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DIVIDING FLOW AT A 90^O OPEN CHANNEL JUNCTION

تقسيم السريان عند تفريعه عمودية لقناه مكشوفة

RASHWAN, I.M.H.[1], TAREK A. SAAFAN [2]

خلاصة

لتخطيط شبكات الترع والمصارف فانه غالبا ما يتم التخطيط لتلك المجارى المائية المكشوفة في خطوط متعامدة وكذلك الحال فى محطات تنقية ومعالجة المياه. ولحل مسألة تفرع مجرى مائى مكشوف الى تفريعة عمودية مع استمرار المجرى الرئيسى فاننا نستخدم معادلات الاستمرارية والطاقة وكمية الحركة. ويمكن باستخدام المعلومات المتوفرة بالمسألة وباستخدام نموذج الحل المستنتج فى هذه الدراسة استنتاج باقى المعلومات المجهولة.
ومسألة التفرع لكي تكون تامة الحل يجب معرفة التصرف وارتفاع المياه في قطاعات ثلاثة (المدخل - امتداد المجرى الرئيسى - التفريع) وعند معرفة عمق المياه والتصرف الداخل وعرض المجرى المائى يمكن إيجاد المجاهيل الأخرى.
فى هذا البحث تم إيجاد حل رياضي إعتمادا علي المعادلات الهيدروليكية الرئيسية (معادلة الإستمرارية ومعادلة الطاقة ومعادلة كمية الحركة). وإعتمادا على المعادلات الرئيسية المذكورة تم الحصول على معادلات إرتباطية بإستخدام كميات لابعدية والتي تم وضعها فى صورة منحنيات.
وتم استخدام نتائج معملية تمت فى بعض الابحاث السابقة للتحقق من دقة وصلاحية استخدام النموذج المستنتج. وقد ثبت ان النموذج المقترح متوافق الى حد كبير مع القراءات المعملية.

ABSTRACT

A theoretical model for division of flow through T-junction over a horizontal bed was obtained for subcritical steady flow through main, extension and branch channels of equal widths. The new proposed model was derived with the aid of continuity, energy and momentum equations.

For a given inflow discharge, the water depth and the width of the channels, using the present model, the downstream depth and discharge could be determined. Experimental data from previous studies were used to verify the proposed new model. The deduced model was found in good agreement with the observations.

It was found that a linear relationship has been existed between the experimental data of the inflow water depth with the branch water depth. The equation of trend line was given and it could then be used to compute the branch water depth by knowing the inflow water depth. The energy head-loss coefficient of a junction was approximated and expressed only in terms of discharge ratio.

1 - Water Engineering Department, Faculty of Engineering, Tanta University, Tanta, Egypt.
2- Assoc. Prof., Irrigation and Hydraulics Department, faculty of Engineering, Mansoura University, Mansoura, Egypt.

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INTRODUCTION

For equal widths right-angled dividing flow over horizontal bed (T-junction), Taylor (1944) studied it by analyzing experimental data and proposed a graphical solution. Grace and Priest (1958) observed the flow division for various junction angles and channel-width ratios and presented their data in graphical form using dimensionless parameters. Rajaratnam and Thiruvengadam (1962-1963) studied a dividing flow with a subcritical flow in a horizontal main channel and a supercritical flow in a sloping branch channel. Law and Reynolds (1966) concluded that for right-angled flow, the momentum and energy principles could both be applied to describe the flow in the main channel extension. Also, they declared that the flow in the branch channel could be predicted from the momentum principle when an appropriate contraction coefficient was applied to account for the presence of extensive re-circulation regions in the branch. They assumed that the ratio of the depths in the main channel upstream and downstream of the junction was assumed to be unity. Hager (1983) proposed a simplified model to evaluate loss coefficients for flow through the branch channel. Best and Reid (1984) solved the dividing flow experimentally and theoretically. Ramamurthy and Satish (1988) found that, for a short branch channel with downstream Froude number exceeding a threshold value, the branch flow exhibits un-submerged re-circulation region.

Ramamurthy et al. (1990) assumed no energy loss along the depth-averaged a stagnation dividing streamline surface to obtain an expression for the momentum transfer rate from the main channel to the branch channel. They used experimental data to validate their proposed model. Hager (1992) derived an expression for the energy loss coefficient across a division. He assumed critical flow at the maximum contracted width section and concluded that the branch discharge coefficient was simply a function of upstream Froude number and the discharge ratio. Neary and Sotiropoulos (1996) were developed and validate a numerical method for modeling 3D lateral-intake.

