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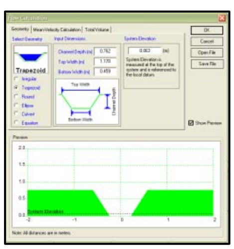
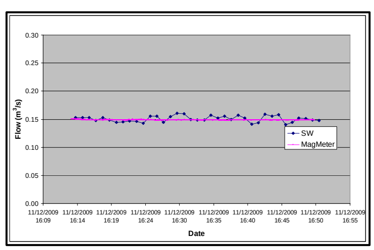
Flow Comparison
Magmeter and SonTek SW





Technical Report

Sontek/YSI

April 2010

IRRIGATION TRAINING AND RESEARCH CENTER

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Irrigation Training and Research Center
April 2010

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INTRODUCTION

Background

A flow comparison study using a SonTek® SW acoustic Doppler profiler (ADP) was conducted at the Water Resources Facility (WRF) of the Irrigation Training and Research Center (ITRC) of California Polytechnic State University, San Luis Obispo (Cal Poly). The WRF has an 85.3 m long hydraulic flume with dimensions of 1.22 m × 1.22 m. The flume has a slope of 0.0018, and is constructed of steel.

Figure 1. Cal Poly ITRC's Water Resources Facility. The flume is in the center background.

Figure 2. Flume

A variable speed pump, capable of delivering up to 0.85 m^3/sec, delivers water through a pipeline to a buffer pond at the upstream end of the flume. A magnetic meter (magmeter) is located in the pipeline, with large air vents located upstream of the magnetic meter. At the downstream end of the flume, water can either flow directly into the pump bay for the pump, or be diverted into a weighing tank with a volume of 13.5 cubic meters. In either case, the water level in the pump bay is maintained at a constant level to maintain a constant pump flow rate.

When a constant flow rate into the flume is desired (as in this case), the pump is set at a constant speed, and the water passes into and out of the buffer pond with no change in position of any of the enroute control structures over time. Measurements are taken after the flow rate has stabilized in the flume test section. Water depths in the flume are controlled by flashboards or gates at the downstream end of the flume.

The recirculated water originates in a pond that contains surface runoff. The pond is large enough that clay particles have settled out. Some single cell algae are found in the water. Once the pump/pipe/flume/sump system is filled with water, the water recirculates, with only a small (0.1 m^3/sec) flow used to maintain the pump sump level.

The magnetic meter is a McCrometer® UltraMag model #UM06-30, 76 cm (30”) meter, which scans data multiple times per second and averages over a 15 second period. The magnetic meter’s data is output using the meter’s standard 4-20ma signal converter. A Control MicroSystems SCADAPack32 is used to convert the analog data to a digital number, which is recorded every 2 seconds using National Instruments Lookout HMI software.

The depth of the water in the flume is measured using a stilling well/site tube. A 152 mm PVC stilling well is connected to the flume using clear 13 mm ID tubing to remove fluctuations due to waves. A site tube is attached to the stilling well using clear 13 mm tubing to allow accurate readings (± 1 mm). The site tube is calibrated by running close to zero flow rate down the flume and measuring the depth with a meter stick; the scale behind the site tube is adjusted to correlate with the measured value.

Figure 3. Measuring the water depth

For this flow comparison study, a trapezoidal cross section was constructed inside the flume. The trapezoidal channel has a bottom width of 0.46 m and a 1:2 side slope. It began 33.5 m downstream from the start of the flume, and had a total length of 36.6 m. The inlet to the trapezoidal cross section converged at a 22.5° angle. The trapezoidal cross section was constructed of 19 mm marine plywood in 2.44 m lengths. The wood was not painted; the smooth sanded side was on the water side. Bypass flow between the metal flume and the wooden trapezoidal section was eliminated by creating a double seal at both the beginning and end of the channel and gluing all seams, ensuring that all the flow that was measured by the magmeter passed through the trapezoidal channel. **Figure 4** shows the two seals that are located at each end of the channel.

Figure 4. Cross section constructed inside the flume

The trapezoidal channel was located 10 m downstream from flow straightening vanes and 6.7 m upstream of the flashboards. The drain is located downstream of the flashboards.

Materials and Methods

The flow comparison study was conducted using a 76 cm (30 inch) magnetic flow meter in a pipe, and a 3.0 MHz SW acoustic Doppler profiler (ADP) in an open trapezoidal canal section, to compare measured flow values. Each test took 60 minutes: 25 minutes for changing flow conditions and allowing flow conditions to stabilize, and 35 minutes for testing. Data from the magnetic flow meter was configured to collect data every 2 seconds.

The SW has two acoustic beams with a slant angle of 45 degrees that are used for velocity profiling. An additional acoustic beam, the vertical beam, is used to determine water depth and calculate the flow area. **Figure 5** presents a schematic of a generic SW deployment highlighting the SW's three acoustic beams. Additionally, the figure presents the concepts of Cell Begin and Cell End. Prior to deployment, the user can configure the instrument to collect data over a certain range by using Cell Begin and Cell End; for the tests described here, Cell Begin was set to 0.07 m and Cell End was set to 6 m. Additionally, the dynamic boundary adjustment was enabled for the experiments; this allows the instrument to automatically adjust the measurement range of the instrument based on water level.

