RECLAMATION
Managing Water in the West

Water Operation and Maintenance Bulletin

No. 235

In This Issue . . .

U.S. Department of the Interior
Bureau of Reclamation

December 2013

This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Bureau of Reclamation personnel and water user groups in operating and maintaining project facilities.

The *Water Operation and Maintenance Bulletin* and subject index may be accessed on the Internet at: **www.usbr.gov/assetmanagement**.

For further information about the
Water Operation and Maintenance Bulletin, contact:

Ben Claggett, Managing Editor
Bureau of Reclamation
Technical Service Center (86-68260)
PO Box 25007, Denver, CO 80225-0007
Email: bclaggett@usbr.gov

***Cover photograph*:** Flood damage after historic September flooding in Colorado. Photo is looking west at what was Highway 34 next to the Big Thompson River at the Hansen Siphon crossing between Loveland and Estes Park, Colorado.

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Epoxy Grouting of the Hansen Siphon Pier Damaged During the Colorado Flooding

by: Westin T. Joy, Technical Service Center's Materials Engineering and Research Laboratory Group

Introduction

Building on the Materials Engineering and Research Laboratory Group's (MERL, 86-68180) expertise in chemical grouting methods and materials, the group recently completed a repair on a damaged concrete pier supporting the Hansen Siphon. The pier was damaged during the September 2013 flooding of the Big Thompson River when a retaining wall and adjoining concrete barrier screen (constructed to prevent vehicular traffic from colliding with the pier support) collapsed and fell onto the pier, leading to a significant amount of cracking in the pier. The collapsed wall and damaged pier can be seen in the before and after photos of Highway 34 on figures 1 and 2. A closeup of the damaged pier reveals several large cracks, some as wide as 0.2 inch, with the widest portions of the cracks on the downstream end of the pier (figures 3 and 4). The cracks are largest on the impacted side (roadside) and gradually become smaller as the cracks wrap around the noses toward the streamside of the pier. At the upstream pier nose, the cracks dip down and decrease in size. Due to the high water flows during the flood event, dirt and debris were observed in areas of the cracks.

Figure 1.—View of Highway 34 looking west before the flood event. Note the retaining wall circled in red.

Figure 2.—View of Highway 34 looking west after the flood event. Note the retaining wall circled in red.

Figure 3.—Cracking on the upstream, roadside face of the pier.

Figure 4.—Closeup of largest cracks. Cracks were largest on the downstream, roadside face and get smaller as they progressed upstream on the roadside face. No cracks were visible on the streamside of the pier.

An examination of the damage by Kurt von Fay and Tim Brown of the Technical Service Center (TSC) lead to the conclusion that it could be repaired and structurally rebonded via epoxy injection. The timeline to perform the repairs was short and urgent due to the construction schedule for rebuilding Highway 34 between Loveland and Estes Park, Colorado, and coincided with the recent Government shutdown. At that time, Westin Joy, Brandon Poos, and Warren Starbuck of MERL performed the repairs.

Repair Method

After the initial site visit and inspection, structural calculations were completed for the pier. TSC personnel determined that the structural capacity of the pier could be regained by injecting a structural epoxy into the cracks. MERL staff had previously conducted epoxy injection into concrete walls and slabs and offered to perform these repairs. The use of Bureau of Reclamation employees would fast-track the repair work, allowing the highway contractor to proceed with work on Highway 34 near the pier.

A successful epoxy injection job has several important steps. As with any repair project, it is important to select the correct material for the application. The material used for these repairs was a two-component, 100-percent solids, 2:1 ratio structural epoxy compatible for use in concrete, and was very low viscosity to allow good penetration into the cracks.

Surface preparation also plays a vital role in achieving a successful, long-lasting repair. In the case of epoxy injection, the surface needs to be prepared to allow for proper adhesion of the injection ports and capping material over the surface of the cracks. This was accomplished by grinding the surface of the concrete directly over and around the cracks (figure 5), which removes debris from the surface and creates a flat surface for the injection port. After grinding is complete, the surface and the inside of the cracks should be air blasted to remove any remaining dust and debris.

Figure 5.—The crew used angle grinders fitted with abrasive discs to remove debris and flatten the surface prior to attaching injection ports and sealing the cracks.

