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Water and Dams Branch

Measuring of discharge in open channel using long throated flumes

Annual project submitted to the department of Building and Construction Engineering of the University of Technology in partial fulfillment of requirements for the degree of B.Sc

In building and construction engineering

Submitted by

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Supervised by

[illegible]

2011 **1432**

بسم الله الرحمن الرحيم

رب اشرح لي
صدري*و يسر لي
امري *واحلل عقدة
من لساني*يفقه قولي

صدق الله العظيم

سورة طه الأية(25-28)

بطاقة الشكر

في مثل هذه اللحظات يتوقف اليراع ليفكر قبل أن يخط الحروف ليجمعها في كلمات ... تتبعثر الأحرف وعبثاً أن يحاول تجميعها في سطور

سطوراً كثيرة تمر في الخيال ولا يبقى لنا في نهاية المطاف إلا قليلاً من الذكريات وصور تجمعنا برفاق كانوا إلى جانبنا

....

فواجب علينا شكرهم ووداعهم ونحن نخطو خطوتنا الأولى في غمار الحياة

ونخص بالجزيل الشكر والعرفان إلى كل من أشعل شمعة في دروب عملنا و

وإلى من وقف على المنابر وأعطى من حصيلة فكره لينير دربنا

إلى الأستاذ الدكتور جعفر صادق المعتوق

الإهداء

إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي الرحمة ونور العالمين..

سيدنا محمد صلى الله عليه وسلم

إلى من به أكبر وعليه أعتمد .. إلى شمعة متقدة تنير ظلمة حياتي..

إلى من بوجوده أكتسب قوة ومحبة لا حدود لها..

إلى من عرفت معه معنى الحياة

زوجي الغالي

الى من عشت في كنف حبها و حنانها

الى من اودعتني بين كنوز جناتها

إلى بسمة الحياة وسر الوجود

الى من وضعت املها في

والدتي الحبيبة

إلى من حصد الأشواك عن دربي ليمهد لي طريق العلم

إلى من جرع الكأس فارغاً ليسقيني قطرة حب

إلى من كلّت أنامله ليقدم لنا لحظة سعادة

إلى القلب الكبير

والدي العزيز

إلى القلوب الطاهرة الرقيقة والنفوس البريئة إلى رياحين حياتي

إخوتي

الآن تفتح الأشرعة وترفع المرساة لتنطلق السفينة في عرض بحر واسع مظلم هو بحر الحياة

وفي هذه الظلمة لا يضيء إلا قنديل الذكريات ذكريات الأخوة البعيدة إلى الذين

أحببتهم وأحبوني

أصدقائي

CONTAINTS

Chapter One

Introduction

1.1 General

The flow measuring structures at a throat section the streamlines run parallel at least over a short distance are called long throated flumes. Hence the hydrostatic pressure distribution can be assumed, the flume comprises a throat of which the invert is truly horizontal in the direction of flow. The crest level of the throat should always higher than the dead water level in the channel i.e. .The downstream water level when there is no flow. The throat is prismatic. The cross section could be arbitrary. However, there should be no or nearly horizontal planes occur in the throat above crest level as it may cause the discontinuity in the head – discharge relationship. The most common flumes are rectangular, V-shaped trapezoidal, truncated V, parabolic or circular throat sections. See fig (1.1) and fig (1.2)

1.2 Objectives

1. Measuring of discharge in open channel with help of program WinFlume
2. To improve the critical depth
3. Get fixed head

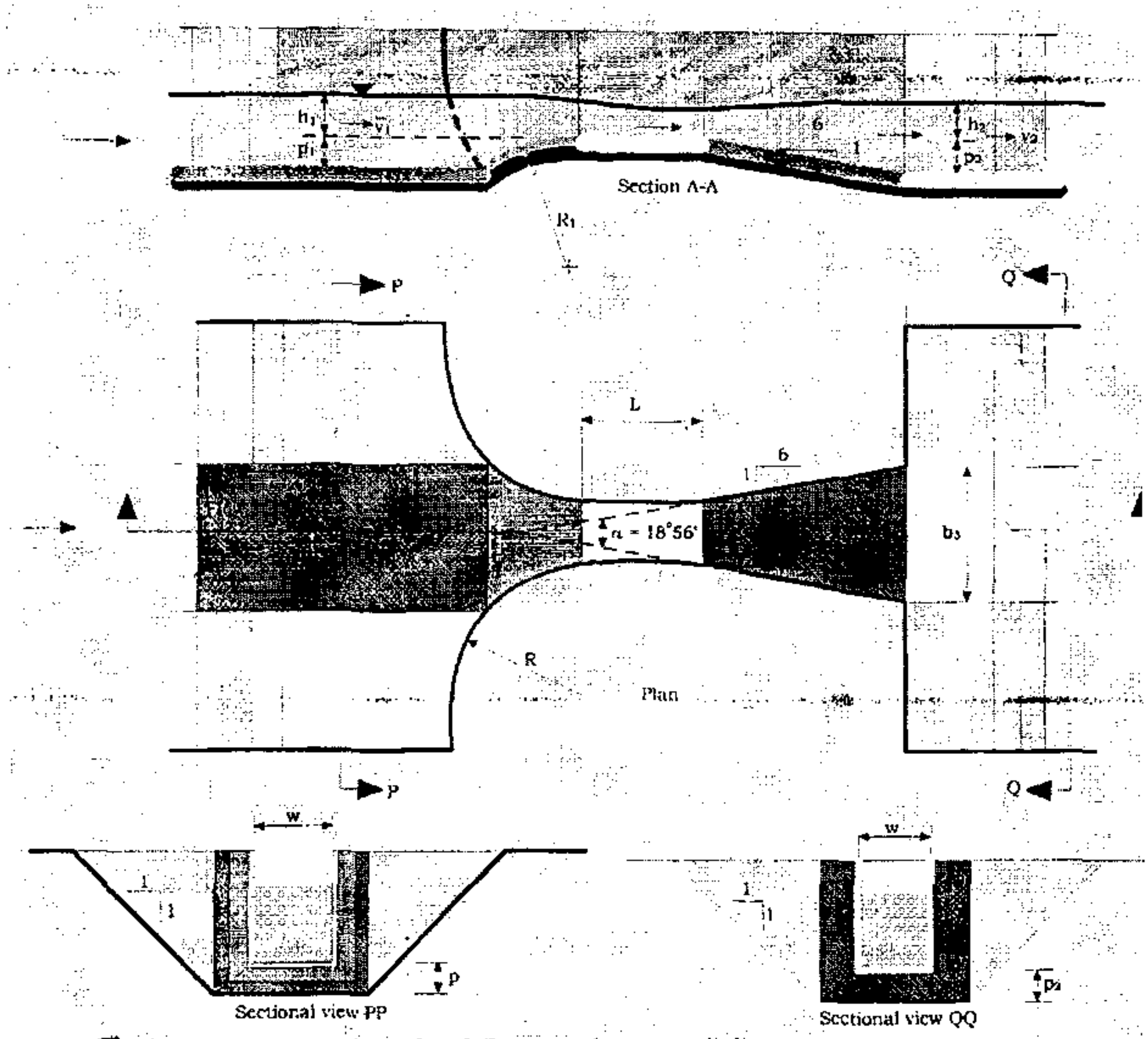


Fig (1.1) Typical Long throated flumes

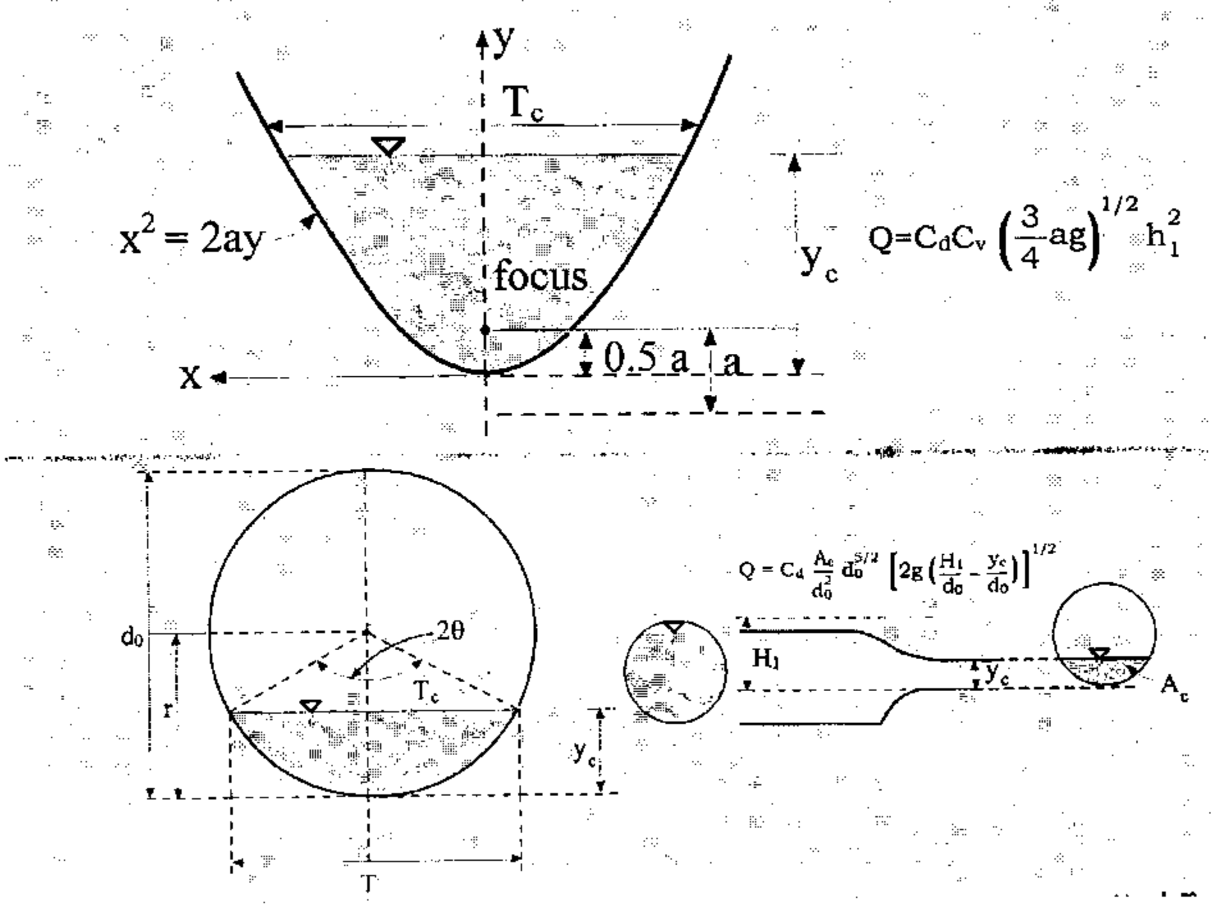


Fig (1.2) Head discharge relationship for long-throated flumes with different types

Chapter Two

Hydraulic Performance

2.1 Head –Discharge Equations

The head –discharge equations based on ideal flow , such as those shown in table (2.1), must be corrected for energy losses , velocity distributions, and streamline curvature by the introduction of a discharge coefficient(C_d). Furthermore , in an open channel it is not possible to measure energy head H_1 directly, and it is therefore common practice to relate the flow rate to the upstream sill-referenced water level (or piezometric head) by using the velocity coefficient, C_v, Define in equation (2.1)

$$C_{v}= \left[\frac{H_1}{h_1}\right]^{u} \text{..................(2.1)}$$

Where:

Cv: The approach velocity coefficient

u: Head-discharge exponent

H: Energy head

h_1: Up stream sill-referenced water level(or piezometric head)

The resulting head-discharge equation for rectangular channel is

$$Q = C_d C_v \frac{2}{3}\left(\frac{2}{3}g\right)^{1/2} b_c {h_1}^{3/2} \text{........(2.2)}$$

Q: Discharge

C_d: Discharge coefficient

C_v: Velocity coefficient

b_c: Bottom width of the control section

The general idea is to measure upstream water level, experimentally determine a value for C_d, estimate C_v, and compute the discharge . this approach has been applied to variety of shapes, as shown in figure(2.1)(Bos 1977a, Bos 1978 and Clemmens et al. 1984b). Tables(2.2) and(2.3)are used to calculate the critical depth y_c, for trapezoidal and circular controls , respectively Tables(2.3) and(2.4) provide useful values for computing head-discharge relationships for circular controls and controls made from placing a bottom sill in the circular section (Clemmens et al. 1984a) .Use these relationships requires determination of C_d and in most cases C_v.

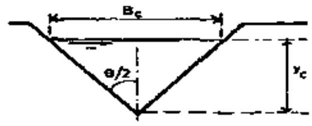
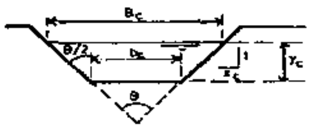
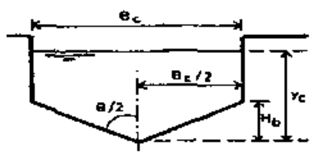
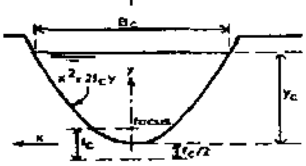
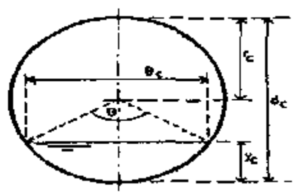
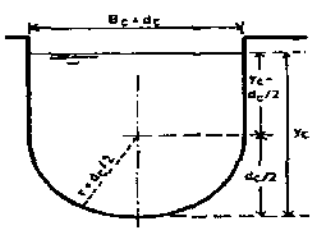
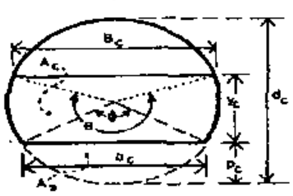
SHAPE OF CONTROL SECTION	HEAD–DISCHARGE EQ. TO BE USED	HOW TO FIND THE y_c - VALUE
	$Q = C_d C_v \frac{2}{3} (\frac{2}{3} g)^{1/2} b_c h_1^{3/2}$	$y_c = \frac{2}{3} H_1$
	$Q = C_d C_v \frac{16}{25} (\frac{2}{5} g)^{1/2} \tan\frac{\theta}{2} h_1^{5/2}$	$y_c = \frac{4}{5} H_1$
	$Q = C_d [b_c y_c + z_c y_c^2][2g(H_1 - y_c)]^{1/2}$	Use Table 6.2
	If $H_1 < 1.25 H_b$ $Q = C_d C_v \frac{16}{25} (\frac{2}{5} g)^{1/2} \tan\frac{\theta}{2} h_1^{5/2}$ If $H_1 > 1.25 H_b$ $Q = C_d C_v \frac{2}{3} (\frac{2}{3} g)^{1/2} B_c (h_1 - \frac{1}{2} H_b)^{3/2}$	$y_c = \frac{4}{5} H_1$ $y_c = \frac{2}{3} H_1 + \frac{1}{6} H_b$
	$Q = C_d C_v (\frac{3}{4} f_c g)^{1/2} h_1^2$	$y_c = \frac{3}{4} H_1$
	$Q = C_d d_c^{5/2} \sqrt{g} [f(\theta)]$ Use Table 6.3 to find $f(\theta)$	Use Table 6.3
	If $H_1 \leq 0.70 d_c$ $Q = C_d d_c^{5/2} \sqrt{g} [f(\theta)]$ Use Table 6.3 to find $f(\theta)$ If $H_1 \geq 0.70 d_c$ $Q = C_d C_v 2 d_c (2g)^{1/2} (\frac{1}{3} h_1 - 0.0358 d_c)^{3/2}$	Use Table 6.3 $y_c = \frac{1}{2} H_1 + 0.162 d_c$
	$Q = C_d d_c^{5/2} \sqrt{g} [f(\phi, \theta)]$ Use Table 6.4 to find $f(\phi, \theta)$	y_c is variable

Fig (2-1) Head-discharge relationships for long-throated flumes

Table (2.1) : Critical depth and discharge relationships for simple prismatic shapes

Shape	*Exponent*	*Critical Depth*	*Discharge*
Rectangular	$u = 3/2$	$y_c = \frac{2}{3} H_c$	$Q = \left(\frac{2}{3}\right)^{3/2} (g)^{1/2} b_c H_c^{3/2}$
Parabolic	$u = 4/2$	$y_c = \frac{3}{4} H_c$	$Q = \left(\frac{3}{4} f_c g\right)^{1/2} H_c^{2}$
Triangular	$u = 5/2$	$y_c = \frac{4}{5} H_c$	$Q = \frac{16}{25}\left(\frac{2}{5} g\right)^{1/2} z_c H_c^{5/2}$

Table 2.2 Values of the ratio y_c/H_1 as a function of z_c and H_1/b_c for trapezoidal control section.

$\frac{H_1}{b_c}$	Side slope of channel, ratio of horizontal to vertical (z_c)									
	Vertical	0.25:1	0.50:1	0.75:1	1:1	1.5:1	2:1	2.5:1	3:1	4:1
0.00	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667
0.01	0.667	0.667	0.667	0.668	0.668	0.669	0.670	0.670	0.671	0.672
0.02	0.667	0.667	0.668	0.669	0.670	0.671	0.672	0.674	0.675	0.678
0.03	0.667	0.668	0.669	0.670	0.671	0.673	0.675	0.677	0.679	0.683
0.04	0.667	0.668	0.670	0.671	0.672	0.675	0.677	0.680	0.683	0.687
0.05	0.667	0.668	0.670	0.672	0.674	0.677	0.680	0.683	0.686	0.692
0.06	0.667	0.669	0.671	0.673	0.675	0.679	0.683	0.686	0.690	0.696
0.07	0.667	0.669	0.672	0.674	0.676	0.681	0.685	0.689	0.693	0.699
0.08	0.667	0.670	0.672	0.675	0.678	0.683	0.687	0.692	0.696	0.703
0.09	0.667	0.670	0.673	0.676	0.679	0.684	0.690	0.695	0.698	0.706
0.10	0.667	0.670	0.674	0.677	0.680	0.686	0.692	0.697	0.701	0.709
0.12	0.667	0.671	0.675	0.679	0.684	0.690	0.692	0.701	0.706	0.715
0.14	0.667	0.672	0.676	0.681	0.686	0.693	0.699	0.705	0.711	0.720
0.16	0.667	0.672	0.678	0.683	0.678	0.696	0.703	0.709	0.715	0.725
0.18	0.667	0.673	0.679	0.684	0.690	0.698	0.706	0.713	0.719	0.729
0.20	0.667	0.674	0.680	0.686	0.692	0.701	0.709	0.717	0.723	0.733
0.22	0.667	0.674	0.681	0.688	0.694	0.704	0.712	0.720	0.726	0.736
0.24	0.667	0.675	0.683	0.689	0.696	0.706	0.715	0.723	0.729	0.739
0.26	0.667	0.676	0.684	0.691	0.698	0.709	0.718	0.725	0.732	0.742
0.28	0.667	0.676	0.685	0.693	0.699	0.711	0.720	0.728	0.734	0.744
0.30	0.667	0.677	0.686	0.694	0.701	0.713	0.723	0.730	0.737	0.747
0.32	0.667	0.678	0.687	0.696	0.703	0.715	0.725	0.733	0.739	0.749
0.34	0.667	0.678	0.689	0.697	0.705	0.717	0.727	0.735	0.741	0.751
0.36	0.667	0.679	0.690	0.699	0.706	0.719	0.729	0.737	0.743	0.752
0.38	0.667	0.680	0.691	0.700	0.708	0.721	0.731	0.738	0.745	0.754
0.40	0.667	0.680	0.692	0.701	0.709	0.723	0.733	0.740	0.747	0.756
0.42	0.667	0.681	0.693	0.703	0.711	0.725	0.734	0.742	0.748	0.757
0.44	0.667	0.681	0.694	0.704	0.712	0.727	0.736	0.744	0.750	0.759
0.46	0.667	0.682	0.695	0.705	0.714	0.728	0.737	0.745	0.751	0.760
0.48	0.667	0.683	0.696	0.706	0.715	0.729	0.739	0.747	0.752	0.761
0.5	0.667	0.683	0.697	0.708	0.717	0.730	0.740	0.748	0.754	0.762
0.6	0.667	0.686	0.701	0.713	0.723	0.737	0.747	0.754	0.759	0.767
0.7	0.667	0.688	0.706	0.718	0.728	0.742	0.752	0.758	0.764	0.771
0.8	0.667	0.692	0.709	0.723	0.732	0.746	0.756	0.762	0.767	0.774
0.9	0.667	0.694	0.713	0.727	0.737	0.750	0.759	0.766	0.770	0.776
1.0	0.667	0.697	0.717	0.730	0.740	0.754	0.762	0.768	0.773	0.778
1.2	0.667	0.701	0.723	0.737	0.747	0.759	0.767	0.772	0.776	0.782
1.4	0.667	0.706	0.729	0.742	0.752	0.764	0.771	0.776	0.779	0.784
1.6	0.667	0.709	0.733	0.747	0.756	0.767	0.774	0.778	0.781	0.786
1.8	0.667	0.713	0.737	0.750	0.759	0.770	0.776	0.781	0.783	0.787
2	0.667	0.717	0.740	0.754	0.762	0.773	0.778	0.782	0.785	0.788
3	0.667	0.730	0.753	0.766	0.773	0.781	0.785	0.787	0.790	0.792
4	0.667	0.740	0.762	0.773	0.778	0.785	0.788	0.790	0.792	0.794
5	0.667	0.748	0.768	0.777	0.782	0.788	0.791	0.792	0.794	0.795
10	0.667	0.768	0.782	0.788	0.791	0.794	0.795	0.796	0.797	0.798
∞		0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800

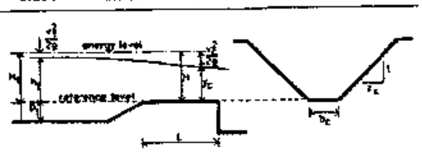


Table 2.3 Ratios for determining the discharge, Q, of broad-crested weirs and long-throated flumes with circular control sections.

