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FLOW OVER SKEW SIDE WEIRS IN NON-PRISMATIC RECTANGULAR CHANNELS

السريان علي الهدارات الجانبية المنحرفة لقنوات مستطيلة متغيرة القطاع

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ملخص البحث :

يقدم هذا البحث دراسة معملية لدراسة انسياب المياه المتدفقة عبر الهدارات الجانبية الحادة الحواف والمنحرفة وذلك في القنوات المستطيلة المتغيرة القطاع . في هذا البحث تم أجراء أكثر من ستين تجربة معملية لدراسة تأثير العوامل المختلفة علي السريان مثل زاوية انحراف الهدار على اتجاه السريان في القناة وكذلك تأثير عمق المياه ومعدل سريانها وذلك مع وجود تغير في عرض المجرى . يشمل البحث تحليل النتائج المعملية بعد تمثيل العوامل المختلفة علي شكل منحنيات غير بعديه.

ABSTRACT

An experimental study of flow over sharp edged skew side weirs in rectangular channels is presented. Experiments were carried out for various angles of skew side weir, discharges and water depths. Dimensional analyses to develop non-dimensional terms affecting the phenomenon were obtained based on the experimental data. Discharge coefficients are obtained for sub-critical regime. Water surfaces are observed for different angles of skew side weir.

INTRODUCTION

A side-weir, also known as a lateral weir, is a free over-flow weir set into the side of a channel which allows part of the water to spill over the side when the surface of water in the channel rises above the weir crest. Side weirs have been used extensively in irrigation, land drainage, flood protection, and urban drainage works.

A complete analytical solution of the equations governing the flow in side weir channels is not possible, Uymaz [13]. Until quite recently, approximate methods have been used, based on experiments conducted over a limited range of the many variables involved. Hydraulic behavior of side-weirs has received considerable interest since the beginning of this century. However, a large number of these studies are empirical in nature, Allen [2]; El-Khashab and Smith [7]; Coleman and Smith [4]; Collinge [5]; Hager [8]; Robinson and McGhee [10]; Subramanya and Awasthy [11]; Swamee et al [12] and Ranga Raju et al [9]. In many cases, the use of such approximate methods has involved very substantial errors in the calculated spill discharge. Probably DeMarchi [6] made the first theoretical approach to the hydraulics of a side weir in a rectangular channel However, sufficient information on the variation of the coefficient used in his equation is not available. Therefore, direct application to practical cases is not generally possible, and their use is tedious.

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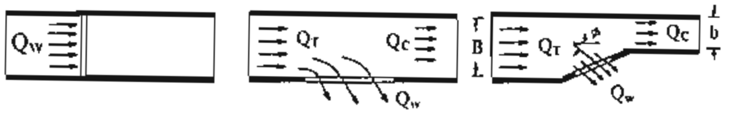
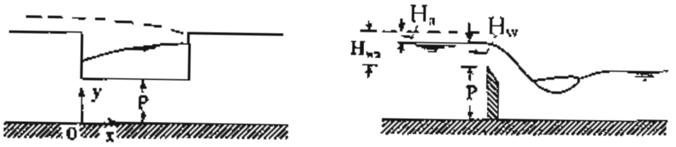
Fig. (1) shows a definition sketch for weirs. From this figure, according to DeMarchi [6], it is evident that, the general differential equation of spatially varied flow modified for a rectangular, prismatic, horizontal, frictionless channel is, Chow [3]

$$dy/dx = Qy(-dQ/dx) / (g.\ B^2.y^3 - Q^2) \text{ ------------------- } (1)$$

in which y is depth of flow at a section located at x; dy/dx is water surface slope relative to bed; Q is discharge in channel at section x; -dQ/dx is discharge per unit width spilling over the side weir; B is width of the channel; and g is acceleration due to gravity.



a) Normal weir b) Side weir c) Skew side weir



d) Longitudinal section of skew side weir e) Transversal section of skew side weir

Fig. 1- A definition sketch for weirs

Discharge over the side weir per unit length q_s is assumed as follow

$$q_s = dQ_s / dx = -dQ / dx = 2/3.Cm\sqrt{2g}\,(y-P)^{3/2} \cdots\cdots\cdots (2)$$

in which P is height of the side weir and Cm is a discharge coefficient known as the DeMarchi coefficient.

