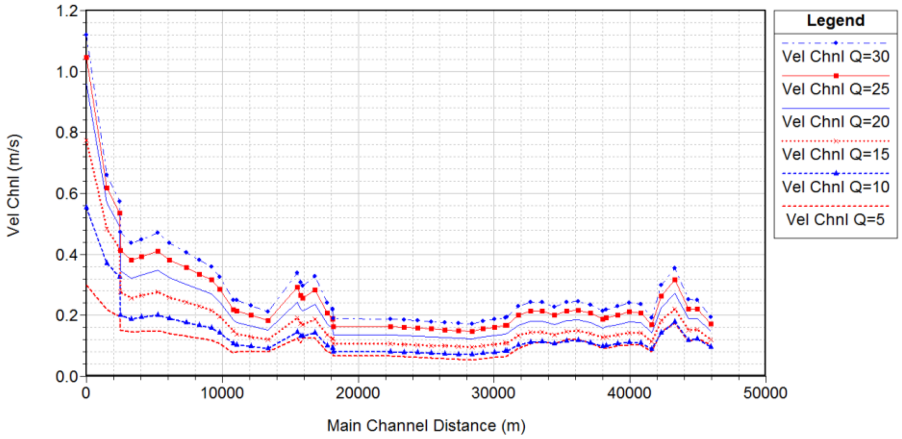


Figure 8: Flow velocity profiles for the considered inflow discharge cases with 1m×1m debris.

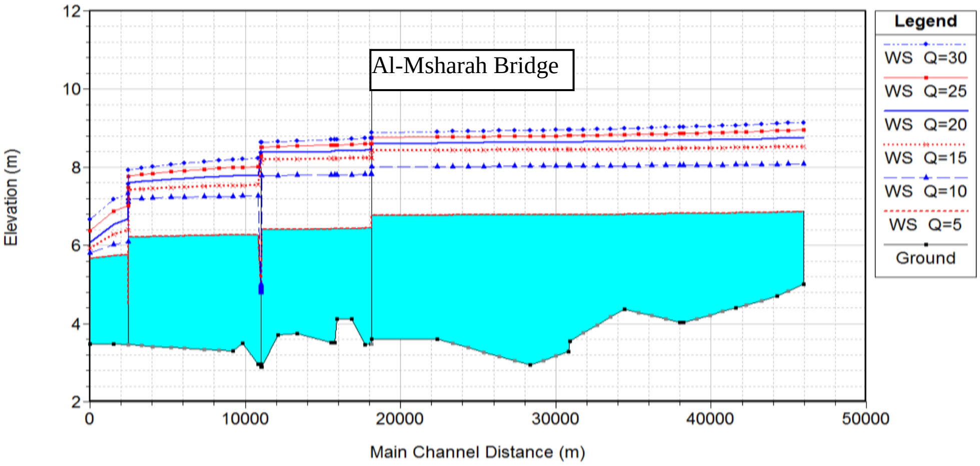


Figure 9: Water surface profiles for the considered inflow discharge cases with 2m×2m debris.