Once the surface is prepared, the next step of the epoxy injection process is to install the injection ports and seal the surface of the cracks. The injection ports used for epoxy injection are typically surface mounted rather than drilled and set packers. Due to the low viscosity of the epoxy material, it is usually not necessary to drill injection holes. The injection ports are affixed to the surface directly above the crack with a fast-setting, high viscosity epoxy. Once the ports are in place, the same epoxy is applied to the surface of the cracks to prevent the low viscosity epoxy from leaking out of the cracks. In some cases, it is necessary to seal the surface of the cracks that do not appear to connect to the crack that is to be injected. The cracks may intersect somewhere within the concrete and could potentially lead to epoxy leakage. Additionally, due to the low viscosity of the material, it may even leak from cracks that are not visible to the naked eye. Figure 6 shows the injection ports and surface sealing in place for the cracks in the pier.

Figure 6.—Injection ports and surface sealing have been applied to the cracks in the pier. Note the cracks without injection ports that have been sealed to prevent possible leakage.

After the epoxy used for the surface seal has cured, the ports are injected with air. This serves three purposes. First, it will help remove any dirt or debris that may have found its way into the crack or the ports throughout the work process. Second, it allows the crew to verify connectivity of the ports and adjacent cracks. Finally, injecting air into the ports (with surrounding ports capped) allows the crew to pinpoint areas in the surface seal that are leaking. A few small leaks were observed and subsequently patched with another application of the surface epoxy. Once the newly applied epoxy was cured, the crew began injection work.

There are numerous ways to pump the epoxy into the ports, including two-component caulking guns, pneumatic caulking guns, and pneumatic pumps. Due to the low temperatures, the crew used a pneumatic pump. The low temperature caused the viscosity of the epoxy to increase to the point where it would be difficult to pump by hand. Figure 7 shows the pneumatic pump used for injection. Also seen in this figure are the reservoirs for the A and B components of the epoxy resin system. The third reservoir contains acetone for flushing the system after the work is completed.

Figure 7.—Pneumatic pump used for epoxy injection. The pier can be seen in the right in the photo.

The injection began at the lowest point of the cracking. By beginning the injection at the lowest point, air is allowed to escape as cracks are filled, leading to a more complete filling. In this instance, there were three main cracks to be injected, and each crack was injected from the lowest point at the upstream end of the pier, and progressed downstream and upward. To facilitate a quicker injection rate, the crew assembled a manifold and injected three ports simultaneously. The manifold and injection lines can be seen on figure 8.

After a port has been injected, a cap is placed over the port to prevent the injected epoxy from leaking out of the crack. The crew pumped just under 2 gallons of epoxy. There was a small amount of leakage around some areas of the capping material and from cracks that we could not see before injection began (figure 9). Additionally, there was material loss associated with removing the injection lines from a port. Accounting for losses, the crew injected approximately 1.6 gallons of epoxy into the cracks. The gel and final cure times of the epoxy vary depending on temperature, and given the concrete temperature of about 42 degrees Fahrenheit, the gel and cure times would be relatively long. After completing the injection work, the crew cleaned up the site and returned a few days later to inspect it. When they returned, the crew removed the injection ports and inspected the exposed portions of the cracks. Figure 10 shows epoxy filling a crack at the site of an injection port.

Figure 8.—Injection lines and manifold. Note the simultaneous injection of three ports.

Figure 9.—Epoxy leaking from hairline cracks and through areas of the capping material.

