National Centre for Hydrology and Meteorology

# Operational Manual

# FOR

# HYDROLOGICAL OBSERVATION

(PR-HWRSD-01)

JULY 2023

National Centre for Hydrology and Meteorology

# Manual

# To Hydrological Observation

(PR-HWRSD-01)

| PREPARED | CHECKED | APPROVED |
|---|---|---|
| TSRD Division | HWRSD Division | NCHM Management |
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**Version 01**

**July 2023**

PR-HWRSD-01- Hydrological Observation

(Water Level, Discharge and Sediment Observation)

## REVISION STATUS

| Version | Date | Chapter/Section | Purpose of amendment | Prepared by | Revised by |
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# Preface

Hydrology is the science that studies the occurrence, distribution, movement, and quality of water on Earth. It is an interdisciplinary field that combines knowledge from geology, meteorology, chemistry, biology, and engineering to understand the complex interactions between water, land, and the atmosphere. This hydrology observation manual is designed to provide a comprehensive overview of the various methods of Hydrological observation for the National Centre for Hydrology and Meteorology that meet international standards.

The Standards for hydrological observation have been published in the Guideline by the World Meteorological Organization (WMO) and Indian Standards Organization (ISO). The methods and procedures described in this manual are intended to complement the recommendations of these standards. The Guideline consists of three chapters dealing with Water Level Observation, Discharge Observation and Sediment Observation.

This Manual has been prepared by the Technical Standard and Research Division. We would like to express our sincere gratitude to the experts who contributed their time, knowledge, and expertise to prepare this manual.

# Content

## DEFINITIONS

***Backwater (BW)*** — a rise in stage produced by an obstruction in the stream channel caused by ice, weeds, control structure, etc. The difference between the observed stage for a certain discharge and the stage as indicated by the stage-discharge relation for the sane discharge is reported as the backwater at the station

***Bank, right or left*** — the margin of a channel as viewed facing downstream. The expression "right" or "left" applies similarly to structures on the right or left, such as abutments and cableway towers.

***Bubble gauge*** — a term commonly applied to a water level recording system that uses a gas purge technique.

***Control*** — the condition downstream from a gauging station that determines the stage-discharge relation. It may be a stretch of rapids, a weir or other artificial structure. In the absence of such features, the control may be a less obvious condition, such as a convergence of the channel or even simply the resistance to flow through a downstream reach. A shifting control exists where the stage-discharge relation tends to change because of impermanent bed or banks.

***Discharge*** — it is expressed in terms of volume, with either a stated or implied reference to time. The term "discharge" is herein considered synonymous with "streamflow."

***Discharge measurement*** — the determination of the discharge at a gauging station on a stream; an observation of no flow is classed as a discharge measurement.

***Float gauge*** —a manual gauge consisting of a float that rides on the water surface, rising and falling with the surface. The float's movements are transmitted to an indicating device.

***Gauge correction*** — any correction that must be applied to the gauge observation or gauge reading to obtain the correct gauge height.

***Gauge datum*** — the permanent horizontal plane to which gauge heights are referred.

***Gauge height*** — the height of the water surface above the "gauge datum"; it is used interchangeably with the terms "stage" and "water level."

***Gauge observation or gauge reading*** — an actual notation of the height of the water surface as indicated by a gauge; it is the same as a "gauge height" only when the 0.000 mark of the gauge is set at the "gauge datum."

***Gauging station*** — a location where systematic records of stage or stage and discharge are obtained. This is also referred to as a "hydrometric station.' '

***Inclined gauge*** — a manual gauge made by setting a staff gauge on an incline.

***Manual gauge*** — a non -recording type of gauge from which observations of stage are obtained.

***Painting*** — this refers to the wide ink trace on water level recorder charts that is caused by short-term water level fluctuations or by a malfunction in a recorder having a gas purge system.

***Reference gauge*** — the gauge to which a water stage recorder is set.

***Reference mark*** — a point of known elevation from which measurements may be made to a water surface. It is also known as a "measuring point."

***Shift*** — a change in the stream control which alters the stage-discharge relationship. This change can be either temporary or permanent.

***Slope-area measurement*** — a method of computing peak flow at a gauging station by determining the water surface profile and channel dimensions over a short reach of a stream.

***Staff gauge*** — see "vertical gauge."

***Stage*** — a general term used to describe the height of a water surface and, in a particular application, may be either a gauge height or a water elevation.

***Streamflow*** — the actual flow in a stream. The term "streamflow" is herein considered synonymous with "discharge."

***Vertical gauge*** — a manual gauge consisting of a graduated plate or rod which is set vertically in a stream bed or attached to a solid structure. It is also known as a "staff gauge."

***Water elevation*** — the height of the water surface as referred to as standard datum.

***Water level*** — see "gauge height."

***Water level recorder*** — an instrument that records water levels in analog or digital form. The recorder may be actuated by a float or by any one of several pressure systems.

# CHAPTER 1
# INTRODUCTION

## 1.1 GENERAL

### 1.1.1 Background

The world's water resources are under increasing pressure due to factors like population growth, economic development, and climate change, amongst other. The need for a reliable water supply, the dependence of the food and energy sectors, and the need for ecosystems protection all require better water resource management. Hydrological observation is a vital part of water resource management and environmental monitoring. It is designed to meet specific needs, including those for river behaviour and other hydrological studies, flood forecasting and management, water pollution control, and environmental management. The goal of observations of the hydrological cycle is to collect reliable data for use in water resources planning and decision-making, including for managing flood and drought conditions, integration into hydrological and climate applications and services, and for research.

The National Centre for Hydrology and Meteorology is mandated to maintain the river information system by collecting the hydrological data from the river network across the nation. The hydrological station is broadly divided into the following categories;

a) Principle River Gauging Station- Primary Hydrological Stations operating permanently to furnish data for long term regional hydrologic studies.
b) Secondary River Gauging Station- Hydrological stations established at smaller rivers to take measurement of water level.
c) Automatic Water Level Stations- Automatic water level station recording and transmitting measurement of various hydrological parameters to the central Database.

The national hydrological monitoring network consists of 22 principal river gauging stations, 8 secondary river gauging stations and 45 automatic water level stations located mostly on the north-south running rivers. There are sediment sampling stations that operate in parallel with some of the river gauging stations. The 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. The above activities involve 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 and tabulation-calculation-compilation of observations made. All of the above activities have been described in detail in the following chapters.

### 1.1.2 Document title

This document is identified as Hydrological Observation Manual, PR-HWRSD-01 prepared and maintained by Technical Standard and Research Division, National Centre for Hydrology and Meteorology.

### 1.1.3 Responsibility

In preparation of this manual, care has been taken to ensure that the information contained herein is accurate, reliable and complete. However, suggestions for improvements or comments concerning apparent errors or omissions should be forwarded in writing to the Management, NCHM.

The Management team shall comprise;

1) Director, NCHM
2) HWRSD, Chief
3) CSD, Chief
4) MSD, Chief
5) TSRD, Chief

Holders of hard-copies of this Manual are responsible for ensuring that the Manual is kept up to date. This includes inserting new chapters or chapter amendments in a timely manner and complying with any instructions on amendment advice.

### 1.1.4 Objective

The objective of the Hydrological Observation Manual is to provide a standardized set of procedures and protocols for conducting hydrological observations, measurements, and data recording. The manual aims to ensure consistency, and reliability of hydrological data by providing guidance on the functional requirement, proper data measuring standards, and quality control measures.

Overall, the objective of the Hydrological Observation Manual is to support hydrologists, engineers, and other professionals involved in water-related research and management by providing them with a comprehensive and standardized set of guidelines for conducting hydrological observations. By following these guidelines, observers can ensure the accuracy and consistency of their data, which is essential for effective water resource management and decision making.

### 1.1.5 Scope

This manual outlines the operational guidelines and international standards for hydrological observation, which are limited to topics like water levels, discharges, and sediments. Naturally, it focuses on the activities pertaining to the mandates and functions of the National Centre for Hydrology and Meteorology of Bhutan.

## 1.2 THE HYDROLOGICAL CYCLE

Water is found on Earth in significant amounts in all three of its physical phases: liquid, solid and gaseous. Water is both a necessity for life and a potential hazard to it, hydrological knowledge is valuable in providing for our continuity and well-being. Two of the basic equations that describe the physics of the hydrological cycle are also pertinent in describing the systems that are used to make measurements of its transient properties: (a) the equation of continuity of mass; and (b) the equation of continuity of energy. For example, one form of the equation of continuity of mass:

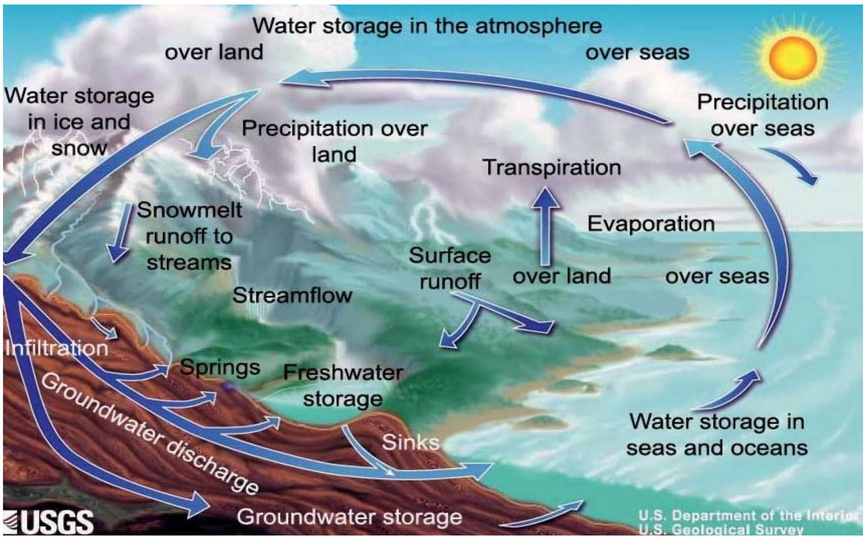



Figure 1.1 The Hydrological Cycle (USGS)

$$Q = AV \qquad (1.1)$$

often serves as the basis for the determination of the flow rate in a stream or canal. In this equation, $Q$ is the instantaneous rate of flow through a cross- section of a channel with area, $A$ and average flow velocity, $V$.

## 1.3 WATER RESOURCES INFORMATION

Hydrology and water resources information may be required for the following purposes of planning, designing and operating of water projects; assessing environmental, economic and social impacts of existing and proposed water resources, providing security for people and property, meeting regulatory requirements etc. Figure 1.2 depicts the elements of a hydrological information system.

