Trash Screen's Performance in the Presence of Weed and Debris Accumulation

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Abstract: An experimental study has been conducted in the physical model to understand the effect of weed and debris accumulation upstream of the trash screen on the hydraulic efficiency of the open channels. A vertically simulated trash screen was installed perpendicular to the water flow during 120 experimental runs, which included five water discharges, and three tailgate openings depths. The aquatic weeds and debris accumulations were installed upstream of the trash screen with three longitudinal distances, three widths, and two heights. The results showed that the water level rapidly increased when the reach length exceeds 40 % of the top wetted width of the screen at the same accumulation reach height and width. At the same accumulation reach length and width, the water level sharply increased when the accumulation height exceeds 50 % of the upstream water depth. The velocity upstream of the trash screen was decreased by increasing the relative accumulation length and height by 40% and 30% respectively. The properties of accumulation and the flow characteristics were empirically related using the multiple linear regression analysis. Finally, the performance of the trash screen was evaluated and a maintenance program could be established periodically in terms of weeds and debris blockage.

Keywords: Hydraulic Characteristics, Aquatic Weeds, Trash screen, Open channels, Heading up, Blockage.

I. Introduction

Clogging and accumulation of aquatic weeds and solid wastes in the waterways cause many problems as increasing water losses, the roughness of channels, water energy losses, obstructing the water flow, and reducing the efficiency of water structures. The trash screen is one of the most common ways used in the management of aquatic weeds in waterways. Therefore, many studies investigated and clarified the use of trash screens for aquatic weed control.

[1] conducted an experimental study to determine the impact of floating weeds on open channel hydraulic characteristics such as water velocity distribution, heading up, discharge decrease, and roughness coefficient.

Experimental tests by [2] on the head losses and velocity of fish-friendly trash racks placed in an open channel with varying parameters, including bar shapes, spacing, and angles, confirmed that the head loss coefficient is a function of the blockage ratio, the bar shape, and the rack angle, and the variations of the trash angles have radical changes in velocity distribution while comparison to changes of bar spacing and bar shape.

Experimental research on the impact of bar cross-sectional forms, bar thickness, bar depths, and bar spacing at a variety of velocities on the head losses over the trash racks was conducted [3].

In a conveyance system, [4] experimented with the flume of the head losses due to the clear space between bars, bars diameter, and discharge.

The triangular V-shaped trash screen with a circular bar was tested by [5] to alleviate the issues with conventional trash screens. The researchers found that using the new design of screens reduced head losses, with a notable increase in losses occurring when the percentage of blockage reached 40%.

The results of an experimental study by [6] on blocked-angled screen models to determine their impact on open channel performance showed that the screen's angle, blockage ratio, and discharge have an impact on the screen's head loss. Based on the various tested variables, a useful new equation for head loss is proposed.

A new average velocity equation is proposed for a rack with an attached large wood plate that takes into account the effects of blockage ratios and Froude numbers for [7] study of the velocity distribution around blocked trash racks in 2021. The results show that the blockage affects the upstream and downstream velocity.

[8] investigated the problem of aquatic weeds accumulation, and the behavior of the trash screen upstream of the new and the old barrages of Naga Hammadi on the Nile River, to prevent submerged aquatic weeds from reaching the hydropower plant intake structure, which consequently led to enhanced the generated hydroelectric power by 26% in July 2014.

The impact of blocked trash racks on open channel infrastructure was researched by [9]; this study views the rack blockages as impermeable and box-shaped accumulations. Flume experiments were conducted to determine the impact of the length and depth of the depression. The results showed that the rack blockage and Froude number influenced the head loss and flow turbulence downstream of the rack, and the head loss coefficient changed in various exploitation scenarios.

A series of flume experiments were carried out by [10] to investigate the impact of initial conditions, bar screen layout, and LW volume on sediment transport. The findings show that 50% less silt is transported when an LW volume blocks 20% of the flow cross-section. LW volume is an essential design factor for inclined bar screens as a result.

[11] studied experimentally the effect of the presence of blocked trash racks on water surface profile, the research results concluded that accumulated weeds depth, length, and area influence the heading up and head loss of water.

[12] studied the seasonal losses caused by the debris accumulated on the trash rack of a 20 MW hydropower plant aggregate, Using a simple temperature-compensated model. Also, predicting the optimal frequency of trash rack cleaning, the findings concluded that the total number of trash rack cleanings per year was reduced, while the extra energy losses due to debris remains unchanged.

[13] used a physical model to analyze how the accumulation of aquatic weeds upstream of a trash rack affected the Nile River's water levels and velocity distributions upstream and downstream of the old Assiut barrage. The results showed that the head loss and heading up of water increased with increasing blockage percentage and flow discharge. As the proportion of the blockage increased, the velocity decreased both upstream and downstream of the trash rack.

According to laboratory tests cited by [14], the theoretical value of head loss determined using Kirschmer's formula is underestimated by a factor of 1.75-2.00. When the rack begins to accumulate with debris, this factor is greatly increased. With 50% blockage, it reaches 4.0.

[15] examined the impact of plant debris accumulation as well as trash rack bar design and angle on head losses. The study suggested using an 80°-inclined cylindrical bar to achieve the best result for head losses.

[16] carried out an experimental study to improve the hydraulic performance of aquatic weed barriers in open channels. Based on the findings, it should have relative weed length and depth below 0.4 for acceptable water velocity downstream barriers and head up.

[17] conducted an experimental comparison of a trash rack with circular bars and a fish protection system (a flexible fish fence made with horizontal cables in place of bars for varied bar and cable spacings). The findings demonstrated that the tested Bar-Reynolds number did not affect the head loss coefficient. Additionally, a design equation that estimates the head loss for both rack alternatives was proposed.

In 2016, [18] conducted an experimental study to examine the head loss caused by various bar shapes, spacing, and orientations in a trash rack as well as the features of turbulent flow close to the trash rack. The results of the studies showed that the shape of the bars had less of an effect on head loss than the placement and orientation of the bars.

This experimental research aims to study the effect of accumulated aquatic weeds and debris upstream of the trash screen on the hydraulic efficiency of the open channels.

II. Methodology

The experimental study was conducted in the physical model in the hydraulic laboratory of the Channel Maintenance Research Institute (CMRI). The artificial open channel is a reinforced concrete trapezoidal cross-section that has the dimensions of 16.22 m long, 0.60 m bed wide, 0.42 m maximum depth, and 1:1 side slope and is provided with a regulator of one vertical sluice gate. The flume bed is horizontal and supplied with water by a re-circulating system. The physical model of the study is simulating an open channel having a bed width of up to 9.00 m, water depth from 3.00 to 4.00 m, and passing discharge within the range of 13.28 and 18.97 m^3/sec.

A trash screen is simulated by using steel sheets in the form of a trapezoidal section and was utilized in the middle of the model. The screen is made of 0.2 cm wide steel ribs which are spaced 2 cm horizontally and 8 cm vertically. Both vertical and horizontal ribs are fixed and welded together to form the trash screen. A general layout of this artificial trash screen is shown in Fig.1.

A wire-mesh box as shown in Photo 1. a is located upstream of the trash screen and tied to it; has a large opening to make the water move easily through aquatic weeds and debris accumulation, has light density, and has the same dimensions as the screen with two heights. The box has been filled with an Upholstery stuffing materialcalled “Karina”which was used to simulate blockage weeds and debris as shown in Photo 1. b.

