13.17.06 RBC FLUME

OPERATING INSTRUCTIONS

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1. Introduction

For the management of irrigation systems it is important that the quantity of water flowing through canals can be measured accurately. In the field of irrigation this is called discharge (flow rate). Discharge is the amount of water flowing through a canal at a certain place at a certain time. The flow rate is usually expressed in litres per second or cubic meters per hour.

The flow rate data are used for the design and monitoring of irrigation canals. This allows for the design of an efficient water distribution system in which a surplus or waste of water is avoided as much as possible. The flow rate is measured frequently in particular at canal splitting or separation structures. At section level it is important to know the flow rate in order to determine whether the crop receives sufficient water.
These operating instructions give brief information on how to use the RBC flume. For detailed information on flumes is referred to literature as listed in appendix 1.

2. The flumes of Eijkelkamp Agrisearch Equipment

Flumes are designed in different types and sizes. Eijkelkamp Agrisearch Equipment offers a trapezium shaped RBC (Clemmens et al. 1984) flume for four flow rate ranges (0.16 - 9.0; 0.93 - 50; 1.55 - 86 and 2.0 - 145 l/s). Compared to the WSC and the Parshall flumes the RBC flume is the most accurate. Compared to other shapes, the trapezium shaped flumes have two more important advantages:

- ❐ Accurate for a wide range of flow rates;
- ❐ Fits better in canals which often are trapezium shaped by design (more reliable flow pattern upstream of the flume and inside the flume).

The RBC flumes are designed mainly for use in furrows or other small earthen canals. All flumes can be equipped with a data logger and a pressure sensor.
This allows for automatic measuring (or activation), storage and reading.

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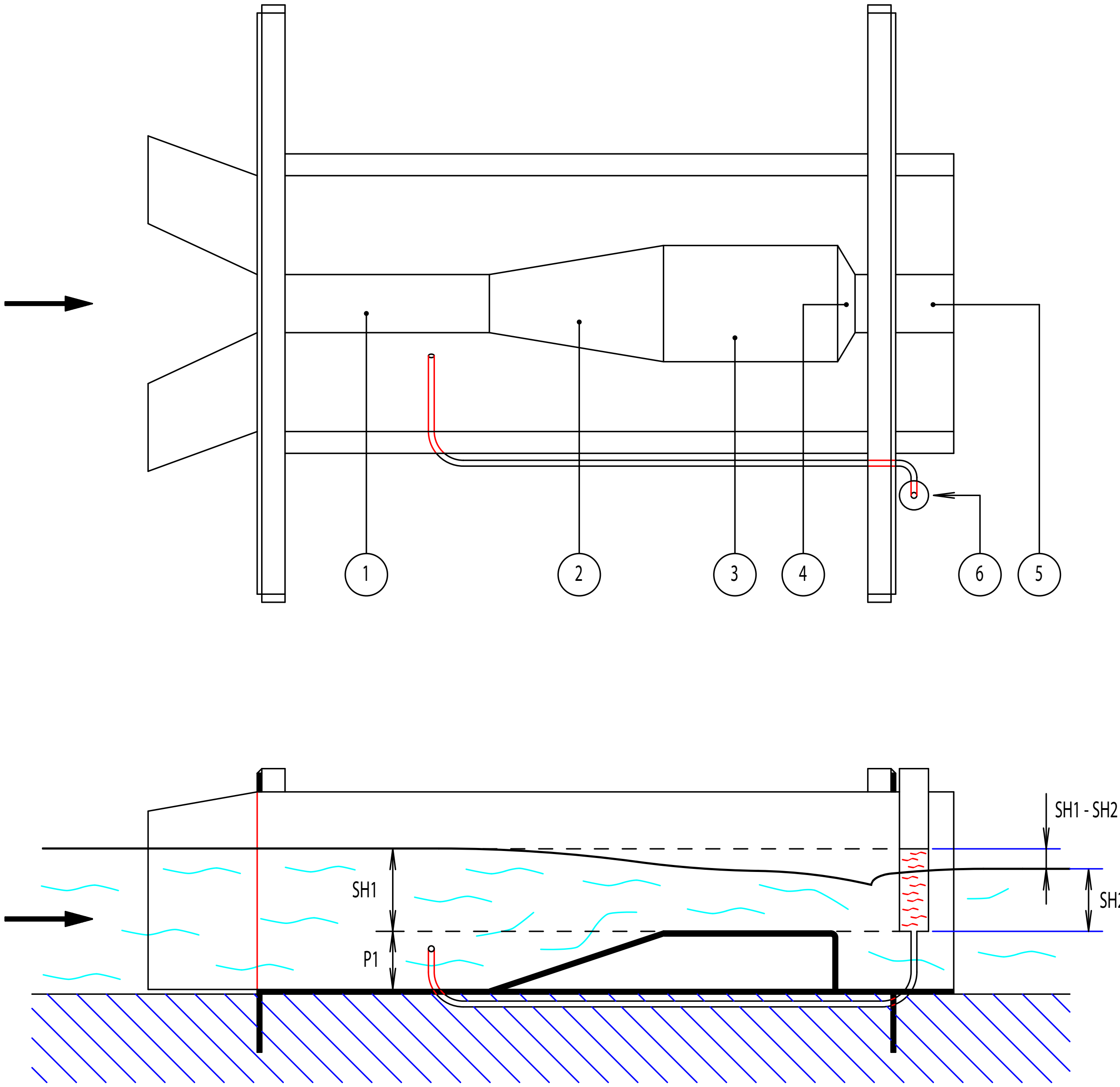


Fig. 1. Top view (above) and side view of the flow profile in the RBC flume.

