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Comparison of Measured Discharges of Designed Trapezoidal Modified Broad Crested Weirs and Estimated Discharge by Winflume Software

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ABSTRACT

Growing populations induces the more withdrawal of water towards agriculture, industry and domestic putting water resources under stress. Good management of scarce water resource is dependent upon quantifying supplies and uses with accurate measurement techniques. Several types of structures have been used for finding discharges in open channel. The terms ''long-throated flume'' and 'broad-crested weir'' comprises a large family of structures used to measure discharge in open channels with highest accuracy. The advantages of this structure include minimal head loss, low construction cost, adaptability to a variety of channel types, and ability to measure wide ranges of flows with custom-designed structures. The WinFlume program serves two primary purposes Calibration of existing flow measurement structures fitting the criteria for analysis as long-throated flumes and Design of new structures. In the present study, the Winflume is used to test existing design. A good correlation is established between the measured and predicted discharges With improving the upstream conditions, the measured and theoretical discharges are in good agreement with best coefficient of determination. The difference between the theoretical and measured discharges varied between 9.81 % to -1.87 for different flumes at different discharges. With modification the average percent of error in case of broad crested weir is – 1.669 and is decreased to -1.005% by using WinFlume software. From the results it is clear that the model has good ability for estimation of the passing discharge through the long throated flume, therefore it can be used successfully to simulate hydraulic process of passing discharge through the long throated flume.

Key words: *Comparison, Crested weirs, Winflume software.*

The prediction of discharge in the open channels is important in irrigation engineering for different hydrological applications. An accurate water measurement at different locations is important in efficient water management in an irrigation system (Raza, 2007). Several types of structures have been used for a long time in performing discharge measurement in open channels such as flumes, gates, and weirs. Examples of such structures used in the past two decades are weirs and flumes. Flumes can be categorized in to short-throated flume and long-throated Flume

In short-throated Flumes, Parshall flumes and other types of flumes have advantages of lower head loss and of passing the sediment on through but are costlier to fabricate and install. The long-throated ramp flume (also known as a broad-crested-weir) has strong advantages in flat ditches or canals as free flow conditions can be maintained at 90% submergence and above (Samad 2009). The broad crested weir considered as a flat-crested structure with a crest length large compared to the flow thickness.

The throat length in long-throated flumes should be at least two times the height of water in the flume to allow hydrostatic pressure distribution in the control section. This property results in generation of a specific equation between discharge and water height in flumes. Keeping the above points in view, the following studies are taken up to compare the discharges of designed trapezoidal modified broad crested weirs for low discharges by using WinFlume software

THE WINFLUME COMPUTER PROGRAM

WinFlume is the latest in a series of long-throated flume design tools originally developed through the cooperative research efforts of the Agricultural Research Service (ARS) and the International Institute for Land Reclamation and Improvement (ILRI). Albert J. Clemmens and John A. Replogle of ARS and Marinus G. Bos of ILRI developed many of the original hydraulic design criteria and computation procedures. (Wahl 2001, WinFlume User's manual).

The WinFlume program serves two primary purposes Calibration of existing flow measurement structures fitting the criteria for analysis as long-throated flumes and Design of new structures (Wahl 2001, WinFlume User's manual). The input parameters generally include flume and canal geometry, hydraulic properties of the structure and the site, and design requirements to be used for later evaluation and review of flume designs. Specific information needs include (Wahl *et al*., 2000) are the hydraulic roughness of the material used for construction of the flume, range of flows to be measured and the associated tail water levels at the site, allowable flow measurement uncertainty at minimum and maximum discharge and required freeboard in the approach channel at maximum flow.

WinFlume uses six design criteria to evaluate the suitability of a given structure for flow measurement. From the reports and graphs menu is used to create flume data report, flume review report, Flume drawing, rating tables and graphs of rating table data, Rating Equation for the flume that can be used in a data logger at the flume site to automate discharge measurements, create wall gages and reports of the data needed to construct wall gages.

