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Low Cost Adaptable Canal Automation for Small Canals*

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Abstract

Low cost canal automation was investigated to determine if such technology could be adapted to existent canal systems to conserve water and improve flexibility in responding to demands. Operational and seepage losses in the test canal over the previous 5 years averaged more than 10% of diversions. In 1993, local officials reported losses had been reduced to less than 5% and attributed the reductions to the automation. The value of water "saved" on the local rental market was twice the total cost of the automation. In July and August 1994, measured savings nearly equalled the cost of the automation system again. Based on these findings, it is concluded that: (1) low cost canal automation can result in substantial water conservation; (2) remote manual control followed by full automatic control can result in significant increases in the frequency and reliability with which canal systems respond to irrigator demands, yielding more flexible and timely service; (3) there are substantial and measurable benefits to both the irrigation company (or district) and their field personnel from reduced travel expense and better, more accurate flow regulation.

Key Words : Canal, irrigation, automation, supervisory control, low cost canal automation.

Résumé

L'automatisation à faible coût des canaux a été étudiée pour déterminer si son adaptation à des systèmes de canaux existants peut résulter en une meilleure conservation de l'eau et une amélioration de la flexibilité de la réponse à la demande. Durant les cinq années précédant 1993, les pertes par infiltration et par opération dans le canal d'essai ont été en moyenne supérieure à 10%. En 1993, les dirigeants locaux ont rapporté que les pertes avaient été réduites à moins de 5% et attribuaient ces réductions à l'automatisation. Sur le marché économique local, la valeur de l'eau "épargnée" équivalait deux fois le coût total de l'automatisation. En juillet et août 1994, les économies mesurées avoisinaient encore le coût du système d'automatisation. A partir de ces résultats, il a été conclu que : (1) l'automatisation à faible coût des canaux peut permettre la conservation significative d'eau; (2) le remplacement d'un contrôle manuel à distance par un contrôle totalement automatique peut permettre des augmentations significatives de la fréquence et de fiabilité avec laquelle le canal répond à la demande des irrigateurs, fournissant le service plus à propos et plus flexible; (3) elle comporte de plus des avantages importants et quantifiables non seulement pour la compagnie (la région) irrigatrice, mais aussi pour son personnel de terrain, grâce à une réduction des frais de déplacement et une meilleure régulation du débit.

Mots clés : Canal, irrigation, automatisation, surveillance, automatisation à faible coût des canaux.

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* **Automatisation à faible coût des petits canaux**

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Introduction

The performance of existing irrigation systems can usually be achieved with better and more responsive management and control. This in turn requires improvements in auxiliary functions such as flow measurement and scheduling. Performance can be characterized by both efficiency (water conservation), and effectiveness (the system's ability to respond faster and more reliably to irrigator demand). To improve system performance, both efficiency and effectiveness must be optimized. This can best be achieved through improved water management (the strategy for water control, distribution, allocation and scheduling) and improved water control (the regulation of water levels and flows).

The conditions which affect water movement in a canal change unpredictably in time and space. The capacity and response of some canals where moss or aquatic weeds are a problem may decline significantly in a period of only weeks. Seepage losses vary from reach to reach and as the water level fluctuates. Similarly, the demand for water is also unpredictable because of weather variability. Historically, these problems have been ignored until they become critical. Many canals simply operate "full", fields are irrigated the same way each time, and deliveries are scheduled whether they are needed or not. Consequently, it is not uncommon for a 30 to 40% loss of water to occur from the stream diversion to the field outlet due to seepage, spills, unregulated turnouts and poor measurement (Walker and Stringam, 1994). Without a much more rigorous approach to management and control, these losses cannot be reduced.

For many years engineers, agronomists, and economists examining the production associated with water at the farm level have argued for more flexible and demand-based delivery schedules (Replogle and Merriam, 1980). How this might be accomplished without complete redesign of an existing system has been difficult to answer, and perhaps canal automation has become the most feasible alternative (Merkley and Walker, 1991). Canal automation can be implemented in several different ways, but if it is to improve control and management, it should include two primary capabilities: (1) real-time information about water levels and flows; and (2) remote manual or automatic gate regulation.

This investigation examined the use of canal automation technologies to conserve water within one distribution system typical of small and medium sized irrigation projects. These systems dominate irrigation in the Western United States but have not historically benefitted from the application of canal automation. Irrigation companies and districts are in increasing competition for water from municipalities, industry, and environmental concerns and must make substantially better use of water. Under these circumstances, canal automation offers new opportunities and solutions which these projects will need.

Project Concept

The premise of this investigation was that water management and control in an irrigation delivery system can be more efficient and effective if the implementation of regulation decisions are adaptive and automated. The concept of "adaptive" canal automation is important in two ways. Most small and medium irrigation schemes cannot afford to replace existing facilities with devices engineered for automation. Thus, canal automation's first requirement is that it be adaptable to existing canal structures. It is also infeasible to apply automation to every structure and device in an irrigation system. Thus, canal automation must be adaptable to operational practices already in use.