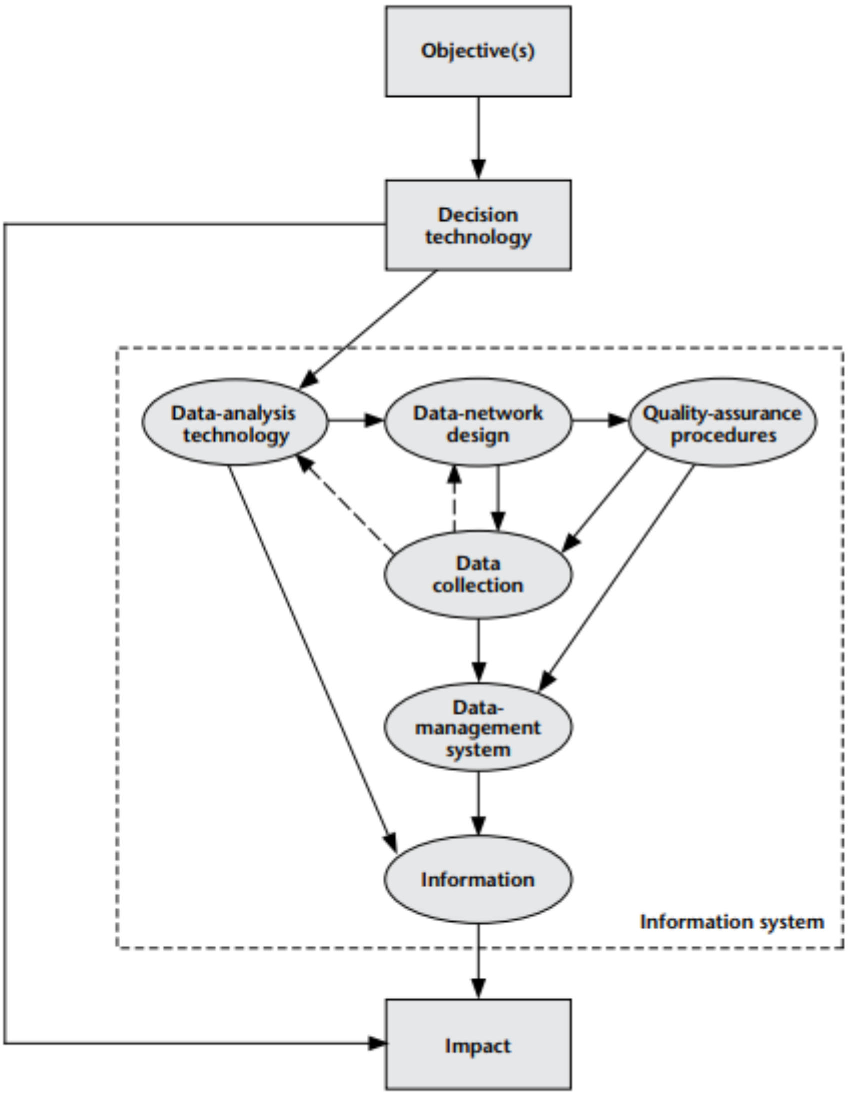



Figure 1.2 Component of Hydrological Information System (WMO)

Types of water resources information elements includes;

- River water level,
- Groundwater,
- River Discharge
- Sediment
- Water Quality
- Precipitation and other meteorological parameters etc.

## 1.4 UNIT AND SYMBOLS

Standardization of units and symbols is desirable and can be achieved through the use of those recommended in Tables 1.1. Commonly used units and conversion factors are also given. All symbols and units used in this Handbook conform to those in the tables. Detailed list can be found at WMO 168.

Table 1.1 Recommended symbols, units and conversion factors (ISO 1993)

| Item | Element | Symbol | Units | | Conversion factor | Remarks |
|---|---|---|---|---|---|---|
| | | | Recommended | Also in use | | |
| 1 | Area(cross-sectional) (drainage basin) | $A$ | $m^2$ | $ft^2$ | 0.0929 | ISO |
| 2 | Runoff | $R$ | mm | in | 25.4 | |
| 3 | Sediment concentration | $c_s$ | kg $m^{-3}$ | ppm | Depends on density | |
| 4 | Sediment Discharge | $Q_s$ | t $d^{-1}$ | ton $d^{-1}$ | 0.907 | |
| 5 | Temperature | $T$ | ºC | ºF | formula ºC=5/9(ºF-32): | |

## 1.5 ACCURACY OF HYDROLOGICAL MEASUREMENTS

For characterization of uncertainty, the 95 percent confidence level is commonly used. That is, in 5 percent of the cases, the error could be outside the stated confidence interval.

The recommended accuracy depends mainly on the anticipated use of the measured data (the purpose of the measurement), on the potentially available instruments and on the available financial resources. Therefore, it cannot be a constant value. Rather it should be a flexible range. The recommended accuracy levels are tabulated in Table 1.2 as a general guidance for instruments and methods of observation.

Table 1.2 Recommended accuracy expressed at 95% confidence interval (WMO)

| | |
|---|---|
| Precipitation (amount and form) | 3–7% |
| Rainfall intensity | 1 mm h–1 |
| Snow depth (point) | 1 cm below 20 cm or 10% above 20 cm |
| Wind speed | 0.5 m s–1 |
| Water level | 10–20 min |
| Wave height | 10% |
| Water depth | 0.1 m, 2% |

| | |
|---|---|
| Width of water surface | 0.5% |
| Velocity of flow | 2–5% |
| Discharge | 5% |
| Water temperature | 0.1–0.5˚C |
| Turbidity | 5–10% |
| Colour | 5% |
| pH | 0.05–0.1 pH unit |

## 1.6 HYDROLOGICAL NETWORKS

A hydrological data network is a group of data collection activities that is designed and operated to address a single objective or a set of compatible objectives.

Network for water resources development, two types of gauging stations are usually needed in a stream gauging network, namely hydrologic and special stations.

(a) **Hydrologic stations** are those established to determine the basic streamflow characteristics of the region. There are two types of hydrologic stations – principal and secondary:

> (i) **Principal hydrologic stations**: are intended to be operated permanently; in showing time trends they furnish data of importance to regional hydrologic studies;
>
> (ii) **Secondary hydrologic 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 principal, or primary, hydrologic station.

(b) **Special stations** are those established to provide specific information at a site for either design of a proposed project, fulfilment of legal requirements etc.

Networks for other hydrological studies such as regional flood frequency studies are used for the design of dam spillways, bridges, and culverts, and for the delineation of flood plains.

For Low Frequency Studies, the data is useful in the planning, design, and management of water supply facilities.

### 1.6.1 Minimum Network

In the early stages of development of a hydrological network, the first step should be the establishment of a minimum network. Such a network should be composed of the minimum number of stations which the experience of NCHM has indicated to be necessary to initiate planning for the economic development of the water resources.

Table 1.3 Recommended minimum densities of stations (area in km2 per station) (WMO 168)

| *Physiographic unit* | *Precipitation* | | *Evaporation* | *Streamflow* | *Sediments* | *Water Quality* |
|---|---|---|---|---|---|---|
| | *Non-recording* | *Recording* | | | | |
| Coastal | 900 | 9 000 | 50 000 | 2 750 | 18 300 | 55 000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mountains | 250 | 2 500 | 50 000 | 1 000 | 6 700 | 20 000 |
| Interior plains | 575 | 5 750 | 5 000 | 1 875 | 12 500 | 37 500 |
| Hilly/undulating | 575 | 5 750 | 50 000 | 1 875 | 12 500 | 47 500 |
| Small islands | 25 | 250 | 50 000 | 300 | 2 000 | 6 000 |
| Urban areas | – | 10–20 | – | – | – | – |
| Polar/arid | 10 000 | 100 000 | 100 000 | 20 000 | 200 000 | 200 000 |

## 1.7 DATA COLLECTION

When a site has been selected and the instrumentation installed, two types of data will be collected: descriptive details of the site and its location, and the hydrological observations that it has been established to measure.

Every permanent site should be given a unique identifier with following information generally needed for station identification: Station Description, Map and Sketch of the Location, Coordinates and Narrative Description.

At all data-collection sites a value must first be sensed, then encoded or recorded, and finally transmitted. Examples of the components of data collection are displayed in Table 1.4.

At manual stations, at the very minimum, observers should be equipped with field notebooks and/or station journals in which the original observations are recorded as they are taken. Forms should also be provided to permit the observer to report observations daily, weekly, fortnightly, or monthly, as required.

Table 1.4 Components of Data Collection (WMO)

<table>
<tr><th colspan="3">Data collection</th></tr>
<tr><th colspan="2">Data capture</th><th rowspan="2">Transmission</th></tr>
<tr><th>Sensing</th><th>Recording</th></tr>
<tr><td>1. Visual<br>Water-level gauge, land use, site description, soil texture, etc.<br><br>2. Mechanical<br>Rain gauge, thermometer, current meter, soil penetrometer, water level gauge</td><td>1. Field notebook<br><br>2. Field data sheet<br>Purpose designed for particular text descriptions and element or parameter values<br><br>May be pre-coded for subsequent computer input purposes<br><br>3. Charts</td><td>1. Manual<br>Field observers<br>Postal services<br>Telephone<br><br>2. Automatic (Telemetry)<br>Telephone<br>Dedicated landline<br>Radio<br>Satellite<br>Internet</td></tr>
</table>

| | | |
|---|---|---|
| 3. Electrical Thermistor, radiometer, pressure transducer, conductivity probe, encoder | Strip charts with element value continuously recorded by pen tracing<br><br>4. Computer compatible media<br>a) Manually recorded Mark sense forms Multiple choice forms<br>b) Automatically recorded<br><br>Solid state memory | Mobile phone networks |
| Note: *The table applies to elements or parameters observed in the field. There are notable groups of data, for example, In soils and water quality, where laboratory analysis or physical samples are performed. Here the data-collection system almost invariably is:*<br>*a) Mechanical sampling*<br>b) *Notebook/data sheet field entries.* | | |

At automatic recording stations, observations are recorded in digital or graphical form. However, the following observations should be recorded at the time of any visits for data retrieval or station maintenance:

(a) Site identification number;

(b) Observations from independent sources at the time of collection, for example, gauge boards and storage rainfall gauges;

(c) Specific comments relating to the recording device, including its status, current observation and time.

Recording stations must report via some transmission facility and due to increasingly complex demand from users of hydrological data in recent years, different possibilities of transmission system may exist; i.e. Manual, Semi-automatic and Automatic.

# CHAPTER 2
# WATER LEVEL OBSERVATION

## 2.1 INTRODUCTION

The *stage* of a stream or lake is the height of the water surface above an established datum plane. 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.

