SUPERVISORY CONTROL AND DATA ACQUISITION MEETS PUBLIC POLICY — A GLENN-COLUSA IRRIGATION DISTRICT CASE STUDY

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ABSTRACT

Looking into the future, water agency managers, consultants, board members and other decision makers will need to assess and consider using today's available technology to make more informed decisions to balance competing needs for water, to demonstrate improved water management, and to implement and manage water conservation programs. The initial investment and "growing pains" of using technology to install or update a system can streamline operations and serve multiple functions to improve efficiency and data acquisition. With this foundation, Glenn-Colusa Irrigation District (GCID) elected to proceed with installing and utilizing a Supervisory Control and Data Acquisition (SCADA) system to improve operations and assist in addressing the myriad challenges associated with operating a large irrigation district in California.

Internal to GCID, the SCADA system is part of a long-term strategic plan to enable improvements to control the distribution and delivery of irrigation water through GCID's extensive canal network. One of the most important components of GCID's SCADA system is the communication system, which is a high-speed endlessly expandable communication network capable of adding an unlimited amount of SCADA sites.

External to GCID, California's policy makers continue to enact new legislation requiring water agencies to prove that they are accurately measuring water, to demonstrate that water is being efficiently managed and beneficially used, and to establish linkages between surface water and groundwater. GCID is in the process of expanding its SCADA system to meet these new public objectives.

INTRODUCTION

Glenn-Colusa Irrigation District's water rights begin on the Sacramento River with an 1883 filing posted on a tree by Will S. Green, surveyor, newspaperman, public official, and pioneer irrigator. His first claim was for 500,000 miner's inches under 4 inches of pressure and was one of the earliest and largest water rights on the Sacramento River.

GCID was organized in 1920, after several private companies failed financially, and a group of landowners reorganized and refinanced the irrigation district, retaining claim to Green's historic water right. The disastrous rice crop failure of 1920–21 nearly destroyed the District at its inception and the Great Depression took a further toll, making it

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necessary for the district to refinance in the 1930s. Additionally, the United States purchased lands within GCID during this period that would later become three federal wildlife refuges totaling over 21,000 acres.

Today, after surviving many challenges, GCID is the largest irrigation district in the Sacramento Valley. Located approximately 80 miles north of Sacramento, California, the District boundaries encompass approximately 175,000 acres, with 141,000 planted acres and over 21,000 acres within three federal wildlife refuges that provide critical wildlife habitat. There are an additional 5,000 acres of private habitat land, and water supplied by GCID to thousands of acres of rice land provides valuable habitat for migrating waterfowl during the winter months.

GCID's main pump station, its only diversion from the Sacramento River, is located near Hamilton City. Prior to water entering the pump station, river water passes through an 1,100-foot long fish screen, built in the late 1990s (Figure 1). Water is then lifted an average of 4 feet before entering the conveyance system (Figure 2). The District's 65-mile long main canal conveys water into a complex system of nearly 1,000 miles of canals, laterals and drains, much of it constructed in the early 1900s.

Figure 1. SCADA allows GCID to monitor the activities of its 1,100-foot long fish screen. The pump station is located directly behind the fish screens.

Figure 2. GCID's main pump station, located on the Sacramento River, has the capability of pumping 3,000 cubic feet per second (cfs). SCADA allows canal operators to make pump changes remotely, monitor water elevations, and measure the water quality entering the District's main canal.

WATER SUPPLY

From the time of its first diversions until 1964, GCID relied upon historic water rights and adequate water supply from the Sacramento River system. This system receives rainfall and snowmelt from a 27,246 square mile watershed with average runoff of 22,389,000 acre-feet, providing nearly one-third of the state's total natural runoff. In 1964, after nearly a decade of negotiations with the United States, GCID along with other Sacramento River water rights diverters entered into "Settlement Water Contracts" with the Bureau of Reclamation (Bureau). These Settlement Contracts were necessary at that time to allow the Bureau to construct, operate, and divert water for the newly constructed Central Valley Project (CVP). The contract provided GCID with water supply for the months of April through October consisting of 720,000 acre-feet of base supply, and 105,000 acre-feet of CVP water that is purchased during the months of July and August. During a designated critical year when natural inflow to Shasta Reservoir is less than 3.2 million acre-feet, GCID's total supply is reduced by 25%, to a total of 618,750 acre-feet.

