PAPER No. 272

Methods of Discharge Observations

BY

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1. Introduction. Discharge denotes the volume of water passing a given section of a stream in a unit of time. It is measured in cubic feet per second, known commonly as 'cusecs' in India.

The subject is not only of great importance to the irrigation engineer who must accurately know the discharges he has to deal with both in basing his irrigation and storage projects on and in distribution of supplies on lands under irrigation, but is also essential to the bridge and railway engineers, for fixing the waterway of the bridges and designing and safely maintaining training works.

The object of this Paper is to describe briefly yet comprehensively the methods followed in the Punjab Irrigation for observing discharges with maximum attainable accuracy under varying conditions. The subject, though very important, has not received the attention it deserves from the engineers, and little apology is needed for bringing it up before the Congress so as to broadcast the technique which is specialised by the Discharge Division.

2. Objects and applications of discharge observations. The objects of discharge observations and uses to which the data so collected are put, are as below :—

(*i*) *Statistical.* By collecting daily discharge data for a sufficient number of years and scrutinizing it, it is possible to forecast the normal supplies for basing the irrigation projects on and also the highest supplies for fixing magnitude of works and storage projects. Accuracy in observation of discharges at all stages is therefore needed. The Sind-Punjab dispute shows the importance of collecting discharge data for inter-provincial distribution of river supplies. The importance of collecting in the first instance correct data for highest discharges is illustrated by the subsequent additions at a comparatively higher cost required at the Panjnad Headworks and Kalabagh Railway Bridge.

(*ii*) *Regulation and distribution.* Accurate measurement of river supplies for distribution among partners of an irrigation system and of canals, branches, distributaries and outlets for equitable distribution, is an essential feature of the successful running of a canal system.

(*iii*) *Scientific and hydraulic investigations.* For this, accurate observations of discharges both in the field and laboratory are necessary. Of the numerous investigations in connection with the advance of hydraulic and

irrigation engineering some are, estimation of absorption losses in channels, determination of co-efficients of roughness for various types of channels both lined and unlined, sluice gate co-efficients, studies of the conditions of flow in streams and investigations of hydraulic laws.

3. Methods of stream gauging. The measurement of discharge is made by the following methods :—

(*i*) Velocity area method, (*ii*) Gauge discharge curve method,
(*iii*) Weir method.

The above three methods are the most commonly employed ones for discharge observations and shall be described in detail hereafter. In addition, the following methods are also used, though they are only of an academic interest for engineers :—

(*iv*) *Pitot tubes.* This method is based on the principle that the dynamic or impact pressure of a current moving with velocity V, and striking a glass tube with a nozzle, pointing upstream makes the water rise inside the tube by an amount 'h' above the surface and that the velocity is represented by the equation $V = C\sqrt{2gh}$. The value of co-efficient C can be determined by calibration of the tube.

(*v*) *By chemical means.* This method is based on the principle that if a weight w lbs. of a chemical is added each second to a stream discharging Q cusecs, and after a thorough mixture, if a lb. of the chemical is contained in n lbs. of water than $\frac{w}{62{\cdot}5\,Q} = \frac{1}{n}$ or $Q = \frac{nw}{62{\cdot}5}$. The method requires special apparatus and arrangements and is not easily applicable under conditions prevailing in the field.

(*vi*) *By venturimeter.* This is applicable only to discharges capable of being passed through a pipe, and its theory is described in all text-books on hydraulics.

(*vii*) *By a travelling screen.* In this method a light varnished canvas screen fixed in a rigid frame is hung from a wheeled carriage and is made to move with the water in a specially prepared rectangular channel. The velocity with which it moves, after being corrected for leakages from sides, is taken as the mean velocity of the stream.

4. Velocity area method. This method involves measurement of area and velocity. It being impossible to determine the mean velocity for the entire section of a channel in one single measurement, the area is divided into vertical strips, of suitable size and mean velocity for each component strip is observed, the total of the discharges for all strips being the discharge of the channel. In other words the cross section of a river is observed by soundings and the mean local velocity perpendicular to the cross section is observed at as many points as possible. The discharges at these points are denoted by the product of the mean velocity and depth. If now a curve is plotted with the water surface width as the base and the discharge at each point represented by product of

depth and velocity as the ordinate, the total discharge is represented by the area of the enclosing polygon. The area of the polygon may be determined either by taking straight averages or by Weddles and Simpson's Rules. The method, therefore, involves the accurate determination of areas and velocities, which are measured as below :—

(*a*) *Measurement of area.* The area of X. Section of a stream involves two elements *viz*., the horizontal width and vertical depth, which are both measured as below :—

(*i*) *Width.* If the discharge site is located at a bridge or other masonry work, the measurement of width is a simple affair. In the case of an open channel of width up to about 1,000′, a wire is stretched across the channel and segments are marked on it by means of pendants. At Rupar on the Sutlej a wire has been stretched across a width of 1,700 ft. of the river. The necessary precaution in such cases is to make a suitable allowance for the sag. Alternatively, the pendants should be fixed by a theodolite. In bigger channels across which wires cannot be stretched, the segments are marked by pivot point method which is based on principle of similar triangles, to be described hereafter.

(*ii*) *Depth.* The points where depths have to be measured are located as above, and in deep and fast streams in which wading is not possible, boats have to be employed for reaching such sounding points. Depth is measured either by direct reading on a sounding rod or log line or by indirect methods.

(*a*) **Direct method.** 1. Sounding rods consist of oval wooden rod with E. I. gauge on it, flat iron of $2'' \times \frac{1}{4}''$ size or bamboos of 2″ to 3″ diameter all graduated in tenths of feet and with iron discs of 4″ to 6″ diameter at bottom to prevent sinking in bed. Bamboo rods have been used even upto 30 ft. depths in low velocities. The depths are measured at downstream ends thus omitting effects of afflux due to velocity.

2. Lead Line. In higher velocities and depths, observations are made with weighted log line. Log lines consist generally of copper cores covered over with hemp. Such a line does not shrink when wet nor stretches under weight and remains free from knots. Alternatively, when such metallic lines are not available as is the case at present due to war weighted manilla rope can be used, but with due precautions regarding stretching and wetting it before use. Constant checking during use is essential.

The lead or sounding weight is generally of the shape of frustum of a cone. The weight varies from 10 lbs. to 56 lbs. depending upon depth and velocity encountered. At Kalabagh a weight of 56 lbs. even has to be used with care and experience to measure depths accurately.

It requires an experienced hand to observe depths properly with a log line. The depth of water surface below a reference point is first measured and marked on the line. The weight is then swung and released a little upstream of the observer. After touching the bed it trails down and the rope or line is pulled, till the weight is vertically

under the observer when the length of the rope is marked againt the reference point. The distance between the two marks gives the depth at the point. A difference of six inches between two consecutive readings is ignored. For larger differences observations have to be repeated.

(*b*) **Indirect method.** In deep and rapid rivers, the observation of depths with log line requires skill, experience and perseverence and the accuracy of results can to some extent be questioned. The problem of measuring depths with ease, rapidity and accuracy has not yet been satisfactorily solved and attempts are being made to apply some indirect type of sounders for the purpose, of which the following are worth mentioning.

1. **Haigh Depth Meter.** This is an ingenious device recently invented by Mr. F. F. Haigh, C.I.E., Chief Engineer, Punjab Irrigation and is based on Boyle's law, *viz.*, PV = constant, and though the observations so far made, give remarkably consistent results, it has not yet passed the experimental stage and is being perfected by the inventor, to suit extremely difficult conditions of excessive velocities and depths met with at sites like Kalabagh on the Indus. It consists of a tube coil in a cylindrical container, in which water under pressure is entrapped by compressing the volume of air in it. The volume of water entrapped is proportional to the depth upto which the meter is immersed and the depth is read from a calibration curve prepared by actual observations before it is brought into use. The details of the meter and some observations with it are shown in Plate I. It will be seen that the results are quite accurate, and the instrument besides being used in discharge observations will be of immense value in observing scour depths at salient points of Headworks, training works and Railway Bridges.

2. **Kelvin tubes.** These have been tried in Sind and have not proved to give consistent and accurate results.

3. **Echoe Sounder.** Suggestion has been made by Mr. Montagu to explore the possibility of using such sounders as are used on ships, for observing depths. This needs further investigation.

