



## Comparative Study of Flow over Rectangular Open Channel Flume

Nwachukwu Peter U.

Department of Mechanical Engineering,  
State University of Medical and Applied Sciences Igboeno Enugu State.  
Email: [peter.nwachukwu@sumas.edu.ng](mailto:peter.nwachukwu@sumas.edu.ng)

### Abstract

Rectangular weirs used for discharge measurement are applied in an open channel hydraulics system and are analyzed experimentally. The aim of this project is to analyze the water flow pattern in the rectangular open channel flume. It focuses on analyzing the water surface profile of the water flow over the weir in the rectangular open channel flume and also to calculate the discharge coefficient,  $C_d$  of the water discharge in the rectangular open channel flume. The review of this project is fundamentally on the description of the different form of weir. It is observed that in order to give account for discharge through a rectangular weir mathematically, the flow analysis is assumed to be frictionless, parallel and horizontally flowing little or no loss. A collection of methods, practices and rules were applied to arrive at the coefficient of discharge for 40mm (11.335, 4.514, 2.857, 2.360, 2.380, 2.668, and 2.041). For 30mm (1.5111, 0.7125, 0.6399, 0.466, 0.495, 0.481, and 0.435). For 20mm (1.508, 0.8007, 0.495, 0.377, 0.479, 0.411, 0.368). For 10m (3.030, 1.495, 0.930, 0.718, 0.540, 0.514, and 0.473). This was done by using mathematical derivation gathered through theoretical bases. There were four experiment carried out with different width of the weir and the widths are 40mm, 30mm, 20mm and 10mm width. These results are affected by the values of volume of fluid used at different point for different width, and the width of the weir. It was observed that when experimenting with the weir of 40mm, 30mm, 20mm, 10mm width, the flow rate tends to vary. It was also observed that as the pressure of water increases, the water increases in height and volume. From my analysis, it can be deduced that the flow rate of 20mm and 30mm are best fitted for smooth flow of water.

**Keywords:** *Rectangular Weirs, Discharge Coefficient, Open Channel Flume, Pressure, Flow Rate*

### 1.Introduction

The project title is used to analyze the Water Flow in the Rectangular Open Channel Flume with Rectangular Sharp Crested Weir. The focus in the analysis was to determine accurate flow of the water in the open channel flume. Regulator was used in order to increase the performance in the open channel flume. In this analysis, the most important is to control and compute the water discharge in the open channel flume. The rectangular open channel flume was choosing as the shape of the open channel flume. The flow measurement in open channel is important in fluid engineering. There are a few of regulator that use in fluid measurement such as weir, orifices, sluice gate etc. Among of these regulators, weirs are the most suitable structures to measure the discharge or the flow in the open channel flume [3]. King and Barter study has stated that weir is define as an obstruction in open channel that water must flow over and is used as an indirect method for obtaining the flow rate based on the weir geometry and head over the weir crest. The sharp crested weir was widely used to compute the flow discharge. The sharp crested were into three types which are rectangular weir, V- notch weir and trapezoidal weir. In this analysis, the rectangular sharp crested weir was choosing as the regulator. This weir is the simplest forms of weirs and further classified into two types which are suppressed rectangular weir and contracted rectangular weir [5]. The figure 1.1 shows example of the sharp crested rectangular weir.

In general, the sharp crested weir has used in the hydraulic laboratories, industries and irrigation pilot schemes where highly accurate discharge measurements are required. Volumetric flow rate over a sharp crested weir (Q) under free flow condition in a channel is expressed in terms of the following mathematical expression.

$$Q = \frac{2}{3} C_d \sqrt{2gb}(h)^{3/2} \quad [7]$$

Where:

Q: Water discharge

$C_d$ : discharge coefficient

L: Width of the weir

h: Water head over the weir

## 1.2 Project Background

This study is to analyze the flow pattern of the water in the rectangular open channel flume. The purpose of this study was to investigate the discharge coefficient of the water flow over the weir in the flume in order to get the accurate flow.

## 1.3 Problem Statement

The flow pattern over a notch or weir is complex and there is no analytical solution to the relationship between discharge and head so that once again a semi-empirical approach has to be used.

## 1.4 Objectives

There are few objectives of this analysis. The objectives are:

1. To analyze the water flow pattern in the rectangular open channel flume.
2. To analyze the water surface profile of the water flow over the weir in the rectangular open channel flume.
3. To calculate the discharge coefficient,  $C_d$  of the water in the rectangular open channel flume.

## 1.5 Scope

In the present study, rectangular weirs are analyzed experimentally. The design that has been choosing for this analysis is rectangular with different dimension and configurations. This project will be used for the student and researcher to get the accurate design of the regulator which is weir in order to compute the water discharge in the open channel. This open channel flume analysis will help the student and other researchers to do their experiment design accurately. The constant weir height that is free from bottom boundary effect, is determined. Finally, the experimental study of different weir openings is made by keeping the weir height constant.

In chapter 2, the theoretical aspect of the subject is classified. In chapter 3 the present experimental setup and procedure are explained. The results experimental study are given in chapter 4. Finally, in chapter 5 conclusions of the deliberation are drawn o

## Methodology

The type of weir is used in practice to measure small-surface flows. From applications of the Bernoulli equation below relating the height of the fluid above the weir crest and the weir width to the flow over the weir.

$$Q = \frac{2}{3} C_d \sqrt{2gb}(h)^{3/2}$$

The flow through a rectangular notch is given by the expression

$$Q = \frac{2}{3} C_d \sqrt{2g} \cdot b \cdot h^{\frac{3}{2}}$$

Where  $C_d$  = is the coefficient of discharge

$B$  is the width of the weir

$h$  = is the height of the load or the height of the water on the crest or weir threshold

Deriving the equation of discharge.