The specific energy of the flow in the rectangular channel should remain constant. The specific energy at any point is

$$E = Y + V^2/2g \text{ -- } (3)$$

in which E is specific energy; Y is depth of flow; V is mean velocity of flow in the channel; and g is the gravitation constant. If A is the cross-sectional area of flow and Q is the discharge at any point in the channel, then

$$E = Y + Q^2/2gA^2 \text{ --------------------------------------- } (4)$$

Because the specific energy, E, is constant along the channel, the discharge in the channel at any section may be written as follow

$$Q = B\ .\ Y\ \ (2g(E-Y))^{1/2} \text{ ------------------------------- } (5)$$

From Eqs. (1), (2) and (5):

$$dy/dx = 4/3\ .\ Cm/B\ .\ [((E-Y)(Y-P)^3)^{1/2} / (3Y-2E)] \text{ -------- } (6)$$

Ackers [1], suggested a value of Cm is 0.625 if y is measured at remote distance from the plan of the side weir and Cm is 0.725 when y is measured in the plane of weir. According to Ackers's assumption Cm is constant for various flow situations. Collinge [5], found that Cm varies with the mean velocity of flow in the up stream main channel. Dimensional analysis indicates that

$$Cm = f\left(F_1 = v_1 / \sqrt{gy_1}, L / B, y_1 / L, P / y_1\right) ---------- (7)$$

in which v_1 is mean velocity of flow. Also, according to the DeMarchi study, discharge coefficient Cm of a side weir of finite height is essentially same as a side weir of zero height.

General assumptions are that the flow in side weir channel is approximately two-dimensional, and pressure in the channel is approximately hydrostatic despite some curvature and irregularity of the water surface. In the present investigation, although the flow over the skew side weir makes a considerable angle with the direction normal to the weir a conventional weir equation for discharge per unit length is assumed as follow:

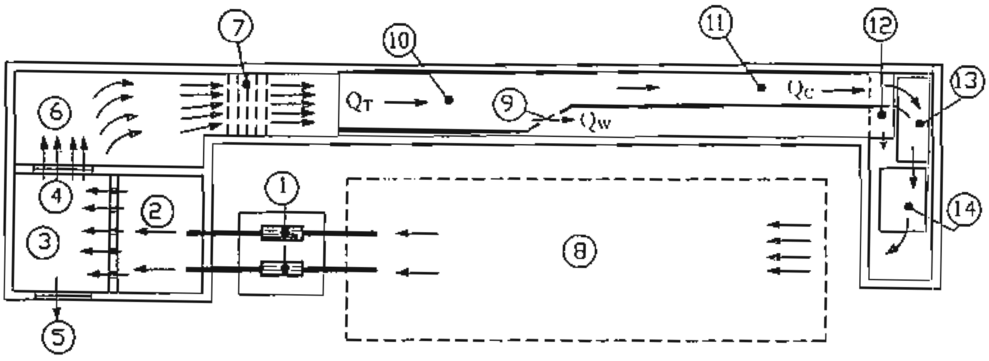
$$q_w = \tfrac{2}{3} cd \sqrt{2g} \left(H_{wa}^{1.5} - H_a^{1.5}\right) ----------- (8)$$

in which q_w is discharge per unit width of side weir; H_{wa} is the total height of water above weir crest; and H_a is the height of water due to velocity of approach. The discharge coefficient, cd, depends on the relative weir height, H_{wa}/Y, the crest shape, and the angle of skew side weir θ.

Compared to plane weir flow, streamlines over a skew side weir deviated from the channel axis by the angle φ. Also, a skew side weir deviated from the channel axis by angle, θ which are considered as 90°; 75°; 60°; 45° and 30°.

EXPERIMENTAL SET-UP

The experiments in this investigation performed in a laboratory rectangular flume as shown in Fig. (2). The main channel was 45 cm wide, 40 cm deep and 9 m long, having been constructed inside a wider flume. The flume mainly consists of head and tail tanks and the flume itself through which the flow is conveyed. A centrifugal pump is used to lift water to the head tank from the ground sump. Water discharge is controlled via a control valve installed on the delivery pipe connected to a feeding pump. The head tank consists of two adjacent tanks connecting together through holes. The delivery of the pump supplies the first tank with the pumped water; consequently, the level of the adjacent tank rises. The aim of using two tanks is to damp water fluctuations. The second tank has two weirs, one of them is to measure the flow, and the other is to allow excess water overflow and to be drained into the ground sump. Thus, water head over the calibrated weir can be maintained at the constant value despite any fluctuations in the pump flow rate. Water acting head over the weir is measured with a vertical scale The flow passes into the flume through an inlet screen to absorb any water eddy.