3. Principles of discharge-measuring flumes

For field measurement of the flow rate in small, usually earthen, irrigation canals, discharge-measuring flumes can be applied. Discharge-measuring flumes for small canals usually are compact and easy to use and transport.

A discharge-measuring flume is illustrated in figure 1 and consists of:

1. Approach section.
2. A converging section in which the speed of the water increases.
3. A throat section, a sill where the speed is increased further.
4. The throat section discharges into a diverging outlet where the flow rate is reduced to its original value. The Eijkelkamp flume has an abrupt transition: the diverging section has a length of 0 cm.
5. A tail water section where the water level is controlled by flow downstream.
6. A measuring tube (stilling well).

In figure 1, the mechanism of a discharge-measuring flume is illustrated:
Water enters the approach section of the flume (1) as indicated by the arrow. The converging section (2) causes an increase of the flow rate in the flume. This flow rate is further increased in the throat section (3). The diverging section (4) of the Eijkelkamp flume has a length of 0 cm, so the water drops immediately to its original value.
The increase of the flow rate causes a reduction of the water level in the tail water section (5), and results in a drop in water stage (SH1 - SH2) inside of the flume. By constructing a flume in this way, the theoretical preconditions are realised allowing the flow rate to be determined by only measuring the water level (SH1) in the flume.
The water level is measured using a stilling well, which has its inlet upstream of the flume. The measured water level is referenced to the sill level (P1).

The sill-referenced water level is converted to discharge or flow rate, using tables or graphs.
The relation between water level SH1 and flow rate (specific to the 13.17.06 Eijkelkamp RBC flume) is given in appendices 4 and 5.
Data in this table and graph are determined using the computer program FLUME (1993), which is developed for assisting in the design and calibration of flumes. For instance, FLUME gives information on the required head loss needed to create optimal measuring conditions.
It can also be used for predicting the flow rate through the flume.
An explanation of the output parameters of the FLUME software is given in appendix 3.

If an automated flume is used, and data are already stored in (spreadsheet importable) files, it is much more convenient to calculate the flow rate in stead of using tables or graphs.

Based on the regression line of the graph in appendix 5, the following equation is used for the
13.17.06 Eijkelkamp flume

$$Q = 3E\text{-}07 \cdot (SH1)^3 + 0.0011 \cdot (SH1)^2 + 0.0569 \cdot (SH1) - 0.4778$$

With Q (discharge) in litres per second
and SH1 (sill referenced water level) in millimeter.

4. Selection and location of the flume

Selection

Before starting discharge measurements the best type of flume for the chosen application has to be selected.
Usually, from a point of view of economy as well as accuracy, the smallest possible type of flume is selected for the flow rate measurement in a canal. As a general rule this is a flume with a top width of approximately 1/3 or ½ times the width of the canal. As no flow rate measurements are possible without a water-level head, a flume must be used which allows the passage of the 'estimated' flow and which provides the required sill-referenced head. The following table can be used as an indication of the discharge capacity of the flume and the required sill-referenced head.

flume type (art. no)	minimum flow (l/s)	maximum flow (l/s)	required head (SH1 - SH2) (mm)
13.17.02	0.16	9.0	20
13.17.04	0.93	50.0	40
13.17.06	1.55	86.0	50
13.17.08	2.00	145.0	60

In addition of the type of flume, also the type of data registration has to be selected: manually versus automatically.

In case of an automated flume, the sill-referenced water level is recorded using a very accurate pressure sensor connected to a data logger.
Advantages of automatic registration over a manual determination of the flow rate are:

- Maximum and minimum values are recorded in relation to time, from which the response rate of the discharge can be deduced.
- Average discharge rates as well as the cumulative discharge are accurately determined by continuous recording.
- Automatically recording flow rates is less time consuming and is very convenient in remote areas.
- High flow rates during rain periods can selectively be recorded.

Location

The flume is placed in the centre of the flow with the stilling well located at the end of the tail water section. The supply flow should preferably be straight and without any head over a substantial distance (a distance of 10 times the average channel width).

The channel bed in the approach section to a certain extend must not be porous because:
a. all the water must flow through the flume in order to obtain reliable measurements.
b. the flume can be undercut and will subside by erosion.
Erosion of the supply channels must be limited in order to prevent pollution or blockage of the flume. The flume must be installed level in vertical as well as in horizontal direction in order to avoid that the flow profile (and thus the measurements) is influenced. If the flume is not installed level in the longitudinal direction then this can easily yield a measuring error of 3%. The vertical direction yields a less important error (approximately 0.5%). Placing the flume upright in the vertical direction of flow of the water can be realised by holding the upstream side of the flume parallel to the water surface. In the longitudinal direction a level can be used.

Both sides of the flume must be sealed (filled up with earth) to prevent water from flowing along side of it. The effluent water must be able to run off unobstructedly and should not hinder the influent water. The flume should not be placed at a depth at which it disappears under the water level (submerged condition). Installing the flume too shallow is not a real problem as the water will soon accumulate in front of the flume (damming up) and an equilibrium water level will soon establish itself.

In case of an automated flume, the pressure sensor protrudes from under the flume. This should be taken into account when installing the flume in order to avoid damaging the sensor. The complete stilling well can be demounted as to facilitate installation. The data logger is placed on a separate mounting base which allows to read the data logger without having to stand in the canal.

