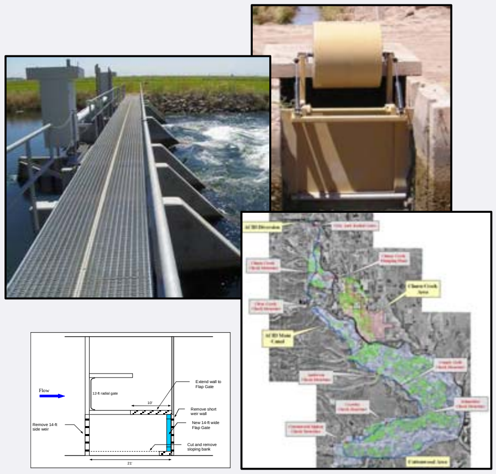

RAPID APPRAISAL PROCESS

Glenn-Colusa Irrigation District

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Introduction

The Irrigation Training and Research Center (ITRC) of California Polytechnic State University, San Luis Obispo conducted a site visit to the Glenn-Colusa Irrigation District (GCID) in October 2006 to perform a Rapid Appraisal Process (RAP) evaluation on behalf of the California Department of Water Resources (DWR). This project was supported by a CALFED Water Use Efficiency Grant. ITRC was asked to identify potential modernization opportunities for water conservation and improved water management. This report describes a district-level strategy for efficient and reliable water use with conceptual engineering recommendations and suggested priorities.

The Rapid Appraisal at GCID focused on both immediate needs, including specific suggestions for SCADA options, as well as more long-term solutions to help address district-level water management. The report is organized into the following main topics:

- SCADA and Main Canal Automation
- ITRC Flap Gates for Improving Water Level Control in Lateral Canals and at Spills
- Suggestions for Long-Crested Weir Designs for Lateral Canals
- Automated Water Level Control in the Lower Main Canal using ITRC Flap Gates
- Integrating the Tehama-Colusa Canal Interties for More Flexible and Efficient Canal Operations

Water management practices within the district have a major influence on the regional water balance and water quality. System improvements will contribute positively to regional objectives.

Background

GCID is one of the largest diverters from the Sacramento River, serving approximately 160,000 acres of which about 100,000 acres are rice. The service area and main control structures of GCID are shown in **Figure 1**.

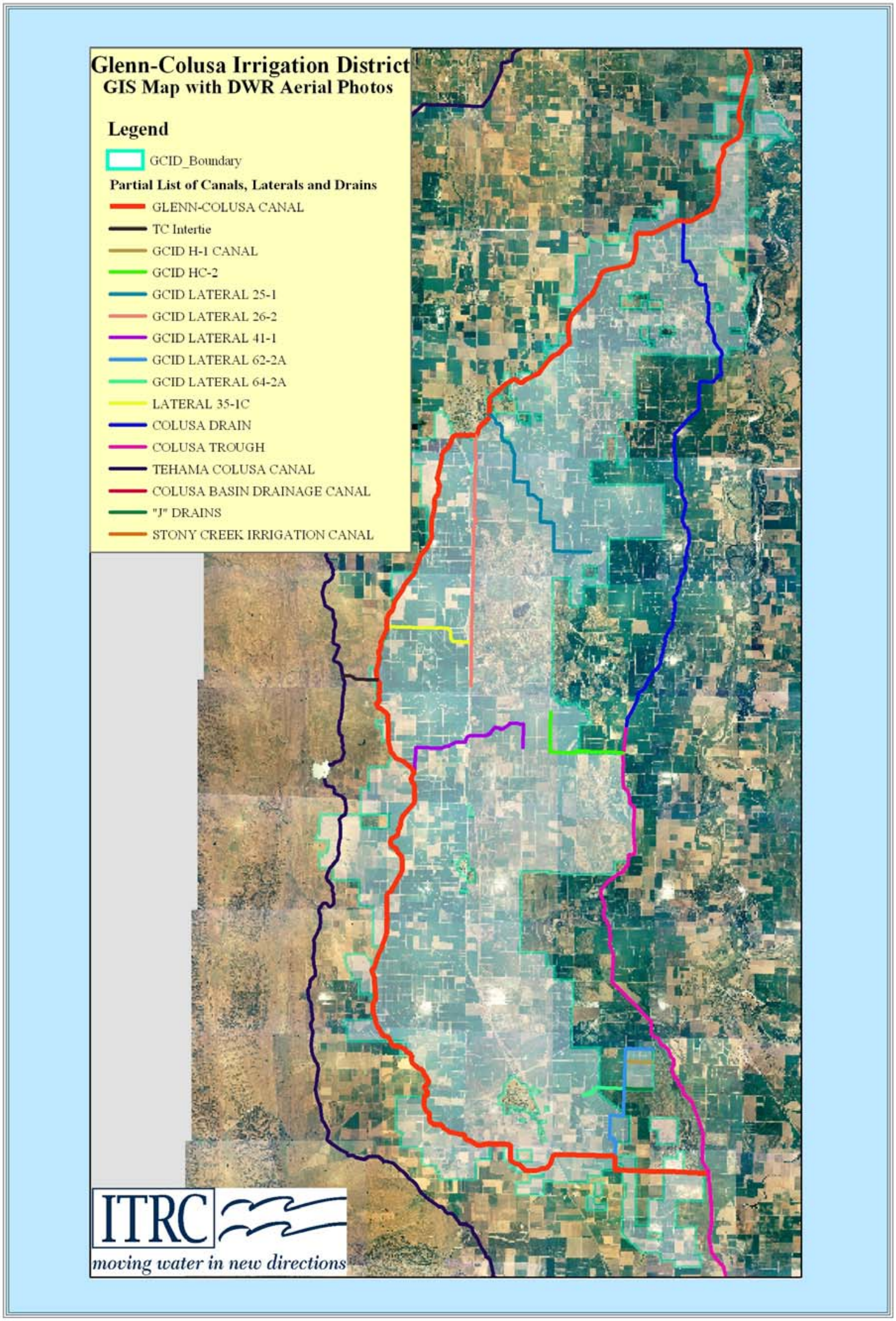


Figure 1. Glenn-Colusa Irrigation District GIS map of main system

Overview of the Main Technical Issues

The following are the key technical points from this Rapid Appraisal of GCID:

<u>Automation</u>
Automation has been a central element of capital improvements done by various irrigation districts in the western U.S. Recent advances in control algorithms and model simulation techniques have resulted in successful, real-life examples of PLC-based automation on large irrigation canals. Canal automation involves advanced electronics and high-speed communications; but just as important, it means transforming minute-to-minute management of how people do their jobs. GCID has laid the groundwork for automating the Main Canal and followed the right approach by starting with remote monitoring so that personnel could learn about the technology and experience some practical benefits of real-time centralized information. We envision in the future that the management structure of the district may evolve further towards *centralized dispatching and centralized changing of target elevations and target flow rates* from the headquarters base station, which will affect how flow changes are made to/from the Main Canal, along with more efficient use of recirculation pumps.

<u>SCADA</u>
SCADA (Supervisory Control and Data Acquisition) systems, if properly designed and implemented, can be excellent management and operational tools for irrigation districts. At present GCID has a SCADA system that lets operators remotely monitor canal flows and pumps at key locations in the system. The existing system covers approximately 40 sites (22 on the Main Canal) but has some technical limitations that need to be addressed in order to expand the number of sites (possibly to over 200 sites) and add automation to the Main Canal. We expect that that district will eventually want to have mobile laptop computers in the water operators' vehicles so they can access real-time information about operations within their area. This is a good time to develop a plan for SCADA expansion and organize the detailed specifications for future hardware/software requirements.

<u>Planning Future Strategies</u>
A comprehensive plan for future strategies entails building a *vision* for how the district will meet prospective challenges, assuming that growers will need increasingly <u>more flexibility</u> while the rules governing river diversions and return flows will become <u>more restrictive</u>. For example, the trend towards more drip/micro irrigation, among many other factors, is driving irrigation districts throughout California to continually evolve towards operations that resemble a controlled industrial process. ITRC has not had the time or the data to develop an excellent modernization plan for the complete GCID system. However, we are comfortable in stating that the following things are common elements of successful future strategies for wide-ranging goals like reducing canal spill, improving water quality, recirculating more drain water, etc.:

- Strategic use of the Maxwell Intertie from the Tehama-Colusa Canal to provide flexibility for the Main Canal (with higher flows and more frequent adjustments than what is done now). This will require changes in the management/operation of the Tehama-Colusa Canal.
- Remote manual control of lateral headings with remote monitoring of spills
- Extensive use of SCADA, including mobile units for canal operators to use in the field
- Coordinated use of recirculation pumps in real-time conjunction with surface water
- Regulating reservoirs at a few key points in the lateral system to buffer discrepancies

Lateral Canals

The next phase of system infrastructure improvements to be undertaken, once the Main Canal is automated, generally involves upgrading water control in the lateral canals and more drain water reuse. The criteria for prioritizing which check structures to upgrade involve (note: these criteria can be conveniently mapped onto a GIS layout of the system according to the conditions noted in parentheses):

a. Turnout head available immediately upstream of the check structure (low)
b. Turnout capacity and area served (large)
c. The percentage change in canal flow rate through the check structure (high)
d. Narrow check structures (they are more sensitive than wide ones)

Review of Accomplishments since Previous ITRC Visits to GCID

ITRC visited GCID in August 1996 to perform an initial Rapid Appraisal and made another short follow-up trip in December 2000. Since starting a modernization program in the mid-1990s, the district has implemented a number of the recommendations:

1. A prototype long-crested weir has been installed in Lateral 59-1 for better water level control in a previously troublesome area. (Details are covered in the *Site Descriptions* section).
2. A Replogle flume was designed and installed to measure the flow rate being delivered to the Delvin Refuge. The site has been equipped for remote monitoring via the SCADA system.
3. The district's SCADA system has been expanded and the RTUs (Remote Terminal Units) have been upgraded with new PLCs (Programmable Logic Controllers). Much of the technical integration work has been done in-house using off-the-shelf equipment.
4. Flow monitoring sites have been designed for various locations using advanced electronic flow meters (Panametrics) and more sites will be installed shortly.

