

HYDRODYNAMIC SIMULATION OF SURFACE WATER CONTROL SLUICE GATES BY HEC-RAS MODEL

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Abstract

The purpose of this study is hydrodynamic simulations of the water control gates in the water transport channels. Hydrodynamic simulations give a proper understanding of how performance and optimize utilization of the gates controlling the water level. Non-linear equations governing the open channel flows due to changes in water flow rate and other parameters of complexity is important. Four different sluice gates simulate the water surface level using HEC-RAS in Moghan main channel. This channel is the main transition channel in the northwestern of Iran and its resources is Aras river in Iran. Aras river originated from Turkey. Hec-Ras model is produced by US Army for analyzing river system. This model could simulate steady and unsteady open channel flow. Model results was assumed and compared with the observed data in real channel. Calibration and verification of data was derived to plot the water surface level of gradually varied flow in different discharges to provide operational instructions.

Keywords: Hydraulic simulation, Sluice gate, Hydrodynamic, Nonlinear flow, Hec-Ras Model.

1. INTRODUCTION

Concrete irrigation channel network design is constructed for uniform and steady-state flow. This flow is only suitable for irrigation in peak season and the perfect level control structures can be used for other seasons. Level control and flow control structures is designed in order to optimize the use of channels. The sluice gate in most of the major channels is used as the control structure. Performance of this gate will cause non-uniform and unsteady flow. In this study, Hec-Ras software is used for simulation of channels and hydraulic structures. Johnson et al. (1999), applied HECARS model in order to predict and determine the limits of humid lands along 10 kilometers of Greybull River in Wyoming, U.S.A. Through water deviation toward a new reservoir and determination of boundary conditions with and without deviation in similar scales, they also predicted that the whole area which undergoes flooding would increase from 167.2 to 149.2 through deviation of 28313 liters of water. These scholars believe that this is a reliable method to determine the quality of deviation effects on humid lands of river bank and it should be more evaluated in order to be used in order to specify the humid lands (touched by water) in similar projects (Johnson et al. 1999). In 1991 (1370), the River Engendering Research Division of Soil Conservation and Watershed Management Center in Ala basin in Marvdasht, Fars and Damavand drainage basin, applied HEC-2 model to determine the maximum numbers of water base level in considered direction in two mentioned cases in which the point numbers were manually transferred to specific profiles of the river in topographic plan and the flood affected province was stated in 5 and 25 year return periods. The profile of water level was also plotted for a 25 year return period (Abasi, 1991). Vahabi, 1997 (p. 1376), used remote sensing methods, Geographic Information Systems, HEC-1 and Mike11 software along with the provided river profiles in Talighan drainage basin for zoning the flood risk. The banned, limited and permitted arias were specified and the conditions were mentioned in the provided zoning map (Vahabi, 1997). Safari, 2001 (1380), proceeded to apply the HEC-RAS model for zoning the flood risk in Neka River located in Mazandaran and concluded that this model is highly efficient to calculate the water level and flood affected provinces (Safari & Mahdavi 2001). In their research, Shahrokhnia and Javan 2009 (1388) determined the sensitivity of hydraulic structures in Doroodzan irrigation network applying HEC-RAS software. In this investigation, in order to investigate the reliability, the mentioned model was at first calibrated with two sets of measured data, discharge and water level numbers. The Manning's roughness coefficient and structure discharge were used to calibrate the model. The sensitivity of structures was estimated. The discharge variation of basins derived by the changes in chokes setting was investigated as well. A new sensitivity coefficient called sensitivity due to variation of channel roughness was introduced in this research. The results also indicated that HEC-RAS model is suitable for investigation and simulation of hydraulic flows in irrigation network of Doroodzan and it can be used as a sort of accurate tool in analysis of such cases (Shahrokhnia & Javan, 2009).

In this research, the HEC-RAS model was applied in order to simulate the water level profiles in the main channel of Moghan with its soil bed located in North West of Iran.

