# CANAL MODERNIZATION IN CENTRAL CALIFORNIA IRRIGATION DISTRICT – CASE STUDY

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## ABSTRACT

Central California Irrigation District (CCID) provides water from the Mendota Dam northward approximately 110 miles, through and to its service area of approximately 120,000 irrigated acres. CCID enjoys a substantial advantage of having some of the most senior water rights in California, but is simultaneously challenged by serious (and increasing) water quality restrictions for its return flows into the San Joaquin River.

Recent California law recognizes water transfer as a reasonable and beneficial use of water. Therefore, CCID has begun an aggressive program to modernize its canal system with the goal of improving water delivery service and increasing project irrigation efficiency. Funds received from conserved and transferred water are used to expand the modernization program. The net effect is improved water supply to other users and improved water management for the downslope drainage system.

This paper will address the district's motivation for modernization, the development of the modernization plan, challenges encountered, the roles of various players (consulting engineer, district, integrator, contractors, ITRC), and technical details regarding project implementation. Currently, approximately 40% of the initial modernization plan has been implemented, including downstream control, upstream control, and a large regulating reservoir – all automated with Programmable Logic Controllers (PLCs).

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## INTRODUCTION

### Location

The CCID service area encompasses approximately 140,000 acres (120,000 irrigated acres) in the central San Joaquin Valley, with the district headquarters in Los Banos. An overview of CCID's location in California is shown in Figure 1. CCID is part of the San Joaquin River Exchange Contractors Water Authority (Exchange Contractors), which holds pre-1914 water rights for water from the San Joaquin River.


Figure 1. Location of CCID in Central California.

The Delta Mendota Canal (DMC) was constructed in the 1940's to provide an additional water supply to the Exchange Contractors' Service Area. In turn, the new canal allowed for the construction of the Friant Unit of the Central Valley Project. Sacramento River water was diverted through the DMC to the Mendota Pool, which continues to serve as the primary diversion point for the Exchange Contractors. The DMC flows southward to the Mendota Pool, which is the location of the original water right point of diversion from the San Joaquin River.

The Mendota Pool serves as the headworks of the two primary canals (the Main Canal and the Outside Canal), which then flow northward.

Figure 2 illustrates the general layout of the CCID canals. The details of the lateral canals are not important for this paper, but one can see that there is a clustering of lateral canals in the southeastern area, and another in the northern area, and numerous consumer operated and maintained ditches serviced by head gates on the two major canals. The Main Canal is about 80 miles long, with a capacity of 1600 CFS; the Outside Canal is about 73 miles long with a capacity of 500 CFS.

