Study Coefficient of Discharge for a Combined Free Flow over Weir and under Gate for Multi Cases

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ABSTRACT :

Weirs and gates are the common and important structures which are used in controlling and adjusting the flow in irrigation channel. One disadvantage of the gates is the possibilities of retaining the floating materials which can be resolved if they combined with the weirs. Also sedimentation problem in weir can be resolved by combination of weirs with sluice gates. These combined structures have a new hydraulic condition that is different with weir condition solely or we have only gate. This study was done in the fluid lab of civil engineering in Babylon University .This research presents the results of an experimental study on the hydraulic characteristics of weirs and combined weirs under multi cases, these cases were (rectangle weir, v-notch weir, semi-circular weir, rectangular combined weir with a rectangular gate, v-notch combined weir with a rectangular gate, semi-circular combined weir with a rectangular gate, and semi-circular combined weir with a semi-circular gate). The results showed that the experiments erected on the notches were obtained for discharge coefficient Cd as follows: Rectangular weir Cd = 0.607 , V_ notch Cd = 0.630 , Semicircular weir Cd = 0.693 , Combined V-notch weir and Rectangular gate Cd = 0.779 , Combined Rectangular weir and Rectangular gate Cd = 0.751 , Combined semicircular weir and Rectangular gate Cd = 0.781 and Combined semicircular weir and semicircular gate Cd = 0.797 . We found the values Cd in the Compound semicircular weir and semicircular gate are the best in terms of being a once hydraulic values Cd higher than the other notches.

Keywords: Flow; Weirs; Gates; Hydraulic models.

دراسة معامل التصريف لجريان حر مركب فوق هدار وتحت بوابة لعدة حالات

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الخلاصة :

السدود والبوابات من المنشأت الهيدروليكيه المهمه التي تستخدم في مراقبة وضبط التصريف في قنوات الري. على الرغم من وجود عيب واحد في البوابات هو احتمال الإبقاء على المواد العائمة التي يمكن حلها إذا كانت مجتمعة جنبا إلى جنب مع السدود. وأيضا مشكلة الترسيب في الهدار يمكن حلها عن طريق الجمع بين السدود مع بوابات السد. هذه المنشأت مجتمعة تكون حالة هيدروليكية جديدة يختلف عن حالة هدار فقط أو بوابة فقط. ويقدم هذا البحث نتائج دراسة تجريبية على الخصائص الهيدروليكية للمياه مع السدود او السدود المركبة تحت حالات متعددة، وكانت هذه الحالات (الهدار المستطيل، الهدار المثلث، الهدار النصف دائري، هدار مثلث مركب مع بوابة مستطيلة، هدار مستطيل مركب مع بوابة مستطيلة ،هدار نصف دائري مركب مع بوابة

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مستطيلة، هدار نصف دائري مركب مع بوابة نصف دائرية.اجريت الدراسة والتجارب في مختبر كلية الهندسة قسم المدني في جامعة بابل. اظهرت النتائج التي تم الحصول عليها من اجراء التجارب التي اقيمت على الهدارات للخروج بقيم معامل التصريف Cd على النحو التالي: الهدار المستطيل Cd= 0.607,الهدار المثلثة Cd= 0.630,الهدار النصف دائري Cd= 0.693,هدار مثلث مركب مع بوابة مستطيلة Cd= 0.770,هدار مستطيل مركب مع بوابة مستطيلة Cd= 0.751 , هدار نصف دائري مركب مع بوابة مستطيلة Cd= 0.781,هدار نصف دائري مركب مع بوابة نصف دائرية Cd= 0.797 , ولمعرفة أفضل شكل من الناحيه الهيدروليكيه أخذ معامل التصريف (Cd) كدالة على ذلك. من اعلاه نلاحظ ان قيمة Cd للهدار النصف الدائري المركب مع بوابة نصف دائرية هو الافضل .

1- INTRODUCTION

The weir applications in the measurement of discharge large and small open channels in the field or the laboratory, and in general can be defined weir as a handicap regularly happen flow from it. More types weirs widespread and commonly is the sharp weirs with a notch of rectangular and triangular, which is often where the coefficient of discharge CD starts from 0.55 for the rectangular notch and 0.59 for the triangular notch, but these transactions are affected by viscosity and surface tension, roughness of the plate and weir.

