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Case Studies of Small-Scale Automation for Existing Water Delivery Systems

by

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ABSTRACT

Low-cost automated equipment added to existing water delivery systems has the potential to revolutionize water management systems. Just as the rapid evolution in microcomputer hardware and software has expanded capabilities, so have the dynamic advances in environmental sensors, telemetry equipment, dataloggers, controllers, and solar technologies widened horizons. Today, real-time monitoring and remote control systems are within the cost range of almost all water user groups, including irrigators, canal companies, water districts, municipal water suppliers, and wildlife management groups.

The U.S. Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers, Natural Resources Conservation Service (NRCS), state and local water development agencies, and private entities have invested billions of dollars in water infrastructure. Real-time monitoring and control holds an important key to improved management of these projects thereby improving economic output, implementing measures to ensure public safety, enhancing environmental conditions, conserving water, expanding recreational opportunities, and reducing operational costs, all in a very cost-effective manner. While some of these idealistic objectives seem contradictory, many can be accommodated through improved water management techniques.

INTRODUCTION

Having responded over the past century to the challenge of helping develop the arid west, Reclamation is now gearing up to meet the present challenge of effective water management. The Federal government is no longer constructing massive water development projects but will now concentrate its focus on improved water management. One activity of particular interest is water conservation through improved operation of existing projects.

Water-user groups are also recognizing the need to change their direction. Water managers are striving to improve the responsiveness of their own supply/delivery systems in order to:

- Conserve Water and Power
- Improve Water Quality
- Meet the Goal of Improved Public Safety
- Enhance the Environment
- Expand Recreation Opportunities
- Reduce Operation and Maintenance Costs
- Improve Crop Yields
- Maximize Hydroelectric Power Generation

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Real-Time Technologies:
an integration of computers, remote terminal units, and communications equipment to connect the water manager with his field sites.

Remote monitoring and control systems are becoming cost-effective water management tools. This development results from major innovations and cost breakthroughs occurring in water management technologies, including computer hardware and software, remote terminal units (RTU's) and dataloggers, communications equipment, sensors, and solar power. Real-time (or near real-time) technologies allow the water manager to continuously compare the way a delivery system is operating with how it should be operating, and to take appropriate corrective steps as required. These innovations allow the water manager to react rapidly and effectively to changing conditions, thereby accommodating both high flow and low flow conditions and reducing spillage and seepage. However, before real-time technologies can receive wide acceptance, they must be tailored to meet the needs of water managers, whether for irrigation, rural culinary water systems, or wildlife refuges. The water managers know their systems and how they respond better than anyone. These enhancements simply add the tools for the managers to better track and adjust the operations.

Reclamation's Provo Area Office (PRO), the Water Resources Research Laboratory (WRRL) and others in the Technical Service Center (TSC) in Denver, and Utah State University (USU) have been working in concert with water managers in Utah to develop and implement low-cost real-time monitoring systems. These systems have been well received and have generated intense interest among water managers in adopting control and automated control into their own systems. For this evolution to occur, the following components are essential:

- Low Initial Cost
- Retrofit Existing Structures
- Reliable Two-Way Communications
- Solar Powered Equipment
- Ease of Installation and Maintenance

But as a word of caution: Americans have always been overly susceptible to idealistic dreams. Robert Hughes (1995), editorializing about the information highway, claims "we will look back on what is now claimed...and consider how we every psyched ourselves into believing all the bulldust about...fulfillment through interface and connectivity. But by then we will have some other fantasy to chase, its approaches equally lined with entrepreneurs and flacks, who will be its main beneficiaries."

A similar claim could be made about the ultimate possibilities of real-time technologies; so let the reader beware. We need to realize the possibilities and practical limitations of real time technologies and remain sensible about the practical limitations involved in implementation.