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.

## 2.2 GAUGE DATUM

*NOTE: The gauge datum may be a recognized datum, such as mean sea level, or an arbitrary datum plane selected for the convenience of using gauge readings of relatively low, but positive, numbers.*

An arbitrary datum plane is usually used for stream gauging sites where it is desirable for all recorded gauge heights to be relatively low numbers.

To avoid negative readings, the gauge should be set so that a reading of zero is below the lowest anticipated stage.

The zero of the gauges should be correlated with a national datum through a station benchmark. The gauge zero and the other gauge divisions should be checked annually with respect to this benchmark.

This procedure allows replacement of the gauge in case of destruction and maintenance of the same stage-discharge relation provided the control section is not modified. At least two independent station benchmarks should be established so that the gauge zero can be conveniently recovered if one of the benchmarks is lost or destroyed.

## 2.3 SITE SELECTION

The site selected for observation of the stage should also be governed by the principles of network design and should be guided by the following criteria for an ideal gauge site: IS 15119 (Part 1)- 2002.

a) The general course of the stream is straight for about 100 m upstream and downstream from the gauge site.

b) The total flow is confined to one channel at all stages and no flow by-passes the site as subsurface.
c) The stream bed is not subject to scour and fill and is free of aquatic growth.
d) Banks are permanent, high enough to contain floods, and are free of brush.
e) Unchanging natural controls are present in the form of a bedrock outcrop or other stable riffle during low flow, and a channel constriction for high flow, or a fall or cascade that is unsubmerged at all stages to provide a stable relationship between stage and discharge. If not satisfactory natural low-water control exists, then installation of an artificial control should be considered.
f) A site is available, just upstream from the control, for housing the stage recorder where the potential for damage by water-borne debris is minimal during flood stages. The elevation of the stage recorder itself should be above any flood likely to occur during the life of the station.
g) The gauge site is far enough upstream from the confluence with another stream or from tidal effect to avoid any variable influences, which the other stream or the tide may have on the stage at the gauge site.
h) A satisfactory reach for measuring discharge at all stages is available within reasonable proximity of the gauge site. It is not necessary that low and high flows be measured at the same stream cross-section.
i) The site is readily accessible for ease in the installation and operation of the gauging station.
j) Facilities for telemetry or satellite relay can be made available, if required.
k) If ice conditions might occur, it will still be possible to record stage and measure discharge'.

Rarely will an ideal site be found for a gauging station and judgment must be exercised in choosing between adequate sites, each of which may have some shortcomings.

## 2.4 ACCURACY

The primary use of stage data is for computation of streamflow records, consequently stage accuracy requirements are very stringent. In accordance with this primary use and because the use of stage data cannot be predicted, the overall accuracy of stage data established for gauging stations is either 0.003 m, or 0.2 per cent of the effective stage, whichever is greater. Effective stage is defined as the height of the water surface above the orifice, intake, or other point of exposure of the sensor to the water body.

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 observations are meant for calculating slope, they should be read corrected to 5 mm. Hence the least count or minimum reading of the staff gauge should be 5 mm. The Automatic water level recorder and recording type of gauges have the least count of the range of 1 mm or less. (CWC)

Table 2.1 Accuracy requirements for individual parameters: Source: WMO

| | |
|---|---|
| Water level | 10-20 min |
| Water depth | 0.1 m, 2% |
| Width of water surface | 0.5% |
| Velocity of flow | 2-5% |
| Discharge | 5% |
| Suspended sediment concentration | 10% |
| Suspended sediment transport | 10% |
| Bed-load transport | 25% |
| Water temperature | 0.1-0.5 Degree |
| Dissolved oxygen (water temperature is more than 10 Degree) | 3% |
| Turbidity | 5-10% |
| Colour | 5% |
| pH | 0.05-0.1 pH unit |
| Notes: *When a range of accuracy level is recommended, the lower value is applicable to measurements under relatively good conditions and the higher value is applicable to measurements under difficult situations.* | |

## 2.5 EQUIPMENT

### 2.5.1 Staff Gauges

A vertical or inclined staff gauge shall be located near the stage sensor, to act as the reference gauge. The water level indicated by the stage sensor should follow the water level indicated by the reference gauge.

NOTE: *Such gauges comprise a scale marked on or attached to a suitable surface.*

### 2.5.2 Pressure Gauges

#### 2.5.2.1 General

Water level may be determined by measuring the height of a column of water with respect to some datum plane.

When the sensor is located below the point in the water column at which the pressure is to be measured, the water pressure may be transmitted directly to the sensor. However, if the sensor is located above the water column, the direct method is usually not satisfactory because gases entrained in the water can create air locks in the line.

#### 2.5.2.2 Gas-purge (bubbler) technique

The gas-purge technique is a widely used method of indirectly transmitting pressure. This technique may be used regardless of the elevation of the pressure detecting device with respect to the water column.

#### 2.5.2.3 Pressure-bulb System

Where there is no gas supply available, a pressure bulb system is sometimes used to transmit pressure to the detector. This device, frequently referred to as an elastic pressure bulb, is usually made of a casting in the form of a short hollow cylinder with one open end.

### 2.5.3 Non-Contact Water Level Sensors

The use of ultrasonic, radar and optical methods are used with instrumentation that will eventually provide accuracy and convenience of measuring water surfaces without direct contact. Most of these types of instruments are still in the development stage and consequently, are relatively expensive. Some are not yet able to achieve the accuracy standards for primary stage records.

Radar (radio detecting and ranging), or radio wave transmission, is a distance measuring method that has been used since prior to World War II. A radio wave is the propagation of an electromagnetic field and, therefore, is performed at the speed of light.

The advantages of radar are that the signal is generally immune to weather conditions and the radio wave used for this application is harmless to humans and wildlife. The usable sensor-to-water sensing range is typically from near zero to about 35 m (115 feet). The technology for using radar for measurement of water levels is still new, although several commercially developed instruments are available and are being tested.

## 2.6 FREQUENCY

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.

During the non-monsoon period the gauge observation can be done three (0800, 1300 and 1800) times a day at uniform intervals 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 purposes. Hence, during monsoon period, gauge observation at every hour is recommended. For flashy rivers the fluctuation in water level is more sudden, which necessitates gauge observations at shorter intervals.

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.

## 2.7 STAGE MEASUREMENT

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.

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.

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.

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.

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.

During periods 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.

When the gauge observer reads the gauge at other, non-standard times, he must ensure that he records the actual time of reading.

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 and record in “Remarks” the reason for the missing record.

## 2.8 RECORDING

### 2.8.1 General

Many water-level measuring devices produce an output, often a mechanical movement or an electrical signal, that is analogous to water level. This output provides the basis for recording water-level data. Recorders can be classified as either analogue or digital depending on the nature of the record produced. The analogue recorder produces a continuous graphical record of the rise and fall of parameter values with respect to time, while the digital recorder produces a record of coded parameter values on a medium such as magnetic tape, or in solid state data storage memory chips a preselected time internals should have a digital display to allow the user to review current and recorded values.

### 2.8.2 DIGITAL RECORDERS

Electronic Data Loggers (EDLs) are devices that can be programmed to electronically record stage data on a specific, regular time interval or on a user-defined schedule which may vary according to stage or other variable.

Electronic data loggers store stage data either internally on a memory module, or the EDL may store the data on a removable memory card. Most allow for both methods of data storage. Data are retrieved either by downloading the data directly from the EDL to a field computer or removing the memory card and transferring the data from the card to a field computer.

### 2.8.3 FORMS FOR RECORDING

Measurement of flow of water in open channels involves accurate and precise recording of several types of observations. These observations may relate to the instruments used, the situations under which the observations are taken or the actual length, area, velocity and location of objects by angles and distances. The recording of the observations should be such as to facilitate calculation of the final value in a simple, direct and convenient manner. Observations once taken will also form part of permanent historical records of conditions of flow at that time. In view of these exacting requirements, the standard forms for recording measurement of flow should be convenient and simple for use by the field personnel and elaborate and clear enough for later calculation and transfer into the year books.

For recording the observed water level, standard forms NCHM/HRF 01-01 for stage, NCHM/HRF 01-02 for hourly stage may be used (refer ANNEXURE).

# CHAPTER 3

# DISCHARGE OBSERVATION (Area-Velocity method)

## 3.1 INTRODUCTION

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. Normally, the discharge shall be related to a corresponding water stage at a gauging station.

The common methods of discharge measurement currently practiced in NCHM are as follows:

Area Velocity Methods:

1 Wading/Boat/Bridge/Cableway using Current meter
2 Float method
3 Ultrasonic method (ADCP)
4 Dilution Method

Following sections will describe discharge measurement using area-velocity methods.

## 3.2 AREA-VELOCITY USING CURRENT METER

Measurement of discharge by the velocity-area method is explained by reference to Figure 3.1. 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 metre 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.

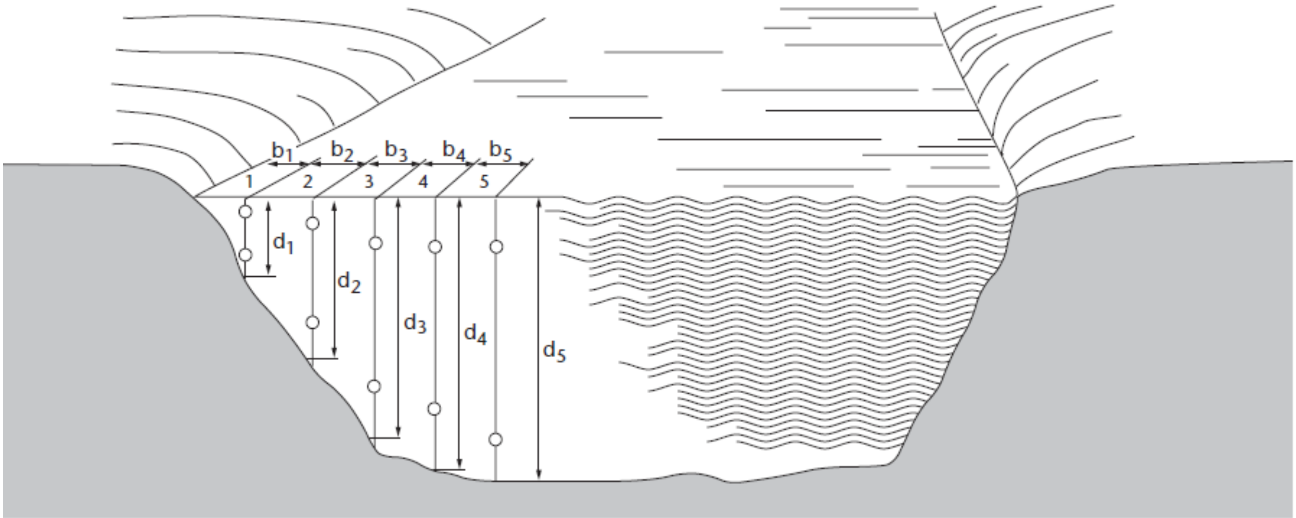



Figure 3.1. View of a stream cross-section showing the location of points of observation (Figure Source: WMO 168)