(*b*) *Measurement of velocity.* Before proceeding to describe the methods of measuring velocity it is desirable to understand the nature of flow met with in streams. Motion of water is of two kinds, *viz.*, simple or steady, when motion of particles at a fixed point is constant, and complex or unsteady motion, in which due to formation of eddies or vortices motion at any point is always varying. An eddy or a vortax is a mass of fluid rotating in a closed circuit, round an axis in the fluid itself. Unsteady motion is due to changes in viscosity, and density, divergence of solid boundaries, still water on sides of streams and curvature. Another observed phenomenon in flowing water is the constant change in velocities at a point, due probably to the eddies and vortices causing interchange of paths of currents moving at different speeds. This necessitates observations of velocities being made for an appreciable period so as to arrive at a correct stable value, as observations for short periods must deviate

from each other due to pulsations mentioned above and be of doubtful value.

Even though the flow in open channels is complex and subject to continuous pulsations, the distribution of velocities in a cross section has some general characteristics. Attempts at determining location and magnitude of one single value for mean velocity for the entire X. Section of a channel have so far not been successful and therefore for discharge measurement mean velocities for component strips of area of cross section are observed. The vertical velocity curve showing velocities at various depths is accepted to be a parabola with a horizontal axis. Actual observations by various investigators in America and India have shown that the position of mean velocity in a vertical occurs under normal conditions of flow at 6/10D. It has been proved mathematically also by Lindell from the parabolic shape of the vertical velocity curve that the mean velocity occurs at 0·6D, if the maximum velocity is at 0·15D. Further, it can be proved that the mean velocity equals the average of the velocities at 0·21D and 0·79D, generally accepted as velocities at 2/10th and 8/10th depth, which is the basis of the " two and eight tenths method." When measurement of velocities at known depth are not possible, surface in segments or even central surface velocities in a cross section are measured and corrected into mean velocities by application of a " reduction co-efficient."

Velocities are measured by the following methods :—

(*i*) *Surface floats.* These consist generally of wooden discs from 3″ to 6″ diameter. Observations with such floats are liable to be influenced by wind, ripples and eddies on the surface of water and bends in the stream. The shape and weight should, therefore, be such as to minimise the effect of the disturbing forces. To be safe against effects of wind, globular floats are better than flat discs. Simpler floats consisting of corked bottles, oranges, blocks of wood, or even floating debris are used when improved types are not available.

The floats register the surface velocity and a reduction co-efficient has to be applied to get the mean velocity. The exact value of this co-efficient is still a controversial matter. The value is stated to be greater for sandy bed rivers and minimum value occurs in beds of gravel. Experiments on different rivers have shown the value between 0·79 to 0·91. In Holland the value has been found to be 0·87 in sandy beds. In the Punjab Mr. Goodman, collected a large number of observations and found the value to be 0·89, which is already in use. The subject is still on the agenda of the Central Board of Irrigation who have recommended further observations. In any case, the method is not of an unquestioned accuracy and is applied in high floods only when observations by more definite and accurate methods are not physically possible.

Some-times subsurface or double floats, consisting of metallic hollow cylindrical weighted submerged floats attached by means of a thin cord

to surface floats were used. They have, however, become obsolete with the development of better methods.

(*ii*) *Rod or tube floats.* A rod float consists of a wooden rod, square or round, in section of width or diameter from 1" to 2" proportional to length for strength against rough field use. It is weighted at bottom by means of a lead weight for immersion to required depth. Hollow tubes of tin or galvanised iron were also used but have been discarded being unsuitable due to bending, cracking and developing leaks.

That a rod float extending from surface to bottom of a channel shall represent very closely the mean velocity in the vertical, is an obvious inference. Cunningham in his Roorkee experiments has, by assuming that the force acting on the rod at any point is proportional to the square of the difference between the velocities of the rod and water in contact with it and that the vertical velocity curve is a parabola, mathematically shown that Vr the velocity of the rod is equal to Vm the mean velocity when the immersed length of the rod is from 0·95 to 0·927 the depth of water, the exact value depending upon position of maximum velocity in the vertical. He takes mean value when length of immersion is 0·94*d*. Parker found that Vr equals Vm if length of immersion is 0·952*d*, with maximum and minimum values of ·97*d* and 0·91*d*. In the Punjab Irrigation, rods with length of immersion of 0·94*d* are used and the rods are made of full length and weighted so as to have ·06 of length out of water.

Parker is of opinion that rod floats give too high a result as compared to weir or current meter. Francis arrived at the following equation for correcting the rod velocity, $Vm = Vr \{ 1 - 0{\cdot}116 (\sqrt{D} - 0{\cdot}1), \}$ when Vm is equal to mean velocity, Vr = rod velocity, $D = \frac{d - li}{d}$, ratio of proportion of depth not covered by rod to total depth. Parker further suggests that 0·2 is better than 0·116 for conditions in the field and that this correction should preferably be applied, otherwise, results are over-estimated. The value of co-efficient given by Francis as 0·116 and by Parker as 0·2, is believed to increase with roughness and applies only for Kutter N = ·020. The method of rod floats is applied only for canal observations and is rarely, if ever, applied to rivers. The rods form a simple, inexpensive and direct method of measuring velocity easily followed by untrained men and are not effected by the nearness of boundaries of channel section. They have, however, defects like larger party for observation, difficulty to control their course, motion along a pulsation without neutralising effects of changes in velocity, observation of more than one cross section and possibility of fouling bed by ·94*d* rods and consequent tendency for use of smaller rods leading to over measurement of discharge. This over estimation of observed discharges by the rod floats is an admitted fact and in order to solve this difficulty the rods described below have been introduced as an alternative.

(*iii*) *Lacey Tubular rods.* This type of rod consists of a hollow closed

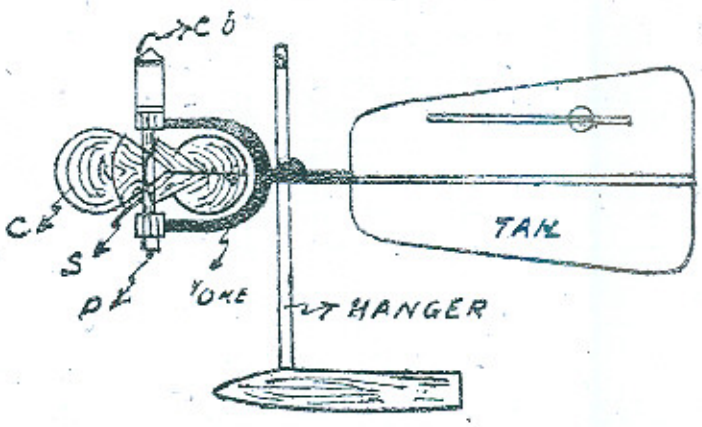
tube working in another hollow tube, closed and weighted at the bottom so as to float in water with only the top about two inches length sticking out. The length can be adjusted by pulling out the inner tube and the depth of immersion remains upto the same point from top, the increased length of the outer hollow tube getting filled up with water. These rods are available in sets which can serve for depths from 1·0′ to 10·0′.

Mr. Lacey has mathematically proved the relation $Vm = 2V_2 - V_1$, where Vm = the mean velocity or velocity at 0·6D and V_2 = velocity for a rod of ·8D immersion and V_1 = velocity for a rod of ·4D immersion. He has, therefore, recommended simultaneous use of two rods immersed to depths ·4D and ·8D and observations and comparison with current meter velocities at ·6D have proved this method to be quite accurate. It, however, involves too elaborate a system and excessive time and suggestions to substitute a single ·8D rod have been made as described hereafter.

(*iv*) *Current meters.* Current meters are of two kinds, *viz.*, cup meters, consisting of a wheel with conical cups revolving on a vertical axis and screw or propellers meters, consisting of vanes revolving on a horizontal axis. To the first kind belong the Price, Ellis and Watt meters and to the second Fteley and Stearns, Haskell, Amsler, Stopponi, Richard and Ott. Price meters known as Gurley meters after the manufacturers, W. and L. E. Gurley are now almost universally employed in America, Egypt and India. A brief description of this type only is, therefore, given below, a reference being invited to Gurley Manual for a detailed account of the instruments :—

Price or Gurley meter and equipment consists of the following five principal parts :—

(1) **The Head,** As shown in the sketch it consists of a ⊃ shaped yoke carrying a wheel of 5″ diameter with six conical cups c, attached to a horizontal frame. This wheel revolves in a counter clockwise direction on a shaft s, resting on a pivot point p at the lower end, and passing into cummutator box c. b. at the upper end in which arrangements to indicate electrically the number of revolutions by single or penta strokes are provided. In Gurley No. 622 single and penta arrangements are provided in the same box and in meter No. 623, separate boxes are provided. Meter No. 623 is in use in the Punjab generally.