Area of the strip =  $b \times dh$

Theoretical velocity of the water flowing through strip  $\sqrt{2hg}$

Discharge through strip =  $dQ = C_d \times \text{area of strip} \times \text{theoretical velocity} = dQ = C_d \times b \times dh \times \sqrt{2gh}$

The total discharge, over the whole notch, may be found out by integrating the above equation within the limits of 0 and  $H$

$$Q = \int_0^H C_d \times b \times \sqrt{2gh} \times dh$$

$$= C_d \times b \times \sqrt{2g} \int_0^H (h)^{\frac{1}{2}} dh$$

$$= C_d \times b \times \sqrt{2g} \left( \frac{2}{3} h^{\frac{3}{2}} \right) \Big|_0^H$$

$$\left( \frac{2}{3} + 1 \right) 0$$

$$= C_d \times b \times \sqrt{2g} \left( \frac{2}{3} H^{\frac{3}{2}} \right)$$

$$\left( \frac{2}{3} \right) 0$$

$$= \frac{2}{3} \times C_d \times b \times \sqrt{2g} H^{\frac{3}{2}}$$

$$Q = \frac{2}{3} C_d \cdot b \cdot \sqrt{2g} H^{\frac{3}{2}} \quad [7]$$

To examine the accuracy of the experiment the gradient of the graph can be compared with the theoretical value.

## 2.1. Apparatus

The equipment for the experiment consist of the following

1. The hydraulic bench
2. Stop watch
3. Weirs module ( delivery nozzle, stilling baffle rectangular weirs)
4. Hook and point gauge
5. Ruler or tape measure.

### 2.1.1 Setting up the apparatus

1. Ensure that the hydraulic bench is level.
2. Screw the rectangular weir plate to the weir plate carrier using the plastic thumb nuts.
3. Screw the delivery nuzzle to the water inlet.
4. Insert the stilling baffle in its grooves with the baffle towards the water inlet.

5. Move the Vernier gauge to a position directly over the weir. Place the needle point on the crest of the weir and set the gauge to zero. Take extreme care of not to damage the weir plate with the point.
6. To record water level measurements, position the gauge about half way between the weir plate and the stilling baffle.

### 2.1.2 Method

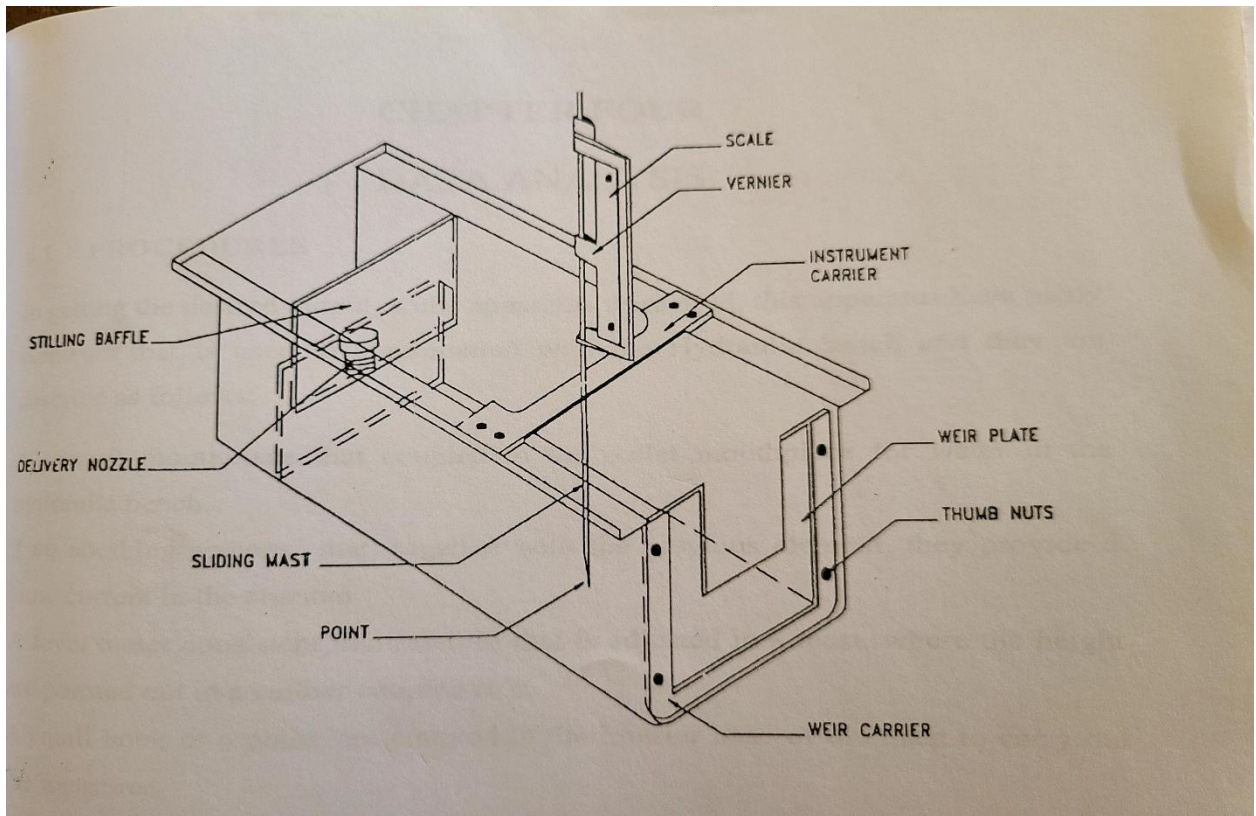
1. Assemble the equipment (screen, mouthpiece and the weir load ) as it is indicated in the diagram.
2. Place the support at the nonius at the half, approximately, of the distance between the weir and the screen.
3. Supply water to the channel until it unloads through the weir.
4. Close the water supply control valve and the stop pump let the water level in the channel stabilize. Once a minimum precise contact between the point of the lancet, or the tangency point of the hook, and the free surface of the water, as taken place adjust and immobilize the nonious of the caliber to zero.
5. Supply water to the channel adjusting the flow control value to obtain successively , step increments of the load height (H).

