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# Setup and Data Collection Process of an Acoustic Doppler Velocimeter (ADV) in a Laboratory Setting

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**PURPOSE**: The purpose of this Coastal and Hydraulics Engineering Technical Note (CHETN) is to outline experimental set up and the data collection process of an Acoustic Doppler Velocimeter (ADV) in a laboratory setting. The Nortek Vectrino ADV will be referenced in this CHETN as will the Nortek Comprehensive Manual for Velocimeters (Nortek AS 2018). Note that Nortek no longer sells the Vectrino, but the Vector, which is similar to the Vectrino aside from only having one configuration, is available.

**INTRODUCTION:** An ADV is an instrument that measures three-dimensional (3D) water velocities with high accuracy. The Nortek Comprehensive Manual for Velocimeters states "A factory-calibrated velocimeter should have a scale-factor bias that is less than 1% of the measured velocity." This instrument uses the Doppler Effect, the change in frequency that is received when either the source or receiver is moving, to generate a 3D velocity profile. A basic schematic of this technology is shown in Figure 1. This profile is often helpful for experiments performed to evaluate or verify hydraulic conditions. One example is the study of bed stability of open channel flows with submerged foliage (Bao and Li 2017). In this study, an ADV was used to measure the velocity and Reynolds stress, which verified the visual observation that the gravel moved faster when the foliage was partially submerged than when it was fully submerged. In another study, the optimum spacing between Floating Treatment Islands (FTIs) was analyzed (Liu et al. 2019). Using an ADV, the velocity field was measured in different spacing scenarios; then, the flow rate was derived from the velocity field data. The flow rate in and out of zones and the residence time in the zones indicate the amount of mass removal per channel length based on the FTI spacing.

This CHETN will describe the use of an ADV during the Red River Structure (RRS) physical model study. The velocity profiles were of critical importance for optimization of the structure's design, assessment of the structure's performance, 3D numerical modeling calibration/validation, and riprap performance (Bell et al. 2020).

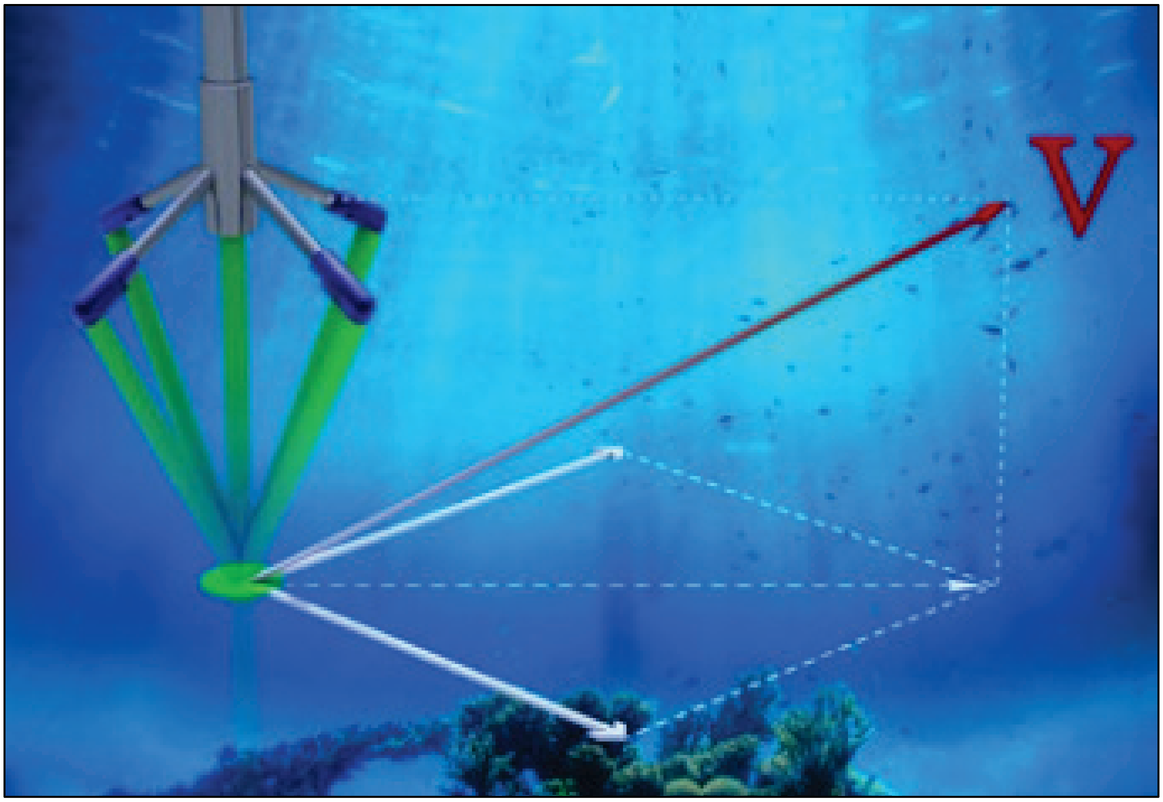


Figure 1. ADV schematic (Nortek AS, n.d.).

