Appendix 3 – Analysis of Data for Selection of Measurement Volume

Introduction

Review of beam checks and other available data is essential to the selection and (or) modification of the measurement volume for index velocity measurements with ADVMs and the ongoing quality assurance of the index velocity data. A brief description of a beam check is provided below followed by descriptions of problems that can be identified by means of beam checks. Analysis of other time-series data, such as signal amplitude, noise level, signal-to-noise ratio, X velocity, Y velocity, and velocity standard error, can be used to quality assure index velocity records.

Description of a Beam Check

Beam checks are useful tools for selecting the measurement volume to be used with the ADVM installed at a site and for trouble-shooting problems that may occur from time to time. A beam check is a plot of signal amplitude for each ADVM acoustic beam. In some cases, manufacturer-supplied software for performing beam checks plots the theoretical decay curve along with the measured signal amplitudes. The decay curve is based on the system frequency, user-selected salinity, measured water temperature, and an assumed concentration for scatterers in the water. The USGS requires that a beam check be performed during every site visit. The ADVM should be configured to perform automatic beam checks at routine intervals between site visits, provided that the firmware and software for the ADVM are capable of doing so. The Index Velocity Gage Inspection Form (appendix 2) should be completed during the site visit. This form contains fields for providing information about the beam check(s) completed. In addition to performing the beam check, the hydrographer should analyze the results while still at the site to verify that no apparent changes or problems are indicated.

The result of a beam check is shown in figure 3-1, illustrating the desired features of a beam check for an ADVM. For this beam check, the main acoustic beams and side lobes do not appear to be affected by reflections from the water surface, the streambed, or any object within or beyond the selected measurement volume. The signal amplitudes for the maximum range of

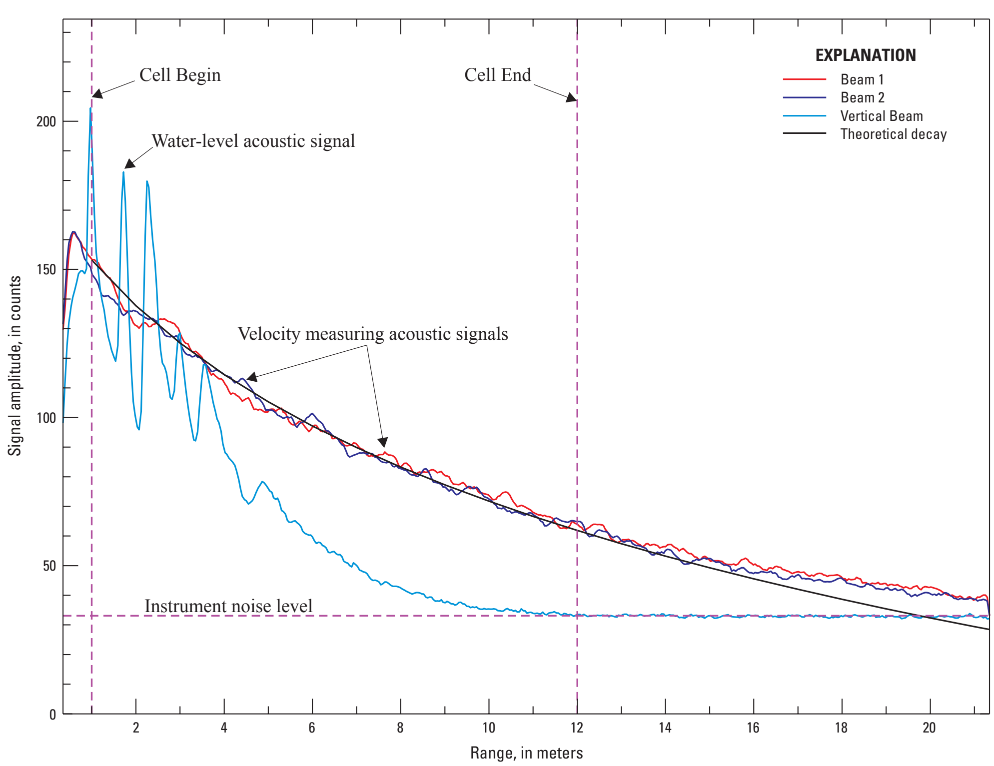

Figure 3-1. Results of a sample beam (signal amplitude) check for a sidelooker ADVM with a water-level acoustic beam.

the measurement volume (12 meters) are well above the instrument noise level (almost 30 counts higher than the noise level for this example). The signal amplitudes are similar in magnitude for each beam within the range of the measurement volume and the trend expected from the theoretical acoustic decay curve. Generally, if the average measured signal-amplitude profiles differ from the theoretical decay curve by more than 20 counts over the full range of the system, a problem may be indicated; however, this could be a natural variation in the scattering strength that may not affect system operation (SonTek/YSI, 2007).

Identifying Potential Problems in Selecting a Measurement Volume

Identifying potential problems in beam checks and using other data recorded by the ADVM is crucial to selection of the proper measurement volume. Because stream conditions change over time, beam checks should be made regularly and results should be accurately interpreted. In this appendix, potential problems are illustrated by means of a series of figures showing beam-check data and other data, along with accompanying text discussing the potential problem(s).

