MODERNIZATION OF THE DELANO-EARLIMART IRRIGATION DISTRICT

Charles M. Burt[1] and Dale R. Brogan[2]

ABSTRACT

Delano-Earlimart Irrigation District (DEID) delivers water through closed reinforced concrete pipelines on an arranged schedule. Farmers are not allowed to operate their own turnouts, and individual turnout flow rate changes impact flow rates at all other turnouts on the same pipeline. DEID is in the process of a complete modernization program which will allow the farmers to operate their own turnouts on a very flexible arranged schedule. The modernization includes (i) a new water ordering program, (ii) new turnout designs with pressure regulators and new flow propeller flow meters, (iii) the use of hand held data recorders to document deliveries to turnouts, (iv) a SCADA system to monitor the pumping stations and key pressures, (v) integration of the SCADA system with the water ordering software, and (vi) installation of variable frequency controllers on some pumps to reduce energy consumption.

DISTRICT DESCRIPTION

Delano-Earlimart Irrigation District (DEID) was formed in 1938 and signed its original water service contract with the U.S. Bureau of Reclamation in 1951 for water delivery from the Friant Unit of the Central Valley Project.

DEID encompasses 56,500 acres situated in southern Tulare County and northern Kern County along the east side of the San Joaquin Valley. The district serves approximately 412 landowners with an average farm size of 135 acres. More than 63% of the landowners own less than the Reclamation Reform Act acreage certification threshold of 240 acres.

The district contracts with the Bureau for its water supply which is managed and used conjunctively with groundwater for long term irrigation needs. DEID holds the largest Class 1 (fairly reliable) contract on the Friant Division of the Central Valley Project totaling 108,800 acre-feet annually. DEID also contracts for 74,500 acre feet of Class 2 (less reliable) water. In an average year the district receives approximately 140,000 acre feet, providing a supply of approximately 3 acre feet per year to eligible lands.

---

[1] Professor and Director, Irrigation Training and Research Center (ITRC), California Polytechnic State University (Cal Poly), San Luis Obispo, CA 93407.

[2] General Manager, Delano-Earlimart ID, 14181 Avenue 24, Delano, CA 93215.

Virtually all of the acreage in DEID has been developed. Approximately 78% of the district is planted in permanent crops, the most prevalent being grapes. Other permanent crops include pistachios, almonds and a variety of tree fruit. Over 29 different crops are grown by DEID farmers with drip and microsprayer irrigation being very popular.

The irrigation water distribution system is entirely pipeline, with meters at each customer turnout. All pipelines receive their water from the Friant-Kern Canal; about one third of the district is uphill of the Canal, and about two thirds is downstream of the Canal. The district owns and operates 18 individual pumping plants that pressurize water deliveries where necessary throughout the district. Pumping stations range from as small as a single 5 horsepower pump to those with connected loads of over 1200 horsepower producing an annual energy consumption of approximately 4,500,000 kilowatts-hours.

PROJECT BACKGROUND

In 1994 DEID was faced with several issues that required eventual attention to water delivery modernization:

- The district watermaster had been employed at DEID for over 30 years, and was discussing near-term retirement. All of the water orders from farmers (phoned into the office 24 hours in advance) were processed by the watermaster, and he was the only person at DEID who had an idea of where the system flow rate bottlenecks were, and how to allocate water at times of congestion. All of this process was in his head.
- At some pump stations the pressure was maintained in standpipes by simply pumping more than needed so that spill always occurred. Electric power costs had increased and were expected to rise further, suggesting that perhaps a more energy efficient means of pressure control should be examined.
- Farmers in the district were rapidly converting to drip/microirrigation, and they needed a more flexible irrigation supply. In order to obtain the flexibility they needed, they were either forced to construct on-farm reservoirs (between the district turnout and their booster pumps) or use groundwater supplies. Reservoirs are expensive to construct and maintain, and a key DEID goal is to reduce groundwater depletion. Although DEID provided water on an arranged schedule (which is typically considered in the literature to be very flexible) the degree of flexibility was insufficient for progressive farmers. Turnouts could only be operated by DEID employees, preventing automation of on-farm irrigation systems. Reasons for the rigidity in operation included:
  - Historically the Friant-Kern Canal required that DEID order its water in advance and carefully adhere to its advance schedule. DEID was forced to pass this restriction on to its farmers

