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Hydraulic Laboratory Technical Memorandum, PAP-1222

Evaluation of Canal Flow Measurement System for the Indian Unit

Yuma Project, Reservation Division
Lower Colorado Region

U.S. Department of the Interior
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Technical Service Center
Hydraulic Investigations and Laboratory Services
Denver, Colorado

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Background

The Indian Unit and the Bard Unit are the two parts of the Reservation Division irrigation and drainage system. The Reservation Division irrigates approximately 14,700 acres and is split almost evenly, with the Bard Unit irrigating 7,100 acres and the Indian Unit irrigating the remaining 7,600 acres. All Reservation System infrastructure is maintained by the Bard Unit.

In 2019, Reclamation's Technical Service Center (TSC) installed flow measurement devices at four sites along the Indian Unit canals, summarized in Table 1 and shown in Figure 1. Flume structures measure flow through the Supai, Pueblo, and Pima canal laterals, and the Waco diversion structure measures flow through a 36-inch slide gate. All sites report only flow information and do not perform automated control or allow supervisory control.

Table 1. Summary of the four canal flow measurement sites in the Indian Unit.

Site	Measurement Method	Sensors	Measurement
Waco	36-inch Slide Gate	2-Port Bubbler	Canal Depth
		Potentiometer	Gate Position
Supai	Ramp Flume	Bubbler	Canal Depth
Pueblo	Long-Throated Flume	Bubbler	Canal Depth
Pima	Long-Throated Flume	Bubbler	Canal Depth

