RECLAMATION

*Managing Water in the West*

# Field Evaluation of Low Cost Ultrasonic Flow Meter

## Research and Development Office
## Science and Technology Program
## ST-2016-8632-1


U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office



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# Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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| **14. ABSTRACT** ***In 2012 Reclamation completed research evaluating low cost ultrasonic flow meters in a laboratory setting. Shortly after funding was expended on that project the Yuma Area Office was interested in installing one of the meters tested and automate a diversion headgate. This report contains a short lessons learned about using a low cost ultrasonic flow meter for automating a gate structure while matching USGS stream gauge site that was nearby.*** | | | | | | |
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## Project and Document Information

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Document Summary of Lessons Learned

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## Review Certification

**Peer Reviewer:** I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Tom Gill

Reviewer ______________________________ Date reviewed 9/22/2106
(Signature)

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# Acknowledgements

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# Background

Area-velocity flow meters are frequently used by irrigation project managers to measure flow in irrigation systems. In general, these meters are attractive because they create minimal head loss, are easily installed, provide SCADA-compatible outputs, and can be applied to a wide variety of flow situations. Most area-velocity flow meters measure water velocity, depth and temperature then compute a flow rate by multiplying the calculated average velocity by the cross sectional area of the flow. Each meter calculates the average channel velocity from sensed velocity measured by the meter in one of three ways; incoherent (continuous) Doppler, coherent (profiling) Doppler, or electromagnetics

**Incoherent or Continuous Doppler:** These devices emit a constant acoustic signal and detect returns from scatterers (particles, air, bubbles, etc.) in the passing fluid. The Doppler shift from acoustic reflections off the scatterers is used to determine an average channel velocity (Vermeyen 2000).

**Coherent Doppler:** Coherent Dopplers emit encoded pulses along multiple beams which target specific scatterers at varying depths or times.
**Non-Profiling:** The Doppler shift from acoustic reflections off the scatterers is used to determine a velocity from targets over a fixed distance. Velocity histograms from the returns are created and then used to determine the average channel velocity.
**Profiling:** The Doppler shift from acoustic reflections off the scatterers is used to determine a velocity in cells of specified depth and size. Velocity profiles are created and used to determine the average channel velocity.

**Electromagnetic:** Water moving through a magnetic field produces a voltage (Faraday's law) which is directly proportional to the velocity of the water. The higher the velocity, the greater voltage created. The measured voltage is used to determine the velocity at the sensor, which is used to estimate the average channel velocity based on theoretical velocity profiles.

Depth measurements are obtained by either a separate ultrasonic sensor or an integrated pressure transducer. Some of the meters utilize both of these technologies. Flow is calculated using a stage-area relationship that is pre-programmed into each of the meters using manufacturer specific software.

In 2012 Reclamation tested nine meters from seven manufacturers in three laboratory test environments as part of S&T Project 6578 (Heiner, 2012). Meters in all these categories were tested during the study. Test results from the nine meters investigated varied based on the test configurations and meter type. Results indicated that when using area-velocity meters in controlled environments errors in excess of ±10 percent in discharge are possible. Project 6578 proposed to conduct laboratory tests, then complete field evaluations for each of the meters in the study.  After initial results were so varied, additional funding for field tests was not applied for.

Shortly after funding for Project 6578 ended, Reclamation's Yuma Area Office (YAO) and Yuma Irrigation District (YID) inquired about utilizing one of the meters to for automating the YID turn out gate from the Gila Gravity Canal.  The Reclamation Hydraulics Laboratory staff saw this an opportunity to conduct a field evaluation on one of the meters tested in the lab study, and document the lessons learned regarding setting the meter up.  S&T Project 8632 was developed to document the lessons learned regarding using an ultrasonic flow meter of this type for gate automation.  Yuma Area Office funding was used to purchase and install the equipment and connect the flow meter for automating the YID gate.

# Meter Selection

After reviewing S&T Project 6578 and discussing with local irrigators and staff of the United State Geologic Survey in their Yuma office, a Sontek IQ was selected as the meter to install for the automation of the YID gate.

From the manufacturer's website the Sontek IQ is capable of working both in man-made as well as natural channels and collects flow and volume data in as little as 3-in of water.  Figure 1 provides an overview of the meter with annotations of the main features.