Chung-Chieh et al. (2002) concluded that the energy heads upstream and downstream the division in the main channel were found to be almost equal. They gave the energy-loss coefficient at the division and was expressed in terms of the discharge ratio, upstream Froude number and depth ratio.

In the present study a new model was developed to solve the dividing flow in an open channel T-junction. For dividing flow at right-angled junctions of rectangular open channels of equal widths an estimating of the discharge ratio, $R_q = Q_2/Q_1$, was obtained in terms of upstream Froude number, F_1, and depth ratio, $R_y = y_1/y_2$.

THEORETICAL ANALYSIS

The flow in the junction itself may be subcritical or supercritical, depending on the state of the extension and the branch channel. Also, the flow in the junction depends on the backwater effect of the two downstream channels below the dividing junction as well as on the dynamic condition existing at the junction. Accordingly, the channel junction with dividing flow indicated that generalization of the problem was not possible or even desirable.

When the flow in a stream is divided by two branches, the division flow between the two channels may be determined with the aid of discharge, energy and momentum equations with the following assumptions:

1. The channels are horizontal and rectangular of equal widths;
2. The flow is from channel 1 into channels 2 and 3, Figure (1);
3. Channels 1 and 3 lie in a straight line;
4. The flow is parallel to the channel walls, and the velocity is uniformly distributed immediately above and below the junction;
5. Ordinary wall friction is negligible in comparison with other forces involved;
6. Energy loss is negligible between sections 1 and 2;
7. The flow at sections AF, BF, and AB, Figure (1), are nearly uniform $Q_1/b = Q_2/b_{21} = Q_3/b_{31}$, and the momentum correction factors at these sections are close to unity.
8. For the dividing streamline BC, the stagnation point at C, and hence, the depth y at an indefinitely small section ds, varies from y_1 at B to $y = y_1\left(1 + F_1^2/2\right)$ at point C, Figure (1). This variation is assumed to follow a very simple relationship $y = y_1 + az^2$ where a is a constant and z is the distance from ds to the line BX (Ramamurthy et al. (1990)).

The variables to be evaluated are six: the depths and discharges at the three sections enclosing the junction. In the present study while the flow was subcritical, the boundary conditions were specified as the inflow discharge and depth and a third downstream condition that could be either a fixed depth or a rating curve. These boundary conditions define three of the six variables in the problem or two variables and one equation. Hence, three additional equations were required for solving the problem. Applying continuity, momentum and energy equations between upstream main channel and its extension provided the three necessary equations.

Applying continuity to the junction gives:

$$Q_1 = Q_2 + Q_3 \tag{1}$$

in which: Q_1 = the discharge in the main channel; Q_2 = the discharge downstream the junction (extension channel); and Q_3 = the discharge in the branch channel.

Applying the momentum equation in the direction of 1 to 2, the component of the hydrostatic force acting across the dividing stream surface in the direction of the main channel, extension could be estimated by the following two methods:

1.Momentum consideration for the main channel extension

The component of the hydrostatic force acting across the dividing surface in the direction of the main channel extension could be estimated by applying the momentum equation in the direction of the main channel and its extension. as follows, Figure (1):

$$F_x = \left(\frac{1}{2}\gamma b y_2^2 + \rho Q_2 V_2\right) - \left(\frac{1}{2}\gamma b_{21} y_1^2 + \rho Q_2 V_1\right) \tag{2}$$

in which: F_x = unknown hydrostatic force acting across the dividing streamline in the direction of the main channel extension; γ = specific weight of water; ρ = density of water; b = width of the main channel and its extension; b_{21} = width of the main channel passing Q_2, ($b_{21} = bR_q$), y_1 = water depth in the main channel; y_2 = depth of the water in the extension channel; V_1 = mean velocity in the main channel ; and V_2 = mean velocity in the extension channel.