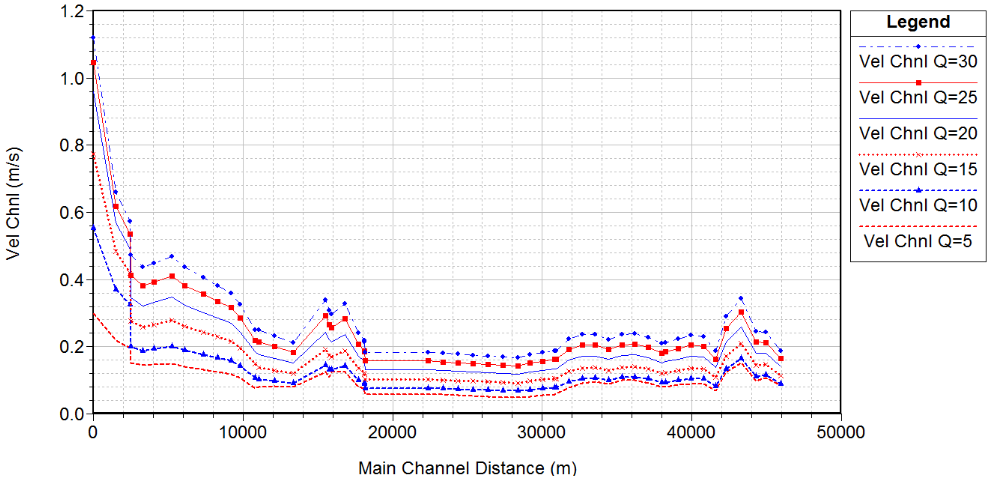


Figure 10: Flow velocity profiles for the considered inflow discharge cases with 2m×2m debris.

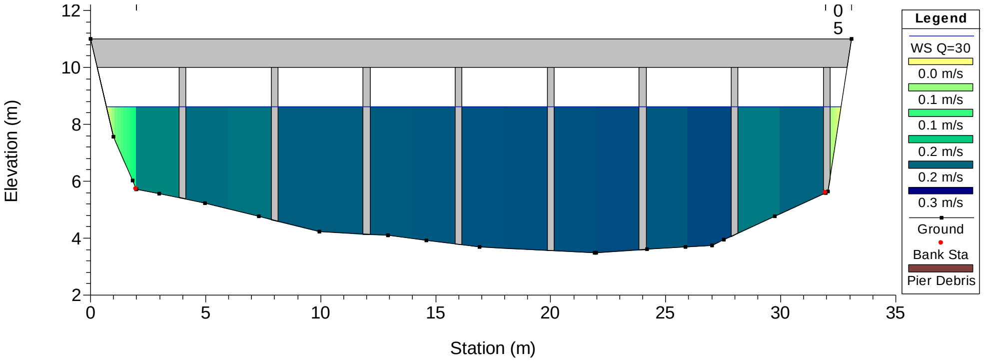
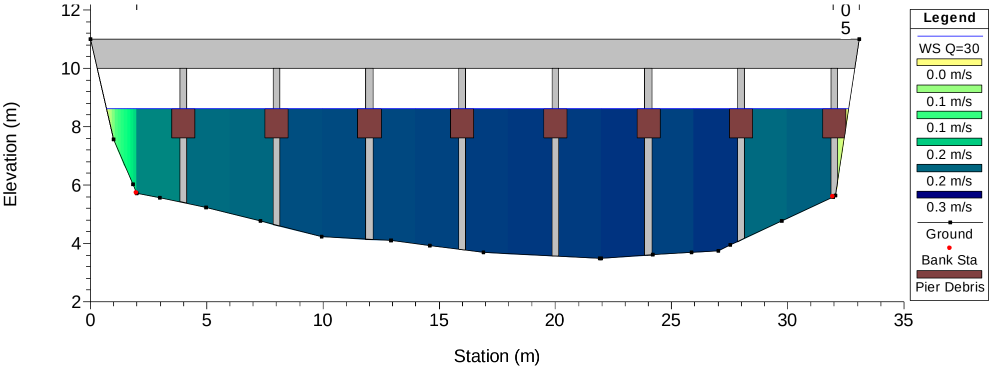


Figure 11: Flow velocity distribution at the bridge cross-section for Q=30 m^3/sec without debris.



Figures 12: Flow velocity distribution at the bridge cross-section for Q=30 m^3/sec with 1m×1m debris.

