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The Development of Broad-Crested Weir by Using Physical Modelling

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***Abstract*— *This study aimed to improve irrigation efficiency by simplify discharge distribution mechanism on, tertiary, sub tertiary, quarter and secondary level where all this time its operation was unreliable. Physical model that being tested was in the form of broad crested weir (channel 2), pipe in diameter 3" (channel 1) and pipe in diameter 4" (channel 3) they will going to distribute discharge to the left, frontal and to the right. Stream flow phenomenon that occurred was used to plan the determining design of new irrigation construction. Measure instrument of discharge in this experiment was calibrated before the experiment took place, in order to decrease the experiment relative error smaller than 5%. Physical model of distribution box has ratio 1 : 1 in prototype and it has used verification in order to get result carefulness that fulfils the prerequisite. There are three conditions in this testing, that is one channel operations, three channels operation and three channels operation with discharge plan on two channels (right and left) and one gate operation to frontal side. This study used six variations discharge testing to stream flow type respectively on distribution box in order to get discharge distribution pattern. One channel has gotten the same headwaters discharge and downstream discharge. Three channels has gotten discharge coefficient (Cd) 0.56 and friction coefficient (f) 0.046, whereas discharge distribution has gotten ratio 11.44%, 71.24% and 18.35% (no gate). Three channels that using gate has gotten discharge distribution in ratio 12.68%, 65.89%, and 21.05% (a = 4 cm, frontal) and 11.77%, 68.90% and 19.33% (a = 8 cm, frontal) on discharge plan has gotten equation on pipe one* $y = 0.1097\,(h)^{1.4901}$ *and on pipe three* $y = 0.1017\,(h)^{1.566}$*, with the result that discharge that happen is reasonable to pipe diameter, discharge variation and high variation of opening gate (a).*

Keywords*— *Weir, Distribution structure, Physical modelling, Coefficient of discharge (Cd).

I. Introduction

Nowadays, the agricultural technology is getting more developed as the modern plant varieties demand an appropriate management of water distribution, hence all infrastructure in agricultural areas must be developed. Regional development requires good technical irrigation networks. Technical irrigation networks are irrigation networks where all constructions and water distribution up to tertiary uptake can be controlled by the Irrigation Service (Anonymous, 1975). Irrigation network planning is made in such a way that water management can be carried out properly. In addition, network utilization and maintenance can be done easily with low costs by farmers who use the water.

An irrigation building is equipped with a measuring gates. The distribution of discharges in tertiary weir, sub tertiary, secondary and quarter by using the gate method is generally less efficient. This condition is caused by the limited operational staff and the procedure for setting complex measuring gates (Anonymous, 1975). The distribution structure (weir) is built between secondary, tertiary and quarterly channels to divide irrigation water throughout agricultural land. The construction plan must be in accordance with the needs of local farmers and meet the needs of agricultural activities in the area concerned at present and in the future. A weir is a construction that has the function to divide water continuously (proportional) or in rotation. The ideal irrigation management is the utilization of water according to the requirements requested precisely in terms of time, quantity and quality.

The ease of use of irrigation water is also influenced by the distribution of tertiary plots, quarters and cropping patterns. To simplify water management, it is recommended to consider the implementation of water distribution operations in the planning of new irrigation networks. One method that can be applied is to divide the tertiary and quarter area uniformly, and apply the same cropping pattern (Anonymous, 1986). Efficiency improvement can be started by simplifying the mechanism of discharge distribution, for example by replacing the measuring gates in tertiary weir, sub tertiary, secondary and quarterly with weir width thresholds and pipes in the right and left channel so that they are able to divide discharges according to the specific necessity.

Water flow in the open channel that passes through the pipe has several conditions, namely free flow, transition flow, and pressure flow. Free flow occurs if the entire length of the pipe has not been filled with water or the upstream end of the pipe has not sunk. Transition flow, on the other hand, occurs when the upstream water level reaches the upper end of the inlet, where this condition will last until it reaches the maximum water discharge in the pipe with a uniform flow state and does not work under pressure. In addition, pressure flow occurs when the entire length of the pipe and the cross section of the flow is fully filled with water (Kim, 1981). The correctness of the distribution pattern of discharges must be tested in advance by physical model test.

This study aims to obtain the value of the discharge coefficient (Cd), the coefficient of friction (f) in the pipe by knowing the proportional flow distribution pattern. The use of broad-crested weir with the addition of pipes is expected to be more practical, because it only regulates one gate, makes it easier to implement, is cheaper, obtains a discharge distribution pattern for each channel, and increases the efficiency of operating gates in the field which usually uses three gates.

