# Measurement of Hydro-meteorological Data

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## 1. Introduction

Water resources assessment, planning and management ultimately rely on the availability of hydrological and hydro-meteorological data. The need for national and regional data and forecasting and other expert services is growing, as awareness of the options and possibilities of modern science and technology increases among end-users. The lecture focuses on the hydro – meteorological observations and its calibration for operational purpose.

## 2. Measurement of Precipitation Data

The amount, intensity and spatial distribution of precipitation are important inputs in most hydrological studies. The total amount of precipitation which reaches the ground in a stated period is expressed as the depth to which it would cover a horizontal projection of the earth's surface. In India, daily observations of precipitation along with other meteorological variables are made at 08:30 am.

*Rain Gauges*

Basically, there are three types of rain gauges:

- Standard or ordinary rain gauges (ORG) are manually read, commonly once a day.
- Self-recording rain gauges (SRRG) record the rainfall depth in the form of a continuous plot.
- Automatic rain gauges with data logger.

An ordinary rain gauge or ORG (Figure - 1) is a simple device consisting of a collector and a funnel. A standard rain gauge consists of a circular collector funnel with a brass or gun metal rim and the rainfall collection area of either 200 $cm^2$ (diameter 159.5 mm) or 100 $cm^2$ (diameter 112.8 mm). The funnel leads to a base unit, partly embedded in the ground and containing, a polythene collector bottle. The gauge is read once (usually) or twice daily and any rain gathered in the polythene collector is poured into a measuring graduated measuring cylinder glass to determine rainfall depth in millimetres.

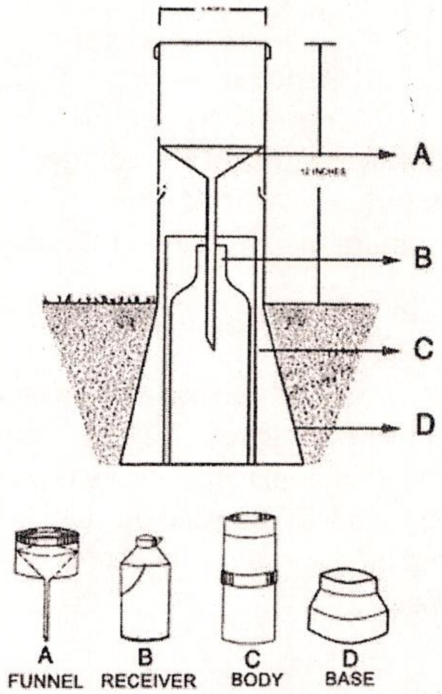



**Figure – 1:** An Ordinary Rain Gauge

*Autographic rain gauge*

Natural syphon rain gauge is frequently used to measure short-period rainfall (Figure 2.0). It consists of a circular collector funnel and rainfall recording mechanism. The collector has a gun metal rim, 200 mm diameter (314 $cm^2$ area) and is fixed at 750 mm above ground level. The funnel leads to a chamber in which a float is located. This float rises when rain water enters the chamber. A syphon chamber is attached to the float chamber. After 10 mm of rain has fallen, the float rises to a certain level and the syphon action is initiated. A pen is attached to the float and records rainfall on a chart placed on a drum in the form of rise of the float. After water is siphoned out, the float returns to the original position.

The drum moves with the help of a mechanical clock such that it completes one rotation in 24 hours. The horizontal axis of the chart is marked with hours and the vertical axis represents depth of rainfall. The chart is changed every day at the set time and the observer reads the hourly rainfalls from the chart and records in data sheets. If no rain has fallen on a given day, the pen will traces a horizontal line on the chart representing zero rainfall. During the periods of rainfall, the pen produces a sloping line; higher is the intensity of rainfall, steeper will be the slope of the curve produced by the pen. Rain water drained by the siphon action may be collected in a vessel and measured when the chart is changed and this will be a check for the total rainfall.

