NEED OF FLOW MEASUREMENT

The branch of engineering science deals with discharge measurement is called "Hydrometery" Management of water resources or engineering mainly depends upon measurement of water at different stages in irrigation system is of great concern. Some important stages need flow measurement or management are discussed here.

- Flow Measurement

The measurement or assessment of volume of water passing per unit time from any point is called measurement of flow

- Distribution of water from head works to main canals

All the main canals have specific design and discharge carrying capacity. To meet the designed water levels of canals off taking from head works, fixed discharge is diverted to these canals to irrigate their command areas. Discharge indicating gauges are fixed at several places in each canal and are monitored continuously to maintain designed discharge.

- Distribution of water among provinces

Average annual water available from all the rivers is proportionally distributed among provinces. Proportionality of water follows the agreement among provinces "Water accord 1991". Electronic Telemetry system has been recently installed at all the head works to monitor flows around the clock to all the provinces.

- Maintaining designed depth of water in canals

To meet the designed discharges of outlets according to their command areas, it is essential to operate/run canals at designed full supply level. For maintaining full supply levels of distributaries and minors, measured discharge is provided/allowed from their parent canals, through regulatory gates.

- Equity in Water Distribution among farmers.

Equal distribution of water among farmers is of great concern. Evaluation of equity in water distribution among farmers can be made possible through regular flow measurements in watercourses or at farm levels.

- Measured irrigation to crops

Saving of precious irrigation water is dire need of current drought situations. At farm level different techniques are adopted for saving of water. Thus it is very important to irrigate crops according to their water requirements and to avoid over or under irrigation by applying measured quantities of water. Over irrigation may participate in waterlogging while under irrigation will cause low yield.

- Watercourse Design

First requirement for deciding design of a watercourse, is the discharge of that watercourse only. Any additional discharge, e.g. tubewells or special quota of rice etc., is also adjusted in design. Hence measurement of discharge is basic need for design of a watercourse.

- Planning and Designing of Irrigation and Drainage Structures

Different types of hydraulic structures are constructed on irrigation channels and on surplus water carrying drains. All such structures are designed for passing of a limited quantity of discharge.

- Pre and Post improvement of irrigation system

For evaluating the performance of water management or irrigation projects, measurement of flow in watercourses or canals before improvement is taken as base line. After completing such projects flow of these water channel is again measured for evaluation/comparison.

- No Water Management without flow Measurement

Keeping in view, the importance of flow measurement at different stages/portion of irrigation system it can be said that without flow measurements, proper water management is not possible.

BASIC TERMINOLOGY USED IN FLOW MEASUREMENT

1 - Discharge.

It is measurement of volume of water in flowing condition.. Units of discharge commonly used are

- **a. Cusec**
- **b. Musec/Cumecs**
- **c. LPS**
- **d. G.P.M**
- **e. A.F**

a. Cusec.

If one cubic foot volume of water is passing in one second form a certain point, then discharge is called 1 cusec or ft^3/sec.

b. Musecs/Cumec.

If one cubic meter volume of water is passing in one second from a certain point, discharge is called 1 cumec/musec or m^3/sec.

c. Liter Per Second.

If one liter volume of water is passing in one seconds from a certain point, discharge is called 1 lps or 1liter per second**.**

d. Gallon Per Minute

If one gallon of water is passing in one minute time from any point, then discharge at that point is called 1 Gallon Per Minutes or G.P.M.

e. Acre Foot

When an area of one acre is filled with water to a depth of one foot, then volume of water is called 1 acre foot (AF). 1-Acre Foot = 43560 ft^3

2 - Conversion Table

1 Cusec	=	**28.31 lps**
1 Cumec	=	**1000 lps**
1 Gallon (US)	=	**3.78 liters**
1 Gallon (UK)	=	**4.55 liters**
One liter	=	**0.001 m^3**
1 A.F	=	**43560 ft^3**
1-Hectare	=	**100m x 100m**
1- Hectare	=	**2.47 acre**
1- acre	=	**198 ft x 220 ft = 60m x 66m**
1 m	=	**3.28 ft**
1 inch	=	**2.54 cm**

3- Gross Command Area (GCA).

It is the total area that is within command of an outlet. It also includes that land to which canal water is not allowed. Canal water is not sanction to some area due to various reasons, e.g topographic position. Gross Command Area is generally expressed in acres.

4 - Culturable Command Area (CCA)

That area of an outlet which is under cultivation within command of outlet. Culturable Command Area is generally expressed in acres or hectares.

5 - Water Allowance.

It is the quantity of irrigation water allowed for 1000 acres of culturable land. This also helps in designing an outlet for its command area.

6 - R.D

Reduce Distance (RD) is measurement of distance from head of channel to any point. This distance is measured in feet. 1 – RD = 1000 ft e.g. distance of 4500 feet is written as RD 4 + 500

7- R.L

Reduced Level (RL) is elevation of any point with reference to sea level. It is shown in feet or meters.

8 - Reach

It is a particular length of a canal/distributary from one point to other point i.e length between two successive points

9 - Location of an Outlet.

Distance of an outlet in feet from head of canal/distributary indicates its numbers. “R” or “L” is added to this number which shows that outlet is off-taking from left (L) or right (R) side of canal/distibutary. e.g 4500- R

10 -Upstream/Downstream.

If we are using a flume or standing on a hydraulic structure, then upstream (U/S) is the side from where water is entering in the flume or structure and downstream (D/S) is the side where water is going out from flume or structure.

11 - Inlet.

It is the point of a hydraulic structure where water is entering to that structure.

12 - Outlet.

It is the point of a hydraulic structure where water is going out from that structure

13 - Perimeter.

Length of cross section or the length of a section of canal/distributary/watercourse, which is in contact with water.

14 - X-Section.

Cross-Section (X-Section) of channel is from which water passes. It is the dimension of a section, i.e. depth and width of flow

15 - Free Flow.

When water passes through a hydraulic structure and downstream water level does not affect the water level of upstream, flow is called free flow.

16 - Submerged Flow.

When water passes through a hydraulic structure and downstream water level affects the water level of upstream, called submerged flow.

17 - Duty of Water:

It is the area irrigated per cusesc discharge, during a base period.

18 - Delta of Water

It is the total requirement of water of a crop from sowing time till maturity

Wheat	= 16 inches
Cotton	= 28 inches
Sugar Cane	= 70 inches
Maize	= 13 inches
Rice	= 55 inches
Potato	= 18 inches
Onion	= 30 inches

19 - Conveyance Efficiency

Ratio of discharge at tail of a watercourse to the discharge at head of a watercourse e.g. if discharge at tail of watercourse is 1.5 cusecs while discharge at head of same watercourse was 2 cusecs then

Conveyance efficiency = 1.5/2 x100 = 75%

Losses = 25%

FLOW MEASUREMENT TECHNIQUES

1) Trajectory Method For Tubewells

This method is used to measure the discharge or flow for rate of tubewells. It is very simple and easy method. It has three essential requirement/condition for discharge determination

- ✓ Inside diameter of pipe
- ✓ Measurement of X-coordinate of flow (Horizontal distance measured from the end of pipe)
- ✓ Measurement of Y-coordinate of flow (Vertical distance measured down from the horizontal point to the top of the water jet)

Formula used For Full Flowing Pipe

Q =0.0174 D^2x X/√Y

$$Q = 0.0174\, D^2 \times X/\sqrt{Y}$$

where

Q = lps
D = inside diameter of pipe (cm)
X = X-coordinate (cm)
Y = Y-coordinate (cm)

Formula used For Partial Flowing Pipe

$$Q = [0.0174\, D^2 \times X\, (a/A)]/\sqrt{Y}$$

where

Q = lps
a = Area of jet
A = Area of pipe
D = inside diameter of pipe (cm)
X = X-coordinate (cm)
Y = Y-coordinate (cm)

LIMITATIONS

- Pipe should be straight
- Discharging in air
- Length of pipe > 6 D
- Error upto 10 %

2 - Float Method

Float method is used to measure discharge in open channels where accuracy is not of important. It is based on velocity- area relationship.