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II. METHOD

A. Constructing the Physical Model

The physical model is made using the scale 1:1 comparison, in which the size of the model is the same as the prototype (Figure 1). The model consists of a rectangular main channel and the left channel uses a pipe with 3 inches (7.65 cm) diameter while the right channel uses a 4 inches (10.2 cm) pipe. The upstream end of the channel is connected to the Rechbox discharge gauge, while the downstream end is connected with three Thompson discharge gauges. Upstream threshold is equipped with a gate that serves to regulate the flow. In the physical model, the elevation of the right and left pipes is the same as the height of the threshold in the frontal direction, which is 20.26 cm. Furthermore, the frontal channel implements b_{sal} = 30 cm ; B_{sal} = 60 cm; Z_{amb} = 20.26 ; b_{amb} = 30 cm ; L_{amb} = 30 cm with varying gate opening.

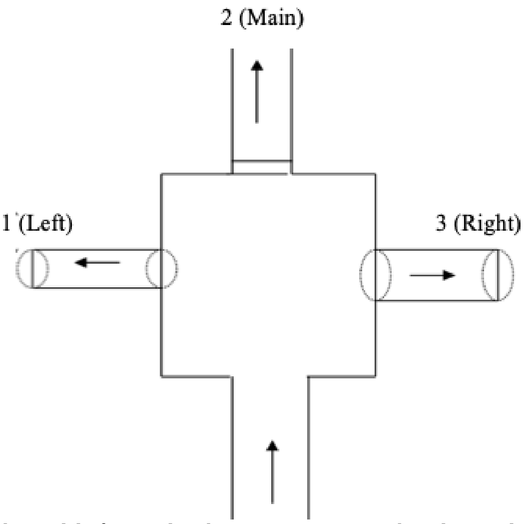

Fig. 1. The model of water distribution structure using broad-crested weir and pipe

B. Testing the Model

The treatment of the model also considers the limitations in the laboratory facilities, both the limitations of the pump capacity and the dimensions of the test channel. The approaches are:

a. Data for the planning of physical model:
- The maximum planning discharge is 40 l/s with normal water depth (H1) is 29.3210 cm.
- Geometric cross section of channel, channel roughness and slope.

b. The planning of broad-crested weir

The width threshold length (L) of 30 cm is still within the technical limits of the width threshold criteria from M.G.Bos (1976). The specific energy equation with a planned threshold width of 30 cm leads to the threshold height (ΔZ) of 20.26 cm.

a. The planning of the pipe installation

The length of the pipe (L) is 100 cm with a pipe diameter on the left channel is 3"(7,620 cm) and the right channel is 4" (10,160 cm).

b. The treatment of distribution channel

The treatments performed in this study include treatment with gates and without gates opening.
- Operation of one channel (with and without gate opening)
- Operation of three channels (with and without gate opening)
- Discharge plans with variations in gate openings.

c. Discharge variations

A series of discharges to be tested for each alternative, including 5, 10, 15, 20, 25, 30, 35, and 40 liter/second.

C. Research Procedures

1. Calibration of discharge measurement tool

The physical model of the weir, the channel and its dimensions is shown in Figure, but the channel is still made with the same dimensions as the frontal direction. In the frontal direction, there is no need to install a threshold or gate. Before calibration is carried out, it is necessary to prepare some equipment such as Rechbox model (size b = 0.955 m, B = 2.63 m D = 2,275 m, Thompson 1 model for the left side (size D = 0.165 m, B = 0.80 m), Thompson 2 model for the main, middle, and frontal side (size D = 0.41 m, B = 1.01 m), Thompson 3 model for the right side (size D = 0.155 m, B = 0.97 m, water pump, water reservoir, stopwatch, buckets (cans) for measurements on the downstream Thompson, measuring cups, water for experiments with several variations of water level (h) on Rechbox (upstream), point gauge, pitot tubes, and water passes.

Measurement of water level is carried out by observing the water surface in a small tank that is connected by a channel through a small opening in the side wall of the channel. The small hole must be located at least 200 mm and the maximum B (channel width) upstream of the front side of the weir is located at least 50 cm lower than the lowest point, the lower beam or the weir's lighthouse is located 50 cm or more above the channel bottom. Around the hole must be slippery and there should be no obstructions. In addition, the accuracy of measurement of water height must be less than 0.2 mm.

D. Data Analisis

The data of $Q_{measure}$ will be obtained by flowing several variations of water level (h), with a certain time. These data will be analyzed further to determine the relationship between variables, including:

a. Water level (h) with $Q_{measure}$

b. Water level (h) with the calibrated $Q_{measure}$, therefore new equation can be obtained.

E. Weir with Three-Channel Operation

The preparations required are:

a. Preparation of the model of the weir, threshold and the gate to be placed above the width threshold in the frontal direction.

b. Installation of pipes; 4 inches diameter for the right channel and 3 inches for the left channel.

c. Checking the condition of the water pump.

d. Opening the right and left channel.

e. Preparation of several variations of the discharge.