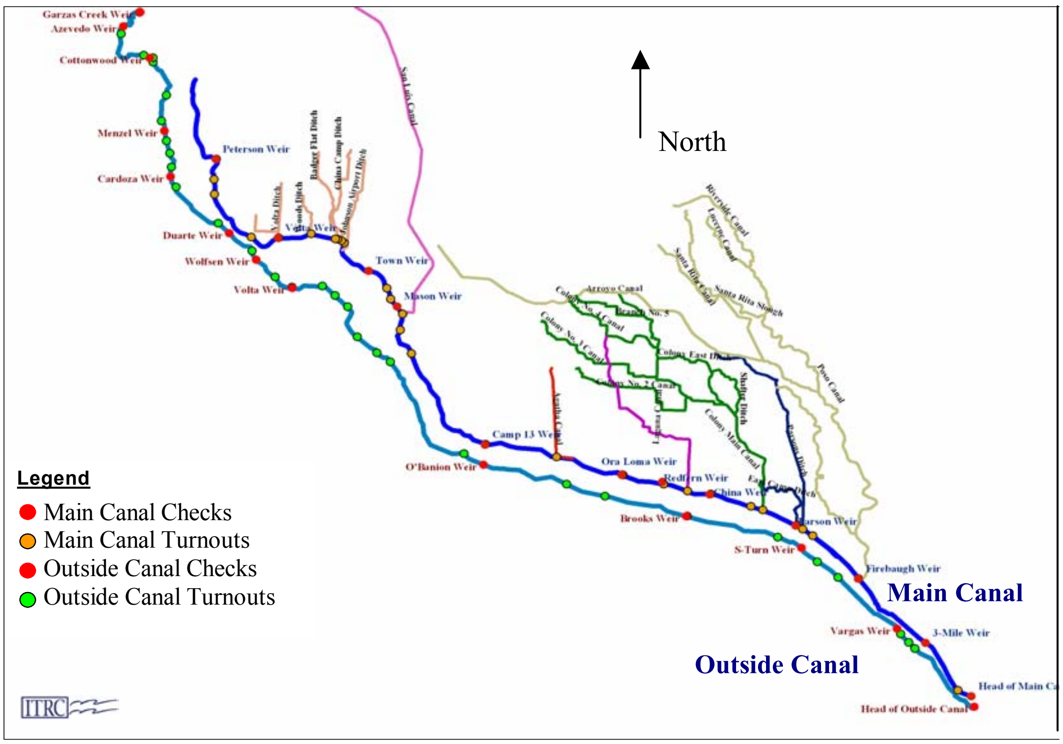

Figure 2. CCID canal layout.

The two primary canals are fairly flat, winding, unlined canals that have remained in about the same condition for the past 100 years. There are also several direct connections from the DMC to the Outside Canal on the western boundary of the service area, which serve as bypasses to provide additional capacity and operational flexibility. Surface drainage outflows from CCID flow northeast into neighboring irrigation districts and into the grasslands and the San Joaquin River.

The schematic layout of the CCID Main Canal and Outside Canal system with storage facilities and bypasses (interconnections) is shown in Figure 3 below. The Ingomar Reservoir is new; it was installed during this modernization program.