### 2.1.3 Procedure – Taking a set of Results

Use the fine adjustment to lower the gauge until the point touches its reflection in the surface to take an accurate height reading. Make sure that the flow rate is large enough to prevent the outflow from the notch “clinging” to the notch place. Determine the volume flow rate by measuring the time required to collect a known volume in the volumetric tank. This should be repeated twice to check consistency and accuracy. Repeat this procedure opening the bench value for further to produce an increase in depth of approximately 10mm. Continue to take the readings with increasing flow rate until the level reaches the top adjacent to the notch. Replace the rectangular notch plate with the Vee notch plate and repeat the above procedure with taking the height increments.

### 2.1.4 Dimensions and weight

1. Approximate dimension:  $400 \times 160 \times 600\text{mm}$
2. Approximate volume :  $0.22\text{m}^3$
3. Approximate weight :  $10\text{kg}$



### 2.1.4 Specifications

1. Dimensions of the weirs :  $230 \times 4 \times 160\text{mm}$ .
2. Dimension of the rectangular notch one  $40 \times 82\text{mm}$ .
3. Dimension of the rectangular notch two  $30 \times 82\text{mm}$ .
4. Dimension of the rectangular notch three  $20 \times 82\text{mm}$ .
5. Dimension of the rectangular notch four  $10 \times 82\text{mm}$ .
6. Scales of the level matter : from 0 to 160mm.

### III. Results and Analysis

Table 4.1 : EXPERIMENTAL DATA ONE

S/NO	VOLUME	TIME	HEIGHT
1	1.50	10	4
2	1.70	10	8
3	2.00	10	12
4	2.50	10	12
5	3.50	10	16
6	4.00	10	24
7	5.00	10	28

Reduce experimental data on the study of flow over rectangular weirs for 0.04(m) width.

Table 4.2 Flow rate table

VOLUME	TIME	FLOW	H	$Q^{2/3}$	LogQ	Logh	h/b	$C_d$
0.0015	10	0.00015	0.0040	0.0028	-3.824	-2.398	0.100	11.335
0.0017	10	0.00017	0.0080	0.0031	-3.769	-2.097	0.200	4.514
0.0020	10	0.00020	0.0120	0.0034	-3.699	-1.921	0.300	2.875
0.0025	10	0.00025	0.0160	0.0039	-3.602	-1.796	0.400	2.360
0.0035	10	0.00035	0.020	0.0049	-3.456	-1.698	0.500	2.380
0.0040	10	0.00040	0.0240	0.0054	-3.398	-1.619	0.600	2.668
0.0050	10	0.00050	0.0280	0.0063	-3.309	-1.553	0.700	2.041