Hundred and twenty operated runs were carried out including seven main cases of experimental work as mentioned in Table 1 and Fig.2 according to accumulation reach’ height, length, and width, in addition to the smooth case where no accumulation upstream the trash screen. Five discharges of 40, 37, 34, 31, and 28 l/s, and three tailgate openings depths of 33, 34, and 35 cm are selected for the experimental work to adjust different water depths.

For each discharge, a test was carried out with three tailgate openings depths, and an accumulation of three lengths (X_{w1}, X_{w2}, and X_{w3}) of 25, 50, and 85 cm respectively which range between 40 to 70 % of top wetted width of the trash screen, three widths (L_{w1}, L_{w2}, and L_{w3}) of 33, 67, and 100 %of top wetted width of the trash screen respectively, and two accumulation height (Y_{w1}, Y_{w2}) of 50 to 70% ofthe upstream water depth respectively at 15, and 10 cm of free water depth underneath the accumulation reach.

For each run, at the centerline of the flume, two velocity distribution profiles were determined upstream, and downstream of the trash screen,water surface profiles were measuredevery 0.50 m along the centerline of the lab flume and intensified for a distance of 1.50 m upstream of the screen to every 0.15m, and the heading up and upstream water slope was determined. The investigated data are belonging to one research study of Channel Maintenance Research.

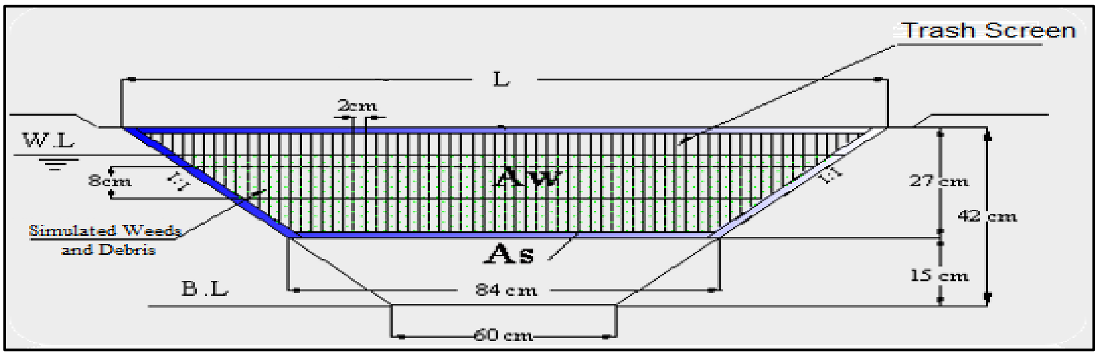


Figure 1 Definition Sketch for the Trash Screen Dimensions

Photo 1. a The box of the accumulating weeds and debris

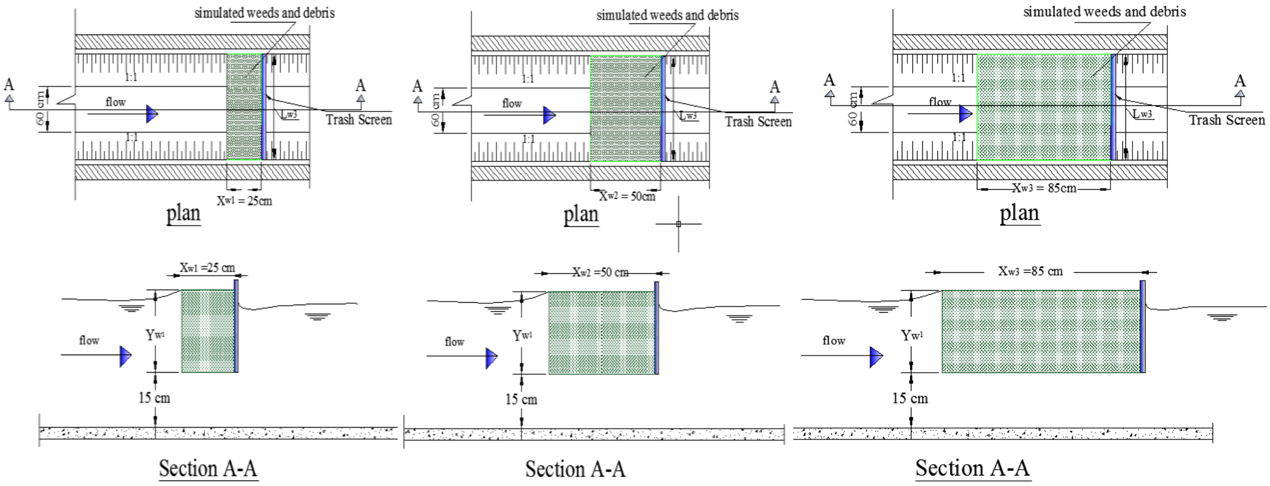
Simulated accumulating Actuallyaccumulating

Photo 1. b Upholstery Horse and accumulating weeds and debris

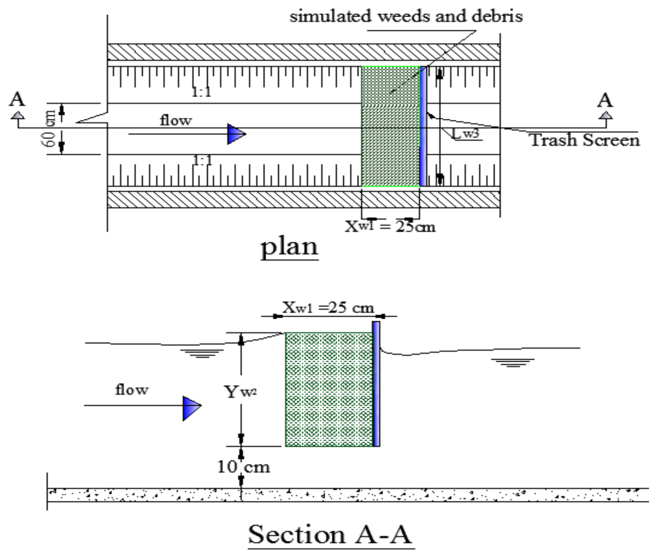
Photo 1 The box and the simulated accumulation of weeds and debris

Table 1 The total number of study scenarios

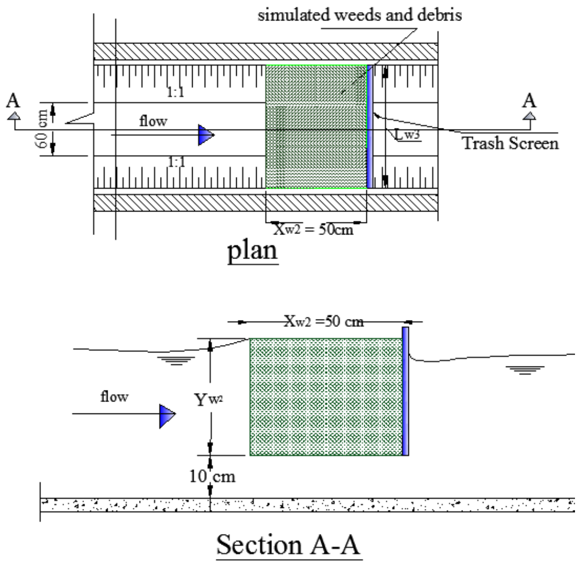
Trash screen alignment	Cases Nº	Nº of discharges	Nº tailgate opening depth	accumulated reach			Total Nº of runs
				height	length	width	
Vertical Trash Screen	smooth	5	3	Smooth case (No accumulation)			15
	1			Y_{w1} (Yu-15 cm)	X_{w1} (25 cm)	L_{w3} (100 % Ts)	45
	2				X_{w2} (50 cm)		
	3				X_{w3} (85 cm)		
	4			Y_{w2} (Yu-10 cm)	X_{w1}	L_{w3}	30
	5				X_{w2}		
	6			Y_{w1}	X_{w2}	L_{w1} (33 % Ts)	30
	7					L_{w2} (67 % Ts)	
The sum of the total runs							120