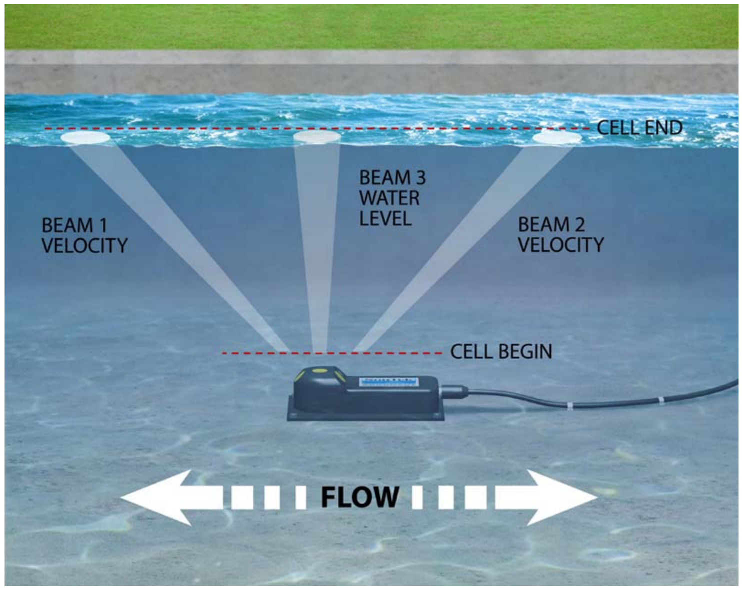

Figure 5. Schematic of SW deployment

Figure 6 presents the Sample Interval and Averaging Interval used in the study. The SW was configured for a 60 second sample rate and 60 second averaging interval, effectively taking 60 readings of velocity each minute and then reporting an average velocity for that minute. All advanced options were activated with the exception of Ice Detection, as conditions in San Luis Obispo were not below freezing. For this study, diagnostic data were stored to monitor system performance, while PowerPing was enabled to minimize measured velocity variance. One Beam Solution was activated for system robustness; in the case that one velocity profiling beam is covered, the system will continue collecting data and calculating flow. AutoSleep and Voltage Protection were activated for the tests described in this study; however, they are typical default settings for the sensor.

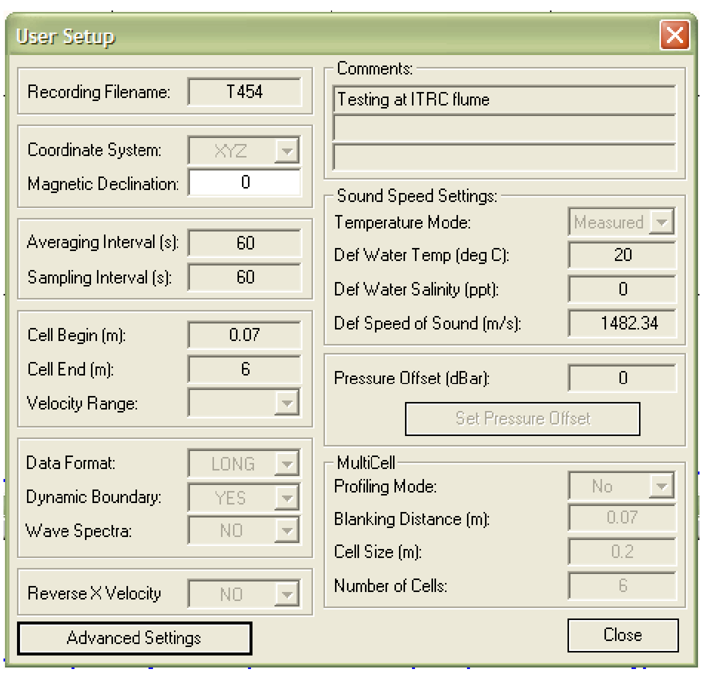

Figure 6. Screen capture of user setup for tests

Figure 7 presents channel geometry details and system elevation information. For the study described here, the trapezoidal channel had a depth of 0.762, a top width of 1.17 m and a bottom width of 0.459 m. System elevation, or the elevation of the vertical beam referenced to channel bottom, was 0.063 m. The SW uses these values along with water depth measured by the instrument to determine flow area. Flow is determined by multiplying calculated flow area by the average water velocity measured by the instrument.

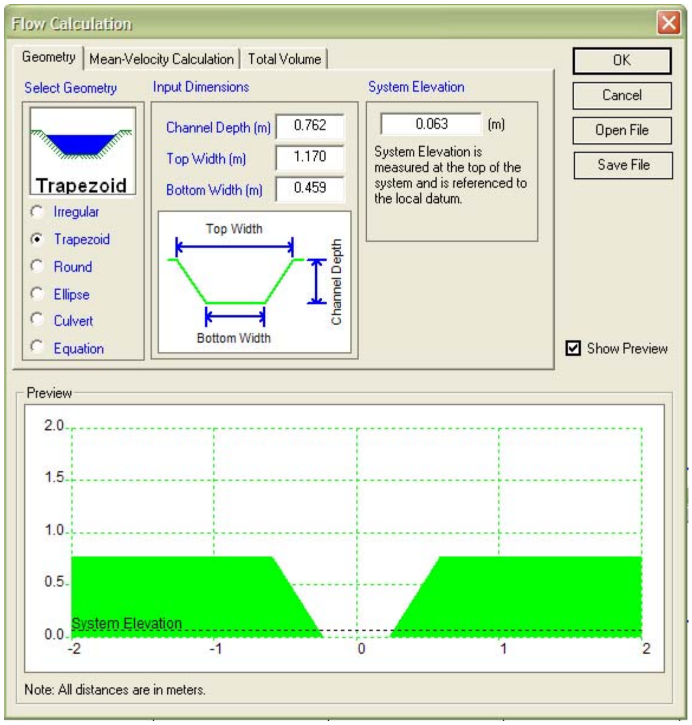

Figure 7. Screen capture of channel geometry used in tests

Figure 8 displays pictures of the canal used in the study. The photograph on the left shows the canal prior to a flow test, while the image on the right displays the canal during the high flow test with average velocities of 1.70 m/s.

Figure 8. Photos of canal prior to and during testing

RESULTS

Figures 9 and 10 present data collected during flow test T454001. **Figure 9** displays a graph of stage (m) and corresponding flow area (m^2) data from the 35 minute test. The blue line represents continuous water level data, while the yellow triangles represent manual readings taken periodically during the study. There is good agreement between manual readings and readings from the SW. The pink line represents flow area calculated from the water level data. It can be observed from **Figure 9** that stage was stable and the corresponding flow area calculation was also stable throughout the test. **Figure 10** displays flow values for the SW and the magmeter. Both flow values correspond well; the average value for the SW was 0.769 m^3/s, while the average value for the magmeter was 0.779 m^3/s. The SonTek SW and magmeter had standard deviations of 0.006 m^3/s and 0.008 m^3/s respectively.