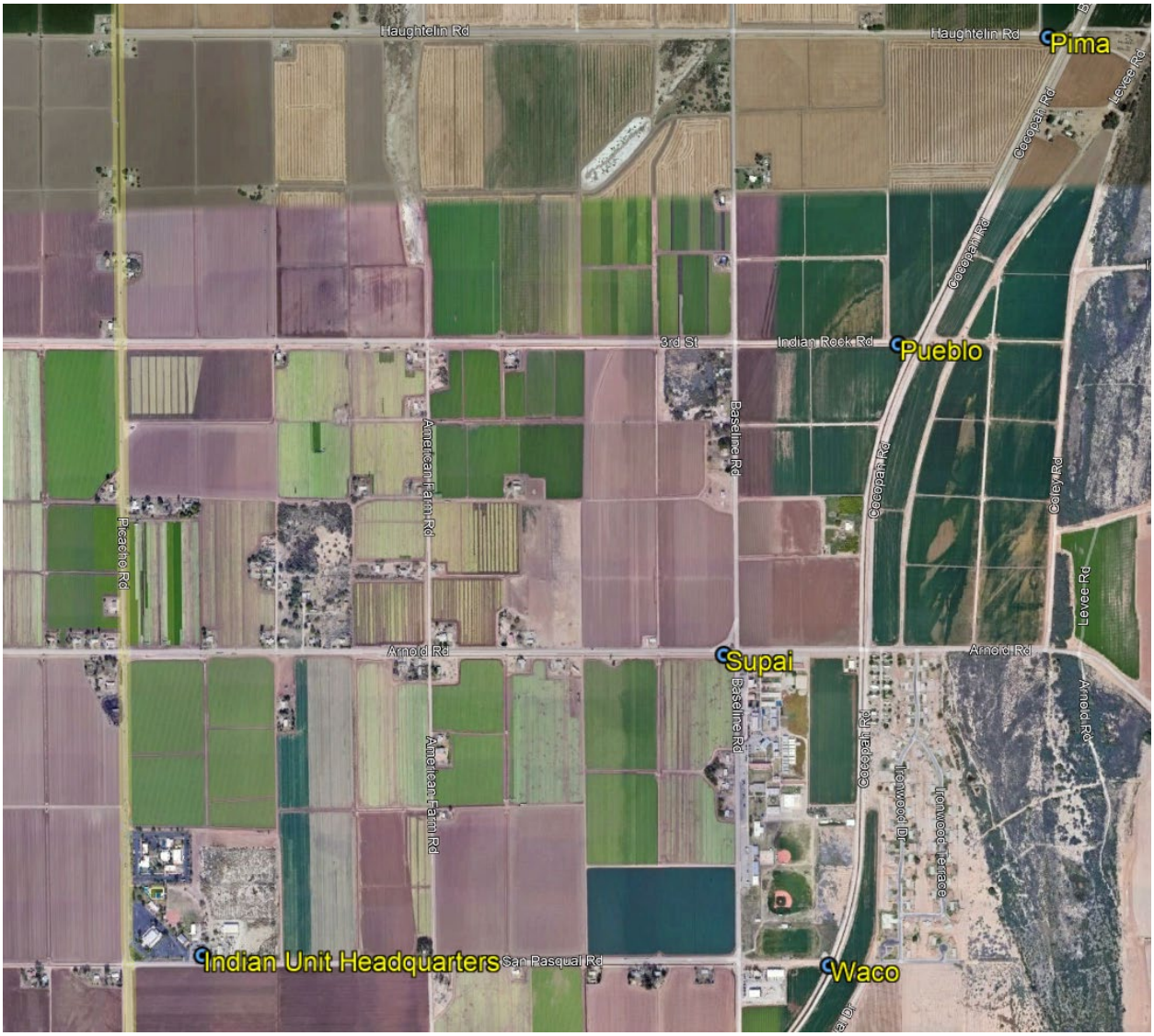

Figure 1. Map showing the location of the four canal flow measurement sites in the Indian Unit.

System Evaluation

Each site contains sensors that are controlled using a radio-telemetered micro-controller unit (RTU). The sensors are the devices that convert physical measurements into an electronic signal that can be understood by an RTU. The RTU is a radio-telemetered device that uses a micro-controller unit (MCU) to convert the signals from the sensors into an understandable measurement (such as canal depth) and transmit the measurements to a "base station" using a narrowband radio. All sites measure canal depth using a bubbler water level sensor (referred herein as "bubbler"). In addition to a bubbler, the Waco site uses a potentiometer to measure the position of the slide gate, needed for estimating flow through the gate. The TSC installed equipment manufactured by Control Designs, Incorporated (CDI) in 2019.

In November 2022, at the request of the Native American Affairs Program in the Yuma Office, TSC installed a base RTU station in the Indian Unit headquarters. During this installation, all four remote measurement sites were inspected and found to be completely non-operational. Upon notifying the Native American Affairs Program in the Yuma office, TSC was requested to evaluate the existing system. This evaluation is summarized in Table 1.

Table 2. Summary of observed problems with flow measurement sites during the 2022 site visit.

Site	Canal Structure	RTU	Bubbler
Waco	Gate position cannot be measured	**Failed**	**Failed**
Supai	Excessive sediment in flume	OK	Needs service
Pueblo	Excessive sediment in flume	**Failed**	Needs service
Pima	Some sediment in flume	**Failed**	**Failed**

Waco Diversion Site

The Waco Site measures diverted canal flow through a 36-inch concrete pipe controlled by a slide gate. The position of the slide gate is measured using a potentiometer connected to a worm gear attached to the lead screw of the gate stem. The geometry of the gate position is determined from the position and is used, along with the upstream and downstream depth, to calculate flow through the gate (Figure 2).

Figure 2. Manually operated 36-inch slide gate at the Waco Diversion Structure.

At the time of the site visit, the Waco site was observed to be completely non-operational. Although the RTU appeared to have power, it was unresponsive to user commands for displaying or conducting measurements. The 12V battery was no longer holding a charge and all power was completely supplied through the solar panels. The worm gear attached to the potentiometer was disconnected from the gate's lead screw (Figure 3). Further investigation revealed that the RTUs firmware had become corrupted, and the bubbler compressor no longer functioned.

