



# **HANDBOOK FOR HYDROMETEOROLOGICAL OBSERVATIONS**

**January, 2017**

## TABLE OF CONTENTS

<b>Sl. No.</b>	<b>Topic</b>	<b>Page Nos.</b>
Chapter 1	Introduction	1-2
Chapter 2	Selection Of HO Stations/Site	3-4
Chapter 3	River Stage Observation	5-11
Chapter 4	Discharge Observation	12-43
Chapter 5	Suspended Sediment Observation And Analysis	44-54
Chapter 6	Meteorological Observations	55-70
R.D.-1	Pro-forma for Daily Discharge Data	71-72
R.D.-2	Pro-forma for First/Second/Third Ten Daily Discharge Observation	73-74
R.D.-3	Pro-forma for Daily Gauge Reading	75
R.D.-4	Pro-forma for First/Second/Third Ten Daily Hourly Flood Levels	76
R.D.-5	Pro-forma for Ground Water Record	77
R.D.-6	Pro-forma for Rainfall Record	
R.D.-7	Pro-forma For Suspended Sediment Analysis	79-80
R.D.-8	Pro-forma For Suspended Sediment for First (Second) Third 10 Days	81-82
R.D.-16	Pro-forma Of Inspection Report	83-86
	Pro-forma of Inspection Report For Telemetry Stations	87-88
	References	89

## Chapter 1 INTRODUCTION

The National water resources are limited & unevenly distributed resulting in seasonal abundance, and even devastating floods in some areas, while large tracts in other regions are persistently drought affected. The above situations have been compounded with the apprehended Climate change which calls for data collection on large scale to carryout climate change studies to help find possible sustainable solutions. This erratic occurrence necessitates precise hydrological observations in rivers for the optimum planning of water resources projects and their subsequent operations.

Following activities are required in this regard:

- (a) Measurement of hydro-meteorological logical parameters in rivers at selected place, time and frequency involving quantity and quality with desired accuracy.
- (b) Compilation and tabulation of hydrological data.
- (c) Data scrutiny, processing and publication.

### Purpose of Stream Flow Observations

The network of stream flow observations is purpose-based on requirements such as for water resources assessment and its distribution, flood forecasting & flood management, pollution control and environmental management, river behaviour and other hydrological studies. Each hydrological station has to offer some relevant and useful information individually and/ or collectively with other stations.

### Type of Stream Flow Observation Stations

A stream flow observation station may be of any of the following three types:

- (a) **Primary** stations are intended to be operated permanently; in showing time trends they furnish the key to general coverage of the region.
- (b) **Secondary** stations are intended to be operated only long enough to establish the flow characteristics of their watersheds, relative to those of a watershed gauged by a primary stream flow observation station.
- (c) **Temporary** stations to provide specific information at a site for design of a potential or proposed project, fulfillment of legal requirements and agreements, management and operation of an existing project.

### Hydrometeorological Parameters for Observations

Following hydro-meteorological parameters are generally measured depending upon the purpose of observation:

- (a) River water level.

- (b) River discharge
- (c) Suspended sediment in river.
- (d) Rainfall and other weather parameters
- (e) Water quality consisting of many different parameters.

The above activities involves selection of site/station on the river , design of network for a basin or river system, type of methodology to be used at the station, selection of suitable equipment and technology for observation of different parameters, tabulation-calculation-compilation of observations made, scrutiny-validation-publication of data. All of the above activities (except water quality ) have been described in detail in the following chapters.

## **Chapter 2 :SELECTION OF HYDROLOGICAL OBSERVATION STATION/SITE**

### **2.1 Requirement of sites**

A thorough reconnaissance by an experienced Engineer is mandatory before finalisation of any hydrological observation site. The reconnaissance survey should be preceded by study of the area using Geographical Information System (GIS) and topographical maps of the area. The reconnaissance should generally be undertaken during fair weather (summer/winter), when the reach is fairly exposed for visual inspection. In selecting a hydrological observation site, the following criteria should be adopted as far as possible.

- i) The river bank and bed should be reasonably straight and stable both upstream and downstream of the gauge line for a distance of at least 4 times the normal width of the river during high flood or 1 kilometre whichever is less.
- ii) The river in this reach should not have either show any signs of progressive aggradation or degradation.
- iii) Ideally the water level will have no slope from bank to bank along the section at the gauge site. However in case of slope is observed then gauges should be fixed on both the banks on the cross-section line and mean of the two gauges taken as the gauge reading.
- iv) The river bed should not have reverse slope, i.e., slope against the current, in this reach and should be free from pools and rapids.
- v) The water level in the reach should not preferably be affected by backwater effect from any structure or river confluences.
- vi) The orientation of the reach should be such that the direction of flow is as closely as possible normal to that of the prevailing wind.
- vii) Sites at which there is tendency for the formation of vortices, return flow or local disturbances should be avoided.
- viii) When gauge site situated near a confluence, its minimum distance upstream from the confluence point on either of the streams should be such that the backwater or disturbances due to floods in the other stream would not affect the gauge even if the stream on which the gauge is fixed is running low.
- ix) Water level at the gauge site should not be affected on account of a falling curve obtained over a weir crest or immediately below a constricted bridge. It is recommended that when the gauge is located

downstream of a structure, a minimum distance between the gauge and the structure should be kept 3 times the width of the section at high flood level in case of smaller streams. In case of big rivers length of 0.5 – 1.0 km below a weir or a bridge may be considered adequate for obtaining normal conditions.

- x) The site should be free from aquatic growth which is likely to interface with the gauge measurement.
- xi) When gauges are observed from railway bridges, it is to ensure that sufficient free board is available even at very high floods. While installing such gauges it is necessary to locate these at points where highest water level will be obtained at the bridge during the passage of flood.
- xii) The site should be such that water flows in a single channel throughout the year and does not over flow banks. If bank spills are unavoidable these should be limited to minimum width and have as uniform a depth as possible. Where a single channel is not available, as in case of braided rivers two or more channels satisfying these conditions should be used.
- xiii) The site chosen should be easily accessible and should have clear and dependable approach at all times of the year. It is preferable to locate a site in the vicinity of an all weather road which does not get submerged during floods. The site should be free from bushes, trees & other obstructions.

## Chapter 3 : RIVER STAGE OBSERVATION

### 3.1.Introduction

In any Engineering field, the observation, compilation and validation of data is the most important aspect which lays the foundation of further activities. The measurement of water level or stage at a gauging station is perhaps the most fundamental in hydrology. Field practice and frequency observation should match with the data needs and the available instrumentation. The greatest frequency of observation is required when the level (and discharge) is changing rapidly, especially during the monsoon season.

Manual observation by staff gauge will remain as the sole means of observation at many stations in the years to come. They will also continue to be used at all stations to check the operation of recording equipment at intervals, as a back-up in the event of instrument failure and in conjunction with discharge measurements for stage-discharge determination.

The water levels are normally recorded using:

- Staff gauges (RCC Post/Wooden post cut to edges).
- Stations with Radar/Pressure sensor (Digital Water level Recorders)

### 3.2.Zero of gauges

The gauge observations to be fully useful should be convertible into Reduced Levels (RL) above or below mean sea level which is the common datum internationally adopted. To enable this, the zero mark on the gauge must be connected with the *RL*. In fixing a gauge zero, the following requirements have to be satisfied.

- i. The zero of the gauge should be lower than the lowest water level
- ii. After installation of a gauge, its zero should be connected to the nearest *GTS* bench mark and reduced level with respect to the mean sea level determined, checked and entered into the record.
- iii. The circuit should be closed preferably on another nearest *GTS* bench mark. The reduction of levels should be made in the office by the Sub-Divisional Officer.
- iv. Once the zero of the gauge is fixed and recorded, it should not be changed except under special circumstances. **If** the old gauge is changed and replaced, its zero value should be retained the same by properly fixing and adjusting it.

- v. When a permanent GTS bench mark is more than 3 km away from the gauge, a new permanent bench mark in a safe position should be established for reference near the gauge site.
- vi. A reference mark on the structure to which gauge is fixed should be made. Reduced level of the reference mark should be obtained independently by levelling and recorded. This can be used for easily and quickly verifying the correctness of the gauge.
- vii. In case of temporary gauges, if these are moved with the shifting of the low water channel during dry season or any other reason, care should be taken to see that the zeros of gauges are accurately correlated.

### 3.3. Staff gauges

- i. The gauge observer will read the water level at an external staff gauge located directly in the river, and record to the nearest 1 mm where the water has little surface fluctuation. Where the water level is unstable due to wind action or turbulence, the observer will assess the mean level by noting the level fluctuation over a period of approximately 30 seconds and take the mean (average) of the normal range. An internal staff gauge situated in a stilling well not normally be used as the primary water level measurement. Observation will be made by making the closest possible approach to the gauge consistent with safety. Where the staff gauge is likely to become too distant for accurate gauge readings during rising flood levels, a simple pair of binoculars may be provided.
- ii. The frequency may also be used to record the maximum and minimum water level during the day in addition to hourly levels, if such additional data is available. In rapidly changing flows, the maximum level may exceed the highest recorded hourly level, when it occurs between the hourly observations. Similarly, the minimum level may be lower than the lowest hourly level.
- iii. The gauge reader is required to maintain good time keeping and the hourly observation will not fall more than 5 minutes before or after the hourly observation time.
- iv. The observer will note on the form whether the gauge is the only gauge, the main gauge, or a supplementary gauge, or gauges, for assessing



surface water slope. A separate form will be used for each supplementary gauge in use. It is important that each gauge is clearly identified on the form. For supplementary gauges the observer will note whether the gauge is upstream or downstream from the main gauge. Where supplementary gauges exist, the upstream gauge will be read first and the downstream gauge as soon thereafter as is consistent with safety. Where the supplementary gauges are some distance apart.

- v. During period of low flow or where the station is equipped with a reliable automatic or digital method of recording, the observer will take readings three times daily at 0800, 1300 and 1800 hours and record on the standard form covering a period of one month per form. Where an internal gauge exists in a stilling well it will be read once daily at 0800 and recorded.
- vi. When the gauge observer reads the gauge at other, non-standard times, he must ensure that he records the actual time of reading.
- vii. When the gauge observer is unable to visit the station for sickness or other reason he will in no instance attempt to estimate or interpolate the missing value(s) but will leave the space blank or note "M" and record in "Remarks" the reason for the missing record.
- viii. The observer will ensure that there is a direct connection between the flowing water surface and the gauge. After flood siltation he will, if necessary, remove sandbars or dig a trench from the gauge to free water. A shovel will be provided for this purpose. The channel to the gauges may require renewal on a daily basis.
- ix. The observer will note in "Remarks" all those occurrences, which may influence the level as observed at the gauges and especially those, which may affect the level-discharge relationship. The time/date and location of occurrences will be noted. The following occurrences in particular will be noted:
  - damaged or destruction of gauges due to flood or other cause
  - scouring and lowering of the river bed level either at the gauges or at the control site
  - construction of bunds downstream to raise water level for abstraction or diversion
  - extraction of sand or gravel from the river channel
  - blockage or partial blockage of the channel by floating or other debris in flood
  - significant weed growth in the channel or on the weir and its subsequent removal

- x. The observer will record the level at which flow ceases and the pool of water at the gauges becomes static. Where the river level falls below the level of the lowest gauge but flow continues, for example due to scouring of the bed at the station, the observer will attempt to continue the observations. In such occasions, the observer will measure downward from the datum of the gauges and record it as a negative stage i.e. he will measure the distance from the zero on the gauge to the water surface. For example if the distance from the gauge zero to the water surface is 0.15 m, then the gauge reading should be recorded as -0.15 m. as soon as possible, the engineer in charge will re-survey the station and reinstall the gauges with a new datum, ensuring that survey details and the change in datum are fully documented in the Station Record.

### 3.3.1 Accuracy of Gauge Observation

When gauge observations are made for use with a gauge-discharge curve or for any other purpose except for measurement of slope, the gauge should be read and recorded correct to 3 cm after averaging several readings. During flood season due to turbulence and wave motion this accuracy is sufficient. In non-flood season it would generally be possible to observe the gauge correct to 5 mm and also when gauge observation are meant for calculating slope, they should be read corrected to 5 mm. Hence the least count or minimum reading of staff gauge should be 5 mm. The Automatic water level recorder and recording type of gauges have least count of the range of 1 mm or less.

### 3.3.2 Frequency of Gauge Observation

The frequency of gauge observation primarily depends on the purpose for which gauge observation is to be made. The characteristics of the river are also important factors in determining the frequency of gauge observations.

During non-monsoon period the gauge observation can be done three times a day at uniform interval because the river flows are generally very low and discharge fluctuations are small. During monsoon season the river rises and fluctuations & disturbances are more and data of water levels are more important for recording HFL and for flood forecasting purpose. Hence, during monsoon period gauge observation at every hour is recommended. For flashy rivers the fluctuation in water level are more sudden, which necessitates gauge observations at shorter interval.

When gauge observation is made in connection with discharge measurement, the gauge is observed both at the time of beginning and at the end of discharge measurement. If the difference in the two gauges is less than 5 cm, the mean value is adopted in discharge computations. If the change in stage is more than 5 cm, the gauges should be observed more frequently at an interval of half an hour or even less. When gauge observation is done for discharge observation by area-slope method, the gauges are generally installed at the centre, upstream & at downstream for measurement of water level for calculating the slope.

### **3.3.3 Checking of Gauges**

In order to ensure accuracy of gauge observations periodical checking of gauges are essential. All gauges should be inspected and checked every year at least twice, once before and once after the flood season. During the checking the useful tools must be taken. Checking of gauge would mainly concern with the condition of the gauge along with accessories and its zero level. It is necessary to check up the levels with reference to the reference bench marks and reference points.

For checking the staff gauges, reduced levels of the top of each section of the gauge should be checked. Reduced levels (RL) obtained by using the recorded zero of gauges should be compared against the reduced levels obtained by levelling. If an error beyond the least count for a gauge is revealed, the zero of gauge or position of any section of the gauge should evidently require correction. In gauges intermediate divisions should be verified for their correctness using a steel tape or level.

### **3.3.4 Record of Gauges**

For proper maintenance of gauge records standard forms are being utilized. For recording the gauge readings the standard river data forms (RD Forms) RD-3 & RD-4 are used. RD-3 form is used for recording daily three times gauge observations at 8:00, 13:00 & 18:00 hrs. RD-4 form is being used during the monsoon season for recording hourly gauge readings.

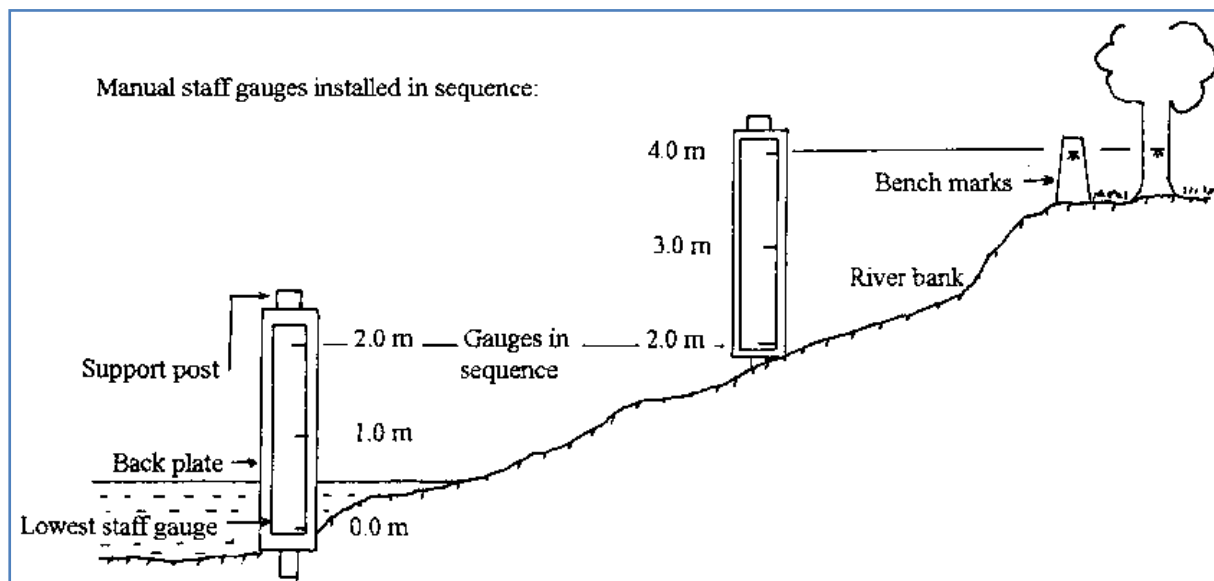


Figure 3.3-STAFF GAUGE

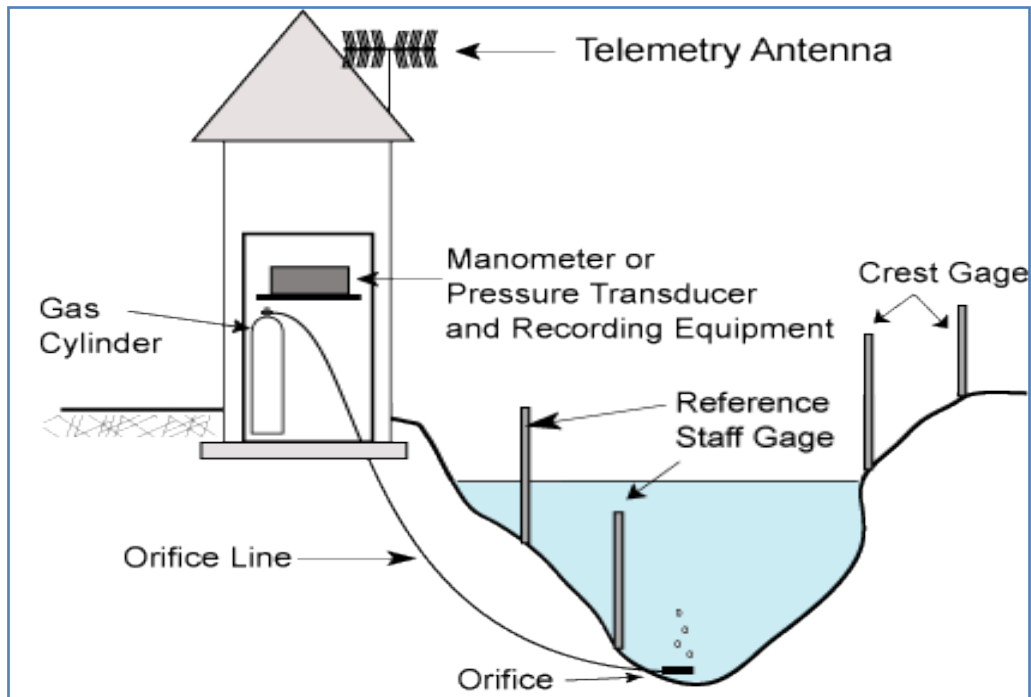
### 3.4.Digital Water Level Recorders

Digital Water Level Recorders (DWLR's) take a variety of forms but have in common the ability to measure and register the water level at a specified interval in digital storage on a data logger. The sensor may take the form of float-operated shaft encoder, a pressure transducer or Radar measurement. Data loggers for water level measurement nowadays have the capability to store the data and facility to retrieve it using USB drive and also transmit the data using GPRS system or satellite based to a predefined location(s).

The methods of setting up and checking DWLR's depend upon the type of logger and sensor and on software specific to a logger type. Visual checking of the performance of the DWLR is possible through on-site display into the logger. Periodical checking involves following steps:

- i. Read the reference staff gauge.
- ii. Check the Permanent termination block for deposition of silt and remove the silt if required so as to make it free upto the nozzle level (bubbler type DWLR).
- iii. Check that the logger clock is within acceptable time accuracy.
- iv. Check the current water level recorded by the DWLR with that of staff Gauge.
- v. Download the logger data, either the full stored contents or the data since last download, as required.
- vi. Clean the solar panel from dust or debris.

- vii. Check for breakage of HDPE pipe.
- viii. Check the battery condition as provided in the data logger display unit.
- ix. Notice any change in the alignment of antenna of the transmitter and inform the Engineer-in-charge accordingly.
- x. Visually inspect the alignment of the Radar.
- xi. Check that the cables and electrical connections are not damaged or loosened.



**Figure 3.4(i) Bubbler type telemetry DWLR**



**Figure 3.4(ii) RADAR type Water Level Sensor**

## Chapter 4 : DISCHARGE OBSERVATION

Stream/River flow measurement involves determination of total volume of water passing through the cross-section of a stream in a measured interval of time. Water discharge in rivers and streams is usually expressed in cubic meters per second (cumec) or cubic feet per second (cusec).

There are various methods for the measurement of discharge, which can be classified into two categories, namely, (a) Direct methods and (b) Indirect methods.

### Direct Methods

Area-Velocity Method using Current Meter

- (a) By wading
- (b) By boat or catamaran or motor launch
- (c) From bridge
- (d) From a cable way

Other Methods

- (a) Float method
- (b) Ultrasonic method (ADCP)
- (c) Color velocity method

### Indirect Methods

- I. Slope-Area method
- II. Stage-Discharge relation
- III. Discharge estimation at Hydraulic Structures

#### 4.1 Area Velocity Method using Current Meter

Discharge Measurement by the Area-Velocity method is the most accurate one and is adopted by various agencies in India for regular discharge observations. In this method, observations of depths and velocities are required to be made in a number of segments along the section.

In this the river section is divided into a number of compartments depending upon the degree of accuracy required. The width and mean depth of each compartment is measured to determine its cross-sectional area. The mean velocity in the compartment is measured by a water current meter. The discharge through each compartment is the product of its cross-sectional area and mean velocity. The discharge of the whole section is obtained by the addition of all such compartmental discharges.