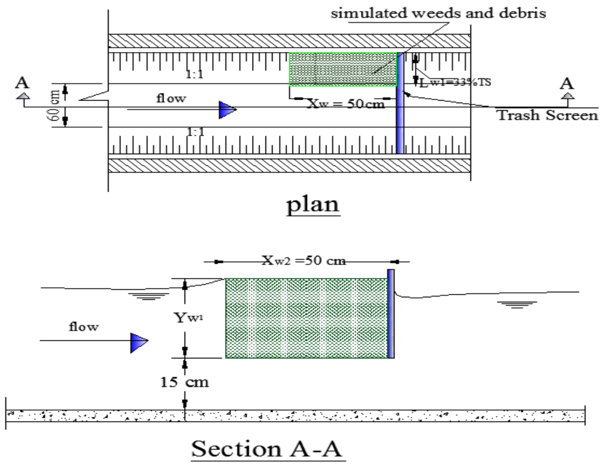
Case 1 Case 2 Case 3



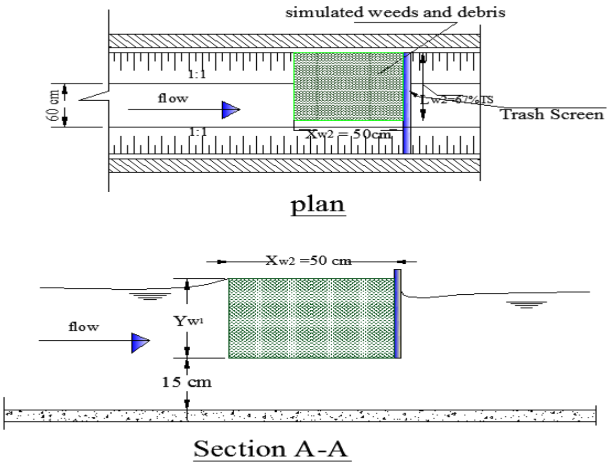
Case 4



Case 5



Case 6



Case 7

Figure 2 Definition Sketch for all cases in the study

III. Theoretical Approach

To determine the change in water depths and velocities as a function of the density of the accumulation, the general equation is derived using dimensional analysis and Buckingham's -theorem.

As seen in Fig.2, the overall relationship between the variables is summarized as follows: -

$$f(Y_U, Y_d, a, V_u, V_{d\,max}, Q, L_w, X_w, Y_w, \rho, g, \mu, \gamma_s, A_s) = 0 \ldots\ldots\ldots\ldots\ldots\ldots Eq. (1)$$

The following relations were established by applying Yu, Vu, and ρ as repeating variables.

$$f\left(\frac{Y_d}{a}, \frac{Y_u}{a}, \frac{Q}{V_{dmax} * Y^2_d}, \frac{Q}{V_u * Y^2_u}, X_r, B\,\%, Fr_u, Fr_{da}, R_e\right) = 0 \ldots\ldots\ldots\ldots \quad Eq.\ (2)$$

Where Y_u is the water depth just upstream the accumulation, Y_{us} is the water depth upstream the trash screen in smooth case - case of no accumulation, Y_d is the water depth just downstream the trash screen, V_u is the average velocity just upstream the accumulation, V_{dmax} is the maximum velocity just downstream the trash screen, Q is the total discharge, X_w , L_w , and Y_w are the accumulation reach length, width, and height upstream the trash screen respectively, a is the free water depth under the accumulation reach, Y_w is (Y_u - a), T_s is the top wetted width of the trash screen, A_s is the wetted cross-sectional area of the screen, g is the gravitational acceleration, ρ is the fluid density, g is the gravitational acceleration, μ is the dynamic viscosity, X_r is the relative accumulation reach length (X_w /T_s), A_w is the area blocked by the accumulation, A_s is the maximum wetted cross-sectional area in the screen, B% is the blockage percentage [(A_w / A_s)*100], Fr_{da} is the downstream Froud number, Fr_u is the upstream Froud number, and Re is the Reynold's number.

IV. Analysis of the Results

The impact of weed and debris accumulation upstream of the trash screen on the hydraulic performance of the open channel is evaluated for each of the research cases, and experimental data are presented.

1. Effect of Weeds and Debris' accumulation Upstream Trash Screen on Flow Characteristics

1.1 Water surface profiles

To study the effect of weeds debris accumulated upstream of the trash screen on water surface profiles, the water surface profiles for all cases along the centerline of the flume were plotted and analyzed. Samples of water surface profiles could be shown in Figs. 3, 4, and 5 which indicate its variations with different accumulations at water discharge of 40 L/s and a 35 cm of tailgate opening depth.

The following observations could be obtained for the same discharge and tailgate opening: -

- At the sameaccumulation reachheight and width, the water level rapidly increased when the reach length exceeds 40 % of the top wetted width of the screen.
- At the sameaccumulation reach length and width, the water level sharply increased when the accumulation height exceeds 50 % of the upstream water depth.
- In comparison with the smooth case, the water surface profile increases for all cases in presence of the same accumulated reach length and height, except case 6 where the accumulation reach width is less than 33 % of the top water width as shown in Fig.5, and a transverse cross sections at 10 and 50 cm upstream the trash screen in Figs. 6 and 7 respectively.
- The water slope increases with increasing accumulation height and length as mentioned in Table 2, where cases 3 and 5 are greater than all cases and are approximately the same.

Table 2 Water slope and heading up upstream of the trash screen for the studied cases

case	S_{up} (cm/m)	h_{up}(cm)
case 1	$4.9x10^{-5}$	0.36
case 2	$1.4x10^{-4}$	0.378
case 3	$4.4x10^{-3}$	2.03
case 2	$1.4x10^{-4}$	0.378
case 5	$4.6x10^{-3}$	1.73
case 6	$7.8x10^{-4}$	-0.32
case 7	$2x10^{-3}$	0.33
case 2	$1.4x10^{-4}$	0.36

Where: S_{up}: refers to the upstream water slope.

h_{up}: refers to the increase of the water depth upstream of the screen which is defined as the difference between the upstream water depth in the smooth case and the study case.

