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Open Channel Discharge Measurement Using 0.127 Metre (5 Inch) Long-Throat Flume

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Abstract: Long-throat flumes are used in flow measurement by developing power curve relationship between water depth and discharge. This structure provides economical and flexible water measurement capabilities for a wide variety of open-channel flow situations. The advantage of these structures includes 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. A series of detailed laboratory measurements were made under steady-state flow conditions through a Long-throat flume of control section width 0.127 m (5″) as there is no data available for 5″ for any flume length. Free flow and submerged flow calibration were done within flow range 0.005 m^3/s to 0.022 m^3/s. The result of the calibration shows discharge within calibrated flow range. The proposed equation can determine accurately the discharge with maximum deviation of $\pm$6% and $\pm$8% for stilling well and gauge data respectively. Henceforth, using proposed equations Ditchrider's table and rated graph was developed for field implementation of the flume.

Key words: Flume, submerged flow, free flow, Ditchrider's table.

Introduction

Water demand increases with every step towards urbanization and industrialization. In agriculture sector, water requirement is also increased because of genetically modified organisms and high yielding crops. Resulting to this, proper water distribution and measurement is necessary for efficient water management. To ensure accurate measure of supply water, measurement devices should be employed which are durable, low-cost, transportable and easy for installation. Structures like flumes are often used for the discharge measurement in open channels in the small irrigation canals and fields. Flumes can be categorized in two groups:

- Short-throat flumes
- Long-throat flumes

Short-throat flumes are so called because they have small length of control section such as Parshall flume, cut-throat flume, H flume etc. They have lower head loss and of passing the sediment on through but are more costly to fabricate and install. Non-level flumes and improper installation (insufficient crest height) are the most common problems. However, cut-throat flumes (Hyatt, 1965; Skogerboe, 1967; Temeepattanapongsa, 2012; Das et al., 2015) are simpler to construct and can operate as free flow conditions at a higher degree of submergence.

Long-Throat Flumes

Long-throat flumes are coming into general use because they can be easily fitted into complex channel shapes as well as simple shapes (Replogle, 1975; Bos et al., 1991). Long-throat flumes have many advantages compared to

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List of Symbols

W	Width of the throat/control section
L_T	Length of the throat/control section
B_C	Width of inlet section
B_D	Width of outlet section
L_1	Axial length of converging inlet section
L_2	Axial length of diverging outlet section
L_C	Length of converging inlet section side wall
L_D	Length of diverging outlet section side wall
L_A	One third of L_1 where h_a is measured
L_B	One third of L_2 where h_b is measured
h_a	Upstream head
h_b	Downstream head
H	Height of the flume
H_C	Sill height of control section
L_{SC}	Horizontal length of converging slope
L_{SD}	Horizontal length of diverging slope
$Q(FF)$	Calculated free flow discharge
$Q(SF)$	Calculated submerged flow discharge
C_f	Free flow discharge parameter
n_f	Free flow discharge exponent
C_s	Submergence flow discharge parameter
n_s	Submergence flow discharge exponent
S	Submergence ratio
S_t	Transition submergence ratio
K	Constant

other measuring devices, including Parshall flumes. The cross-sectional flexibility of long-throat flumes allows them to fit various channel shapes more conveniently than short-throat flumes, which have fixed sizes and shapes. Because of the ability to match the channel shape, the construction of forms is usually simplified. Also, field observations have shown that the structure can be designed to pass sediment transported by channels with subcritical flow.

The hydraulic theory for predicting discharge through long-throat flumes has resulted from over a century of development. Theoretical predictions of flow were investigated by Ackers and Harrison (1963) and further Replogle (1975), Bos et al. (1984) and Clemmens et al. (2001) described the theory for determining discharge through these flumes.

Clemmens et al. (2001) and Bos et al. (1991) provide calibration tables in metric (S.I.) and English units for a set of Long-throat flume dimensions that covers a discharge range from about 2.8 to 280 ft^3/s for trapezoidal channel shapes with side slopes of 1:1 to 1:1.5 horizontal and with bottom widths from about 1 to 5 ft. They also provide instructions for construction and field placement. Calibration tables for Long-throat rectangular flumes are also presented.

Discharge equation for the long-throat flume is given by

For free flow condition

$$Q = C_f \; h_a^{n_f} \tag{1}$$

For submerged flow condition

$$Q = C_s\left(h_a - h_b\right)^{n_f} / \left(-\log\left(S\right) + K\right)^{n_s} \tag{2}$$

where Q is discharge, m^3/s, C_f = coefficient of free flow, C_s = coefficient of submerged flow, h_a = height of water in the upstream section, m, h_b = height of water in the downstream section, m, n_f = free flow exponent, n_s = submerged flow exponent, S = submergence ratio and K = constant.

However from previous study it is evident that very few experiments were carried out for 5″ throat-width Long-throat flume for any flume scale length. To improve the areas (free flow and submergence) of small Long-throat flume, an attempt is made in the present study to develop, design and propose new equations for both free flow and submerged flow condition of these flumes. In the field sometimes installing the stilling well becomes difficult. Moreover maintenance of stilling well is a concern when the flow contains suspended particles which may block the inlet of the stilling well. Hence in those cases measurements are taken from a scale fixed on the wall of the flume. In the present work a point gauge is used instead of the scale to measure the head.