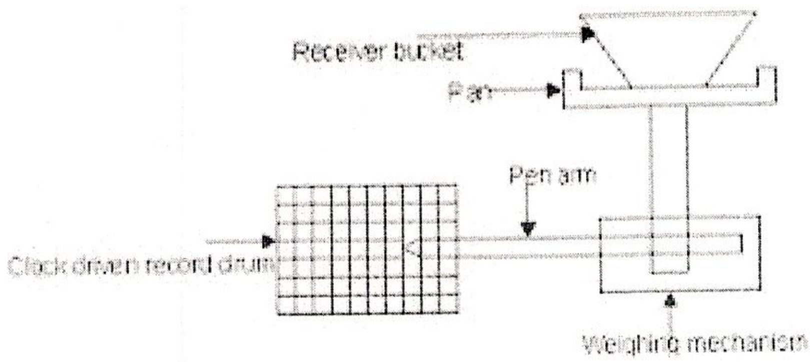
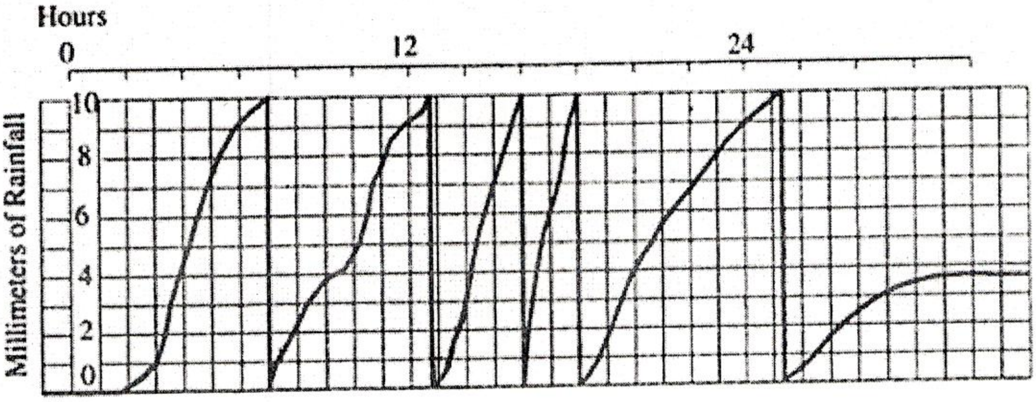



**Figure – 2:** A Self Recording Rain Gauge




Commonly, an ORG is also installed at the site of recording station and the daily rainfall recorded at the two stations may be different due to different exposure conditions, different levels of the rims, etc. Traditionally, the daily ORG data is considered to be more correct where there is a discrepancy between the two.

*Tipping Bucket Rain Gauge*

A tipping bucket rain gauge consists of a circular collector funnel with a brass or gunmetal rim that directs the rain into a pair of tipping buckets which sit on a knife edge (Fig. 3). After rain water has filled one side of the bucket with a small amount (say, 0.025cm) of rain, the assembly tips. An electrical pulse is generated on each tilt and is recorded to provide data of rain fallen with time. At the same time, rain water begins to fill the second side of bucket, and so on. A data logger records the occurrence of each tip along with the time of tip and the data may be downloaded as per convenience and need. Since manual input is not used in data observation or recording, there are little chances of errors.

