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RAPID ASSESSMENT OF FLOW DATA FOR FLOOD AND DROUGHT MANAGEMENT A ROBUST TECHNIQUE FOR PRECISE DISCHARGE MEASUREMENT

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RAPID ASSESSMENT OF FLOW DATA FOR FLOOD AND DROUGHT MANAGEMENT A ROBUST TECHNIQUE FOR PRECISE DISCHARGE MEASUREMENT

By:

Dr. Muhammad Riaz [(1)], Zia-ul-Hassan [(2)] and Habib-ul-Rehman [(3)]

ABSTRACT

Irrigated agriculture is the major determinant of economic growth potential of the Punjab Province as it accounts for 26 percent of the GDP and caters for over 40 percent of the province's work force. The traditional system of flow monitoring in Punjab Irrigation Network is quite old and incapable to serve the purpose of efficient planning and management of irrigation water. The deteriorated conditions of the gauges, conventional system of gauge readings and delay in communication of the readings are the main factors causing poor quality of data, inadequate measurement and unreliable estimations. It leads to low performance of irrigation system in the province. Punjab Irrigation Department (PID) is operating and maintaining the largest integrated system in the world. In order to ensure equitable distribution of canal water to the irrigation network, discharge observations of main canals, branch canals, distributaries, minors and sub minors especially at critical points of channels, need to be carried out on seasonal basis.

Various methods for discharge measurement of Irrigation canals and watercourses including flow meter, tin flumes and velocity rod are commonly used but these have limited application in view of nature / size of channel. Current Meter is also commonly and extensively used for discharge measurement having two types i.e., Price Type-A Current Meter and Price Pygmy Current Meter. Current meter has now become obsolete all over the world as its use for discharge measurement is laborious, hectic & time consuming. The latest modern equipment used for discharge measurement of Rivers and Irrigation Canals is Acoustic Doppler Current Profiler (ADCP) with fixed and moveable types but there a need arises how to compare these discharges and upto what extent these are accurate. Through this study, an effort has been made to compare the discharges by both methods alongwith its degree of accuracy.

Comparing results of simultaneous measurements taken with current meters and an ADCP for more than 20 rivers and main canal sites reflects that conventional Current Meter gives 10% higher discharge as compared to that with ADCP. The main reason for the higher discharge is that during discharge measurement of rivers & unlined /earthen channels, current meter compresses the bottom layer sediments of the channel resulting more depth and consequently more area & discharge than that for ADCP. Results also depicts that discharge observation by ADCP is more reliable, accurate and robust as compared to conventional current meter method. Moreover, ADCP measures velocity at every point while for current meter, it is not possible to measure velocity at every point of selected section. In view of the accurate & reliable results by ADCP, the author recommends the use of ADCP for discharge measurement on rivers and at critical points

of irrigation canals all over Pakistan especially for resolution of water distribution conflicts between the upper and lower riparians.

Key Words: Current Meter, Acoustic Doppler Current Profiler (ADCP), Tine Flume and Velocity Rod and Water Distribution Conflicts

1 GENERAL

Mostly, the discharge is not measured directly, but is computed over the measured depth of water, since this is a function of depth of water. Small discharges can be measured directly. For large discharges, there are standardized profiles, which are built into the stretch of waters or channel. Following are the equipments commonly used for discharge observation of irrigation channels.

i. Tin Flumes
ii. Velocity Rod
iii. Current Meter
iv. Acoustic Doppler Current Profiler (ADCP)

1.1 Tin Flumes

Tin Flumes are commonly used to determine the discharge of *Moghas* (outlets) having unlined watercourses. After the site has been selected, it is necessary to determine certain design criteria. The maximum quantity of water to be measured, the depth of flow in the channel corresponding to this discharge, and the allowable head loss through the flume must be determined.

Measurements should be made in the Tin Flume by the use of piezometers connected to stilling wells. The staff gauges must be carefully referenced to the elevation of the flume floor. The Stilling wells have the advantage of providing a calm water surface compared with the fluctuation of the water surface that usually exists within the Cutthroat Flume.

1.2 Velocity Rod

It is only suitable for wadeable streams with laminar or semi-laminar flow. The range of depth has to be from 5 to 75 cm. The velocity range needs to be from 0.1 to 0.9 m/s

1.3 Current Meter

Current Meter is a commonly and extensively used discharge measuring equipment. Two of the commonly used vertical-axis current meters are the Price Type A current meter and the Price Pygmy current meter, which are used for shallow flow depths and low velocities. Usually, the larger current meter is employed when the flow depth is greater than 1.5 feet (45 cm) while Pygmy current meter is used in case the depth of water is less than 1.5 ft, The large current meter is commonly used for measuring discharge rates in the Secondary Canals (distributaries and minors), as well as the Primary Canals (main and branch canals) while the others are used for Tertiary irrigation channels (e.g., watercourses).