MATERIAL AND METHODS

All of the measured quantities from the experiments conducted in the course of this study were taken from Reddy *et al.,* (1993). The experiments have been carried out in an earthen channel covered by polyethene sheet of dimensions 6 m in length and 1 m wide. In order to study the flow characteristics of modified trapezoidal broad crested weirs three models of the weirs with Three crest lengths i. e 15 cm, 20 cm and 25 cm were selected for study (Table1). The weirs were designed and fabricated for different discharges. At the upstream side, an inclined ramp with 1:1 slope and vertical ramp on downstream side was provided. The flumes were mainly designed for low discharges. For the physical models four flow conditions i.e 2.9 lps, 2.7 lps, 2.4 lps and 2.1 lps were selected. The models were installed, and tested.

In order to collect the needed data during the tests the water depth of flow over the entire flow model were recorded accurately. After the flow equilibrium was attained, water levels were recorded at each 1 cm interval along the center line of the trapezoidal broad crested weir starting from the point a little upstream of the crest to the point downstream of the crest. With using of the achieved results with 3 kinds of models, in the following sections results of experiments were analyzed and summarized. WinFlume32 - Version 1.06.0003 software has been used to verify the discharges of the designed flumes. Initially the original dimensions of the weir were taken for verification.

RESULTS AND DISCUSSION

By introducing geometrical specifications of the three models into the WinFlume software, and also the hydraulic conditions of the flow and the roughness of the channel to the software, it was paid to the hydraulic simulations (Figure 1). WinFlume determined a curve-fit equation of the form:

$$Q = K_1(h_1+K2)^{u}$$

K_2 = 0 may also be forced when performing the curve-fit calculations. Theoretical discharge (Q) is determined by the WinFlume model, using hydraulic theory and empirical relationships determined from laboratory testing. It is the most accurate estimate of discharge. The K_1 and U values and the C_d for different conditions are given in Table 2.

In order to investigate the capability of the model to estimate the passing discharge through the flume, the results of the measured discharge in the experimental condition was compared with the calculated discharge by model. The discharge measured at different heads by the weir was compared with discharges by the WinFlume with actual weir and proposed weir (Figure 2 to 4). At lower heads the WinFlume model computed higher discharges than the actual with increase in head, the reverse trend is observed. The difference between the theoretical and measured discharges varied between -12.23 to 9.81 % in case of first flume and -8.34 to -1.87 and -5.29 to 6.83 for second

Table 1. Models and discharge ranges used in the present study.

S. No	Throat width, w, cm	Throat Length, L, cm	U. S. Slope	D. S. Slope	Range of discharges tested, lps
1	25	15	1;1	abrupt	2.1-2.9
2	25	20	1;1	abrupt	2.1-2.9
3	25	25	1;1	abrupt	2.1-2.9

Table 2. K_1 and U coefficient in different scenarios.

S. No	Sill height, cm	Crest length, cm	Upstream ramp slope	K_1	U	C_d
1	10	15	1:1	0.3895	1.653	0.99999653
2	10	20	1:1	0.3214	1.743	0.99999998
3	10	25	1:1	0.3810	1.663	0.99999741
4	10	15	2.5:1	0.3878,	1.654	0.99999667
5	10	20	2.5:1	0.3834	1.660	0.99999688
6	10	25	2.5:1	0.3793	1.665	0.99999752

Figure 1. Flume drawing generated by WinFlume.