Additionally, the District has rights under a State Water Resources Control Board (SWRCB) permit for "winter water" from November 1 through March 31 at a 1,200 cubic feet per second (cfs) diversion rate. This water supply is used for rice straw decomposition and waterfowl habitat. The permit provides 150,000 acre-feet for rice straw decomposition and 32,900 acre-feet for crop consumption. Groundwater can also be used to supplement GCID's supplies, with 5,000 acre-feet available from District wells, and approximately 45,000 acre-feet from privately owned wells.

IMPROVEMENTS TO FLOW MEASUREMENT AND DATA MANAGEMENT PROCESSES

GCID continues to improve its flow measurement and related data management processes. Existing processes have evolved in a manner that adequately supported water operation and administration, but do not necessarily support more recent efforts to refine water management policy and practice in response to existing and anticipated challenges to water supply reliability.

GCID has prepared an annual *Water Measurement Report* (Annual Report) since 1964 that serves as a record of annual water diversions, operations, and uses. It consists primarily of a series of tables that summarize water diversions, deliveries, drain flows and drain water recapture on a monthly and annual basis, and contains a large amount of information and enables tracking of trends in certain operating parameters. The Annual Report also documents the water rates, rainfall, cropping patterns, and policies in effect each year.

Until 2009, GCID maintained a spreadsheet-based data management system that had been designed to produce operational reports and summary tables contained in the Annual Report. The spreadsheet system employed macro programs to enable semi-automated data entry, but the data was stored in a highly compartmentalized manner, making data access, analysis and reporting difficult. The system performed adequately for nearly 20 years for routine operations but was cumbersome for investigative analyses and ad hoc reporting, and it was not structured to receive and manage data from GCID's expanding SCADA network.

In early 2009, GCID migrated its spreadsheet data system to a Microsoft Access relational data base. This involved extracting data stored in hundreds of spreadsheets and assembling the data in one large Access data base. All of the historical data was salvaged. The new data base retained as much of the terminology as possible from the old system, including measurement site reference numbers and names. Like the old one, the new system includes data input screens designed to facilitate hand entry of operator reports submitted orally by radio and in writing.

One major objective of the conversion to a data base environment was to accommodate the growing volume of operational data that was expected to come from GCID's SCADA system. Over time, it is expected that GCID's reliance on SCADA information will increase and manual operator reporting will decrease. This trend is typical of many irrigation districts that are implementing SCADA systems for remote monitoring and control of water distribution systems.

It is anticipated that the capacity limits of Access will be exceeded and the data base system will have to be migrated to a higher capacity platform, such as SQL server or Oracle. This migration will be relatively straightforward now that data is stored in data base tables. Eventually, GCID intends to house or access all of the data needed for water balance analysis in an integrated Water Information System (WIS). A major consideration in the design of the WIS is to enable routine updates of GCID's water balance model.

SUPERVISORY CONTROL SYSTEM OVERVIEW

GCID's delivery system is comprised of the main canal, which is the major conveyance feature that extends 65-miles in length from the north to the south end of the District, 24 check structures that maintain upstream water level elevation, approximately 500 miles of laterals that convey water from the main canal, and approximately 2,500 field turnouts. The District's conveyance system includes 19 recapture pump sites and 17 gravity recapture sites that recycle over 200,000 acre-feet annually.

For control purposes, GCID's SCADA Project was designed to maintain constant upstream water elevations. As all water delivered to GCID customers either comes directly from the main canal or laterals from the main canal, it was vital that constant water elevations were maintained which would ensure constant flow deliveries from the main canal. Historically, water operators would make manual gate changes in the main canal check structures (Figure 3) in attempt to match water orders and flow requirements; however, in most instances, it was difficult to match these changes perfectly. The result would be that the water levels in the main canal would fluctuate and result in fluctuating flows to the District's customers.

Figure 3. Typical check structure along the main canal; SCADA allows the radial gates to move automatically, maintaining a selected or targeted upstream water elevation.

In order to meet California's new legislative requirements and to demonstrate that water is being efficiently managed and beneficially used, improving the water deliveries to customers was a critical first step. Due to the hydraulic complexity of the main canal, GCID consulted with Irrigation Training and Research Center (ITRC) personnel at California Polytechnic State University, San Luis Obispo, who developed the technical specifications, conceptual designs, and control strategies. The design phase began in July of 2007, and was followed by a radio survey conducted in June of 2008. Actual construction of the project commenced in the fall of 2008 and was completed in December 2010. The 2011 irrigation season was the first full season of operations with the SCADA system in place.