5. Measurements using the flume

After the flume is placed into the canal, the conditions as described in chapter 4 are met and the water level in the flume has become in equilibrium with the new situation, discharge measurements can be started. As already described, using the Eijkelkamp RBC flume, only the sill-referenced water level has to be measured to determine discharge.

The water level in the approach section of a flume can be measured in several ways:

- Graduation fitted on the side of the approach section.
- Level measurement via surface level measurement (for instance ultrasonic).
- Level measurement applying a stilling well.

In the Eijkelkamp RBC flumes, the stilling well is used for measuring the water level without the need to measure inside the flume itself and disturbing the level in the process (wave action caused by current and wind). The still also dampens water level fluctuations caused by longitudinal flowing water in the flume. The passage towards the stilling well is provided in the wall of the approach section under the sill height. In order to avoid blocking by debris or sediment, the opening is located slightly raised from the bottom of the flume.
After the water level has been measured in the stilling well and referenced to the sill height, the discharge is determined, either by using the table in appendix 4, the discharge graph in appendix 5 or the formula in chapter 3.

The frequency of measurements, or the time interval between successive measurements, completely depends on the user wished application of the flume.
If one wants to make a continuous registration of the discharge rate of a natural stream, it is important to carry out measurements at the same points of time, as to minimise the effect of natural daily discharge fluctuations.
If one wants to determine maximum discharge rates after heavy rainfall, the frequency of measurements will be low during dry periods, but very high during splash rains.

6. Maintenance and measuring problems

Inside the flume and the stilling well pollution in the form of sediment, waste, algal growth, weeds etc. may accumulate in time. For this reason the flume and in particular the stilling well and the supply must be checked for pollution frequently. In case of blockage of the supply towards the measuring opening this line can be blown through. In case of measuring problems with the automated flume the pressure sensor should be handled with care. The sensor can only sustain limited over pressure. By slackening the lower ring of the stilling well the sensor can be demounted for cleaning.

To prevent damage of the sensor this must be removed when temperature drops below zero.

If the flume is not working properly, or if there is any doubt regarding the flow profile or the installation, the necessary flow profile can be obtained by raising the entire flow a small amount. Or if that is not feasible, the same result may be obtained by lowering and cleaning the canal for a short distance downstream so that the water may flow freely away below the flume.

Appendix 1: References

Bos, M.G. (editor). 1989. Discharge Measurement Structures . Third revised version. ILRI Publication no. 20. The Netherlands.

Bos, M.G. and J.A. Replogle. 1984. Flow Measuring Flumes for Open Channel Systems. A Wiley-Intersience Publication. John Wiley & Sons. New York.

Bos, M.G. (editor). 1976. Discharge Measurement Structures. Published in co-operation with ILRI and Wageningen Agricultural University, Department of Hydraulics and Irrigation. Publication no. 161.

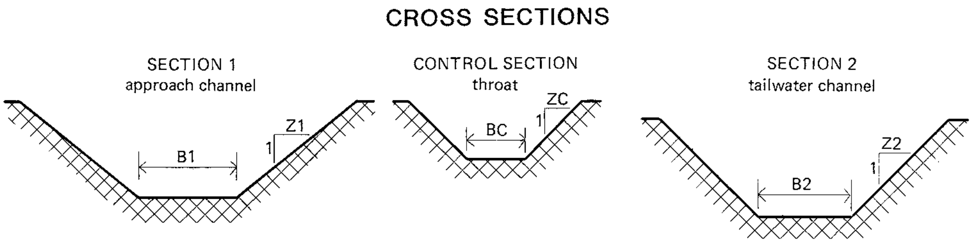
Clemmens, A.J., M.J. Bos and J.A. Replogle. 1993. FLUME Design and Calibration of Long-Throated Measuring Flumes. Version 3. ILRI Publication no. 54. The Netherlands. Including 1 HD disk.

Eijkelkamp. Operating Instructions 13.17.10.06 Flume Software.

Withers, B. and S. Vipont. 1988. Irrigation: Design and Practice. BT Batsford Limited. Londen.

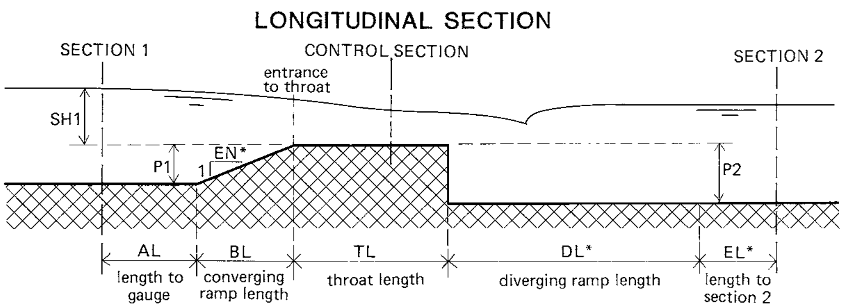
Appendix 2: RBC Flume 13.17.06 Data

Cross section data:



Approach channel, simple trapezoid:	Bottom width	B1	=	.125 m
	Side slope	Z1	=	.500 : 1
Throath section, simple trapezoid:	Bottom width	BC	=	.250 m
	Side slope	ZC	=	.500 : 1
Tailwater channel, simple trapezoid:	Bottom width	B2	=	.125 m
	Side slope	Z2	=	.500 : 1

Longitudinal section data:



SH1	=	Sill-referenced head		
AL	=	Distance between converging ramp and gauging station	=	0.125 m
BL	=	Converging ramp length	=	0.375 m
TL	=	Throath length	=	0.375 m
P1	=	Sill height relative to approach channel	=	0.125 m
P2	=	Sill height relative to tail water channel	=	0.125 m
EN*	=	Converging transition ratio (hor./vert.)	=	3.000:1
DL*	=	Diverging ramp length	=	0
EL*	=	Length to section 2	=	3.125 m
SH2	=	Sill-referenced head in tail water section		
SH1-SH2	=	Head loss		
RK	=	Absolute roughness height of material	=	0.0001 m

An * indicates that these data are not specified by the user

Appendix 3: Explanation of program output for computed rating table

Column	Value	Description
1	$SH1 = h_1$	The sill-referenced head. This is the head measured at the gauging station for determining discharge.
2	Q	The predicted flow rate for the given h_1.
3*	$FR1 = Fr_1$	The Froude number of the flow in the approach channel. This value should be less than 0.5 in all cases and less than 0.45 when the approach conditions are not totally smooth.
4	$H1/TL = H_1/L$	The ratio of energy head to throath length. The head, h_1, over which rating can be reliably computed is limited to $0.075 < H_1/L < 0.75$
5	$CD = C_d$	Discharge coefficient, the ratio between actual and ideal flow.
6	$CV = C_v$	The velocity coefficient which is computed for reference purposes only. It is the ratio between flow based on energy head, H_1, and water depth h_1
7	DH = DH	This is the required energy loss across the flume, $H_2 - H_1$. This may differ from the required difference in water levels, $Dh = h_2 - h_1$
8	$Y2 = y_2$	This is the maximum flow depth in the tail water channel for which there is no influence of this depth on the Q - h_1 relationship, $y_2 = h_2 + p_2$
9	ML	This is the modular limit defined in terms of the ratio of downstream to upstream energy heads, H_2/H_1, at the limit between modular and nonmodular flow. Modular flow exists when the Q - h_1 relationship is not affected by the flow in the tail water channel.

* = the Froude number F1 at the gauging station is defined as:

$$Fr_1 = \frac{v_1}{\sqrt{(gA_1/B_1)}}$$

with:

v_1 = the average flow velocity at the gauging station
g = the acceleration due to gravity
A_1 = the cross sectional area perpendicular to the flow
B_1 = the water surface width at the gauging station.

The Froud number gives an indication for the expected turbulence. When there is a rapid change in depth of flow from a low to a high stage, the water level will rise abruptly, creating a hydraulic jump, visible through its turbulence. The higher the Froud number, the higher the turbulence.
To obtain a relatively smooth water surface for which the elevation can be determined accurately, the Froud number should not exceed 0.5.

For channels with high sediment loads, the Froude number should be kept high in order to prevent sedimentation.

APPENDIX 4-5 DATA FROM COMPUTER PROGRAM FLUME

Appendix 4: Rating table RBC flume 13.17.06

SILL REFER. LIMIT HEAD	**FLOW RATE**	FROUDE NO.		DISH. COEFF.	VELOC. COEFF.	REQ'D HEAD LOSS	MAX. T-WATER DEPTH	MODULAR
SHI MM	**Q LIT/SEC**	FR1	H1/TL	CD	CV	DH MM	Y2 MM	
15.0	0.715	0.026	0.040	0.8910	1.0040	5.3	134.6	0.649
16.0	0.795	0.029	0.043	0.8981	1.0040	5.5	135.3	0.655
17.0	0.879	0.031	0.045	0.9044	1.0050	5.8	136.1	0.661
18.0	0.965	0.034	0.048	0.9099	1.0050	6.0	136.8	0.672
20.0	1.146	0.039	0.054	0.9193	1.0060	6.5	138.4	0.677
21.0	1.241	0.042	0.056	0.9233	1.0070	6.7	139.2	0.682
22.0	1.339	0.045	0.059	0.9269	1.0080	6.9	140.0	0.687
23.0	1.439	0.047	0.062	0.9302	1.0080	7.1	140.7	0.692
24.0	1.542	0.050	0.064	0.9332	1.0090	7.3	141.5	0.696
25.0	1.647	0.053	0.067	0.9359	1.0100	7.5	142.3	0.701
26.0	1.755	0.056	0.070	0.9384	1.0110	7.7	143.1	0.705
27.0	1.866	0.059	0.073	0.9408	1.0110	7.9	143.9	0.709
28.0	1.979	0.062	0.075	0.9430	1.0120	8.1	144.8	0.714
29.0	2.095	0.064	0.078	0.9451	1.0130	8.3	145.6	0.718
30.0	2.213	0.067	0.081	0.9470	1.0140	8.4	146.4	0.721
31.0	2.333	0.070	0.083	0.9486	1.0140	8.6	147.2	0.725
32.0	2.456	0.073	0.086	0.9503	1.0150	8.8	148.1	0.729
33.0	2.582	0.076	0.089	0.9518	1.0160	8.9	148.9	0.732
34.0	2.710	0.079	0.092	0.9532	1.0170	9.1	149.8	0.736
35.0	2.840	0.082	0.094	0.9545	1.0180	9.2	150.6	0.739
36.0	2.973	0.084	0.097	0.9558	1.0180	9.4	151.4	0.743
37.0	3.108	0.087	0.100	0.9570	1.0190	9.5	152.3	0.746
38.0	3.246	0.090	0.103	0.9581	1.0200	9.6	153.2	0.749
39.0	3.386	0.093	0.105	0.9590	1.0210	9.8	154.0	0.753
40.0	3.528	0.096	0.108	0.9601	1.0220	9.9	154.9	0.756
41.0	3.673	0.099	0.111	0.9610	1.0230	10.0	155.7	0.759
42.0	3.820	0.101	0.114	0.9620	1.0240	10.2	156.6	0.762
43.0	3.969	0.104	0.116	0.9628	1.0250	10.3	157.5	0.765
44.0	4.121	0.107	0.119	0.9637	1.0260	10.4	158.4	0.767
45.0	4.275	0.110	0.122	0.9645	1.0260	10.5	159.2	0.770
46.0	4.432	0.113	0.125	0.9652	1.0270	10.6	160.1	0.773
47.0	4.590	0.116	0.128	0.9661	1.0280	10.7	161.0	0.776
48.0	4.751	0.118	0.130	0.9668	1.0290	10.8	161.9	0.778
49.0	4.914	0.121	0.133	0.9674	1.0300	10.9	162.8	0.781
50.0	5.080	0.124	0.136	0.9681	1.0310	11.0	163.7	0.783
51.0	5.248	0.127	0.139	0.9687	1.0320	11.1	164.6	0.786
52.0	5.418	0.129	0.142	0.9692	1.0330	11.2	165.5	0.788
53.0	5.591	0.132	0.144	0.9697	1.0340	11.3	166.4	0.791
54.0	5.765	0.135	0.147	0.9702	1.0350	11.4	167.3	0.793
55.0	5.942	0.138	0.150	0.9708	1.0360	11.5	168.2	0.795
56.0	6.122	0.140	0.153	0.9713	1.0370	11.6	169.1	0.798
57.0	6.303	0.143	0.156	0.9719	1.0380	11.7	170.0	0.800
58.0	6.487	0.146	0.158	0.9722	1.0390	11.8	170.9	0.802
59.0	6.673	0.148	0.161	0.9728	1.0400	11.8	171.8	0.804
60.0	6.862	0.151	0.164	0.9731	1.0410	11.9	172.7	0.806
61.0	7.053	0.154	0.167	0.9735	1.0420	12.0	173.6	0.808
62.0	7.246	0.156	0.170	0.9741	1.0430	12.1	174.5	0.810
63.0	7.441	0.159	0.173	0.9745	1.0440	12.1	175.4	0.812
64.0	7.639	0.162	0.175	0.9749	1.0450	12.2	176.4	0.814