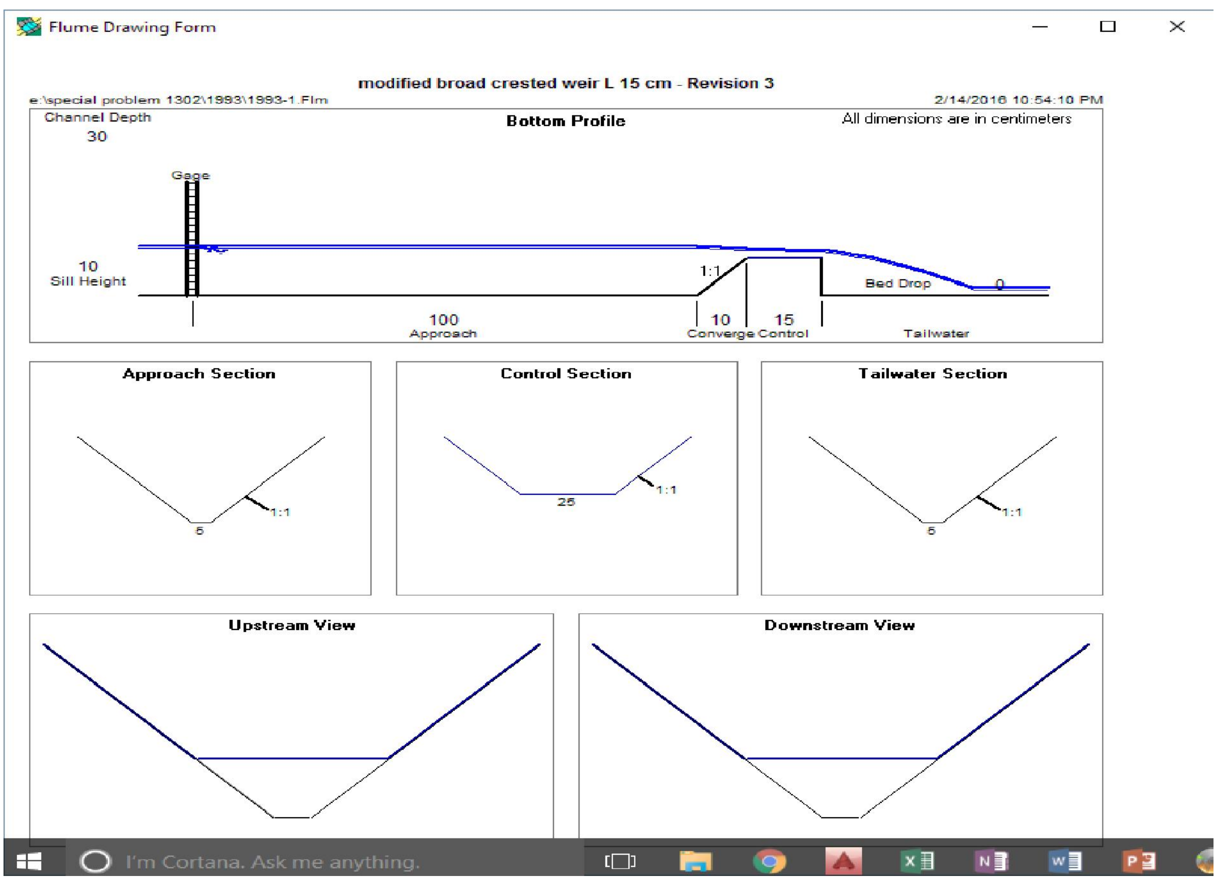


Figure 2. Comparison of measured and theoretical discharges of weir -I and modified weir.

