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ANALYSIS OF THE HYDRAULIC CHARACTERISTICS OF AL MAHAWIL STREAM USING HECRAS: A FIELD STUDY

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ABSTRACT

A water resources management for earthen canal/stream is introduced through creating a combination procedure between a field study and the scientific analytical concepts that distinguish the hydraulic problems on this type of stream with using the facilities that are available in HECRAS software; aiming to point the solutions of these problems. Al Mahawil stream is an earthen canal which is subjected to periodic changes in cross sections due to scour, deposition, and incorrect periodic dredging processes due to growth of the *Ceratophyllum* plants and weeds on the bed and banks of the stream; which affect the characteristics of the flow. This research aims to present a strategy of water resources management through a field study that conducted to analyse the hydraulic characteristics of this stream. The flow in the stream is simulated by one dimensional steady flow mathematical model using HECRAS software with three cases; case1 (design); case2 (actual); and case[3] (without impermissible fish lakes). The flow characteristics are analysed as a steady gradually varied flow. The verification of the HECRAS program is carried out through field works. The results showed that the Al Mahawil stream is sufficient for irrigation purposes of the design case; while there is a fluctuation in the flow characteristics, and deficit in the discharge in the other cases. It is concluded that the control on the illegal watercourse, water plants, and fish lakes and redistribution them along this stream are the justified ways that insure the justice distribution of water and avoid the conflicts among farmers.

KEY WORDS : Hydraulic characteristics of flow, Steady gradually varied flow, Al Mahawil Stream, HECRAS, Periodic dredging processes

INTRODUCTION

Streams are one of the important sources of water that are either man made or natural branches from one of the main rivers located within a given area. The urgent requirements from these streams are the distribution and delivery of water to different agricultural lands within the villages and for various purposes such as water plants, irrigation, and various municipals uses. The problems in some of these streams; especially the earth one; it is not matching the sections of the actual stream with the design sections as a results of scours and depositions processes, after a long time of design, and the growth of weeds on the banks and bed of the stream. This leads to failure in achieve the required discharges and change in water levels as well as change in the velocity of water flow as a result failure to achieve the goal and purpose from these streams.

Several researches described the procedure of using HECRAS to analysis the hydraulic characteristics of the streams around the world; however (Barber and Perkins, 2000) presented a simulation to evaluate stream restoration options after dam removal using HECRAS where once the dams are removed, the streams will create channels through the sediments, scouring this material and carrying it downstream. (Lee *et al.*, 2006) determined the influence of the bridge blockage and the BaTu overbank flow on the water stages in the Keelung River during Typhoon Nari. The floating-pier-debris module and the lateral-weir module in the Hydrologic Engineering Center–River Analysis System_HECRAS_unsteadyflow routing model were applied to investigate water stage variation due to the bridge blockage and overbank flow. (Traore *et al.*, 2015) used HecRAS model to compute the flow characteristics to analyze the hydraulic behavior of Kayanga River in Senegal to develop irrigated agriculture through rice cultivation to promote the food safety. This study provides an opportunity for stakeholders to identify important elements of irrigated agriculture for investment plans in this area. Husain (2017) described the application of HECRAS to provide a flood control system in river training issues. It is found in this research that HECRAS is a suitable tool to simulate flood depth in different part of the flood plains. (Mustafa *et al.*, 2017) used HECRAS to evaluate the sediment transport and to assess the quality of water for a reach of Euphrates River with a length of (124.4 km), beginning from downstream of Haditha dam which represents the upstream of study, and ends at Heet station in Heet city which represents the downstream by using the model of onedimensional HECRAS model (Boudaghpour and Rezapurem, 2018) evaluated Ajichy River pollution at flood through inventing new methods of counting pollutions that they cause saltiness at around river grounds on flooding times by applying HecRas software (Ogras and Onen, 2020) studied the flood hazard in Turkey. It is found in this study that the HECRAS model is able to simulate the surface profiles formed in different recurrent flows of the Tigris River in Diyarbak1r, as well as that the flood boundaries in a public area can be easily obtained by using the HECRAS package program.