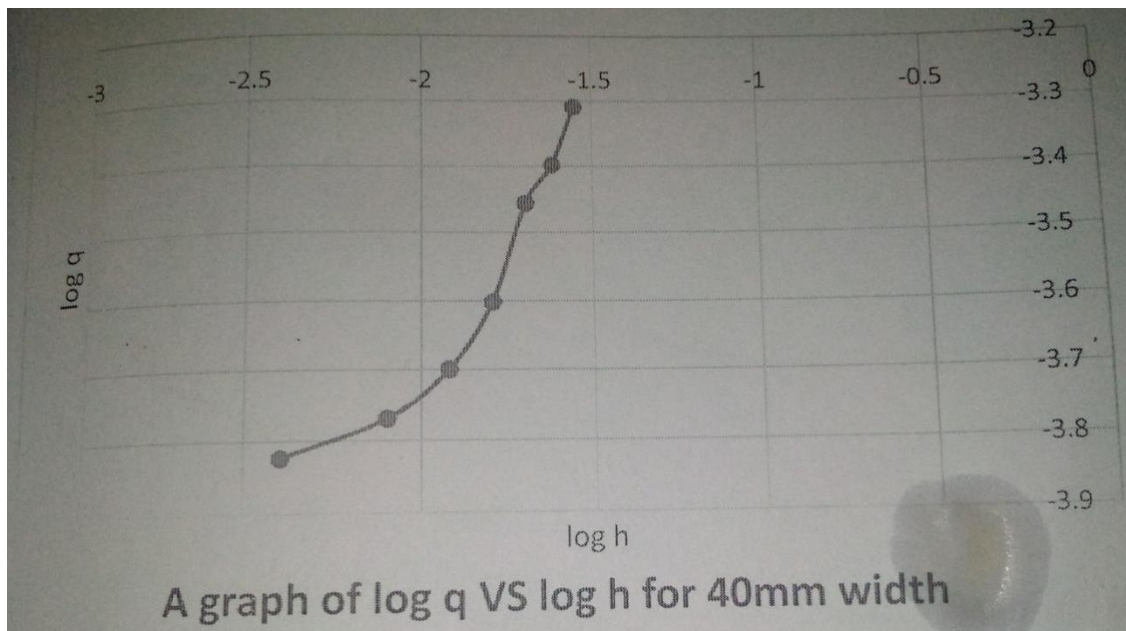


Fig 3.1

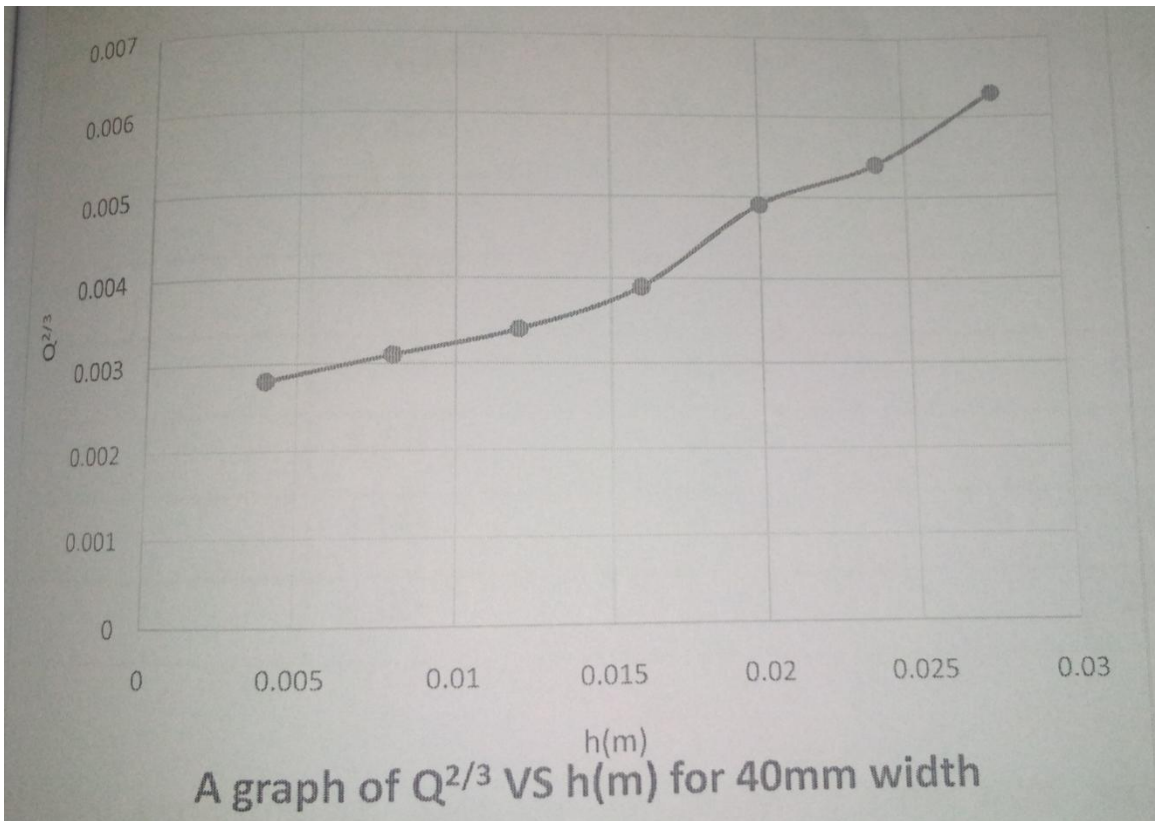


Fig 3.2

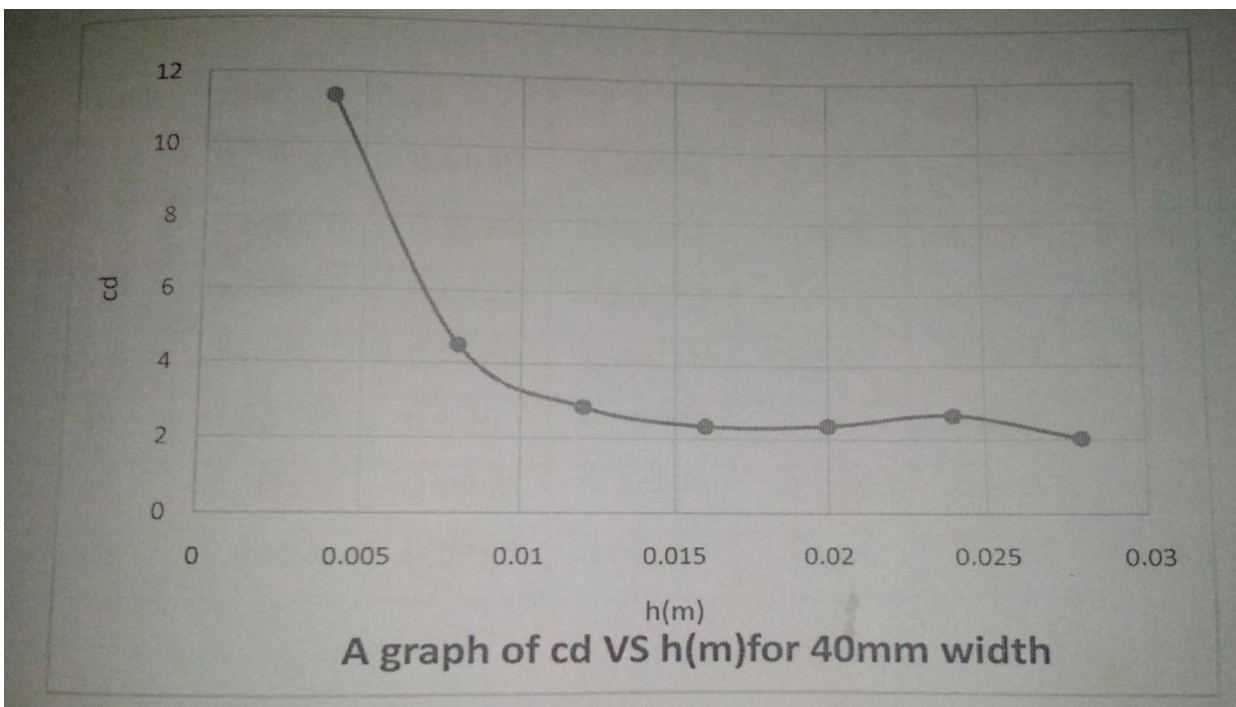


Fig 3.3

Table 3.3: EXPERIMENTAL DATA TWO

S/N	Volume	time	Height
1	1.50	10	4

2	2.00	10	8
3	3.30	10	12
4	3.70	10	12
5	5.50	10	16
6	7.00	10	24
7	8.00	10	28

Reduced experimental data on the study of flow over rectangular weirs for 0.03(m) width

Table 3.4 Flow rate table

volume	time	Flow	H	$Q^{2/3}$	LogQ	Logh	h/b	Cd
0.0015	10	0.00015	0.004080	0.00249	-3.823	2.3398	0.133	1.5111
0.0020	10	0.00020	0.0080	0.00341	-3.699	-2.097	0.266	0.7125
0.0033	10	0.00033	0.00120	0.00492	-3.481	-1.921	0.400	0.6399
0.0037	10	0.00037	0.00160	0.00516	-3.432	-1.796	0.533	0.466
0.0055	10	0.00055	0.020	0.00670	-3.259	-1.698	0.667	0.495
0.0070	10	0.00070	0.00240	0.00790	-3.155	-1.619	0.800	0.481
0.0080	10	0.00080	0.00280	0.00860	-3.096	-1.533	0.933	0.435