F. The design and Construction of Weir with 3 Channels Operation

1. Free flow without gate opening

TABLE 1. Operation of 3 channels with free flow

No	Discharge (Q)	Frontal Direction						Left Pipe (1)			Right Pipe (3)		
		Water Level			Velocity			Water level			Water level		
		Upstream $_{amb}$	Atas $_{amb}$	Downstream $_{amb}$	Upstream $_{amb}$	Atas $_{amb}$	Downstream $_{amb}$	Upstream $_{pipe}$	As $_{pipe}$	Downstream $_{pipe}$	Upstream $_{pipe}$	As $_{pipe}$	Downstream $_{pipe}$
	lt/second	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
1	15	6.75	5.30	9.82	1.42	2.35	0.83	6.00	5.00	3.50	5.50	4.60	4.30
2	20	7.28	6.49	8.78	2.13	2.87	1.50	6.70	5.70	4.30	6.20	5.10	4.70
3	25	8.99	7.54	9.50	2.23	3.16	2.00	6.10	6.40	4.70	7.30	6.00	5.70
4	30	9.40	8.26	9.41	2.73	3.62	3.15	8.40	6.80	6.40	8.20	6.80	6.30
5	35	11.74	9.20	9.50	2.57	3.87	4.20	8.10	7.10	8.20	8.50	7.50	6.50
6	40	13.07	9.94	7.80	2.53	4.33	8.00	7.80	7.30	8.50	7.10	7.15	7.30

2. Free flow with gate opening (a) 4 cm

TABLE 2. Operation of 3 channels with gate opening (a) 4 cm

No	Discharge (Q)	Frontal Direction						Left Pipe (1)			Right Pipe (3)		
		Water level			Velocity			Water level			Water level		
		Upstream $_{amb}$	Top $_{amb}$	Downstream $_{amb}$	Upstream $_{amb}$	Top $_{amb}$	Downstream $_{amb}$	Upstream $_{pipe}$	As $_{pipe}$	Downstream $_{pipe}$	Upstream $_{pipe}$	As $_{pipe}$	Downstream $_{pipe}$
	lt/second	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
1	15	8.95	4.30	15.47	1.37	4.32	7.48	5.30	4.40	1.50	3.80	4.80	3.50
2	20	12.83	4.28	22.77	1.80	6.87	8.01	6.70	5.30	2.00	4.80	6.10	4.50
3	25	16.88	4.35	23.26	1.73	8.77	7.68	8.30	7.40	3.15	6.50	7.70	5.80
4	30	20.13	4.08	9.32	2.47	11.93	7.31	7.80	6.90	4.20	6.60	6.80	6.80
5	35	22.92	4.37	9.98	2.77	11.93	7.84	8.00	6.90	4.20	6.70	7.80	7.60
6	40	23.52	5.23	8.45	2.90	20.67	5.65	8.40	7.20	7.33	8.50	7.80	10.90

III. RESULT AND DISCUSSION

A. The Calibration of Discharge Measurement Tool

Before conducting the research, the discharge measuring instrument is calibrated according to the Vessel law, which said that if the water level in the three vessels is in a constant condition, then Q1 = Q2 = Q3. The calibration process is done by calculating the magnitude of the relative error that occurs between the measuring discharge ($Q_{measure}$) with the calculation discharge ($Q_{theoretical}$). The limit of the relative error is 5%. If the average of relative error is less than 5%, then calibration is only done by adjusting the curve. Conversely, if the relative error is greater than 5%, then the calibration coefficient needs to be found (Priyantoro and Suprijanto, 1998). The calibration results show that the greater the discharge, the greater the water level. The calculation of $Q_{theoretical}$ is done after the value of $Q_{measure}$ is obtained. Furthermore, the results of the calculation are:

* Thompson 1 = $0.0144 (h)^{2.5087}$
* Thompson 2 = $0.0117 (h)^{2.6035}$
* Thompson 3 = $0.0148 (h)^{2.476}$

The operation of three channels (frontal/Q2 direction) without gate opening use the discharges of 15 lt/sec, 20 lt/sec, 25 lt/sec, 30 lt/sec, 35 lt/sec and 40 lt/sec, and the Q value of the downstream (Q2) is 71.24% (see table 3). The difference in discharges of the maximum planned discharge has a relative error less than 10% (see table 4). In channel 1 (left/Q1 direction), a discharge of 11.44% is obtained (see table 5), while channel 3 (right/Q3 direction) has a discharge of 18.35% (see table 6). The relationship between Q1-h1 and Q3-h1 can be seen in Figure 2 which shows the proportional discharge distribution according to the model of the weir.