$\frac{y_c}{d_c}$	$\frac{v_c^2}{2gd_c}$	$\frac{H_1}{d_c}$	$\frac{A_c}{d_c^2}$	$\frac{y_c}{H_1}$	$f(\theta)$	$\frac{y_c}{d_c}$	$\frac{v_c^2}{2gd_c}$	$\frac{H_1}{d_c}$	$\frac{A_c}{d_c^2}$	$\frac{y_c}{H_1}$	$f(\theta)$
0.01	0.0033	0.0133	0.0013	0.752	0.0001	0.51	0.2014	0.7114	0.4027	0.717	0.2556
0.02	0.0067	0.0267	0.0037	0.749	0.0004	0.52	0.2065	0.7265	0.4127	0.716	0.2652
0.03	0.0101	0.0401	0.0069	0.749	0.0010	0.53	0.2117	0.7417	0.4227	0.715	0.2750
0.04	0.0134	0.0534	0.0105	0.749	0.0017	0.54	0.2170	0.7570	0.4327	0.713	0.2851
0.05	0.0168	0.0668	0.0147	0.748	0.0027	0.55	0.2224	0.7724	0.4426	0.712	0.2952
0.06	0.0203	0.0803	0.0192	0.748	0.0039	0.56	0.2279	0.7879	0.4526	0.711	0.3056
0.07	0.0237	0.0937	0.0242	0.747	0.0053	0.57	0.2335	0.8035	0.4625	0.709	0.3161
0.08	0.0271	0.1071	0.0294	0.747	0.0068	0.58	0.2393	0.8193	0.4724	0.708	0.3268
0.09	0.0306	0.1206	0.0350	0.746	0.0087	0.59	0.2451	0.8351	0.4822	0.707	0.3376
0.10	0.0341	0.1341	0.0409	0.746	0.0107	0.60	0.2511	0.8511	0.4920	0.705	0.3487
0.11	0.0376	0.1476	0.0470	0.745	0.0129	0.61	0.2572	0.8672	0.5018	0.703	0.3599
0.12	0.0411	0.1611	0.0534	0.745	0.0153	0.62	0.2635	0.8835	0.5115	0.702	0.3713
0.13	0.0446	0.1746	0.0600	0.745	0.0179	0.63	0.2699	0.8999	0.5212	0.700	0.3829
0.14	0.0482	0.1882	0.0688	0.744	0.0214	0.64	0.2765	0.9165	0.5308	0.698	0.3947
0.15	0.0517	0.2017	0.0739	0.744	0.0238	0.65	0.2833	0.9333	0.5404	0.696	0.4068
0.16	0.0553	0.2153	0.0811	0.743	0.0270	0.66	0.2902	0.9502	0.5499	0.695	0.4189
0.17	0.0589	0.2289	0.0885	0.743	0.0304	0.67	0.2974	0.9674	0.5594	0.693	0.4314
0.18	0.0626	0.2426	0.0961	0.742	0.0340	0.68	0.3048	0.9848	0.5687	0.691	0.4440
0.19	0.0662	0.2562	0.1039	0.742	0.0378	0.69	0.3125	1.0025	0.5780	0.688	0.4569
0.20	0.0699	0.2699	0.1118	0.741	0.0418	0.70	0.3204	1.0204	0.5872	0.686	0.4701
0.21	0.0736	0.2836	0.1199	0.740	0.0460	0.71	0.3286	1.0386	0.5964	0.684	0.4835
0.22	0.0773	0.2973	0.1281	0.740	0.0504	0.72	0.3371	1.0571	0.6054	0.681	0.4971
0.23	0.0811	0.3111	0.1365	0.739	0.0550	0.73	0.3459	1.0759	0.6143	0.679	0.5109
0.24	0.0848	0.3248	0.1449	0.739	0.0597	0.74	0.3552	1.0952	0.6231	0.676	0.5252
0.25	0.0887	0.3387	0.1535	0.738	0.0647	0.75	0.3648	1.1148	0.6319	0.673	0.5397
0.26	0.0925	0.3525	0.1623	0.738	0.0698	0.76	0.3749	1.1349	0.6405	0.670	0.5546
0.27	0.0963	0.3663	0.1711	0.737	0.0751	0.77	0.3855	1.1555	0.6489	0.666	0.5698
0.28	0.1002	0.3802	0.1800	0.736	0.0806	0.78	0.3967	1.1767	0.6573	0.663	0.5855
0.29	0.1042	0.3942	0.1890	0.736	0.0863	0.79	0.4085	1.1985	0.6655	0.659	0.6015
0.30	0.1081	0.4081	0.1982	0.735	0.0922	0.80	0.4210	1.2210	0.6735	0.655	0.6180
0.31	0.1121	0.4221	0.2074	0.734	0.0982	0.81	0.4343	1.2443	0.6815	0.651	0.6351
0.32	0.1161	0.4361	0.2167	0.734	0.1044	0.82	0.4485	1.2685	0.6893	0.646	0.6528
0.33	0.1202	0.4502	0.2260	0.733	0.1108	0.83	0.4638	1.2938	0.6969	0.641	0.6712
0.34	0.1243	0.4643	0.2355	0.732	0.1174	0.84	0.4803	1.3203	0.7043	0.636	0.6903
0.35	0.1284	0.4784	0.2450	0.732	0.1289	0.85	0.4982	1.3482	0.7115	0.630	0.7102
0.36	0.1326	0.4926	0.2546	0.731	0.1311	0.86	0.5177	1.3777	0.7186	0.624	0.7312
0.37	0.1368	0.5068	0.2642	0.730	0.1382	0.87	0.5392	1.4092	0.7254	0.617	0.7533
0.38	0.1411	0.5211	0.2739	0.729	0.1455	0.88	0.5632	1.4432	0.7320	0.610	0.7769
0.39	0.1454	0.5354	0.2836	0.728	0.1529	0.89	0.5900	1.4800	0.7384	0.601	0.8021
0.40	0.1497	0.5497	0.2934	0.728	0.1605	0.90	0.6204	1.5204	0.7445	0.592	0.8293
0.41	0.1541	0.5641	0.3032	0.727	0.1683	0.91	0.6555	1.5655	0.7504	0.581	0.8592
0.42	0.1586	0.5786	0.3130	0.726	0.1763	0.92	0.6966	1.6166	0.7560	0.569	0.8923
0.43	0.1631	0.5931	0.3229	0.725	0.1844	0.93	0.7459	1.6759	0.7612	0.555	0.9297
0.44	0.1676	0.6076	0.3328	0.724	0.1927	0.94	0.8065	1.7465	0.7662	0.538	0.9731
0.45	0.1723	0.6223	0.3428	0.723	0.2012	0.95	0.8841	1.8341	0.7707	0.518	1.0248
0.46	0.1769	0.6369	0.3527	0.722	0.2098						
0.47	0.1817	0.6517	0.3627	0.721	0.2186						
0.48	0.1865	0.6665	0.3727	0.720	0.2276						
0.49	0.1914	0.6814	0.3827	0.719	0.2368						
0.50	0.1964	0.6964	0.3927	0.718	0.2461						

Note: $f(\theta) = (A_c/d_c^2)\{2(H_1/d_c - y_c/d_c)\}^{1/2}$

$= (\theta - \sin\theta)^{1.5}/\{8[8\sin(\theta/2)]^{1/2}\}$

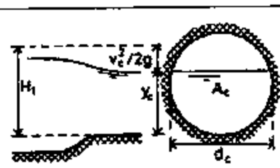
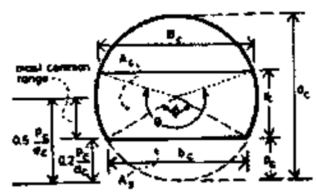


Table 2.4 Ratios for determining the discharge, Q, of broad-crested weirs in circular pipes.[a]

$\frac{p_c - H_1}{d_c}$	values of $f(\phi,\theta) = \frac{(\theta - \phi + \sin\phi - \sin\theta)^{1.5}}{8(8\sin\frac{1}{2}\theta)^{0.5}}$ for values of p_c/d_c 0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
0.16	0.0004							
0.17	0.0011							
0.18	0.0021							
0.19	0.0032							
0.20	0.0045							
0.21	0.0060	0.0004						
0.22	0.0076	0.0012						
0.23	0.0094	0.0023						
0.24	0.0113	0.0036						
0.25	0.0133	0.0050						
0.26	0.0155	0.0066	0.0005					
0.27	0.0177	0.0084	0.0013					
0.28	0.0201	0.0103	0.0025					
0.29	0.0226	0.0124	0.0038					
0.30	0.0252	0.0145	0.0054					
0.31	0.0280	0.0169	0.0071	0.0005				
0.32	0.0308	0.0193	0.0090	0.0014				
0.33	0.0337	0.0219	0.0110	0.0026				
0.34	0.0368	0.0245	0.0132	0.0040				
0.35	0.0399	0.0273	0.0155	0.0057				
0.36	0.0432	0.0302	0.0179	0.0075	0.0005			
0.37	0.0465	0.0332	0.0205	0.0094	0.0015			
0.38	0.0500	0.0363	0.0232	0.0115	0.0027			
0.39	0.0535	0.0396	0.0260	0.0138	0.0042			
0.40	0.0571	0.0429	0.0289	0.0162	0.0059			
0.41	0.0609	0.0463	0.0320	0.0187	0.0077	0.0005		
0.42	0.0647	0.0498	0.0351	0.0214	0.0097	0.0015		
0.43	0.0686	0.0534	0.0383	0.0242	0.0119	0.0028		
0.44	0.0726	0.0571	0.0417	0.0271	0.0143	0.0043		
0.45	0.0767	0.0609	0.0451	0.0301	0.0167	0.0060		
0.46	0.0809	0.0648	0.0487	0.0332	0.0193	0.0079	0.0005	
0.47	0.0851	0.0688	0.0523	0.0365	0.0220	0.0100	0.0015	
0.48	0.0895	0.0729	0.0561	0.0398	0.0249	0.0122	0.0028	
0.49	0.0939	0.0770	0.0599	0.0432	0.0279	0.0145	0.0043	
0.50	0.0984	0.0813	0.0638	0.0468	0.0309	0.0170	0.0061	
0.51	0.1030	0.0856	0.0678	0.0504	0.0341	0.0197	0.0080	0.0005
0.52	0.1076	0.0900	0.0719	0.0541	0.0374	0.0224	0.0101	0.0015
0.53	0.1124	0.0945	0.0761	0.0579	0.0408	0.0253	0.0123	0.0028
0.54	0.1172	0.0990	0.0803	0.0618	0.0443	0.0283	0.0147	0.0044
0.55	0.1221	0.1037	0.0847	0.0658	0.0479	0.0314	0.0172	0.0061
0.56	0.1270	0.1084	0.0891	0.0699	0.0515	0.0346	0.0198	0.0080
0.57	0.1320	0.1132	0.0936	0.0741	0.0553	0.0379	0.0226	0.0101
0.58	0.1372	0.1180	0.0981	0.0783	0.0592	0.0413	0.0255	0.0123
0.59	0.1423	0.1230	0.1028	0.0826	0.0631	0.0448	0.0285	0.0147
0.60	0.1476	0.1280	0.1075	0.0870	0.0671	0.0484	0.0316	0.0172
0.62[b]		0.1382	0.1172	0.0960	0.0754	0.0559	0.0381	0.0225
0.64		0.1486	0.1271	0.1053	0.0840	0.0637	0.0449	0.0283
0.66		0.1593	0.1373	0.1149	0.0929	0.0718	0.0522	0.0346
0.68		0.1703	0.1477	0.1247	0.1020	0.0802	0.0597	0.0412
0.70		0.1815	0.1584	0.1348	0.1114	0.0888	0.0676	0.0481
0.72		0.1929	0.1692	0.1451	0.1211	0.0978	0.0757	0.0554
0.74		0.2045	0.1804	0.1556	0.1310	0.1070	0.0841	0.0629
0.76		0.2163	0.1917	0.1663	0.1411	0.1164	0.0928	0.0707
0.78		0.2283	0.2031	0.1773	0.1514	0.1260	0.1016	0.0788
0.80		0.2405	0.2148	0.1884	0.1618	0.1355	0.1107	0.0870
0.82		0.2528	0.2267	0.1997	0.1725	0.1458	0.1200	0.0955
0.84		0.2653	0.2386	0.2111	0.1833	0.1559	0.1294	0.1047
0.86		0.2780	0.2508	0.2227	0.1943	0.1662	0.1390	0.1130
0.88		0.2907	0.2630	0.2344	0.2054	0.1767	0.1487	0.1220
0.90		0.3036	0.2754	0.2462	0.2166	0.1872	0.1586	0.1311
0.92		0.3166	0.2879	0.2581	0.2279	0.1979	0.1686	0.1404
0.94		0.3297	0.3005	0.2701	0.2394	0.2087		
0.96		0.3428	0.3131	0.2823	0.2509			
0.98		0.3561	0.3259	0.2944				
1.00		0.3694	0.3387					



[a] $C_d = 1.0$; $\alpha_c = 1.0$; $H_1 = H_c$

[b] Change in increment

2.2 Effects of H_1/L on the value of the discharge coefficient, C_d

The discharge coefficient corrects for such phenomena as the energy loss between the ganging and control sections ,the non-uniformity of the velocity distribution ,and the streamline curvature in these two sections .These phenomena are closely related to the value of the ratio ($H_1\backslash L$),let us compare the figures(2.2A& B), In the upper figure, the head is small with respect to the length ,L, of the sill. The thin layer of water above the sill very close to the rough boundary, and as a result, energy lost through friction is a relatively large part of H_1. In figure(2.2B), the energy loss due to friction is a smaller percentage of H_1. To correct for this relative difference in friction losses, the C_d value of the weir of figure(2.2A) with a ratio($H_1\backslash L$=0.1) must be lower than that of figure (2.2B) having an ($H_1\backslash L$) ratio of (0.33).

Comparison of figures (2.2B& C) illustrates why there is also significant difference in their C_d values. Both weirs flow under the same head h_1 and have equal values of y_c. Because of the difference in ($H_1\backslash L$) ratios, however, the pressure distribution at the control section of figure (2.2B) is hydrostatic , As shown in figure (2.3) while ,because of streamline curvature, figure(2.2C) has a modified pressure distribution similar to that of figure (2.4) . Because of the related difference in velocity distribution , the weir flowing with an (H_1/L) ratio of (1.0) has a much higher C_d value the weir in figure (2.2B), for which (H_1/L =0.33)

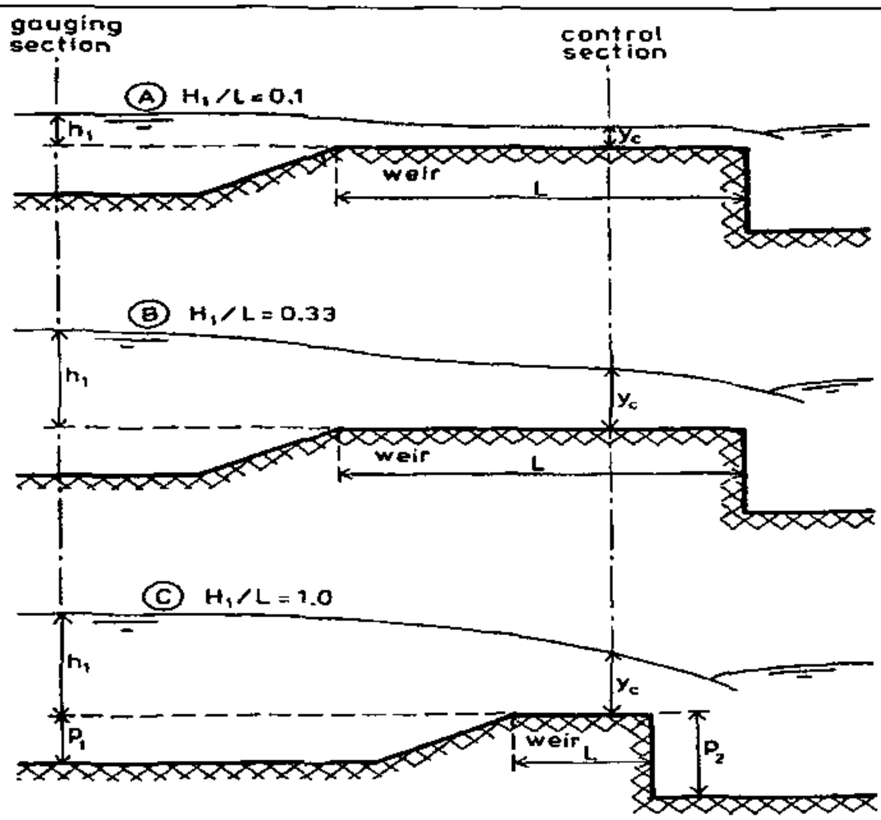


Fig (2-2) Water surface profiles over weir crests

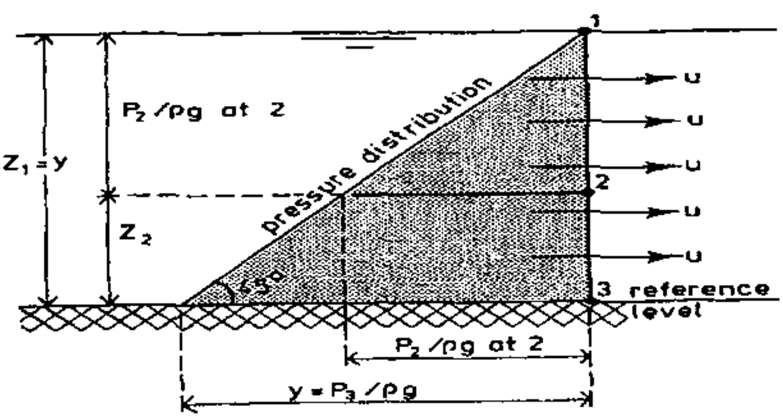


Fig (2-3) Hydrostatic pressure distribution perpendicular to straight and parallel streamline

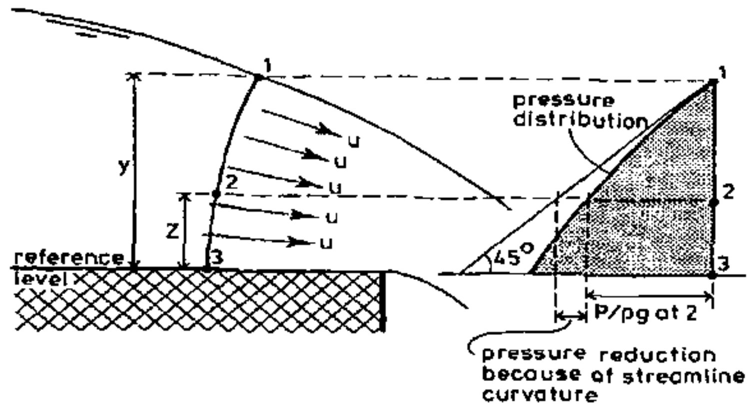


Fig (2-4) Influence of streamline curvature on pressure distribution

2.3 values and accuracy of discharge coefficient C_d

Values of the discharge coefficient, C_d, are shown in figure (2.5) as a function of (H_1/L).the range of application for this figure is

$$0.1 \leq H_1/L \leq 1.0 \text{ ....(2.3)}$$

Where:

L: throat length

H_1: Upstream head

The most important reasons for these limits are that for values $H_1/L < 0.1$, minor changes in the boundary roughness of the weir still cause an increasingly large variation of the C_d value ;for values of ($H_1/L > 1.0$), the stream line curvature and non-hydrostatic pressure distribution at the end of the throat exert an increasing

influence that extends back the control section. this makes the discharge coefficient sensitive to the slope of the downstream transition and other factors that affect the stream line curvature at the control section. One such factor is a high tail water level so as a result at values of ($H_1/L > 1.0$) the allowable tail water level is reduced, and the required head loss is increased.