There are different types of weir. It may be a simple metal plate with a V-notch cut into it, or it may be a concrete and steel structure across the bed of a river. A weir that causes a large change of water level behind it, as compared to the error inherent in the depth measurement method, will give an accurate indication of the flow rate. Some weirs are used as bridges for people to walk along. Michael, R. and Robert, H., (2006). Broad-crested weir, Sharp crested weir, Combination weir, V-notch weir, Rectangular weirs, Minimum Energy Loss weir and Semicircular weir.

Weirs and gates are the common and important structures which are used in controlling and adjusting the flow in irrigation channel. Weirs widely used for flow measurements. One of the weirs demerits is they need to be cleaned of sediment and trash periodically. Sluice gates are used extensively for flow control and water measurement for long time. One disadvantage of the sluice gates is they retained the floating materials. In order to maximize their advantages, weirs and gates can be combined together in one device, so that water could pass over the weir and below the gate simultaneously. Figure 1 shows this structure, this compound device create a new hydraulically condition in compression with weir or gate, each other alone. The combined weir and gate systems can be used in minimizing sedimentations and depositions. Several works can be found in combined overflow and underflow that the first idea of simultaneous flow over the weir and under the gate was introduced by Majcherek (1984). Negm (1995, 1996) analyzed the characteristics of the combined flow over contracted weirs and below contracted gates of rectangular shape with unequal contractions. Alhamid (1999) studied combined flow over V-notch weir and below contracted rectangular gate. This study covered both free and submerged gate flow conditions, under different weir-gate dimensions. Based on dimensional analysis and using non-linear regression analysis, discharge equation was

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developed for both free and submerged gate flows. Ferro (2000) reported the results of an investigation carried out to establish the stage discharge relationship for a flow simultaneously discharging over and under a sluice or a broad crested gate. Negm et al. (2002) conducted some experiments to study the characteristics of the combined flow over the sharp-edged rectangular weir and below the sharp-edged rectangular gate with contractions. He introduced a general dimensionless relationship for predicting the discharge of the combined flow. Samani and Mazaheri (2007) presented a new physically based approach for estimating the stage discharge relationship of combined flow over the weir and under the gate for semi submerged and fully submerged conditions.

2- Theoretical Background

The derivation of any simple weir formula obviously requires drastic simplification of the problem which leads to an approximate result; however, by such methods the form of the relationship between flow rate and head can found and an experimental coefficient defined. To derive a simple weir equation, let it be assumed that (1) velocity distribution upstream from the weir is uniform, (2) all fluid particles move horizontally as they pass the weir crest, (3)the pressure in the nappe is zero (4)the influence of viscosity, turbulence, secondary flows, and surface tension may be neglected.

Figure 1 shows definition sketch for the free flow over rectangular notch weir and triangular notch weir and semi-circular notch weir and combined weir type rectangular notch weir with submerged rectangular gate and V-notch weir with submerged rectangular gate and semicircular notch weir with submerged semicircular gate and semicircular notch weir with submerged rectangular gate. We can be described as equivalent discharge passing over a rectangular weir in Eq. (1) as follows:

$$Qa = Cd \times \frac{2}{3} \times (2g)^{0.5} \times L \times h^{(3/2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

We can be described as equivalent discharge passing over V_ notch weir in Eq. (2) as follows**:**

$$Qa = \frac{18}{5} \times Cd \times (2g)^{0.5} \times \tan\left(\frac{\theta}{2}\right) \times h^{2.5} \qquad \ldots\ldots\ldots\ldots\ldots.. (2)$$

We can be described as equivalent discharge passing over a semicircular weir in Eq. (3) as follows**:**

$$Qa = Cd\ (2gh)^{0.5} \times \left(\frac{d^2}{8}(\Theta - \sin\theta)\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

We can be described as equivalent discharge passing over and throw a combined device as follows Equation. (4),(5).

