IRRIGATION SYSTEM MODERNIZATION IN THE MIDDLE RIO GRANDE VALLEY

David Gensler[1]
Ramchand Oad[2]
Kristoph-Dietrich Kinzli[3]

ABSTRACT

The Middle Rio Grande Conservancy District (MRGCD) was officially founded in the 1920's, but it may well be the oldest operating irrigation system in North America. Prior to the arrival of European explorers, the area's Pueblo cultures were practicing flood irrigation along the banks of the Rio Grande. More elaborate irrigation practices were introduced to the Middle Rio Grande Valley by Spanish explorers in the 1600's and irrigation and water delivery practices have remained virtually unchanged for the past 300 to 400 years. Currently the MRGCD serves about 55,000 acres of irrigated land and provides additional benefits to the Middle Rio Grande (MRG) Valley by providing water for domestic, industrial, and environmental needs.

In recent years the demand for water in the Middle Rio Grande Valley has increased drastically due to explosive population growth, expanding industry, and water allocated for environmental and ecological concerns, that include two federally listed endangered species -- the silvery minnow (Hybognathus amarus), and the southwestern willow fly catcher (*Empidonax traillii extimus).* In response to the call for more efficient water use, the MRGCD embarked on a program of irrigation system modernization with SCADA incorporation. Over the past few years, the MRGCD has developed a SCADA system with the focus being to improve water use efficiency throughout the Middle Rio Grande Valley. This paper examines the five components of the system and how each component was developed and incorporated in the overall SCADA system. The SCADA system and related improvements in operational practices have reduced MRGCD river diversions from 600,000 AF/year to an average of 350,000 AF/year over the last three years.

INTRODUCTION

Middle Rio Grande Valley

The Middle Rio Grande (MRG) Valley extends 175 miles, north to south, through central New Mexico from Cochiti Reservoir to the headwaters of Elephant Butte Reservoir (Oad and Kullman, 2006). The Rio Grande passes through this valley on its journey from the high country of Colorado and northern New Mexico, to the Gulf of Mexico (Figure 1). Throughout the MRG valley, the Rio Grande is bordered by bosque, or riverside forest. Adjacent to the bosque, but within the narrow historic floodplain of the river, there is widespread irrigated agriculture. The City of

[1]Hydrologist, Middle Rio Grande Conservancy District, Albuquerque, NM; dgensler@mrgcd.com
[2]Professor, Department of Civil and Environmental Engineering Colorado State University, Fort Collins, CO; oad@engr.colostate.edu
[3]Graduate Research Assistant, Department of Civil and Environmental Engineering Colorado State University Colorado State University, Fort Collins, CO; kkinzli@engr.colostate.edu

Albuquerque and several smaller communities are located in and adjacent to the MRG Valley. Although the valley receives less than 10 inches of rainfall annually, the MRG supports both productive agriculture, and a rich and diverse ecosystem of fish and wildlife (Oad and Kullman, 2006).