1.4 Acoustic Doppler Current Profiler (ADCP)

The ADCP is a high performance water current profiler. It measures water current with sound using a principle of sound waves. It receives the velocity of water using a physical

principal called Doppler shift. The main external components of an ADCP are transducer assembly and a pressure case. The transducer assembly consists of four transducers that operate at a fixed, ultrasonic frequency, typically 300, 600, or 1200 kilohertz (KHz). The transducers are horizontally spaced 90 degree apart on the transducer assembly; all transducers have the same fixed angle from the vertical, referred to as "beam angle" that is typically 20 or 30 degrees.

When an ADCP is deployed from a moving boat, it is connected by a cable to power source and to portable microcomputer. The computer is used to program the instrument, monitor its operation, and collect and store the data.

2. METHOD FOR DISCHARGE MEASUREMENT

2.1 Using Current Meter

Discharge is the volume of water flowing through a cross section of waterway per unit time. The unit used to measure discharge is usually ft^3/sec (cusecs) or m^3/sec (cumecs). Stream flow records are primarily continuous records of flow passing through a particular section of the stream. Stream flow data are analyzed to determine the magnitude and variability of surface waters. These records are input in planning, design, and operation of surface water projects and are also used in design of bridges and culverts, flood forecasting systems, and flood plain delineation. The sections where discharge measurements are carried out are known as stream gauging stations.

A network of these stations is established to collect data about surface water resources of a region. There exists a relationship between stage and discharge at a section. This relation is termed as stage-discharge relationship or rating curve.

2.2 Measurement of Velocity

Velocity of flow at a point is usually measured by counting revolutions of a current meter rotor during a short time period measured with a stop-watch. The current meter is suspended in the flow on a rod or on a wire. A current meter measures velocity at a point. The method of making discharge measurements at a cross-section requires determination of the mean velocity in each of the selected verticals. The mean velocity in a vertical is obtained from velocity observations at many points in that vertical. The mean can be approximated by making a few velocity observations and using a known relation between those velocities and the mean in the vertical.

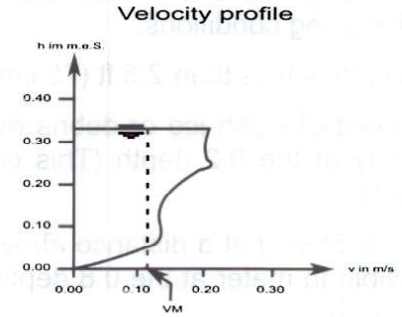


Figure 2.1: Velocity profile along the depth of flow in a channel

Three commonly used methods for measurement of velocity (v) are as follows;

2.2.1 Two Point Method

In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the water surface. The average of these two observations is taken as the mean velocity in the vertical. This method is based on many studies of actual observation and mathematical analysis. Experience has shown that this method gives more consistent and accurate results than any of the other methods.

The two-point method is not used at depths of less than 2.5 ft (75 cm) because current meter would be too close to the water surface and to the stream bed to give dependable results. Fig 2.2 indicates conversion of x-section into subsections.

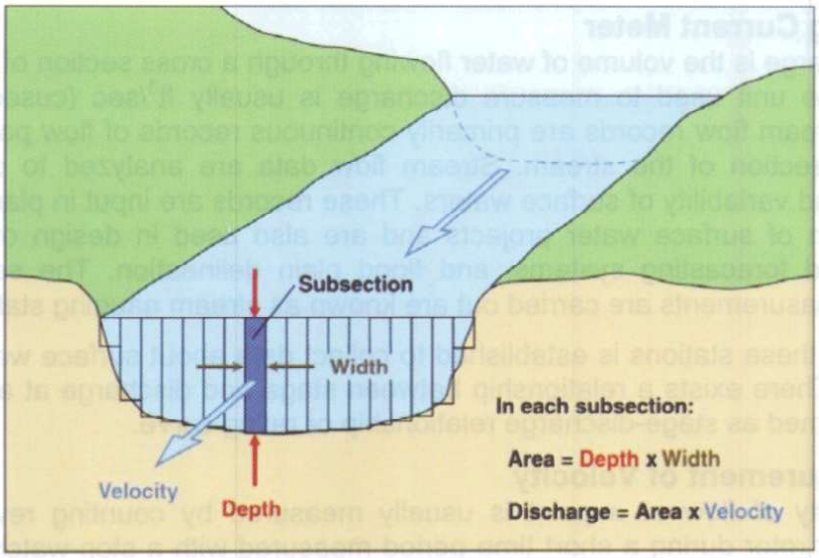


Figure 2.2: Schematic diagram indicating x-section into subsections

2.2.2 Six-tenth Depth Method

In six-tenth depth method, an observation of velocity at 0.6 of the depth below the surface in the vertical is used as the mean velocity in the vertical. Actual observation supported by mathematical analysis has shown that 0.6 depth method gives reliable results and is used under the following conditions:

i. Whenever the depth is less than 2.5 ft (75 cm).

ii. When large amount of slush ice or debris make it impossible to observe velocity accurately at the 0.2 depth (This condition prevents the use of two-point method).

iii. When the meter is placed at a distance above the sounding weight which makes it impossible to meter at the 0.8 depth (This also prevents the use of two-point method).

iv. When the stage in a stream is changing rapidly and a measurement must be made quickly.

