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Bureau of Meteorology

WATER MONITORING
STANDARDISATION
TECHNICAL COMMITTEE

National Industry Guidelines for hydrometric monitoring

PART 9: APPLICATION OF IN-SITU
POINT ACOUSTIC DOPPLER VELOCITY
METERS FOR DETERMINING
VELOCITY IN OPEN CHANNELS

NI GL 100.09–2019
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In 2017 and 2018 the Water Monitoring Standardisation Technical Committee (WaMSTeC) led a periodic review of the National Industry Guidelines for hydrometric monitoring. WaMSTeC subcommittees conducted the review process and coordinated extensive industry consultation.

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(Note that at the time of contribution, individuals may have been employed with different organisations and some organisations were known by other names).

Foreword

This guideline is part of a series of eleven National Industry Guidelines for hydrometric monitoring. It has been developed in the context of the Bureau of Meteorology's role under the *Water Act 2007* (Cwlth) to enhance understanding of Australia's water resources.

The Bureau of Meteorology first published these guidelines in 2013 as part of a collaborative effort amongst hydrometric monitoring practitioners to establish standardised practice. They cover activities relating to surface water level, discharge and water quality monitoring, groundwater level and water quality monitoring and rainfall monitoring. They contain high level guidance and targets and present non-mandatory Australian industry recommended practice.

The initial versions of these guidelines were endorsed by the Water Information Standards Business Forum (the Forum), a nationally representative committee coordinating and fostering water information standardisation. In 2014, the functions and activities of the Forum transitioned to the Water Monitoring Standardisation Technical Committee (WaMSTeC).

In 2017, as part of the ongoing governance of the guidelines, WaMSTeC initiated a 5-yearly review process to ensure the guidelines remain fit-for-purpose.

These revised guidelines are the result of that review. They now include additional guidance for groundwater monitoring, and other updates which improve the guidelines' currency and relevance. WaMSTeC endorsed these revised guidelines in December 2018.

Industry consultation has been a strong theme throughout development and review of the eleven guidelines. The process has been sponsored by industry leaders and has featured active involvement and support from the Australian Hydrographers Association, which is considered the peak industry representative body in hydrometric monitoring.

These guidelines should be used by all organisations involved in the collection, analysis and reporting of hydrometric information. The application of these guidelines to the development and maintenance of hydrometric programs should help organisations mitigate program under-performance and reduce their exposure to risk.

Organisations that implement these guidelines will need to maintain work practices and procedures that align with guideline requirements. Within the guidelines, the term “shall” indicates a requirement that must be met, and the term “should” indicates a recommendation.

The National Industry Guidelines can be considered living documents. They will continue to be subject to periodic WaMSTeC review at intervals of no greater than five years. In the review phase, WaMSTeC will consider any issues or requests for changes raised by the industry. Ongoing reviews will ensure the guidelines remain technically sound and up to date with technological advancements.

National Industry Guidelines for hydrometric monitoring

This document is one part of the National Industry Guidelines for hydrometric monitoring series, which can be found at

<http://www.bom.gov.au/water/standards/niGuidelinesHyd.shtml>.

The series contains the following parts:

Part 0: Glossary

Part 1: Primary Measured Data

Part 2: Site Establishment and Operations

Part 3: Instrument and Measurement Systems Management

Part 4: Gauging (stationary velocity-area method)

Part 5: Data Editing, Estimation and Management

Part 6: Stream Discharge Relationship Development and Maintenance

Part 7: Training

Part 8: Application of Acoustic Doppler Current Profilers to Measure Discharge in Open Channels

Part 9: Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels (*this guideline*)

Part 10: Application of Point Acoustic Doppler Velocity Meters for Determining Discharge in Open Channels

Part 11: Application of Surface Velocity Methods for Velocity and Open Channel Discharge Measurements

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National Industry Guidelines for hydrometric monitoring

Part 9: Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels

1 Scope and general

1.1 Purpose

The purpose of this document is to provide guidelines for recommended practice to ensure that the collected measured streamflow data are:

- a) accurate;
- b) defensible; and
- c) consistent across water monitoring organisations operating under these guidelines.

This is the minimum guideline that shall be followed to allow the collected data to withstand independent validation and integrity checks. Additional field procedures may vary between organisations and States.

1.2 Scope

This document deals with the use of in-situ acoustic Doppler velocity meters (ADVMS) for determining streamflow in open channels. It specifies the required procedures and methods for collecting data by Australian operators. It specifies procedures for the collection and processing of surface water velocity data collected by ADVMS.

This document does not include or rewrite instrument manufacturers' operating instructions for their individual instruments. Nor does it detail Standard Operating Procedure's (SOP's) of organisations using these instruments. However, it is expected that those SOPs are sufficiently robust to withstand independent scrutiny.

This document contains images and examples sourced from instrument manufacturers or suppliers. Inclusion of these images, with reference to the source, is solely for the purpose of providing examples, additional information and context, and is not to be interpreted as endorsement of any particular proprietary products or services.

1.3 References

This document makes reference to the following documents:

- Helsel, D.R., and Hirsch, R.M., 2002, *Statistical methods in water resources* U.S. Geological Survey Techniques of Water Resources Investigations, book 4, chapter A-3.
- International Organization for Standardization/Technical Report 2012, *Hydrometry – Acoustic Doppler profiler – Method and application for measurement of flow in open channels*, ISO/TR 24578:2012.
- International Organization for Standardization 2010, *Hydrometry – Guidelines for the application of acoustic velocity meters using the Doppler and echo correlation methods*, ISO 15769:2010.
- International Organization for Standardization/International Electrotechnical Commission 2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*, ISO/IEC Guide 98-1:2009.
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- International Organization for Standardization 2007, *Hydrometric uncertainty guidance (HUG)* ISO/TS 25377:2007.
- International Organization for Standardization 2005, *Measurement of fluid flow – Procedures for the evaluation of uncertainties*, ISO 5168:2005.
- Mueller, D.S., Wagner, C.R., 2009, *Measuring discharge with acoustic Doppler current profilers from a moving boat*, U.S. Geological Survey Techniques and Methods 3A–22, viewed 2 October 2018, <<http://pubs.usgs.gov/tm/3a22/>>.

1.4 Bibliography

Cognisance of the following was taken in the preparation of this guideline:

- Levesque, V.A., and Oberg, K.A., 2012, *Computing discharge using the index velocity method*, U.S. Geological Survey Techniques and Methods 3-A23.
- Ruhl, C.A., and Simpson, M.R., 2005, *Computation of discharge using the index velocity-method in tidally affected areas*, U.S. Geological Survey Scientific Investigations Report 2005-5004.
- Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, *Guidelines and standard procedures for continuous water quality monitors – Station operation, record computation, and data reporting*, U.S Geological Survey Technique and Methods 1-D3.
- Wang Fajun, and Huang, Hening 2005, *Horizontal acoustic doppler profiler (H-ADCP) for real-time open channel flow measurement: flow calculation model and field validation*, IAHR Congress paper 2005.

1.5 Definitions

For the purpose of this document, the definitions given in National Industry Guidelines for hydrometric monitoring, Part 0: *Glossary*, NI GL 100.00–2019 apply.

2 Acoustic Doppler Velocity Meters

2.1 General description

Acoustic Doppler Velocity Meters (ADVMS) can be classified into three general groups:

1. Point velocity – uses converging beams to measure the velocity of a small sample volume.
2. Single bin – uses divergent beams that can have the size of the measurement sample (depth cell, bin) adjusted and therefore change the sample volume that the mean velocity is calculated from. Used primarily for index velocity.
3. Profiler – utilises complex processing software that enables the calculation of multiple velocities from within the divergent beams. The beams are broken down into a number of user-determined depth cells (bins) each containing a calculated mean velocity that may be used to determine discharge.

Both single bin and profiler ADVMS are installed in-situ and may be configured to measure velocities looking upwards, downwards, and horizontally.

For the purpose of this document, ADVM refers to the profiler group of acoustic velocity meters.

2.2 Horizontal/side-looking ADVM

Installed on the edge of a channel, a profiler measures the velocities across a single horizontal profile. This profile is divided into a number of cells, the size and number of which is determined by the user and instrument capabilities. The instrument calculates a mean velocity for each of these cells. Horizontal profilers generally consist of two main transducers one of which sends a beam diagonally across the channel in an upstream direction, the other looks diagonally downstream. Velocities used for discharge computation are derived from the mean velocities in the x-component i.e., at 90° to the measuring profile (Figures 1a and 1b). These instruments profile velocities only and require a form of index rating based on a user-supplied cross-section data to calculate discharge. Additional sensors may include temperature and pressure for determining water level.