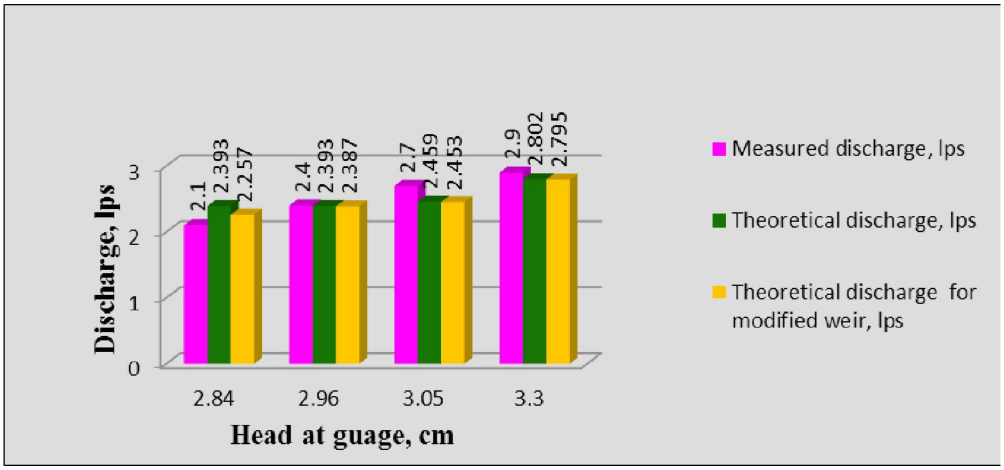


Figure 3. Comparison of measured and theoretical discharges of weir -2 and modified weir.

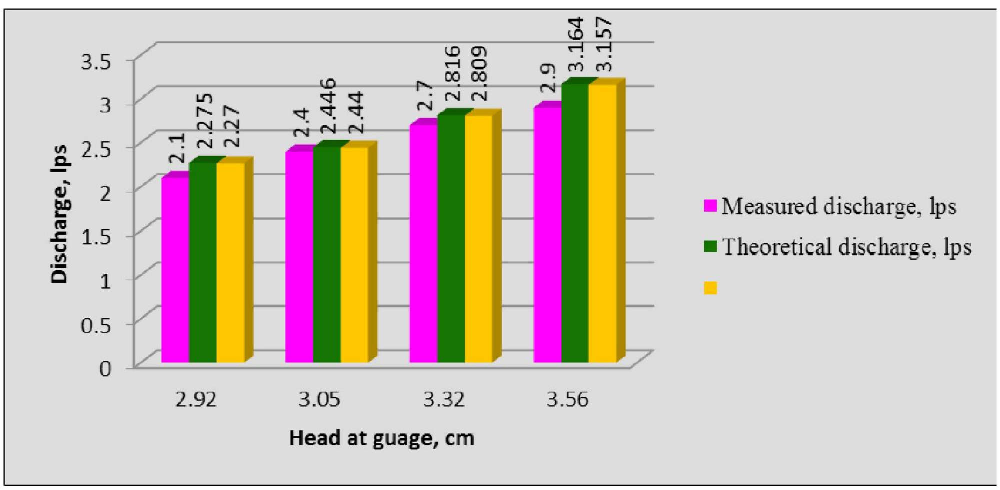


Figure 4. Comparison of measured and theoretical discharges of weir -3 and modified weir

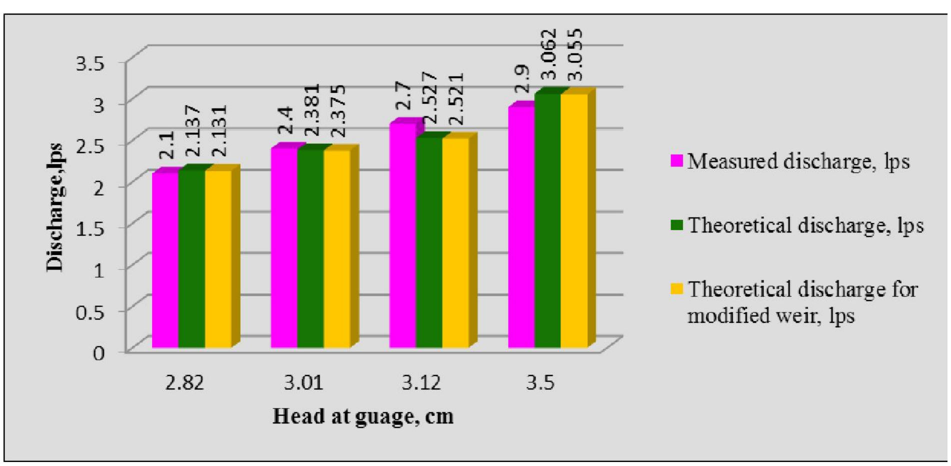


Figure 5. Q-theoretical and Q-measured relationship in broad crested weir (crest height 10 cm, crest length 15 cm and upstream ramp 1:2.5)