The SCADA system has enhanced water management by maintaining constant water levels in the main canal. This allowed water operators to conserve water at the operational spill points, and results in water users conserving water due to the flows into their fields remaining consistent. The project has improved system efficiency by removing the wave actions that historically created difficulties in determining whether river diversions needed to be increased or decreased.

GCID's conveyance system consists of drains supplementing laterals and, in other cases, laterals supplementing other laterals. In order to fully utilize the District's system, it is important to have as much real time information available as possible. Managing the main canal is only the first phase of a long-term strategic plan to enable GCID to monitor all critical points within the system to minimize drain outflows, and beneficially use the water rights of the District.

Technical Information

GCID's SCADA network consists of a dedicated system running ClearSCADA software (2009 version) on dual (redundant) servers in a Windows Server 2003 environment. The main SCADA workstation is a separate desktop computer connected to a 33-inch widescreen flat panel monitor that uses ClearSCADA View X. The SCADA system allows water operations staff to remotely operate the main canal system from work stations located at GCID's main office, or from laptops in the field using an internet connection. (Figure 4) depicts SCADA sites currently being monitored.

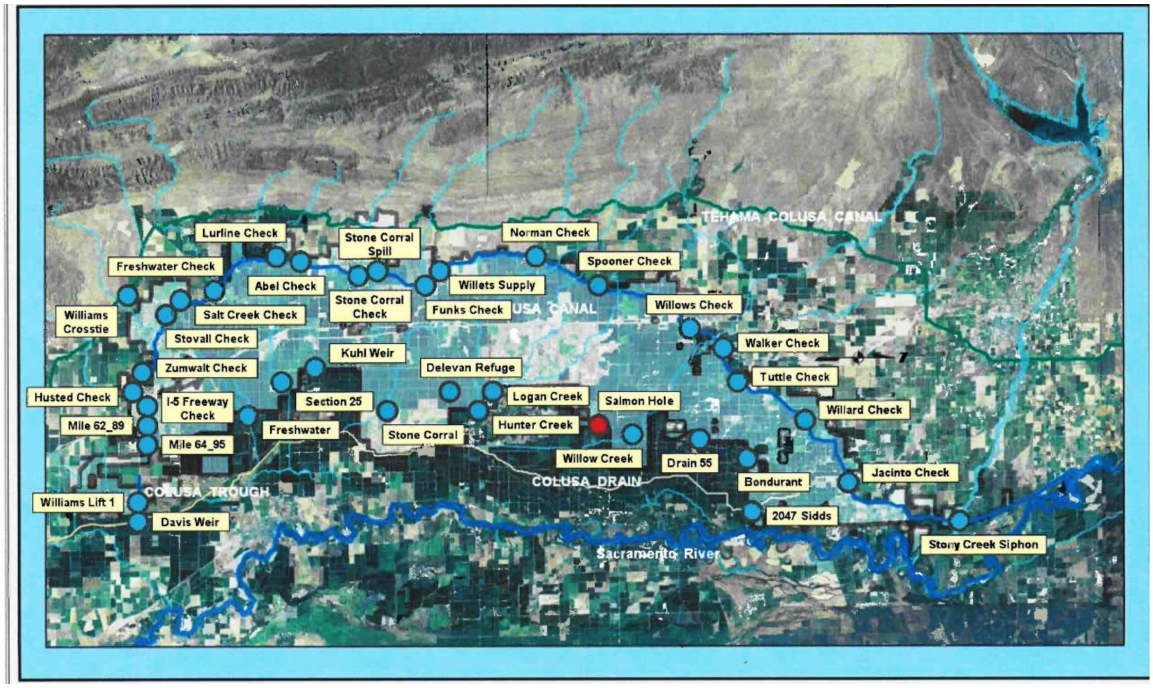

Figure 4. Currently monitored SCADA sites

Project Considerations

After completion of the design phase by ITRC, the next task was to select an integrator to perform all the technical phases of the project. During the selection process, potential integrators with extensive knowledge in the SCADA field were asked to provide a list of similar projects that they have been involved with, and their work experience was carefully reviewed. Another consideration was ensuring that the company is an established business that will be available to consult in future years.