$$\rho Q_2 V_1 = \frac{\gamma}{g}\frac{Q_2}{Q_1} Q_1 V_1 = \frac{\gamma}{g y_1}\frac{Q_2}{Q_1} V_1^2 b y_1^2 = \gamma b y_1^2 R_q F_1^2 \tag{3-a}$$

$$\rho Q_2 V_2 = \frac{\gamma}{g y_2} V_2^2 b y_2^2 = \gamma b y_2^2 F_2^2 \tag{3-b}$$

$$F_2^2 = \frac{V_2^2}{g y_2} = \frac{V_2^2}{g y_2}\frac{Q_1^2}{Q_1^2} = \frac{Q_2^2 V_1^2 b^2 y_1^3}{Q_1^2 g y_2 b y_2^2 y_1} = F_1^2 . R_q^2 . R_y^3 \tag{3-c}$$

in which: F_1 = Froude number in the main channel ($F_1^2 = V_1^2/gy_1$); F_2 = Froude number in the extension channel ($F_2^2 = V_2^2/gy_2$); R_q = discharge ratio ($R_q = Q_2/Q_1$); and R_y = water depth ratio ($R_y = y_1/y_2$).

Substituting Eqs. (3-a), (3-b) and (3-c) into Eq. (2) F_x can obtained as follows:

$$F_x = \left(\frac{1}{2}\gamma b y_2^2 + \gamma b y_2^2 F_1^2 . R_q^2 . R_y^3\right) - \left(\frac{1}{2}\gamma b R_q y_1^2 + \gamma b y_1^2 R_q F_1^2\right) \quad (4)$$

Putting the ratio of the hydrostatic force acting on the dividing surface to the hydrostatic force acting on the upstream section as $F_{x*} = F_x / 1/2\gamma b y_1^2$ Eq. (4) can be written in the following form:

$$F_{x*} = R_q\left[2F_1^2\left(R_q R_y - 1\right) - 1\right] + \frac{1}{R_y^2} \quad (5)$$

2.Integration of hydrostatic force acting across the dividing stream surface

The second method to get the component of the hydrostatic force acting across the dividing stream surface in the direction of the main channel, an extension may be estimated using the integration of the hydrostatic force at the dividing streamline (Ramamurthy et al. (1990)). This method can be written as follows:

$$F_x = \int \frac{1}{2}\gamma y^2 ds.\cos\varphi \quad (6)$$

in which: y = the water depth at an indefinitely small section ds, which varies from y_1 at B to $y = y_1\left(1 + F_1^2/2\right)$ at point C. This variation was assumed to follow a very simple relationship $y = y_1 + az^2$, in which a is a constant and z is the distance from ds to the line BX, and φ = the angle between the branch channel axis and the stream line.

From the eighth assumption, substituting $y = y_1 + \frac{F_1^2 y_1}{2b_{31}^2} z^2$, where b_{31} = the width of main channel breadth which passing Q_3 $(b_{31} = bQ_3/Q_1 = b(1 - R_q))$, and $dz = ds.\cos\varphi$. Then, integrating equation (6) one can obtain (Appendix B):

$$F_x = \frac{1}{2}\gamma y_1^2 b(1 - R_q)\left(1 + \frac{F_1^2}{3} + \frac{F_1^4}{20}\right) \quad (7)$$

Putting the dimensionless variable as $F_{x*} = F_x/\left(1/2\gamma b y_1^2\right)$, Eq. (7) could be reduced to the following form:

$$F_{x*} = (1 - R_q)\left(1 + \frac{F_1^2}{3} + \frac{F_1^4}{20}\right) \tag{8}$$

Then, an estimate of the dimensionless parameter F_{x*} in Eq. (8) could be obtained by using the variables F_1 and R_q.

From the two Eqs. (5) and (8) the following equation could be derived:

$$R_q\left[2F_1^2(R_q.R_y - 1) - 1\right] + \frac{1}{R_y^2} = (1 - R_q)\left(1 + \frac{F_1^2}{3} + \frac{F_1^4}{20}\right) \tag{9}$$

SPECIFIC ENERGY UPSTREAM AND DOWNSTREAM THE DIVISION AT MAIN CHANNEL AND EXTENSION

To get the relationship between upstream and downstream specific energy heads the division, previous experimental data were used. The appendix (Table A) shows the results of the previous experimental work made by Chung-Chieh et al. (2002).

The specific energy heads in streamwise direction for the main channel and extension, which can be treated as an expansion from width b_{21} to width b with discharge Q_2, are calculated as follows:

$$E_1 = y_1 + \frac{\alpha_1 Q_2^2}{2g(b_{21}y_1)^2} \tag{10}$$

and

$$E_2 = y_2 + \frac{\alpha_2 Q_2^2}{2g(by_2)^2} \tag{11}$$

in which: E_1 and E_2 are the specific energy heads before and after junction, respectively, α_1 = energy coefficient at section 1, and α_2 = energy coefficient at section 2.