2.2.3. Three-Points Method

This method is used when the velocities in the vertical appear to be abnormally distributed, such as having an unusual velocity distribution & where the flow depth is greater than 2.5 feet. The three point method combines both the two point method and the six-tenths depth method. Therefore, current meter measurements are taken at 0.2, 0.6 and 0.8 of the flow depth.

The mean velocity in the vertical is obtained by first averaging the velocities measured at 0.2 and 0.8 of the flow depth (two points method); then, averaging this result with the velocity measured at 0.6 flow depth. Thus, the mean velocity, V in the vertical would be:

$$V_{avg} = \left(\frac{\frac{(V_{0.2} + V_{0.8})}{2} + V_{0.6}}{2} \right) \qquad (2.1)$$

Where,

V_{avg} = the mean velocity in the given vertical (ft/s);

$V_{0.2}$ = the velocity at 0.2 of flow depth (ft/s);

$V_{0.6}$ = the velocity at 0.6 of flow depth (ft/s); and

$V_{0.8}$ = the velocity at 0.8 of flow depth (ft/s).

3. COMPUTATION OF DISCHARGE

Discharge is computed either arithmetically or graphically depending upon field procedure used to obtain the observation. There are two arithmetic methods for computing the discharge, i.e. the mean section method and mid-section method. Of these methods, the mid-section method has less procedural error; therefore, it is used for computing canal discharges.

3.1 Mid-Section Method

In the Mid-Section Method of computing a current meter measurement, the velocity is measured at mid-point of each section. The section area is obtained by multiplying width of section to its mean depth. The discharge is then computed for any section at vertical x by use of the equation,

$$q_x = \frac{V_x(b_x - b_{(x-1)})\,(dx - d_{(x-1)})}{2} \qquad (3.1)$$

Where

q_x = Discharge at section x;

V_x = Velocity at mid-point of section x;

$b_{(x-1)}$ = Distance from initial point to start point of section x;

b_x = Distance from initial point to end point of section x;

d_{x-1} = Distance from initial point to start point of section x; and

d_x = Distance from initial point to end point of section x.

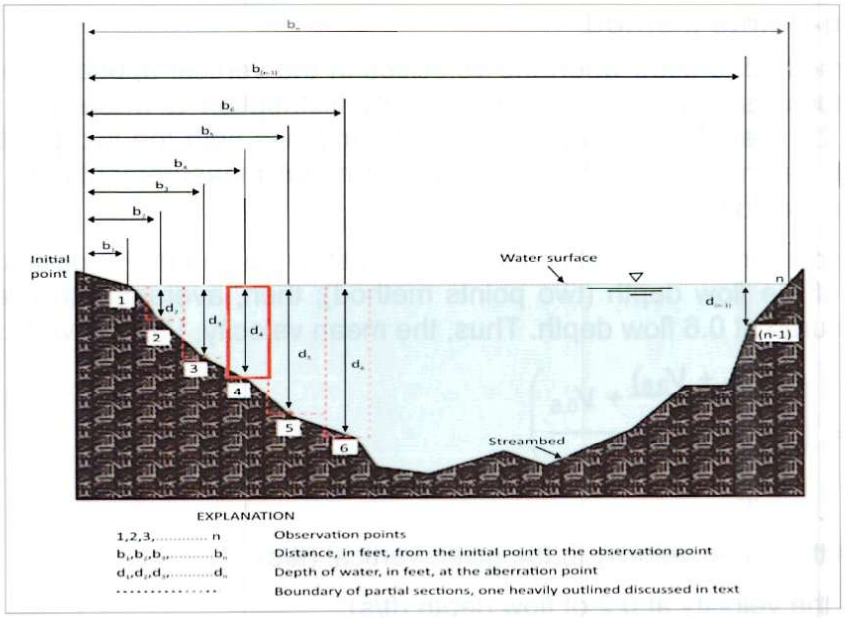


Figure 3.1: A typical River X-section showing the Mid-section method of measuring discharge.

3.2. Current Meter Ratings

Usually, a current meter is calibrated in a towing tank. The current meter is attached to a carriage that travels on rails (tracks) placed on the top of the towing tank. Then, a series of trials are conducted wherein the current meter is towed at different constant velocities. For each trial, the constant velocity of the carriage is recorded, as well as the revolutions per second (rev/s) of the current meter. This data is plotted on rectangular coordinate graph paper to verify that a straight-line relation exists; then, the equation is determined by regression analysis. Equation of our current meters is:

The velocity in English units is:

Velocity (ft/s)= 2.2048 (rev/s) + 0.0178

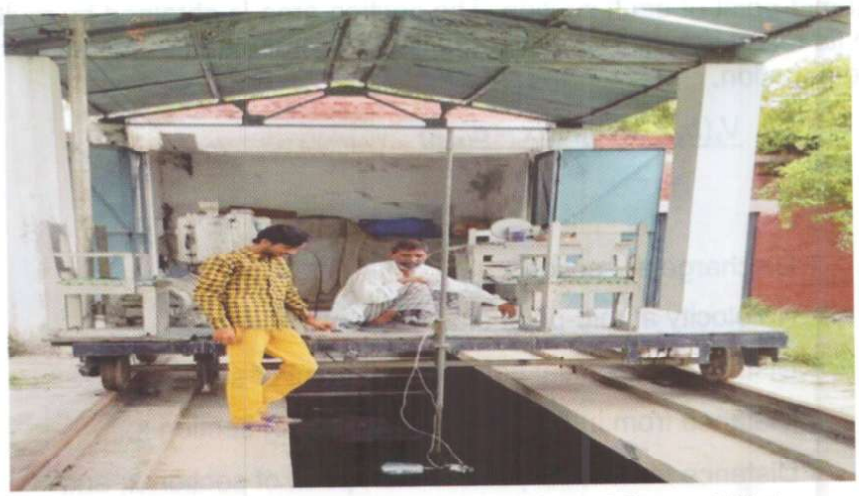


Figure 3.2: Trolley used for Calibration of Current Meter



Figure 3.3: Demonstration of Calibration of Current Meter

3.3 Methods of Using Current Meter

3.3.1 Wading Method

The wading method involves having the hydrographer stand in the water holding a wading rod with the current meter attached to the rod. The wading rod is graduated so that the water depth can be measured. The rod has a metal foot pad which sets on the channel bed. The current meter can be placed at any height on the wading rod and is readily adjusted to another height by the hydrographer while standing in the water. A tag line is stretched 'from one bank to the other, which can be a cloth or metal tape. This tag line is placed perpendicular to the flow direction. The zero length on the tag line does not have to correspond with the edge of the water on one of the banks. This tag line is used to define the location of the wading rod each time that a current meter measurement is made;

The channel cross-section is divided into smaller segments. Tin pendants should be attached to the section ropes at all the points of the main soundings which are also velocity stations; and the wading rod is held at the tag line. The hydrographer stands sideways to the flow direction and facing towards one of the banks. The hydrographer stands 5-10 cm downstream from the tag line and approximately 50 cm aside from the wading rod in order to ensure free flow. During the measurement, the rod needs to be held in a vertical position and the current meter must be parallel with the flow direction. Usually, the note keeper can signal to the hydrographer whether or not the rod is vertical in relation to the flow direction.

3.3.2 Boat Method

For some extremely wide channels, a boat is commonly employed. Discharge measurements are made from a boat where no cableway or suitable bridge is available and the stream is too deep to wade. Personal safety is the limiting factors in the use of a boat on a stream having high flow velocity.

4. DISCHARGE OBSERVATION OF RIVER & MAIN CANAL USING CONVENTIONAL CURRENT METER AND ADCP

A research study has been carried out by PMIU, Irrigation Department in order to determine the variation of discharge between the methods using Current Meter and

ADCP. In this regard, Eastern Sadiqia (ES) and Hakra Branch system were selected for discharge observation using both methods. Moreover, discharge measurements on River Jhelum and Chenab were also carried out using ADCP and traditional current meter. For rivers, the observation were carried at three stages of flow i.e., at low, Medium and high flows.

In this context, a preliminary survey was carried out in order to finalize the discharge measuring sites for both ES and Hakra Branch Systems and both rivers. Finally, 7 sites on ES and Hakra Branch Systems were selected while one site on Chenab river was selected on 500 meters downstream side of Alexandra Bridge, near GT Road Bridge, at Wazirabad and one site on Jhelum River was selected at New GT Road Bridge on 30 Km Upstream of Rasul Barrage. These channel sites have been selected keeping in view the location where distributaries have been taking off while rivers sites are so selected where Discharge Division of PID has already been using for discharge observations.

4.1 Discharge Observation at Channel sites

For comparison of discharge measured through current meter and ADCP, channels of Hakra Division were selected with the advantages that Real Time Flow Monitoring System (RTFMS) have been installed. Table 4.1 and Fig 4.1 reflects the location of channels on Google map where discharge observation by current meter have to be done;

Table 4.1: Location of channels at ESC System

Sr. No.	Channel sites Location	
1	Eastern Sadiqia Canal	(D/S Awami Canal)
2	Hakra Branch RD 74+350	(D/S 2R)
3	Hakra Branch RD 165+000 HB	(D/S 6R)
4	Hakra Branch RD 211+000	(D/S 7R)
5	Hakra Branch RD 232+000	(D/S 8R)
6	Hakra Branch RD 256+000	(D/S 9R)
7	Sadiq Ford Feeder (SFF) 187+650	