Discharge = Area x Velocity

$Q = A \times V$

$Q = m^3/sec$

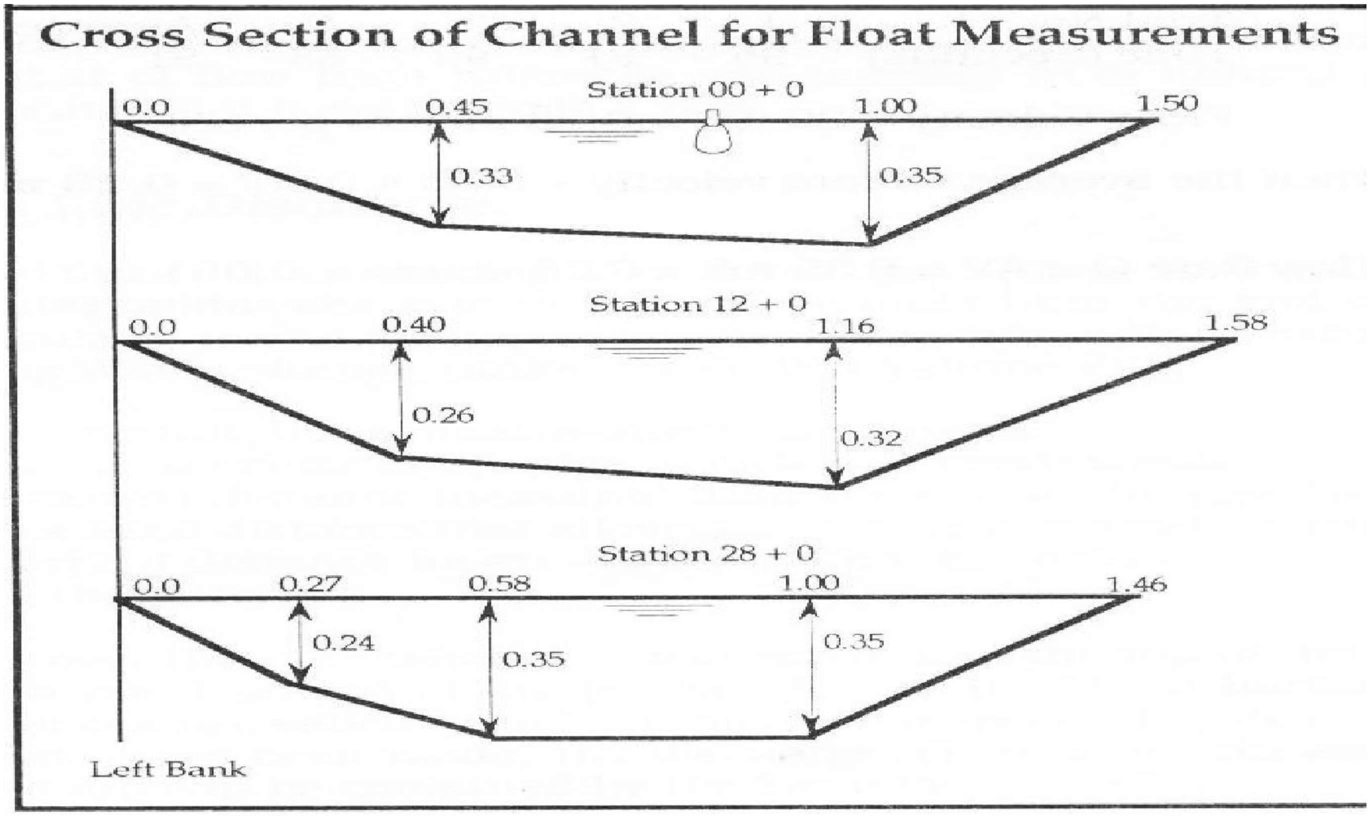
$V = S/t$ (m/sec)

A = Cross Section Area of flow (m^2)

Cross sections of water channels vary, i.e Rectangular Section, Trapezoidal or Parabolic Section

- Take 30 meter straight and long section of watercourse, and mark A and B points.
- Put float 1 m before point A.
- Float e.g. round wooden block, wooden sphere, orange, long necked bottle partly filled & capped
- Note time taken by float for distance from point A to B.
- Find Velocity (v)
- Repeat 3 to 4 times
- Measure average depth of flow (d), not of w/c
- Measure width of flow (b)Calculate area (A)
- Calculate discharge **Q = 0.9 x A x V for lined watercourse**

- Select fairly uniform and straight section of watercourse
- Mark 30 meter from A to B points on section
- Measure average depth of flow (d) at several points
- Measure width of flow (b) at several points
- Take “b” and at “d” at 3 to 4 points within section for average valuesPut float 1 m before point A.
- Float e.g. round wooden block, wooden sphere, orange, long necked bottle partly filled & capped
- Note time taken by float for distance from point A to B.
- Find Velocity (v)
- Repeat 3 to 4 timesCalculate average area (A)
- Calculate discharge
- **Q = 0.8 x A x Vfor katcha watercourse.**
- **A sample for Katcha watercourse discharge calculation is given in on next page**



Cross Section Data

Station 0+00		Station 12+0		Station 28+0	
Distance (m)	Depth (m)	Distance (m)	Depth (m)	Distance (m)	Depth (m)
0.00	0.00	0.00	0.00	0.00	0.00
0.45	0.33	0.40	0.26	0.27	0.24
1.00	0.35	1.16	0.32	0.58	0.35
1.50	0.00	1.58	0.00	1.00	0.35
				1.46	0.00

$$\text{Area}_{00+0} = \frac{0.33 \times 0.45}{2} + \frac{[0.33 + 0.35] \times (0.55)^{*}}{2} + \frac{0.35 \times 0.50^{\&}}{2}$$

$= 0.07 + 0.19 + 0.09 =$ **0.35 m2** * (1.00 - 0.45 = 0.55) & (1.50 - 1.00 = 0.50)

$$\text{Area}_{12+0} = \frac{0.26 \times 0.40}{2} + \frac{[0.26 + 0.32] \times (0.76)}{2} + \frac{0.32 \times 0.42}{2}$$

$= 0.05 + 0.22 + 0.07 =$ **0.34 m2**

$$\text{Area}_{28+0} = \frac{0.24 \times 0.27}{2} + \frac{[0.24 + 0.35] \times (0.31)}{2} + [0.42 \times 0.35] + \frac{0.35 \times 0.46}{2}$$

$= 0.03 + 0.09 + 0.15 + 0.08 =$ **0.35 m2**

Then the average cross section area = 0.35 + 0.34 + 0.35 = 0.35 m2

Velocity Data:

Time for **float** (wooden sphere) to travel 30 meters

Trial No.	1	2	3	4	Average
Time (Seconds)	95	91	90	88	91

Float Velocity = 30/91 = 0.33 meters per sec.