##### 4.1.1 Equipments Used for Discharge Measurement

The equipment used at CWC Gauging Stations can be grouped into three categories as indicated below:

### Equipment for measurement of velocity

- a. Current meters & Accessories
- b. Wading Rod
- c. Protractor

### Equipment for measurement of depth

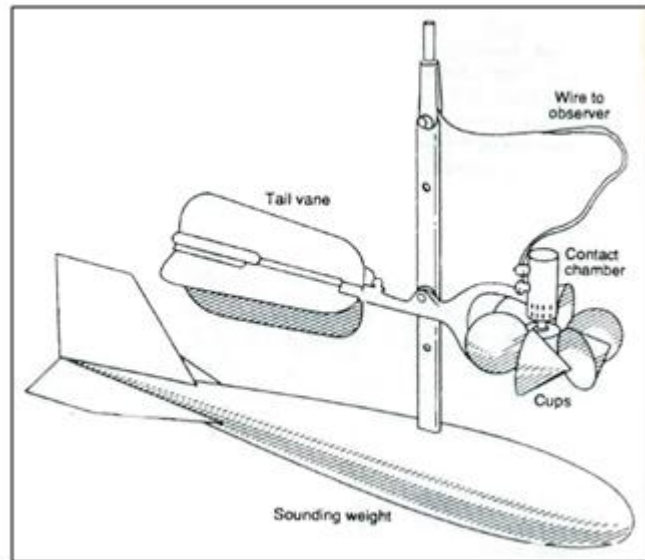
- a. Sounding rod
- b. Echo Sounder

### Miscellaneous equipment

- a. Stop Watch/ CM Counter
- b. Fish Weight
- c. Battery box with Earphone
- d. Thermo-meters
- e. Navigational Equipment
- f. Life Saving Devices
- g. Dumpy Level
- h. Prismatic Compass
- i. Screw drivers and spanners set
- j. Knife

#### ***4.1.1.1 Current meters & Accessories***

Current Meters (CM) are used to measure velocities at selected verticals along the discharge section. They are broadly classified as vertical axis cup type meters and horizontal axis screw or propeller type current meters. Vertical axis cup type current meters are widely used at sites. Some time few current meters of propeller type called Neyrpic current meters also used. They are used at sites where velocity is high in the order of 3.5 m/Sec and above. Pigmy current meter is used when the velocity of flow is very less.



*Fig 4.1.1.1. Current meter*

The accessories include suspension equipment, headphones, electronic counters, battery etc. The current meters are rated in the rating tank in the recognised Institutions such as IITs etc. After current meter is calibrated in a tank, a statistical rating curve is prepared to enable direct reading of velocity while using the current meter during field observations. The curve approximately takes the form of a straight line with equation  $V = aR + b$  where  $V$  is the velocity and  $R$  the revolutions per second. A rated current meter should be used for total 180 days or for 90 working days before its rating period expires. International Organisation for Standardization specifies this period to be 100 working hours.

Whenever a current meter is being replaced, it should be compared with the freshly rated current meter on last three days. If the difference in discharges observed by the two meters go beyond 5% a third current meter should be brought in for comparison and confirmation of the values. If the CM being used is damaged due to some reason then the comparison may not be done as this will give wrong information. The current meters are tested daily for spin before starting and after completing the discharge observations. If the spin is below 40 Sec the current meter should be discarded and a fresh current meter obtained. The spin should not be adjusted by movement of screws, spindle and pivot. It must be remembered that the discharge is a direct function of the observed velocities. In order to ensure that the observed velocities are correct, it should be handled carefully always in the wooden box and oil them daily before and after discharge observations for free rotation of spindle. A rating chart also be supplied along with the current meter to enable to deduce velocities from the observed values of revolutions of the current meter rotor and time taken. This rating chart must be preserved in a good file for any later reference.



#### 4.1.1.2 Wading Rod

It is a metallic rod circular in section and is of 1.5 M length with a base plate at the bottom. The length of the rod (1.5M) is composed of 3 pieces of each 0.5M in length. The pieces can be detached when not in use and packed up in the wooden box supplied. The wading rod is graduated in lengths of 1 cm so as to know the depth at which the current meter is lowered. The wading rods are used to suspend the current meters for observation of velocities by wading in low depths say up to 1 m, or more if possible. The current meters are suspended by means of a suspension rod and clamp bolts. A separate wading rod of 8 mm diameter rod is also used for lowering of pigmy CM at depth below which the cup type CM cannot be used.



*Fig 4.1.1.2 Wading Rod*

#### 4.1.1.3 Protractor

The direction of the current is many times not normal to the discharge section and hence it becomes necessary to apply correction for obliquity to the observed values of the velocities. For this purpose a wooden protractor graduated in degrees with a bottle or a wooden piece of sufficient size and having cut water shape attached to its pivot by means of a thread is supplied to measure the inclination of the current to the Discharge Section.

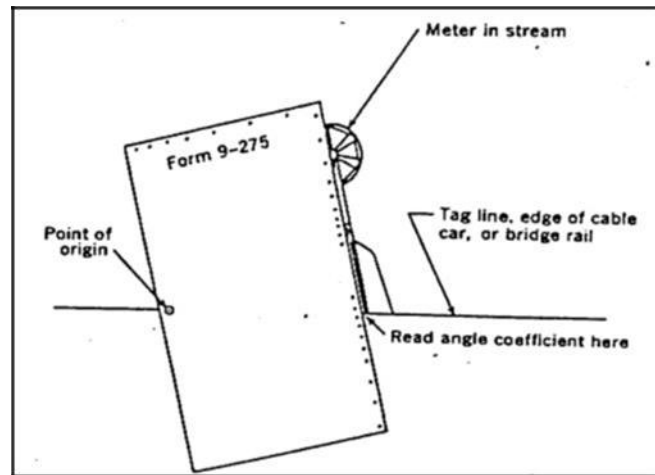


Fig. 4.1.1.3 using the protractor on the gauging form to determine oblique angle of flow

#### 4.1.1.4 Sounding rod

These are circular or oval in section and are 3 m in height. They are graduated to read nearest to a centimetre with a base plate at the bottom. They are used to measure depths (In case depth is not more than 3 m) at the selected verticals. However, bamboo sounding rods can be used to measure depths upto 6M. Marking on the bamboo should be truly vertical and along the body of the bamboo.

#### 4.1.1.5 Echo Sounder

Echo Sounders are used to measure large depths in floods. When the length of the sounding rods becomes insufficient to measure depths and could not be held vertical due to high velocity. An accurate and rapid, method of measuring and recording depths is by means of an echo sounder. The conventional method of sounding line may introduce error on account of three sources:

- a. Deflection of the line due to the current
- b. Error in judging when the line becomes truly plumb
- c. The bottom weight may sink in the bed depending on the bed material

These errors are obviated by use of an echo sounder. As the same suggests, the echo sounder works on the principle of sending out a pressure wave for a very short duration, receiving back the echo, that is the reflected wave, and measuring and translating the interval of time between start of the sound impulse and receiving of the return echo in terms of depth of flow. The depths observed by Echo Sounders

are prone to errors and hence should invariably be compared with the depths observed by sounding rods in low floods when both can be conveniently used to ascertain its accuracy. No air bubble should be available on the transducer face, which will cause progressive deterioration of waves and instrument depth indicating capability.

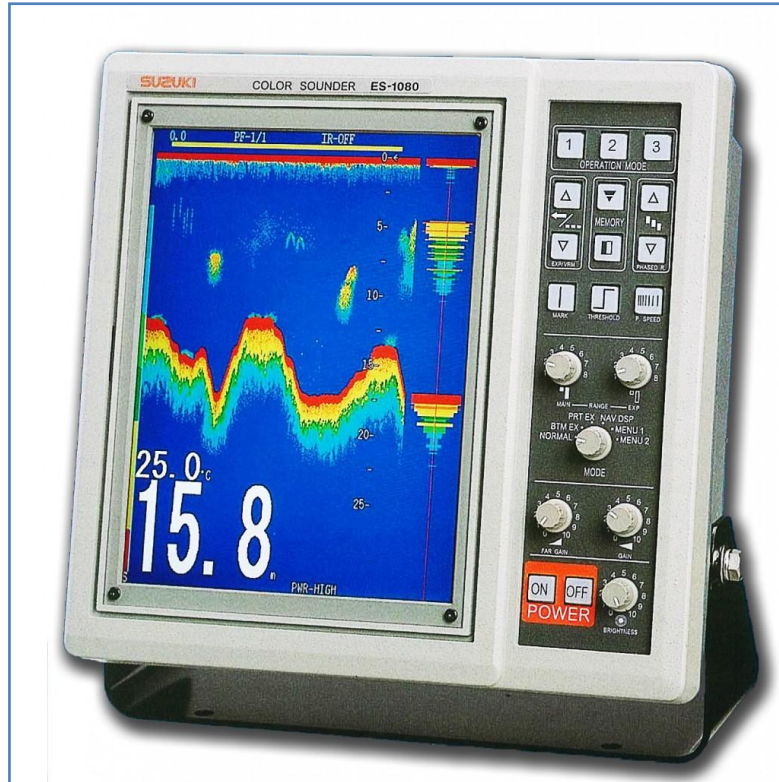


Fig. 4.1.1.5 Echo Sounder

#### 4.1.1.6 Stop Watch/ CM Counter

In gauging stations it is used to count the time taken for a number of revolutions of the current meter rotor. It is also used for noting time in float observations and in sediment analysis. Now counter with facility to preset time/ revolutions are being commonly used.



Fig 4.1.1.6 Current meter counter

#### 4.1.1.7 Fish Weight

Weights in the shape of a fish are added to the sounding link (sounding link is a wire with a Suspension rod at the bottom to suspend the fish weight and used to measure depth) or cable to keep reasonably vertical during measurement velocity and depth in rivers with sufficiently high velocity. The weights are in different sizes and weight according to the size. Heavy fish-weights are used for high velocities. The following formula may be useful guidance when choosing weights for different velocities.

Fish weight in Kg = 5 (max depth x max velocity)



Fig. 4.1.1.7 Fish Weight

#### 4.1.1.8 Thermo-meters

Each of the station is also supplied with the thermometers to measure temperature of river water at 0800 hours daily. In addition to the above, temperature of river water are also observed before starting discharge observations and after completing discharge observations.

#### 4.1.1.9 Navigational Equipment

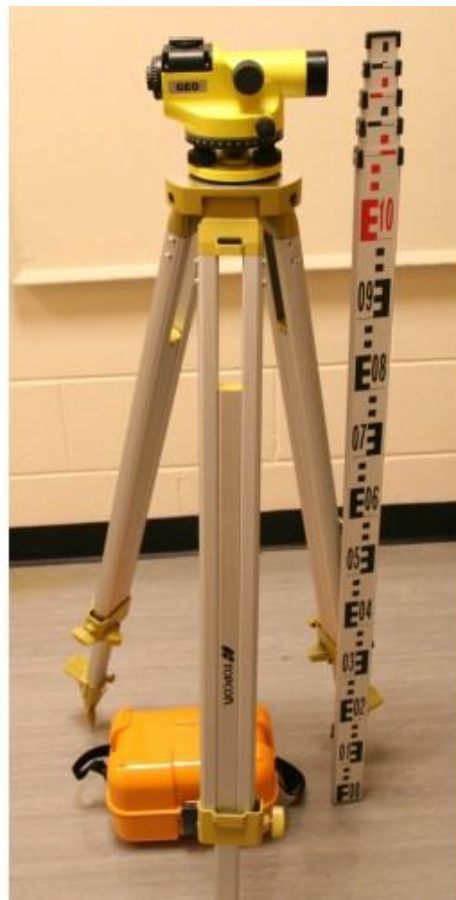
In order to observe velocities and depths at selected verticals along a discharge section, sites are provided with navigational equipment such as wooden/ FRP/ steel boat /launch of sufficient size and buoyancy, with a cable way/ O.B. Engine of sufficient horse power (25 to 90 HP) and persons sufficient numbers to position the boat. In the case of Bridge Sites no such equipment would be necessary for movement since observations are conducted from bridge using a bridge outfit. This equipment must be kept in good condition and painted neatly. They must be washed daily to remove mud and stains.

#### ***4.1.1.10 Life Saving Devices***

As the officials will be going out into the river by boats there is always a certain amount of risk due to certain short-comings like failure of O.B. Engine and unforeseen conditions like sudden rise of water. Precautionary steps have to be taken for such unforeseen eventualities. For that purpose gauging stations are supplied with Life Jackets and Life-buoys (Life Saving Devices). Every person must normally wear the Life Jacket and enter the boat so that in the case of any mishap, the person shall still be afloat and be saved by the other. In case the person did not wear the Life Jacket and had fallen into the river, someone must throw the Life buoy to him so that the drowning person can catch hold of it and float away to the bank safely.

#### ***4.1.1.11 Auto Level or Dumpy Level***

An Auto Level or Dumpy level is a levelling instrument and it is also supplied to all the sites to check the levels of all the gauge values periodically for correctness of the values. The level should also be tested for permanent adjustments on every 1st day of the month.



*Fig 4.1.1.11 Auto Level*

#### 4.1.1.12 Prismatic Compass

Gauging Stations are also supplied with a prismatic compass for measurement of angles and direction to accurately position the boats and power launches on a particular RD's and other measurements.

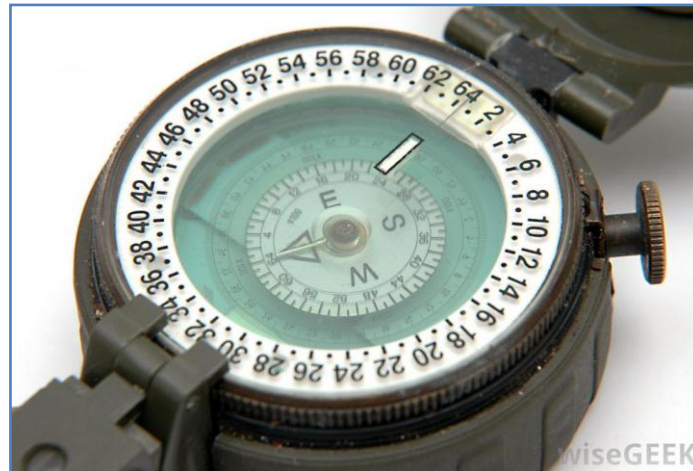


Fig. 4.1.1.12 Prismatic Compass

#### 4.1.2 Segmentation of Area of Cross-section

For discharge measurement, observations of depths and velocities are required to be made in a number of segments along the section. Fixing of the number and position of segments is known as segmentation. Method of segmentation presumes that measurement of depth and mean velocity made on any vertical gives a true average of these values within half the widths of adjoining segments on either side of a vertical. The segmentation & the width of segments are taken as per the following

Description of channel	Number of observations Verticals	Maximum width of Segment in Meters
(1) Channel not exceeding 15m or where its bed changes abruptly	15	1.5
(2) Channel with width of waterway from 15 to 90m	15	6
(3) Channel with width of waterway from 90 to 180m	15	15
(4) Channel with width of waterway from greater than 180m	25	-

The segmentation is also made in such a way that not more than 10% of the total discharge passes through each compartment and preferably not more than 4% variation exists between the discharges through any two adjacent compartments and in fixing segments, equal spacing of verticals should be preferred wherever possible.



Although the verticals are spaced at equal distances (Common width) there shall still be two segments at either end of the discharge section, which may or may not have the common width. Here the width of the first and the last segments are less than the common width. Hence correction should be applied for these two segments. This correction should be deducted to get the final corrected area. The formula used for first RD is:

Area Correction = (Common Width –  $\frac{1}{2}$  the sum of the segments on either

Side of the first RD in water) x depth at that RD

Or  $\frac{1}{2}$  X uncovered width X depth at the first RD of observation.

Likewise area correction for the last RD is equal to:

Area Correction = (Common Width –  $\frac{1}{2}$  the sum of the segments on either

Side of the last RD in water) x depth at that RD

Or  $\frac{1}{2}$  X uncovered width X depth at the last RD of observation.

Similarly for discharge observations, there are two end segments which may or may not have the common width. A correction has to be applied for this as in the case of computation of area of the discharge section. The same formula given above hold good by just replacing the term depth by the product of the velocity and depth observed at the first/last RD. This should be deducted to arrive at the final discharge figure.

#### 4.1.3 Marking of Segments

Where the width of channel permits, the width of each compartment is measured by direct means, i.e., a steel tape/wire suitable marked pendants. Where the channel is too wide, the distance would be measured by optical or electronic distance meters or by any of the usual surveying methods.

After deciding on the number of segments in which the cross-sectional area is to be divided, it is necessary to mark these on the section line to facilitate correct positioning of the sounding line and current meter on different verticals. For this the most popular method is the pivot point method. When the discharge observation are

proposed to be made from a bridge, segments are marked directly on the bridge parapet, railing or structural members.

When wire rope is used for segmentation then on the rope, tags, pendants or tally marks are attached to indicate every vertical on which observations are to be made. Depth and velocity measurements are made by wading or from boat at these verticals.

### ***Pivot Point Method***

When river is wide and land is available the pivot point method is the most suitable method for marking the segments. In this method, as shown in the figure below distance AP is approximately half the width of the river and PD is about one-fifth of AP. On a line DD', points are marked at fixed intervals depending on the width between the selected verticals. The boat moving on the line AA' can be fixed in the selected vertical by lining up with points P and E<sub>1</sub>, E<sub>2</sub>, E<sub>3</sub> etc. A second set of pivot points on the other bank can also be used, if required.

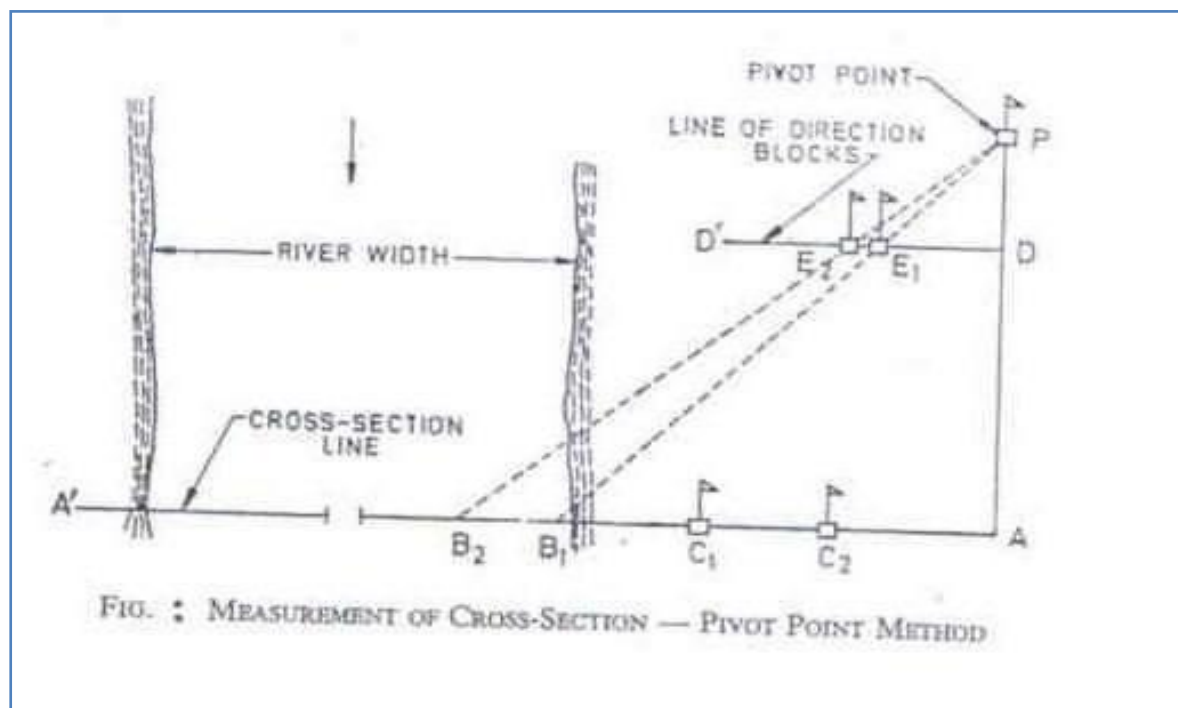


Fig. 4.1.3 Pivot Point Method

### **4.1.4 Measurement of Depth**

Measurement of depth and velocity by current meter are generally made in successive operations. The measurement of depth can be taken by using wading rods, sounding rod, log line or echo-sounder.



*Wading Rod* is used when velocities are low (1 m/s) and depths are small up to 1 m, wading observations using wading rod suspension can be made. If depth of flow permits, these rods may be used when observations are made from a boat or from a channel crossing. The rod is generally upto 3 m in length with arrangement to attach the current meter and a detachable base plate to prevent its sinking in the bed.

*Sounding Rods* are circular or oval in section and are 3m or more in height. They are graduated to read nearest to a centimetre with a base plate at the bottom. They are used to measure depths at the selected verticals. However, bamboo sounding rods can be used to measure depths upto 6m. Marking on the bamboo should be truly vertical and along the body of the bamboo.

*Eco-Sounder* is used to measure large depths in floods. When the length of the sounding rods becomes insufficient to measure depths and could not be held vertical due to high velocity. An accurate and rapid, method of measuring and recording depths is by means of an echo sounder.

When a sounding rod or sounding line is used at least two readings are taken at each vertical and the mean adopted for calculations. When the difference between the two readings is more than 5% of the large value, in which case two further readings should be taken. If these are within 5%, they should be accepted for the measurement and the two earlier readings discarded. If they are again different by more than 5%, no further readings should be taken, but the average of all four should be adopted for measurement.

When an echo-sounder is used, the average of several readings should preferably always be taken at each point, but regular calibrations of the instrument are required under the same conditions of salinity and temperatures of the water.

#### **4.1.5 Measurement of Velocity**

The velocity is measured by means of cup type or propeller type current meter. The current meter should be held in the desired position in any vertical by means of a wading rod in case of shallow channels or by suspending it from a cable or rod from bridge, trolley or boat in the case of deeper channels. After a current meter is placed at a selected point in the vertical, it is permitted to become adjusted to the current for at least a period of half a minute before the reading of the current is started. For low velocity of 0.3 m/sec or less, this time should not be less than 2

minutes. The length of time taken for each measurement shall be not less than 120 seconds or 150 revolutions of the meter, whichever is earlier, in order to eliminate the pulsating effect of the current.

Velocity is measured at all the selected verticals where, and at the same time, depth is measured. Velocity is not uniformly distributed from the surface to the bed at any vertical. It is approximately found to be maximum at 0.2 depth and minimum at the bed level. It is also found by vertical velocity distribution (VVD) experiments that the mean velocity occurs between 0.58d to 0.62d approximately and is equal to 0.89 times the surface velocity at the vertical. This is normally accepted and hence, velocities are measured at 0.6 depths by current meter. However experiments also being conducted on vertical distribution of velocity to verify the assumptions. After the depth at a vertical is observed either by a sounding rod or Echo-sounder, the current meter is lowered to 0.6 depth to measure the mean velocity at the vertical by counting the time taken for the current meter rotor for a number of revolutions. The greater the number of revolutions it is counted the more accurate value of the velocity we get.

Sometimes it may not be possible to lower the current meter to 0.6 depth, especially at bridge sites in high floods. In that case surface velocity is observed and later converted to mean velocity by multiplying with the factor 0.89. Many times the current is not normal to the discharge section and hence correction is necessary for obliquity by measuring the angle of the current to the discharge section. This correction must be deducted from observed mean velocities to get final corrected velocities normal to gauge line.