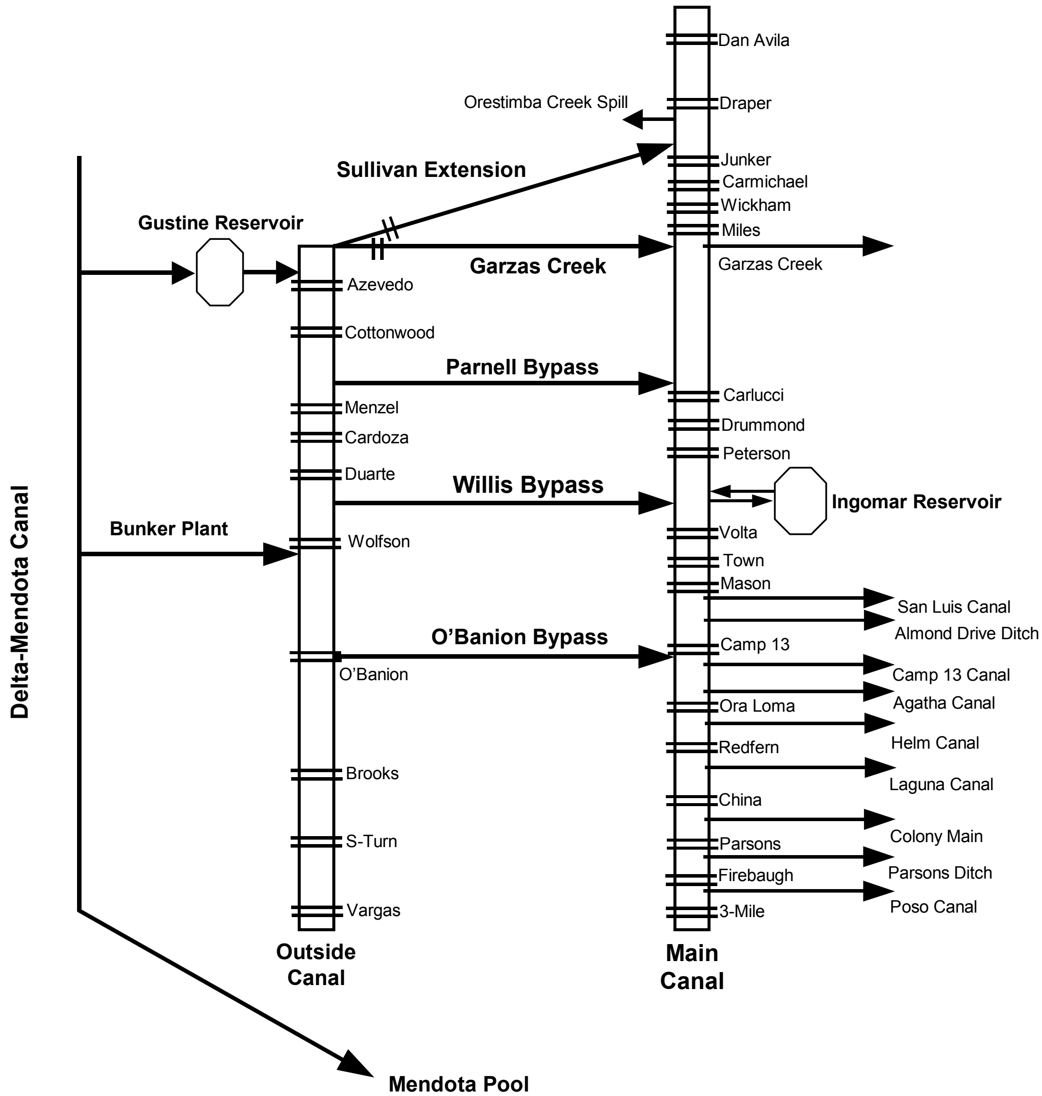


Figure 3. Layout of the CCID Main Canal, Outside Canal and Bypasses.

## Modernization Process

In 1992, the CCID Management and Board of Directors decided to improve canal operations. The first step was to examine ways to reduce the operational spill and quantify the water savings. This work was performed by Stoddard & Associates in 1992. This study recommended that new structures be constructed on the Lower Main Canal and the gates be automated on "downstream control". A new regulatory reservoir was recommended to be built between the Upper Main and the Lower Main. Changing the control strategy to "downstream control" was based on the demand responsiveness characteristics, the canal geometry, and the desire to locate storage within the system rather than at the terminus of the canal. Prior to that time, the canals were operated with upstream control, using manual flashboards in check structures. The "Lower Main Canal" begins at the Peterson Check and extends northward to the Dan Avila Check (refer to Figure 3).

New water control structures were built and fitted with dual radial gates. Initially the gates were operated on upstream control and a SCADA system to remotely monitor the operations of the Lower Main Canal was installed. This was an important first step, as the CCID staff gained practical experience, and recommendations were provided regarding SCADA components such as sensors, radios, remote monitoring, gate actuators, etc. The plan was to get the Lower Main canal automated on upstream control to gain experience with the new technology as the District proceeded with construction of the reservoir and refine the modernization plan including modeling by the ITRC to develop control algorithms and predict the performance of the Lower Main Canal operation under downstream control before placing the canal operation in this mode.

During this time, CCID also co-sponsored water balance studies (conducted by ITRC) for itself and neighboring districts. These studies gave CCID a good idea of what types and amounts of conservable water were available.

The District expanded the modernization project to include the remainder of their major canal system. The overall control strategy for the two canals and the interties between the canals needed to be developed as well as what type of hardware and software would be best, and what quality of water level control was needed. Staff also had a sense that the original SCADA system and existing controls needed some modification based on the experience gained in operating the Lower Main Canal. There were several motivating factors for expanding the canal modernization including:

1. Stabilizing water levels in the canal would stabilize water delivery flow rates which would improve water use efficiency.

2. The understanding that farm runoff was having a noticeable impact upon water quality and quantities. With better canal control, it was anticipated that CCID would be able to stabilize water levels to stabilize water delivery flow rates to reduce farm runoff.

3. A sense was beginning to develop in California that, regardless of each district's individual water rights, the over-riding water rights rule lies in the Public Trust Doctrine. One interpretation of the Public Trust Doctrine states that it is the responsibility of the irrigation districts to ensure efficient and reasonable use of their water – regardless of what their present water right is. Down the road, water rights might be reduced for districts that are not proactive in making efficient use of water.

4. The canal system operation depended heavily upon the personal experience of a few individuals with many years of experience. Upon their eventual retirement, it is important to have better operational tools in place for those who will replace them.

5. Many of the existing water control structures were in need of replacement and CCID desired "state of the art" facilities and control.

In 2003 ITRC worked together with Stoddard & Associates and CCID to develop the strategic modernization plan for the Main Canal and Outside Canal and to identify the potential for water savings (conservation) associated with the implementation of the project. The final modernization plan was intended to provide:

1. An inventory of current water operations and management,
2. A strategic plan for how water would be controlled throughout the main canal network,
3. Modernization needs at each control point including equipment, operational strategy, communications, SCADA, etc.,
4. Preliminary estimates of annual water savings with the modernization plan fully implemented, and
5. Approximate preliminary costs for hardware and software at each site.