Figure 3-2 shows the subtle, yet important, signal-strength characteristic that can be caused by side-lobe reflections from a boundary occurring at about 60 meters from the ADVM. Typically the acoustic beam signal amplitudes should decrease with range, although there are some exceptions. If the signal amplitudes show a leveling out (signal strength stays relatively the same as range increases) for a short distance then continue to decrease with increasing range, side lobes from one or both beams may be striking a strong reflector (water surface or streambed) causing the signal strength to remain nearly constant as the distance from the transducers increases.

Signal amplitudes shown in beam checks should not increase substantially over the range where velocity is to be measured. An increase in signal amplitude with range (rapid or gradual) indicates that one or more acoustic main beams are reflecting from a fixed or large object, the streambed, or the water surface. There are some rare exceptions when return-signal amplitudes increase with range and do not adversely affect the velocity measurement volume. Figure 3-3 is a beam-check plot that shows the effect of frazzle ice on the return signal strengths. Water temperature was at or below freezing prior to and during this beam check. Previous beam checks did not indicate any boundary-like effects in the signal amplitudes. Small chunks of ice were on the water surface but were moving with the river flow. The data did not indicate any rapid increase or decrease in the velocity. Based on the velocity data time series and discussions with the manufacturer, the velocity data did not appear to be affected by these unusual return signal strengths.

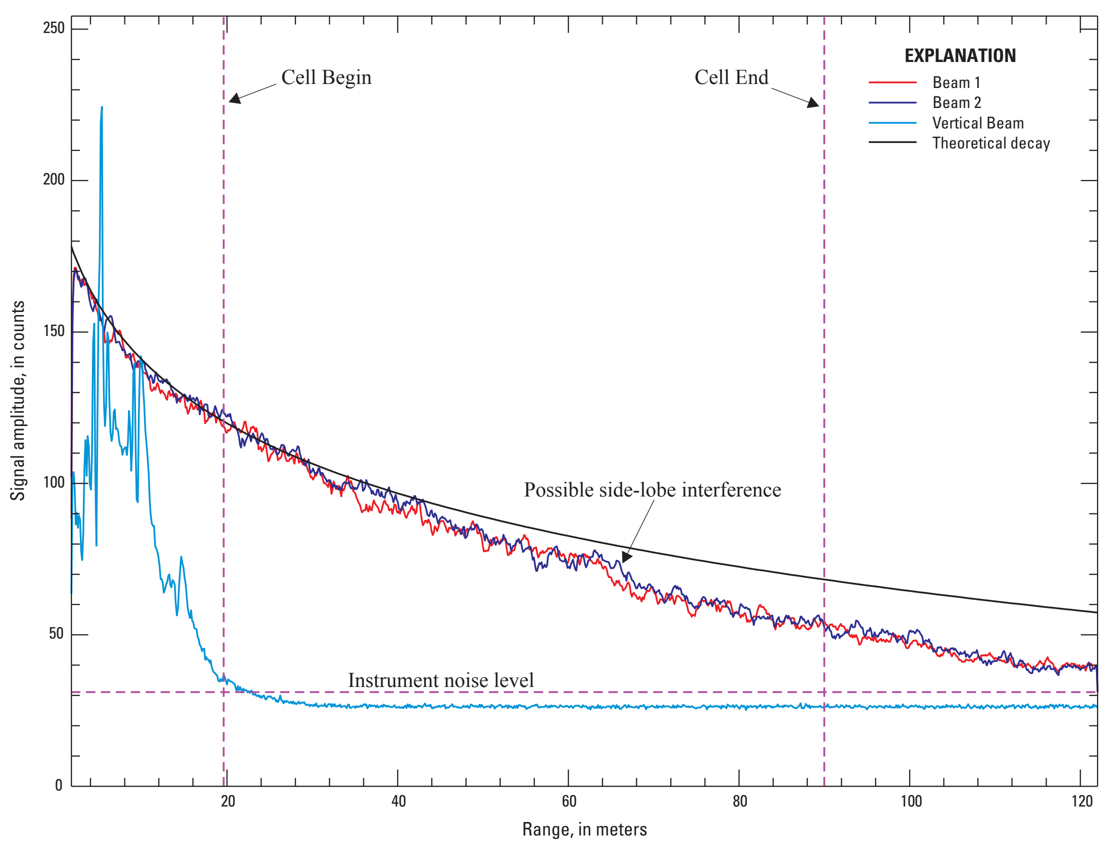

Figure 3-2. Beam-check data indicating possible side-lobe interference.