$$Q_{the} = Q_w + Q_g \qquad \ldots\ldots\ldots\ldots.. (4)$$

Where:

$$Q_w = \frac{2}{3}\sqrt{2g} \times B \times h^{(3/2)}$$

$$Q_g = \sqrt{2gH} \times (Ag) \qquad \ldots\ldots\ldots\ldots.. (5)$$

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g :acceleration due to gravity (m/s^2) ,d : the width of the gate (m) ,h : the head through the weir (m) ,y : the distance below the weir and over the gate edge (m) ,H : the total head H=h + y + d/2 (m) ,B : the width of the weir (m) ,Ag : the area of the gate

$$Q_{act} = Cd\ Q_{the} = Cd \times (Q_w + Q_g) \quad \ldots\ldots\ldots\ldots (6)$$

Q_{the}: is the total discharge through the combined device which is calculated as follows.

Q_g : Discharge through gate (m^3 / s), Q_w : discharge through weir (m^3 / s)

3- Experimental Work

This study was done in the fluid lab of civil engineering in Babylon University. The tools used in the laboratory were Gauge level ((hook gauge)), Hydraulic table and Stopwatch. the specifications models were rectangular notch weir(4x8 cm) and triangular notch weir(Θ=90^o) and different diameter semi-circular notch weir was three different models radius (3cm,4cm,5cm) and compound weir type rectangular notch weir (4x8 cm) with rectangular gate (4x3 cm) and V-notch weir (Θ=90^o) with rectangular gate (4x3cm) and semicircular notch weir (4cm radius) with semicircular gate (3cm radius) and semicircular notch weir (4cm radius) with rectangular gate (4x3cm) see figure (1), all models in the same conditions in temperature. Models were made of fiber glass. The work was carried out in hydraulic table. The water discharge was measured by a volumetric method. The head over the weir models was measured by using a point gauge; water temperature was recorded by a thermometer. The detail of the all models combined and uncombined device used is shown in table (1).

Table 1: The detail of the all models combined and uncombined device

Model No.	Model	Run No.	Dimension weir (cm)	Dimension gate (cm)	Cd
1	Rectangular Notch Weir	1-7	y_1 = 8cm B = 3cm	-	0.607
2	Triangular Notch Weir	1-5	Θ = 90^o B = 6cm	-	0.630
3	Semi-Circular Notch Weir	1-5	D = 8cm	-	0.693
4	Combined Rectangular Notch Weir with Rectangular Gate	1-7	y_1 = 4cm B = 8cm	y_o = 3cm b = 4cm	0.751
5	Combined V-Notch Weir with Rectangular Gate	1-6	Θ = 90^o B = 8cm y = 6 cm	y_o = 3cm b = 4cm	0.779
6	Combined Semicircular Notch Weir with Semicircular Gate	1-6	D = 8cm y = 6cm	d = 6cm	0.797
7	Combined Semicircular Notch Weir with Rectangular Gate)	1-6	D = 8cm y = 6cm	y_o = 3cm b = 4cm	0.781

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4- Experimental Procedure:

1- Place the flow stilling basket of glass spheres into the left end of the weir channel and attach the hose from the bench regulating valve to the inlet connection into the stilling basket. See figure (2).
2- Place the specific weir plate which is to be tested first and hold it using the five thumb nuts. Ensure that the square edge of the weir faces upstream.
3- Start the pump and slowly open the bench regulating valve until the water level reaches the crest of the weir and measure the water level to determine the datum level H zero.
4- Adjust the bench regulating valve to give the first required head level of approximately 10mm. Measure the flow rate using the volumetric tank or the rotameter. Observe the shape of the nappe.
5- Increase the flow by opening the bench regulating valve to set up heads above the datum level in steps of approximately 10mm until the regulating valve is fully open. At each condition measure the flow rate and observe the shape of the nappe.
6- Close the regulating valve, stop the pump and then replace the weir with the next weir to be tested. Repeat the test procedure.