In the 1960-70s, GCID developed a Master Plan for the Main Canal system, which has been about 95% implemented. The district is now considering developing a similar master planning document for the lateral canal system. Coping with a reduced water allocation in future drought years is a major emphasis for potential system improvements. In addition, new solutions are being sought to help address regional water management issues; specifically, to reduce operational canal spill.

SCADA and Main Canal Automation

SCADA has benefited GCID by improving real-time water accounting, record keeping for historical analysis and forecasting, and response times to user inputs or alarms. Several topics related to SCADA are discussed in detail in this report to respond to questions that were raised during the visit. Extensive use of SCADA is a central element of the future modernization of the district.

The current SCADA system is characterized by the following:

- The district has built up the information management capabilities of the SCADA system. The reports printed out every day from the SCADA system consolidate an operations summary with flow rates at key points throughout the water distribution system.
- The radio network is essentially at full capacity for the hardware that is currently installed in the field.
- The existing SCADA system mainly focuses on the Main Canal check structures. There are numerous opportunities to add additional control and monitoring functions for the lateral headings, lateral spills, and recirculation pump stations.

- The existing system has been well received by both the Board and operations staff. The district is well prepared to expand into mobile SCADA units that are specifically created for use by canal operators in their pickups.
- There is no autodialer connected to the SCADA system at the district headquarters to alert personnel to alarm conditions. There is an autodialer at the main pumping plant base station.

GCID Main Canal at Willows Check

Some of the check structures on the GCID Main Canal have been equipped with various sensors and RTUs for remote monitoring through the district's SCADA system. Older telemetry equipment was upgraded with the installation of SCADAPack PLCs and submersible pressure transducers. For this report, Willows Check (**Figure 2**) was visited to examine the existing hardware and make recommendations for future automation.

Figure 2. Willows Check on the GCID Main Canal

In order to automate this check structure for automatic upstream water level control, and other ones like it in the Main Canal, there are several different issues that need to be addressed. Each of the following topics will be discussed in detail in the following sections:

1. Upgraded radio communications
2. Gate position sensors
3. Redundancy of sensors, power supplies and I/O boards
4. Automation planning and SCADA specifications

SCADA Radio System

The RTU shown in **Figure 3** at Willows Check uses a TeleSAFE Micro 16 control processor and Ritron DTX 454 radio. This RTU replaced older Modicon controllers and Motorola radios. The original Motorola RNet 450s telemetry radios are no longer manufactured and the Ritron was selected as a compatible replacement. The district has a license for 456 MHz frequency and runs the radio network at 1200 baud in simplex mode (one-way signal transfer). This means that it takes approximately 2 minutes to poll all the sites, which is not sufficient for the modern control codes and equipment that are required to automate the Main Canal.

To automate the Main Canal using modern control logic requires a PLC that can accept ITRC control code. The additional cost of upgrading to ISaGRAF-compatible firmware for the controller, or buying a new PLC if necessary, is more than offset by savings in programming time. Automation requires much faster polling rates and higher radio speeds. In addition, there are important issues of reliability and security that can be better addressed with radios made specifically for SCADA systems. When the number of SCADA sites increases in the future, the speed of radio of transmission becomes even more of an issue.

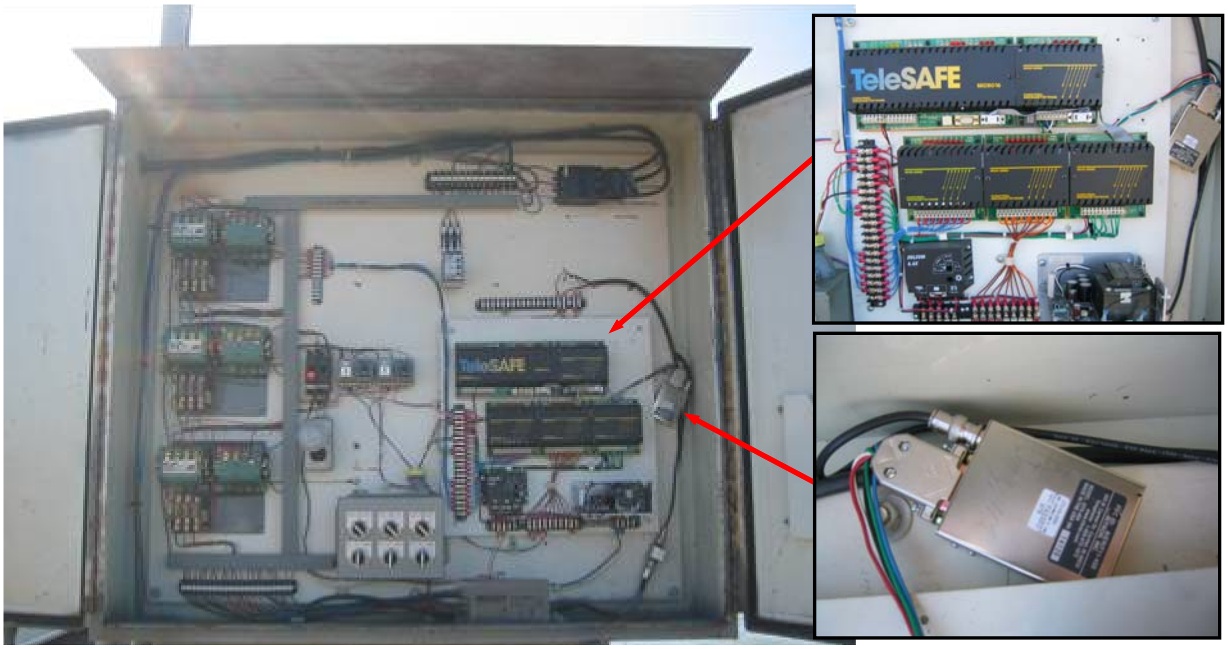


Figure 3. Willows Check Remote Terminal Unit
PLC = TeleSAFE Micro 16 control processor
Radio = Ritron DTX454

The radio network is a central element of the future SCADA expansion. The district has a license for 456 MHz and runs the radio network at 1200 baud in simplex mode (one-way signal transfer). This means that it takes approximately 2 minutes to poll all the sites.

There are two basic options to consider:

1. Upgrade the existing radios with high-speed licensed transceivers such as the MDS (Microwave Data Systems) 4710 model, or approved equivalent, and modify the existing FCC license to allow 5 watt transmission power
2. Upgrade the existing radios with spread spectrum transceivers (900 MHz) such as the TransNET model or another approved equivalent. The TransNET provides reliable long range data transmission at speeds up to 115 kbps.

ITRC briefly discussed the above options with district staff during the RAP visit, but we were not able to make specific recommendations without examining the detailed results from a radio field site survey report. To determine the final selection of radio model and whether to use a licensed or spread spectrum solution, some additional information is required. This information should be collected as part of developing detailed SCADA specifications.

Table 1 summarizes the basic advantages and trade-offs for different radio options. A major factor to consider for automation needs is transmission speed. The speed of the MDS 4710/9810 radios of 19.2 kbps is about 8 times faster than the existing system and will probably be sufficient for the Main Canal sites (in half-duplex mode). However, if one considers the large number of potential sites in the district and the desirability in the future of monitoring additional parameters like water quality, selecting an even faster radio like the MDS TransNET makes sense over the long-term.

Table 1. Advantages and Trade-Offs of SCADA Radio Options

Option	Advantages	Trade-Offs
Licensed data radio; *MDS 4710* or approved equivalent	May be possible to use existing FCC license Better ability with limited line of sight conditions	Possibly more inference Slower speed/older technology Speed = 19.2 kbps
Spread Spectrum data radio; *basic models*	No FCC license required More secure than licensed radio	Requires line of sight More radio repeaters Slower speed/older technology Speed = 19.2 kbps
Spread Spectrum high-speed data radio; *MDS TransNET* or approved equivalent	No FCC license required More secure than licensed radio Low power consumption Store and forward Speed = 115.2 kbps	Requires line of sight More radio repeaters
Spread Spectrum high-speed network radio; *MDS iNET* or *entraNET*	Long range, wireless IP/Ethernet Multiple security layers Photo/video imagery Store and forward Vehicle-mounted mobile SCADA package available No FCC license required Speed = 106-512 kbps	Requires line of sight More radio repeaters Higher per unit cost

A possible alternative to spread spectrum radios would be a licensed radio system with upgraded hardware. However, right now the allowable transmission power in the existing GCID license is less than what is typically used for SCADA radios. It is not certain what would be involved with converting the existing license to use the full 5 watts possible instead of the current 2 watts. In addition, before a final choice of licensed vs. spread spectrum is made, radio tests would have to be conducted in order to determine the actual range the spread spectrum radios can achieve in the conditions throughout the service area and how many repeater stations would then be needed.