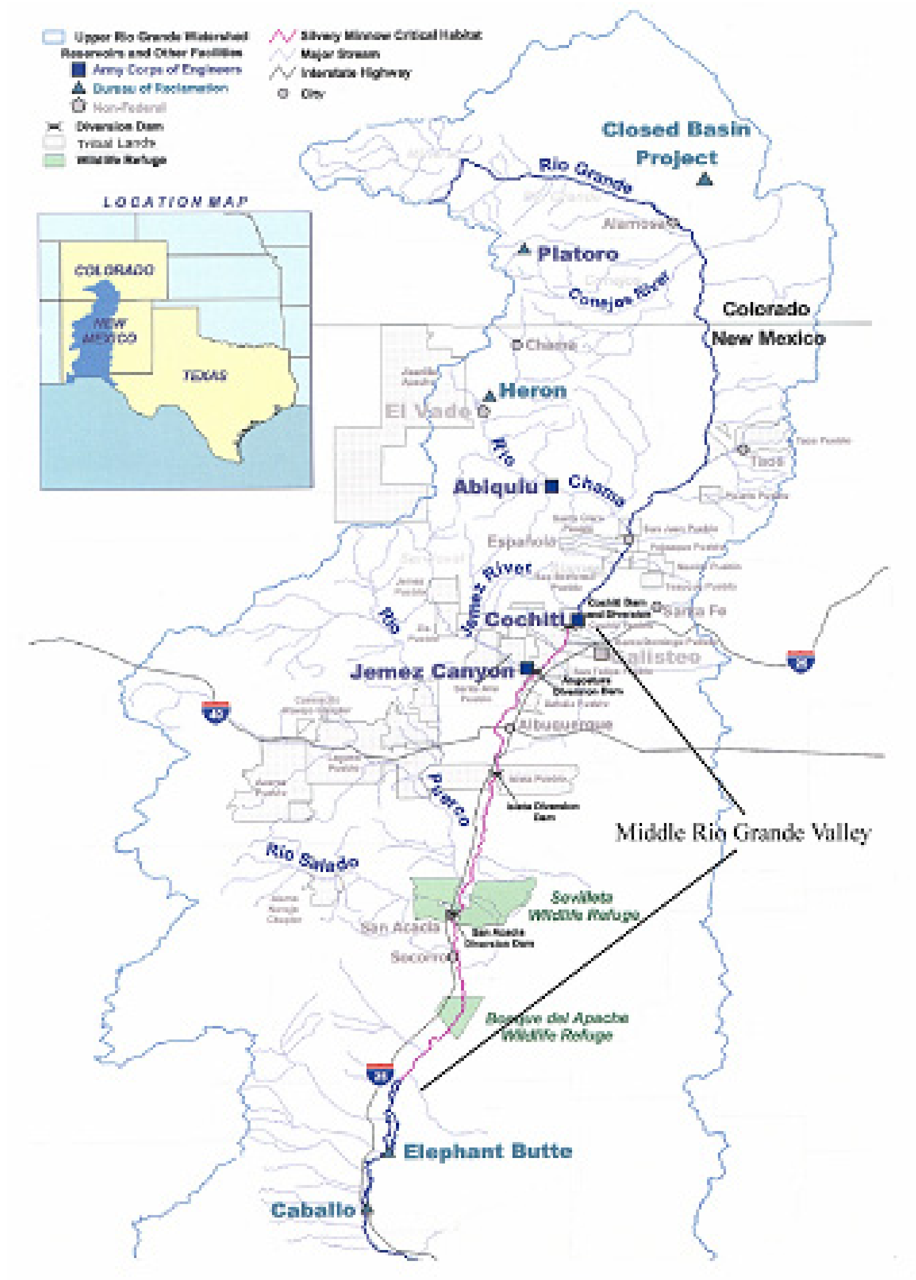

Figure 1. The Middle Rio Grande Valley

Water supply available for use in the MRG Valley includes: native flow of the Rio Grande and its tributaries, allocated according to the Rio Grande Compact of 1938; San Juan-Chama (SJC) project water, obtained via a trans-mountain diversion from the Colorado River system; and groundwater

(Rio Grande Compact Commission, 1997). Water is fully appropriated in the MRG Valley and its utilization is limited by the Rio Grande Compact. The Compact sets forth a schedule of deliveries of native Rio Grande water from Colorado to New Mexico and from New Mexico to Texas (Rio Grande Compact Commission, 1997).

In addition to agricultural and domestic consumers, there is major water use in the MRG associated with riparian vegetation. Open water evaporation from reservoirs and the river is also substantial. Across the American West, irrigated agriculture uses roughly 80 to 90% of available surface water. In the MRG use is more or less equally divided between agriculture, domestic use, and riparian consumption. Superimposed on these demands are river flow targets associated with two federally-listed endangered species: the silvery minnow (Hybognathus amarus) and the southwestern willow fly catcher (*Empidonax traillii extimus)* (USFWS, 2003).

Middle Rio Grande Conservancy District (MRGCD)

The MRGCD may well be the oldest operating irrigation system in North America. Irrigation practices introduced by Spanish explorers in the 1600's supplanted pre-historic flood irrigation by the area's Pueblo Indians. At the time of Albuquerque's founding in 1706, the ditches which now constitute the MRGCD were in existence, operating as independent Acequia associations. Acequias consisted of small farmer groups that maintained individual irrigation canals. Irrigated agriculture in the MRG valley reached its greatest extent in the 1880's, but thereafter underwent a significant decline.

Surprisingly, this decline was caused by an overabundance of water. By the early 1920's inadequate drainage, periodic flooding, and climatic variables had resulted in water logged soils throughout the MRG valley. Swamps, seeps, and salinization of agricultural lands were the result. In 1925, the State of New Mexico passed the Conservancy Act, which authorized creation of the MRGCD, which was accomplished by combining 79 independent Acequia associations into a single entity (Figure 2). Irrigated lands of six Indian Pueblos were also incorporated within the service area of the MRGCD. Physical construction began in 1928, and was completed by 1932 with river headings of Acequias becoming laterals, consolidated by building 6 diversion works and a series of main canals. A high mountain storage reservoir, El Vado, was completed in 1935.

