PARTNERSHIPS IN APPLYING NEW AND INNOVATIVE TECHNOLOGY

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ABSTRACT

The Roza Irrigation District (Roza), in the Yakima Valley of Washington State, received only 37 percent of its water right entitlement in the 1994 and 2001 irrigation seasons due to its junior water status in the basin. A reduction in water allocation of this magnitude places a great deal of stress on farmers and their crops, and hinders the District's ability to deliver water. Faced with having to operate with less than 50 percent (600 cfs) of design flow, Roza has become one of the most progressive irrigation districts in the Pacific Northwest with respect to water conservation by applying new and innovative technology.

Since 1991, Roza has developed numerous partnerships to help fund and apply resourceful technology to water conservation measures. Initially, Armtec and UMA introduced the automated single-leaf over shot gate, which was applied to numerous main canal checks to provide constant level control for pipeline turnouts and pumping plants. One of Roza's most successful partnerships has been with the United States Bureau of Reclamation (Bureau) Water Conservation Field Services Program in Yakima, and Aqua Systems 2000 Inc. (AS2I) from Lethbridge, Alberta, Canada. The partnership began in 1997 when an existing flashboard check structure was replaced with an automated Langemann gate. The success of this project, cost shared with the Bureau, prompted Roza to discontinue building new multi-bay single-leaf over shot structures and building or retrofitting eight structures with a single Langemann gate, the largest being 24-feet wide.

The partnership with the Bureau and AS2I expanded to include Supervisory Control and Data Acquisition (SCADA) on two existing main canal checks and a re-regulation reservoir. These innovative projects include flow control using undershot gates, spill flow monitoring using ultrasonic level technology, downstream canal level control using a variable speed pump and modulating valve, and remote communications via spread spectrum radio, dedicated phone line, and cellular digital modem technology. The SCADA system was recently expanded with the incorporation of an Acoustic Doppler Flow Meter (ADFM) downstream of the diversion point. In addition, Roza also partnered with MagnaDrive, Inc. (MagnaDrive) and AS2I to demonstrate variable speed pump control on an existing pumping plant. MagnaDrive supplied a magnetic coupler rather than a variable frequency drive (VFD), and AS2I provided the controls

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design and software to the flow control project.

The success of these projects has enabled Roza to reduce low-end operational flows from 600 cfs to 280 cfs in water short years and still provide reliable service to its water users.

INTRODUCTION

The Roza Irrigation District (Roza) is located in South Central Washington, along the eastern slopes of the Cascades Mountains in the lower Yakima River Basin. Water is supplied to the basin from the Yakima River and five storage reservoirs. Irrigation water is diverted from the Yakima River in the Ellensburg Canyon at the Roza Diversion Dam. The Roza Main canal is 94.8 miles long, serving 72,000 acres lying along the northern rim of the lower Yakima Basin. The District delivers water to 45,000 acres below the main canal by gravity and 27,000 acres above the main canal via 18 pumping plants.

Roza has a junior water right entitlement for 375,000 acre-feet of contract water. In water short years, senior water rights are met first and the remaining water is shared or prorated among the junior water right holders. There have been 9 years of pro-ration since the Roza was constructed; the worst by far were 1994 and 2001 when Roza received only 37% of its water entitlement. For Roza, conservation has always been a top priority due to its junior water right status.

The District has had a Bureau approved Comprehensive Water Conservation Plan (CWCP) since 1992. The plan includes the replacement of open ditches and concrete pipes with PVC pipes, termed the Enclosed Conduit System (ECS): lining earthen laterals with geo-membranes; constructing automated check structures; retrofitting existing Bureau structures into automated check structures; construction of re-regulation reservoirs; and SCADA. To date, Roza has converted 33,000 acres from open ditches or concrete pipe to the ECS, constructed seven new automated check structures, retrofitted 25% of the original Bureau check structures with automated gates, built two re-regulation reservoirs and nearly completed the SCADA system. This aggressive program has been completed in collaboration with the Bureau and private industry.

SINGLE-LEAF OVERSHOT GATES

Check structures are instrumental in conserving water by regulating water level at diversion points, regardless of the main canal flow rate. Without check structures, additional "operational" water would have to be diverted beyond that required to satisfy irrigation demand in order for the main canal to operate effectively.