**BACKGROUND:** The Nortek Vectrino ADV has one transmit transducer and four receiver transducers. The transmitter produces an acoustic pulse that reflects off particles in the water, and the four receivers absorb the echo. These signals are collected and saved on a computer using Vectrino Software. Further details on how the program works are included in the set-up section later in this CHETN.

ADVs can have two different prong configurations, side-looking and down-looking, (Figure 2). The difference in these configurations is the orientation of the probes. In the side-looking configuration, the probes are oriented to the side of the ADV. In the down-looking configuration, the probes are oriented downwards away from the ADV. Although the two types are very similar, there are a few differences that make one more suitable for certain conditions than the other. Nortek states that the side-looking probes may be more ideal for high-velocity environments due to fewer "weak spots" and the down-looking may be more suitable in environments where velocities close to the bed are needed (Nortek Support 2021). Side-looking probes are ideal for horizontal measurements while down-looking probes are more ideal to use to obtain the z-component and the vertical.

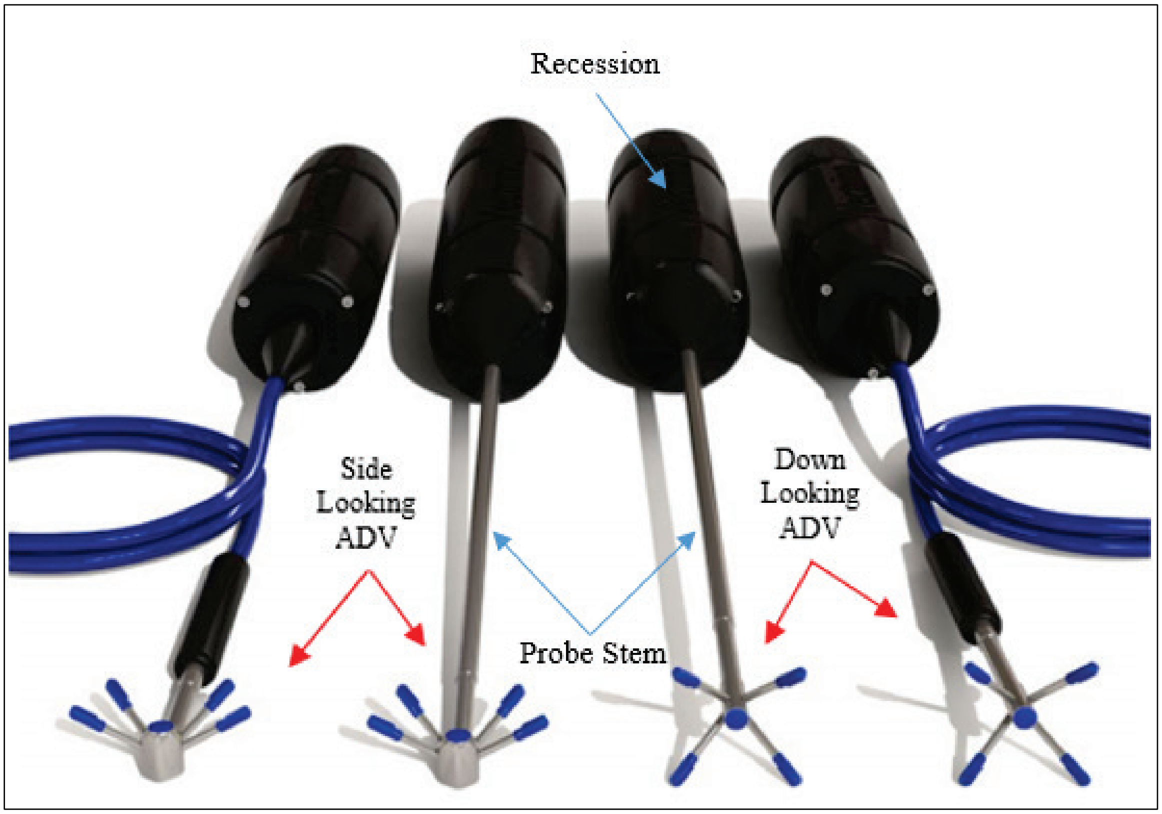



Figure 2. Nortek Vectrino ADV configurations (Nortek AS, n.d.).

**SETUP:** The procedures and methods discussed in this section were developed during the RRS physical model study. Due to their high precision, ADVs are very sensitive to any vibration or external movement. To get the best results, the ADVs were rigidly fastened to a stationary frame to eliminate any movement of the instrument. The frame was built out of a T-slotted 80/20 aluminum structural framing shown in Figure 3. A major advantage of this framing was its mobility, which allowed for easy repositioning of the ADVs throughout testing. The framing was fastened to a rigid bridge spanning the measurement location, which is pictured in Figure 4. Furthermore, the location within the project coordinate system was known for each ADV measurement location. This was important so that each set of measured data had an associated X-Y coordinate along with a depth in the water column that could be applied/compared to the numerical modeling results/calibration.