TABLE 3. Relationship between h and Q in channel 2

No	Discharge treatment (Q)	h1 (lt/sec)	h2 (lt/sec)	Q2 (lt/sec)	Discharge (%)
1	15	6.75	7.80	10.76	71.73
2	20	7.28	8.78	14.26	71.30
3	25	8.99	9.41	17.63	70.52
4	30	9.40	9.50	20.93	69.77
5	35	11.74	9.60	24.41	69.74
6	40	13..07	9.82	27.35	68.38
The average of discharge in channel 2					70.24

B. Free Flow without Gate Opening

TABLE 4. Relative error of the channel 2

No	Qupstream (lt/sec)	A (cm2)	h mean	Vmeasure (lt/sec)	Qmeasure (lt/sec)	Vtheoretical (lt/sec)	Qtheoretical (lt/sec)	Relative error (%)
1	15	201.5	1.45	53.40	10.76	55.32	11.15	3.61
2	20	216.6	2.21	65.85	14.26	71.87	15.57	9.15
3	25	268.0	2.20	65.70	17.61	67.66	18.13	2.98
4	30	279.9	2.85	74.78	20.93	79.53	22.26	6.35
5	35	348.6	2.50	70.04	24.41	73.73	25.70	5.27
6	40	388.2	2.53	70.45	27.35	73.18	28.41	3.86
The average of relative error								5.20

TABLE 5. Water level in channel 1

No	Discharge/Q (lt/sec)	h1 (cm)	E (cm)	Hf (cm)	f	h2 (cm)	Eg (cm)	Hf (cm)	f	Q1 (lt/sec)	Discharge (%)
1	15	6.00	6.614	0.700	0.087	3.50	4.214	1.400	0.174	1.582	10.55
2	20	6.10	7.852	0.350	0.089	4.30	5.454	1.400	0.093	2.167	10.84
3	25	6.70	7.965	0.450	0.141	4.70	6.565	1.700	0.070	2.757	11.03
4	30	8.10	11.572	0.360	0.057	6.40	9.572	0.400	0.010	3.596	11.99
5	35	8.40	12.700	0.860	0.064	8.20	12.800	-1.100	-0.018	4.330	12.37
6	40	8.50	13.339	0.580	0.077	8.50	14.039	-1.200	-0.017	4.752	11.88
The average of discharge in pipe 1											11.44

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TABLE 6. Water level in channel 3

No	Discharge/Q (lt/sec)	h1 (cm)	Eg (cm)	Hf (cm)	f	h2 (cm)	Eg (cm)	Hf (cm)	f	Q3 (lt/sec)	Discharge (%)
1	15	5.50	6.049	1.200	0.222	4.30	4.849	0.300	0.056	2.659	17.73
2	20	6.20	7.193	1.850	0.189	4.70	5.693	0.400	0.041	3.577	17.88
3	25	7.30	8.979	2.250	0.136	5.70	7.379	0.300	0.018	4.651	18.60
4	30	8.20	10.520	2.560	0.112	6.30	8.620	0.500	0.022	5.467	18.22
5	35	8.50	11.551	3.460	0.115	6.50	9.551	1.000	0.033	6.269	17.91
6	40	8.70	11.951	6.280	0.132	7.30	12.151	0.150	0.003	7.905	19.76
The average of discharge in pipe 3											18.35

TABLE 7. Data of the operation of three free flow channels without gate opening

No	Upstream	Downstream											
	Q test	Channel 1					Channel 2		Channel 3				
	(lt/sec)	Q1 (lt/sec)	h1 (cm)	Eg (cm)	Hf (cm)	f	Q2 (lt/sec)	h1 (cm)	Q3 (lt/sec)	h1 (cm)	Eg (cm)	Hf (cm)	f
1	15	1.582	6.00	6.614	0.700	0.087	10.76	6.75	2.659	5.50	6.049	1.200	0.222
2	20	2.167	6.10	7.852	1.350	0.089	14.26	7.28	3.577	6.20	7.193	1.850	0.189
3	25	2.757	6.70	7.965	3.450	0.141	17.63	8.99	4.651	7.30	8.979	2.250	0.136
4	30	3.596	8.10	11.572	2.360	0.057	20.93	9.40	5.467	8.20	10.520	2.560	0.112
5	35	4.330	8.40	12.700	3.860	0.064	24.41	11.74	6.269	8.50	11.551	3.460	0.115
6	40	4.752	8.70	13.339	5.580	0.077	27.35	13.07	7.905	8.60	11.951	6.280	0.132