SILL REFER. LIMIT **HEAD SHI MM**	**FLOW RATE Q LIT/SEC**	FROUDE NO. FR1	H1/TL	DISH. COEFF. CD	VELOC. COEFF. CV	REQ'D HEAD LOSS DH MM	MAX. T-WATER DEPTH Y2 MM	MODULAR
65.0	7.839	0.164	0.178	0.9753	1.0460	12.3	177.3	0.816
66.0	8.040	0.167	0.181	0.9756	1.0470	12.3	178.2	0.818
67.0	8.245	0.170	0.184	0.9760	1.0480	12.4	179.1	0.820
68.0	8.452	0.172	0.187	0.9763	1.0490	12.5	180.0	0.822
69.0	8.661	0.175	0.190	0.9767	1.0500	12.5	181.0	0.824
70.0	8.872	0.177	0.193	0.9770	1.0510	12.6	181.9	0.826
71.0	9.085	0.180	0.195	0.9773	1.0520	12.7	182.8	0.827
72.0	9.301	0.182	0.198	0.9776	1.0530	12.7	183.7	0.829
73.0	9.519	0.185	0.201	0.9780	1.0540	12.8	184.7	0.831
74.0	9.740	0.187	0.204	0.9783	1.0550	12.8	185.6	0.832
75.0	9.962	0.190	0.207	0.9785	1.0560	12.9	186.5	0.834
76.0	10.187	0.192	0.210	0.9788	1.0570	12.9	187.5	0.836
77.0	10.415	0.195	0.213	0.9791	1.0580	13.0	188.4	0.837
78.0	10.644	0.197	0.216	0.9794	1.0590	13.0	189.3	0.839
79.0	10.876	0.200	0.218	0.9796	1.0600	13.1	190.3	0.840
80.0	11.110	0.202	0.221	0.9799	1.0610	13.1	191.2	0.842
81.0	11.346	0.205	0.224	0.9801	1.0620	13.2	192.2	0.843
82.0	11.585	0.207	0.227	0.9804	1.0630	13.2	193.1	0.845
83.0	11.826	0.210	0.230	0.9806	1.0640	13.3	194.0	0.846
84.0	12.069	0.212	0.233	0.9809	1.0650	13.3	195.0	0.848
85.0	12.315	0.214	0.236	0.9811	1.0660	13.4	195.9	0.849
86.0	12.563	0.217	0.239	0.9813	1.0670	13.4	196.9	0.850
87.0	12.813	0.219	0.242	0.9815	1.0680	13.4	197.8	0.852
88.0	13.065	0.222	0.245	0.9817	1.0690	13.5	198.8	0.853
89.0	13.320	0.224	0.248	0.9820	1.0700	13.5	199.7	0.854
90.0	13.577	0.226	0.250	0.9822	1.0710	13.5	200.6	0.856
91.0	13.836	0.229	0.253	0.9824	1.0720	13.6	201.6	0.857
92.0	14.098	0.231	0.256	0.9826	1.0730	13.6	202.5	0.858
93.0	14.362	0.233	0.259	0.9828	1.0740	13.7	203.5	0.860
94.0	14.628	0.235	0.262	0.9830	1.0750	13.7	204.5	0.861
95.0	14.897	0.238	0.265	0.9831	1.0760	13.7	205.5	0.862
96.0	15.168	0.240	0.268	0.9833	1.0770	13.8	206.4	0.863
97.0	15.441	0.242	0.271	0.9835	1.0780	13.8	207.3	0.864
98.0	15.717	0.244	0.274	0.9837	1.0790	13.8	208.3	0.865
99.0	15.995	0.247	0.277	0.9839	1.0800	13.8	209.2	0.867
100.0	16.275	0.249	0.280	0.9840	1.0810	13.9	210.1	0.868
101.0	16.557	0.251	0.283	0.9842	1.0820	13.9	211.1	0.869
102.0	16.842	0.253	0.286	0.9844	1.0830	13.9	212.0	0.870
103.0	17.129	0.255	0.289	0.9845	1.0840	13.9	212.9	0.871
104.0	17.419	0.258	0.292	0.9847	1.0850	14.0	214.0	0.872
105.0	17.711	0.260	0.295	0.9849	1.0860	14.0	214.9	0.873
106.0	18.005	0.262	0.298	0.9850	1.0870	14.0	215.9	0.874
107.0	18.299	0.264	0.300	0.9850	1.0880	14.1	216.8	0.875
108.0	18.598	0.266	0.303	0.9852	1.0890	14.1	217.8	0.876
109.0	18.899	0.268	0.306	0.9854	1.0900	14.1	218.8	0.877
110.0	19.203	0.270	0.309	0.9855	1.0910	14.1	219.7	0.878
111.0	19.509	0.273	0.312	0.9856	1.0920	14.1	220.7	0.879
112.0	19.817	0.275	0.315	0.9858	1.0930	14.2	221.6	0.880
113.0	20.128	0.277	0.318	0.9859	1.0940	14.2	222.6	0.881
114.0	20.441	0.279	0.321	0.9861	1.0950	14.2	223.6	0.882
115.0	20.756	0.281	0.324	0.9862	1.0960	14.2	224.5	0.883
116.0	21.074	0.283	0.327	0.9864	1.0970	14.3	225.5	0.884

