DEMARCATION AND ESTABLISHMENT OF DISCHARGE SITE

By

B.N. Sharma,
Director
Central Training Unit, Pune.

1. The various requirements for selection of Hydrological Observation station have been covered in the earlier section. Once the site is selected, the next step is to go for demarcation and establishment and design of station depending upon site features. This section has been planned to cover these aspects.

2. The topographical surveys required to design the station are summarized as under :-

i) Preparation of plan in the scale 1:1000/1:500/1:200 covering minimum of two times of bank full width during higher water of the channel in each direction (u/s & d/s) from the proposed measuring section. The plan should indicate

- the width of water surface
- the edges of the natural banks of the channel
- the line of any discontinuity of the slope of these banks
- toe and crest of any artificial flood bank
- all obstruction in the channel

ii) Longitudinal section of channel showing the level of deepest part of the bed and water surface gradients at low and high stages. The longitudinal section should extend from below a control where this exists to the u/s limit.

iii) At least five cross sections in the measuring reach. Two cross sections each u/s and d/s of a measuring section. All control sections should be taken normal to the direction of flow and should be extended to an elevation well above the highest anticipated stage of flood. The spacing of levels or soundings should be close enough to reveal any abrupt change in the contour of channel.

3. In addition to the above, exploratory velocity observations at all the five cross sections by current meter and by floats spread across the width of channel should be done to ascertain the abnormality in the flow if any. These measurements should be done for various stages of discharge to have full understanding of velocity pattern. The design of the station i.e. the location of the measuring section for low and high flows and the methodology to adopted for gauge and velocity observations would depend largely on the features disclosed by the surveys.

After fixing the gauge location, the axis of measuring section shall be marked by means of concrete or masonry pillars erected on the two banks.

4. After a gauging station has been constructed, a final detailed survey is made of all the station features, including all structural installations. Of particular importance are the elevations of the station bench mark and the zero of the reference gauge.

The plan should give the location and details of the station features, as follows :

i) The instrument shelter or house
ii) Staff gauges and other non-recording gauges/recording gauges
iii) Station bench mark and any auxiliary bench mark or datum marks within the instrument house for checking and setting the recorder.
iv) The following sections are required :

   a) A longitudinal section of the stream reach at the station showing the bed profile, including the lowest point on the control (stage of zero flow), the staff gauge, intakes for stilling well, and current-meter measuring section.
   b) Cross - sections extended up each bank of a section control.
   c) A cross section through the staff gauge extended up to each bank above historical flood level.
   d) Cross sections of the current-meter measurement section.

5. Four main types of structures are used at gauging stations :

i) Water-level gauge and bench mark. The gauge is usually a non-recording vertical staff gauge or an inclined staff gauge.
ii) Automatic water-level recorder. The automatic recorder is usually a float-actuated recorder with house and stilling well or digital recorders with sensors.
iii) A structure for taking current-meter measurements.
iv) An artificial control.

The first item is required at all gauging stations. The second item is needed if the stage is to be continuously recorded. The two last items may or may not be needed.

The highway bridges used in streamflows measurements must be utilized as they are found. The only problem they present is whether or not they will be practicable for making discharge measurements. The advantage of using existing bridges is the saving in construction and maintenance costs that is associated with cableways, but this advantage is often outweighed by the poor measuring conditions at the bridge, the inconvenience entailed in using some bridges and the safety hazards caused by traffic conditions. A bridge that is used regularly for discharge measurements is marked at suitable intervals on the handrail or some similar feature of the bridge for convenient spacing of the verticals during discharge measurements.

5.1 Measurement of Stage

The Reference gauge shall be located as closely as possible to the measuring section in the case of measurement using a current meter or near the mid point of the measuring reach in the case of any other method of measurement.

The 'Reference Gauge' shall be a vertical staff gauge or an inclined gauge. The marking shall be clear and accurate to within 5 mm. The lowest marking on the 'Reference Gauge' should be at least 0.15 m below the lowest anticipated water level, and the highest marking at least 0.3 m above the highest anticipated flood level.

The 'Reference Gauge' shall be securely fixed to an immovable rigid support. The 'Reference Gauge' datum should be related by precise leveling to the national datum, that is, G.T.S. datum. It shall have stilling arrangements, whenever necessary, so that the water level can be read accurately.

Vertical Staff Gauge - This staff gauge shall be vertical. It shall be preferably of enameled plate gauge. The marking shall be clear and sufficiently accurate for the purpose for which the measurements are required with bold line secured firmly to a stable post of wood, concrete or other suitable material. The gauge may be fixed in sections in which case each section shall be of 2 m length, that is, the first section reading from 0 to 2 m, the next from 2 m to 4 m and so on all corresponding to the same zero level. Streamlined triangular section gauge posts are preferable in open channels, with apex facing upstream.