Experimental Set-up and Methodology

The Long-throat flume was constructed at the Fluvial Hydraulics Laboratory of the School of Water Resources Engineering, Jadavpur University, Kolkata. The flume was installed in a recirculating transparent flume. The recirculating transparent flume was 6 m long, 0.5 m deep and 0.355 m wide as shown in Figure 1(a). One centrifugal pump of 3.7 kW rated power and 1420 rpm rated speed used was capable of delivering a maximum flow rate of approximately 27 lps or 0.027 m^3/s (Das et al., 2014).

Water is delivered to the flume with the help of a 0.1 m diameter delivery pipe. The flow rate was regulated by means of a valve located on the delivery line and bypass line. Discharge was measured with the help of water meter attached to delivery pipe. One baffle wall is installed across the length of the flume, just after the delivery pipe outlet before entering the flume to remove unsteadiness of the flow. The flow passes through the flume and is discharged into the 6 m long, 0.6 m deep, and 0.4 m wide reservoir or pump from where it was recirculated by means of a 0.1 m diameter suction pipe as shown in Figure 1(a). A point gauge mounted on a movable trolley was used to measure the water level profile or water depth in the flume. Downstream water depth is increased and desired submergence ratio is obtained by regulating the tail gate.

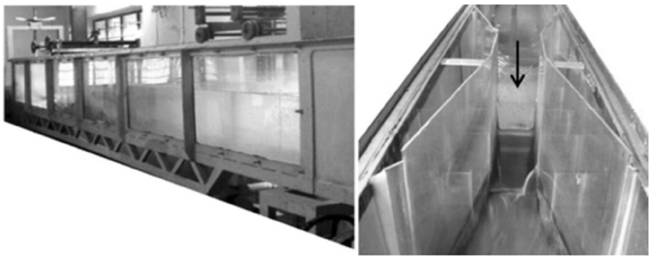

Figure 1: The entire experimental setup (a) recirculation transparent flume, (b) long-throat flume (plan view).

Design

The designed Long-throat flume was made by 0.006 m transparent acrylic sheet of throat width (W) 0.127 m and length (L) 1.6 m. The vertical side wall height was kept 0.5 m considering 0.2 m free board.

Converging Inlet Section

The entrance section of the Long-throat was divided into two equal parts. The first part was the horizontal floor in the direction of flow and in the second part the floor was inclined upward with a slope of 1 vertical to 3 horizontal as shown in Figure 2.

The horizontal length L_{SC} and vertical length H_C was equal to 0.3 m and 0.1 m respectively. The vertical walls of the inlet section converge longitudinally with 1:6 ratio. The axial length of the vertical wall was 0.61 m, width of the entrance of the inlet converging section (B_C) was taken as 0.327 m and the throat section (W) was 0.127 m. Stilling Wells are incorporated at a distance of one third the length of converging section (L_A) i.e. 0.20 m from the entrance section. This was for measuring the inlet/upstream head (h_a).

Diverging Outlet Section

The exit section of the Long-throat also has two parts. In the first part the floor was inclined downwards with a slope of 1 vertical to 1 horizontal in the direction of flow and in the second part the floor was horizontal as shown in Figure 2. The horizontal length L_{SD} and vertical length H_C are both 0.1 m. The side walls diverge in the direction of flow. The outlet section diverges with a slope of 1 transversal to 7 longitudinal. The axial