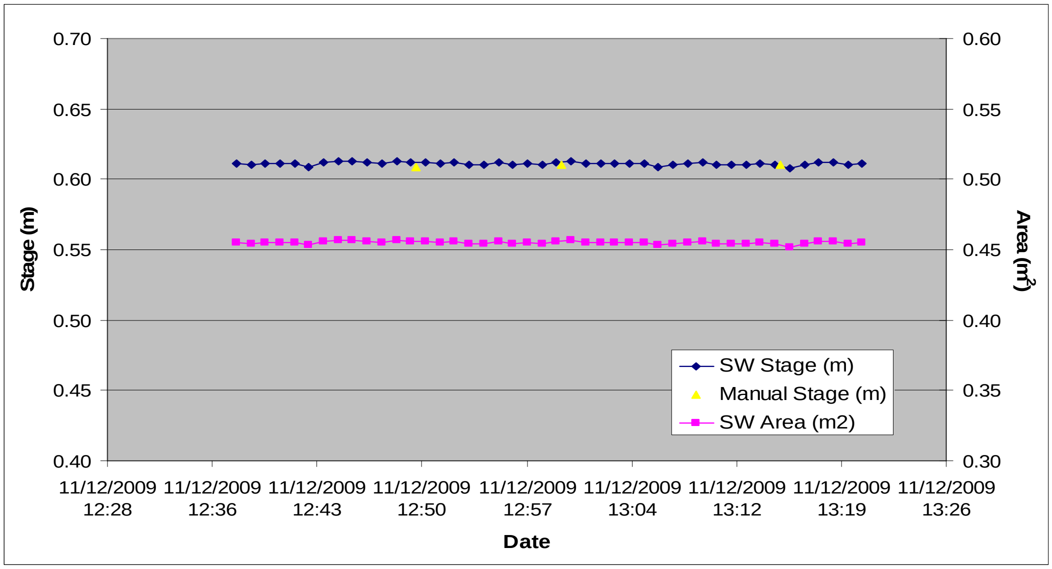

Figure 9. Stage measurements for test T454001

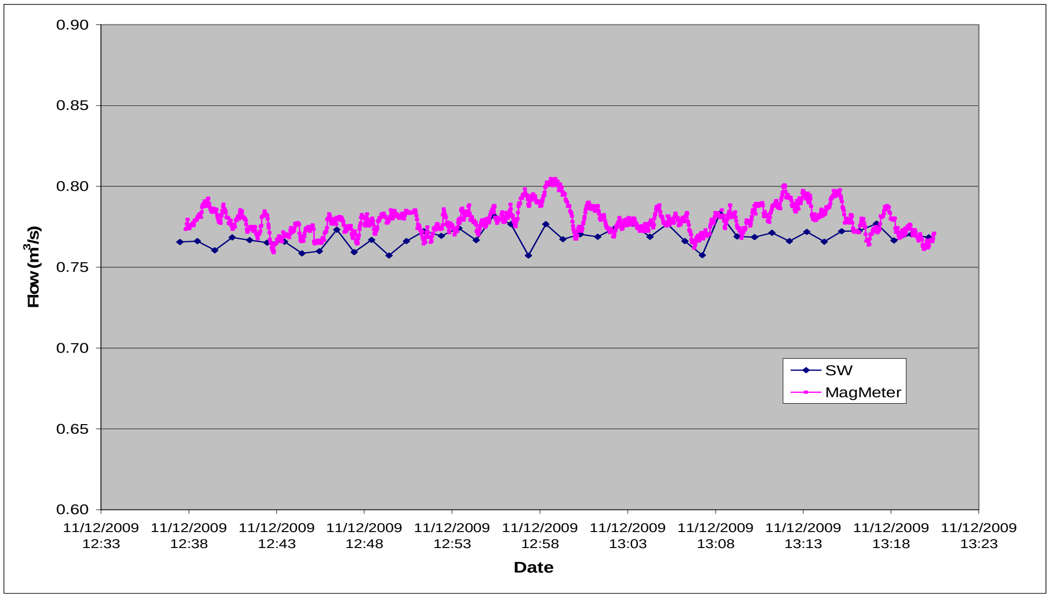

Figure 10. Flow comparison for test T454001

Figures 11-12 present 30 minutes of flow comparison data collected during flow test T454003. **Figure 11** presents stage data (m) and corresponding flow area (m^2). There is good agreement between manual readings and readings from the SW. The pink line represents flow area calculated from the water level data. **Figure 11** shows that stage was stable and the corresponding flow area was also stable throughout the test. **Figure 12** presents flow values for the SW and the magmeter. Flow values corresponded well, with an average value of 0.602 m^3/s for the SW and 0.612 m^3/s for the magmeter. The standard deviations from the SW and magmeter were 0.009 m^3/s. and 0.010 m^3/s respectively.