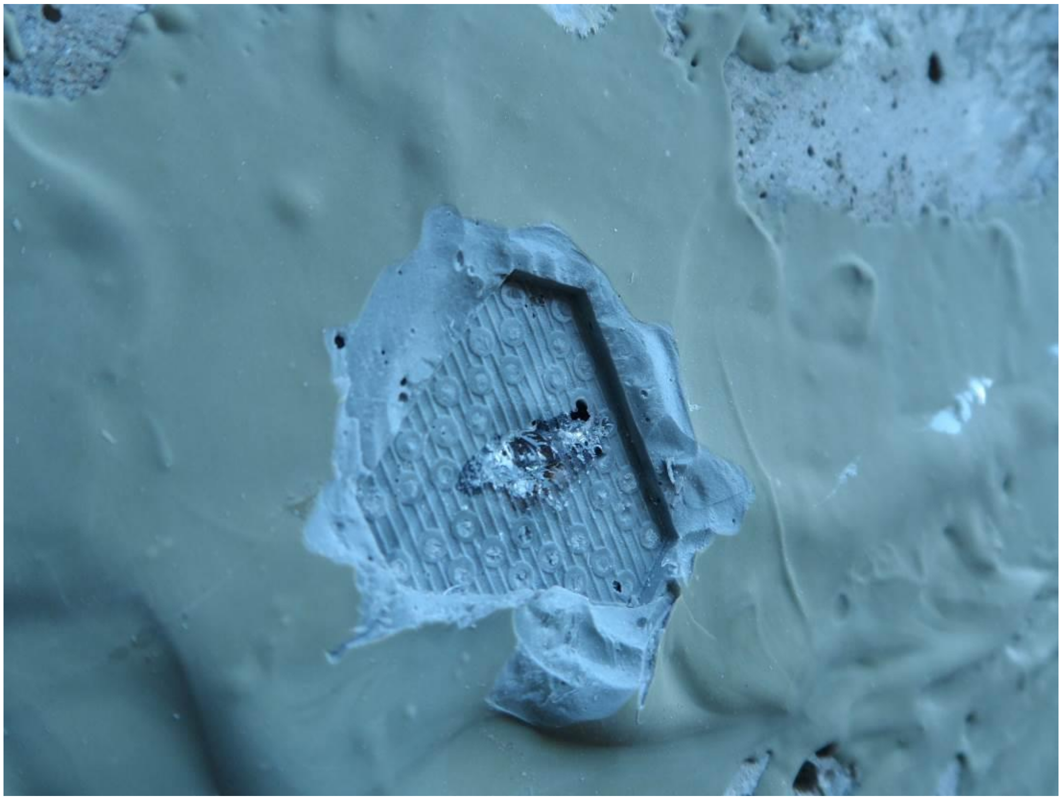

Figure 10.—Epoxy can be seen within the crack after a port was removed.

Summary

Personnel from MERL have experience using epoxy resins to repair cracked concrete. Using this experience, MERL staff performed emergency epoxy injection of a concrete pier supporting the Hansen Siphon. The pier was damaged during the recent flooding of the Big Thompson River and required repair before Highway 34 could be rebuilt. The injected epoxy has structurally rebonded the cracked concrete, providing a stable support for the siphon above. With this repair, work to rebuild Highway 34 could continue as planned.

Contact Information:

For more information about this project or other MERL capabilities, please contact Westin Joy at wjoy@usbr.gov; 303-445-2382 or Kurt von Fay at kvonfay@usbr.gov; 303-445-2399.

COST-EFFECTIVE SCADA DEVELOPMENT FOR IRRIGATION DISTRICTS: A NEBRASKA CASE STUDY

by: Clinton Powell, Agricultural Engineer, Bureau of Reclamation, Nebraska-Kansas Area Office, Water Conservation Program, and Tom Gill, Hydraulic Engineer, Bureau of Reclamation, Hydraulic Investigations and Laboratory Services Group

Abstract

Irrigation districts across the West face economic hardship brought about by increased maintenance costs, reduced water supplies, and a shortage of skilled labor. One opportunity for a district to offset these challenges is by implementing a Supervisory Control and Data Acquisition (SCADA) system. However, historically these systems have been out of reach for smaller and less-affluent districts because of the large capital outlays required for adoption.

The Bureau of Reclamation's (Reclamation) Nebraska-Kansas Area Office, in cooperation with Reclamation's Hydraulic Investigations and Research Laboratory, is working with the Bostwick Irrigation District in Nebraska to create a monitoring and control system suitable to the needs of a small irrigation district with limited resources. Specifically, the project has focused on low acquisition and installation costs, district-driven solutions to SCADA operational issues, and minimization of technical expertise for maintenance purposes.

This paper chronicles the efforts to develop a SCADA solution for the Bostwick Irrigation District that meets each of these needs through innovative product choices, materials fabrication, and low-cost solutions. The current project status and future project direction are discussed in context of the district's operating environment in light of the complex issues facing all the water users in the Republican River Basin upstream of Kansas.