Near both the upper and lower (H_1/L) the error in empirical C_d value is $X_c \approx \pm 5\%$(95% confidence level from laboratory and field data Bos 1989).

Between these limits, the error is slightly lower and can estimated from the equation

$$X_c = \pm\left(3\left|\frac{H_1}{L} - 0.55\right|^{1.5} + 4\right)\% \text{ ....(2.4)}$$

Figure (2.2) shows the control section at a constant distance of L/3 from the end of the weir crest. In the realty however , flow will become critical at a variable location for high H_1/L ratios , it is upstream of the shown location ;for high (H_1/L) ratios, it is slightly downstream, additionally, if the weir crest or flume throat is not horizontal in the direction of flow, the average location of the control section will differ dramatically from that shown in figure (2.2), A downward sloping crest or causes the control section to move to the upstream end of crest in both cases the control section is in an area with stream line curvature , and this produces a higher C_d value . A slope of 2 degrees may cause a positive error in C_d of up to 5% (bos 1989). Because it is difficult to correct for longer slopes, we recommended leveling the crest or throat rather than correcting C_d for these slopes. Anything that causes the control section to move further downstream (e.g., high *H1/L* ratio or an upward sloping throat) will place the control section in a region of increasing streamline curvature and makes C_d more

sensitive to changes in tail water level that affect this streamline curvature. This can reduce the modular limit dramatically, so that the structure requires significantly more head loss to operate in the modular flow range. For example, an upward slope of 2 degrees in the throat section causes the modular limit to drop from about 0.70 to 0.30 (Bos 1989).

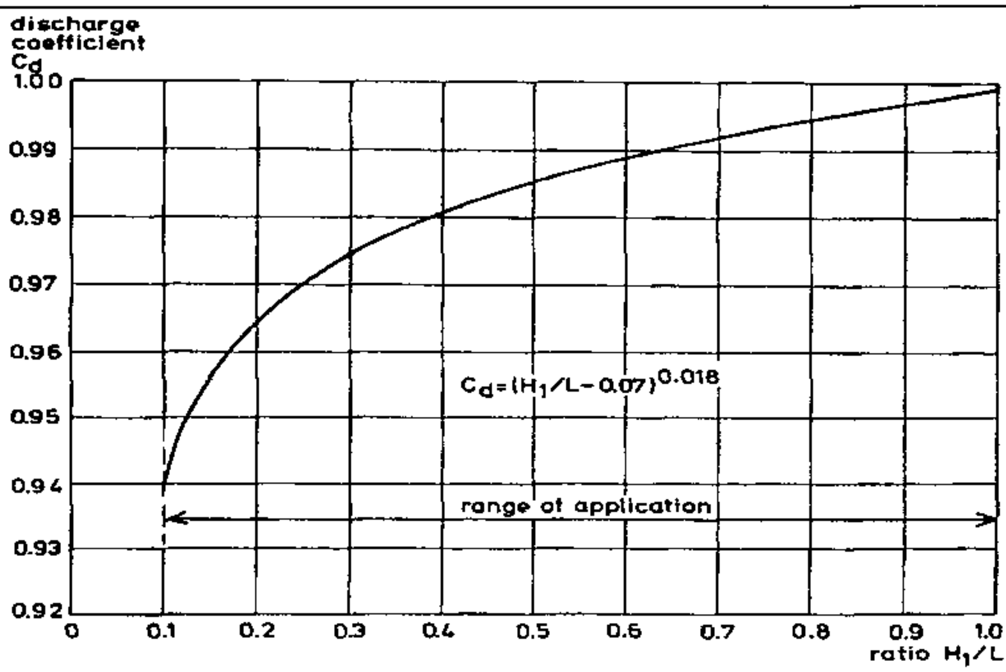


Fig (2-5) C_d as a function of H_1/L

2.4 Values of the approach velocity coefficient, C_v

The head-discharge equations were developed in terms of energy head, assuming $H_c = H$, but the upstream water level h_1, is much easier to measure. If one measures h_1 and uses the head discharge equation for H_1, the velocity head, $(\alpha_1\ v^2{}_1\ /2g)$, is being neglected. The approach velocity coefficient, $C_v = (H_1/h_1)u$, corrects for this difference, the magnitude of which can be seen in

Figure (2.6).

Because the discharge is mainly determined by the area of flow at the control section (Equation 2.4) and the related approach velocity is determined by the area of flow at the gaging station, it was found to be convenient to correlate C_v to the area ratio $(a_1)^{0.5}A^*/A_1$, (Bos 1989). In this ratio, A^* is the imaginary projected area of flow at the contro*l were equal to h_1 see figure (2.7). Values of C, as a function of the area ratio ($\alpha_1^{0.5}$ A^*/A) are shown in Figure (2.6) for various control shapes. Because of the use of A^* in the area ratio, the C_v value is almost the same for all control shapes.*

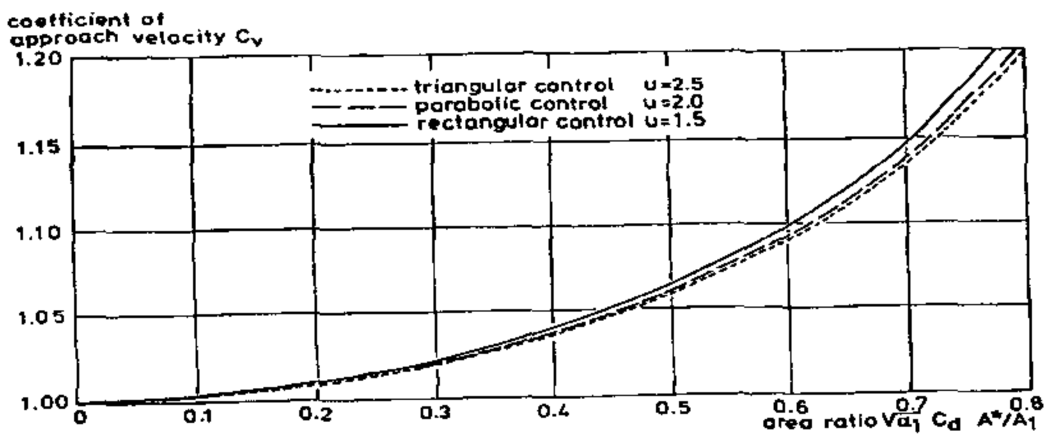


Fig (2-6) C_v as a function of ratio $\sqrt{\alpha_1}\ C_d\ A^*/A_1$

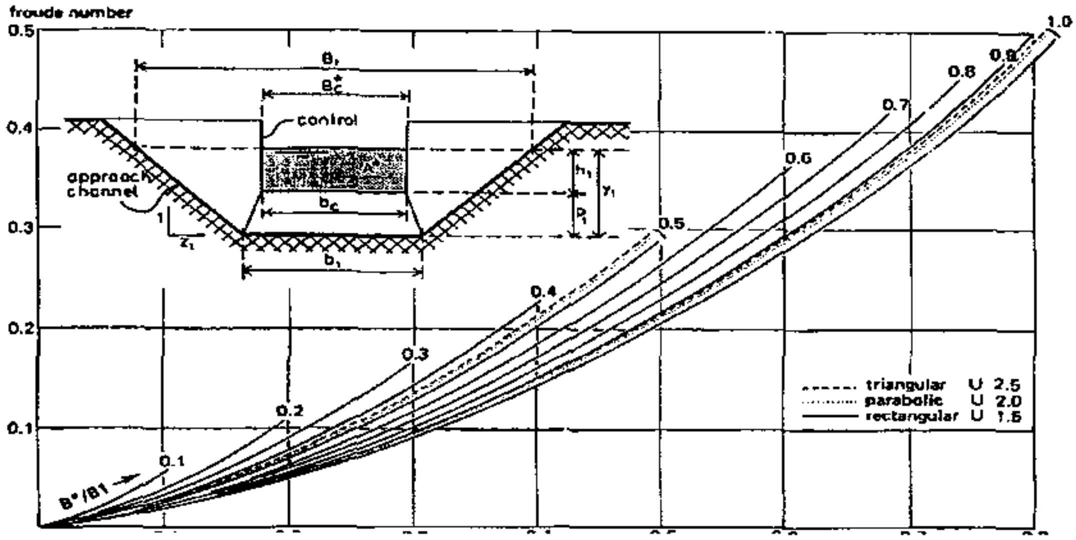


Fig (2-7) Relationship between the ratios A^*/A_1 and $B^*/B_1$and Froude number,Fr_1 with section over gaging station and view of control

2.5 Calculating head-discharge relationship based on experimentation

2.5.1 Computing discharge when head is known

When only the upstream sill-referenced head is known, determination of discharge is an iterative process, even when using C_d and C_v, although convergence is rapid (and often ignored). Start by assuming that C_d and C_v, are both unity and compute the discharge with the appropriate equation from Figure (2.1). With this discharge, compute the velocity head and add it to h_l, giving the energy head H_l (from Equation 2.5 with a_l = *1.0)*.

Compute the ratio H_l/L and read the value of C_d from Figure (2.5). Compute the ratio $(\alpha_1)^{0.5} C_d A^*/A$ and read the value of C_v from Figure (2.6). Next, recomputed the discharge with the new values for C_d and C_v. Repeat this process until the discharge converges. The procedure converges rapidly since C_d and C_v change very little with small changes in discharge. Because C_v is weakly dependent on the head-discharge exponent, *it,* it is necessary to assume a value for *u* based on the throat section shape. For odd shapes, the procedure should be repeated at several heads so that a more refined value for *u* can be determined. This should have a negligible effect on the result, since the u-value has only a small influence on Cv.

$$H_l = h_l + \frac{\alpha_1 v_1^2}{2g} = h_l + \frac{\alpha_1 Q^2}{2gA_1^2} \quad \text{.......................(2.5)}$$

Where:

H_l: Energy head

h_l: piezometric head

α: Value vary between(1.03 & 1.10)

Q: Discharge

V: Velocity

A: The cross-section area

2.5.2 Computing head when discharge is known

When discharge is known, the head-discharge equations based on experimentation can only be used to determine head by an iterative procedure. The above procedure is repeated by adjusting the head until the calculated discharge matches the known discharge. The procedure would start with a guess for h_l. The critical-flow equations could be used to determine the total energy head, from which an initial estimate for h_l could be made.

2.6 Adjustments to rating tables with C_v

Rating tables are often given for a particular throat cross-section and a particular approach cross-section, for example a rectangular throat and a rectangular approach, both with the same width, or a trapezoidal flume made by adding a bottom contraction in a trapezoidal channel. However, there may be situations when site conditions call for use of an approach channel section other than those assumed in the development of the rating tables. For example, a trapezoidal (or rough-form earthen) approach to a rectangular weir, or a nonstandard approach bottom or water level for a movable rectangular weir. In most cases, these alterations can be accommodated through adjustments in C_v. Tables R.3 and R.4, Appendix 4, give values for Q versus h_1 for rectangular-throated flumes, based on the relationship expressed by Equation (2.2), but with C_d and C_v computed from theory. For a given weir width and h_l value, only C_d and C_v can change. It can be assumed that C_d does not change with minor changes in the approach channel velocity head since H_l/L changes very little. Thus we need only evaluate C_v to adjust the rating table values. The new discharge for a given value of h_l can be found from

$$Q_{new} = Q_{rate} \frac{C_{v\,new}}{C_{v\,rate}} \qquad (2.6)$$

Where :

Q_{rate} : Value obtained from the printed rating table

$C_{v\,rate}$: Velocity coefficient for the approach section assumed in developing the rating table

$C_{v\,new}$: Velocity coefficient for the actual or design approach section.

Values of C_v can be obtained for each value of h_l from Figure (2.6) or Table (2.5).

Chapter Three

Head Loss over Structures

3.1 Maintaining critical flow

Maintaining critical flow in the throat requires that the energy head downstream from the structure be somewhat less than the energy head in the critical section for any given discharge. When critical flow occurs, the structure is operating as a flow measurement module, hence the term modular flow. The energy head downstream from the structure is controlled by the channel conditions and structures downstream. Therefore, the flume must be designed so that the energy head in the critical section (and the approach channel) are high enough above these levels to ensure modular flow. This certainly will occur if the downstream energy level, H_2 , see Figure (3.1), is less than the critical depth, y_c at the control section. In such a case, the available head loss $(H_1 - H_2)$ exceeds $(H_1 - y_c)$ and there is no need to transform the kinetic energy at the control section ($v_c^2/2g$) into potential energy downstream from the transition (h_2). In other words, there is no need for a gradual transition between the throat and the downstream channel , see Figure(3.2).

If the head loss over the structure is limited to such an extent that the downstream water level, h_2, becomes higher than the y_c level, a gradual transition can be added to regain potential energy. The amount of potential energy that can be regained depends mainly on the degree of expansion of the transition and on the ratio of cross-sectional flow areas at the

control section, A_c, and at the section where h_2 is determined, A_2. The amount of potential energy that can be regained will define the limiting value of h_2, and the related H_2 value, that permit critical flow to occur in the control section. These limiting values must be determined whenever the available head is less than$(H_1 - y_c)$. The modular limit is the highest ratio between downstream and upstream energy head referenced to the flume sill or crests, H_2/H, at which the flow is still modular (i.e., where the upstream head-discharge relation is not affected by downstream conditions).

Determining the energy loss across the structure is needed to determine whether or not flow is modular. This energy loss can be divided into three parts:

(a) *The losses between the upstream head measurement section (gaging station) and the control section in the throat, mainly due to friction;*

(b) *The losses due to friction between the control section and the section where* h_2 *is measured; and*

(c) *The losses due to incomplete conversion of kinetic energy into potential energy over the downstream transition (i.e., the expansion loss).*

The losses described in (a) affect the rating of the structure since they change the relation between h_1 and Q. The losses described in (b) and (c) affect the modular limit of the structure.

The head-discharge relationship is determined experimentally by using a discharge coefficient , C_d then the energy losses can he estimated from (Bos 1976 and Bos and Reining 1981)

$$\Delta H_1 = H_1 - Hc \cong H_1(1-C_d^{1/u}) \quad (3.1)$$

Where:

ΔH_1: Upstream head loss

H_1: Upstream energy head

H_c: Energy head at the control section

C_d: Discharge coefficient

u: Head-discharge exponent

Equation (3.1) gives a good estimate of the energy losses upstream from the control section.

The frictional energy losses downstream from the Bulimic throat are relatively small Compared with the turbulent energy losses. Thus ,some rough approximations are sufficiency. The friction losses can he estimated width sunken by boundary-layer drag methods. Just as for the approach channel, a constant drag coefficient 0.00235can be used. The head loss downstream Awn the Flumes throats computed With Equation (3.2). No information is available for estimating the velocity distribution coefficients. α_2, and since it also has little effect compared with the turbulent energy losses, it is assumed equal ion unity. (Alternately, the energy loss could be estimated with the Manning equation, but this is unnecessary considering the small energy loss when compared to the expansion loss). Equations (3.2) is applied to the reach containing the diverging transition of the bottom and side walls, and to the canal reach from the end of the transition to the section at which h_2 is measured. Since h_2 is not

actually measured at most sites. The appropriate location for h_2 is the point at which all energy recovery has taken place. This section is estimated in the Win Flume program to have a length $L_e = 10\ (P_2 + L/2) - L_d$, where L is the length of the throat section, p_2 is the sill height relative to the downstream channel invert, and L_d is the length of the diverging transition , see Figure(3.1).

The total energy loss due to friction over the downstream part of the structure is

$$\Delta H_f = \Delta H_d + \Delta H_e \quad \text{..............................(3.2)}$$

Where:

ΔH_f: Friction loss downstream from the structure

ΔH_d: Friction loss over the downstream transition

ΔH_e: Friction loss in the tail water channel section

The energy loss for the downstream expansion (diverging transition) can be computed from

$$\Delta H_k = \left(\xi \frac{v_c^2 - v_2^2}{2g}\right) \quad \text{................................(3.3)}$$

Where:

ΔH_k : Energy loss due to the rapid expansion

V_c: Velocity at the control section

ξ: Expansion energy loss coefficient that can be obtained from (adapted from Bos and Reinink 1981)

$$\xi = \frac{log_{10}\left[114.59 \arctan\left(\frac{1}{m}\right)\right] - 0.165}{1.742} \qquad (3.4)$$

Where:

$\log_{10}$: The base 10 logarithm, arctan is the inverse tangent in radians,

m: The expansion ratio of the downstream diverging transition, see Figure(3.3).

For a flume with only a bottom contraction (e.g., the broad-crested weir), the expansion ratio is straightforward. It is simply the length of the transition divided by the downstream sill height, p_2. For flumes with a side contraction or a combination of a side and a bottom contraction, the proper value of the expansion ratio is less obvious. In general, the expansion of the flume bottom has a greater effect on the energy loss and recovery than the side contraction, because it affects the full width of the flow. Thus, for flumes with a sizable bottom contraction, the expansion ratio of the bottom should be used in head-loss calculations. When the contraction is primarily from the side, the expansion ratio for the sidewalk should be used. Obviously, in some cases, both play a role, and there is no definite way to determine which to use. The Win Flume program uses only one expansion ratio (entered on the bottom profile form as the diverging transition slope) and assumes it applies equally to the bottom and side transitions. Observed data indicate that the values of ξ from Equation (3.4) are conservative and can be used for most structures. For a sudden expansion, the value of ξ is 1.2.