A further consideration is using the SCADA radio system for mobile communication among vehicle-mounted, hardened laptops/tablet PCs. The concept of real-time access to information about the flows at lateral headings and canal spills is part of an overall future strategy to improve the control of water in the distribution system. Modern SCADA radios come equipped with Ethernet ports that can connect directly to mobile computers just like they would connect to an RTU in the field. However, this doesn't necessarily mean that access has to be through district-owned Ethernet SCADA radios. In fact, in some areas of California high-speed Internet access for mobile computers is available from private companies for a monthly subscription fee (via radio modems).

The final configuration of the radio system will depend on several factors which have not been analyzed in detail as part of this report. To start the process, the district should inquire about the rules governing their existing FCC license to see if it can be updated for 5 watt transmission power. The choice between a licensed or unlicensed radio can be made as part of preparing the SCADA specifications for the district. Radio tests should be done with the actual equipment that is anticipated to be used in the deployment. Based on a preliminary assessment of the terrain and size of the district, 3, or 4 repeater stations situated throughout the district may provide sufficient coverage for spread spectrum radios. Mobile SCADA access for canal operators would probably double the number of repeaters needed, if the concept of Ethernet radios was used.

Recommendations:

1. Determine how a mobile SCADA system for canal operators is going to be integrated as part of the long-term Master Plan. How many canal operators? Coverage areas? Etc.
2. Follow up on the rules of the existing license for modifying transmission power.
3. Add up the number of future sites that will be added in the medium-term and long-term plan.
4. Conduct radio tests.
5. Formulate a radio specification and network configuration as part of the development of SCADA specifications for future expansion.

Gate Position Sensors

There are no gate position sensors installed at the Willows Check, or other check structures in the Main Canal, that could be used for canal automation. For either remote manual operation (an operator moves the gate to a different position from the office) or automated operation (gate automatically maintains a target upstream water elevation), gate position sensors would have to be installed on every gate. Each gate would move independently and thus need its own position measurement. For redundancy, two sensors are required at every gate (discussed in the next section). Ideally, the two gate position sensors would each be a different kind, and probably from different manufacturers.

ITRC has worked with irrigation districts that have had good experience with two particular models:

i. Hohner Model 0310-4007-0210 with 4-20 mA output (sample model number): referred to as a multi-turn series 03 analog encoder. The model number explains the sensor's characteristics as follows:
    a. 03 refers to series 03
    b. 10 is the Hohner shaft diameter (mm)
    c. 40 is a generic number for Hohner encoders
    d. 07 (or 05) refers to the electrical connection. 07= 4 pins
    e. 0210 refers to the sensor's resolution or in this case the ability to give a full 4-20 mA output in 4 turns. A 0309 model gives the same output but over 8 turns. The number of turns can be customized depending on the shaft diameter and gate movement characteristics. The sensor should be ordered to provide the highest possible resolution over the gate's full range of motion.

ii. Celesco Model PT9420 cable-extension position transducer with 4-20 MA output. Another model with a smaller measurement range is the PT8420. These sensors are industrial NEMA 4× rated for measuring up to 0-60 inches (PT8420) or 0-550 inches (PT9420) of movement. The sensor model should be selected that has the smallest measurement range for the full range of gate movement. This will be determined in part by how the sensor is mounted to the gate or shaft (discussed below).

It is necessary to determine how the sensors will be mounted before they are ordered because of the different options available. For the Hohners, the usual practice is to attach the sensor to the shaft with a flexible coupling or gear head assembly. Hohner manufactures flexible couplings for their encoders that would require a small extension welded to the gate shaft. However, it appears that there is a small amount of clearance (**Figure 4**) available for mounting an encoder to the shaft.

Figure 4. Short clearance at the end of the gate shaft for mounting an encoder to measure gate position (Willows Check)

For mounting the Celesco sensors there are 2 basic options: a) attach the cable around the shaft, or b) attach the cable to the gate arm. If the sensor is attached to the shaft and the gate hoists use a cable assembly to attach to the gate itself, it is possible that if the gate cable breaks the sensor would still indicate the gate was moving when in fact it wasn't. It is also possible to mount the Celesco so that it is attached to the gate arm as indicated in **Figure 5**.

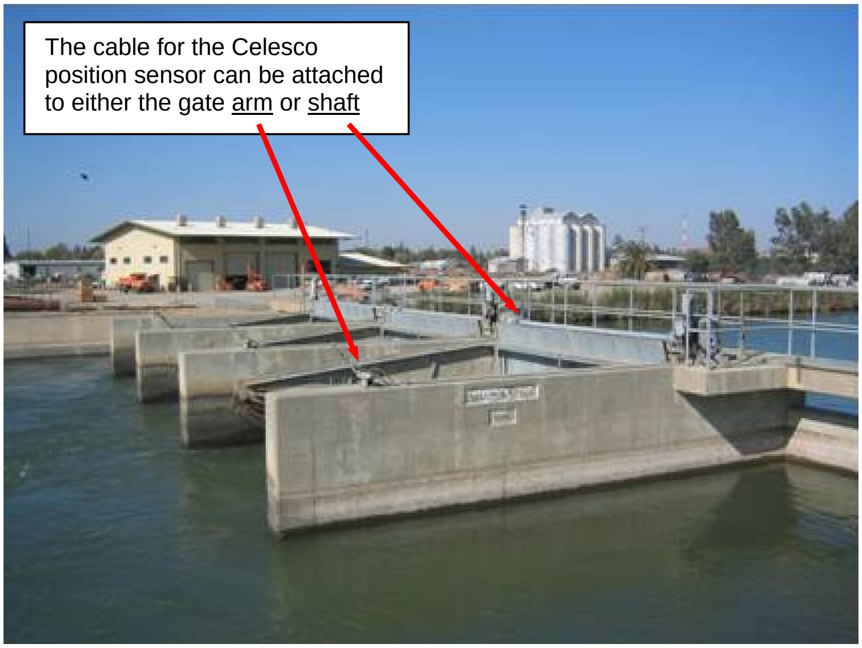


Figure 5. Radial gates at the Willows Check

However, there is a relatively short distance between most of the gate arm and the top of the adjacent concrete wall. It is very important that the sensor is mounted so that the relationship between gate movement and cable movement is always in the same orientation. That is, the sensor must always be above the attachment point on the gate.

If the sensor is mounted to the gate arm, a bracket will have to be built in order to position the sensor several feet above the top of the concrete wall, high enough that the sensor will always be above the gate arm when the gate is fully open.

Another option which has not been examined in detail for this report is to use an inclinometer to measure the angle of the gate opening. The 4-20 mA output from the inclinometer could be converted to gate arc length and height (opening) in the PLC. The Celesco IT9000 series of inclinometer can measure angles from 0-45° to 0-270°.

Recommendations:

1. Investigate the possible mounting options for a shaft encoder, spring-loaded transducer, and/or inclinometer on each of the gates. Two different devices are required for each gate.
2. As part of preparing the SCADA specifications the existing RTUs, terminal blocks, power supplies, etc. have to be checked to see if any modifications are required in order to accommodate the gate position sensors.
3. Install two (2) gate position sensors, primary and redundant, on each gate in the Main Canal that will be controlled through PLC-based automation or remotely.

Redundancy for All SCADA Systems

ITRC always recommends that when a SCADA system is used for controlling canal check structures, pump stations, spill gates, etc., redundancy is incorporated into the system for particular key items. When ITRC is responsible for implementing the control code, we insist on it. This includes the sensors that provide data to the PLC (water level, gate position, etc.) and also the power supplies and A/D converters. We know for a fact that it isn't a question of "if" something will break, but only "when." We have also found that putting in software-based techniques to check for bad sensors adds extreme complexity to the control code that isn't very robust and isn't necessary if redundant sensors are used.

Therefore, for the existing sensors (e.g., pressure transducers for water level) and the new sensors (e.g., gate position), a full examination should be done to determine what additional RTU components are required in order to have sufficient redundancy. Keep in mind that a sensor system includes the sensor itself, the cable, the power supply, the A/D converter, and the stilling well itself in some cases.

For automatic control, the code will be based on the value of one sensor (designated the "primary" sensor) rather than on the average of the two sensors. The selection of which is the "primary" sensor is made by the operator via the HMI and is not automatically assigned by the PLC. After all, the PLC would not know which one is giving a correct reading.