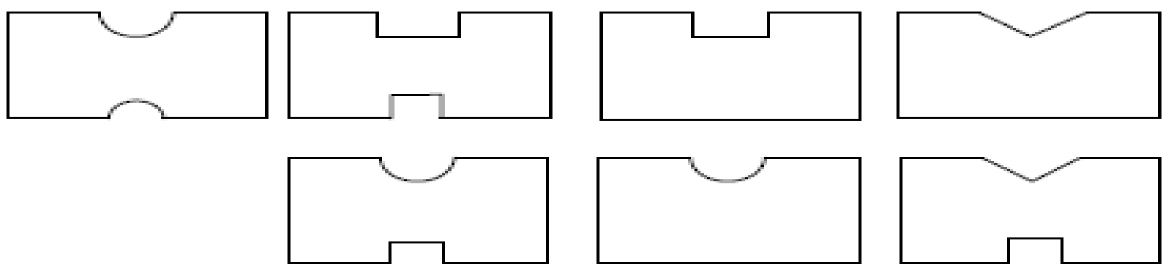

Figure 1: Shows definition sketch for the free flow over combined and uncombined weir for seven models

Figure 2: Shows the hydraulic table which used in experimental work in the lab with one models.

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5- Analysis of Results:

Table 2 explains the results the all experimental work of models which used in this study and coefficient of discharge (Cd) for each the models were calculated. Through our observation of the results average coefficient of discharge (Cd) for Rectangular weir was 0.607. The results average coefficient of discharge (Cd) for V_ notch weir was 0.63. The results average coefficient of discharge (Cd) for Semicircular weir was 0.693. The results average coefficient of discharge (Cd) for Compound v-notch weir and Rectangular gate was 0.779. The results average coefficient of discharge (Cd) for Compound Rectangular weir and Rectangular gate was Cd = 0.751**.** The results average coefficient of discharge (Cd) for Compound semicircular weir and Rectangular gate was 0.781. The results average coefficient of discharge (Cd) for Compound semicircular weir and semicircular gate was average Cd = 0.797.

Table 2: the results calculated coefficient of discharge for all models.

No. of Run	Rectangular Notch Weir	Triangular Notch Weir	Semi-Circular Notch Weir	Combined V-Notch Weir with Rectangular Gate	Combined Rectangular Notch Weir with Rectangular Gate	Combined Semicircular Notch Weir with Rectangular Gate)	Combined Semicircular Notch Weir with Semicircular Gate
	Cd						
1	0.619	0.688	0.659	0.789	0.759	0.787	0.781
2	0.598	0.678	0.688	0.809	0.742	0.773	0.809
3	0.635	0.591	0.725	0.775	0.719	0.771	0.798
4	0.556	0.611	0.69	0.771	0.759	0.795	0.8
5	0.623	0.582	0.706	0.77	0.766	0.795	0.796
6	0.6			0.764	0.768	0.763	0.797
7	0.62				0.743		
Cd average	0.607	0.630	0.693	0.779	0.751	0.781	0.797

The figures from 2 to 8 showed the relationship between the discharge (Q) and the head (h) over the weir and under gate.

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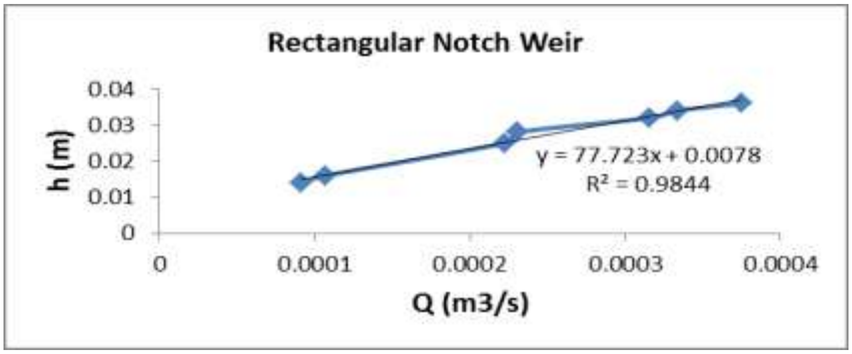