The total energy loss downstream from the throat can now be calculated by adding the friction losses (Equation3.2) and expansion losses (Equation 3.3), which yields

$$\Delta H_2 = \Delta H_d + \Delta H_e + \Delta H_k = \Delta H_f + \Delta H_k \quad \text{....................(3.5)}$$

$$\Delta H_1 = \Delta H_a + \Delta H_b + \Delta H \quad \text{..(3.6)}$$

Where:

ΔH_2: Downstream head loss

ΔH_f: Friction loss downstream from the structure

ΔH_d: Friction loss over the downstream transition

ΔH_e: Friction loss in the tail water channel section

ΔH_k : Energy loss due to the rapid expansion

And the ΔH_a , ΔH_b,& ΔH_L correspond to the head losses in the approach channel , converging, and throat

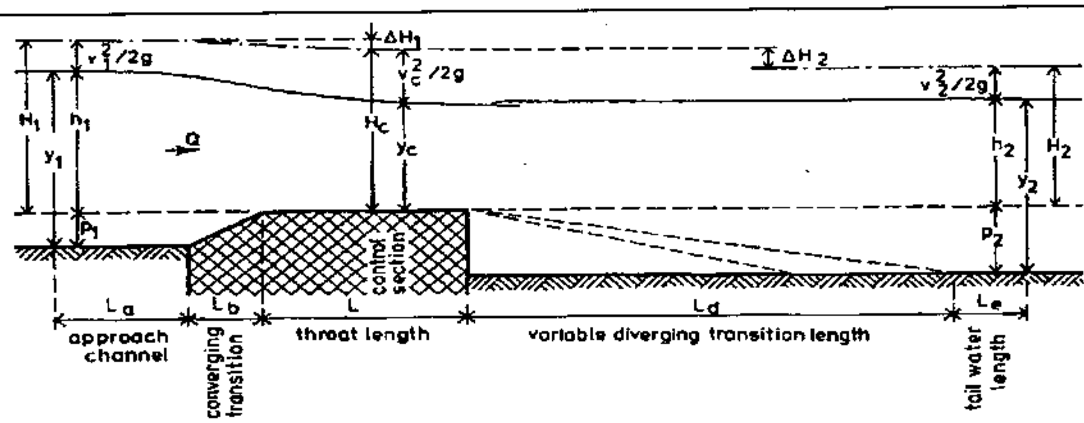


Fig (3-1) Illustration of terminology related to flume head losses

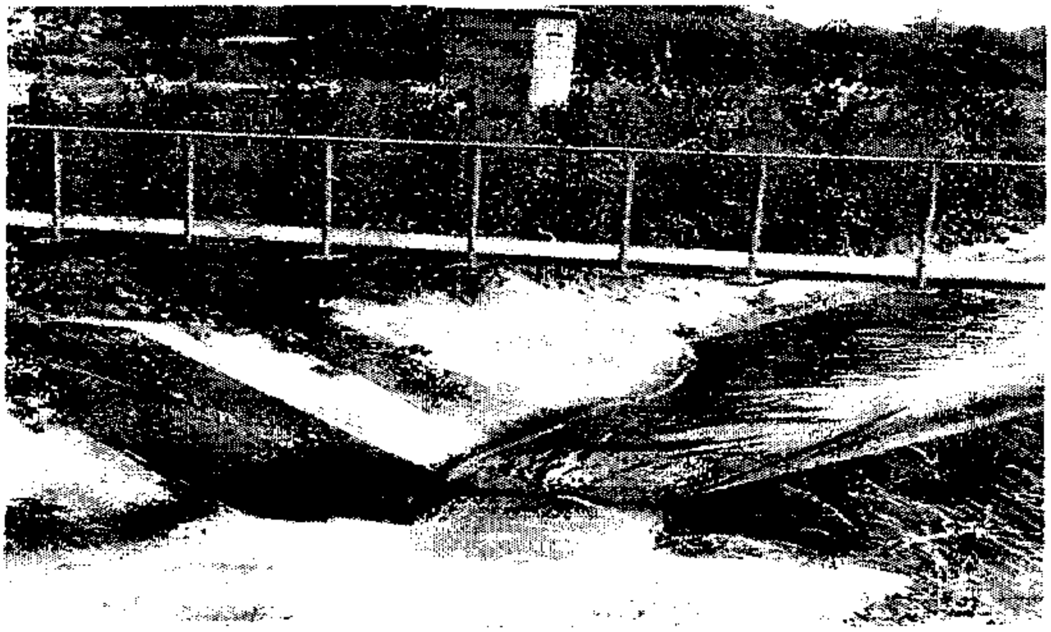


Fig (3-2) If no kinetic energy needs to be recovered, a sudden downstream expansion is adequate (the Netherlands)

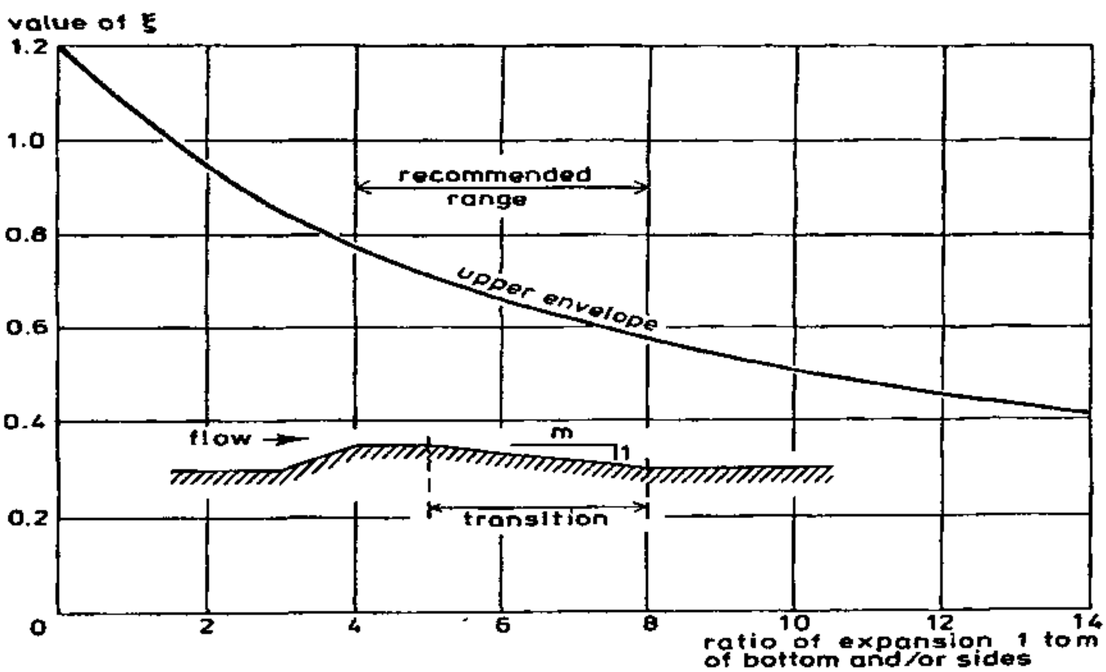


Fig (3-3): ξ as a function of expansion ratio of downstream transition

3.2 Determining the modular limit (allowable tail water level)

The flume designer would usually like to find the maximum tail water level and energy head, H_2, for which modular flow exists (Figure 3.4). These are found by combining Equations (3.6) and (3.5) to compute the minimum amount of energy loss required through the structure. The modular limit is the ratio of the associated downstream and upstream energy heads at this minimum energy loss condition.

$$H_2 = H_c - \Delta H_2$$

$$= (H_1 - \Delta H_1) - (\Delta H_f + \Delta H_k)$$

$$= H_1 - \Delta H_a - \Delta H_b - \Delta H_l - \Delta H_d - \Delta H_e - \Delta H_k$$

$$ml = \frac{H_2}{H_1} \qquad (3.7)$$

We can also use Equation (3.1) to a obtain a more general expression for the modular limit of any long-throated flume or broad-crested weir:

$$H_2 = (H_1 - \Delta H_1) - (\Delta H_f + \Delta H_K)$$

$$= H_1 - H_1(1 - C_d^{1/u}) - \Delta H_f - \Delta H_k$$

$$ML = \frac{H_2}{H_1} = C_d^{\frac{1}{u}} - \frac{\Delta H_f}{H_1} - \xi \frac{v_c^2 - v_2^2}{2gH_1} \qquad (3.8)$$

That part of Equation (3.8) that expresses the sum of the energy losses due to friction becomes a large portion of the total energy loss for very gradual expansion ratios .This is mainly because the relatively high flow velocities in the downstream transition arch maintained over a greater length. Long , but very gradual. Downstream transitions thus have a favorable energy conversion (low ξ value) but lose some energy due to friction (high ΔH_f-value). As a result, Very gradual transitions (more

than10:1) lose more energy than more rapid but shorter transitions. Because the construction cost of a very gradual transition is also higher than that of a shorter one, we advise that the ratio of expansion be no greater than about 6:1 Rather sudden expansion ratios such as 1:1 or 2:1 are not very effective for energy conversion because the high velocity jet heaving the throat cannot change direction suddenly to follow the boundaries of the transition. In the flow separation zones that result, eddies are formed that convert kinetic energy into heat and noise. Therefore, we do not recommend the use of the expansion ratios 1:1, 2: 1, or 3: 1. if the length downstream from the throat is insufficient to accommodate a fully developed gradual transition, we recommend truncating the transition to the desired length rather than using a more sudden expansion ratio (see figure 3.5). Truncating the transition to half its full length has a negligible effect on the modular limit. The truncation should not be rounded since that would guide the water into the channel bottom, causing additional energy losses and possible erosion. The total energy losses are maximum if a weir or flume has a sudden expansion ($\Delta H_f = 0$, and $\xi = 1.2$) and the discharge is into stagnant water ($v_2 = 0$). The energy loss can be estimated as (with $C_d = 1.0$ for convenience)

$$\Delta H_{max} = 1.2\frac{v_c^2}{2g} \qquad \text{(3.9)}$$

For a rectangular control section $v_c^2/2g = H_1/3$; hence $\Delta H_{max} = 0.40H_1$. Data for other control shapes are given in Table (1.3). The value of the modular limit increases rapidly with increasing tail water velocity and the addition of a diverging transition (decreasing ξ value). To obtain a conservative design of the structures, the modular limit should be assumed to be less than 0.90.

Table 3.1' Head-loss requirement under most unfavorable conditions.[a]

Shape of control section	*Power u of h_1*	*y_c/H_c*	*Minimum modular limit H_2/H_1*	*ΔH_{max}*
Rectangle	1.5	0.67	0.60	$0.40H_1$
Average trapezoid or parabola	2.0	0.75	0.70	$0.30H_1$
Triangle	2.5	0.80	0.76	$0.24H_1$

[a] $\xi = 1.2$ and $v_2 = 0$.

3.3 Computational procedure for estimating the modular limit

Once the head-discharge relationship for the flume is known, for a given head-discharge (h_1, *Q)* pair the following are also known: the energy head at the control section, H_c ; the velocity at the control section, v_c; and the upstream head loss, ΔH_1. Equation (3.4) is used to compute the expansion-loss coefficient, ξ, based on the expansion ratio, *m*. An estimate of the downstream water level and velocity are needed to estimate the downstream energy losses, ΔH_f and $H\Delta_k$. A reasonable starting point is $h_2 = y_c$ Next, compute the downstream water depth, $y_2 = h_2 + p_2$, and Velocity, v_2, based on h_2, *Q,* and the downstream cross-section, where p_2 is the downstream sill height.

The downstream distances to consider in determining head loss can be estimated from

$$L_d = p_2 m$$

$$L_e = 10(p_2 + L/2) - L_d \qquad (3.10)$$

Where:

L: Length of the throat section

p_2: Sill height relative to the downstream channel invert

L_d : Length of the diverging transition

m: The expansion ratio

Equation (3.10) provides sufficient length to get away from the downstream turbulence. Then the downstream friction losses can be computed from

$$\Delta H_e = \frac{0.00235 L_e v_2^2}{2gR_2}$$

$$\Delta H_e = \frac{0.00235 L_d}{4g}\left[\frac{v_c^2}{R_c} + \frac{v_2^2}{R_2}\right] \qquad (3.11)$$

Where:

ΔH_e: Friction loss in the tail water channel section

L_d : Length of the diverging transition

R : The hydraulic radius (area divided by wetted perimeter).

Now H_2 can be computed from(Equations 3.2 through 3.7). This value will likely be different from the value of H_2 implied by our initial guess of h_2. The next guess for the downstream water level can be found from

$$y_{2,new} = y_{2,guess}\left[\frac{H_{2,new} + P_2}{H_{2,guess} + P_2}\right] \qquad (3.12)$$

Where the subscript *guess* refers to the trial value and new refers to the new value computed from the energy calculations (Equations 3.2 through 3.7). A new value of h_2 is computed based on $y_{2,new}$ and the process is repeated until H_2 converge

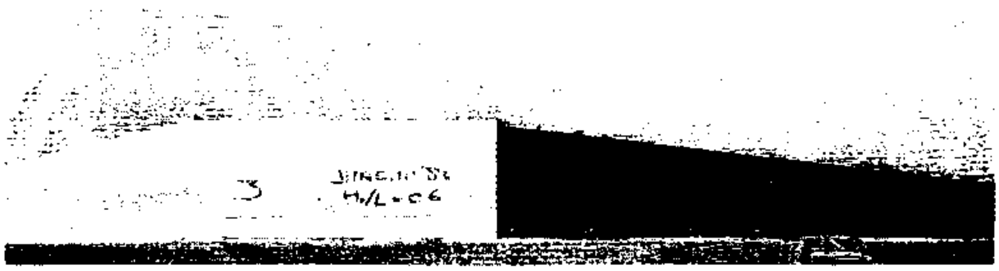


Fig (3-4) Research on submergence of a flume

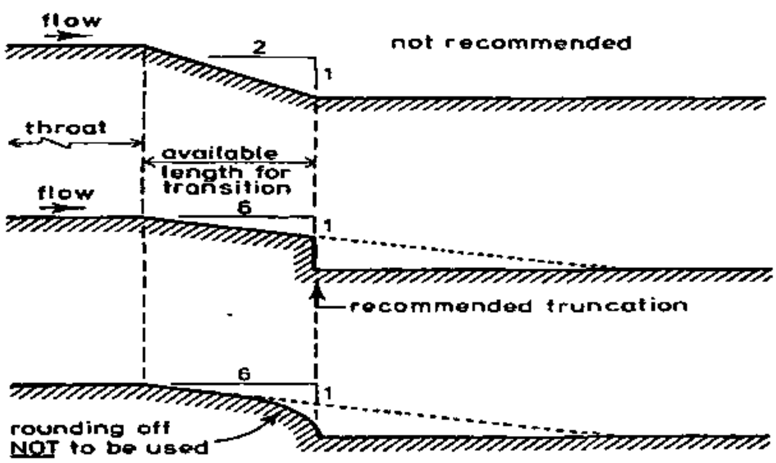


Fig (3-5) Truncation of a gradual downstream transition

Chapter four

WinFlume

Software for Design and Calibration of Long-Throated Flume and Board-Crested Wires for Open Channel Water Measurement

4.1 Introduction

The WinFlume program is the latest version of this flume design software, rewritten to operation in the windows computing environment. the new program makes use of the same hydraulic theory used in previous FORTRAN-and Clipper-based programs, but has an improved user interface, a new design optimization analysis routine , and several additional features not contained in any of the previous programs.
The WinFlume program is available in a 32-bit version for windows 95, Windows 98,and Windows NT system

4.2 Propose

The WinFlume program serves two primary purposes:
1)**Calibration of existing flow measurement structures fitting the criteria for analysis as long-throated flumes-** Winflume can be generate rating tables ,Q vs. h_1 charts, curve-fit equations for use in data logger .and wall gage data and plots.
WinFlume can also compare field-measured Q vs. h_1 data to the theoretical rating

curve of a structure. WinFlume can be used as a design review tool to identify design deficiencies in existing structures.

2) **Design of new structures** - WinFlume can be used to design new flow measurement structures for new and existing canal systems. Designs can be developed manually by the user and analyzed using WinFlume to ensure proper operation, or WinFlume's design module can be used to develop designs that have desired head loss characteristics and meet other performance requirements

4-3 Menu Reference

4-3-1 File Menu .see fig (4-1)

a- New Flume

Creates a new flume based on a copy of an existing flume, or using default dimensions provided by WinFlume.

b- Open Existing Flume File

Loads an existing flume file into memory.

c- Load Flume from FLUME 3.0 Database

Loads a flume originally created with the FLUME 3.0 program. To load the flume, specify the name of the dBase file containing the flume, usually FLM.DBF or FLMBAK.DBF. Then browse through the list of flumes contained in that file to select the flume you wish to load. The flume definition will be loaded and converted into

WinFlume's .

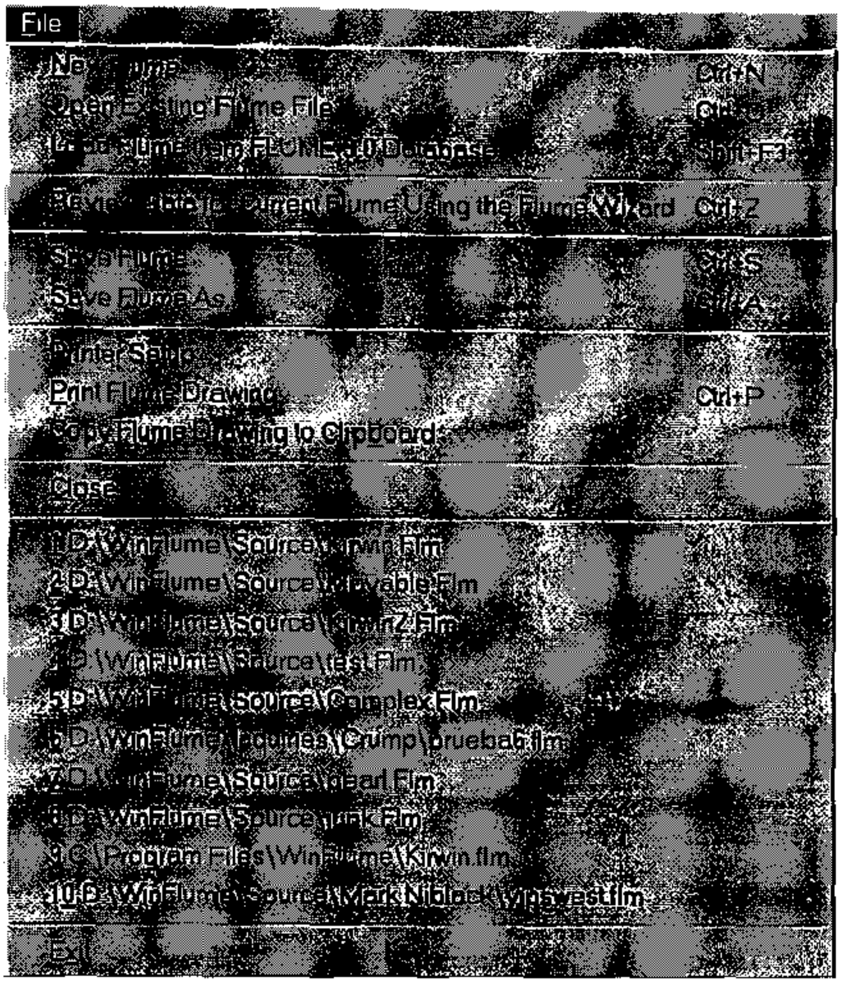


Fig (4-1) File Menu

4-3-2 Flume & Canal Menu .see fig (4-2)

The Flume and Canal Menu provides access to those screens needed when defining the geometric and hydraulic properties of an existing flume to be calibrated using WinFlume.

a- Flume Properties & Canal Data

Opens the form used to specify the flume crest type and construction material, as well as the required discharge range and associated tailwater levels.

b- Dimensions

Displays the screen used to edit the bottom profile and cross-section shapes for the flume and the approach and tailwater channels.

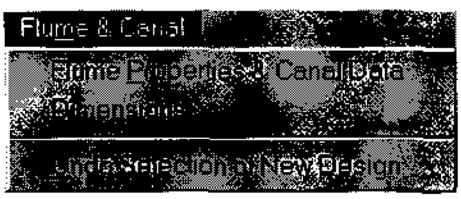


Fig (4-2) Flume & Canal Menu

4-3-3 Design Menu .see fig (4-3)

The Design Menu offers the user access to the screens necessary to design a new flume.

a- Flume Wizard

Starts the flume wizard, which leads the user through a series of screens that prompt for all necessary geometric and hydraulic properties of the flume and canal. The wizard is most useful when creating a new flume, but can be invoked at any time as a means of reviewing the input data for the flume currently in memory.

b- Flume Properties, Canal Data, & Design Requirements

Opens the form used to enter the non-geometric properties of the flume and canal, and the user-chosen design requirements. Information is needed in four primary areas:

1) **Flume construction material and associated roughness height** - The material entered should be that used to

construct the flume crest, not the material used to construct the canal. Several materials and their roughness heights are pre-programmed into WinFlume, or you may type in your own material description and roughness height. The roughness height value is used to calculate head loss due to friction, an important factor in determining the flume rating curve.