Background

The Bostwick Division was authorized in December 1944 and is comprised of two subunits: (1) Bostwick Irrigation District in Nebraska that currently serves approximately 20,500 acres in Nebraska and (2) the Kansas-Bostwick Irrigation District that currently serves approximately 62,000 acres. Harlan County Lake, a multiple use water storage and flood control facility constructed by the U.S. Army Corps of Engineers on the Republican River near Republican City, Nebraska, serves as storage for both the Nebraska and Kansas Bostwick Districts. Lovewell Reservoir on White Rock Creek provides additional storage for the Kansas-Bostwick Irrigation District.

The Bostwick Irrigation District in Nebraska is geographically in the middle of the area that was the focus of recent U.S. Supreme Court litigation among Kansas, Nebraska, and Colorado regarding the use of Republican River Basin water resources. In 2004, with Harlan County Lake at approximately one-third normal storage capacity, no water was delivered to district shareholders for the first time since water delivery operations were initiated in the 1950s. In 2005, again a water short year, and for the second consecutive year, no deliveries were made to Nebraska Bostwick irrigators. With return of precipitation in the basin to rates closer to the historical norm, Nebraska Bostwick water deliveries resumed in 2006 and have continued through 2009. Going into the 2010 season, Harlan County Lake is at full storage, which bodes well for normal deliveries in 2010.

With these recent uncertainties in its operations, Nebraska Bostwick has been aggressive in enhancing water conservation capabilities in their delivery network. The district has taken advantage of the comparatively high elevation of the Franklin Canal relative to the delivery areas served by laterals off the canal and, in spring 2010, is completing a multiyear project to replace multiple open laterals with buried pipe. In an effort initiated in 2009, Nebraska Bostwick began to integrate electronic control and radio communications equipment that will enable local automation and/or remote operation and monitoring of structures in the canal system. The control/communications project is the focus of this paper.

Project Scope

All field locations included in the initial phase of Nebraska Bostwick's control/communications project are located on the main stem of the district's Franklin Canal. The Franklin Canal runs along the north side of the Republican River beginning at the turnout gates just below Harlan County Dam. The canal continues for almost 47 canal miles eastward, paralleling the Republican River along the north side of the valley. The upper end design capacity of Franklin Canal is 230 cubic feet per second.

The sites selected for equipment installation included 10 check structures along the canal reach between Harlan County Dam and Red Cloud, Nebraska. The selected checks represent approximately every third check structure. The distance in canal miles between instrumented checks ranges from a low of 2.1 miles to a high of 5.6 miles. The average distance is approximately 3.6 miles.

Lands under Nebraska Bostwick are subject to frequent, intense, and often localized thunderstorms. As a result, irrigators routinely need to drop scheduled deliveries on short notice. Additionally, storm water runoff can lead to significant unanticipated canal inflows. Throughout its operating history, Nebraska Bostwick has experienced significant spillage losses due to impacts of weather events.

Primary among upgraded capabilities being sought by the district were (1) improved delivery reliability and (2) the capability to utilize in-canal storage to limit spillage losses. Additional benefits such as reduced vehicle mileage and staff travel time required to monitor the system were considered secondary to improving system performance and enhancing water conservation.

To meet district objectives, Reclamation engineers worked with district staff to develop a plan for equipping the 10 designated check structures for local, automated upstream level control with the capability to adjust target levels either onsite or remotely. Additionally, Reclamation engineers attempted to develop a methodology for using the installed gates as a flow measurement device to determine the flow passing the instrumented check structures.

Evaluation of Existing Structures

The 10 selected checks represented two general design configurations. The upper seven checks were each three-bay structures, the two outer bays were stop-log controlled, and the center bay was a vertical slide gate. None of the gates were motorized. District staff indicated that the vertical slide gates had remained in closed position at all times for as far back as presently employed personnel could remember. The district opted to rebuild existing gates prior to installing the control and communications equipment. Since district staff were tied up on the project of converting open laterals to buried pipe, the district contracted with a local welding shop to construct new gates for the seven upper three-bay structures. Figure 1 shows the three-bay 5.4 check.

The three checks lower on the canal that the district selected for motorized gate operation initially had no gates installed. Each of these sites was a two-bay structure with stop-log control in each bay. District staff fabricated new vertical slide gates to install in one of the stop-log bays at each of these checks. Figure 2 shows the 34.2 check site.