Then the average stream velocity = 0.33 × 0.80* = **0.26 m/ sec.**
* correction factor

Flow Rate Q = AV = 0.35 m2 x 0.26 m/sec = **0.091 m3/sec** or say about 90 l/sec.

Session-2

3- Cut-Throat Flume

- Device to measure discharge in unlined watercourses only
- Results satisfactory under
  -Free Flow Conditions
  -Submerged Flow Conditions

- Less Head loss (Difference of FSL on U/S & D/S of CTF)
- Accurate even in flat gradient channels
- Error < 5 %
- Free Flow?
- Submerged Flow?

Selection of Cut-Throat Flume

Flumes are available in different sizes, which have varying capacity to measure discharge. Sizes f some flumes are given below with their discharge measuring capacity.

Flume sizes	Q (Range)
4" x 3'	upto 1 cfs
8" x 3'	1 – 2.75 cfs
12" x 3'	2.75 – 4 cfs
16" x 3'	> 4 cfs

4" x 3' Size of flume
W x L
W - Throat width
L - Length of flume

How to install Cut-Throat Flume ?

For installation of cut-throat flume, following points must be taken into consideration

- Away from structures (Culverts, Nakka, Outlet)
- Converging section towards upstream
- Diverging section towards downstream

- Place Flume in center of channel
- Place Flume Parallel to flow lines
- Place Flume in Straight Section of Channel
- Near Mogha, can cause submergence of mogha, and reduced flow
- Place on/above bed level of channel
- Flume should not be hammered for leveling Properly level the flume (Transverse & Longitudinal)
- Place mud on both sides of flume
- Check leakage from sides and below the bottom
- Ensure that both holes are free from dirt
- Scales in observation wells are clear

Data Collection

After complete installation and control of leakage, flow data should be recorded as steps given below. Take reading after 20 minutes of complete installation

- Record reading Hu & Hd for upstream and downstream from observation wells
- Variation in readings indicates leakage.
- Take 5-6 readings with interval of 5-6 minutes for Hu & Hd

Check Flow conditions

S = Submergence = Hd/Hu

a) If $S < 0.7$, free flow for Flume 8" x 3'

e.g Hu = 0.66,
Hd = 0.4,
S = 0.6, it is *Free Flow*

b) If $S > 0.7$ for Flume 8" x 3'
Submerge flow
e.g Hu = 0.60,
Hd = 0.50,
S = 0.83, it is *Submerge Flow*

Find Discharge For Flume 8"x 3'

a) - *For Free Flow*

$$Q = C_f \, Hu^{nf} = 2.858 \times H_u^{1.826}$$ or

- Consult table-7 for free flow discharge
- Read for flume of 8" x 3' against 0.66 in the column of H_u,
- Q = 1.34 cfs

b) ***For submerge formula***

$$Qs = \left[\frac{Cs(Hu - Hd)^{nf}}{(-\log S)^{ns}}\right]$$

Cs = 1.6,
ns = 1.489,
nf = 1.826 or
consult, table-7 & table-9

Qf = 1.125 cfs

Qs / Qf = 0.931
Qs = 0.931 x 1.125
Qs = 1.05 cusecs

Free flow Discharge Ratings for Cutthroat Flumes — Table 7

For 1.5, 3.0 and 4.5 foot flumes in English units

1.5 Foot Flume

Hu ft	2in cfs	4in cfs	6in cfs	8in cfs
0.30	0.089	0.184	0.283	0.387
0.32	0.101	0.209	0.321	0.439
0.34	0.114	0.235	0.362	0.494
0.36	0.128	0.263	0.405	0.552
0.38	0.142	0.293	0.450	0.613
0.40	0.157	0.324	0.497	0.677
0.42	0.173	0.356	0.547	0.744
0.44	0.190	0.391	0.599	0.814
0.46	0.207	0.426	0.653	0.887
0.48	0.226	0.463	0.710	0.964
0.50	0.245	0.502	0.769	1.043

3.0 Foot Flume

Hu ft	4in cfs	8in cfs	12in cfs	16in cfs
0.30	0.153	0.317	0.489	0.668
0.32	0.173	0.357	0.550	0.750
0.34	0.193	0.399	0.614	0.837
0.36	0.214	0.442	0.681	0.927
0.38	0.237	0.488	0.751	1.022
0.40	0.260	0.536	0.824	1.121
0.42	0.285	0.586	0.900	1.223
0.44	0.310	0.638	0.979	1.330
0.46	0.336	0.692	1.061	1.441
0.48	0.364	0.748	1.146	1.555
0.50	0.392	0.806	1.234	1.673
0.52	0.422	0.866	1.325	1.796
0.54	0.452	0.928	1.419	1.922
0.56	0.483	0.991	1.515	2.051
0.58	0.515	1.057	1.615	2.185
0.60	0.548	1.125	1.717	2.322
0.62	0.583	1.194	1.822	2.463
0.64	0.618	1.265	1.930	2.608
0.66	0.654	1.338	2.040	2.756
0.68	0.691	1.413	2.154	2.908
0.70	0.728	1.490	2.270	3.063
0.72	0.767	1.569	2.388	3.222
0.74	0.807	1.649	2.510	3.385
0.76	0.847	1.732	2.634	3.551
0.78	0.889	1.816	2.761	3.721
0.80	0.931	1.902	2.891	3.894
0.82	0.975	1.989	3.023	4.071
0.84	1.019	2.079	3.158	4.251
0.86	1.064	2.170	3.295	4.434
0.88	1.110	2.263	3.435	4.622
0.90	1.157	2.358	3.578	4.812
0.92	1.204	2.454	3.723	5.006
0.94	1.253	2.553	3.871	5.203
0.96	1.302	2.653	4.021	5.404
0.98	1.353	2.754	4.174	5.608
1.00	1.404	2.858	4.330	5.815

4.5 Foot Flume

Hu ft	6in cfs	12in cfs	18in cfs	24in cfs
0.30	0.237	0.491	0.757	1.034
0.32	0.265	0.548	0.844	1.152
0.34	0.294	0.607	0.935	1.275
0.36	0.324	0.670	1.030	1.404
0.38	0.356	0.734	1.129	1.537
0.40	0.389	0.802	1.231	1.675
0.42	0.423	0.871	1.337	1.818
0.44	0.458	0.943	1.447	1.966
0.46	0.495	1.017	1.560	2.118
0.48	0.532	1.094	1.676	2.274
0.50	0.571	1.173	1.796	2.436
0.52	0.611	1.254	1.920	2.601
0.54	0.652	1.338	2.046	2.772
0.56	0.694	1.423	2.176	2.946
0.58	0.737	1.511	2.309	3.125
0.60	0.781	1.601	2.445	3.307
0.62	0.827	1.694	2.585	3.495
0.64	0.873	1.788	2.728	3.686
0.66	0.921	1.884	2.873	3.881
0.68	0.969	1.983	3.022	4.080
0.70	1.019	2.083	3.174	4.284
0.72	1.069	2.186	3.329	4.491
0.74	1.121	2.291	3.487	4.703
0.76	1.174	2.397	3.648	4.918
0.78	1.227	2.506	3.812	5.137
0.80	1.282	2.617	3.979	5.360
0.82	1.337	2.729	4.149	5.587
0.84	1.394	2.844	4.321	5.817
0.86	1.452	2.961	4.497	6.051
0.88	1.510	3.079	4.675	6.289
0.90	1.570	3.200	4.856	6.531
0.92	1.630	3.322	5.040	6.776
0.94	1.692	3.446	5.227	7.025
0.96	1.754	3.572	5.417	7.278
0.98	1.818	3.700	5.609	7.534
1.00	1.882	3.830	5.804	7.794
1.05	2.047	4.163	6.303	8.459
1.10	2.217	4.507	6.820	9.146
1.15	2.394	4.862	7.352	9.854
1.20	2.576	5.228	7.901	10.583
1.25	2.763	5.606	8.466	11.334
1.30	2.956	5.994	9.047	12.105
1.35	3.154	6.393	9.644	12.896
1.40	3.358	6.802	10.256	13.708
1.45	3.567	7.222	10.883	14.539
1.50	3.782	7.652	11.526	15.390