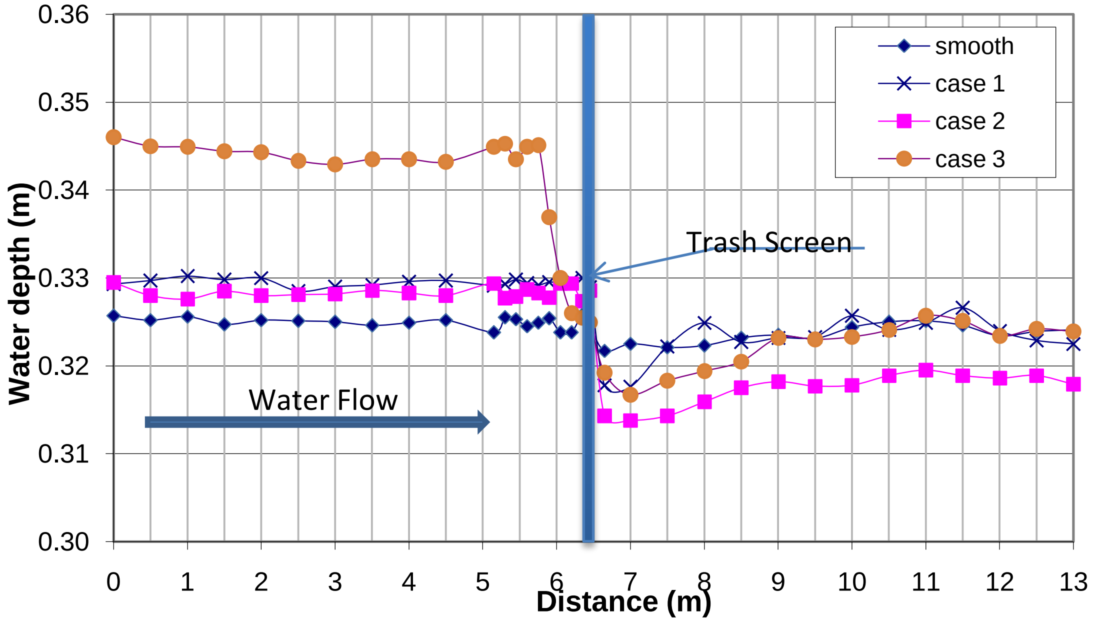


Figure 3 The effect of the variation in the length of the accumulation reaches upstream trash screen in case of constancy of the reach height and width (Q= 40 L/s and G= 35 cm depth).

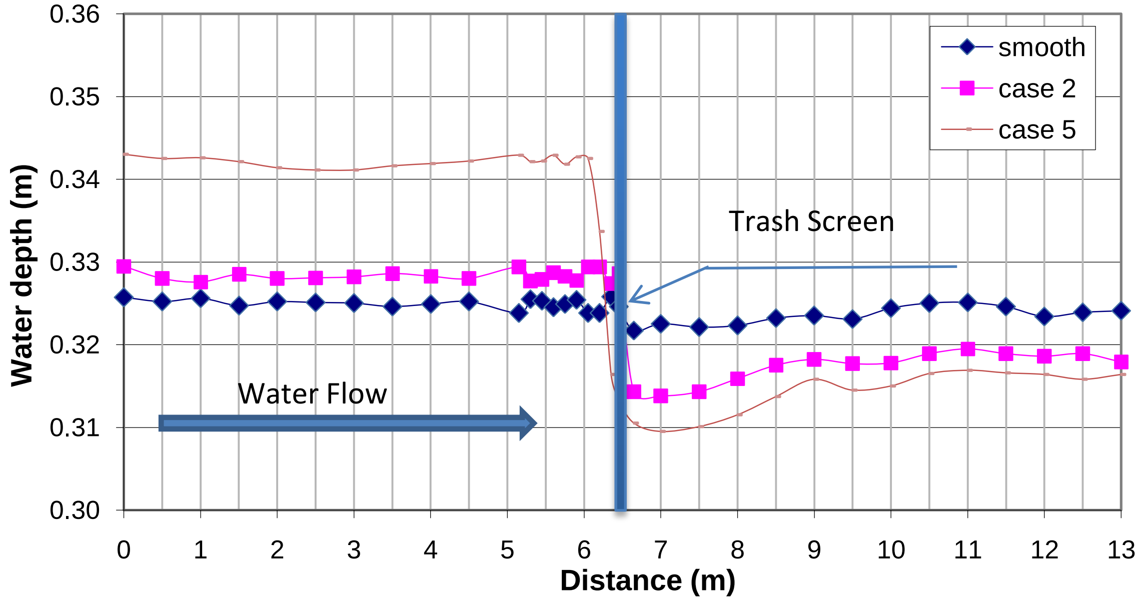


Figure 4 The effect of the variation in the height of the accumulation reach upstream trash screen in case of constancy of its length and width (Q= 40 L/s and G= 35 cm depth)

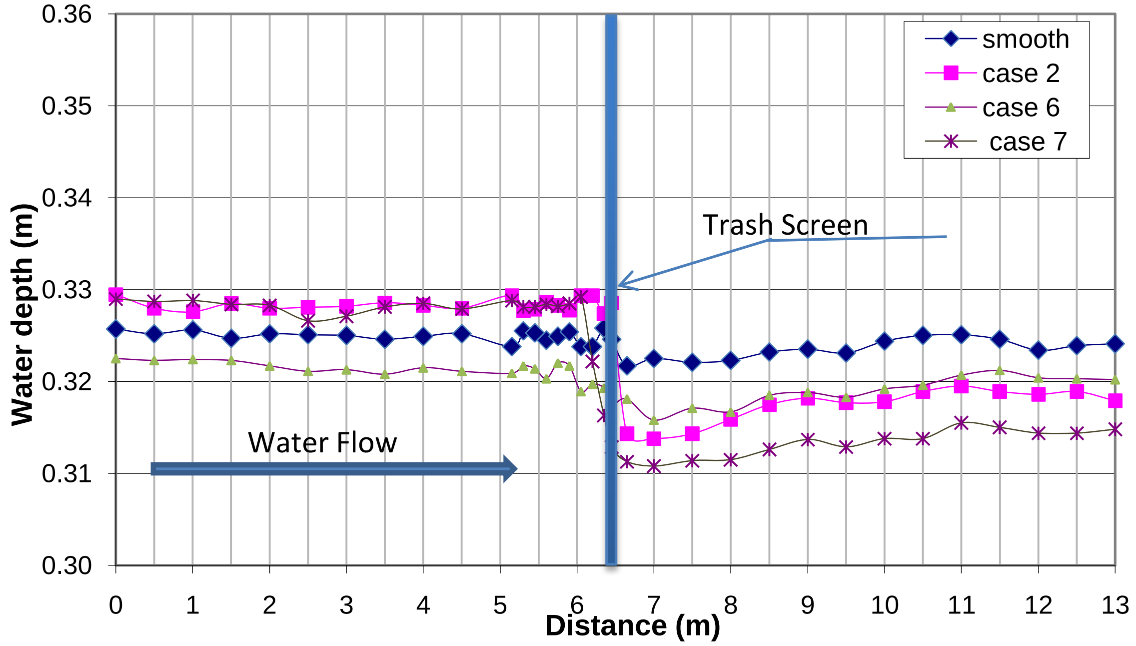


Figure 5 The effect of the variation in the accumulation reaches width upstream trash screen in case of constancy of its height and length (Q= 40 L/s and G= 35 cm depth)