- The pumps which supplied some of the pipelines and district reservoirs were manually operated, and there was no way to rapidly respond to downstream demands. This is not a problem on most of the gravity-fed downhill side of the district.
- The turnout design was incompatible with flexible deliveries. The district delivers water into a district-owned open standpipe. A vertical bonnet-type propeller meter is located on the top of a discharge pipe located inside the open standpipe. All the flow control is accomplished with a valve located between the DEID supply pipeline and the open standpipe. If a farmer reduces his flow, the standpipe overflows. Also, if a DEID employee changes the flow rate at any turnout on a given lateral, the employee must cycle through all the turnouts on that lateral and adjust the turnout flows that have changed due to the new DEID supply pipeline pressure. Adjusting the flow rate at a single turnout is time consuming because an employee must adjust the flow control valve, climb a flimsy ladder to the top of the standpipe (often 10-15 feet in the air), check the flow meter reading, climb down, readjust the flow control, climb back and re-check the flow meter, etc.
- Water is sold and allocated by volume, and therefore it is important to have accurate records of turnout deliveries. Presently the propeller meter readings are recorded by hand in the field and then copied in the office.
- If there are failures at pump stations, DEID employees do not know about the failures until the impact shows up on the deliveries (i.e., when farmers call up with complaints about water shortages at the turnouts).

MODERNIZATION STEPS

Variable Speed Drives

In 1994 DEID received a low interest loan from the California Energy Commission (CEC) to install a single automated variable speed drive (VFD) controller at one of its pump stations. This first step involved the use of Programmable Logic Controllers (PLCs) to monitor water levels in standpipes and then control the speed of the pumps. From that initial installation, an additional CEC loan was obtained that funded another 5 VFD controllers at 5 other pump stations. ITRC provided technical review of the conversion and conducted an energy analysis of the operation. The introduction of the VFD controllers by themselves did not significantly impact the flexibility of water delivery since the previous control strategy utilized overpumpage and spillage of water to achieve the same result. An energy analysis showed a payback period of about 8 years for the investment.

However, this was the first "sophisticated" control adopted by DEID. The installations proved to DEID staff and board members that automation with high quality microprocessor equipment was feasible and reliable. The Remote Terminal Units (RTUs) containing the PLCs were selected so that they could eventually be tied into a Supervisory Control and Data Acquisition (SCADA) system and be monitored from the district office.

Water Delivery Flexibility from the Supplier

Because it is a goal of DEID to provide water to its customers almost “on demand”, the restrictions by DEID’s supplier, the Friant-Kern Canal (FKC), needed to be removed. DEID worked with the management of the Friant Water User’s Authority, the operators of the FKC to receive permission to deviate from a very rigid water ordering program. The Authority was able to accommodate DEID because a large regulating reservoir (Lake Woolomes) is located immediately downstream of DEID on the FKC. The FKC is also being upgraded with a new SCADA system which allows it to monitor conditions more accurately than before.

First Phase of SCADA

In 1996 DEID secured another low interest loan from the CEC to install its first SCADA system. This was installed on the "County Line Lateral" pipeline network (a.k.a. lateral 119.1E) that is uphill from the Friant-Kern Canal. The network consists of 5 pumping plants, 3 reservoirs, 12 laterals, and serves a total of about 8000 acres and 90 turnouts.

ITRC worked closely with DEID management to help the board of directors understand the function of SCADA systems, and the types of equipment which would be involved. ITRC also developed a Request for Qualifications that provided technical details about the proposed project and enabled DEID to select a group of qualified integrators[3] who were eligible for bidding on the final job. Following this, ITRC developed a Request for Proposals (RFP) and worked with DEID to explain the project to the various integrators. There was almost a 100% difference in bid prices for the SCADA system. DEID selected the lowest bidder because the equipment and specifications had been laid out in detail in the RFP.