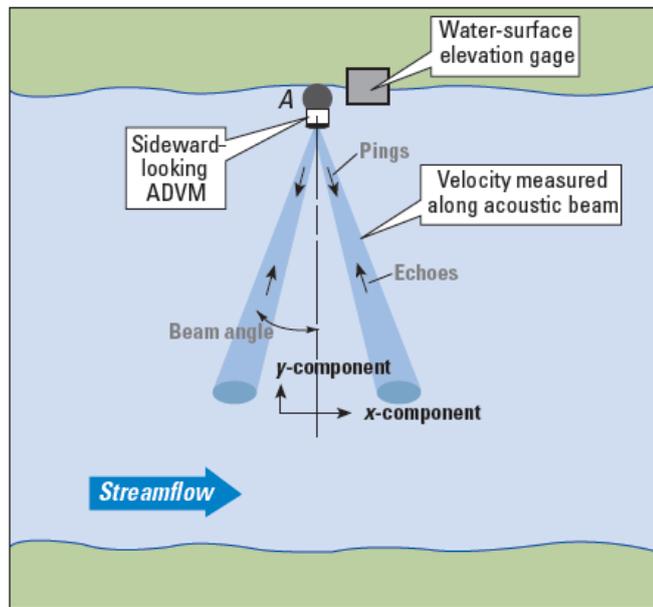


Figure 1a. Plan illustration of a horizontally mounted ADVM profiler installation
(Source: USGS, Ruhl, C.A., and Simpson, M.R., 2005)

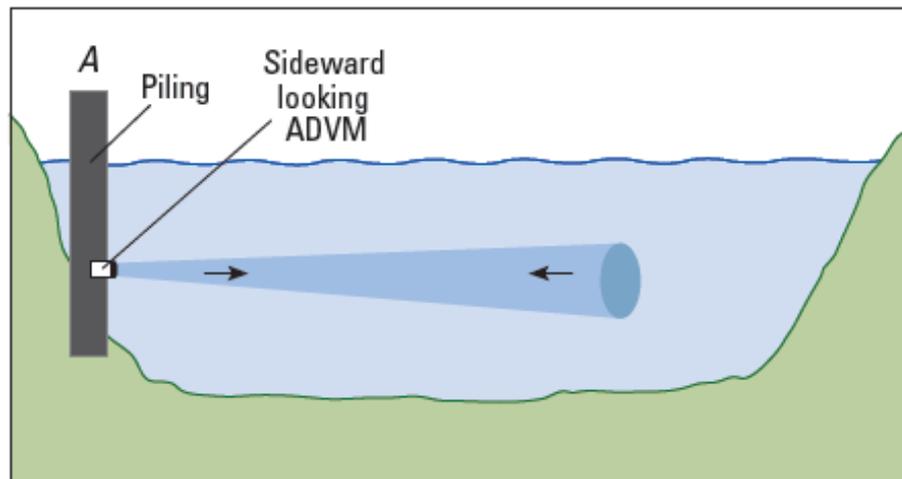


Figure 1b. Cross-sectional illustration of a horizontally mounted ADVM profiler installation
(Source: USGS, Ruhl, C.A., and Simpson, M.R., 2005)

2.3 Bottom/bed-mounted ADVM

Bottom or bed-mounted ADVM's are normally designed to be installed in small channels and streams and mounted in a position to continuously measure the mean velocity.

Where possible, bottom or bed-mounted ADVMs shall not be installed in locations affected by dynamic flow patterns. Where this is not possible, this shall be noted with recorded readings, and adjustments shall also be made to the recorded uncertainty.

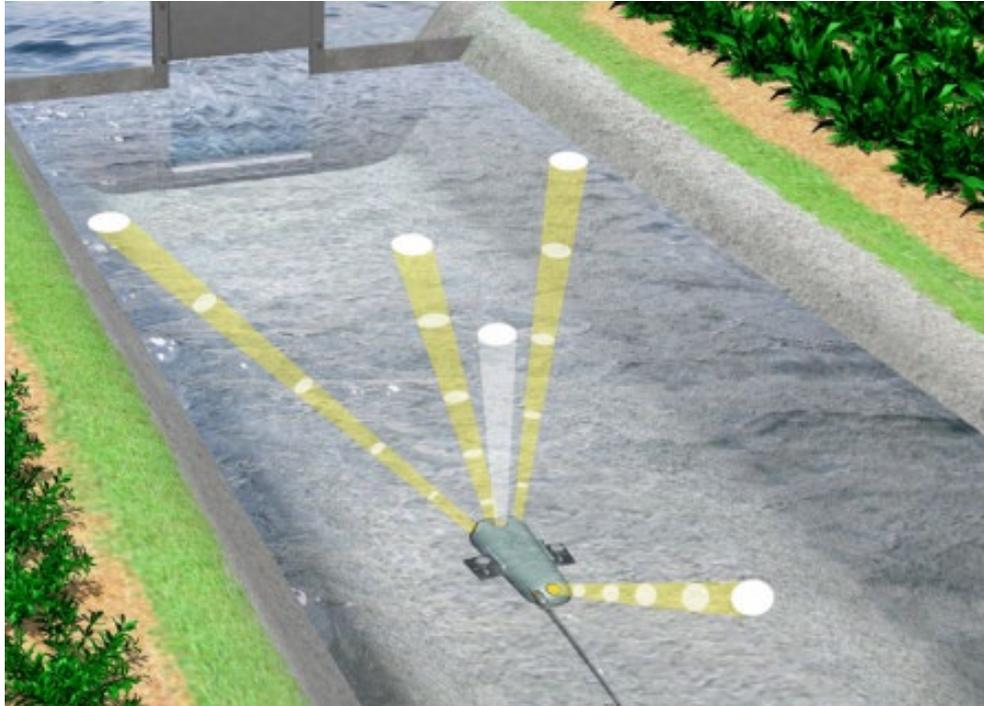


Figure 2. An illustration of a typical bed-mounted ADVM
(Source: Sontek IQ product brochure, 2015, viewed 2 October 2018, <http://www.sontek.com/productsdetail.php?SonTek-IQ-Series-15#>)

3 Instrument management

Each organisation shall have its own ADVM management record that contains instrument specific records containing details of:

1. The details of the person making the entry with details of the work carried out. In the case of manufacturer servicing, the details of work done, and a copy of the maintenance report from the service provider.
2. Time and date of the entry.
3. All calibration and operational checks carried out.
4. Installed software/firmware and/or relevant programs/modes that control the operation of the instrument.

Organisations may also choose to record other relevant information.

3.1 Instrument maintenance

Each organisation should have a maintenance schedule set in place and recorded in the ADVM management record. These maintenance procedures should be in accordance with the ADVM manufacturer's guidelines.

Due to the length of time ADVM units can spend submerged, they should be inspected regularly for bio-fouling and damage caused by suspended debris. ADVMs removed for maintenance inspections shall be replaced in the same position and orientation to maintain the validity of any index velocity rating (IVR) at use for that site.

Any ADVM demonstrating maintenance issues that could compromise data integrity shall not be used to record data.

Each organisation shall have instrument maintenance servicing requirements identified in their SOPs based on manufacturer's specifications and recommendations.

3.2 Instrument tests

ADVMs shall be periodically tested to ensure the validity of the data recorded by the following methods:

1. Running internal diagnostic/validation checks (e.g. an acoustic beam test). Where an ADVM possesses an internal diagnostic check, it shall be run during an ADVM setup in accordance with the manufacturer's guidelines. This diagnostic check verifies that the ADVM is functioning correctly and will issue a 'pass' or 'fail' to that unit.
2. Undertake independent gaugings to confirm velocity measurements.
3. Each of the following:
 - a) Compare the ADVM reported water depth to a reference measured water depth.
 - b) Compare the temperature reported by the ADVM thermistor with a measured stream temperature. The ADVM measured temperature should be within 2°C of an independent calibrated measuring device. The temperature difference shall be recorded in the measurement quality documentation. A 5°C difference in temperature results in a 2% bias error in the measured discharge (Mueller *et al* 2009). If the ADCP temperature is less than the independently measured temperature, the bias introduced will be negative. Conversely, if the ADCP temperature is more than the independently measured temperature, the bias introduced will be positive.
 - c) Measure electrical conductivity at the ADVM face and enter the value within the measurement software when operating in environments where the salinity may differ from that of freshwater, such as estuarine environments. In tidal sections, salinity shall be measured at the start and end of the measurement and the mean salinity entered into the data processing software. Salinity is critical in the speed of sound calculation to accurately measure water velocities and depth and is therefore a significant source of potential error.

NOTE: A salinity change of 12 parts per thousand (PPT) equates to a 1% bias error in the speed of sound calculation and a 2% error in the velocity

calculation. Freshwater is 0 PPT and sea water is 30-35 PPT. If the salinity entered is less than the independently measured salinity, the bias introduced will be negative. If the salinity entered is more than the independently measured salinity, the bias introduced will be positive.

The ADVN uses these three measurements to calculate the stage area and speed of sound calculations used to calculate velocity and discharge. Any error in the ADVN's ability to accurately measure these variables is transferred to the IVR.

Any ADVN that tests outside the operational error specifications as stated by the manufacturer shall not be used for measuring stream velocity. Appropriate defect management processes shall be implemented to resolve the failure.

3.3 Firmware and software upgrades

Software and firmware upgrades should be installed as recommended by the ADVN manufacturer and with guidance from national and international industry users (i.e., peer feedback and recommendations).

All firmware upgrades shall be recorded in an ADVN instrument record. Details of the software and firmware used when undertaking and processing a discharge measurement shall be recorded in the measurement details for future reference to allow a measurement to be reprocessed using a software update.

4 Operating personnel

The integrity of ADVN data is determined by the experience of the operator at the time of collection. Operating personnel shall therefore have completed training that covers the deployment of ADVNs as well as the collection and post processing of their data.

This training should be specific to the brand of ADVN unit, and the associated software that will be used to post process the data.

Training should be sought from an individual or organisation that has demonstrated expertise in the use of ADVN technology.

ADVN data shall not be collected by an untrained individual without an experienced operator being present.

Post processed data shall be reviewed by an additional trained and experienced operator before the data are archived.

ADVN technology is continually evolving and users should remain up to date on software updates, improvements to the equipment, and changes in recommended operational methodologies. Refresher training for field deployment, data collection, processing, and quality control procedures should also be sought.

5 Pre-deployment checks

Before entering the field or placing the instrument in the water, the following pre-deployment checks shall be carried out:

1. All instrumentation is checked to ensure that it is in good working order.
2. The most approved firmware and software is in use.
3. The ADVN is communicating with any external data loggers required for the deployment.
4. Any ancillary equipment is in calibration.
5. There is an adequate power supply for all devices to complete the measurement.
6. The ADVN unit selected is appropriate for the environmental conditions expected at the measurement site to ensure the integrity of the data.
7. All workplace health and safety requirements have been fulfilled.

6 Field deployment guidelines

6.1 Site selection

The site selection criteria for ADVN instruments, as with surface water monitoring sites, should comply with a set of guidelines to ensure that the site is within the hydraulic and manufacturer requirements for the development of an accurate index velocity rating within the cross section.