Submerged flow Correction Factors for Cutthroat Flumes — Table 9

For 1.5, 3.0 and 4.5 foot flumes in English units

1.5 Foot Flume

S	2in Qs/Qf	4in Qs/Qf	6in Qs/Qf	8in Qs/Qf
0.610	0.993			
0.620	0.990			
0.630	0.987			
0.640	0.983			
0.650	0.979			
0.660	0.974			
0.670	0.968	0.999		
0.680	0.962	0.998		
0.690	0.956	0.996		
0.700	0.949	0.994		
0.710	0.941	0.991		
0.720	0.932	0.988		
0.730	0.923	0.984		
0.740	0.914	0.980		
0.750	0.903	0.974	0.999	
0.760	0.892	0.969	0.998	
0.770	0.880	0.962	0.996	
0.780	0.867	0.955	0.994	
0.790	0.854	0.946	0.991	
0.800	0.839	0.937	0.987	
0.810	0.824	0.927	0.982	
0.820	0.808	0.916	0.977	0.998
0.830	0.790	0.905	0.971	0.997
0.840	0.772	0.891	0.963	0.994
0.850	0.752	0.877	0.955	0.990
0.855	0.742	0.869	0.950	0.988
0.860	0.731	0.861	0.945	0.985
0.865	0.720	0.853	0.940	0.983
0.870	0.709	0.844	0.934	0.980
0.875	0.697	0.835	0.928	0.976
0.880	0.685	0.825	0.921	0.973
0.885	0.673	0.815	0.914	0.969
0.890	0.660	0.805	0.907	0.964
0.895	0.646	0.793	0.899	0.959
0.900	0.632	0.782	0.891	0.954
0.905	0.618	0.770	0.882	0.948
0.910	0.603	0.757	0.872	0.942
0.915	0.587	0.743	0.862	0.935
0.920	0.571	0.729	0.851	0.927
0.925	0.554	0.713	0.839	0.919
0.930	0.536	0.697	0.826	0.910
0.935	0.517	0.680	0.813	0.900
0.940	0.498	0.662	0.798	0.889
0.945	0.477	0.642	0.781	0.877
0.950	0.455	0.621	0.764	0.863

3.0 Foot Flume

S	4in Qs/Qf	8in Qs/Qf	12in Qs/Qf	16in Qs/Qf
0.610	0.998			
0.620	0.996			
0.630	0.994			
0.640	0.992			
0.650	0.989			
0.660	0.986			
0.670	0.982			
0.680	0.978			
0.690	0.973	0.999		
0.700	0.967	0.998		
0.710	0.961	0.997		
0.720	0.955	0.995		
0.730	0.948	0.992		
0.740	0.940	0.989		
0.750	0.931	0.986		
0.760	0.922	0.981		
0.770	0.912	0.976	0.999	
0.780	0.902	0.971	0.998	
0.790	0.890	0.964	0.996	
0.800	0.878	0.957	0.994	
0.810	0.865	0.949	0.991	
0.820	0.851	0.940	0.987	
0.830	0.835	0.931	0.982	0.999
0.840	0.819	0.920	0.977	0.998
0.850	0.802	0.908	0.970	0.996
0.855	0.793	0.901	0.966	0.994
0.860	0.783	0.894	0.963	0.993
0.865	0.773	0.887	0.958	0.991
0.870	0.763	0.880	0.954	0.989
0.875	0.752	0.872	0.949	0.986
0.880	0.741	0.863	0.943	0.984
0.885	0.730	0.855	0.938	0.981
0.890	0.718	0.845	0.932	0.977
0.895	0.706	0.836	0.925	0.973
0.900	0.693	0.825	0.918	0.969
0.905	0.679	0.814	0.911	0.965
0.910	0.665	0.803	0.902	0.960
0.915	0.651	0.791	0.894	0.954
0.920	0.635	0.778	0.884	0.948
0.925	0.619	0.764	0.874	0.941
0.930	0.602	0.750	0.863	0.934
0.935	0.584	0.734	0.851	0.926
0.940	0.565	0.717	0.838	0.916
0.945	0.545	0.699	0.824	0.906
0.950	0.524	0.680	0.808	0.895

4.5 Foot Flume

S	6in Qs/Qf	12in Qs/Qf	18in Qs/Qf	24in Qs/Qf
0.610				
0.620				
0.630				
0.640	0.999			
0.650	0.997			
0.660	0.996			
0.670	0.994			
0.680	0.991			
0.690	0.988			
0.700	0.984			
0.710	0.980			
0.720	0.976			
0.730	0.970	0.999		
0.740	0.965	0.998		
0.750	0.958	0.996		
0.760	0.951	0.993		
0.770	0.944	0.991		
0.780	0.935	0.987		
0.790	0.926	0.983		
0.800	0.916	0.978		
0.810	0.905	0.973	0.999	
0.820	0.894	0.966	0.997	
0.830	0.881	0.959	0.995	
0.840	0.868	0.951	0.992	
0.850	0.853	0.942	0.988	
0.855	0.845	0.937	0.986	
0.860	0.837	0.931	0.983	
0.865	0.828	0.926	0.980	0.999
0.870	0.819	0.920	0.977	0.998
0.875	0.810	0.913	0.974	0.997
0.880	0.800	0.907	0.970	0.996
0.885	0.790	0.900	0.966	0.995
0.890	0.780	0.892	0.962	0.993
0.895	0.768	0.884	0.957	0.991
0.900	0.757	0.876	0.952	0.989
0.905	0.745	0.867	0.947	0.986
0.910	0.732	0.857	0.941	0.983
0.915	0.719	0.847	0.934	0.980
0.920	0.705	0.836	0.927	0.976
0.925	0.690	0.824	0.919	0.972
0.930	0.674	0.811	0.910	0.967
0.935	0.657	0.798	0.901	0.961
0.940	0.639	0.783	0.890	0.955
0.945	0.621	0.767	0.879	0.947
0.950	0.600	0.750	0.866	0.939

4 -WEIRS

General Flow Equation

$Q = C \times L \times H^{1.5}$

Q - Discharge
C - constant
L - Width of crest
H - Head

Weir - Vertical Contraction
Flume - Horizontal Contraction

Types of Weirs

1) Rectangular Weirs (Suppressed)

$Q = 1.84 \times L \times H^{1.5}$ $Q = m^3/s$

L & H in meters

(Applicable to Drop Structures of W/Cs)

2) Rectangular Weirs (Contracted)

$Q = 1.84 (L - 0.2H) H^{1.5}$

Limitations

- **Depth of flow (H) over crest > 0.03 m**
- **Crest of weir above channel bottom > 0.3 m**
- **Width (L) > 0.15 m**
- **D/s FSL > 0.06 m below weir crest**