It was noticed that the specific energy upstream and downstream junction were found practically equal as given by Chung-Chieh et al. 2002. Thus; $E_1 \cong E_2$ as shown in Table (1):

$$E_1 = y_1 + \frac{\alpha_1 Q_2^2}{2g(b_{21}y_1)^2} \cong E_2 = y_2 + \frac{\alpha_2 Q_2^2}{2g(by_2)^2} \tag{12}$$

From the assumptions $Q_1/b = Q_2/b_{21}$, and α_1 and α_2 are equal unity, Eq. (12) can be written as:

$$E_1 = y_1 + \frac{Q_1^2}{2g(b\,y_1)^2} \cong E_2 = y_2 + \frac{Q_2^2}{2g(by_2)^2} \qquad (13)$$

or

$$y_1\left(1+\frac{F_1^2}{2}\right) \cong y_2\left(1+\frac{F_2^2}{2}\right) \qquad (14)$$

Depth ratio (R_y)

Imposing Eq. (3-c) into Eq. (14), the following relationship could be obtained:

$$R_y^3 - \left(\frac{2}{F_1^2 R_q^2} + \frac{1}{R_q^2}\right)R_y + \left(\frac{2}{F_1^2 R_q^2}\right) = 0 \qquad (15)$$

The depth ratio, R_y can be solved using a third-degree polynomial provided that R_q and F_1 are known. If the depth ratio, R_y, and the upstream Froude number are known then Eq (15) takes the following form:

$$R_q = \sqrt{\frac{R_y\left(2+F_1^2\right)-2}{F_1^2 R_y^3}} \qquad (16)$$

The predicted values from Eq. (15) are plotted in Figure (2).

Branch channel:

The flow approaching the branch channel separates from the main channel and begins to contract. Eventually, it attains a width equals to $C_c b$ at the section of maximum contraction, as shown in Figure (1).

Contraction coefficient (C_c)

The location of the contracted section in the re-circulation region and the contraction coefficient, C_c, were practically determined. The contraction coefficient C_c was determined by Chung-Chieh et al. (2002) and he concluded that the contraction coefficient was increased linearly with the discharge in the branch channel Q_3.

Branch water depth (y_3)

Figure (3) presents the relationship between the inflow water depth, y_1, and the branch water depth, y_3. Thus, a linear trend line was plotted for this relationship between the two depths, as shown in Figure (3). The trend equation of this line is given by the following equation:

$$y_3 \cong 0.9846 y_1 + 0.0374 \tag{17}$$

Energy head-loss ($h_{L\,1\text{-}3}$)

The specific energy upstream and downstream the junction at the branch channel, sections 1 and 3, can be written as follows:

$$E_1 = E_3 + h_{L\,1\text{-}3} \tag{18}$$

$$y_1 + \frac{\alpha_1 Q_1^2}{2g(by_1)^2} = y_3 + \frac{\alpha_3 Q_3^2}{2g(by_3)^2} + h_{L1\text{-}3} \tag{19}$$

in which: E_3 = specific energy after the junction at the branch channel, $h_{L\,1\text{-}3}$= energy head-loss between sections 1 and 3, and y_3 = water depth in the branch channel.

The energy head-loss between the two sections, 1 and 3, can be written as follows:

$$h_{L1\text{-}3} = \frac{\alpha_1 Q_1^2}{2g(by_1)^2} - \frac{\alpha_3 Q_3^2}{2g(by_3)^2} = \frac{\left(\alpha_1 Q_1^2 - \alpha_3 Q_3^2 / R_{y3}^2\right)}{2g(by_1)^2} \tag{20}$$

where R_{y3} = the water depth ratio ($R_{y3} = y_3 / y_1$).

or

$$h_{L1\text{-}3} = \left(1 - \left(\alpha_3 (1 - R_q)^2 / R_{y3}\alpha_1\right)\right)\frac{\alpha_1 V_1^2}{2g} \tag{21}$$

For theoretical assumptions R_{y3}=1.0 and $\alpha_1 \cong \alpha_3 \cong 1$, and so Eq. (21) can be reduced to:

$$h_{L1\text{-}3} = R_q (2 - R_q)\frac{V_1^2}{2g} \tag{22}$$

Energy head-loss coefficient (K_e)

The energy head-loss equation can be expressed in terms of inflow velocity head and the energy head-loss coefficient as follows:

$$h_{L1\text{-}3} = K_e \frac{V_1^2}{2g} \tag{23}$$

in which: K_e ≡ head-loss coefficient.