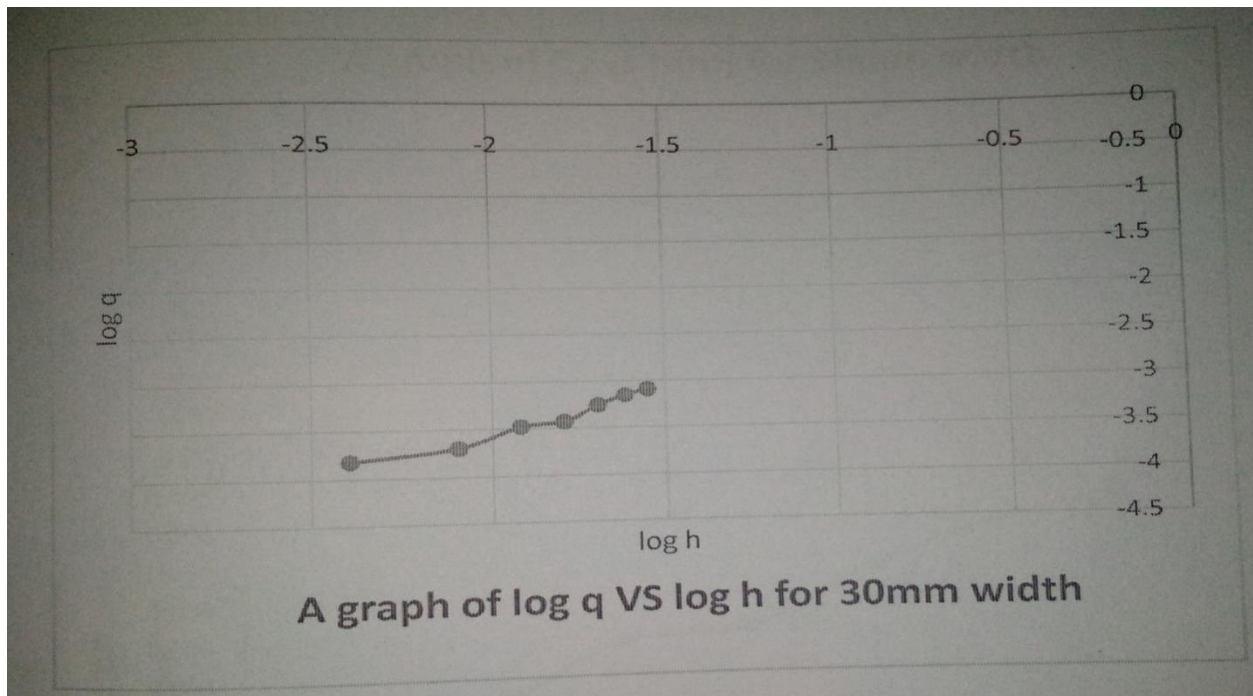


Fig. 3.4

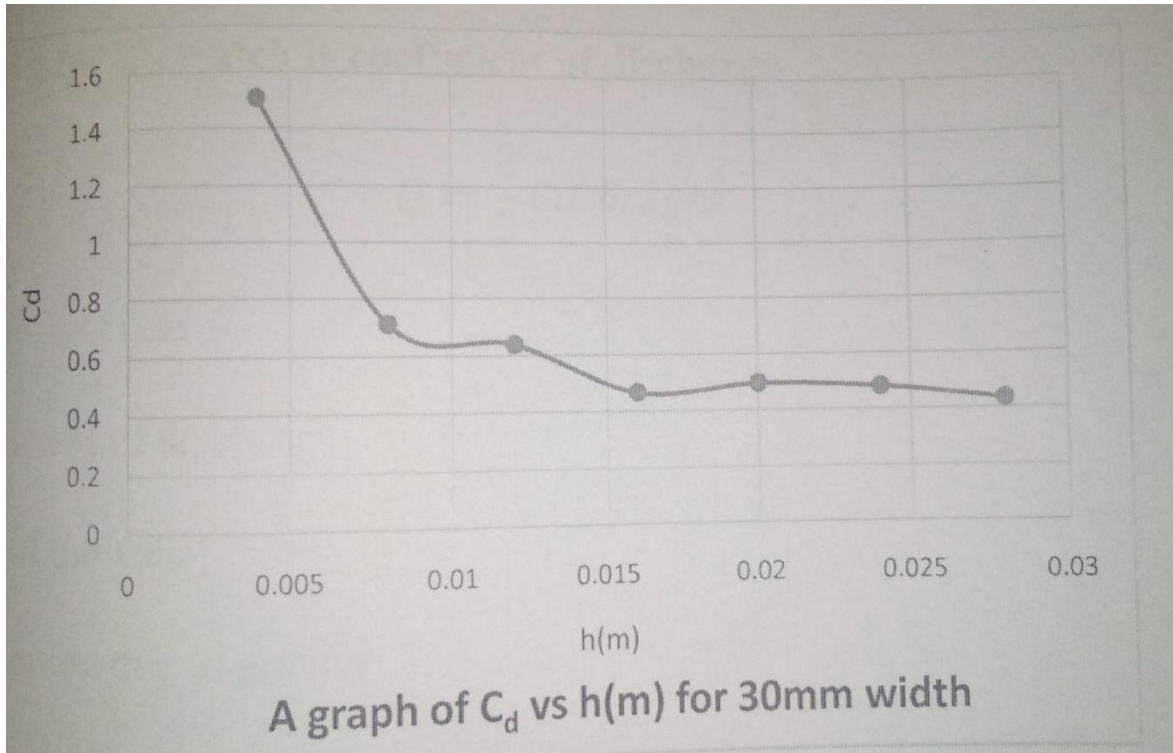


Fig.3.5

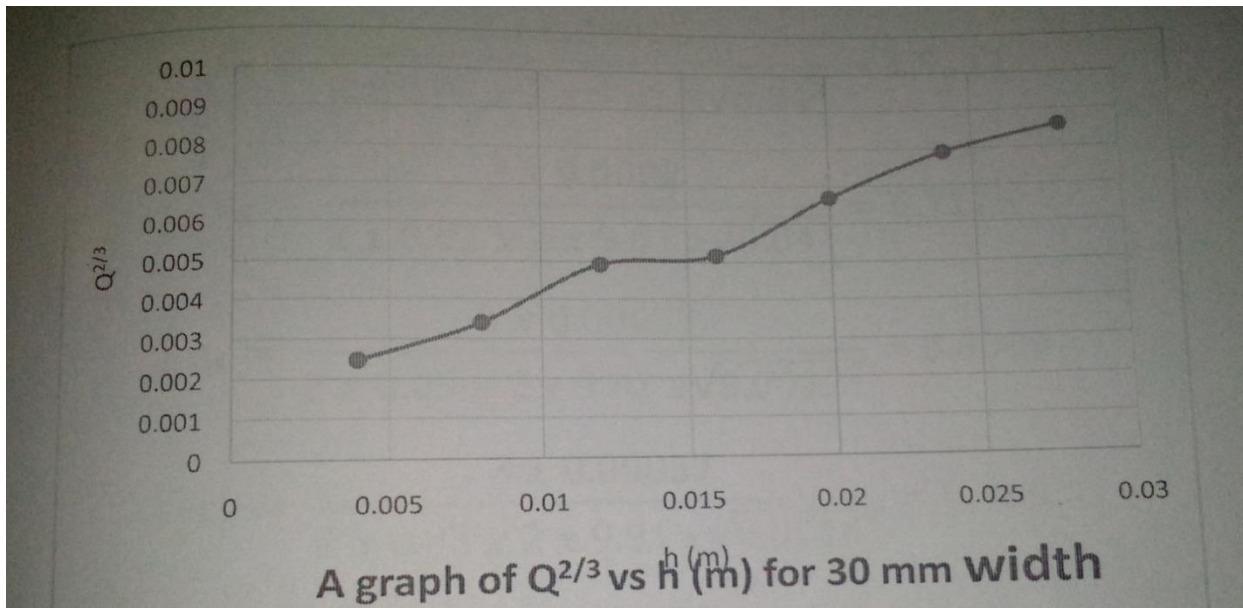


Fig.3.6

Table 3.5: Experimental Data Three

S/N	Volume	time	height
1	1.50	10	4
2	2.00	10	8
3	3.30	10	12

4	3.70	10	12
5	5.50	10	16
6	7.00	10	24
7	8.00	10	28

Reduced experimental data on the study of flow over rectangular weirs for 0.03(m) width.