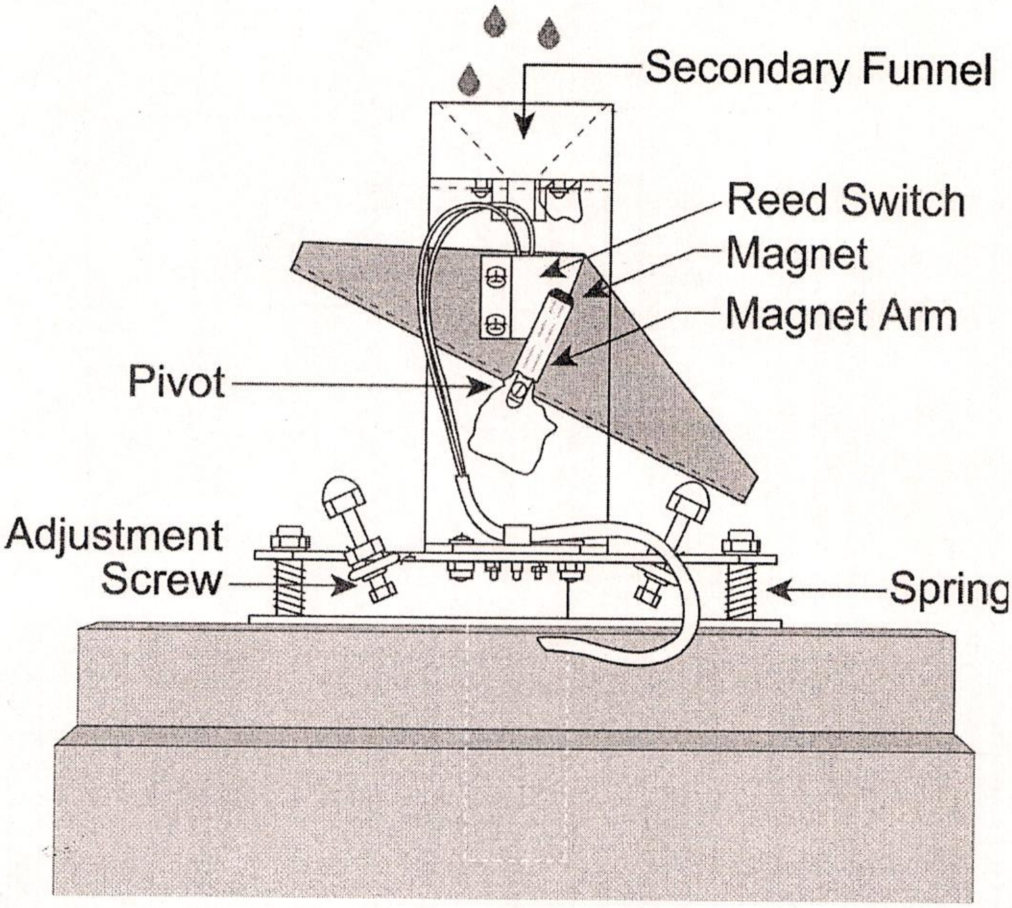



**Figure – 3:** Tipping Bucket Rain Gauge

### 3. Sunshine Duration

The potential maximum sunshine duration depends on latitude and season; the actual sunshine hours vary due to clouds, fog, etc. The amount of bright sunshine in urban areas may be reduced by atmospheric pollution and smog. The instrument commonly employed in India for observation of the sunshine duration is the Campbell Stokes sunshine recorder (Fig. 4). It is a glass sphere mounted on a section of a spherical bowl. The sphere focuses sun's rays on a card held in the grooves of the bowl and graduated in hours. The sun's rays burn the card day when the sun is shining. The card is changed daily after sunset. Note that, the sunshine recorder uses the movement of the sun instead of a clock to form the time basis of the record. Different grooves in the bowl must be used in winter summer and the equinoxes, taking different card types. The lengths of burnt traces on the sunshine card indicate the sunshine duration. Sunshine duration data at required resolution is tabulated from the card. The use of the sun as a timing device avoids timing errors.

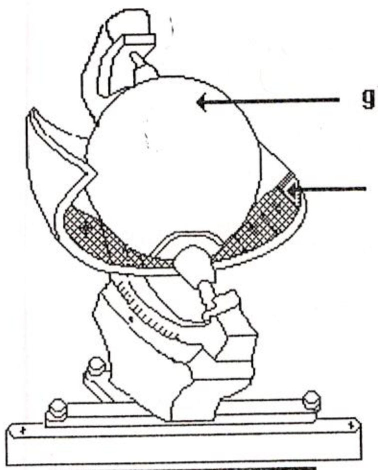



**Figure – 4:** Sunshine Recorder

## 4. Thermometers

For routine observations of air temperature, including maximum, minimum, wet-bulb and soil temperatures, liquid-in-glass thermometers are commonly used. Such thermometers make use of the differential expansion of a pure liquid with respect to its glass container to indicate the temperature. The stem is a tube having a fine bore attached to the main bulb: The volume of liquid in the thermometer is such that the bulb is filled completely but the stem is only partially filled at all temperatures to be measured. The changes in volume of the liquid with respect to its container are indicated by changes in the length of liquid in the stem; by calibration with respect to a standard thermometer, a scale of temperature can be marked on the stem, or on a separate scale tightly attached to the stem.