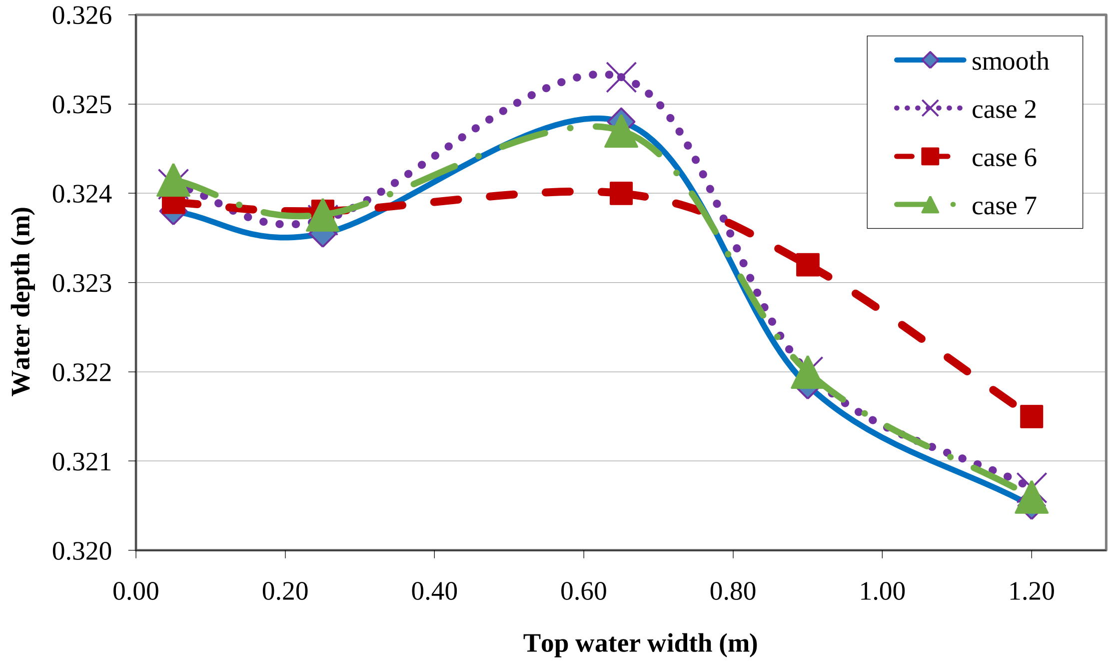


Figure 6 Effect of variation in accumulation reaches width on the transversal water surface profile just upstream the accumulated reach at the same length and height of the reach.

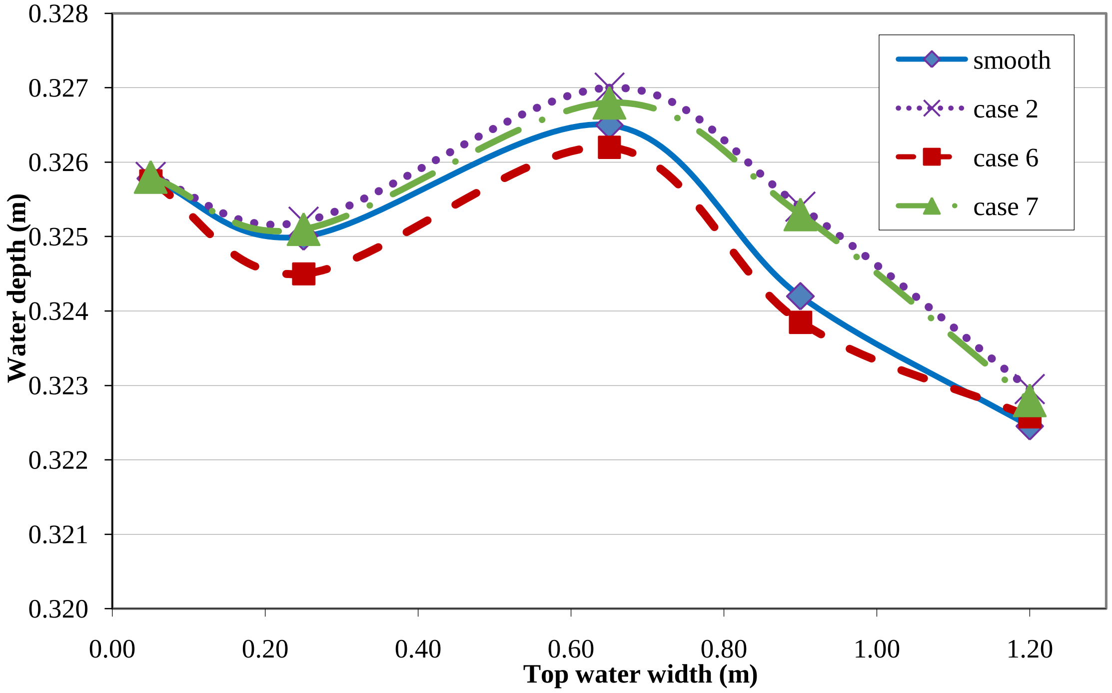


Figure 7 Effect of variation in accumulation reaches width on the transversal water surface profile at a distance of 0.50 m upstream the reach at the same length and height.

1.2 Effect of Weeds and Debris' accumulation Upstream Trash Screen on the Heading up

The heading up is the difference in level between the water surface for any case in the study and the smooth case upstream of the trash screen.For the discharge of 40 L/s and a 35 cm tailgate opening depth, the heading up for all cases was determined as shown in Figs. 3, 4, and 5, and Table (3), the following results were observed:-

- At constant accumulation reach height and width, theh_{up} increased from 0.36 cm to 2.03 cm, with the length of the accumulation reach varying between 40% and 70% from the top wetted width of the screenas shown in Fig.3 and Table 2.
- At constant accumulation reach length and width, theh_{up} increased from 0.378 cm to 1.73 cm, with the height of the accumulation varying between 50 to 70 %of the water depth upstream of the accumulation reach as shown in Fig.4 and Table 2.

The heading-up percentage represents the percentage of the increase of water depth related to the smooth case depth at the upstream cross section due to accumulation reach and is mentioned in figure 8 and table (3). h_{up}% is equal to $[(Y_{ucase}-Y_{usmooth})/ Y_{usmooth}) * 100]$, where ($Y_{ucase}$) is the water depth just upstream of the infested reach, ($Y_{usmooth}$) is the water depth upstream of the screen in the smooth case.

- For the same accumulation, the heading up increased with increasing water discharge as shown in Fig.8.
- The greatest heading-up percentage was 6.252 % of case 3 more than case 5 of 6.103% as shown in Table 3, which means that the accumulation reach length is more effective than its height.

Table 3 The heading-up percentage related to the smooth case

Q (L/s)	h_{up}%							
	smooth case	case 1	case2	case 3	case 4	case 5	case 6	case 7
40	0	2.075	2.039	6.252	1.456	6.103	-1.492	1.079
37	0	1.807	1.991	5.324	1.373	5.390	-1.690	0.515
34	0	1.606	1.819	4.829	1.089	3.983	-1.860	-0.036
31	0	0.899	1.080	4.215	0.332	2.305	-1.874	-0.699
28	0	0.892	0.832	3.705	0.324	2.094	-2.100	-1.262