The aim of this research is to analysis the hydraulic characteristics of AlMahawil stream; located in Al Mahawil city within Babylon Government in Iraq; using the facilities which available in HECRAS. The hydraulic characteristic includes all parameters that may strongly affected by the incorrect periodic dredging processes; such as; flow capacity, velocity, flow profile, flow depth and so on. These parameters effect on the efficiency of Al Mahawil stream for irrigation purposes and human activities.

This aim achieved through steady the effects of the following parameters on the flow characteristics and the capacity of stream:

1. Steady the effects of scour and deposition processes, after a long time more than 80 year of design on the actual sections of the current stream.
2. Steady the effects of growth the weeds and the Ceratophyllum plants on the banks and bed of the stream.
3. Evaluate the effects of periodic dredging (removal accumulation of sediment, debris, and plants from stream). Seasonally, Al Mahawil Stream set to dredging by government office to insure reaching water to the farthest region downstream the stream for irrigation and other uses; as shown in Fig. 1.

Fig. 1. Dredging process on AlMahawil stream

4. Evaluate the effects of unpermissible fish lakes. There are a large number of unpermissible fish lakes and water plants at different locations; as shown in Fig. 2.

MATERIALS AND METHODS

Theoretical Background

The flow in open channels can be simulated using steady or unsteady hydraulic models. These models can be implemented using limited software. HECRAS is the one of this limited popular software that used to analyze the flow in open channels. It is designed for interactive use in a multitasking, multiuser network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities (Gary, 2016). One of the

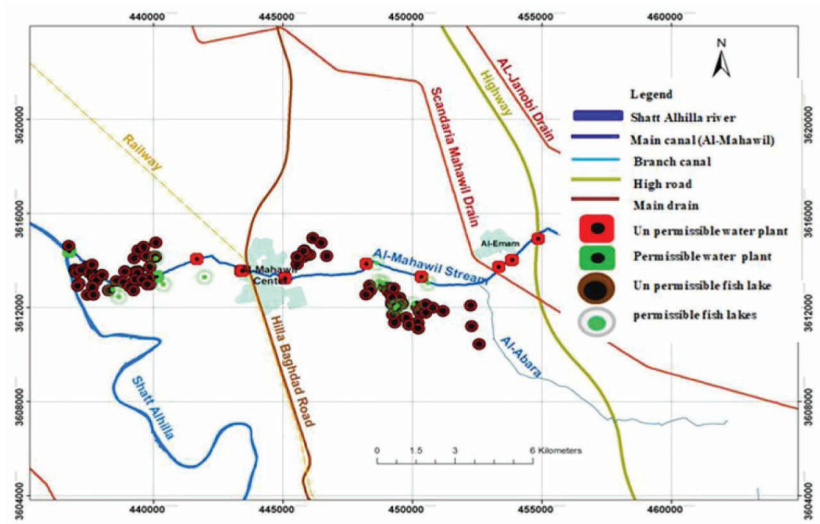


Fig. 2. Permissible and unpermissible features on AlMahawil stream

important principles usually used in analyzing the flow in open channel that is the conservation of energy (Chow, 1959). The energy equation is:

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

Description of steady area

Al Mahawil Stream is an earthen canal branched from the left side at 9.08 Km of Shatt Alhilla River which is located in Babylon City, Iraq; and have two branches; namely; Al Abarra and Amyat AlBasha; as shown in Fig. 3. It is 29.50 kM long and feeds water to the 72 right watercourses and 84 left watercourses. These watercourses service about 25250 hectare of irrigation areas, 625 hectare are orchards and 24625 hectare are agricultural lands (Directorate of Water Resources in Babylon, 2019).