Figure 3. 80/20 square four open T-slots (80/20 Inc. 2021).

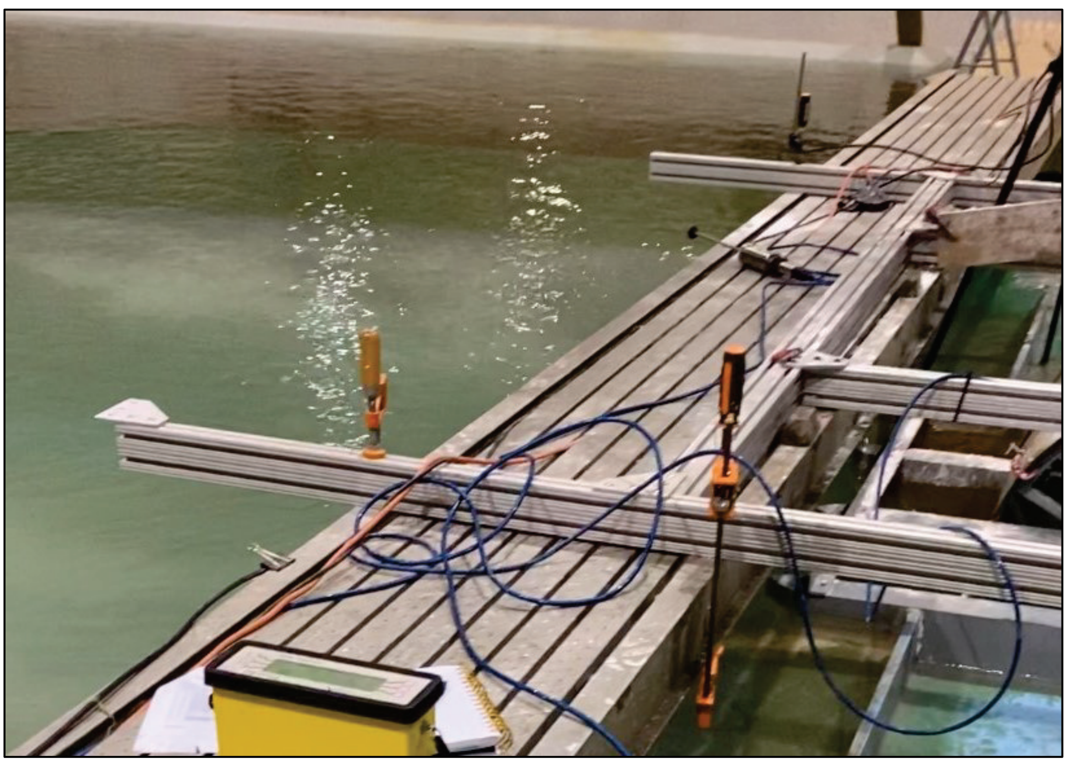


Figure 4. Frame fastened to bridge.

The ADVs were rigidly mounted to the frame using rods (Figure 5). The system that the ADV was mounted on needed to have little to no movement or vibration during collection due to the high sensitivity of the ADVs. The ADV should be mounted using the recessions, never via the probe stem (see Figure 2 for recession and probe stem identification) to avoid damage to the instrument/cabling. The rods could move upward, downward, and laterally; however, ADV 2 was the only ADV to move laterally. The framing that the three ADV rods were attached to was movable so they could be moved longitudinally. Figure 5 shows the setup and mobility.