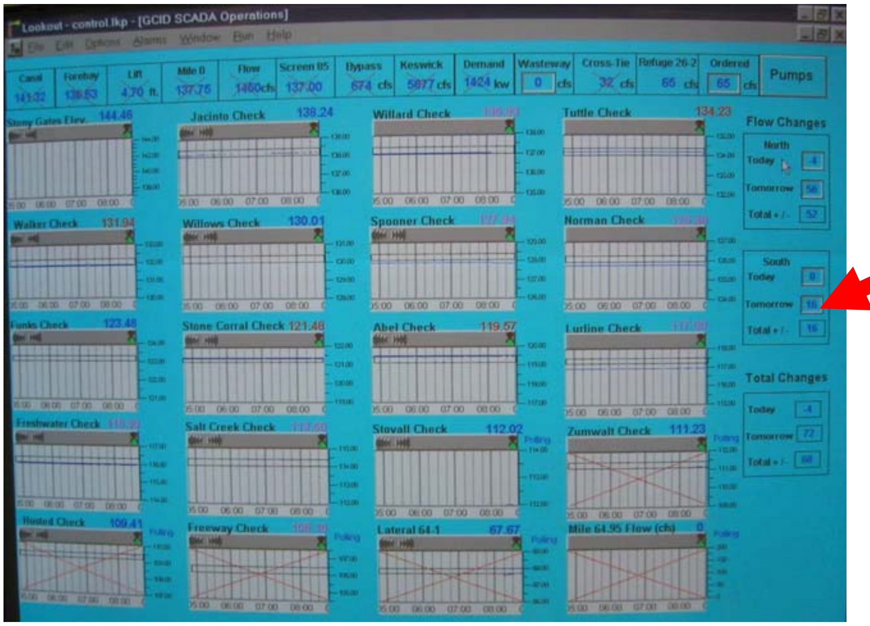
Recommendations:

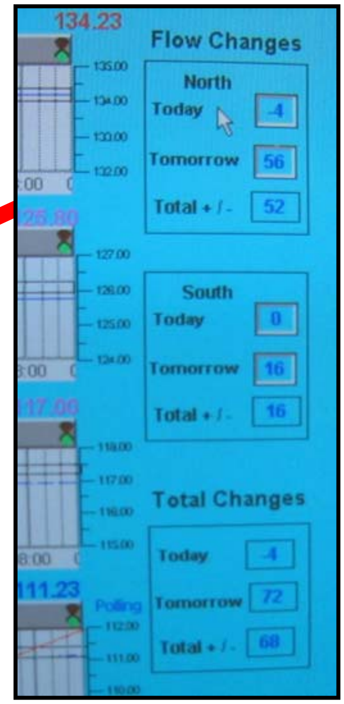
1. Make a list of the RTU equipment installed at each site including sensors, PLCs, power supplies, A/D converters, etc.
2. Determine if the existing PLCs, power supplies, etc. can accommodate redundant sensors.
3. As part of the SCADA specifications, a complete list of all the additional hardware items will be compiled for each site. The number and type of items required for acceptable redundancy will likely vary depending on the specific site conditions and existing configurations.

Automation Planning and SCADA Specifications

It was noted during the visit that there are slightly different configurations of equipment installed at the various sites. Furthermore, the district is in the process of installing new flow meters, such as the Panametrics units to measure refuge deliveries. SCADA technology for irrigation systems has evolved rapidly in the last few years and manufacturers have released new products that are considerably better and cheaper compared to what the district had available when it started its system.

At present there are approximately 40 remote monitoring sites in the district. **Figure 6** shows the main SCADA HMI screen. So far the district has achieved important objectives with its SCADA system in regard to improving service to water users and improving safety conditions for workers. Most of the ideas for how to integrate the various parts of the SCADA system have been developed internally. The district has benefited from having an experienced and technically competent staff who can work on electronics and troubleshoot problems.





The Main HMI Screen displays real-time water levels at the Main Canal check structures, main pump station, and flow rate measurement points.

Supervisors also incorporate information from the *Daily Operations Summary* to display aggregated totals for today and tomorrow's changes in water orders.

Figure 6. Main HMI screen highlighting the daily summary of ± flow changes

In the future, we can envision that the number of SCADA sites could easily be over 100-200 (or 3-5× what the district has now). Furthermore, many will be control sites, which have many more sensors, adjustable constants, etc. than does a typical remote monitoring site. For all these reasons, it seems now is a good opportunity to prepare a comprehensive Automation Plan for GCID. This master plan would address items in enough detail so that any new sites use the best off-the-shelf equipment and are still compatible with the existing system. The single largest issue to resolve is probably upgrading the radio system, followed by new HMI software. Determining what the best option is requires more detailed planning information, which would be part of developing the SCADA specifications.

The development of an automation plan and the preparation of SCADA specifications involve a series of steps as described below. The process is illustrated in **Figure 7**.

1. Meetings and field visits to each of the existing sites to prepare a complete inventory of hardware and functions
2. Meetings and field visits to proposed sites to determine hardware and software requirements, along with any construction or structural modifications involved
3. Presentation to district staff and board members of the automation and monitoring plan
4. Simulation modeling and developing of the control code
5. Radio testing and a thorough evaluation of the communication options
6. SCADA & Engineering Specifications
7. Presentation of the SCADA & Engineering Specifications
8. Requests for Proposals (RFP)
9. Construction
10. Field verification per specifications
11. Continued support and training

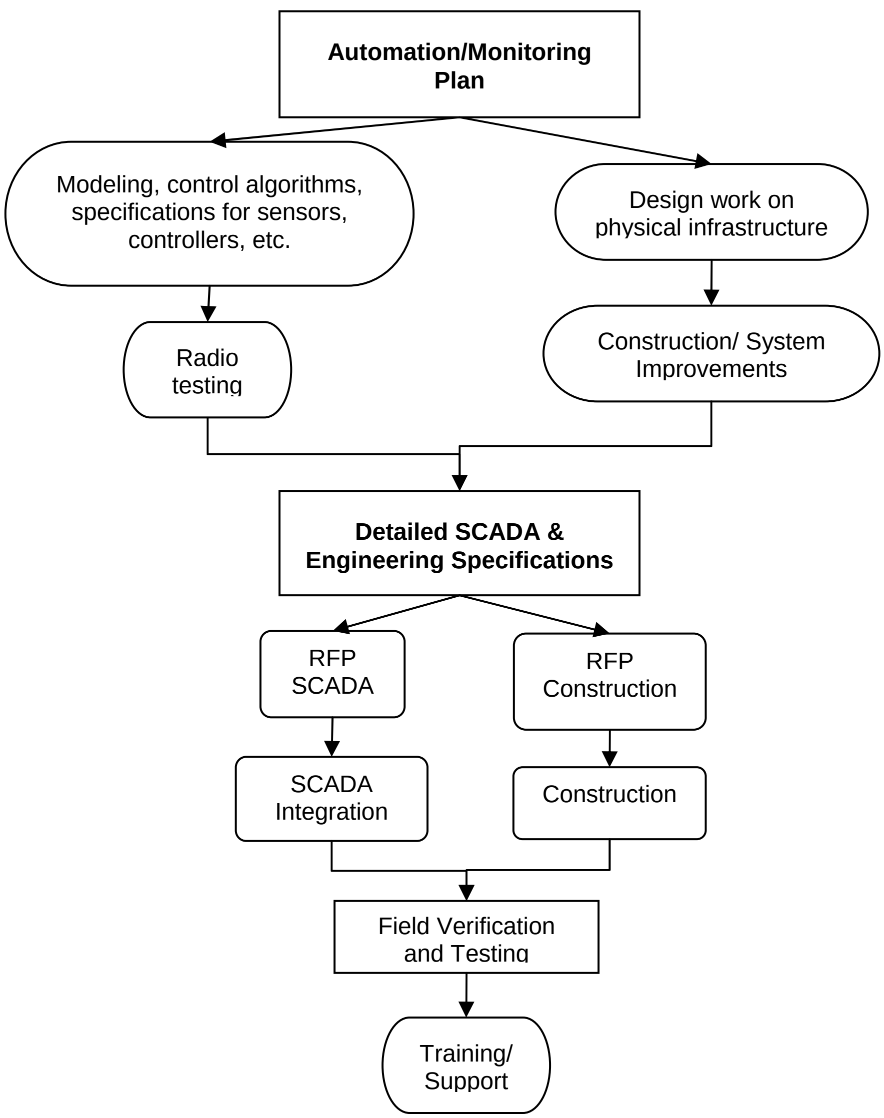


Figure 7. Steps in a typical irrigation district automation project

The Automation Plan must be considered integral to the long-term modernization strategy that the district will implement.

All the following items would be addressed as part of developing a comprehensive Automation Plan and SCADA Specifications:

i. Upgrading the radio system after a thorough evaluation of various technical options. These options are discussed in this report.
ii. Standardizing updated hardware/software specifications for devices like sensors and RTUs.
iii. Fully documenting the procedures, software programs, wiring diagrams, etc. for the existing system. An SOP Manual is needed that instructs new users how to make changes to the system, how to troubleshoot problems, how to re-boot the system, etc.
iv. Installing gate position sensors and other items needed for redundancy in order to implement remote manual operation of the Main Canal check structures.
v. Setting up more monitoring stations at the major lateral spill sites and connecting them to the office SCADA system.
vi. Dispersing mobile SCADA units to operators to put real-time information and control in the field.
vii. Upgrading the central office system including Ethernet connections, base station computer systems, HMI software, alarm autodialer system, etc.
viii. Re-organizing staff functions and responsibilities. For example, in the future the SCADA system would always have a watermaster constantly observing the system. There may also be scope to consolidate the water operators' zones through the application of mobile SCADA units.