Fig. 3. Aerial image of Al-Mahawil stream

Mathematics Model

The one dimensional hydraulic model is prepared by HECRAS for simulation the flow in Al Mahawil stream, is considered as a steady gradually varied flow. Three cases are considered in the modelling: case1 (design) which is the original situation at designed stage since 1940AD; case2 (actual) which is represented the current situation of the stream with unpermissible fish lakes; and case3 (without unpermissible fish lakes); to describe the effects of unpermissible fish lakes on each of discharge, water level and velocity at the sections along the stream.

To simulate the stream in HECRAS software; some important data should be available to enter to this software; such as discharge, Manning value (n), and cross-sections of the stream (i.e., geometric data) (Haghiabi and Zaredehdasht, 2012; Mehta *et al.*, 2017). The crosssections of the designed and actual cases are either collected from Directorate of Water Resources in Babylon or by field works. The geometric data are as following:

For case1 (design), there are five trapezoidal cross sections with 1H:1V side slope and 13 cm/km bed slope (Directorate of Water Resources in Babylon, 2019), the bed width and flow depth along the length of stream are as illustrated in Table 1 and shown in Fig. 4.

Table 1. Geometric data for case1 (design) (Directorate of Water Resources in Babylon, 2019)

Station (kM)	Bed width (m)	Total depth (m)
0-8	10.5	1.55
814.2	9.3	1.48
14.217.2	7.8	1.38
17.220.6	6.5	1.26
20.629.5	2	1.16

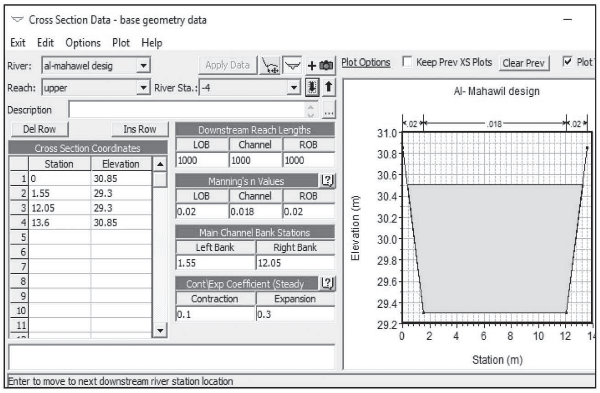


Fig. 4. Geometric data for case1

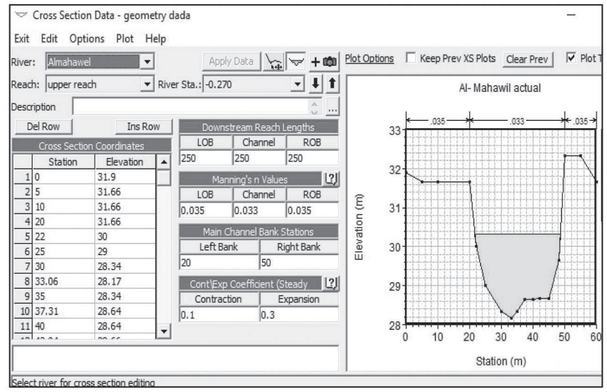


Fig. 5. Geometric data for case2 and case3

For case2 (actual) and case3 (without unpermissible fish lakes); the cross sections from investigated works taking at each 250 m along the length of stream (i.e. 29.50 kM) are as shown in Fig. 5.

The flow discharge is (8 m^3/sec) for all cases. The out let discharge for the three models from AlMahawil stream are as given in Table 2, but, for case1 and case3, they have not unpermissible fish lakes and water plants .

The manning coefficient roughness for case1 are 0.02 for right and left banks and 0.018 for main channel, while for case2 and case there are 0.035 for right and left banks, and 0.033 for main channel.