#### ***4.1.5.1 Current meter Measurements by Wading***

A measuring tape or tag line is stretched across the river at right angles to the direction of flow. The position of successive verticals used for depth and velocity are located by horizontal measurements from a reference point on the bank. The position of the operator is important to ensure that the operator's body does not affect the flow pattern at or approaching the current meter. The best position is to stand facing one or other of the banks, slightly downstream from the meter and at arm's length from it. The rod is kept vertical throughout the measurement and meter parallel to the direction of flow.

#### 4.1.5.2 Current meter Measurements from Boats & Power Launches

When wading observation are not possible and a bridge in the vicinity is also not available, depth and velocity observations are made using boat or power launch. Depth are measured using sounding rods etc and the distance above the water surface should be subtracted from the depth measurement and corrected depth used for proper placing of the current meter. When the boat is correctly brought at the vertical, it is anchored or operated in position by using a stay line cable. If the current is too fast and a power launch is used, its speed is adjusted so that it remains reasonably steady against the current.

When current meter observations are made, the meter must remain steady. This implies that the boat from which the meter is suspended must also remain stable in position. If any movement of the boat takes place, velocities recorded by the meter will not be accurate. This is because the current meter then records velocities of the current relative to the moving boat. These velocities are less than the actual velocity. Anchorages are used to keep boat stationery while launches can be made stationery on their engine power. Sometimes in high velocities a boat even anchored or a launch even at full speed begins to drift downstream. The drift velocities in such cases have to be found and added to the velocity recorded from the meter to obtain correct velocity of the current as per the following formula: -

$$\underline{V_p} = 0.064 + 0.98 \underline{V_b} + 0.98 \underline{V_d}$$

Where  $\underline{V_p}$  = true velocity in meters per second

$V_b$  = velocity in meter per second, observed at the point with the boat drifting

$V_d$  = drift velocity in meters per second

$$\begin{aligned} & \text{Drift in meters} \\ & = \frac{\text{-----}}{120 \text{ seconds (period of observation)}} \end{aligned}$$

Personal safety is an important consideration in boat gauging, and velocity of flow in relation to the power of the boat will limit the conditions under which gauging is possible. All members of the crew should wear life jackets. There should be one member specially assigned to the task of propelling, controlling and positioning of the boat.

Moving Boat method is useful in the cases when –

- i) The river is too wide and the discharge measurement by conventional method is impractical/tedious and costly.
- ii) The site is very remote without the Normal facilities required by the usual method.
- iii) The facilities at the site are inundated or inaccessible during floods.
- iv) The site is situated in a tidal reach where it may be necessary to observe the discharge not only frequently but continually throughout the tidal cycle.
- v) The flow at the site is very unsteady and should be observed as quickly as possible.

#### ***4.1.5.3 Current meter Measurements from Cableways***

Cableways are normally used when the depth of flow is too deep for wading, when wading in a speedy current is considered dangerous or when the measuring section is too wide to string a tag line or tape across it. The operating procedure depends on the type of cableway, whether it is an unmanned instrument carriage controlled from the bank by means of a winch, or a manned personnel carriage or cable car which travels across the river to make the observations.

In the case of unmanned cableway, the operator on the bank is able to move the current meter and sounding weight and to place the current meter at the desired point in the river by means of distance and depth counters on the winch. The electrical pulses from the current meter are returned through a coaxial suspension cable and registered on a revolution counter.

The manned cableway is provided with a support for a gauging reel, a guide pulley for the suspension cable and a protector for reading the vertical angle of the suspension cable. The procedure involved is as follows-

- i. Identify and record the water edge (RB or LB) in relation to a permanent initial point on the bank by means of a tag line or by the use of painted marks on the track cable, used for spacing the observation verticals.
- ii. Lower the current meter at the first vertical until the bottom of the weight just touches the water surface and set the depth counter to zero.
- iii. Lower the current meter assembly until the weight touches the bed, read the counter and record as depth.

- iv. Raise the meter back to the surface and place the meter axis at the water surface and zero the depth counter again. Calculate  $0.6 D$  etc. and lower the meter to the required position.
- v. When river is speedy and deep and the suspension cable suffers drag, measure the angle that the meter suspension makes with the vertical using a protector, as a basis for correcting the soundings to obtain the correct depth.
- vi. Measure the velocity at the selected depths in the verticals.
- vii. Raise the current meter occasionally for inspecting floating debris or weed in the river for cleaning the current meter.

#### ***4.1.5.4 Current meter Measurements from Bridges***

When a river cannot be waded, suitable bridges may be used for current meter measurements. The advantage of this is that in this there is saving in initial cost of erecting a cable way or purchase boats etc. Its site is accessible at all times of the year. During heavy flow, rivers which spill enormously over miles beyond the banks pose a difficult problem in stream gauging than a bridge under such conditions provide excellent site for gauging where all the river discharge is confined and flows only through the bridge openings. At the same time it also has dis-advantages like- usually ideal conditions will not be obtained at bridge site for stream gauging. The bridge may not be normal to the flow; bridge piers offer obstructions and may cause non-uniform and turbulent flow to occur which is unfavourable if accurate discharge observations are to be made. When current meter is lowered from the downstream of the bridge (which is more convenient) unseen floating debris might get entangled with the current meter. On the other hand, if the upstream of the bridge is used the drag causes the current meter to be hidden under the bridge deck.

Measurements are made from the downstream parapet and not from the upstream side of the bridge because by this the possibility of current meter fouling pier is thus minimised. In this the distance from this point to the water surface is measured by lowering the rod until the base plate just touches the water. The rod is then lowered to the bed and the reading again noted at the index point. The difference in these readings is the depth of water in that vertical.

For road bridges care must be taken to ensure that road traffic does not endanger the gauging team or other road users. For higher bridges and for greater depths, the

current meter and weight are suspended on a cable controlled by gauging reel mounted on a bridge derrick or bridge outfit.

*Wet Line & Dry Line Corrections* are used when suspending the current meter in deep swift water, as it is carried downstream before the weight touches the bottom. The length of cable paid out is more than the true depth. In order to obtain the corrected depth, dry line and wet line corrections, which are function of vertical angle  $\alpha$ , are applied to the observed depth, where the angle  $\alpha$  is measured by a fixed protector. Below in the figure the air line correction is given by  $CD = AD - CD$  & represented by  $K_{la} = (\sec \alpha - 1) L_1$ . The wet line correction  $K_{lw}$ , also expressed as a percentage, to be deducted from the measured length of the sounding line below the water surface and it is taken from the table with respect to the vertical angle.

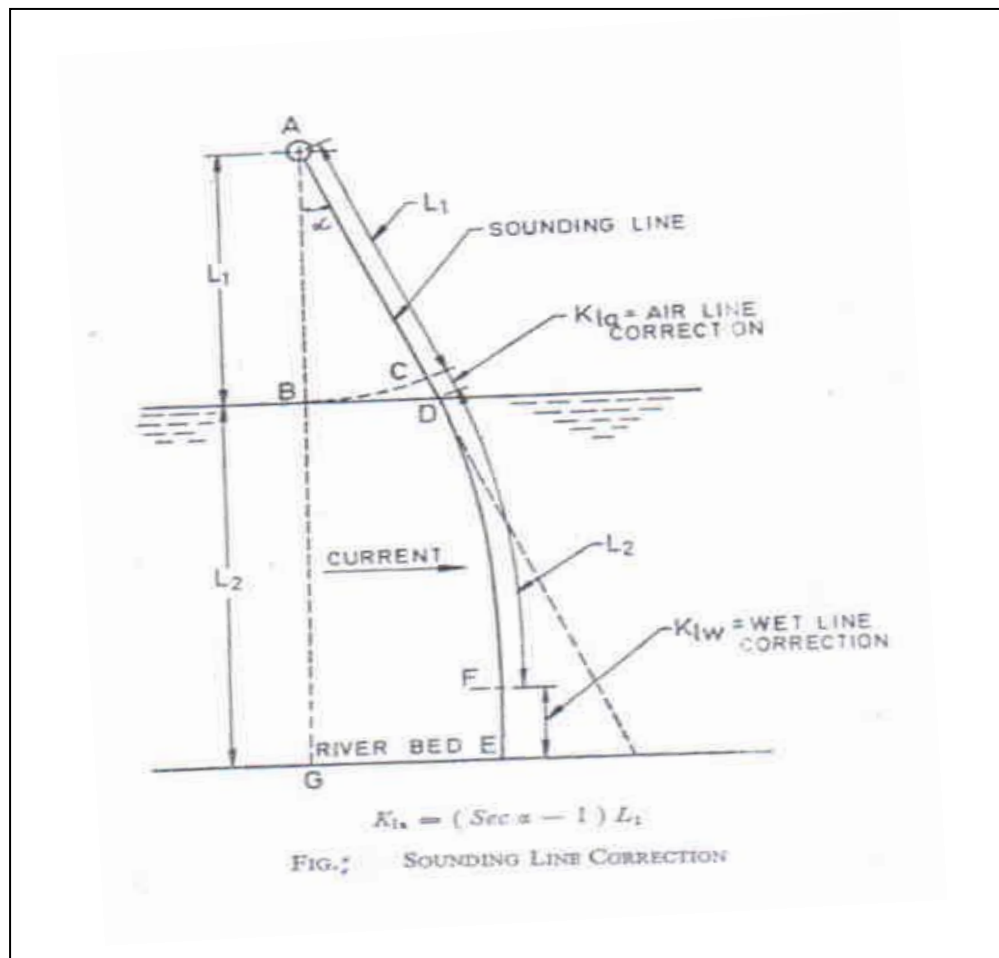


Fig. 4.1.5 Wet line correction

#### 4.1.6 Limitations and Precautions in Current Meter Observations

- i. The current meter should not be used beyond the range of velocity for which it has been calibrated.
- ii. Errors may arise if the flow is unsteady and if material in suspension interferes with the rotation of the current meter.

- iii. If the flow is unsteady, the time for the observation of velocity should be as short as possible otherwise it will lead to a corresponding decrease in accuracy.
- iv. The distance of the axis of the current meter from the side or the bed of the channel shall be not less than 0.75 times the diameter of the propeller or 0.2m, whichever is greater. The distance of the current meter from the side of the boat should, in no case, be less than the distance between the gauging section and the upstream end of the boat.
- v. For depth of water less than one meter, the current meter observation may be made with the help of wading rods, wherever the velocity of flow would permit such measurement.
- vi. Current meter is calibrated in still water but used in flowing water with turbulence. This introduces certain amount of error, which, however, may be ignored.
- vii. If the flow is oblique the angle between the direction of the flow and the section line is measured by a float attached to cotton or nylon cord and a protractor/sextant. The component of the velocity normal to the section line is obtained by multiplying the observed velocity by the sine of this angle. For ready use and computation, a modified velocity table is prepared and used during the observation.
- viii. If the boat or motor launch drifts during the discharge observation, the drift should be measured carefully and correction to the observed velocity should be made.
- ix. The assumption that the mean velocity is given by measurement at 0.6 depth or by taking mean of the velocities observed at 0.2 and 0.8 depths is based on a parabolic velocity distribution. This is not always correct. This assumption needs to be verified occasionally by the velocity distribution method and a suitable coefficient applied, if necessary.

#### 4.1.7 Computation of Discharge

The river section is divided into a number of compartments depending upon the degree of accuracy required. The width and mean depth of each compartment is measured to determine its cross-sectional area. The mean velocity in the compartment is measured by a water current meter. The discharge through each compartment is the product of its cross-sectional area and mean velocity.



There are numerous methods of calculating discharge. The one followed by CWC is the "Mid-Section Method". In this method the depths and the velocities observed at all the verticals are first multiplied and such products summed up and finally multiplied by the common width of the segments. It is given as follows -

### Depth Velocity Integration Method (Mid-Section Method)

The discharge in the stream is calculated by the summation

$$Q_m = \sum d_i b_i v_i$$

Where  $Q_m$  = calculated discharge

$B_i$  = width of the  $i$ th segment

$D_i$  = depth of the  $i$ th segment

$V_i$  = mean velocity in the  $i$ th segment

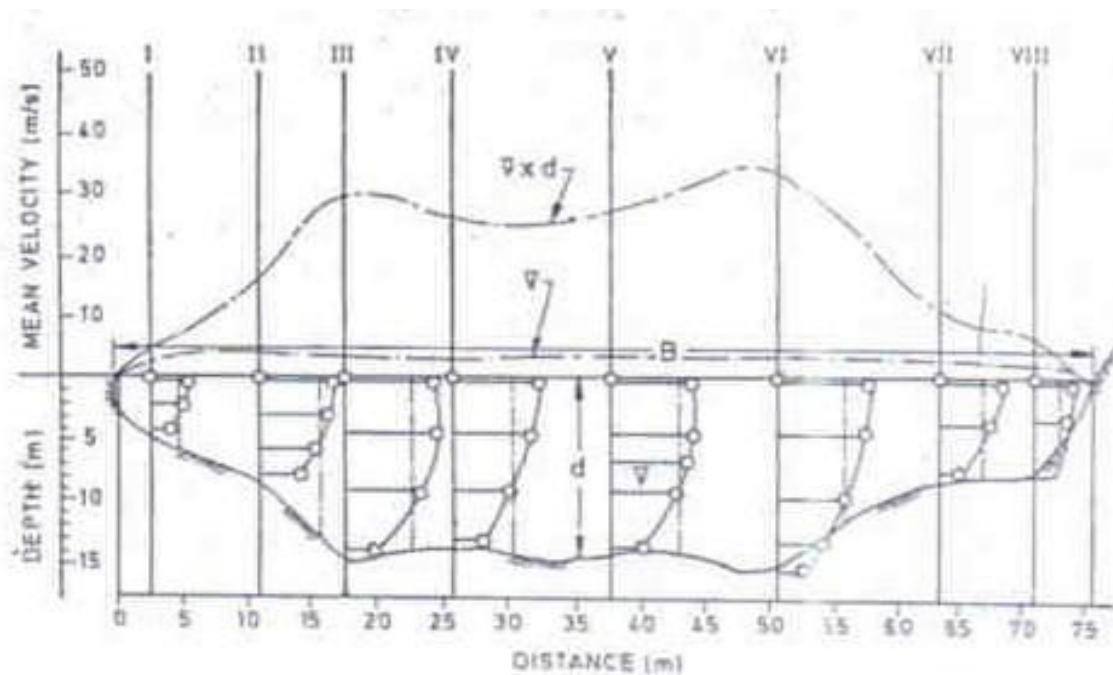


FIG. 2. COMPUTATION OF DISCHARGE FROM CURRENT-METER MEASUREMENTS DEPTH VELOCITY INTEGRATION METHOD

### Arithmetical Method (Mean-Section method)

$$q \text{ (segment)} = \frac{(\bar{V}_1 + \bar{V}_2)}{2} \times \frac{(d_1 + d_2)}{2} \times b$$

Where  $\bar{V}_1$  = mean velocity at segment 1

—  $\bar{V}_2$  = Mean velocity at segment 2

$d_1$  = depth at segment 1

$d_2$  = depth at segment 2

$b$  = horizontal distance between the two segments



The total discharge is obtained by adding the discharge from each segment.

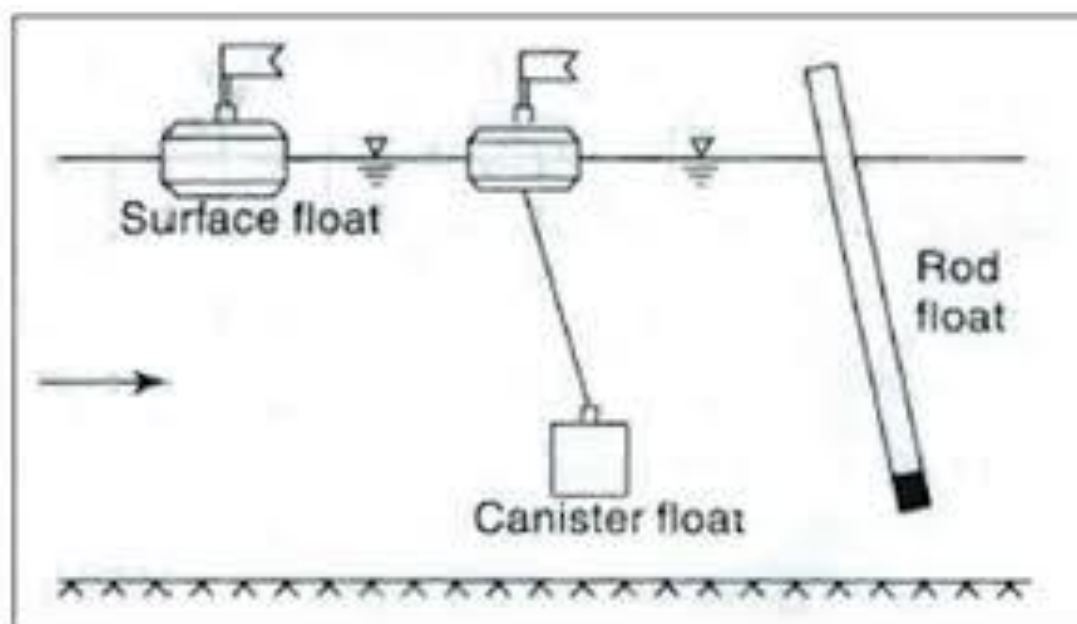
## 4.2 Area-Velocity Method using Float

### 4.2.1 Scope

During very high floods it may not be possible to venture into the river by boat to observe velocities by current meters. In such circumstances it is advisable to follow the float observations. The methods of float (surface) observations is designed and have to be adopted as the regular method for daily observations for those sites which are not too wide and where the current meter observations cannot be taken for want of powered navigational equipment, not possible to venture into the river due to high flood, etc.

### 4.2.2 Type of float

In view of the difficulty of recovery of floats the floats shall be inexpensive and made of the locally available material like jungle wood, bamboo etc., in high floods, floating debris in the river may be used as a float.



### 4.2.3 No. of floats

The number of floats will depend on the width of the river and the convenience of observations and shall vary from 8 to 15 inclusive of the two floats to be thrown 5 to 10 M away from the water edge on either side of the river. Keeping the end floats comparatively nearer to water edges is very essential.

#### 4.2.4 Float run

The float run shall start from 100 M upstream of the station gauge and shall end 100 M downstream of the station gauge. The distance could be reduced if there are practical difficulties of keeping this distance as 200 M. But in any case the minimum distance between the upper and lower sections should be such that duration of float movement is not less than 40 seconds. For marking the float run, wooden poles or flags should be erected along both the upper and lower section lines of the float run on both the banks. The float shall be released from a boat or thrown from a bank at a minimum of 15 to 20 M above the upper cross-section so that the float attains the velocity of the flow before reaching the upper cross-section. In case of those sites where railway bridges are available, the floats could be thrown from such bridges.

#### 4.2.5 Measurement of Velocity

For the purpose of discharge calculations, the position of float on the station gauge has to be known. The path of the float shall be determined by angular measurement from a known reference point when the float passes the upper and lower cross section lines. This can be achieved by any of the following two semi graphical methods, which involve the use of compass or theodolite on one of the banks.

**Method-I:** In this method the theodolite or the prismatic compass is kept on bank at a convenient location on the station gauge line. In case of theodolite, the zero angle should be made to coincide with the station gauge line, and in case of prismatic compass the bearing of the station gauge line should be noted. The moment the float is released, the theodolite or the prismatic compass is brought in line with the float and the float is followed. The moment the float crosses the upper/upstream line, a person stationed there gives a whistle. The angle that is recorded by the instrument with the station gauge line section is noted. The float is continued to be followed till it again crosses the lower/ downstream line when another whistle is given by another person standing along that section. This angle with the station gauge line is also noted. This is repeated for each float. A sketch is then prepared showing the upper and the lower section lines as well as the station gauge and the location of the instrument. The angles observed by the instrument are then plotted as shown in

figure-1 and the points “A” and “B” at which the float has crossed the upper and the lower cross-sections are thus obtained. The points “A” and “B” are joined to intersect the station gauge at “C”. The location of “C” gives the RD at which the velocity indicated by the float is applicable. The location of water edges shall be obtained by actual measurement.