2) **Flume discharge range and associated tailwater levels** - The user should enter the minimum and maximum flow for which accurate flow rate measurements are required. These data are used to evaluate the expected error in the flow rate measurements at minimum and maximum flow and compare those errors to user-specified limits. The tailwater data are used to ensure that the flume does not become submerged and operates with modular flow (i.e., critical depth in the control section) over the full discharge range. For detailed information about determining tailwater levels, see Determining Tailwater Levels.

3) **Head measurement method and allowable discharge measurement error at minimum and maximum flow -**

The user should choose a head measurement method from the list, or type in their own description of the head measurement method. If a method is chosen from the list, WinFlume supplies a default measurement error for the method, otherwise, the user must enter their own value. This value should be the expected error in any one

measurement of the sill-referenced head due to factors such as waves, difficulty seeing the staff gage or water surface, electronic noise, resolution of the device, etc. The user also specifies allowable discharge measurement errors at minimum and maximum flow. WinFlume combines the errors due to the accuracy of the rating table with the errors related to head measurement to determine an overall discharge measurement error. If this error exceeds
the user-specified criteria, WinFlume's design module can attempt to improve the design, or WinFlume will provide the user with suggestions for modifying the design.

4) **Required freeboard** - The user can specify the required freeboard in the approach channel as either an absolute vertical distance, or as a percentage of the upstream energy head. WinFlume will require that the vertical distance between the top of the approach channel and the upstream energy grade line (not the upstream water surface) be
equal to or greater than the specified amount.

c- Dimensions

Displays the form used to enter dimensions for the canal and flume bottom profile and cross-section shapes.

d- Review Current Design

Performs a review of the current design based on the six design criteria:

1) Upstream Froude number < 0.5

2) Upstream freeboard >= user-specified limit

3) Allowable tailwater > actual tailwater level at minimum flow

4) Allowable tailwater > actual tailwater level at maximum flow

5) Expected discharge measurement error meets design requirement at minimum flow

6) Expected discharge measurement error meets design requirement at maximum flow

A report is generated on-screen summarizing the results of the review. If the design does not meet one or more of the design criteria, WinFlume will make suggestions for improving the design. The report can be printed, saved to a text file, or copied to the system clipboard.

e- Evaluate Alternative Designs

Opens the design module form used to develop alternative designs based on the current flume definition.

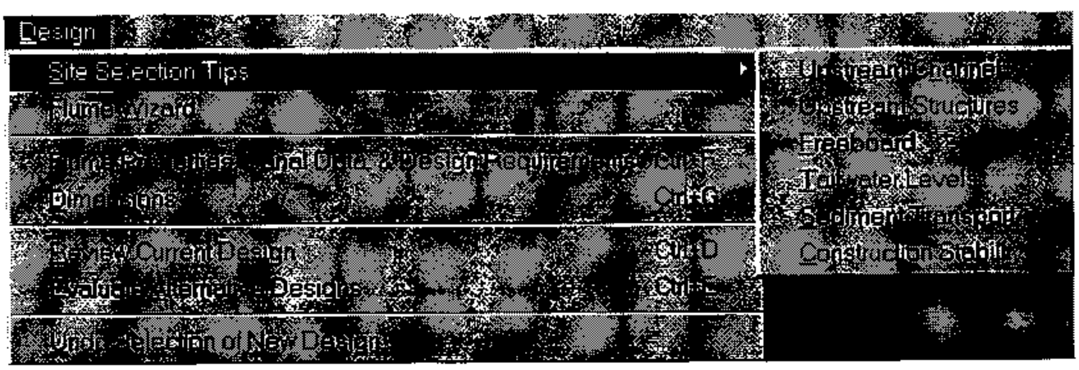


Fig (4-3) Design Menu

4-3-4 Reports/Graphs Menu. See fig(4-4)

a- Rating Tables & Graphs

Opens the Rating Table Output Form used to create rating tables and graphs of rating table data (for example, Q vs. $h1$ curves).

b- Rating Equation

Opens the Rating Equation Form used to determine a simplified rating equation for the flume that can be used in a data logger at the flume site to automate discharge measurements.

c- Measured Data Comparison

Opens the Measured Data Comparison Form used to compare the theoretical rating curve developed by WinFlume to actual field measurements of discharge vs. upstream sill-referenced head. The discharge measurements are made independently of the flume structure, perhaps with current-metering techniques or other flow measurement structures.

d- Wall Gages

Opens the Wall Gage Output Form used to create wall gages and reports of the data needed to construct wall gages. Wall gages can be previewed on screen and then printed full-scale on your Windows system printer.

e- Flume Data Report

Creates a text report of the flume and canal properties and the user-specified design requirements. The report can be printed, saved in a text file, or copied to the clipboard.

f- Flume Drawing Printout

Prints an image of the flume bottom profile and cross-sections to the Windows system printer.

g- Copy Flume Drawing to Clipboard

Copies an image of the flume bottom profile and cross-sections to the Windows clipboard. Once on the clipboard, the image can be pasted into a word-processor or other application.

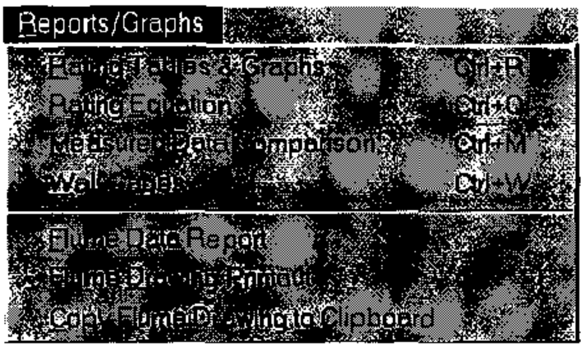


Fig (4-4) Reports/Graphs Menu

4-4 Primary Forms And Dialog Boxes

4-4-1 Flume Geometry and Dimensions Form

This form is used to edit the dimensions and geometry of the flume structure and the upstream and downstream Canals. See fig (4-5).

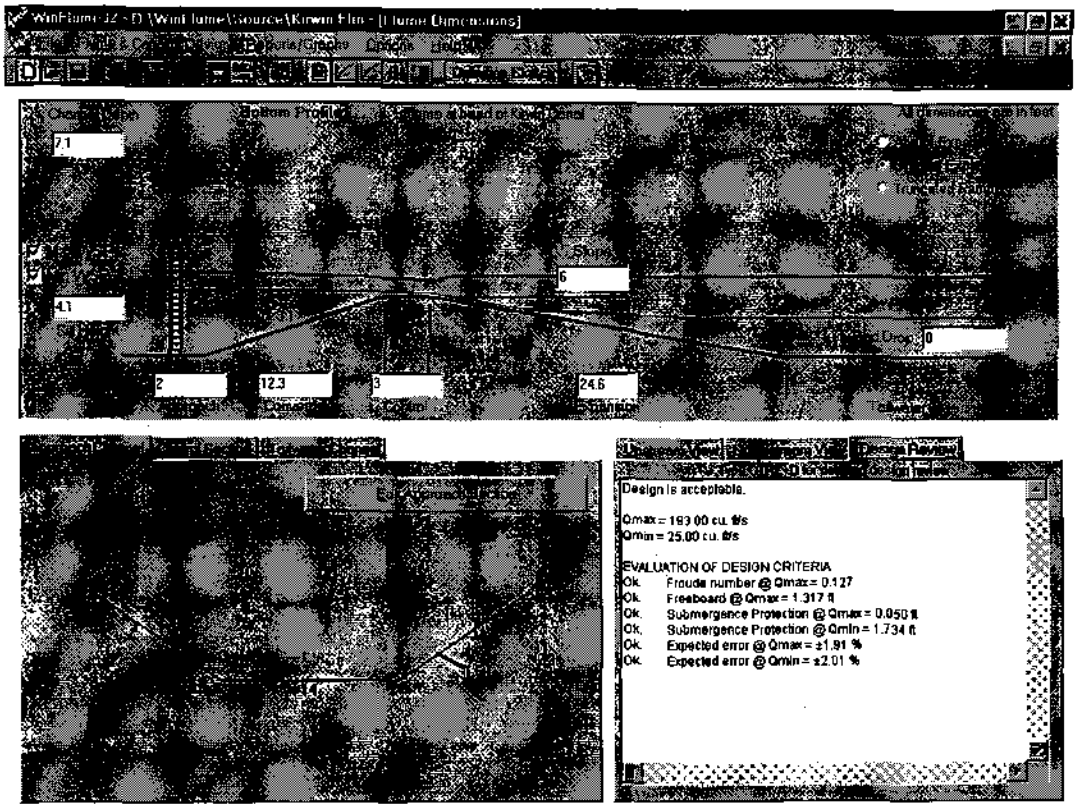


Fig (4-5) Flume Geometry and Dimensions Form

4-4-2 Section Shape & Dimensions Form

Use this form to edit the section shape and dimensions for the approach, control, and tailwater sections of the Structure. See fig (4-6).

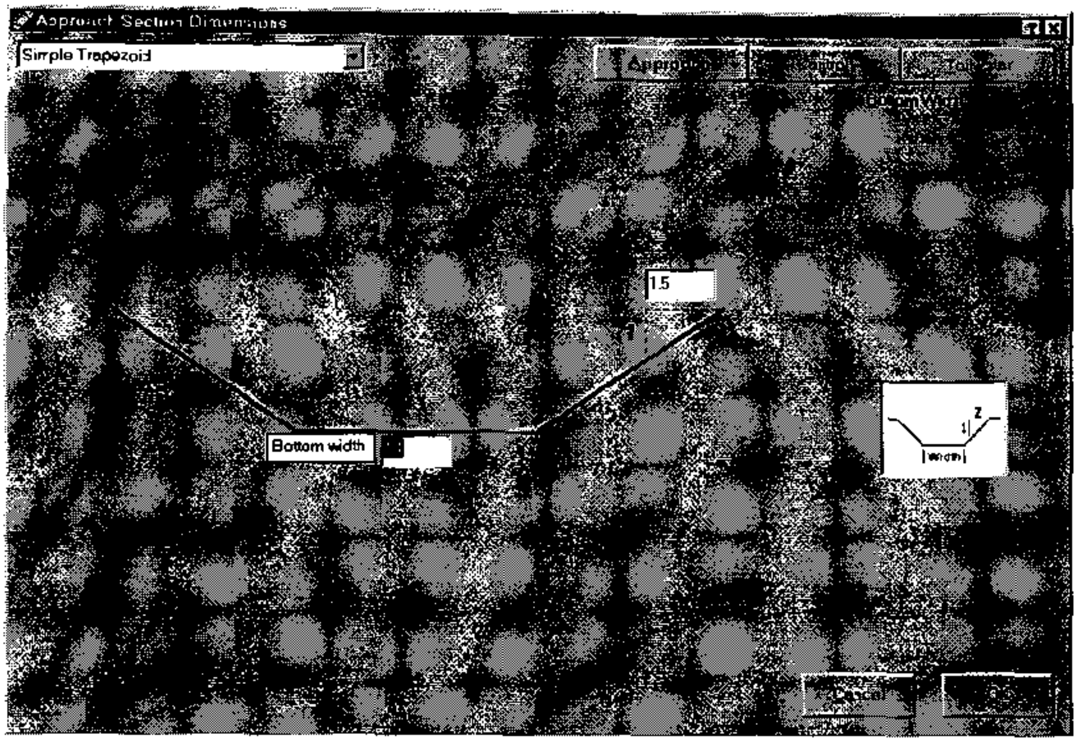


Fig (4-6) Section Shape & Dimensions Form

4-4-3 Flume and Canal Properties & Design Requirements Form .see fig (4-7)

This form can be opened from the toolbar, or from the Design menu. Information is needed in four primary areas:

1) **Flume construction material and associated roughness height -** The material entered should be that used to construct the flume crest, not the material used to construct the canal. Several materials and their roughness heights are pre-programmed into WinFlume, or you may type in your own material description and roughness height. The roughness height value is used to calculate head loss due to friction, an important factor in determining the flume rating curve.

2) **Flume discharge range and associated tailwater levels** - The user should enter the minimum and maximum flow.

for which accurate flow rate measurements are required. These data are used to evaluate the expected error in the flow rate measurements at minimum and maximum flow and compare those errors to user-specified limits described in 3) below. The tailwater data are used to ensure that the flume does not become submerged and operates with modular flow (i.e., critical depth in the control section) over the full discharge range. For detailed information about determining tailwater levels, see Determining Tailwater Levels.

3) **Head measurement method and allowable discharge measurement error at minimum and maximum flow**

The user should choose a head measurement method from the list, or type in their own description of the head measurement method. If a method is chosen from the list, WinFlume supplies a default measurement error for the method, otherwise, the user must enter their own value. This value should be the expected error in any one measurement of the sill referenced head due to factors such as waves, difficulty seeing the staff gage or water surface, electronic noise, resolution of the device, etc. The user also specifies allowable discharge measurement errors at minimum and maximum flow. WinFlume combines the errors due to the accuracy of the rating table with the errors related to head measurement to determine an overall discharge measurement error. If this error exceeds the user-specified criteria, WinFlume's design module can attempt to improve the design, or WinFlume will provide the user with suggestions for modifying the design.

4) **Required freeboard** - The user can specify the required freeboard in the approach channel as either an absolute vertical distance, or as a percentage of the upstream energy head. WinFlume will require that the vertical distance between

the top of the approach channel and the upstream water level be equal to or greater than the specified amount.

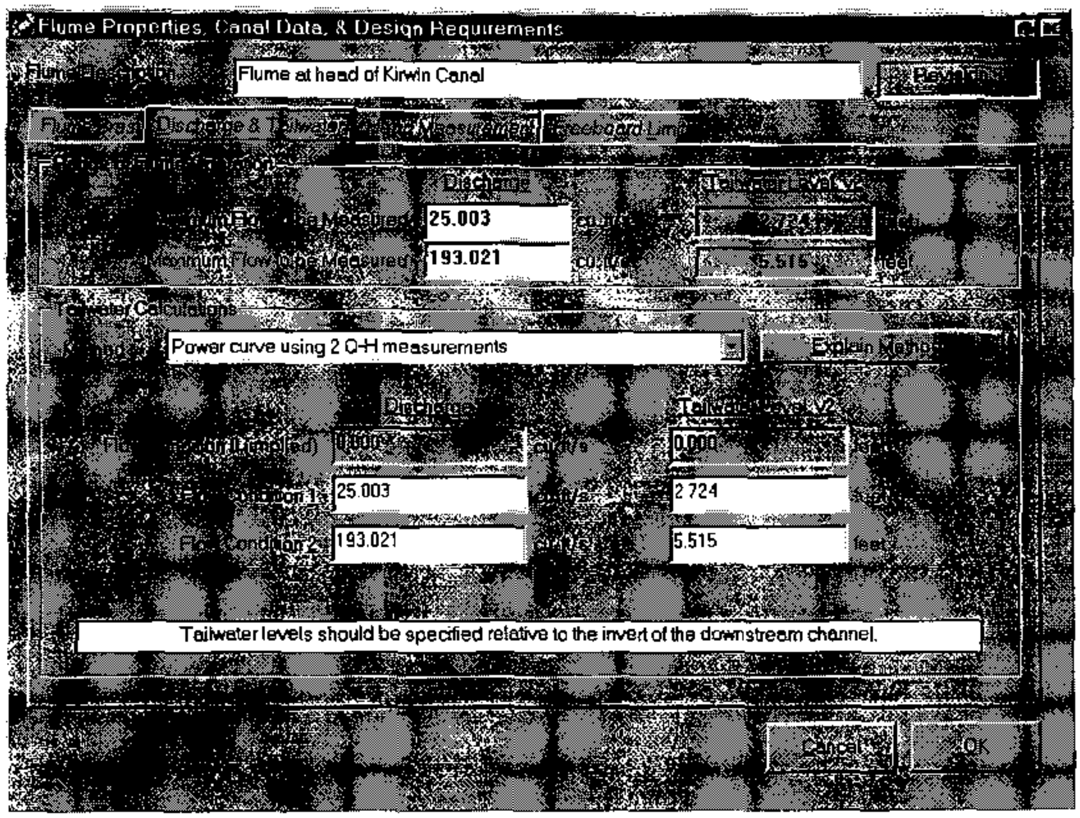


Fig (4-7) Flume and Canal Properties & Design Requirements Form

4-4-4 Flume and Canal Properties Form

This is an abbreviated version of the Flume and Canal Properties & Design Requirements Form, showing only the tabs for flume construction material and discharge and tailwater data . See fig (4-8).

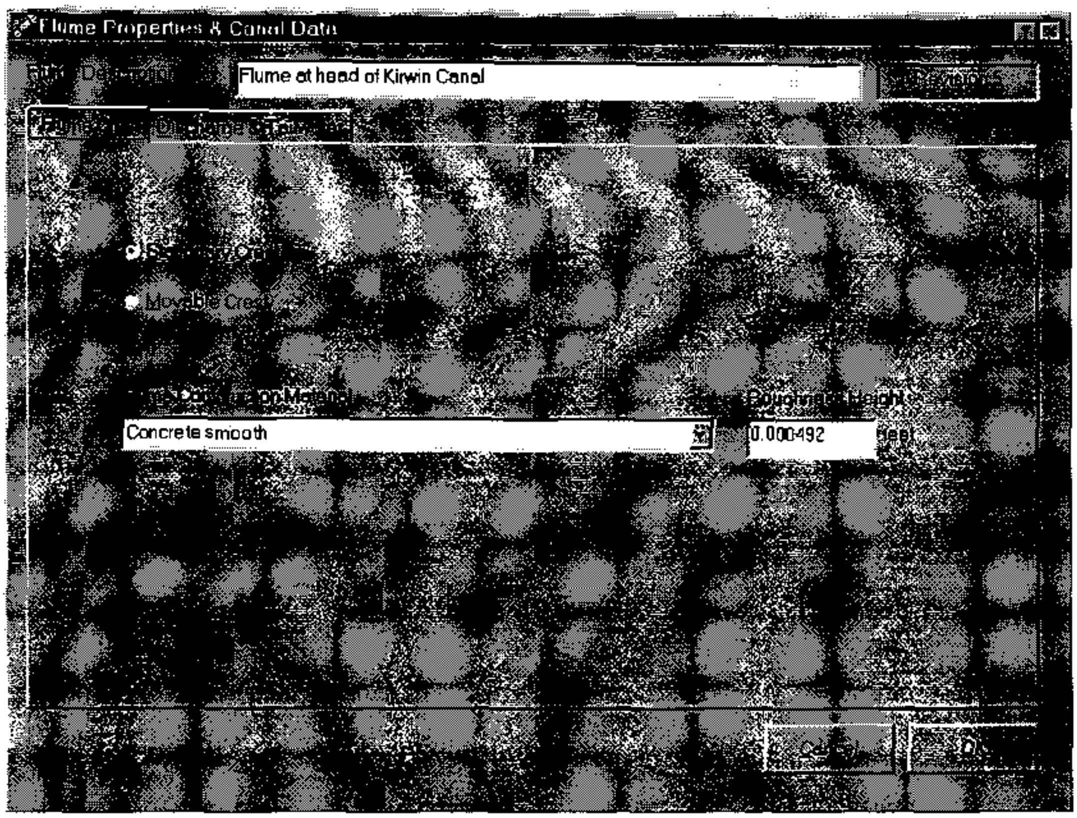


Fig (4-8) Flume and Canal Properties Form

4-4-5 Flume Wizard Dialog

The flume wizard leads the user through a step-by-step process that prompts for all necessary geometric and hydraulic properties of the flume and canal. See fig (4-9).