GCID learned that conducting a radio survey and confirming that the proper radio system was selected was very important. Failure to do this early in the process resulted in time delays and increased costs. While the integrator supplies the necessary information, it is essential to review the decisions based on the technology of the District's system and the area. Deciding what types of SCADA operating screens will be optimal for the system early in the process saves time and effort as the integrator can design them as specified, avoiding the need to alter screens at a later date.

After the completion of the SCADA project, the system requires annual maintenance on all the components. This can be accomplished by establishing an annual maintenance agreement with the integrator, or training personnel to perform these duties. GCID elected to train personnel who conduct inspections and maintenance on the entire system, and consult with the integrator as necessary.

Careful selection of the types of components used as part of the SCADA system, can save time and expense. It is beneficial to avoid the use of proprietary equipment and to choose "shelf items," so that when components inevitably fail there is not a need to wait for specialized parts that are not readily available. Another area to consider during the planning phase is whether there is capacity to expand the SCADA system in the future, as it can be very costly to expand and replace the existing equipment with components that could have been used during the initial installation.

GCID employs a variety of flow measurement methods, ranging from continuous recording ultrasonic acoustic velocity meters to once-per-day weir depth measurements. Here, too, measurement has evolved to support routine water operations and administration, with primary emphasis on Sacramento River diversions and secondary emphasis on major internal operations (flow division) sites and drain outflows.

GCID recently completed a comprehensive evaluation and ranking of existing and prospective flow measurement sites that considers site importance, the annual volume of water passing the site, and measurement cost. Highest priority was placed on large, currently unmeasured operational and boundary measurement sites. Identified flow measurement improvements will be implemented over a period of several years.

CHALLENGES

One of the challenges canal operators face is the timing of pump changes as they relate to demand. Prior to the installation of the SCADA system, canal operators would either store water in selected pools along the canal or intentionally lower pools depending on the water orders for the next day. This resulted in fluctuating water elevation in the canal that caused laterals to either spill excess amounts at the end of the lateral, or short the lateral and interrupt service to the water user until the canal pool elevation returned to its original elevation. One of the positive aspects of the SCADA system is that it moves water up and down the canal more quickly and maintains the same water elevation at each check. This is a better result than the operators could accomplish by moving the water manually. Canal operators now make pump changes and are able to conserve water and maintain constant flows into fields, and the only remaining issue is to resolve the timing of when to make the changes with the SCADA system to achieve the best results.

Water velocity in the canal varies between 0.2 feet per-second during low flow condition, and 4.0 feet per-second, during high flow conditions. The period of time it takes the water to move 65 miles down the main canal increases during high demand periods and decreases during the low demand periods. It is imperative that the timing of increasing or decreasing river diversions is precise and has always been a difficult part of operating the system. The SCADA system provides the ability to adjust water elevation targets in selected areas, and helps to prevent either drying up the bottom of the conveyance system or spilling an excess amount of water.

Adjusting the water level sensors to accommodate water levels during the off-peak season has been one of the challenges of fine-tuning the system. Maintaining redundant sensors for water elevations has proven to be time consuming as discrepancies result in continual adjustments and unnecessary alarms. The strategic placement of stilling wells and accurate calibration of sensors to cover all flow conditions has been an important part of achieving proper operating parameters.

Calibrating gate position sensors is as challenging as calibrating water level sensors. Having a stationary gauge mounted above the water level on each water control gate allows for occasional site visits to actually confirm gate positions with gate sensors. Gate position is critical because the flow at each check structure is based on head pressure versus gate opening. As canal operators started to fill the canal system in spring 2011 and prepared each SCADA site for full automation, it was soon apparent that the flows at each site were not calibrated properly. Once the canal was filled with water the gate openings could not be measured accurately to verify the redundant sensor positions.

The majority of the District's SCADA sites are located in rural areas that experience frequent power outages. In most instances, the SCADA technician has been able to reset fuses or change batteries at the site. However, in some cases it was necessary for the technician to call the integrator to receive direction on how to fix the problem. Some of the older check structures had inadequate electrical equipment, and as the SCADA program constantly moves the gates up and down to maintain a constant water elevation, stress was placed on older components. Eventually the older components were overloaded and would fail, resulting in an alarm being triggered and water elevations not meeting the target. This equipment will be updated and replaced in the future.