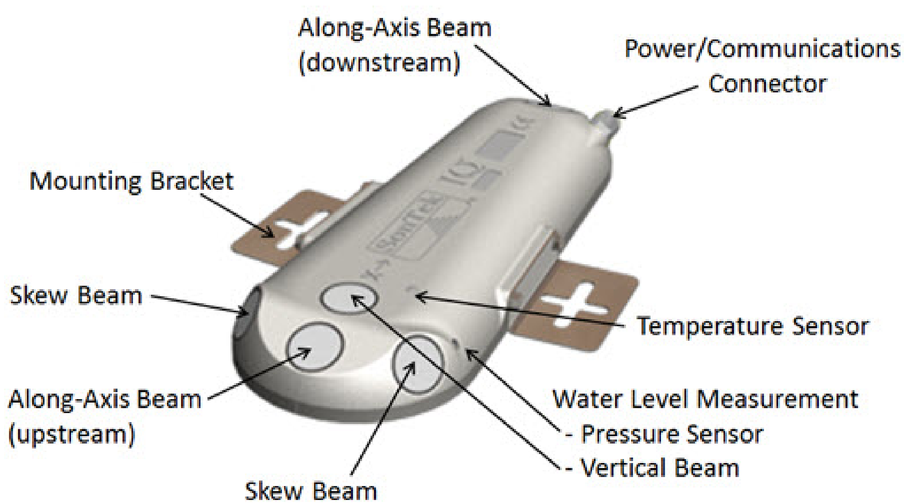


**Figure 1 - Overview of the Sontek-IQ with annotations of the main features.**

# Site Selection

YAO selected the YID headgate as a pilot project for automating a control gate through the Water Conservation Field Services program.  Figure 2 provides an overview of the site with labels of relevant features.  Flow travels down the Gila

Gravity Canal and water is withdrawn into the YID canal through a single vertical slide gate style headgate. Several years ago the City of Yuma build a large headworks structure that withdraws water from the Gila Gravity Canal 170 feet downstream of the YID headgate. Since the construction of the City of Yuma Headgate, YID has been subject to fluctuating water surface elevations in the Gila Gravity Canal each time the City of Yuma operates their headgates (opens or closes). These fluctuations make it difficult for YID to maintain a constant flow down their canal, without making adjustments to their headgate setting.


**Figure 2 - Overview of the YID headgate with annotations of relevant features.**

The site labeled in Figure 2 as "BOR Flow Meter" was selected to install the Sontek IQ. The YID canal at this location is a trapezoidal shaped canal with 5-ft bottom width and 1.5:1 H:V side slopes. The site is in close proximity to the USGS gauge (09522800) for easy comparison.

# Lessons Learned

Once the Sontek IQ was installed it was necessary to make sure the meter output was consistent with the USGS gauge measurements. To complete this comparison data was collected over several intervals and compared to the USGS output available on the USGS web site. Early comparisons showed large disagreements between the two readings for the same data point. In order to correct these issues researchers contacted USGS and discussed how their flow calculations were conducted. Researchers discovered that USGS was modifying the output of their gauge site to align with flow measurements obtained with Accoustic Doppler Current Profilers (ADCP). BOR implemented a velocity index parameter in the IQ to improve the measurement agreement with the USGS measurements. As seen in Figure 3 both the USGS and BOR meters compare very well up to about 80 $ft^3$/sec in the canal, when the USGS meter starts to read higher than the BOR meter. This differential appears to be due to USGS modifying the inputs to their meter to more closely align with their ADCP measurements. Conversations with the USGS office indicate that they only use outputs of velocity from the sensor they have installed and all flow calculations are performed in the USGS NWIS system using a specified index-velocity method.


**Figure 3 - Flow rate comparison between BOR and USGS meters.**

The lesson learned from the comparison portion of the study is that it can be challenging to get the same readings from two meters installed in the same location. Researchers continue to work with YAO and YID to get good agreement at all flow rates in the canal.

Other lessons learned during the study include the follow:

- Ensure that battery life is sufficient to power your meter for several days. We encountered periods of long overcast where limited solar energy was available at the site and the battery expended its charge and data was lost.
- Using as few data transfers as possible from the sensor to the control unit will prevent undesirable data miss communication.
- Not all meters and control units will communicate effectively with each other. One of the control units we attempted to use would not talk to the Sontek IQ's Modbus output.

- Cleaning of the sensor is required on a regular basis.  From communications with USGS they clean their sensor of a monthly basis to ensure proper operation.
- Having a retrievable sensor mount system facilitates maintenance when required.  BOR installed the sensor on a track system that allows the sensor to be pulled up the canal lining side slope with limited effort.