(2) **The Tail,** consists of a steam on which there are two vanes,

one being rigidly fixed and the other capable of being pulled out by sliding a groove. An adjustable weight in a slot is provided on one of the vanes. The functions of the tail are to balance the head and keep the meter parallel to the current.

(3) **The hanger,** consists of a thin steel bar, passing through the frame of the meter, with torpedo shaped weight at the bottom, of which the function is to keep the meter in plumb when hung by a cable.

(4) **The recording or indicating device,** consists of a telephone receiver with necessary battery equipment and ticks are conveyed to the observer, on closing of circuit after the single or penta number of revolutions according to the commutator box in use.

(5) **Suspending device.** This consists of a rod, cable or rack and pinion and provides for lowering the meter and weight (when used) in water. The rod is used in shallow streams of wadeable depth. The cable is used from boats and bridges, but it has the defect of bowing and being deflected from the point of observation in high velocities. In order to ensure the location of the meter being truly at the point and depth of observation, a rack and pinion device is used in the Punjab. This consists of a rigid rack rod with teeth which works by means of toothed gear and can be made to stand at any depths in the water. Details of such an appliance are shown in Plate II. The rack rod is graduated by reducing each foot to 6/10 ths as the velocities are measured at 0·6D. At present velocities upto depths of 20′ can be easily measured by rack and pinion arrangement and designs for measuring velocities at greater depths are in hand.

The Gurley meters possess reliability in service, under most trying conditions in the field, simplicity in design, rigidity in construction, adaptability for use in all sizes of streams, compact size and are now used to the exclusion of all other meters in the Punjab.

In using a meter, revolutions are recorded, and the relation between the revolutions and the velocity is determined by rating the meter. The process of rating consists in towing a meter through still water at known uniform speeds and noting time, number of revolutions and distance. Revolutions per second and velocity in feet per second are calculated. For each meter under rating, some eight such observations are taken at different speeds, and relation between velocity and revolutions per second is determined by either plotting the curve or by method of least squares. The relation has a straight line equation of the form $V = \alpha N + \beta$, where V is velocity in feet per second, N is revolutions per second and β is the intercept of the straight line on velocity axis representing minimum velocity at which wheel starts revolving. A rating table for each meter in use is prepared from this. For Gurley meters in use in the Punjab α lies between 2·18 to 2·38 and β between 0·0 to 0·05. An up to date arrangement for rating meters consisting of a masonry tank 400 ft. long, 8′ wide and 7′ deep with an electric trolly fitted with distance, time and revolutions recording devices, exists at Lahore.

Rating is carried out in still water and at the temperature of the season and it will not be out of place to mention briefly the effects on the performance of meters, of turbulent flow and changes in temperature. Turbulence postulates variations in both magnitude and direction of velocity in pulsations, durations of which depend upon degree of turbulence. Investigations in America have shown that cup meters over register and screw meters under register velocities and some authorities have recommended mean of observations by both kinds of meters to be taken as the correct discharge. Regarding effect of temperature, Blench found by analysing the discharge data at the Head of the Lower Jhelum Canal that a Price meter over registers by 1 per cent for every 6°C fall in temperature. This may be attributed to changes in viscosity. Observations by the writer confirm the above results and the matter is still under investigation in the Discharge Division.

The mean velocity in a vertical is observed by a current meter in one of the following ways :—

(*i*) *Six-tenths method.* The meter is held at 6/10th the depth from surface and the observed velocity is taken as the mean velocity. This method is invariably employed in the Punjab, except in the conditions of turbulent flow.

(*ii*) *Vertical velocity curve method.* This consists in measuring velocities at a point 0·5 ft. below surface, every tenth of depth and a point nearest possible to bed and plotting a curve with velocities as abscissae and corresponding depths as ordinates. The area of this curve divided by the depth gives the mean velocity. This method is employed where due to turbulence, the position of mean velocity does not occur at 0·6D, as can be the case in some hill sites only.

(*iii*) *Surface velocity method.* The velocity is measured at 0·5′ or 1·0′ below surface depending upon velocity and turbulence at the surface. Mean velocity is obtained by applying a reduction factor. This method is employed only when (*i*) and (*ii*) are physically not possible, say in floods in hill torrents.

(*iv*) *Two point or two and eight-tenth method.* Velocities are obtained at two-tenth and eight-tenth depth and average of the two gives the mean velocity of the vertical.

(*v*) *Summation or integration method.* In this method, the meter is lowered to the bed and then raised to surface at a uniform rate. The reading of the meter, which represents the mechanical average of the rates at which it turns during its journeys up and down is assumed to correspond to the mean velocity. Cup type meters are not suited for this method and this method is never used in the Punjab.

As stated above, six-tenth method is employed practically at all sites in the Punjab, except where the conditions of flow show variation in position of the mean velocity in a vertical. Further, observations by Mr. Blench and the writer show that a current meter is influenced by

the rigid boundaries of a channel if it is within $1\frac{1}{2}$ ft. of the bed or sides and registers lesser velocities. This leads to the practice, that current meters are used for streams both natural and artificial with depths of 4·0′ and over. For channels with lesser depths, velocity rods are the only accurate means of observing velocities. As the 0·94D rods are apt to foul the bed, the latest system, which is however still in experimental stage, is to use rods of 0·8D length of immersion and to correlate velocities observed with these to current meter velocities for channels with more than 4·0′ depth and 0·94D rod velocities for smaller channels. In Sind from observations in 1942 and 1943, equation $Vcm = ·9800\ V_{·8D} - 0636$ has been arrived at where V_{cm} is mean velocity at ·6D with current meter and $V_{·8D}$ is velocity with rod of ·8D immersion. In the Punjab the matter is still under investigation and it is proposed to work out a suitable relation between mean velocity and $V_{.8D}$ when sufficient data are collected. The data so far collected have given the regression formulae : $Vm = ·9484\ V_{·8D} + ·0785$ and $V_{·94D} = ·8193\ V_{·8D} + ·2446$.

5. River Discharges. The following procedure is adopted for observation of river discharges :—

(*a*) *Selection of discharge site.* The essential feature for the accurate measurement of a discharge at a site is that the flow should be streamline and regular, devoid of errors caused by irregularities in the motion of water. This postulates the following deciderata in selecting the site :—

(*i*) It should be in a straight reach of the river, with regular streamline flow, undisturbed by bends leading to unequal distribution of velocities, cross flow and eddies, which effect accuracy of measurements.

(*ii*) The section should be regular and deep with least tendency for wide spills even at high discharges.

(*iii*) The section should have reasonably stable bed and sides and be amenable to a regular gauge discharge relationship as far as possible.

(*iv*) It should be far removed from confluences and structures causing vitiation by back water heading up.

(*v*) The site should be easily accessible and free from creeks.

(*vi*) In case of hill sites, the stream should be straight atleast for 500′, site should be free from projections in bed and from sides and away from disturbing influences of rapids, falls, and confluence of torrents.

(*b*) *Segmentation or spacing of sounding points.* The distance between sounding points depends upon the width of the stream, profile of the bed and accuracy desired. In short, the greater the number of sounding points, the more accurate the area measured and discharge observed, as there are more chances of the fluctuations in velocities being evened out. The following rules have been laid down in Punjab for segmentation of river discharge section lines :—

(*i*) The number of segments should not be less than fifteen.

(*ii*) For river width in excess of 2,500 ft. segmentation is to be fixed by the Executive Engineer, keeping in view the prevailing cross section, distribution of discharge across the cross section, equipment available and time involved in completing an observation.

(*iii*) For river widths from 1,500′ to 2,500′ segments should be 100′ apart over the portion of section passing 75 per cent of total discharge and 200′ apart for the remainder.