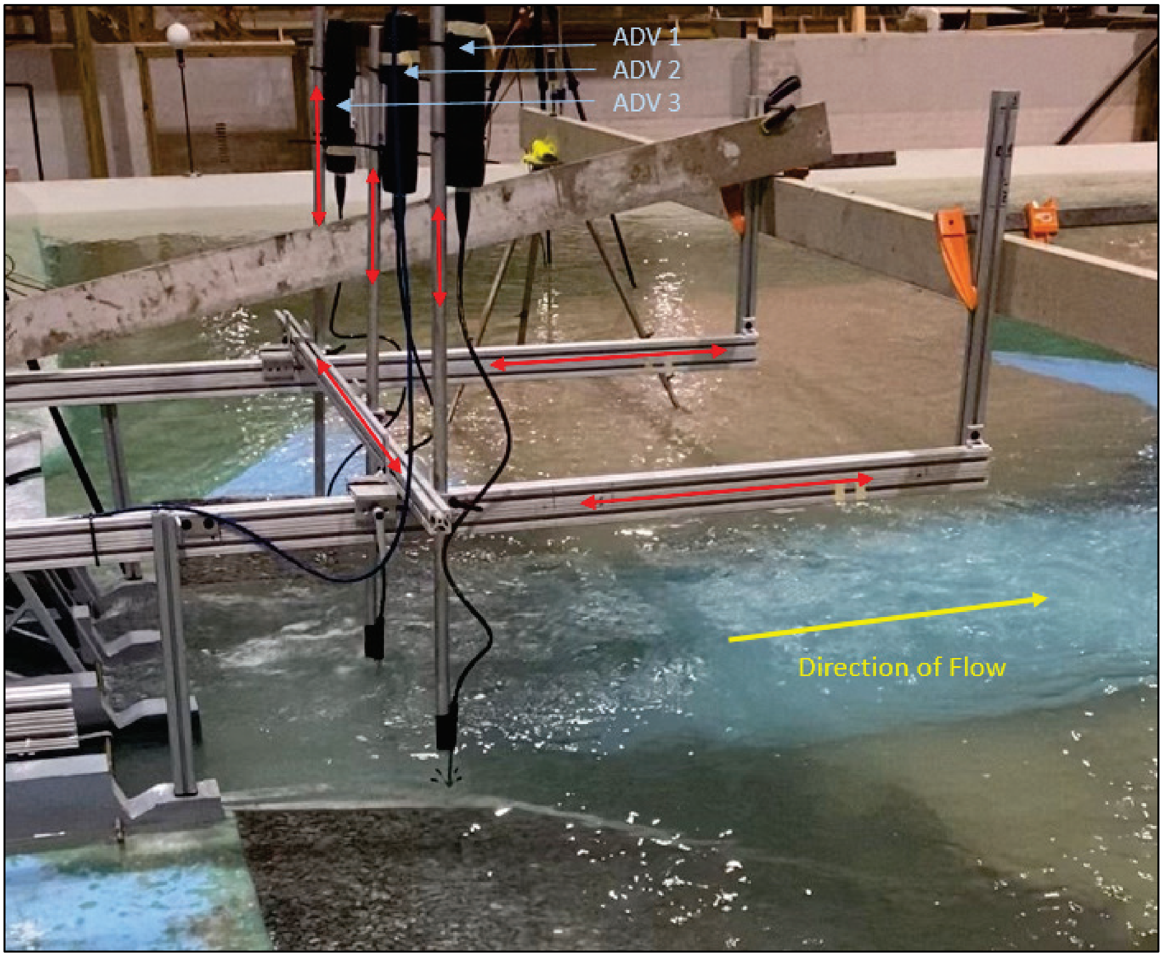



Figure 5. RRS physical model study ADV setup.

The ADV measurement locations can be found in Figure 6, and an example of a post-processed test can be seen in Figure 7. The processing resulted in a figure that displayed the velocity vector and magnitude in the X, Y, and Z directions. The configuration of the framing and number of ADVs used was based on these locations. For locations inside of the downstream wing walls (D01, D02, D03, D08, D09, D10, D11, D12, D13, D14, D15), ADV number 2 was used. For locations on the descending right side of the structure outside of the wing walls (D07 and D05), ADV number 1 was used. For the locations on the descending left side of the structure outside of the wing walls (D04 and D06), ADV number 3 was used. Using three ADVs was necessary to avoid having to detach the ADV from the rods when moving to different testing location and thus losing the known location within the physical model coordinate system. Locations upstream of the structure (U01-U11) are not relevant to this CHETN as an ADV was not used for those locations.

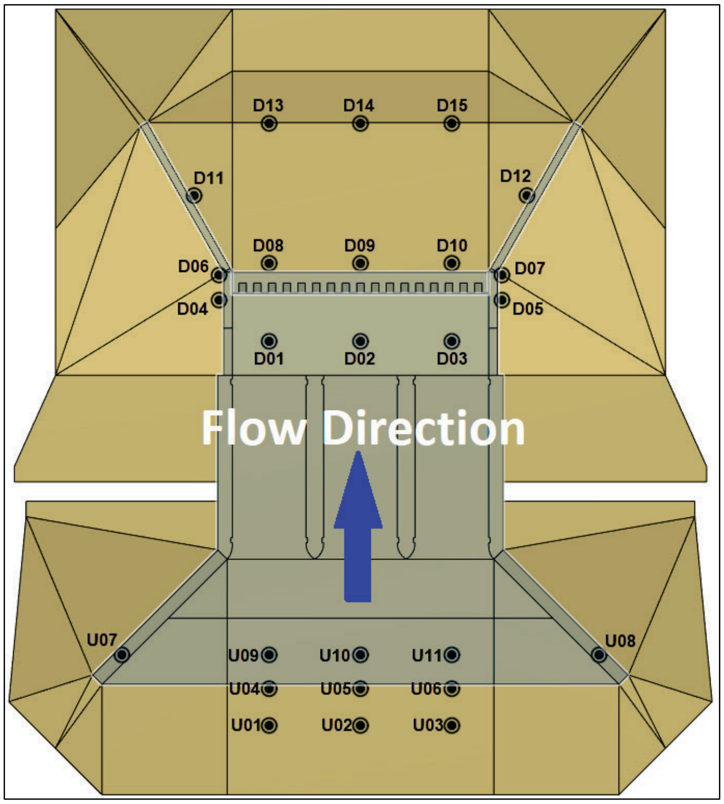



Figure 6. ADV measurement locations (Bell et al. 2020).