DATA ACQUISITION AND MANAGEMENT BENEFITS

While SCADA has resulted in better control of the conveyance system, GCID considers the data acquisition, the management and use of that data to be equally important. In fact, the communication requirements, system architecture, and data-carrying capability of the District's SCADA system were weighed equally to the need for automated control in order to meet the current and future reporting and accounting guidelines at the District, regional, state, and federal level.

Water Measurement Reporting and Water Balance Model

As discussed previously, GCID has converted to a data base environment to accommodate the growing volume of operational data. With its system in operation, GCID is now looking to use data directly from SCADA to populate its Annual Report. Eventually, GCID intends to house or access all of the data needed for water balance analysis in an integrated Water Information System (WIS). A major consideration in the design of the WIS is to enable routine updates of the water balance model.

The objective of the water balance model is to enhance the value of the data presented in the Annual Report by augmenting and combining it in the form of a water balance that accounts for all water entering, leaving and stored within the District over specified periods of time. Beyond tracking trends in certain individual operating parameters, the water balance will allow GCID managers to assess historical operational performance under different water supply and demand conditions. The main outcome from the water balance will be an improved understanding of GCID system characteristics and operational performance, which, in turn, will provide an improved basis for identifying, assessing and planning potential water management and facility improvements. It is also expected that the water balance will reveal opportunities to improve GCID's water measurement and data management processes.

A particular purpose in developing the water balance is to characterize exchanges of water between GCID canals, laterals, drains and irrigated lands and the underlying groundwater system through the processes of recharge (by canal seepage and deep percolation of applied water) and discharge (groundwater pumping). It is generally accepted that the diversion and application of surface water in GCID results in appreciable net recharge to underlying groundwater aquifers. The water balance will help to improve recharge estimates, and will improve GCID's ability to manage underlying groundwater, including improved calibration of groundwater models.

GCID is currently developing the database component of SCADA so that measurements will feed directly into the Water Balance model, thus eliminating the need to transcribe data into the model, which is time consuming and prone to error. Additionally, GCID will also be able to generate its Annual Report data directly from SCADA.

Legislative Mandates

As mentioned previously, California's policy makers have and will continue to enact legislation requiring agricultural water suppliers (irrigation and water districts) to prove that agricultural water use is efficient and beneficial. In 2009, the legislature passed and the Governor enacted a Comprehensive Water Package that required water agencies to: i) report surface water diversions to the State Water Resources Control Board; ii) monitor and report groundwater elevations to show the health of groundwater basins; iii) provide measurement and volumetric pricing to customers; and iv) quantify agricultural water use efficiency.

Surface Water Diversion Reporting. In 2009, the California Water Code was modified to require diverters, including pre-1914 water right holders, to file Statements to measure their monthly water diversions beginning in January 2012. California Water Code section 5103 subdivision (e)(1) states the following:

> *"On and after January 1, 2012, [each statement shall include] monthly records of water diversions. The measurements of the diversion shall be made using best available technologies and best professional practices."*

GCID's SCADA system includes real time monitoring of surface water diversions, including water quality, at its Hamilton City Pumping Plant (HCPP) from the Sacramento River. Currently, fifteen minute data from the HCPP diversion is collected by SCADA; this information is averaged daily and then sent to GCID's Annual Report via SQL server. This information can also be pushed externally to the District's website.

SCADA offers the potential for the entire Sacramento River system to be managed and monitored on a real-time basis. If funding were available to allow other local agencies to install SCADA on their delivery systems, data could be pushed from locally owned, operated, and maintained SCADA systems to a centralized database and operations center that would allow more real-time operations. For example, the Central Valley Operations (CVO) center of the Bureau of Reclamation operates the Sacramento River system from Shasta Reservoir to the California Delta. GCID, along with other Sacramento River Settlement Contractors (SRSC), diverts water between Shasta and the Delta. If real-time SCADA systems existed on all of those diversions, the SRSC and the CVO could jointly operate the system more efficiently to minimize operational losses. While all the SRSC diversions are measured, most do not have an active SCADA system; however, if funding were made available most water agencies would add SCADA to their existing systems.

Groundwater Monitoring and Reporting. In addition to the surface water diversion reporting, the State Legislature amended the Water Code with SBX7-6, which mandates a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal, the amendment requires collaboration between local monitoring entities and the Department of Water Resources (DWR) to collect groundwater elevation data. Collection and evaluation of such data on a statewide scale is an important fundamental step toward improving management of California's groundwater resources.