The lowest bidder had an impressive set of qualifications on big jobs, but no experience with irrigation districts. Unfortunately, the integrator wasted time on insignificant details, such as constructing detailed and beautiful screens for the office computers while simple screens would have been sufficient. When some

[3] An "integrator" is a company that will install a turn-key project. This includes all of the hardware, software, communications equipment, etc. It is essential to provide the integrator with excellent direction. The integrator is responsible for making certain that the final project is operating according to specifications.

problems appeared, the integrator blamed the software and/or hardware suppliers, and the suppliers blamed the integrator. Sometimes the blame rightfully belonged to both parties. However, the important thing about selecting an integrator and wording the contract properly is that there should be no finger pointing - the integrator assumes full responsibility for putting the final project on-line. After the contract wording was pointed out to the integrator, the finger pointing stopped. ITRC worked with DEID management to make certain that the integrator understood the obligations. DEID's experience showed that the higher bids were probably based on more realistic cost estimates. Because of the integrator's procrastination on some items and DEID's desire to incorporate its own technician in the design and installation, a new integrator has been selected for the next phase of DEID's SCADA modernization.

ITRC recommends that all SCADA equipment be off-the-shelf and of excellent industrial quality. The software must also be standard off-the-shelf monitoring/control software such as Lookout® or Intellution®. Communications must be very reliable. Irrigation districts always want the least expensive options, and ITRC's opinion is that the least expensive option rarely occurs with the least expensive equipment. Neither ITRC nor most irrigation districts have the time to hassle with equipment that vendors might be experimenting with. Cheap and unreliable equipment has given SCADA systems a bad name throughout irrigation districts in California, and that bad reputation is now being rapidly replaced by adhering to high standards on new projects. There are always enough problems that appear even with good equipment and software, but they are not insurmountable.

The purpose of the first SCADA system was to monitor the pumping plants on the County Line Lateral. The system utilizes "distributed control", which means that the actual intelligence for control and the closed loop exists in the field. From the office operators can monitor the status of numerous items and can change controller target depths or functions. A typical pumping plant has the following items:

- RTU (Remote Terminal Unit) for pump automation. This provides the necessary on site control to stage pumps and control VFDs to maintaining necessary up-stream reservoir or standpipe level.
- Radio communication with a DEID-licensed 900Mhz system.
- Automated pump selection in the RTU for optimum energy conservation and re-start safety.
- HOA switches for on-site control of pump.
- Trash screen control where applicable.
- RTU un-interruptible power supply (UPS) for 30 minutes of off-power use.
- On-site alarm notification (lights).
- Installation of VFDs on the largest pumps in the parallel unit.

- Sensors for:
  - Pump status (on or off)
  - Power failure
  - HOA
  - Reservoir water level
  - Stand water level
  - Redundant high water sensor on reservoirs
  - Plant discharge pressure
  - Plant flow rate
  - Automatic oilers
  - VFD speed

The DEID office is equipped with three LAN networked PC computers with one running Windows® NT and Intellution® software with the primary purpose of graphical central monitoring and control of pumping plants, and related equipment. The central computer also monitors and calculates (based on pump discharge flow rate curves and regulating reservoir changes) the total flow rates being delivered in defined sections of the lateral and at each pumping plant.

The first phase of SCADA installation was completed in early 1999, and it was debugged until May 1999. DEID staff have been trained in the operation and maintenance of the system, and are pleased with its performance.

Second SCADA Implementation Phase

Now that the first phase is completed, DEID is progressing with the installation of SCADA at all key points throughout the district. In addition, the central office software is being expanded to transfer water order turnout data to the graphical lateral overview screen in the SCADA software from the DEID order software.