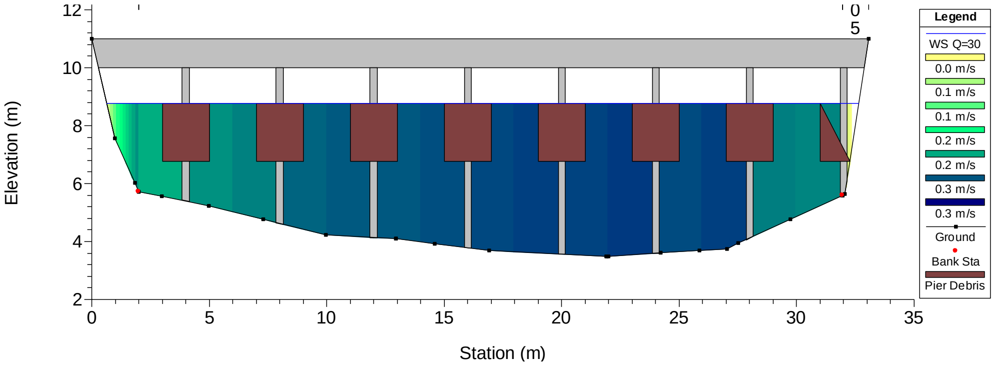


Figure 13: Flow velocity distribution at the bridge cross-section for Q=30 m^3/sec with 2m×2m debris.

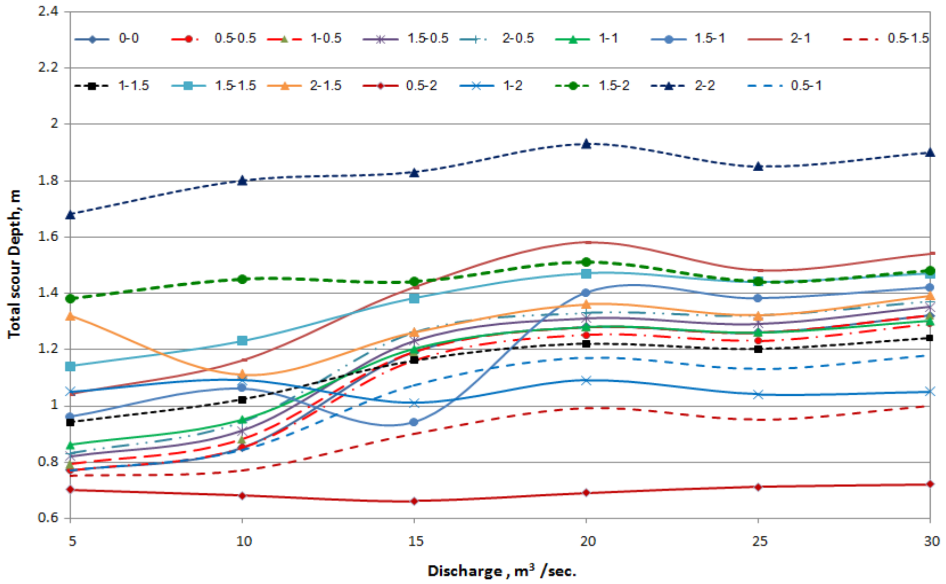


Figure 14: Estimated total scour depth for the studied cases.

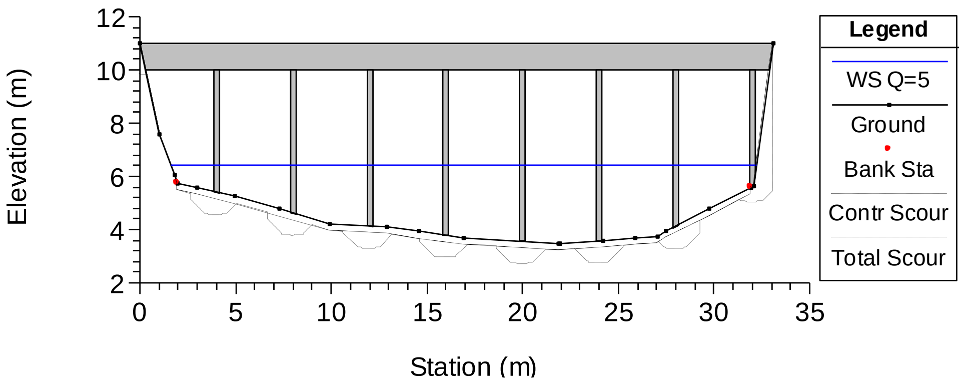


Figure 15: Estimated scour depth at the bridge cross-section for Q=5 m^3/sec without debris.