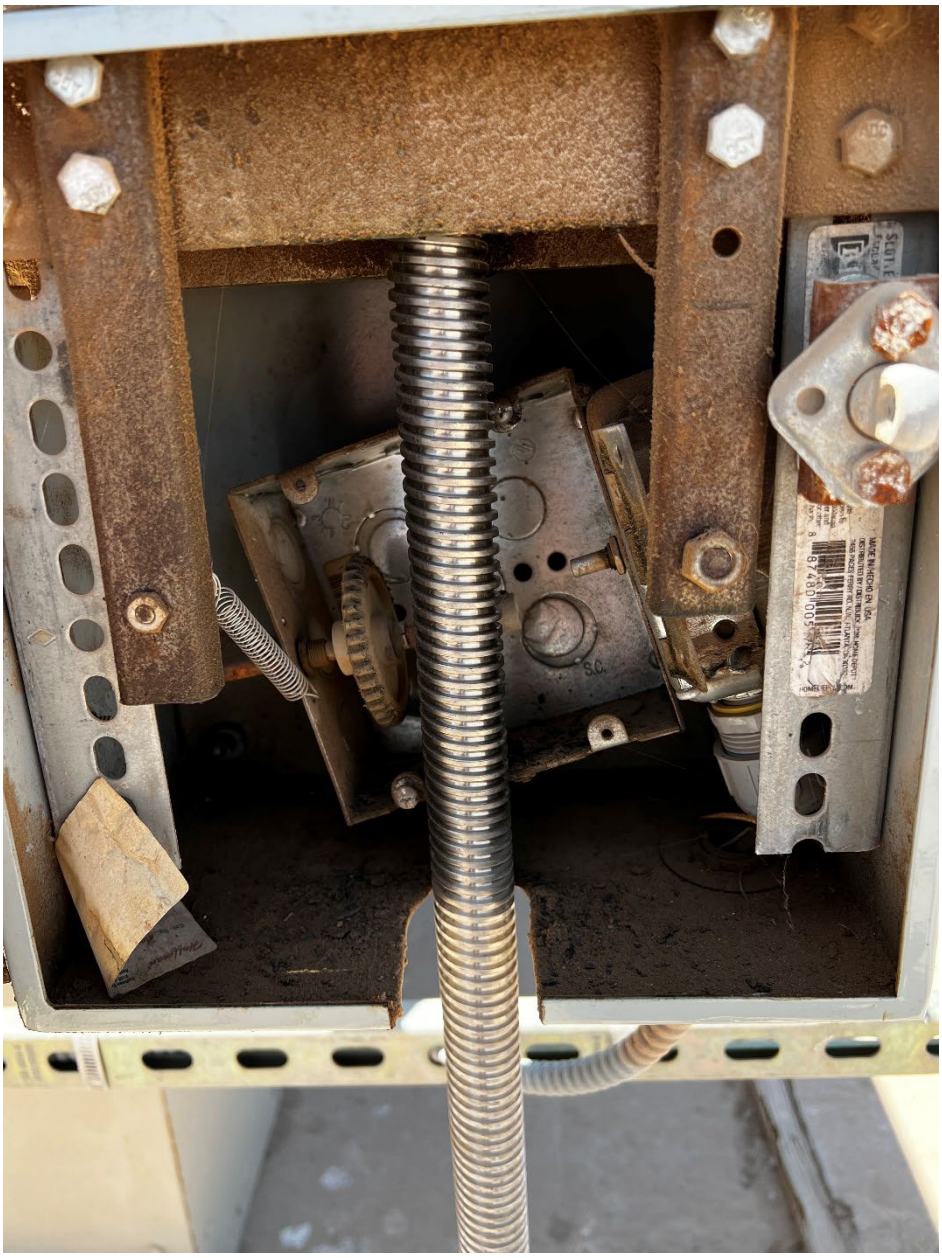

Figure 3. Worm gear assembly for the Waco Diversion structure. The assembly does not function because the worm gear is detached from the lead screw of the gate stem.