In the mid 1990's the MRGCD encountered the same pressures for change currently being experienced by irrigated agriculture throughout the world. An ever expanding urban population began looking toward agriculture as a source for water and the endangered species act placed constraints on water use. Information on climate variability and groundwater resources produced a realization that water resources were less plentiful in the region than was previously believed. In order to proactively address water shortage and agricultural water delivery, the MRGCD embarked on a comprehensive program of canal modernization and SCADA incorporation.

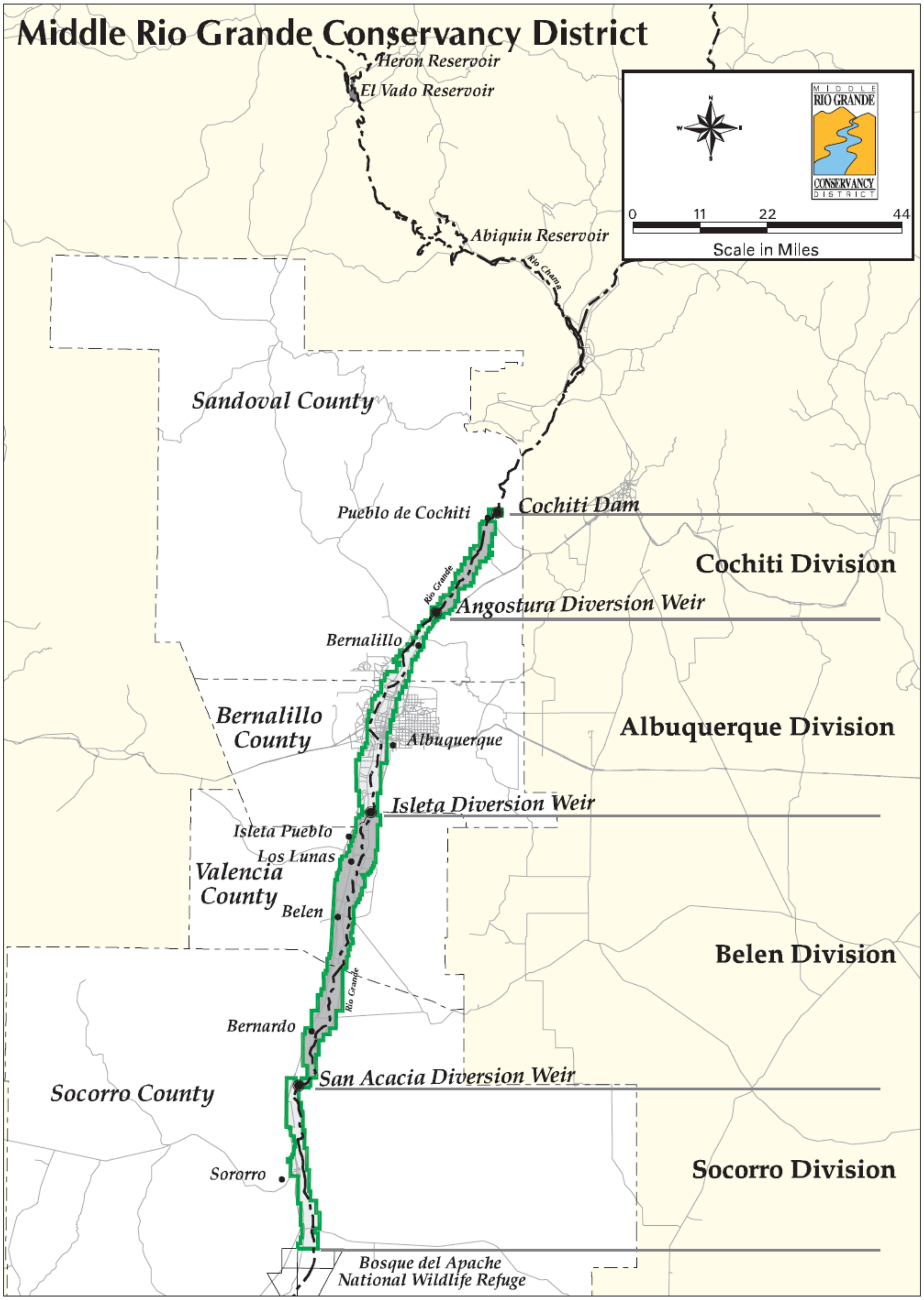

Figure 2. The Middle Rio Grande Conservancy District

MRGCD SCADA DEVELOPMET AND USE

The MRGCD program of measurement and automation was built entirely in-house using inexpensive components due to budget constraints. The components used in the system are a combination of traditional agricultural SCADA technology and adaptations of technology from other sectors of industry, most notably, the steel manufacturing industry. This combination and integration of technology makes the MRGCD SCADA setup unique. The MRGCD SCADA system can be broken into the following components:

- Flow Measurement Structures
- Automated Control Structures
- Instrumentation
- Telemetry
- Software

Water Measurement

Water measurement is the single most important component of the MRGCD's SCADA experience, since all operational decisions require sound knowledge of available water supplies and the demand throughout the system. When the MRGCD was initially constructed, considerable thought to water measurement was given. Over the years, gauging stations equipped with measurement instrumentation gradually deteriorated and quality of flow records declined.