The emphasis of the modernization recommendations for CCID was five-fold:

1. Providing upgraded water delivery service to users, and
2. Simplifying water operations for CCID staff, and
3. Conserving water.
4. Replacing the aged water control structures with new structures.
5. Reestablish the capacity of the Outside Canal lost to regional land subsidence over the years.

The strategic plan envisioned how the complete network of the primary canal system would work together. It provided a means for quickly adjusting to new flow demands anywhere in the system, and automatically moving excess and deficit flows to manageable locations.

The key physical and routing ingredients, presented in Figure 4, include:

1. Automated upstream control, with new check structures on both the upper Main Canal and the Outside Canal.
2. A new regulating reservoir (Ingomar Reservoir) to absorb variations in demand.
3. Improved interties between the Outside Canal and the Main Canal.

4. New linkages to the DMC for quick response in the downstream reaches of the CCID canal system.
5. Downstream control on the Lower Main Canal, downstream of Ingomar Reservoir.
6. New flow control structures at various heads of canals and interties.
7. A comprehensive SCADA system that will monitor numerous variables at all automated structures, and enable an operator at the office to make target flow or water level changes remotely and also monitor canal operations at remote locations.

To accomplish the modeling of the Lower Main Canal, Stoddard & Associates provided detailed surveying of the canal profile and cross sections to ITRC for modeling purposes, which was to be operated under automatic downstream control using ITRC's control algorithm.

Together, ITRC and Stoddard & Associates, in conjunction with WAVE Engineers and CCID staff, developed specifications for the integrator work. CCID decided to utilize the integrator who had furnished and installed the initial SCADA system.

Similar work has been completed on the Upper Main Canal and is underway on the Outside Canal. New control structures have been designed and constructed on the Upper Main utilizing a new type of control gate based on ITRC recommendations and an evaluation of gate options performed by Stoddard & Associates. Separate sets of plans and specifications were prepared for construction of the electrical systems and for system control.