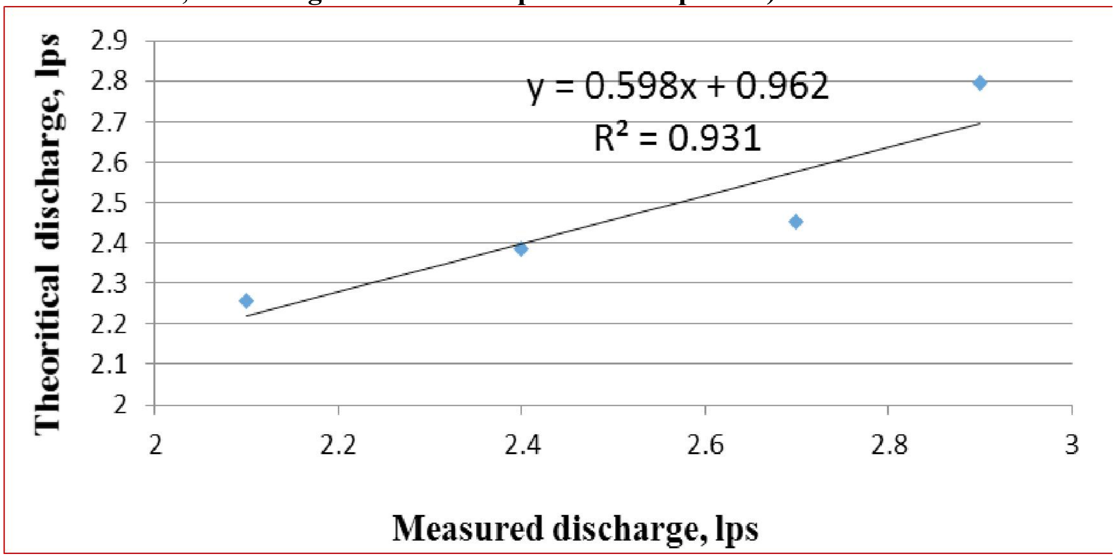


Figure 6. Q-theoretical and Q-measured relationship in broad crested weir (crest height 10 cm, crest length 20 cm and upstream ramp 1:2.5).

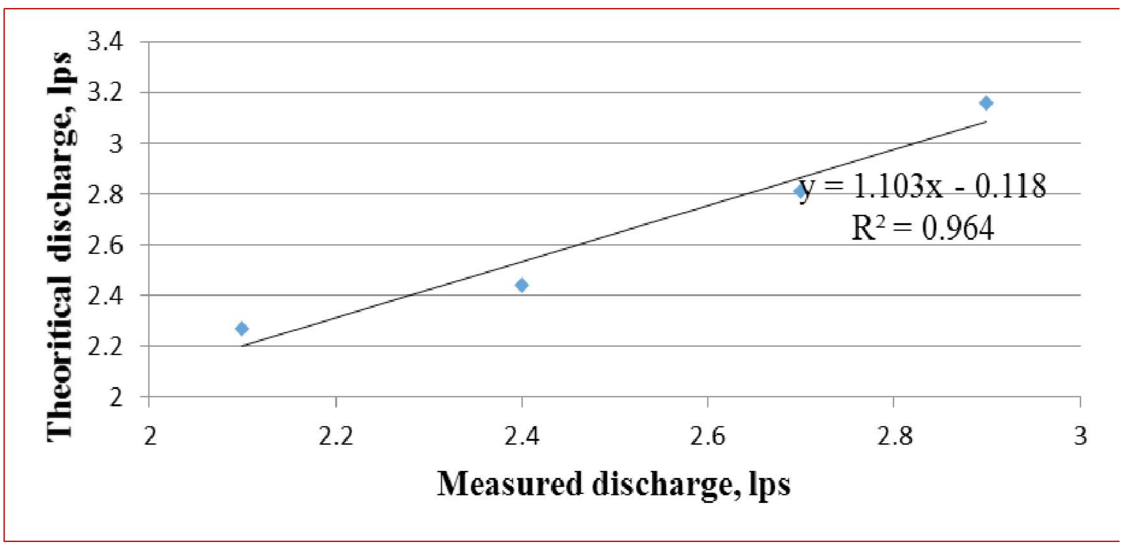


Figure 7. Q-theoretical and Q-measured relationship in broad crested weir (crest height 10 cm, crest length 25 cm and upstream ramp 1:2.5).