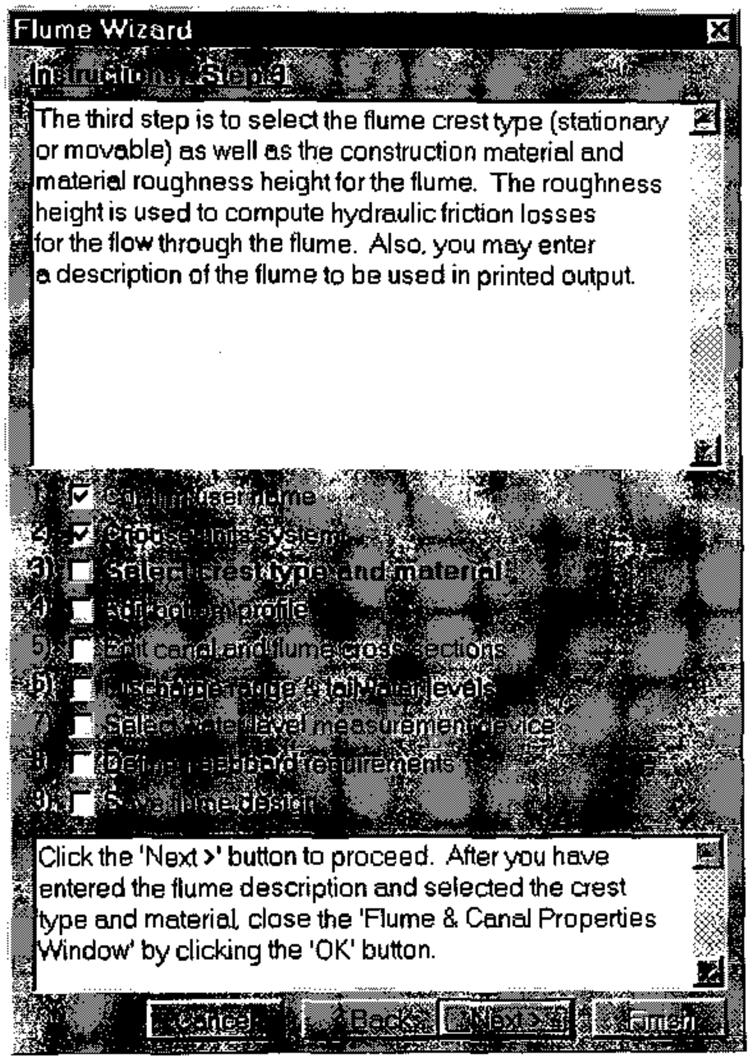


Fig (4-9) Flume Wizard

4-4-6 Create New Flume Dialog

The form creates a new flume based on a copy of an existing flume, or using default dimensions provided by WinFlume. You may choose to start the flume wizard at the same time that the new flume is created. The wizard will guide you through all screens necessary to define the basic geometry and hydraulic properties of the flume and canal. See fig (4-10).

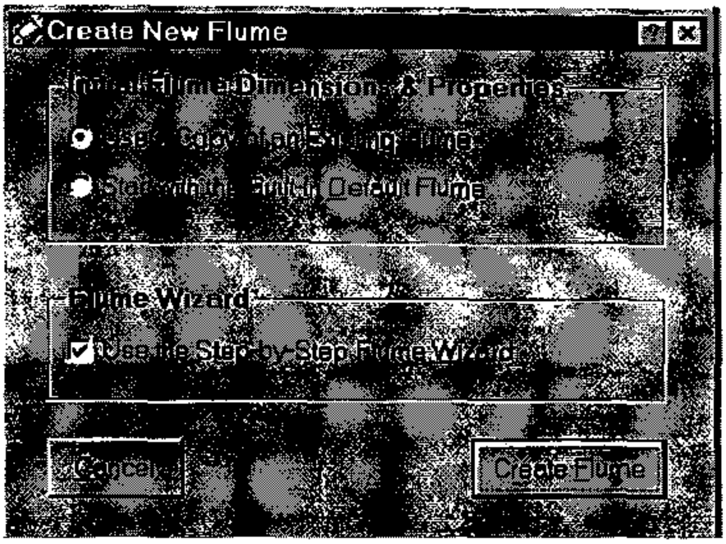
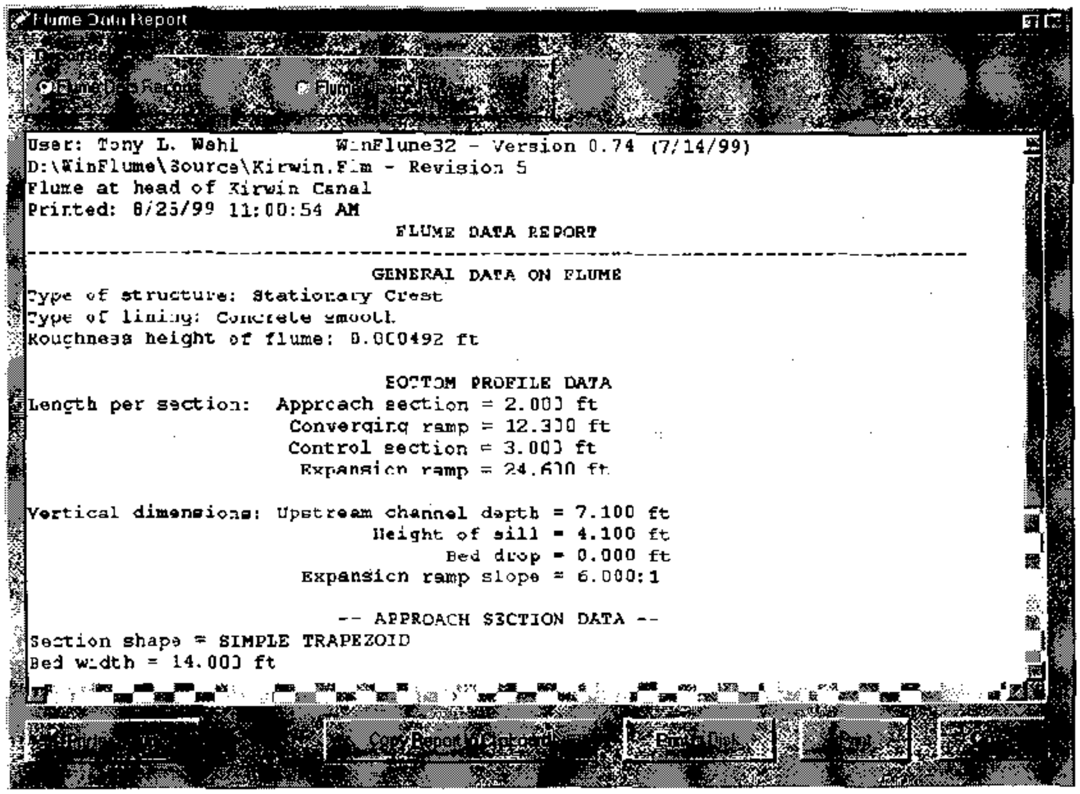


Fig (4-10) Create New Flume

4-4-7 Flume Reports Form

This form is used to present the Flume Data Report and Flume Design Review Report. The reports can be printed, copied to the clipboard, or saved to a text file .See fig (4-11).


Flume Data Report

```
User: Tony L. Wahl        WinFlume32 - Version 0.74 (7/14/99)
D:\WinFlume\Source\Kirwin.Flm - Revision 5
Flume at head of Kirwin Canal
Printed: 8/25/99 11:00:54 AM
                              FLUME DATA REPORT
--------------------------------------------------------------------------------
                            GENERAL DATA ON FLUME
Type of structure: Stationary Crest
Type of lining: Concrete smooth
Roughness height of flume: 0.000492 ft

                             BOTTOM PROFILE DATA
Length per section:  Approach section = 2.000 ft
                      Converging ramp = 12.300 ft
                      Control section = 3.000 ft
                       Expansion ramp = 24.600 ft

Vertical dimensions: Upstream channel depth = 7.100 ft
                             Height of sill = 4.100 ft
                                   Bed drop = 0.000 ft
                      Expansion ramp slope = 6.000:1

                        -- APPROACH SECTION DATA --
Section shape = SIMPLE TRAPEZOID
Bed width = 14.000 ft
```

Fig (4-11) Flume Reports Form

4-4-8 Rating Table Output Form

The rating table output form is used to create rating tables and graphs of rating table data for existing or new flume designs. In addition to Q vs. $h1$ curves and data tables, the rating tables can include numerous additional parameters that may be of interest to the designer .See fig (4-12).

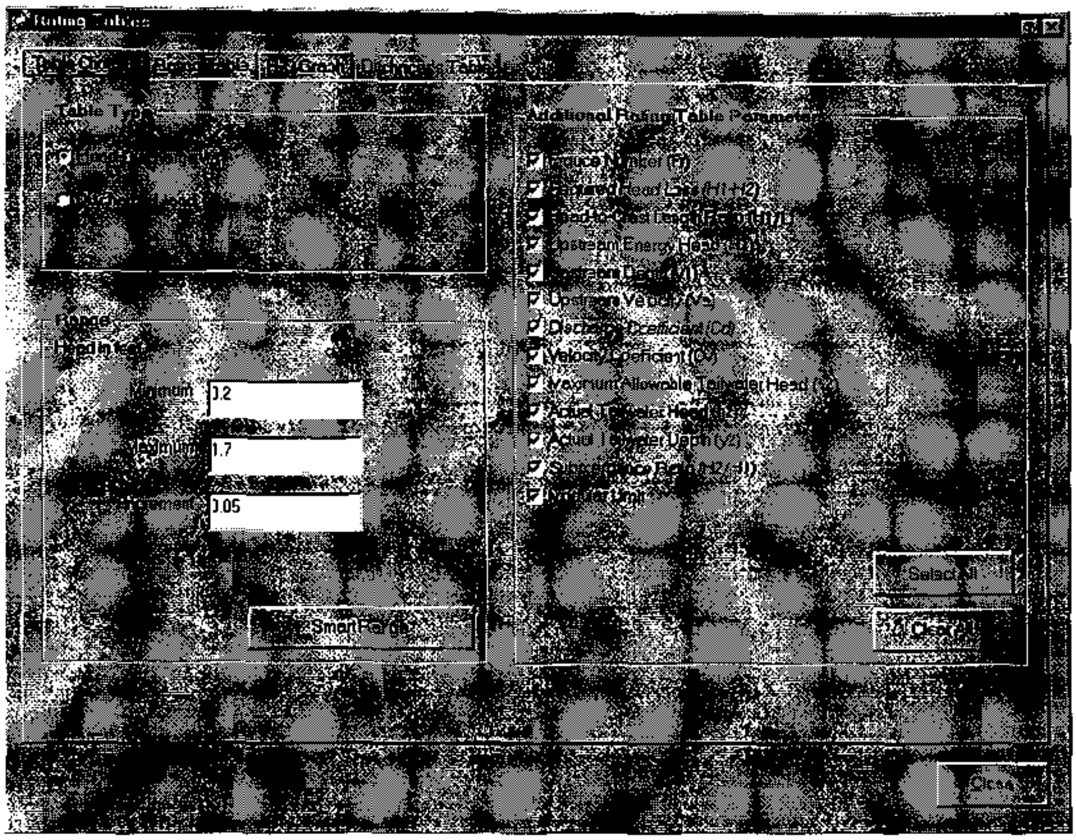


Fig (4-12) Rating Table Output Form

4-4-9 Measured Data Comparison Form

This form allows the user to compare field measurements of discharge vs. sill-referenced head against the rating curve computed by WinFlume. See fig (4-13). Such a comparison may be helpful in debugging potential problems, such as errors in zero-setting of the head sensor. The user enters field- measured values of discharge and sill-referenced head into a data table. WinFlume then computes the rating table for the structure and presents a comparison in both tabular and graphical form.

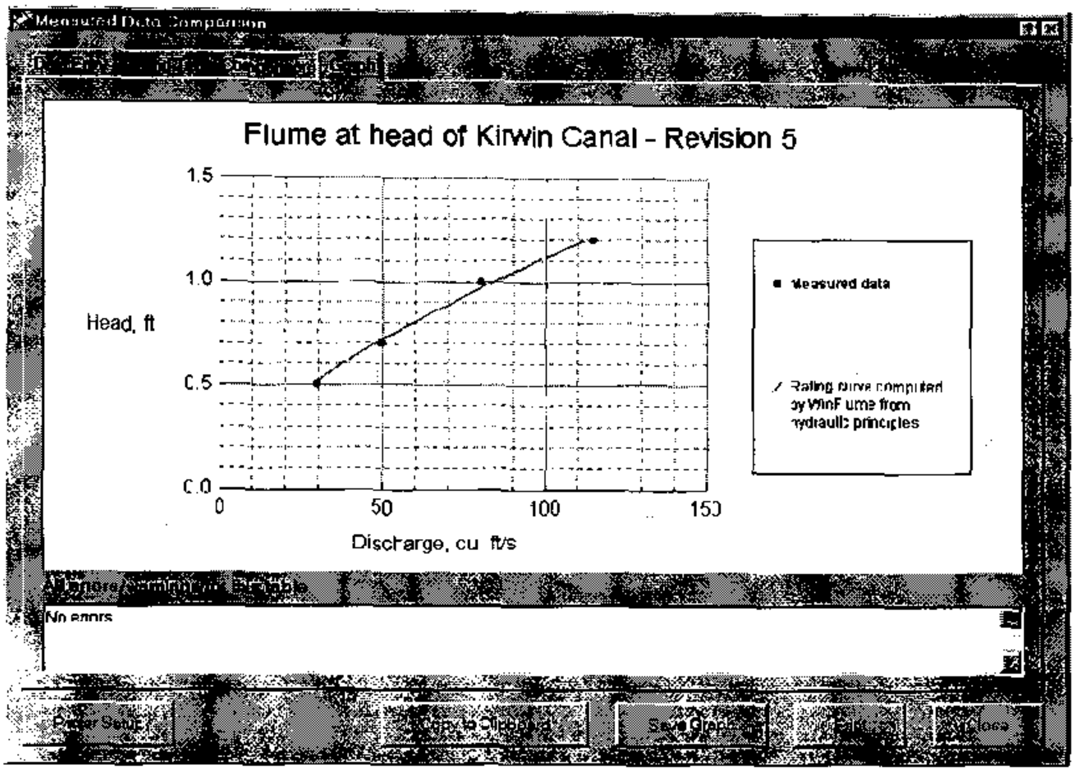


Fig (4-13) Measured Data Comparison Form

4-4-10 Equation Output Form. See fig (4-14)

This form is used to generate a power-curve equation that approximates the Q vs. $h1$ rating curve of the flume. This equation can be programmed into a data logger for automating the measurement storage of discharge data. WinFlume determines a curve-fit equation of the form:

$$Q=K_1\,(h_1 + K_2)^{u}$$

You may also force $K_2 = 0$ when performing the curve-fit calculations. The resulting simplified equation form may be more easily programmed into some data loggers. The curve-fitting routine uses a rating table generated by WinFlume. The user specifies the type of rating table

(range of heads vs. range of discharges) and the range and increment for the rating table on the Options tab. The second and third tabs of the form allow the user to review the rating table and curve-fitting results in tabular and graphical form. At least 6 data points are needed in the rating table to develop a rating equation.

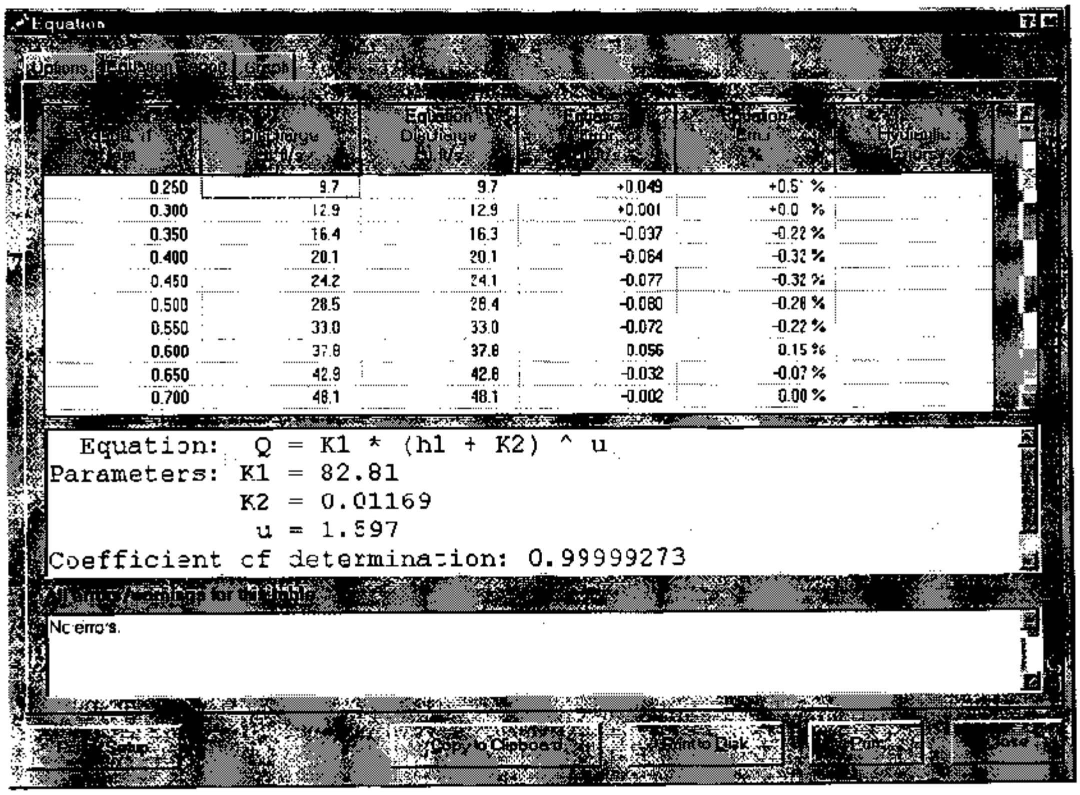


Fig (4-14) Equation Output Form.

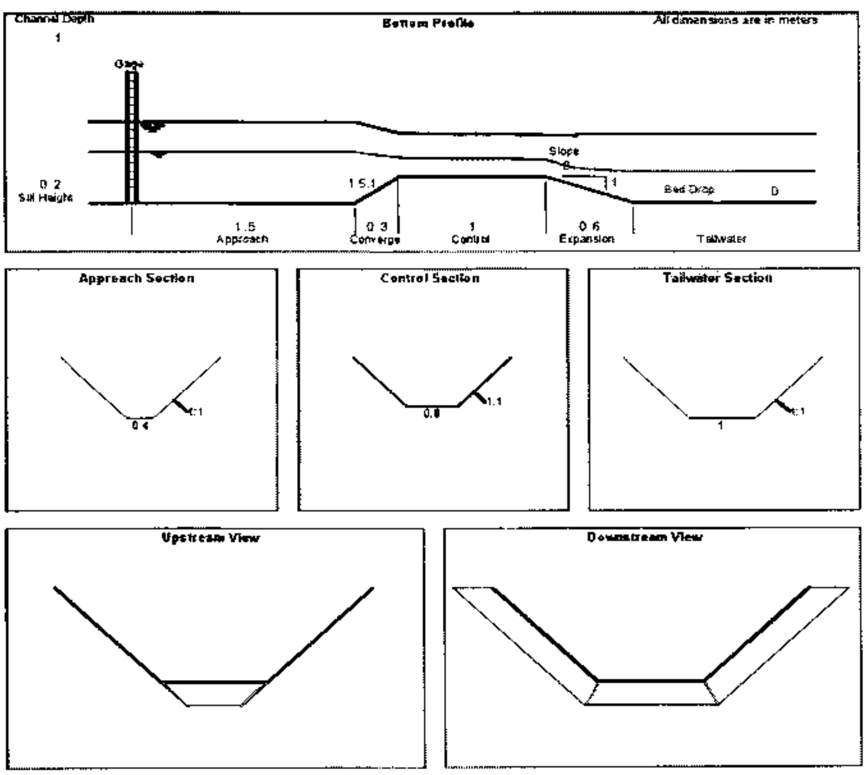
Chapter Five

Analysis & design of some examples

5.1 Introduction

The wine flume program is the latest version program of this flume design software rewritten to operate in the windows computing environment.
The new program makes use the same hydraulic theory and clipper based program but has an improved user interface a new design optimization/ analysis routine and several additional features not contained in any of the previous program. This program result gives many graphic curves to show that data and tables to simplified the measuring of discharge in the open channel long throated flumes as theoretical and give high accuracy value.

