

# USCID

U.S. Committee on Irrigation and Drainage

*The U.S. Society for Irrigation and Drainage Professionals*



## ***President's Message***

Dear USCID Members,

What an inspiring and successful Fall Conference we enjoyed this year! From October 21–24 in Reno Nevada, where nearly 125 professionals gathered to explore all matters relating to irrigation and drainage. The engaging sessions, informative workshop, insightful field tour, and spirited discussions reminded us why USCID is a vital community for irrigation and drainage leaders.

A Heartfelt Thank You: Thank you to every speaker, exhibitor, sponsor, and attendee. Your shared expertise, enthusiasm, and collaboration made this conference truly memorable. Special recognition goes to our dedicated volunteers and committee members whose efforts behind the scenes ensured everything ran smoothly.

Save the Date – Fall 2026 Conference: We're thrilled to announce that USCID's 2026 Conference will be held October 20–23, 2026, at the Eldorado Resort Casino in Reno, Nevada. Please mark your calendars—we look forward to gathering in the Sierra Nevada foothills for another inspiring event.

New: Half-Day Workshop for Irrigation Districts: Building on feedback and needs from our members and attendees, we're introducing a new half-day workshop designed specifically to support irrigation district staff. This interactive session will cover practical topics—ranging from infrastructure management and regulatory compliance to workforce development and best practices. More details will be shared early next year.

*Continued on page 2*

## **2026 USCID Conference** **October 20-23 in Reno, Nevada**

Join us this fall! As details become available, we will post them on the USCID website - [www.uscid.org/events](http://www.uscid.org/events). We hope you can join us in Reno for conference activities that offer time for networking and reconnecting with colleagues!

Continued from page 1

Seeking 2026 Planning Committee Volunteers: To make this workshop—and the full conference—as impactful as possible, we need your help. If you’d like to serve on the 2026 Planning Committee, please reach out by January 31, 2026. Your perspectives and expertise are invaluable in shaping the agenda and ensuring we deliver maximum value to irrigators and district personnel.

Start Thinking About 2026 Presentations: The Call for Abstracts for our 2026 Conference will be released in early 2026, with abstract submission deadline around March 15th. I encourage you to consider submitting a proposal—whether technical research, case studies, field innovations, or policy insights. Our community thrives on your real-world experience and new ideas.

Thank you again for contributing to our shared mission of advancing sustainable, effective irrigation and drainage practices. I look forward to continuing our journey together—through volunteerism, knowledge-sharing, and community-building—over the coming year.

Warm regards,  
Therese Ure Stix  
President  
U.S. Committee on Irrigation and Drainage (USCID)

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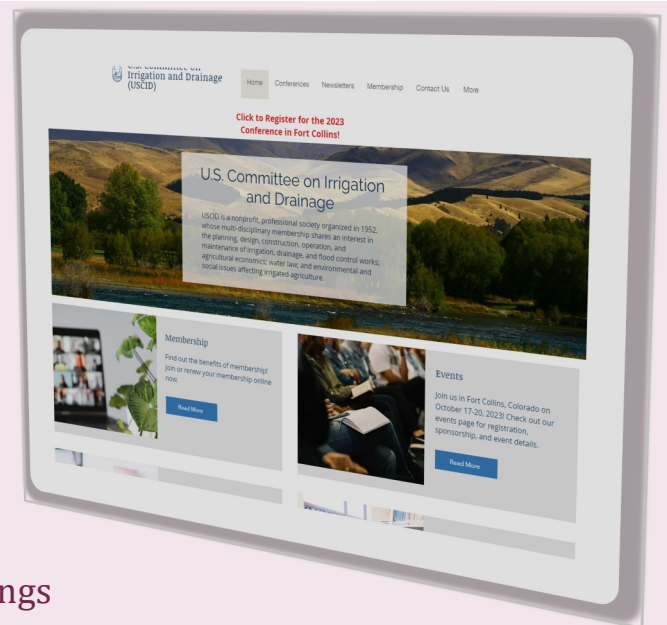
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# IRRIGATION DISTRICT PUMPING WITH VFDS