At first glance, few systems would appear to exhibit any capability toward adaptive control. However, many field personnel develop considerable skill in reacting to the dynamic changes in an irrigation project. Because of this capability, there is a hesitance on the part of the field personnel and the water users to use a canal automation system which is fully automatic. The individuals involved are comfortable with system as it exists and hesitate or resist surrendering the system to automatic computer control.

Despite the efficient distribution of water which can be proven for an automatic control system, the controller cannot be programmed to anticipate every possible problem that may arise in the operation of the system. As an automation system performs its programmed tasks, the break downs in the control system and in the canal itself are hard to anticipate and for the most part do not happen often enough to justify generating program code that could deal with the obscure problems. For this reason, a member of the canal operation personal, should always be present if an automatic control system is in operation.

Considering the skill of the canal operators and the fact that a fully automatic canal control system cannot be completely trusted, a reasonable evolutionary step in automating a canal system is to design it to operate in remote manual or supervisory control. Several benefits can be realized when this intermediate step is taken. First the skill of the canal personnel can be utilized to its fullest. As the operation personnel become familiar with the control system, they can enhance their skills and are better able to meet the demands of the water users. They will also gain confidence in the control system and its capabilities and be more trusting of the system if full automatic control is implemented in the future.

Experimental Design

The work plan for this investigation involved four tasks: (1) instrumentation; (2) software development; (3) field implementation, evaluation and demonstration; and (4) technology transfer. There were two purposes of an instrumentation phase. Initial installations will be infeasible if equipment costs are not minimized. Sensors and RTUs (Remote terminal units) are expensive pieces of equipment and may account for more than 50% of the automation costs. Thus, the first purpose of an instrumentation phase was to determine if less expensive controller equipment would work satisfactorily as an RTU and if locally fabricated sensors would prove reliable and accurate.

In addition to the important need for field testing of any new concept, the field implementation phase of this project was aimed at two important problems that are in the minds of the irrigators: (1) can canal automation cost-effectively improve a canal company's (or an irrigation district's) ability to supply water on-demand; and (2) will automaton reduce conveyance losses. These two questions are related and the selection of an area to implement and test canal automation in Utah was based on a local interest to address both questions simultaneously.

During the last 10 years or so, the stockholders of the Delta Canal Company and the Melville Irrigation Company of Delta, Utah have demanded a more "on-demand" operation, i.e., the willingness to wait very long for water has diminished substantially. But one thing is obvious, as the operators have tried to be more responsive, the losses have increased significantly. Of course one might argue that the "losses" were mostly administrative. To the users, however the losses are real since they cannot be sure they received the water. The 11% losses in 1991 occurred in a relatively dry year. The 7,000 acre-feet (8.6 million m^3) of loss from the main supply canal to the companies, "Canal A" was worth about $210,000 in the local rental market, or in terms of water at the field level, about one irrigation on the lands served.

The development of the microcomputer software to connect the management function of a central office to the control locations along a canal system was a major focus of this project. The principal software objective was to develop an integrated supervisory control and a RTU software package that would allow a canal manager to make the same judgements from the office that he or she would make from the field, but with substantially more precision and on a more periodic basis. A critical function of the software was to indicate how the canal and its structures were changing, and what effects these changes were having on the operation of the canal.

Canal automation which is adaptive and low cost must be operated, maintained, replaced, and updated by the water users themselves. Pressing concerns over water supplies for non-agricultural uses suggest that canal automation be adopted and applied to many systems in Utah and throughout the West. It is very important therefore, that canal automation technology be "transferred" to local interests. Federal and state resources are inadequate to provide extensive technical support to the number of irrigation companies and districts that should eventually implement canal automation.

Description of Field Site

Figure 1 is the monitoring map from the base station software and illustrates the location and setting of the field site near Delta, Utah. The Delta Canal Company and the Melville Irrigation Company divert water from DMAD Reservoir into a common canal named "Canal A". Canal A is an earthen conveyance of 6 miles (9 km) long which follows the southern bank of the Sevier River.

Software

Two software packages were developed for the Canal A automation system. The first was an extensive program for the base station PC computer. This software provided an interface for the water master to perform several functions. First, he could monitor water levels and flow at both ends of Canal A and determine if gate changes were necessary. Second, he could remotely control the gates at DMAD Reservoir and at the divide to either regulate their position or their discharge. And third, he could examine conditions over any pervious monthly or daily period either graphically or digitally (he could also print data if desired). The base station software also conducted regular polls for the system as part of its routine monitoring function.