Field works and the verification

Because there is no irrigation planning through the seasons, the operation discharge is taken as 3 m^3/s (Directorate of Water Resources in Babylon, 2019); as

Table 2. Flow rate of intakes in mathematical hydraulic model for AlMahawil stream (Field measurement by the Authors)

Location (km)	Intake Types	No.	Total Outlet (m^3/sec)
0-4	Watercourses	14	0.177
4-6	Watercourses	12	0.396
Un-Permissible fish lakes	10	0.05	
Water plant	1	0.0016	
6-8	Watercourses	14	0.391
Un-Permissible fish lakes	12	0.06	
Permissible fish lakes	4	0.02	
8-10	Watercourses	14	0.57
Un-permissible fish lakes	10	0.05	
Permissible fish lakes	4	0.02	
Water plant	0.0023		
10-12	Watercourses	8	0.326
Permissible fish lakes	1	0.005	
Un-Permissible Water plants	3	0.0069	
12-14	Watercourses	18	1.239
Un-Permissible fish lakes	9	0.045	
14-16	Watercourses	18	0.309
Un-Permissible fish lakes	28	0.14	
Permissible fish lakes	5	0.025	
Un-Permissible Water plants	1	0.0023	
16-20	Watercourses	32	2.445
Un-Permissible fish lakes	3	0.015	
Un-Permissible Water plants	3	0.0069	
20-24	Watercourses	18	1.266
24-28	Watercourses	14	0.373
28-29.5	Watercourses	6	0.239

shown in Fig. 6. The discharges, velocities, and water depths have been measured by using River Surveyor Tool, as shown in Fig. 7. These measured quantities are used to compare with the results of HECRAS as a verification task. The results are illustrated as given in Table 3.

It is shown from Table 3; there is a convergence between measured and computed discharges with correlation coefficient ((R=0.998); as shown in Fig. 8; but there are some different in the velocities and depth of water. In fact, this is due to Ceratophyllum plants, stones, and trash in the side and bed of the stream; which are complex and could not be simulated in HECRAS. The variations between measured and computed flow depth for stations; specially for stations 12, 13, and 14 are due to differences in bed elevations with respect to the width of cross section; as shown in Fig. 9; and the HECRAS taking the maximum value for bed elevation when computed water depth; while at the field the measured water depth are taking on the left or right banks, as shown in Fig. 9.

Fig. 6. The pump station of AlMahawil stream with operation of 3 m³/s (Directorate of Water Resources in Babylon, 2019)

Fig. 7. Field measurement of Al–Mahawil stream using River Surveyor Tool

RESULTS AND DISCUSSION

Effects on Flow Characteristics

The velocity profile for case1 (design) is shown in

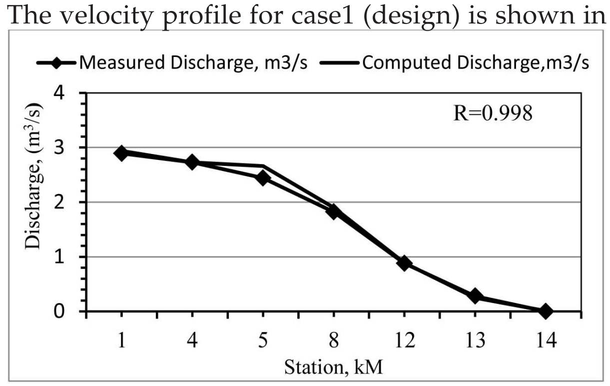


Fig. 8. Measured and computed discharge in selected stations a verification

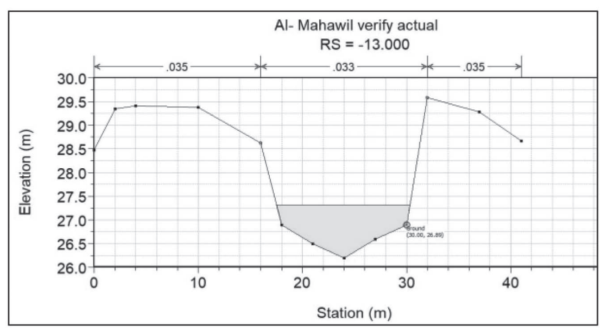
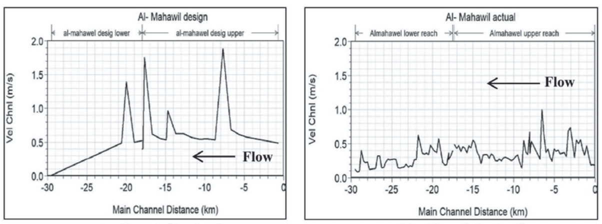