Obviously, the authors of this paper do not share Mr. Hughes' pessimism. There have been days while doing some particularly difficult troubleshooting on a system that doubt has crept in, but it is overcome when order is restored and the water manager is once again in complete charge of his system. There is one fact that does need to be acknowledged. Installation of real-time systems can dramatically change the job description of a ditchrider, watermaster, river commissioner, etc. He moves away from the endless trips in a pickup truck to turn a gate, toward being a computer user. This transition is not always an easy one. However, by moving away from being a gate turner, he also becomes more of an irrigation system manager.

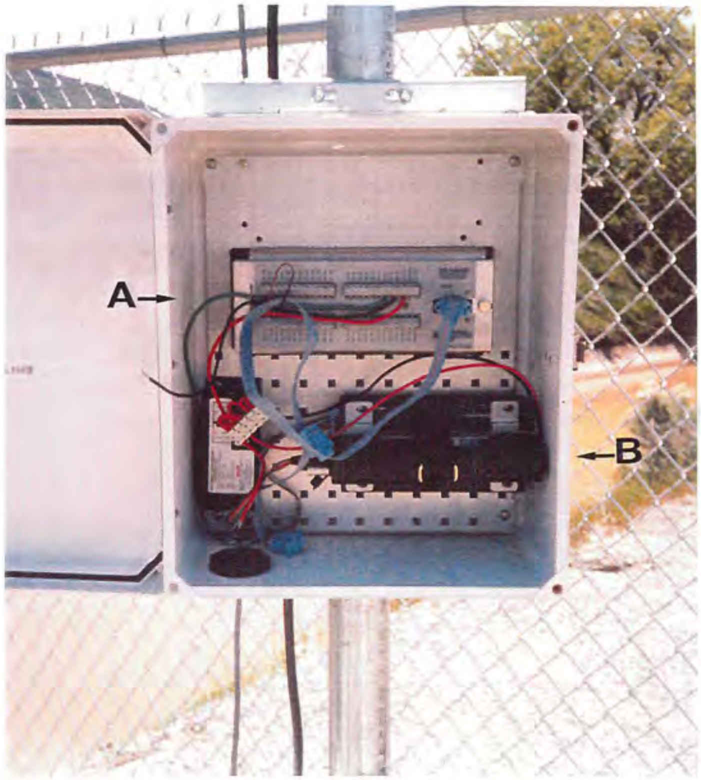
TECHNOLOGY TRANSFER

Encouraging water users to try real-time systems involves the practical application of technology transfer. To make the transfer sustainable, Reclamation has developed a process to eliminate frustration and confusion by implementing the following measures: (1) standardizing equipment, (2) designing systems capable of evolving, (3) utilizing modular design, and (4) involving users closely with installation.

Standardizing Equipment

To simplify the technology transfer effort and facilitate Reclamation's support of specific applications, we are currently standardizing equipment. For example, each field station, regardless of its use, contains a datalogger/controller, a VHF transceiver for two-way communications to a base station and a radio modem (see Photograph 1).

Setting up the base station, which is the water user's access to the real-time system, requires only a VHF transceiver, a radio modem, a telephone modem, and a personal computer. The radio-telephone interface is important because it allows PRO staff and the WRRL to monitor systems by telephone and to assist with troubleshooting.



Photograph 1 - Real-time equipment currently in use on the majority of projects includes: (A) a datalogger/controller; (B) an RF modem and a transceiver.

Allowing Expandability

For many applications, the utilization of real-time technology will be evolutionary, starting with straightforward monitoring systems and evolving into more complex automation applications (see Figure 1). It is important that this process is evolutionary because as real-time technologies evolve, so will water-user interest. As interests evolve, water managers will recognize that new, expensive equipment is not required for each expansion.

Figure 1 - For many applications, the utilization of real-time technologies will be evolutionary over time.