### 3.2.1 Site Selection

Discharge measurements need not be made at the exact location of the stage gauge because the discharge is normally the same throughout a reach of channel in the general vicinity of the gauge. Sites selected for measurements should ideally have the following characteristics in addition to the site selection described in section Chapter 2.3; (IS 1192)

(a) The velocities at all points are parallel to one another and at right angles to the cross-section of the stream;

(b) The curves of distribution of velocity in the section are regular in the vertical and horizontal planes;

(c) The velocities are greater than 0.150 m s–1;

(d) The bed of the channel is regular and stable;

(e) The depth of flow is greater than 0.300 m;

(f) There is no aquatic growth;

(g) There is minimal formation of slush or frazil ice

Additional desirable requirements of site selection is detailed in WMO 1044 and IS 1192(1981)

### 3.2.2 VERTICALS OF CROSS-SECTION

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.
- The discharge of any verticals should not be more than 10 per cent of the total discharge, ideally no more than 5 percent of total expected discharge.
- In fixing verticals, equal spacing should be preferred wherever possible. However, make the width of the verticals less as depths and velocities become greater.

### 3.2.3 MEASUREMENT OF WIDTH

The measurements of the width of the channel and the widths of the individual segments may be obtained by measuring the distances from or to a fixed reference point, which shall be in the same plane as the cross-section at the gauging site.

Where the width of the channel permits, these distances shall be measured by direct means, for example, a steel tape or suitable marked wire, care being taken to apply the necessary corrections for sag, correction of pull, correction of slope and correction of temperature as per IS 1192-1981.

The horizontal distance to any vertical in a cross section is measured from an initial point on the bank. Cableways and bridges used regularly for making discharge measurements are commonly marked at 1, 2, 3, or 6 m intervals by paint marks.

Distance between markings is estimated or measured with a rule or pocket tape. For measurements made by wading, from boats or from unmarked bridges, steel or metallic tapes or tag lines are used. For very wide streams of about 750 m or more, where conventional measuring methods cannot be used, surveying methods and Global Positioning Systems (GPS) may be used.

Where the channel is too wide for the above methods of measurements, the distances shall be determined by optical or electrical distance meters, or by other surveying methods.

### 3.2.4 MEASUREMENT OF DEPTH

#### 3.2.4.1 Number of Verticals

Measurement of depth shall be made at intervals close enough to define the cross-sectional profile accurately. It would be safe to use 25 verticals for the observations of depth. The use of at least 20 verticals would restrict the error, while the use of 15 vertical means risking the introduction of errors of importance. This condition applies to big as well as small rivers.

#### 3.2.4.2 Location of Verticals

It is recommended to locate a number of verticals in characteristic parts of the cross-section. The remaining verticals should be equally spaced within these parts. However, in the overland flow sections, the observations may be at a lesser number of equally-spaced verticals.

#### 3.2.4.3 **Equipment**

**a) Wading rod**

Depth may be read directly on a graduated rod set on the stream bed if measurement is by wading. 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. (CWC)

**b) Sounding line**

If the drum-wire-weight system is used for measurement, the current meter and weight are lowered until the bottom of the weight just touches the water surface, and the depth dial reading is set at zero. The weight is then lowered until it rests on the stream bed, and the depth is read on the dial.

These are circular or oval in section and are 3 m in height. They are graduated to read nearest to a centimeter 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 up to 6M. Marking on the bamboo should be truly vertical and along the body of the bamboo. (CWC).

**c) Echo sounders**

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 vertically due to high velocity. An accurate and rapid method of measuring and recording depths is by means of an echo sounder (CWC)

#### 3.2.4.4 Measuring Procedure

The depth should be measured employing either wading/sounding rods or sounding lines, or other suitable devices as described above. Wading/Sounding rods shall be used for measuring depths up to 6 m and sounding line (log line) shall be used for depths greater than 6 m. Where the channel is of sufficient depth and velocity is high an echo-sounder may be used.

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

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 temperature of the water.

### 3.2.5 MEASUREMENT OF VELOCITY

#### 3.2.5.1 General

Velocity observations are normally made at the same time and in the same verticals as measurements of the depth. This method is used in the case of unstable beds. Where, however, the two measurements are out of necessity made at different times, the velocity observations shall be taken at a sufficient number of places, ordinarily at least twenty verticals, and the widths of segments shall be measured as described in 3.2.3. The discharge in anyone segment should not exceed 10 percent of the total. Selection of verticals according to equidistance criterion leads to results which are slightly better than those obtained when using the criterion 'segments of equal flow'. A smaller number of verticals may be used if the depth and velocity profiles are uniform.

#### 3.2.5.2 Number of points in the verticals

The nature of the velocity profile in the verticals is obtained by measuring velocities at a number of points in each vertical. Although there are many methods as described in 5.3.1.6, the velocity profile gets sufficiently determined by measurement at four points. The result can be improved by increasing the total measuring time at each point or by increasing the number of points. In practice, for routine observations a two-point method should generally be preferred instead of a one-point method, although the one-point method is sufficient when there is a previously established relationship between the mean velocity and the measured point velocity.

#### 3.2.5.3 Current meter

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.

The current meters are rated in the rating tank/lab. After the 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 a total 180 days or for 90 working days before its rating period expires. *The 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 in the 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 current meter 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 the spindle. A rating chart is also supplied along with the current meter to enable it 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. CWC

Velocity is observed at one or more points in each vertical by counting revolutions of the rotor during a period of not less than 30 seconds.

For shallow channels, the current meter should be held in the desired position by means of a wading rod. For channels too deep or swift to wade, it should be positioned by suspending it from a wire or rod from a bridge, cableway or boat. When a boat is used, the meter should be held so that it is not affected by disturbances to the natural flow caused by the boat. After the meter has been placed at the selected point in the vertical, it should be allowed to become aligned with the direction of flow before readings are started.

#### 3.2.5.4 Measuring procedure

The current meter should be held in the desired position in any vertical by means of a wading rod in the case of shallow channels or by suspending it from a cable or rod from a bridge, trolley or boat in the case of deeper channels. Suspension equipment should conform to IS 6064-1971

Wherever possible, efforts should be made to avoid measurements by the area-velocity method from a bridge, particularly, high bridges, as such measurements involve large errors. In fact, this should be avoided if the objective is the determination of the stage discharge relationship.

A suspension bridge or a bridge with fewer piers and spans is to be preferred to a bridge with a greater number of pier obstructions. The piers should be long and slender and streamlined and aligned in the line of flow. The bridge should not be on a curved reach and the approach and exit should be straight. It should confine the whole river flow through the bridge spans.

A bridge with less obstructive members facilitating the suspension of the meter without damage and a masonry or RCC structure subject to less wind and traffic vibrations is to be preferred. Measurements are more conveniently made on the downstream side from the downstream parapet of a bridge, provided care is taken to avoid drift materials from damaging the current meter.

For measurements made by the one-point method, the current meter should be exposed for 120 seconds or for 150 revolutions whichever occurs later. If measurements are made at more than one point in each vertical, the current meter should be exposed for a period of at least 30 seconds at each point in the vertical. If the water velocity is known to be subject to periodic pulsations, it is advisable that the current meter should be exposed at each selected point for at least two (preferably three consecutive periods) consecutive periods of 60 seconds or for periods of sufficient duration to cover at least two periods of pulsation and the average of all the separate readings is taken as the velocity at the point. The velocity at the point should then be taken to be the average of all the separate readings, unless it is apparent that the difference is due to some cause other than pulsation of the flow.

#### 3.2.5.5 Methods for mean velocity measurement in each vertical

The mean velocity of the water in each vertical can be determined by any of the following methods, depending on the time available and having regard to the width and depth of the water, to the bed conditions, and to changing stage and whether there is ice cover, as well as to the accuracy which is to be obtained:

##### 3.2.5.5.1 One-point method

i) **0.6 Depth method** - Velocity observations should be made at each vertical by exposing the current meter at 0.6 of the depth below the surface. The value observed should be taken as the mean velocity in the vertical. The assumption of the point of mean velocity at 0.6 depth should, however, be verified occasionally by the velocity distribution method and a suitable coefficient should be applied if found necessary. When this relation cannot be established, observations may be made at 0.63 depth instead of at 0.6 depth if greater accuracy is desired, since in logarithmic velocity distribution the mean velocity point on the vertical is located at 0.632 depth.

Actual observation and mathematical theory have shown that the 0.6-depth method gives reliable results (see Table 3.1), and is generally used under the following conditions:

- Whenever the depth is between 0.1 m and 0.75 m;
- When large amounts of slush ice or debris make it impossible to observe the velocity accurately at the 0.2 depth. This condition prevents the use of the two-point method;
- When the meter is placed a distance above the sounding weight which makes it impossible to place the meter at the 0.8 depth. This circumstance prevents the use of the two-point method;
- When the stage in a stream is changing rapidly and a measurement must be made quickly.

ii) **Surface one-point method**- Velocity should be measured at one point at the surface or just below the surface. The depth of submergence of the current meter should be uniform over all the verticals, and care should be taken to ensure that the current meter observations are not affected by random surface waves and wind.

This 'surface' velocity may be converted to the mean velocity in the vertical by multiplying it by a predetermined coefficient. The coefficient should be computed for all stages by correlating the 'surface' velocity with the velocity at 0.6 depth or, where greater accuracy is desired, with the mean velocity obtained by the integration method. Where it is not possible to check the coefficient directly, it may be noted for guidance that in general the coefficient varies between 0.84 and 0.90 depending upon the shape of the velocity profile. The higher values between 0.88 and 0.90 are usually obtained when the bed is smooth but values outside this range may occur under special conditions. The higher values are usually associated with smooth streambeds and normally shaped vertical-velocity curves whereas the lower values are associated with irregular streambeds and irregular vertical velocity curves. WMO 1044 and IS 1192

iii) **Other one-point methods** - Alternative one-point method and Continuous one-point method should be used as per IS 1192-1981.