Fig. 9. Computed flow depth through cross section at station 13

Table 3. Comparing between measured and computed velocity and water depth

Station (kM)	Measured by River Surveyor Tool Q (m³/s)	Measured V (m/s)	Measured Water depth (m)	Computed by HECRAS Q (m³/s)	Computed V (m/s)	Computed Water depth (m)
1.00	2.89	0.20	0.80	2.94	0.31	0.76
4.00	2.73	0.25	0.78	2.73	0.26	0.91
5.00	2.44	0.30	0.76	2.66	0.29	0.75
8.00	1.82	0.35	0.70	1.90	0.23	0.91
12.00	0.88	0.50	0.67	0.89	0.07	1.16
13.00	0.28	0.20	0.44	0.25	0.03	1.14
14.00	0.00	0.00	0.24	0.01	0.01	1.68

Fig. (10 a and b). It is clear that the velocities are increasing instantaneously at stations (7, 14, 17, and 20) km; and this is due to decreasing in water depth at these sections after distributed water to water courses that services farmers; so due to design consideration; the bed width of cross sections is decreased after these stations to increase the water level and discharge of water courses; (Fig. 11); while when comparing with Fig. 10b of case2 (actual); the velocities is diverting along the stream rabidly; this is because after a long period of design the cross sections become in regular due to scour and deposition process and incorrect application to dredging process.

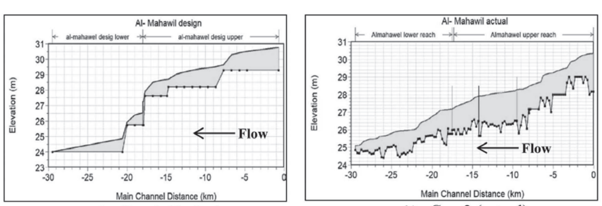


a) Case1 (design) b) Case2 (actual)

Fig. 10. Velocity profile

In other hand; Fig. (11 a and b) shows the cross sections of stations (4, 7, 8 , 17, and 20 kM) for case1 (design) and case2 (actual) to illustrate the changes in cross sections after a long period of design more than 80 years.

Fig. (12 a and b) shows the differences in water surface elevations between case1 (design) and case2 (actual); respectively. In fact; these differences are a result many reasons; such as the periodic dredging process, the unregulated distributions of the fish lakes, water plants and the un–permissions constructions wrong planning and finally the rapid distribution of watercourses on Al–Mahwil stream.



a) Case1 (design) b) Case2 (actual)

Fig. 12. Longitudinal profile

The flow area and top width of the cross sections for case2 (actual) is greater by (84%) and (85%) than of case1 (design); as shown in Figures (13 and 14); respectively. It is shown from these figures that these differences are at (kM0.00 to kM15.00) as a result of

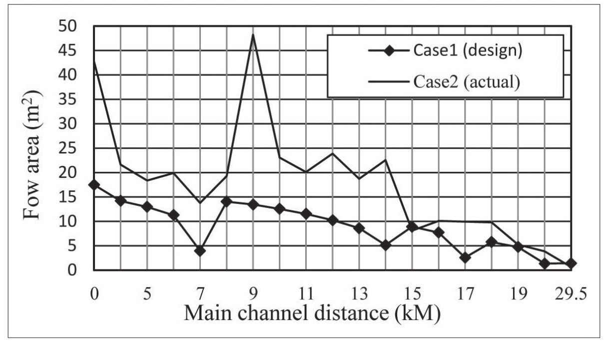


Fig. 13. Cross section flow area

the intensive combination of the fish lake and water plants at the beginnings section of the stream and this will causes these large differences shown in Fig.2; previously.