Utilizing Modular Design

Reclamation staff are currently developing modular water management systems that extend from the farm to the watershed, as indicated below (present cooperators are shown in parenthesis):

On-farm Module - (NRCS/Utah Climate Center)
Distribution System Module - (USU)
Reservoir/Watershed Module - (NRCS)
Early Warning System Module - (River Forecast Center)
Water Quality Module - (NRCS)

These components of modular systems allow water-user groups to mix and match, depending on their needs.

Involving Water Users Closely with Installation

Where possible, water-user groups, water conservancy districts, and others who sponsor a project are encouraged to become closely involved with the planning and installation of equipment. This has taken place successfully on two recently completed projects: (1) Low-end Adaptive Canal Automation (USU's effort with Delta Canal and Melville Irrigation Companies) and (2) Emery County Water Measurement and Control.

SPECIFIC PROJECTS

Reclamation and USU have been involved in a variety of projects throughout the State of Utah, including the development and installation of real-time systems for irrigation companies, rural culinary water suppliers, and wildlife refuges. With all of these projects, low cost and easy maintenance have been a major consideration.

Delta Canal and Melville Irrigation Systems

The Delta Canal and Melville Irrigation Companies, spearheaded by USU and partially backed with Reclamation research funds, have automated a 6-mile-long section of canal in the Delta, Utah, area. A description of the project was recently published in Utah Science (Walker, 1993). Demonstration projects like the Delta and Melville System are important because they provide water user groups with a first-hand opportunity to evaluate the technology and observe the benefits.

Photograph 2 - Group of Utah water users inspecting the Delta Canal automation project.

Richfield Area Canal Automation System

During 1993, in a joint effort with Richfield Irrigation Company, PRO staff designed and installed a real-time monitoring station at the Parshall flume at the head of Richfield Canal. The station allowed the canal manager to observe changing conditions and improve system operation. After a year of monitoring canal flows, the company decided to upgrade to real-time control.

During the early spring of 1994, the telemetry equipment and datalogger/controller were moved 200 feet from the Parshall flume to the diversion structure. Subsequently, the gates on the diversion structure were motorized with solar-powered DC motors, and the datalogger/controller was reprogrammed for remote control. This new system proved to be a highly useful water conservation tool.

Photograph 3 - Richfield Diversion Structure after conversion. The system is solar powered and protected from weather and vandals. The installation includes; (A) limit switches and a gate position sensor on the gate stem; (B) a DC motor, with chain and sprocket, connected to the gate wheel; (C) equipment for control and telemetry; and (D) a solar panel and an antenna.

During 1995, the Richfield diversion structure was automated. This was accomplished by installing enhanced software at the field site. Now, instead of moving the gates by remote control, the canal manager merely has to set a canal flow target and the gates automatically move to maintain the required flow. In addition to automating the gate, two flow monitoring sites were added along the canal; (1) one at the midway point, and (2) a second near the end. These two sites are assisting the manager to better deliver water throughout the system.

Because of the success of the Richfield Irrigation Company real-time project, other companies in the Richfield area are installing similar equipment. For example, the Sevier-Piute Canal, because of its 65-mile length, has historically been complicated to operate. Directing water to the end of the canal is a challenging task. It is also difficult to maintain a steady flow at the head of the canal because of fluctuations in Sevier River flow.

To correct these problems, two initial actions were taken. First, five low-cost flow monitoring sites were installed along the canal. These real-time stations allowed the water manager to survey system-wide conditions from his home. He could then compare how the system was working with how it should be working, and take corrective action as necessary.