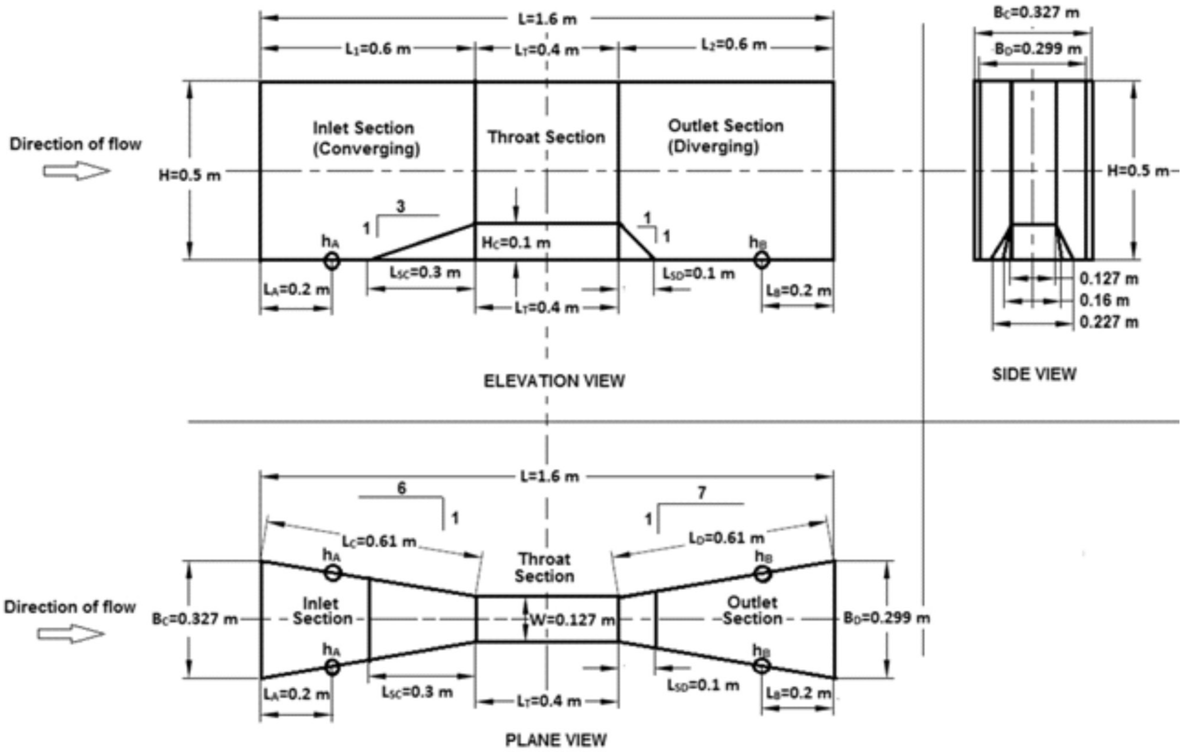

Figure 2: Complete layout of 0.127 m (5 inch) long-throat flume: (a) elevation view, (b) side view and (c) plan view.

length was 0.61 m. Width of the exit cross section of the outlet diverging section (B_D) was taken as 0.299 m and at the throat section was 0.127 m. Stilling Wells were incorporated at a distance of one third the length of diverging section (L_A) i.e. 0.20 m from the exit section. This was for measuring the outlet/downstream head (h_b).

Throat Section

The throat section constitutes the middle portion of the flume. The width of the throat (W) and length of the throat (L_T) was 0.127 m and 0.4 m respectively. The bed level of the throat was 0.1 m high above the datum known as the flume crest. The depth of water in the stilling well was measured with respect to flume crest as datum.

Results and Discussion

Number of free flow experiments carried out was 18. Discharges were varied from 0.005 m^3/s to 0.022 m^3/s and corresponding upstream head was measured using stilling well. The submerged flow calibration was done for the same discharges as for free flow calibration. A total of 66 experiments were carried out in case of submerged flow calibration. Desired Submergence ratio $S = h_b/h_a$ was obtained by regulating the tail gate. For plotting of Water Surface Profile for free flow, 60% submergence, 70% submergence, 80% submergence and 90% submergence, the gauge reading was taken at 24 points (a mesh was formed with eight longitudinal and three transversal sections) of the entire flume. For each longitudinal position, the mean values of the transverse points were taken for drawing the water surface profile. The water surface profile of free flow and different submergence conditions for 0.011 m^3/s discharge are shown in Figure 3; here the free flow and the submergence water level can be seen very clearly.

The water profiles of free flow and submerged flow for different discharges are plotted in single graph indicating the similar flow behaviour as shown in Figure 4.

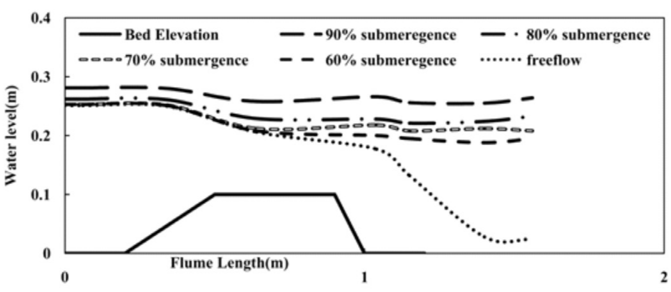

Figure 3: Water profile for discharge at 0.011 m^3/s.