### 3.2.5.5.2 Two-point method

Velocity observations should be made at each vertical by exposing the current meter at 0.2 and 0.8 of the depth below the surface. The average of the two values should be taken as the mean velocity in the vertical. The two-point method is the one generally used for depths of 0.75m or greater. The two-point method is not used at depths less than 0.75m because the current meter would be too close to the water surface and to the streambed to give dependable results. On average, the two-point method gives results that are within 1 per cent of the true mean velocity in the vertical if the vertical velocity curve is substantially parabolic in shape (Table 3.1).

Table 3.1 Coefficients for standard vertical velocity curve (WMO 1044)

| Ratio of observation depth to depth of water | Ration of point velocity to mean velocity in the vertical |
|---|---|
| 0.05 | 1.160 |

| | |
|---|---|
| 0.1 | 1.160 |
| 0.2 | 1.149 |
| 0.3 | 1.130 |
| 0.4 | 1.108 |
| 0.5 | 1.067 |
| 0.6 | 1.020 |
| 0.7 | 0.953 |
| 0.8 | 0.871 |
| 0.9 | 0.746 |
| 0.95 | 0.648 |

#### 3.2.5.5.3 Other methods

Other velocity measurement methods such as Velocity distribution method, Three-point method, Integration method should be used as per IS 1192-1981

### 3.2.5.6 Current meter measurement 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.

### 3.2.5.7 Current meter measurement using boats

When wading observations 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 is 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: -

$V_p = 0.064 + 0.98\ V_b + 0.98\ V_d$

Where $V_p$ = 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

$$vd = \frac{Drift\ in\ meters}{120\ seconds\ (period\ of\ observation}$$

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.

#### 3.2.5.8 Current meter measurement using cableway

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 tagline 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.

### 3.2.6 COMPUTATION OF DISCHARGE

#### 3.2.6.1 Arithmetical Methods

##### 3.2.6.1.1 Mean-section method

The cross-section is regarded as being made up of a number of segments bounded by two adjacent verticals. If $\underline{v1}$ and $\underline{v2}$ are the mean velocities at the first and second verticals respectively, if $d_1$, and $d_2$ are the total depths measured at verticals 1 and 2 respectively, and b is the horizontal interval between the said verticals, the discharge of segment is taken to be:

$$q = \left(\frac{\underline{v1} + \underline{v2}}{2}\right) + \left(\frac{d1 + d2}{2}\right) b$$

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

##### 3.2.6.1.2 Mid-section method

The discharge in each segment is computed by multiplying $v_d$ in each vertical by a width, which is the sum of half the distances to adjacent verticals. The value of d in the two half-widths next to the banks can be estimated. Referring to Figure 3.2, the total discharge Q is computed as (IS 1192):

$$q = \underline{v}_1 d_1 \left(\frac{b2 + b1}{2}\right) + \underline{v}_2 d_2 \left(\frac{b1 + b2}{2}\right) + \ldots + \underline{v}_n d_n \left(\frac{bn + bn{-}1}{2}\right)$$

Between the mid-section and mean section method, there is no appreciable difference in the field procedure for either method of computation, but the mid-section is preferable for the following reasons;

a) The mid-section method yields a slightly more accurate figure of discharge, being on average approximately 0.6 percent closer to the true discharge. Figure 3.2 gives comparative results of computation of discharge by both the methods.

b) The mid-section method results in a considerable saving of time as compared to the mean-section method.

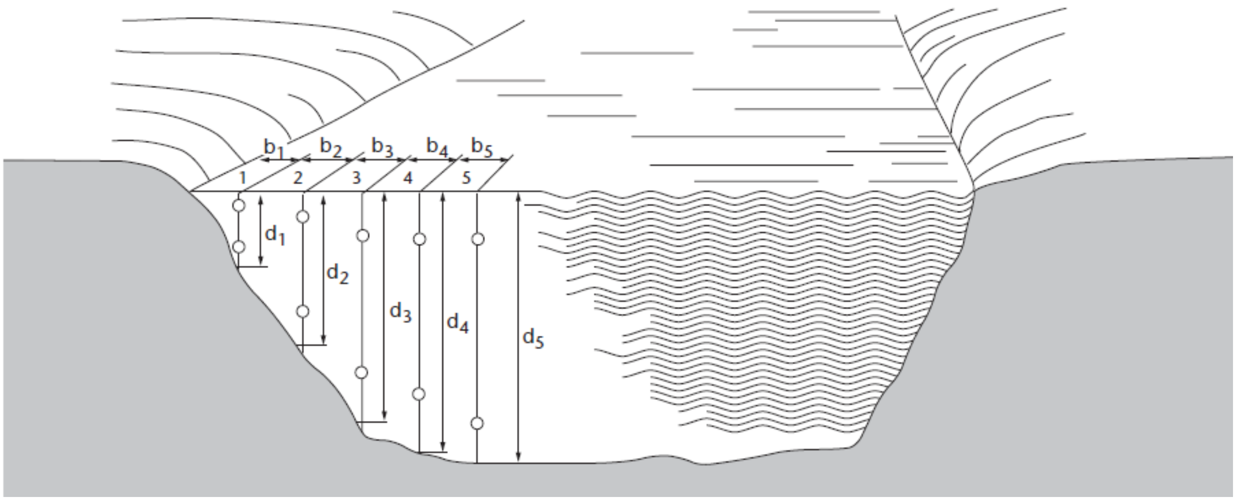



Figure 3.2. View of stream cross-section showing the location of points of observation

#### 3.2.6.2 Graphical methods

##### 3.2.6.2.1 Depth-velocity integration method

The first step consists in drawing, for each vertical, the depth velocity curve, the area of which represents the product of the mean velocity and the total depth. The value of this product at each vertical is then plotted versus lateral distance and a curve is drawn through the points. The area defined by this curve is the discharge in the cross-section.

##### 3.2.6.2.2 Velocity-contour method

Based on the velocity distribution curves of the verticals, a velocity distribution diagram for the cross-section is prepared showing curves of equal velocity. Starting with the maximum, areas enclosed by the equal velocity curves and the water surface should be measured and then plotted in another diagram, with the ordinate indicating the velocity and the abscissa indicating the area. The area enclosed by the velocity area curve represents the discharge of the cross-section (WMO 168).

## 3.3 AREA-VELOCITY USING FLOATS

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

### 3.3.1 Site Selection

Three cross-sections should be selected along the reach of the channel as described in section 3.2.1; at the beginning, midway and at the end of the reach. The cross-sections should be far enough apart for the time which the floats take to pass from one cross-section to the next to be measured accurately. The midway cross-section should be used only for the purpose of checking the velocity measurement between the cross-sections at the beginning and the end of the reach. A minimum duration of float movement of 20 seconds is recommended.

### 3.3.2 Floats

#### 3.3.2.1 Functional Requirements

a) The float shall be sufficiently heavy or weighted so that its greater part would be submerged in water to reduce interference due to wind. At the same time the float should be light enough to attain the velocity of the current within a short distance after being introduced into the river and it shall be sufficiently stable.

b) The paint on the float shall be such that it is conspicuously identifiable from a distance with alternate bands of paint which are durable in or under water (black and white or red and white).

c) If a flag is used with the float, it shall be of a permanent color, conspicuously identifiable, and provision shall be made to prevent it from sliding down.

#### 3.3.2.2 Tests

The tests shall be made on three floats for every 24 of identical shape, materials and dimensions.

a) The surface velocity in a canal as obtained by a standard cup type current meter placed as near the surface as possible (without any of its rotor components being exposed) and the surface velocity as obtained by the float when wind interference is negligible shall not vary by more than 5 percent.

b) In the selected reach, measurements shall be made at as near a stage as possible by current meter, preferably by integration method and the coefficient for obtaining the mean velocity in the vertical worked out for the float. In the absence of a more reliable figure a reduction coefficient of 85 may be adopted.

NOTE -*The reduction coefficients generally vary from 0'79 to 0'92. This reduction coefficient is not a constant even for a particular channel, since it varies with depth, slope, and relative roughness of the channel boundary. It may also be obtained from Von Karman's logarithmic velocity distribution law.*

#### 3.3.2.3 Materials

a) Depending upon the nature and conditions, surface floats may be made of almost any distinguishable article that floats, such as wooden desks, bottles, etc. Floating ice cakes or a distinguishable piece of drift may also be used.

b) Wooden floats are meant to be used in rivers under moderate velocity conditions with less turbulence, whilst metallic floats are meant for large turbulent rivers. Bottle floats weighted with cement mortar may also be used in conditions of relatively smooth flow.

c) Typical examples for materials to be used for different components are given in subsequent sections, however these do not preclude the use of alternative materials having characteristics equivalent to or superior to those specified.

##### *3.3.2.3.1 Base and Stem*

Sal wood of the best quality or any other heavier type of wood available locally shall be used. It shall be well seasoned. Specific gravity shall not be less than 0.5.

##### *3.3.2.3.2 Metallic Sheet*

G.I sheet, stainless steel sheet or any other suitable material.

##### *3.3.2.3.3 Paint*

Paint shall be color fast, durable and as specified by the purchaser.

#### 3.3.2.4 Types of floats

The velocity of water in each segment can be determined by;

a) Surface floats

These may be used during floods when velocity measurements are to be made quickly. They should not be used when their movement is likely to be affected by winds.

Note: Where it is not possible to check the coefficient directly, it may be noted for guidance that in general the coefficient of the surface float varies between 0.84 and 0.90 depending upon the shape of the velocity profile. The higher values are usually obtained when the bed is smooth, but values outside this range may occur under special conditions.

b) Other type of floats

Other type of floats includes double floats positioned at 0.6 of depth below the surface or at depths to obtain direct velocity measurements at these depths; sub-surface floats sometimes called multiple floats consist of separate elements suitably attached together to permit flexibility and supported by surface float should be approximately equal to the water depth but shall in no case tough the bottom.

### 3.3.3 Measuring Procedure

The float should be released far above the upper cross-section to attain a constant velocity before reaching the first cross-section. The time at which the float passes each of the three cross-sections is then noted. This procedure should be repeated with the floats at various distances from the bank of the river. The distances of the float from the bank as it passes each cross-section may be determined by suitable optical means, for example, a theodolite.

The width of the channel should be divided into a certain number of segments of equal width. If, however, the channel is very irregular each segment should have approximately the same discharge. The number of segments should not be less than three, but where possible a minimum of five should be used, the actual number of segments depending on the time available for these observations at the particular stage of the river.

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.