(*iv*) For river widths 750′ to 1500′ segments are to be 50′ apart.

(*v*) For smaller widths segments to be 40, 30, 20′ or less, subject to condition (*i*).

The principle to be followed is that in the portion of the section where the discharge is concentrated, the segments must be nearer and farther apart in the slack portion so as to have segments of more or less equal discharges.

(*c*) *Procedure and Equipment.* At each discharge site the following equipment is required :—

(*i*) Boat. This is required for reaching the points for observations of depths and velocities. A 35' long Sukkur type boat of which the details are shown in Plate II is in use in the Punjab. An improvement upon this with pointed stream line ends is under design by Mr. Fletcher which is intended to be easier to pull up in high velocities for reaching successive points.

(*ii*) Suitable anchor with about 250′ long 1″ diameter Manila rope.

(*iii*) Sounding rods of line and weight according to conditions of site.

(*iv*) Current meter with accessories complete in all respects including a swivel. At each site a check meter is also kept and the local meter in use is checked with this once a fortnight to make sure that it works satisfactorily under conditions in the field. A bracket for hanging check meter is also provided.

(*v*) Rack and pinion suspension arrangement, described above.

(*vi*) Stop watch for use with meter. An extra check stop watch is also kept at each site.

(*vii*) A torpedo float with cotton cord for indicating direction of current.

(*viii*) Pocket sextant, with which angle made by the current with the section line as indicated by the float is read. In order to work out the component of the velocity, normal to the section line, the observed velocities are multiplied by the sine of this angle and a table for such corrections is provided at each site.

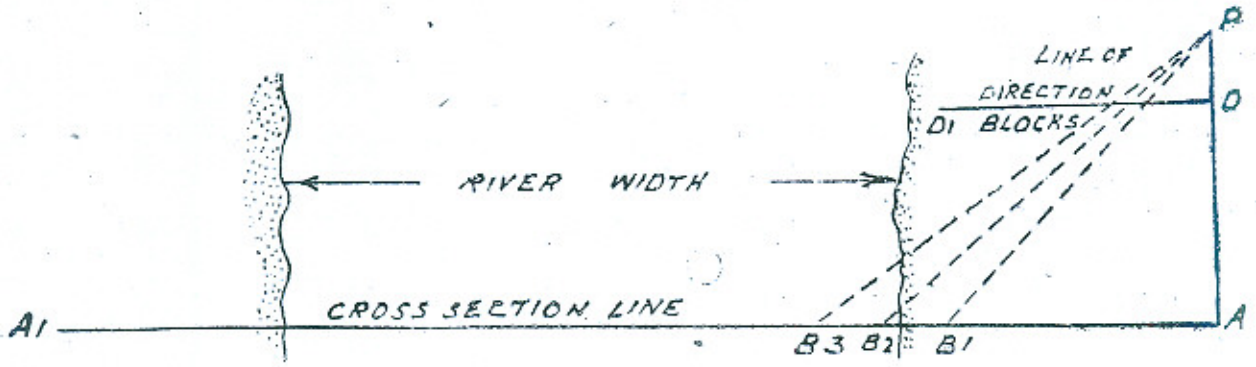
(*ix*) A levelling instrument for checking R.Ls of gauges and a theodolite for reading angles.

(*x*) The cross section line is marked by three flags, 200′ apart on each bank. In case of swift currents, the boat drifts down and drift

flags 25′ apart are fixed for a requisite distance downsteam of the X. section line.

(*xi*) In case of narrow streams, say upto a width of 1,000′ as is the case with all the Punjab rivers in winter, the section line is marked across the stream by a wire, on which pendants are hung at sounding points. The boat is held by another wire, stretched a little upstream, so as to have the rack and pinion under the pendants.

(*xii*) When streams are too wide for stretching a wire rope, the sounding points are located by pivot point method, which is illustrated in the figure below :—



From point A on the cross section line on the bank, a line AP at right angles is drawn and from a point D on it, a line parallel to the section line is drawn. The ratio PD : PA is generally kept 1:5 and the length of AP is 1,000′ or upto half the width of the river. On line DD_1 points say 20′ apart are marked and rays from P passing through these points intersect the section line at B_1, B_2, B_3 etc., each 100′ apart, as is evident from principle of similar triangles. The point P is called the *pivot* point. For accurate daily work the position of flags along the section line, *pivot* point and direction line are marked by cement concrete blocks with holes for flags and the arrangement is thus marked semi-permanently. The layout can be checked by the theodolite, as angles subtended by B_1P, B_2P etc., with AP should have tangents increasing in ratio of segments *e.g*, with 100′ segment and 500′ length of AP, tangent $\theta_1 = \frac{100}{500}$ tangent $\theta_2 = \frac{200}{500}$, tangent $\theta_3 = \frac{300}{500}$ etc.

For rivers wider than 2,000′ pivot points layouts are made on both banks, for work by two different parties from the two banks. Pivot point layout for Harike site on the Sutlej is shown in Plate III and is self evident.

In case of physical difficulties like uneven ground the length and angle of the pivot point line, can be varied, and the observer can easily locate the sounding points with theodolite by his knowledge of trigonometry. The section line is marked by R.Ds and the water edges go on changing with season.

In slack velocities and low depths the boat is kept in position by a boatman standing in water and in high velocities or greater depths, the boat is kept in position by an anchor. Up to about 5′ per second velocities, the boat can be rowed from station to station. In higher velocities while pulling out the anchor it loses headway and to be brought to bank or in slacker water for being rowed up. This detouring involves lot of time. To reduce number of detours the anchor is thrown about 300′ upstream of the section line by means of a subsidiary flag line or pivot point arrangement, and at every station a little headway is lost, enabling about 3 or 4 stations to be done at a time without detour, in velocities as high as 8 to 10 ft. per second. The difficulty and risk involved in pulling out the anchor under such conditions are appreciable, and the latest method of securing the anchor shown in Plate II as introduced by Mr. Fletcher, is the safest, though it involves introduction of some drift. Trained crew can, however, cope with even the most difficult conditions met with at some sites during floods. Under extreme conditions, provision of power launches may be necessary which shall facilitate the process of observation.

(*xiii*) Having divided the section into segments, first procedure of discharge observations consist in taking the boat to a station by wire rope or pivot point method as in use at site, and observing the depth. The current meter is then lowered by rack and pinion to 0·6 depth and velocity is recorded. The angle of the current with the section line is then read by means of the torpedo float and pocket sextant. These observations are noted in a discharge note book, a specimen copy of which is shown in Appendix I, which shows full procedure for calculating the discharge. The velocity at each station is modified for its angle and the product dxV_m gives the ordinate of the discharge curve at each station. The total discharge is found by straight averaging. Further, the wetted perimeter is also calculated and slope observed for working out the value of Kutter's N. This is taken as the mean of the slopes on the two banks. Details of meters and other equipment used, along with calculations for discharge and Kutter's N as prepared by observers at each site daily are shown in the form, a specimen of which is given in Appendix I for the Harike site on the Sutlej. The method of recording is clear, self-evident and foolproof and the data collected can be used to check the accuracy of field work from day to day.

In the absence of boats, improvised arrangements consisting of bull skins and charpoys, called khatnaus are prepared for discharge observation in hills. Photograph No. I shows such a khatnau in use at Larji on the Beas.

When discharge is observed by holding a boat from a bridge the section line should be atleast 500′ downstream so as to have the observations removed from the disturbance caused by the effect of the piers. In case, under unavoidable circumstances, a discharge is observed from a bridge, the segments should be spaced so that no observation point lies too near a pier, or within the zone of disturbed water.

In some hill sites, where it is impossible to hold a boat or khatnau in extremely high velocities in monsoon months, observations of section are made from available suspension bridges and surface velocities with current meters are observed. Photograph No. 2 shows such an observation being taken at Larji. Where no such bridges exist, surface floats are used for measuring velocities, by extending wires across the rivers at the ends of straight lengths. In cases, where soundings are not possible, cross section taken in low supplies are used, by superimposing increase in gauge. This method is practically out of use now except in some hill sites where actual measurement of section in floods is physically impossible.