5.2 Sample 1



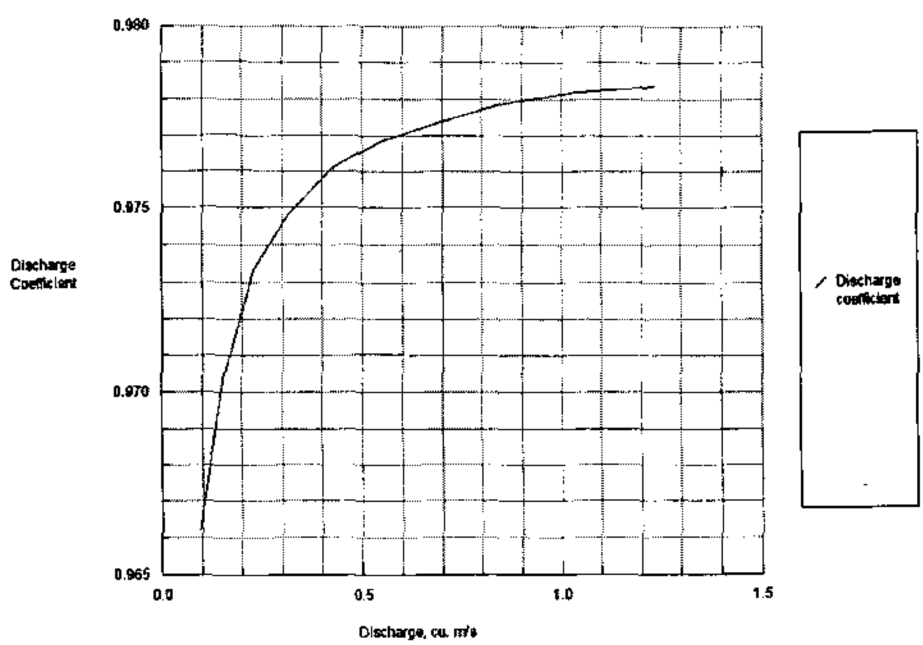


Fig (5.1)
Relation between discharge & discharge coefficient
for sample 1

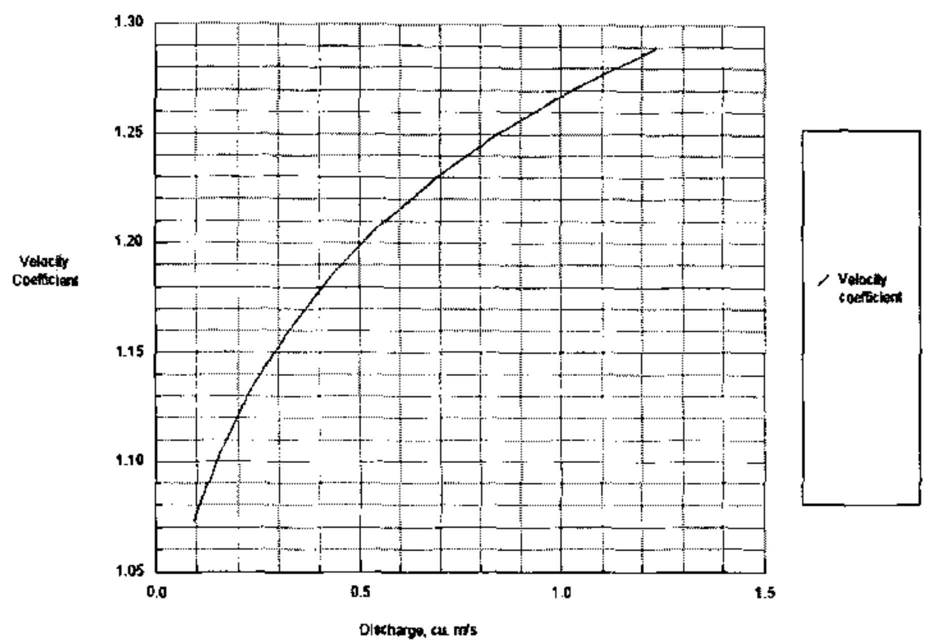


Fig (5.2)
Relation between discharge & velocity coefficient
for sample 1

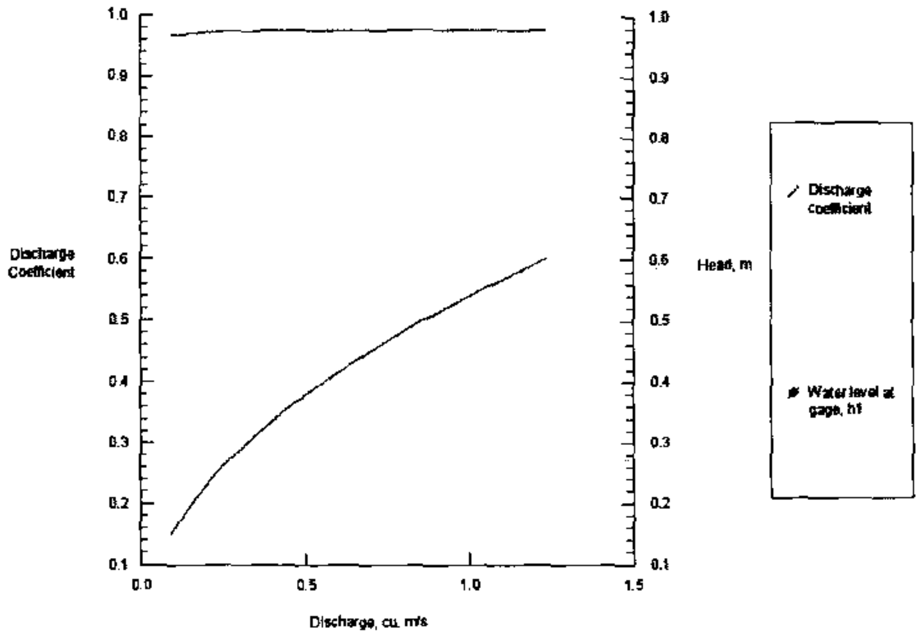


Fig (5.3)
Relation between discharge coefficient, discharge & head for sample 1

Table (5.1)
Equation rating for sample 1

h1 Sill Referenced Head at Gage meters	Q Theoretical Discharge cu. m/s	Q_fit Curve Fit Equation Discharge cu. m/s	D=Q_fit-Q Difference cu. m/s	(D/Q)*100% Difference %	Warnings
0.156	0.100	0.100	0.000	+0.07	10
0.232	0.200	0.200	0.000	-0.19	10
0.289	0.300	0.300	0.000	+0.01	10
0.337	0.400	0.400	0.000	+0.12	10
0.380	0.500	0.501	+0.001	+0.10	10
0.417	0.600	0.600	0.000	+0.01	10
0.452	0.700	0.699	-0.001	-0.12	1, 10

Equation: Q_fit = K1 * (h1 + K2) ^ u
Parameters: K1 = 3.138
K2 = 0.03546
u = 2.087
Coefficient of determination: 0.99999715

Theoretical discharge (Q) is determined by the WinFlume model, using hydraulic theory and empirical relationships determined from laboratory testing. It is the most accurate estimate of discharge. Curve fit discharge (Q_fit) is computed with the equation above, which was fitted to the theoretical discharge values. The 'difference' columns show the difference between the flow rates computed from the simplified equation and those obtained from the theoretical WinFlume model.

Summary of Warning Messages

1 - Froude number exceeds 0.5 at the gage.
10 - Converging section is too short (ramp is too steep).

Table (5.2)
Rating table comparison for sample 1

Head at Gage, h1 m	Measured Discharge cu. m/s	Theoretical Discharge cu. m/s	Discharge Difference cu. m/s	Discharge Difference %	Upstream Energy Head, m	Upstream Velocity m/s	Discharge Coeff.	Velocity Coeff.	Tailwater Head, h2 m
0.050	0.002	0.019	-0.02	-89.38	0.051	0.116	0.933	1.022	-0.130
0.100	0.048	0.059	-0.01	-18.65	0.104	0.281	0.956	1.066	-0.061

Summary of Warning Messages

5 - Upstream energy head / control section length is less than 0.07.
10 - Converging section is too short (ramp is too steep).

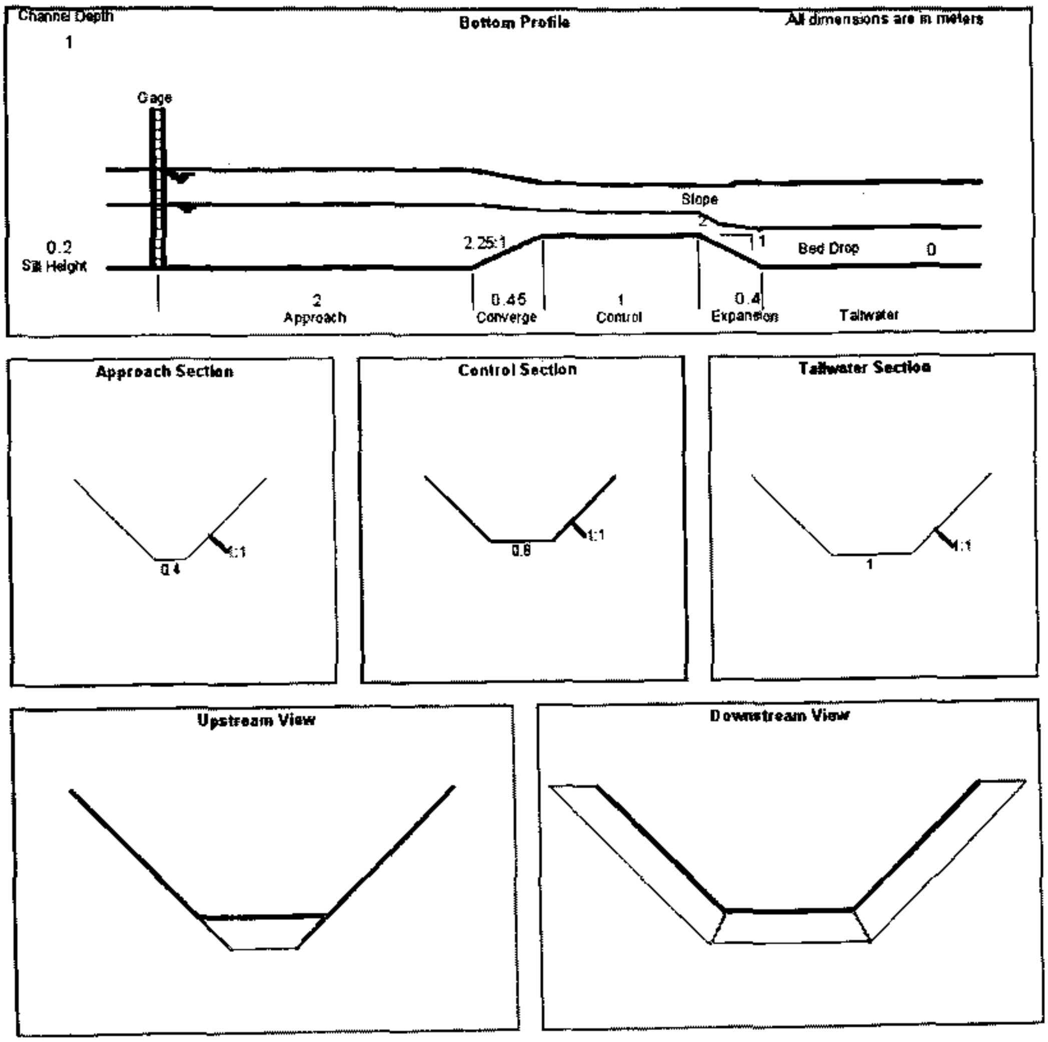
Table(5.3)
Rating table for sample 1

Head at Gage, h1 meters	Discharge m^3/s	Froude Number	Required Head Loss m	H1/L Ratio	Upstream Energy Head, m	Submerge. Ratio	Warnings
0.080	0.041	0.153	0.016	0.082	0.082	0.000	10
0.100	0.059	0.196	0.019	0.104	0.104	0.000	10
0.120	0.080	0.237	0.021	0.126	0.126	0.000	10
0.140	0.105	0.276	0.023	0.149	0.149	0.042	10
0.160	0.133	0.314	0.025	0.172	0.172	0.213	10
0.180	0.164	0.349	0.026	0.196	0.196	0.344	10
0.200	0.198	0.383	0.028	0.220	0.220	0.448	10
0.220	0.236	0.415	0.029	0.245	0.245	0.532	10
0.240	0.277	0.446	0.030	0.270	0.270	0.601	10

Summary of Warning Messages

10 - Converging section is too short (ramp is too steep).

5.3 Sample 2


Channel Depth
1
Bottom Profile
All dimensions are in meters
Gage
Slope
2
1
2.25:1
0.2
Sill Height
Bed Drop
0
2
Approach
0.45
Converge
1
Control
0.4
Expansion
Tailwater
Approach Section
0.4
1:1
Control Section
0.8
1:1
Tailwater Section
1
1:1
Upstream View
Downstream View

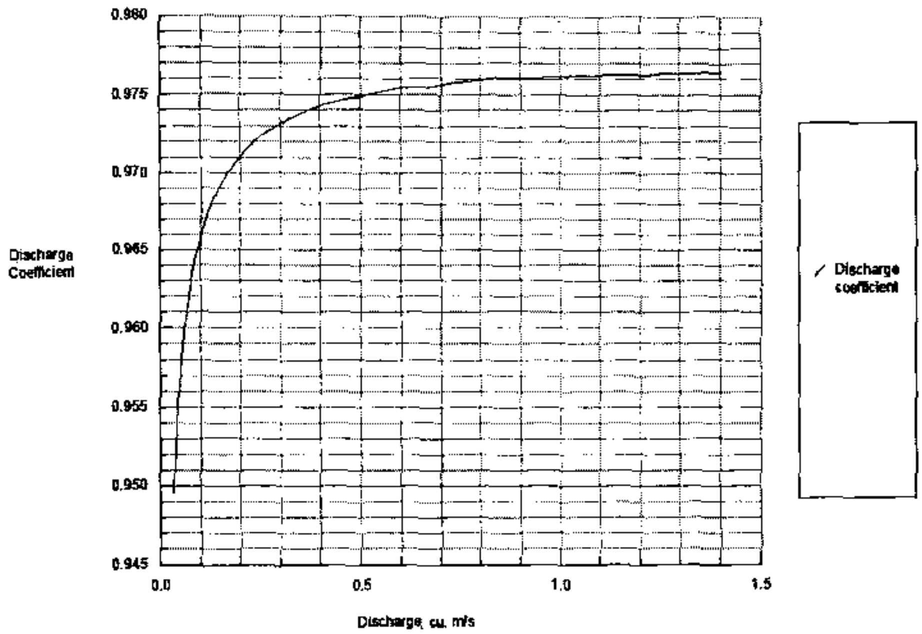


Fig (5.4)
Relation between discharge & discharge coefficient
for sample 2

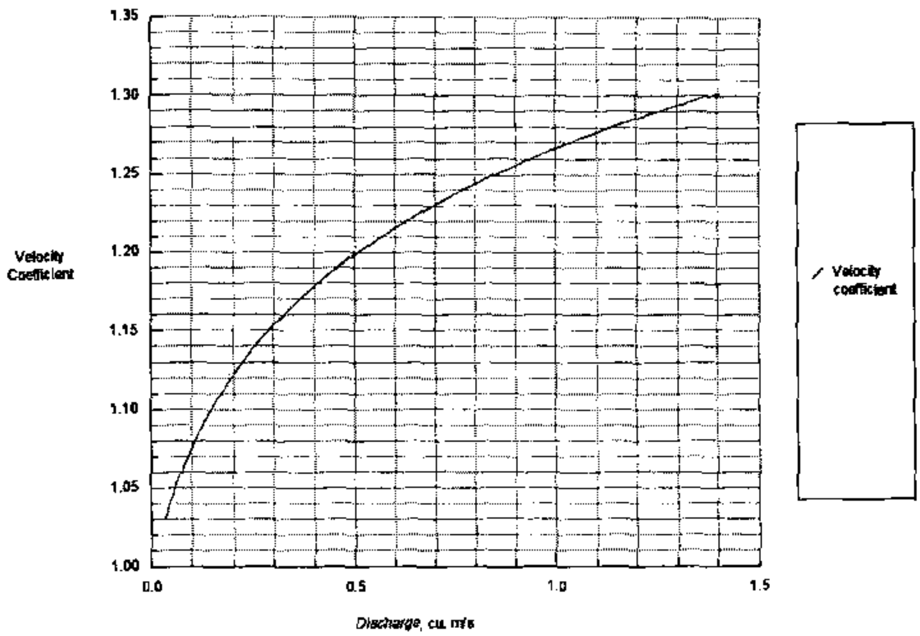


Fig (5.5)
Relation between discharge & velocity coefficient
for sample 2

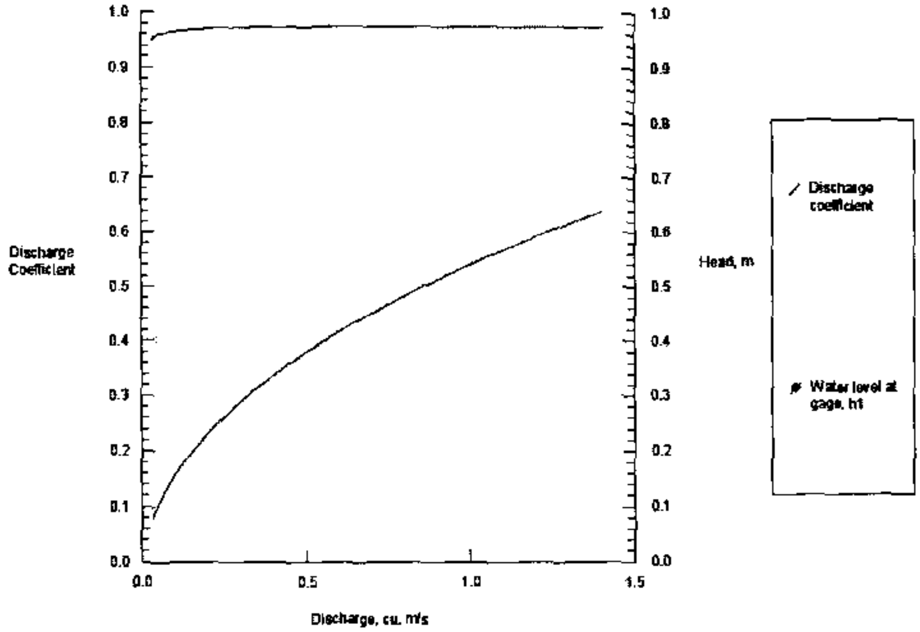


Fig (5.6)
Relation between discharge coefficient, discharge & head for sample 2

Table (5.4)
Equation rating for sample 2

h1 Sill Referenced Head at Gage meters	Q Theoretical Discharge cu. m/s	Q_fit Curve Fit Equation Discharge cu. m/s	D=Q_fit-Q Difference cu. m/s	(D/Q)*100% Difference %	Warnings
0.156	0.100	0.100	0.000	+0.07	10
0.232	0.200	0.200	0.000	-0.19	10
0.289	0.300	0.300	0.000	+0.01	10
0.337	0.400	0.400	0.000	+0.12	10
0.380	0.500	0.501	+0.001	+0.10	10
0.417	0.600	0.600	0.000	+0.01	10
0.452	0.700	0.699	-0.001	-0.12	1, 10

```
  Equation:  Q_fit = K1 * (h1 + K2) ^ u
Parameters:      K1 = 3.138
                 K2 = 0.03546
                  u = 2.087
Coefficient of determination: 0.99999715
```

Theoretical discharge (Q) is determined by the WinFlume model, using hydraulic theory and empirical relationships determined from laboratory testing. It is the most accurate estimate of discharge. Curve fit discharge (Q_fit) is computed with the equation above, which was fitted to the theoretical discharge values. The 'difference' columns show the difference between the flow rates computed from the simplified equation and those obtained from the theoretical WinFlume model.

Summary of Warning Messages

1 - Froude number exceeds 0.5 at the gage.
10 - Converging section is too short (ramp is too steep).