Inclined Gauge - The inclined gauge shall fit closely and be solidly anchored to the slope of the natural bank of the channel. It may be calibrated on the site by precise levelling.

Stilling Well - Stilling well should be provided wherever there are significant fluctuations, and where it is provided, it shall be connected to the river by an inlet pipe or oblique slit, or channel; and where a stilling well is provided for continuos water level recorder, it shall be vertical and have sufficient height and depth to allow the float to travel the full range of water levels.

Continuous Water Level Recorders - These are particularly useful in channels where large fluctuations of discharge occur during short intervals of time or where continuous record is required. Wherever installed, the 'Reference Gauge' shall be placed near the point of measurement of the recorder and an additional gauge shall be installed inside the float well to serve as a check. The water level recorder shall be such that it gives a record which is not affected by any phenomenon other than the changes in water level. The recorder shall provide either a continuous graphical record of the changing water level or may register the water levels digitally at suitably close intervals of time.

6. Measurement of Cross sectional area

The area of cross-section of the waterway shall be determined by measuring the width of the waterway and the depths from the surface of water to the bed of channel across the normal cross-section.

The intervals at which the depths of water shall be measured along the cross-section for channels with different widths of waterway shall normally be as given in Table I. The interval specified may be such that there shall be not more than 10 per cent and preferably not more than 4 per cent variation in the discharge between any two adjacent segments. The discharge through any segment shall be not more than 10 per cent of the total discharge.

TABLE 01
WIDTH OF INTERVALS FOR MEASURING DEPTHS

Sr. No.	Description	Number of observation points	Maximum width of interval
i)	For channels not exceeding 15 m or in channels where the river bed changes abruptly.	15	1.5 m
ii)	For channels with width of waterway from 15 to 90 m	15	6 m
iii)	For channels with width of waterway ranging from 90 to 180 m	15	15 m,
iv)	For channels with width of waterway greater than 180 m	25	--

After deciding on the number of segments in which the cross sectional area is to be divided, it is necessary to mark these on the section line to facilitate correct positioning of the sounding line and current meter on different verticals. Method of marking segments varies according to method of discharge observation.

6.1 Segments Marked on Wire Rope : If the width of the section is upto 500 ft. (or 152.4 m) either a coir or a steel wire rope is stretched across the section line using a winch, if necessary.

On the rope, tags, pendants or tally marks are attached to indicate every vertical on which observations are to be made. Depth and velocity measurements are made by wading or from a boat, at these verticals. If velocity is high, boat is controlled by means of coir rope or steel cable, stretched for the purpose a little upstream of the tag line to locate the sounding line correctly on the measuring verticals.

6.2 Winch with Endless Cable or Tag line : In narrow gorges where velocities are so high that a boat or a launch cannot be held in position and provision of a cradle on a cable is prohibitive in cost, verticals are easily located by using an endless tag-line and a winch (see fig. 1). With this equipment all operations of positioning, lowering and raising of the current meter can be made from the bank.

For smaller widths up to 200 ft. (61 m) a simple double drum with endless tag line (fig. 2) can be used.

6.3 From Cableways : For longer lengths a cable line erected on towers at either end is used on which a cradle is mounted and moved to the desired vertical. A subsidiary wire may be run to mark the segments by means of tags etc.

7. Indirect Methods when using Boats or Launches :

When observations are proposed to be made by using boat, in case of a narrow streams less than 500 ft. (152.4 m) wide, the segments can be demarcated by means of tag-line stretched across from bank to bank on the section line. Boat is maneuvered by another wire stretched a little upstream so that rack and pinion or other suspension can be correctly located at the vertical demarcated by the tag or tally mark. If a structure like a bridge is in the near vicinity, segments can be demarcated with respect to the marks painted on the bridge. When, however, any such direct reference is not available, segments may be marked by indirect methods. These comprise of the following :

i) **Pivot Point Method** : When width of the section is more than 500 ft. (152.4 m) and land is available for laying pivot points, Pivot Point method may be used (see fig.3.) From point A sufficiently away from the bank line on the cross section, line AP is laid at right angles. This should generally have a length of about 1000 ft. (304.8 m) or up to half the width of the river. From point D on line AP, a line DD1 is drawn parallel to the section line. The ratio of PD to PA is generally kept 1:5. On line DD1 points are marked at fixed intervals, depending upon the distance between verticals. For example, for verticals 100 ft. apart points E2, E1 are placed 20 ft. apart, so that radii rays from P passing through these points will intersect the section line at points B1, B2, B3, etc. each 100 ft. (30.5 m) apart. Since all rays pass through the point P, it is called the pivot point. A boat or a launch can now fix its position correctly by moving on line AA1 and anchoring at point B1, when it is correctly in line with points P and E1.