Figure 3: Explain the stage – discharge relationship for rectangular weir

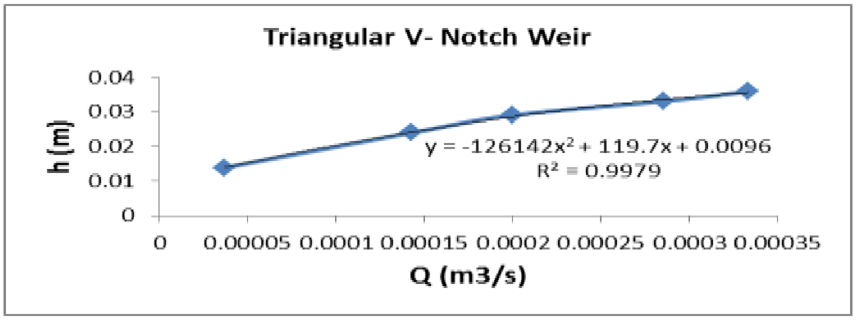

Figure 4: Explain the stage – discharge relationship for Triangular V- Notch Weir

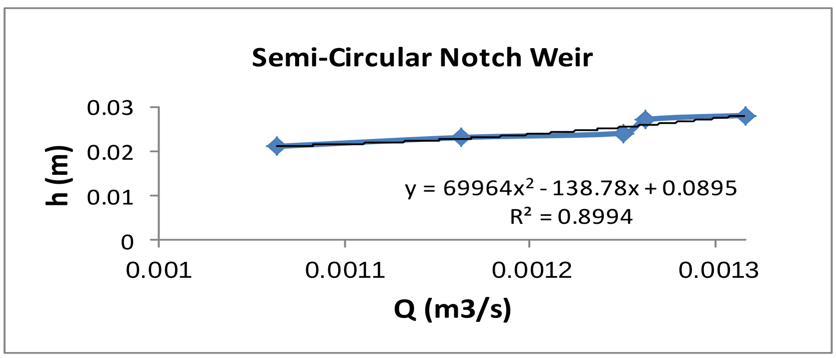

Figure 5: Explain the stage – discharge relationship for Semi-Circular Notch Weir

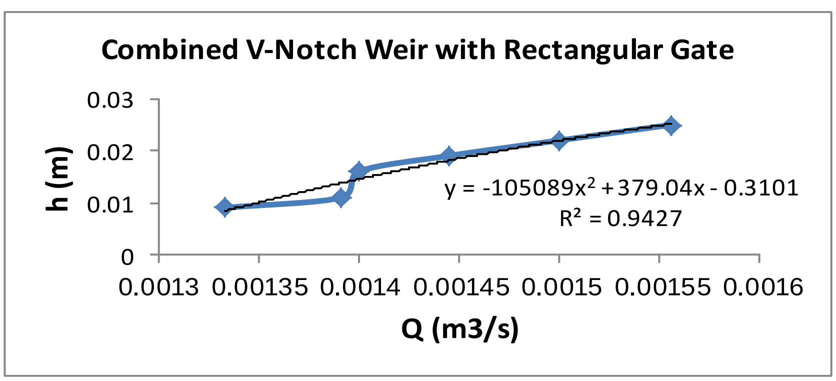

Figure 6: Explain the stage – discharge relationship for Combined V-Notch Weir with Rectangular Gate

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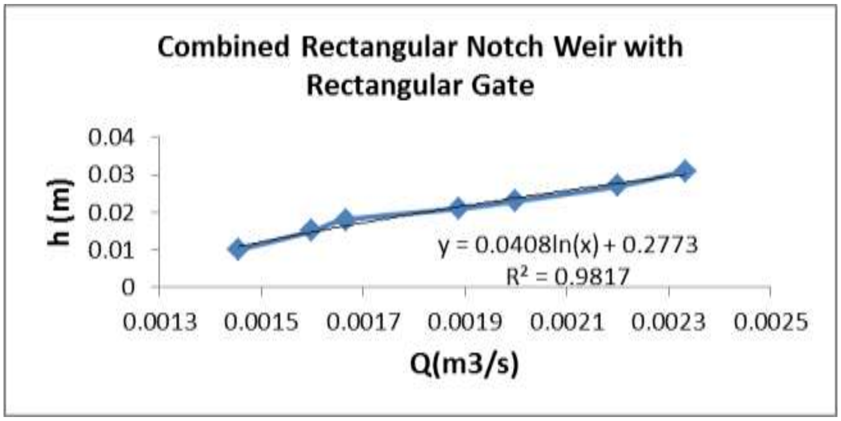

Figure 7: Explain the stage – discharge relationship for Combined Rectangular Notch Weir with Rectangular Gate