Effects of Un-Permissible Fish Lakes

Fig.15 illustrates that there is a lowering on the discharge of stream and a deficit to supply water to more than 10 water courses at the stations from 25 to 29 kM for case2 (actual); while for case3 (without unpermissible fish lakes); the water is sufficient. This is due to an incorrect planning of the distributions watercourses and the large number of unpermissible fish lakes which accumulated at upstream of the stream.

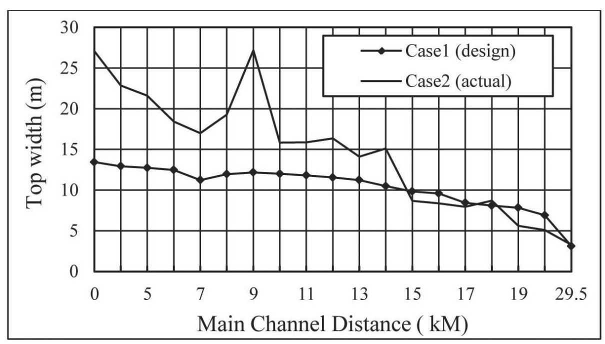


Fig. 14. Cross sections top width

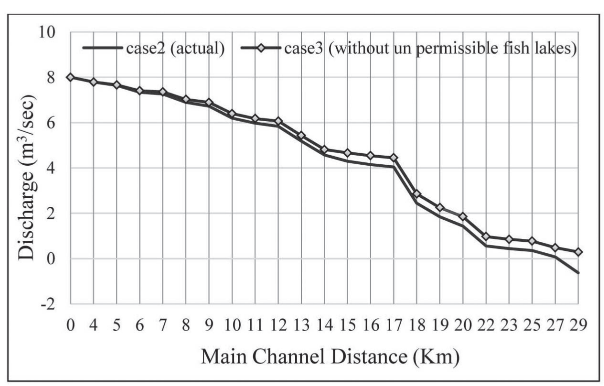


Fig. 15. Discharge along the stream for Case2 and Case3

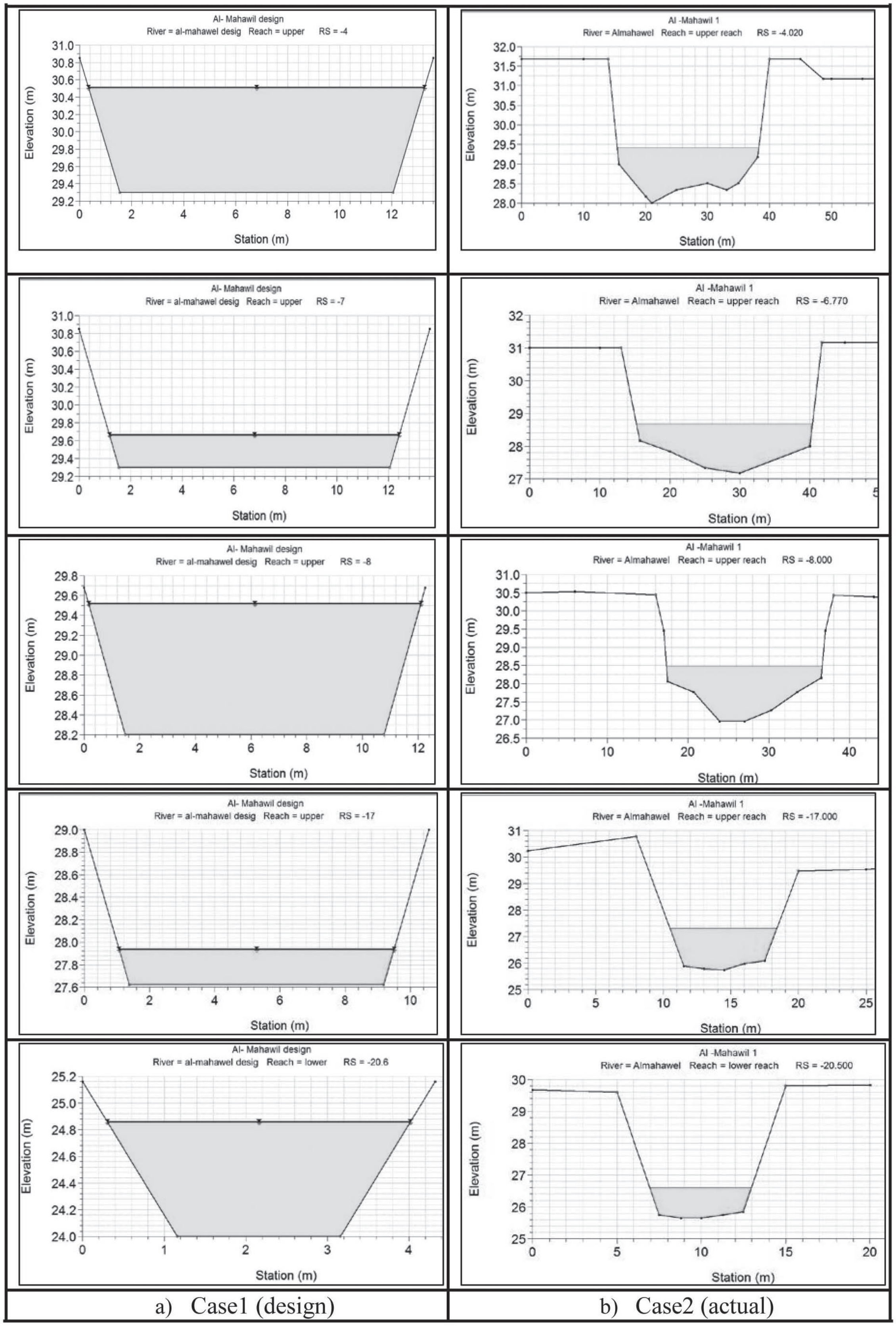


Fig. 11. Cross sections for stations (4, 7, 8, 17, and 20 kM)

CONCLUSION

The periodic analysis of the hydraulics characteristics of any earthen canal is the one important that could be concluded from this research. Al Mahawil stream is an earthen canal has many problems that lead to make it inefficient for irrigation purposes and human activities within the land areas that passes though in. The field study which is adapted in this research focuses on the problems that are affected on the hydraulic characteristics of this stream which are related with incorrect periodic degradation process, growth of the Ceratophyllum plants and weeds on the bed and banks of the stream, incorrect planning about water resources management for the water courses that distributed from this stream, unpermissible fish lakes and water plants that collected at the upstream of this stream, and the farmer conflicts that may be happen as a result of these problems. It is also concluded that HEC-RAS is a suitable tool to simulate this types of stream for analyzing the hydraulic characteristics such as flow capacity, velocity, flow profile, flow depth and so on.

In addition to the aforementioned conclusions above; hydraulically; it is concluded the following:

1. Decreasing the velocity in case2 (actual) by 52% from the velocity in case1 (design).
2. Periodic dredging process increases top width and area of flow of the cross sections of Al Mahawil Stream in case2 (actual) by twice and 2.5 times than case1 (design); respectively.
3. There is a deficit of supply water to more than 10 water courses at the stations from 25 to 29 km for case2 (actual), while for case3 (without un-permissible fish lakes) the water is sufficient.
4. Al Mahawil stream is efficient for irrigation purposes only at the beginning sections of the stream.
5. The effects of *Ceratophyllum* plants on design capacity which are complex and could not be simulated in HEC-RAS.

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