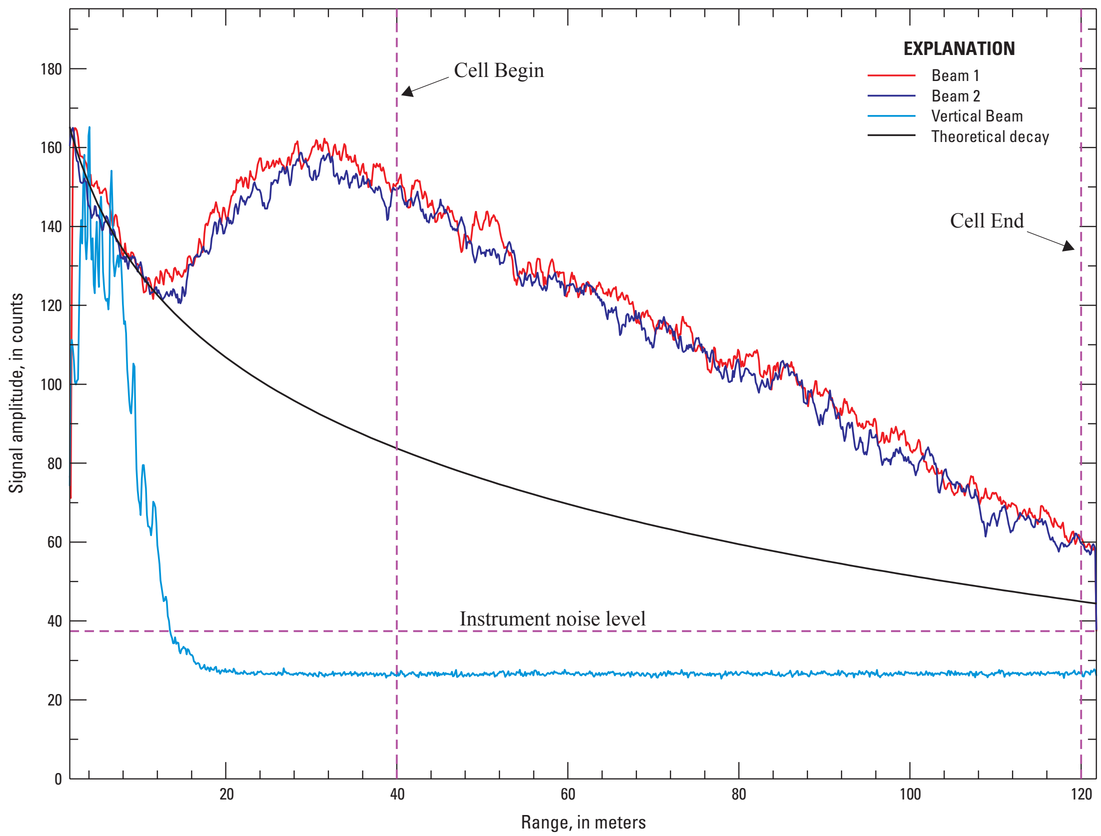

Figure 3-3. Effects of frazzle ice on signal amplitudes in a beam check.

As previously mentioned, signal amplitudes should decrease as the range increases. Based on signal amplitude alone, the end of the range-averaged velocity (cell end) and (or) the far edge of the last multiple velocity cell should be chosen to be a minimum of 10 percent of the distance to the location where the first increase in signal amplitudes is detected or typically one-half the pulse length of the transmitted signal, whichever is greater (consult manufacturer's specifications to determine ADVM pulse length). Figure 3-4 shows a beam check that has subtle changes in signal amplitudes because of possible side-lobe reflections from boundaries along the path of both beams. Signal amplitudes begin to level off just before a distance of 55 meters and remain nearly constant until about 70 meters. For this example, the end of the measurement volume should be configured to be approximately 45 meters. At this range, the signal amplitudes are greater than 100 counts for this beam check and should provide strong signal amplitudes even if backscattering conditions change over time. Similarly, for this example, the ADVM should be configured so that the cell begin is set to be free from near-field flow disturbances that are discussed later in the appendix.

The beam-check data shown in figure 3-5 indicates that the signal amplitudes increase substantially between 10 and 13 meters from the transducers. In this example, the spike in the beam check was caused by the acoustic signals from the main beams reflecting from the far bank. For this ADVM, the cell begin for the range averaged cell was set to 3 meters because of the possibility of flow disturbance from the ADVM mount and channel features upstream from the ADVM. A shorter, more conservative cell end was chosen for this site, even though the signal amplitudes do not show an increase until about 9 meters. The stage at this site during low flow is known to be substantially less than the stage during this beam check. For this reason, a cell end of 6 meters was selected to reduce the possibility that the acoustic beams would be affected by reflections from the water surface at lower stages.

Results from a beam check used to configure an ADVM cell begin and cell end and the overlapping multi-cell volumes are shown in figure 3-6. Based on this beam check, the cell begin and cell end selected by the hydrographer appear to be appropriate for the site. Figure 3-7 shows the X component of velocity (X velocity) for the range-averaged measurement volume along with the standard error of the X-velocity data for the same ADVM configured using beam check data shown in figure 3-6. X-velocity data are shown in the top plot, and the standard error of the X velocity is shown on the bottom plot. Based on the beam-check data, cell begin was set at 2 meters, and the cell end was set at 15 meters. The ADVM was configured to measure multi-cell velocity data. The range-averaged X-velocity data do not exhibit unusual values, and the standard errors are reasonable. The standard error data show a slight increase as the magnitude of the X velocity increases, indicating that turbulence in the channel increases when velocity increases as would be expected.