Roza has constructed six 3-bay single leaf overshot check structures since 1992. The bays range in size from 7 to 10 feet, providing design capacity ranges from 350 cfs to 1150 cfs. For the first structure, Roza partnered with UMA, Inc. (UMA) and Armtec, both out of Lethbridge, Alberta, Canada, whereby UMA provided the structure design and gate sizing while Armtec provided the gates,

hoists, control equipment, gate installation supervision and commissioning. Roza provided the design criteria and the construction.
During this time, Hydrogate, Inc. began manufacturing overshot leaf gates, and the bid process was separated into two contracts, one for the purchase of the overshot gates and one for the supply, installation and commissioning of control equipment. In 1996 Roza partnered with UMA to purchase a control software site license for future overshot leaf gate structures.

In general, the overshot leaf gates have performed very well and continue to operate with very few problems. The partnerships formed with UMA, Armtec, Hydrogate and local electrical contractors were satisfactory.

LANGEMANN GATES

In 1997 Roza was approached by AS2I to utilize a Langemann gate. Due to the uniqueness of the gate, Roza approached the Bureau's Field Services Program to evaluate the utility of the gate in a Demonstration Project. The Demonstration Project Program is a "win-win" partnership for the Bureau and any interested district. The Bureau promotes water conservation projects that demonstrate applications of new technology or a unique application of an existing technology while the Districts acquire conservation projects at one-half the cost. The Langemann gate was a perfect candidate for a demonstration project, and with the Bureau sharing half of the project costs, the District's financial risk was minimized.

The unique and simple design of the Langemann gate makes it easy to retrofit into existing flashboard check structures. The double-hinged, two leaf folding Langemann gate operates in a vertical plane upstream of the structure sill as opposed to the 60-degree horizontal plane of the single leaf gate operating downstream of the sill. Compared to the single leaf over shot gate, installation of a Langemann gate requires very little structure modification. Initially, both the Bureau and the District had concerns about sediment and debris buildup upstream of the gate. However, the low power, standalone Langemann gates have made operation much easier for the watermasters and ditch riders, and concerns of sediment build up and weed and debris clogging proved to be unwarranted. Ditch riders seldom need to pull weeds from a Langemann gate structure.

The success of the first Langemann gate prompted the District to build a new 1150cfs Langemann gate check structure. By utilizing a single 24 ft Langemann gate rather than three 8 ft single leaf gates, Roza was able to reduce the concrete volume and save approximately 15% of the cost when compared to an 800cfs leaf gate structure 20 miles closer to the Roza main office. This was the first check structure in the world built solely for a Langemann gate, the site continues to operate problem free.

The simplicity and versatility of the initial Langemann gate projects convinced the District that all of the remaining check structure projects should be retrofit with Langemann gates. The partnership with AS2I also allowed the District to return to single source responsibility for supply of automated gates. To date, Roza has installed and commissioned a total of 9 Langemann gates of various sizes and flow capacities.

FLOW CONTROL WITH UNDERSHOT GATES

The Roza main canal was constructed with seven waste way sites that utilize undershot gates. For most of the sites, the primary purpose of the undershot gate is to dam up and spill water in case of a canal failure downstream. However, two sites, Waste Way 5 (WW5) and Waste Way 6 (WW6) utilize undershot gates to manage both operational spill and the flow rate downstream.

WW5 is situated at the midway point of the main canal. It consists of a two-bay, 15-foot wide by 7.5-foot radial gate check structure, an automatic siphon and waste way with a gauging station upstream of the check, and a canal gauging station downstream. Prior to automation, the site was operated manually based on upstream and downstream gauge readings, the time of year, and experience. Based on flow rate demand downstream, the gates were adjusted by "turns of the wheel" on the gate hoist. The experience to operate this site was limited to two or three people at the District. As a vital control point in the canal, the site would require adjustments several times a day during periods when main canal fluctuations were critical such as spring frost and drought years. Unwanted fluctuations were typically the result of changes in demand upstream, debris in the canal, or an emergency situation.

WW6 is located approximately three quarters of the way down the main canal. It consists of a single 6-foot wide sluice gate check structure and automatic siphon. There is a waste way and gauging station upstream of the check similar to WW5. Immediately downstream of the gate, the flow is super critical prior to entering a siphon that crosses Snipes Canyon There is a gauging station on the outlet of the siphon. This site was initially automated by the Bureau with Littleman technology. A level transmitter, located at the gauging station across the canyon, was connected to the process control equipment at the upstream check control building. Operation was generally reliable; however a failure of the buried cable crossing the canyon floor prompted the District to re-evaluate automatic control of the site.