The site selection criteria as stipulated in National Industry Guidelines for hydrometric monitoring, Part 2: *Site Establishment and Operations*, NI GL 100.02–2019, Section 4.2.1.1.B: Discharge monitoring sites, should be adhered to during ADVN site selection.

The following additional criteria shall also be taken into consideration when selecting an ADVN installation site:

1. The channel should have a stable cross-section. Sites that have very mobile beds that result in significant change to the cross-sectional area will not allow the development of a stable IVR.
2. The site should ideally contain well mixed flows with uniform horizontal and vertical flow distributions.
3. The unit should sample velocities away from the stream edge and in an area of maximum velocity.
4. Expected measurement velocities shall be within the ADVN operational boundaries as stated by the manufacturer.
5. Where available and practicable, the installation site should be located on a straight reach of channel.

6. There shall be a suitable cross-section for gauging located at the installed ADVN. The section shall be gauged at regular intervals to confirm the validity of the index velocity rating.
7. The line of sight of a side-looking ADVN shall be free from obstructions such as weed or logs; this includes the stage referencing transducer. Points of flow disturbance in either an upstream or downstream location should also be avoided.
8. Correct placement of bed mounted ADVNs is critical for obtaining representative velocity measurements. In a natural channel, the velocity distribution is not uniform across the channel (Figure 3) and the velocity profile will alter as the stage increases. When this happens, the ADVN may be measuring an unrepresentative sample and the uncertainty of the measurement will increase. The ADVN shall be installed in a position that will measure a representative velocity sample throughout the stage range to be measured. If this is not possible then an IVR should be applied.
9. For bed-mounted ADVNs the rule of $5 \times$ channel width = the length of straight channel required to ensure well mixed flows should be applied as given in ISO 15769:2010.
10. Channel geometry should be regular in shape, avoiding sudden changes in depth. This will allow a less complex IVR to be developed.
11. Side looking ADVNs require a channel depth that enables the acoustic beams to view a representative flow sample. As the beams travel, the wider and more conical in shape they become. This often results in the channel bed or the water surface contaminating the beam and degrading the returned signal. As a general rule, a 1:10 aspect ratio rule may be applied, i.e. 10m distance requires 1m of depth. With good site conditions this may be improved upon with a ratio of 1:20 or better achievable. The point of installation should be tested for boundary and side lobe interference before any permanent fixtures are put in place.
12. If installation is to occur in a tidally affected location the user shall consider the possible impacts that a salt wedge will cause to the instrumentation and collected data. An example of these impacts is provided at Appendix C.

Failure to comply with these guidelines may result in the development of an inaccurate index velocity rating.

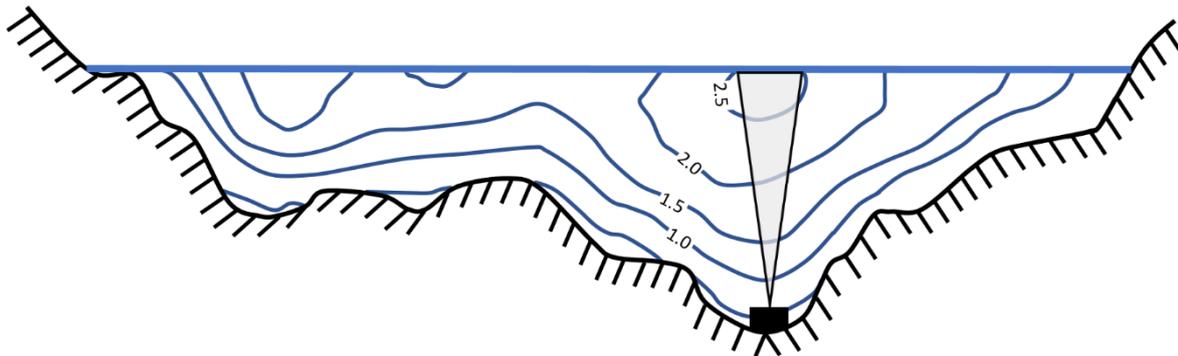


Figure 3. An illustration of a velocity distribution within a natural irregular channel. Bed mounted ADVMs should be installed to measure a representative distribution.

(Credit: Rebekah Webb, adapted from <http://onlinecalc.sdsu.edu/onlinevelocitycoefficients.php>)

6.2 Site installation

The methods of installation may vary at each site and should be appropriate for specific local features. Installation considerations should include instrument stability, protection from debris carried with the flow, and potential vandalism. For remote installations where the unit will be installed out of water to capture flood velocities, additional protection from the weather, especially direct sunlight, should be taken into consideration. For standalone installations i.e. internal logging, provisions shall be made for an adequate power source that, along with the cabling, shall also be readily secured.

6.2.1 Horizontal/Side-looking ADVM

Once a measurement site has been selected, the following apply to the installation of horizontal/side-looking ADVMs:

1. Pitch and roll – The pitch and roll of the unit shall be set as close as possible to 0° . The instrument may be set at a larger pitch where this is necessary to improve the quality of the instrument's line of sight and reasons should be documented in the installation field notes. The roll does not have the same degree of error tolerance as the pitch because both beams need to sample across the same velocity plane. Check the manufacturer's documentation for instrument specific tolerances and associated uncertainties.
2. Where the instrument contains a pressure sensor this shall be zeroed out before being submerged.
3. The instrument line of sight shall sit perpendicular to the direction of flow. Instrument orientation shall minimise cross beam velocities or y velocities. This allows the optimal measurement of downstream x velocities.
4. The beam signals shall be free from contamination by obstructions, the channel bed or water surface. Check the distance from the instrument to the point of the pulse to ensure it is not the opposite bank. Determine whether the measurement is valid.

5. Check the signal amplitude is not within 10 counts or less of the instrument noise floor within the measuring section. Where the amplitude is within 10 counts of the instrument noise, it is deemed an invalid measurement.
6. Check beam signals against the natural decay curve (if available). A difference of 20 counts or more may indicate interference from the boundary layers or a natural scattering of particles and result in an invalid measurement.
7. Manually validate the thermistor reading at the transducer face. The ADV M measured temperature should be within 2°C of an independent calibrated measuring device.

NOTE: A 5°C difference in temperature results in a 2% bias error in the measured discharge (*Mueller et al, 2009*). If the ADCP temperature is less than the independently measured temperature, the bias introduced will be negative. Conversely, if the ADCP temperature is more than the independently measured temperature, the bias introduced will be positive.

8. Electrical conductivity shall be measured at the transducer face and entered within the measurement software as parts per thousand when operating in environments where the salinity may differ from that of freshwater, such as estuarine environments. In tidal sections, salinity shall be measured at the start and end of the measurement and the mean salinity entered into the data processing software of the gauging. Salinity is critical in the speed of sound calculation to accurately measure water velocities and depth and is therefore a significant source of potential error.

NOTE: A salinity change of 12 parts per thousand (PPT) equates to a 1% bias error in the speed of sound calculation and a 2% error in the velocity calculation. Freshwater is 0 PPT and sea water is 30-35 PPT. If the salinity entered is less than the independently measured salinity, the bias introduced will be negative. If the salinity entered is more than the independently measured salinity, the bias introduced will be positive. Refer to Appendix A.

9. The ADV M clock shall be set within a two minute tolerance of the measurement location time and zone as reported by a GPS unit. GPS time is an accurate and verifiable time source by which all time pieces shall be set.

Where an invalid measurement is found, the installation or equipment used shall be altered to ensure a valid measurement is made.

6.2.2 Bottom mounted ADV M

When installing a bottom mounted ADV M the following apply:

1. Beams amplitudes shall be in accordance with Clause 6.2.1 point 5.
2. Validate the thermistor reading in accordance with Clause 6.2.1 point 7.
3. Validate the salinity in accordance with Clause 6.2.1 point 8.
4. Validate the time and date in accordance with Clause 6.2.1 point 9.
5. The pressure sensor shall be zeroed out in accordance with Clause 6.2.1 point 2.
6. The unit beams shall be orientated in the flow according to manufacturer instructions.

7. The unit shall be securely mounted. Where siltation or damage from moving debris is expected or discovered, the unit should be raised or protected to avoid debris.
8. The unit shall be mounted in a position near the region of maximum velocity.

NOTE: A site survey using a boat mounted ADCP will help to identify the most representative location.
9. The unit installed shall be able to accommodate the maximum and minimum stages to be encountered.

7 Instrument configuration

The configuration parameters shall be site specific and focussed on what the target information is, i.e., daily streamflow or short term streamflow variations. The nature of the deployment shall also be taken into consideration, including but not limited to the following factors:

- a) available storage memory; and
- b) power restrictions.

7.1 Averaging interval

The averaging interval (AI) is the time duration over which data are averaged for each sample. For a rapidly changing streamflow and stage a shorter AI should be set compared to a less responsive basin. The AI has an impact on the power management of the ADVN deployment and shall be considered where batteries are used to ensure that the instrument continues to operate throughout its deployment period.

In general, the optimum routine averaging interval is somewhere between 15 to 60 seconds less than the sampling interval.

The standard deviation of the velocity measurement is determined by the duration of the averaging interval.

7.2 Sampling interval

The sampling interval (SI) is the time interval between logged samples. The SI impacts on the amount of internal memory used during an ADVN deployment. The SI shall be set so that the data is able to represent the streamflow being measured. As with the AI, a smaller SI should be set if a measurement site is very responsive.

SI shall always be greater than or equal to AI.

NOTE: The size of available internal memory is dependent on the unit. Some units operate as loop recorders therefore stored data may be overwritten if not downloaded before storage capacity is reached. The manufacturer's documentation should therefore be consulted.

7.3 Measurement volume

When determining the measurement volume for an ADVN, the instrument should be installed and configured so that it is measuring an area of relatively undisturbed velocity. Disturbance to the velocity can occur from objects and submerged channel or stream bank features. The measurement volume should also be located in an area of maximum or near maximum velocity.