2.MATERIALS AND METHODS

The purpose of this study is to simulate hydrodynamic of control gates performance at the water surface in water channels. Hydrodynamic simulation of control structures give understanding of syntactic function and optimal utilization of water level control gate. Because of the nonlinear equations governing water channels flow is of particular complexity. Gradual changes in water depth and other characteristics of flow along channel length should be determined with reasonable accuracy.

Regardless of the example objective, the calculation of longitudinal profile of water level would end in integration of this equation:

$$\frac{dE}{dy} = S_0 - S$$

Equation (1):

$$\frac{dy}{dx} = \frac{S_0 - S}{1 - F^2}$$

Or equation (2):

Although there are different solutions to solve various examples of variations of water level curves and different forms of flow profiles and each is suitable to solve a specific one, the common point in all of them is that the calculation should get stated from controlling profile of the flow.

Here are several methods for calculation of linear profile:

- A) Step by step method- the calculation of distance unto depth.
- B) Direct integration methods.

A) Step by step method- the calculation of distance unto depth:

In this method, the differential equation would be used in the following way. The differential form of the equation is:

$$\frac{dE}{dX} = \frac{\Delta(y + \frac{V^2}{2g})}{\Delta X} = S_0 - S_f = S_0 - \frac{V^2}{C^2 R}$$

Equation 3:

$$\Delta E = \Delta(y + \frac{V^2}{2g})$$

Where

In these formulas, ΔX is the distance of two profiles, ΔY id the flow depth, S_0 is the bottom slope, S_f is the slope of the energy line, C is the Chézy coefficient, R is the hydraulic radius and ΔE is the energy variation.

B) Direct integration methods:

The basis of numeral methods to solve the equations of gradual variable flows is the integration of

$$\frac{dy}{dx} = \frac{S_0 - S}{1 - F^2}$$

Instead of S_f and F^2 their equal amount would be placed in the equations $S_f = \left(\frac{nQ}{AR^{\frac{2}{3}}} \right)^2$ and

$$F^2 = \frac{BQ^2}{gA^3} \quad [6].$$

Thus:

Equation (4)

$$\frac{dy}{dx} = \frac{S_0 - \left(\frac{nQ}{2}\right)^2}{1 - \frac{AR^3}{gA^3}}$$

And through integration:

Equation (5)

$$X = \int_{y_1}^{y_2} \frac{S_0 - \left(\frac{nQ}{2}\right)^2}{1 - \frac{AR^3}{gA^3}} dy$$

and the equation:

Equation (6)

$$X = \int_{y_1}^{y_2} F(y) dy$$

the amount of X would be obtained.

In these formulas, X is the distance, Y is the flow depth, Q is the flow discharge, S_0 is the bottom slope, S_j is the slope of the energy line, n is the Berry coefficient, R is the hydraulic radius, A is the flow section, and B is the upper flow width.

2.1 Hec-Ras Introduction

HEC-RAS software is the advanced version of HEC-2 which has been presented by the U.S. Army Corps of Engineers as a river analysis system. HEC-RAS is a complex software system designed for mutual application in multi-purpose and multi-user networks. This system consists of a Graphical User Interface (GUI), separated hydraulic analysis components, saving capacities and data management, graphical features and reporting. The present version of HEC-ARS supports the calculation of water level profile for steady and unsteady flows.

The simulation software has been provided in order to calculate the water level profiles in gradually variable states of flows. The system is able to consider a whole network of channels, a branch system or a single interval of the channel the component of steady flow is capable of simulating the water level profiles in sub-critical, super-critic and mixed flows. Equation (7) and Figure (1) illustrate the main computing process based on solution of one-dimensional energy equation through standard step by step method (U.S. Army Corps of Engineers. 2001).

Equation (7)

$$Y_1 + Z_1 + \alpha_1 V_1^2 / 2g = Y_2 + Z_2 + \alpha_2 V_2^2 / 2g + h_L$$

Where Y_2, Y_1 is the water level in profile, Z_2, Z_1 is the height of channel bottom from the base level, α_2, α_1 is the weighted speed coefficient, g is the gravitation acceleration and h_L is the friction loss.