Another approximate method of estimating a flood discharge in the absence of suitable equipment, is to observe the slope and flood level at the time. A cross section is observed at lower supplies and from it the X. Section at the highest flood deduced. Having determind the slope S and hydraulic mean depth R, the mean velocity is determined by one of the following empirical formulae :—

(*a*) Chezy's formula $V = C\sqrt{RS}$ where value of C is determined either by Kutter's or Bazin's formula given in all books on hydraulics.

(*b*) Manning's formula $V = \frac{1{\cdot}4858}{N} R^{2/3} S^{1/2}$

(*c*) Lacey formula $V = \frac{1{\cdot}3458}{N_a} R^{3/4} S^{1/2}$

6. Canal Discharges. This is the subject with which all irrigation engineers must be well conversant as it forms part of their every day routine. The discharge site should be in a straight reach of not less than ten times of the width, not in close proximity of a fall, bridge or any disturbing factor, with trimmed berms and should preferably have pitched slopes and part bed. In main canals and branches, segmentation is made so as to have two slope segments one on each side, two side segments one on each side and one central segment with six equal subsegments. Velocities are measured with the current meter at the centres of slope segments and ends of all other segments. The discharge is measured by the area of the curve, formed by ordinates at each point formed of the product of velocity and depth. The areas are measured as below :—

(*a*) Slope segments by Simpson's rule *viz.* area of an irregular figure divided into any even number of equal parts $A = \frac{S + 4E + 2N}{3} \times d$, where S = sum of first and last ordinate, E = sum of intermediate even segments, N = sum of intermediate odd segments and d = common distance.

(*b*) Side segments by straight averaging like area of a trapezium.

(*c*) Centre segment by Weddle's Rule *viz.* Area $= \frac{3h}{10}$ [sum of odd +5 (sum of even) + sum of every third excluding extremes], where h is common distance.

Plate IV shows the segmentation, velocity measurement points and method of calculating area of discharge curve for main canal and branches. Forms for observing discharges are accordingly prepared.

For observing discharges of canal with velocity roads or floats, lengths of runs are 100 ft. for main canals, 50 to 75′ for branches and distributaries, 15 to 25′ for minors and 10 to 15′ for water courses.

In addition to the centre section line, similar segments are marked at the two ends of the run also. In first class observations, depths are measured at the three sections and meaned, for second class observations depths are measured at the upper and lower ends of the run only and for third class observations, depths are measured at the centre section only. In all three types of runs, three satisfactory runs through each velocity station over the whole run are taken, deviations not being permitted to exceed half a segment width.

The principle to be followed in segmentation for distributaries is that 5 segments, *viz.*, two slope, two side and one cente are marked out, and the centre segment is subdivided according to its length.

Parker states that all Punjab observations with rods over estimate the discharge by about 3 per cent and correction by Francis empirical formula allows for about half of the excess. He has therefore suggested raising of the constant from 0·116 to 0·2. With Francis formula the correction factors are :—

$$\frac{I}{D} = 0{\cdot}75,\ 0{\cdot}80,\ 0{\cdot}85,\ 0{\cdot}90,\ 0{\cdot}93,\ 0{\cdot}95,\ 0{\cdot}96,\ 0{\cdot}97,\ 0{\cdot}98,\ 0.99$$

$$\frac{V\text{mean}}{V\text{ rod}} = 0{\cdot}954,\ 0{\cdot}961,\ 0{\cdot}968,\ 0{\cdot}975,\ 0{\cdot}981,\ 0{\cdot}986,\ 0{\cdot}989,\ 0{\cdot}992,\ 0{\cdot}996,\ 1{\cdot}00$$

The discharges of drains are similarly measured in pitched runs of suitable length, by current meter if velocity is more than 0·75′ per second, by rods, if velocity is less than 0·75 but depth is more than 1·0′ and by surface floats using co-efficient 0·7, if velocity is less than 0·75′ and depth less than 1·0′.

For water courses, discharge is best measured from the outlets by applying appropriate formulae for A. P. Ms., open flumes, pipes or barrels. An ingenius device, consists in the use of a portable iron or wooden flume, which can be introduced into the water course, and made to work as a free fall.

7. Gauge Discharge Curve Method. Gauge is a device which reads the elevation of the water surface in a stream with respect to a certain datum. It either reads in feet, with zero at the lowest bed level of the stream or directly in reduced levels. A permanent gauge is fixed at or near a discharge site, the reading of which has always some relation to the prevaillng discharge. To be of statistical value, for studying the behaviour of a river, it is essential that the zero R. L. of the gauge should remain unchanged. Gauges are fixed in a line, at right angles to the

flow, and when necessary due to changes in the river course, they are shifted in the same section line. The gauges should be sited so as to represent truly the magnitude of discharge in a river, and be in a safe, unerodible and easily accessible place.

The daily discharges of a stream can be determined by finding out the relation between the gauge readings at a site and the corresponding observed discharges. This relation is of the form $Q = f(G) = C\ G^n$, where the values of C and n depend upon the form of cross section of the channel. The easiest method to determine the gauge discharge relationship is to plot the observed discharges as abscissae and corresponding gauges as ordinates and drawing a smooth curve through these points. A smooth curve shall be obtained so long as the general aspect of the X. Section of the river bed does not alter materially within the limits of gauge under consideration. From this curve by interpolation or extrapolation, discharges corresponding to daily gauge readings can be read off, or a discharge table can be prepared. The accuracy of discharges, and the table deduced therefrom shall depend upon the accuracy of the observed discharges. As the discharge depends upon area and mean velocities corresponding to the observed gauges, the deviation of a plotted discharge point from the smooth gauge discharge curve, can be investigated in relation to the velocity and area curves and the cause of in accuracy traced.

For extrapolation purposes, a straight line is preferable to a curve, being less liable to errors. The gauge discharge relationship is therefore plotted on a logarithmic scale, which gives a straight line, the relation becoming $\log Q = n \log G + \log C$, which is a straight line equation. The equation for the curve can also be determined from this, n being the slope of the straight line and log C its intercept on the Y axis.

The period for which the gauge discharge curve, so determined will hold, depends upon the stability of the site. It shall be practically permanent if the channel is in regime. For alluvial river sites, however, where the section is ever changing, such relationship applies only for one season and has to be revised every year. The orders in the Punjab are that for interpolation of discharges curves on the dates immediately preceding are prepared and used. Plate IV shows the Gauge Discharge, area and velocity curves for Harike site on Sutlej for 1943-44. The equation for this curve by Logarithmic plotting is $Q = 19{\cdot}2\ G^{3{\cdot}5}$.

8. Weir Method. This consists in measuring the depth of water over the crest of a weir, including the velocity of approach and the use of this depth or head in a suitable weir formula. Rectangular weirs of two types *viz.*, sharp crested and broad crested are used for discharge observations and have the following characteristics :—

(*i*) *Sharp crested weirs.* The discharge over a sharp crested weir is effected by (*a*) the sharpness of the crest, (*b*) smoothness of upstream face of the weir, (*c*) distribution of velocities in the approach channel and (*d*)

ventilation beneath the nappe. The discharge is quite accurately given by Rehbock's formula,

$$Q=\frac{2}{3}\sqrt{2g}\,L\,H^{3/2}\left(0{\cdot}605+\frac{1}{320H-3}+\frac{0{\cdot}08}{p}H\right)$$

where L=length of weir and P=height of crest above floor of upstream approach channel.

It is, however, difficult to maintain a weir in the standard condition and a departure from such conditions means increased discharge. This type of weir is used mainly for experimental purposes and is rarely found on the irrigation channels.