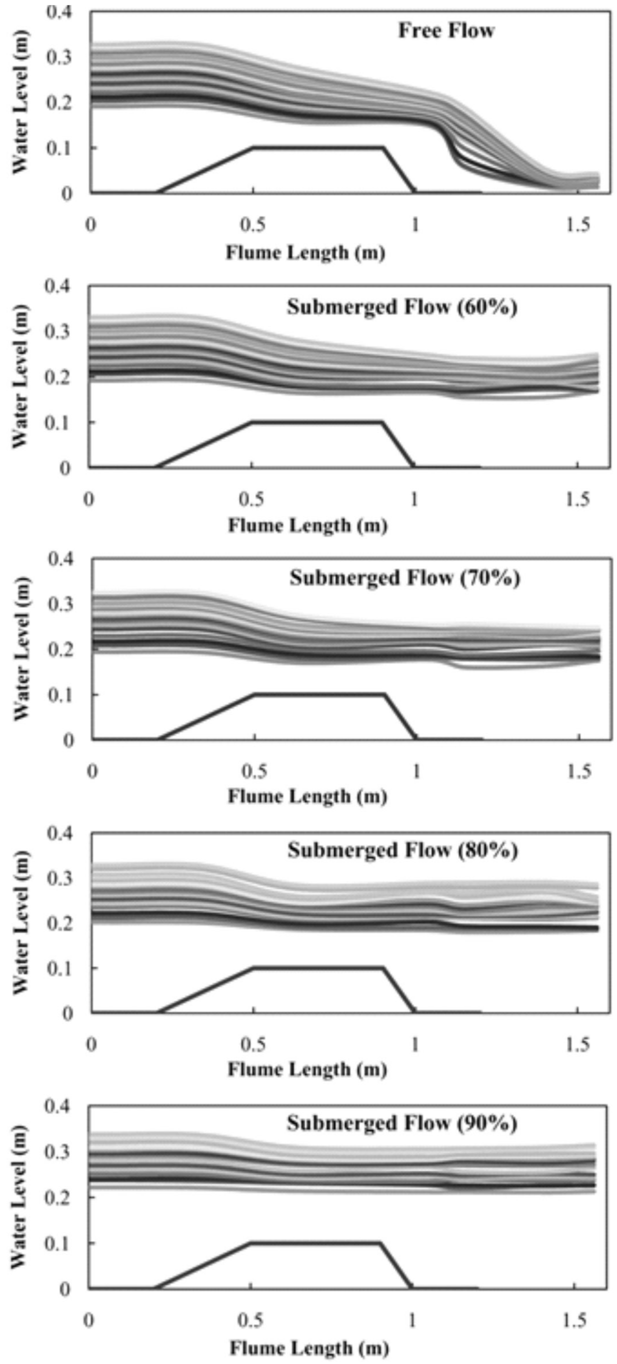

Figure 4: Comparison of flow behaviour of free flow and submerged flow condition.

Rating Equation Using Stilling Well Data

The free flow rating curve was obtained by plotting measured discharge, $Q_{measured}$ against upstream flow depth h_a in logarithmic scale with $Q_{measured}$ as ordinate and h_a as abscissa as shown in Figure 5 (a). The free flow discharge parameter C_f and exponent n_f comes out to be as 0.2568 and 1.6514 respectively.

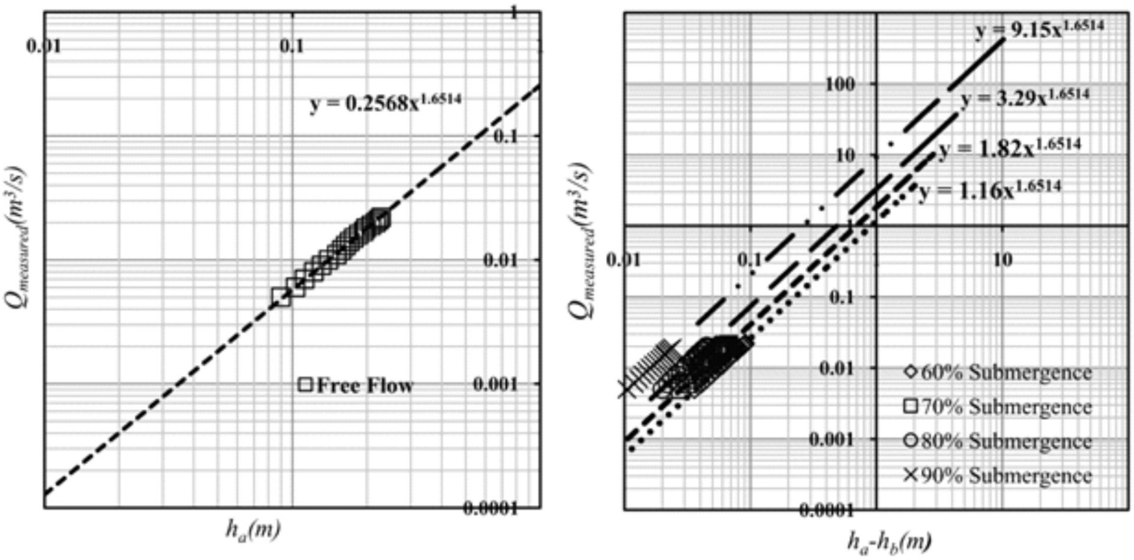

Figure 5: The rating curve using stilling well data: (a) free flow and (b) submerged flow.

The proposed free flow rating equation of long-throat flume is given by

$$Q(FF) = 0.2568\, h_a^{1.6514} \tag{3}$$

Submergence calibration curve shown in Figure 5 (b) was obtained by plotting discharge measured $Q_{measured}$ (m^3/s) and difference between upstream head (h_a) and downstream head (h_b) for submergence ratio 60%, 70%, 80% and 90%. Discharges at 60%, 70%, 80% and 90% submergence is 1.16 m^3/s, 1.82 m^3/s, 3.29 m^3/s and 9.15 m^3/s respectively for head difference of 1 m. It was found that derived discharge equation for submerged flow is a function of head difference and negative logarithm of submergence. The proposed submerged flow rating equation for Long-Throat flume is given by

$$Q(SF) = 0.2035\left(h_a - h_b\right)^{1.6514} / \left(-\log S - 0.012\right)^{1.1247} \tag{4}$$

The obtained submerged flow discharge parameters are $C_s = 0.2035$ and exponent $n_s = 1.1247$.