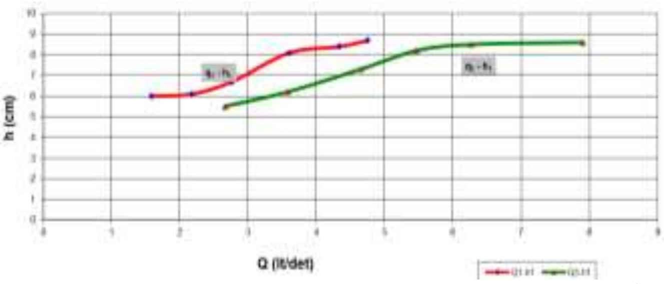

Fig. 2. Relationship between h and Q in channel 1-3 with the operation of 3 channels

C. Free Flow with Gate Opening (a) 4 cm

The treatment of gate opening is done to equalize the distribution of water discharge in each channel, so that the value of F (Froude) above the threshold is equal to one (F = 1). Tests on the operation of the three channels are carried out by flowing several variations of discharge and by opening the gate up to 4 cm above the width threshold. Discharge flowing in each channel is monitored by a downstream discharge meter. Table 8 displays the data and calculation results for Q2 which show the magnitude of each discharge coefficient (Cd) on the gate. In pipe one (left/Q1 direction), discharge values were obtained for each treatment (table 9). By using the same equation, it is obtained the discharge value in the third pipe (right direction / Q3), the value of the discharge coefficient (Cd), and the value of the coefficient of friction (f) (see table 10). Finally, the results (table 11) shows that the distribution of discharge occurs proportionally to each channel with a gate opening of 4 cm.

TABLE 8. Water level in channel 2 with gate opening (a) 4 cm

No	Discharge/Q (lt/sec)	h1 (cm)	h2 (cm)	A (cm)	B (cm)	Cd	Q2 (lt/sec)	Discharge (%)
1	15	8.95	7.31	4.00	30	0.76	12.15	80.99
2	20	12.83	7.48	4.00	30	0.78	14.85	74.25
3	25	16.88	7.68	4.00	30	0.78	17.10	68.40
4	30	20.13	7.84	4.00	30	0.79	18.79	62.64
5	35	22.92	8.01	4.00	30	0.79	20.13	57.51
6	40	23.52	8.20	4.00	30	0.80	20.62	51.56
The average of discharge in channel 2								65.89

TABLE 9. Water level in channel 1 (a = 4cm)

No	Discharge/Q (lt/sec)	h1 (cm)	Cd	Eg (cm)	Hf (cm)	f	h2 (cm)	Eg (cm)	Hf (cm)	f	Q3 (lt/sec)	Discharge (%)
1	15	8.46	0.167	5.54	3.160	1.021	3.300	3.536	1.1	0.3553	0.981	6.54
2	20	9.89	0.302	7.60	3.190	0.268	4.100	5.004	1.2	0.1011	1.918	9.59
3	25	12.06	0.413	10.36	3.760	0.139	5.200	7.261	2.2	0.0813	2.896	11.58
4	30	14.86	0.555	12.38	7.060	0.118	8.500	13.077	-1.6	-0.027	4.320	14.40
5	35	15.06	0.682	15.682	7.060	0.077	8.500	15.501	-1.6	-0.017	5.344	15.27
6	40	21.50	0.800	22.800	8.360	0.046	8.500	22.260	-1.3	-0.007	7.489	18.72
The average of discharge in pipe 1												12.68

TABLE 10. Discharge in channel 3 (a = 4cm)

No	Discharge/Q (lt/sec)	h1 (cm)	Cd	Eg (cm)	Hf (cm)	f	h2 (cm)	Eg (cm)	Hf (cm)	f	Q3 (lt/sec)	Discharge (%)
1	15	8.46	0.179	5.07	3.660	1.364	3.500	3.773	0.3	0.1118	1.8738	12.49
2	20	9.89	0.198	6.91	3.790	0.475	4.500	5.311	0.3	0.0376	2.2316	11.16
3	25	12.06	0.402	9.65	4.360	0.228	5.800	7.747	0.7	0.0365	5.0077	20.03
4	30	14.86	0.498	10.49	8.060	0.222	6.800	10.489	-0.2	-0.006	6.8935	22.98
5	35	15.06	0.684	14.85	7.260	0.105	7.600	14.650	-0.9	-0.013	9.5305	27.23
6	40	21.50	0.779	20.86	8.960	0.070	10.900	23.955	-2.4	-0.019	12.9685	32.42
The average of discharge in pipe 3												21.05

TABLE 11. Data of water discharge on the operation of three free flow channel with gate opening 4 cm