Recommendation:

It would be a good idea to involve board members and senior staff in a one-day SCADA short course to go over the main issues involved with an expansion and upgrade of the existing system. This can help to answer questions about what kind of budgets are required, how to involve staff, the role of outside integration firms, timelines, priorities, etc. SCADA is a very complex effort that affects many aspects of district operations, including people's day-to-day work tasks, and it's essential to have *on-going* communication with everyone involved for the project to meet its goals.

Site Observations and Recommendations

The following sections describe technical observations based on the field inspections conducted during the Rapid Appraisal.

Lateral 21-2 Flap Gate at Spill

At the end of Lateral 21-2, the canal serves two turnouts (21-2-65R and 21-2-66L), along with a spill structure consisting of 2× 5-ft flashboard bays (refer to **Figure 8**). There is only about 1 ft of elevation change across the turnout gates, meaning that any water level fluctuations occurring here cause the flow rate delivered to the turnouts to unintentionally vary over time. For downstream operational demands, the district usually has about 10 cfs spilling here all the time (the water is recaptured in the Western Canal downstream of this point). The district is interested in designing and installing an ITRC Flap Gate at this location because it has wide potential application for improving water level control at other spill structures.

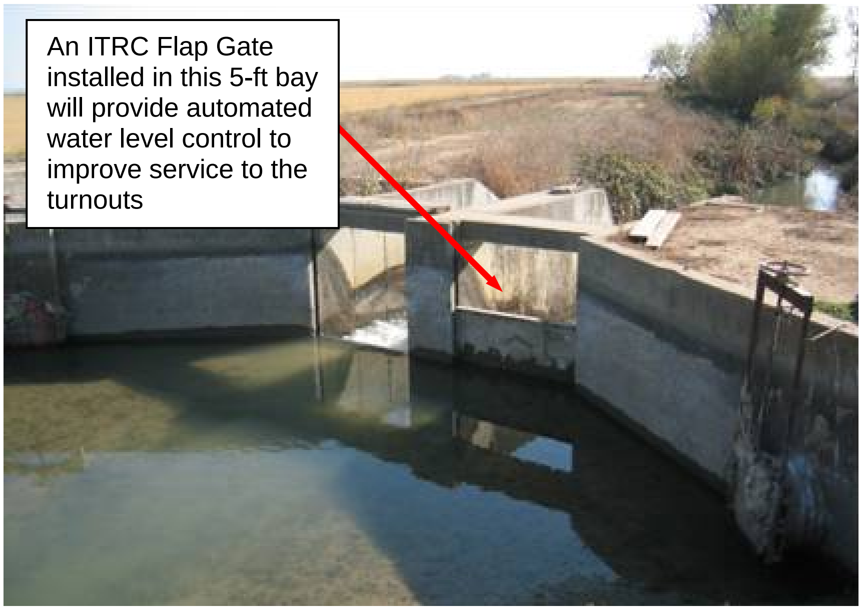


Figure 8. Proposed ITRC Flap Gate site at the end of Lateral 21-2

The features of the ITRC Flap Gate include:

- Operates steadily at varying flow conditions
- Maintains water level elevation typically within ±0.5 inches of design, allowing maximum flow through the canal with little deviation
- Maintains consistency in water travel times
- Contains fewer mechanical parts than most other gates
- Can be completed in one week, from initial design to installation completion, with experience
- Is often installed in less than two hours while water is flowing
- Water delivery flexibility is enhanced because canals become easier to operate

The flap gate typically requires several feet of headloss and can't be submerged on the downstream side. There are two main design variables to consider: i) width of the structure, and ii) maximum flow rate. In this case the 5-ft bay with the flap gate would have to handle a design flow rate of approximately 20 cfs. A complete design was not prepared for this site because detailed structural dimensions and surveyed elevations would be required. However, some guidelines are reviewed to aid in the design and construction process.

An example flap gate for a similar situation in Imperial Irrigation District is shown in **Figure 9**. The gate in **Figure 9** has a larger design flow rate and narrower width but the design is basically the same as what would be installed at Lateral 21-2. For a 5-ft wide gate to handle 20 cfs, the gate leaf would have to be about 1.25 ft tall. Depending on how tall the final gate design is, several rows of flashboards can be placed below the gate to position it at the right elevation in the bay opening.

Figure 9. Example ITRC Flap Gate (Imperial Irrigation District). View from upstream.

When the flap gate is installed, the other flashboard bay should be set high enough that all the flow goes through the flap gate. In some cases, flap gates can become unstable if they are used in combination with overflow (weir) structures.

A spreadsheet design program allows users to customize the gate size and weight for the desired location. The updated design spreadsheets are available at http://www.itrc.org/reports/flapgate/flapgate.htm.

Recommendations:

1. Categorize check structures in lateral canals according to the criteria presented in this report
2. Identify the highest priority spill sites that have acceptable hydraulic conditions
3. Design and construct ITRC flap gates, with technical review on the first few designs

Lateral 59-1 Long-Crested Weir

GCID has built a long-crested weir in Lateral 59-1 in a section of canal where highly variable flows were causing difficulties (**Figure 10**). This demonstration project has been highly beneficial for the district because it solved a 'real' problem, and also it provided an opportunity to learn about different design features. The design flow rate is 50 cfs and the total crest length is 20 ft (2× 10-ft long walls). A short 2-ft flashboard is located at the upstream nose and operators can pull the boards to drain the canal. However, there are no silt flushing gates on the downstream side of either wall.

Figure 10. Demonstration long-crested weir in Lateral 59-1

There are several technical elements that should be incorporated into future designs. All long-crested weirs should have silt flushing gates to avoid sediment building up that can progressively diminish the effectiveness of the structure. Another desirable feature is to install a single row of flashboards on top of the concrete crest wall (or a piece of steel) so the final crest can be adjusted in the field (**Figure 11**). This simplifies construction because precise surveying is not necessary as the board height can be easily fine-tuned.

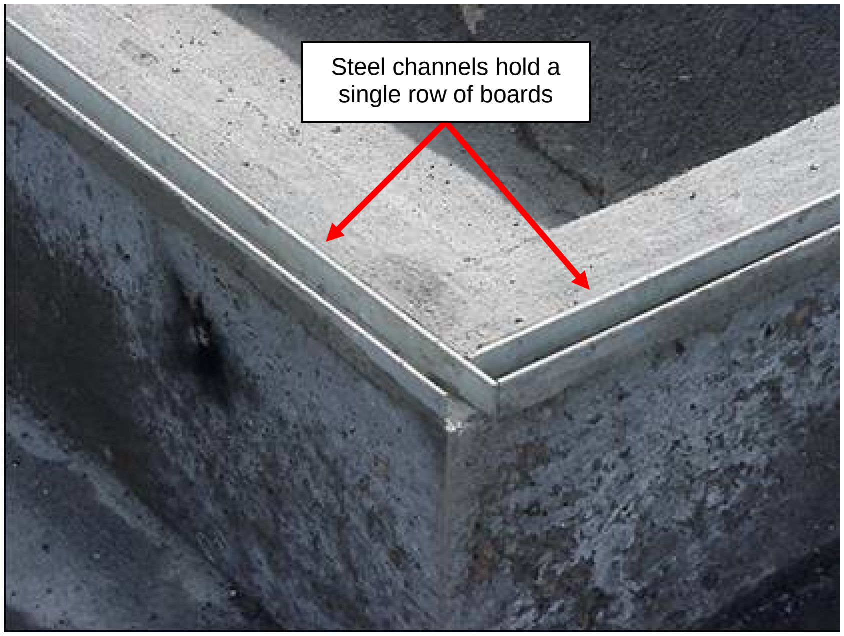


Figure 11. A steel channel placed in the top of the concrete walls of a long-crested weir holds a single row of flashboards for adjusting the final crest elevation.

For medium-sized canals (30-60 cfs) like Lateral 59-1, a practical design has been developed based on a steel frame and walkway with multiple flashboard bays. A 12-inch concrete pad is poured, with footings if necessary (weepholes are needed for ones pointing upstream). Steel angle iron and channel iron provide structural strength and can be fabricated in a variety of customized sizes. An example of a steel and flashboard long-crested weir is shown in **Figure 12**. This design can be built with a tapered nose.

Figure 12. Recommended long-crested weir design (example from Chowchilla WD, Calif.)

The concept of a long-crested weir is simple – the additional (longer) weir length makes it possible to pass a variety of flow rates through the canal with only a small change in the elevation of the water surface. From an operations point of view this means that compared to shorter crested check structures, large changes in flow rate over the long-crested weir will result in smaller changes in head, leading to minimal changes in the flow into the upstream laterals.

The 20-ft long demonstration weir is relatively short for a canal flow rate of 50 cfs as illustrated in **Table 2**. For example, with a 20-ft crest and assuming that the average turnout has 1 foot of head available, if the flow in the canal reduces by -20 cfs from an initial 50 cfs, the turnout flow would unintentionally decrease by 12%. For a -30 cfs reduction in canal flow rate, the turnout flow would decrease by 20%.

By comparison, if the design crest length were increased to 40 ft, the associated % turnout variation would only be 7% for a -20 cfs reduction in canal flow rate, and still be about 10% if the canal flow rate dropped by 30 cfs. This represents a significantly better degree of water level control and better service to the turnouts. The effectiveness of the long-crested weir is proportional to its length. The longer the weir, the better it can control the water level upstream of the weir for a change in flow rate. A longer weir is also inherently safer for emergency spills purposes to avoid over-topping canals.