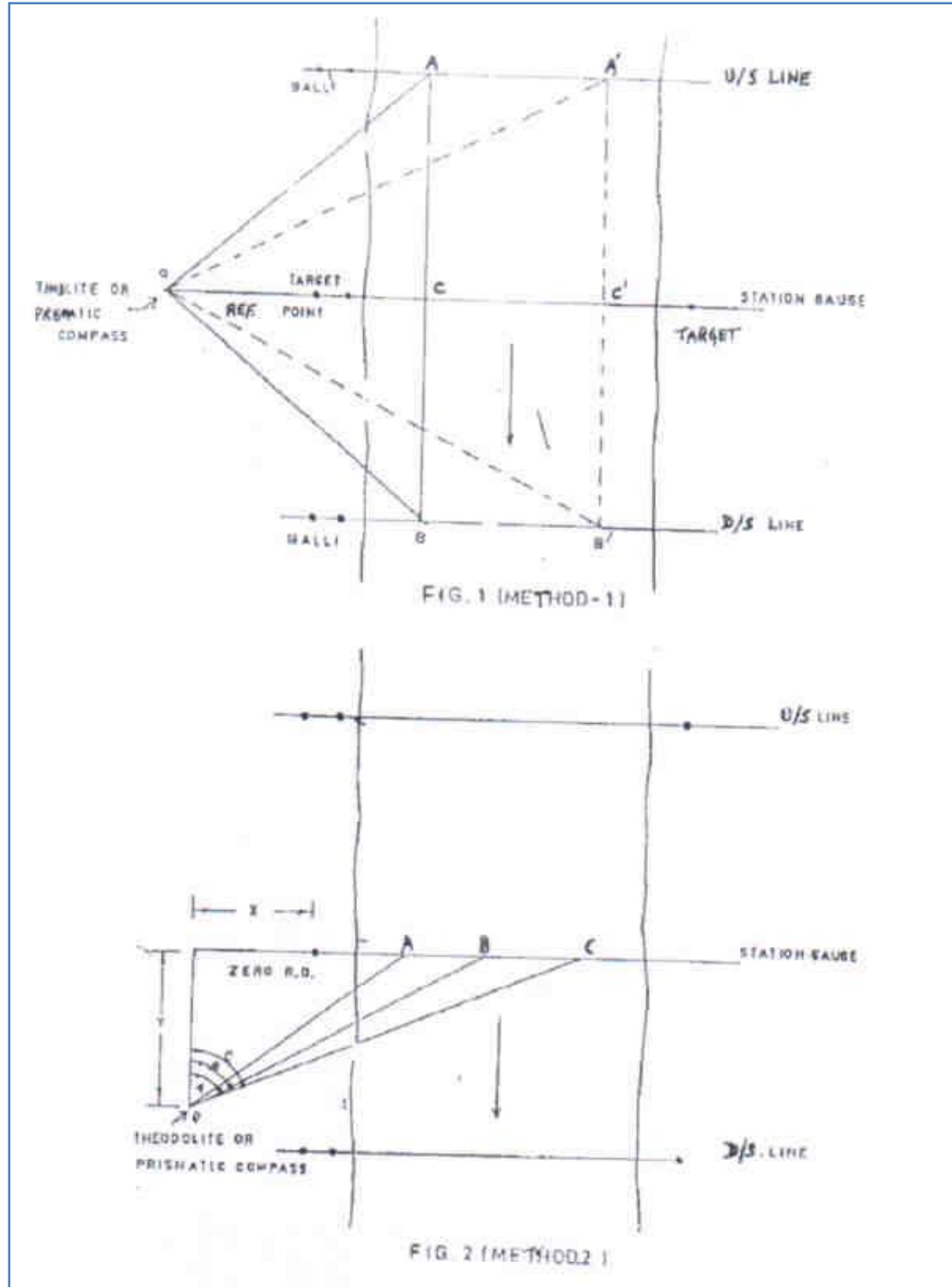


Fig.4.2.5 Angular measurement using theodolite

**Method II:** In this method, the theodolite or the prismatic compass is kept on a bank at a convenient point either upstream or downstream of the station gauge line, say at

a distance of about 100 to 200 m from the point where the instrument has been kept, a line perpendicular to the station gauge line is set out and the bearing noted in case of prismatic compass and in case of theodolite, the zero angle made same as this perpendicular line. The float is followed by the instrument as in case of Method I. However, an extra person is required at the station gauge line to give signal when the float crosses the station gauge section. The angle to be measured by the observer shall only be one angle i.e., at the time the float crosses the station gauge line. No angles needed to be measured when the float crosses the upstream or downstream section. Then as shown in figure 2 above, a sketch is prepared to show the location of station gauge line and the position of the instrument. The angles measured by the instrument with respect of the perpendicular to the station gauge line are plotted so as to give the points "A" "B", "C" etc., on the station gauge giving the RD at which the float has crossed the station gauge section. The water edges are in this case also measured by actual measurement. The time at which the float crosses the upper and lower cross-section lines shall be noted. This shall be repeated with the floats at various positions along the width of the river from one bank to the other. The velocity (surface) of flow of water shall be determined by dividing the distance between the upper and lower cross section by the time taken. This gives the velocity of the float normal to the station gauge section at the RD at which it has crossed the station gauge.

#### **4.2.6 Depth Measurements**

The RDs depth shall be taken from the latest available cross section for the station gauge line. By cross-section here means the plot of the under water portion based on the actual depths.

#### **4.2.7 Method of Calculations**

The RDs at which the velocities have been observed are first marked on a straight line drawn to scale on a graph sheet representing the station gauge line cross section. The corresponding velocities are then plotted normal to this line to a convenient scale and these values are then joined to form a horizontal velocity distribution curve across the station gauge line. The depths at various RDs (at equal intervals) are determined from the cross sections. The velocities at these RDs are obtained from the velocity distribution curve mentioned above. Knowing the velocity

and depth, the discharge could be worked out as in case of current meter observations.

### 4.3 Discharge Estimation by Area-Slope Method

In this method, discharge is worked out by multiplying cross-sectional area by average velocity of the whole stream which is found indirectly, using one of the open channel flow formulae. The method lacks accuracy since both, area as well as velocity, can be determined only approximately. Generally area of cross-section measured during dry weather season has to be adopted in computation of flood discharge. However, there may be some differences in dry weather and flood sections of a river unless the bed is rocky. In alluvial rivers variation in section in narrow reaches can be considerable. Assessment of the proper value of the coefficient in an open channel flow is another limitation in this method. Similarly accurate data of river slope may not many times precisely available. Due to these limitations discharge estimated by Area-Slope method can at best be approximate and cannot be accepted at par with discharge measured by current-meter observations. When width of the river is more than 60 m, it is necessary that gauges on both the banks be installed and the mean gauge value is used in slope calculations.

#### 4.3.1 Area

It is desirable to observe the flood sections for calculating the cross-section area but in case, if it is not possible then area of cross-section measured during dry weather season has to be adopted for computation of flood discharge. In such cases it is likely that changes which have occurred in river bed in the intervening period might affect the result.

#### 4.3.2 Velocity

The velocity is deduced indirectly by observing the slope of water surface and using Manning's formula:

$$V = (1/n)(R^{2/3} S^{1/2}) \text{ m/sec}$$

V= Velocity in meter/sec

R= Hydraulic mean radius = A/P (Area of the Discharge Section/  
Wetted perimeter of the discharge section).

(Wetted Perimeter is some time taken as water width itself for simplicity)

$S$  = Slope of water surface per meter.

(It is calculated by observing the gauge readings of the U/S Section and D/S section)

$n$  = Rugosity Co-efficient.

(This should be based on the actual value determined previously by Area-Velocity method for the same Water level).

#### **4.4 Discharge Estimation from Stage-Discharge relation**

When it is not possible to observe discharge daily on considerations of expenditure or during flood stages, discharges are computed from a stage discharge curve (Rating curve) developed on the basis of stage discharge data earlier observed.

The rating curve should be prepared from actual observations spread over the whole range of flow at the site. Where it is not possible to observe the discharge in extraordinary high floods the rating curve is extrapolated for estimation of the high flood discharge. The method normally used in the field is to plot the rating curve on a log-log paper and then extrapolation of it for the high stage required.

#### **4.5 Special Methods of Discharge Measurement**

##### **4.5.1 Discharge Measurement using ADCP**

In recent years, advancement in technology has allowed us to make discharge measurements by use of an Acoustic Doppler Current Profiler (ADCP). An ADCP uses the principles of the Doppler Effect to measure the velocity of water. The Doppler Effect is the phenomenon we experience when passed by a car or train that is sounding its horn. As the car or train passes, the sound of the horn seems to drop in frequency.

The ADCP uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. Due to the Doppler Effect, sound waves bounced back from a particle moving away from the profiler have a slightly lowered frequency when they return. Particles

moving toward the instrument send back higher frequency waves. The difference in frequency between the waves the profiler sends out and the waves it receives is called the Doppler shift. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. Sound waves that hit particles far from the profiler take longer to come back than waves that strike close by. By measuring the time it takes for the waves to bounce back and the Doppler shift, the profiler can measure current speed at many different depths with each series of pulses. The sound is transmitted into the water from a transducer to the bottom of the river and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom and back to the ADCP.

To make the discharge measurement, the ADCP is mounted onto a boat with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using  $\text{discharge} = \text{area} \times \text{velocity}$ , similar to the conventional current-meter method.

The ADCP has proven to be beneficial to stream gauging in several ways. The use of ADCPs has reduced the time it takes to make a discharge measurement. The ADCP allows discharge measurements to be made in some flooding conditions that were not previously possible. The ADCP provides a detailed profile of water velocity and direction for the majority of a cross section instead of just at point locations with a mechanical current meter; this improves the discharge measurement accuracy.

A number of ADCP's of RDI make has been deployed at many of the CWC Hydrological Observation stations. The models presently in use are RDI Workhorse and the more recent one called River Ray. The Workhorse model is to be fixed on an OBE propelled boat with some anchoring arrangement, whereas the River Ray which consists of trimaran has to be towed with help of the boat and communication between the laptop and ADCP can be done using Bluetooth.



*Fig 4.5.1(i). Rio Grande Work Horse ADCP*



*Fig 4.5.1(ii). River Ray ADCP*

#### **4.5.1.1 Salient features of Rio Grande Work Horse ADCP**

The Rio Grande Work Horse ADCP has several operating modes, which can be selected via the lap-top. The selection of the most appropriate operating mode is dependent on site conditions. The selection of operating modes is referred to briefly in the following paragraphs. However, for detail the users should refer to the manufacturer's user manual.

The Work Horse 600 kHz and 1200 kHz, has four operating modes i.e. modes 1, 4, 5 and 8. A comparison of these different operating modes which has been taken from the manufacturer's user manual is contained in Table 4.5.5.1. The major site constraint on the use of the ADCP is the channel depth

- Operating mode 1 only functions in depths greater than 1.0 m;
- Operating mode 4 only functions in depths greater than 3 m;



- Operating mode 5 only functions in depths greater than 1.25 m;
- Operating mode 8 only operates in depths greater than 0.8 m.

	<b>Mode 1</b>	<b>Mode 4</b>	<b>Mode 5</b>	<b>Mode 8</b>
Minimum recommended cell size	0.10 m 0.20 m	0.25 m 0.50 m	0.10 m 0.20 m	0.10 m 0.20 m
Single ping standard deviation (min. cell size)	0.6 m/s <i>0.50 m/s</i>	0.13 m/s <i>0.13 m/s</i>	0.01 m/s <i>0.01 m/s (at 0.50 m/s flow velocity)</i>	0.15 m/s <i>0.10 m/s (at 1.0 m/s flow velocity)</i>
Minimum depth of water	1.0 m <i>1.2 m</i>	2.5 m <i>3.0 m</i>	2.0 m <i>2.0 m</i>	1.0 m <i>1.0 m</i>
Maximum range (Mode 5 & 8 for <50 cm/s flow velocity)	20 m <i>50 m</i>	20 m <i>60 m</i>	4 m <i>8 m</i>	4 m <i>8 m</i>
Maximum relative velocity	10 m/s <i>10 m/s</i>	10 m/s <i>10 m/s</i>	1 m/s <i>1 m/s</i>	1 m/s <i>2 m/s</i>
Typical application	Very fast water of all depths. Rough and dynamic situations. Good in streams too fast or deep for modes 5 & 8, and not deep enough or too rough for mode 4.	General purpose for most streams more than 3 m deep	Slow, shallow water with low shear and turbulence conditions	Shallow streams with velocities < 2 m/s and with high shear (rough bed and /or turbulence. Works where mode 5 does not work well.
<p>1 .Maximum range depends on water temperature and depth cell size. Use BBSETUP to compute the maximum range for a particular ADCP set-up and water temperature. The standard deviation of modes 5 &amp; 8 varies with water velocity, boat speed, bed form roughness, channel depth and turbulence. Reference should be made to the ADCP for further discussion on these modes</p> <p>2 The figures in normal type are for the 1200 kHz system and those in italics for the 600 kHz system</p>				

Table 4.5.1.1(i): Comparison of performance of RDI 1200 kHz and 600 kHz ADCPs, both with transducers at 0.25 m deep & blank set to 0.30 m

**However, it is recommended that the effective depth should be greater than 1.5 m for at least 95% of the cross-section.**

**NOTE:** The depth is actually the effective depth i.e. the position from the transducers to the bed of the river. Therefore if the transducers are positioned 0.3 m below the surface, then an actual depth of 1.5 + 0.3 m = 1.8 m is required.

Another major site consideration is flow velocity:

- Mode 8 can accurately measure flow velocities greater than 0.06 m/s.
- Modes 1 & 4 can measure velocities up to 10 m/s;
- Modes 5 and 8 can only measure velocities up to 1 and 2 m/s respectively;
- The uncertainties in Mode 1 velocity readings are significantly higher than other modes.

The velocity and depth constraints can be combined together as follows in the table 4.5.1.1(ii) given below:

Depth (m)	Velocity - v (m/s)					
	v < 0.04	0.06 > v > 0.04	0.05 > v > 0.06	1.0 > v > 0.05	2.0 > v > 1.0	10 > v > 2.0
< 1.0	none	none	none	none	none	none
1 < d < 1.5	none	none	mode 8	mode 8	mode 1	mode 1
1.5 < d < 3.0	*	mode 5	mode 5	mode 5	mode 1	mode 1
3.0 < d < 4.0	*	mode 5	mode 5	mode 4	mode 4	mode 4
D > 4.0	none	none	none	mode 4	mode 4	mode 4

\*- Minimum water velocity in mode 5 at these depths has not been ascertained.

#### 4.5.1.2 DEPLOYMENT OF ADCP

The ADCP should be deployed from an outboard motor propelled boat, which has been specially adapted for the task. The boat should be of a shallow draft type, preferably not greater than 0.5 m when laden with the equipment and the required number of operatives... Also, the boat should be relatively flat bottomed, stable and easily manoeuvred.

The ADCP should be fixed to the boat by means of a mounting arrangement. It should be possible to fit the mounting arrangement to any boat. This arrangement should be such that the ADCP transducers can be raised and lowered to different positions below the water surface in 0.1 m increments from 0.1 to 1.0 m. A rigging facility is required to prevent the ADCP to lean back during (fast) sailing. The rigging should be such that when the ADCP impacts with anything solid it can give way and swivel to the surface. An adequate shelter should be provided on the boat to protect the operator and laptop PC from sun and rain. A rigid working table should be provided on which to place the laptop PC and field data forms.

However the latest model of ADCP's are mounted on floating trimaran, which are towed by the Outboard motor propelled boat using strong and flexible synthetic rope which is anchored to the boat. In such type of ADCP's on trimaran the communication between the laptop and the ADCP is carried out using Bluetooth connectivity.

ADCPs can be deployed in self-contained and real-time mode. The latter is preferred since anomalies and problems with the data being collected can be spotted immediately by means of the laptop. In some situations it might be necessary to operate the equipment in self-contained mode, i.e. without a laptop PC connected but recording data in internal memory. The ADCP should be fitted with such memory then. A PC is required anyway to set-up the ADCP before and to retrieve the collected data after the deployment.

#### 4.5.1.3 OPERATING SET-UP

Prior to commencing a measurement various set up parameters must entered into the ADCP via the PC lap top and deck box. The appropriate operating mode must be selected. Certain deployment parameters can be set within each operating mode:

- i. Bin size (size of each depth cell measured);
- ii. Blanking distance;
- iii. ADCP depth (depth of transducers below the surface).
- iv. The time between 'pings' can also be set-up. Experience has shown that if the time is set to continuous (the default setting) interference can possibly occur

between consecutive sets of pings. The manufacturers have therefore recommended that the time be set to a small amount, say 0.025 milli-seconds. Even though the third point above is set when the ADCP is bolted onto the boat but is not required in case of latest models installed on trimaran. The bin, blanking and transducer depth depend on the water depth and channel conditions. No data is collected less than 1 bin from the bottom. No data is collected less than the sum of all three parameters from the water surface. Water velocities in these upper and lower regions of the profile are estimated. The literature on the ADCP states that a minimum of two depth cells must produce good velocity data to give accurate flow measurements.

There are certain rules to note:

- i. Always ensure that the depth specified in the deployment file is the depth at which the transducers are set (ignore for trimaran installed ADCP);
- ii. Never use a blank of less than 0.2 m. It has shown that this will result in erroneous velocities being recorded in the top bin;
- iii. In turbulent or high velocities ensure that the transducer depth is sufficient to be below the level of aeration (at least 0.3 m); and in case of trimaran the ADCP should not jump above the river surface in air.
- iv. When reading the data make sure the configuration file has the same parameter values as the deployment file;
- v. Make a note of the width of the channel between the end of the ADCP traverse and the bank. If this distance is significantly large relative to the overall width it can be used to adjust the calculated flow. This should not be a problem if the site is carefully selected i.e. avoid shallow water.

The settings appropriate for an RDI, are contained in Table 4.5.1.3 below are provided as a general guide:

Channel conditions	Mode	Bin (m)	Blank (m)	Transducer depth
Low velocity, shallow channels	5	0.1	0.2	0.1
Shallow channels	8	0.1	0.2	0.1
Shallow channels, high velocities	1	0.1	0.2	0.3
Channels 1.5 - 3.0 deep	5 ( $v < 2.0$ m/s)	0.1	0.2	0.2
	1 ( $v > 2.0$ m/s)	0.1	0.2	0.3
Channels > 3.0 m deep	4	0.5 (< 10 m)	0.5	0.5
		1.0 (> 10 m)	0.5	0.5

#### 4.5.1.4 MEASUREMENT RUNS

Once the ADCP has been set-up the measurement of traverses can be commenced. When in real-time mode the run can start immediately. However, operating the ADCP in self-contained (remote) mode the cable from the laptop to the ADCP has to be disconnected prior to starting in case of Rio Grande Work Horse. A dummy connector has to be placed on the ADCP plug socket to avoid damage of the electrical contacts by water and dirt.

Even though the boat can traverse the river following an irregular path it is recommended that as much as possible the boat traverses the river at right angles to the flow / banks. The boat speed should be as slow as reasonably possible while at the same time being sufficient to maintain a steady, smooth on-line course. The course should be kept stable and, if needed, only gradual changes are permitted. This speed should be low enough to take at least several minutes to complete a full traverse. On wide channels the speed over the ground may be increased to about the average flow velocity.

It is recommended that at least four traverses are made i.e. across and back twice and the calculated discharges compared for consistency and repeatability for each run. If bottom-tracking errors occurred in any calculated discharge or the calculated discharge deviates by more than 5% from the average of the calculated discharges, the traverse should be set apart and another 2 traverses should be made. For the estimation of the discharge, the unmeasured flow should be estimated by the provided software; the observer should enter his estimates for the distance to the start and end banks. Both the top and bottom layers should be automatically extrapolated by software applying the standard power fit method.

It is recommended that the boat pauses (remains stationary while collecting data) in a fixed position at the start and end of each traverse for a period of 30 - 60 seconds since this can assist with the final interpretation and processing of the data. The start and stop of movement should be extremely gradual to avoid bottom-tracking failure.

#### 4.5.2 Colour Velocity Method/ Radio-Tracer

There are other methods also in vague with a limited field of application under special circumstances. Their use is not recommended when more reliable method like area-velocity method with a current meter is possible. It is therefore used only for approximate estimation and is economically feasible in case of very small streams.

In this method, discharge is computed from observed area of cross-section and velocity measured by using a suitable colouring matter. Fluorscein, a red powder, when dissolved in slightly alkaline water produces an easily distinguishable greenish

colour even if in very dilute solution. Any other red or green aniline dye can also be used. Can of the colouring matter is quickly emptied and exact time of travel of the cloud of the dye to a downstream station on the stream is measured by a stop watch. Distance between the point of introduction of the dye and its detection should be sufficiently long depending on the velocity of the water since longer time of travel would yield greater accuracy in observation. Distance travelled divided by the time of travel gives the average velocity of the current.

#### **4.6 Record of Discharge**

For proper maintenance of Discharge records standard forms are being utilized. For recording the discharge observed the standard river data forms (RD Forms) RD-1 & RD-2 are used. RD-1 form is used for recording daily discharge observations at 8:00 hrs. RD-2 form is being used for the summary record of observed discharge for 10 daily.

In the Sub-division office and in the Division office the recorded gauge & discharge in the RD forms is entered into the e-SWIS online data entry system for storage, retrieval and dissemination purposes and further processing for preparing year books etc.

## Chapter 5 SUSPENDED SEDIMENT OBSERVATION AND ANALYSIS

### 5.1 INTRODUCTION

Knowledge of sediment passing in a stream is essential in the solution of variety of problems associated with flow in rivers. Existing theories and empirical formulae for computation of transport give values that are unverified for areas for which they have to be applied. These can be continued where specific data for verification is not available, due to various constraints. Actual data gathering help in better verification, and lead to better problem solving and designs of water use facilities.

The quantity of sediment passing a section can be determined either directly or indirectly. The direct method aims at determining the weight or volume of sediment passing a section in a period of time. Indirect methods aim at measuring the concentration of sediment flowing in the moving water. This approach needs the measurement of sediment concentrations, the cross sections areas and velocities. This will also need looking at the sediment being transported as wash load, and bed load. Bed load measurement, though very important for unstable river channels, may not have much relevance for peninsular rivers. The use of empirical methods for bed load estimation may remain within desired accuracy ranges. Suspended particle load is amenable for practicing alongside quantity measurements and is not too demanding in terms of extra financial and manpower requirements. Another important information needed in respect of sediment is particle size distributions for design of sediment exclusion arrangements etc,

Briefly the objectives of sediment measurements are listed below:

- i. Estimation of sediment inflow into reservoirs at the planning and design stage - by estimating the suspended load and bed loads separately
- ii. Studies for river training and river regimes – data may have to be gathered by mounting intensive gathering drill for short periods.
- iii. Evaluation of catchment erosion and identifying conservation measures

Sediment is fragmented material derived from the physical and chemical disintegration of rocks present on earth's crust. Such particles may range from boulders to particles of colloidal sizes. Their shapes, influenced by constituent minerals, may range from angular to round. Once particles are detached from their resting-place they may be transported by gravity, wind, water or by a combination of these agents. Where the transporting agent is water the transported material is

'Fluvial sediment' and the process of detaching the particles and setting them in motion is called 'Erosion'. Erosion may be sheet erosion where the finer grains are detached and moved by rain drops, splash and sheet flow. Further transport is in water flowing in channels. Due to topography of the catchment sheet flow does not occur continue over large areas, but quickly concentrates into small rills or channels and streams which grow in size as each joins the other. Within the channels the flowing water erodes the material in the bank or in the bed till the stream is 'loaded'.

## 5.2 Suspended Sediment Sampling

The most widely utilised principle for suspended load measurement is to determine the concentration of sediments in river water. Samplers of different types and makes are available on the market, but CWC uses point sampler known as Punjab type Bottle sampler. A point-integrating sampler is equipped with a device for opening and closing the sampler nozzle or mouth - for controlling the sampling time.