No	Upstream	Downstream														
		Channel 1						Channel 2			Channel 3					
	Q test (lt/sec)	Q1 (lt/sec)	h1 (cm)	Cd	Eg (cm)	hf (cm)	f	Q2 (lt/sec)	h1 (cm)	Cd	Q3 (lt/sec)	h1 (cm)	Cd	Eg (cm)	hf (cm)	f
1	15	0.981	8.46	0.167	5.54	3.160	1.021	12.15	8.95	0.76	1.8738	8.46	0.179	5.07	3.660	1.364
2	20	1.920	9.89	0.302	7.60	3.190	0.268	14.85	12.83	0.78	3.2316	9.89	0.198	6.91	3.790	0.475
3	25	2.899	12.06	0.413	10.36	3.760	0.139	17.09	16.88	0.78	5.0077	12.06	0.402	9.65	4.360	0.228
4	30	4.320	14.86	0.555	12.38	7.060	0.118	18.78	20.13	0.79	6.8935	14.86	0.498	10.49	8.060	0.222
5	35	5.342	15.06	0.682	15.00	7.060	0.077	20.13	22.92	0.79	9.5303	15.06	0.684	14.85	7.260	0.105
6	40	7.489	21.50	0.800	22.16	8.360	0.046	20.62	23.52	0.80	12.9690	21.50	0.779	20.86	8.960	0.070

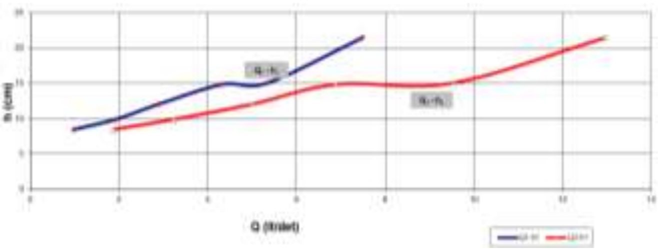

Fig. 3. Relationship between h and Q in channel 1-3 with a = 4 cm (the operation of 3 channels).

D. Water discharge in channels

The discharge variations applied for pipes 1 and 3 aims to irrigate the fields as needed. In this case, the upstream discharges implemented are 20 lt/sec and 40 lt/sec. To obtain the value of Q1 and Q3, a gate operation is performed in the frontal direction with a variation of the gate opening (see tables 12 to 14), ignoring the amount of discharge in the channel 2 (frontal) which is runoff discharge. The gate opening variation is done to get the water level (h) which will be used to get the value of the velocity coefficient (Cv) and the contraction coefficient (Cc). Next, the discharge coefficient (Cd) value is used to calculate the discharge value for pipe 1 and pipe 3.

Figure 4 shows the relationship between the water level and the discharge coefficient in pipe 1. By looking at the graph, the higher the gate opening in the 2-way frontal channel, the smaller the value of the discharge coefficient, as well as the speed coefficient. Meanwhile, the coefficient of contraction will be greater. Figure 5 shows the relationship between the water level and the coefficient of discharge in pipe 3. It can be seen that the higher the gate opening in the channel 2 (frontal direction), the smaller the value of discharge coefficient, as well as on the speed coefficient. On the other hand, if flowed an equal discharge with a higher gate opening, the contraction coefficient will be higher. Figure 7 shows the relationship between the water level with the discharge in pipe 1 and pipe 3. Discharge in pipe 1 (Q1) and pipe 3 (Q3) increases constantly in accordance with the height of the gate opening that adjusts to the discharge plan.

TABLE 12. Variation of gate openings in the two discharge treatments in channel 2

No	Q Test (lt/sec)	hi (cm)	a (cm)	a/h1	Cc	Cd	Q2 (lt/sec)
1	20	10.00	5.00	0.50	0.560	0.58	12.26
2		15.00	3.00	0.20	0.530	0.53	8.23
3		18.00	2.00	0.11	0.540	0.54	6.10
4	40	20.00	4.00	0.20	0.530	0.53	12.67
5		25.00	3.00	0.12	0.500	0.50	9.98
6		28.00	2.00	0.07	0.450	0.45	6.33

TABLE 13. Variation of gate openings in the two discharge treatments in channel 1

No	Q Test (lt/sec)	hi (cm)	Cv	Cc	Cd	Q1 (lt/sec)	Diameter of pipe (cm)	Height (cm)
1	20	10.00	0.807	0.706	0.569	3.64	7.620	5.00
2		15.00	0.804	0.804	0.710	5.55	7.620	3.00
3		18.00	0.802	0.802	0.736	6.31	7.620	2.00
4	40	20.00	0.858	0.858	0.757	13.14	7.620	4.00
5		25.00	0.853	0.853	0.803	13.44	7.620	3.00
6		28.00	0.851	0.851	0.821	15.12	7.620	2.00

TABLE 14. Variation of gate openings in the two discharge treatments in channel 3