Water Ordering Software

Prior to the introduction of Water Ordering software at DEID the watermaster took all water orders by phone and entered them in a hand written ledger. Many district pipelines are undersized for the demands that occur in the peak part of the season, so when the watermaster took orders during this time period he made decisions of capacity based on "experience". The DEID Water Ordering software was developed by ITRC to automate the water order system, by allowing orders to be entered in a user-friendly input screen. The orders are then checked by the program throughout their order period against system hydraulics to see if sufficient pressure is available at all turnouts. The program notifies the dispatcher of the results of the check and the dispatcher can then process the order. If the order is denied (because hydraulic calculations showed a pressure below the minimum pressure requirement) then the program automatically displays a screen that shows the orders currently placed on the specified lateral for that order's time

period. This order screen helps the dispatcher make a judgment call as to when an order may be accommodated. The program also provides continual data archival, day-to-day operation reports, SCADA interface of flow rates, and user-friendly custom reports.

Program Description: The water order program for DEID has been designed to track water orders for all turnouts in the district. Written in Microsoft Access 7.0, this program consists of a large database, complete with tables, forms, and reports. The tables in the database serve the purpose of storing owner, turnout, and pipe information, as well as storing temporary information for calculations. Within these tables are various fields which range from "Turnout Numbers" to "Phone Numbers." This makes it possible to view information associated with a specific turnout, owner, or order.

The program was designed to accept any number of water orders from any turnout at any time. The orders can be made in advance with no limits, giving a farmer the ability to place orders for future water use. The program also stores orders that have already been made, giving the dispatcher the ability to analyze past orders and even print reports. These reports include:

- Month-to-date report on water usage by turnout or owner (as estimated by orders).
- Monthly totals of water usage by turnout or owner (as estimated by orders).
- Orders for any specified time period and lateral by turnout.

The program does not integrate actual turnout volumetric readings for billing purposes.

The flow charts in Figure 1 depict the program procedures and the relationship between the SCADA system and the water order program.