Table 3.6: Flow rate table

volume	time	Flow	H	$Q^{2/3}$	logQ	logh	h/b	$C_d$
0.0015	10	0.00015	0.004080	0.00252	-3.000	-2.298	0.200	1.508
0.0020	10	0.00020	0.0080	0.00400	-2.824	-2.097	0.400	0.8007
0.0033	10	0.00033	0.00120	0.00520	-2.769	-1.921	0.600	0.495
0.0037	10	0.00037	0.00160	0.00630	-2.698	-1.796	0.800	0.377
0.0055	10	0.00055	0.020	0.00740	-2.456	-1.698	1.000	0.479
0.0070	10	0.00070	0.00240	0.0083	-2.398	-1.619	1.200	0.411
0.0080	10	0.00080	0.00280	0.0092	-2.346	-1.553	1.400	0.368

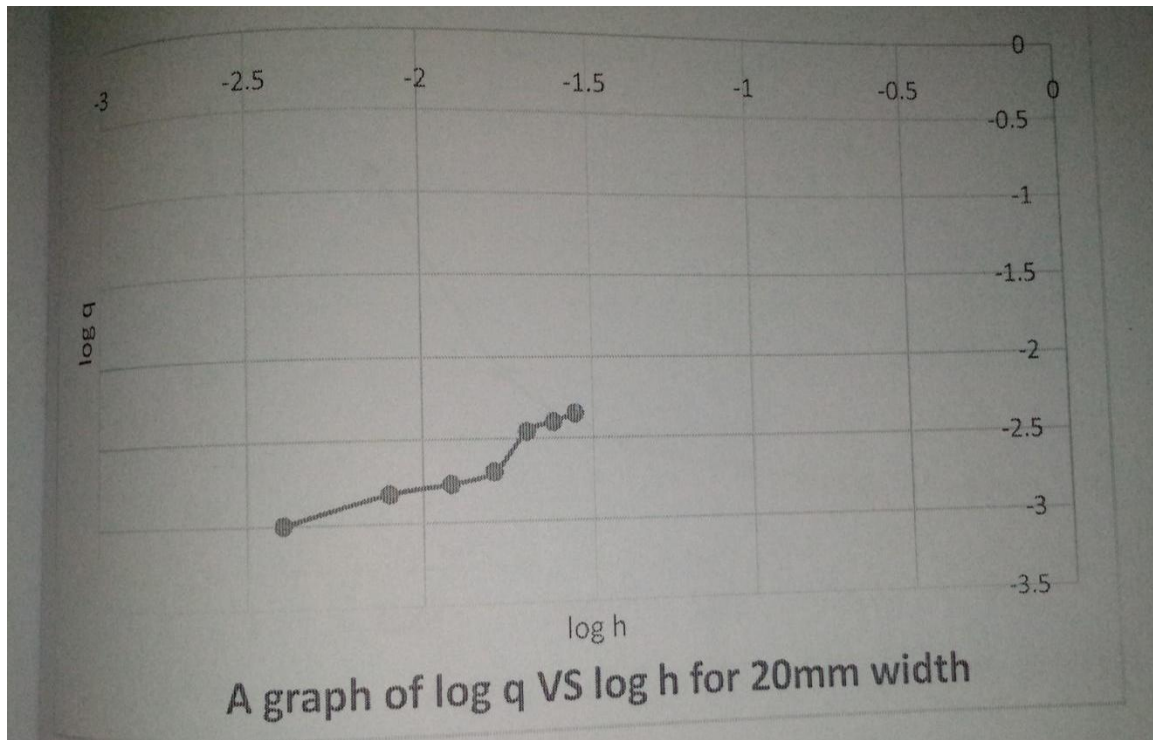


Fig.3.7

Volume	time	flow	H	$Q^{2/3}$	LogQ	Logh	h/b	Cd
0.001	10	0.001	0.004	0.001	-4.000	-2.398	0.100	3.030
0.0014	10	0.0014	0.0080	0.006	-3.854	-2.097	0.800	1.495
0.0016	10	0.0016	0.00120	0.0012	-3.796	-1.921	1.200	0.930
0.0019	10	0.0019	0.00160	0.0015	-3.721	-1.796	1.600	0.718
0.002	10	0.002	0.020	0.0043	-3.698	-1.698	2.000	0.540