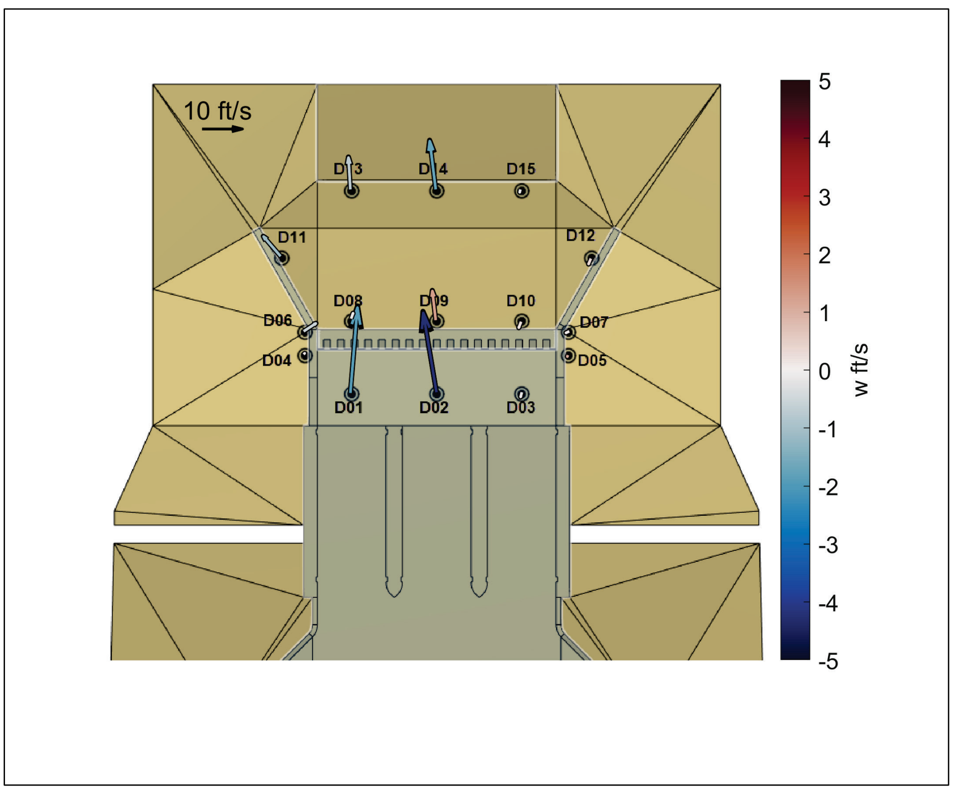



Figure 7. Post-processing example of velocity vectors from one of the RRS physical model experiments.

The mobility of the ADV should be considered when designing the framing and mounting mechanisms. The ADV should be positioned at the desired depth and x-y position with the x-direction prong in the direction of flow (Figure 8). This will ensure the data are positive in the direction of flow. The depth at which measurements are taken depends on the area of interest in the water column. For the RRS physical model, measurements were taken 1 in.[*†] and 3 in. off the floor. Nortek's reminders for installing the ADV include verifying there are no obstructions in the sampling volume. The sampling volume is determined by the user and is discussed more in the data configuration section of this CHETN.