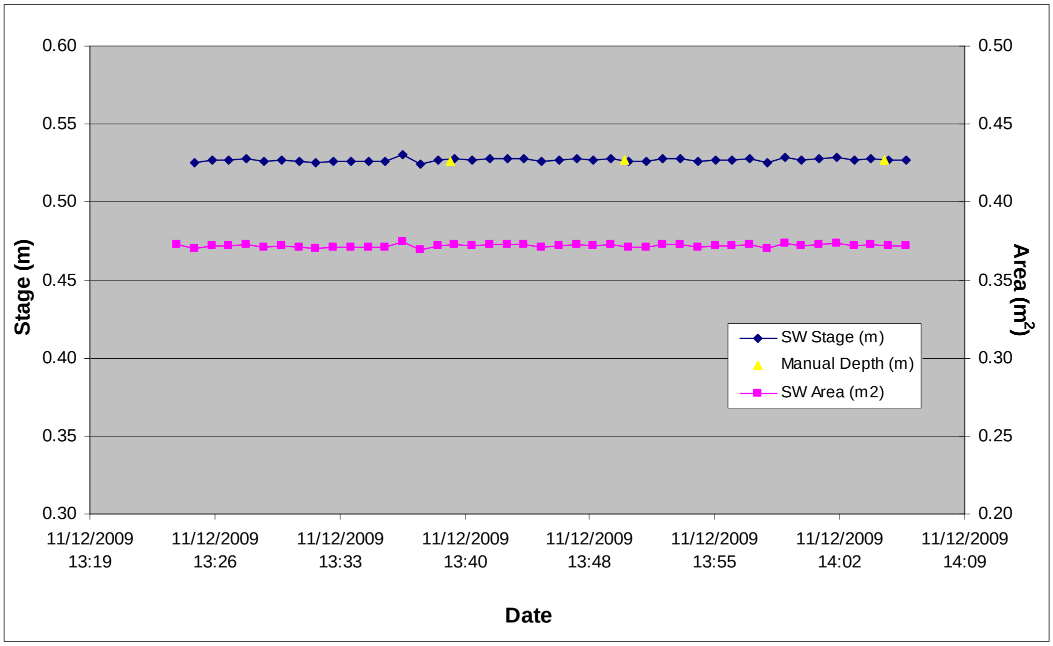

Figure 11. Stage measurements for test T454003

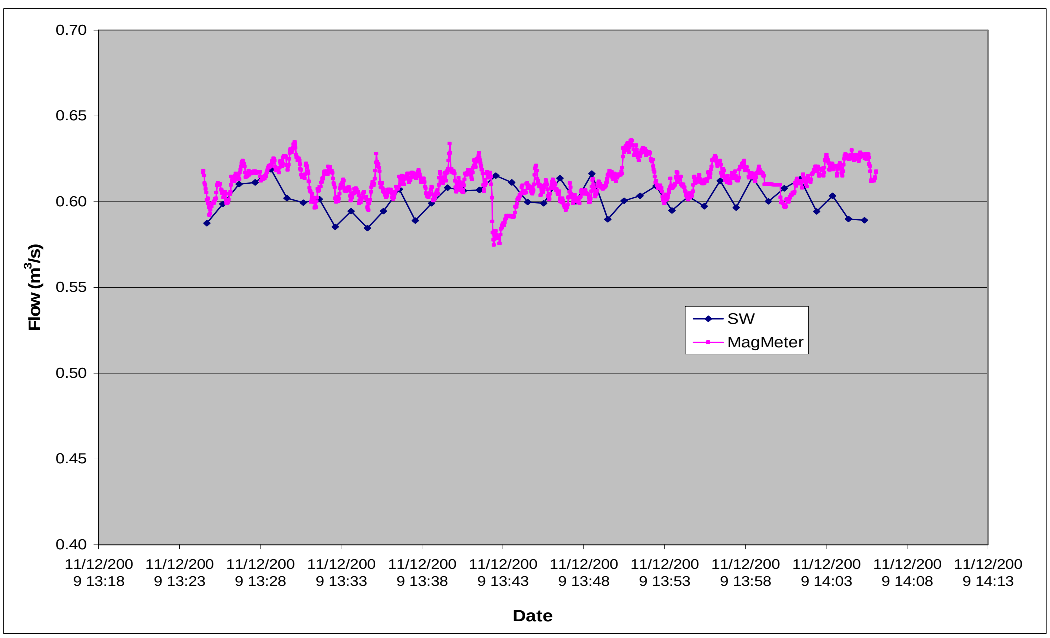

Figure 12. Flow comparison for test T454003

Figures 13-14 present 36 minutes of data collected during flow test T454004. **Figure 13** presents stage data (m) and corresponding flow area (m^2), with the blue line representing continuous water level data during the flow test, while the yellow triangles highlight manual readings collected periodically during the period of study. It can be observed that there is good agreement between manual readings and readings from the SW. The pink line in **Figure 13** displays flow area calculated from the water level data; it can be observed from the data that stage and flow area were stable throughout the test. **Figure 14** displays flow values for the SW and the magmeter. Both flow values correspond well, with an average value of 0.418 m^3/s for the SW and 0.415 m^3/s for the magmeter. The standard deviation for the SW was 0.006 m^3/s, while the standard deviation of the magmeter was 0.001 m^3/s.