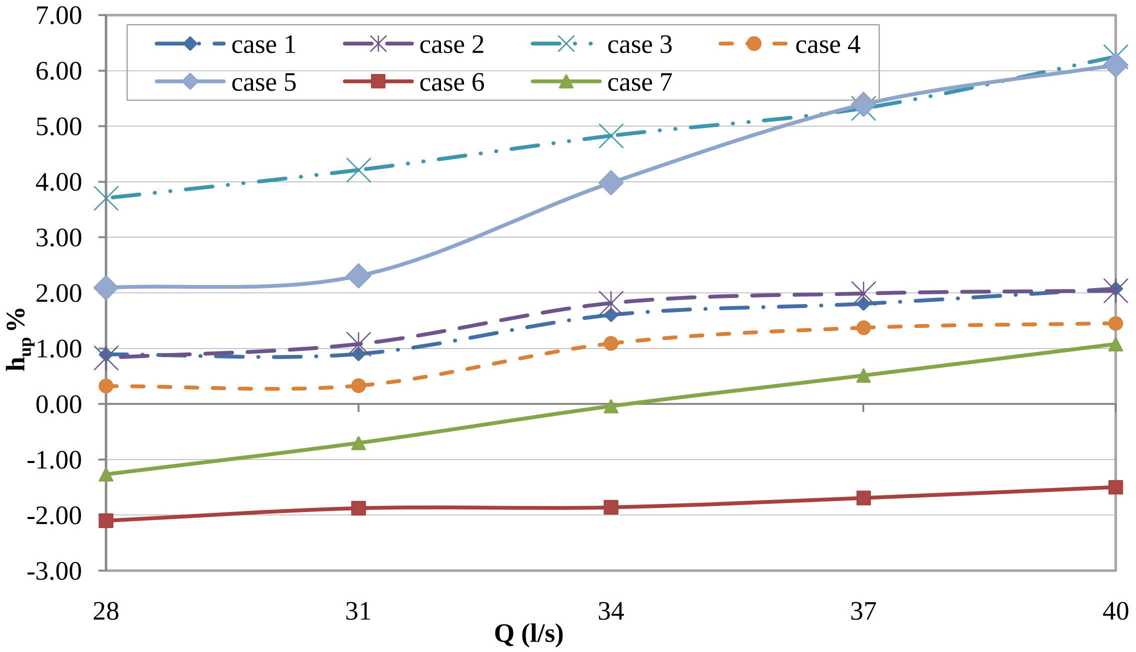


Figure 8Heading up percentage relative to the change in discharge for all cases

2. Empirical Relationships

Multiple linear regression analysis and ANOVA Test were performed using a 95% confidence level to establish empirical relationships between the characteristics of the accumulated weeds and debris (independent variable) (B%, Xr, Yw, a) as shown in Table 4, and the flow characteristics (dependent variable) (Yu, Yd, Vu, Vd). Quadratic functions were found to provide the best-fit data. From the theoretical approach and multiple regression analysis, the hypothetical relationships can be as follow;

$$\left\{ Fr_{da}, \left(\frac{Q}{V_{d\,max} * Y_d^2}\right), \left(\frac{Q}{V_u * Y_u^2}\right) \right\} = \phi\left(\frac{Y_w}{Y_u}, B\%, X_r\right) \ldots\ldots\ldots\ldots\ldots\ldots \; Eq.\ (3)$$

$$\left\{ \left(\frac{Y_d}{a}\right) \right\} = \phi\left(\frac{Y_u}{a}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; Eq.(4)$$

Table 4 The correlation matrix for the hypothetical relationships, which shows the strength of the relationship between the independent parameters and the dependent variables

	Y_w/Y_u	$(Y_w/Y_u)^2$	$(B\%)^2$	B%	Xr	$(Xr)^2$	$Q/(V_u*Y_u^2)$	$Q/(V_{dmax}*Y_d^2)$	Fr_{da}	Y_u/a	Y_d/a
Y_w/Y_u	1										
$(Y_w/Y_u)^2$	0.954	1									
$(B\%)^2$	0.214	0.328	1								
B%	0.205	0.310	0.993	1							
Xr	0.150	0.093	-0.082	-0.065	1						
$(Xr)^2$	0.142	0.094	0.029	0.040	0.980	1					
$Q/(V_u*Y_u^2)$	-0.582	-0.647	-0.515	-0.516	-0.582	-0.646	1				
$Q/(V_{dmax}*Y_d^2)$	-0.742	-0.723	-0.899	-0.890	-0.065	-0.135	0.716	1			
Fr_{da}	0.817	0.927	0.447	0.431	-0.061	-0.064	-0.573	-0.746	1		
Y_u/a	0.997	0.998	0.503	0.477	-0.384	-0.350	-0.636	-0.691	0.916	1	
Y_d/a	0.993	0.994	0.506	0.478	-0.406	-0.362	-0.633	-0.688	0.897	0.995	1

- The highlighted number in the previous table shows the influence of each independent variable on the dependent terms.

2.1 Relation between the accumulation characteristics and (Q/ (Vu*Y^{2}u))

The relationship between (Q/ (Vu*Y^{2}u)) and the relative accumulation height was plotted for the relative length of accumulation between 20 % to 100 % as in Fig. 9, and the empirical formula which describesthe relationship between them is mentioned in “equation 5”

$$\left(\frac{Q}{V_u{*}Y_u^2}\right)=\left(4.800+1.960\left(\frac{Y_w}{Y_u}\right)-3.590\left(\frac{Y_w}{Y_u}\right)^2+1.8\mathrm{E}-04(B\%)^2-0.031(B\%)+0.0225(X_r)-0.00035(X_r)^2\right)..(R^2=0.90)...Eq.5$$

The relationship between the measured and the predicted (Q/V$_u$*Y^{2}u) were shown in figure 10. The resulting trendline equation is

Y = 0.9998 X (R2 = 0.90) ……………………….*Eq. 6*

“equation 6” means that the measured and the predicted value (Q/V$_u$*Y^{2}u) are approximately the same value and “equation 5” could be trusted to determine the value of (Q/V$_u$*Y^{2}u).

It can be concluded from Figs. 9 and 10 that: -

- With the same relative accumulation height, extending the length upstream of the trash screen led to a rise in the water level upstream of the screen, and (Q/Vu*Y^{2}u) was decreased by increasing the relative length percentage by more than 40%.
- With the same relative accumulation length and an increase of the relative accumulation height by more than 30%, the value of (Q/Vu*Y^{2}u) decreases.

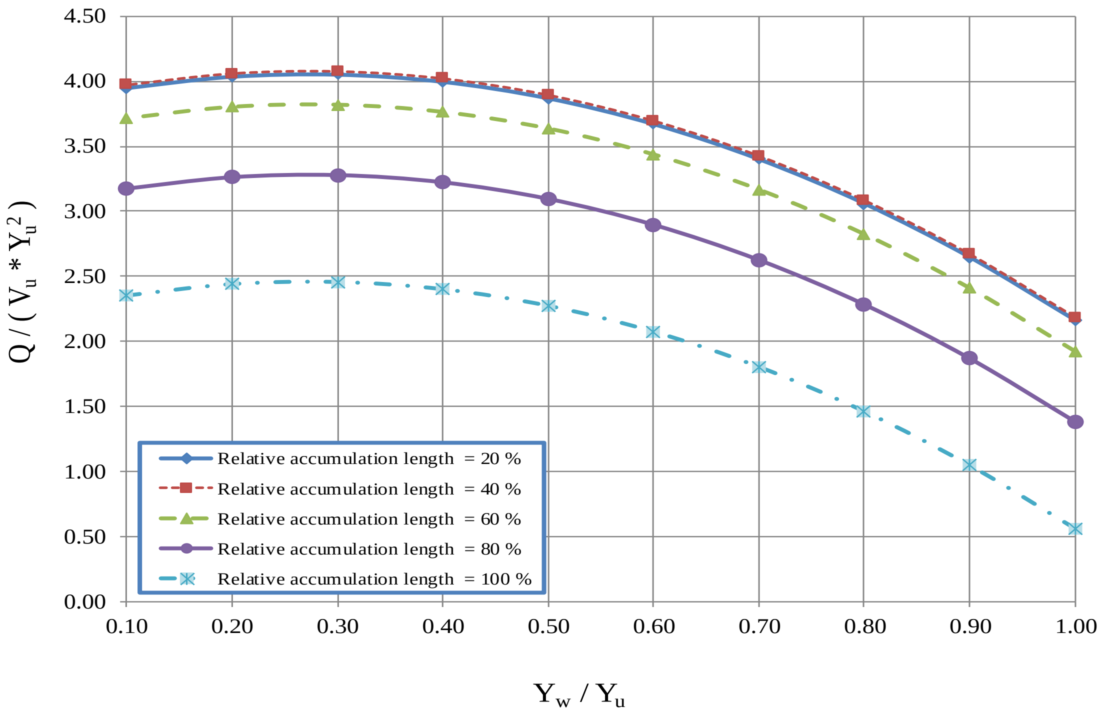


Figure 9 The relation between (Q/ (V$_u$*Y^2_u)) and the accumulation height at different relative accumulation reach lengths (X$_r$) and constant accumulation reach width