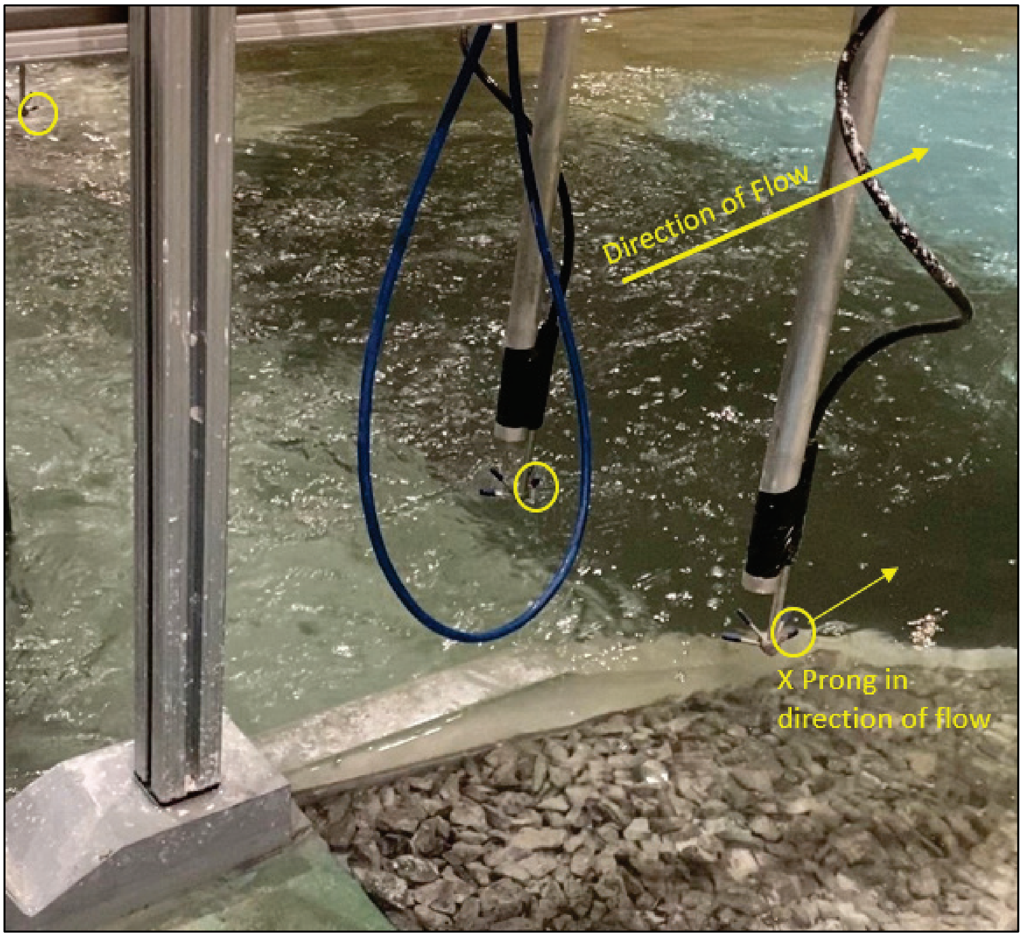



Figure 8. X-prong in direction of flow.

[*] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

[†] For a full list of the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 345-7, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

**DATA CONFIGURATION:** The Nortek Vectrino ADV comes with a software package called Vectrino that configures the ADV and collects the data. The ADV should be configured based on the flow velocity and flow direction. If these flow conditions change, the ADV must be reconfigured to obtain the highest quality data. Another factor in obtaining high-quality data is that particles must be present in the water, so the water has a high enough turbidity for the acoustic pulses to reflect. The Potters Industries Inc. Spherical 110P8 (UL Prospector 2021), which is a powder-like substance comprised of microbial glass beads, was used during the RRS Physical Model testing. Throughout this CHETN, the microbial glass beads will be referred to as *seed* as this is the traditional name for a material with the purpose of creating a conducive environment for data collection. The effects of flow velocity and flow direction will be discussed in detail in the data quality section of this CHETN.

The ADV should be placed in the water without any seed material to obtain a baseline reading for configuration. After the baseline is established, seed should be added to the water to find the appropriate methods and amounts of seed necessary to obtain quality data. If the seed does not appear to be making a difference, increase the amount of seed until the highest data quality is reached. From this point on, the water should remain constantly seeded while data are being collected.

The Vectrino software has a single window for configuration (Figure 9). Four main parameters in this window should be adjusted: the sampling rate, nominal velocity range, transmit length, and the sampling volume. The sampling rate for RRS physical model study testing was 25 Hz, which was the maximum sampling rate for the ADV model used. The maximum sampling rate was used because there were no concerns with data storage. According to Nortek's comprehensive manual, the sampling rate should be at least twice as fast as the occurrence of the signal of interest. This parameter should be determined first and then kept constant throughout testing. This is the only parameter that is not changed when the ADV is introduced to a new flow environment.