Supai Canal Flume

A ramp flume on the Supai Canal translates a single canal depth into flow. It is a prefabricated flume structure that was existing prior to the initial TSC equipment installation in 2019(Figure 4). During the 2022 site visit, the ramp flume was filled with sediment, preventing flow measurement through the flume (Figure 5). Although the battery was no longer holding a charge, both the bubbler and RTU seemed to function. Depth measurements from the RTU, however, were incorrect.

Figure 4. Supai canal ramp flume shown during dewatering.

Figure 5. Supai canal ramp flume pictured during a 2022 site visit showing excessive sediment with vegetation against the ramp of the flume.

Pueblo Canal Flume

TSC fabricated a long-throated flume for the Pueblo Site in 2019 (Figure 6). During the 2022 site visit, excessive sediment with plant growth was found both upstream and downstream of the flume (Figure 7), leaving the flume incapable of reliably measuring flow. The battery was no longer holding a charge and the RTU was completely non-responsive, regardless of the solar power. Further investigation revealed corrupted firmware.

Figure 6. Pueblo canal long-throated flume pictured shortly after its construction in 2019.

Figure 7. Pueblo canal long-throated flume pictured during a site visit in 2022 showing excessive sediment and vegetation upstream of the flume.

Pima Canal Flume

The Pima canal flume is a long-throated flume constructed from 6-inch engineered wood boards (Figure 8). Although the flume was relatively free from excessive sediment, the wood planks are beginning to deteriorate from submergence. This deterioration warps the boards which causes significant energy loss from turbulence and affects the flow measurements. The battery was no longer holding a charge and the RTU was completely non-responsive, regardless of the solar power. Further investigation revealed that the RTUs firmware had become corrupted, and the bubbler compressor no longer functioned.

Figure 8. Pima canal flume pictured during a site visit in 2022.

Recommendations

Operation and Maintenance

The Indian Unit flow measurement system needs to be maintained. All RTU's require (at least) annual maintenance. Without continuous maintenance, serious problems may arise from incidents that can easily be avoided. Such problems may include failed batteries, minor visible corrosion, short circuit or disconnected wiring, and bubbler tube leaks. During the 2022 site visit, none of the batteries would hold a charge. Although this is normally a minor, easily corrected problem, when left alone the solar panel will cycle the RTU power in the early mornings and evenings when the voltage fluctuates around 5V. If this fluctuation is repeated enough, it can corrupt the RTU's firmware, requiring factory service. Three of the four RTUs had corrupt firmware.

Regardless of the state of the electronics, flow cannot be accurately measured in a flume with excessive sediment. Sediment deposition may block a portion of the regulating control section or change the velocity at the head measurement device, which affects the accuracy of the relationship between head and discharge. Although minor errors of this type are common (and expected) with most flumes, excessive sediment can result in errors too large for a reasonable flow measurement. The sediment needs to be periodically removed from the canal in and near the flume structures.

Repair or Replace Electronic Equipment

Most of the electronic equipment used for flow measurement in the Indian Unit need to be repaired or replaced. Because flow measurements in the flumes depend on water depth measurements, these sites should continue using bubblers. Despite two of the four bubblers becoming nonfunctioning since their installation in 2019, they remain a relatively reliable and affordable sensor for measuring water depth. The RTUs, however, present a decision for two recommended options: 1) continue using the same type of RTU made by Control Design, Inc. (CDI), or 2) switch to a different RTU from another company.

Option 1 – Continue using existing CDI RTUs

The CDI model CD110 RTUs that were installed in 2019 can be repaired or replaced and redeployed to the flow measurement sites. The CD110 RTUs have a programmable logic controller (PLC) that communicates with other RTUs using the MODBUS protocol via short-wave radio. If the Indian Unit continues to use the CD110s, the three non-responsive RTUs removed during the November 2022 site visit will need to be repaired or replaced. The remaining RTU should also be thoroughly tested prior to re-deployment. The existing directional antennas at each site should be replaced with a non-directional (or omni) antenna to allow communication with both the Bard Unit and Indian Unit headquarters.