To improve water management, Roza partnered with AS2I and the Bureau to implement automated flow control and SCADA monitoring of both sites. AS2I supplied complete controls packages including hardware, software, commissioning and training. Roza installed equipment, supplied and installed interconnecting cabling and assisted during commissioning. Once again, the Bureau provided incentive for the projects by funding them as Demonstration Projects.

The control packages consisted of programmable logic controller (PLC) based control panels, instrumentation and devices, control software, communication link and SCADA host. The control software is based on a multi-bay, undershot gate, level/flow control algorithm developed by UMA Engineering, which was selected because of its proven ability to provide reliable and stable automatic control over a wide range of site parameters and conditions.

The objective of the control software at WW5 was to i) maintain the desired downstream canal flow at an operator selectable set point, ii) provide upstream level overrides to maintain a maximum and minimum canal level upstream of the check and iii) provide flow measurement of the operational spill down the waste way. The objective of the control software at WW6 was similar except that an automated re-regulation reservoir located upstream of the check provided control of the upstream canal level.

Downstream flow control at WW5 is accomplished using the two radial check gates as flow measurement and control elements. Flow through the gates is calculated using a submerged orifice flow formula using the two gate openings and the upstream and downstream levels. Flow control is accomplished by adjusting the gates in response to changes in the measured gate flow. Under normal operations, the automatic siphon provides some hydraulic high level override and assists in maintaining a relatively constant upstream level. However, when canal flow changes dramatically, site control automatically switches to upstream level control. When the upstream canal level exceeds the high-level override set point, or falls below the low-level override set point, flow surpluses or deficits are passed downstream. The waste way flow is calculated using an ultra sonic level transmitter and Manning's equation.

Flow control at WW6 is accomplished using the slide gate as the flow measurement and control element. Flow is calculated using free discharge orifice formula using the gate opening and the upstream level. Flow control is achieved by adjusting the gate in response to changes in gate flow. An ultrasonic level transmitter is also used to measure the waste way level and the flow is calculated using Manning's equation.

A spread spectrum radio provides a real-time communications link between the site and a SCADA system host computer at the RID office. A Windows based graphical user interface manages bidirectional transfer of data from the site providing both graphical and text based representation of current site conditions, and allowing operational set point changes to be made.

A previous attempt to remotely monitor the re-regulation pond at WW6 utilized leased telephone lines for the communications link to the RID office. The original monitoring system was abandoned and the lease line was utilized as the link into the SCADA host computer for the first year of operation of the WW6 flow control system. Operating screens were added to the original WW5 configuration and the addition of a communications multiplexer at the host allowed concurrent communications to the two sites utilizing the different media. A new project completed the following year saw the leased line abandoned in favor of cellular digital wireless technology.

RE-REGULATION PONDS

Operational spills down waste ways 5, 6 and 7 were historically required as part of the operation of the Roza main canal. Manually read gauging stations on these waste ways provided a means to determine instantaneous spill flow once or twice in a day, but Roza knew this return flow would better serve the District needs if it could be stored and used at a later time. As such, Roza designed and constructed two re-regulation ponds upstream of WW6 and WW7. Even though the final configuration of the two systems were different, the intended operation of both ponds was to capture excess flow that would otherwise be diverted down the waste way and utilize the stored water to make up short falls in downstream flow demand.

The pond at WW6 is comprised of a 150 acre-foot reservoir, side spill weir and pump plant. The side spill weir is located upstream of the WW6 check gate and was constructed to allow excess canal flow to spill into the pond. The pumping plant consists of one 25hp variable speed and two 50hp fixed speed vertical turbine pumps with the pump intake structure located inside the banks of the pond and discharging back into the canal. The system was designed for stand-alone operation and was initially controlled using analog process controllers that would start, stop, alternate the pumps and, control the speed of the variable speed pump based on the signal from a level transmitter located in the canal near the side spill weir. Following construction and initial operation, a remote monitoring system was installed that relayed pump and alarm status to the RID office via leased telephone lines. Roza had originally partnered with two local contractors for the supply of the electrical, controls and monitoring systems, but those firms are no longer in business. Following the installation of the WW6 flow control automation, the District once again partnered with AS2I to assist with integrating the WW6 re-reg controls into the District SCADA system.