(*ii*) *Broad crested weirs.* A broad crested weir, working modularly forms accurate means of measuring the discharge and this method is in use on most of the Punjab canals now. The previous practice, which is being replaced, was to frame a discharge table for the earthen section of a channel, from accurately observed discharges in the form $Q=K\,D^{5/3}$. The discharge over a broad crested weir is given by the formula $Q=C\,L\,(h+ha-hf)^n$ where C=3·087, the maximum theoretical value under any conditions and n=1·5. The head due to friction h_f varies with velocity, silt contents, water temperature and viscosity, and is negligible. Further, due to local peculiarities of construction the theoretical values of C and n are not attained in actual practice and the weirs are calibrated before being applied for discharge measurements. The process of calibration consists in actual observations of discharges with extreme accuracy and care at $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and full supply conditions and thus at least seven observations are collected at different gauges. The equation for the meter is then worked out by the method of least squares applied to logarithams of the observed data. The head to be used in the formula is the depth of still pond level over the crest, *i.e.*, the gauge plus head due to the velocity of approach. It is, however, more convenient to find the relation of the discharge with direct gauge reading without adding the head due to velocity of approach and this shall apply only within the range of gauges observed. Two meters have recently been calibrated and the following relations have been obtained :—

Site of meter.	Equation in terms of $H=h+ha$	Equation in terms of gauge reading.
R. D. 27000 L. B. D. C.	$q=3{\cdot}18643\ H^{1{\cdot}50298}$	$q=3{\cdot}11277\ G^{1{\cdot}542887}$
R. D. 1000 L. J. C.	$q=3{\cdot}03309\ H^{1{\cdot}5031}$	$q=2{\cdot}96868\ G^{1{\cdot}5821}$

It will be seen that the co-efficient and index of head vary appreciably from the theoretical values, and the reasons can be traced to peculiarities in construction. It is held by Parker that " a weir is a very accurate measuring instrument but like all other measuring instruments it must be carefully standardised in order to get the best results from its use and the standard should be copied in details, which at first site appear

to have no real effect upon the discharge." The necessity for standardisation of such weirs in respect of shape and splay of wing walls, position of gauge wells etc. is manifest from the above facts.

The accuracy of calibration depends upon the accurate measurement of Q and H, the two elements in the weir formula, and precautions like proper selection of discharge site and siting of gauge upstream of draw down point with zero at mean crest level and calculation of velocity of approach at gauge section line, should be observed.

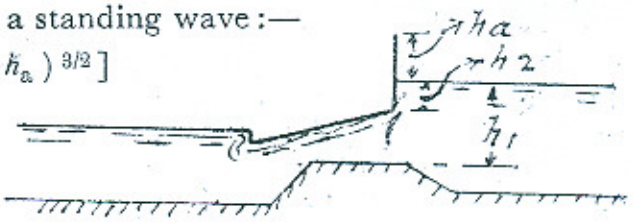
Observation of discharges should be taken with a pair of newly rated meters to obviate effects of temperature. Two observers should simultaneously take the observations in the form of a double traverse first from left to right and then right to left. The gauge should be kept steady during observations and should be read every fifteen minutes. Observations with a variation of ·02 ft. should be rejected.

As stated above, the deviations in the values of C and n from the theoretical shall depict the effect of local peculiarities in the construction of the meters, the theoretical values being for ideal conditions.

Lately, attention has been drawn in the Punjab to the desirability of determining the formulae applicable to measurement of discharge through barrage gates and over weirs and the following formulae, selected by Mr. Goodman are being tested by comparison with observed discharges with a view to ascertain the exact values of co-efficients, applicable in the cases of gates and weirs :—

(*a*) Gate on weir crest with a standing wave :—

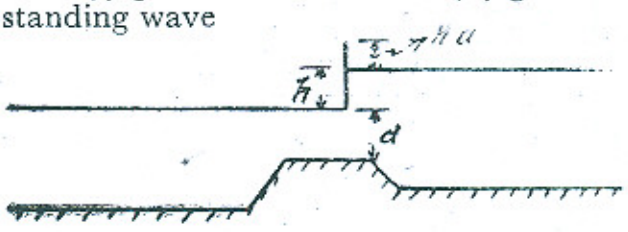
$$Q = C\,B\,[\,(h_1+h_a)^{3/2} - (h_2+h_a)^{3/2}\,]$$



(*b*) Submerged surface between (*i*) gate and raised crest (*ii*) gate and flat floor (*iii*) two gates and no standing wave

$$Q = CB\,d\sqrt{h+h_a}$$

where so far accepted value of C = 6·5 and actual is being determined.



(*c*) Gate clear with flow on weir.

$$Q = C_1 B\,(H+h_a)^{3/2}$$



where C_1 varies drowning ratio, generally from 3·3 to 3·0.

Observations so far made at Ferozepur show a rise in the value of C in formula (*a*) with rise in discharge. The matter is being investigated in the Research Institute also and can be taken up by the engineers-in-charge of Headworks.

Weir method being the most accurate one especially for smaller discharges is used for experimental and research work. In the Irrigation Research Institute at Lahore, the contrivances used are round crested weir, sharp crested weir and V notches. The weir have been calibrated by actual volumetic measurements and calibration curves have been prepared, which for the sharp crested weir agrees remarkably closely with Rehbock's formula. The V notches are made in steel plates with brass sharp edges. A 90° V notch was calibrated and gave the formula $Q=2{\cdot}25\ H^{2{\cdot}5}$ with H from 0·1 to 0·6 against the following formulae arrived at previously :—

Thompson $Q=2{\cdot}54\ H^{2{\cdot}5}$ —with H from 0·1 to 0·6.

King $Q=2{\cdot}52\ H^{2{\cdot}47}$—with notch cut in commercial steel plate.

Barr $Q=2{\cdot}48\ H^{2{\cdot}48}$—Polished brass plate.

No calibration for a 60° notch has been done so far in the Institute. This notch is used for small discharges as the smaller angle gives greater head for the same discharge and more accuracy. In calibrating V notches the gauges were read up to ·0004′ with a vernier scale. In the Institute, discharge up to 5·5 Cs. are measured with sharp crested weirs and 2·0 Cs. with the V notches.

Further investigations regarding discharge measurements. The subject of accuracy in measurement of discharges is still on the agenda of the Central Board of Irrigation and attempts at research in this direction are being made in various provinces. In the Discharge Division, investigations regarding the following subjects are in hand :—

(*i*) Minimum time required for observations of velocities with a current meter so as to even out the effect of variations in velocity. In the Punjab 2 minutes is the minimum period and has given satisfactory results, but some doubt has sometimes been shown by some authorities especially in hill sites.

(*ii*) Position of mean velocity point in a vertical in hill sites, where presence of turbulence upsets the 0·6d figure accepted for the plains. At present actual position is worked out daily for a certain number of verticals before discharge observations in the hill sites.

(*iii*) Relation between surface and mean velocities in rivers. The reduction factor 0·89 applies universally in the Punjab as deduced by Mr. Goodman, but the C. B. I. have required institution of further observation. The factor may vary slightly for deeper and swifter channels.

(*iv*) Effect of proximity to rigid boundaries on the performance of current meters, leading to rod observations in channels of less than 4·0′ depth and determination of relation between ·8D rod velocities

and ·94D and current meter velocities. The results of investigations in the Punjab so far made have been stated and further work is in hand.

(*v*) Effect of turbulence and temperature on performance of current meters.

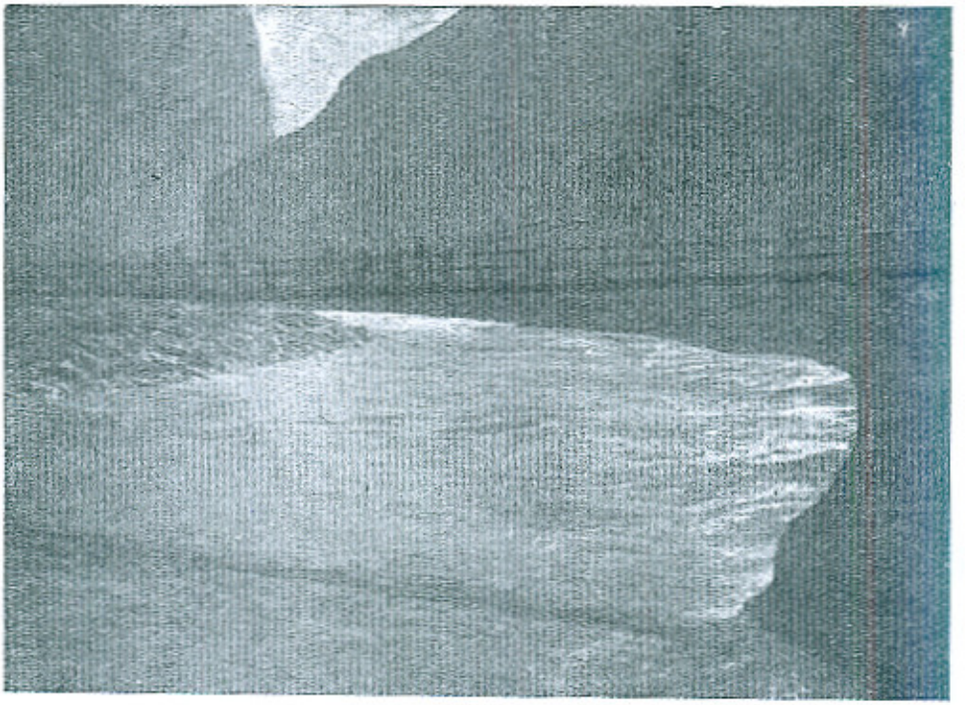
In conclusion, the writer wishes to stress the importance of accurate measurement of discharges for the irrigation engineers both in practice and research work. The subject is becoming more important with the enhancement of the value of water with the development of irrigation and it is hoped that desired co-operation will be offered by the profession in perfecting the methods being developed by the Discharge Division.