A signal amplitude check shall be undertaken during installation and on routine service visits to ensure that the measurement volume is suitable. Flow disturbance and turbulence is identifiable by an increased velocity standard error, changes in noise levels, and changes in the velocity magnitudes and/or direction between cells.

The measurement volume can be controlled by setting appropriate cell size, beginning, and end. These settings and all changes to these settings shall be recorded with the ADVN instrument record that is specific for that installation.

All ADVN beams used to measure velocity shall also be measuring the same volume. Changes to these values can result in different velocities being sampled and a different index velocity being created.

Care shall be taken to ensure that these measurements are not changed without making changes to the index velocity rating.

7.4 Cell size, beginning and end

This is a site and instrument specific determination, and as a general rule the operator shall configure the instrument to collect as much valid data as possible across the width of the channel. Some manufacturers provide deployment planning software which highlights the results and consequences of a deployment configuration.

The blanking distance should be sufficient to avoid any backwater or turbulence effects located in front of the ADVN.

8 Communications and data logging

Most ADVNs allow the use of an external logger to record the data instead of writing it to the internal memory. This eliminates the limitations of internal memory storage. Communications usually take place via RS232 or SDI-12. Some ADVN units, when communicating data via SDI-12, have a reduced sampling capacity. The ADVN and logger manufacturer documentation should be consulted for further information.

ADVNs should always be configured to sample and communicate as much data as the individual unit and logger will allow for the duration of the deployment.

9 Instrument field servicing and data calibration

9.1 Field service

When servicing the instrument in the field, the following procedure shall be followed:

1. Record the ADVN reported stage level and gauge height, as well as time.
2. Download data, check for irregularities.
3. Check the ADVN orientation noting pitch and roll against previous settings to ensure the unit has not moved or the compass failed.
4. Check ADVN thermistor in accordance with Clause 6.2.1 Point 7.
5. Check salinity in accordance with 6.2.1 Point 8.
6. Check the pressure sensor and/or vertical beam reported depth.
7. Record a beam check to ensure that beam signal amplitudes are acceptable (50 ping minimum).
8. Clean any bio-fouling that may have occurred. In cases where the instrument needs to be removed, it shall be replaced in the same position and orientation as it was previously. The installation method shall allow for this to be easily achieved.

NOTE: Failure to replace the instrument in the same location and at the same orientation shall result in the creation of a new index velocity rating.

9. If it is not possible to return the ADVN to the same position and orientation, then the new details shall be recorded, and a new index velocity rating established.
10. If a calibration discharge measurement is taking place, follow procedures outlined in Clause 10.2.2.
11. Record the instrument time/date. All time pieces shall be in accordance with Clause 6.2.1 Point 9.
12. Set the start date and time.
13. Deploy the instrument.

10 Calculating discharge methodologies

There are two methodologies currently available to calculate discharge from the ADVN recorded velocity and stage data; they are the index velocity rating (IVR) method and the numerical (theoretical) method. The major differences between the two are:

1. The numerical method should only be used as an interim methodology until data are able to be validated by a calibration gauging program.
2. The IVR method requires calibration gaugings for setup. The numerical method does not require calibration gaugings during setup.¹

¹ Calibration gaugings should be undertaken to validate this methodology as opportunities arise.

3. The numerical method requires the whole of the cross-section in its profiling range/line of sight. The IVR does not.
4. The numerical method can tolerate a change in the ADVM mounting position using the same IVR. The IVR method requires a new IVR to be created where the ADVM position is changed.

NOTE: Comparisons of both methods for real time streamflow monitoring by Wang and Huang 2005 demonstrated that both are valid methodologies for calculating discharge but both methods should be validated by calibration gaugings as part of quality assurance processes.

10.1 The velocity extrapolation method

The velocity extrapolation method (VEM) is an independent method provided by some instrument manufacturers to calculate stream discharge from ADVM velocity and stage (water level) data. This is undertaken via computational software and may not be available for all brands of ADVMS.

Advantages of VEM include:

- VEM can be applied to many of the same measurement scenarios as index velocity;
- VEM does not require the development of a new index rating should the position of the ADVM be changed; and
- VEM does not require multiple onsite ADCP calibration measurements covering multiple flow events.

The VEM is therefore ideally suited for remote site installations or where peak flow events commonly occur during the night. VEM may be used in conjunction with surface velocity methods such as Space Time Image Velocimetry (STIV), to provide multiple two-point velocity measurements across the width of the channel.

VEM processing methods correct each ADVM velocity bin by its position within the vertical and corrects the ADVM measured velocity to a mean velocity based on a user specified power law. Discharge is calculated for each measured velocity section. VEM may be used over a range of stage heights encountered during flood events.

The following criteria apply to data collected for use with the VEM:

1. Calibration gaugings are not required to calculate discharge but can be used to determine the velocity exponent required to correct individual bin velocities. The exponent is used to correct the measured bin velocities based on where the instrument is measuring within the vertical.
2. The ADVM shall profile multiple velocities across the whole of the cross section.
3. The ADVM shall be mounted at a position in the cross section where it can measure representative velocities over the expected stage range.
4. The transverse flow structure at the installation site shall ideally be uniform.
5. The mounting position may be changed.

6. The VEM calculates discharge from the actual measured velocities and is therefore a useful method to identify discharge rating hysteresis.
7. The accuracy of this method is dependent on using the correct power law exponent. This may change during different flow events. Confirmation measurements should be undertaken where possible to ensure the exponent used is representative of the flow conditions.
8. The user should consider the ADVM frequency required to measure across the channel width.

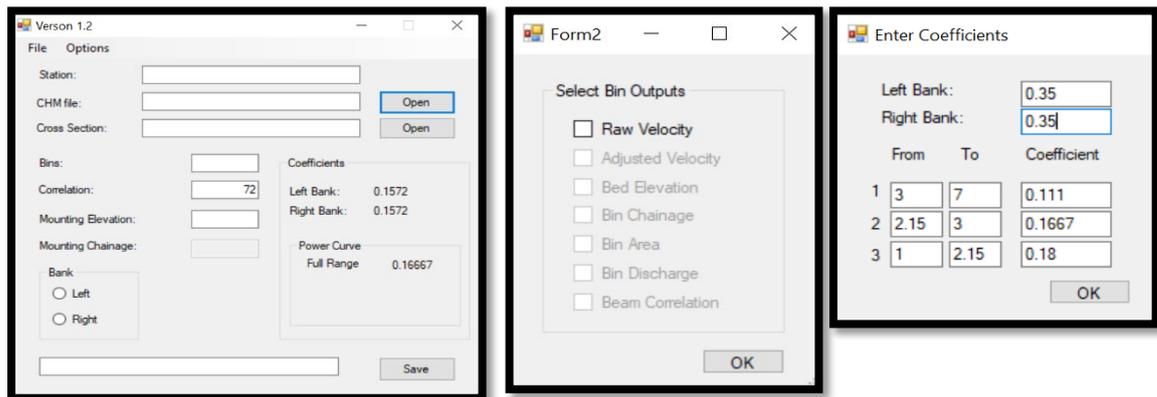


Figure 4. Example of a VEM program. The program allows various data outputs from ADVM data files. Discharge calculation can have three power exponents applied to three separate stage ranges.

(Credit: Mark Randall, Stephen Wallace, Queensland Government Department of Natural Resources, Mines & Energy)

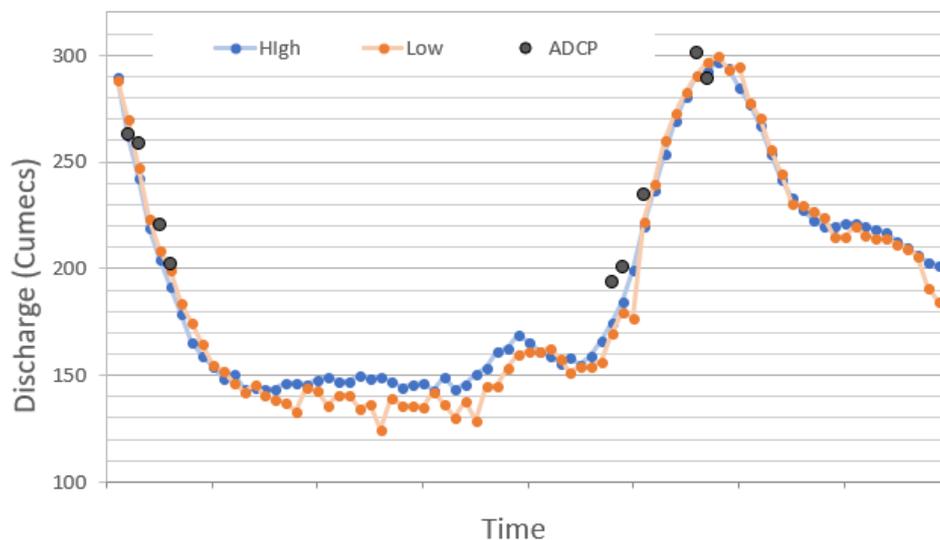


Figure 5. Example VEM derived discharge data from two ADVMS mounted at different elevations at the same cross section. Low = 2.71m GHT and High = 4.6m GHT. The data covers two days during which on site ADCP measurements were undertaken during daylight hours. Stage range was 5.2m to 6.5m GHT. ADVM data was processed using 0.1111 power exponent.

(Credit: Mark Randall, Queensland Government Department of Natural Resources, Mines & Energy)

10.2 The index velocity method

To apply the index velocity method, the following two separate ratings shall be available:

1. Stage-area rating; and
2. Index velocity rating.

NOTE: Both ratings are used to develop the final index to mean velocity rating for discharge calculation.