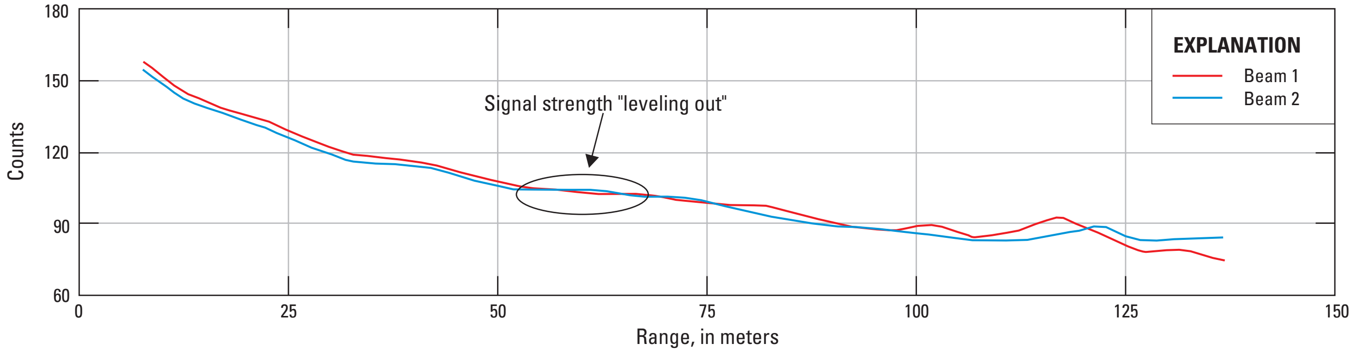

Figure 3-4. Signal strength check with subtle increases in return signal amplitudes 55 to 70 meters from the ADVM.

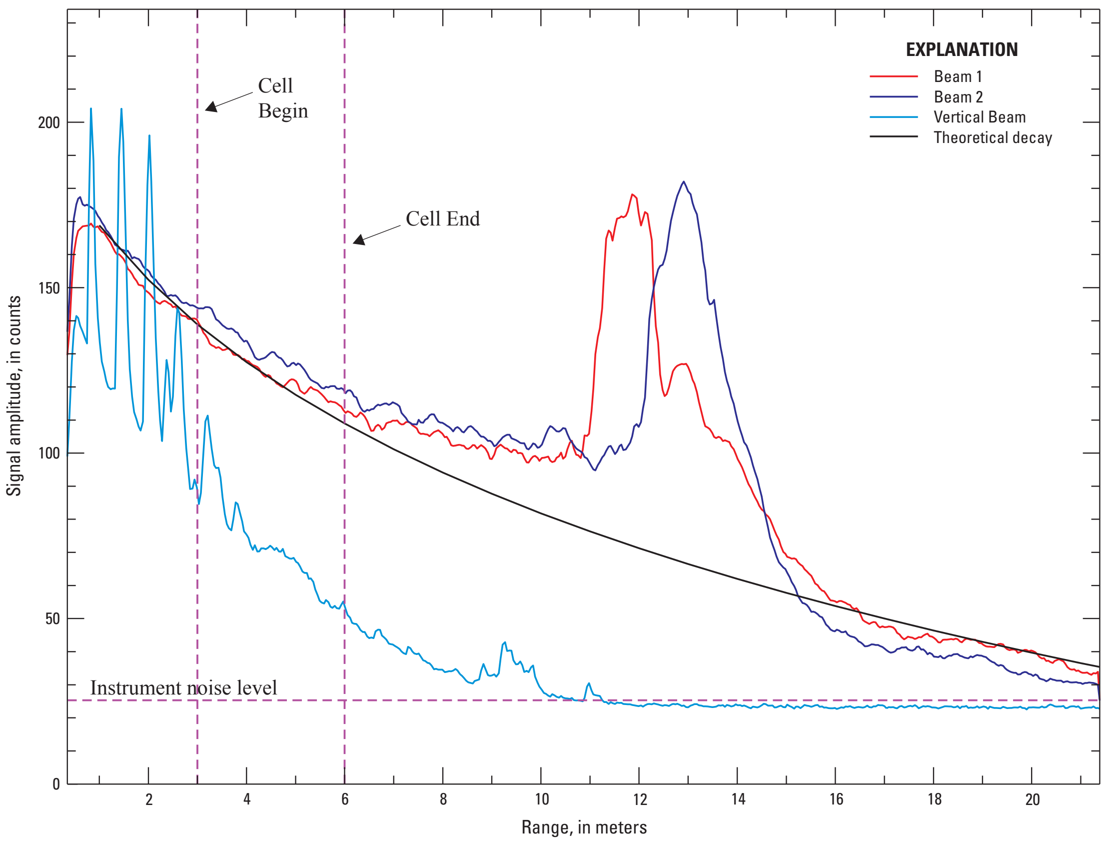

Figure 3-5. Beam check with substantial increases in return signal amplitudes 10 to 13 meters from the ADVM.