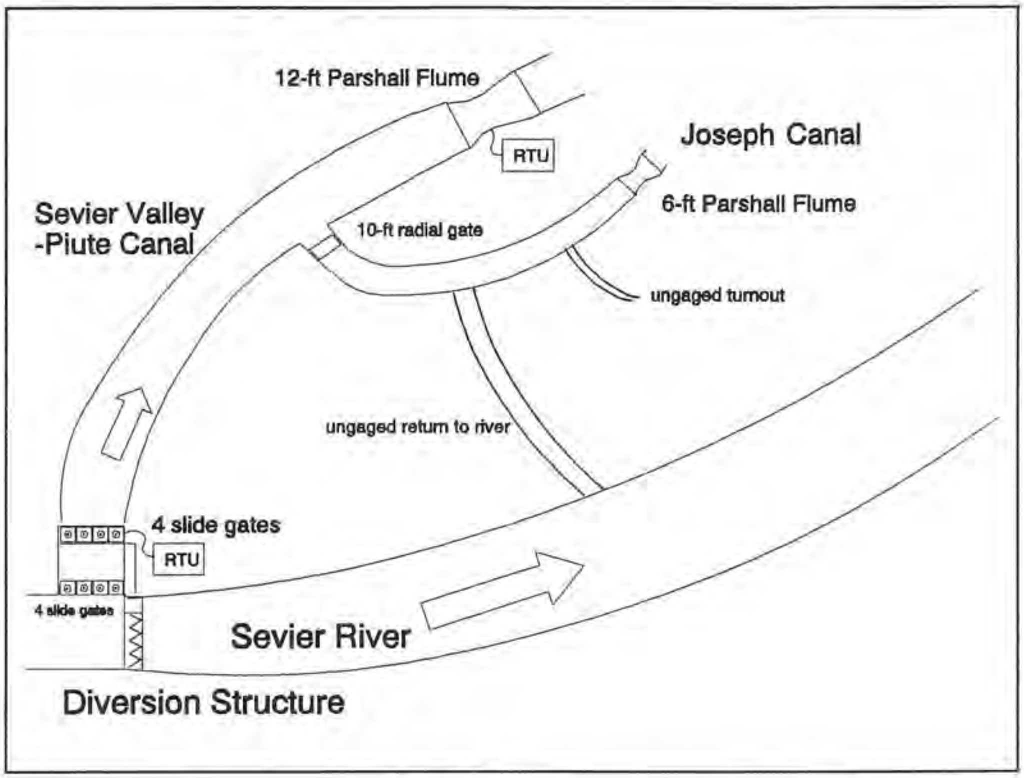


Figure 2 - Schematic diagram of Sevier-Piute Canal diversion from the Sevier River, Utah.

Second, at the diversion structure, the gates were motorized using fractional-horsepower, 12-volt solar-powered motors. Figure 2 shows the layout of the canal system at the diversion structure. The movement of these gates is controlled by a low-cost RTU (see Photograph 2). The gate operator model for this retrofit is described by Ehler (1995). The gate position targets are directed by the water manager through the telemetry system. By 1996, the manager will be able to set flow targets so that the gates will adjust automatically to maintain the required flow.

A simple algorithm is planned to communicate with an RTU located about 1 mile down the canal at a Parshall flume. The RTU at the headworks will estimate the gate movement required to effect the flow change needed at the flume. After a time delay, the same cycle will be repeated to fine-tune the desired flow within a specified deadband. Plans are also underway to remotely control the releases from Piute Dam to optimize the timing of deliveries to the Sevier Valley-Piute Canal.

Photograph 3 - Sevier Valley-Piute Diversion after the retrofitting of solar-powered automation equipment.

Strawberry High Line Canal System

The High Line System demonstrates that real-time technologies can be integrated into older facilities.

The Strawberry High Line Canal was one of Reclamation's first water projects; it was completed during the 1920's. To enhance operation along a 17-mile-long canal system, real-time monitoring and control equipment has been added to existing structures. At the head of the canal, a ramp flume and flow monitoring equipment were installed. This installation provides water managers with a continuous record of flow into the canal.

A second monitoring point was added on a storage pond, located adjacent to the canal. This pond is used by the Payson City secondary irrigation system (which provides untreated, pressurized water for outdoor urban use). By monitoring water elevation, the small storage pond is better utilized to the advantage of both the canal company and city.