In 1996, crisis struck the MRGCD in the form of drought, endangered species flow requirements, and development of municipal water supplies. At the time, the MRGCD was operating only 15 gauges on 1200 miles of canals. The following year, MRGCD officially embarked upon its modernization program. The construction of new flow gauges was the first step in this program. New gauges were constructed at key points in the canal system, notably at diversion structures and at return flow points. The acquisition of data from these locations led to determining where additional gauges would be most useful.

Along with the increase in numbers of gauging stations, efforts were made to improve the quality of measurement. Open channel gauging sites with no control structures gave way to site specific measuring structures. A variety of flow measurement structures were built in the MRGCD and include sharp crested weirs, broad crested weirs, adjustable weirs and Parshall flumes. Soon after beginning the modernization program, the Bureau of Reclamation WINFLUME software became available. Since that time new gauges are constructed with broad-crested weirs using WINFLUME for design and calibration (Figure 3). Currently, MRGCD is operating 75 gauges.

Figure 3. Broad Crested Weir Gauging Station with Radio Telemetry

Automated Control Structures

With the advent of better data collection, it became apparent to the MRGCD that automated control was necessary. Data from gauges revealed that many operational problems occurred because canal operators could not be physically present at all times. Automation followed shortly thereafter with an experimental effort at a wasteway that had been fitted with an automated Langemann gate for water measurement, and was therefore a practical starting point. The MRGCD built the electronic controller and created the control software for this first automated gate, borrowing heavily from Bureau of Reclamation experience in Utah. Success with the first automated structure led to installation of over 40 additional automated structures. After the first in-house development of automation, it was found practical to use existing commercial control products, although the experience gained from initial development has proved invaluable.

Most of MRGCD's recent automation efforts have involved the installation of Langemann overshot gates (Aqua Systems, 2006). The majority of these can be easily retrofitted to existing structures, though some involve the construction of new check or heading structures. The Langemann Gate has the capability to maintain a constant upstream water level as a check structure or it can provide a constant flow rate to downstream users (Figure 4). The Langemann gate is equipped with solar panels to power both gate operation and telemetry units. The gates employ integrated electronic controllers built around IC Tech radio terminal units (RTU's) and Aqua Systems 2000 software. Langemann gates in the MRGCD are used as checks, turnouts, spillways, and diversion structures.

Figure 4. Langemann Gate

Some existing radial gates have also been automated. Conversion involves selection of a gearbox, motor, and controller. Some fabrication is involved to adapt the drive unit to the existing gate hoist shaft, but this is all done in-house by MRGCD shop personnel. Early conversion attempts used an AMI controller supplied by Aqua Systems 2000, but recently the MRGCD has used the IC Tech RTU (Figure 5), which can be programmed to calculate flow through automated radial gates. Though not as accurate as overshot gates, this is useful for setting target bypass flows at diversion structures for endangered species flow requirements.

Instrumentation

Flow measurement and automated control must include some level of instrumentation. In the 1930's, a float in a stilling well driving a pen across a revolving strip of paper was adequate. In fact, at the beginning of modernization efforts, the MRGCD was still using 15 Stevens A-71 stage recorders. Diversions into the canal system were only known after the strip charts were collected and reduced at the end of the irrigation season.

Modernization meant a device was needed to generate an electrical or electronic output that could be digitally stored or transmitted. Initially, shaft encoders were used for this purpose, providing input for electronic data loggers. Experimentation with submersible pressure sensors soon followed, and these have been adopted, although a number of shaft encoders are still in use. Recently, sonar sensors have been used satisfactorily at a number of sites. The MRGCD has learned that different situations call for specific sensor types and sensors are selected for applications where they are most appropriate.

Telemetry

Data from electronic data-loggers was initially downloaded manually and proved to be only a minimal improvement over strip chart recording, though processing was much faster. To address data downloading concerns telemetry was adopted to bring the recorded data back to MRGCD headquarters at regular intervals (Figure 3). MRGCD's initial exposure to telemetry was through the addition of GOES satellite transmitters to existing electronic data loggers. This method worked, but presented limitations. Data could only be transmitted periodically, and at regularly scheduled intervals. Of greater consequence was that the GOES system, at least as used by MRGCD, was a one-way link. Data could be received from gauging stations, but not sent back to them. As experiments with automation progressed, it was clear that reliable 2-way communication would be a necessity.