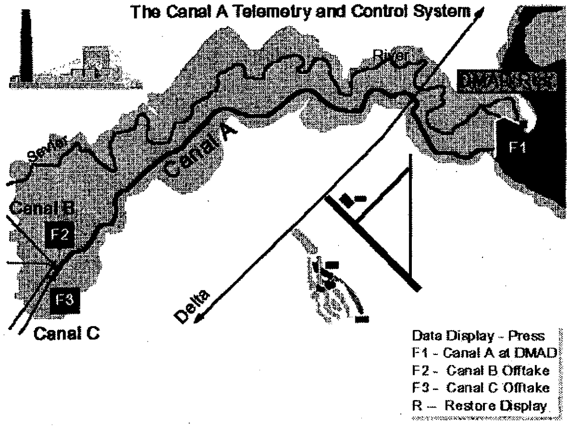

Figure 1. Location and setting of the field site

The second software program was the instruction set for the RTUs which was necessary to coordinate sensor inputs and initiate gate controls. The RTU software included routines that checked sensor data for errors and included such errors in its base station transmission. The software included logic to control gates in the system under two modes of operation, remote manual gate position control and automatic flow control.

Sensors

Despite a well-designed control system or expensive components, system parts will eventually fail and require replacement. The components used in this project were common devices that could be easily obtained in a short period of time (Stringam 1992). When this project was first considered, a major deterrent was the cost of the water level and gate position sensors. The initial estimate for the sensors alone was over $15,000. After considering several alternative sensors, a potentiometer-based sensor was designed and used to measure both water levels and gate positions. The total cost for these sensors was approximately $6600.

These initial sensors were designed with a return spring and they worked favourably for gate position measurement. Unfortunately, these sensors did not give precise readings for water level due to a hysterisis problem. The water level sensors were modified for a weighted float and pulley design which made a simple and accurate water level sensor.

As indicated in Figure 1, three sites were instrumented for this study. Gate position sensors were installed at the canal inlet at DMAD reservoir as well as Canal B and Canal C inlets. A submersible pressure transducer was also required at DMAD reservoir to measure the water elevation. The canal company already had flumes in place just downstream from the canal inlets (A long throated flume at the Canal inlet, a Parshall flume at the Canal B inlet and a ramp flume at the Canal C inlet). These flumes were located between 100 to 300 meters from the inlet gates. Float and pulley water level sensors were installed at these flumes. In addition float and pulley water level sensors were installed on the upstream and downstream sides of the Canal B and C gates.

The DMAD control site was powered with a 45 watt solar panel while Canals B and C were powered with AC to DC converters. All sites were designed with battery back ups for the preservation of data.

Gate Mechanization

The responsibilities for designing, building and maintaining the gates, gate motors and power supplies were assigned to the canal companies prior to the initiation of the project. This has encouraged significant involvement by the companies and freed USU to concentrate on software and RTU. The gate mechanization was accomplished with exceptional skill and except for minor wiring or chaining problems, the gates functioned satisfactorily.

Canal A Losses

The irrigation companies report that 1993 losses were about 3,300 acre-feet (4 mm^3). The losses from 1985 through 1992 averaged nearly, 6,300 acre-feet (7.8 mm3). Both the water master and the DMAD Secretary have stated that the Canal A monitoring capacity provided by the project was substantially responsible for the lower losses. The value of this water on the 1993 local rental market was $90,000. No attempt is made to evaluate these figures using the monitoring data from 1993. Setting up the system and correction equipment problems left large gaps in the electronic record, but as a rule the flume and weir measurements agree closely with the companies' data.

Figure 2 shows how the cumulative loss plots over the two month period. During the first three weeks of July, the loss increases at the rate of 20 acre-feet (25,000 m^3) per day. If this rate had been sustained for the two full months, the total loss would have been 6.2% or a full 3.2% below the last 8 year average. From about day 203 to day 220, Canal A shows a gain rather than a loss. From day 225 to 243, the loss again amounts to about 20 acre-feet per day.