In CWC, the methods and instruments for suspended load measurements have been kept as simple as possible:

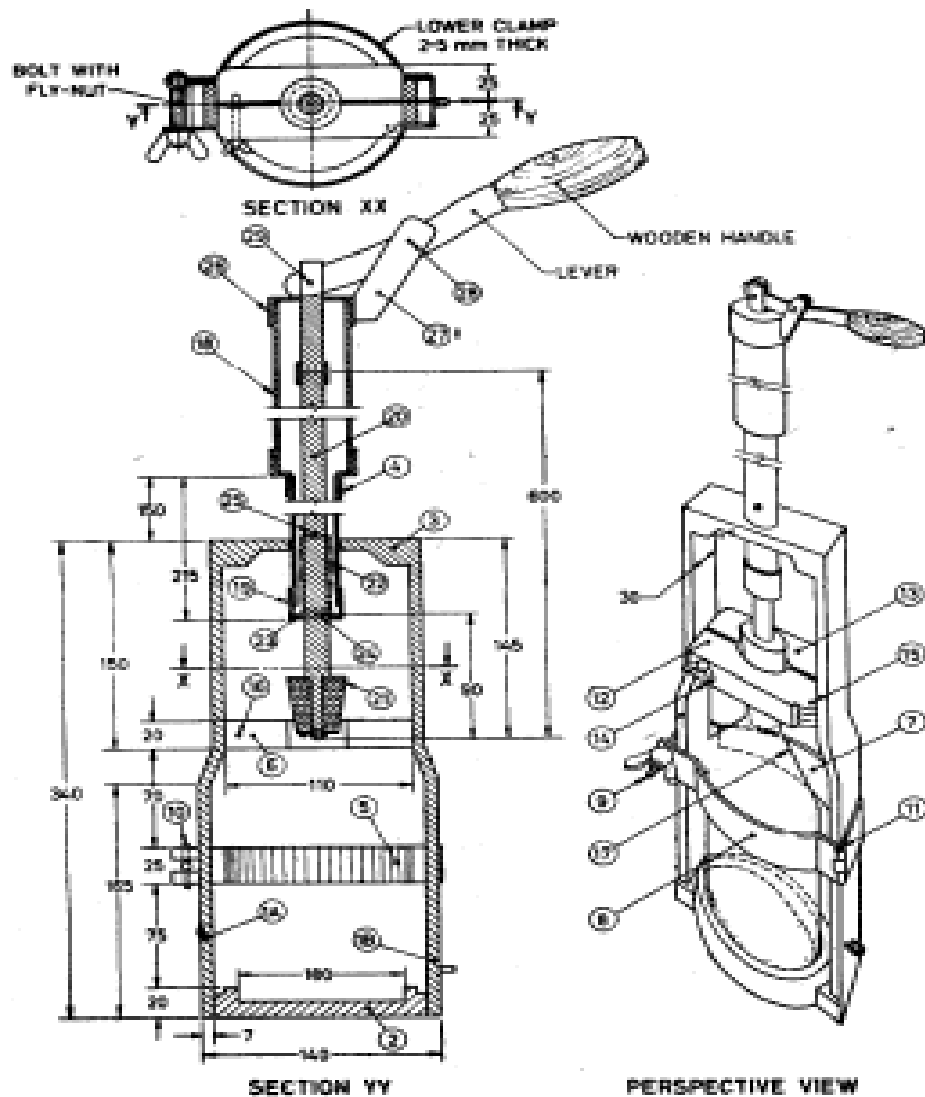
- The samples are taken generally from each vertical at which the velocity measurements are taken.
- The number of composite samples taken has to be as small as possible depending upon the river characteristics and specific requirements, if any.
- The sampling has to be done at one level only (0.6 of the depth).
- Punjab type bottle sampler is used at all stations of CWC.

### 5.2.1 PUNJAB SAMPLER BOTTLE SAMPLER

The sampler is appropriate for rivers with suspended load almost exclusively composed of wash load, with no or little coarse and medium particle size fractions.

Principal advantages, limitations of bottle samplers; alternatives or corrections

- Bottle samplers are very simple and easy to use; they can be appropriate for operation in rivers containing only wash load in suspension, the coarse and medium particle size fractions being very limited in concentration
- The Punjab bottle sampler was designed in India in 1935 for slow flowing, shallow rivers and canals, and does not work efficiently at large depths
- The Punjab-type bottle sampler does not work efficiently at high velocities, mainly due to the difficulty to keep it vertical, also when suspended or hung from a line with a fish-weight.
- The water does not enter the bottle with the velocity and direction of the surrounding stream velocity (not iso-kinetic sampling)



Part No.	Nomenclature	Part No.	Nomenclature
1A	Vertical Side	15	Pin
1B	Base Plate	16	Hole (Threaded)
2	Base Plate	17	Bottle
3	Elbow Clamp	18	Pipe Extension
4	Lower Pipe Spring Cylinder	19	Half Socket
15	Lower Clamp	20	Rod
16	Upper Clamp	21	Cork
7	Semi-circular Shaped Strip	22	Spring Strong Coiled
8	Semi-circular Shaped Strip	23	Washer
9	Bolt	24	Rivet
10	Pin	25	Screws
11	Pin	26	Half Socket
12	Rectangular piece	27	Elbow Shaped Flat Plates
13	Rectangular piece	28	Pin
14	Fly-Nut Headed Screw	29	Bolt

\* for the sake of convenience details 5 and 8 have been numbered, which comprise of several smaller details which have also been numbered.

NOTE: Part numbers are given inside circles  
All dimensions are in millimeters

Fig 5.2.1 (i) Sketch of components of Punjab Type Bottle Silt Sampler



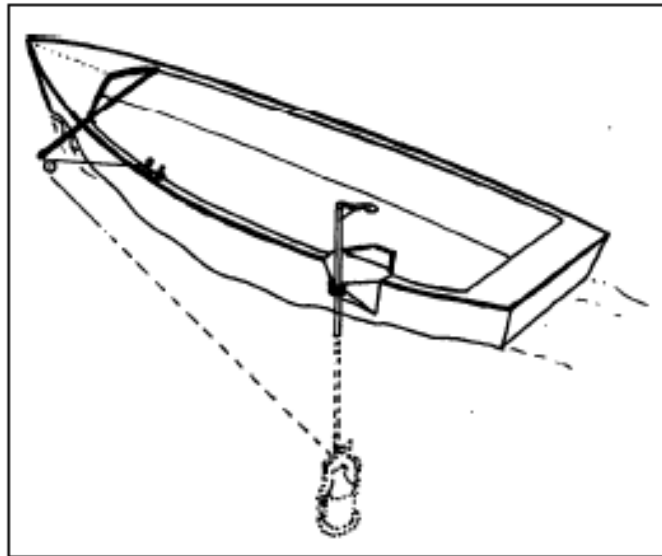


Fig. 5.2.1(ii) Boat mounted Silt sampler

## 5.2.2 INSTRUCTIONS FOR USE OF PUNJAB SAMPLER

### *i. Before sampling, check*

#### *Sampling bottle*

- A metallic bottle, if deformed (out of shape) or damaged (especially its mouth) has to be replaced by a spare one
- A glass bottle, if breached, has to be replaced by a spare one

#### *Bottle cork*

- Must close tightly to avoid leaking
- May never be painted
- Damaged corks must be replaced
- Cork must be suitably tapered to enter 0.5 to 1 cm in bottle mouth
- Eventually, rub smoothly lower end of cork with emery paper if cork does not enter far enough into the bottle mouth

#### *Bottle holder (frame)*

- Clamps at neck and mid-portion may not be damaged and should hold tightly the bottle with the cork seating perfectly axial in the mouth
- Fly nuts for locking must operate easily; they should be replaced if they don't lock gently
- Socket thread may not be damaged

#### *Pipe, rod, spring and lever*

- Brass rod and pipe may not be bending
- Spring must be checked and dead springs replaced

### *Sampler leakage*

- The sampler must be tested for possible leakage by holding it tightly closed under water for 5 minutes and collected sample needs to be less than 5 cc.
- In case of leakage, do not try to repair on the spot and use spare sampler

## ***ii. During sampling, instructions and precautions***

### *In general*

- The sampler must be oriented with the vertical frame perpendicular to the flow so that it does not disturb the flow at the mouth
- The time required to fill the sampling bottle must be checked by trial and error, so that sampled volume would total between 80 and 90 % of the bottle volume (i.e. 0.4 l to 0.45 l for a 0.5 l bottle)
- Samples from partially or fully filled bottles must be rejected and a new sample taken
- Sampler may never touch the stream bed
- The distance between sampler bottom and the streambed must always be larger than 20 cm

### *When sampling from a survey vessel*

- If flow permits, the survey vessel should be kept stationary to hold the sampler vertical
- In high flows, use a fitting to the hull and a line for keeping the sampler vertical whenever possible (Figure 8.2-3)
- In flows too strong for keeping the sampler vertical, drifting from the vessel may be allowed exceptionally to reduce the drag on the sampler as to keep it vertical, this only if sampling can be performed in the selected vertical (this procedure should be first tested in presence of the assistant research officer and/or junior officer)

### *When sampling while wading*

- During sampling, keep the bottle upstream and well in front of you
- Avoid sampling when the product of flow velocity (in m/sec) with depth (in m) exceeds 1

### *When sampling from a bridge*

- The bottle sampler should not be used if it cannot be kept vertical in the flow
- When flow is too strong for measuring at 60 % of the depth (0.6 d), a water surface sample may be taken, but with the bottle mouth at least 0.5 m under water
- Operation of the bottle sampler with a fish weight should be avoided if this is not specifically designed to contain the bottle
- When operated with a suitable fish, the drift angle measured at the protractor should not exceed 15 degrees

### ***iii. After sampling, instructions and precautions***

- Reject the sample if there is any floating debris hanging to the sampler or trapped between bottle mouth and cork
- The sample must be collected carefully, without spilling any water
- The volume of the collected sample must be measured precisely before rinsing, even if sediment remains in the bottle, to be rinsed later with clean water
- If water or sediment is spilled during collection of sample, this must be rejected and a new sample taken
- The rinsing water with its sediment must be added to the collected sample

## **5.3 SEDIMENT ANALYSIS**

The sediment analysis methods used for the sediment samples collected using samplers are described below.

- Analysis using sieves and a hydrometer for Coarse ( C ), Medium(M) and Fine (F) fractions
- Dry sieving for the medium and coarse fractions.
- Hydrometer analysis

The suspended load are measured only the percentage of coarse, medium and fine grades. The choice of the method and equipment needed for determining sediment particle size distributions would depend on:

- The kind in information requested (what do we want to know? for what purpose?)
- The skills of the personnel in the laboratory
- The need for particle size analysis of the complete sample, or only of part of it (e.g. do we need the size distribution of the sand/silt/clay fractions?)
- The number of samples to be analysed per day
- The sample volumes
- The kind of “size” needed

### **5.3.1 ANALYSIS FOR ESTIMATION OF COARSE AND MEDIUM GRADE FRACTIONS**

From the samples of water and sediment mixture collected in the enamelled buckets normally about 5 litres, the same is allowed to settle for about 30 minute. The supernatant water is carefully decanted off. The residue is passed into a numbered beaker for further analysis of coarse and medium fractions of sediment

Each sample in the beaker is then passed through a IS – 212 micron sieve placed over a beaker marked upto 10 cm height. The sediment retained by the sieve is washed thoroughly with a jet of clean water till all the coarse grade particles are separated and particles of medium and fine-grained size have passed through, into the beaker. The particles retained by the sieve after washing and removing organic matter are transferred to silt measuring tubes. Its volume in cubic centimetres (cc) is

noted after tapping on a rubber pad. This can later be expressed as cubic centimetres per litre.

The sediment and water passing IS – 212-micron sieve collected in the beaker is made up upto 10-cm height. The mixture is stirred in for a few seconds and allowed to stand for the required interval of time given in table below, according to the temperature of water in the beaker.

Time taken for particles above 0.075 mm to fall through 10 cm column of water at different temperature:

Water temp. in Celsius	Time of fall for particles of 0.075 mm to fall 10 cm in seconds
5	31
6 - 10	28.5
11 - 15	25
16 - 20	22
21 - 25	20
26 – 30	18
31 - 35	16.5

*Table 5.2.3.1: Time taken for particles above 0.075 mm to fall through 10 cm column of water at different temperature*

The supernatant water is poured off. This process of separation of medium grade sediment by decantation of supernatant liquid, followed by filling the beaker upto the marked height is repeated, till the supernatant water is rendered clear. The medium grade sediment settled in beaker after the final washing and decantation process is transferred to a measuring tube and the volume is measured in cc as in the earlier case. The material is also washed down on to a pre-weighed filter paper, initially drained of all water, and then subjected to drying in an oven. It is allowed to cool in a dessicator and then weighed along with the collected dried sediment for obtaining its weight. This gives the concentration of medium fraction in gms per litre.

The concentrations together with the observed water level and discharge are put in the “Record of suspended sediment summary data. The results are presented in metric tonnes per day.

### 5.3.2 Estimation of Fine-Grained Fraction of Sediment

#### 5.3.2.1 By Hydrometer Method

The fine grained sediment fraction can be estimated with the help of a sensitive calibrated hydrometer (see Figure 5.3.2.1). A hydrometer calibrated initially in distilled water is to be used. The hydrometer is to be placed for about five minutes in a separate sample of sediment and water to allow it to attain the water temperature. This helps also to eliminate effect of temperature change due to sudden placing of the hydrometer. The hydrometer is then taken out of the sample water. The water is stirred vigorously to put the sediment entirely into suspension and later poured into a double jacket metallic cylinder. The hydrometer is then immersed into the water in the cylinder and stopwatch started simultaneously. The level of immersion of the hydrometer in the cylinder is read after lapse of time intervals given in table below, depending on water temperature in the cylinder.

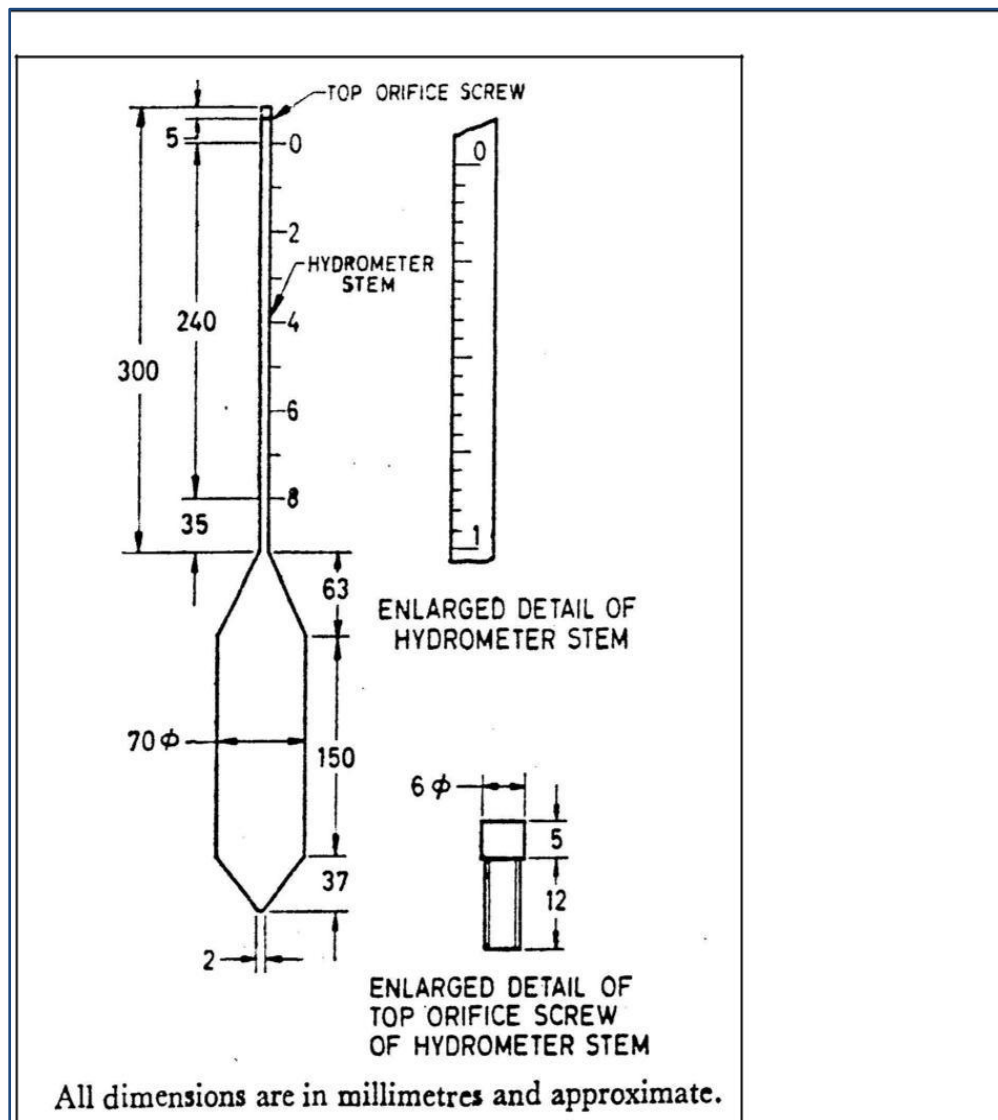


Figure 5.3.2.1: Hydrometer

A time interval after which hydrometer is to be read for estimating fine sediment, versus water temperatures:

Water temperature ° Celsius	Time interval in seconds after which hydrometer to be read
5	105
6 – 10	100
11 – 15	87
16 – 20	77
21 – 25	70
26 – 30	63
31 – 35	58

Table 5.3.2.1: A time interval after which hydrometer is to be read

The point upto which the hydrometer is immersed can be used to derive the concentration of fine grained material and dissolved material in gms per litre as given below:

$$F + D = (R^1 - R) K$$

where: F = Concentration of fine sediment in gms per litre

D = Concentration of dissolved material in gms per litre

$R^1$  = Hydrometer reading taken in the cylinder water as described  
 R = Hydrometer reading in distilled water at the same temperature  
 K = Factor for the hydrometer for converting to value in gms per litre

Next filter the water containing the sediment through filter paper and take readings of hydrometer in filtered river water for obtaining the concentration of dissolved material as below:

$$\text{Thus: } D = (r^1 - r) K$$

Where:  $r^1$  = Hydrometer reading for the filtered water  
 r = Hydrometer reading in distilled water

For arriving at value of F = (F+D) – D is to be evaluated in gms per litre

### **Precautions**

- The water sample should be at room temperature
- The hydrometer should be kept immersed in the water sample for about 5 minutes so that it attains the water temperature.
- The water sample should be thoroughly stirred before pouring into the jacket cylinder.
- No air bubbles should be sticking to the hydrometer stem and hydrometer should not touch the cylinder sides

### 5.3.2.2 By filtering process

The sample available after removing the Coarse and medium sediment is put on a pre-weighed filter paper and the water is allowed to completely drain off through the filter paper, which may take 12 to 24 hours depending upon the fineness of the silt and its quantity. After the water is completely drained out, the filter paper containing the fine sediment is put inside the oven with temperature such that the water gets evaporated without causing damage to the filter paper.

After the sample gets completely dried up, it is removed from the oven. The dried up sample (filter paper with fine sediment) is weighed on a physical balance or electronic balance.

The difference between weight of the empty filter paper and filter paper with fine sediment provides the weight of the fine sediment in grammes/milligrammes. The same is converted based on the discharge of the river on the particular day in metric tonnes per day.

#### **Precautions**

- i. The empty filter paper should be completely dried before weighing.
- ii. The water sample should be thoroughly stirred before pouring into the filter paper so that no fine sediment remains stuck to the beaker or container.
- iii. The filter paper with sediment should be completely dried up without any traces of water on the filter paper and in the sediment.
- iv. The filter paper with dried sediment should be weighed at the earliest after removal from oven as the filter paper may absorb atmospheric moisture if left for a long time.

#### **EQUIPMENT FOR SEDIMENT SAMPLING AND SEDIMENT LABORATORY**

S. No.	Equipment
1	Bottle type Samplers
2	Metallic 1 Litre bottle
3	Metallic Conical Flask
4	Metallic Beaker 500 ml.
5	Double Jacketed cylinder
6	Filtering apparatus
7	Hydrometer
8	Set of 3 sieves
9	Oven
10	Other Sundry items
11	Analytical Balance
12	Enamel or Stainless steel (SS) trough

13	Buckets S S or Enamel
14	Bowls 500 ml
15	Tripod stand
16	Pipette stand
17	Beakers glass 500 ml
18	Measuring cylinders 1 lit.
19	Desiccator 20 cms dia
20	Funnel glass 100 cms
21	Pipette glass 100 ml
22	Porcelain basin 10 cms
23	Thermometer 110 deg C
24	Bottle glass 500 ml
25	Rubber Corks assorted
26	Filter Paper assorted
27	Pressure rubber tubing
28	Glass tubing assorted
29	Glass marking pencil
30	Watch glass 10 cm dia



## Chapter 6 METEOROLOGICAL OBSERVATIONS

### 6.1 INTRODUCTION

The water available in our rivers, lakes, reservoirs and below the ground is received through precipitation in various forms i.e. rain, snow, hail etc. A number of other atmospheric factors also play an important role in precipitation and availability of waters, both on the surface and below the ground. A good understanding of such meteorological parameters is very important for proper assessment of available water resources over a short or longer period of time and for devising measures to overcome the extreme effects of hydrological phenomenon such as floods and droughts. The important meteorological parameters are also observed by CWC at selected stations. The details of observation methodology of such parameters are described below.

### 6.2. RAINFALL

#### 6.2.1 RAINFALL MEASUREMENT BY STANDARD RAIN GAUGE (SRG)

The amount of rainfall at a station in a specified period is measured as the depth to which it would cover a flat surface. The measurement of this is made by a standard rain gauge, which in India is made of Fibre Glass Reinforced Polyester (FRP) and shown in Fig. 6.2.1.

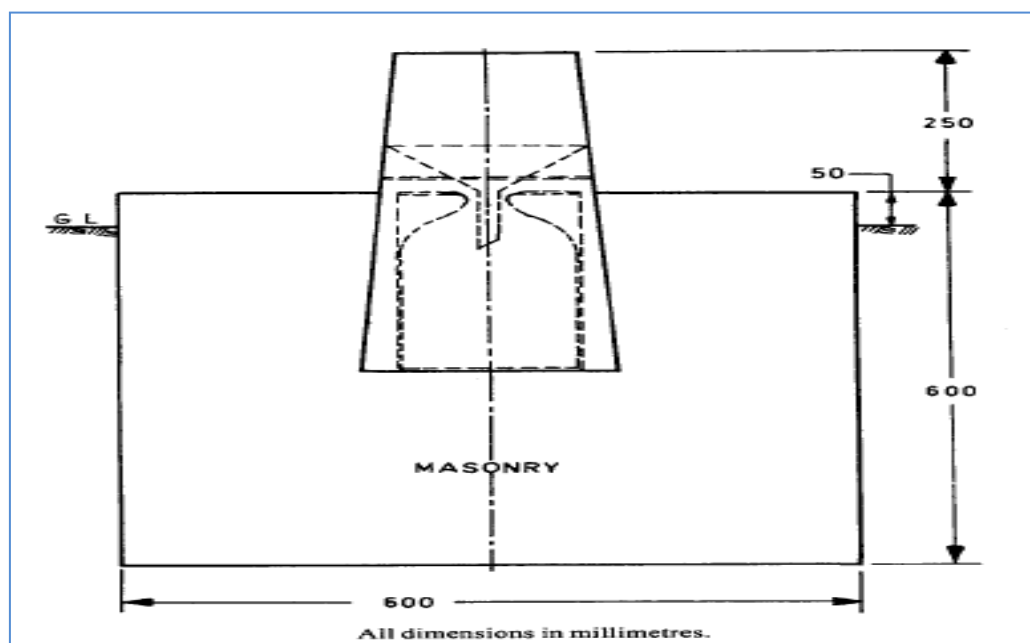


Fig 6.2.1 Standard Rain Gauge (SRG)

#### 6.2.1.1 INSTALLATION OF STANDARD RAIN GAUGE

The amount of precipitation collected by a rain gauge depends on its exposure and special care be taken into consideration in selecting a suitable site.