Radio Pathway Check

In March 2009, Reclamation engineers worked with Nebraska Bostwick personnel to test radio transmission signal strength. Radio/control units manufactured by Control Design, Inc. (CDI), were selected for the tests based on the successful performance of their equipment on other projects. Compared to other available alternatives, CDI equipment was cost effective and demonstrated good signal strength. For the tests, an antenna was temporarily installed on the

Figure 1.—Reclamation engineer Clinton Powell (left) and Nebraska Bostwick Manager Mike Delka inspect the 5.4 check in February 2009.

Figure 2.—Nebraska Bostwick 34.2 check in February 2009.

communications radio tower at the district's Red Cloud Office. A battery-powered radio was connected to the antenna at the tower base. A second antenna was attached to a 10-foot mast and taken to each check structure, beginning with the site nearest Red Cloud and working outward. A second battery-powered radio/control unit programmed with a calibration algorithm to determine receiver signal strength indicator levels was linked to the field antenna.

Communications with the Red Cloud Office were tested at successively further west sites until a site was reached at which a reliable link could not be established. At that time, the field antenna was taken to the district's Franklin Office and temporarily installed on the Franklin communications radio tower to attempt direct contact with Red Cloud. Attempts to make direct contact between the office sites were unsuccessful. To continue the tests, the antenna at Red Cloud was taken down and mounted to the 10-foot mast to use at remaining field sites in checking communications linkage with the Franklin Office. The later tests showed that communications from Franklin were possible with the westernmost check that could be contacted from Red Cloud and with all of the rest of the field sites west from that point plus the gate house at Harlan County Dam.

Based on findings of the radio pathways testing, a comparatively simple radio network was sufficient to establish communications among all sites and both offices without including any dedicated repeater sites. Each office base could be programmed to communicate directly with field sites within its range. The system was designed such that for out-of-range sites, each office would repeat first through the field site (the 28.6 check) that could directly communicate with both offices. A second repeat could be made through the base at the other office and then back to the selected field site. Built-in networking configuration tools in the CDI equipment enabled each unit to perform as a base or as a field remote transmission unit and simultaneously function as a repeater. Figure 3 is a sketch of the project layout showing relative positions of Harlan County Lake, instrumented check sites, the Franklin and Red Cloud Offices, along with the check site that also functions as a repeater.

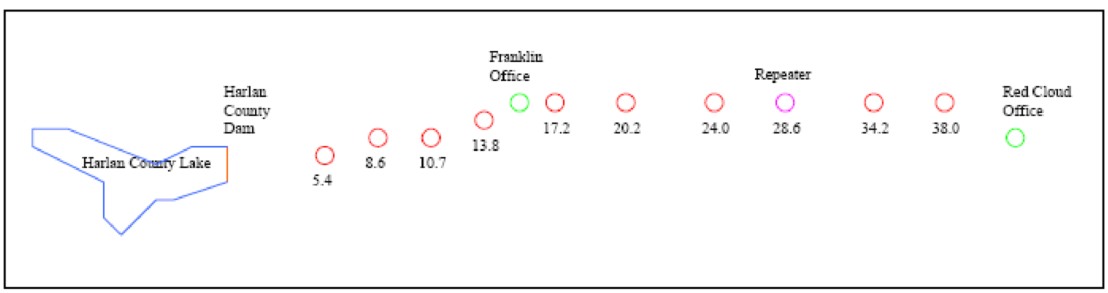

Figure 3.—A layout sketch of approximate locations of the radio/communication sites.

A sense of scale may be derived from figure 3 from check identifier names. The identification number for the Franklin Canal checks represent the number of canal miles they are located from the gate house below Harlan County Dam. It should be noted in the context of the discussions on radio transmission paths that the landscape throughout the project area can be characterized as rolling hills. Much of the radio pathway being utilized is not line of sight.

Gate Motorization

Nebraska Bostwick considered a range of gate motorization alternatives. Prior to embarking on this project, two members of the district staff participated in a Reclamation-sponsored Canal Modernization Workshop held in February 2009 in Hot Springs, South Dakota. During the workshop, staff of the Belle Fourche (South Dakota) Irrigation District reported on their canal modernization project that included using linear actuators on previously hand-operated gates. Belle Fourche has also installed commercially produced canal gate actuators by Limitorque. Information was also presented on a chain-drive gate motorization that was developed by Reclamation over a decade ago that has been in service over an extended time period at sites in multiple States.