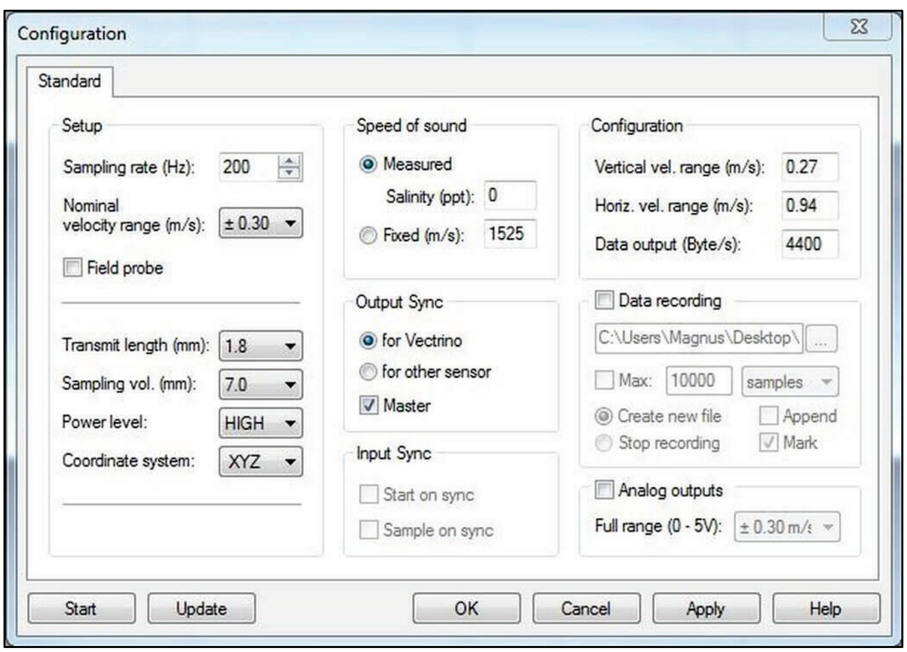
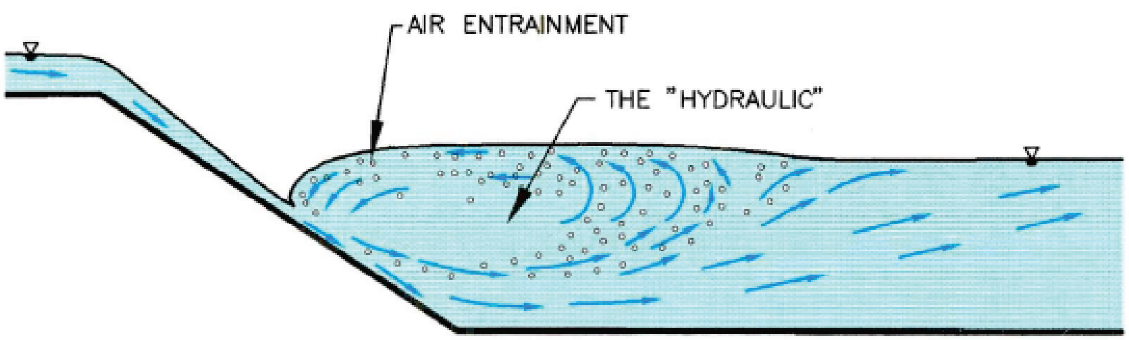


Figure 9. Vectrino configuration window (Nortek Support 2019).

The nominal velocity range is from ±4.00 m/s to ±0.03 m/s. In the most ideal case, the velocity range is small (±0.03 m/s) indicating there is little fluctuation in the velocity data. A starting range can be estimated based on observation from the flow conditions. For laminar flows, the range can be small but will need to be increased with turbulent flows due to the variation in velocity. If the nominal velocity range is too large for the flow conditions, the signal to noise ratio (SNR) will be low and result in poor quality or noisy data. If the nominal velocity range is too small for the flow conditions, all the velocities will not be captured. This parameter should be adjusted until the data quality is best, which is discussed in more detail in the data quality portion of this CHETN.

The next parameter to be adjusted is the transmit length and sampling volume. The transmit length is the length of the acoustic pulses and has a range of 0.3 mm to 2.4 mm. Generally, smaller transmit lengths produce better data, but if the transmit length is too small, the SNR will be compromised due to the decrease in signal. Beginning with the smallest transmit length and working up is the best practice to finding the transmit length that produces the highest-quality data. The sampling volume range, which can vary from 1 to 9.1 mm, is a function of the transmit length. As the transmit length increases, the range of sampling volume slightly increases. The transmit length should be adjusted before the sampling volume since the sampling volume is dependent on the transmit length. The adjustment of the sampling volume will not have a large impact on the data but should be adjusted until high-quality data are achieved.

**DATA QUALITY:** There are three main plots of data that will help the user determine if the data are suitable: the velocity, the SNR, and the correlation. The velocity data plot is the velocity versus time. This plot will likely show little variation at lower-velocity areas and higher variation at higher-velocity areas. The variation in the data will also be greater if the flow is changing directions often. Figure 10 shows a scenario of velocity occurring in several directions. This particular hydraulic behavior is called a vertical eddy or a “roller.” During the RRS physical model study, ADV data were collected in a roller, which made calibration challenging. It is important to visually observe the ADV collection locations so the data can be validated visually.




Courtesy of Wright Water Engineers, Inc. and ASDSO.
Source: Wright, Kenneth R., Kelly, Jonathan M., Houghtalen, Robert J., & Bonner, Mark R. "Emergency Rescues at Low-Head Dams." Paper presented at Dam Safety 1995, the 12th annual conference of the Association of State Dam Safety Officials, Atlanta, GA, September 1995.

Figure 10. Profile view of a roller (Brigham Young University 2013).