- i) The gauge shall be placed on level ground not upon a slope or terrace and never on a wall or roof.
- ii) On no account the rain gauge shall be placed on a slope such that the ground falls away steeply on the side of the prevailing wind.
- iii) The distance between the rain gauge and the nearest object should generally be four times the height of the object, but never shall be less than twice the height of the object.
- iv) Great care shall be taken at mountain and coastal stations that the gauges are not unduly exposed to the sweep of the wind. A belt of trees or a wall on the side of the prevailing wind at a distance, preferably four times its own height but exceeding at least twice its height, shall form an efficient shelter.
- v) The rain gauge shall be fixed on a masonry or concrete foundation 600 mm X 600 mm X 600 mm on a level ground surface (Fig 6.2.1).
- vi) The base of the gauge shall be cemented so that the rim of the gauge is horizontal and exactly 300 mm above the ground level.
- vii) In flood prone areas the level of rain gauge should be kept at least 300 mm above the HFL.
- viii) A sketch showing the various objects with their height and distance from the rain gauge should be prepared and kept in the records.
- ix) A fence should be erected around the rain gauge to protect it from stray cattle etc. The fence height should be such that it is not more than half the distance of the fence from the gauge (Fig 6.2.2).
- x) The rain gauge should be kept locked.

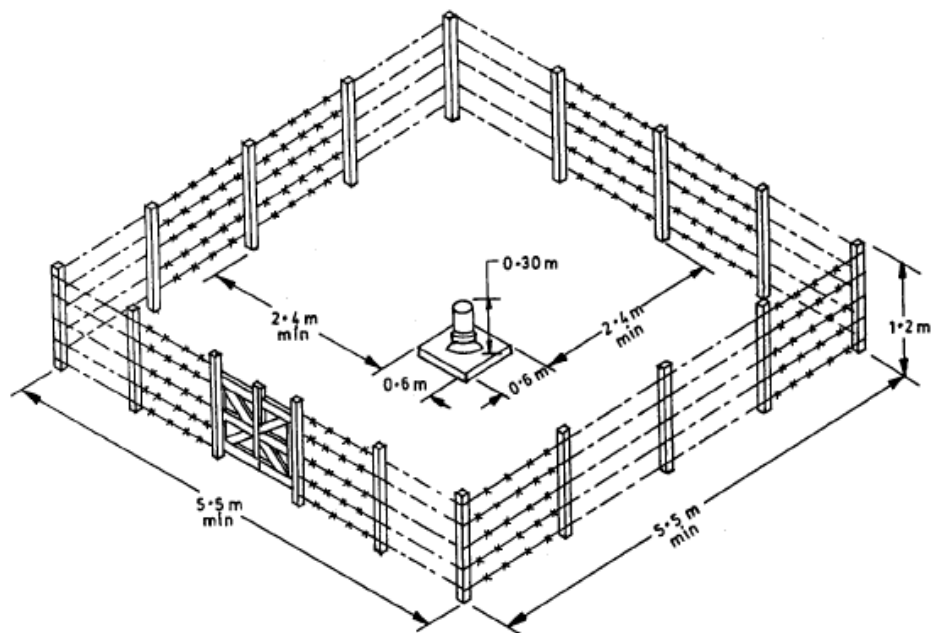


Fig 6.2.2 Fencing for Standard Rain Gauge (SRG)

#### 6.2.1.2 MEASUREMENT OF RAINFALL BY SRG

The rain falling into the funnel collects in the bottle kept inside the base and is measured by a measure glass. The measurement is made daily at 0830 hrs IST in the morning and 1730 hrs in the evening or any suitable interval in between as

decided by the Department. The following procedure is used for measurement of rainfall:

- i) Remove the funnel of the rain gauge and take out the polythene bottle.
- ii) Place the measure glass in an empty basin and slowly pour the rainwater from the receiver (polythene bottle) into the measure glass to avoid spilling. If by chance, any rainwater is spilled into the basin, add it to the rainwater in the measure glass before arriving at the total amount collected.
- iii) While reading the measure glass, hold it upright or place it on a horizontal surface. Bring the eye to the level of the rainwater in the measure glass and note the graduation (scale) reading of the lower level of the curved surface of water. The reading is recorded in mm to one decimal place.
- iv) If the rainfall is more than 20 mm (for the 200 cm<sup>2</sup> gauge), the measurement should be taken in two or more instalments depending upon the amount of rainfall.
- v) After the first measurement, the rainfall amount is checked by re-measurement, before the rainwater is thrown away.
- vi) During heavy rain, check the rain gauge at hourly intervals to avoid overflow. If necessary, take out the rainwater in a separate bottle, securely corked for measurement at the time of observation.
- vii) All rainfall observations are made at 0830 hrs IST daily. The amount recorded at 0830 hrs is the rainfall of the preceding 24 hours ending at 0830 hrs of the observation day (Today's date). In other words, the rainfall of the day is the total rainfall collected in the rain gauge from 0830 hrs IST of previous day to 0830 hrs IST of the day and is recorded (entered) against today's date.
- viii) If there is no rain, enter 0.0 (Note: The column should not be left blank or '-' should not be used for indicating '0' rainfall) and if the rain is below 0.1 mm, enter "t" (trace) in the prescribed form and also in the Register. Daily rainfall data, recorded on the prescribed form, is sent to the controlling office daily as per the arrangement fixed for the field station.

#### **6.2.1.3 ROUTINE MAINTENANCE SRG**

The following routine inspection and maintenance procedures should be used to ensure that the gauge continues to provide accurate records.

- i. The collector (funnel) of the rain gauge should be inspected for blockage with dirt/dry leaves etc and cleared if necessary.
- ii. The collector, receiving bottle and the base should be checked for leakage. If leakage is found, immediate repair / replacement is to be undertaken.

- iii. While replacing the collector on the base, it should be ensured that the two locking rings are engaged properly.
- iv. The enclosure should be kept clean. No shrubs or plants be allowed to grow near the instrument as they will affect exposure conditions and the catch.
- v. A spare measure glass should invariably be kept at the field station and sufficient number of glass bottles with cork for closure should be kept in case of emergency (when both the measuring cylinder breaks down).

### 6.2.2 RAINFALL MEASUREMENT BY AUTOGRAPHIC RAINGAUGE (ARG)

The autographic (siphon type) rain gauge enables automatic, continuous measurement and recording of precipitation. This type of rain gauge consists of a receptacle to collect precipitation and a measuring part to measure and record its amount. The measuring part consists of a float with a recording pen attached, a storage tank with a siphon to drain a fixed amount of water, and a clock-driven drum. Rainwater gathered by the receptacle is led from the rain receiver to the storage tank through an adjustment vessel. As a result, a float in the storage tank moves upward. A recording pen is connected to the float. When rainwater in the storage tank reaches a level equivalent to a fixed amount, it is drained by the siphon. This procedure is repeated as long as rainfall continues, and the pen repeats traces from zero to the maximum on the recording paper. When the rainfall stops, the pen traces a horizontal line. The photograph and different components of autographic (Siphon type) rain gauge is shown in fig 6.2.2.



Figure 6.2.2: Natural siphon recording rain gauge

#### 6.2.2.1 METHOD OF OBSERVATION

The traced mark on the recording paper is read to measure the amount of precipitation. For one-hour precipitation, for example, intersection points at the two consecutive hour lines and the tracing of precipitation are read. The one-hour amount is calculated from the difference between the two readings. The siphon operates when the pen reaches the maximum position on the recording chart. During heavy rain, however, it may start this action before the amount of precipitation reaches the predetermined level because of the wet interior. As the top of the tracing mark in such cases will not indicate the maximum level, the amount should be calculated as the sum of the readings for the top of the mark. A typical autographic rain chart is depicted in fig 6.2.2.1.

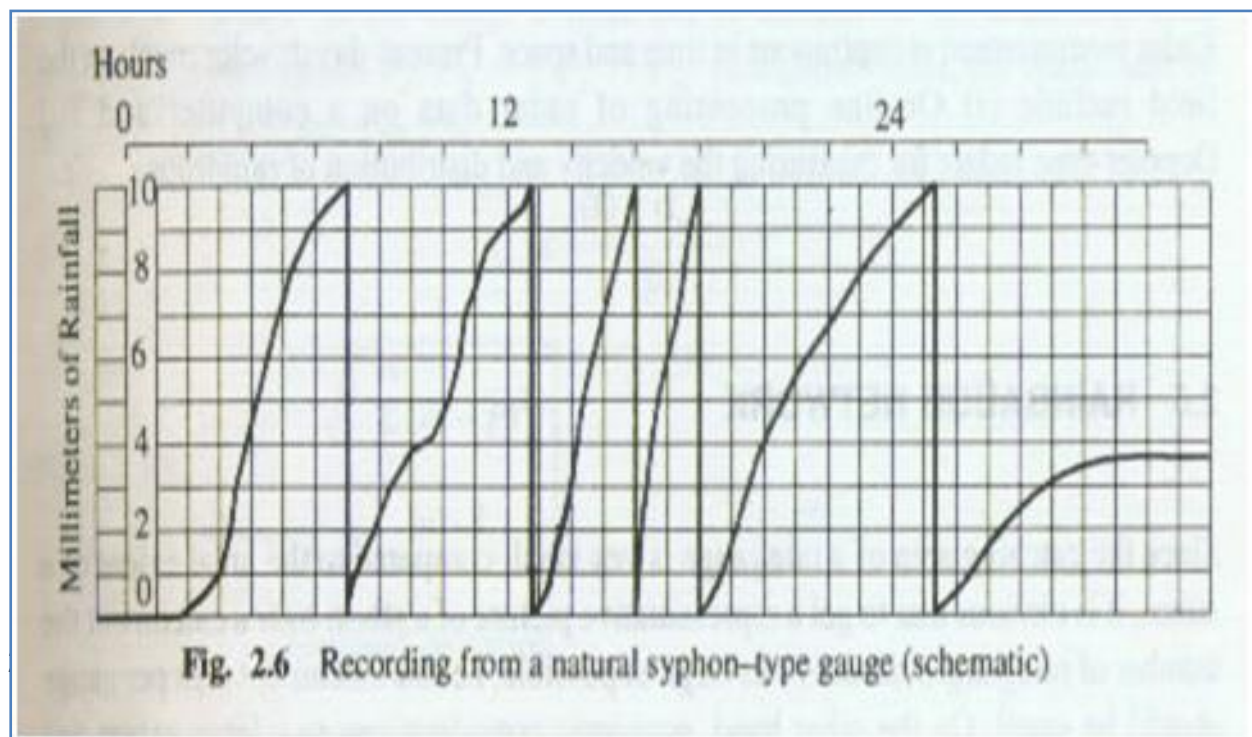


Fig 6.2.2.1 Autographic rainfall chart

#### 6.2.2.2 INSTRUMENT SETTING, OPERATIONS AND TABULATION

##### A Instrument Setting

- i. Wrap a chart on the clock drum taking care that the corresponding horizontal lines on the overlapping portions are coincident and that the bottom of the chart touches the flange. Fix the chart in place with the spring clip. The essential components of Autographic (siphon type) rain gauge are shown in fig 6.2.2.2.
- ii. Replace the cover and pour water into the tube leading to the float chamber till the water begins to siphon. The pen should come down to the zero line on the chart after all the water is siphoned.
- iii. Next, measure out the equivalent of 10 mm of rainfall in a measure glass and pour this water gently into the receiver as before, and the pen should touch the 10 mm line of the chart. If it does not, loosen the set-screw fixing the collar in the lid and slightly raise the collar by turning it till the correct range is obtained on the chart.

##### B Operations

- i. The chart is changed at 0830 hrs IST daily in the morning. First remove the previous day chart and put the fresh chart on the clock drum and set the instrument as explained at 'A' above.

- ii. Put sufficient ink in the pen, wind the clock and set the pen to the correct time. To set the correct time, turn the clock drum slowly from left to right until the pen indicates the correct time. Give a time mark on the chart by gently tapping the pen. The instrument is now set for recording.

### C Tabulation

- i. Tabulate hourly rainfall values from the 'removed' autographic chart and make entries as per proforma supplied. The autographic chart gives a continuous record of rainfall during the past 24 hours on a daily basis. If SRG and ARG are installed side by side, it is expected that the total rainfall recorded during the past 24 hours by both the rain gauges should agree. In case of any discrepancy, the rainfall amount recorded by the SRG is taken to be correct.
- ii. Despatch tabulated performas to the Controlling Office on monthly basis or as prescribed.

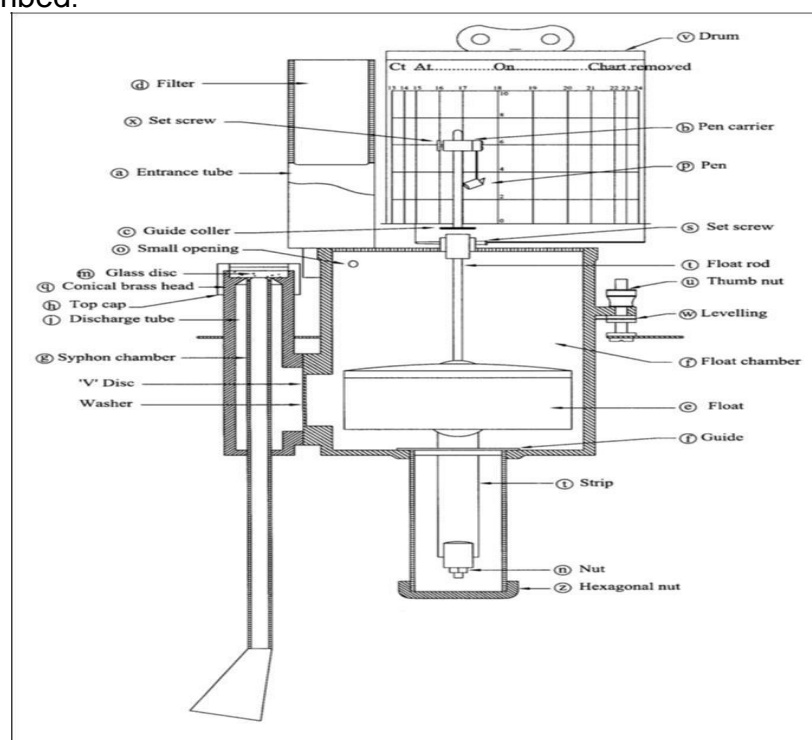


Fig 6.2.2.2. showing essential component of Autographic Rain Gauge

### 6.2.2.3 ROUTINE MAINTENANCE OF ARG

The rain gauge should be regularly checked for dirt and debris in the funnel. In the rainy season, the wire-gauge filter should be cleaned once a week or immediately after a thunderstorm or dust storm. The inside of the glass disc should be kept clean. This is very necessary for proper siphoning. For cleaning the receiver, the float and the funnel, proceed as follows:



- i. Lift off the cover, remove the chart drum and the three thumb nuts. Remove the three small screws and washers, who hold the receiver lid in place. Gently lift the float from the chamber.
- ii. To clean the float chamber, lift it off the base, flush it out with water after unscrewing the hexagonal nut.
- iii. To clean the siphon tube, unscrew the top cap and see if the fibre gasket is in good condition. Then remove the glass disc and lift off the conical brass head with a bent pin. Clean the siphon tube. After cleaning, reassemble the parts carefully.
- iv. Next, the hallite washer between the float chamber and siphon is checked. The chamber should be replaced, if it leaks at this joint.
- v. The time of siphoning should be checked occasionally, to see whether the outlet tube is choked. The time taken for this should be 15 to 20 seconds.
- vi. Special ink is used in the pen to obtain a thin and fine trace on the chart. During summer, a minute drop of glycerine may be added to reduce evaporation of the ink from the nib. The tip of the nib is kept clean with methylated spirit.
- vii. Minor leaks or cracks in the body of the rain gauge can be sealed by using adhesive material.

The following are typical problems, which arise and cause the instrument to become out of adjustment. The listed actions may be used to correct.

- i. Incorrect siphoning: the float may not go up to the 10 mm mark but siphoning takes place. Actions:
  - a. Check and adjust the levelling of the float chamber using a spirit level.
  - b. Reduce the friction by rubbing the float rod with a lead pencil.
  - c. Check whether the threaded collar is limiting the movement of the float. If so, raise the collar slightly after loosening the set-screw.
- ii. Unstable zero: when no rain, the trace on the chart is not along the zero line. Actions:
  - a. Check the alignment of the drum
  - b. Check the wrapping of the chart on the drum. If a fault appears in the drum, it should be replaced.
- iii. Prolonged siphoning: siphon tube is partly blocked. Action:
  - a. To clear the siphon tube, unscrew the top cap (h), remove the fibre gasket, glass disc and then lift off the conical brass head (q) with a bent

pin. Clear the tube by pushing a piece of soft wire through it. Clean and replace the conical brass head and glass disc. Change the fibre washers, if necessary.

- iv. Gradual fall of pen: either due to a leak in the float chamber or the pen arm is loose on the float rod. Actions:
  - a. For the leak at the joint of the float chamber and siphon chamber, the hallite washers between them should be replaced.
  - b. Tighten the pen arm properly on the float rod.
- v. Siphoning occurs after more than 10 mm of rain occurs: this happens if the float develops a leak. Action:
  - a. Float is to be replaced.
- vi. During the period of heavy rainfall siphoning may be triggered before the pen reaches the 10 mm line. Action
  - a. Take it that each siphon represents 10 mm of rain.
- vii. Keep the observatory enclosure locked, clean and fencing intact.



### 6.2.3 RAINFALL MEASUREMENT BY TIPPING BUCKET RAINGAUGE (TBR)

The principle of this type of recording gauge is very simple. A light metal container is divided into two compartments and is balanced in unstable equilibrium about a horizontal axis. In its normal position the container rests against one of two stops, which prevents it from tipping completely. The rain is led from a conventional collecting funnel into the uppermost compartment. After a predetermined amount of rain has fallen, the bucket becomes unstable in its present position and tips over to its other position of rest. The compartments of the container are so shaped that the water can now flow out of the lower one and leave it empty. Meanwhile, the rain falls into the newly positioned upper compartment. The movement of the bucket, as it tips over, is used to operate a relay contact and produce a record that consists of discontinuous steps. The amount of rain which causes the bucket to tip should not be greater than 0.2 millimetres.

The main advantage of this type of instrument is that it has an electronic pulse output and can be recorded at a distance or for simultaneous recording of rainfall and river stage on a water stage recorder. Its disadvantages are:

- i. The bucket takes a small but finite time to tip, and during the first half of its motion, the rain is being fed into the compartment already containing the calculated amount of rainfall. This error is appreciable only in heavy rainfall
- ii. With the usual design of the bucket, the exposed water surface is relatively large. Thus, significant evaporation losses can occur in hot regions. This will be most appreciable in light rains; and because of the discontinuous nature of the record, the instrument readings may not be satisfactory for use in light drizzle or very light rain. The time of beginning and ending of rainfall cannot be determined accurately.

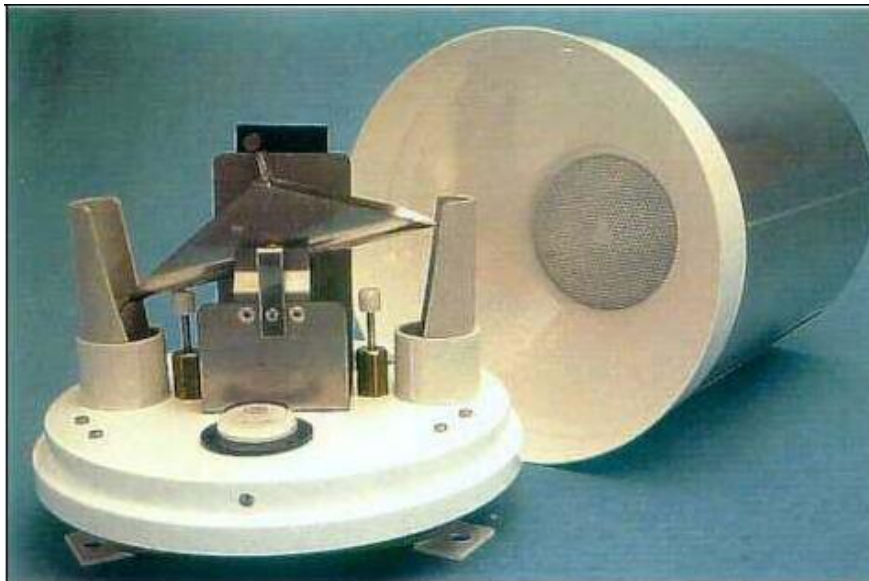


Figure 6.2.3: Tipping Bucket rain gauge

The Tipping Bucket rain gauge is a widely used for recording rainfall amounts and intensities in remote and unattended places. Once the TBR is installed and calibrated, it is ready for use.

#### **6.2.3.1 STANDARD MEASUREMENT PRACTICE TBR**

The TBR is equipped with a data logger, which automatically stores the number of tipplings per unit of time or the timings of each tipping. The data stored in the data logger is either transmitted through satellite or GPRS based telemetry system at the required location. Else the logger can be read out using data downloading device at any point of time or interval. The functioning of the equipment is to be checked as per instructions of the supplier on routine basis.

#### **6.2.3.2 ROUTINE MAINTENANCE TBR**

Maintenance of TBR should be carried out in accordance with the instructions supplied with the equipment.

- i. The collector should be kept clear of obstructions and it should be gently cleaned for dust and debris without disturbing the tipping bucket switch. This should be carried out on regular interval basis.
- ii. If the bucket does not tip, it is probably sticking on its bearings.
- iii. If the bucket does tip but the counter reading fails to advance, the trouble may be due to a faulty counter or switch. For rectification of these defects, only an expert mechanic needs to attend.

### 6.3 MAXIMUM & MINIMUM ATMOSPHERIC TEMPERATURE

The maximum and minimum atmospheric temperature plays a vital role in various natural processes including the hydrological cycle.