Midway along the canal, an automated pneumatically operated gate was inserted into an existing stoplog structure (Wahl, 1995). With this gate in place, either upstream or downstream control can be implemented. For the present, the gate is maintaining a constant upstream elevation, thereby providing more reliable flows into adjacent laterals.

A diversion into a major lateral, near the end of the canal, was also automated. Releases from the canal can not be made by remote control, thus allowing for more timely adjustments (see Photographs 3 and 4).

The High Line monitoring and control system has enhanced water management along the canal and proved to be a cost-effective conservation tool. The canal company plans to expand the system incrementally over the next few years.

Emery Water Measurement and Control

> *The Emery System demonstrates that real-time systems have applications over the full range of water resource management needs.*

The Emery Water Conservancy District (Emery district) has set up a real-time system that utilizes every module so far developed by the PRO and WRRL in Denver. All modules use the same basic technology.

Canal Monitoring and Control: A complete real-time water monitoring system has been installed on the distribution system for Cottonwood Creek-Huntington Canal, Huntington North Reservoir, and Huntington North Service Canal. The Huntington North Reservoir and Service Canal were recently automated, and the remainder of the system will be automated in the near future (see Photograph 5). With the real-time control equipment installed, Emery district staff can change reservoir releases and canal flows from their office and eliminate the need to make frequent trips to the field sites. Selective automation has made their distribution system more responsive to changing conditions and has proven to be a cost-effective water management tool.

Photograph 3 - Strawberry Highline Canal lateral just after its construction (circa 1920).

Photograph 4 - Lateral 30, Strawberry High Line Canal, after installation of gate actuators and canal automation equipment (1995).

Photograph 5 - Upgrading the real-time system from monitoring to remote control, on Huntington North Reservoir. Emery district staff can now change reservoir releases from their office or mobile unit.

Early Warning System: An early warning system was installed on Joes Valley Dam and Reservoir which monitors reservoir elevation and weather conditions at two locations in the watershed. Should an unusual weather event occur, the National Weather Service is immediately notified. With the early warning system in place, the dam meets Federal and State hydrologic safety of dam requirements.

Real-time data available from the early warning system presents other opportunities. By computerizing the reservoir operation curves and incorporating forecasts from the River Forecast Center in Salt Lake City, software will be developed to assist the water manager with reservoir releases.

<u>Water Quality/Quantity</u>: Emery district has installed a complete flow monitoring system in San Rafael watershed. Monitoring points above diversions and below return flow junctions with the watercourse are continuously monitored. A low-cost salinity sensor has been added to this system, so that the district has a comprehensive real-time water quality monitoring system in place. This system has excellent water management potential, particularly as it relates to Reclamation and NRCS salinity investigations. The system has further potential for monitoring other water system pollutants, such as insecticides, herbicides, and fertilizers.

It is important that water users get feedback on the impact of their management measures. The Emery district's system has the potential to provide feedback, but the methods are not developed at this time. This is an important aspect that we intend to develop during upcoming years.

Comprehensive On-farm Irrigation Scheduling: Emery district has expressed an interest in being an information resource to improve water management at all levels. Currently, seven real-time weather stations are operating in the district's service area. These could be integrated into a comprehensive irrigation scheduling program, with the district serving as coordinator. Such a system, coupled with on-farm improvements, could have a major impact on reducing pollution loads.

Ogden River Project System

The Ogden River System demonstrates that real-time technologies are useful on urban water projects.

The Ogden River Water Users Association (WUA) distributes water with two existing canal systems: South Ogden/Highline Canal and Ogden/Brigham Canal. The former, which includes 6 storage and regulating ponds, had an existing obsolete supervisory control system. During 1995, Reclamation staff worked with the water users to upgrade to a modern low-cost real-time system.

The Ogden/Brigham Canal, which includes 14 regulating ponds, has no gate actuators. These will need to be added to the existing gates. It is planned that this canal system will eventually be integrated into the real-time system being developed for the South Ogden/Highline Canal.