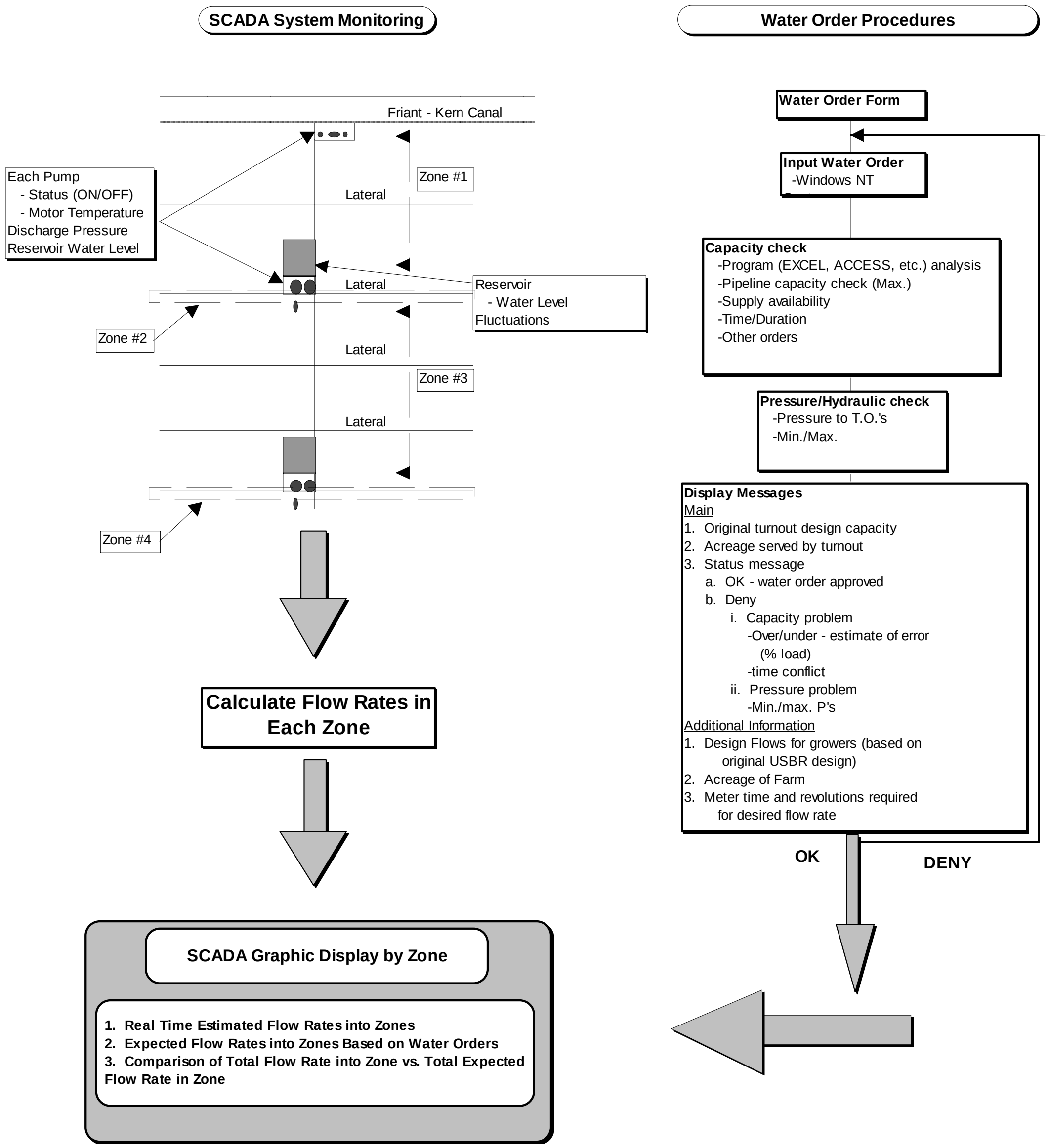

Figure 1. Flow Charts for DEID Water Order Software and Its Integration with the SCADA System.

Hand Held Data Recorders

ITRC has worked with the Mid-Pacific Region of the U.S. Bureau of Reclamation (USBR) to acquaint irrigation districts with Hand Held Data Recorders (HHDR). A HHDR is used to collect data from the field and to download that data to a database to generate reports for meters in the districts. The data can be collected intermittently or on a daily basis since these are not route based data collectors. The data is collected by means of a hand held portable unit that scans a bar code identification label that is permanently affixed to the turnout. Data is then entered by means of a keypad and the operator goes to the next meter. At the end of the

day the unit is brought back to the office and the information is downloaded into the database. This provides a quick and error-free way to enter data that is better than manually entering the information into a logbook.

The software for interpreting the data collected is written in Microsoft® Access 7.0. This program consists of a large database, complete with tables and forms. A district would be required to have Microsoft® Access 7.0 on its computer in order to run this software. The Scan-IT® System does not produce reports and is more suited to districts that can provide their own programmers to customize the software. The EasyReader® System provides reports and is more of a turnkey system and therefore costs more, but does not require nearly as much in-house expertise as Scan-IT®.

Scan-IT® licenses the use of the software, whereas EasyReader® typically sells the software. EasyReader® can also license the use of software. Both suppliers can provide customized programming of the HHDR units for input of additional items such as crop type. Typical additional programming costs are about $1000 - $2000.

Components for a typical Hand Held Data Recorder System would be:

- The portable scanning unit.
- Base or docking unit.
- Software to download/upload data and manage information.
- Meter bar code labels.

Table 1 shows typical costs for equipment and software from two manufacturers. ITRC examined numerous HHDR units and is presently recommending that districts contact these two companies. DEID has purchased 5 Scan-IT® units and has had them in use since early summer 1999.

Table 1. Comparison of a Typical 4 Unit Setup for a District with 500 Meters to Read.