### 3.3.4 Computation of Velocity

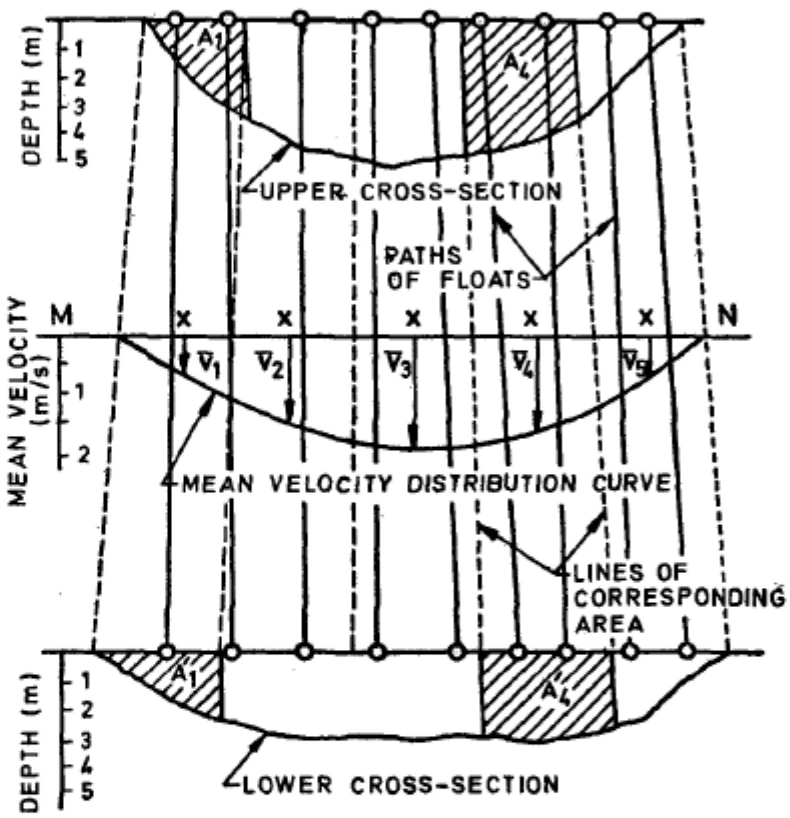
The float velocity shall be determined by dividing the distance between the cross-sections by the time taken by the float to travel this distance. Several readings of the float velocities shall be taken and the mean of the readings shall be multiplied by the appropriate coefficient to obtain the mean velocity in the segment. The coefficient derived from current meter measurements at the site at a stage as near as possible to that during the float measurement may be used for converting the float velocity to mean velocity. It is evident that this method necessarily gives an approximation to the float rate.

### 3.3.5 Measurement of Depth

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

### 3.3.6 Computation of Discharge

If the upper and lower cross-sections are plotted as shown in Fig. 3.3 and then divided into a suitable number of segments of equal width the cross-sectional areas of each of these segments can be determined. Halfway between the two cross-sectional lines, another line (MN in Fig. 3.3) shall be drawn parallel to the cross-sectional lines. The starting and ending points of each float can then be plotted and joined by firm lines, while the surface points separating the various panels of the two cross-sections can be joined by dotted lines. Where the firm lines cross the line *MN,* the corresponding mean velocity (float velocity multiplied by the appropriate coefficient) shall be plotted normal to *MN* and the end points of these velocity vectors joined to form a velocity distribution curve.




$$Q = \sum_{1}^{m} q = \sum_{1}^{m} \bar{V} \frac{(A + A')}{2}$$

NOTE 1 — *X* indicates the mid-points of the panels in the mid-section.

NOTE 2 — $\bar{V}_1$, $\bar{V}_2$ ... $\bar{V}_5$ are the mean velocities in each of the five panels.

Fig. 3.3 Computation of Discharge from Float Measurement

## 3.4 FREQUENCY OF OBSERVATION

The frequency of observation depends on the site conditions, the variation of stage and discharge with time and the objects for which measurements are taken. When there is rapid shift in control, or rapid change in stage and discharge, which happens particularly during floods, the observations have to be more frequent, at least once a day *(twice per month when condition permits current practice in NCHM).* In other cases, the frequency can be reduced depending upon the stability of control.

## 3.5 FORM FOR RECORDING

For recording the observed discharge, standard forms NCHM/HRF 01-01 for stage, NCHM/HRF 01-02 for hourly stage, NCHM/HRF 02-01 and NCHM/HRF 02-02 for Discharge measurement may be used.

## 3.6 DISCHARGE OBSERVATION (Other methods)

### 3.6.1 Dilution Method

The measurement of discharge by this method depends on determining the degree of dilution by the flowing water of an added tracer solution. The method is recommended for sites with excessive turbulence flows. The two principal tracer methods used for discharge measurements are the constant-rate-injection method and the sudden injection method.

#### 3.6.1.1 General requirements

A solution of a stable tracer is injected into the stream at either a constant rate or all at once.

Computation of the stream discharge requires knowledge of the following factors:

(a) The rate of injection for the constant-rate-injection method or the total amount injected for the sudden-injection method;

(b) The concentration of the tracer in the injected solution;

(c) The calibrated relationship between tracer concentration and the recorded property (for example, conductivity, colour and radioactivity) at the measuring site after it has been well mixed laterally.

The accuracy of these methods critically depends upon:

(a) Adequate mixing of the injected solution throughout the stream cross-section at the sampling section. If the tracer solution is continuously injected, the concentration of the tracer should be essentially constant throughout the sampled section. If the tracer is injected all at once, $\int_0^{\square} cdt$ should essentially be the same at all points in the section, where $c$ is the concentration and $T$ is the time for all of the tracer to pass a particular point in the section;

(b) No absorption or adsorption of the added tracer by stream bottom materials, sediments, plants or organisms, and no decomposition of the added tracer in the stream water. The concentration should be determined at the sampling section and at least one other cross-section downstream to verify that there is not a systematic difference in the mean concentration from one sampling section to another.

#### 3.6.1.2 Selection of Site

The primary criterion for the selection of sites for measurement of discharge by dilution is adequate mixing of the injected solution with the stream water in a short length of channel. Mixing is enhanced by high boundary roughness and features that cause the channel flow to be highly turbulent, such as at waterfalls, bends or abrupt constrictions. A small injection of rhodamine dye or fluorescein can help to assess the mixing condition at the measuring site. Large dead-water zones between the injection site and the sampling site will often affect the mixing so that the tracer will not be adequately mixed in the cross-section at the sampling site.

#### 3.6.1.3 Tracer and Detection Equipment

Any substance may be used as a tracer if:

(a) It dissolves readily in the stream's water at ordinary temperatures;

(b) It is absent in the water of the stream or is present only in negligible quantities;

(c) It is not decomposed in the stream's water and is not retained or absorbed by sediment, plants or organisms;

(d) Its concentration can be measured accurately by simple methods;

(e) It is harmless to humans, animals and vegetation in the concentration it assumes in the stream.

The cheapest tracer is common salt. Where the tracer is instantaneously injected into the stream, the required quantity is not particularly large and detection by conductivity methods is relatively simple.

#### 3.6.1.4 Computation of Discharge

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

$$Q = \frac{Qtrci}{cs}$$ Continuous injection

$$Q = \frac{ciV}{\int_0^\infty csdt}$$ Sudden injection

Where $Q_{tr}$ is the rate of injection, $c_i$ is the concentration of injection solution, $c_s$ is the concentration in the stream at the sampling section, $V$ is the volume of injected solution and $t$, is time.

The detailed guideline can be found in IS 9163 (Part 1): 1973- Dilution methods of measurement of steady flow: Part 1 Constant rate injection method

### 3.6.2 ADCP Moving Boat Method

The ADCP method uses a moving boat to traverse the stream, just as the manual and automatic methods, however instrumentation is different. The ADCP method measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column providing essentially a complete vertical velocity profile. It also tracks the bottom providing stream depth and boat positioning.

*Note: The use of ADCP System is in pilot phase at the time of writing this guideline.*

# CHAPTER 4

# SUSPENDED SEDIMENT OBSERVATION

## 4.1 INTRODUCTION

The term sediment covers all the solid particles that are transported or deposited in water. Sediments therefore include bed load, suspended load, floating solids and ice. Suspended and bed loads are recorded through a special measuring network using appropriate instruments and installations. Sediment is transported by flowing water in different ways.

### 4.1.1 Principles of Measurement

The concentration of suspended sediment ($c_i$) and the current velocity ($v_i$) are measured practically simultaneously at a large number ($m$) of points in the sampling area of a cross-section. Each concentration and velocity is representative of a small area ($a_t$) of a sampling cross-section. The sum of all the areas ($a_i$) is the sampling area ( $A$ );

The average static concentration $c_s$ is given by:

$$cs = \frac{\sum_0^m \quad ci}{m}$$

The mean concentration of suspended sediment load in motion cm is given by:

$$cs = \frac{\sum \quad civiai}{\sum \quad aivi} \text{ or } cs = \frac{\sum \quad civiai}{Q}$$

where

$Q = \sum \quad aivi$ is the discharge in the sampling area.

The suspended sediment load through the sampling area is the product of the mean concentration in motion and the discharge, that is $c_m$ x $Q$

Thus, for one year the total weight of solids transported is

$$\sum_{1}^{365} cmiQi$$

### 4.1.2 Units of Measurements

The concentration of suspended sediment is expressed in g/l (Kg/m3 ) or parts per million ( by weight ).

## 4.2 SELECTION OF SITE

Since sediment load is obtained as a product of mean concentration of the sediment load in motion and the corresponding discharge in the river, the site for silt observation should normally be the same as that for discharge observations.

## 4.3 REQUIREMENTS FOR SAMPLING OF SUSPENDED LOAD

### 4.3.1 General

The concentration of suspended load not only changes from point to point in a cross-section but also fluctuates from moment to moment at a fixed point. The kind of sampler and the technique of sampling used will depend on a large number of factors. The discharge of sediment load per unit width at a vertical in a cross-section can be determined either by integrating over the depth the products of the concentration of the suspended load and the velocity measured simultaneously at each of a number of points in the vertical or by using an integrating depth sampler which automatically takes a sample in which the concentration of suspended load is the mean concentration in motion.

The suspended sediment concentration as well as the grade of sediment in a flowing stream increase from top to bottom and it also varies transversely across the section. The variation depends upon the size and shape of the cross-section, the stage of flow and other channel characteristics. Hence a preliminary investigation has to be made to select the sampling points on a vertical and also the number and location of the sampling verticals, taking into consideration the accuracy desired and the resources available.