The Ogden River WUA delivers water to a rapidly urbanizing area. The principal use of the water is for dual water systems which serve outdoor urban (lawn and garden) needs.

Bear River Migratory Bird Refuge System

The Bear River System demonstrates that real-time technologies are useful on wildlife projects.

The Bear River Migratory Bird Refuge is a 74,000 acre wetland complex located adjacent to the Great Salt Lake near Brigham City. The facility is Federally owned and operated by the Fish and Wildlife Service (FWS). This facility experiences average annual water diversions of approximately 280,000 acre-feet, with associated annual depletions to the river system of approximately 84,000 acre-feet. Even with these large diversions, a high percentage of the marsh goes dry each summer due to inadequate water supply and there is a problem with inadequate refreshing of the water in the marshes to prevent outbreaks of botulism in the waterfowl population.

Over the past 2 years, a real-time monitoring and control system was installed at the refuge. Thirty-four flow measurement and pond elevation sites, 14 in-marsh water quality monitoring facilities, and two weather stations were installed as a part of this activity. Remote-control water diversion capability will be provided at four critical locations. The control gates at the refuge are being equipped with commercially available actuators. Due to the relatively remote nature of the facilities, all monitoring and most control equipment is 12-VDC solar-powered.

This real-time system is being used to better circulate water through the shallow refuge ponds, to improve poor water quality conditions which can lead to entrenched botulism that accounts for annual decimation of the waterfowl population. Because of the substantial size of the refuge and the continual political pressure to reduce staff, the real-time system is being designed to automatically handle water allocation between ponds, or allow remote changes from the Refuge office, particularly during the late season when water is scarce (see Photograph 6).

Photograph 6 - Real-time monitoring and control unit on the Bear River Migratory Bird Refuge.

ONGOING APPLIED RESEARCH

Pneumatic Gates

A canal check structure on the Strawberry Highline Canal near Payson, Utah was recently rehabilitated by PRO and the WRRL using a solar-powered inflatable gate. An upstream water level controller based on a PID (proportional-integral-derivative) algorithm was developed for the site, to automatically maintain a constant water level upstream of the check structure. Canal operators can now remotely control and monitor the operation of the gate using a computer and a telephone/radio link to the site. The rehabilitated check structure was operated during the summer of 1994 and 1995 with a minimum of manual intervention. The pneumatic technology, when integrated into a real-time control system, has great potential for more efficient canal operation (see Photograph 7).

Photograph 7 - A Fort Collins, Colorado, company manufactures a gate that is raised and lowered by an air bladder.

Canal Model

A unique indoor canal model has been recently added to the laboratory facilities at the WRRL in Denver. The canal model is used to test control equipment and develop canal algorithms. Water measurement methods are also tested and demonstrated in canal model. A variety of computer equipment, flow measurement equipment, and control equipment on the canal model are used to demonstrate, develop, and test control methods. The 260 ft. long clear-acrylic walled model canal is divided into five reaches with an electric-powered control gate in each reach. The canal model is also designed for use in training courses on canal automation techniques. The model is used to demonstrate various control basics, different approaches to canal control, and various control equipment and software.

Video Images

During the current fiscal year (1994), PRO and the Denver TSC have been developing a real-time video monitoring system. A video monitoring system uses a camera to replace several sensors, and has several potential advantages over a standard real-time system, including (1) enhancing warning systems, (2) minimizing vandalism, and (3) reducing costs.

CONCLUSION

PRO, WRRL, and USU have been instrumental in implementing real-time water conservation measures in existing projects throughout the state of Utah. This technology transfer effort has resulted in cost-effective water management and control on projects in Delta, Richfield, Emery district, Southern Utah County, Ogden River, and Bear River. Through the demonstration projects, water managers of small- to medium-scaled water projects are recognizing that real-time technologies can meet their needs for environmental enhancement, automated irrigation releases, and improved rural culinary supplies. These technologies are very cost effective when compared to structural improvements and have application for improving water management globally.

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