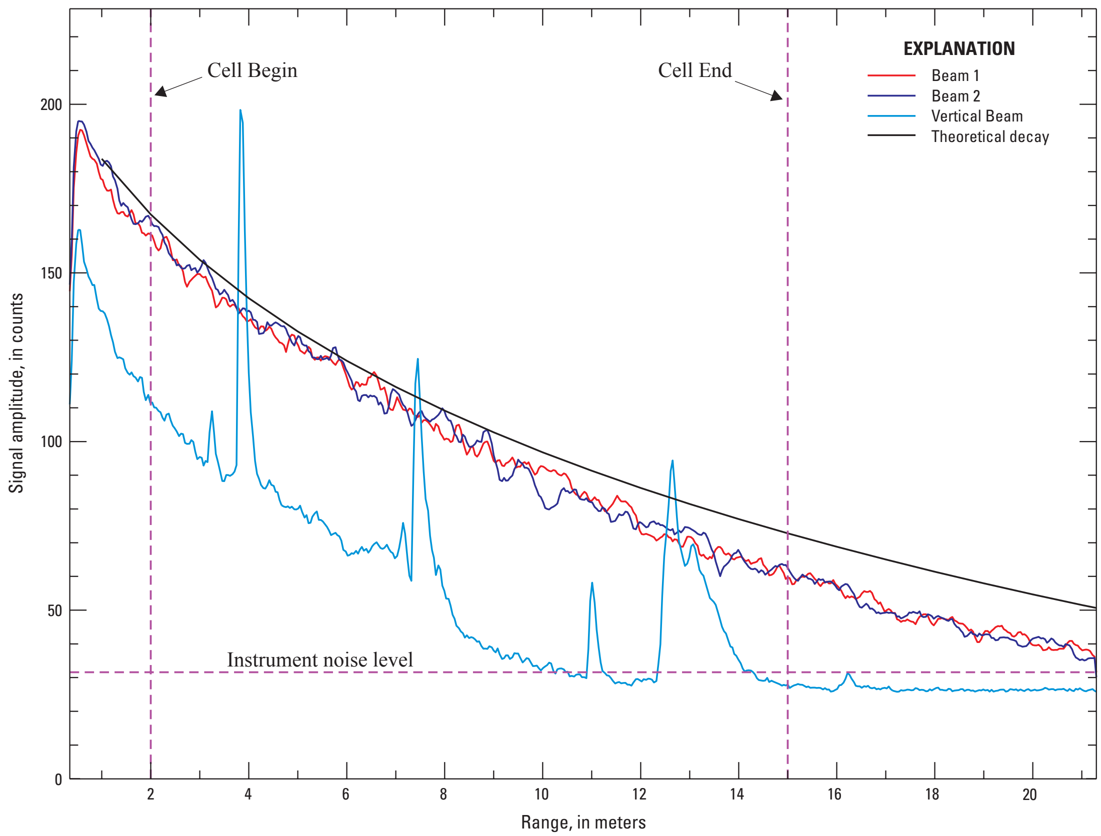

Figure 3-6. Data from a beam check with cell begin and cell end chosen based on the return signal amplitudes.

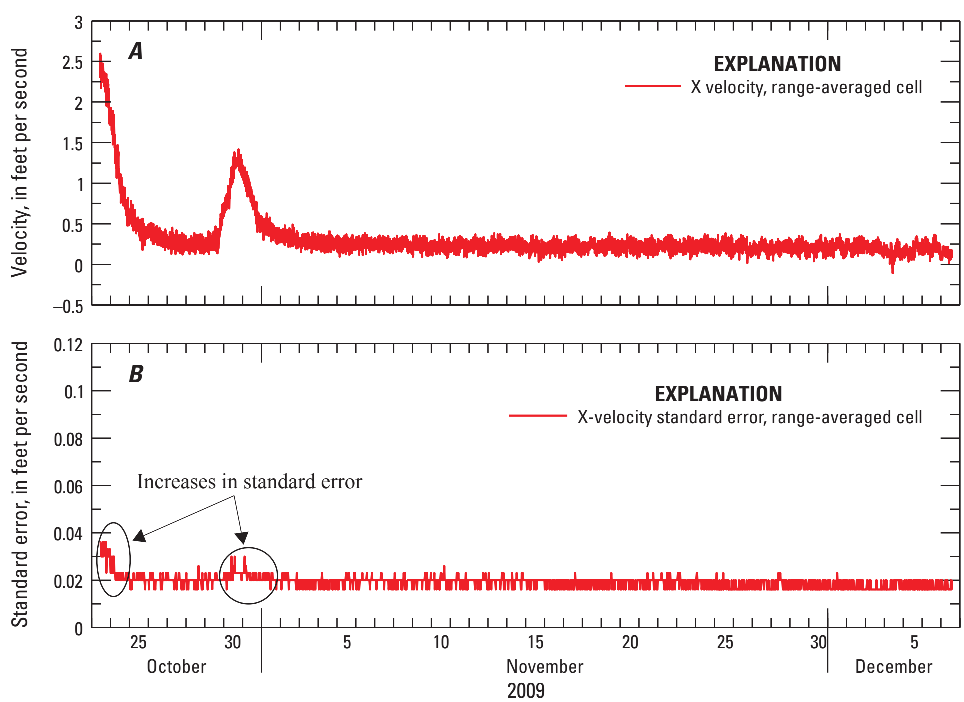

Figure 3-7. Time series of range-averaged (*A*) X velocity and (*B*) X-velocity standard error data.