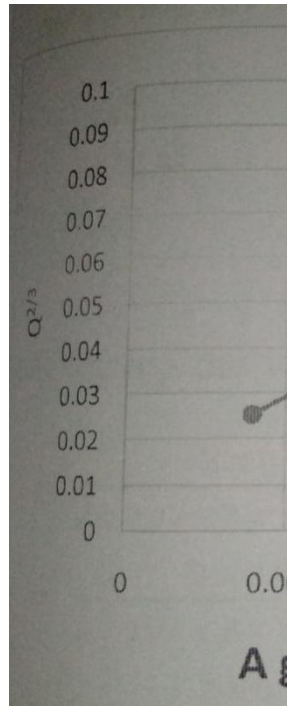


Fig.3.8

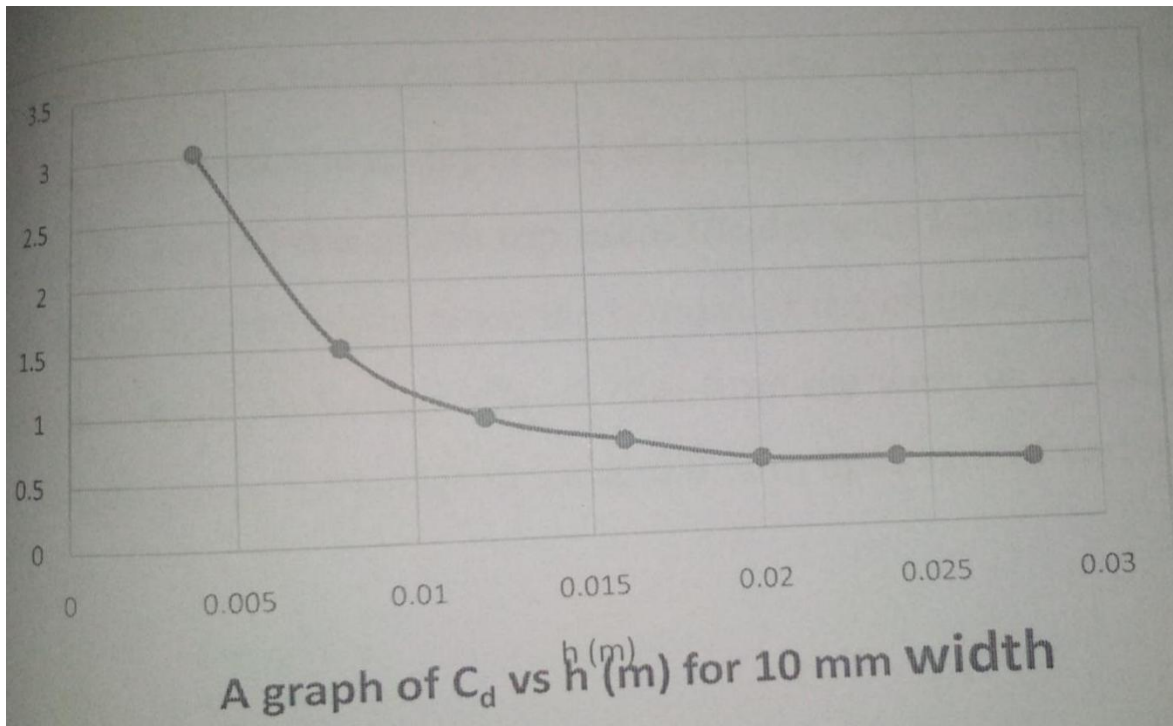


Fig.3.9

0.0025	10	0.0025	0.00240	0.0039	-3.602	-1.619	2.400	0.514
0.0029	10	0.0029	0.00280	0.0044	-3.558	-1.533	2.800	0.473

Table 3.7

#### IV. Conclusion

The experimental result obtained for the discharge coefficient and the flow magnification factors generally, increase with decrease in notch dimension of 0.003m and 0.002m width, performed best than that of 0.004m and 0.001m width notch. This finding are in good agreement with that of Beghei et al(2003) Bhazadtahssen (2005). I also observed that the general relation between “Q” and “H” was noticed experimentally to be empirical and direct, where and increase in water level at the upstream was accompanied with an increase in the rate of flow.

#### References

1. Aydin, I., et al., (2002). “Measurement of Small Discharges in open Channels by Slit Weir”. Journal of Hydraulic Engineering, Vol.128, No.2, 234-237.
2. Bos, M. G.(1989). “Discharge Measurement Structures”. International institute for Land Reclamation and improvement, 3<sup>rd</sup> Edition, Wageningen, The Netherlands.
3. Chow, V. T. (1959). “Open Channel Hydraulics.” McGraw-Hill Book Company Inc., New York.
4. Coxon, W. F. (1959). “Flow Measurment and Control.” Heywood & Company Ltd., London.
5. Franzini, J. B. and Finnemore, E. J (1997). “Fluid Mechanics with Engineering Applications.” McGraw-Hill Company Inc., New York.
6. Henderson, F. M. (1966). “Open Channel Flow.” Prentice-Hall Inc., London.
7. Kinsdvater, C. E. and Cater, R. W. (1957). “Discharge Characteristics of Rectangular Thin-palte Weirs.” Journal of Hydraulics Division, Vol. 83, No. 6, December, 1-36.
8. Subramanya, K. (1986). “ Flow in Open Channels.” McGraw-Hill Publishing Company Limited, New York.
9. Bhzad M.A.N and tahssen A.H.C (2005). “Characteristics of flow over normal and other shapes”. Longman, New York.
10. Rehbock, T. (1988). “Discussion of precise Measurements”. Journal of CDF. Vol.93, 1143-1162.