Plate 1.

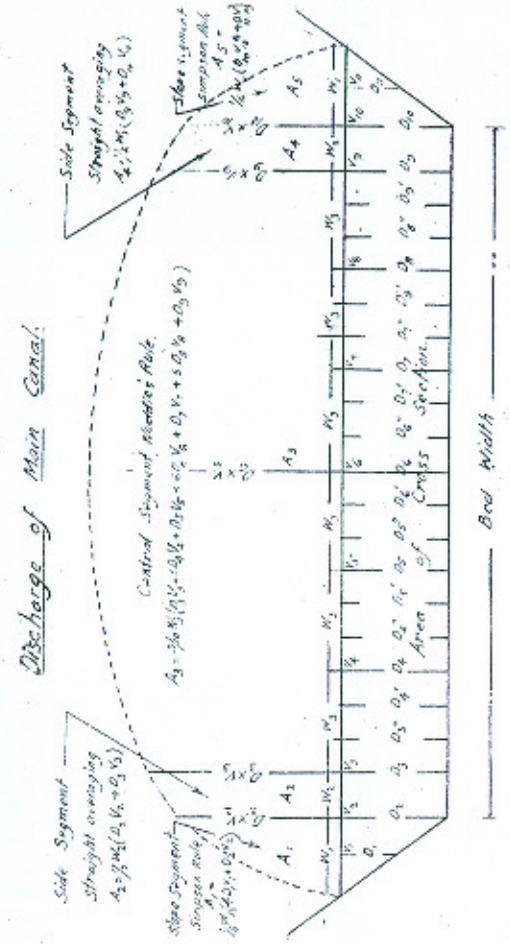


Discharge Observation from a Khatnau at Larji on Beas.

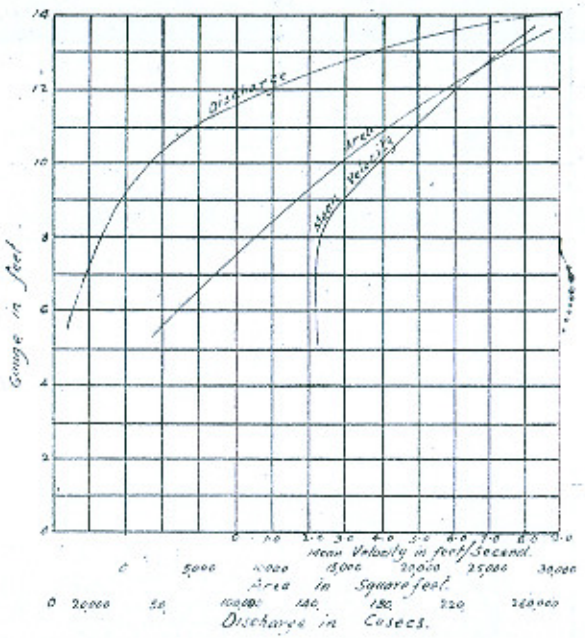
Plate 2.



Discharge Observation from Suspension Bridge at Larji on Beas.

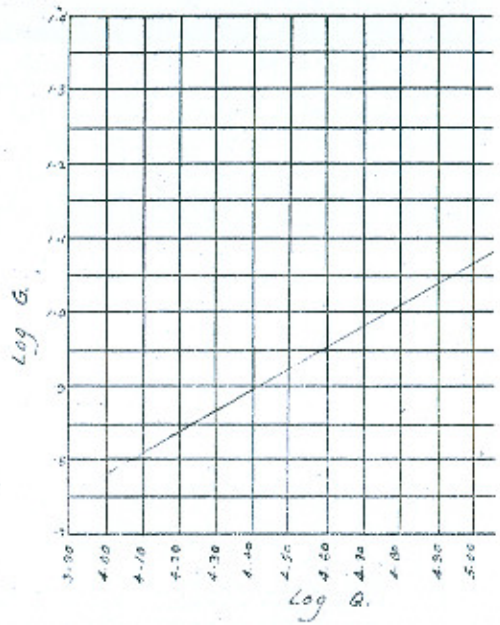


Discharge area and mean Velocity Curves of The River Sutlej at Harike.



Logarithmic Plot for Gauge Discharge C

$Q = 19{\cdot}2\,G^{3{\cdot}30}$



PUNJAB GA

DAILY DISCHARGE DATA 10-9-44.

R. D. on Section.	Water Depth.	Difference of Depth.	Increase of Bed.	Time.	Revolutions of meter.	Surface Velocity.	Mean Velocity.	Angle of current with the section line. = a	Correction for Angle.	Modified Velocity Col. 8 × Col. 10.	Drift in feet.	Velocity Correction for Drift.	Final Modified Velocity.	Col. 2 × Col. 14.	Correction + or − for unequal Segments.	Kind of Boat used.	Weather unfitted or not.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
L. B. 0—2400	Dry.	...	...	m. s.	...	Velocity observed at 6 D.	...	...	...	...	Nil	Nil	...	...	...	S. T. Boat.	Anchored.	
2369	0·6	0·4	...	2·24	25		0·44	82°	...	0·44			0·44	0·18				
2606	1·7	1·3	·01	2·26	96		0·72	98	—	0·72			0·72	1·22				
2700	3·5	1·8	·01	2·32	63		1·11	97	·01	1·10			1·10	3·85				
2800	6·4	2·9	·04	2·42	60		1·97	99°	·02	1·95			1·95	9·92				
2869	11·4	5·0	·18	2·52	125		2·44	98	·02	2·42			2·42	27·99				
3009	16·5	5·1	·05	2·52	269		2·88	100	·04	2·84			2·84	44·18				
3106	17·8	2·7	·03	2·60	256		4·05	92	—	4·05			4·05	53·69				
3200	9·3	2·0	·02	2·14	250		4·41	89	...	4·41			4·41	49·82				
3380	13·0	3·2	·05	2·27	250		4·03	88	...	4·03			4·03	32·99				
3469	19·2	2·9	·03	2·34	203		3·54	89	—	3·54			3·54	39·11				
3508	11·9	0·3	...	2·05	868		3·14	95	—	3·14			3·14	39·54				
3600	11·5	0·3	...	2·08	180		2·97	93	·01	2·96			2·96	34·04				
3700	10·2	1·3	·01	2·06	190		3·01	95	·03	2·98			2·98	30·40				
3800	9·6	0·6	...	2·12	183		2·69	103	·04	2·65			2·65	25·94				
3900	7·8	1·8	·02	2·20	225		2·13	104	·05	2·08			2·08	16·15				
4000	2·7	5·1	·13	2·34	25		0·50	104	·01	0·49			0·49	1·32				
4040	...	2·7	·09	...	...		...	...	...	...			...	...	...			

Total ... 139·5 Total ... ·92 — — —

PAPER No. 272

APPENDIX I

DAILY DISCHARGE DATA.

Form DI.

River SUTLEJ Site HARIKE Date 10-9-1944

Meter No. and make GURLEY No. 171 – 22,304 – S Time from 7/30 HRS. To 12/0 HRS.

Equation of Meter V = 2·35 N + ·03

Date of last rating 6-4-1944

Description of surface floats .....

Length of float run .....

Float run marked with .....

Section line marked with PIVOT POINTS

Sounding taken with SOUNDING RODS

Method of suspending meter RACK AND PINION

Timepiece used STOP WATCH

Weight used lbs.