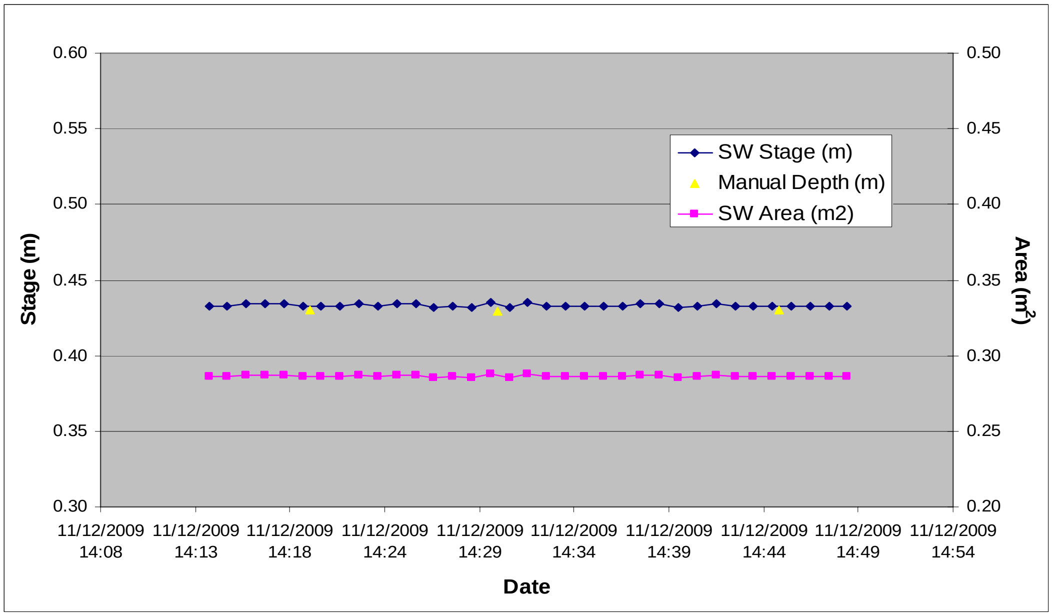

Figure 13. Stage measurements for test T454004

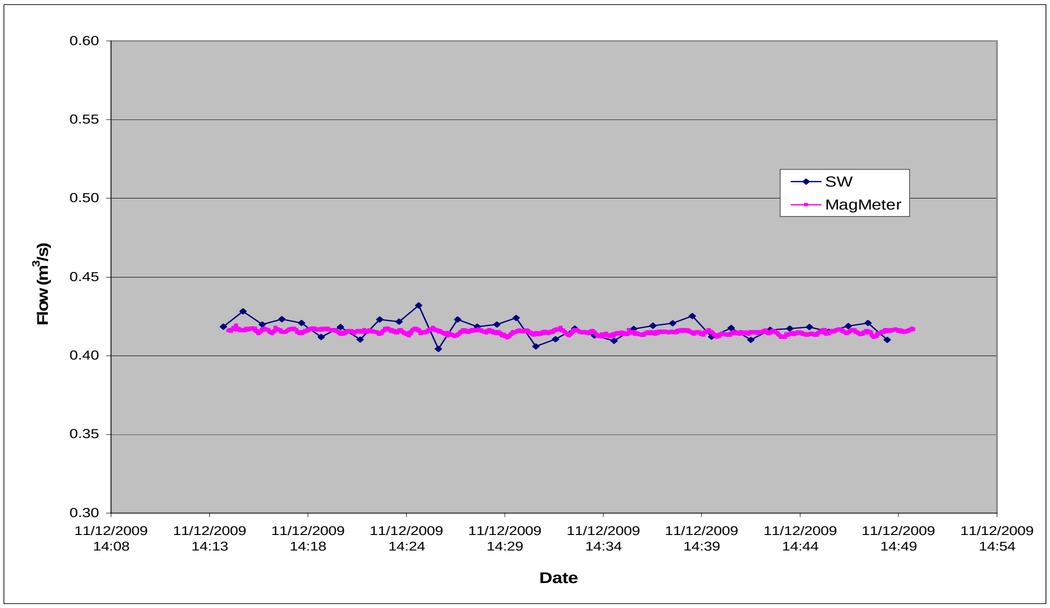

Figure 14. Flow comparison for test T454004

Figures 15-16 present 36 minutes of data collected during flow test T454005. **Figure 15** presents stage data (m) and the corresponding flow area (m^2). It can be observed that there is good agreement between manual readings and readings from the SW. The pink line represents flow area calculated from the water level data. It can be observed that stage and flow area data were stable throughout the test. **Figure 16** presents flow values for the SW and the magmeter. Both flow values correspond well; the SW had an average value 0.231 m^3/s and the magmeter had an average of 0.225 m^3/s. Overall, the standard deviations of the instruments were low; the standard deviation of the SW was 0.008 m^3/s and that of the magmeter was 0.001 m^3/s.