Equating of Eq. (21) to Eq.(23), the following equation for the energy head-loss coefficient is obtained:

$$K_e = \left(1 - \frac{\alpha_3 (1 - R_q)^2}{R_{y3}\alpha_1}\right) \qquad (24)$$

For theoretical assumptions R_{y3}=1.0 and $\alpha_1 \cong \alpha_3 \cong 1$, and so Eq. (24) can be reduced to:

$$K_e = R_q (2 - R_q) \qquad (25)$$

Eq. (25) is plotted as shown in Figure (4).

Table (1): Results of the energy head losses and branch energy head-loss coefficients.

No.	R_q	R_y	R_{y3}	E_1 (cm)	E_2 (cm)	E_3 (cm)	h_{L1-2} (cm)	h_{L1-3} (cm)	h_{L1-2} %	h_{L1-3} %	K_e
1	0.875	0.925	0.998	6.648	6.611	5.352	0.037	1.297	0.557	19.504	0.991
2	0.871	0.935	0.998	5.620	5.600	4.599	0.021	1.022	0.367	18.179	0.992
3	0.833	0.905	0.983	6.028	5.946	4.615	0.083	1.414	1.369	23.450	1.026
4	0.826	0.889	0.995	5.490	5.463	4.282	0.028	1.209	0.501	22.016	0.982
5	0.692	0.958	0.985	9.631	9.602	8.805	0.028	0.825	0.294	8.568	1.057
6	0.674	0.950	0.988	9.893	9.862	9.010	0.031	0.883	0.315	8.924	1.011
7	0.613	0.939	0.981	9.244	9.201	8.364	0.044	0.880	0.472	9.524	0.995
8	0.604	0.947	0.994	8.862	8.797	8.160	0.066	0.702	0.740	7.922	0.898
9	0.503	0.960	0.990	10.893	10.833	10.294	0.060	0.599	0.553	5.497	0.903
10	0.496	0.963	0.997	10.323	10.300	9.901	0.023	0.422	0.222	4.088	0.792
11	0.411	0.950	0.990	9.860	9.846	9.392	0.014	0.468	0.147	4.748	0.780
12	0.409	0.950	0.981	10.172	10.118	9.587	0.053	0.585	0.525	5.747	0.897

The proposed model

In a typical field problem, the rating curves for the upstream channel ($Q_1 \rightarrow y_1$) or extension channel ($Q_2 \rightarrow y_2$) and the branch channel ($Q_3 \rightarrow y_3$) will be known. For subcritical flows, knowing Q_1, y_1 and F_1, the other unknown parameters y_2, Q_2 and Q_3 can be determined from Eqs. (1), (5), (8) and (15) applying the following procedures:

- Assume a trial value of y_2, which must be greater than y_1 and less than E_1, and compute the depth ratio, $R_y = y_1 / y_2$;
- Obtain the discharge ratio $R_q = Q_2 / Q_1$ by using Eq. (16), where the upstream Froude number is now known;
- Using the discharge ratio R_q, the depth ratio R_y and upstream Froude number F_1 to compute F_{r*} from Eqs. (5) and (8). If the trial value of y_2 do not give the same value of F_{r*} from the two equations, assume a new value of y_2 and repeat the procedures until the two Eqs. (5) and (8) give the same value (or with an acceptable difference);
- Get the downstream discharge from $Q_2 = R_q Q_1$ and the branch discharge Q_3 using Eq. (1).

A comparison between the predicted values of the downstream depth, y_2, and discharge, Q_2, and the corresponding experimental data (Chung-Chieh 2002) are given in Table (2).

Table (2): Comparison between the predicted values of the downstream depth, y_2, and discharge, Q_2, and the corresponding experimental data (Chung-Chieh 2002).