At transition submergence the discharge obtained from free flow equation is equal to the submerged flow equation i.e.

$$C_f\, h_a^{n_f} = C_s\left(h_a - h_b\right)^{n_f} / \left(-\log S_t - 0.012\right)^{n_s} \tag{5}$$

Dividing both side with $C_s\ h_a^{n_f}$ we get

$$C_f / C_s = (1 - S_t)^{n_f} / (-\log S_t - 0.012)^{n_s} \tag{6}$$

By putting the values of C_f, C_s, n_f and n_s in equation (6) the value of transition submergence comes out to be 63.35%.

On comparing the calculated data obtained from rating equations with the measured data as shown in Figure 6, it can be seen that only few points of submergence condition deviates more than ±6% from the perfect agreement line.

Rating Equation Using Gauge Data

Sometimes, measurement of water level in flumes is not possible due to blockage of inlet of stilling wells by debris. Hence it is wiser to clean the tappings of stilling well regularly. However, in natural practice this cleaning is not carried regularly as it is very tiresome to clean it regularly, sometimes due to extreme climate or due to our ignorance and awareness. Hence we need other equipment like point gauge to measure the water depth.

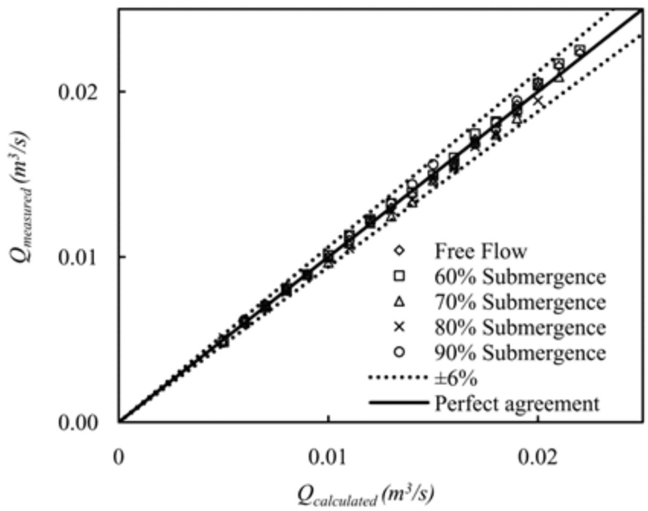

Figure 6: Comparison of free flow and submerged flow calculated discharge with measured discharges (Stilling well).

Table 1: Discharge for free flow (m^3/s) using stilling well data

Head	*Discharge for free flow* (m^3/s)									
(h_a)m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.09				0.0049	0.005	0.0051	0.0052	0.0053	0.0053	0.0054
0.1	0.0055	0.0056	0.0057	0.0058	0.0059	0.006	0.0061	0.0062	0.0063	0.0064
0.11	0.0065	0.0066	0.0067	0.0068	0.0069	0.007	0.0071	0.0072	0.0073	0.0075
0.12	0.0076	0.0077	0.0078	0.0079	0.008	0.0081	0.0082	0.0083	0.0084	0.0086
0.13	0.0087	0.0088	0.0089	0.009	0.0091	0.0093	0.0094	0.0095	0.0096	0.0097
0.14	0.0098	0.01	0.0101	0.0102	0.0103	0.0105	0.0106	0.0107	0.0108	0.011
0.15	0.0111	0.0112	0.0113	0.0115	0.0116	0.0117	0.0119	0.012	0.0121	0.0122
0.16	0.0124	0.0125	0.0126	0.0128	0.0129	0.013	0.0132	0.0133	0.0135	0.0136
0.17	0.0137	0.0139	0.014	0.0141	0.0143	0.0144	0.0146	0.0147	0.0149	0.015
0.18	0.0151	0.0153	0.0154	0.0156	0.0157	0.0159	0.016	0.0162	0.0163	0.0165
0.19	0.0166	0.0168	0.0169	0.0171	0.0172	0.0174	0.0175	0.0177	0.0178	0.018
0.2	0.0181	0.0183	0.0184	0.0186	0.0188	0.0189	0.0191	0.0192	0.0194	0.0196
0.21	0.0197	0.0199	0.02	0.0202	0.0204	0.0205	0.0207	0.0209	0.021	0.0212
0.22	0.0213	0.0215	0.0217	0.0218	0.022	0.0222				

Table 2: Discharge for 60% submergence (m^3/s) using stilling well data

Head	*Discharge for 60% submergence* (m^3/s)									
(h_a-h_b)m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.03								0.0049	0.0051	0.0054
0.04	0.0056	0.0058	0.0061	0.0063	0.0066	0.0068	0.0071	0.0074	0.0076	0.0079
0.05	0.0082	0.0085	0.0088	0.009	0.0093	0.0096	0.0099	0.0102	0.0106	0.0109
0.06	0.0112	0.0115	0.0118	0.0122	0.0125	0.0128	0.0132	0.0135	0.0139	0.0142
0.07	0.0146	0.0149	0.0153	0.0157	0.016	0.0164	0.0168	0.0171	0.0175	0.0179
0.08	0.0183	0.0187	0.0191	0.0195	0.0199	0.0203	0.0207	0.0211	0.0216	0.022
0.09	0.0224									