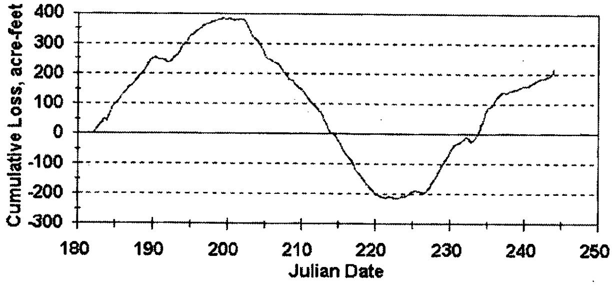

Figure 2. Cumulative losses in Canal A during July-August

The reasons for the loss and gain in Canal A are not obvious from the data. The sensor calibrations were checked weekly with no noticeable problems. When this result was mentioned to a retired Sevier River commissioner, he indicated that during the 1968-1983 periods, it was not unusual to experience net gains rather than net losses in Canal A. There is perhaps three other explanations. First, the water level in Canal A dropped substantially during the period of the gains and it is possible that water did flow from surrounding areas into the canal. The water table is often above the bottom of the canal bottom. Secondly, there has been some discussion locally about the transition submergence of the Canal B Parshall flume. There appears to be some evidence that a value of 70% is more realistic that the published 75%. If this turns out to be true, then it is possible that some of the gains periodically computed in Canal A may be due to under-estimation of flows in Canal B. Third and equally likely is the observation that the losses are well within the accuracy of the flumes and weirs. Differential mossing or other growths on one structure of could shift the measurements enough to produce similar results.

Although one might argue the absolute magnitude of the water savings associated with the automation of Canal A, it is difficult to discount the conclusion that the automation produced savings. Even if the savings were as little as 3% per year, the economic value of the project would still exceed the cost of the automation by twice each year.

General Conclusions

The estimates of water conservation presented above along with the reports from the water master about travel savings and increased response are significant incentives for the other canal companies to consider canal automation. This is in fact happening in Utah. There are however, several other observations the authors have made during the three years of this study that need to be mentioned.

The first observation is that equipment maintenance and calibration are problems the irrigation companies or districts will have to master if canal automation is to achieve its full potential. Some would perhaps argue that it is possible to buy perfectly reliable sensors, RTUs, etc., but this is probably unrealistic. At DMAD reservoir, more than 1500 measurements on water level were made in July 1994. Of these, less than 4% were inaccurate as judged by the authors. More than 80% of these errors were associated with the depth sensor on the reservoir itself. This sensor is a $750 submersible pressure transducer. Only 20 % of the errors found were associated with either the $300 USU-built water level sensors at the Canal A flume or the RTU/telemetry system. Any canal automation project must anticipate problems with sensors and design a maintenance/ replacement routine accordingly.

The second observation is that most irrigation projects in Utah and perhaps elsewhere have flow measurement structures downstream of their regulating structures. In other words, measurement (management) is divorced from control. Implementation of automatic controls faces a serious constraint - the need to develop accurate calibrations of the control structures. An alternative would be to tie gate control into the water measurement readings. This option can be accomplished with little difficulty.

A third observation is that in the absence of automation, a water master makes substantial effort to maintain stability in order to minimize the time required for adjustments. Further, an experienced water master knows that transients can magnify and build until the system is nearly out of control. With automation, this no longer is as important because the water master can make as many adjustments as necessary from the convenience of a truck or office. There is a strong likelihood that the automation will simplify and streamline the stations where it is implemented and indirectly complicate downstream stations that are not automated. Full automatic control would eliminate this problem entirely and needs to be encouraged.

Finally, a fourth observation is that some redundancy, duplication, and overlap of sensors can be a significant aid to the canal manager. Where a flow measurement is downstream of flow control, systematic comparisons of gate flows and measured flows can reveal gates plugging with debris, flume submergence and related problems that require maintenance.

Conclusions

Canal automation can reduce losses from conveyance and distribution of irrigation water through canal networks. In this study, the seasonal losses for 1993 and 1994 were reduced by more than 50%. The precise and frequent monitoring of water levels and gate positions substantially improves water measurement and thus reduces the water that cannot be accounted for and allocated. The ability to monitor the entire system accurately from a central local aids the canal operator in making more reliable and timely gate or flow adjustments. When the canal operator becomes comfortable with the automation, water levels in the canals in the canals can be reduced to lower seepage and thereby eliminate unregulated spills.

Canal automation can improve the flexibility and responsiveness of canal systems. The capability of an operator to make gate and flow changes almost instantly from an office or mobile base station allows the system to respond substantially faster than traditional manual control practices. Canal automation is likely to be the only feasible means for some irrigation projects to implement on demand scheduling.

It is likely that widespread acceptance of canal automation will occur rapidly. The importance of accurate flow measurement, lower operations levels, and more timely and reliable system response to irrigator demands are already understood by canal managers and farmers. The automation, however, must be adaptive and low-cost at least initially. The principal requirement for meeting both conditions is that automation is adaptable to existing regulation and outlet structures where possible. It must also be useable within existing management practices and be easy to adjust, diagnose, and repair.

Personnel within the irrigation community are quite capable of mechanizing existing gate structures. They will need technical assistance with the design and installation of sensors, canal-side and base station processing, and control equipment. These people are also quite capable of diagnosing and correcting problems with the electronic components like sensors, radios, modems, computers, etc. Since technical assistance for irrigation companies and districts is limited, redundancy in many cases will be cost-effective, not only to safeguard the canal operation but also to diagnose and correct problems like flow structure submergence and gate plunging.

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