1- Centrifugal pump
2- First head tank
3- Second head tank
4- Flow measuring weir
5- Escape weir
6- Approach basin
7- Inlet screen
8- Laboratory sump
9- Skew side weir
10- Up-stream channel
11- Downstream channel
12-Tail hinged gate
13- Collecting tank
14- Graduated tank

Fig.2- Experimental set-up.

The main channel consists of two reaches. The first reach was constructed at the upstream of skew side weir with width B and the second reach at the downstream site of the skewed weir with width b. Skew side weir is constructed as a sharp-crested weir with rounded walls. Precision point gauges measured the depths of flow in the main channel, which is mounted on the x-y carriage. The carriage travels on two sets of rails. Water depth in the main channel is controlled using an adjustable weir fixed at the channel end. For all values of skew angle, weir side A is kept at a fixed distance from the right wall of main channel, see Fig. (3).

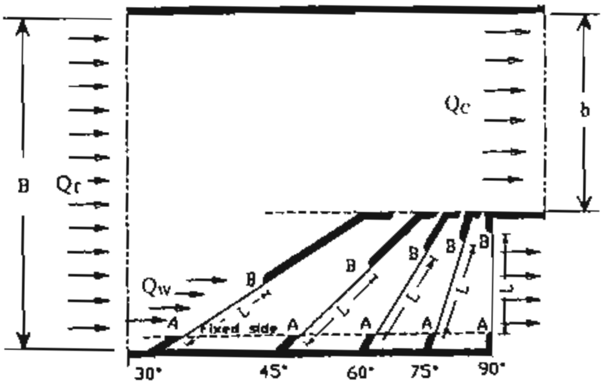


Fig. 3- Arrangement of skew side weirs

THE EXPERIMENTAL PROCEDURE

In this work, four discharges for main channel were considered, (Q_T =14.117, 11.244, 8.598, and 6.806 Liter / sec.). Mean velocities ranged from 13.63 to 32.39 cm /sec. Discharges over crest of the side weir ranged from 0.45 to 4.675 L/sec and height of the water above the crest of the skew side weir ranged from 1.7 to 6.6 cm. Sixty runs were conducted considering width ratio b/B=0.66.

Incoming water across the screen enters the first reach of the channel under gravity. As the water enters the skew side weir location, some of it spills over the weir and the remainder continues through the second reach of channel towards the graduated water tank. The drained water flux, which represents the downstream channel discharge, was measured by collecting water in graduated water tank in a certain time. The difference between the upstream discharge and the downstream discharge is the side weir discharge.

RESULTS AND ANALYSIS

Experimental data were collected and analyzed to provide some relations between parameters that affect the flow across a skew side weir.

Relationship between discharge coefficient, cd, and Froude number that computed at the main channel up-stream the weir site is shown in Fig. (4). From this figure, it is evident that, discharge coefficient decreases with increasing Froude number. Increasing Froude number from 0.20 to 0.33 decreases discharge coefficient from 0.73 to 0.45.

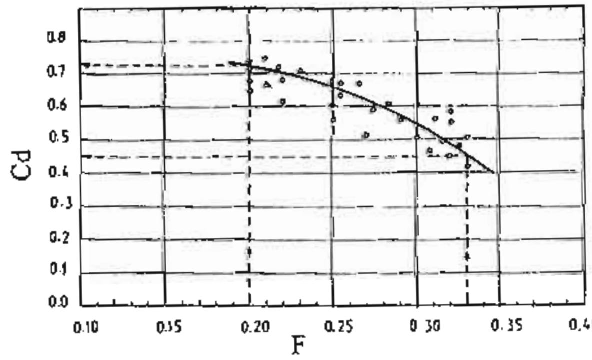


Fig. 4- Variation of Cd with Froude number for skew side weir.