10.2.1 Stage-area rating

The stage-area rating is developed first from a surveyed standard cross-section. The standard cross-section shall be located as close to the ADVN as possible and be clearly identifiable so that it can be easily located and resurveyed as required. The development of the stage-area rating shall be well documented, and all information shall be located together. The documentation shall specify how the data was collected, what data was used to create the rating, how it was developed, and why the final rating was chosen. The following shall also apply when developing a stage-area rating:

1. Cross-section start and end points shall be recorded using GPS with a relevant site description included.
2. Cross-sections shall be performed inline of the ADVN.
3. The cross-section survey shall be in a recognised datum such as Australian Height Datum and be able to be referenced to gauge height/instrument height.
4. If possible, the survey should exceed the maximum expected stage (gauge height).
5. Time and date datum shall be included.
6. Water level data measured during the survey shall be included. In tidal sites, this may require water level adjustments over the duration of the survey when surveying the wetted perimeter.
7. For long term installations, cross-sections that are not stable should be routinely checked for channel changes. Cross-section checks should be conducted annually for the first three years of installation, then once every three years thereafter. Where there is a departure in the index velocity rating, or following a high flow event, cross-section checks should be carried out.
8. Always measure at the same cross-section location; a new cross-section requires a new IVR.

Cross-sectional areas specific to stage (gauge height) increments shall be calculated for use in the index velocity rating to calculate discharge.

Cross-section survey data shall be collected by an individual experienced in surveying.

10.2.2 Discharge calibration data.

To develop and calibrate an accurate index velocity rating it is necessary to collect discharge measurements over the full range of flows and flow conditions experienced at the ADVm installation site. While the discharge measurement location does not need to be at the surveyed standard cross section, it shall be close enough to the ADVm to ensure that the same discharge is being measured. Care shall be undertaken to ensure that the discharge measurements do not interfere with the velocity data being collected by the ADVm.

The following procedures shall be adhered to during the collection of discharge calibration data:

1. The ADVm should be configured for a sampling interval (SI) and averaging interval (AI) for continuous data measurement of ideally 60 seconds for the duration of the discharge measurement. Some site characteristics such as large channel width and/or low velocities may require a larger interval period.
2. If an ADCP is used to collect discharge data, then the measurement section should be located a minimum of five channel depths away from the ADVm. This avoids acoustic interference between instrumentation.
3. All timepieces involved in the data collection process shall be set and synchronised to GPS time for that location. Time discrepancies between measurement devices can cause erroneous relations between index and measured mean channel velocities.
4. The duration of a discharge measurement shall be sufficiently short to reduce uncertainties within the horizontal and vertical velocity distribution associated with changes in flow yet long enough to minimise discharge uncertainty.
5. Discharge measurements shall define short term as well as seasonal variability in flow. This is particularly important in tidally influenced sites.
6. The original site configuration shall be reloaded onto the ADVm following completion of the measurement.

10.2.3 Index velocity rating

The index velocity rating method was developed by the USGS and has been in use for over 25 years to establish a rating or regression equation to describe the relationship between the channel mean velocity and the index velocity measured by an ADVm.

When using measured discharge from the calibration gauging data, mean velocities shall be calculated using the channel area from the standard cross section of the stage area rating and not from the actual measurement location.

10.2.3.1 Graphical analysis.

The creation and analysis of data plots should be the first stage in the development of an index velocity rating. Plotting the data allows visual confirmation of trends or anomalies within the data that statistical analysis alone cannot clearly differentiate between. The types of data plots used should consist of but not be limited to:

- ADVM measured index velocity (x axis) and measured mean velocity (y axis).
- Measured mean velocity (x axis) and ADVM cross stream index velocity (Y velocity for horizontal ADVM). Stage and index velocity squared may also be used.
- Measured mean velocity (y axis) and ADVM range averaged index velocity and/or individual bin index velocity.

NOTE: Graphical data analysis will assist in determining which of the three rating methods is to be used.

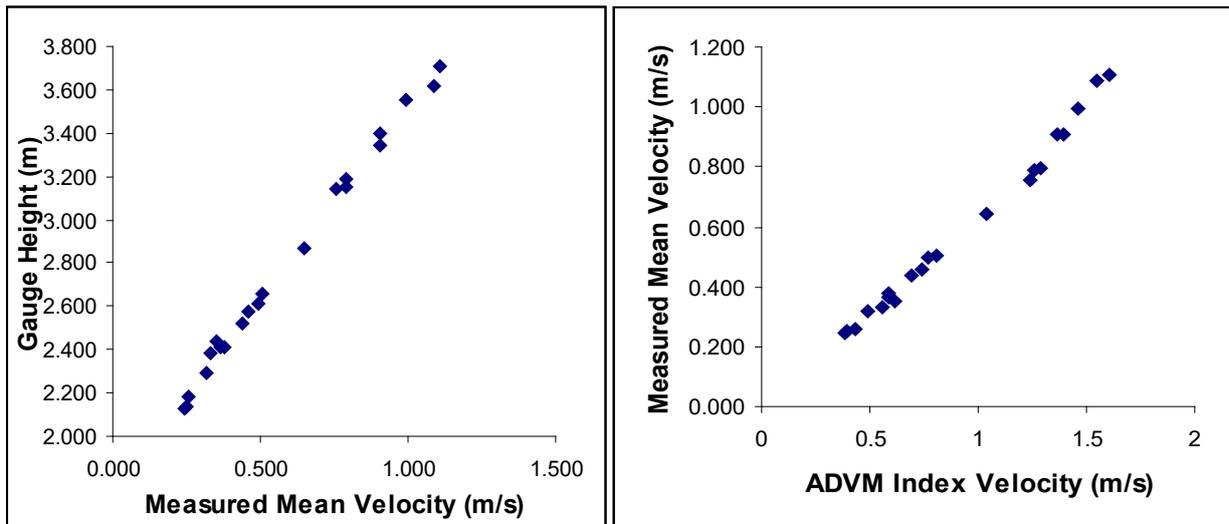


Figure 6. Graphical analysis of ADVM data. Left, gauge height plotted against measured mean velocity demonstrating a linear relationship between the two variables. Right, measured mean velocity plotted against ADVM index velocity demonstrating the presence of two linear relationships.

(Credit: Mark Randall, Queensland Government Department of Natural Resources, Mines & Energy)

10.2.3.2 Simple linear regression rating.

A simple linear rating uses the ordinary least squares (OLS) linear regression method to fit a straight line to a data set and allow the computation of one variable (mean velocity) from another (index velocity).

$$y = mX + b + \text{error}$$

where:

y = computed mean velocity

m = slope of the line (X variable coefficient)

X = index velocity

b = y intercept

error = error around regression line (ignored for the purpose of index rating development).

The assumptions associated with linear regression are:

- a) y is linearly related to X ;
- b) data used in the regression are representative of the data of interest;
- c) variance of the residuals are constant, i.e., homoscedastic;
- d) the residuals are independent; and
- e) the residuals are normally distributed.

To correctly use linear regression to predict mean velocity from an index velocity requires only the first two assumptions to be met (Helsel and Hirsch 2002). The more assumptions are met the more accurate the rating will be.

To evaluate the accuracy of the regression, five statistical outputs shall be used:

1. R – square (coefficient of determination). Indicates the strength of the regression between the variables.

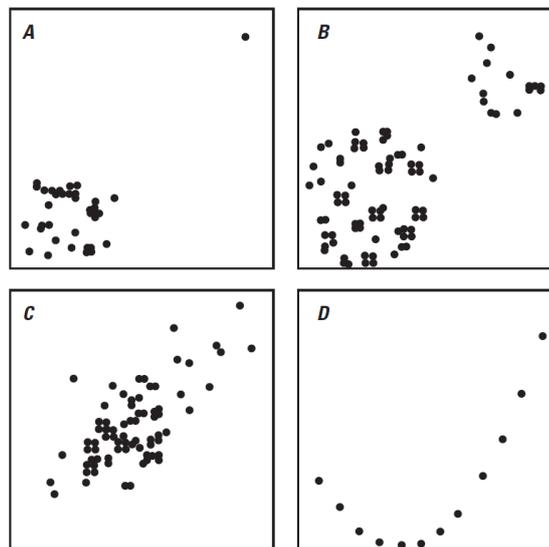


Figure 7. Scatterplot variation in points for the same R-square value, highlighting the way the R-square value is not sufficient on its own to determine the strength of a regression line

(Source: USGS, Levesque, V.A., and Oberg, K.A., 2012)

2. Standard error. Measures the reliability of the regression and is useful for comparing two regression analyses. Lower values are desirable.
3. Number of observations. Helps determine reliability of the regression. A minimum of 10 to 20 observations should be used for each independent variable.
4. Coefficients. These define the index rating.
5. p value of each coefficient. Should be less than 0.05 and indicates how well the coefficient in the regression equation is related to mean channel velocity.

Regression analysis should be performed even with a limited number of observations as it can confirm whether or not the ADV is located correctly.

Following regression analysis further graphical analysis of the residuals shall be undertaken.

NOTE: Residuals are the difference between the measured mean velocity and the calculated mean velocity from the regression equation.

Variables that should be plotted against residuals (y axis) include:

- index velocity;
- computed mean velocity from regression equation;
- stage; and
- time.

These plots should indicate uniform distribution about zero throughout the range of the variable plotted on the x axis. This indicates the index velocity is an accurate indicator of mean channel velocity.

Any residual plot that displays a trend indicates that:

- a) one or more variables affect the relation to mean channel velocity and therefore a compound or multiple linear rating may be required;
- b) the ADVN is located incorrectly; or
- c) the ADVN is incorrectly configured.

Any outlier points should be investigated for possible errors within the data collection and processing procedures. Refer to Figure 9.

10.2.3.3 Compound linear regression rating.

A compound or bimodal rating occurs when a rating has at least two distinct slopes caused by the hydraulic conditions at a site. This is related to stream morphology, channel/section controls, and tidal influence.