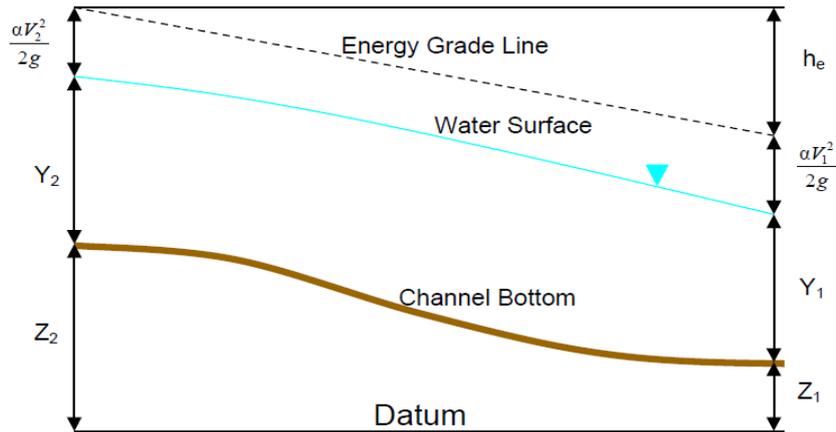


Figure 1. The energy equation between two spots

The energy losses are evaluated based on friction loss (Manning's equation), expansion and contraction (the coefficient applied in variations of speed load).

Equation (8)
$$he = LS_f + C(\alpha_2 V_2^2 / 2g - \alpha_1 v_1^2 / 2g)$$

Where he is the total energy loss, L is the direction length, C is the expansion and contraction coefficient and S_f is the friction slope (average of two profiles).

The ... equation is used when the water level profile changes quickly. Such situations include the calculation of mixed flow regimes (such as hydraulic jump), the hydraulic of water level regulatory installations, flumes, siphons, and the existing structures in flow direction and evaluation of profiles in channel junction.

The special characteristics of steady flow components are:

- the analysis of multiple plans
- calculation of multiple profiles
- the analysis of the opening transitions or multiple culverts and optimization of divergent flow

2.3 Study Area

This research was performed in Moghan zone located in North West of Iran. The main channel of Moghan was generated in 1974 as a soil channel with 80 cubic meter capacity, But after the destruction of channel parapet and the decrease in transmission capacity and losing the optimum profile caused some problems for this soil channel. Four different sluice gates simulate the water surface level using HEC-RAS in Moghan main channel. This channel is the main transition channel in the northwestern of Iran and its resources is Aras river in Iran. Aras river originated from Turkey.

3 RESULTS AND DISCUSSION

Optimal Management of Irrigation and Drainage networks requires accurate information about the physical condition of a hydraulic network, accurate information lead up to desirable operation and maintenance. It is necessary for the proper operation and maintenance of irrigation networks to identify current values at different times in different parts of the network in order to perform flow control and level control by available facilities and equipment and to improve network by accurate criterion for decision-making.

The main Moghan channel is natural; the channel has been changed during utilization and performance Irregular channel bottom slope has a lot of peaks and valleys that channel has a great effect on the flow regime. However, increasing the capacity of the main channel are expected to intensify flow hydraulic regime changes. In order to improve the networks, the designer must carefully calculate the elevation of the water in the channel (channel structures is quadratic). Samples of water level control structures in Moghan irrigation networks are shown in Figure 2.

Study area in the Moghan main channel is from km 375+55 to km 375 +67. The area was divided into three intervals due to siphon structures 1,2 and 3 along channel path:

First interval: the output of siphon 1 to the input siphon 2 from 375 +55 to 415 +62.
 Second interval: the output of siphon 2 to the input siphon 3 from 723 +62 to 415 +65.
 Third interval: the output of siphon 3 to the Beginning of the lining from 200+66 to 375+67.