Table 2. Summary of the water level change for a -20 cfs reduction in canal flow
(design flow rate = 50 cfs, assumes turnout head = 1.0 ft)

Item	Crest Length (feet)					
	10	**20**	30	**40**	50	60
Drop in water level (feet)	0.43	**0.27**	0.20	**0.17**	0.15	0.13
Unintentional reduction in flow to turnout (%) when canal flow rate reduces	20%	**12%**	9%	**7%**	6%	5%

Construction Features

Long-crested weirs have been built from a variety of materials including concrete, wood and steel. The best design is one that is easy to build, robust, flexible in operation, and cost-effective. The design in **Figure 12** has the following features:

- The structure is inherently stable and strong. The walkway provides structural stability for the walls.
- Slotted flashboard bays allow operators maximum flexibility in setting the final target water level elevation.
- Silt can be easily flushed anytime by removing one set of flashboards at the downstream end. No additional silt flushing gates are required.
- The only concrete work is a simple floor under the structure, much less expensive and easier to build than formed walls. Note: the floor in **Figure 12** should have weepholes to relieve upstream hydrostatic pressure. The floor should be a 12-inch thick concrete slab.
- The same basic design can be utilized for different weir crest lengths by adding more flashboard bays on the sides of the structure.

Recommendations:

1. Use silt flushing gates on all long-crested weir designs.
2. Use a row or flashboards or steel plate for top 0.5 ft of the weir crest.
3. Size the length of the weir based on trying to maintain a very constant turnout flow rate(with ±5-7% variation for a major change in canal flow rate).
4. Evaluate alternate design materials like the steel frame and flashboard design.
5. Taper the nose.

Main Canal Check Structure Upgrade (I-5 at Tomato Cannery)

The last section of the Main Canal (east of I-5) has a series of check structures like the one shown in **Figure 13**, which consist of a manually operated radial gate in the center of two side weirs. The typical flow change at this point in the system is ±75-100 cfs, while the minimum flow needed to maintain the canal pools is about 20-30 cfs. The change in water elevation across the gate is only about 2 ft, which means that at low flows the upstream water level can quickly rise by a large amount to build up enough head to pass an increased flow through the 12-ft radial gate. We clearly understand why this canal section is so difficult to control.

Figure 13. Main Canal check structure in the lower portion of the district (east of I-5)

A practical solution was developed for improving water level control at this structure, and similar ones downstream, without using expensive PLC-based automation. The proposed modifications are illustrated in the conceptual sketch in **Figure 14**. The downstream side of the check structure is shown in **Figure 15**.

The key features of the proposed design are the following:

- A 14-ft wide ITRC Flap Gate would be installed at the downstream end of the modified structure. Assuming that approximately 2-ft of headloss is available (upstream – downstream water elevations) the flap gate could handle about 120 cfs without any changes being made to the radial gate.
- For large changes in flow rate, or during winter flood flows, the operator would manually adjust the radial gate as needed.
- The upstream side weir on the right-hand side (looking downstream) of the radial gate would be removed down to be flush with the canal bottom (approximately 6 ft).
- The sloping concrete bank would be cut and removed to create a rectangular entrance section for the ITRC Flap Gate.
- The downstream short weir overpour wall would be cut and removed to match the width of the ITRC Flap Gate.

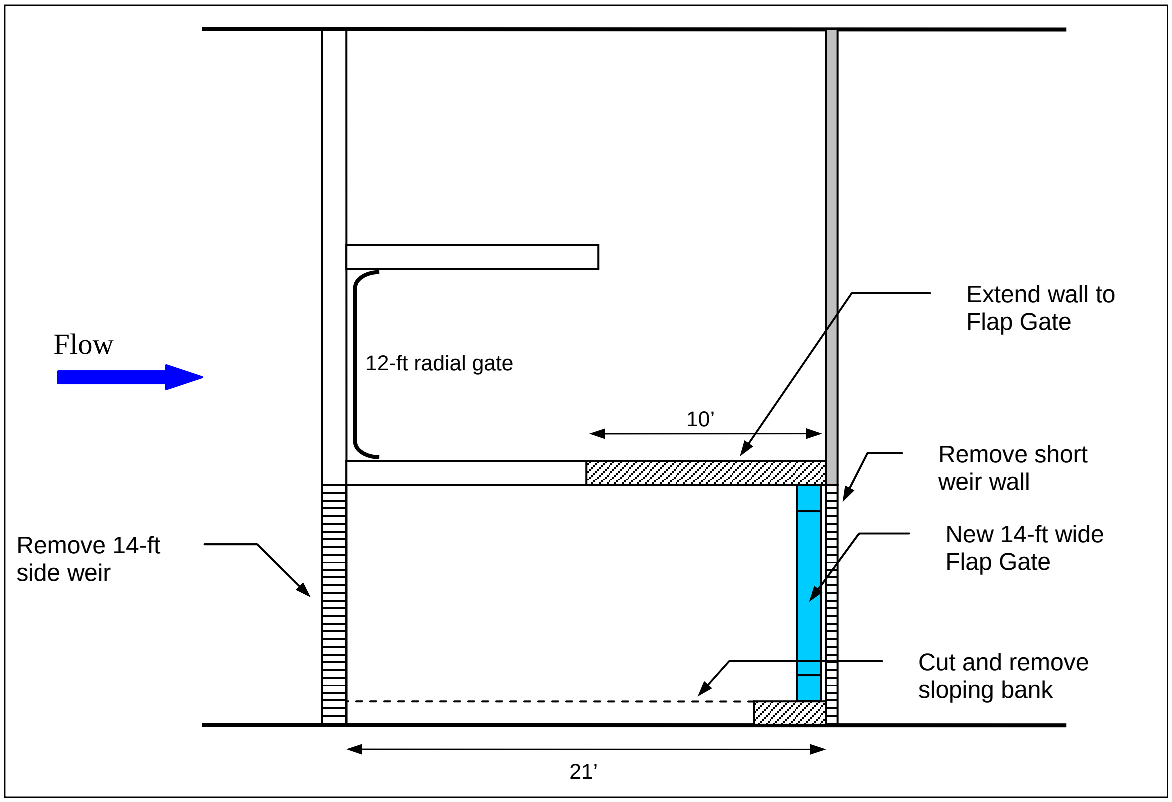


Figure 14. Conceptual sketch of modifications to the Main Canal check structures (east of I-5).

Figure 15. Downstream side of the Main Canal check structure showing where the ITRC Flap Gate is to be installed

Integrating the Interties from the Tehama-Colusa Canal to Improve Water Management

There are two existing gravity interties that connect the upslope Tehama-Colusa Canal with the GCID Main Canal (located in **Figure 16**). These inter-connections could provide a relatively inexpensive source of flexibility so the Main Canal can be operated to meet varying demands in the system while reducing lag-times and operational spill. Normally on long upstream-controlled canals such as the GCID Main Canal, a regulating reservoir would be the recommended solution for buffering out the plus and minus (±) errors that arise due to long lag-times from the headworks and the mismatches between demands and canal flows. As more flexibility is required to keep up with rapidly changing on-farm irrigation practices, the need for a reservoir or another solution becomes more evident.

In this case, the district is very fortunate to have access to a large capacity intertie with the Tehama-Colusa Canal near the middle of the distribution system where it can be used effectively. ITRC has previously done modeling and simulation of the Tehama-Colusa Canal that indicates the canal could be operated in a more flexible manner, and therefore could provide variable flows to the district via the existing bypass channel. It would certainly be much less expensive to utilize the Maxwell Intertie to the full extent possible rather than construct a large regulating reservoir. For comparison purposes, a conservative estimate of the total storage size of a regulating reservoir that would generally be applicable for this system is about 400-500 acre-feet. Obviously, such a large reservoir would be expensive to construct, but that level of flexibility is what will be required to handle future operational needs.