Supporting Factors for this option

1. This is the least expensive option if the existing CD110s can be repaired without purchasing replacements.
2. The CD110s are ruggedized and reliable when properly maintained.

3. The CD110s use a shortwave radio allowing long-range, reliable communication.

Supporting Factors against this option

1. CDI has limited resources for supporting their equipment.
2. The CD110s have limited data-logging capability. Data must be downloaded periodically from each RTU directly, or from a computer using a short-wave radio.
3. The Bard Unit is using SCADA equipment from a different manufacturer, and the CD110s may be difficult to integrate into their system.

Option 2 – Replace existing RTUs

The existing RTUs can be replaced with a variety of RTUs from different manufacturers. Two of the more common companies used throughout Reclamation include Campbell Scientific and Opto-22. If the Indian Unit decides to replace the equipment, the following requirements should be considered:

1. Product Support. The manufacturer needs to be well established with enough resources to support their product.
2. Widespread Use. The equipment should be commonly used throughout the industry. The Indian Unit should be able to choose from a variety of entities capable of servicing their equipment.
3. Current Technology. The equipment needs to be supported by current and near future technology. Most equipment is programmed and set up using a computer program. This program needs to be maintained by the manufacturer to assure compatibility with current operating systems.
4. Robust Construction. The equipment needs to be able to perform in harsh, remote environments. Many RTUs are designed to withstand problems that may arise from dead batteries or short circuiting. Testing data, supplied by the manufacturer, needs to be considered.

Supporting Factors for this Option

1. Increased reliability in the performance of the electronic equipment.
2. More available support for the electronic equipment.
3. Easier for Indian Unit staff to maintain equipment.

Supporting Factors against this Option

1. Increased cost for equipment.

The Bard Unit is currently in the process of installing "Click-Plus" programmable logic controllers (PLCs) that are telemetered using TCP/IP through WiFi transceivers. The PLCs are a lower-cost solution manufactured by Automation Direct. Although the PLCs can provide flow measurement at the Indian Unit sites, they are designed for indoor use. TSC is not confident these PLCs will be able to withstand the harsh environment at the flow measurement sites. Heat, dust, corrosion, and short circuiting are amongst some of the factors likely to fail the Automation Direct PLCs. Furthermore, TCP/IP communication is difficult (and can be costly) to establish in compliance with Federal

Information System Modernization Act (FISMA) standards, especially if automatic or supervisory controls are used.

The Waco diversion structure depends on measurements of both canal depth and gate position. This is currently achieved using a worm gear connected to the lead screw of the gate stem (Figure 3). TSC recommends replacing the 36-inch gate valve stem with a prefabricated actuator stem with a built-in sensor for measuring gate position. Repairing the existing sensor requires additional labor and will likely exceed the cost of purchasing a prefabricated replacement actuator stem.

Conclusion

TSC inspected the flow measurement structures along with the corresponding electronic equipment in 2022 and concluded the existing flow measurement systems at the four sites (Table 1) are no longer functional. To repair the four sites, TSC presents the Indian Unit with two options: repair existing electronic equipment or replace existing electronic equipment. Regardless of the selected option, the measurement structures need to be physically maintained for operation. This maintenance mostly includes periodic removal of excessive sediment in the flume structures. Sediment should be removed to restore the original cross section geometry of the flumes from the head measurement station to the downstream end of the throat. Further details for removing sediment and physically maintaining the flume structures are beyond the scope of this report and should be addressed in the standing operating procedure for the canal. If directed by the Native American Affairs Program in the Yuma Office, TSC can develop project plans for either option presented in this report.