In this study, the range has been analyzed under different hydraulic conditions and the results were obtained. the main channel of the intervals studied under the following scenarios:

- The first scenario - terrestrial channels regardless of water level control structures.
- The second scenario - the natural channel considering taking water level control structures.
- The third scenario – channel cover considering the water level control structures.

To evaluate the combined effects of hydraulic structures along the channel for every three scenarios and the channel water surface elevation, flow modeling software HEC-RAS with 3, 7.34 and 9.84 cms were performed for each of the three intervals. The effects of water level control structures along the main channel are shown in Figures 3 to 8. Average free board (FB) in the main channel under various scenarios are shown in Table 1.



Figure 2. Example of water level control structures of Moghan irrigation network.

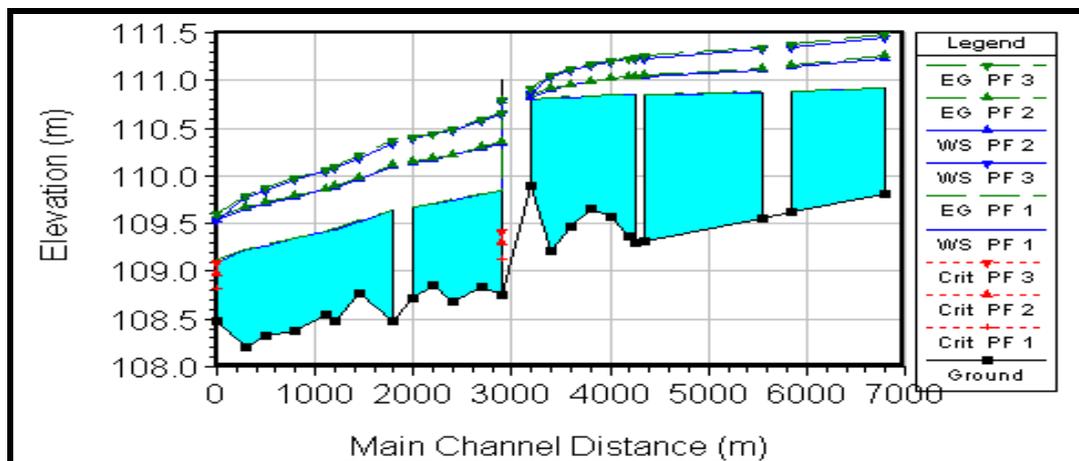


Figure 3. Water surface profile considering the first interval.

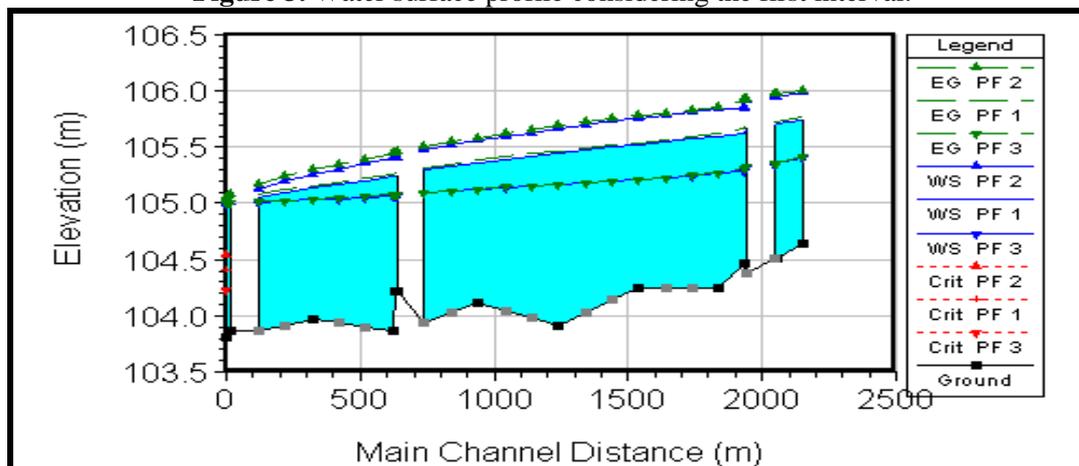


Figure 4. Water surface profile considering the second interval.

