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HYDROLOGY PROJECT
Technical Assistance

DHV CONSULTANTS & DELFT HYDRAULICS with HALCROW, TAHAL, CES, ORG & JPS

VOLUME 4
HYDROMETRY

FIELD MANUAL - PART V

FIELD APPLICATION OF ADCP

Table of Contents

GENERAL

The Field Manual on Hydrometry, comprises the procedures to be carried out to ensure proper execution of design of the hydrometric network, and operation and maintenance of water level and streamflow gauging stations. The operational procedures are tuned to the task descriptions prepared for each Hydrological Information System (HIS) function. The task description for each HIS-function is presented in Volume 1 of the Field Manual.

It is essential, that the procedures, described in the Manual, are closely followed to create uniformity in the field operations, which is the first step to arrive at comparable hydrological data of high quality. Further, reference is made to the other volumes of the manual where hydro-meteorology, sediment transport measurements and water quality sampling and analysis is described. It is stressed that hydrometry cannot be seen in isolation; in the HIS integration of networks and of activities is a must.

This Volume of the Field Manual consists of 8 parts:

- Part I deals with the steps to be taken for network design and optimisation. Furthermore, site selection procedures are included, tuned to the suitability of a site for specific measurement procedures.

- Part II comprises operation of water level gauging stations equipped with staff gauges, autographic chart recorders or digital water level recorders.

- Part III comprises the preparatory activities and execution of float measurements, including selection of float type, reach preparation, observation practice and discharge computation

- Part IV comprises the preparatory activities and execution of current meter measurements by wading, and from cableways, bridges and boats. The procedure for discharge computation is included.

- Part V deals with the field application of the Acoustic Doppler Current Profiler (ADCP). It covers operating modes and site conditions, deployment, operating set-up and measurement runs as well as the data handling and recording.

- Part VI presents the required activities for the execution of the Slope-Area Method and the procedure to be applied to arrive at a discharge.

- Part VII comprises Field Inspections and Audits, with required check lists and standard forms.

- Part VIII, finally, deals with routine maintenance of gauging stations and calibration of equipment.

The procedures as listed out in this manual are in concurrence with the ISO standards as far as available for the various techniques and applicable to the conditions in peninsular India.

1 INTRODUCTION

The principles of operation of the Acoustic Doppler Current Profiler (ADCP) are described in Chapter 6 of Volume 4, Design Manual, Hydrometry. Though several systems are on the market now, the majority of operating experience in river flow applications has been obtained with RDI Broadband and Workhorse systems. The RDI Workhorse is the successor of the Broadband models. The RDI Rio Grande is a model of the Workhorse series specifically developed for flow measurements on rivers. Recently also ADP instruments - manufactured SonTek - became available for flow measurement in rivers. The ADP 1000 has been purchased by the Central Water Commission. Therefore the suggested observation practices laid out in this section of the manual are in some instances specific to the SonTek system.

The ADCP is a high tech, sophisticated and rather costly flow measurement device. This has the following implications:

1. Staff with a high level of technical ability and computer literacy are required to operate the equipment;
2. Even though the ADCP itself is fairly rugged, the transducers can be seriously damaged if they are struck by a submerged, hard object such as a rock or tree trunk. Also, the associated laptop PC required to download the data is often not really suitable for use in harsh operating environments. Therefore the ADCP and its associated equipment has to be handled with care;
3. In view of the specialist nature of the equipment and its high capital cost, the technique is only suitable for special sites where the value of the collected data is extremely high e.g. major rivers at inter-State boundary or larger tidal reaches; when results are required quickly and for special studies where the vector averaging and / or high detail is of importance.
4. If there are several important sites in close proximity of each other consideration should be given to having a mobile team which can move from site to site with the ADCP.

2 OPERATING MODES AND SITE CONDITIONS

RDI ADCP

The RDI ADCP has several operating modes, which can be selected via the lap-top. The selection of the most appropriate operating mode is dependent on site conditions. The selection of operating modes is referred to briefly in the following sections of the manual. However, for detail the potential user should refer to the manufacturer's user manual.

Example:

The 600 kHz and 1200 kHz, 20^0 RDI Broadband systems have four operating modes i.e. modes 1, 4, 5 and 8.

A comparison of these different operating modes which has been taken from the manufacturers user manual is contained in Table 1:

The major site constraint on the use of the ADCP is the channel depth

- Operating mode 1 only functions in depths greater than 1.0 m;
- Operating mode 4 only functions in depths greater than 3 m;
- Operating mode 5 only functions in depths greater than 1.25 m;

- Operating mode 8 only operates in depths greater than 0.8 m.

Channels are usually shallower nearer the banks than in the main part of the channel. To avoid losing too much of the flow the following rules have been applied in practice:

- When using mode 8 the gauging section should be at least 0.8 m deep;
- When using mode 5 the gauging section should be at least .5 m deep;
- When using mode 4 the gauging section should be at least 3 m deep.