The multi-cell velocity data also may be used to verify that the cell end has been appropriately chosen. Velocities measured in the various cells by the ADVM should show similar patterns and magnitudes when compared to one another and to the range-averaged cell. In figure 3-8 the range-averaged X-velocity data and the cell 1 X-velocity data are shown on top, and the standard errors for the range-averaged X velocity and cell 1 X velocity are shown in the bottom plot. The cell begin and the blanking distance were both set to 2 meters, and the cell end was set to 15 meters. The size of the velocity cells was set to 1.3 meters, and 10 multi-cells were measured and recorded; therefore, the range-averaged measurement volume and the multi-cell volume are measuring the same region in the channel from 2 meters to 15 meters (multi-cells 1 through 10).

The magnitudes for cell 1 X velocity (measurement volume is located from 2 to 3.3 meters) are substantially less the range-averaged X velocity data (2–15 meters). At the same time, the standard error of the cell 1 X-velocity data is greater than the range-averaged X velocity, which is to be expected. The range-averaged velocity measurement volume is 13 meters long, and the multi-cell velocity measurement volume is 1.3 meters long. For ADVMs, larger cell sizes (larger measurement volumes) have lower standard error than smaller cell sizes, so it is not unusual to see greater standard error in smaller multi-cell measurement volumes compared to larger measurement volumes. Plots of velocity and velocity standard error in figure 3-8 indicate that cell 1 and the cell begin for the range-averaged measurement volume may be too close to the transducers (2 to 3.3 meters) and may be measuring in a region of velocity that is affected by the channel banks or the ADVM mount.

Another set of time series plots (fig. 3-9) shows the same ADVM velocity and standard error data as before with the addition of cell 2 (3.3–4.6 meters) X velocity and standard error data. The cell 2 X-velocity magnitude is approximately two times the magnitude of cell 1 X velocity and approximately equal to the range-averaged velocity. The standard error of the cell 2 X velocity is also less than the cell 1 X-velocity standard error. This information confirms the preliminary analysis, namely that the cell begin and the blanking distance should be increased to measure only in a region of higher velocity (and correspondingly lower standard errors). In figure 3-10, cell 3 X-velocity data are added to the plots; data indicate that the velocity from 4.6 to 5.9 meters is approximately one-third greater than cell 2 X velocity. The standard error of cell 3 X velocity is approximately the same and sometimes slightly less than cell 2 X-velocity standard error. Based on these observations and plots, the cell begin and the blanking distance should be increased to approximately 5 or 6 meters in order to measure in the region of flow that is near the maximum velocity (and lower standard error) while also avoiding the possible effects of flow disturbance.

In figure 3-11, X-velocity data from the range-averaged cell from 2 to 15 meters (red), multiple cells 3, 7, and 8, with corresponding ranges of 4.6–5.9, 9.8–11.1, and 11.1–12.4 meters, respectively, are shown. The magnitudes of cell 7 and 8 X velocity are less than the other cell velocities, and the velocity standard error for cell 7 is greater than the velocity standard error for cell 3. In addition, the velocity standard error for cell 8 shows an apparent decrease compared to the other cells. The decrease in standard error for cell 8 is not as meaningful as the substantial increase in the variability of cell 8 X-velocity data. This plot illustrates how velocity and standard error data should be used together to assess the quality of the measured velocity and the end of the measurement volume. The multi-cell velocity data evaluation combined with the beam-check data indicate that the maximum range for this site and ADVM installation should be no greater than approximately 10 meters.