Table 3: Discharge for 70% submergence (m^3/s) using stilling well data

Head	*Discharge for 70% submergence* (m^3/s)									
(h_a-h_b)m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.02									0.0047	0.005
0.03	0.0053	0.0056	0.006	0.0063	0.0066	0.0069	0.0073	0.0076	0.008	0.0083
0.04	0.0087	0.0091	0.0095	0.0099	0.0103	0.0107	0.0111	0.0115	0.0119	0.0123
0.05	0.0128	0.0132	0.0137	0.0141	0.0146	0.015	0.0155	0.016	0.0165	0.017
0.06	0.0175	0.018	0.0185	0.019	0.0195	0.02	0.0205	0.0211	0.0216	0.0222

Table 4: Discharge for 80% submergence (m^3/s) using stilling well data

Head	*Discharge for 80% submergence* (m^3/s)									
(h_a-h_b)m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.02	0.0048	0.0052	0.0057	0.0061	0.0066	0.0071	0.0076	0.0081	0.0086	0.0091
0.03	0.0097	0.0102	0.0108	0.0114	0.012	0.0126	0.0132	0.0138	0.0145	0.0151
0.04	0.0158	0.0165	0.0172	0.0179	0.0186	0.0193	0.0201	0.0208	0.0216	0.0224

Table 5: Discharge for 90% submergence (m^3/s) using stilling well data

Head	*Discharge for 90% submergence* (m^3/s)									
$(h_a\text{-}h_b)$m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.01	0.0041	0.0048	0.0055	0.0064	0.0072	0.0081	0.0091	0.0101	0.0111	0.0122
0.02	0.0133	0.0145	0.0157	0.0169	0.0182	0.0195	0.0208	0.0222		

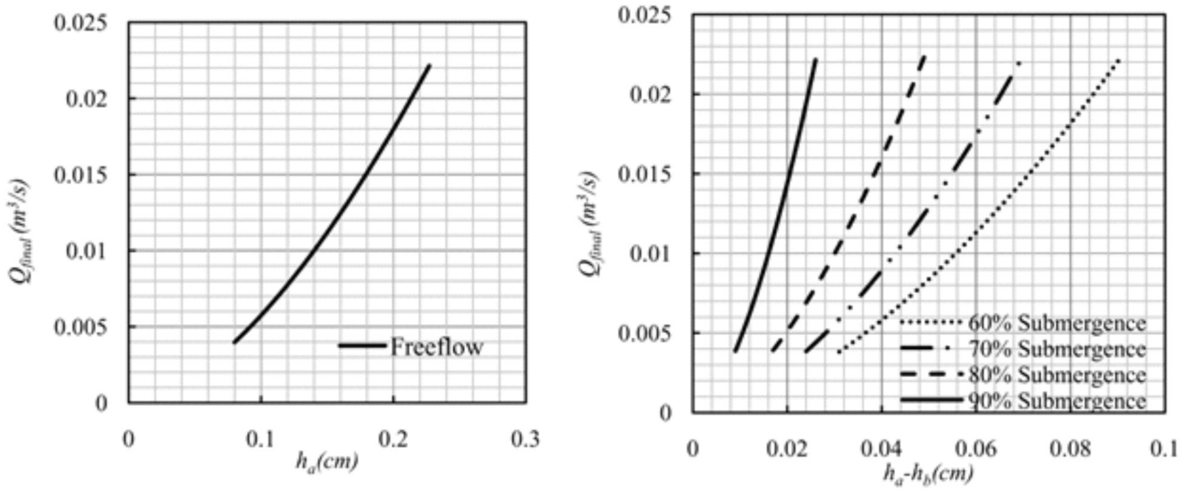

Figure 7: Rated graphs for free flow and submerged flow, using stilling well data.

Similarly like stilling well data, the data collected using point gauge is also used to develop rating equations. The graph for free flow and submerged flow conditions are plotted and shown in Figure 8 (a-b).

The free flow and submerged flow rating equations for Long-throat flume obtained using the gauge data are given below:

$$Q(FF) = 0.285\, h_a^{1.7116} \quad (7)$$

$$Q(SF) = 0.2223\left(h_a - h_b\right)^{1.7116} / \left(-\log S - 0.008\right)^{1.184} \quad (8)$$

The free flow discharge parameter C_f and exponent n_f comes out to be as 0.285 and 1.7116 respectively and the obtained submerged flow discharge parameters are C_s = 0.2223 and exponent n_s = 1.184.

While comparing with calculated discharge obtained from equations (7) and (8) with measured discharge,