The pond at WW7 is comprised of an 11 acre-foot reservoir and combination pump/discharge structure on the main canal. This structure consists of a combination intake and discharge well constructed in the side of the canal bank that includes a variable speed 15hp vertical turbine pump and an 18 inch electrically actuated butterfly drain valve. The pump discharge and the drain valve are connected to the same pipe that connects to the low level inlet structure in the elevated pond. Initially, Roza partnered with local electrical and controls contractors to assist with automating the facility, but the system was never able to operate for more than a few hours at a time due to deficiencies in the installation and equipment.

With the onset of several consecutive water short years, Roza partnered with AS2I to provide design, control equipment, programming and commissioning of a new control system for the site. The original variable frequency drive was replaced by the District and an automated Langemann gate was installed at the top of the downstream waste way structure. The system was programmed to perform downstream level control in the canal upstream of the waste way gate by pumping excess canal flow into the reservoir and releasing stored water to make up flow deficits. The primary objective of no spill down the waste way was achieved.

HIGH LIFT PUMPING PLANT CONTROL

Initially, all gravity laterals were to be enclosed with PVC pipe prior to expanding the ECS to the pump laterals. However, specific right-of-way and water quality issues brought about the necessity to enclose the Pump 10 lateral. The Pump 10 pumping plant consisted of two 150hp, 480volt, 1760rpm motors driving horizontal split case pumps operating in parallel. Water was pumped 139 feet above the pumping plant into a head weir box and spilled over a 48-inch weir and into an open gravity ditch flowing to farmer deliveries. The flow rate was manipulated by manually adjusting gate valves on the discharge of the pumps until the desired flow rate was measured over the head weir. Piping the lateral and replacing weir blades with flow meters increases the farmer's flexibility. With weir blades, farmers were unable to shut off there water unassisted if there pipe broke or they needed to move a wheel line. But with the ECS system, farmers are equipped with valves and thus the ability to turn off their deliveries at any time. This would cause water to stack up at the head weir box and overflow if the pump flow rate were not immediately reduced.

Roza recognized the need for automatic flow control at the pumping plant, and decided to retain the head weir box with the ECS pipe delivering from the box and maintain a water level set point in the weir box, regardless of the demand for water. Traditionally, this would be accomplished using a VFD to vary the pump speed. However MagnaDrive was interested in using a Roza application as a showcase and offered a financial incentive to utilize their product on this project. Once again, the use of new technology provided an opportunity to enter into a Demonstration Project partnership with the Bureau as only nine MagnaDrives had been installed worldwide and none at an irrigation district.

The MagnaDrive utilizes the principle of magnetic induction or induced eddy currents. The MagnaDrive coupler (coupler) consists of two components, the magnet rotor assembly and the conductor rotor assembly, which make no physical contact. Relative motion between these two components results in a powerful coupling force between the two rotors, and precisely varying the air gap between the magnets and the copper conductor results in a controlled output. Based on this principle, the motor can operate at its optimal design speed. The coupler varies the pump speed and, thus the flow rate, by manipulating the air gap, by way of an electric actuator, between the rotors and thus controlling the amount of slip.

For the design of the hardware and software to provide level control using the coupler, Roza again partnered with AS2I. Based on the AS2I design, Roza purchased the necessary controller and instrumentation and fabricated and installed the system hardware. A magnetic insertion flow meter from MSR Magmeter was installed in the lower portion of the penstock and connected to the PLC in order to monitor total discharge flow from the pumping plant. An ultra sonic level transmitter, connected to the PLC with buried instrumentation cable, was used to measure the water level in the head weir box. The coupler actuator was controlled via an instrument signal from the PLC, and the software utilized a proportional + integral + derivative (PID) loop to vary the coupler air gap based on the difference between the water level and the set point.

The installation of the MagnaDrive required several modifications of the pumping plant and 4 unsuccessful attempts to complete the project due to miscues by both Roza and MagnaDrive. The magnetic flow meter did not perform as well as expected and in discussion with the supplier it was determined that the location of the sensor was likely too close to the discharge of the pumps creating excessive turbulence. The sensor was relocated further up the penstock and will be tested in the coming operating season.

Even though there was initial uncertainty regarding the final outcome of the project, Roza recognized that this was a demonstration project utilizing new technology in a unique application. In the end, both the District and MagnaDrive learned a great deal from this partnership and are pleased with the successful outcome.