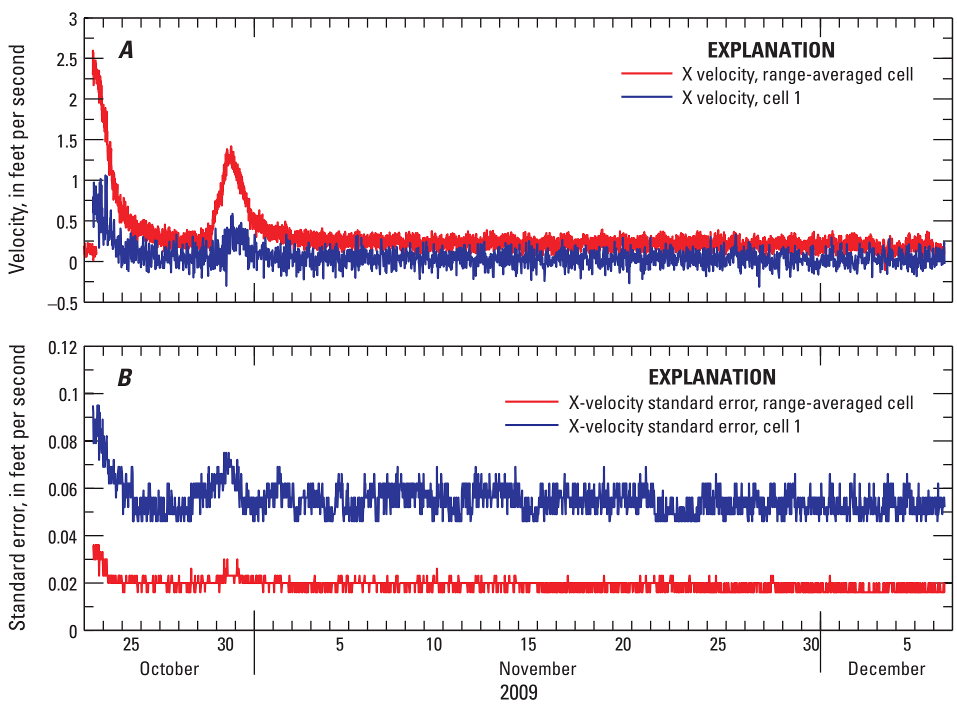

Figure 3-8. Time series of (*A*) range-averaged X velocity and cell 1 X velocity and (*B*) their corresponding standard errors.

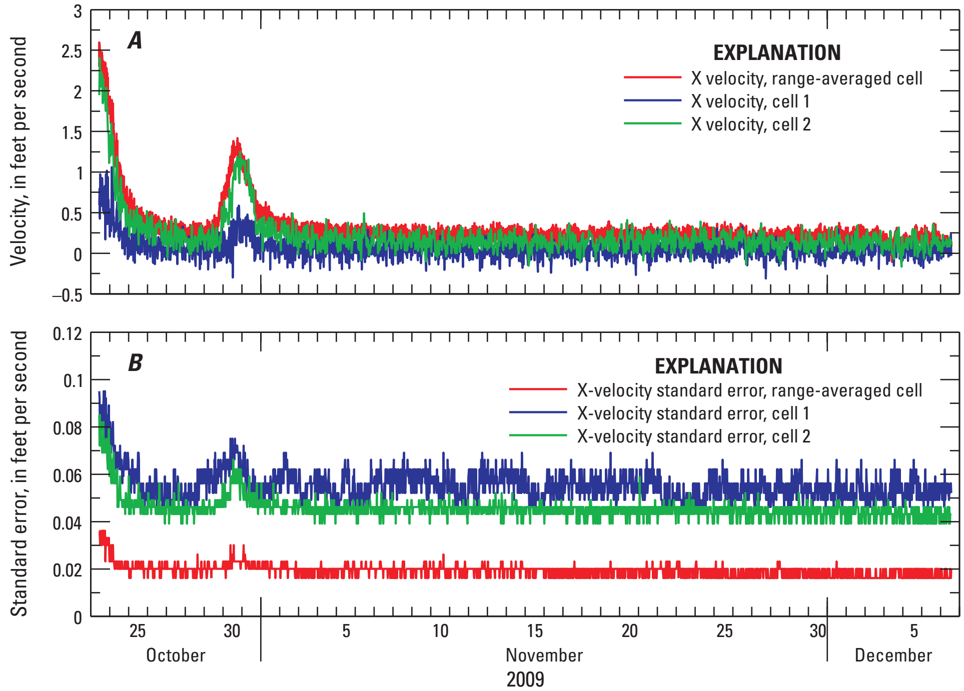

Figure 3-9. Time series of (*A*) range-averaged X velocity, cell 1 X velocity, cell 2 X velocity, and (*B*) corresponding X-velocity standard errors.