## 5. Windvane

Surface wind is best measured by a wind vane and anemometer. Wind direction should be reported to the nearest ten degrees. Wind direction is defined as the direction from which the wind blows and is measured clockwise from geographical north. The windvane consists of a metal sheet of rectangular form fastened to a metal rod, pivoted and capable of rotating around a vertical axis with a minimum of friction. The weight of the metal sheet is balanced by a metal counter weight at the other end of the rod. For the purpose of obtaining a satisfactory measurement, a windvane will be suitable if it is well balanced so as not to have a preferred position in case the axis is not vertical and if it is sufficiently well designed to have single equilibrium position with respect to each wind direction.

## 6. Anemometer

The wind speed is measured using anemometer. The instrument has a cup wheel consisting of three conical cups with beaded edges, free to rotate in a horizontal plane. The cup wheel spindle is connected by worm gearing to a revolution counter mounted inside a waterproof housing. The gear ratio between the cup and counter spindles is so chosen that the run of the wind is shown directly in kilometers. The surface wind for synoptic purpose is reported in knots. To determine the wind speed at the time of observation, take two successive readings of the anemometer at an interval of three minutes. Subtract the first reading from the second one and multiply the difference by 20. This gives the mean wind speed over a period of three minutes in kilometers per hour. To obtain the mean windspeed in knots multiply this by 0.54.

## 7. Evaporimeter

The evaporimeter measures the amount of water evaporated from soil and free water surfaces. The rate of evaporation is defined as the amount of water lost by evaporation from a unit area of a surface in unit time. The pan evaporimeter consists of a pan, wire mesh cover, fixed point gauge, measuring cylinder, thermometer with clamp and wooden platform (Figure - 5).

The observation is made as follows. At the prescribed time read the thermometer and anemometer, if any. Then add water to the pan using the measuring cylinder, until the tip of the fixed point coincides with the surface of the water in the pan. The measuring cylinder is so graduated that the graduations run from the top to the bottom. Fill the cylinder so that the water comes to the zero line on the top of the scale. Add water from cylinder to the pan till the water rises to the tip of the gauge. Usually more than one filling of the cylinder will be necessary to bring the water level to the standard height. Suppose 51 cm of water from the cylinder has been added to the pan. This divided by 100 viz. 5mm is the amount of evaporation from the pan, if no precipitation has occurred since the previous hour of observation. If precipitation has occurred during the interval between the two observations and exceeds the water lost by evaporation, water has to be removed from the pan, instead of being added. Water added to the pan is marked positive and water removed from the pan negative. Record the amount of water added or removed to the nearest cm. Enter precipitation, since last observation in the next column. If the amount of water removed is 58 cm and the precipitation 6.7 mm, the water lost by evaporation is given by 6.7 – 5.8 = 0.9 mm.

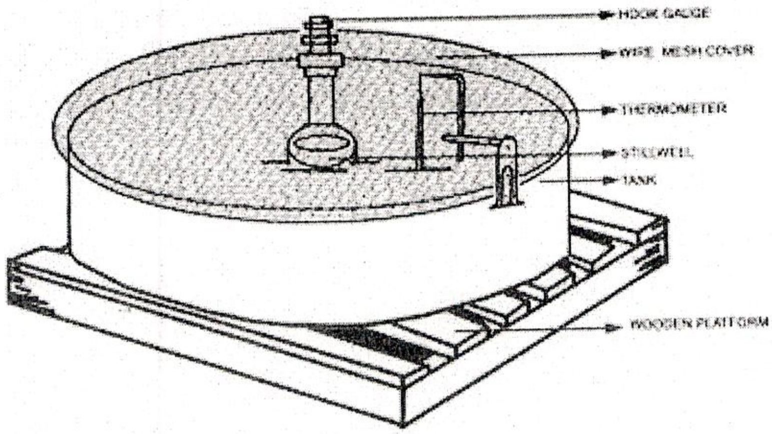



**Figure – 5:** Pan Evaporimeter

## 8. Thermograph

The instrument consists of a temperature sensitive bimetallic element, in the form of a flat strip or helix, connected by a system of magnifying linkage to a recording pen moving on a chart which is fixed on a drum driven by clockwork.