	Mode 1	**Mode 4**	**Mode 5**	**Mode 8**
Minimum recommended cell size	0.10 m *0.20 m*	0.25 m *0.50 m*	0.10 m *0.20 m*	0.10 m *0.20 m*
Single ping standard deviation (min. cell size)	0.6 m/s *0.50 m/s*	0.13 m/s *0.13 m/s*	0.01 m/s *0.01 m/s* (at 0.50 m/s flow velocity)	0.15 m/s *0.10 m/s* (at 1.0 m/s flow velocity)
Minimum depth of water	1.0 m *1.2 m*	2.5 m *3.0 m*	2.0 m *2.0 m*	1.0 m *1.0 m*
Maximum range (Mode 5 & 8 for < 50 cm/s flow velocity)	20 m *50 m*	20 m *60 m*	4 m *8 m*	4 m *8 m*
Maximum relative velocity	10 m/s *10 m/s*	10 m/s *10 m/s*	1 m/s *1 m/s*	2 m/s *2 m/s*
Typical application	Very fast water of all depths. Rough and dynamic situations. Good in streams too fast or deep for modes 5 & 8, and not deep enough or too rough for mode 4.	General purpose for most streams more than 3 m deep	Slow, shallow water with low shear and turbulence conditions	Shallow streams with velocities < 2 m/s and with high shear (rough bed and/or turbulence. Works in shallow water where mode 5 does not work well.
NOTES: 1 .Maximum range depends on water temperature and depth cell size. Use BBSETUP to compute the maximum range for a particular ADCP set-up and water temperature. The standard deviation of modes 5 & 8 varies with water velocity, boat speed, bedform roughness, channel depth and turbulence. Reference should be made to the ADCP for further discussion on these modes 2 The figures in normal type are for the 1200 kHz system and those in italics for the 600 kHz system				

Table 1: Comparison of performance of RDI 1200 kHz 20 ^{0} and 600 kHz 20^0 ADCPs, both with transducers at 0.25 m deep & blank set to 0.30 m

However, it is recommended that the effective depth should be greater than 1.5 m for at least 95% of the cross-section.

NOTE: The depth is actually the effective depth i.e. the position from the transducers to the bed of the river. Therefore if the transducers are positioned 0.3 m below the surface, then an actual depth of 1.5 + 0.3 m = 1.8 m is required.

Another major site consideration is flow velocity:

- Mode 4 is not suitable for gauging velocities less than 0.5 m/s;
- Mode 5 can accurately measure flow velocities a slow as 0.01 m/s;

- Mode 8 can accurately measure flow velocities greater than 0.06 m/s.
- Modes 1 & 4 can measure velocities up to 10 m/s;
- Modes 5 and 8 can only measure velocities up to 1 and 2 m/s respectively;
- The uncertainties in Mode 1 velocity readings are significantly higher than other modes.

The velocity and depth constraints can be combined together as follows in Table 2:

	Velocity - v (m/s)					
Depth (m)	v < 0.04	0.06 >v>0.04	0.5 > v > 0.06	1.0 > v > 0.5	2.0 > v > 1.0	10 > v > 2.0
< 1.0	none	none	none	none	none	none
1 < d < 1.5	none	none	mode 8	mode 8	mode 1 (?)	mode 1
1.5 < d < 3.0	*	mode 5	mode 5	mode 5	mode 1 (?)	mode 1
3.0 < d < 4.0	*	mode 5	mode 5	mode 4	mode 4	mode 4
d > 4.0	none	none	none	mode 4	mode 4	mode 4

* - Minimum water velocity in mode 5 at these depths has not been ascertained.

Table 2: Guidance Table for Selecting RDI ADCP Operating Mode

It should be noted that the information provided above is based on current operating experience and the manufacturer's guidelines. It is possible that this table can be further developed and refined once the appropriate operating experience under Indian conditions has been obtained and the make and models of ADCPs purchased are known.

SonTek ADP

The major site constraint on the use of the ADCP is the channel depth. Channels are usually shallower nearer the banks than in the main part of the channel.

To limit the size of unmeasured fraction of the cross section, the following guidelines have been applied in practice:

Minimum cell size	0.25 m
Minimum depth of water	1 m
Maximum practical depth range (flow velocity)	20 m
Single ping standard deviation (min. cell size)	0.94 m/s
Maximum velocity relative to instrument	10 m/s

Table 3: Some limitations of the SonTek ADP 1000 kHz

However, it is recommended that the effective depth should be greater than 1.6 m for at least 95% of the cross-section.