Fig. (5) illustrates the relationship between discharge coefficient, cd, and the relative water height, H_{wa}/P, for different values of skew angle,θ. These angles are 90°, 75°, 60°, 45° and 30°. From this figure, it is noticed that as the relative water height increases the coefficient of discharge, Cd increases. Also, for the same value of relative water height Cd increases with decreasing angle of skew side weir. For the considered cases, discharge coefficient ranged from 0.45 to 0.73.

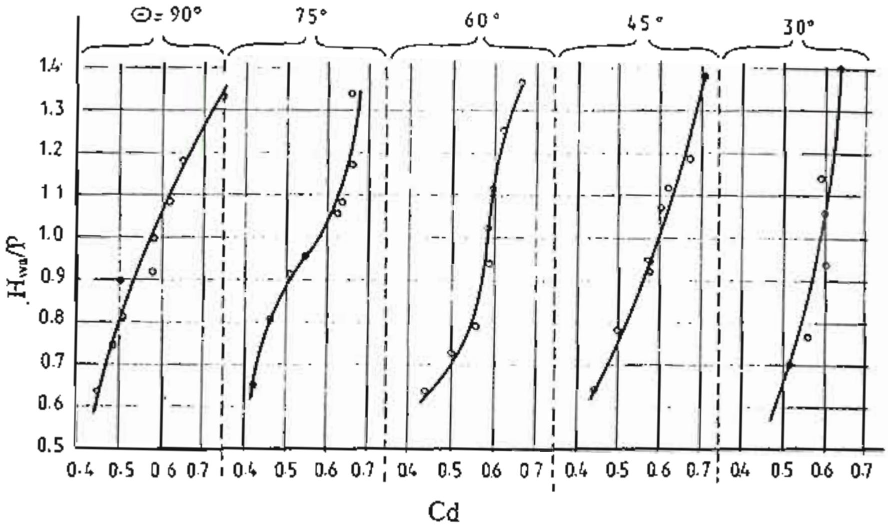


Fig. 5- Variation of Cd with Hwa/P for different skew angels.

Fig. (6) illustrates the relationship between discharge weir ratio, Q_W/Q_T, and relative water height, H_{wa}/P, for different values of Froude number ratio $1/F^2$ and for different values of skew angle, θ. From this figure it is clear that, for the same value of relative water height, discharge ratio increases with increasing the Froude number ratio, i.e., decreasing Froude number.

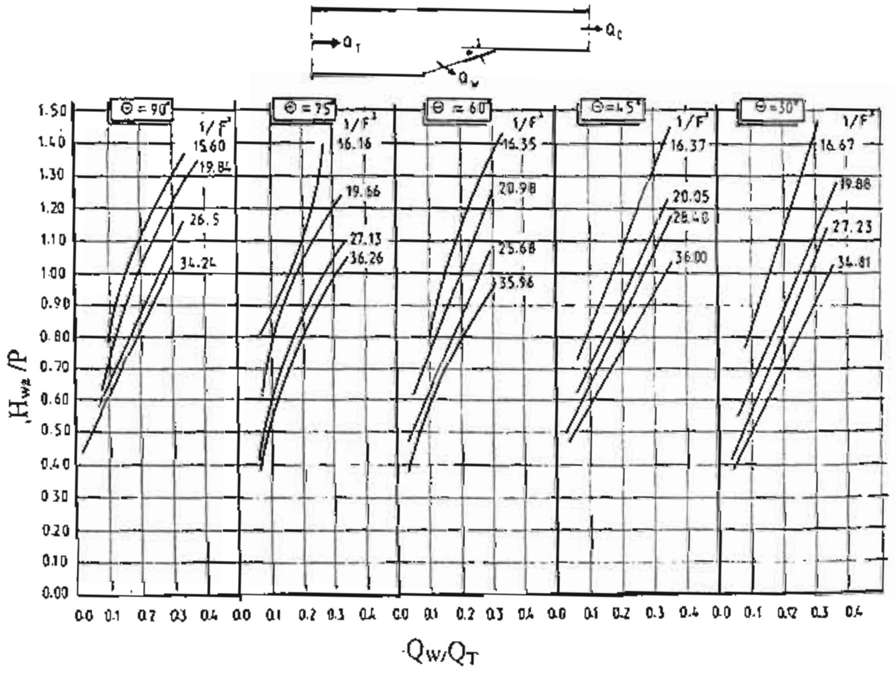


Fig.6- Variation of discharge ratio, Q_w/Q_T, with water height ratio, H_{wa}/P for different values of $1/F^2$.