No.	y_2 (cm) Cal	y_2 (cm) Exp.	Discrepancy %	R_y Cal	R_q Cal	F_{r*} Eq. (5)	F_{r*} Eq. (8)	Q_2 (l/sec.) Cal	Q_2 (l/sec.) Exp.	Discrepancy %
1	5.80	5.77	0.52	0.921	0.875	0.1382	0.1474	3.43	3.43	-0.05
2	4.95	4.91	0.81	0.927	0.870	0.1421	0.1510	2.63	2.63	-0.12
3	5.30	5.14	3.11	0.877	0.829	0.2023	0.2083	2.93	2.95	-0.57
4	4.85	4.79	1.25	0.878	0.821	0.2105	0.2161	2.51	2.52	-0.59
5	9.29	9.24	0.54	0.953	0.693	0.3255	0.3251	3.52	3.51	0.15
6	9.53	9.49	0.42	0.946	0.681	0.3412	0.3398	3.66	3.62	1.08
7	8.96	8.90	0.67	0.933	0.608	0.4295	0.4207	3.08	3.10	-0.79
8	8.62	8.53	1.06	0.937	0.594	0.4426	0.4334	2.71	2.76	-1.71
9	10.74	10.66	0.75	0.953	0.504	0.5301	0.5176	2.71	2.70	0.28
10	10.20	10.17	0.29	0.960	0.501	0.5283	0.5178	2.30	2.275	1.00
11	9.77	9.75	0.21	0.948	0.409	0.6396	0.6173	1.89	1.905	-0.66
12	10.07	10.02	0.50	0.945	0.418	0.6319	0.6094	2.06	2.01	2.26

ANALYSIS AND DISCUSSION OF RESULTS

Practical application:

For a subcritical, right-angled, equal-width, open channel dividing flow over a horizontal bed, the principals of momentum , energy and continuity can be applied to predict a theoretical model for the junction flow. The new proposed model is easy to be applied to predict the flow through the junction. For a given inflow discharge, water depth and the width of the channels, using the present model, the downstream depth and discharge can be determined.

The component of the hydrostatic force acting across the dividing surface in the direction of the main channel an extension is estimated by applying the momentum equation in the direction of the main channel and its extension and by integrating the hydrostatic force at dividing streamline, Eqs. (5) and (8).

To get the a relationship between upstream and downstream specific energy heads at junction, previous experimental data (Chung-Chieh et al. 2002), were used in the present study. It was noted that the specific energy heads upstream and downstream the division were found practically equal, Eq. (16).

For subcritical flows, knowing Q_1, y_1 and F_1, the other unknown parameters: y_2 and Q_2 could be determined from Eqs. (1), (5), (8) and (15) using the present proposed model.

Data from earlier investigations (Chung-Chieh et al. 2002), are presented to validate the proposed model. Experimental data Chung-Chieh et al. (2002) were proved to be suitable than that of Ramamurthy et al. (1990) and Sridharan (1966) because no measurements of the branch water depth, y_3, were available in Ramamurthy et al. or Sridharan data. The comparison of experimental data (Chung-Chieh et al. 2002) concerning the downstream depth, y_2, and downstream discharge, Q_2, with predicted values are given in Table (2). The calculated values by using the proposed model were found in a good agreement with the observations by Chung-Chieh et al.

Branch channel:

The water depth through the branch channel, y_3, was nearly equal to the upstream water depth, y_1. Eq. (19) was presented a linear trend relationship between the two observed water depths.

Eq. (24) showed that the energy-loss coefficient, K_e, could be expressed in terms of the discharge ratio, R_q, water depth ratio, R_{y3}, and energy coefficients, α_1

and α_3. The energy-loss coefficient, K_e, could be approximately expressed only in terms of the discharge ratio, R_q, Eq. (25).

CONCLUSIONS

These analyses lead to the following major conclusions:

1. In the design of dividing flow in rectangular open channels a theoretical model was developed to relate the discharge ratio $R_q = Q_2/Q_1$ with the Froude number F_1 and the depth ratio $R_y = y_1/y_2$. The proposed model was validated by the experimental data and appeared in good agreement.
2. The specific energy heads upstream and downstream the junction were found practically equal.
3. The water depth through the branch channel, y_3, was nearly equal to the upstream water depth, y_1.
4. The energy-loss coefficient, K_e, could be approximately expressed only in terms of the discharge ratio, R_q.