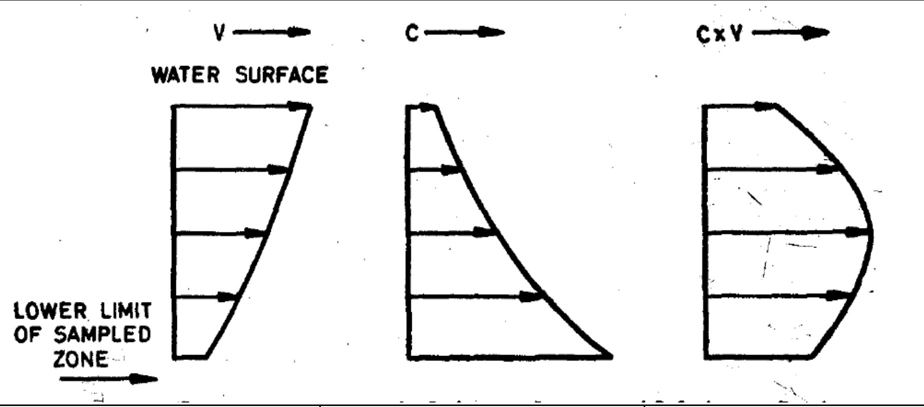
Both for measurements and the determination of the point of mean concentration of sediment, sediment concentration should be determined at several points in a vertical like 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.7, 0.8 and 0.9 depth (or the lowest practicable point).

### 4.3.2 Procedures

The procedures for obtaining the mean sediment discharge per unit area and the mean sediment concentration in motion at the vertical are:

a) Draw the velocity distribution and sediment concentration curves as in Fig. 4.1 (1A) and (1B). The curves shall be drawn up to the sampled zone.
b) Find the products of $c$ (concentration) x $u$ (velocity) at corresponding points and draw the rate of sediment discharge curve as in Fig. 4.1 (1C).
c) Assuming unit width, find the areas of Fig. 4.1 (1A) ( $qw$ ) and Fig. 4.1 (1C) ( $q_s$ ). This may be done graphically by plan metering or numerically by a rule such as the trapezoidal rule giving the water and sediment discharges.
d) The mean sediment concentration in motion at the vertical and the mean sediment discharge per unit area at the vertical are $c_m = q_s/q_w$ and $q_s = q_s/D$. where $D$ is the depth (up to sampled zone).

NOTE I- *This method is more laborious than would ordinarily be justified for routine sediment measurement. However, for preliminary investigation for determining the point of mean concentration such experiments should be repeated for various stages of flow.*




| | | |
|---|---|---|
| 1A Velocity Distribution | 1B Sediment Concentration Distribution | 1C Sediment Discharge Distribution |

Fig. 4.1 Sediment Discharge Computation

### 4.3.3 Selection of Verticals

For the determination of the minimum number of verticals representing the sediment distribution across the stream, one of the following two procedures should be followed:

a) The section should be divided into as large a number of equally spaced segments as practicable to be completed in one observation. The mean concentration in motion in each vertical in the centre of the segment procedure (d) should be obtained and weighted with respect to the stream discharge in the respective segment. This wil1 gives an indication of the distribution of sediment in the entire section for the particular stage of flow.

b) The stream section is divided into a large number of segments of approximately equal discharge and sediment samples are taken at the centroid vertical of each equal discharge segment. This gives the required sediment distribution across the stream for the particular stage of flow.

There is no firm relationship between the stage and the location of the point of mean concentration in motion. Therefore, the above observations shall be made for different stages of flow. It is desirable to have a larger frequency of observations on a limited number of verticals at the high flood stages; and the endeavour should be to ensure measurements at least once a week during high Rood stages and once during the highest floods or during the occurrence of a flashy spate. The more frequent the observations the better the overall estimate is likely to be and, wherever possible, sediment observations should be made as frequently as discharge observations are made on perennial streams.

Table 4.1: Selection of Verticals

| SL | Width of the River | Number of Verticals | Location of Verticals in Normal Section with Sloping Sides | Location of Verticals in Stream of Uniform Depth and Velocity |
|---|---|---|---|---|
| 1 | Less than 30m | 3 | 25,50 and 75 percent of the width | 17, 50 and 83 percent of the width |
| 2 | 30-300m | 5 | 20, 35, 50, 65 and 80 percent of the width | 10, 30, 50, 70 and 90 percent of the width |
| 3 | Over 300m | 7 | 15, 30, 40, 50, 70 and 85 percent of the width | 7, 21, 36, 50, 64, 79 and 95 percent of the width |

### 4.3.4 Methods for Routine Sampling

#### 4.3.4.1 General

The best-known method is for the determination of the point of mean concentration in motion. A number of other commonly used methods have been developed for determining the average sediment concentration in motion in a vertical. In general, these methods are based upon analysis of factors which influence the movement of sediment loads in streams and are therefore to be preferred to the one-point and two-point methods.

#### 4.3.4.2 One-point Method

In this method the sampler shall be immersed to the point of mean sediment concentration in motion as determined from the preliminary experiments. The depth from the surface $h_{cm}$ at which to take the water sediment sample corresponding to the mean concentration in motion $c_m$ may be obtained from Fig. 4.1. The sediment concentration of the sample taken at this depth, $h_{cm}$ is multiplied, by $q_w$ (that is, water discharge per unit width in the vertical to get the suspended sediment discharge per unit width in the vertical $q_s$. The mean suspended sediment discharge per unit area is obtained by dividing $q_s$, by $D$, the depth of the sampled zone.

a) If the sample is taken at one point only of a single vertical at the centre of the stream the position in the vertical at which the sample is taken should be that at which the concentration of suspended load is the mean concentration of suspended load in motion for the whole cross-section. If this is not known, then the sample is taken at the position on the central vertical where the concentration is the mean concentration of suspended load m motion in that vertical. This concentration is multiplied by the discharge of the stream to give the total suspended sediment load.
b) More correctly the value of the concentration should be multiplied by the discharge of the sampled area of the stream but since this is usually not known, the concentration is multiplied by the total discharge, as an approximation.
c) Since the sediment concentration distribution curve is different for different size ranges, a sample taken at the mean sediment concentration point (for the sample as a whole) will not generally give the true size distribution. Only a composite representative sample taken either by a depth integrating sampler or made up of point samples taken at more than one point on the vertical and weighted in proportion to velocity can give the overall average concentration and size distribution of the sediment load in motion. If the point sampling method is used it is better to make a size analysis on each sample and to plot the product of the velocity and the concentration of particles in a given size range against the depth.
d) In the absence of previous experiments, a common practice has been to sample at O-5 or Cl.6 depths, but this method will give only approximate results for the overall mean concentration. Size distribution may not be obtained by this method.
e) At -times, where the sampling at ~the position of mean concentration of sediment in motion is-not possible (for example, in hilly or boulder streams flowing at high velocity) the samples are collected from a point near the surface and their values multiplied by an appropriate factor (if any), determined from preliminary experiments for converting the concentration at the surface to approximate mean concentration in motion. This conversion factor can be strictly applied only to the particular stage of flow and the channel and sediment conditions under which it has been obtained. However, size distribution cannot be obtained by this method.

#### 4.3.4.3 Multi-point Method

Samples should be taken at 2, 3 or more points in the vertical and if weighted in proportion to the corresponding current velocities, the concentration of the weighted sample can be taken as the mean concentration in motion. However, for simplicity as an approximation (particularly where it is difficult to determine the corresponding velocities), samples are taken at 2 in two-point method or 3 or more points in three-point method along the vertical and their average taken as the mean static concentration, and this is multiplied by the average velocity to give the mean concentration in motion. In general, the greater the number of sampling points the greater will be the accuracy of results.

#### 4.3.4.4 Other Methods

##### *4.3.4.4.1 Depth Integration Method*

This method of sampling is based on the premise that the sampler designed specifically for the purpose fills at a rate proportional to the velocity of the approaching flow and that by traversing the depth of the stream at a uniform speed the sampler will receive at every point in the vertical a sample of the water sediment mixture, at a rate which will be proportional to instantaneous velocity. Only a slow-filling type of sampler shall be used for depth integration.

The sampler shall be lowered to the bottom of the stream at a uniform rate and shall be raised again without pausing at the bottom to the surface at a uniform but not necessarily at the same rate, sampling continuously during both periods of transit, or it may be designated to sample at a uniform rate one way only. However, if the sampler is opened at the bottom of the vertical and is integrated on the ascending trip only, a specially designed sampler should be used where the air pressure in the container at the time of opening is balanced by the hydrostatic pressure surrounding the sampler. The depth integration method of sampling requires only one sample from each vertical and gives a fairly reliable average of the size distribution of the particles of the stream. This method offers an easier field procedure for computation of suspended sediment loads. Use of the depth integrating sampler is only possible if the sampler can be lowered to the bottom and raised again to the surface before the sample container fills with water. The depth of water in which it may be used varies inversely as the product of the velocity and the size of the sampling nozzle. Under favourable circumstances it may be used to sample in depths up to 6 m.

### 4.4 COMPUTATION OF SUSPENDED SEDIMENT LOAD

For computation of sediment load passing down a cross-section it is assumed that the average sediment discharge per unit area between two verticals is equal to the mean of the sediment discharge rates observed at each vertical. The product of this mean and the area between the verticals gives the sediment discharge for the area. The total sediment load passing the cross-section is obtained by totalling the sediment and the discharges passing through each of these segmental areas into which the cross-section has been divided by the verticals.

In the equal-discharge-increments (EDI) method, a measurement of water discharge is made from which the spacing of verticals so as to divide the water discharge into equal segments is determined. Then the sampler is lowered and raised hm top to bottom and back at the centroid vertical of each equal discharge zone. The quantity in each centroid sample should be proportional to the water discharge in the segmental section, however, if the location of verticals has been precisely determined equal volumes of sediment sample should be taken. The composite sample represents the mean concentration in motion at the stream section.

If equally spaced verticals are used, the mean concentration of sediment load in motion is determined for each vertical. These concentrations are multiplied by the partial discharge in the two half segments on both sides of the vertical and the products are added to give the total sediment discharge. The computation of sediment load with equally spaced verticals is facilitated if a depth integrating sampler is used. Since the sampler is designed to admit water sediment mixture at a rate nearly proportional to the local velocity of the stream at the sampler intake, the samples from each vertical in this equal transit rate (ETR method) is automatically weighted by discharge. The composite of all the samples is a nearly correct sample of the whole stream concentration. This concentration multiplied by the discharge yields the total suspended sediment discharge.