## 9. Hygrograph

The humidity sensor consists of a bundle of human hair held between two adjustable jaws, the whole assembly being mounted on a hair movement plate. The variations with length of the hair strands due to changes in the relative humidity are measured by the displacement of the center of the hair strands transmitted by a lever and a pair of cams to the pen arm, so that the movement of the pen is linear function of the relative humidity.

## 10. Calibration of Instruments

All surface meteorological instruments are manufactured in accordance with the Indian Standards (IS). It is obligatory on the part of the manufactures to send these instruments to India Meteorological Department (Instrument Division, Pune) for "certification" before the instruments are supplied to the users. IMD, on their part, carry out the testing and calibration of surface meteorological instruments and each instrument with its serial number is provided with a certificate. It is essential to procure meteorological instrument with certification for the sake of uniformity in the field operations, which is the first step to arrive at comparable hydro-meteorological data of high quality.

### 10.1 Standard Raingauge (SRG)

Standard raingauge and rain measure glass are tested for their general appearance, dimensions, locking ring and leak. Rain measures are calibrated for every 0.5 mm using a standard burette. A polythene bottle of capacity of 2 litres, 4 litres or 10 litres is kept within the base. (10 litre bottle is used in very heavy rainfall areas). The mouth of the bottle shall be not less than 45 mm in diameter. It is ensured that these conform to the Indian Standard (IS: 5225 and IS: 4849) and authenticated by IMD Certification.

### 10.2 Autographic Raingauge (ARG)

Autographic raingauge is tested for its general appearance, dimensions, calibration, clock rating and syphon time conforming to the Indian Standard (IS: 5235) and authenticated by IMD Certification. ARG is calibrated under controlled laboratory conditions by slowly running water of fixed quantity equivalent to 16.2 mm from a controlled burette to a 203 mm internal diameter ARG to get one syphoning of 10 mm rainfall and siphoning time is adjusted to 15 seconds. The clock work mechanism of ARG is also calibrated and tested with a standard clock and compensated for all temperatures between 0 and 400C. The charts used in ARG should conform to Indian Standard (1S : 5947) for good result.

All the autographic raingauges shall be tested before the onset of monsoon rains. The instrument needs recalibration if the clockwork mechanism is replaced.

### 10.3 Tipping Bucket Raingauge (TBR)

Tipping Bucket raingauge is tested for its general appearance, dimension, calibration and data logger system. TBR assembly is calibrated by measuring the volume of water required to cause one tip of the bucket. A controlled burette is filled with rainwater until it reads '0' (zero). Water is poured slowly from the burette into the collector to produce 3 tips of the bucket, the rate of flow being reduced to discrete drops before each tip, the burette reading is noted after each tip. The process is repeated to give a total of 12 tips and the average volume per tip calculated. For a 750 cm sq collector (MK 3 IMD), each tip will be V/75 mm of rainfall, where V is the average volume of water per tip. The calibration value of V/75 mm must lie within the range 0.196 to 0.204 mm per tip. All TBR shall be tested before the onset of the monsoon rains.

### 10.4 Wind Instruments

***Windvane:*** Mechanical windvanes are tested for general appearance, dimensions, assembly, sensitivity (Friction test) and balancing, conforming to the Indian Standard (IS: 5799) and authenticated by IMD Certification. For calibration purposes, the 4

Direction arms are fixed with the help of a magnetic compass and for the sensitivity of the instrument, the complete instrument on final assembly is held firm at bottom and the balance weight is imparted an impact by a hammer weighting 0.72 kg and having a handle length of 240 mm, it shall make not less than 5 and not more than 10 complete revolutions before coming to rest.

***Anemometer:*** Cup counter Anemometers are tested for general appearance, dimensions, counter changing, bearing test (sensitivity test) and cup balancing, conforming to the Indian Standard (IS : 5912) and authenticated by IMD Certification. For calibration purposes, a wind tunnel generating wind upto 125 km per hours conforming to Indian Standard (IS : 5912) is used. After calibration, the instrument is tested within the tolerance limit of +/-12% for speed below 5 km per hour and +/-10% for speed above 5 km per hr. For the sake of sensitivity, the ball bearings and other moving parts should be kept clean and suitably lubricated every week.