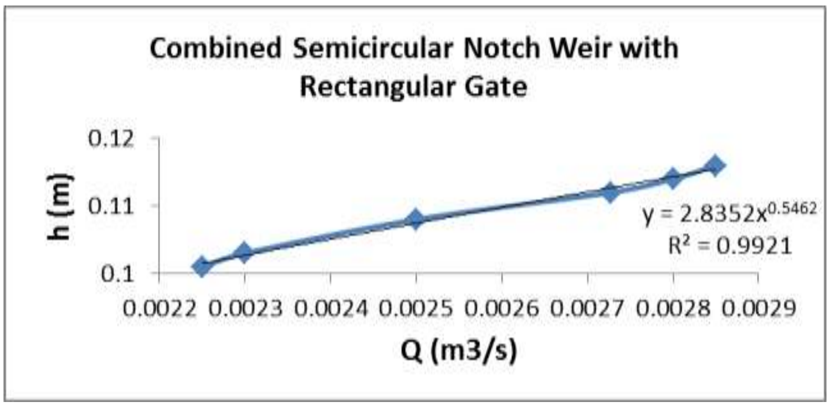

Figure 8: Explain the stage – discharge relationship for Combined Semicircular Notch Weir with Rectangular Gate

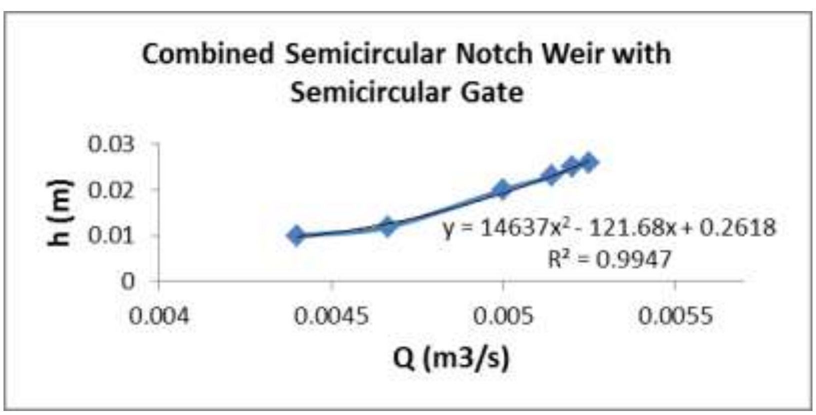

Figure 9: Explain the stage – discharge relationship for Combined Semicircular Notch Weir with Semicircular Semicircular Gate

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6- Conclusions

1- Through experiments works on combined and uncombined weir we obtained for maximum coefficient of discharge (Cd) for Compound semicircular weir and semicircular gate was 0.797, while minimum coefficient of discharge (Cd) for Rectangular weir was 0.607. From that we note the values Cd in the combined semicircular weir and semicircular gate was the optimal hydraulic section for weir in case high discharge.

2- From plot the relationship between discharge and the head (h) (height the water over weir) the figures (3 to 9), the best fit were applied to estimate equations the shown in table 3 for each models which was used in this research. Where y= head (m), x= discharge (m^3/s).

Table 3: The best fit to estimate relationship between discharge and the head (h) (height the water over weir)

Model No.	Model	Empirical Equations	R^2
1	Rectangular Notch Weir	$y = 77.723x + 0.0078$	0.9844
2	Triangular Notch Weir	$y = -126142x^2 + 119.7x + 0.0096$	0.9979
3	Semi-Circular Notch Weir	$y = 69964x^2 - 138.78x + 0.0895$	0.8994
4	Combined Rectangular Notch Weir with Rectangular Gate	$y = 0.0408\ln(x) + 0.2773$	0.9817
5	Combined V-Notch Weir with Rectangular Gate	$y = -105089x^2 + 379.04x - 0.3101$	0.9427
6	Combined Semicircular Notch Weir with Semicircular Gate	$y = 14637x^2 - 121.68x + 0.2618$	0.9947
7	Combined Semicircular Notch Weir with Rectangular Gate)	$y = 2.8352x^{0.5462}$	0.9921

Where: y = head (m), x = discharge (m^3/s)

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