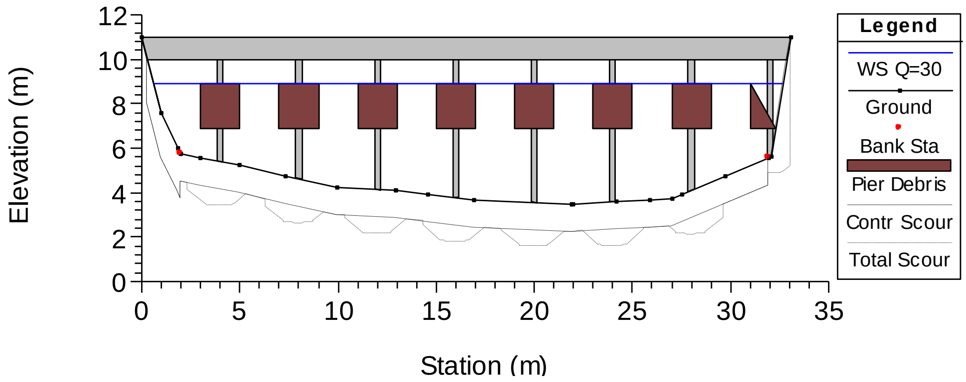


Figure 16: Flow velocity distribution at the bridge cross-section for Q=30 m^3/sec with 2m×2m debris.

نحر قاع النهر بسبب تراكم الانقاض عند جسرالمشرح

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الخلاصة:

يهدف هذا البحث إلى اعداد وتشغيل نموذج محاكاة هيدروليكي باستخدام برنامج HEC-RAS لمحاكاة الجريان في نهر المشرح ودراسة تأثير تراكم الحطام العائمة على اعمدة الجسر تحت ظروف الجريان في مقدم ومؤخر الجسر وزيادة النحر وفقا لهذا التأثير.

كل البيانات الخاصة بالشكل الهندسي والبيانات الهيدروليكية وخصائص مواد قاع النهر تم تجهيزها من قبل وزارة الموارد المائية، العراق. وقد اعتمدت هذه البيانات لتنفيذ نموذج المحاكاة الهيدروليكي للجريان الثابت احادي البعد.

تم دراسة تأثير تجمع المواد الطافية على دعامات الجسر وفقاً للحالة الحالية للنهر من خلال دراسة ستة حالات من التصاريف 5 و 10و 15 و 20 و 25 و 30 م^{3}/ثا كل تصريف تم دراسته مع مدى من ابعاد المواد الطافية المتجمعة (عرض, م × طول, م) لغاية (2×2).

بينت نتائج تطبيق النموذج الهيدروليكي المعد ان تجمع المواد الطافي على دعامات جسر المشرح بابعاد اكثر من 1م ×1م يؤدي الى زيادة منسوب سطح الماء في مقدم الجسر حوالي 1م عند حالة التصريف الاقصى 30م^{3}/ثا وابعاد مواد طافية 2م×2م ويزيد من سرعة الجريان ويغير توزيع سرع الجريان عند مقطع الجسر بحوالي 15 الى 20%.

كما ان نتائج تطبيق النموذج بينت ان عمق النحر في القناة الرئيسية يزداد من و 0.77م في حالة عدم وجود مواد طافية مع حالة اقل تصريف, 5م^{3}/ثا, الى 1.9م لحالة وجود مواد طافية بابعاد 2م×2م مع حالة التصريف الاعظم, 30م^{3}/ثا.

وفقاً لهذِهِ النتائج تم التوصية بان يتم مراقبة تجمع المواد الطافية عند دعامات جسر المشرح بعناية وخاصة عندما تصبح ابعادها اكثر من 1م×1م ويجب ازالة المواد الطافي المتجمعة من دعامات الجسر عندما تصبح ابعادها اكثر من 2م×2م لان عمق النخر في هذِهِ الحالة قد يكون كبيراً الى درجة تدمير الجسر.