### 10.5 Thermometers

All liquid in glass thermometers (Dry bulb, Wet bulb, Maximum, Minimum) are tested for general appearance, uniform graduation, no break(s) in liquid column and corrections, conforming to the Indian Standard (IS : 5681) and authenticated by IMD Certification. For calibration purposes, the instrument is kept in a constant temperature water bath between 0 to 500 °C after removing possible breaks in the liquid column. The true temperatures of the water bath are obtained from 'Reference Thermometers'. Relevant correction factor is also determined and the value put on a card and attached to the instrument to determine the correct temperature. Instrument needs daily checking for possible break(s) in the liquid column.

### 10.6 Thermograph

All thermographs are tested for general appearance, friction, clockwork mechanism and calibration, conforming to the Indian Standard (IS: 5901) and authenticated by IMD Certification. For calibration purposes, the instrument is kept in a thermostatic chamber working within the temperature range of –200C to +600 °C. Temperature is controlled with a laboratory 'Reference thermometer'. The scale error of the instrument is determined by immersing the sensing element (bimetallic element) successively in comparison baths kept well stirred and maintained at 3 or 4 different temperatures, the difference between lowest and highest temperature being about 400 °C. The range of temperature indicated by the reference thermometer and instrument shall be correct to within +/- 10 °C.

### *10.7 Hygrograph*

All hair hygrographs are tested for general appearance, friction, clearing, clockwork mechanism and humidity comparison, conforming to Indian Standard (IS: 5900) and authenticated by IMD Certification. For calibration purposes, the instrument is kept in a properly designed and operated humidity cabinet, giving sufficient time for the instrument to reach equilibrium. Humidity is checked against a psychrometer and adjusted to read the ambient relative humidity of 95% after attaining equilibrium when the hair is wetted with distilled water. The error should not exceed +/- 5% at any point above 20%.

### *10.8 Pan Evaporimeter*

Open Pan Evaporimeter is tested for general appearance, dimensions, leak, chlorinated rubber paint inside and stilling well reference rod, conforming to Indian Standard (IS : 5973) and authenticated by IMD. The calibration is mainly of the graduated measuring cylinder from which water is poured into the pan and is graduated with a scale 0 to 20 cm. It has a diameter exactly one tenth that of the pan viz. 122 mm as the diameter of the pan is 122 cm, so that the cross sectional area of the cylinder is 1/100 of the pan. It means 200 mm water from the cylinder added to the pan, raise the level in the pan by 2 mm,. Measurement can be made correct to 0.1 mm. A thermometer to measure the temperature of water in the pan fixed to the side of the pan and wind instruments to measure the wind speed and direction are installed at a height of 2 m above the ground near the pan.

### *10.9 Sunshine Recorder*

Sunshine recorder is tested for general appearance, dimensions, movement of the standard gauge, quality of burning and centre of the sphere and the bowl must be coincident, and conforming to Indian Standard (IS: 7243) and authenticated by IMD. For calibration purposes, the instrument must conform to following conditions:

- The centre of the sphere and the bowl must be coincident

- The bowl must be level in the east-west direction

- When a card is in position, the hour lines printed across it must be in meridian planes of the celestial sphere corresponding to the hour angle 15, 30, 45 degree etc. measured from the geographical meridian.

Above three conditions are ensured during manufacture. Finally the installation of the instrument is to be carried out by an expert who should refer to the proper diagram giving variations of the sun's altitude and azimuth at different times of the year and in different latitudes 0-34 degree North, with the hours of the day in local apparent time marked on the curves. 3 types of cards are used: the long curved during summer, the short curved during winter and straight one during equinoxes.

## 11. Precipitation Networks

The optimum density of a precipitation gauge network depends on the purpose for which the data are to be used. For example, measurements of precipitation for flood forecasting require denser networks as compared to that for rainfall-runoff modeling. WMO (2008) has recommended the following (Table 1) as minimum network densities for precipitation stations.