DIVERSION FLOW METERING

Irrigation water for District use is turned into the Roza main canal at the 11 Mile bifurcation works, and was historically measured at the 11 Mile gauging station located just downstream of the bifurcation works. The gauging station is in a trapezoidal lined section of the main canal, and the Littleman controller that controls the radial head gates is housed in the gauge station building. There is also a metering bridge in a rectangular lined flume section of the main canal about ½ mile downstream of the gauge station.

The water depth at the gauge station was reported via radio to the water master once daily, and the water master determined the flow rate from a rating curve chart supplied by the Bureau. The Bureau developed the rating curve of corresponding flow rates and water depths by using a current meter at the measuring station. The Bureau also uses the same rating curve to set a flow rate for the District by determining the required gage height and using the Littleman controller to maintain the target elevation.

Providing flow control for the District in this manner has been contentious as accumulations of moss and debris downstream create backwater at the gauging station which results in overestimates of flow for a given gauge reading. The Bureau periodically performs flow measurements at the metering section to establish correction factors for the rating curve but these corrections sometimes came too late to rectify the difference between actual and measured flow.

Drought situations make it more critical that measured flow equal actual flow. The District decided the 2001 water short year was a good time to install a better metering device. Roza partnered with MGD technologies, Inc. (MGD) to purchase an Acoustic Doppler Flow meter (ADFM). The ADFM uses acoustic pulses and the Doppler affect to measure velocity along with an ultra sonic sensor to measure depth to calculate flow in a known canal cross section. Roza also partnered with AS2I once again to expand the SCADA system to incorporate the 11 Mile gauging station to acquire real time data on flow rate and velocity, and with the Bureau to include this site as a demonstration project for new technology.

Following the first season of operation, it was determined that the ADFM did not perform as well as anticipated due to wave action created by the meter's proximity to the diversion gates. MGD claims the ADFM should be accurate within 2 % of the average of the total flow readings, but instantaneous readings were found to be 4 % to 8 % off of the actual flow rate. In an attempt to improve performance, Roza moved the ADFM ½ mile farther downstream to the rectangular metering section where the wave action is substantially reduced, and AS2I added a moving averaging algorithm to the site RTU. If the ADFM proves to be a superior flow measurement instrument, the hope is that the Bureau will utilize the device to automate the canal inlet radial gates and ultimately solve the issue of backwater affecting the main canal flow rate.

SCADA SYSTEM & COMMUNICATIONS TECHNOLOGY

Over the course of implementing its Comprehensive Water Conservation Plan Conservation Plan (CWCP), Roza has moved towards implementing a SCADA system that connects the key operation points in the District to the Roza office. From the District's point of view, automated main canal checks performing level control do not warrant remote communications, but key flow measurement and control points, such as 11 Mile gauging station, WW5, WW6 and WW7 are of significant importance. Some consideration may be given to remote communications with the pumping plants associated with many of the main canal checks in the future, and a re-regulation reservoir planned for upstream of WW5. Early automation and remote monitoring systems were implemented with varying degrees of success, but a coordinated plan was not put together.

With the assistance of AS2I and the automation projects implemented at the key measurement and control points, an approach to implementing an open SCADA system has been mapped out. As such, the District has now standardized on Modbus communications protocol using two different types of wireless communications media. The implementation of Modbus allows the District to communicate with numerous brands of PLC's, including the Modicon and TeleSAFE units that are currently installed at various sites in the District.

Roza has also utilized various communications media including license-free spread spectrum radio, leased telephone line and cellular digital packet data (CDPD). The use of the communication multiplexer at the Roza office allowed all three of these media types to be implemented for a portion of one operating season, but eventually the leased telephone line to WW6 was abandoned in favor of CDPD once its viability was proven. This "hybrid" communications network allows the District to maintain a single host computer for the system, and the use of remote control PC to PC software provides remote access for operations personnel in all areas of the District.

SUMMARY

The partnerships that Roza has formed over the past decade for implementing new and innovative technology have assisted the District with the successful implementation of its CWCP, and have formed valuable relationships both inside and outside the District's sphere. The significant partners have worked with the District with the principal goal of water conservation in mind and have endeavored to provide support and solutions that are consistent with the philosophy of the District. With more projects planned for the future and the certainty that water will require more active stewardship, Roza has positioned itself so that it can call upon its conservation minded partners to help the District apply the right technology.