Purchased from **SCAN-IT** (916)987-9880

Component	Quantity	Price
Scanning Unit	4	$5,300
Base Station	1	$481
Software	1	$2,000
Bar Code Labels	500	$395
		$8,176

Purchased from **EasyReader** (805) 650-7888

Component	Quantity	Price
Scanning Unit	4	$4,466
Base Station	1	$205
Software	1	$7,200
Bar Code Labels	500	$395
		$12,266

Redesigned Turnouts

A typical DEID turnout (TO) consists of a vertical 36” diameter concrete vertical standpipe which is buried 2.5’ below ground and extends 8’ – 12’ above ground level. Water enters the floor of the standpipe from the district pipeline through a

12" concrete pipe which extends vertically several feet from the standpipe floor. The pipe then transitions to a 2' length of 10" transite pipe (to within a foot of the top of the standpipe) containing 16" straightening vanes before finally passing through a bonnet type propeller meter. Once through the propeller meter the water spills out the end of the 10" transite pipe and into the open standpipe. The water then exits the standpipe via a 12" concrete line located 3" above the standpipe floor. The desired water elevation within the standpipe varies between the top of the TO exit pipe and the total standpipe height.

The operation of these turnouts requires considerable art. The district operators are the only persons permitted to change the flow rate. All flow rate control is done at the district inlet pipe to the standpipe. If the flow rate into the standpipe does not exactly match what the farmer is using, there will be either a deficit or excess of water. Excesses are easy to spot – the top of the standpipe overflows.

If the flow rates at any other turnouts along the supply pipeline are changed, this changes the hydraulic grade line (HGL) at all points along the supply pipeline, which results in a changed flow rate at every turnout. It takes hours for the operators to stabilize flows each day from just one set of changes.

In the past, most farmers used furrow or border strip irrigation. Although fluctuations in delivered flow rate are not ideal, these methods will continue to function if the flow rate varies slightly, or if the flow rate is not exactly what is needed. With drip and microirrigation methods, it is a completely different story. These pressurized methods have pumps that deliver specific flow rates that match the emitter discharge characteristics. The flows into the systems must exactly match what is needed; the systems cannot adjust their flows to what is being delivered. Additionally, the flow rates required by such irrigation systems can change hourly as the system filters backflush or different blocks (with different sizes) are turned on or off. The existing turnouts are simply incompatible with the modern on-farm irrigation methods which are being widely adopted in DEID.

ITRC, with initial funding by CEC and later by USBR, worked with DEID to develop some new turnout designs that would provide pressure regulation for low pressures and high flow rates. The first design to be tried is shown in Figure 2.

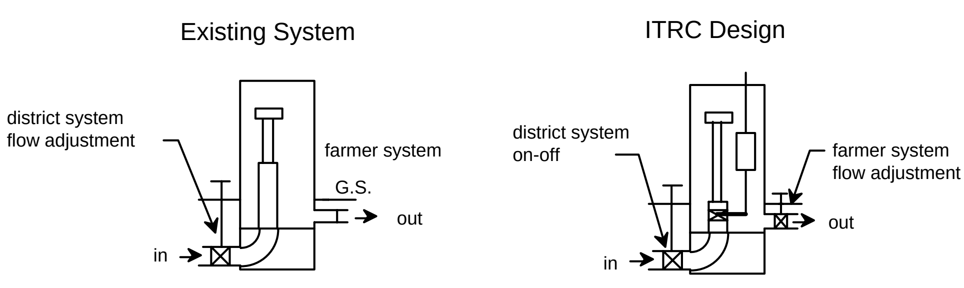

Figure 2. Existing Turnout and First Pressure Regulator Design.

The first pressure regulator design used a styrofoam float and linkage assembly connected to a butterfly valve on the vertical pipe inside the standpipe. ITRC designed a configuration with a 12”-10” reducer immediately downstream of the butterfly valve; this reducer converted the distorted velocity profile downstream of the butterfly valve into a classic undisturbed uniform pipeline velocity profile under a wide range of flows and inlet pressures.

This first design functioned very well in field tests, but it was difficult to install. DEID staff also determined that the existing district on-off valves were deteriorating, and that they needed to be replaced. Therefore, a second design that incorporates a new DEID shutoff valve and an up-and-over pipeline supply was developed and field tested. The top of the design is shown in Figure 3.