To facilitate daily observation semi-permanent arrangement may be made by means of masonry or concrete blocks constructed at pivot point P and at points E1, E2, E3, etc. on line DD1 with a piece of pipe in the centre of each block to hold flags. The layout can be easily checked by setting up a theodolite on the pivot point and checking the angles APB1, APB2, APB3, etc. Tangents of these angles should be equal to AB1/AP, AB2/AP, etc. If river is wider than 2000 ft. (609.9 m) pivot layouts may be made on both banks as shown in fig. 04. Two parties can then work independently but simultaneously from the two banks of the river.

Another version of the Pivot Point method is shown in fig. 05. Here, instead of drawing the line DD1, parallel to the section line as in fig. 04, line NM is drawn parallel to AP. This line is then subdivided into NN1, N1N2, N2N3 etc. Lines passing through the pivot point P and points N1, N2, N3 etc. on line NM intersect the cross-section line AA1 at points B1, B2, B3, etc. These points of intersection determine the positions of verticals on which observations can be made.

Once the pivot point and points N1, N2, N3 etc. are fixed on the ground and marked by flags, the boatman can easily define his position and bring the boat to the correct vertical by moving on the section line and aligning with PN1, PN2, PN3, etc.

ii) **Stadia Method** : When sufficient land is not available or ground is very uneven for the pivot point layout, Stadia-method is used Fig. 06. In this method, a theodolite is placed on the section line AD while stadia rod is held in the boat. The distance of the boat is determined from the reading of the stadia rod made by theodolite. Normal precautions should be taken and adjustments made to the theodolite before use. An error is likely to be caused on account of parallax unless care is taken to remove it.

iii) **Angular Method** : In angular method, the cross-section is first fixed by means of two flags as usual. A normal is laid out from the inner flag on any of the banks as shown by CE in fig. 07. Theodolite is placed at point E. Distance MC of the boat can be determined by observing angle CEM by the theodolite. Knowing distance CE, MC = CE tan α.

8. MEASUREMENT OF VELOCITY

8.1 Measurement of Velocity Using Current Meter

The cross section selected for making velocity measurements shall be divided into compartments. In each compartment, a number of verticals shall be selected along which velocity measurements shall be made. Their maximum spacing shall be such that the mean velocity of two adjacent verticals shall not differ by more than 20 percent with respect to the lower value of the two. In no case shall these be less than 5 verticals. Soundings shall be taken at each of the verticals.

The current meter shall be held in the desired position in any vertical by means of wading rod in the case of shallow channels or by suspending it with a cable from bridge, trolley or boat. The ideal arrangement is to suspend the meter vertically with suitable fish weights from a trolley, running on a cable across the river. When a boat is used, the current meter shall not be affected by obstructions or deviation of the flow caused by the boat.

The ideal arrangement, from a boat or a power vessel for measurement of velocity in rivers with depth upto 10 m(or 30 ft) is the suspension of the current meter by means of a vertical rack and pinion.

8.2 Measurement Of Velocity Using Floats -

Floats are used when the flow is rapid and, therefore, it is not possible to anchor the boat in the stream and measurement with a current meter is impracticable. Floats, however, shall not be used if the wind is strong and the velocity of water is low.

The float shall be released from a sufficiently powered vessel about 15 m (or 50 ft) above the upper cross-section so as to enable the float to attain a constant velocity by the time it reaches the cross-section. The time at which the float crosses each of the three cross-sections shall be noted. This shall be repeated with the floats at various positions along the width of the channel from one bank to the other.

The distance of the float from the bank as it crosses each section may be determined by angular observations with a theodolite. For this purpose, a base line perpendicular to the cross-section chosen shall be laid on one bank of the river and the theodolite stationed on this line, so that all the cross-sections are visible. The angle made and the time shall be observed as the float crosses each section.

9. Cableways

To obtain the discharge measurements and sediment samples required at gauging stations, it is necessary to suspend the measuring and sampling equipment at numerous points across the stream channel. The most practical way of suspending the equipment is by a cableways spanning the channel. Suspension from cableways avoids the difficulties met in gauging from bridges with piers and from boats. There are two basic types of cableways, namely;

1. Those with an instrument carriage controlled from the bank by means of a winch.
2. Those with a manned carriage in which the operator travels across the stream and makes the observations.

Cableway with Instrument Carriage

The cableway system with instrument carriage consists of : (Refer Fig. 08

Supporting posts (towers)
Track (main) cable.
Anchorages.
Staylines (backstay)
Towing cable.
Instrument suspension cable.
Instrument carriage
Double drum winch or two independent winches.

Cableway with Personnel Carriage
The manned-carriage cableway system consists of (Refer Fig. 09)

Supporting towers.
Track cable.
Anchorages.
Staylines.
Personnel carriage.