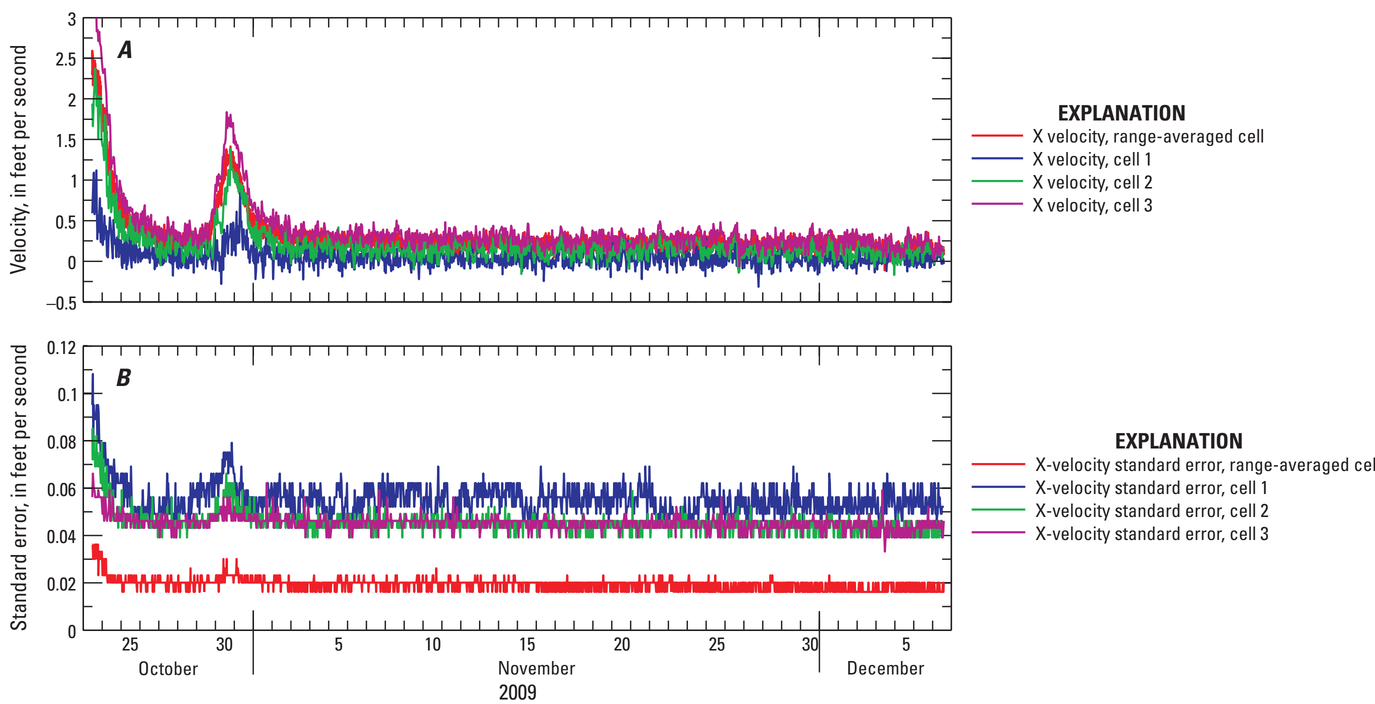

Figure 3-10. Time series of (*A*) range-averaged X velocity, cell 1 X velocity, cell 2 X velocity, cell 3 X velocity, and (*B*) the corresponding X-velocity standard errors.

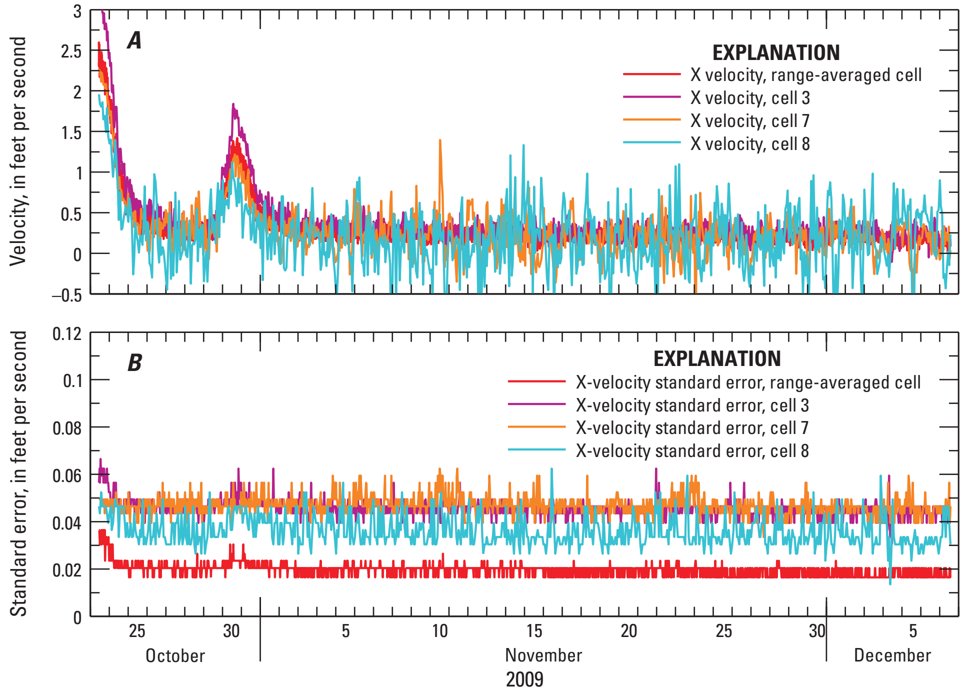

Figure 3-11. (*A*) Range-averaged X velocity, cell 3 X velocity, cell 7 X velocity, cell 8 X velocity, and (*B*) the corresponding X-velocity standard errors.

Beam checks and velocity data plots are useful tools for configuring the measurement volume for ADVMs as well as evaluating changes that can occur over time at a site. USGS requires that a beam check be performed during each site visit and that, if possible, the ADVM be configured to perform periodic, automatic beam checks between sites visits.

Reference

SonTek/YSI, 2007, SonTek/YSI Argonaut acoustic Doppler current meter technical documentation: San Diego, Calif., SonTek/YSI Corporation, 234 p.