Charles M. Burt, Ph.D., P.E.<sup>1</sup>

## ABSTRACT

Irrigation district pumping plants often utilize motors plus variable drive (VFD) controllers, which enable motors to operate over a range of RPMs. Compared to municipal systems, irrigation district pumping plants often have higher flow rates with a smaller elevation lift. Compared to typical on-farm irrigation systems which are usually dependent upon an irrigation or pump dealer, irrigation districts sometimes provide specifications for procurement.

This paper discusses four related items which can be challenging in irrigation district VFD installations:

- The pumps themselves
- VFD specifications
- Control logic
- Lack of adherence to project specifications by contractors, pump manufacturers, suppliers and engineers

## PUMPS

This section will briefly discuss specific items that commonly need to be considered in irrigation district applications:

- Continuously rising pump curves
- Steep rising (to the left) pump curves
- Allowable operating range (AOR)
- NPSHr and Submergence

Irrigation districts often use pumps with relatively short pipelines, lifting from canal-to-canal, from drain-to-canal, and to/from canals and regulating reservoirs. There may be little friction – most of the pressure requirement can be for elevation lift. A manufacturer's pump curve for such a vertical pump is seen in Figure 1.

<sup>1</sup> I&D Science and Engr. Consultant. 171 Twin Ridge Dr., San Luis Obispo, CA 93405. 805-748-3863 charlesmburt@gmail.com

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## IRRIGATION DISTRICT PUMPING WITH VFDS (Continued)

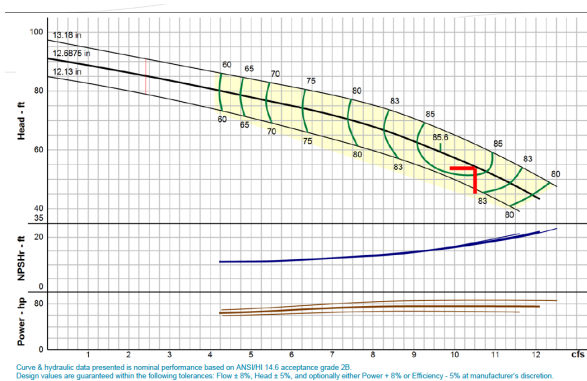


Figure 1. Example pump curve. Flow rate is CFS.

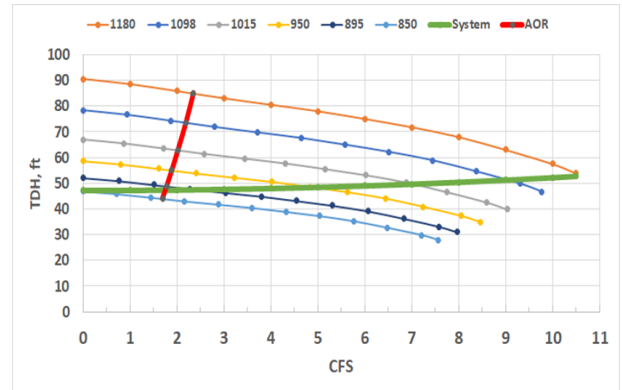


Figure 2. Anticipated operation of the pump with a VFD.

This pump was selected for an application because the curve has the following desirable characteristics:

- The efficiency is high at the maximum flow point (10.4 CFS).
- The maximum flow point occurs on the “right hand side of the efficiency curve”. With a VFD application, much of the time the pump may operate at lower flow rates so it is important to have a good efficiency over a wide range of flows.
- The Net Positive Suction Head required (NPSHr) is low at the maximum flow rate (less than 20 feet), indicating that there will be no cavitation problems unless air is entrained.
- The AOR (not labeled, but seen as a light red vertical line at about 2.75 CFS) is far to the left – indicating that the pump can operate across a wide range of flows.
- In small print at the bottom, the ANSI/HI 14.6 acceptance grade is listed. Many pumps are purchased without any acceptance grade requirement. For the acceptance grade 2B (listed on the curve), design values are guaranteed within the following tolerances: Flow  $\pm 8\%$ , Head  $\pm 5\%$ , either Power  $+8\%$  or Efficiency  $-5\%$ . In this case, the acceptance grade was changed for the final specifications.