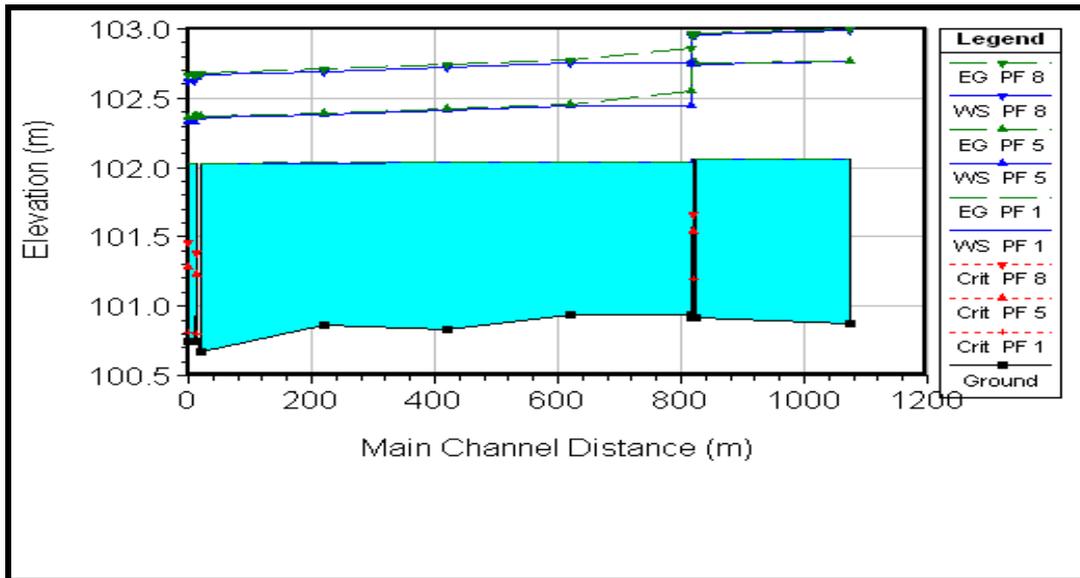


Figure 5. water surface profile considering the third interval

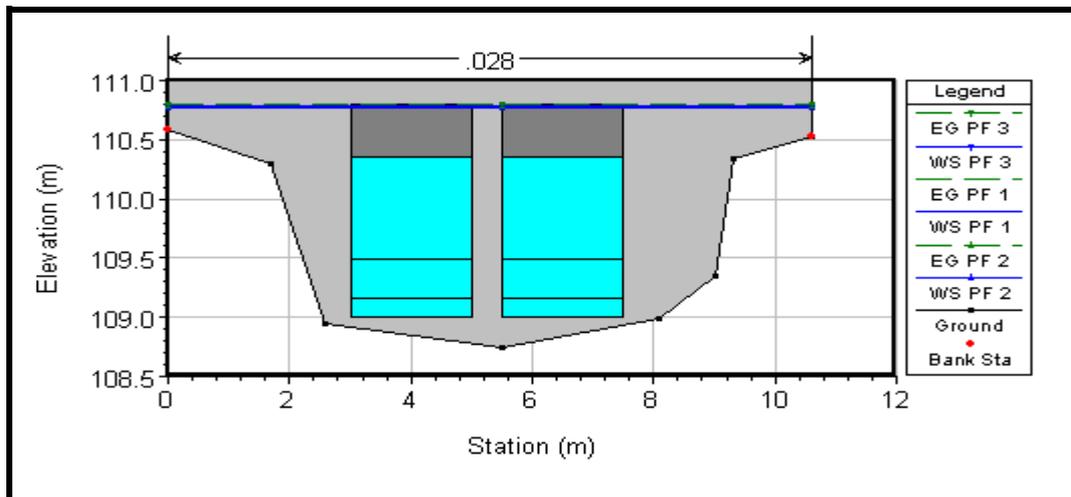


Figure 6. Cross-section simulation of first interval