The SNR is a measure of the level of the signal with reference to the background noise level using the amplitudes as described in the equation below.

$$\boldsymbol{SNR = 20log_{10}\frac{Amplitude_{signal}}{Amplitude_{noise}}} \quad (1)$$

Nortek recommends an SNR greater than 15 dB to obtain quality data, but it was found that an SNR of 20 – 25 dB produced the highest quality data from Bell et al. 2020. The SNR graph should be steady with no spikes. The SNR is dependent on how conducive the water is to testing. If there is not enough seed, the background noise will be too high, causing a low SNR. The more seed, the better data quality. During the RRS physical model study it was found that there are some cases where the SNR cannot reach the desired SNR value. This behavior usually occurs only in low-velocity areas because the seed material is not distributed sufficiently by the flow. However, typically in high-velocity areas, the seed material is being mixed well into the water, which causes a very high and steady SNR.

The correlation is the amount of variance in the data being collected and is calculated by taking the difference between the two pulses. The range is 0% – 100%, where 0% means there are no similarities between the two pulses and 100% means there are no differences in the two pulses. The goal is to have 100% correlation, which results in little to no outliers in the data. This is easy to achieve for low-velocity flows that do not change direction. If the flow has a high velocity and/or changes direction frequently (e.g., turbulent areas), then the correlation plot could fluctuate greatly. This is not a bad thing if it is consistent with what is being shown in the velocity plots and what is being visually observed.

**SUMMARY:** ADVs are a useful velocity measurement instrument in laboratory studies because of their accuracy and versatility. Setting up the ADV to be rigid is the first step to successful usage. It should be stable and should not experience any movement or vibration while gathering data. After installation, ADVs must be properly configured to ensure high-quality data will be measured. The ADV software configurations should be adjusted according to the known flow conditions (high velocity, low velocity, flow directional changes). Whether the areas of interest are susceptible to bad data must also be considered. Areas with very low velocity or high turbulent intensity may not be able to reach the desired SNR and correlation values, which produce lower quality data. The amount of seed material used to increase the turbidity of the water must also be considered. If the data appear to be low quality, adding more seed material should be considered before adjusting any of the software configurations. If an ADV is set up and deployed correctly, the velocity data measured can be highly accurate for laboratory applications.

**ADDITIONAL INFORMATION:** This CHETN was prepared by Locke M. Williams, research mechanical engineer, US Army Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS. Questions about this CHETN can be addressed to Ms. Williams at 601-634-2258 or *Locke.M.Williams@usace.army.mil*.

This CHETN should be cited as follows:

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## REFERENCES

80/20 Inc. 2021. Part No. 25-2525. 80/20 Inc. https://8020.net/25-2525.html

Bao, M. X., and C. W. Li. 2017. "Hydrodynamics and Bed Stability of Open Channel Flows with Submerged Foliaged Plants." *Environmental Fluid Mechanics* 17: 815–831.

Bell, Gary L., Jeremy A. Sharp, Locke M. Williams, Howard E. Park, Duncan B. Bryant, and Gaurav Savant. 2020. *Red River Structure Physical Model Study*. ERDC/CHL TR-20-20. Vicksburg, MS: US Army Engineer Research and Development Center.

Brigham Young University. 2013. Video Presentation: Submerged Hydraulic Jumps. KRC Project Groups. https://krcproject.groups.et.byu.net/

Chao Liu, Yuqi Shan, Jiarui Lei, and Heidi Nepf. 2019. "Floating Treatment Islands in Series along a Channel: The Impact of Island Spacing on the Velocity Field and Estimated Mass Removal." *Advances in Water Resources* 129: 222–231. https://doi.org/10.1016/j.advwatres.2019.05.011

Nortek AS. n.d. *Vectrino–3D Water Velocity Sensor Lab Probe-Data Sheet*. https://www.environmental-expert.com/downloads/vectrino-3d-water-velocity-sensor-lab-probe-datasheet-834473

Nortek AS. 2018. *The Comprehensive Manual for Velocimeters*. https://www.nortekgroup.com/assets/software/N3015-030-Comprehensive-Manual-Velocimeters_1118.pdf

Nortek Support. 2019. *How Do I Synchronize Vectrinos?* Nortek Support Group. https://support.nortekgroup.com/hc/en-us/articles/360029499492-How-do-I-synchronize-Vectrinos-

Nortek Support. 2021. *What Are the Differences between and Advantages of Side-Looking and Down-Looking Vectrino Probes?* Nortek Support Group. https://support.nortekgroup.com/hc/en-us/articles/360029820091-What-are-the-differences-between-and-advantages-of-side-looking-and-down-looking-Vectrino-probes-

UL Prospector. 2021. Spherical 110P8. Potters Industries Inc. Prospector. https://www.ulprospector.com/en/na/Coatings/Detail/25921/572868/Sphericel-110P8