NOTE: The minimum depth is based on the assumption that the blanking range is 0.5 m and that the ADCP transducers are not deeper that 0.25 m below the surface. A water depth of 1.65 m would allow for 3 cells and 0.15 margin for side lobe interference. The primary set-up could be based upon the suggestions of SonTek's SetUp Assistant. However, the Assistant does not anticipate shoals in the cross section (it assumes a canal type of river) and might suggest a large cell size (to reduce the single ping standard deviation). If shoals have to be crossed, the operator should decrease the cell size to a useful value.

ADCPs are still under development and new models are introduced in rapid succession. Some of the improvements are: smaller cells, higher accuracy and operation in shallower water as a result of smaller cells and reduced blanking range.

3 DEPLOYMENT

The ADCP should be deployed from an outboard motor propelled boat, which has been specially adapted for the task. The boat should be of a shallow draft type, preferably not greater than 0.5 m when laden with the equipment and the required number of operatives. The crew should preferably consist of no more than the Hydrologist, Assistant and boat driver. Also, the boat should be relatively flat bottomed, stable and easily manoeuvred.

The ADCP should be fixed to the ADCP by means of a mounting arrangement. It should be possible to fit the mounting arrangement to any boat. This arrangement should be such that the ADCP transducers can be raised and lowered to different positions below the water surface in 0.1 m increments from 0.1 to 1.0 m. A rigging facility is required to prevent the ADCP to lean back during (fast) sailing. The rigging should be such that when the ADCP impacts with anything solid it can give way and swivel to the surface. On some boats, like the survey boats as obtained under the Hydrology Project for Integrated Bathymetric Surveying, it is possible to install the ADCP in a moon pool / well / trunk pipe in the hull of a boat. This type of arrangement is normally found on boats for bathymetric surveying. An adequate shelter should be provided on the boat to protect the operator and laptop PC from sun and rain. A rigid working table should be provided on which to place the laptop PC and field data forms.

The X-direction of the ADCP should be parallel with the longitudinal access of the boat. The three-beam configuration of the SonTek ADPs prevents the installation with the beams in parallel with the boat.

ADCPs can be deployed in self-contained and real-time mode. The latter is preferred since anomalies and problems with the data being collected can be spotted immediately by means of the laptop PC. However, to run the ADCP in real-time mode an **external** power (battery) source is required to connect to the PC. Most of the current generation of laptop PCs will rarely run on their internal batteries for more than two hours. Hence, a reliable and sturdy power adapter should be included with the laptop PC to run both the laptop PC and the ADCP on a car battery. In some situations it might be necessary to operate the equipment in self-contained mode, i.e. without a laptop PC connected but recording data in internal memory. The ADCP should be fitted with such memory then. A PC is required anyway to set-up the ADCP before and to retrieve the collected data after the deployment. Presently, the CWC ADCPs are not equipped with internal memory for data storage.

4 OPERATING SET-UP

RDI ADCP

Prior to commencing a measurement various set up parameters must entered into the ADCP via the PC lap top and deck box. The appropriate operating mode must be selected. This is discussed in Chapter 2. For most rivers greater than 3.0 m deep, RDI Instruments (600kHz & 1200 kHz) Mode 4 will probably be appropriate. Certain deployment parameters can be set within each operating mode:

1. Bin size (size of each depth cell measured);
2. Blanking distance (parameter indicating which signals to ignore);
3. ADCP depth (depth of transducers below the surface).

4. The time between 'pings' can also be set-up. Experience has shown that if the time is set to continuous (the default setting) interference can possibly occur between consecutive sets of pings. The manufacturers have therefore recommended that the time be set to a small amount, say 0.025 milli-seconds .

Even though the third point above is set when the ADCP is bolted onto the floats, not within the operating mode, the information must be included in the deployment command file.

These values are set in whole decimetres. The bin, blanking and transducer depth depend on the water depth and channel conditions. No data is collected less than 1 bin from the bottom. No data is collected less than the sum of all three parameters from the water surface. Water velocities in these upper and lower regions of the profile are estimated. The literature on the ADCP states that a minimum of two depth cells must produce good velocity data to give accurate flow measurements.

There are certain rules to note:

1. Always ensure that the depth specified in the deployment file is the depth at which the transducers are set;
2. Never use a blank of less than 0.2 m. It has shown that this will result in erroneous velocities being recorded in the top bin;
3. In turbulent or high velocities ensure that the transducer depth is sufficient to be below the level of aeration (at least 0.3 m);
4. When reading the data make sure the configuration file has the same parameter values as the deployment file;
5. Make a note of the width of the channel between the end of the ADCP traverse and the bank. If this distance is significantly large relative to the overall width it can be used to adjust the calculated flow. This should not be a problem if the site is carefully selected i.e. avoid shallow water.