To address the rising cost of phone service, experiments with FM radio telemetry were conducted. These began as a way to bring multiple stream gage sites to a central data logger, which would then be relayed via GOES to MRGCD. First attempts with FM radio were not encouraging; however a successful system was eventually developed. As this use of FM radio telemetry (licensed 450 mHz) expanded, and knowledge of radio telemetry grew, it was soon realized that data could be directly transmitted to MRGCD headquarters without using the GOES system.

The shift to FM radio produced what is one of the more unique features of the MRGCD telemetry system. The data link proved so reliable, that there was no longer a need to store data on site, and the use of data loggers was mostly discontinued, the exception being weather stations. In effect, a single desktop computer at the MRGCD headquarters has become the data-logger for the entire stream gauge and gate system, being connected to sensors in the field through the FM radio link. Three repeater sites are used to relay data up and down the length of the valley, with transmission being up to 75 miles. Also, this has the benefit of being a 2-way link, so various setup and control parameters can be transmitted to devices along the canals.

The MRGCD telemetry network consists exclusively of IC Tech RTU’s (Figure 5). Several different types of these units are used, depending on the application. The simplest units contain only a modem and radio, and transmit collected and processed weather station data from Campbell Scientific CR10X dataloggers.

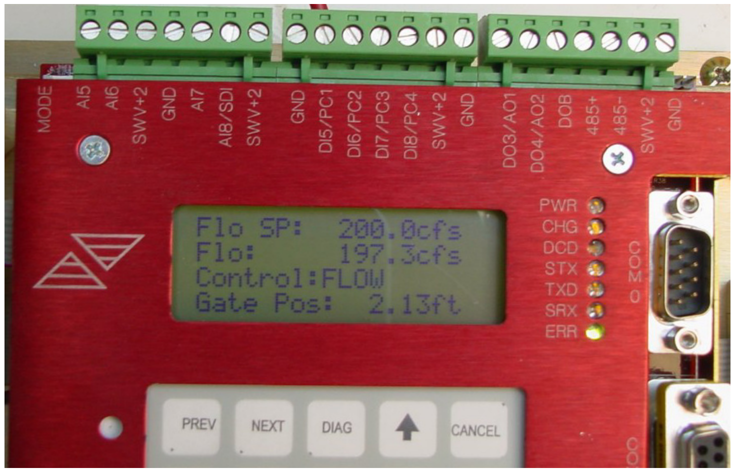

Figure 5. IC Tech Controller

The majority of the RTU's contain a modem, radio, and an input/output (I/O) board packaged into a single unit. Sensors can be connected directly to these and read remotely over the radio link. A variety of analog (4-20ma, 0-20ma, 0-5v) and digital (SDI-12, RS-485) output devices can be accommodated this way. Another type includes a programmable (RP-52 BASIC) controller in the modem/radio/(I/O) unit. This style is used for all automatic control sites and places where unusual processing of sensor outputs such as averaging values, combining values, or timed functions, are required. At the present time, the MRGCD telemetry network gathers data from 75 stream flow gages and 18 ag-met stations, and controls 50 automated gates (Figure 6).