3) Trapezoidal Weir

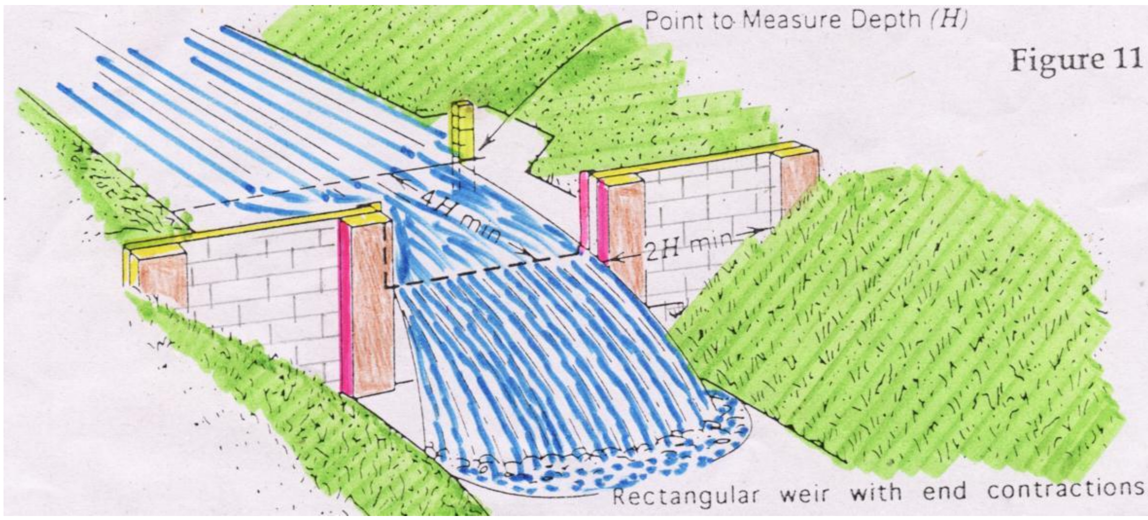
$Q = 1.86 \times L \times H^{1.5}$

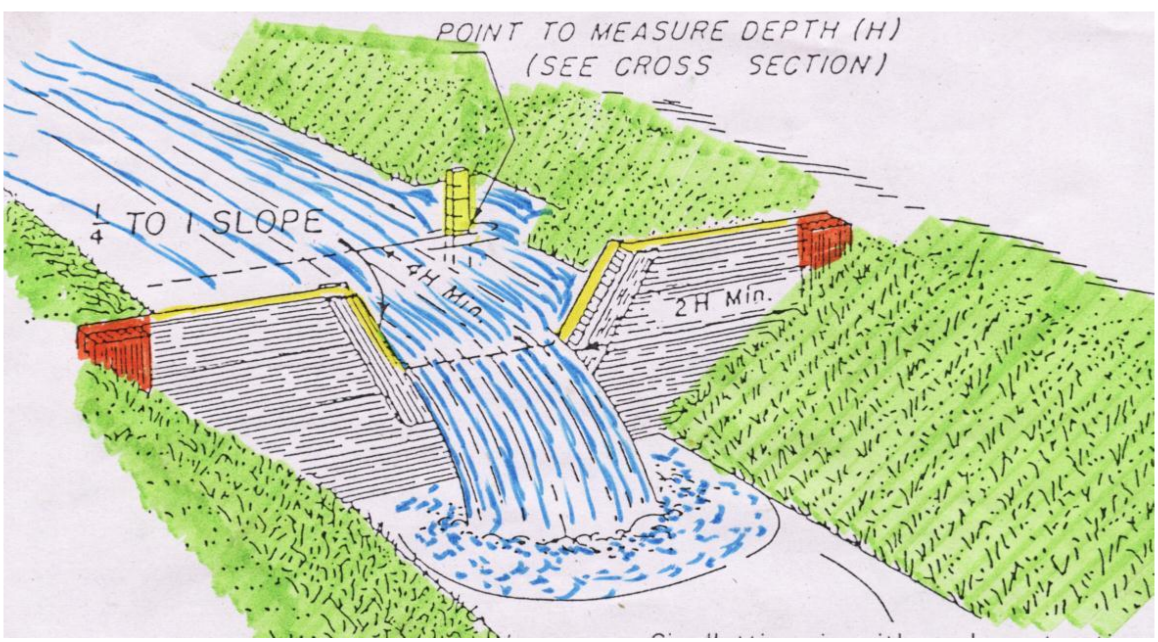
$Q = m^3/s$

L & H in meters

Limitations

- **Weir crest height > 0.3 m**
- **Head 0.06 - 0.6 m**
- **Head / L < 0.5**
- **FSL of D/S should be 0.06 m below the crest of weir**





Session-3

CURRENT METER

Working principle

- Currentmeter Measures Velocity (V)
- Direct / By counting revolutions per unit time
- Area of Segments (A)
- Q = A X V

Methods of Determining Velocities

1. Two point method (0.2 & 0.8) if depth of water > 60 cm
2. One point method (0.6 from top/0.4 from bed) shallow depths (< 60cm)
3. V = 0.123 N + 0.007 where N = Revolution / second or from chart

SEGMENTAL AREA

- Measure top width of water / channel
- Measure bottom width of channel
- Divide width in segments (each segment area = 10% of total area)
- Record width of each segment
- Mark distance from initial point for each segment
- Take average depth of water in each segment
- Measure velocities at 0.2 & 0.8 if depth >60 cm
- Measure velocities in center of each segment
- Find average velocity by counting pings/table
  V= 0.123 N +0.007N = Revolutions/Second
- Calculate Q of each segment by Q = A x V
- Add Q of all segments for total discharge

Types

- Pygmy -Depth < 60 cm - watercourses
- Price Type - Depth > 60 cm - canals
- Vertical or Horizontal Axis

Session-4

IRRIGATION OUTLETS

Definition:-

It is a hydraulic structure, which conveys irrigation water from a state-owned distributary to private-owned watercourse.

State-owned distributary:
A water channel which owned, and operate and maintained at the cost of government.(Canal – Branch Canal –Distributary – Minor – Subminor)

Private-owned watercourse:
A water channel, which is maintained at the cost of farmers.

The following characteristics are assumed for the performance of an outlet

i) Flexibility
It is the rate of change of outlet discharge to the rate of change of discharge of parent channel

ii) Sensitivity:-
It is defined as the ratio of the rate of change of discharge of an outlet to rate of change in the level of distributary water surface i.e normal depth of channel

iii) Efficiency
This is defined as the ratio of the head recovered to the head put in

iv) NOTATIONS & DEFINITIONS

A.O.S.M	Adjustable Orifice Semi Modular
A.P.M	Adjustable Proportionate Modular
Bt	The width of the throat of a view flume etc
F.S.D	Full Supply Depth
F.S.L	Full Supply level
Hm	Minimum working head

v) Minimum Modular Head
It is the minimum difference of water levels or pressure between supply and delivery sides to enable the semi module to work as designed

vi) Modular Limits
The extreme values of any factors at which modular or semi modular ceases to be capable of acting as such

vii) Modular Range
The range of conditions between the said limits within which a modular or semi modular works as designed

viii. Drawing Ratio
The ratio between depth of water over the crest level downstream to depth of water over the crest level on upstream side.

ix. Module
A device for ensuring a constant discharge of water passing from one channel into an other irrespective of water level in each , within specified limits.