**Table - 1**

Recommended minimum densities of stations (area in $km^2$ per station) [Source: WMO (2008)].

| Physiographic unit | Precipitation | | Evaporation |
|---|---|---|---|
| | Non Recording | Recording | |
| Coastal | 900 | 9000 | 50000 |
| Mountains | 250 | 2500 | 50000 |
| Interior plains | 575 | 5750 | 5000 |
| Hilly/undulating | 575 | 5750 | 50000 |
| Small islands | 25 | 250 | 50000 |
| Urban areas | - | 10-20 | - |
| Polar/arid | 10000 | 100000 | 100000 |

The optimum network should make it possible to derive required information with desired accuracy. The optimum number of rain gauge stations (N) in a network is given by (Singh, 1992):

$$N = [Cv / p]^2$$

where Cv is the coefficient of variation of the precipitation values of the existing rain gauge stations, and p is the desired percentage error in the estimate of basin mean rainfall. A typical value of p is 10 percent. Here, Cv is computed by:

$$Cv = 100 * s / Pm$$

In which *s* is the standard deviation and Pm is the mean rainfall of the existing stations. Obviously, a decrease in the percentage error would mean an increase in number of gauges required. Mukherjee and Kaur (1987) have proposed a modified form of eq. by including the mean correlation (r) of precipitation over the area:

$$N = [Cv / p]^2 (1 - r)$$

WMO recommends that the precipitation (amount and form) should be measured with an accuracy of 3–7% and rainfall intensity with 1 mm/hr at the 95 per cent confidence interval.Snow depth below 20 cm should be accuracy of less than 1 cm and depth above 20 cm should not have more than 10% error. The recommended accuracy for evaporation range 2–5% and for wind speed 0.5 m/sec.

## 12. Water Level and Discharge Measurement

### *12.1 Water Level*

Water level, or stage, is the elevation of the water surface of a stream, lake, or other water body relative to a datum. It should be observed with a precision of one centimetre in general and to three millimetres at continuous-record gauging stations. The site selected for observation of stage should be governed by the purpose for which the records are collected and by the accessibility of the site. Hydraulic conditions are an important factor in site selection on streams, particularly where water levels are used to compute discharge records. Gauges on lakes and reservoirs are normally located near their outlets, but sufficiently upstream to avoid the influence of drawdown.

#### *12.1.1 Gauges for measurement of stage*

*Non-recording gauges*

Several types of non-recording gauges for measuring stage are used in hydrometric practice. The common gauges are of the following types:

(*a*) Graduated vertical staff gauge;

(*b*) Ramp or inclined gauge;

(*c*) Wire-weight gauge installed on a structure above the stream; and

(*d*) Graduated rod, tape, wire or point gauge for measuring the distance to the water surface.

*Recording gauges*

Many different types of continuously recording stage gauges are in use. They may be classified according to both mode of actuation and mode of recording. A commonly used installation consists of a stilling well connected to the stream by pipes and a float in the stilling well connected to a wheel on a recorder by a beaded wire or perforated tape. In high velocity streams, it may be necessary to install static tubes on the end of the intake pipes to avoid drawdown of the water level in the well.

#### *12.1.2 Frequency of stage measurement*

The frequency of recording of water level is determined by the hydrological regime of the water body and by the purposes for collecting the data. Where a nearly continuous record is needed, systematic recordings, twice a day, supplemented by more closely-spaced readings during floods, are sufficient for many streams.

Installation of water level recorders are essential for streams where the level is subject to abrupt fluctuations. The non-recording gauge is frequently used as a part of floodforecasting systems, where a local observer is available to report on river stage. For purposes such as flood forecasting or flood management, telemetering systems may be employed to transmit data whenever the stage changes by a predetermined amount.

### 12.2 Discharge Measurement

River discharge, which is expressed as volume per unit time, is the rate at which water flows through a cross-section. Discharge at a given time can be measured by several different methods, and the choice of methods depends on the conditions encountered at a particular site.

#### *12.2.1 Velocity - Area Method*

The depth of flow in the cross-section is measured at verticals with a rod or sounding line. As the depth is measured, observations of velocity are obtained with a current meter at one or more points in the vertical. The measured widths, depths, and velocities permit computation of discharge for each segment of the cross-section. The summation of these segment discharges is the total discharge.

*Measurement of cross-sections*

The accuracy of a discharge measurement depends on the number of verticals at which observations of depth and velocity are obtained. Observation verticals should be located to best define the variation in elevation of the stream bed and the horizontal variation in velocity. In general, the interval between any two verticals should not be greater than 1/20 of the total width and the discharge between any two verticals should not be more than 10 per cent of the total discharge.