The MAXIMUM / MINIMUM thermometer records the highest and lowest atmospheric temperatures seen by the thermometer between settings. A "U" shape tube holds a clear liquid and columns of mercury. As the temperature increases, the liquid expands forcing the mercury up the maximum scale. When the temperature falls, the liquid contracts and the mercury follows it back up the minimum scale. Small glass and wire floats called limit markers are pushed to the temperature limits by the two sides of the mercury column. The markers are held in position by a magnet in the back of the case and the maximum / minimum temperatures are read at the bottom point of the markers. A setting magnet will easily reset both scales so you can take periodic readings without worrying about recording the wrong information. The current or immediate temperature can always be read at the top of the mercury column as in a single tube thermometer. One limb of the thermometer reads the maximum temperature while the other limb is used to read the minimum temperature. The range of the thermometer should be between  $-35^{\circ}\text{C}$  to  $+55^{\circ}\text{C}$  with minimum readable graduation as  $0.5^{\circ}\text{C}$ .

*It is important to note that the minimum scale is inverted with the lower temperatures above the higher. The observed should become accustomed to reading this "upside down" scale, for which some care may be required to get accurate readings.*

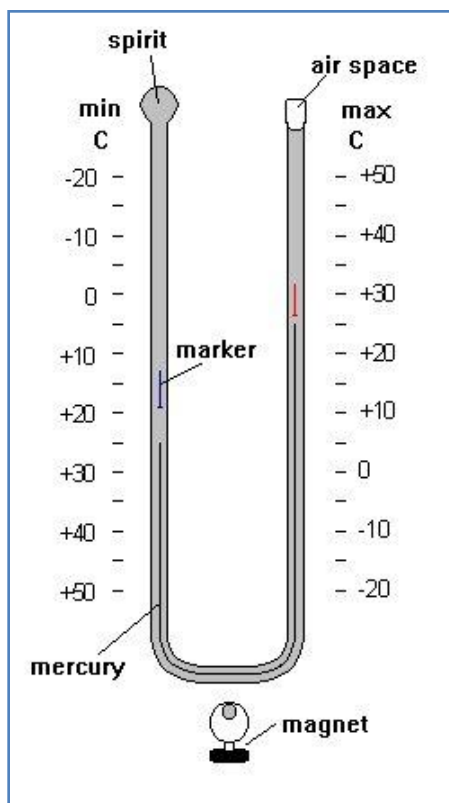
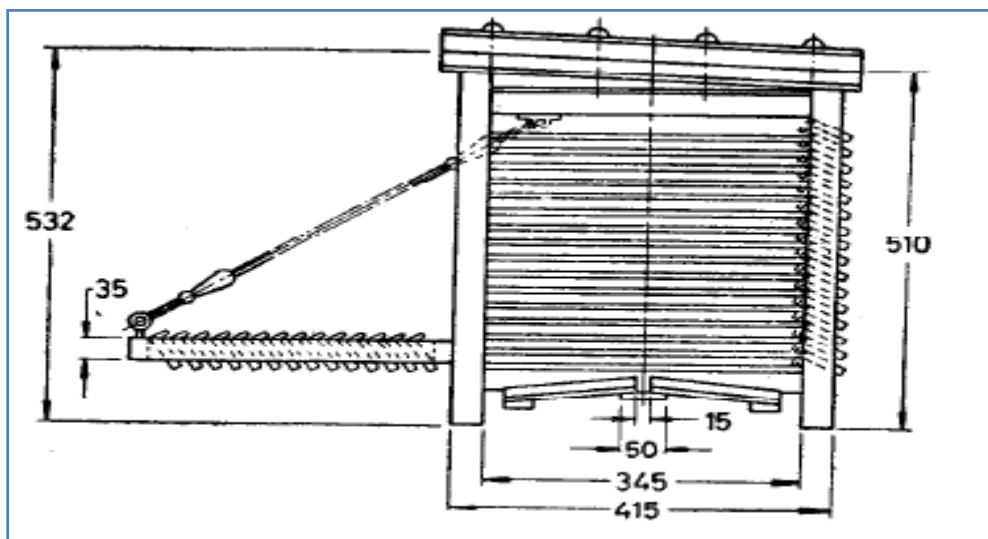
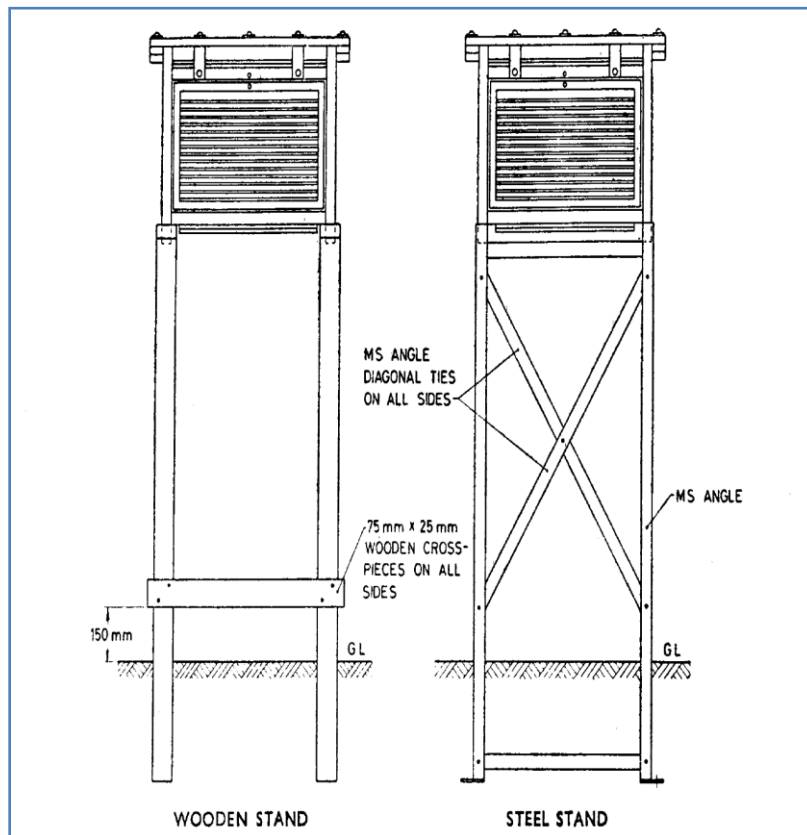


Fig 6.3 Maximum-Minimum atmospheric temperature thermometer

### 6.3.1 Stevensons Screen

In order to record the correct atmospheric temperature, the thermometer should be exposed to the atmosphere and should not be kept indoors in a room or shelter. However placing the thermometer under the open sky would render it to direct exposure of sun, wind, dust, rain, snow, hail etc which will provide erroneous readings. In order to have ambient atmospheric conditions, free from any disturbance, the thermometers are placed inside a wooden enclosure, with proper arrangement for hanging/clamping the thermometer.

The above enclosure is known as Stevensons screen and is made up of wood with spaces in between the wooden louvers for proper circulation of the air. A typical Stevenson's screen (small) sketch for housing max/min thermometers as per BIS standard is shown below with dimensions.



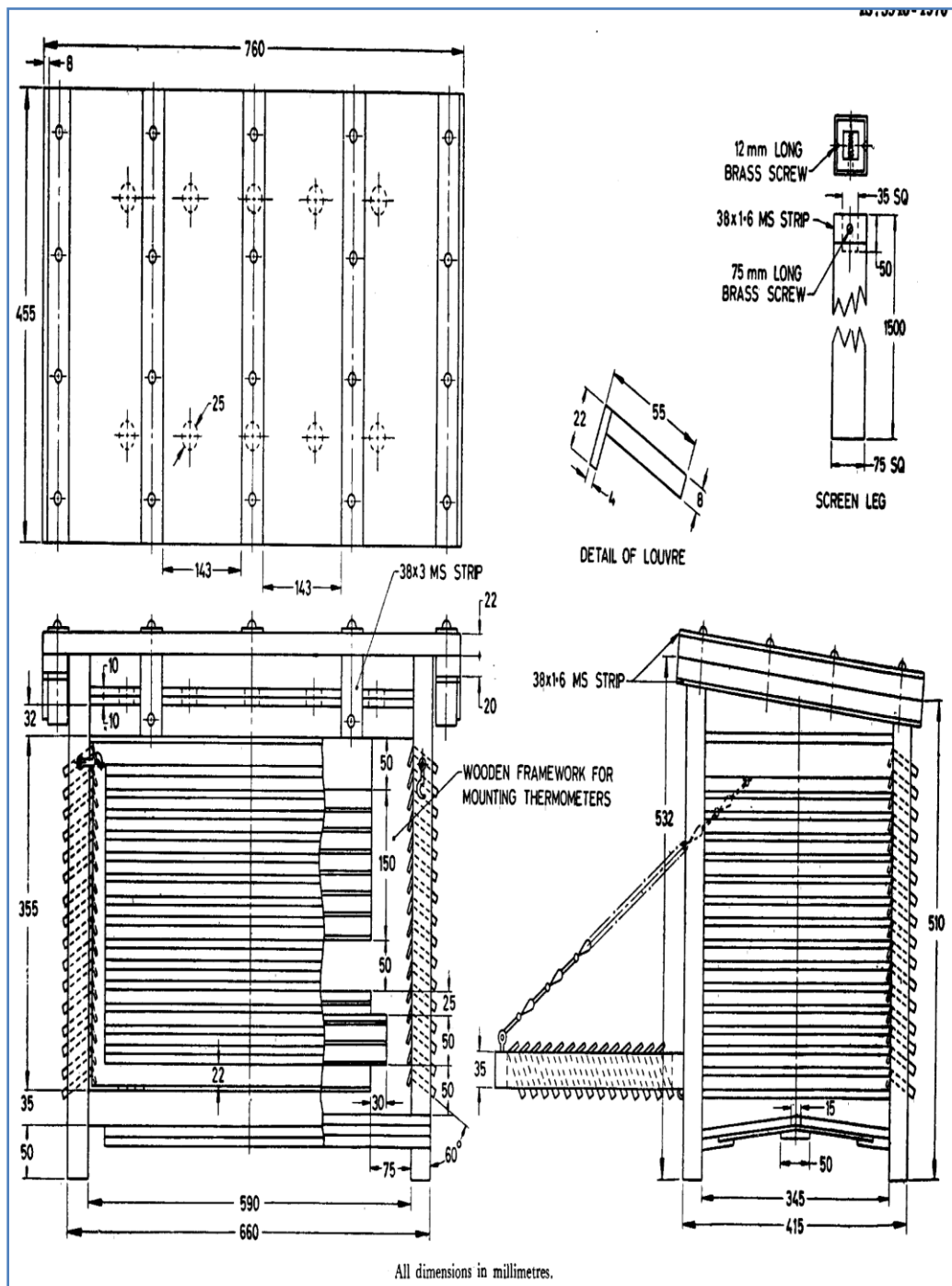


Fig 6.3.1. Typical small size Stevensons screen

## 6.4 EVAPORATION

Under natural conditions, the rate of evaporation, or the amount of water turned to aqueous vapour in a given time, is a function of the following meteorological factors: (a) solar and sky radiation, (b) the vapour pressure deficit of the atmosphere surrounding the evaporating surface water, (c) the flow of air past the evaporating surface, (d) the air temperature which controls the temperature of the liquid and also determines the upper limit of the vapour pressure deficit. Measurement of evaporation from a free water surface provides a value which could be used as an expression of the integrated effect of all these meteorological factors.

The pan evaporimeter used for measurement of evaporation consists of a cylindrical reservoir of fixed diameter and depth, filled with water to a few centimetres below the rim. A fixed-point gauge in a stilling well serves to indicate the level of water in the pan. A calibrated measuring cylinder is used to add or remove water at each observation to bring the water level to the fixed point. The cross-sectional area of the measuring cylinder is such that, the number of millimetres of water added from the measuring cylinder divided by 100 gives the amount of water in millimetres which has evaporated from the pan during a given interval of time. The reservoir is covered with wire-mesh netting to protect it from birds, animals or flying debris. The pan used for evaporation measurement is the US "Class A" evaporation pan which rests on a carefully levelled, wooden base and is often enclosed by a fence. Evaporation is measured daily as the depth of water (in mm/cm) evaporates from the pan.

As per BIS Standard, a typical Pan Evaporimeter should be in circular shape made up of Copper and having arrangement for clamping thermometer and should have a fixed gauge inside a stilling well made up of brass to observe the water level in the Pan (Fig 6.4 (i)). A measuring cylinder made up of either acrylic plastic or brass is used to add water to the Pan Evaporimeter (Fig 64. (ii)).

### 6.4.1 Procedure for measurement of Evaporation

To calculate the evaporation it is necessary to measure the rainfall and the water level in the pan at the same time.

A. Read the rain gauge every day at 8:30 hrs to get the past 24 hours cumulative rainfall.

B. Class A Pan Evaporimeter reading:

Case1: Water level in the pan is below the fixed point gauge:

- i. Take the measuring cylinder and fill it completely with water and start pouring the water slowly in the Pan Evaporimeter and keep a tab on the fixed point gauge. Stop pouring the water as soon as the water level in the Pan touches the top of the fixed point gauge.
- ii. Observe/measure the amount of water (in mm) poured into the Pan Evaporimeter.
- iii. The actual evaporation during the past 24 hours is the amount of water (mm) added to the Pan Evaporimeter + the rainfall (mm) occurred during the past 24 hours.

Case2: Water level in the pan is above the fixed point gauge:

- i. Take the measuring cylinder and start removing the water using the measuring cylinder till the water level touches the fixed point gauge.
- ii. Observe/measure the amount of water (in mm) taken out into the Pan Evaporimeter.

- iii. The actual evaporation during the past 24 hours is the amount of water (mm) removed from the Pan Evaporimeter - the rainfall (mm) occurred during the past 24 hours.

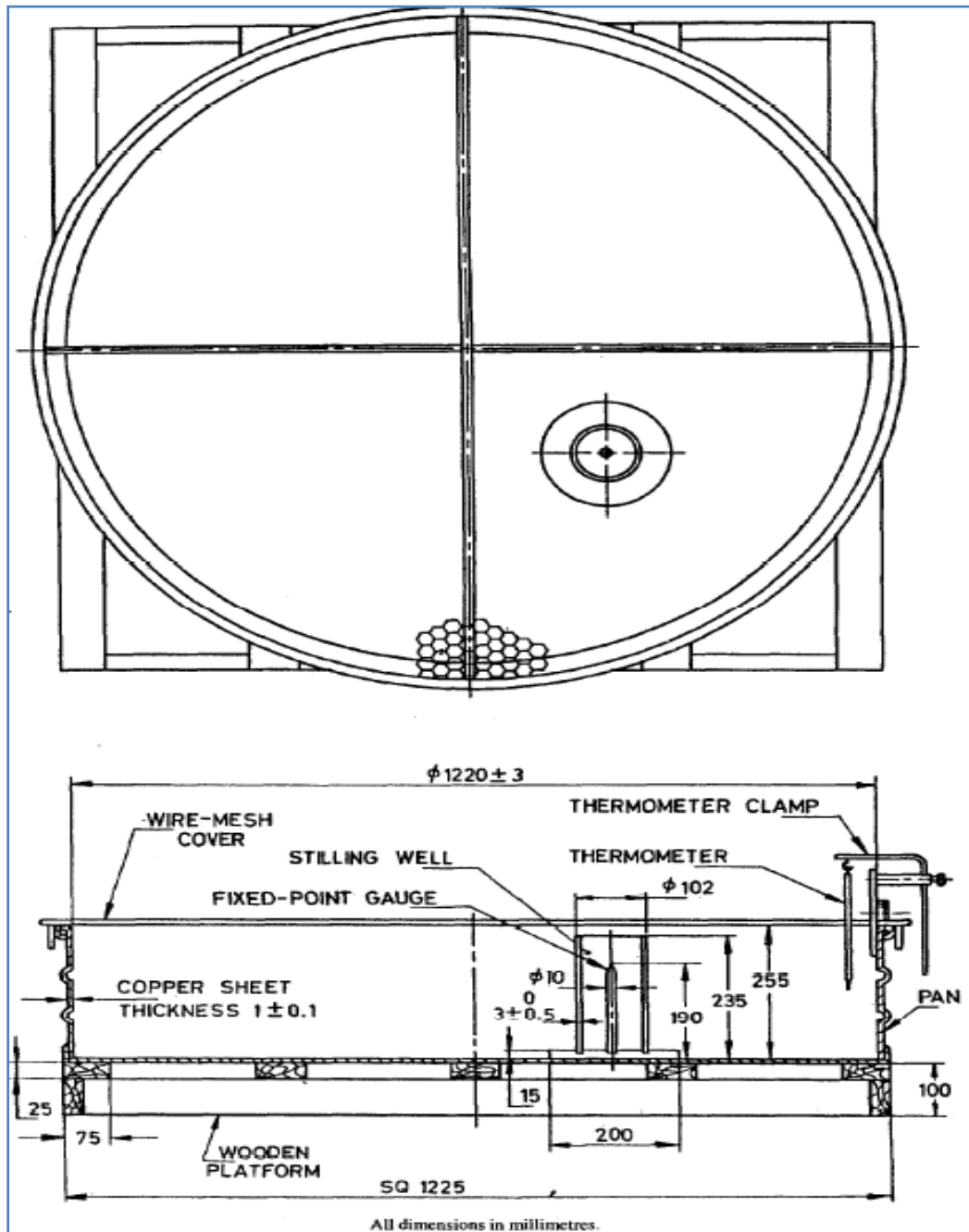


Fig 6.4(i) Pan Evaporimeter



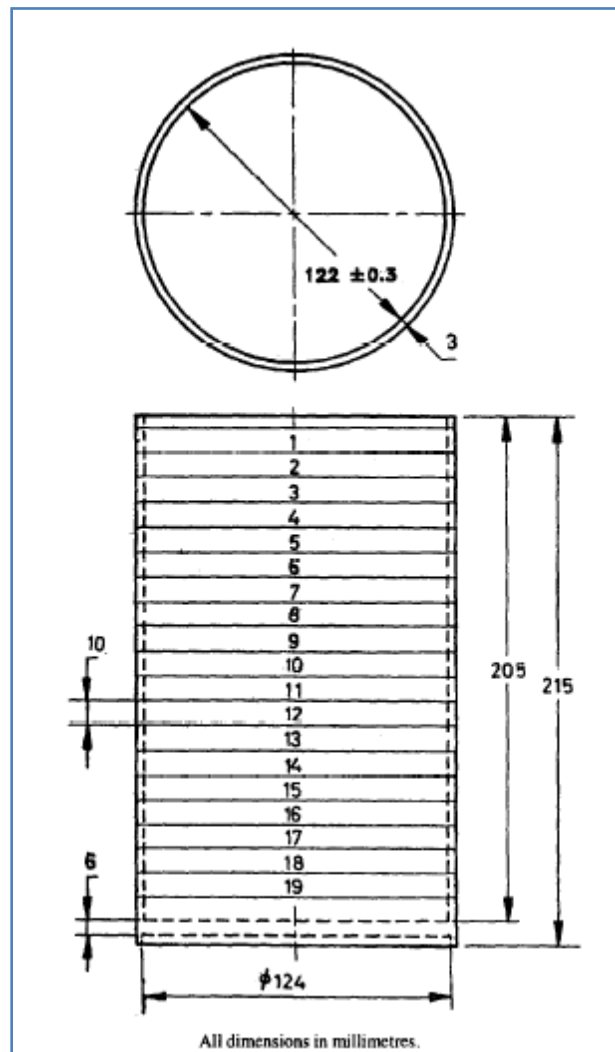


Fig 6.4 (ii) Measuring Cylinder (Acrylic Plastic)



[illegible]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

योग

सार्वनिष्ठ चौड़ाई से  
गुणा करें  
गुणनफल

क्षेत्रफल संशुद्धि  
घटायें  
क्षेत्रफल (A)


योग

सतह की चौड़ाई  
(W) जोड़ें

भीगा परिमाण (P)

योग

सार्वनिष्ठ चौड़ाई से  
गुणा करें।  
गुणनफल

स्तम्भ 20 का योग  
घटायें  
निस्सरण (Q)


## प्रेक्षित सतह ढाल (S)

मध्य रेखा से दूरी	दायाँ तट			वायाँ तट		
	पीछे	आगे	अन्तर	पीछे	आगे	अन्तर
..... मीटर अनुप्रवाह						
0						
..... मीटर प्रतिप्रवाह						
..... मीटर में कमी						

मुख्य आँकड़े

1.  $V =$  औसत वेग  $= Q/A =$
2.  $V (\max) =$  अधिकतम बिन्दु वेग  $=$
3.  $R =$  जलीय औसत गहराई  $= A/P =$
4.  $C (\text{चेजी}) = V/\sqrt{RS} =$
5.  $N (\text{मैनिंग}) = R^{1/6}/C$
6. औसत गहराई  $= A/W =$
7. जहाँ  $W =$  जल की सतह चौड़ाई

S = 0.00

प्रति मीटर

अन्य सूचनायें

1. नदी तल के लक्षण :
2. खुरदुरेपन की श्रेणी जिसमें यह आता है :
3. प्रत्येक माह अथवा प्रत्येक परिवर्तन की दशा में नदी के सामान्य प्रवाह की दिशा, स्थायी व अस्थायी गेज की स्थिति तथा मध्य रेखा से उनकी दूरी समेत अन्य स्थायी चिन्हों को दर्शाता हुआ स्थल के 500 मीटर प्रतिप्रवाह व 500 मीटर अनुप्रवाह तक के नदी की आकृति का एक मुक्त हस्तचित्र बना लेना चाहिए।

प्रेक्षक का हस्ताक्षर  
नाम  
पद

निरीक्षणकर्ता अधिकारी का हस्ताक्षर  
नाम  
पद

सूचना —

1. 0.6 गहराई पर जो वेग है वही सामान्यतया औसत वेग (स्तम्भ 12) होगा। जहाँ सतह वेग से औसत वेग का परिणाम निकाला जाए वहाँ प्रयोग में लाये गये गुणांक को अभ्युक्ति-स्तम्भ में लिख देना चाहिये। जब तक विशेष रूप से प्रमाणित न हो तब तक गुणांक 0.89 को ही प्रयोग में लाना चाहिए।
2. यदि कोई अपवहन (ड्रिफ्ट) न हो तो स्तम्भ 16 में शुन्य दर्शाना चाहिए। इस स्तम्भ को कभी रिक्त नहीं छोड़ना चाहिये।
3. क्षेत्रफल संशुद्धि = असमान छोर खण्डों के क्षेत्रफल संशुद्धि का योग  
[प्रत्येक असमान छोर खण्ड के लिए संशुद्धि = (खण्डों की सार्वनिष्ठ चौड़ाई - छोर सापेक्ष दूरी के उस असमान खण्ड की चौड़ाइयों के योग का  $1/2 \times$  छोर उर्ध्वाधर पर गहराई]
4. स्तम्भ 20 = निस्सरण संशुद्धि = असमान छोर खण्डों के निस्सरण संशुद्धि का योग  
[प्रत्येक असमान छोर खण्ड के लिए संशुद्धि = (खण्डों की सार्वनिष्ठ चौड़ाई - छोर सापेक्ष दूरी के उस असमान खण्ड की चौड़ाइयों के योग का  $1/2 \times$  स्तम्भ 19]

माह/Month.....20..... के दौरान प्रथम/द्वितीय/तृतीय दस दिनों के निस्सरण प्रेक्षण का दस दिवसीय विवरण/Statement Showing Details of First/Second/Third Ten Daily Discharge Observation

नदी ..... स्थल ..... कोड सं. ....