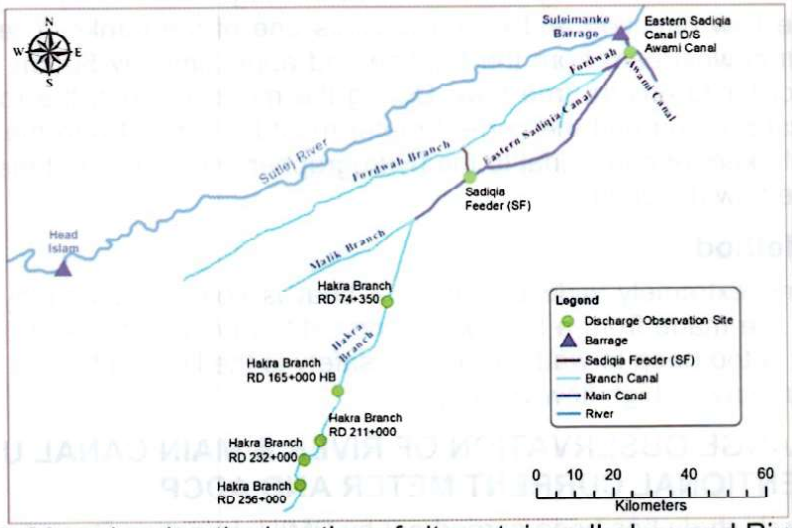


Figure 4.2: Map showing the location of sites at river Jhelum and River Chenab

Current Meter Price –A type has been used for discharge observation at the following locations. At some places boat has been used while for other locations wading method has been employed. Table 4.2 reflects the discharge observed using current meter. The Location of these channels have been marked on the google sheet.

Table 4.2: Discharge Observation of channels located at ESC System

Sr. No.	Date of Observation	Channel sites Location	Observed Discharge (Cusecs)
1	18.11.2018	Eastern Sadiqia Canal D/S Awami Canal	4200
2	19.11.2018	Hakra Branch RD 74+350	2289
3	19.11.2018	Hakra Branch RD 165+000 HB	1200
4	20.11.2018	Hakra Branch RD 211+000	1081
5	20.11.2018	Hakra Branch RD 232+000	1019
6	20.11.2018	Hakra Branch RD 256+000	735
7	18.11.2018	Sadiq Ford Feeder (SFF)	350

For river sites, two main active rivers have been selected for this study and discharge observation exercise was done simultaneously with various flow volume i.e. Low, Medium and High Flows. The location of these river sites are shown in Table 4.3 and Figure 4.2 as follows;

Table 4.3: Details of discharge measuring locations at River Chenab and Jehlum

Sr. No	River	Location	GPS Coordinates	
			Latitude (°N)	Longitude (°E)
1	Chenab	D/S old GT Road Bridge near Alexandra Bridge, Wazirabad	32.485554	74.098335
2	Jhelum	U/S side of Rasul Barrage & D/S side of Mangla Dam	32.906952	73.719215



Figure 4.2: Map showing the location of sites at river Jhelum and River Chenab

4.2 Special Arrangement for Discharge observation of River using Bridge Method

Discharge at River Chenab & Jhelum has been observed by using special arrangement of Trolley System. Trolley system consist of Depth-o-Meter, steel wire & fish weight. Fish weight of 52 lbs has been used for discharge observation of River Chenab & Jhelum. Trolley system has been used in order to attain straight & uniform sections throughout the width of the river as well as to avoid turbulence of flow which is usually caused by using motor boat. Special arrangement of Trolley system has been provided by the Discharge Division of Punjab Irrigation Department (PID). This system has been used for discharge observation of Rivers throughout the Punjab by the Discharge Division.

4.2.1 Discharge Observation By Using Current Meter

Discharge has been observed during May, 2019 by using Current Meter at following points.

i. River Chenab
ii. River Jhelum

4.2.1.1 River Chenab

Discharge of River Chenab has been observed at downstream side of old GT Road Bridge near Alexandra Bridge, Wazirabad on 09.05.2019. Discharge has been observed by three point method and single observation was made on 09.05.2019. Discharge at the same point was again observed on 15.05.2019 and two observations by three point method were made on 15.05.2019.

4.2.1.2 River Jhelum

Discharge of River Jhelum has been observed at upstream side of GT Road Jhelum Bridge on 22.05.2019. This point is located upstream side of Rasul Barrage & downstream side of Mangla Dam. Three observations were made out of which one observation was made by three point method and two observations were made by Six-tenth Depth method.

Table 4.4: Detail of Discharge observed using Current meter at River Chenab & River Jhelum

Sr. No	River	Date of observation	Observed Discharge (Cusecs)
1	Chenab	09.05.2019	8750
2	Chenab	15.05.2019	8300
3	Chenab	15.05.2019	8350
4	Jhelum	22.05.2019	50018
5	Jhelum	22.05.2019	50430
6	Jhelum	22.05.2019	50172



Figure 4.3: Discharge observation of River Jhelum by Current Meter using Trolley



Figure 4.4: Discharge observation of River Jhelum by Current Meter using Trolley

4.3 Discharge Observation Using ADCP

The ADCP measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column. The ADCP transmits pairs of sort acoustic pulses along a narrow beam from each of the four transducers. As the pulses travel through the water column, they strike with suspended sediment and organic particles that reflect some of acoustic energy back to the ADCP. The ADCP receives and records the reflected pulses. The reflected pulses are separated by time differences into successive, uniformly spaced volumes called "depth cells".