For reasons of simplified installation and for the attractive affordability offered, the district opted to motorize the vertical slide check gates using linear actuators. The availability of units with built-in travel limit switches, as well as built-in position sensors, was perceived as a key benefit over the chain-drive option. From an affordability standpoint, the linear actuators are almost an order of magnitude lower in cost than commercial actuators.

The new gates, which were either built by district staff or by a contractor, were configured during construction for linear actuator operation. In lieu of the threaded rods previously used to lift gates, a short section of smooth shaft was affixed to the gate on the lower end and had a clevis-type connector for linkage to the linear actuator on the upper end. The function of this rod is to keep all components of the linear actuator above the water surface at any gate position.

2009 Installations

New gates were installed at each of the selected check sites in early June prior to the initial water-up of the system. Tubing and protective conduit for bubbler level sensors were also installed at check structures prior to watering up the system. Each site was equipped for upstream and downstream level measurement if submergence conditions were present.

Installation of linear actuators, along with batteries, solar charging systems, and manual operation toggle switches began prior to water-up and continued throughout much of the irrigation season. Limitations on the time commitments of Reclamation staff proved to be a bottleneck in completion of this task. Reclamation's staff was primarily responsible for calibration and testing of the electrical and electronic components. At sites where gate motorization was not yet functional, canal stage adjustments were made by adjusting stop logs in bays adjacent to the gated bays in the same manner the system had been operated in previous years. Figure 4 shows the final stages of hardware installation at the 20.2 check, and figure 5 shows the same site from a different angle.

Figure 4.—Reclamation engineer Clinton Powell makes wiring connections on the linear actuator at the Nebraska Bostwick 20.2 check.

Control System Components

As noted earlier, bubbler level sensors were selected to measure upstream canal pool level. Downstream levels are needed for gate flow measurement where submergence is present. The bubbler equipment employs a single bubbler setup plumbed through a bidirectional solenoid valve to enable the same sensor to measure water level at two locations. The installation was made easier because CDI had previously provided a board with all the components needed for this multiple level bubbler sensor for use with a submerged flume measuring system Reclamation has been field testing in Arizona.

Figure 5.—Completed hardware installation at the Nebraska Bostwick 20.2 check.

This multiple location bubbler level sensor was a cost-competitive alternative for measuring two levels. The bubbler technology also eliminates water quality concerns associated with use of submersible pressure transducers, functions effectively without a stilling well, and does not require the temperature compensation that is often needed with ultrasonic level sensors.

Gate operation circuitry that Reclamation (and others) have utilized at multiple DC-powered canal gate installations utilizes triple-pole, double-throw plug-in relays with relay contacts located in a sealed chamber filled with inert gas. Two relays are utilized for each gate. When a relay coil is energized, two of the normally open triple pole contacts close to complete both the ground and positive legs of the gate motor circuit. The coil energizing circuit utilizes normally closed contacts on the third pole of the companion relay. Thus, when one relay coil is energized, all normally closed poles are opened. It is not possible to simultaneously energize both relay coils.

CDI has created a circuit board with sockets for the plug-in relays that utilize the same circuitry as hand-wired installations Reclamation has used successfully along with diodes to protect against reverse current flow resulting from collapsing fields as circuits are switched. Additional features built into the CDI boards are

Figure 6.—Control components (upper enclosure) and user-interface components (lower enclosure).

terminal connections for installation of toggle switches to switch control from the onsite programmable logic controller to hand-operated toggle switches to raise and lower gates.

The CDI radio control units are assembled as a single unit consisting of a programmable logic controller, a modem, and the radio. The current product line, which was introduced in 2007, may be configured with or without an onboard 4 x 20 display and with or without an onboard 6-button keypad. At similar installations where CDI equipment has been utilized, an onsite user interface has proven to be a desirable configuration. Figure 6 shows installed control equipment at a Nebraska Bostwick check site with a remotely located display and 4 x 4 keypad.

A drawback to the onboard display and keypad is that if these user interface components are frequently accessed, there is high potential for the enclosure cover to be insufficiently closed and sealed, leading to issues with moisture and/or insects disrupting the function of electronic components. For the Nebraska Bostwick project, external display and keypad components are located in a separate enclosure to reduce the potential for exposure of sensitive electronic components to the elements. To further isolate sensitive components from potentially corrosive agents, the battery is housed in a separate enclosure on the opposite side of the pole from the control equipment.