No	Q Test (lt/sec)	hi (cm)	Cv	Cc	Cd	Q3 (lt/sec)	Diameter of pipe (cm)	Height (cm)
1	20	10.00	0.507	0.714	0.362	4.11	10.16	5.00
2		15.00	0.495	0.905	0.448	6.23	10.16	3.00
3		18.00	0.492	1.000	0.492	7.50	10.16	2.00
4	40	20.00	0.868	0.768	0.786	14.17	10.16	4.00
5		25.00	0.862	0.821	0.821	16.56	10.16	3.00
6		28.00	0.860	1.860	0.860	18.35	10.16	2.00

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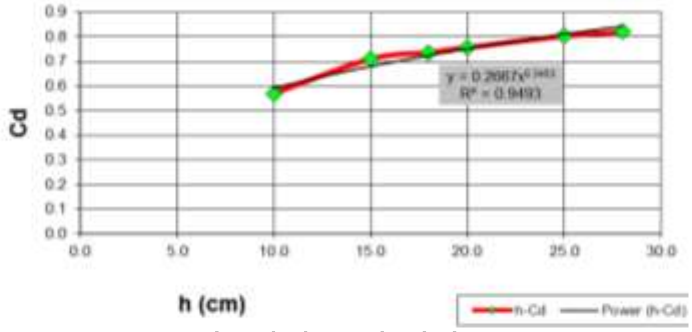

Fig. 4. Relationship between h and Cd in pipe 1

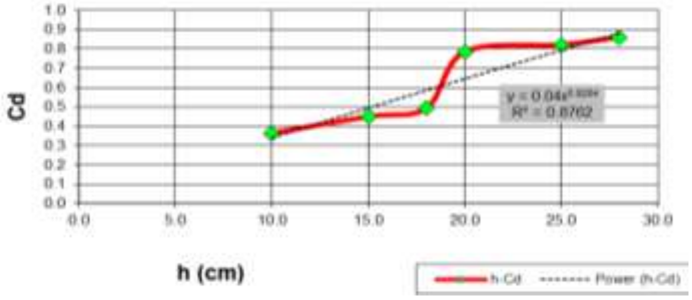

Fig. 5. Relationship between h and Cd in pipe 3

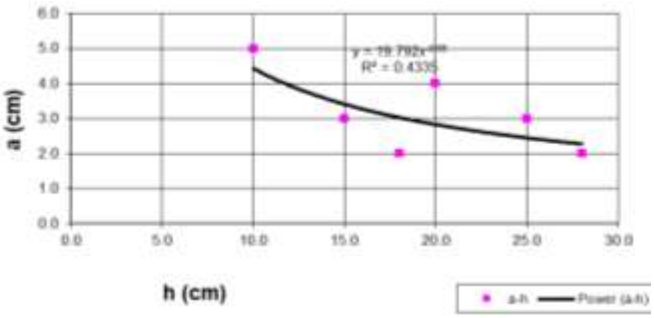

Fig. 6. Relationship between a and h in pipe 1 and 3

In the second treatment, the upstream discharge is varying from 10 lt/sec to 40 lt/sec, with the discharges in pipe 1 and pipe 3 are constant. It aims to meet the needs of the certain plant in the farmland, thus a constant flow is required. By looking at the discharge plan, it is necessary to vary the height of the gate opening in the frontal direction to obtain the same water level for each upstream discharge variation in order to obtain the plan discharge. Thus, the discharge value of channel 2 will be obtained which varies, but in this case it does not really affect the distribution of water because it is only runoff discharge.

TABLE 15. Data of discharge in the operation of three channels with variations in gate openings.

No	Upstream	Downstream									
		Channel 1			Channel 2			a	Channel 3		
	Q test (lt/sec)	Q1 (lt/sec)	h1 (cm)	Cd	Q2 (lt/sec)	h1 (cm)	Cd		Q3 (lt/sec)	h1 (cm)	Cd
1	20.0	3.64	10.00	0.569	12.26	10.00	0.583	5.00	4.11	10.00	0.362
2		5.55	15.00	0.710	8.23	15.00	0.533	3.00	6.23	15.00	0.448
3		6.31	18.00	0.736	6.10	18.00	0.541	2.00	7.50	18.00	0.492
4	40.0	13.14	20.00	0.757	12.67	20.00	0.533	4.00	14.17	20.00	0.786
5		13.44	25.00	0.803	9.98	25.00	0.501	3.00	16.56	25.00	0.821
6		15.12	28.00	0.821	6.33	28.00	0.450	2.00	18.35	28.00	0.860