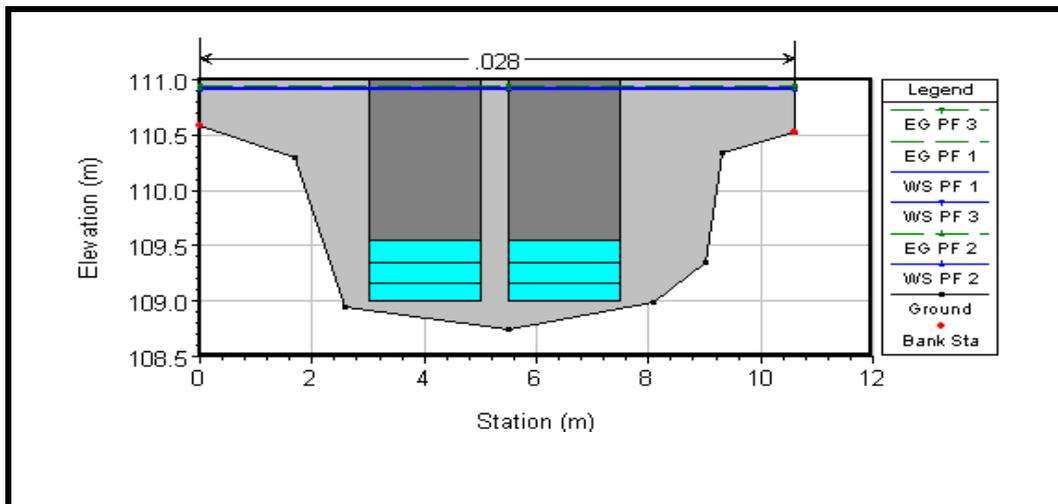


Figure 7. Cross-section simulation of second interval

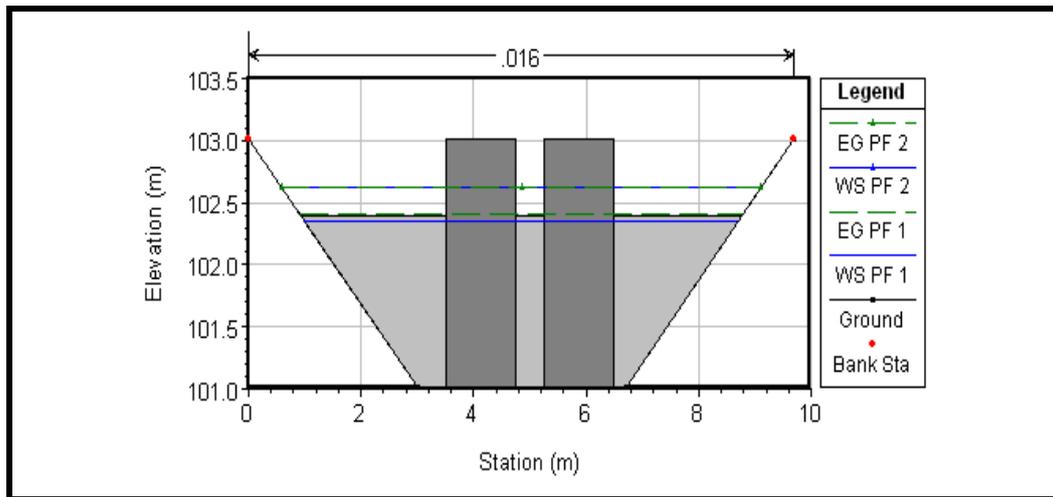


Figure 8. Cross-section simulation of third interval.