Table (5.5)
Rating table comparison for sample 2

Head at Gage, h1 m	Measured Discharge cu. m/s	Theoretical Discharge cu. m/s	Discharge Difference cu. m/s	Discharge Difference %	Upstream Energy Head, m	Upstream Velocity m/s	Discharge Coeff.	Velocity Coeff.	Tailwater Head, h2 m
0.050	0.002	0.015	-0.01	-86.70	0.050	0.093	0.932	1.014	-0.138
0.100	0.048	0.047	0.00	2.66	0.103	0.223	0.956	1.042	-0.079

Summary of Warning Messages

5 - Upstream energy head / control section length is less than 0.07.
10 - Converging section is too short (ramp is too steep).

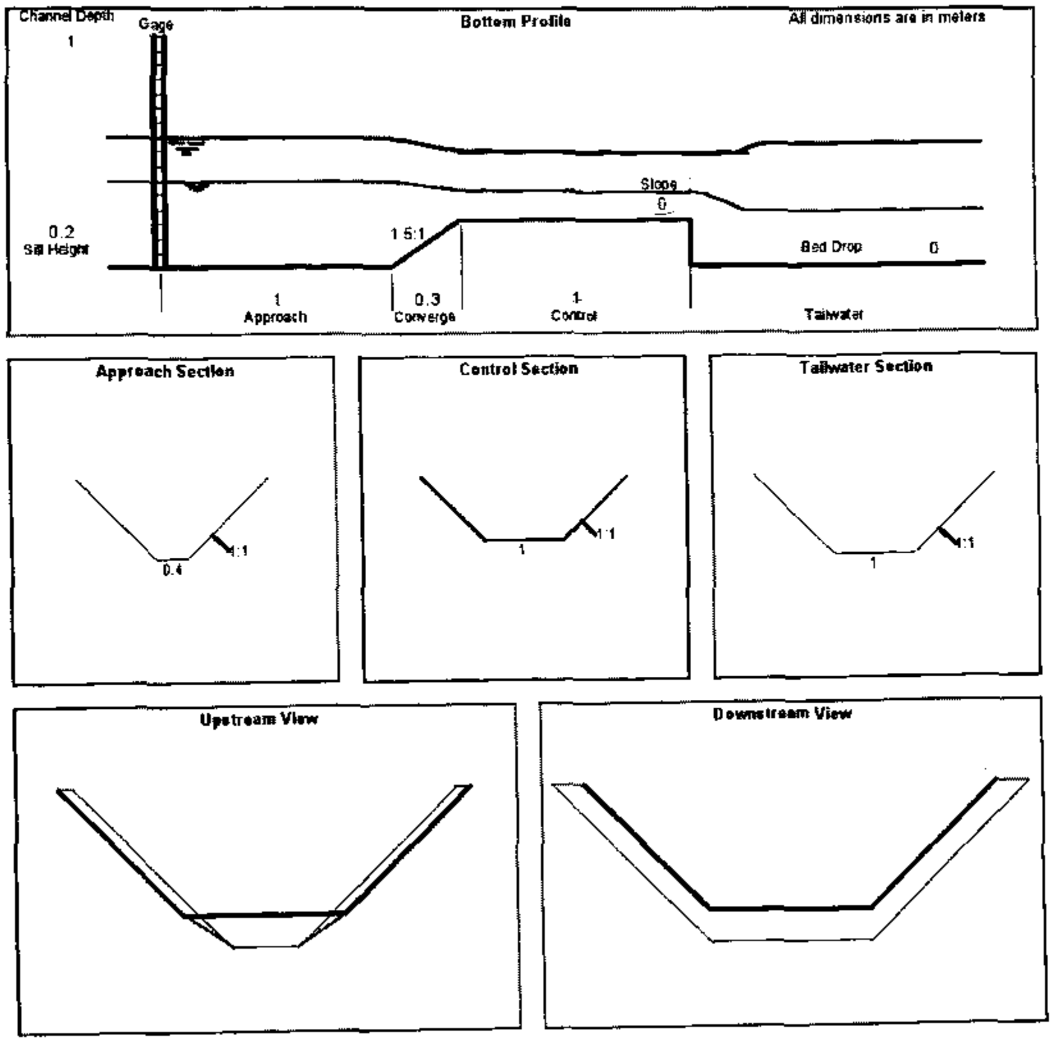
Table(5.6)
Rating table for sample 2

Head at Gage, h1 meters	Discharge m^3/s	Froude Number	Required Head Loss m	H1/L Ratio	Upstream Energy Head, m	Submerge. Ratio	Warnings
0.080	0.032	0.122	0.019	0.082	0.082	0.000	10
0.100	0.047	0.155	0.022	0.103	0.103	0.000	10
0.120	0.063	0.187	0.025	0.124	0.124	0.000	10
0.140	0.083	0.217	0.027	0.146	0.146	0.000	10
0.160	0.104	0.245	0.029	0.168	0.168	0.029	10
0.180	0.128	0.272	0.031	0.190	0.190	0.164	10
0.200	0.154	0.297	0.033	0.212	0.212	0.272	10
0.220	0.182	0.320	0.035	0.235	0.235	0.359	10
0.240	0.213	0.342	0.036	0.258	0.258	0.432	10
0.260	0.246	0.363	0.038	0.281	0.281	0.493	10
0.280	0.282	0.383	0.039	0.304	0.304	0.545	10
0.300	0.320	0.401	0.041	0.327	0.327	0.590	10
0.320	0.361	0.419	0.042	0.350	0.350	0.629	10
0.340	0.405	0.435	0.043	0.374	0.374	0.663	10
0.360	0.451	0.451	0.044	0.397	0.397	0.693	10
0.380	0.500	0.466	0.045	0.421	0.421	0.720	10
0.400	0.552	0.480	0.046	0.445	0.445	0.744	10
0.420	0.607	0.493	0.047	0.469	0.469	0.766	10
0.440	0.664	0.506	0.048	0.493	0.493	0.785	1,10
0.460	0.724	0.518	0.049	0.517	0.517	0.803	1,10
0.480	0.787	0.530	0.049	0.541	0.541	0.819	1,10
0.500	0.854	0.541	0.050	0.565	0.565	0.834	1,10
0.520	0.923	0.552	0.051	0.589	0.589	0.847	1,10
0.540	0.995	0.562	0.052	0.614	0.614	0.860	1,10
0.560	1.070	0.572	0.052	0.638	0.638	0.871	1,10
0.580	1.148	0.581	0.053	0.663	0.663	0.882	1,10
0.600	1.230	0.591	0.053	0.687	0.687	0.892	1,10
0.620	1.315	0.599	0.054	0.712	0.712	0.901	1,6,10
0.640	1.403	0.608	0.055	0.736	0.736	0.910	1,6,10

Summary of Warning Messages

1 - Froude number exceeds 0.5 at the gage.
6 - Upstream energy head / control section length exceeds 0.7.
10 - Converging section is too short (ramp is too steep).

5.4 Sample 3


Channel Depth
1
Gage
Bottom Profile
All dimensions are in meters
Slope
0
0.2
Sill Height
1.5:1
Bed Drop
0
1
Approach
0.3
Converge
1
Control
Tailwater
Approach Section
1:1
0.4
Control Section
1:1
1
Tailwater Section
1:1
1
Upstream View
Downstream View

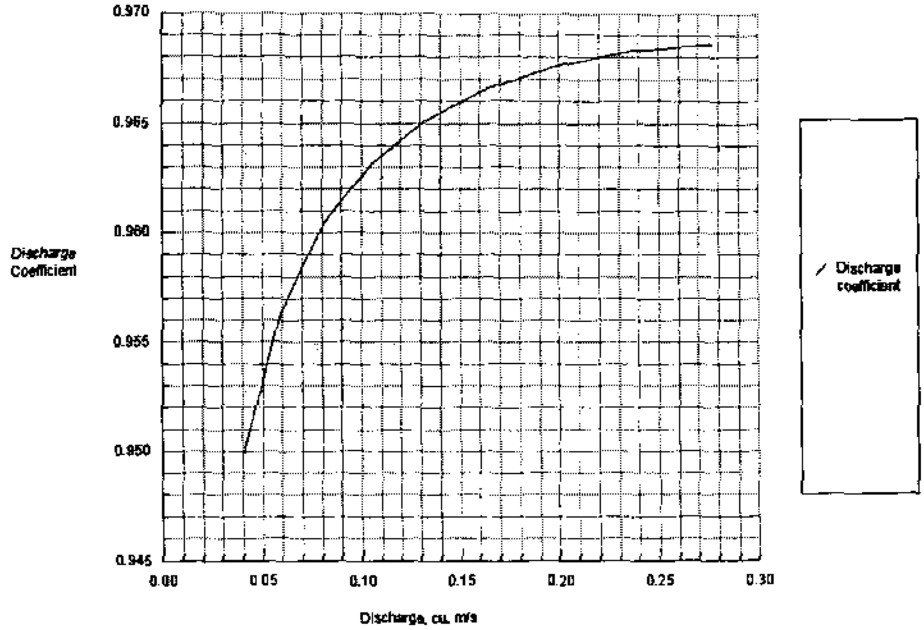


Fig (5.7)
Relation between discharge & discharge coefficient
for sample 3

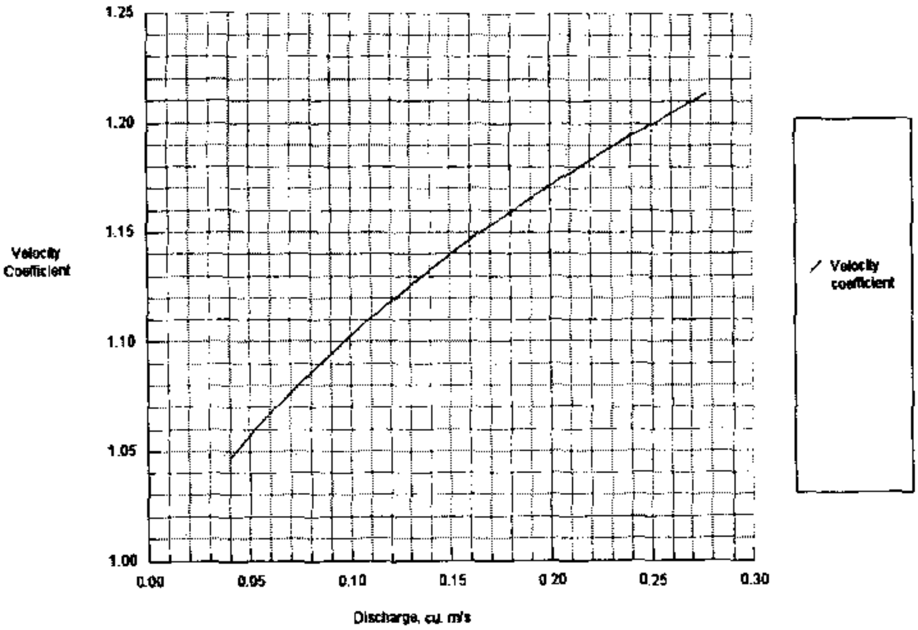


Fig (5.8)
Relation between discharge & velocity coefficient
for sample 3

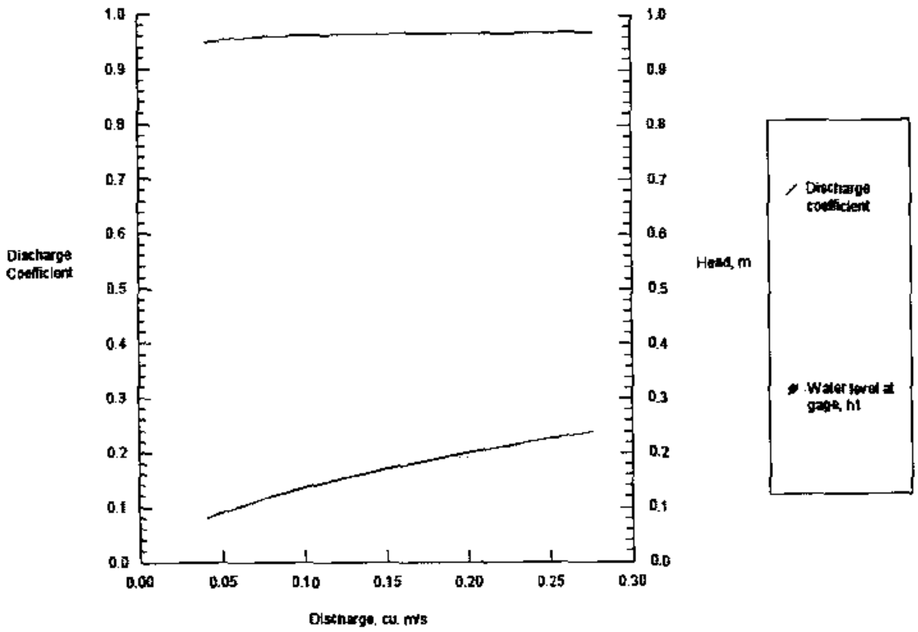


Fig (5.9)

Relation between discharge coefficient, discharge & head for sample 3

Table (5.7)

Equation rating for sample 3

h1 Sill Referenced Head at Gage meters	Q Theoretical Discharge cu. m/s	Q_fit Curve Fit Equation Discharge cu. m/s	D=Q_fit-Q Difference cu. m/s	(D/Q)*100% Difference %	Warnings
0.156	0.100	0.100	0.000	+0.07	10
0.232	0.200	0.200	0.000	-0.19	10
0.289	0.300	0.300	0.000	+0.01	10
0.337	0.400	0.400	0.000	+0.12	10
0.380	0.500	0.501	+0.001	+0.10	10
0.417	0.600	0.600	0.000	+0.01	10
0.452	0.700	0.699	-0.001	-0.12	1, 10

Equation: $Q\_fit = K1 * (h1 + K2) \wedge u$

Parameters:

K1 = 3.138

K2 = 0.03546

u = 2.087

Coefficient of determination: 0.99999715

Theoretical discharge (Q) is determined by the WinFlume model, using hydraulic theory and empirical relationships determined from laboratory testing. It is the most accurate estimate of discharge. Curve fit discharge (Q_fit) is computed with the equation above, which was fitted to the theoretical discharge values. The 'difference' columns show the difference between the flow rates computed from the simplified equation and those obtained from the theoretical WinFlume model.

Summary of Warning Messages

1 - Froude number exceeds 0.5 at the gage.
10 - Converging section is too short (ramp is too steep).

Table (5.8)

Rating table comparison for sample 3

Head at Gage, h1 m	Measured Discharge cu. m/s	Theoretical Discharge cu. m/s	Discharge Difference cu. m/s	Discharge Difference %	Upstream Energy Head, m	Upstream Velocity m/s	Discharge Coeff.	Velocity Coeff.	Tailwater Head, h2 m
0.050	0.002	0.019	-0.02	-89.38	0.051	0.116	0.933	1.022	-0.130
0.100	0.048	0.059	-0.01	-18.65	0.104	0.281	0.956	1.066	-0.061

Summary of Warning Messages

5 - Upstream energy head / control section length is less than 0.07.
10 - Converging section is too short (ramp is too steep).

Table(5.9)
Rating table for sample 3

Head at Gage, h1 meters	Discharge m^3/s	Froude Number	Required Head Loss m	H1/L Ratio	Upstream Energy Head, m	Submerge. Ratio	Warnings
0.080	0.020	0.232	0.036	0.157	0.157	0.000	10
0.100	0.033	0.297	0.042	0.212	0.212	0.273	10
0.120	0.045	0.353	0.047	0.269	0.269	0.465	10
0.140	0.058	0.402	0.051	0.327	0.327	0.591	10
0.160	0.073	0.444	0.055	0.386	0.386	0.680	10
0.180	0.092	0.481	0.057	0.445	0.445	0.745	10
0.200	0.114	0.513	0.060	0.505	0.505	0.795	1,10
0.220	0.137	0.542	0.062	0.565	0.565	0.835	1,10
0.240	0.160	0.568	0.064	0.626	0.626	0.867	1,10

Summary of Warning Messages

1 - Froude number exceeds 0.5 at the gage.
10 - Converging section is too short (ramp is too steep).

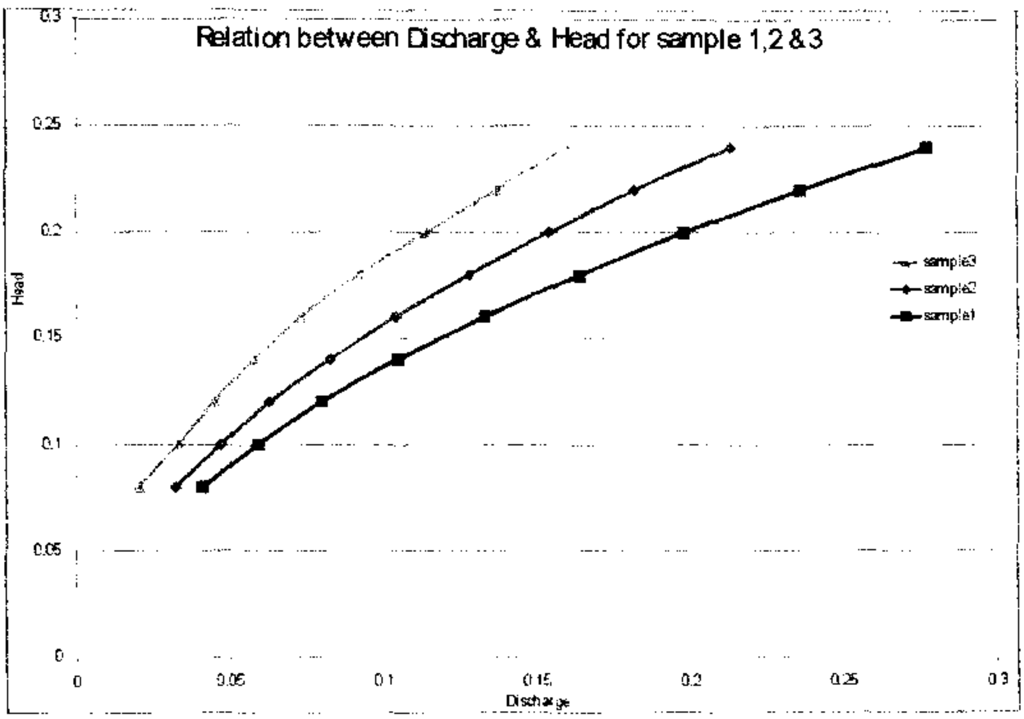

Relation between Discharge & Head for sample 1,2 & 3
Head
Discharge
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.05
0.1
0.15
0.2
0.25
0.3
sample3
sample2
sample1

Fig (5.10)

5.5 Discussion

The fig (5.10) shows above that the head of varies discharge for three samples vary as increase the discharge with head and with length of throat.

The first sample explain the dimension of flume and gives the curve between head and discharge and increasing the discharge cause the increasing the head.

The second sample explain less dimension of flume cause the decreasing of discharge and increasing of head.

The third sample explain less dimension of the flume of the second cause the decreasing the discharge and increasing the head.

For the same discharge and assume the discharge is(0.15)m^3/sec.
The head of sample (1) is (0.17)m and the sample (2) is (0.2)m and the sample (3) is (0.24)m.
There is refer that with a constant discharge will be increasing for the head three sample different dimensions

Summery

This project is give the relationship between discharge , head and slope in open channel when using long throated flume and get result that help operator to get the difference if the slope are changed as in the fifth chapter by using Winflume program and take their result as three sample and discus there result as graphic to see the difference between them and the effect of each part of the design of the three channel when the discharge is fixed and make some study to see the theoretical equations and get there derivative from there source as in chapter two.

References

- **Chow,V.T,1959,open Channel flow , McGrow_Hill, NewYork**
- **Winflume User's Manual Version 1.05-september 2001**
- **Jhon A. Rrobeson ett. Al."Hydraulic Engineering" John Wiley and Sons,Inc.1998**
- **United State Geological Survey ,1953 Computation of peak**
- **discharge at Contractions , USGS Circular No.284.**
- **The Winflume program on the Internet at** http://www.usbr.gov/pmts/hydraulics_lab/winflume/
- **Water Measurement with Flumes and Weirs (Clemmens, Wahl, Bos and Replogle 2001). This book is available from International Institute for Land Reclamation and Improvement,** www.ilri.nl