Effect of skew angle, θ, on the relative discharge ratio, Q_w/Q_T, for different values of Froude number is shown in Fig. (7). From this figure, it is observed that, for Froude numbers $0.27 \le F \le 0.33$, increasing skew angle, θ, increases discharge ratio while, for $0.17 \le F \le 0.225$, increasing skew angle decreases the ratio of discharge.

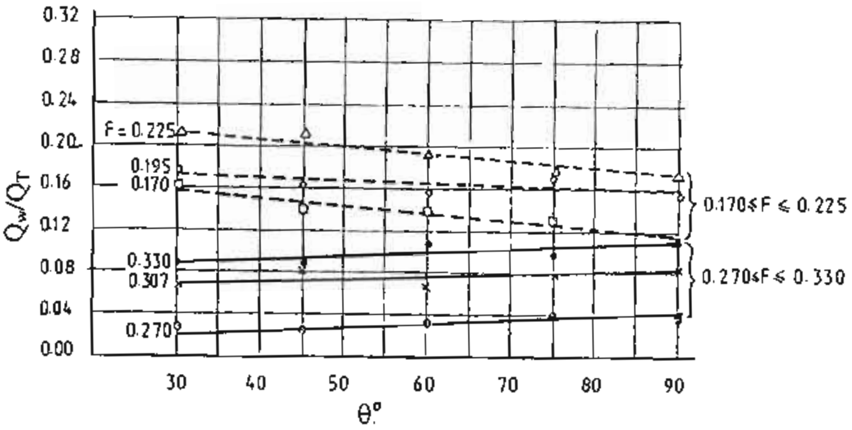


Fig.7- Variation of Q_w/Q_T with skew angle for different values of Froude number.

Water surface profiles over the crest of skew side weir are plotted for different skew angles, discharges, and Froude numbers as shown in Fig. (8). From this figure, it is clear that, for all cases, water levels over the weir crest decrease on the half lies adjacent to the canal side, side A in Fig. (3), and increase on the other half of the weir, side B in Fig. (3). Generally, for the same canal discharge, increasing skew angle decreases water levels on the half of the weir lies adjacent to the canal side.

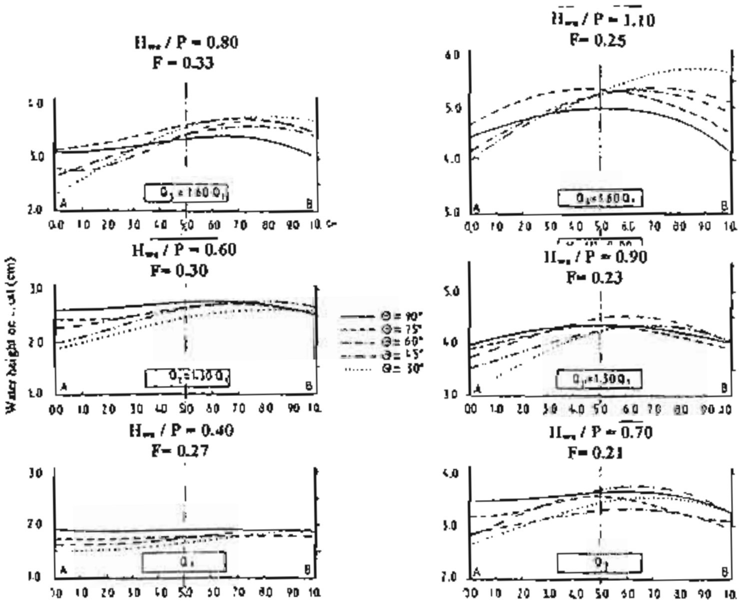


Fig.8- Water surface profiles for flow over the crest of skew side weir for different discharges and skews angles.

The following is an illustrative example of the measured and computed values for three of the conducted runs, H_{wa}/p= 0.60, 0 80, and 1.10), for θ = 30°.