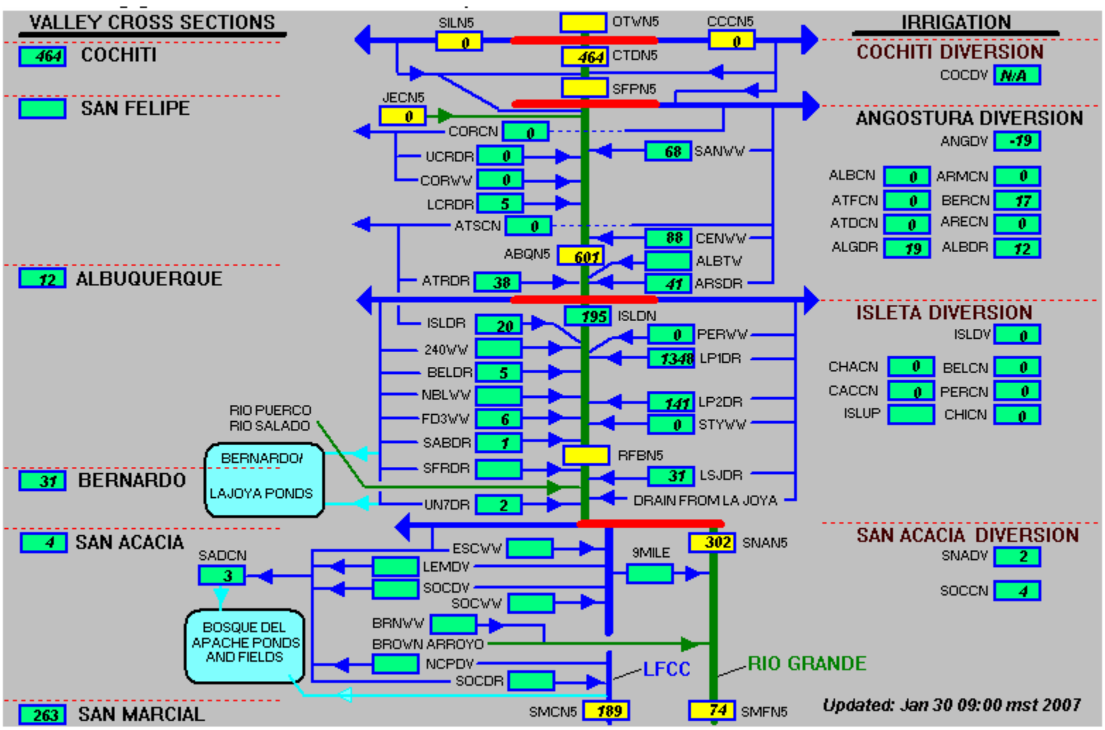

Figure 6: MRGCD Telemetry Network

Control Software

Measurement, automation, and telemetry components were developed simultaneously, but largely independent of one another. While each component functioned as expected, components did not exist as a harmonious whole, or what could truly be called a SCADA system. The missing component was software to tie all the processes together. There are a variety of commercially available software packages for such use and MRGCD experimented with several. Ultimately, the MRGCD chose to purchase the commercial software package Vsystem and to employ the vendor Vista Controls to develop new features specific to the control of a canal network. Installation and setup was done by the MRGCD.

This system, known affectionately as the Supervisory Hydro-data Acquisition and Handling System (SHAHS), gathers data from RTU's on a regular basis. With the capability to define both timed and event driven poll routines, and specify a virtually unlimited number of RTU's and MODBUS registers to collect, virtually any piece of information can be collected at any desired time. The Vsystem software can process data through a myriad of mathematical functions, and combine outputs from multiple stations. Vsystem also incorporates the ability to permanently store data in its own internal database, MS Sequel databases, or export data in other formats. Data can be displayed in a user-created graphical user interface (GUI) which MRGCD water operations personnel use to monitor water movement. The screens can also execute scripts to generate data, control parameters, control gate set points, and monitor alarm conditions for automated control structures. Finally, the GUI's can be used to control automated structures by transmitting new parameters and setpoints. Figures 7 and 8 illustrate operation, display, and use of Vsystem components.