SILL **REFER.** LIMIT **HEAD** **SHI** **MM**	**FLOW** **RATE** **Q** **LIT/SEC**	FROUDE NO. FR1	Hl/TL	DISH. COEFF. CD	VELOC. COEFF. CV	REQ'D HEAD LOSS DH MM	MAX. T-WATER DEPTH Y2 MM	MODULAR
117.0	21.394	0.285	0.330	0.9865	1.0980	14.3	226.4	0.885
118.0	21.716	0.287	0.333	0.9866	1.0990	14.3	227.4	0.886
119.0	22.041	0.289	0.336	0.9868	1.1000	14.3	228.4	0.887
120.0	22.368	0.291	0.339	0.9869	1.1010	14.3	229.3	0.887
121.0	22.701	0.293	0.342	0.9872	1.1020	14.3	230.3	0.888
122.0	23.033	0.295	0.345	0.9873	1.1030	14.4	231.3	0.889
123.0	23.367	0.297	0.348	0.9874	1.1040	14.4	232.2	0.890
124.0	23.704	0.299	0.351	0.9875	1.1050	14.4	233.2	0.891
125.0	24.043	0.301	0.354	0.9877	1.1060	14.4	234.1	0.892
126.0	24.384	0.303	0.357	0.9878	1.1070	14.4	235.1	0.892
127.0	24.728	0.305	0.360	0.9878	1.1080	14.4	236.1	0.893
128.0	25.075	0.307	0.363	0.9879	1.1090	14.4	237.0	0.894
129.0	25.423	0.309	0.366	0.9880	1.1100	14.5	238.0	0.895
130.0	25.775	0.311	0.369	0.9881	1.1110	14.5	239.0	0.896
131.0	26.125	0.312	0.372	0.9881	1.1120	14.5	239.9	0.896
132.0	26.481	0.314	0.375	0.9883	1.1130	14.5	240.9	0.897
133.0	26.839	0.316	0.378	0.9884	1.1130	14.5	241.9	0.898
134.0	27.200	0.318	0.381	0.9885	1.1140	14.5	242.8	0.898
135.0	27.563	0.320	0.384	0.9886	1.1150	14.5	243.8	0.899
136.0	27.929	0.322	0.387	0.9888	1.1160	14.5	244.8	0.900
137.0	28.297	0.324	0.391	0.9889	1.1170	14.6	245.7	0.901
138.0	28.668	0.325	0.394	0.9890	1.1180	14.6	246.7	0.901
139.0	29.041	0.327	0.397	0.9891	1.1190	14.6	247.7	0.902
140.0	29.416	0.329	0.400	0.9892	1.1200	14.6	248.6	0.903
141.0	29.794	0.331	0.403	0.9894	1.1210	14.6	249.6	0.903
142.0	30.174	0.333	0.406	0.9895	1.1220	14.6	250.6	0.904
143.0	30.557	0.334	0.409	0.9896	1.1230	14.6	251.5	0.905
144.0	30.942	0.336	0.412	0.9897	1.1240	14.6	252.5	0.905
145.0	31.330	0.338	0.415	0.9898	1.1250	14.6	253.5	0.906
146.0	31.720	0.340	0.418	0.9899	1.1260	14.6	254.4	0.907
147.0	32.112	0.342	0.421	0.9900	1.1270	14.6	255.4	0.907
148.0	32.507	0.343	0.424	0.9901	1.1280	14.6	256.4	0.908
149.0	32.905	0.345	0.427	0.9902	1.1290	14.6	257.3	0.909
150.0	33.304	0.347	0.430	0.9903	1.1300	14.7	258.3	0.909
151.0	33.707	0.349	0.433	0.9904	1.1300	14.7	259.3	0.910
152.0	34.112	0.350	0.436	0.9905	1.1310	14.7	260.2	0.910
153.0	34.519	0.352	0.439	0.9906	1.1320	14.7	261.2	0.911
154.0	34.929	0.354	0.442	0.9908	1.1330	14.7	262.2	0.912
155.0	35.341	0.355	0.445	0.9909	1.1340	14.7	263.1	0.912
156.0	35.756	0.357	0.448	0.9910	1.1350	14.7	264.1	0.913
157.0	36.176	0.359	0.452	0.9911	1.1360	14.7	265.1	0.913
158.0	36.596	0.360	0.455	0.9912	1.1370	14.7	266.2	0.914
159.0	37.018	0.362	0.458	0.9913	1.1380	14.7	267.2	0.914
160.0	37.443	0.364	0.461	0.9914	1.1390	14.7	268.1	0.915
161.0	37.867	0.365	0.464	0.9914	1.1400	14.7	269.1	0.915
162.0	38.297	0.367	0.467	0.9917	1.1410	14.7	270.1	0.916
163.0	38.729	0.369	0.470	0.9918	1.1410	14.7	271.1	0.916
164.0	39.164	0.370	0.473	0.9918	1.1420	14.7	272.0	0.917
165.0	39.601	0.372	0.476	0.9919	1.1430	14.7	273.0	0.917
166.0	40.041	0.373	0.479	0.9920	1.1440	14.7	274.0	0.918
167.0	40.483	0.375	0.482	0.9921	1.1450	14.8	275.0	0.918
168.0	40.928	0.377	0.485	0.9921	1.1460	14.8	275.9	0.919
169.0	41.375	0.378	0.489	0.9922	1.1470	14.8	276.9	0.919
170.0	41.825	0.380	0.492	0.9923	1.1480	14.8	277.9	0.920