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NOTATION

The following symbols are used in this paper:

A = cross-sectional area of flow;
a = constant;
b = width of the main channel and its extension;
b_{u} = width of main channel breadth which passing;
C_c = Contraction coefficient;
d_s = indefinitely small section of stream line;
E_1 = specific energy at section 1;
E_2 = specific energy at section 2;

F = Froude number;
F_{x*} = dimensionless force;
g = gravitational acceleration;
H = total energy;
$h_{L_{1-2}}$ = energy head-loss between sections 1 and 2;
$h_{L_{1-3}}$ = energy head-loss between sections 1 and 3;
K_e = head-loss coefficient;
Q_1 = discharge in the main channel;
Q_2 = discharge in the extension channel;
Q_3 = discharge in the branch channel;
R_q = discharge ratio, (Q_2/Q_1);
R_y = depth ratio, (y_1/y_2);
R_{y3} = depth ratio, (y_3/y_1);
S_o = slope of the channel bed;
S_f = friction slope;
V = mean flow velocity;
V_1 = mean velocity in the main channel ;
V_2 = mean velocity in the extension channel;
X = one dimensional space coordinate defined as positive in the direction of flow;
y = water depth at gradually varied flow;
y_1 = depth of the water in the main channel;
y_2 = depth of the water in the extension channel;
z = distance from dividing surface to axis;
Z = height of the channel bed of the section above datum;
α = energy coefficient;
γ = specific weight of water;
θ = channel bed slope;
ρ = density of water; and
φ = the angle between the branch channel axis and stream line.

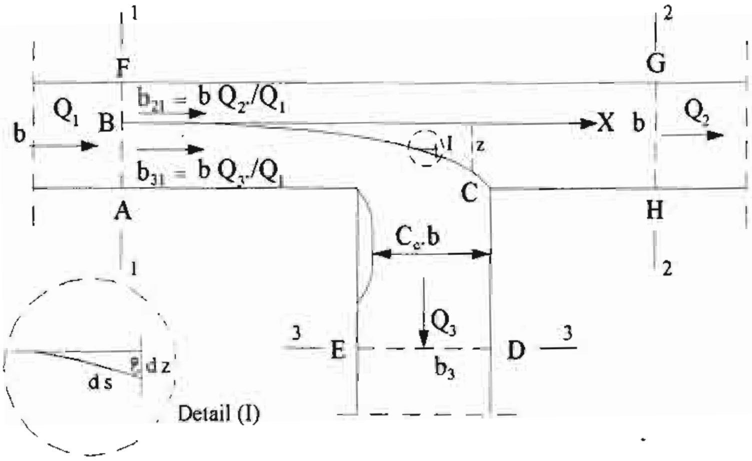

Fig. (1) Dividing flow in open channel T-Junction equal widthes.

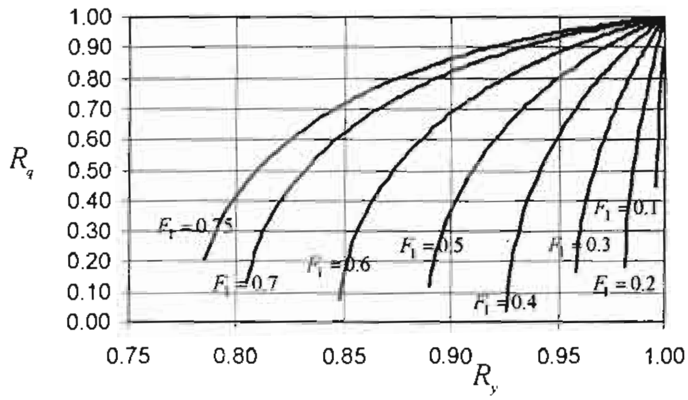

Fig. (2) Relationship between discharge ratio R_q and depth ratio R_y for different values of upstream Froude number F_1.

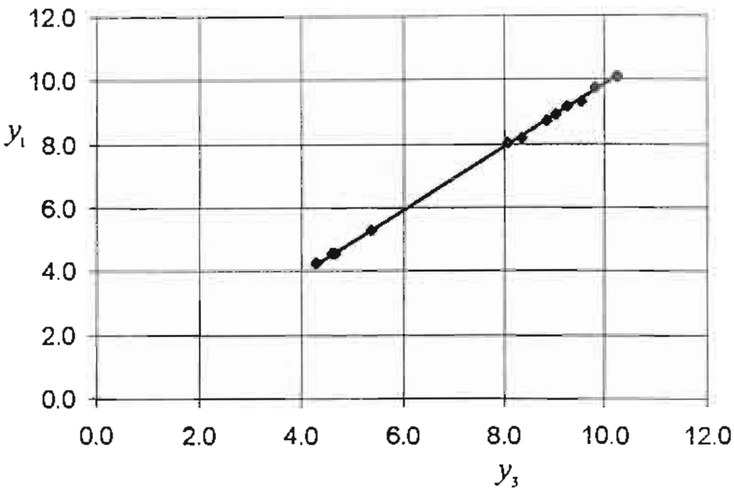

Fig. (3) Relationship between upstream water depth y_1 and branch water depth y_3.