Once the need for a compound linear rating has been determined then the data shall be separated into their respective linear groupings. Each data group shall then undergo simple linear regression rating.

The calculation of a compound linear regression rating may not be possible within the ADVN software itself and shall therefore require the use of external data processing software.

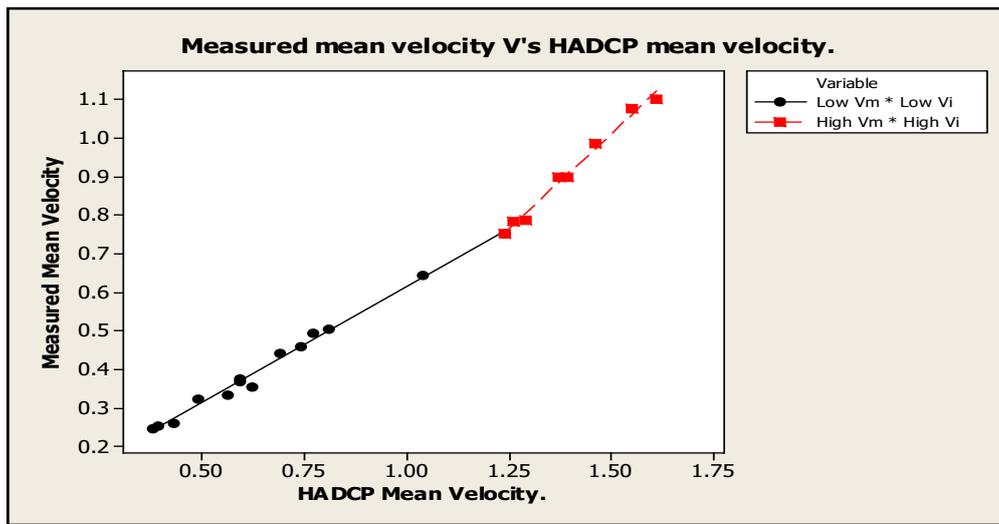


Figure 8. An example of the need to develop a compound linear regression rating for high and low mean velocities

(Credit: Mark Randall, Queensland Government Department of Natural Resources, Mines & Energy)

Graphical analysis of the residuals should be undertaken as outlined under 10.2.3.2.

10.2.3.4 Multiple linear regression rating.

A multiple linear regression rating is required when data analysis demonstrates that index velocity by itself is not sufficient to calculate mean channel velocity.

Non-linearity between index velocity and mean channel velocity can be associated with:

- additional independent variables need to be included in the regression analysis;
- calibration data which is incorrectly synchronised with ADVm data;
- the location of the index velocity measurement volume;
- significantly large stage range;
- up/downstream channel geometry; or
- a combination of c), d) and e) (above).

The multiple linear regression equation takes the following form:

$$y = aX_1 + bX_2 + nX_n + l + error$$

where:

- y = computed mean velocity
- a, b, n = slope coefficients for each independent variable
- X₁, X₂, X_n = independent variables
- l = y intercept
- error = error around the regression line (this term is ignored).

The assumptions associated with multiple linear regression are the same as those associated with simple linear regression. The most important assumption to be met is that independent variables and the dependent variable or residuals are linearly related. Suitable data transformations may be used to achieve this.

Where graphical analysis of the data has indicated that a multiple linear regression is required, a simple linear regression should be undertaken first to quantify the degree of improvement that a multiple linear regression achieves.

Stage is a common factor for inclusion in multiple linear regression analysis. Stage dependency is most common in horizontal ADVMs. When stage alone is the variable to be included in the multiple linear regression it can be multiplied by index velocity to form a separate independent variable.

In this case the following equation should be used:

$$y = a * \text{index velocity} + b * (\text{index velocity} * \text{stage}) + I$$

where:

a = slope coefficient for index velocity

b = slope coefficient for index velocity*stage

I = intercept of y.

NOTE: When using this form of the equation the regression statistics may indicate that the coefficient for index velocity is not significant. However, if this coefficient was significant during simple linear regression analysis then it should still be used in multiple linear regression.

Further analysis of the multiple linear regression statistics and residuals should be undertaken as described in 10.2.3.2.

The calculation of a multiple linear regression rating may not be possible within the ADVM software itself and shall therefore require the use of external data processing software.

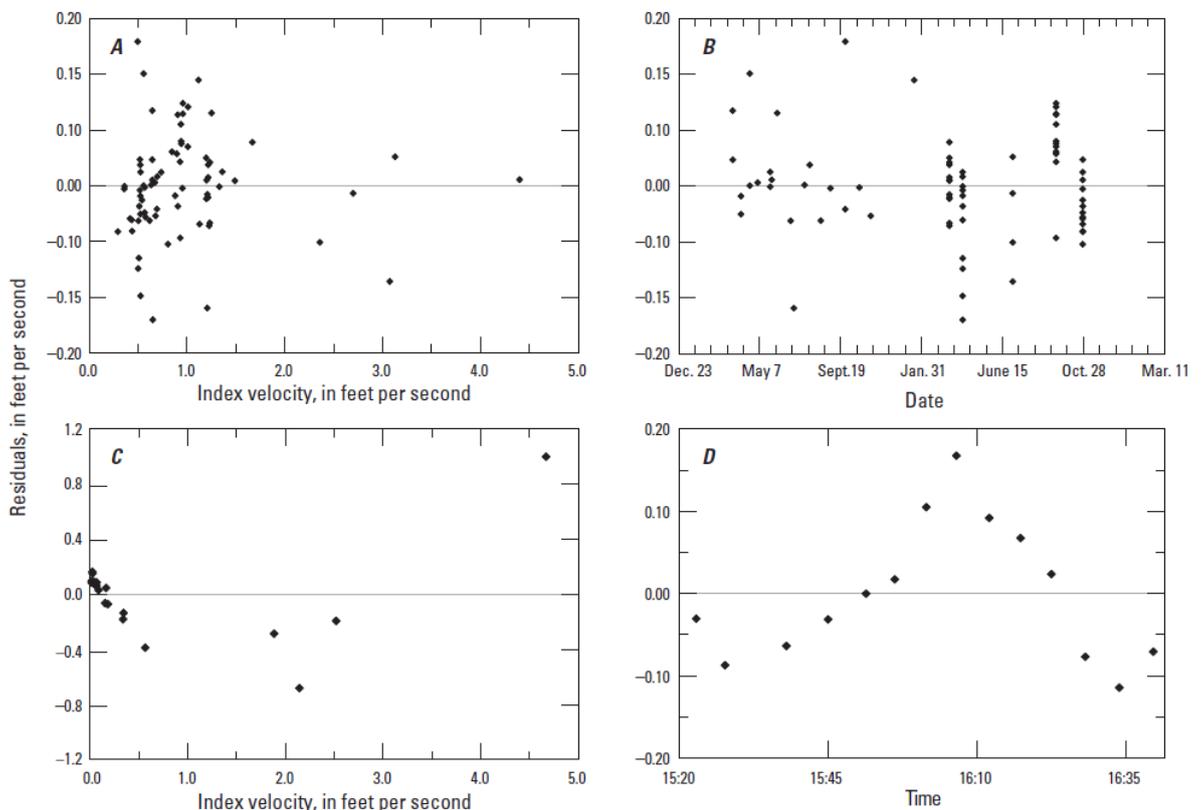


Figure 9. Residual plots demonstrating no trend (A and B), and trends (C and D). Residual plots should demonstrate a random appearance with reasonable variance equally distributed around zero along the x axis variable. An identifiable pattern can mean that a compound or multiple linear relationship exists.

(Source: USGS, Levesque, V.A., and Oberg, K.A., 2012)

10.3 Real time discharge monitoring

Most ADVMs allow the output of real time discharge during a deployment. Where an ADVM is used for real time output of discharge, the ADVM shall be programmed in accordance with one of the following:

- a) the site-specific regression equation calculated by the index velocity method; or
- b) the channel cross-section. ADVM measured mean velocities are multiplied by the area calculated from the ADVM measured stage and user input cross-section data.

11 Uncertainties in discharge measurement

The following information regarding hydrometric and discharge measurement uncertainties has been sourced from ISO/TR 24578:2012 which makes reference to ISO 5168, ISO/TS 25377, ISO/IEC 98-1, ISO/IEC 98-3 and ISO 15769. It is the responsibility of the operator to refer to the original documents for future ISO updates on measurement uncertainties.

11.1 Description of measurement uncertainty

All measurements of a physical quantity are subject to uncertainties and therefore the result of a measurement is only an estimate of the true value and only complete when accompanied by a statement of its uncertainty. The discrepancy between the true value and the measured value is the measurement error which is a combination of component errors that arise during the performance of the various elementary operations of the measurement process.

When a measurement depends on several component quantities then the total measurement error is a combination of all the component errors. Therefore, the determination of a measurement's uncertainty is a combination of all the identified component measurement errors, quantification of their corresponding uncertainties and then a combination of those component uncertainties.

The component uncertainties are combined in a manner that accounts for both systematic and random errors and are termed 'standard uncertainties' which correspond to one standard deviation of the probability distribution of measurement errors. One standard deviation equates to a confidence level of 68%. The uncertainty at two standard deviations is twice the standard uncertainty which if estimated can be multiplied by two to obtain the uncertainty at two standard deviations, or 95% confidence level. The multiplication factor is termed as the coverage factor. Therefore, if the uncertainty is expressed at three standard deviations the coverage factor would be three and represent a confidence level of 99%.

When stating uncertainties, it is also necessary to state the confidence level or the coverage factor i.e. the number of standard deviations.

NOTE: For example, if a discharge measurement of 50 cumecs had an uncertainty of 9% at the 95% confidence level the statement of uncertainty should be documented as follows:

Discharge = 50 m³s⁻¹ with an uncertainty of 9% at the 95% confidence level based on a coverage factor of k=2.