The frequency shift (known as "Doppler effect") and the time-lag between successive reflected pulses are proportional to the velocity of the scatters relative to the ADCP. The ADCP computes a velocity component along each beam; because the beams are positioned orthogonally to one another and at a known angle from the vertical (usually 20 or 30 degree), trigonometric relations are used to compute three-dimensional water velocity vectors for each depth cells. Thus, the ADCP produces vertical velocity profiles composed of water speeds and directions at regular spaced intervals.

ADCP provides the capability to make accurate, rapid and cost-effective measurements of river discharge.



Figure 4.5: Discharge observation by ADCP

An **Acoustic Doppler Current Profiler** (ADCP) is a hydro-acoustic current meter, used to measure water current velocities and discharge over a depth range using the Doppler effect of sound waves scattered back from particles within the water column

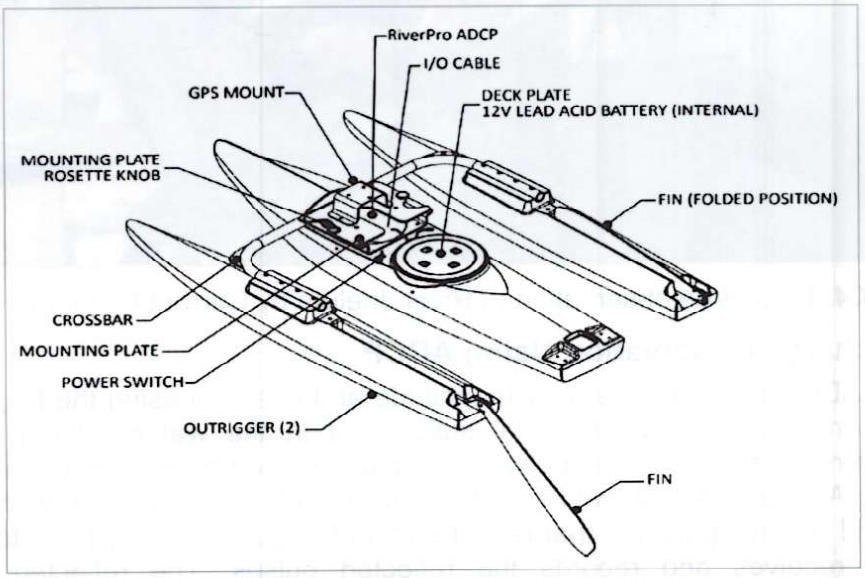
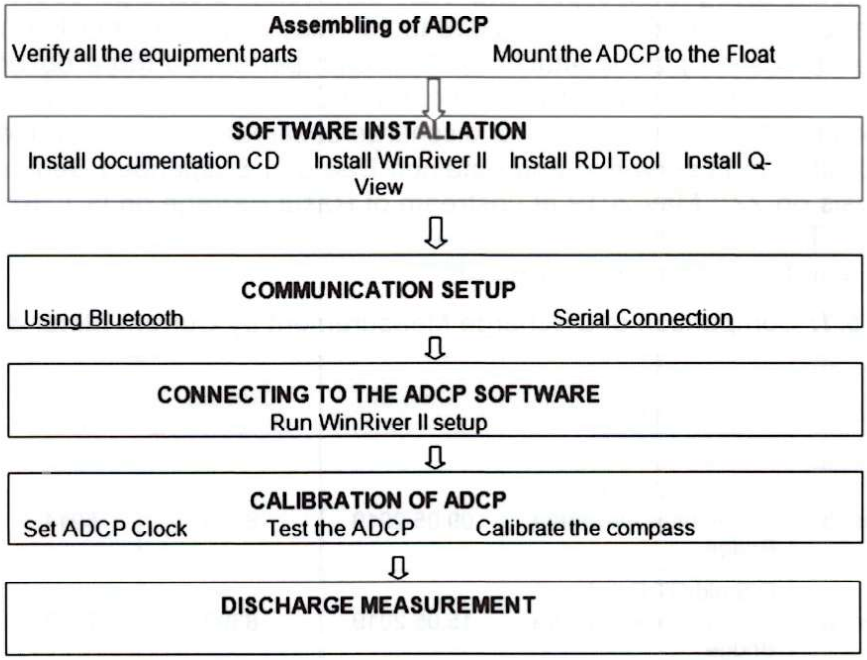


Figure 4.6: ADCP Float Overview

4.3.1 ADCP Operation Overview



Simultaneously, discharge observation activity was also carried out using ADCP on ESC system as well as river sites. The results are shown in Table 4.5 and 4.6.