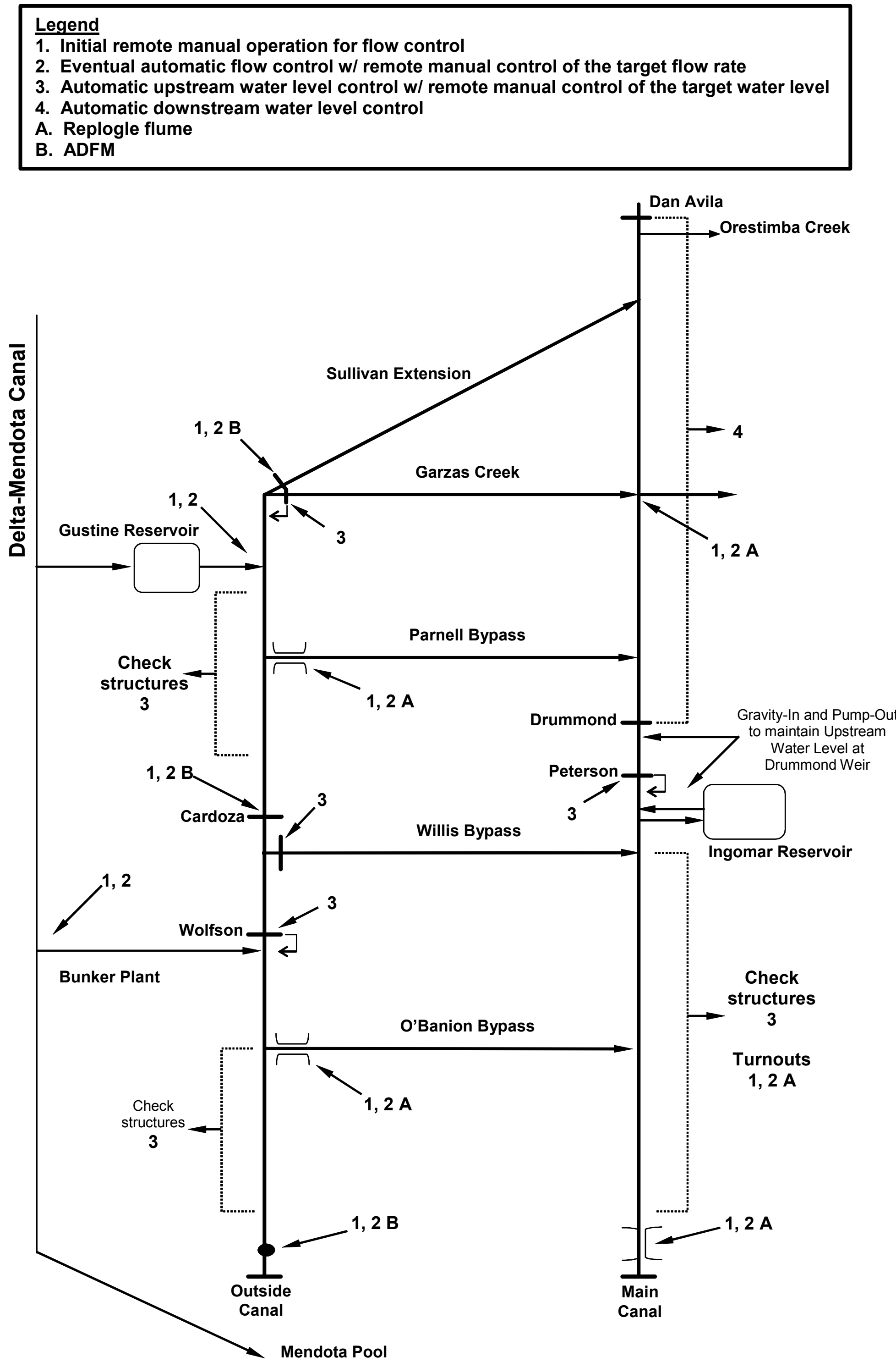


Figure 4. Strategy for future control throughout CCID's primary canal network.

Construction of the new structures required installation of canal bypasses around the structure sites with capacities up to 1000 cfs. At many sites right-of-way was restricted. The project was competitively bid, and bids substantially exceeded the engineer's estimates due to the project risk perceived by the contractors. The contractor procurement method and the construction contracts were revised. The new proposals received were near or below estimates. Canal profile and cross section data has been gathered to support the canal modeling to develop the control algorithms.

Pre-design level planning proceeded on the Outside Canal. The canal has been subsiding as a result of regional land subsidence due to groundwater overdraft to the point that demand on the canal cannot be met when water delivery is solely from Mendota Pool. A new canal profile has been established to better utilize the available energy (head) in the system. As with the Upper Main Canal, the programming of the PLCs will be performed by the ITRC utilizing the profile and cross section data.

## STATUS OF THE PROJECT IN AUGUST 2005

As of August 2005, the following items have been completed:

1. The Ingomar Reservoir has been constructed with inflow automatically controlled with gravity inlet gates and outflow automatically controlled by pumps (with 1 VFD pump and 2 single speed pumps). The inlet/outlet controls maintain a target water level at the downstream end of the next pool, at the head of the Drummond Check. The purpose of controlling the water level at this point is that Drummond Check is the first in a series of downstream-controlled check structures. Water must be available on a very flexible basis at that point. The Peterson Check, which controls the water level in the canal adjacent to the reservoir, operates on automatic upstream control. The reservoir captures operational spill from the Upper Main Canal and water that would otherwise be lost in the Lower Main Canal. The water is then stored and available to meet future demands on the Lower Main.

2. The SCADA system, including the base station with Wonderware HMI, is operating excellently.

3. The downstream control in the Lower Main Canal (8 check structures) is excellent.

4. New Langemann gates have been installed in new check structures on the Upper Main Canal – replacing the old flashboard structures. The Upper Main Canal has been modeled for automatic upstream control, and the programming for the PLCs has been 90% completed by ITRC.

5. The Outside Canal structures are in the design stage and an evaluation is underway to determine the most cost effective way to reconstruct the canal

banks to allow all demand to be satisfied by water taken from the Mendota Pool if required to do so.

## MOVING FROM PLANNING TO THE PRESENT STATUS

Successful SCADA and modernization projects are processes that require dedication, persistence and acceptance of new challenges by all the parties involved. It is rare that everything works flawlessly at the beginning – and this project is no exception. The process of completion had a variety of challenges. Some are listed below:

1. The optimum site for the Ingomar Reservoir was immediately upstream of the Drummond Check as this would make the control relatively simple. Because that site was deemed to be a wetland by the US Army Corps of Engineers, another site was chosen further upstream, which made the automatic control of the water level upstream of Drummond considerably more challenging. The Peterson Check could not be operated on downstream control because of the characteristics of the pool between the Peterson Check and the Drummond Check.