## 4.5 SAMPLERS

### 4.5.1 Functional Requirements

In order that samples taken by a sampler should be truly representative, of the sediment concentration of a stream at the point of sampling the ideal samplers should fulfil the following technical requirements:

a) The sampler should be stream-lined so as to avoid disturbance in the sediment flow;

b) The velocity of inflow at the mouth of the sampler should be equal to the velocity of stream flow;

c) The mouth of the sampler should always face the direction of current;

d) The mouth should be outside the zone of disturbance of flow set up by the body of the sampler and its operating gear;

e) Filling arrangement should be very smooth without causing sudden in rush or gulping;

f) The container should be easily removed, readily capped and transported to a laboratory without loss of contents;

g) The sampler should be able to collect samples at the desired depth (from surface down to O-3 metre from the bed) without disturbing or contaminating the water sediment mixture at other points while the sampler is being raised or lowered;

h) The sampler should- be portable but sufficiently heavy to minimize deflection from the vertical due to current drag;

j) It should be robust and simple in design and construction and require minimum care for maintenance and repair; and

k) The volume of the sample should be sufficient for determination of concentration and size analysis.

None of the samplers at present in use may satisfy all the requirements. Some of the samplers approaching the ideal conditions are unfortunately very costly and cumbersome for use in the field.

### 4.5.2 Types of Samplers

Various types of suspended sediment load samplers have been designed with a view to complying with most of the above requirements and a Few of these types are:

a) Vertical,

b) Instantaneous vertical,

c) Instantaneous horizontal,

d) Bottle,

e) Bottle (modified),

f) Point integrating,

g) Depth integrating, and

h) Pump.

The characteristics and drawbacks of each of these samplers have been briefly described in Table 4.2.

Table 4.2 Classification of suspended-sediment samplers

| SL | Type | Description | Disturbance to flow characteristics | Intermixing of sample with water | Sampling action | Field handling | Adaptability to various field conditions |
|---|---|---|---|---|---|---|---|
| 1 | Vertical pipe | With a vertical cylinder or pipe forming the container. Valves at either end close and trap the sample | Excessive | Generally excessive | Instantaneous | Necessary to transfer into another container | Offers considerable resistance to current. Not satisfactory when close to the stream bed. |
| 2 | Instantaneous vertical | A vertical sampler with arrangement to open the sampler for the instantaneous (rapid) intake of samples at the desired time and depth | Effect not evaluated | None | Instantaneous | Necessary to transfer into another container | Not satisfactorily streamlined or adapted for use near stream bed |
| 3 | Instantaneous horizontal | With a horizontal cylinder equipped with end valves which can be closed suddenly to trap instantaneous samples at any | Tendencies minimized effects not evaluated | Slight Possibility | Instantaneous | Necessary to transfer into another container | Allows sampling very close to the stream bed. Adaptable to any stream or depth |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | desired time and depth | | | | | |
| 4 | Bottle | Consisting of a standard container held in a case with a device for lowering and opening at the sampling point. The mouth is kept open for the minimum time required to fill up the bottle | Excessive effect no evaluated | Excessive, if not opened and closed at site | Bubbling or slow-filling after initial rush | Container with sample removable | Not capable of sampling close to the bed of the stream. Has got high efficiency in trapping fine grade sediment and the efficiency is less with the increase in grade. |
| 5 | Bottle (modified) | Consisting of a litre capacity container fitted in a case with a device for lowering or raising and opening at the sampling point. Provided also with separate water intake and air exhaust device for equalising pressure | Appreciable. Effect not evaluated | Excessive, if not opened and closed at the sampling | Slow-filling; no initial inrush present | Container with sample detachable | Not capable of sampling close to the stream bed |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | inside and outside the container | | | | | |
| 6 | Point integrating | Designed **to** fill continuously at a given point over an interval of time and hence is provided with an opening and closing mechanism and as well with a pressure equaliser to minimise initial in rush of water | Tendencies minimized by not evaluated | Some extent, if not opened and closed at site | Smooth filling, minimum initial inrush | Container with sample removable | May be limited by depth of stream |
| 7 | Depth integrating | Designed to fill continuously during lowering from surface to bed (as well on the return trip from bed to surface). The samplers designed to fill during the lowering | Excessive | Possibility to some extent | Smooth filling. Although the sampled filament will enter the intake nozzle at an angle, provisions exist for making inlet velocity essentially equal to the local velocity of the steam | Container with sample removable | Capable of sampling close to the bed of the stream |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | only are provided with foot trigger which closes both inlet and exhaust upon contact with the bed | | | | | |
| 8 | Pump | The sediment mixture is sucked in through a pipe or hose, the intake of which is placed at the desired sampling point. By regulating the intake velocity, an undisturbed sample can be obtained | Tendencies minimized with proper control of intake tube and velocities | None | Time-integrated | Container with sample removable | Present design no portable. Somewhat limited in use due to resistance to current. Heavy sediment loss in the pipe line may limit use. |

## 4.6 FREQUENCY AND TIMING OF SAMPLING

The desirable timing and frequency of sampling depends on the runoff characteristics of the basin. For many streams, an average of 70 to 90 per cent of the annual sediment load is carried down the river during the flood season. Suspended sediment should be sampled more frequently during the flood period than during low flow periods. During floods, hourly or even more frequent sampling may be required to define sediment concentration accurately.

During the rest of the year sampling frequency can be reduced to daily or even weekly sampling. For watersheds with a wide variety of soil and geological conditions and an uneven distribution of precipitation, sediment concentration in the stream depends not only on the flood event in the year, but also on the source of the runoff in the basin. Under such conditions, no definite sediment measurement schedule can be assigned. Besides, the sampling of sediment concentration should be properly timed to check the temporal variation in sediment. In general, the accuracy needed from the sediment data determines how often a stream should be sampled. The greater the required accuracy and the more complicated the flow system, the more frequently it will be necessary to take measurements.

## 4.7 FORMS FOR RECORDING

For recording the sediment data, standard forms NCHM/HRF 03-01 for handheld sampling, NCHM/HRF 03-02 for suspended sampling, NCHM/HRF 03-03 for water slope readings may be used.

## ANNEXURE I: STAFF GAUGE READING

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

# STAFF GAUGE READING

River : ______________________ Station no :

Location : ______________________ Year :

Gauge Reader : ______________________ Month :

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| Day | | | 0900Hrs | | | | 1500Hrs | | | | Remarks |
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Signature Hydrometriest ______________ R. Hydrometriest ______________ Hydrologist QC ______________

Date:

## ANNEXURE II: HOURLY STAFF GAUGE READING

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

### HOURLY STAFF GAUGE READING

River : ______________________ Station No :

Location : ______________________ Year :

Gauge Reader : ______________________ Month :

______________________

| Day | 0900Hrs | 1000Hrs | 1100Hrs | 1200Hrs | 1300Hrs | 1400Hrs | 1500Hrs | 1600Hrs | 1700Hrs | Average | Remarks |
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Signature Hydrometriest ______________ R. Hydrometriest ______________ Hydrologist QC ______________

Date:

## ANNEXURE III: DISCHARGE MEASUREMENT

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

# Discharge Measurement

River ____________________

Station Name ____________________

Measured by ____________________

____________________

Computed by ____________________

Checked by ____________________

RATING STATION NO

DD/MM/YYYY

STAGE

VELOCITY

FLOW

AREA

WITDH .

Approved for HYDATA input ____________________

Current meter make ____________________

number ____________________

Propeller Material ☐ Polyamid ☐ Metal number ____________________

Measured by ☐ Cableway ☐ Bridge ☐ Boat ☐ Wading

Size of sinker weight ____________ kg Fixed time period, T ____________ sec

Measuring Site ____________________

Note Distance between current meter and ground Sensor (tick distance used)

☐ 10Kg sinker weight 0.19m

☐ All other sinker weights 0.15m

| | Time (Hrs) | Gauge Height (m) |
|---|---|---|
| Start | | |
| Middle | | |
| Stop | | |
| **Mean** | | |

Comments:

## ANNEXURE IV: DISCHARGE MEASUREMENT FORM

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

### DISCHARGE MEASUREMENT FORM

Measurement date: ________________ Page

| Distance from initial point (m) | Width of Section (m) | Winch Reading (m) | | Depth (m) | | | | Impulses | | Velocity (m/s) | | Area Section | Discharge in Section | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | River bed level | River Surface level | Total | Method used | Below surface | Above bed | Total I | Per Second n | at point | Mean in Vertical | | | |
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## ANNEXURE V: HANDHELD SAMPLING FORM

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

# HANDHELD SAMPLING FORM

River: : ______________________ Location : ______________________ Station No:______________________

Gauge Reader : a)______________________ b)______________________ Start Date :______________________

Bottle Box No : ______________________ End Date :______________________

| Date | Time | Bottle No | Gauge Height (m) | Water Level Bottle (mm) | Comments |
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# ANNEXURE VI: SUSPENDED SEDIMENT SAMPLING

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

## SUSPENDED SEDIMENT SAMPLING

River: : ____________________ Location : ____________________ Station No:____________________

Gauge Reader : a)____________________ b)____________________ Start Date :____________________

Bottle Box No : ____________________ End Date :____________________

| Date | Time | Bottle No | Upstream gauge height | Downstream Gauge height | Distance from shed X | Max sampling depth | Max lowering time TL | Used Raising time TL | Used total time TT | Depth Measured | Water Level in bottle | Comments |
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## ANNEXURE VII: WATER SURFACE SLOPE READINGS

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

**WATER SURFACE SLOPE READINGS/**Class 3 sediment station

River :

Location :

Gauge Reader :

Station No :

MM/YYYY :

Distance b/w gauges L :

Type of measurement : Staff/crest gauge

Calculations :

Upstream datum :

Time of observation :

Calculations :

Downstream datum :

(All readings in metres)

| Day | | | | | | | Comments |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
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| 31 | | | | | | | |

Signature Hydrometriest ____________ R. Hydrometriest ____________ Hydrologist QC ____________

Date:

## ANNEXURE VIII: WATER TEMPERATURE READING

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY

# WATER TEMPERATURE READING

River : ______________________ Station No :

Location : ______________________ Year :

Gauge Reader : ______________________ Month :

______________________

| Day | | | 0900Hrs | | | | 1500Hrs | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
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Signature Hydrometriest ______________ R. Hydrometriest ______________ Hydrologist QC ______________

Date:

## ABBREVIATIONS AND ACRONYMS

AWLS - Automatic Water Level Station

AWS – Automatic Weather Station

CSD - Cryosphere Service Division

DBMS - Database Management System

HWRSD – Hydrology and Water Resources Service Division

ISO – Indian Organization for Standardization

MSD - Metoerological Service Division

NCHM – National Centre for Hydrology and Meteorology

RGoB - Royal Government of Bhutan

TSRD – Technical Standard and Research Division

USGS - United State Geological Survey

WMO - World Meteorological Organization

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