Condition of water { Fairly Clear / Ordinarily Silty / Intensely } Yes. ,,

Gauges.	Permanent.	Temporary. R.B.	Temporary. L.B.
Zero R. L.	670·56	670·56	670·56
Beginning.	9·10	8·95	8·97
End.	9·08	8·93	8·95
Mean.	9·09	8·94	8·96

Weather CLEAR

Wind direction and strength .....

→ very slight.
→ slight.
→ strong.
→ very strong.

Current

SURFACE SLOPE OBSERVED.

	Right Bank. Back.	Fore.	Difference.	Left Bank. Back.	Fore.	Difference.
500′ D./S.	7·25			6·76		
0						
500′ U./S.		7·06			6·58	
Fall in 1,000 ft. ...			0·19			0·18

Mean = 0·185

∴ S = 0·00019

V = Mean Velocity = $\frac{Q}{A}$ = 3·05

R = H.M.D. = $\frac{A}{p}$ = 8·62 $\sqrt{R}$ = 2·94

$\sqrt{RS}$ = 0·040

$C = \frac{V}{\sqrt{RS}} = 76·25$

$X = 41·6 + \frac{·0281}{S} = 56·40$

$Y = \frac{CX}{\sqrt{R}} = 1,463$

$Z = C - X = 19·90$

$N = \frac{\sqrt{Z^2 + 7·244Y}) - Z}{2Y} = 0·028$

Character of river bed SANDY

Class of roughness under which it falls II

Passed for check by INITIALS S.D.O. II dated.....

Checked by COLLATOR dated.....

Rough volumed by COLLATOR dated.....

Compared & recorded by HEAD COLLATOR dated.....

ON HIS MAJESTY'S SERVICE.

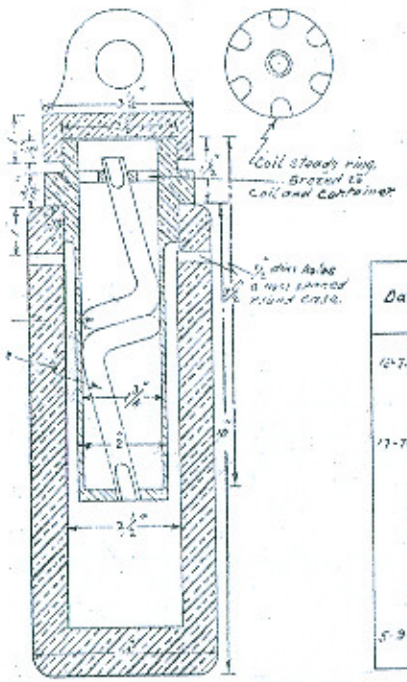
THE SUB-DIVISIONAL OFFICER,
DISCHARGE SUB-DIVISION.

STAMP

Observed by (Sd.) Pritam Singh Dhaliwal, O. S.
10-9-1944.

HAIGH'S DEPTH METER

scale 3/8" = 1"



Some tests made with

HAIGH'S DEPTHMETER No 1

at kalnagh on 16.7, 17.7, and 5.9.44.

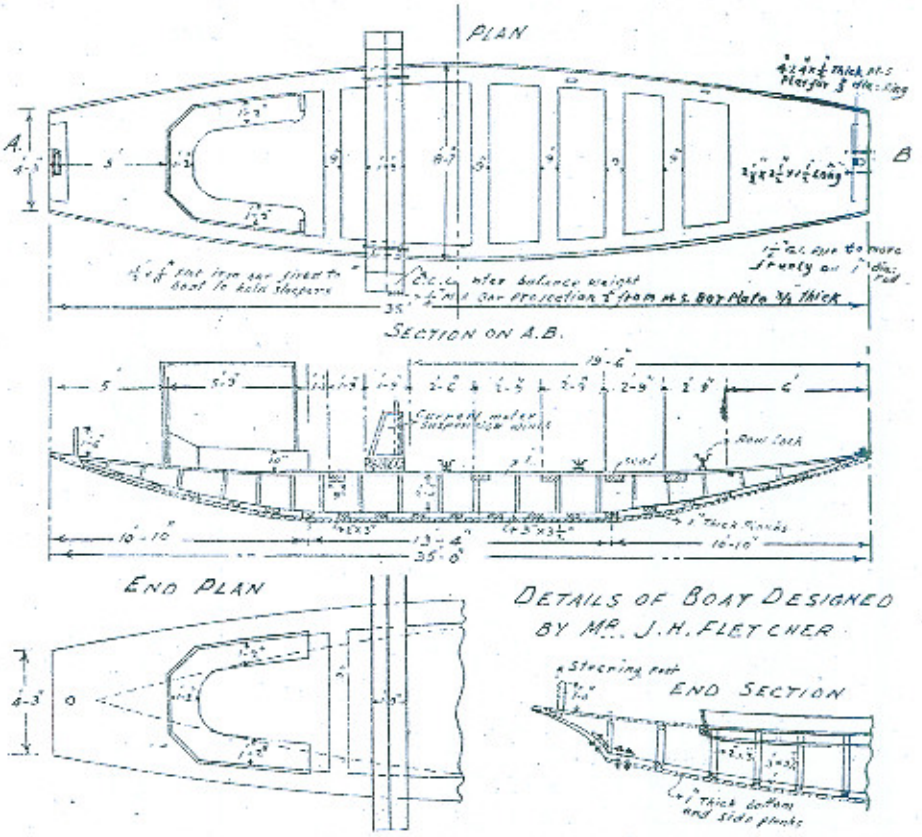
Dates	Stations	Mean depth with rope and weight	Mean Volume of water submerged in c.c.	Depth from Calibration Curve
16.7.44	0/1	29·4	196·0	29·2
	1/2/3	40·6	135·0	41·0
17.7.44	1/1	7·0	56·6	8·1
	1/1	29·1	147·0	29·6
	1/3/3	39·2	133·0	39·3
	1/1/2	27·6	182·0	27·2
	1/1/3	31·9	159·0	34·0
5.9.44	1/1/2	18·0	103·3	17·0

CALIBRATION CURVE for DEPTHMETER No 1

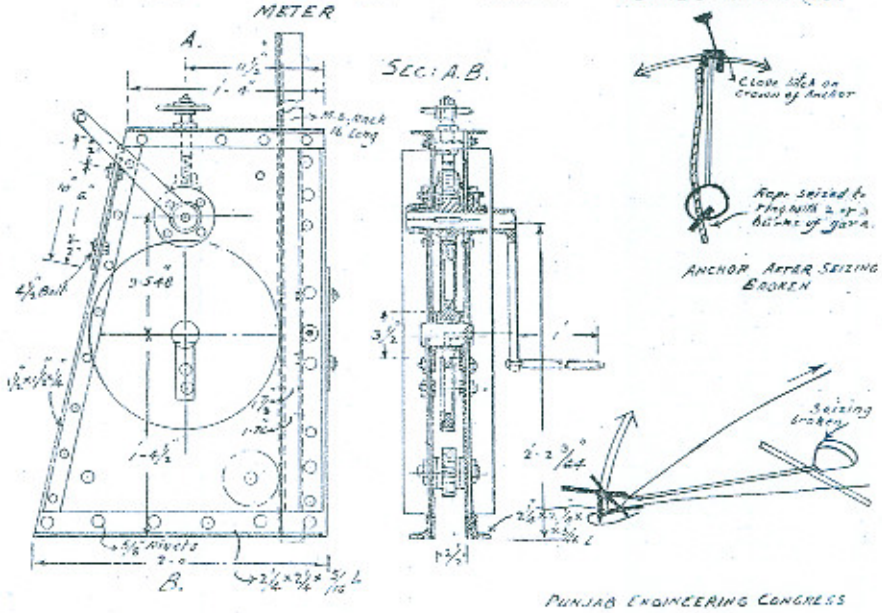


PLATE 2
PAPER 2T2

DISCHARGE EQUIPMENT
35' SUKKUR TYPE BOAT



RACK AND PINION
SUSPENSION ARRANGEMENT FOR CURRENT METER



METHOD OF TYING ANCHOR

ANCHOR AFTER SEIZING BROKEN

PUNJAB ENGINEERING CONGRESS
1945

PLATE 3
PAPER 272

PIVOT POINT LAYOUT
AT HARIKE
ON THE SUTLEJ RIVER