Figure 2 shows how this particular pump should work once installed. Figure 2 adds pump curves at various RPMs, the AOR at those RPMs, and the system curve.

The system curve (thick green) is relatively flat – due to a short, large diameter discharge pipe plus no check valve (the discharge pipe drains upon shutoff), and a high lift (about 48 feet). The AOR designates the recommended minimum flow rate to be about 1.8 CFS, at an RPM of 880. The flow rate range is wide – from a minimum of 1.8 CFS to a maximum of 10.4 CFS. Furthermore, the RPM range is reasonable – from 1180 RPM to 880 RPM.

The specifications for this project included details of required materials, dimensions, and hydraulic characteristics. The contractor submitted the pump curve below:

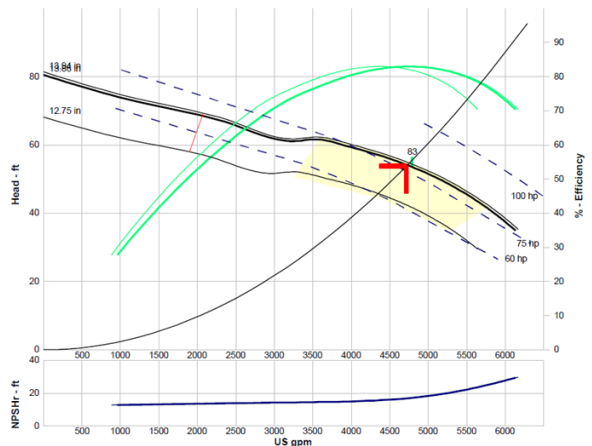


Figure 3. Curve submitted by the contractor and pump company.

The pump curve for Figure 3 was rejected for a number of reasons, including:

- The “system curve” goes through a TDH of zero, even though

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## IRRIGATION DISTRICT PUMPING WITH VFDS

(Continued)

values of the system curve were provided.

Because pump manufacturer software usually enables an engineer to show the system curve, this is a warning that perhaps the pump company representative did not understand VFD applications

- The efficiency was lower than specified, and the highest flow rate was not on the “right hand side of the efficiency curve”.
- The AOR is about 2100 GPM (4.6 CFS), rather than 2.75 on the specifications. Figure 4 shows that the AOR meets the system curve at about 3.9 CFS, compared to 1.8 CFS on the specified pump.
- The curve is too flat – which means a very small change in RPM produces a large change in flow rate.
- But the biggest problem is the “dip” in the curve, even though it was explicitly stated that no dips or flat sections were allowed on the pump curve.

Figure 4 shows that at about 1015 RPM, the pump curve crosses the system curve twice. The flow rate could violently and repeatedly shift by about 1.5 CFS, damaging the system.

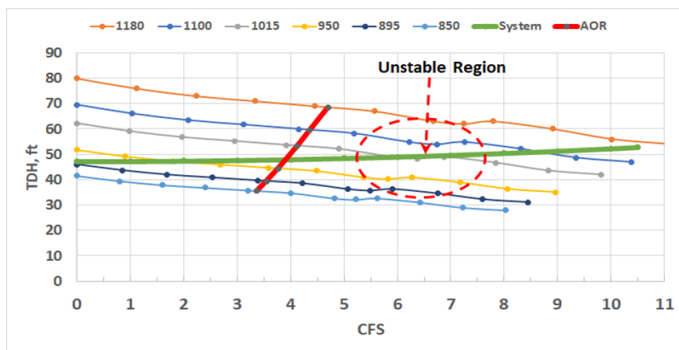


Figure 4. Predicted operation of the submitted pump in the system.