Table 1. The average occupied free board of the main channel under various scenarios

	First interval	Second interval	Third interval
First scenario	20.3%	0%	20.9%
Second scenario	51.6%	2%	49.1%
Third scenario	54.12%	12%	54.4%

3.1 HEC-RAS Calibration

Bed resistance coefficient such as manning roughness coefficient or chezy coefficient is one of the parameters in the mathematical and hydrodynamic models that should be calibrated. Bed resistance coefficient should be changed in various cross sections so that flow depth would be equal to the measured depth. According to the parameters obtained from the hydrodynamic calculations, it is necessary initially calibrating hydraulic model. Manning coefficient was calibrated for the main Moghan channel hydraulic simulation. Manning roughness coefficient was used to study the model and the model simulation was performed for different values. Numerical range of the Manning roughness coefficient (0.013 to 0.04) was tested. The best value of Manning roughness coefficient and model performance was 0.016 for concrete channels and 0.028 for terrestrial channels. The measured hydrograph was used to evaluate the accuracy of the results predicted by the model, The results of the model indicated that 0.016 and 0.028 had a better match with the measured values of Manning roughness coefficient. Figure 9 shows changes in water level relative to the Manning roughness coefficient.

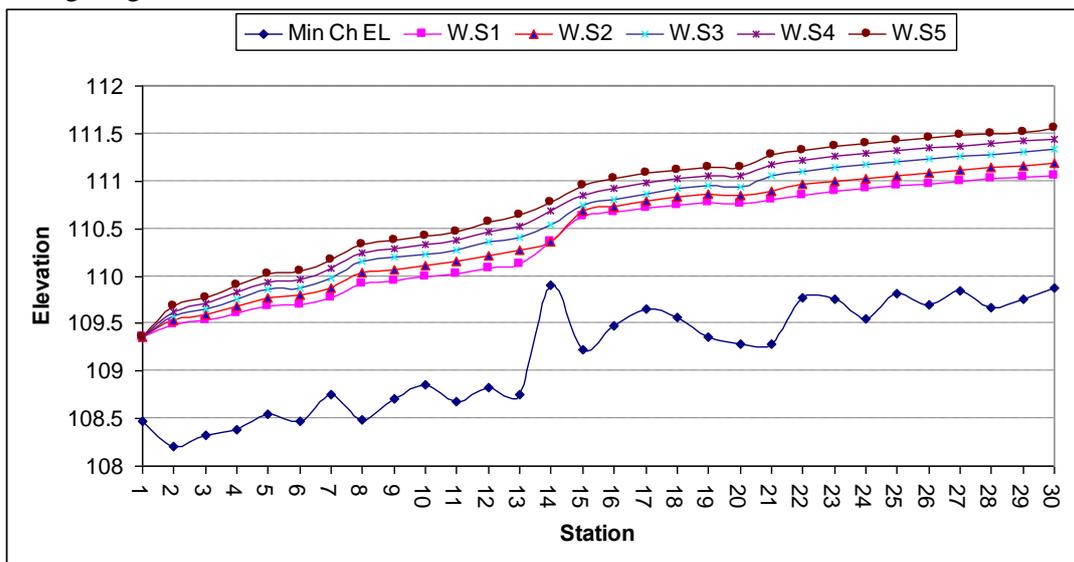


Figure 9. Changes in water level relative to the Manning roughness coefficient.

4 DISCUSSION

In this study, hydrodynamic simulation of water surface control gates were used by HEC-RAS. Channel flow simulation model scenarios were: the existing terrestrial channels, channels with soil and water level control structures and concrete channel with water level control structures. The performance of the model was studied after sensitivity analysis and the following results were obtained:

1. Hydrodynamic simulation of water level control structures sequentially with HEC-RAS model is feasible.
2. The improvement of terrestrial channels by hydraulic regime and water level control structures can be considered as a continuous and integrated model.
3. Control structures with submerged downstream effect on free board and increasing depth loss.
4. The mean relative model error regarding the effect of water level control structures are less than 1 percent. This model can also be used for unsteady flow.
5. Model error rises by increasing the number of flow control structures and control the water level.
6. Using this simulation to investigate the effects of sudden changes in water level on the stability of the channel side walls can be studied as a new research project.

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