In accordance with this amendment to the Water Code, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The intent of the CASGEM program is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins. The CASGEM program will rely and build on the many established local long-term groundwater monitoring and management programs. DWR's role is to coordinate the CASGEM program, to work cooperatively with local entities, and to maintain the collected elevation data in a readily and widely available public database.

To comply with this legislation, GCID volunteered to become a local monitoring agency for groundwater elevations within its service areas, which also includes significant portions of Glenn and Colusa counties. Historically, these wells were monitored by GCID staff in the spring and fall of each year, and for those multi-completion monitoring depths, a data recorder was used that measured water levels on a 15-minute interval and was downloaded on monthly intervals.

GCID’s SCADA system now allows for these well sites to be measured remotely, with on-off control being a future option. The data collected and pushed to CASGEM is also pushed to GCID’s Annual Report, which significantly reduces the time required for GCID personnel to perform the monitoring, and also minimizes the possibility of data being reported incorrectly.

Measurement and Volumetric Pricing to Customers. Also legislated in 2009, California Water Code §10608.48(i)(1) requires the Department of Water Resources to adopt regulations that provide for a range of options that agricultural water suppliers may use or implement to comply with the measurement requirements in paragraph (1) of subdivision (b) of §10608.48, which states:

> "Agricultural water suppliers shall implement all of the following critical efficient management practices:
> (1) Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).
> (2) Adopt a pricing structure for water customers based at least in part on quantity delivered."

To comply with this legislative mandate, GCID is expanding its SCADA system to measure all laterals and other larger diversions from its main canal, which will interrogate flow meters on a real-time basis. Measurement records will be batched to the *Water Measurement Report* to provide for a complete record of District deliveries, and then to the Water Accounting Program that will be used to generate water user billings. The acreage and cropping pattern in each lateral service area is available in GIS format allowing for exact determination of acreage and crop type within each service area. This information is obtained from water users during the water application process and then is confirmed by District personnel during mid-year field inspections.

The Water Accounting Program will utilize the information from SCADA and the crop information from GIS to develop an application rate (acre-feet/acre) within each service area that will satisfy the pricing requirement based on "in part quantity delivered." GCID also charges land and crop based assessments in addition to the volumetric charge.

Quantification of Agricultural Water Use Efficiency. Quantifying the efficiency of agricultural water use was directed by policy statements and other language in the 2009 legislation – SBX7-7. Specifically, §10608.64 of the Act states that the Department of Water Resources shall develop a methodology for quantifying the efficiency of agricultural water use and shall report to the Legislature on a proposed methodology and a plan for implementation. The plan shall include the estimated implementation costs and the types of data needed to support the methodology.

One approach for quantifying the efficiency of agricultural water use is to focus on the elements of a water balance (accounting) within an established boundary; for GCID it would be the District boundaries. Using SCADA, GCID is able to measure and record all sources and dispositions of water into, within, and out of a defined boundary. From these water flow elements, various relationships can be evaluated to describe the current water management conditions and assess opportunities for change. As described previously, GCID has developed a water balance program, and SCADA will be a vital tool in quantifying efficiency at the district-scale level.

CONCLUSION

The total initial cost of the SCADA project is currently about $2.7 million; however, GCID expects this cost to increase as more sites are added. While an expensive investment, GCID is adding tools to the toolbox that will improve conveyance system efficiency, conserve water, improve water quality by reducing Sacramento River diversions by approximately 40,000 acre-feet annually, improve river water temperature to benefit the endangered salmon, and conserve roughly 500,000 KWH annually. From a data perspective, it is now possible to collect real-time, historical, relational and transactional data to create a single virtual data resource that can access, aggregate, correlate and present role-appropriate information to canal operators, supervisors and management. Not all benefits have been realized in the short period of time that SCADA has been implemented, but it is anticipated that in future years GCID will meet and possibly exceed all the primary objectives.

The 2011 irrigation season was the first full season in which GCID operated the main canal in the fully automated position. The benefits were apparent in that service to the growers increased, and fewer man-hours were needed to operate the canal system. SCADA has enabled the District to meet all public policy requirements, while continuing to adhere to the District's mission statement of delivering a reliable supply of water, while protecting the environment and economic viability in the region.