2. Unsatisfactory shallow groundwater levels appeared adjacent to the reservoir which required installation of an interceptor tile drain.

3. The biggest challenge occurred with the original integrator. The tasks of installing the PLCs, designing and debugging the HMI, solving radio communications problems, programming the ITRC control algorithm, etc., should have taken about 4 months. Instead, the task took about 18 months. Some of the specific difficulties that occurred were:

    a. The integrator had a team of persons working on the project, but those individual team members appeared to shift with time, creating a lack of cohesive effort.
    b. The integrator thought the job would be much the same as similar jobs they had previously performed. It appeared that as the integrator budget ran low, there was increased reluctance to address problems as they arose.
    c. ITRC had originally assumed that the integrator would take an expanded description of the control algorithms and program them into ladder logic, as was ITRC's experience with other integrators. ITRC would then review the integrator's ladder code and provide appropriate feedback. In the end, in order to get the job completed, ITRC ended up deeply involved in the ladder programming. As a result of that experience, ITRC now prefers to provide all or about

90% of the completed PLC programming to the integrator, with more carefully defined lines between responsibilities.

d. The coordination between people programming the PLCs and those programming the office HMI was not as good as it should have been.

For the Upper Main Canal work currently underway, CCID has selected another integrator.

4. After implementation, operations personnel still were unclear on a few points of how the system was supposed to operate and what they could and could not do within the capabilities of the new system. For example, the system was designed to operate automatically under downstream control, which means that a check structure midway down the canal cannot be taken out of automation and operated manually. This was not a major challenge – it just points to the need for checking progress after implementation when the system is actually being operated.

5. Early in the automation implementation, the downstream control began to function poorly – waves developed that propagated upstream to Drummond Check. There was a natural tendency of CCID operators to want to adjust algorithm tuning constants in an attempt to resolve the problem, even though the modeling indicated that the control was not the source of the problem. It was discovered that the primary downstream water level sensor on one of the check structures was reading water levels in a stilling well with a partially plugged access hole, significantly dampening the response in the stilling well. Once the control was shifted to the redundant sensor (in a redundant location – not the same stilling well), the problem was immediately corrected.

   This, plus similar ITRC experiences in other critical automation projects, confirms the importance of having robust redundancy in terms of the sensors (two different types), sensor locations, A/D boards, and PLC power supplies. All of these components have failed at some time or another on ITRC projects – even with very good equipment. Redundancy allows operators to quickly spot a problem, and then allows the automated control to proceed immediately while the poor sensor is repaired/replaced.

Despite these inevitable challenges, it is important to note that CCID has moved forward a tremendous distance in a relatively short amount of time, and the project components completed thus far are functioning as originally planned.

## SUMMARY

The CCID experience with canal modernization demonstrates the following points:

1. A district modernization program that utilizes a team of district personnel, a consulting engineering firm, an integrator, and a firm specializing in canal modernization/automation can provide an excellent product.

2. Successful modernization is a process that requires significant effort beyond planning and theoretical analysis. Furthermore, the process will always have hurdles. The challenges are to learn from the hurdles, to expect to encounter new ones, and to persevere until a quality product is obtained.

3. Close cooperation is required between all parties.

4. Once a new SCADA/automation system is "up and running", problems will still appear. The team must have sufficient financial and technical capacities, as well as resolve, to solve those problems as they appear.

5. Until the system works as planned, the operators will rightfully look at the new process with a high degree of skepticism. They must live with the system on a minute-to-minute basis, and they are the ones who receive complaints. In addition, an automated system removes some of the control from their hands that they took years to develop and refine. Putting reliance on an unproven, automatic system is asking a lot from the operators. It is imperative that these operators be asked frequently if there are any problems or questions. They must also be involved in the early discussions of system configuration.

6. It was pointed out in the initial feasibility which recommended automation of the Lower Main Canal that operation and maintenance costs would increase because the nature of the work to maintain an automated water control system is vastly different compared to a manually operated system. One should expect that it may take more than one irrigation season to "work out the bugs" and gain operating experience such that district personnel gain confidence in and are comfortable with the new system. This learning curve must not be overlooked and the operators, upon which much of the success of the project rests, should be engaged the process early to provide adequate transition time and some sense of "ownership".