*Measurement of velocity*

Velocity of flow at a point is usually measured by counting revolutions of a current meter rotor during a short-time period measured with a stop-watch. Two types of current-meter rotors are in general use: the cup type with a vertical shaft, and the propeller type with a horizontal shaft. Both types use a make-and-break contact to generate an electric pulse for indicating the revolutions of the rotor. Optical, non-contact type counters are also in use with cup type meters.

### *12.2.2 Measurement of discharge by the float method*

This method should be used when either it is impossible to use a current meter because of unsuitable velocities or depths, or the presence of material in suspension, or when a discharge measurement must be made in a very short time.

#### *Selection of sections*

Three cross-sections should be selected along a reach of straight channel. The cross sections should be spaced far enough apart for the time that the float takes to pass from one cross-section to the next to be measured accurately. A travel time of 20 seconds is recommended, but a shorter time may have to be used on small rivers with high velocities where it is often impossible to select an adequate length of straight channel.

#### *Floats*

Surface floats or rod floats may be used. A surface float has a depth of immersion less than one-quarter the depth of the water. Surface floats should not be used when they are likely to be affected by wind. A rod float has a depth of immersion exceeding one-quarter the depth of the water. Rod floats must not touch the channel bed. Floating trees or ice cakes may serve as natural floats during periods when it is unsafe to be on the river.

#### *Computation of velocity*

The velocity of the float is equal to the distance between cross-sections divided by the time of travel.

### *12.2.3 Measurement of discharge by dilution methods*

Measurement of discharge by this method depends on determining of the degree of dilution by the flowing water of an added tracer solution. The method is recommended only for those sites where conventional methods cannot be employed because of shallow depths, extremely high velocities, or excessive turbulence and debris. The two principal tracer methods used for discharge measurements are the constant-rate-injection method and the sudden-injection method. The general requirements for both methods are the same.

#### *Computation of discharge*

Equations used to compute the stream discharge, $Q$, are based on the principle of continuity of the tracer

$$\frac{Qtr\, Ci}{Cs} \text{ (continuous injection)}$$

and

$$\frac{CiV}{\int_0^{\infty} Csdt} \text{ (sudden injection)}$$

where *Qtr* is the rate of injection, *Ci* is the concentration of injection solution, *Cs* is the concentration in the stream at the sampling section, *V* is the volume of injected solution, and *t* is time.

### *12.2.4 Non-traditional methods of stream gauging*

Determination of discharge by the velocity-area method, the dilution method, and by means of a hydraulic structure has certain limitations and is not applicable in some instances. Three relatively new methods of flow measurement in open channels are the moving boat method, the ultrasonic method, and the electromagnetic method.

#### *Moving boat method*

In this method, a boat is fitted with a specially designed component current-meter assembly that indicates an instantaneous value of velocity. A measurement is made by traversing the stream along a preselected path that is normal to the flow. During the traverse, which is made without stopping, an echo sounder records the geometry of the cross-section, and the continuously operating current meter measures the combined stream and boat velocities. These data, collected at some 30 to 40 observation points (verticals) across the path, are converted to discharge.

#### *Ultrasonic (acoustic) method*

The principle of the ultrasonic method is to measure the velocity of flow at a certain depth by simultaneously transmitting sound pulses through the water from transducers located on either side of the river. The transducers, which are designed both to transmit and receive sound pulses, are located on opposite banks, so that the angle between the pulse path and the direction of flow is between 30° and 60°. The difference between the time of travel of the pulses crossing the river in an upstream direction and those travelling downstream is directly related to the average velocity of the water at the depth of the transducers. This velocity can be related to the average velocity of flow of the whole cross-section. The incorporation of an area computation into the electronic processor allows the system to output discharge.

*Electromagnetic method*

The motion of water flowing in a river cuts the vertical component of the Earth's magnetic field, and an electromotive force (emf) is induced in the water that can be measured by two electrodes. This emf, which is directly proportional to the average velocity in the river, is induced along each traverse filament of water as the water cuts the line of the Earth's vertical magnetic field.

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