Table 4.5: Discharge Observation of channels by ADCP located at ESC System

Sr. No.	Date of Observation	Channel sites Location	Observed Discharge (Cusecs)
1	18.11.2018	Eastern Sadiqia Canal D/S Awami Canal	4050
2	19.11.2018	Hakra Branch RD 74+350	2160
3	19.11.2018	Hakra Branch RD 165+000 HB	965
4	20.11.2018	Hakra Branch RD 211+000	861
5	20.11.2018	Hakra Branch RD 232+000	820
6	20.11.2018	Hakra Branch RD 256+000	540
7	18.11.2018	Sadiq Ford Feeder (SFF)	354

Table 4.6: Detail of Discharge observed using ADCP at River Chenab & River Jhelum

Sr. No	Date of observation	River sites	Observed Discharge (Cusecs)
1	09.05.2019	Chenab	5914
2	15.05.2019	Chenab	7883
3	15.05.2019	Chenab	7819
4	22.05.2019	Jhelum	44728
5	22.05.2019	Jhelum	42939
6	22.05.2019	Jhelum	42892

4. RESULTS AND DISCUSSION

The team along with supporting staff conducted discharge observation using current meter and ADCP from 9th May 2019 to 15th May 2019 at Old G.T. Road bridge of River Chenab (Location plan is attached). The team performed three observations with current meter and ADCP mounted with a boat. For Current meter observation, a special trolly mounted mechanism was used for discharge observation. Similarly, the same team performed discharge observation and obtained Bed and Suspended Sediment samples for lab analysis on 22nd May 2019 at upstream of Rasul Barrage on G.T. Road Bridge of River Jhelum. The same mechanism as mentioned above was also used for discharge observation using current meter and ADCP.

Table 5.1: Comparison of Discharge Measurement by Current Meter & ADCP

Sr. No	River	Location	Date of observation	Current Meter (Cs)	ADCP (Cs)	Diff. (%) from Current Meter
1	Chenab	D/S old GT Road Bridge near Alexandra Bridge	09.05.2019	8750	5914	-32
2	Chenab	D/S old GT Road Bridge near Alexandra Bridge	15.05.2019	8300	7883	-5
3	Chenab	D/S old GT Road Bridge near Alexandra Bridge.	15.05.2019	8350	7819	-6
4	Jhelum	U/S GT Road Jhelum Bridge	22.05.2019	50018	44278	-11
5	Jhelum	U/S GT Road Jhelum Bridge	22.05.2019	50430	42939	-14
6	Jhelum	U/S GT Road Jhelum Bridge	22.05.2019	50172	42892	-14
7	ESC	ESC D/S Awami Canal	18.11.2018	4200	4050	- 4
8	HB-1	HB RD 74+350 (2R D/S)	19.11.2018	2289	2160	-6
9	HB-2	HB RD 165+000 (6R D/S)	19.11.2018	1200	965	-19
10	HB-3	HB RD 211+000 (7R D/S)	20.11.2018	1081	861	-20
11	HB-4	HB RD 232+000 (8R D/S)	20.11.2018	1019	820	-19
12	HB-5	HB RD 256+000 (9R D/S)	20.11.2018	735	540	-26
13	SF	Sadiq Ford Feeder	18.11.2018	350	354	1

Graphs have been plotted in two categories, one having river discharges while other for channels of Eastern Sadiqia Canal (ESC) system. The same are represented at Figure 5.1 and 5.2. These graphs clearly depicted the variation of discharge observation ranging from -04% to -26 % less than that of current meter. Some value of discharge measured by current meter is on higher side which may be due to the reason that during the low flow season, the river converts into various creaks and some of them have very low flow with less depth resulting some errors with the current meter.

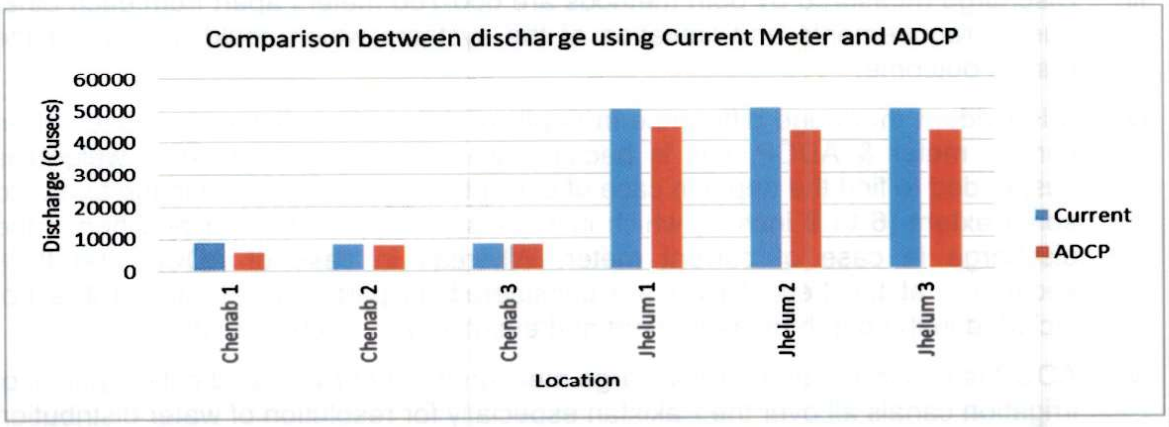


Figure 5.1: Comparison of discharge using current meter and ADCP (Rivers)