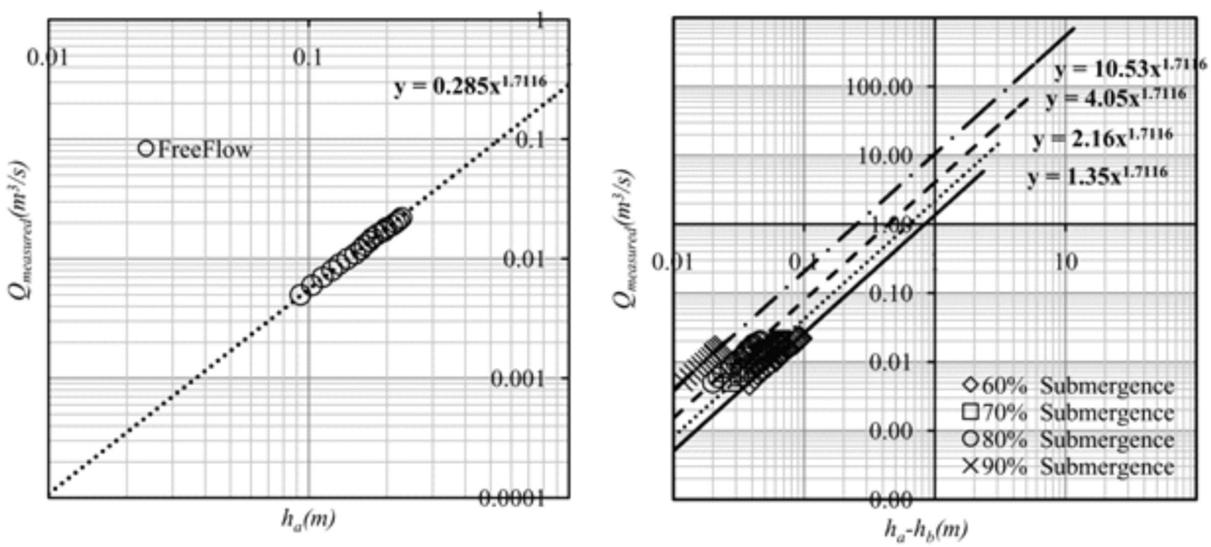

Figure 8: Rating curve using point gauge data: (a) free flow and (b) submerged flow.

that only ±8% deviation from perfect agreement line is found as shown in Figure 9. However, it is also important to note that the equations proposed and predictions using the stilling well data are quite better than the equation proposed using the gauge data.

The Ditchrider's Table (Tables 6-10) are also developed using the gauge data and the rated graphs are shown in Figure 10.

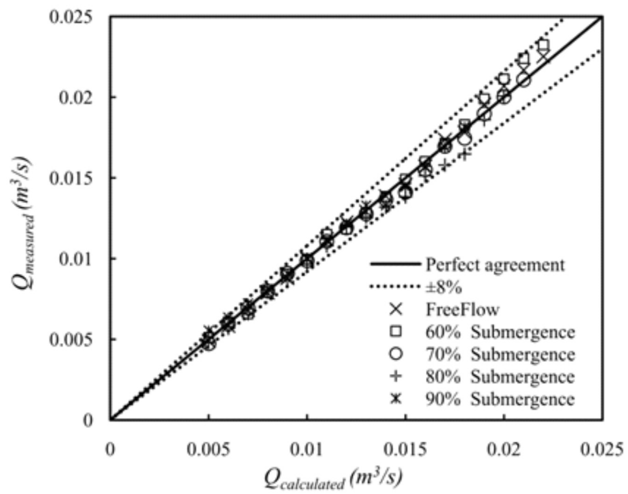

Figure 9: Comparison of free flow and submerged flow calculated data with measured gauge data.

Conclusions

The design and calibration of 5 inch long-throat flume was tested and the results of the experiments have been presented in this work. The measured depth-discharge relationships for free flow and submerged flow were plotted within a limited range of discharge (0.005 m^3/s to 0.022 m^3/s).

The transition from the free to submerged flow occurs at 63.35%.

From the experimental results and proposed equations it is evident that the accuracy of the rating equations using stilling well data is better than the data recorded using the point gauge. But in case of blockage of stilling wells the discharge needs to be measured using the point gauge. The accuracy of the discharge measurement can be enhanced by avoiding the error in observation of flow depth and flow rate measurement.

Using the rating equations Ditchrider's Table and graphs are developed for field implementation of flume. Using these one can easily monitor discharge(s) where needed.

Having an advantage of construction and horizontal bed in throat section, Long-Throat flume can efficiently be used in sewage channel.

Table 6: Discharge for free flow (m^3/s) using gauge well data

Head	*Discharge for free flow* (m^3/s)									
(h_a)m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.09		0.0049	0.005	0.0051	0.0052	0.0053	0.0054	0.0055	0.0056	0.0057
0.1	0.0058	0.0058	0.0059	0.006	0.0061	0.0062	0.0063	0.0064	0.0065	0.0066
0.11	0.0067	0.0068	0.0069	0.007	0.0071	0.0072	0.0073	0.0074	0.0076	0.0077
0.12	0.0078	0.0079	0.008	0.0081	0.0082	0.0083	0.0084	0.0085	0.0086	0.0087
0.13	0.0089	0.009	0.0091	0.0092	0.0093	0.0094	0.0095	0.0097	0.0098	0.0099
0.14	0.01	0.0101	0.0102	0.0104	0.0105	0.0106	0.0107	0.0108	0.011	0.0111
0.15	0.0112	0.0113	0.0115	0.0116	0.0117	0.0118	0.012	0.0121	0.0122	0.0123
0.16	0.0125	0.0126	0.0127	0.0128	0.013	0.0131	0.0132	0.0134	0.0135	0.0136
0.17	0.0138	0.0139	0.014	0.0142	0.0143	0.0144	0.0146	0.0147	0.0148	0.015
0.18	0.0151	0.0153	0.0154	0.0155	0.0157	0.0158	0.016	0.0161	0.0162	0.0164
0.19	0.0165	0.0167	0.0168	0.017	0.0171	0.0172	0.0174	0.0175	0.0177	0.0178
0.2	0.018	0.0181	0.0183	0.0184	0.0186	0.0187	0.0189	0.019	0.0192	0.0193
0.21	0.0195	0.0196	0.0198	0.0199	0.0201	0.0203	0.0204	0.0206	0.0207	0.0209
0.22	0.021	0.0212	0.0213	0.0215	0.0217	0.0218	0.022	0.0221		