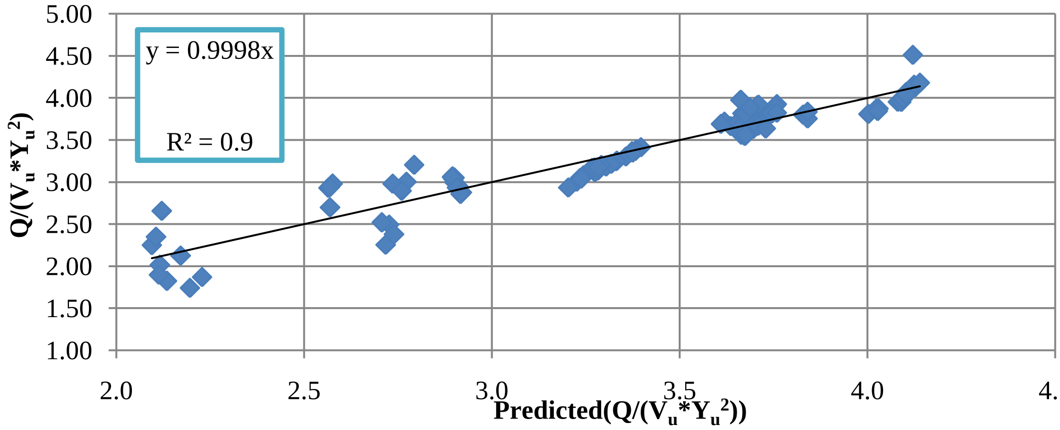


Figure 10 Predicted (Q/V_u*Y^2u) against the measured(Q/V_u*Y^2u)

2.2 Relation between the accumulation characteristics and ($Q/(V_{dmax}*Y^2_d)$)

Fig.11 displays the relationship between ($Q/(V_{dmax}*Y^2d)$) and the relative accumulation length for relative accumulation blocking ranging from 20% to 100%. "equation 7" mentions the empirical formula that characterizes the link between them.

$$\left(\frac{Q}{V_{d\max}*Y_d^2}\right)=\left(\begin{array}{l}10.236-13.884(\frac{Y_w}{Y_u})+7.176(\frac{Y_w}{Y_u})^2+1.5E-04(B\%)^2-0.039(B\%)\\-0.020(X_r)+0.00013(X_r)^2\end{array}\right).....(.R^2=0.9)....Eq.7$$

Fig. 12 displays the predicted and measured values of ($Q/(V_{dmax}*Y^2d)$), while "equation 8" presents its trend line.

Y = 0.9672 X (R2 = 0.89) ………………………*Eq. 8*

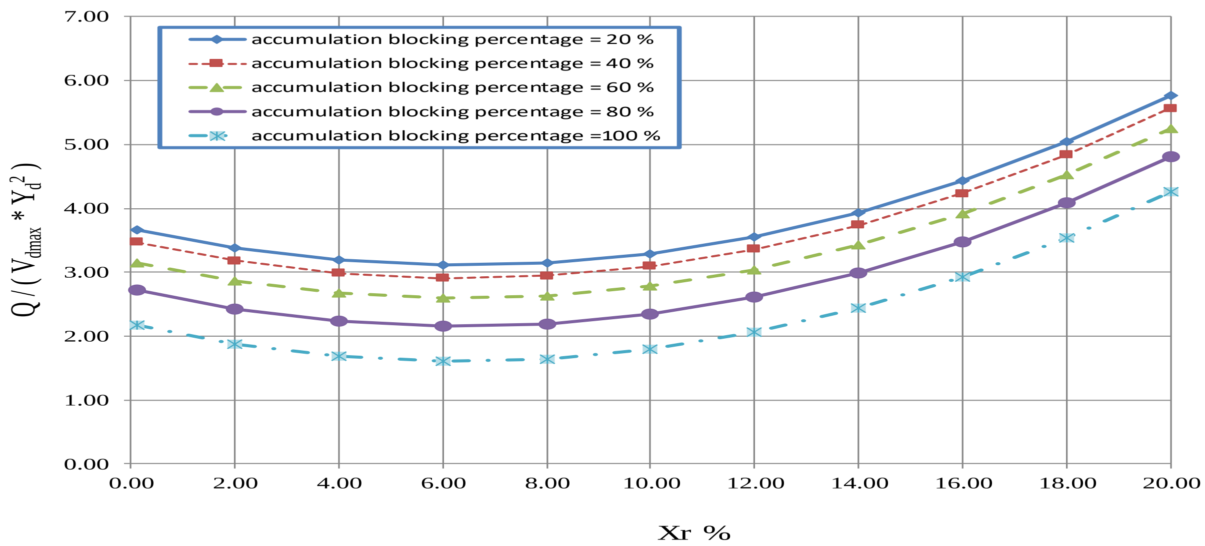


Figure 11 The relation between ($Q/(V_{dmax}*Y^2_d)$) and the accumulation length at different relative accumulation reach height and width.

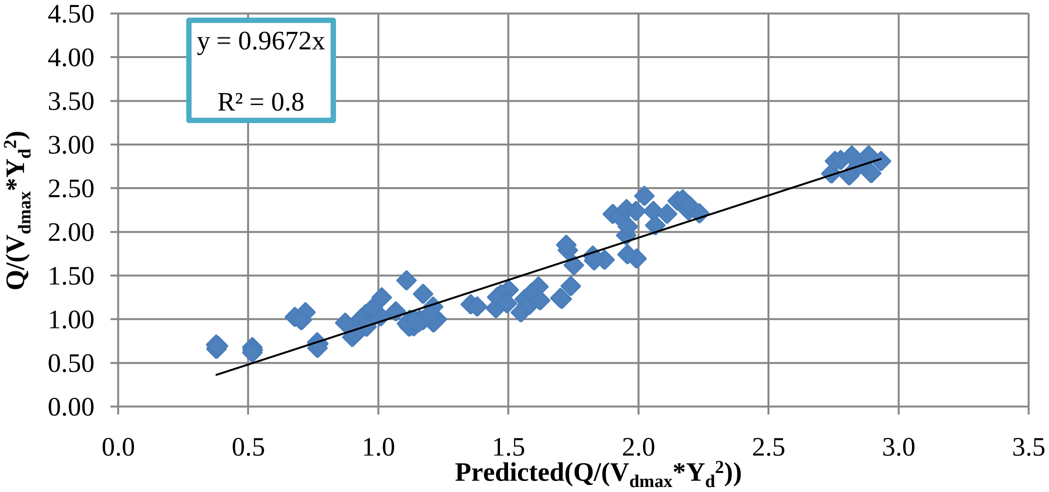


Figure 12Predicted ($Q/(V_{dmax}*Y^2_d)$) against the measured ($Q/(V_{dmax}*Y^2_d)$)

From Fig.11, it can be concluded that: -

- An increase in the accumulation-blocking area percentage results in a reduction in the water-free area beneath the trash screen, an increase in downstream velocity, and a decrease in ($Q/(V_{dmax}*Y^2_d)$) at constant relative accumulation length.
- The downstream velocity increased as the relative accumulation length increased between about 0% to 6% and reduced once exceeding 6% causing an increase in ($Q/(V_{dmax}*Y^2_d)$).