Q_T	Q_C	Q_W	Y	V	H_w	H_a	H_{wa}	H_{wa}/P	F	C_d
Lit/sec	Lit/sec	Lit/sec	Cm	Cm/sec	Cm	Cm	Cm	---	---	---
11.244	10.45	0.79	8.60	28.8	2.9	0.42	3.32	0.60	0.30	0.465
14.117	12.788	1.329	9.60	32.39	3.90	0.53	4.43	0.80	0.33	0.503
14.117	11.48	2.637	11.80	26.35	6.10	0.35	6.45	1.10	0.25	0.552

CONCLUSIONS

The present research analysis the skew side weirs by including the effects of angles of skew weir, discharges, flow depth and velocity of approach. A detailed procedure is presented for the determination of discharge coefficient for different values of angle of skew side weir. The variation of discharge coefficient, with respect to the Froude number, shows a second-degree curve. The discharge coefficient decreases with increasing Froude number. The discharge coefficient increases with increasing the relative water height. Also, for the same value of relative water height the discharge coefficient increases with decreasing angle of skew side weir. For the same value of relative water height the discharge ratio increases with decreasing Froude number.

REFERENCES

1- Ackers, P., "A Theoretical Consideration of Side Weirs as Storm Water Flows", Proc. Institution of Civil Engineering, London, 6, 1957.

2- Allen, J.W., "The discharge of water over side weirs in circular pipes." Proc., Institution of Civil Engineering, London, England, 6, 1957.

3- Chow, V T.,"Open Channel Hydraulics, McGraw-Hill Book Co., Inc., New York, N.Y., 1959.

4- Coleman, G S., and Smith, D.,"The discharge capacity of side weirs", Selected Engineering paper No. 6, Inst. Of Civ. Engrgs. London, England, 1932.

5- Collinge, V.K.C , "The discharge capacity of side weirs." Proc Institution of Civil Engineers, London, England, 6, Feb. 1957.

6- De Marchi, G., "Essay on the performance of lateral weirs", L'Energia Electica, Milano, Italy, 11(11), 849-860, Nov. 1934

7- EL-Khashab, a., and smith, K. V H., "Experimental investigation of flow over side weirs." J. Hydr. Engrg., ASCE, 102(9), 1255-1268, September 1976.

8- Hager, W, H., " Lateral Outflow Over Side Weirs." Journal of Hydraulic Engineering, ASCE, Vol.113, No 4, April 1987.

9- Ranga Raju, K.G., Parasad, B., and Gupta, S.K., "Side weir in rectangular channel", J. Hydr. Div., ASCE, 105 (5), 547-554, 1979.

10- Robinson, D I., and McGhee, T.J.," Computer Modeling of side-Flow weirs." Journal of Irrigation and Drainage Engineering, ASCE, Vol. 119, No.6, November/December, 1993

11- Subramanya, K., and Awasthy, S. C., " Spatially Varied Flow Over Side Weirs." Journal of the Hydraulics Division, ASCE, Vol.98, No.HY1, Jan. 1972,pp.1-10.

12- Swamee, P. K., Pathak, S. K., and Ali, M S., " Side-Weir Analysis Using Elementary Discharge Coefficint "Journal of Irrigation and Drainage Engineering, ASCE, Vol.120, No.4, July / August, 1994.

13- Uymaz, A., and Muslu, y., " Flow over Side Weirs in Circular Channels. " Journal of Hydraulic Engineering, ASCE, Vol.111, No.1, January 1985.

NOTATION

The following symbols are used in this paper:

A = Cross-sectional area of the channel;
B = Channel width before side weir;
b = Channel width after side weir,
Cd = Discharge coefficient of side weir;
Cm = De Marci coefficient;
E = Specific energy;
F = Froude Number;
g = gravitational constant:
H_a = Height of water due to velocity of approach, ($V^2/2g$);
H_w = Height of the water, above the crest of the weir;
H_{wa}= Total height of water above weir, ($H_w + H_a$);
L = Skew side weir length;
P = Height of weir crest;
Q_C = Channel discharge after side weir;
Q = Discharge at any point in the channel;
q_w = Discharge over side weir per unit length;
Q_T = Channel discharge before side weir;
Q_W = Skew side weir discharge;
V =Channel velocity before side weir;
Y = Flow depth at a section located at x,
Y_1 =Flow depth before side weir;
θ = Angle of side weir;