Table 7: Discharge for 60% submergence (m^3/s) using gauge data

Head	*Discharge for 60% submergence* (m^3/s)									
$(h_a\text{-}h_b)$m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.03								0.0049	0.0051	0.0054
0.04	0.0056	0.0058	0.0061	0.0063	0.0066	0.0068	0.0071	0.0074	0.0076	0.0079
0.05	0.0082	0.0085	0.0088	0.009	0.0093	0.0096	0.0099	0.0102	0.0106	0.0109
0.06	0.0112	0.0115	0.0118	0.0122	0.0125	0.0128	0.0132	0.0135	0.0139	0.0142
0.07	0.0146	0.0149	0.0153	0.0157	0.016	0.0164	0.0168	0.0171	0.0175	0.0179
0.08	0.0183	0.0187	0.0191	0.0195	0.0199	0.0203	0.0207	0.0211	0.0216	0.022
0.09	0.0224									

Table 8: Discharge for 70% submergence (m^3/s) using gauge data

Head	*Discharge for 70% submergence* (m^3/s)									
$(h_a\text{-}h_b)$m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.02									0.0047	0.005
0.03	0.0053	0.0056	0.006	0.0063	0.0066	0.0069	0.0073	0.0076	0.008	0.0083
0.04	0.0087	0.0091	0.0095	0.0099	0.0103	0.0107	0.0111	0.0115	0.0119	0.0123
0.05	0.0128	0.0132	0.0137	0.0141	0.0146	0.015	0.0155	0.016	0.0165	0.017
0.06	0.0175	0.018	0.0185	0.019	0.0195	0.02	0.0205	0.0211	0.0216	0.0222

Table 9: Discharge for 80% submergence (m^3/s) using gauge data

Head	*Discharge for 80% submergence* (m^3/s)									
$(h_a\text{-}h_b)$m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.02	0.0048	0.0052	0.0057	0.0061	0.0066	0.0071	0.0076	0.0081	0.0086	0.0091
0.03	0.0097	0.0102	0.0108	0.0114	0.012	0.0126	0.0132	0.0138	0.0145	0.0151
0.04	0.0158	0.0165	0.0172	0.0179	0.0186	0.0193	0.0201	0.0208	0.0216	0.0224

Table 10: Discharge for 90% submergence (m^3/s) using gauge data

Head	*Discharge for 90% submergence* (m^3/s)									
$(h_a\text{-}h_b)$m	*0*	*0.001*	*0.002*	*0.003*	*0.004*	*0.005*	*0.006*	*0.007*	*0.008*	*0.009*
0.01	0.0041	0.0048	0.0055	0.0064	0.0072	0.0081	0.0091	0.0101	0.0111	0.0122
0.02	0.0133	0.0145	0.0157	0.0169	0.0182	0.0195	0.0208	0.0222		

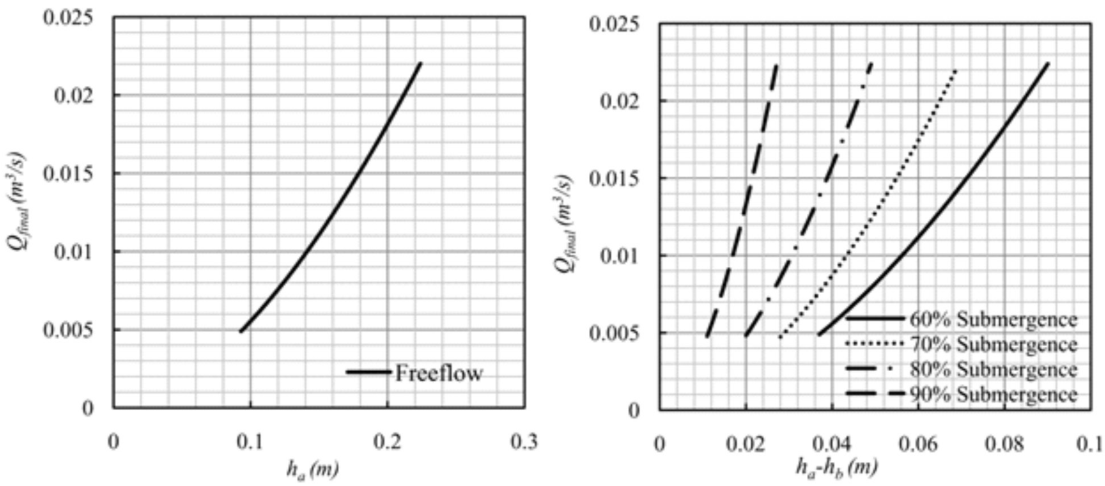

Figure 10: Rated graph for free flow and submerged flow using gauge data.

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