11.2 Estimating the uncertainty in an ADVm discharge determination

ADVms calculate streamflow by measuring velocity and area. Therefore, the accuracy of an ADVm is dependent on how it is set up and how it is operated. ADVm manufacturers provide potential values of error within their technical specifications for the ADVm sensors. These error values are for the measured velocity of the reflective particles in the sampled section of the water column and not for the accuracy of the streamflow measurement. Further points of introduced error occur from:

1. Depth measurement – Depth is an important factor within the streamflow calculation therefore the accuracy and sensitivity of the depth measurement is critical.
2. Thermistor – The speed of sound calculations required to calculate velocities are greatly affected by changes in temperature. A 5°C difference in temperature results in a 2% bias error in the measured discharge (Mueller *et al* 2009).
3. Salinity – A change of 12 parts per thousand equates to a 1% bias error in the speed of sound calculation and a 2% error in the velocity calculation. Refer to Appendix A.
4. Determination of the cross-sectional area.
5. Acoustic beam contamination.

The key to minimising uncertainty in ADVm measurements is to ensure that operating staff have the required level of training and experience to ensure that the correct operational procedures are adhered to and that the data are accurately processed to quantify all introduced sources of uncertainty. Field procedures should be implemented according to the environmental conditions encountered at the measurement site. All equipment shall be checked regularly to identify any potential sources of error that could be introduced to a measurement. These checks shall be documented to demonstrate due diligence.

Appendix A Conductivity conversion table

[$\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; ppt, parts per thousand; (00480), ADAPS parameter code for salinity in ppt]

Specific conductance, in $\mu\text{S}/\text{cm}$	Salinity, in ppt (00480)	Specific conductance, in $\mu\text{S}/\text{cm}$	Salinity, in ppt (00480)	Specific conductance, in $\mu\text{S}/\text{cm}$	Salinity, in ppt (00480)
100	0.040	11,000	6.229	38,000	24.124
300	0.131	13,000	7.463	41,000	26.252
500	0.226	15,000	8.714	44,000	28.405
700	0.324	17,000	9.983	47,000	30.582
1,000	0.474	20,000	11.914	50,000	32.783
2,000	0.997	23,000	13.878	53,000	35.008
3,800	1.984	26,000	15.872	56,000	37.257
5,000	2.664	29,000	17.895	59,000	39.530
7,000	3.826	32,000	19.945	62,000	41.826
9,000	5.016	35,000	22.022	65,000	44.146

(Source: USGS, Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, p. 37)

Appendix B ADVM Field service sheet

INDEX-VELOCITY INSTRUMENT INSPECTION FORM

Station Number		Station Name			
Party	Date	Watch Time	Logger Date	Logger Time	Reset?
					Y / N @
Battery voltage	Weather (Air temp., Wind speed & direction, etc.)				
Field Observations					
Time (Zone)	DCP/Logger	ETG/TI	OG	RP to WS	Velocity
ADVM Recorder Data					
Retrieve Data	Names of downloaded file(s)				
Yes or No					
Beam Check					
Beam Check Acceptable?	Beam Check Filename(s)				
OK or Not OK					
Describe Results/ Corrective Measures					
ADVM Observations / Configuration					
Log File Name					
ADVM Sensor Readings	ADVM Date	Watch Time	ADVM Time	Reset Clock?	
				Y / N @	
	Heading	Pitch	Roll	ADVM Stage	
Deploy Sensor	SDI-12 or Autonomous	Water Temp	ADVM Temp	Meas. Salinity	ADVM Salinity
ADVM Recording Info	Start Date	Start Time	Intervals	Sampling Int.	Averaging Int.
Save Setup!					
Comments:					

(Source: USGS, Levesque, V.A., and Oberg, K.A., 2012)

Organisations may consider recording salinity, turbidity and temperature reference and deployment values.

Appendix C An example of salt wedge impacts

To develop a velocity index relationship at Johnstone River at Innisfail (-17.526020, 146.037612), a series of measurements over two days was conducted over the daily range of tidal flows at the Innisfail gauging station. Johnstone River @ Innisfail is a tidal site, 300 metres wide located around 5 kilometres from the river mouth. Installed at the site is a 300 kHz Horizontal ADCP (HADCP). It was found the freshwater slice of water sitting atop the salt water below affected the velocity index relationship.

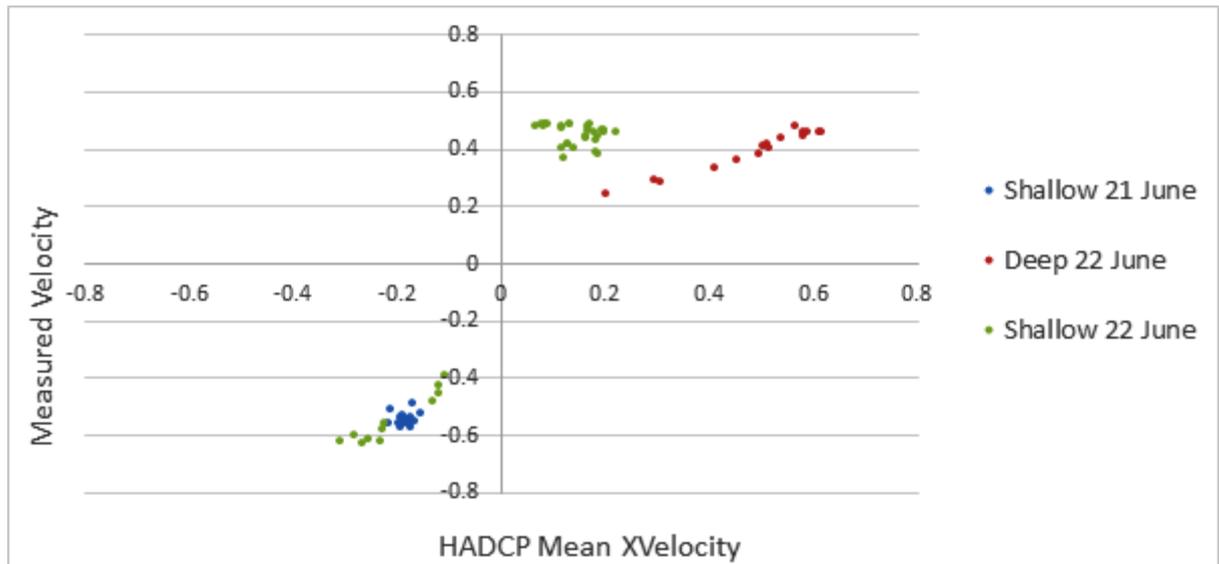


Figure C1: Salt wedge impacting shallow water velocity index results, June 21-22, 2017
(Credit: Stephen Wallace, Queensland Government Department of Natural Resources, Mines & Energy)

Figure C1 shows the velocity measured by the HADCP stagnating around $0.1\text{--}0.2\text{ms}^{-1}$ while the measured velocity is $0.4\text{--}0.5\text{ms}^{-1}$. Where there is shallow depth of water above the HADCP, the HADCP is only measuring a slice of freshwater sitting on top of the salt wedge. The freshwater is essentially dammed by the salt water downstream and hence there is no correlation between channel velocity and the measured velocity in the fresh water.

Horizontal ADCP velocities impacted by salt wedge should not be used for velocity index determination or calculations.

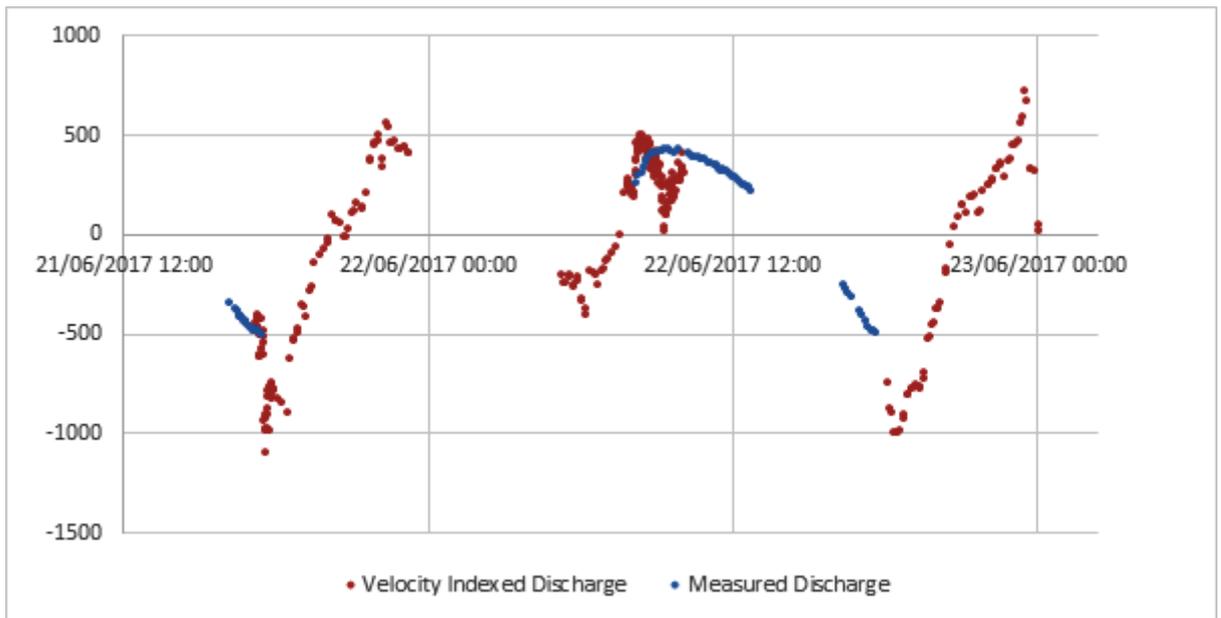


Figure C2: Gaugings undertaken on 21-22 June 2017

(Credit: Stephen Wallace, Queensland Government Department of Natural Resources, Mines & Energy)

Figure C2 is a time series of velocity indexed computed discharge data for Johnstone River @ Innisfail overlaid with actual manned boat ADCP measurements. There is no velocity index relationship for the measured velocities in shallow water affected by salt wedge as seen in Figure C1. Those HADCP measurements are excluded from the time series and discharge is interpolated between the outgoing and incoming tide data.