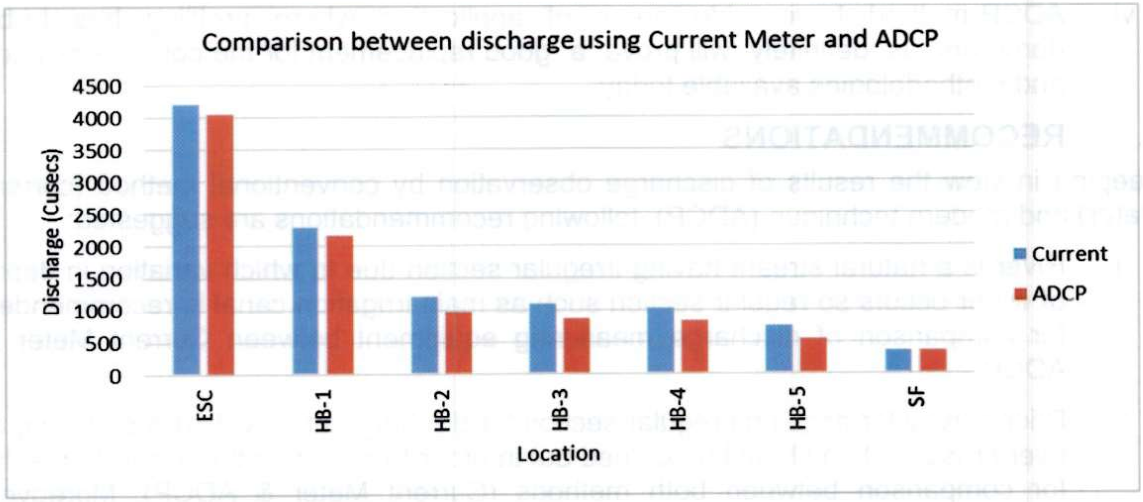


Figure 5.2: Comparison of discharge using current meter and ADCP (SESC System)

6. CONCLUSIONS

The ADCP advanced technique will be very helpful for the Water resource Engineers as well as planners. The difference of discharge between the two methodologies adopted has many logical explanations. These methods are different and few things must be considered before establishing relationship between two.

i. In case of discharge observation at River Chenab on 09.05.2019, difference -5% to -32% with average of -14% observed between discharge measurement of current meter & ADCP as ADCP boat could not float due to silted river bed and

regular section could not be attained in spite of searching different sections for discharge observation by ADCP. While in main canals, the variation ranging from -4% to -26% was observed with an average of -13%.

ii. The size of section in current meter (conventional method) is in feet whereas in case of ADCP size of ensembles in few centimeters which increase the accuracy of ADCP.

iii. Discharge measured by both methods are 600-700 meters apart from each other due to requirements and limitation of the systems which could also affect the results outcome.

iv. It is evident that huge difference in depth of different sections was observed in current meter & ADCP, this is because when artificial weight (fish weight) is suspended to find the depth in case of current meter, it is inserted in the bed upto some extent (6 to 9 inches) which increases the depth of water and hence the discharge in case of current meter. Whereas in case of ADCP, the thick sediments at the bed of river are considered as part of the bed and it is not included in the depth measurement and eventually in discharge calculation.

v. ADCP is recommended for discharge measurement of rivers and critical points of irrigation canals all over the Pakistan especially for resolution of water distribution issues between the provinces.

vi. ADCP method have wide areas of application where profiling has to be done and is definitely will prove a good replacement for the complex devices and methodologies available today.

7. RECOMMENDATIONS

Keeping in view the results of discharge observation by conventional method (current Meter) and modern technique (ADCP), following recommendations are suggested:

i. River is a natural stream having irregular section due to which variation in depth of water occurs so regular section such as main irrigation canal is recommended for comparison of discharge measuring equipment between Current Meter & ADCP.

ii. Prior survey for acquiring regular section for discharge observation & sounding of river cross section should be carried out in order to ascertain the accurate results for comparison between both methods (Current Meter & ADCP). Moreover, sedimentation analysis of discharge observing section should also be carried out before the measurement of discharge as sediment effects on the result of ADCP.

iii. The greater variability in the ADCP results is, therefore, likely caused by the not measurement of the complete width at edge of the bank as some of the area is being occupied by the moving boat.

iv. The disturbances in turbulence and velocity associated with the wakes from moving boat introduce variability in the velocity measurement and to a much lesser extent in the discharge.

v. The use of the profiling version of the instrument may also have contributed somewhat to the variability in the discharge, in that it does not allow for as long a sequence of data to be used for computing velocity at a particular elevation, as would a fixed-path installation. Increasing the analysis block size result in spatial variations being is included in the velocity calculation, which may have prevented it from reducing the variability. Moving the frame at a slower rate or measuring the discharge at a series of fixed width might result in some variability improvement.

vi. Further work could examine the link between the management of other natural resources and water resources in order to more effectively direct municipal priorities.