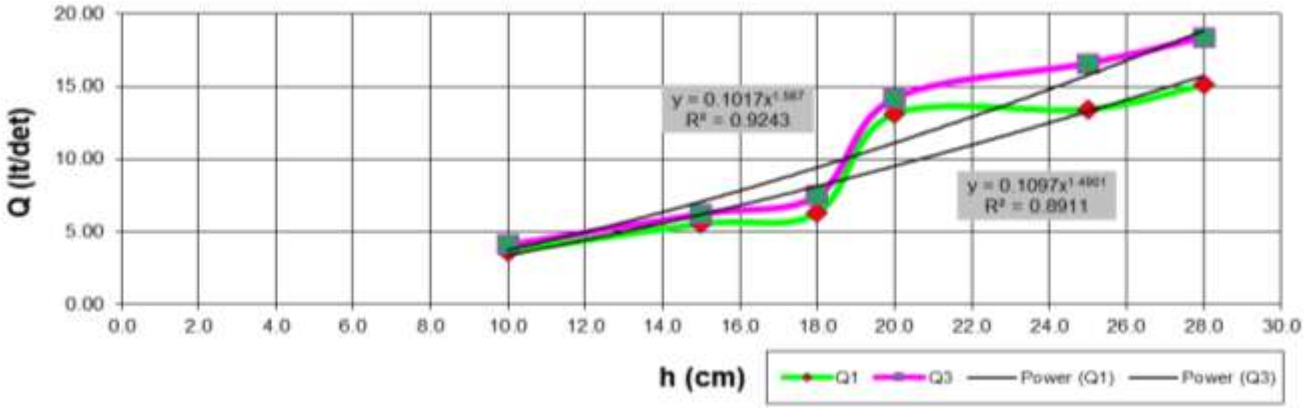

Fig. 7. Relationship between water level and discharge in channels 1 and 3 on the planned discharge with gate opening variations

TABLE 16. Discharge with a variety of gate openings in Channel 2

No	Q Test (lt/sec)	h1 (cm)	A (cm)	a/h1	Cc	Cd	Q2 (lt/sec)
1	15	9.64	1.50	0.16	0.560	0.56	3.48
2	20	9.64	5.60	0.58	0.530	0.56	12.87
3	25	9.64	8.00	0.83	0.540	0.56	18.18
4	30	9.64	10.00	1.04	0.540	0.56	23.27
5	35	9.64	12.00	1.24	0.540	0.56	27.68
6	40	9.64	14.50	1.50	0.540	0.56	33.44

TABLE 17. Discharge with a variety of gate openings in Channel 1

No	Q Test (lt/sec)	h1 (cm)	Cv	Cc	Cd	Q1 (lt/sec)
1	15	9.64	0.363	1.265	0.459	2.88
2	20	9.64	0.363	1.265	0.459	2.88
3	25	9.64	0.363	1.265	0.459	2.88
4	30	9.64	0.363	1.265	0.459	2.88
5	35	9.64	0.363	1.265	0.459	2.88
6	40	9.64	0.363	1.265	0.459	2.88

TABLE 18. Discharge plan with a variety of gate openings in Channel 3

No	Q Test (lt/sec)	h1 (cm)	Cv	Cc	Cd	Q3 (lt/sec)
1	15	9.64	0.391	0.918	0.359	4.00
2	20	9.64	0.391	0.918	0.359	4.00
3	25	9.64	0.391	0.918	0.359	4.00
4	30	9.64	0.391	0.918	0.359	4.00
5	35	9.64	0.391	0.918	0.359	4.00
6	40	9.64	0.391	0.918	0.359	4.00

In addition, the second treatment is carried out if the discharge in pipe 1 and pipe 3 is desired to have a fixed magnitude, while the discharge in the upstream varies. Therefore, variations in gate openings are required (see tables 16 to 19).

TABLE 19. Data of water discharge on the operation of three channels with variations in gate openings

No	Upstream	Downstream									
	Q test (lt/sec)	Channel 1			Channel 2				Channel 3		
		Q1 (lt/sec)	h1 (cm)	Cd	Q2 (lt/sec)	h1 (cm)	Cd	a (cm)	Q3 (lt/sec)	h1 (cm)	Cd
1	15	2.88	9.64	0.459	3.48	9.64	0.56	1	4.00	9.64	0.359
2	20	2.88	9.64	0.459	12.87	9.64	0.56	5	4.00	9.64	0.359
3	25	2.88	9.64	0.459	18.18	9.64	0.56	8	4.00	9.64	0.359
4	30	2.88	9.64	0.459	23.27	9.64	0.56	10	4.00	9.64	0.359
5	35	2.88	9.64	0.459	27.68	9.64	0.56	12	4.00	9.64	0.359
6	40	2.88	9.64	0.459	33.44	9.64	0.56	14	4.00	9.64	0.359

IV. CONCLUSION

The results of the analysis demonstrated that the value of the discharge coefficient (Cd) from the gate opening is 0.56. Nevertheless, the results obtained can still be developed. Thus, the authors recommend the future studies to apply a higher level of accuracy, use two gate operations, and apply several variations in pipe diameter and elevation.

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