2.3 Relation between the accumulation characteristics and Fr_{da}

The relationship between (F_{rda}) and the relative accumulation height for relative accumulation lengths ranging from 20% to 100% is shown in Fig.13, and “equation 9” which mentions the empirical formula that represents this relationship.

$$(Fr_{da}) = \begin{pmatrix} -0.047 - 1.377(\frac{Y_w}{Y_u}) + 2.747(\frac{Y_w}{Y_u})^2 - 1.3\text{E}-05(B\%)^2 - 0.004(B\%) \\ + 0.004(X_r) - 0.00004(X_r)^2 \end{pmatrix} ....(R^2 = 0.93)....Eq.9$$

As illustrated in Fig. 14, the validity of the predicted (Frda) is used to determine the value of R^2, where it represents the degree of fit of the experimental data, and trendline “equation 10” determines the relationship between the predicted and measured values.

Y = 0.872 X (R^2 = 0.86)………………………*Eq. 10*

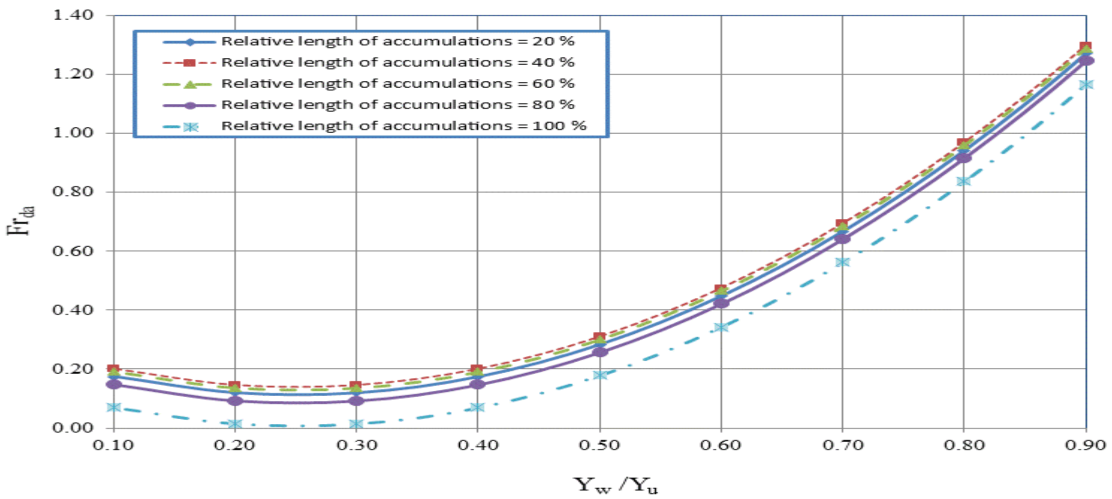


Figure 13 the relation between (Fr_{da}) and the accumulation heightat the different relative lengths of accumulation (Xr %) and constant accumulation’ width

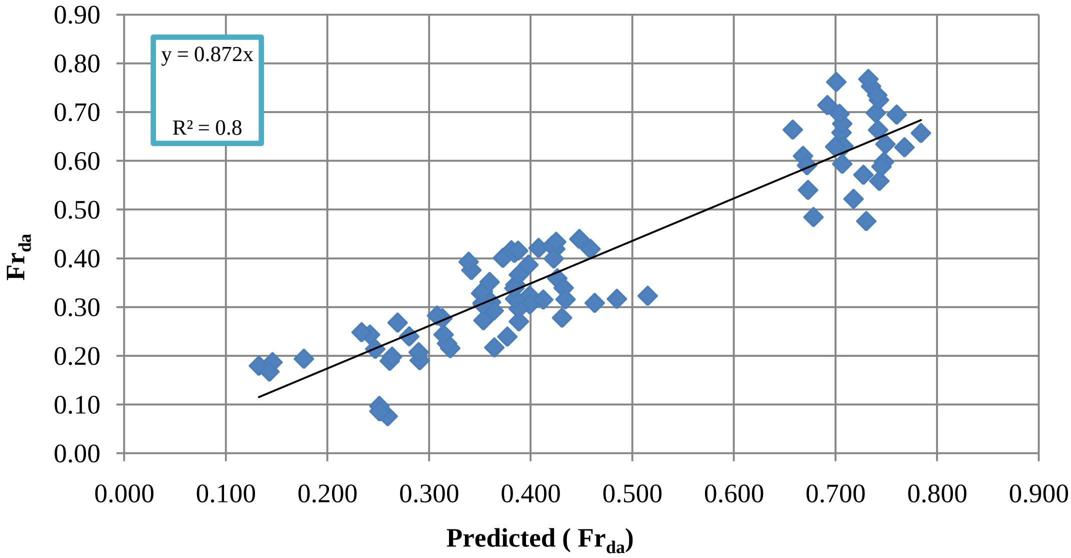


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Figure 14 Predicted (Fr_{da}) against the measured (Fr_{da})

It was concluded in Fig.13 the followings: -

- The Froude number is inversely proportional to the relative accumulation length at constant relative accumulation height and directly proportional to the relative accumulation height at constant relative accumulation length.
- The flow is critical downstream the screen (F_{rda} = 1) when the relative accumulation height was between 80% and 90%, and subcritical when its percentage was less than 80%.

V. Conclusions and Recommendations

The research was carried out to study the effect of weeds and debris accumulation upstream of the trash screen on the hydraulic characteristics of open channels, and concluded the following:

- In the case of increasing the height of weed and debris accumulation; the flow passes roughly under pressure with higher velocities underneath the screen.
- For the same weed accumulation, when the discharge increases the heading-upwill be increased.
- The greatest heading-up percentage was 6.252 % of case 3 more than case 5 of 6.103%, which means that the accumulation length is more effective than the accumulation height.
- With constant relative accumulation height, Increasing the extended length upstream of the trash screen led to an increase in the water depth upstream of the screen, and (Q/Vu*Y^2u) was decreased with increasing the relative length percentage by more than 40 %.
- With constant relative accumulation length, the increase of the relative accumulation height of more than 30 % leads to a decrease in the value of (Q/Vu*Y^2u).
- At constant the relative accumulation length, increasing the accumulation blocking area percentage leads to a decrease in the water-free area under the trash screen, increases the downstream velocity, and decreases (Q/(Vdmax*Y^2d)).
- The downstream velocity increased with increasing the relative accumulation length from 0 % to 6% approximately and decreased when the relative accumulation length exceeds 6% and causes the increase of (Q/(Vdmax*Y^2d)).
- The flow is critical downstream the screen (Fr_{da} =1) when the relative accumulation height was between 80 % to 90 % of the upstream water depth, and subcritical when its percentage is less than 80 %.
- Different equations were developed to describe the relationship between the characteristics of the accumulation independent variable, and the flow characteristics.
- It is recommended to keep a routine maintenance program to keep accumulation length below 6% of the upstream length and accumulation height 30% from the upstream water depth.
- It is necessary to carry out two programs for maintenance upstream of the trash screen, one program during maximum water requirements and the other within minimum water requirements.

- Maintenance programs should be done for removing accumulation upstream trash screens regularly because changing water levels upstream and downstream screen create a fake water level which affects the water distribution, and calibration of the gates' opening.

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