Types of Outlets

Non-Modular:
It is an outlet in which discharge of outlet depends in water level of watercourse and the parent channel. This means that a cultivator can be drawn more discharge of water illegally by lowering the water level in watercourse (pipe or banal type and secretly outlet)

Semi Modular:
It is an outlet in which the discharge of outlet depends upon the water level in the distributray only and is independent of the water level watercourse (open flume and A.O.S.M)

Modular:
It is rigid module in which discharge is independent of the level in the distributary as well as watercourse (Gibbs, Module, Khans Module)

Types of Outlet used in Punjab

i) Open Flume
ii) Adjustable Orifice Semi Modular
iii) Pipe Outlet
iv) Scratchy
v) Pipe – Cum – OF/AOSM

1. <u>OPEN FLUME OUTLET</u>

Formula

$Q = KBt\ G^{3/2}$

Where

Q = Discharge in lps

Bt = Throat width in meter

G = Head (Depth of water above Crest in m)

= F.S.L of canal – Crest level

Max F.S.L of watercourse = F.S.L of canal - Hm

Hm = 0.2 G

"Hm" is minimum modular head required for satisfactory performance of outlet.

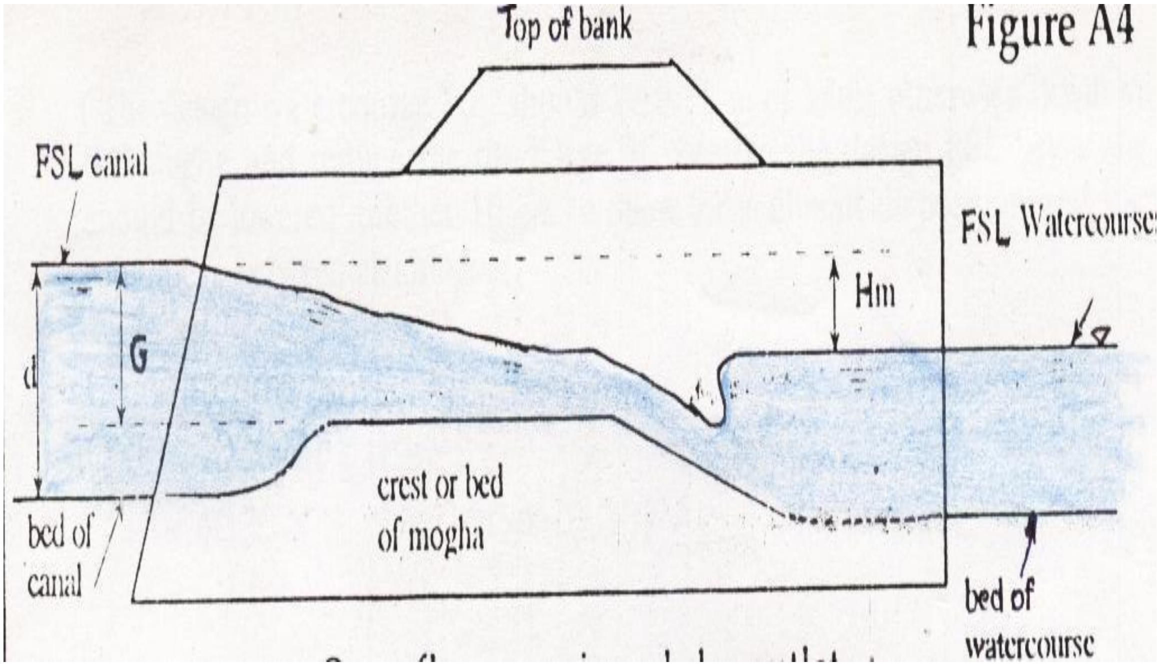
Values of K & Bt in MKS system are given below.

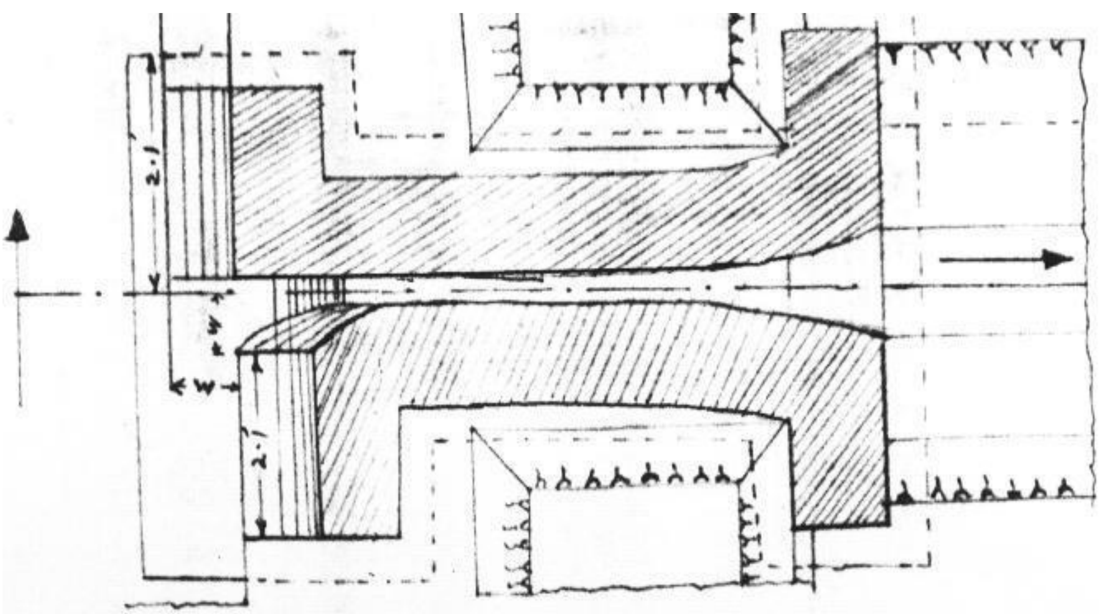
K	**Bt (m)**
1600	0.06 – 0.09
1630	0.09 m – 0.12
1650	greater than 0.12

Value of K & Bt for FPS system are as under, discharge will be in cusecs

K	**Bt** (ft)
2.90	0.2 – 0.29
2.95	0.3 – 0.39
3.0	> 0.40

OPEN FLUME OUTLET





ii. PIPE OUTLET

- Simplest and oldest type
- Placed in the bank of distributary
- Semi-Modular, if outlet has free fall
- Non-Modular, if outlet is submerged
- Major Drawback is that discharge coefficient (Cd) varies outlet to outlet & time to time

$$Q = C_d A \sqrt{2gH}$$

Free Flow Condition.