SILL REFER. HEAD	**FLOW RATE**	FROUDE NO.		DISH. COEFF.	VELOC. COEFF.	REQ'D HEAD LOSS	MAX. T-WATER DEPTH	MODULAR LIMIT
SHI MM	**Q LIT/SEC**	FR1	H1/TL	CD	CV	DH MM	Y2 MM	
171.0	42.278	0.381	0.495	0.9924	1.1490	14.8	278.9	0.920
172.0	42.733	0.383	0.498	0.9925	1.1490	14.8	279.8	0.921
173.0	43.190	0.384	0.501	0.9925	1.1500	14.8	280.8	0.921
174.0	43.650	0.386	0.504	0.9926	1.1510	14.8	281.8	0.922
175.0	44.113	0.388	0.507	0.9927	1.1520	14.8	282.8	0.922
176.0	44.578	0.389	0.510	0.9928	1.1530	14.8	283.7	0.923
177.0	45.049	0.391	0.513	0.9929	1.1540	14.8	284.7	0.923
178.0	45.519	0.392	0.516	0.9930	1.1550	14.8	285.7	0.924
179.0	45.992	0.394	0.520	0.9931	1.1560	14.8	286.7	0.924
180.0	46.467	0.395	0.523	0.9932	1.1570	14.8	287.7	0.925
181.0	46.945	0.397	0.526	0.9932	1.1570	14.8	288.6	0.925
182.0	47.426	0.398	0.529	0.9933	1.1580	14.8	289.6	0.926
183.0	47.909	0.400	0.532	0.9934	1.1590	14.8	290.6	0.926
184.0	48.394	0.401	0.535	0.9935	1.1600	14.8	291.6	0.926
185.0	48.883	0.403	0.538	0.9936	1.1610	14.8	292.6	0.927
186.0	49.374	0.404	0.541	0.9937	1.1620	14.8	293.5	0.927
187.0	49.868	0.406	0.544	0.9938	1.1630	14.8	294.5	0.928
188.0	50.345	0.407	0.547	0.9935	1.1630	14.8	295.5	0.928
189.0	50.801	0.408	0.551	0.9927	1.1640	14.8	296.5	0.928
190.0	51.300	0.409	0.554	0.9928	1.1650	14.8	297.5	0.929
191.0	51.802	0.411	0.557	0.9929	1.1660	14.8	298.4	0.929
192.0	52.306	0.412	0.560	0.9929	1.1660	14.8	299.4	0.930
193.0	52.813	0.414	0.563	0.9930	1.1670	14.8	300.4	0.930
194.0	53.323	0.415	0.566	0.9931	1.1680	14.8	301.4	0.930
195.0	53.835	0.416	0.569	0.9930	1.1690	14.8	302.3	0.931
196.0	54.350	0.418	0.572	0.9933	1.1700	14.8	303.3	0.931
197.0	54.867	0.419	0.576	0.9933	1.1710	14.8	304.3	0.932
198.0	55.387	0.421	0.579	0.9933	1.1710	14.8	305.3	0.932
199.0	55.910	0.422	0.582	0.9934	1.1720	14.8	306.2	0.932
200.0	56.435	0.423	0.585	0.9935	1.1730	14.8	307.2	0.933
201.0	56.963	0.425	0.588	0.9935	1.1740	14.8	308.2	0.933
202.0	57.494	0.426	0.591	0.9936	1.1750	14.8	309.2	0.933
203.0	58.027	0.427	0.594	0.9937	1.1760	14.8	310.1	0.934
204.0	58.562	0.429	0.597	0.9938	1.1760	14.8	311.1	0.934
205.0	59.101	0.430	0.601	0.9938	1.1770	14.8	312.1	0.934
206.0	59.642	0.431	0.604	0.9937	1.1780	14.8	313.1	0.935
207.0	60.185	0.433	0.607	0.9938	1.1790	14.8	314.0	0.935
208.0	60.732	0.434	0.610	0.9939	1.1800	14.8	315.0	0.935
209.0	61.280	0.435	0.613	0.9939	1.1800	14.8	316.0	0.936
210.0	61.832	0.437	0.616	0.9940	1.1810	14.8	317.0	0.936
211.0	62.386	0.438	0.619	0.9940	1.1820	14.8	317.9	0.936
212.0	62.943	0.439	0.623	0.9941	1.1830	14.8	318.9	0.937
213.0	63.503	0.440	0.626	0.9942	1.1840	14.8	319.9	0.937
214.0	64.065	0.442	0.629	0.9942	1.1840	14.8	320.9	0.937
215.0	64.630	0.443	0.632	0.9943	1.1850	14.8	321.9	0.938
216.0	65.197	0.444	0.635	0.9943	1.1860	14.8	322.8	0.938
217.0	65.768	0.446	0.638	0.9944	1.1870	14.8	323.8	0.938
218.0	66.341	0.447	0.642	0.9945	1.1880	14.8	324.8	0.939
219.0	66.916	0.448	0.645	0.9945	1.1880	14.8	325.8	0.939
220.0	67.495	0.449	0.648	0.9946	1.1890	14.8	326.7	0.939
221.0	68.075	0.451	0.651	0.9946	1.1900	14.8	327.7	0.939
222.0	68.659	0.452	0.654	0.9947	1.1910	14.8	328.7	0.940
223.0	69.246	0.453	0.657	0.9948	1.1920	14.8	329.7	0.940
224.0	69.835	0.454	0.660	0.9948	1.1920	14.8	330.6	0.940