A method for determining influence of freshwater/saltwater interaction, such as salinity profiling, could be useful as an independent factor in velocity indexing.

Appendix D Training

D.1 Training session outline

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
Identify and understand the 1.1 Purpose and 1.2 Scope of this guideline	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the purpose of the procedural guideline for acoustic Doppler velocity meters. Outline its scope.	Face to face delivery
2 Acoustic Doppler Velocity Meters	Copies of all guidelines and definitions documents. Access to all reference material.	Define three types of ADVN: <ul style="list-style-type: none"> • point velocity; • single bin; and • profiler. 	Face to face delivery
2.2 Horizontal/side-looking ADVN	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the installation and function of a horizontal/side looking ADVN.	Face to face delivery
2.3 Bottom/bed-mounted ADVN	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the installation of a bottom/bed-mounted ADVN.	Face to face delivery
3 Instrument management	Copies of all guidelines and definitions documents. Access to all reference material.	Address instrument management records.	Face to face delivery
3.1 Instrument maintenance	Copies of all guidelines and definitions documents. Access to all reference material.	Address instrument maintenance and effect on data integrity.	Face to face delivery
3.2 Instrument tests	Copies of all guidelines and definitions documents. Access to all reference material.	Explain instrument testing by checking against a known velocity structure, depth and temperature.	Face to face delivery
3.3 Firmware and software upgrades	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss firmware and software upgrades and records.	Face to face delivery

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
4 Operating personnel	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss training of ADVN operating personnel, data processing and technology evolution.	Face to face delivery
5 Pre-deployment checks	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss the need to carry out checks prior to entering the field or placing the instrument in the water.	Face to face delivery
6 Field deployment guidelines 6.1 Site selection	Copies of all guidelines and definitions documents. Access to all reference material.	Explain site selection and the suitability of the: <ul style="list-style-type: none"> • cross-section; • flow characteristics; • ADVN chosen for the site; and • reach location and characteristics. 	Face to face delivery
6.2 Site installation	Copies of all guidelines and definitions documents. Access to all reference material.	Address site installation and instrument protection	Face to face delivery
6.2.1 Horizontal/Side-looking ADVN	Copies of all guidelines and definitions documents. Access to all reference material.	Address the installation of a horizontal/side-looking ADVN in a stream with respect to: <ul style="list-style-type: none"> • orientation; • preliminary checks; and • clear line of sight to a sufficient sample of the stream. 	Face to face delivery
6.2.2 Bottom mounted ADVN	Copies of all guidelines and definitions documents. Access to all reference material.	Address the installation of a bottom mounted ADVN in a stream with respect to: <ul style="list-style-type: none"> • preliminary checks; • location and security; and • clear line of sight to a sufficient sample of the stream. 	Face to face delivery
7 Instrument configuration	Copies of all guidelines and definitions documents. Access to all reference material.	Address general instrument configuration.	Face to face delivery
7.1 Averaging interval	Copies of all guidelines and definitions documents. Access to all reference material.	Address the selection of an appropriate averaging interval.	Face to face delivery

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
7.2 Sampling interval	Copies of all guidelines and definitions documents. Access to all reference material.	Address the selection of an appropriate sampling interval.	Face to face delivery
7.3 Measurement volume	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss considerations relevant to determining measurement volume.	Face to face delivery
7.4 Cell size, beginning and end	Copies of all guidelines and definitions documents. Access to all reference material.	Address the selection of site-appropriate cell size, beginning and end.	Face to face delivery
8 Communications and data logging	Copies of all guidelines and definitions documents. Access to all reference material.	Address configuring communication and data logging for optimum data collection.	Face to face delivery
9 Instrument field servicing and data calibration 9.1 Field service	Copies of all guidelines and definitions documents. Access to all reference material.	Address the procedure for servicing and instrument in the field.	Face to face delivery
10 Calculating discharge methodologies	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the differences between the numerical method and the IVR method for calculating discharge from ADVM recorded data.	Face to face delivery
10.1 The velocity extrapolation method	Copies of all guidelines and definitions documents. Access to all reference material.	Explain the numerical method and its limitations for calculating discharge.	Face to face delivery
10.2 The index velocity method	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss the data necessary to apply the index velocity method.	Face to face delivery
10.2.1 Stage-area rating	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss the development and maintenance of a relevant and accurate stage-area rating.	Face to face delivery

LEARNING ELEMENTS	RESOURCES	DESCRIPTION	
10.2.2 Discharge calibration data	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss the collection of discharge calibration data.	Face to face delivery
10.2.3 Index velocity rating	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss the index velocity rating and the development of a sufficiently accurate regression equation.	Face to face delivery
10.3 Real time discharge monitoring	Copies of all guidelines and definitions documents. Access to all reference material.	Discuss real-time discharge monitoring.	Face to face delivery
11 Uncertainties in discharge measurement	Copies of all guidelines and definitions documents. Access to all reference material.	Identify international standards relevant to discharge measurement uncertainty.	Face to face delivery
11.1 Description of measurement uncertainty	Copies of all guidelines and definitions documents. Access to all reference material.	Define and explain the uncertainty of measurement of physical quantities and the level of confidence in recorded and calculated values.	Face to face delivery
11.2 Estimating the uncertainty in an ADVN discharge determination	Copies of all guidelines and definitions documents. Access to all reference material.	Give examples of sources of uncertainty in estimating ADVN discharge determination. Discuss use and maintenance for error minimisation.	Face to face delivery

D.2 Training learning resources

D.2.1 Introduction

Welcome to the learner resource for National Industry Guidelines for hydrometric monitoring, Part 9: *Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels*, NI GL 100.09–2019. The purpose of this resource is to develop your knowledge and skills and improve your competency in this guideline.

D.2.2 Section References

The table below shows elements of the guideline that are covered in this learner resource. This may help the learner to map their progress as they work their way through this resource.

Section	Unit element
1 Scope and general	1.1 Purpose 1.2 Scope
2 Acoustic Doppler Velocity Meters	2.1 General description 2.2 Horizontal/side-looking ADVN 2.3 Bottom/bed-mounted ADVN
3 Instrument management	3.1 Instrument maintenance 3.2 Instrument tests 3.3 Firmware and software upgrades
4 Operating personnel	4 Operating personnel
5 Pre-deployment checks	5 Pre-deployment checks
6 Field deployment guidelines	6.1 Site selection 6.2 Site installation 6.2.1 Horizontal/Side-looking ADVN 6.2.2 Bottom mounted ADVN
7 Instrument configuration	7.1 Averaging interval 7.2 Sampling interval 7.4 Cell size, beginning and end
8 Communications and data logging	8 Communications and data logging
9 Instrument field servicing and data calibration	9.1 Field service
10 Calculating discharge methodologies	10.1 The velocity extrapolation method 10.2 The index velocity method 10.2.1 Stage-area rating 10.2.2 Discharge calibration data 10.2.3 Index velocity rating 10.3 Real time discharge monitoring
11 Uncertainties in discharge measurement	11.1 Description of measurement uncertainty 11.2 Estimating the uncertainty in an ADVN discharge determination

D.2.3 Who needs this competency?

This learning material covers the skills and knowledge required for a person to use and understand National Industry Guidelines for hydrometric monitoring Part 9: *Application of in-situ Point Acoustic Doppler Velocity Meters for Determining Velocity in Open Channels*, NI GL 100.09–2019.

D.2.4 Learning outcomes

At the completion of this learner resource you will be competent in the following:

- use the guideline document for reference
- use the guideline in day to day operations
- access the material referenced in the guideline document
- understand procedural standards for using acoustic instruments to gather water data
- use and understand related internal procedures and work instructions.

D.2.5 Health and safety considerations

Health and safety legislation shall always be considered when implementing National Industry Guidelines, workplace procedures and work instructions.

Employees carrying out work related to the National Industry Guidelines should be adequately trained in all relevant health and safety matters.

D.2.6 Environmental considerations

Compliance with this guideline may involve working in the environment. As such care should be taken to:

- prevent unnecessary damage to river banks
- prevent unnecessary disturbance of the river system
- carefully construct any infrastructure to minimise impacts on the environment and river flow conditions
- plan access roads to sites to minimise impacts during all seasonal conditions.

D.2.7 What resources will I need?

- Workplace policies and procedures
- Manufacturer manuals, requirements and specifications
- Codes of practice
- Workplace equipment, tools and instruments
- Workplace reports

- Workplace maps, plans and instructions
- Permits and access to locations and worksites

Other useful resources

- Relevant Health and Safety Act
- Manufacturer's Instruction manuals
- Organisations procedures and work instructions
- Herschy, Reginald W. (1985), Stream flow Measurement, Elsevier Applied Science Publishers, New York, NY, USA
- Australian Standards

World Meteorological Organization (WMO)

- World Meteorological Organization 2008, Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information. WMO-No. 168. Sixth edition, 2008. ISBN 978-92-63-10168-6, viewed 2 October 2018, <<http://www.whycos.org/hwrrp/guide/index.php>>
- World Meteorological Organization 2009, Guide to Hydrological Practices, Volume II: Management of Water Resources and Application of Hydrological Practices, WMO-No. 168, Sixth edition, 2009, viewed 2 October 2018, <<http://www.whycos.org/hwrrp/guide/index.php>>
- World Meteorological Organization 2010a, Manual on Stream Gauging, Volume I: Fieldwork. WMO-No. 1044, 2010. ISBN 978-92-63-11044-2, viewed 2 October 2018, <<http://www.wmo.int/pages/prog/hwrrp/manuals.php>>
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