2010 Project Status and Future Plans

During the 2009 irrigation season, as linear actuators along with batteries and charging systems were installed, ditchriders adjusted the motorized check gates manually using toggle switches (seen in figure 6 below the display and keypad faceplate). The current project schedule calls for the CDI units on each check to be programmed and tested for upstream level control operation during the 2010 irrigation season.

After manually operating the motorized gates in 2009, ditchrider staff is in favor of a program to upgrade all stop-log bays with gate structures. The district recognizes the advantages of the configuration of the three-bay checks in the upper reaches of the Franklin Canal whereby the center vertical slide gate enables passage of bed sediments while flow passing over stop logs on the side bays can enable much of the floating debris to also pass the structure.

To maintain the ability to pass floating debris, overshot gates were identified as the preferred alternative for upgrading stop-log bays at checks where vertical slide gates already exist. Following a scoping-level investigation of prices for commercially available overshot gates, the district opted to participate in a Reclamation Science and Technology Program research project that is seeking to develop guidelines for overshot gates that irrigation districts can self-construct. The research project is focused on structures that can be fabricated as “drop-in” units for existing stop-log structures.

In this effort, the district has constructed overshot gates to install in stop-log bays at three of the checks where motorized slide gates were installed in 2009. Similar to the motorization alternative selected for vertical slide gates, the overshot gates will also be operated by DC-powered linear actuators. Based on a projection of forces that will act on the gates, two actuators with gear heads linked by a drive shaft will be used to operate the gates.

As operation of the overshot gates is incorporated into the automated upstream level operation, the algorithm will call for coarse adjustments to be accomplished with overshot gate movements, while small adjustments will be made with vertical slide gate movements. Once the automation system is functional, water level target adjustments may be entered onsite following on-screen prompts and keypad input or remotely via radio. Manager Mike Delka sees the district expanding this modernization effort at an affordable rate until ultimately all main canal checks have similar automated or remote operating capability. Figure 7 shows the district's 28.6 check where motorized gates have been installed in previously stop-log controlled bays prior to the beginning of the 2010 irrigation season.

Figure 7.—Vertical slide and overshot gates at the 28.6 check both motorized using DC linear actuators.

Summary

For an initial experience with integration of electronic control and communications equipment into canal operations, the scope of Nebraska Bostwick's project represents a comparatively ambitious step. The seemingly boldness of the initial project scope is tempered considerably when considered in the context of current operating realities, including the complete shutdown of deliveries in 2004 and 2005. Improving the district's water management capabilities to enable more efficient delivery operations is a key focus for district staff and district water users alike.

The situation Nebraska Bostwick finds itself in is similar to the plight of many irrigation systems throughout the western United States. Many water users are being faced with the alternative of seeking affordable means of stretching limited water supplies, or risk being unable to afford to remain viable. The approach Nebraska Bostwick has selected is to rely on in-house talents and develop new in-house capabilities to the extent possible to make adoption of new technologies in system operations an affordable process that can help sustain the district with limited reliance on external expertise.

Mission

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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Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Darrel Krause, Bureau of Reclamation, ATTN: 84-57000, PO Box 25007, Denver, CO 80225-0007; email: DKrause@usbr.gov

Ben Claggett, Bureau of Reclamation, ATTN: 86-68260, PO Box 25007, Denver, CO 80225-0007; email: bclaggett@usbr.gov

James Dean, Pacific Northwest Region, ATTN: PN-3200, 1150 North Curtis Road, Boise, ID 83706-1234; email: JDean@usbr.gov

Paul Caruso, Mid-Pacific Region, ATTN: MP-4300, 2800 Cottage Way, Sacramento, CA 95825-1898; email: PCaruso@usbr.gov

Scott Foster, Lower Colorado Region, ATTN: LC-6600, PO Box 61470, Boulder City, NV 89006-1470; email: SFoster@usbr.gov

Rick Scott, Upper Colorado Region, ATTN: UC-1000, PO Box 11568, Salt Lake City, UT 84147-0568; email: RScott@usbr.gov

Dave Nelson, Great Plains Region, ATTN: GP-2400, PO Box 36900, Billings, MT 59107-6900; email: DENelson@usbr.gov