SILL	**FLOW**	FROUDE		DISH.	VELOC.	REQ'D	MAX.	MODULAR
REFER.	**RATE**	NO.		COEFF.	COEFF.	HEAD	T-WATER	LIMIT
HEAD						LOSS	DEPTH	
SHI MM	**Q LIT/SEC**	FR1	H1/TL	CD	CV	DH MM	Y2 MM	
225.0	70.426	0.456	0.664	0.9949	1.1930	14.8	331.6	0.941
225.0	70.426	0.456	0.664	0.9949	1.1930	14.8	331.6	0.941
226.0	71.021	0.457	0.667	0.9949	1.1940	14.8	322.6	0.941
227.0	71.618	0.458	0.670	0.9950	1.1950	14.8	333.6	0.941
228.0	72.218	0.459	0.673	0.9951	1.1950	14.8	334.5	0.942
229.0	72.820	0.460	0.676	0.9951	1.1960	14.8	335.5	0.942
230.0	73.426	0.462	0.679	0.9952	1.1970	14.8	336.5	0.942
231.0	74.034	0.463	0.683	0.9953	1.1980	14.8	337.5	0.942
232.0	74.644	0.464	0.686	0.9953	1.1990	14.8	338.4	0.943
233.0	75.258	0.465	0.689	0.9954	1.1990	14.7	339.4	0.943
234.0	75.874	0.466	0.692	0.9954	1.2000	14.7	340.4	0.943
235.0	76.493	0.468	0.695	0.9955	1.2010	14.7	341.4	0.943
236.0	77.115	0.469	0.698	0.9956	1.2020	14.8	342.6	0.944
237.0	77.739	0.470	0.702	0.9956	1.2020	14.8	343.6	0.944
238.0	78.366	0.471	0.705	0.9957	1.2030	14.8	344.5	0.944
239.0	78.996	0.472	0.708	0.9958	1.2040	14.8	345.5	0.944
240.0	79.628	0.473	0.711	0.9957	1.2050	14.8	346.5	0.945
241.0	80.264	0.475	0.714	0.9957	1.2050	14.8	347.5	0.945
242.0	80.902	0.476	0.718	0.9958	1.2060	14.8	348.5	0.945
243.0	81.543	0.477	0.721	0.9958	1.2070	14.8	349.5	0.945
244.0	82.187	0.478	0.724	0.9959	1.2080	14.8	350.4	0.946
245.0	82.833	0.479	0.727	0.9959	1.2080	14.8	351.4	0.946
246.0	83.482	0.480	0.730	0.9960	1.2090	14.8	352.4	0.946
247.0	84.134	0.481	0.733	0.9961	1.2100	14.8	353.4	0.946
248.0	84.789	0.482	0.737	0.9961	1.2110	14.8	354.3	0.947
249.0	85.446	0.484	0.740	0.9962	1.2110	14.7	355.3	0.947
250.0	86.107	0.485	0.743	0.9962	1.2120	14.7	356.3	0.947

Appendix 5: Discharge graph

Discharge graph RBC flume 13.17.06 $y = 3E\text{-}07\,x^3 + 0.0011\,x^2 + 0.0569\,x - 0.4778$

$$Q = 3E\text{-}07 \cdot (SH1)^3 + 0.0011 \cdot (SH1)^2 + 0.0569 \cdot (SH1) - 0.4778$$