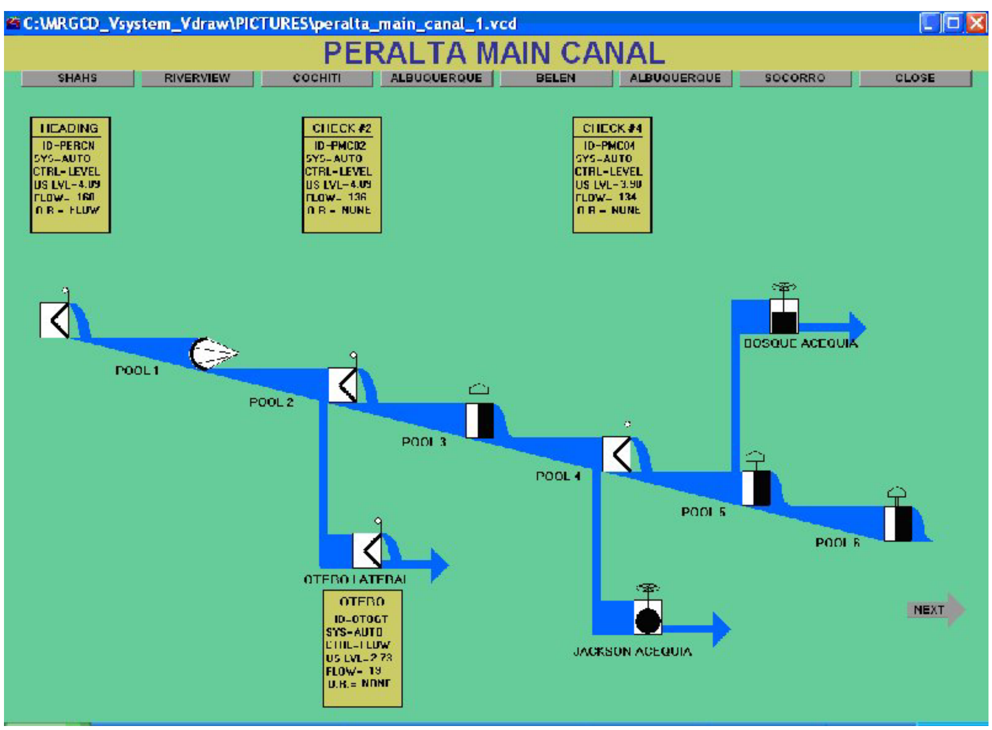

Figure 7. Vsystem Screen Displaying Check Structures and Pools on a Main Canal

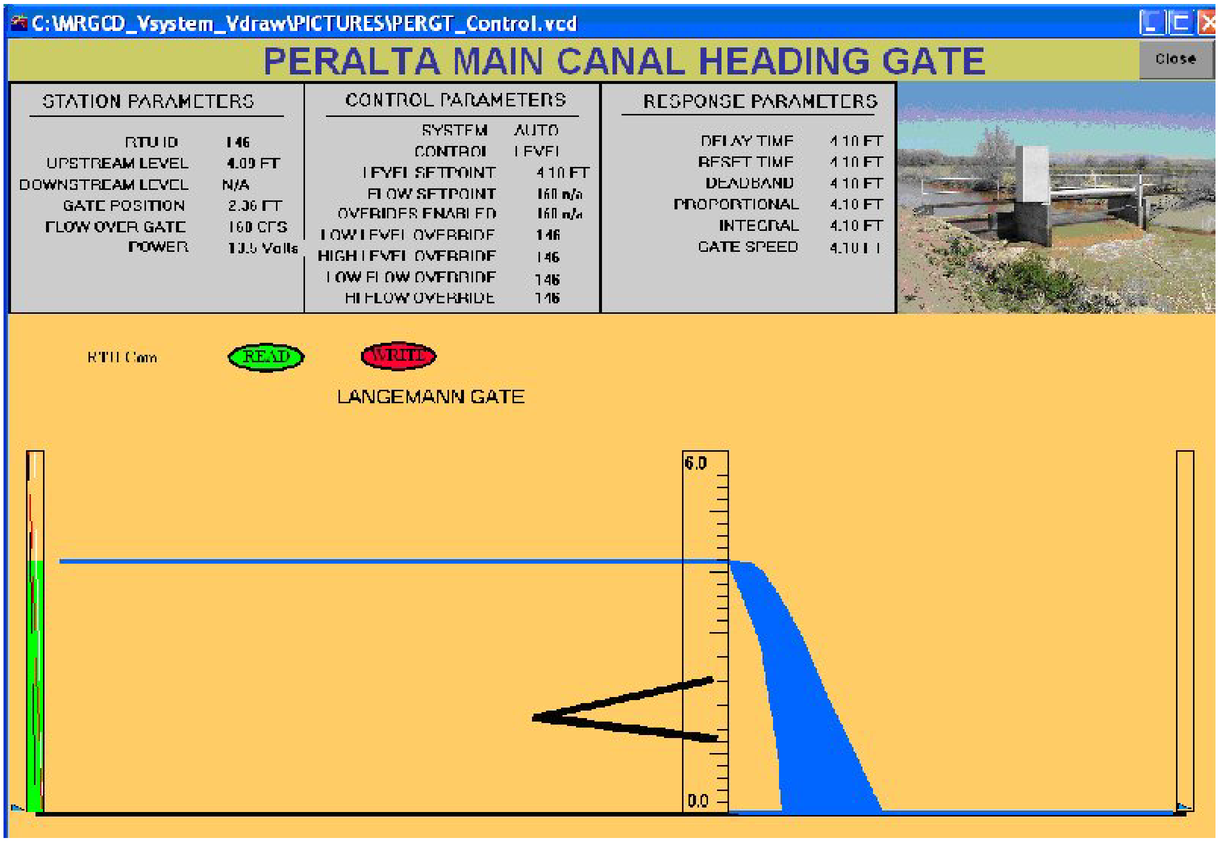

Figure 8. Vsystem Control Screen for a Langemann Gate

<u>Decision Support System for Rotational Water Delivery</u>

A new and very useful component is currently being incorporated into the MRGCD SCADA system. A Decision Support System (DSS) had been developed by Colorado State University to encompass irrigated agriculture in the MRG (Oad et.al, 2006). The DSS monitors soil moisture and includes a model to calculate crop water demands for lateral service areas on a real time basis. The model then develops rotational water delivery schedules to meet the crop demand. The DSS will give MRGCD operators a required irrigation delivery on a lateral level based on crop demand. This required delivery will be imported into the GUI of the MRGCD SCADA system so that actual deliveries along the canal system can be compared to required deliveries. The GUI will allow water managers to remotely change automated gate settings so that actual diversions closely represent water requirements. This will provide better water management within the MRGCD and allow for a minimized river diversion as the required and actual diversion values converge.