निस्सरण स्थल की स्थिति .....

खंडीकरण (सेगमेंटेशन) की विधि .....

गहराई किस से नापी गई/प्रयुक्त भार .....

0.6 गहराई/सतह पर वेग प्रेक्षण किससे किया गया .....

निस्सरण प्रेक्षण की विधि .....

मानक गेज बायें/दायें तट पर है .....

गेज का शून्य सापेक्ष तल (जी०टी०एस०) ..... मी०

जाँच की पिछली तिथि .....

[illegible]

टिप्पणी :

1. वास्तविक प्रेक्षित निस्सरण को लाल स्याही से लिखा जाये।
2. संगणित निस्सरण को काली स्याही से लिखा जाये।

प्रेक्षक के हस्ताक्षर  
नाम  
पद

उपमण्डल अधिकारी के हस्ताक्षर  
उपमण्डल

अधिशसी अभियन्ता  
केन्द्रीय जल आयोग

स्थल :

योग

**केन्द्रीय जल आयोग / Central Water Commission**

माह/Month.....20..... के दौरान गेज पाठ्यांक का विवरण / Statement Showing Daily Guage Reading

नदी ..... स्थल..... कोड सं. ....

शून्य सापेक्ष तल (जी.टी.एस.).....मी. स्थल की प्रकृति :

दिनांक	मध्य रेखा पर गेज पाठ्यांक (मी.)			जल तल (मी.)			नदी जल का तापमान (°से.ग्रे.)	वायुमण्डलीय तापमान		निरीक्षणकर्ता अधिकारी की टिप्पणी
	8 बजे	13 बजे	18 बजे	8 बजे	13 बजे	18 बजे		अधिकतम (°से.ग्रे.)	न्यूनतम (°से.ग्रे.)	
1	2	3	4	5	6	7	8	9	10	11
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										
11.										
12.										
13.										
14.										
15.										
16.										
17.										
18.										
19.										
20.										
21.										
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										
31.										

प्रेक्षक के हस्ताक्षर

नाम

पद

उपमण्डल अधिकारी के हस्ताक्षर

उपमण्डल

अधिसासी अभियन्ता

केन्द्रीय जल आयोग

## केन्द्रीय जल आयोग / Central Water Commission

माह/Month.....20..... के दौरान प्रथम/द्वितीय/तृतीय दिनों के घंटेवार बाढ़ जल तल का दस दिवसीय विवरण/Statement Showing First/Second/Third Ten Daily Hourly Flood Levels

नदी ..... स्थल..... कोड सं. .... गेज का शून्य सापेक्ष तल (जी.टी.एस.) ..... मी.

[illegible]

माह के दौरान अधिकतम जल तल ..... मीटर

वर्ष के दौरान अधिकतम जल तल ..... मीटर

कभी भी रिकार्ड किया गया अधिकतम जल तल तथा घटित होने की तिथि .....

स्थल प्रभारी के हस्ताक्षर  
नाम  
पद

उपमण्डल अधिकारी के हस्ताक्षर  
उपमण्डल

अधिशसी अभियन्ता  
केन्द्रीय जल आयोग

**केन्द्रीय जल आयोग / Central Water Commission**

माह/Month.....20..... के भूजल तल का अभिलेख

नदी .....

स्थल.....

कोड सं. ....

कुएँ की स्थिति (गाँव) .....

मध्य रेखा से अनुमानित दूरी .....

कुएँ किस उपयोग में आ रहा है .....

कुएँ के शीर्ष पर निर्देश बिंदु की ऊँचाई .....

कुएँ के चारों ओर भूमि सतह की औसत ऊँचाई .....

कुएँ के तल (बेड) की ऊँचाई .....

कुएँ के भूविज्ञानीय लक्षण .....

दिनांक	निर्देश (मी.) बिंदु से नीचे की गहराई		कुएँ में जल तल की ऊँचाई		कुएँ के जल तापमान (°से.ग्रे.)		माप की अवस्था	टिप्पणी
	5 बजे	8 बजे	5 बजे	8 बजे	5 बजे	8 बजे		
1	2	3	4	5	6	7	8	9
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								
26.								
27.								
28.								
29.								
30.								
31.								

**मासिक औसत जल तल**

- निम्नलिखित विवरण के अनुसार स्तंभ 8 में उपयुक्त चिन्ह भरें :  
 (क) पिछले माप से भारी अवक्षेपण (वर्षा और/या हिम)  
 (ख) पिछले माप से संतुलित (माडरेट) अवक्षेपण (वर्षा और/या हिम)  
 (ग) पिछले माप से मामूली या शून्य अवक्षेपण (वर्षा और/या हिम)  
 (घ) जल से प्रायः भरे गर्त, तालाब और खाई  
 (ङ) प्रायः सूखे गर्त, तालाब और खाई .....  
 (च) क्या जमीन जीम हुई है .....  
 (छ) क्या कुएँ में सतह का जल बह कर गया है .....
- यदि कुओं उपयोग में है तो टिप्पणी के स्तंभ में माप तथा प्रयोग की समाप्ति के बीच समय अंतराल (घंटों में) दर्शाया जाये।
- यदि पास के किसी कुएँ का पानी पंप से निकाला जाये तो टिप्पणी के स्तंभ में इसकी दूरी, पंप करने की अवधि तथा अनुमानित निस्सरण का उल्लेख करें।

प्रेक्षक के हस्ताक्षर

नाम

पद

उपमण्डल अधिकारी के हस्ताक्षर

उपमण्डल

अधिशाली अभियन्ता

केन्द्रीय जल आयोग

सरकार / Government of India  
**केन्द्रीय जल आयोग / Central Water Commission**

के.ज.आ./आर.डी.-6  
 C.W.C./R.D.-6

माह/Month.....20..... के वर्षा का अभिलेख / Record of Rainfall

नदी .....

स्थल.....

कोड सं. ....

वर्षा मापी का प्रकार : साधारण/स्वतः अभिलेखी

दिनांक	पिछले दिन 20. 30 बजे हुई वर्षा (मि.मी.)	08.30 बजे हुई वर्षा (मि.मी.)	पूरे दिन में हुई कुल वर्षा (मि.मी.)	माह के लिए संचयी वर्षा (मि.मी.)	वर्ष के लिए संचयी वर्षा (मि.मी.)	टिप्पणी
1	2	3	4	5	6	7
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						
31.						
योग						

वर्ष में हुई कुल वर्षा :

1. पिछले माह के अन्त तक ..... मि.मी.

2. चालू माह के अन्त तक ..... मि.मी.

चालू माह में वर्षा के दिनों की संख्या .....

प्रेक्षक के हस्ताक्षर  
 नाम  
 पद

उपमण्डल अधिकारी के हस्ताक्षर  
 उपमण्डल

अधिशाली अभियन्ता  
 केन्द्रीय जल आयोग



भारत सरकार / Government of India  
**केन्द्रीय जल आयोग / Central Water Commission**

के.ज.आ./आर.डी.-7  
C.W.C./R.D.-7

**निलंबित तलछट विश्लेषण का दैनिक अभिलेख / Daily Record of Suspended Sediment Analysis**

नदी/River..... स्थल/Site ..... स्थल कोड सं./Site Code No. .... दिनांक/Date.....  
प्रतिचयन काट/Sampling Section ..... गेज रेखा/पुल/अस्थाई काट/ Gauge line / Bridge / Temporary Section ..... समय/Time..... से/From..... तक/To.....  
प्रतिचयन की विधि लांच/रज्जु मार्ग/आउट बोर्ड इंजन सहित या रहित नाव/पैदल (वेडिंग से) ..... नदी जल का रंग/River Water Colour.....  
Mode of Sampling /Launch/ Ropeway/Boat with or without O.B.E./Gauge Line/ Bridge /Wading नदी जल का ताप/Temp/ of River Water .....  
प्रयुक्त निलंबित तलछट सैम्पलर का प्रकार/Type of Suspended Sediment Sampler ..... मौसम/Weather .....

प्रतियचन का अभिलेख/Sampling Record									तलछट विश्लेषण/Sediment Analysis												
काट/ Section	जल की गहराई (मी.)/ Water Depth (m)	प्रतिचयन गहराई (मी.)/ Sampling Depth (m)	वगे (मी./से)/ Velocity (m/s)	नमूना बोतलों की सं/ No. of Sampling bottles	समूह सं/ Group No.	संयुक्त नमूनों का आयतन (ली.)/ Volume of Composite Samples	समूह निस्सर्ण (मी. <sup>3</sup> /से.)/ Group Discharge M <sup>3</sup> /s	समूह अपवाह 1000 हे.मी. /Group Run Off 10 <sup>3</sup> (Hect. M)	स्थल तलछट 0.2 मिमी. से ऊपर Coarse Sediment Above 0.2 mm						मध्य तलछट 0.2 मिमी. से नीचे व 0.075 मिमी. से ऊपर Medium Sediment between 0.2 mm and 0.075 mm						अभिवृत्तियाँ/ Remarks
									डिश सं/ Dish No.	खाली डिश का भार (ग्रा.)/ Weight of empty dis h(gm)	डिश + शुष्क तलछट का भार (ग्रा.) / Weight of dish + dry Sediment (gm)	तलछट का भार (ग्रा.)/ Weight of Sendiment (Gm)	सान्द्रता (ग्रा./ ली.)/ Conc. (g/l)	भार (टन/ दिन)/ Load (Tonnes /Day)	डिश सं/ Dish No.	खाली डिश का भार (ग्रा.)/ Weight of empty dis h(gm)	डिश + शुष्क तलछट का भार (ग्रा.) / Weight of dish + dry Weight of dish + dry	तलछट का भार (ग्रा.)/ Weight of Sendiment (Gm)	सान्द्रता (ग्रा./ ली.)/ Conc. (g/l)	भार (टन/ दिन)/ Load (Tonnes /Day)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
योग / Total																					
औसत / Average																					
भारित सान्द्रता / Weight Concentration																					

भारित माध्य सान्द्रता (ग्रा./ली.) / Weighted mean Concentration (g/l) =  $\frac{\text{कुल भार (टन/दिन)}}{\text{Total Load (Tonnes/day)}}$   
(अपवाह / Run Off) X 10<sup>4</sup>

सूक्ष्म तलछट / Fine Sediment

सूक्ष्म तलछट की सान्द्रता (0.75 मिमी से कम) Concentration of Fine Sediment (below 0.075mm)		घुलित पदार्थ / Dissolved Solid		गेज एवं निस्सरण / Gauge and Discharge	
फिल्टर पेपर का भार (ग्रा.) Weight of Filter Paper (gm.)		खाली डिश की भार (ग्रा.) Weight of Empty Dish (Gram)		विवरण / Details	मिट्रिक ईकाई / M.K.S.
				प्रारंभ में गेज / Initial Gauge	
फिल्टर पेपर + शुष्क तलछट का भार (ग्रा.) Weight of Filter Paper + Dry Sediment (gm.)		खाली डिश + घुलित पदार्थ का भार (ग्रा.) Weight of Empty dish + Dissolved Solid (Gm)		अंत में गेज / Final Gauge	
				मध्य गेज / Average Gauge	
तलछट का भार (ग्रा.) Weight of Sediment (Gram)		घुलित पदार्थ का भार (ग्रा.) Weight of Dissolved Solid (Gm)		शून्य सापेक्ष तल / Zero R.L.	
				माध्य जल तल / Average Water Level	
सान्द्रता (ग्रा./ली.) Concentration (gm/l)		सान्द्रता (ग्रा./ली.) Concentration (gm/l)		निस्सरण / Discharge	
				अपवाह प्रतिदिन / Run Off Per day	
भार (टन/दिन) Load (Tonnes/Day)		सान्द्रता पी.पी.एम. में Concentration (PPM)		माध्य वेग / Average Velocity	

तलछट का सार / Abstract of Sediment				
	कोटी / Grade	सान्द्रता (ग्रा./ली.) / Concentration (g/lit.)	मात्रा (टन/दिन) / Load (Tonnes/Day)	
	स्थूल / Coarse			
	मध्यम / Medium			
	सूक्ष्म / Fine			
	योग / Total			

प्रेक्षक के हस्ताक्षर / Signature of the Observer.....

नाम / Name .....

पद / Post .....

सहायक अनु. अधिकारी / अनुसंधान अधिकारी

Asstt. Research Officer/Research Officer

अधिशासी अभियन्ता / Executive Engineer

केन्द्रीय जल आयोग / Central Water Commission

## केन्द्रीय जल आयोग / Central Water Commission

माह ..... के दौरान प्रथम (द्वितीय) तृतीय दस दिवस क लिए निलंबित तलछट का दस दिवसीय विवरण

**During the Month of .....Details of suspended sediment for First (Second) Third 10 Days**

नदी/River..... स्थल/Site ..... स्थल कोड सं./Site Code No. ....

स्थल पर चट्टान और / या मिट्टी का प्रकार .....गेज का शून्य सापेक्ष तल .....  
Type of River Bed Rocky/Sandy .....Zero reduced level of gauge .....

[illegible]

**दैनिक निलंबित तलछट का भार/ Weight of Daily Suspended Sediment**

[illegible]

```

    प्रेक्षक के हस्ताक्षर/ Signature of the Observer.....

```

नाम/ Name .....

पद / Post .....

सहायक अनु. अधिकारी/अनुसंधान अधिकारी  
Asstt. Research Officer/Research Officer

अधिशासी अभियन्ता / Executive Engineer  
केन्द्रीय जल आयोग / Central Water Commission

## Inspection Report Central Water Commission

(Please do not leave any item blank. Fill up the form completely indicating N.A. against items not applicable)

	River	Site	Code No.	Date
1	Period of present inspection		From	To
2	When was this site last inspected and by whom?			
<b>I</b>	<b>Gauge and Discharge Observation</b>			
1	Type of navigational equipment (Boat/Motor Launch/OBE/Jet Boat etc.) in use and its condition			
2	Mention if sufficient number of life buoys, life jackets, oars etc. are provided			
3	Type of engine, if any, and its condition			
4	Total running hours of the engine.			
5	Date of change of gear oil.			
6	Verify log book and fuel consumption			
7	Comments on condition and performance of:			
	(i) Stop watch			
	(ii) Sounding rod			
	(iii) Wading rod			
	(iv) Suspension equipment			
	(v) Tape			
	(vi) Other scientific and mathematical instruments			
8	Levelling operation			
	(i) Level No.			
	(ii) Check permanent adjustment and state the result			
	(iii) Check zero level of gauge and state the result			
9	Is there a standard bench mark within easy reach ?			

- 10 When the site B.M. was last checked with Musto type B.M. ?
- 11 Type of river Gauge (wooden/concrete/steel/enamel plate/vertical/inclined/permanent/temporary etc) and their condition
- 12 Describe the river condition at site (please indicate the number of channels, prevailing flow conditions including overflow of banks, river morphology, erosion problems, if any, etc.),
- 13 Describe method of segmentation.
- 14 If pivot-point lay out is testing, state if it has been checked for its correctness. If yes, when and by whom?
- 15 If a cable way and cable exist indicate their condition.
- 16 No of current meter, make its rating equation
- 17 General condition (Please indicate if the current meter and its accessories are in working condition without any damages).
- 18 Can the observer handle it efficiently?
- 19 When was it last re rated?
- 20 Check spin before and after use and record result.
- 21 No, of check meter, make and its rating. Equation.
- 22 Mention the result of complete joint observation, with both meters and record result if done during the inspection and enclose both discharge observations forms.
- 23 Possible reasons for the difference in the two results and remedies suggested.
- 24 Submit a statement of daily gauge discharge and value of 'C', 'S', 'n' for the last ten days and n (Manning) comment on the data with detailed reasons for variation, if any.

## **II Field Sediment Observation and Analysis**

- 1 Type of suspended sampler used and its condition
- 2 Whether the samples are collected from 0.6D. If not state the sampling point and reason for non-collection of samples according to the prescribed norms.
- 3 Describe the arrangement for keeping the samples in the boat and the carriage of samples to the laboratory
- 4 Make joint observation with the observer and record results.
- 5 Distance between the site and silt laboratory.
- 6 Is the laboratory kept neat and in proper order?
- 7 Check all the instruments in the lab. Give your comments, if any.
  - (a) Physical balance
  - (b) Chemical balance
  - (c) pH meter.
  - (d) Weights
  - (e) Other instruments
- 8 Is laboratory fully equipped? If not, mention the apparatus required.
- 9 Have any special experiments been conducted? If so, state the nature and number of experiments conducted and suggestions for improvement, if any.
- 10 Has bed material survey been conducted at the site? If so state position and number of samples collected during the month.
- 11 Is the bed material sampler in working order?

## **III Water Quality Work**

- 1 Number of sampling sections and other location.
- 2 Number of samples collected from each section and exact position of sampling (width-wise and depth-wise).
- 3 Tests conducted at site and the comments of the inspecting officer thereon

- 4 Number of samples sent to Division/Circle laboratory and purpose thereof.

#### **IV Rain Gauge**

- 1 Type of rain-gauges and their conditions.
- 2 Whether the rain gauges are installed as per described norms (please indicate if the site is free from obstructions).
- 3 Check the working of the self-recording rain-gauge.

#### **V Wireless Station**

- 1 Mention the type and condition of wireless set at site.
- 2 Mention the condition of the building and its surroundings
- 3 Condition of battery in use.
- 4 Condition of the generator, if any.
- 5 Condition of the masts and antenna.

#### **VI General**

- 1 Have the points noted in this last inspection report fully attended?
- 2 Have the data in relevant formats been sent by the JE/RA promptly and regularly ? Please indicate the action taken in case of delay.
- 3 Examine all records maintained at site (including attendance register) and point out shortcomings. If any.
- 4 General Remarks and Suggestions

Signature of Site Incharge  
Date  
Name & Designation

Signature of Inspecting Officer  
Date  
Name & Designation



**CENTRAL WATER COMMISSION**  
**INSPECTION REPORT FOR TELEMETRY STATIONS**

(To be submitted alongwith RD-16 form)

Name of Station:		River/Sub-Basin:	
Type of Station:		Date & Time of Inspection:	

**1. Name & Designation of Inspecting Officer:**

**2. Date of previous inspection by CWC officer and by whom:**

**3. Date of previous visit by the vendor with name of the representative and works carried out by him –**

**4. Telemetry Enclosure**

- i. Is the installed telemetry system (data logger, Solar Panel, GPS, Antena etc.) safe and secure-
- ii. Whether Solar Panel is clean and free from shadow of tree/building etc-
- iii. Check and ensure that there are no loose cable connections and there is no damage to cable/wires-
- iv. Whether the date and time being displayed in the data logger display unit is correct-
- v. Check the battery status in the display unit and mention the voltage-
- vi. Whether the area inside the telemetry enclosure is neat and clean-

**5. Rain Gauge (TBR) Sensor:**

- i. Check to ensure that the TBR is securely placed on foundation/mast-
- ii. Check the cable and its connections between the TBR and Data Logger-

- iii. Whether the TBR was found clean and free from debris/dust-
- iv. Whether regular cleaning is carried out by the Staff and entered in the Log book-
- v. Give the latest rainfall measurement available in the Datalogger (may be 0.0 mm) with time-
- vi. Check through calibration equipment the rainfall recorded by the TBR and record it-

**6. Bubbler Water level Sensor:**

- i. Check whether the HDPE pipe is firmly laid and whether any dislocation/breakage is observed-
- ii. Whether the orifice tube is firmly connected to the datalogger-
- iii. Check the RL of the top surface of PTB (if exposed) to ascertain any dislocation/tilting of the PTB and mention the observation-
- iv. Compare and record the instant actual water level of river and that displayed in the data logger-
- v. In case the river water level is below the bubbler nozzle level, check through calibration equipment the reading recorded by the data logger and record it.

**7. Whether the observations made during the previous inspections have been fully complied with, if not reasons thereof-**

**8. Repairs/Works requiring immediate attention-**

**9. General Observation on the status and functioning of the Telemetry System:**

**(Signature of Inspecting Officer)**

## References

1. “Stream Gauging”, By MG Hiranandani & SV Chitale.
2. World Meteorological Organisation, Guide to Hydrological Practices, WMO No. 168, 2008.
3. **BIS Codes:**
  - i. BIS 4896 (2002)- Installation of Rain gauge (Non-recording type) and measurement of rain.
  - ii. BIS 5225:1992, Meteorology- Rain gauge Non-recording type specification.
  - iii. BIS 4987: 1994 (Reaffirmed 2004)- Recommendations for establishing network of Rain gauge Stations.
  - iv. BIS 4890: 1968, Methods of measurement of suspended sediment in Rivers.
4. **Manuals prepared under Hydrology Project-Phase-I:**
  - i. Hydro-Meteorology, Volume-3, Field Manual Part-I, Network Design and site selection.
  - ii. Hydro-Meteorology, Volume-3, Field Manual Part-III ARG or TBR O&M.
  - iii. Hydro-Meteorology, Volume-3, SRG O&M.
  - iv. Hydro-Meteorology, Volume-3, Field Manual- Part-IV, Field inspections, Maintenance and calibrations.
  - v. Hydrometry, Volume-4, Design Manual.
  - vi. Hydrometry, Volume-4, Reference Manual.
  - vii. Hydrometry, Volume-4, Field Manual Part-II, River Stage Observation.
  - viii. Hydrometry Volume-4, Field Manual Part-III, Float Measurements.
  - ix. Hydrometry Volume-4, Field Manual Part-IV, Current meter gauging.
  - x. Hydrometry Volume-4, Field Manual Part-V, Field applications of ADCP.
  - xi. Hydrometry Volume-4, Field Manual Part-VI, Slope-Area method.
  - xii. Sediment Transport Measurement, Volume-5, Design Manual.
  - xiii. Sediment Transport Measurement, Volume-5, Field Manual.
  - xiv. Sediment Transport Measurement, Volume-5, Reference Manual.