$Q = C_d A \sqrt{2gH}$

Q = Discharge in cubic meter per second

H = FSL of Canal – Center of pipe

A =Area of pipe (m^2), g = 9.80 m/sec/sec

C_d=0.63

Submerge Flow Condition

$Q = C_d A \sqrt{2gH_d}$

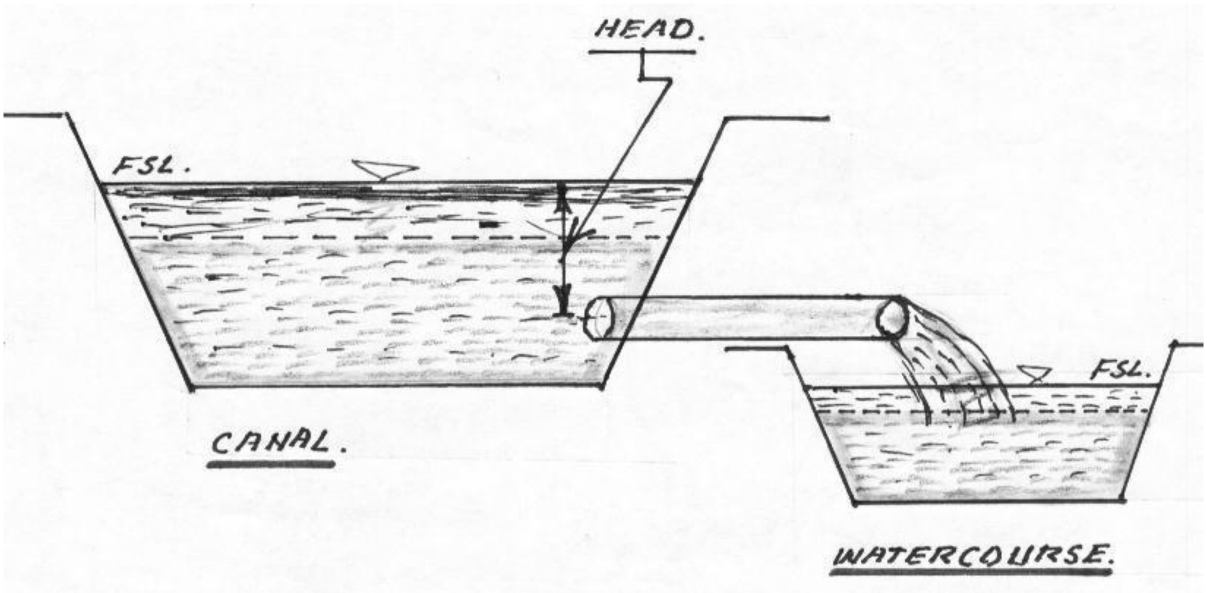
Q = Discharge in cubic meter per second

Hd = FSL of Canal – FSL of Watercourse

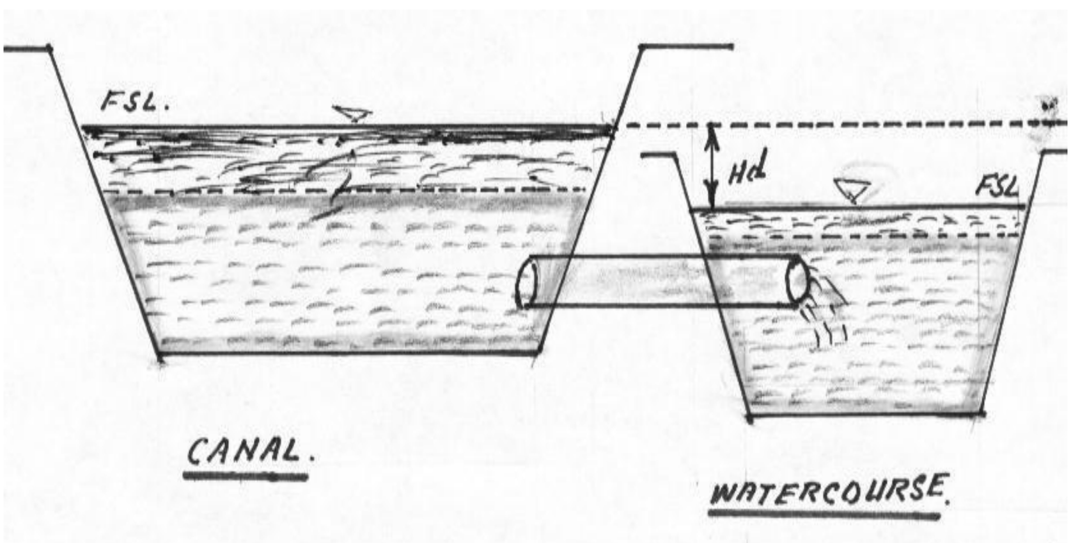
A =Area of pipe (m^2)

Cd=0.74

Pipe Outlet Free Condition



Pipe Outlet Submerged Condition



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IRRIGATION OUTLETS CONTINUE

iii. Adjustable Orifice Semi Modular

Formula for MKS system

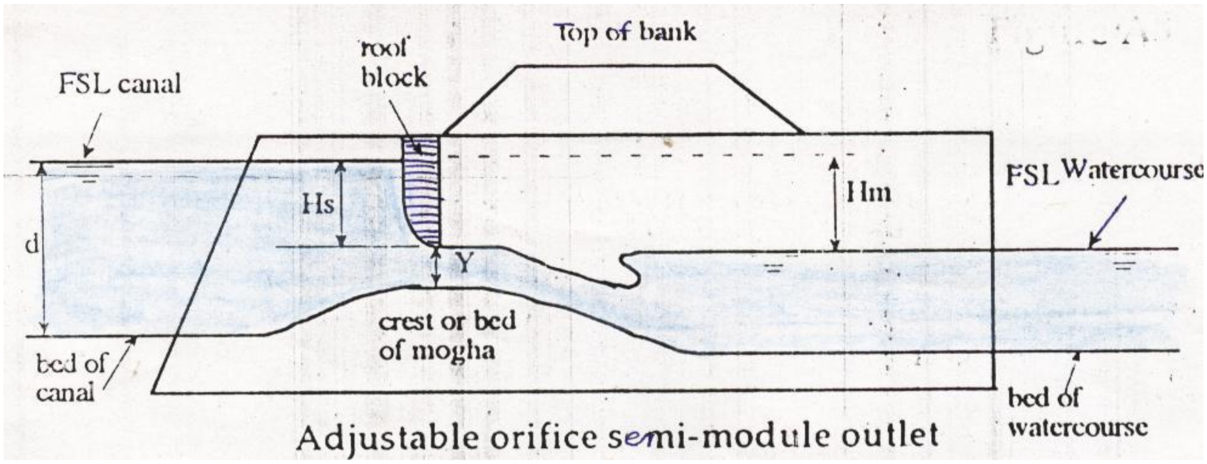
Q = 4030 Bt Y √Hs

where
Q = lps
Bt = Throat width (m)
Y = Distance between Lower Tip of Roof Block & Crest
Hs = FSL of Canal – Lower tip of Roof Block
FSL of Watercourse = FSL of Canal – Hm
Hm = 0.83 Hs – 0.5 Bt

Formula for FPS system

Q = 7.3 Bt Y √Hs

where
Q = cusecs
Bt = Throat width (ft)
Y =Distance between Lower Tip of Roof Block & Crest (ft)
Hs=(ft)



Example of Adjustable Orifice

Given

FSL (Canal)	**= 9.90 m**
Roof block Lower Tip Elevation	**= 9.60 m**
Crest Elevation	**= 9.40 m**
Throat width Bt	**= 0.12 m**

Find

a) Discharge

b) Max. FSL of watercourse for free flow

Solution

a)Q = 4030 Bt Y √Hs

Hs = 9.90 – 9.60 = 0.30 m

Y = 9.60 – 9.40= 0.20 m

Q =4030 x 0.12 x 0.2 √0.3

=53 lps

b). Max. FSL of Watercourse

= FSL of Canal – Hm

Hm = 0.83 x 0.30 – 0.5 x 0.12

= 0.189 m

Max-FSL of Watercourse

= 9.90 – 0.189 = 9.711

m or lower for free flow

iv - Scratchley Outlet

- Hydraulic conditions are same
- Coefficient of discharge (Cd) is same for drowned conditions
- Pipe or Barrel opens in cistern
- Cistern 2-3 Foot Square
- Cast iron or stone orifice fixed on other side of cistern