RESULTS AND CONCLUSIONS

The adoption of new technology has resulted in a simple, inexpensive, and reliable SCADA system. When coupled with modified operational practices, the results have been significant. A decade ago the MRGCD was diverting over 600,000 AF/year from the Rio Grande. Over the last 3 years diversions have averaged less than 350,000 AF/year (Figure 9). With a delivery obligation of 190,000 AF/yr, there is still the opportunity to further minimize river diversions. The incorporation of the previously mentioned DSS will greatly assist the MRGCD in reducing diversions to more closely represent the required crop demand in the coming years.

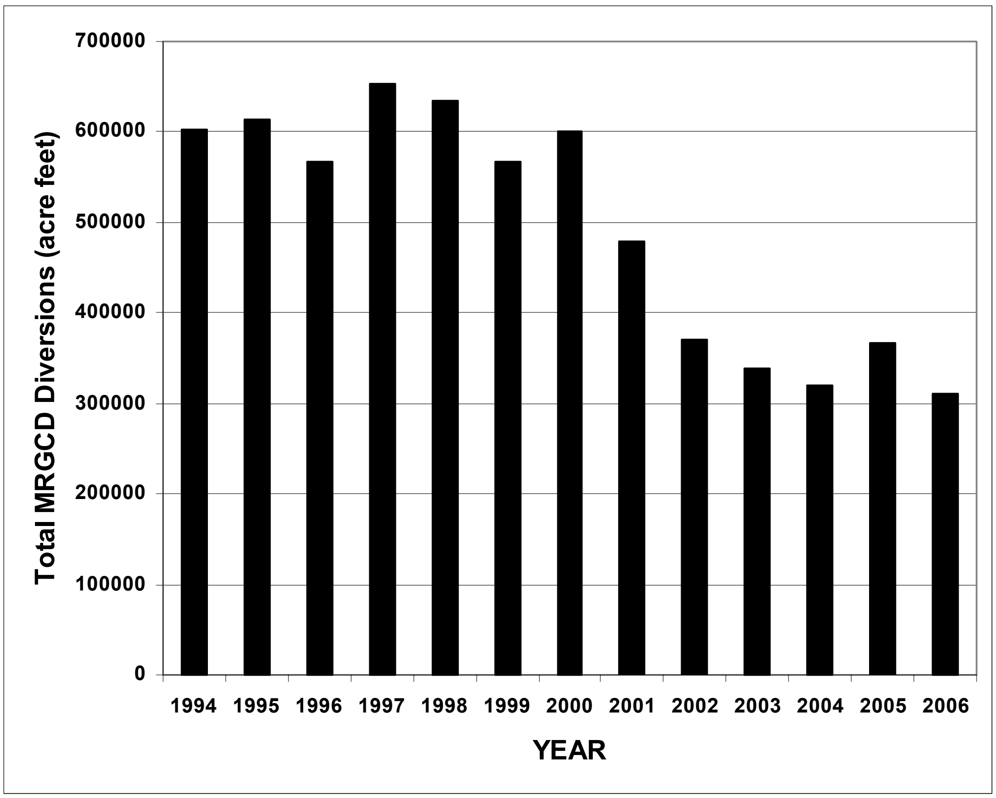

Figure 9. MRGCD River Diversions by Year

Although many irrigators miss the old days of unscheduled irrigation at the time of their choice, they have reaped a major benefit from these changes. New Mexico has experienced a decade of drought and reservoir storage has been minimal. Due to the modernization and accompanying improvement in efficiency, a much smaller volume of water is released from upstream storage reservoirs to meet a given demand. Therefore, the limited supply of stored water is stretched farther. During the recent drought the MRGCD has not had to curtail deliveries for any extended periods of time, and irrigators have continued to receive their full annual deliveries.

Additionally, New Mexico has done unusually well in meeting Rio Grande Compact delivery obligations over the last few years. This is due to many factors, but one major reason is the more efficient movement of water through the middle valley by the MRGCD. Annual carryover storage has also increased as a result of efficiency improvements. This translates to less empty storage space to fill during spring runoff. Currently, more water goes downstream during runoff mimicking the hydrograph before the advent of storage reservoirs. This is a subtle change, possibly overlooked by many, but one which may ultimately provide more good for endangered species and the general welfare of the river system than additional artificial releases for those purposes.

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