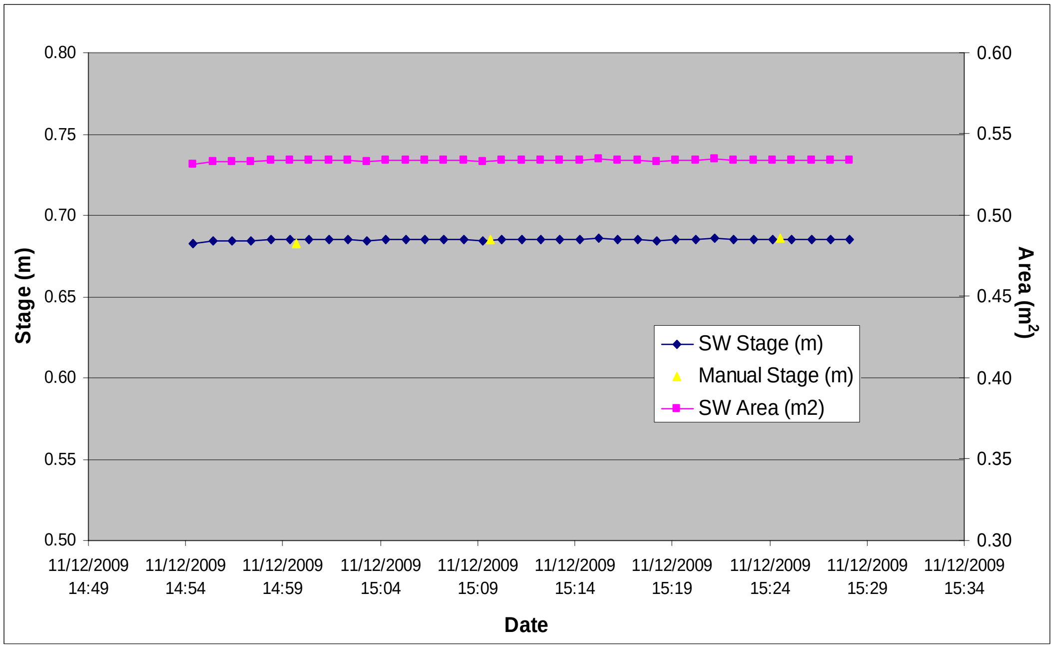

Figure 15. Stage measurements for test T454005

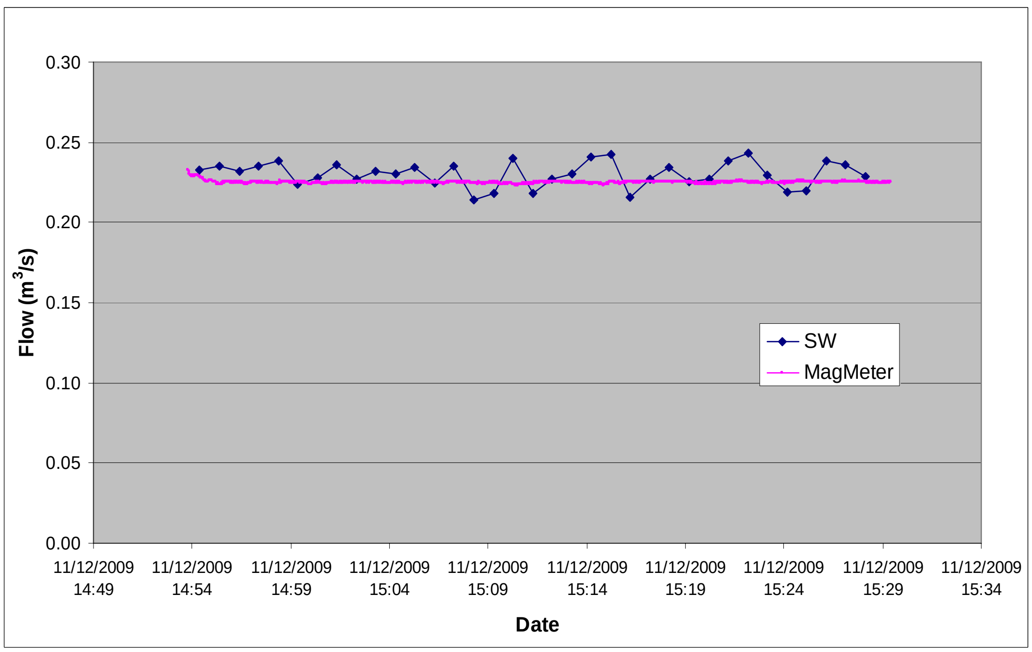

Figure 16. Flow measurements for test T454005

Figures 17-18 present data collected during flow test T454006 that lasted 36 minutes. **Figure 17** presents stage data (m) and corresponding flow area (m^2). There is good agreement between manual readings and readings from the SW. The pink line represents flow area calculated from the water level data. It can be observed from **Figure 17** that stage was stable and the corresponding flow area was also stable throughout the test. **Figure 18** displays flow values for the SW and the magmeter. Both flow values correspond well; the average value for the SW was 0.176 m^3/s, while the average value for the magmeter was 0.173 m^3/s. The standard deviation for the SW corresponded to 0.005 m^3/s, while the standard deviation of the magmeter was 0.001 m^3/s.

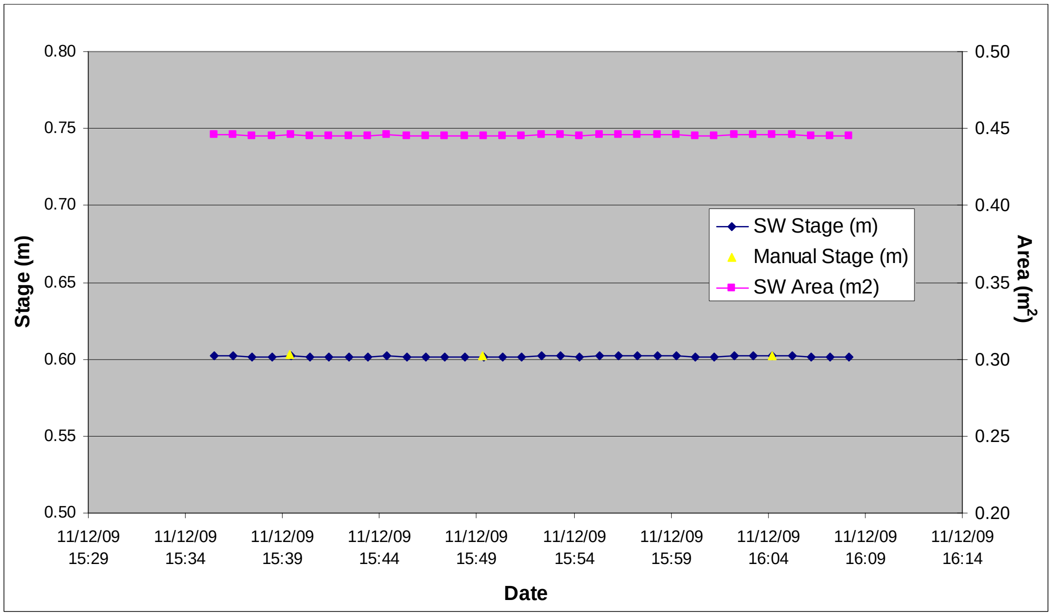

Figure 17. Stage measurements for test T454006

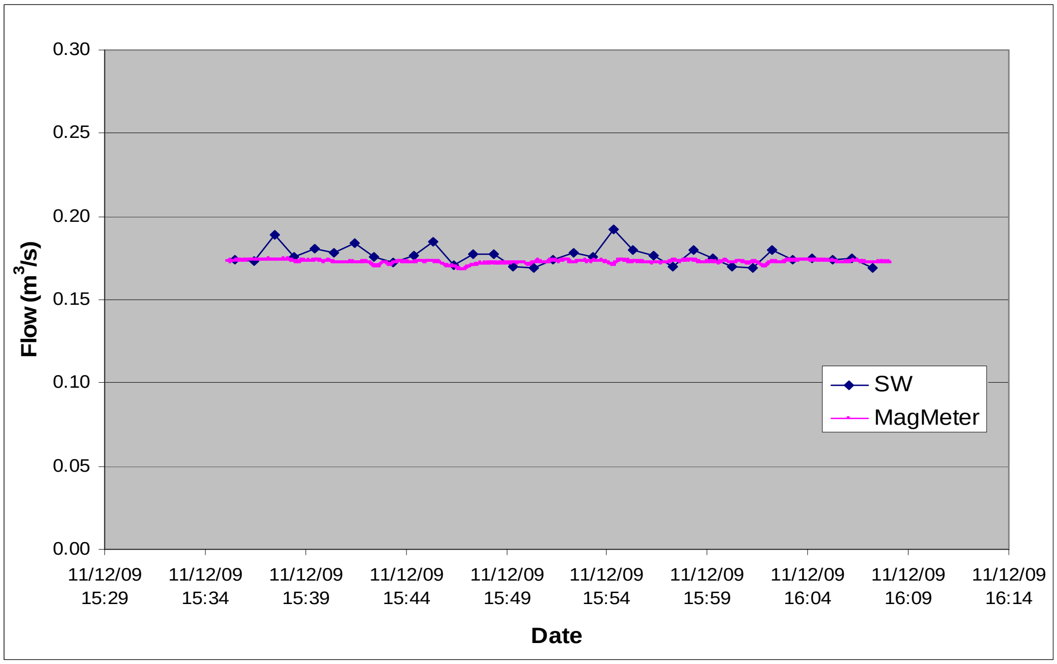

Figure 18. Flow comparison for test T454006

Figures 19-20 present data collected during the 36-minute flow test T454007. **Figure 19** shows that there is good agreement between manual stage readings and data collected from the SW. Data from the graph also indicate that stage and flow area were stable throughout the measurement period. **Figure 20** displays a graph of flow values for the SW and the magmeter. Flow values correspond well throughout the study and the average value for the SW was 0.151 m^3/s and the magmeter was 0.149 m^3/s. The standard deviation for the SW was 0.005 m^3/s, while the magmeter was essentially zero.