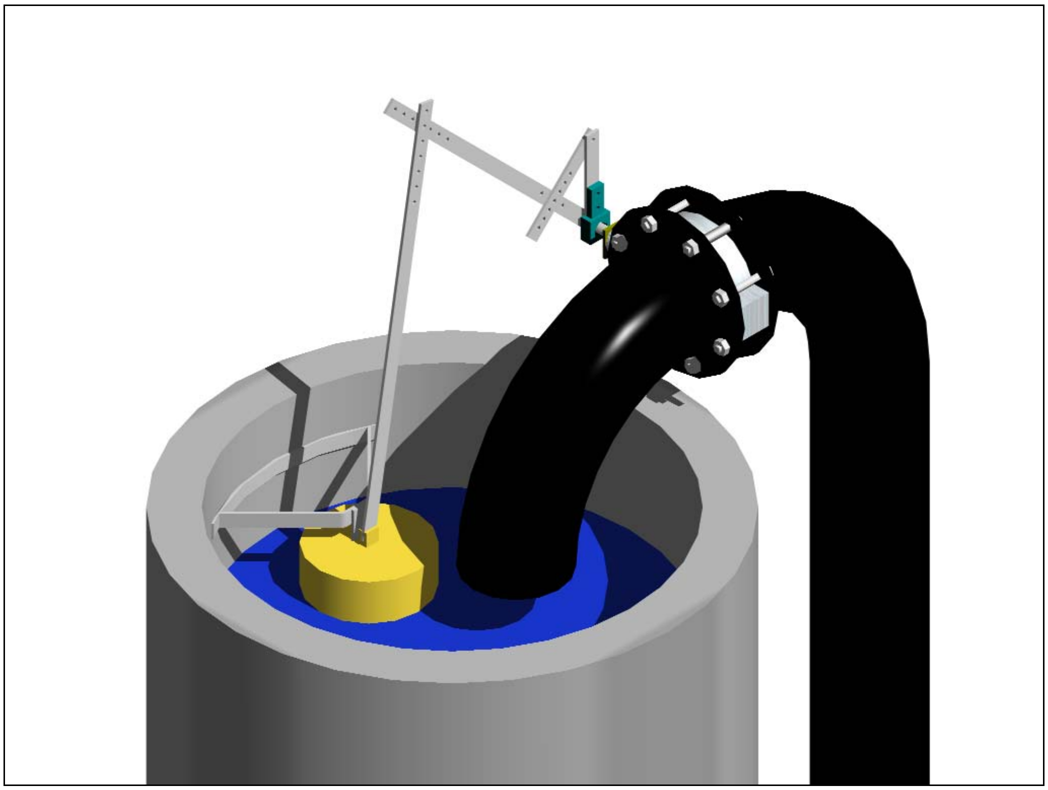

Figure 3. Present Design of an Up-and-Over Pressure Regulator for DEID.

The new pressure regulator design is easier to install and uses a new flow meter as well as a new on-off valve. The in-line propeller flow meter is installed vertically upstream of the pressure-regulating butterfly valve. This provides very easy access for meter reading; the operators will not need to climb up rickety ladders to obtain the meter readings. Several models of propeller meters were tested, including electronic meters.

If the district turnout is directly connected to a closed pipeline for a drip or microirrigation system, the open standpipe is not necessary. The pressure regulator and the open standpipe can be eliminated, with considerable cost savings. However, many turnouts are used for multiple purposes and the new turnout design will eliminate the hassles associated with the existing turnouts without eliminating the standpipes. DEID is currently planning to renovate all of its turnouts.

SUMMARY

Delano-Earlimart Irrigation District has embarked on an ambitious modernization program with the assistance of agencies such as the California Energy Commission and the Mid-Pacific Region of the U.S. Bureau of Reclamation. Cal Poly's ITRC played a key role in providing technical assistance. There was no single modernization action which was sufficient, by itself, to enable DEID to provide the farmers with more flexible deliveries. A combination of improved turnout designs (for pressure regulation and easy meter reading), a SCADA system, incorporation of Variable Speed Drives on some pump motors, improved water ordering software, and hand held data recorders will allow DEID to provide the improved flexibility with high reliability. The improved flexibility will help the farmers automate their irrigation systems, reduce district operational hassles, and reduce reliance by farmers on groundwater as a means of obtaining flexibility.