The settings appropriate for an RDI, 600 kHz ADCP are contained in Table 3 below are provided as a general guide:

Channel conditions	Mode	Bin (m)	Blank (m)	Transducer depth (m)
Low velocity, shallow channels	5	0.1	0.2	0.1
Shallow channels	8	0.1	0.2	0.1
Shallow channels, high velocities	1	0.1	0.2	0.3
Channels 1.5 - 3.0 deep	5 (v < 2.0 m/s) 1 (v > 2.0 m/s)	0.1 0.1	0.2 0.2	0.2 0.3
Channels > 3.0 m deep	4	0.5 (< 10 m) 1.0 (> 10 m)	0.5 0.5	0.5 0.5

Table 4: General guide to ADCP set-up settings

SonTek ADP

Prior to commencing a measurement various set-up parameters must be entered into the ADCP via the laptop PC. Certain deployment parameters can be set within each operating mode:

1. Cell size (size of each depth cell measured)
2. Blanking distance (parameter indicating which signals to ignore);
3. ADCP draft (depth of transducers below the surface).
4. Ping rate (for real time application should be set to highest rate to reduce the velocity standard deviation by averaging)

The cell, blanking distance and transducer depth depend on the water depth and channel conditions. No data is collected less than 1 cell from the bottom. No data is collected at a depth less than the sum of draft + blanking distance + cell size from the water surface. Water velocities in these upper and lower regions of the profile are estimated. The literature on the ADCP states that a minimum of two depth cells must produce good velocity data to give accurate flow measurements.

There are certain rules to note:

1. Always ensure that the depth specified in the set-up file is the actual depth at which the transducers are mounted. That depth is measured from the water surface to the centre of the transducer faces. The transducers are assumed to be in a horizontal plane;
2. Never use a blanking distance of less than 0.5 m.
3. In turbulent flow or high velocities ensure that the transducer depth is sufficient to be below the level of aeration (at least 0.3 m) because trapped air is virtually blocking the passage of the acoustic signals;
4. Make a note of the width of the channel between the departure point of the ADCP traverse and the starting bank and the end point of the ADCP traverse and the ending bank. If this distance is significantly large relative to the overall width it can be used to adjust the calculated flow. This should not be a problem if the site is carefully selected i.e. avoid shallow water.

5 MEASUREMENT RUNS

Once the ADCP has been set-up the measurement of traverses can be commenced. When in real-time mode the run can start immediately. However, operating the ADCP in self-contained (remote) mode the cable from the laptop PC to the ADCP has to be disconnected prior to starting. A dummy connector has to be placed on the ADCP plug socket to avoid damage of the electrical contacts by water and dirt.

Even though the boat can traverse the river following an irregular path it is recommended that as much as possible the boat traverses the river at right angles to the flow / banks. The boat speed should be as slow as reasonably possible while at the same time being sufficient to maintain a steady, smooth on-line course. The coarse should be kept stable, if needed, only gradual changes are permitted. The same applies to the traversing speed over the ground. This speed should be low enough to take at least several minutes to complete a full traverse. On wide channels the speed over the ground may be increased to about the average flow velocity.

It is recommended that at least four traverses are made i.e. across and back twice and the calculated discharges compared for consistency and repeatability for each run. If bottom-tracking errors occurred in any calculated discharge or the calculated discharge deviates by more than 5% from the average of the calculated discharges, the traverse should be set apart and another 2 traverses should be made. For the estimation of the discharge, the unmeasured flow should be estimated by the RiverSurveyor software (SonTek), the observer should enter his estimates for the distance to the start and end banks. Both the top and bottom layers should be automatically extrapolated by RiverSurveyor applying the standard power fit method.

It is recommended that the boat pauses (remains stationary while collecting data) in a fixed position at the start and end of each traverse for a period of 30 - 60 seconds since this can assist with the final interpretation and processing of the data. The start and stop of movement should be extremely gradual to avoid bottom-tracking failure.

6 DATA HANDLING AND RECORDING

On completion of the runs an initial analysis of the collected data should be undertaken. In real- time mode the data will be automatically loaded onto the PC. In self-contained mode it is necessary to re-connect the ADCP to the laptop PC to download the data. As a rule of thumb the time taken to download the data from the ADCP will be roughly the same as the time taken traversing the river. Once the data has been downloaded a preliminary flow estimate can be obtained to see if the calculated discharges are reasonable. A final flow estimate can be made when convenient.

A standard field sheet should be prepared which records relevant information for each traverse run. This sheet should include fields or columns for the following information, which should be duly entered during each traverse run:

1. date
2. site and river name
3. name(s) of observer(s)
4. ADCP Serial or Reference No.
5. method of deployment e.g. boat - real time or self contained
6. traverse number
7. name of data file
8. set-up parameters - cell size, draft of ADCP, blanking distance, ping rate
9. time of start of each traverse run
10. distance of traverse departure to start bank
11. gauge post reading at start of each traverse run
12. time of finish of each traverse run
13. distance of traverse finish to end bank
14. gauge post reading at finish of each traverse run
15. remarks