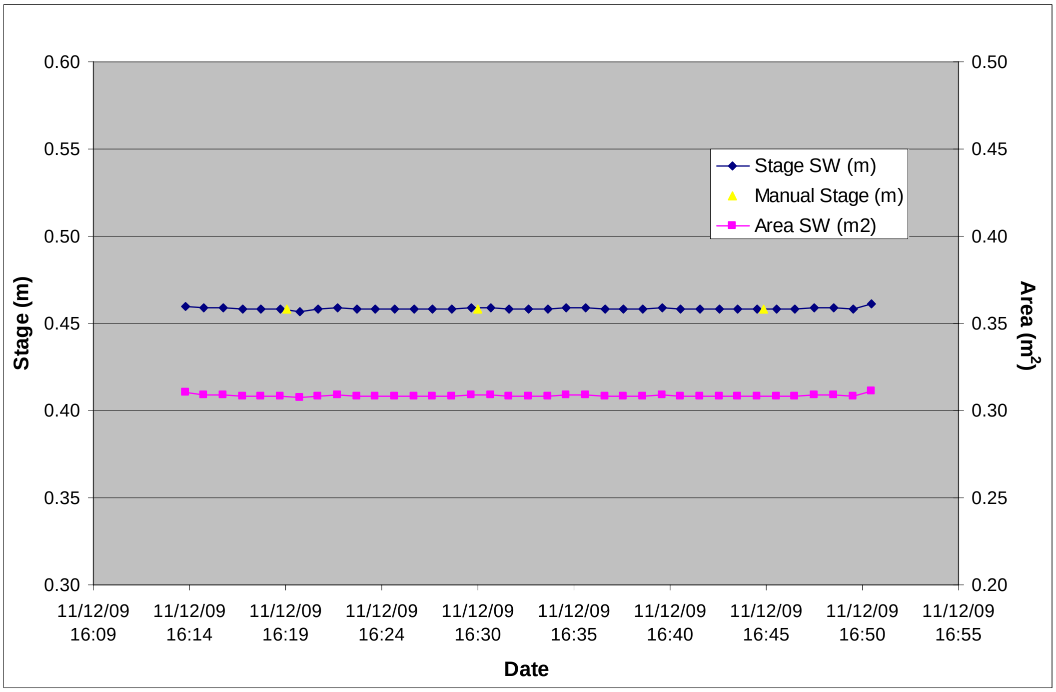

Figure 19. Stage measurements for test T454007

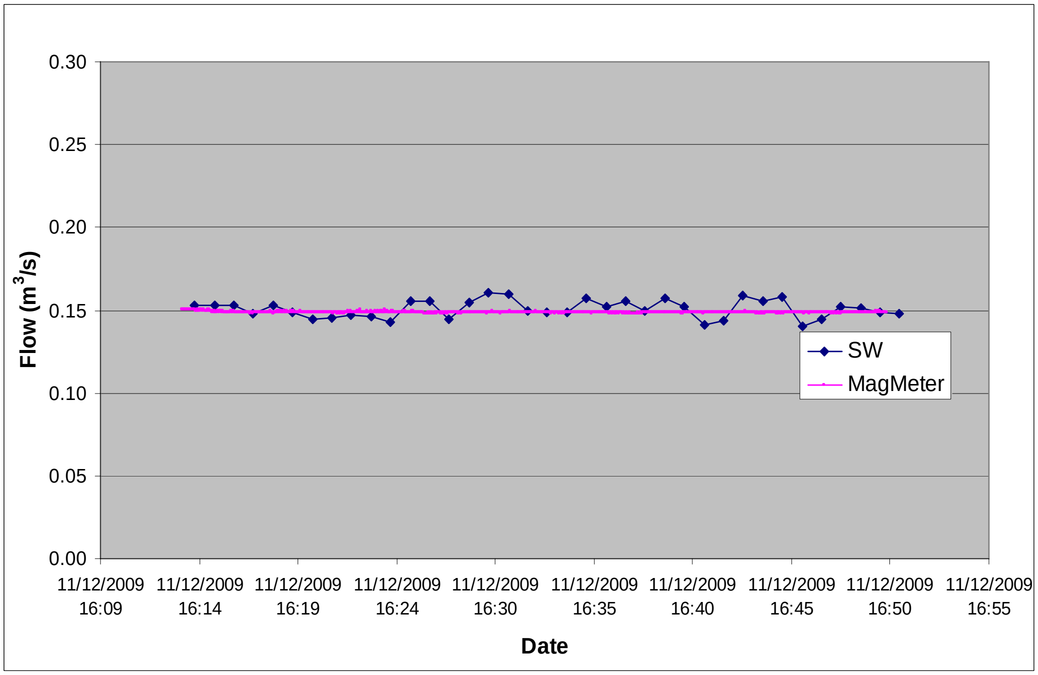

Figure 20. Flow comparison for test T454007

Figures 21-22 present data collected during flow test T454006 that occurred overnight, starting at 4:55 PM and ending at 7:38 AM. **Figure 21** presents stage data (m) and flow area (m^2). Although no manual readings were taken during this test, stage and area data are relatively constant during the test. **Figure 22** presents flow data for the SW and the magmeter. Both flow values correspond well with an average of 0.203 m^3/s for the SW and 0.199 m^3/s for the magmeter. The standard deviations for the SW and the magmeter were 0.006 m^3/s and 0.001 m^3/s, respectively.