Discharge Formula

$$Q = Cd\, A \sqrt{2gHw}$$

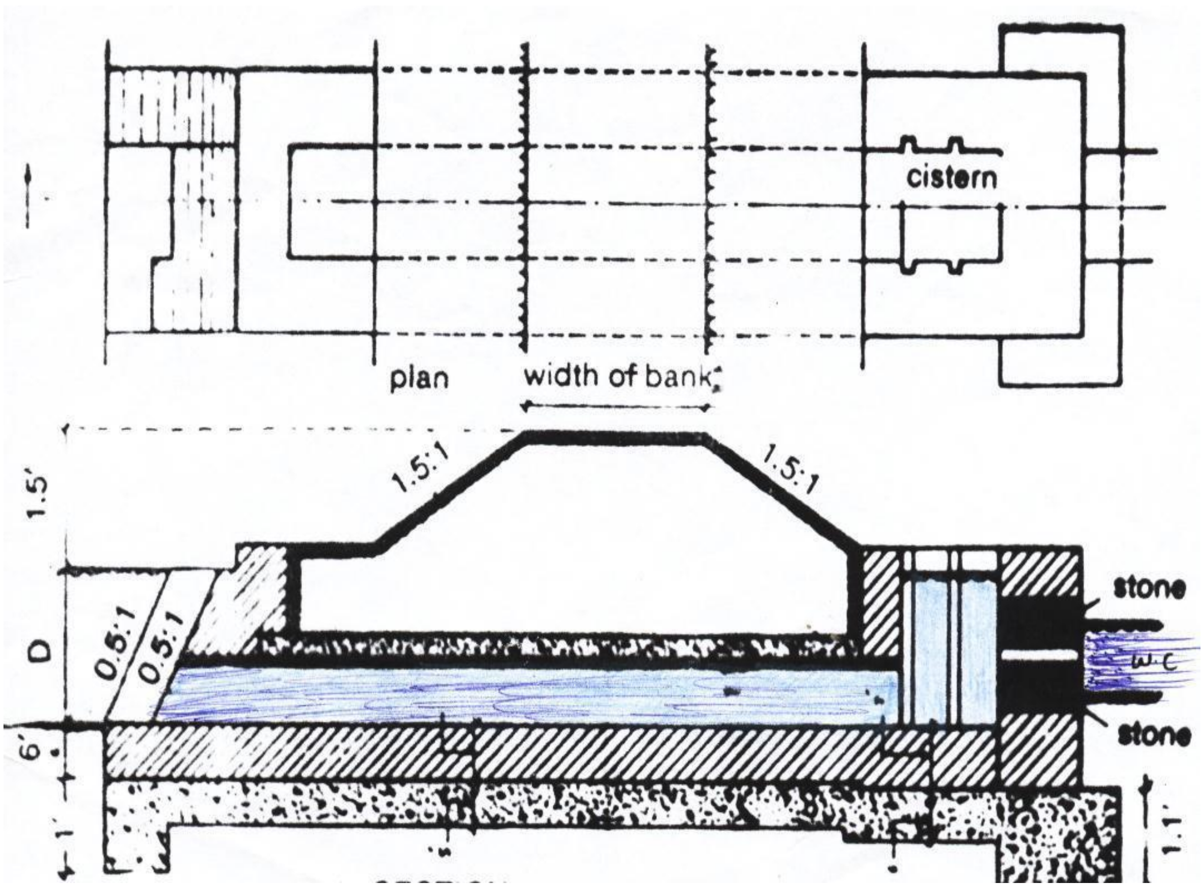
Where

Q	=	Discharge in cubic meter per second
Hw	=	working head in m (FSL of Canal – FSL of Watercourse)
A	=	Area of pipe (m^2)
g	=	9.80 m/sec/sec
Cd	=	0.82

Merits of Scratchley Outlet

- Size of orifice can be changed with running channel
- Cd is same for all orifices
- Low cost for any change in design
- Open to inspection at all times

Scratchley Outlet

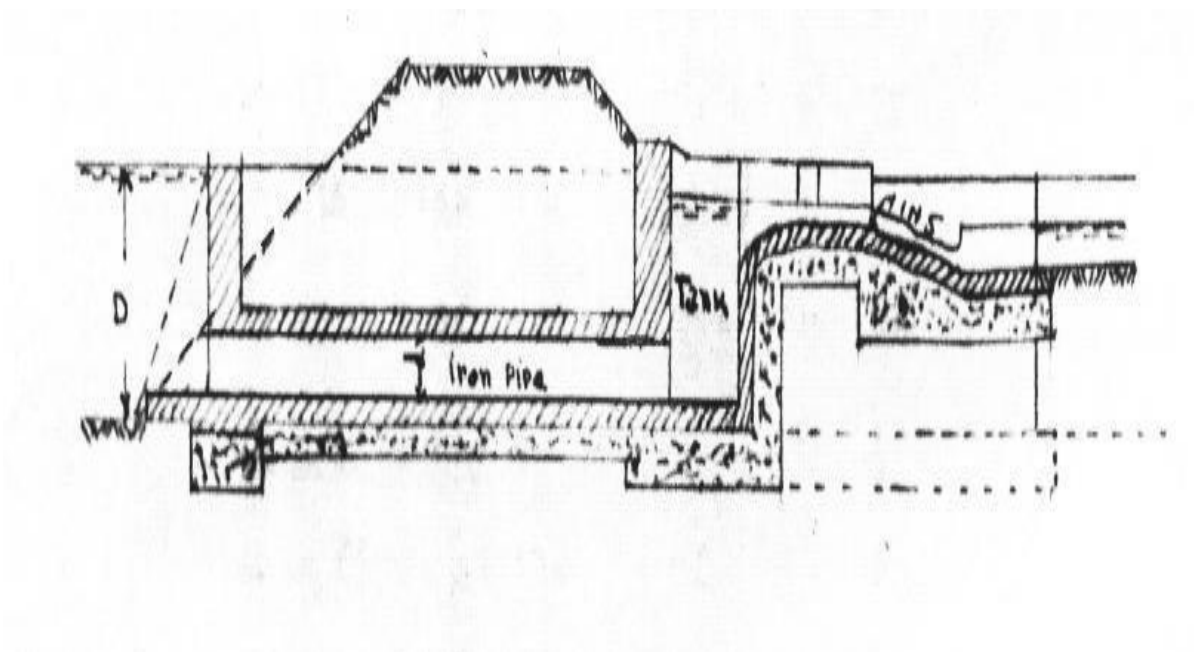


v- Pipe-cum-AOSM

- Pipe from canal leads to a sump or cistern
- Sump is usually round in shape
- It can replace submerged Scratchley outlet
- On lined distributaries being installed
- Head will be measured in cistern
- Discharge will be equal to the semi-module fixed at its lower end

Merits of Pipe-cum-Semi Module

- High degree of immunity
- Large range of modularity (good at even at low supply)
- Low head required
- Cheaper in heavy banks
- Easy inspection
- Easy and cheaper adjustment
- Adjustment possible even with running channel
- **Note**: Formulae is same as for OF or AOSM as the case may be



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IRRIGATION OUTLETS CONTINUE

DATA REQUIRED FOR DISCHARGE MEASUREMENT

a). **For Open Flume**

- **FSL of Canal**
- **Crest level of Mogha**
- **Bt**

b). AOSM use Level Set for measuring

- **FSL of Canal**
- **Lower tip of Roof Block**
- **Crest level of Mogha**
- **Bt**
- **Y**

c). For Pipe & Scratchley use Level Set for measuring

- **FSL of Canal**
- **FSL of watercourse**
- **Diameter of pipe**