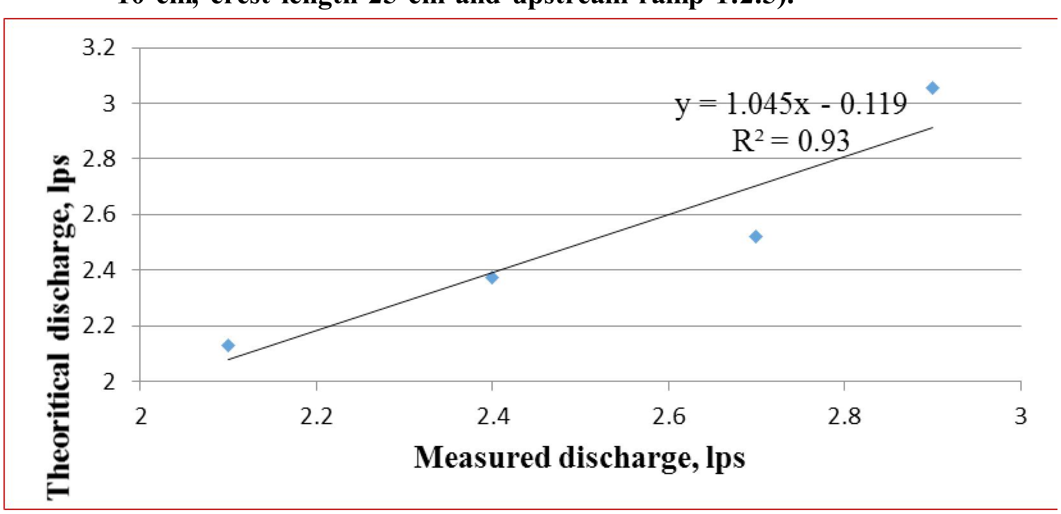
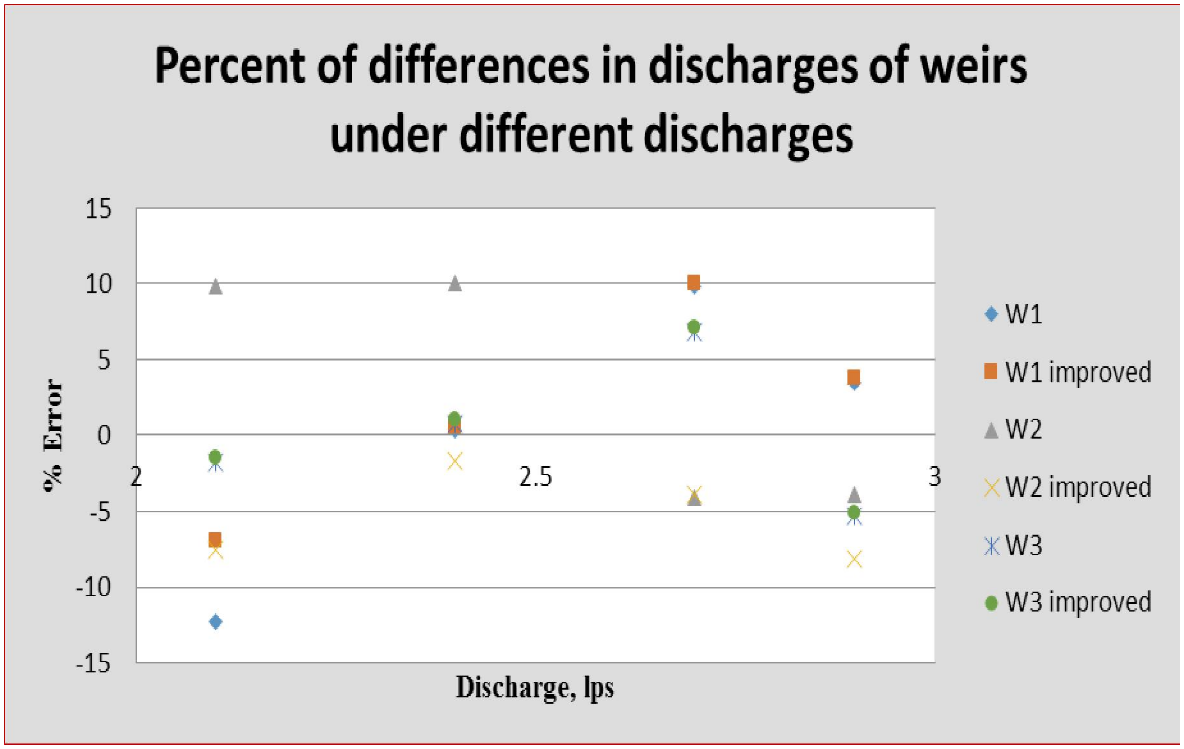