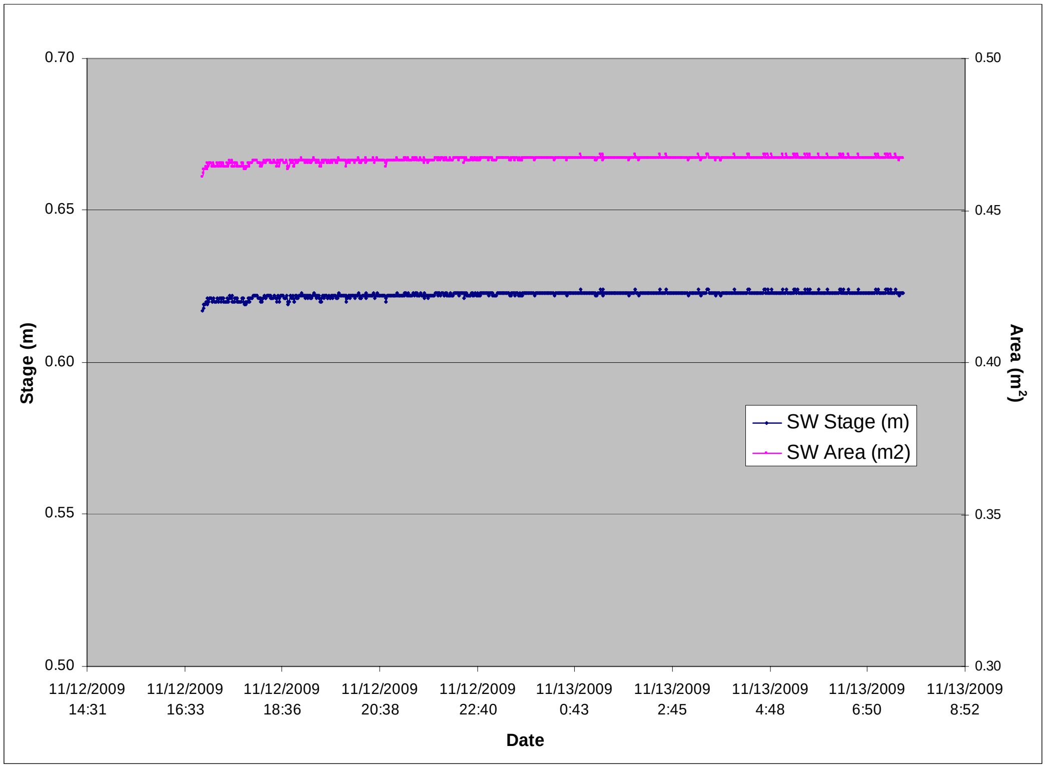

Figure 21. Stage measurements for test T454008

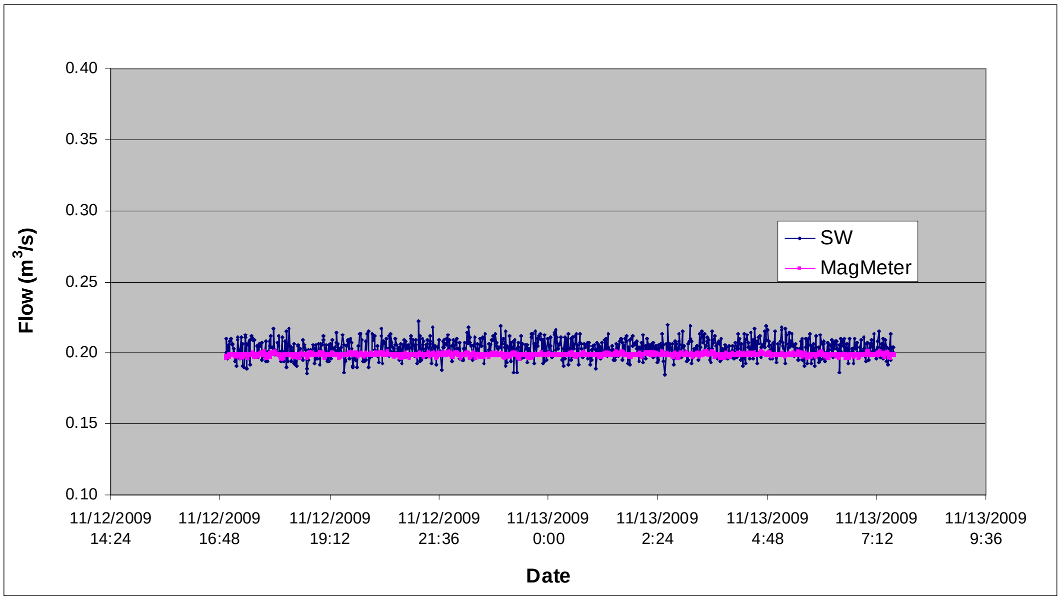

Figure 22. Flow comparison for test T454008

Table 1 presents a comparison of flow data from the SW and the magmeter. The data indicate that there is good agreement between the flow instruments, with the SW reporting values slightly lower than the magmeter under high flow conditions and slightly higher than the magmeter at low flow conditions.

Table 1. Comparison of flow values for 3.0 MHz SW and magmeter

Test	Sontek SW Flow (m^3/s)	Magmeter Flow (m^3/s)	% Difference of means
T454001	0.769±0.006	0.779±0.008	-1.4
T454003	0.602±0.009	0.612±0.010	-1.7
T454004	0.418±0.006	0.415±0.001	0.7
T454005	0.231±0.008	0.225±0.001	2.5
T454006	0.176±0.005	0.173±0.001	2.1
T454007	0.151±0.005	0.149±0.000	1.4
T454008	0.203±0.006	0.199±0.001	2.2

Summary and Conclusions

1. The SW provided stable readings for stage and corresponding calculated flow area.
2. Excellent overall agreement of flow values was obtained between the SW and magmeter – without on-site advance calibration of the SW.
3. The SW has noisier electronic readings than a magmeter.
4. The SW flow noise falls within a relatively small standard deviation, but requires averaging over time if the SW is to be used for automatic flow control.

THE IRRIGATION TRAINING AND RESEARCH CENTER (ITRC)

The Irrigation Training and Research Center (ITRC) is a center of excellence at California Polytechnic State University (Cal Poly), San Luis Obispo. Clients are irrigation districts, government agencies such as USBR, the California Dept. of Water Resources, the California Energy Commission, electric utilities, manufacturers, and various international organizations such as the World Bank and FAO of the United Nations. About 65% of ITRC's work is direct technical assistance for applications in the field; 25% is research, and 10% is training – with approximately 60 short courses per year.

ITRC has worked with calibration issues, research, and field installations of acoustic Doppler flow meters (ADFMs) for over 15 years. Field installations have ranged from small (0.2 cms) to very large (71 cms) capacity canals, plus a variety of full and partially full pipeline applications. Device orientations have included side and bottom mounts, as well as on boats. A variety of brands and models of ADFMs have been used.

The Center was one of the first institutions to recognize the importance of proper field calibration of typical ADFMs in canals, and as a result developed new velocity indexing procedures. Special mounting and channel stabilization needs have been addressed as the technology matures. Recently, ITRC has conducted research on special channel sections that condition the flow streamlines to minimize calibration work that is needed after installation. ITRC has also used ADFMs as the flow measurement device for automated canal and dam gate operation, using special flow control algorithms in PLCs. A recent development was a special silt-purging mount for installations in silty canals.