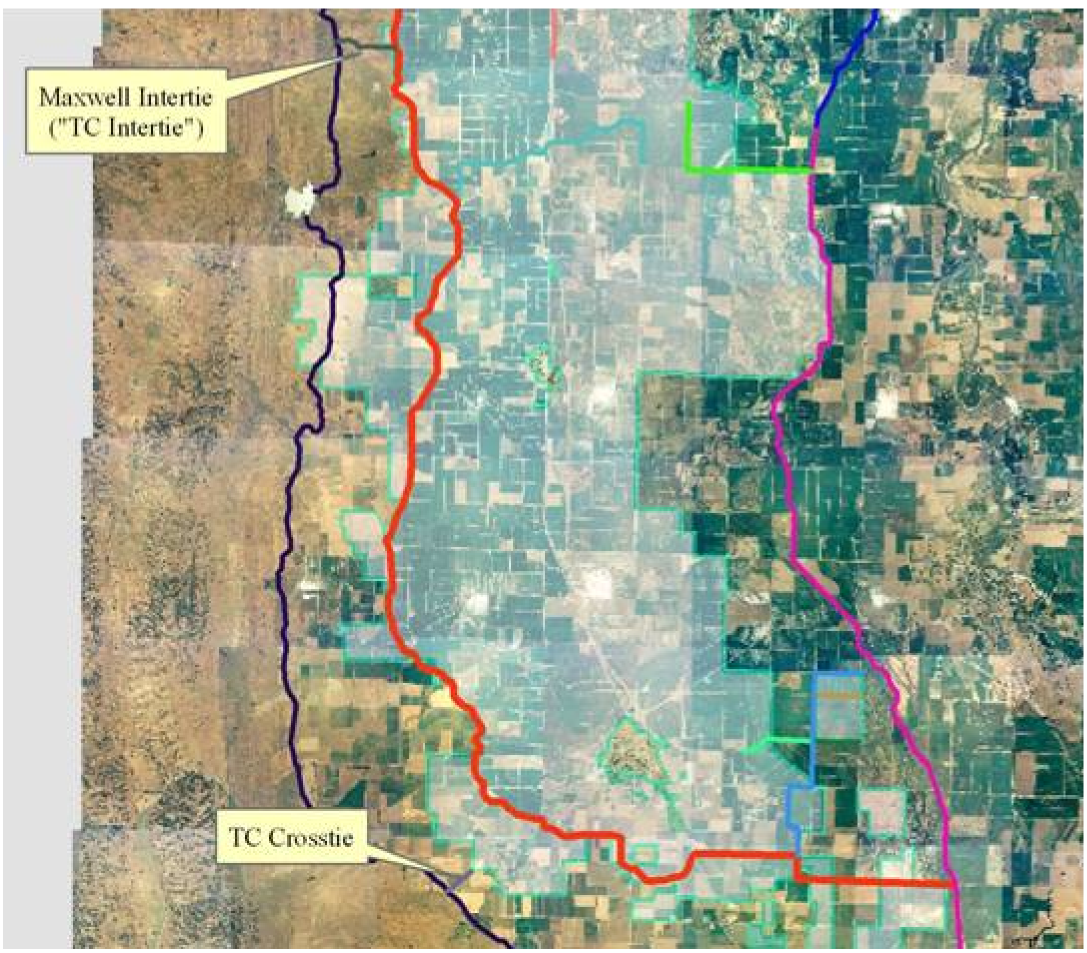


Figure 16. Location map of canal interties between the Tehama-Colusa Canal and the GCID Main Canal

The Maxwell Intertie has an operating capacity of about 1,000 cfs. The Main Canal has a maximum flow rate of approximately 1,500 cfs in this section. The radial gates at the outlet from the Tehama-Colusa Canal are operated via remote manual control by the Tehama-Colusa Canal Authority. The layout of the intertie is shown in **Figure 17**.

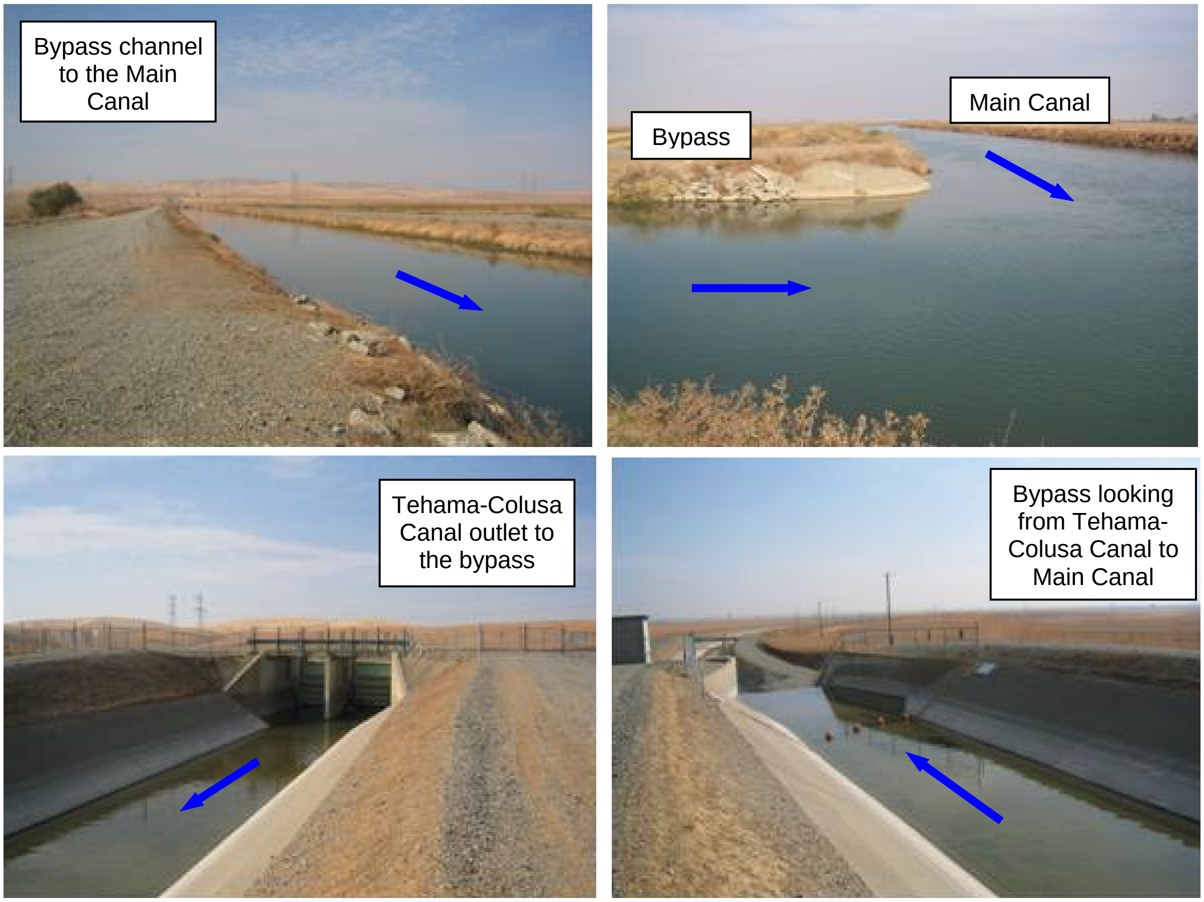


Figure 17. Maxwell intertie from the Tehama-Colusa Canal to the GCID Main Canal

The Maxwell Intertie is already being used selectively to augment flows in the Main Canal during certain situations, such as when tomatoes are flooded early in the year before the Main Canal is fully operational.

Future Operation

The proposed future operation of the Main Canal and the Maxwell Intertie is illustrated in **Figure 18**. To operate the system to take advantage of the intertie requires some new automated infrastructure, along with some modifications to the rules governing the delivery of water from the Tehama-Colusa Canal.

The key features of the proposed modifications include:

- Automated upstream water level control at the existing gates supplying the Maxwell Intertie from the Tehama-Colusa Canal. The control system would maintain a constant (target) water level in the Main Canal immediately upstream of a new flow control structure.
- Automated flow control structure in the Main Canal at a new gated structure located downstream of the discharge of the intertie channel.
- The *Operations Strategy* would be to attempt to always run the Main Canal about at least about 100 cfs short at the intertie, supplying the remaining water from the Tehama-Colusa Canal. This would provide an on-demand flexible source for operations without the long lag-time from the headworks.

- Discrepancies in the Tehama-Colusa Canal would be buffered in the Funks Reservoir, similar to what is being done now.

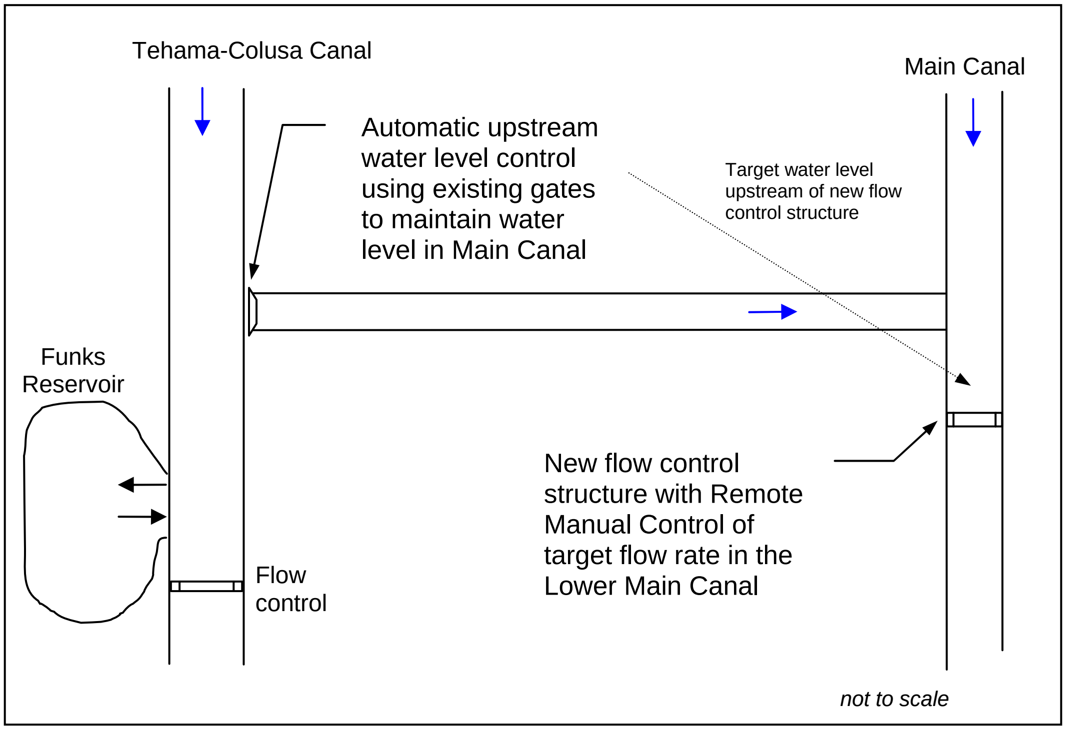


Figure 18. Schematic of the proposed future operation of the Maxwell intertie

This project represents a comprehensive and integrated change to both the hardware and management of GCID. The benefits of implementing more extensive use of the Maxwell Intertie and re-starting the Main Canal are the following:

1. Flows into the downstream portion of the Main Canal would be available "on demand" to:
    a. Provide more flexibility to the canal operators in meeting water orders. Instead of needing to wait for changes to arrive from the main pumping plant, the water would be available for *increases* ***or*** *decreases* in flow at the lateral headings at any time.
    b. Minimize spill and shortages at the tail ends of canals, because of the faster response time.
2. Turnouts on the upper portion of the Main Canal (upstream of the intertie) could be operated almost "on demand." Excesses or deficits would flow downstream, where they would be compensated for by the flexible supply from the intertie. This will minimize spills and shortages at the tail ends of the laterals upstream of the intertie, and provide farmers with more flexibility. It also reduces diversions.

The southern intertie from the Tehama-Colusa Canal serves the 56-1 lateral system with a capacity of 130 cfs. Irrigation demand has changed in recent years from peak flows of 110-120 cfs down to 80 cfs as more orchards have moved into the area. This has resulted in the idling of the two hydropower plants that used to operate in the system (with no SCADA). It appears that 30-40 cfs may be available for buffering flows in the Main Canal at Williams while satisfying irrigation demand in the area. If the flow in the intertie were coordinated with Main Canal operations, along with adding some buffer storage in the system downstream of this point, it may be possible to re-start the hydropower plants in a cost-effective manner.

Summary of Key Findings from the Rapid Appraisal

ITRC envisions major opportunities to improve system operations in GCID. This Rapid Appraisal identified a number of technical concepts and design recommendations. In addition to the details of some physical improvements at various structures, the components of an overall roadmap for the future are outlined. These include canal automation for the Main Canal and lateral headings, strategic use of the Tehama-Colusa Canal interties, coordinated drain water recirculation, mobile SCADA units for canal operators, and eventually re-regulation reservoirs to buffer flow discrepancies at key points. Implementation of a district-level modernization plan is a multi-year process that will evolve as participants see what works best in particular conditions and which practices are most cost-effective.

The main findings from this Rapid Appraisal are the following:

1. Automation of the Main Canal requires upgrades to the sensor systems (new gate position sensors, redundancy, etc.) along with overhauling the existing radio system. We expect that in the future the district may incorporate mobile SCADA units so operators can have remote monitoring/control capabilities in the field. It is recommended that at this time the district undertakes a planning effort to address the number of potential expansion sites, standardize on hardware/software specifications, and define how SCADA will be integrated with the overall system improvements.
2. The steps for developing an Automation Plan and SCADA specifications are outlined in this report. A related priority that should be done immediately is to fully document the existing system, along with detailing the technical deficiencies of the existing hardware.
3. Designing, installing and operating various modernization components – remote monitoring of spills, remote control of lateral headings, ITRC Flap Gates, Replogle flumes, etc. – in a designated zone of the district as a "package" (covering perhaps one Lateral Service Area) would provide managers and operators a valuable experience to assess various technical options under real-life conditions. This would allow time for people to learn the practical details of new ideas and new devices in a workable fashion. It would also make it possible to independently quantify the benefits and costs before such improvements are scaled up to the whole system.
4. One of the first steps in preparing a master plan for the lateral canal system is to categorize the check structures according to their relationship with turnouts regarding the area served, available headloss, and degree of canal flow variability (in terms of the percentage of canal flow change experienced on a daily basis).
5. ITRC Flap Gates can be an optimal solution for upgrading check structures with a drop of 30 inches or more. It appears there are some applications for this hydraulic gate that uses no electricity and can be constructed locally. ITRC Report No. R 01-003, a technical paper describing the Flap Gate, can be found at (http://www.itrc.org/reports/reports.htm). One site in Lateral 21-2 was identified in the Rapid Appraisal as a good site for a flap gate.
6. GCID has developed a prototype long-crested weir design that functions well. Suggested enhancements for future long-crested weir designs involve silt flushing gates and an adjustable crest height. The overall weir length can be increased to reduce the amount of water level fluctuations for turnouts where little headloss is available.
7. In the Lower Main Canal the existing check structures could be upgraded with ITRC Flap Gates as an alternative to PLC-based automation. A simple conceptual design was developed that would automatically handle about 100-120 cfs. The proposed modifications would improve control and canal safety, especially at low flows.
8. The Maxwell Intertie represents a major opportunity to increase the flexibility of Main Canal operations. The current limitations affecting how flows can be routed to the Main Canal from the

Tehama-Colusa Canal should be re-assessed because the basic physical infrastructure is already in place. The district would have to install a new flow control structure to re-start the Main Canal, but the necessary modifications are much less expensive than the costs associated with a new large regulating reservoir.

9. Eventually, the district may need re-regulation reservoirs in the lateral canal system at certain key points. The size and location of these reservoirs were not examined as part of this RAP.

Quantifiable Objectives

GCID is within Quantifiable Objective Regions 2, 3 and 4. GCID has been involved with various state and federal programs that promote CALFED objectives including the cooperative development of the Sacramento Valley Water Management Agreement. The proposed projects mentioned in this report support CALFED's objectives for reducing diversions from the Sacramento River (QOs 13, 20 and 30) and providing long-term diversion flexibility to the increase the water supply for beneficial uses (QOs 27 and 35). This RAP was not intended to quantify the values in the various quantifiable objectives.

The strategy of canal operators using remote control and monitoring with mobile SCADA units represents a major step towards achieving a reduction in operational spill. In addition, automation of the Main Canal, along with more flexible use of the Tehama-Colusa Canal interties, are key components of enhancing service to water users to allow them to improve their farm irrigation management.

The following are listed by CALFED as the pertinent quantifiable objectives:

13. ERPP: More closely emulate seasonal streamflow patterns in dry and normal year- types by allowing a late winter or early-spring flow event of approximately 8,000 to10,000 cfs in dry years and 15,000 to 20,000 cfs in below normal water-years to occur below Keswick Dam; Maintain base flows of 6,000 to 8,000 cfs during fall.

    QO: 44 - 180 TAF per year
    - Improve farm irrigation management (such as irrigation scheduling) and more uniform irrigation methods (such as shorter furrows, sprinkler, or drip).
    - Reduction in operational spill through improved management, canal automation or regulatory storage.
    - Reduction in canal seepage through canal lining or piping.

20. ERPP: More closely emulate seasonal streamflow patterns in dry and normal year- types by allowing a late winter or early-spring flow event of approximately 8,000 to10,000 cfs in dry years and 15,000 to 20,000 cfs in below normal water-years to occur below Keswick Dam; Maintain base flows of 6,000 to 8,000 cfs during fall.

    QO: 44 - 180 TAF per year
    - Improve farm irrigation management (such as irrigation scheduling) and more uniform irrigation methods (such as shorter furrows, sprinkler, or drip).
    - Reduction in operational spill through improved management, canal automation or regulatory storage.
    - Reduction in canal seepage through canal lining or piping.

27. ERPP/Core: Cooperatively manage ____ acres of ag lands and restore ____ acres of seasonal, semipermanent, and permanent wetlands consistent with the CV Habitat Jt Venture and N. Am. Waterfowl Mgmt. Plan.

    QO: 7.9 TAF per year
    - Improve farm irrigation management (such as irrigation scheduling) and more uniform irrigation methods (such as shorter furrows, sprinkler, or drip).
    - Reduction in operational spill through improved management, canal automation or regulatory storage.
    - Reduction in canal seepage through canal lining or piping.

30. ERPP: More closely emulate seasonal streamflow patterns in dry and normal year- types by allowing a late winter or early-spring flow event of approximately 8,000 to10,000 cfs in dry years and 15,000 to 20,000 cfs in below normal water-years to occur below Keswick Dam; Maintain base flows of 6,000 to 8,000 cfs during fall.

    QO: 44 - 180 TAF per year

- Improve farm irrigation management (such as irrigation scheduling) and more uniform irrigation methods (such as shorter furrows, sprinkler, or drip).
- Reduction in operational spill through improved management, canal automation or regulatory storage.
- Reduction in canal seepage through canal lining or piping.

35. ERPP/Core: Cooperatively manage ____ acres of ag lands and restore ____ acres of seasonal, semipermanent, and permanent wetlands consistent with the CV Habitat Jt Venture and N. Am. Waterfowl Mgmt. Plan.

    QO: 4.5 TAF per year

    - Improve farm irrigation management (such as irrigation scheduling) and more uniform irrigation methods (such as shorter furrows, sprinkler, or drip).
    - Reduction in operational spill through improved management, canal automation or regulatory storage.
    - Reduction in canal seepage through canal lining or piping.