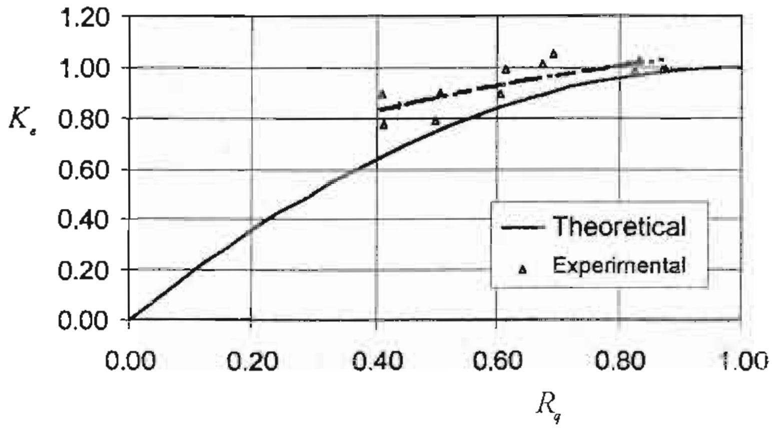

Fig. (4) Relationship between Discharge Ratio R_q and branch head-loss coefficient K_e.

Appendix A

Table (A) Experimental data prepared by (Chung-Chieh Hsu et al. 2002).

No.	Q_1 (l/sec.)	Q_2 (l/sec.)	Q_3 (l/sec.)	y_1 (cm)	y_2 (cm)	y_3 (cm)	F_1	F_3	F_2
1	3.92	3.43	0.49	5.34	5.77	5.33	0.7	0.54	0.09
2	3.02	2.63	0.39	4.59	4.91	4.58	0.67	0.53	0.09
3	3.54	2.95	0.59	4.65	5.14	4.57	0.77	0.56	0.14
4	3.05	2.52	0.53	4.26	4.79	4.24	0.76	0.53	0.14
5	5.07	3.51	1.56	8.85	9.24	8.72	0.42	0.28	0.14
6	5.37	3.62	1.75	9.02	9.49	8.91	0.44	0.28	0.15
7	5.06	3.10	1.96	8.36	8.90	8.2	0.46	0.26	0.20
8	4.57	2.76	1.81	8.08	8.53	8.03	0.44	0.25	0.18
9	5.37	2.70	2.67	10.23	10.66	10.13	0.36	0.18	0.18
10	4.59	2.275	2.315	9.79	10.17	9.76	0.33	0.16	0.17
11	4.63	1.905	2.725	9.26	9.75	9.17	0.36	0.14	0.22
12	4.92	2.01	2.91	9.52	10.02	9.34	0.37	0.14	0.23

Appendix B

$$F_x = \int \frac{1}{2}\gamma y^2 ds.\cos\varphi$$

$$F_x = \int_0^{b_{31}} \frac{1}{2}\gamma\left(y_1 + \frac{F_1^2 y_1}{2b_{31}^2} z^2\right)^2 dz$$

$$F_x = \int_0^{b_{31}} \frac{1}{2}\gamma\left(y_1^2 + \frac{F_1^2 y_1^2}{b_{31}^2} z^2 + \frac{F_1^4 y_1^2}{4b_{31}^4} z^4\right)dz$$

$$F_x = \frac{1}{2}\gamma y_1^2 \int_0^{b_{31}}\left(1 + \frac{F_1^2}{b_{31}^2} z^2 + \frac{F_1^4}{4b_{31}^4} z^4\right)dz$$

$$F_x = \frac{1}{2}\gamma y_1^2 \left(z + \frac{F_1^2}{3b_{31}^2} z^3 + \frac{F_1^4}{20b_{31}^4} z^5\right)^{b31}$$

$$F_x = \frac{1}{2}\gamma y_1^2 \left(b_{31} + \frac{F_1^2 b_{31}}{3} + \frac{F_1^4 b_{31}}{20}\right)$$

$$F_x = \frac{1}{2}\gamma y_1^2 b_{31}\left(1 + \frac{F_1^2}{3} + \frac{F_1^4}{20}\right)$$

$$F_x = \frac{1}{2}\gamma y_1^2 b(1 - R_q)\left(1 + \frac{F_1^2}{3} + \frac{F_1^4}{20}\right)$$