Figure 8. Plotted error in percentage against discharge.



and third flumes respectively. Though the error is acceptable, it is also required to further improve to reduce losses.

By considering the hydraulic losses due to steep upstream ramp, the design is modified by increasing the ramp length to 25 cm i.e by taking a upstream ramp slope of 2.5:1 (suggested between 2:1 to 3:1). In general, the converging upstream ramp should have a slope between 2:1 to 3:1 (H : V). If flatter the ramp is, there will be additional hydraulic losses which detract from calibration accuracy. If the ramp is too steeper than 2:1 unnecessary turbulence may be created in the converging section also causing additional head loss (Michel 1999). On comparison of theoretical and measured discharges for the modified weir, it is clear that the error is decreased -6.95 to 2.15 % and accuracy increased for 15 cm ramp similarly, -8.14 to -1.63 and -5.08 to 5.08. With improving the upstream conditions, the measured and theoretical discharges are in good agreement with best coefficient of determination.

The discharge's estimated by WinFlume model in most of cases got more than the actual discharge. This result similarly wasreported by Wahl *et al*., 2000 and Samad *et al.* 2009. For all the weirs, the characteristics like velocity coefficient, discharge coefficient, upstream energy, upstream velocity, Froude number remained constant for all weirs under same flow conditions. But with gentle upstream slope of weir, the values are increased slightly. In the present study, this is consistent with the hypothesis that critical depth is occurring in the throat with increasing upstream ramp length

The relation between measured and predicted discharges is shown from Figure 5 to 7. The R^2 values for the modified weir are 0.931, 0.964 and 0. 93 for crest lengths include 15 cm, 20cm and 25 cm. The theoretical discharge obtained from the relation of discharge proposed by WinFlume Software and measured discharges are not significantly different. A good correlation is established between the measured and predicted discharges

Reffering the Figure 8, the error against discharge show that at low discharges, as the crest length is increased, the percent of error is decreased. In all the cases, the sign of error was changed with increase in discharge. The average percent of error in case of broad crested weir is –

1.669% and this average were decreased to -1.005% with modification by using WinFlume. From the results it has been concluded that the model has good ability for estimation of the passing discharge through the long throated flume, therefore it can be used successfully to simulations hydraulic process of passing discharge through the long throated flume.

CONCLUSION

On comparison of the laboratory results of modified broad crested weir by keeping the sill height constant and changing the crest length and the results of the simulations using the Win Flume model, showed that the Win Flume model has good ability to estimation of passing discharge through long throated flume. The average percent of error in case of broad crested weir is – 1.669% and this average were decreased to -1.005% with modification by using WinFlume. From the results it is also clear that design deficiencies can also be corrected by using the Winflume software. The results of developed equation and predicted by WinFlume are in close agreement with each other. Finally, it is concluded that the WinFlume can simulate hydraulic process of passing discharge through long throated flume, and it can be used for calibration of any flume.

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