Morals of the story:

1. You can specify great performance, but do not assume that the pump suppliers will follow the specifications.
2. As an engineer, do not completely depend upon a pump company’s recommendation unless you know the person you are talking to, and have full confidence in that person’s technical abilities (related to pumps) and ethics.
3. This is not an isolated incident. I see it over and over again. Even in this case, the curve seen in Figure 1 and the associated technical specs (not shown) were the result of going back and forth with the manufacturer four times – and I began those discussions with knowledge of their curves and with very specific requests.
4. Imagine what you can get if you do not specify performance and materials details.

### VARIABLE FREQUENCY DRIVES (VFDS)

The morals of the story for VFD drives are the same as they are for pumps and motors. Rather than provide a comparison example as was done above for pumps, the following will discuss a few critical items that are often overlooked and/or under-appreciated. More details of VFD and motor specifications can be found at <https://www.itrc.org/VFD/index.html>

#### What is a VFD?

Simplistically, a “VFD controller” is a box with electronics that converts alternating current (AC), to direct current (DC), and back to a simulated AC but with a different and adjustable frequency (e.g., 45 Hz rather than the incoming 60 Hz). A motor RPM changes as its incoming Hz changes. The VFD controller requires numerous auxiliary equipment items such as enclosures, air conditioning, harmonic mitigation, and surge protection devices. The total package is a VFD system.

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## IRRIGATION DISTRICT PUMPING WITH VFDS

(Continued)

### Cooling

Overheating can be a major problem. First, the temperature rating of the VFD should be at least 50 degrees C (122 deg F). But if one considers the sum of:

- the outside air temperature,
- inefficiencies of the VFD itself,
- inefficiencies of the auxiliary protection equipment such as harmonic mitigation and surge protection,
- heating due to direct sunlight,

it should be obvious that the temperature rating can be quickly exceeded. So what can be done?

1. Specify a reasonably high (96.5%) VFD efficiency. Inefficiency shows up as heat.
2. Specify a reasonably high (93%) overall VFD system efficiency.
3. Put the heat-producing auxiliary protection equipment in a separate enclosure; the temperature rating of that equipment is typically

higher than that of the VFD. This is almost never done – not because it is bad; it is just not a common configuration and falls outside of what a supplier may think is needed.

4. If the enclosure is exposed to sunlight, paint it white and be sure that there are several inches of clear space all around the enclosure (in other words, do not hang it directly in contact with a backboard). Better yet, shade the whole unit.
5. Do NOT bring outdoor air into the VFD panel. This is common, but filters may not get changed frequently enough if at all, filters are sometimes located near the dusty ground surface, and VFD electronics are extremely sensitive to dust. Instead, use heat sinks to convey the heat outside the enclosure. But in the desert heat, relying on hot air for cooling is insufficient.

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## IRRIGATION DISTRICT PUMPING WITH VFDS

(Continued)

6. Use air conditioning on the enclosures themselves, or place the enclosures in an air conditioned building. If they are inside an air conditioned building, drawing air from within the building into the VFD enclosure and expelling it through an exhaust port is fine – assuming there are clearly marked air filters on the enclosures and replacement filter elements. An internal fan is usually needed to move the clean air through an enclosure.

### Sizing

Perhaps the second most common error is that VFD systems are under-sized. For example, a 100 HP VFD system is too small for a 100 HP motor. The 100 HP motor is based on the motor's OUTPUT HP, but the VFD must be sized large enough for the motor INPUT amps. Usually, the full load amps (FLA) listed on the nametag of a motor is used as a reference.

Although it is common to find pump motors with an overload of 5-10%, it is considered unwise to have any overload with VFD applications.

### **AUTOMATIC CONTROL OF VFD SPEED CHANGES**

VFD systems usually have a small built-in programmable logic controller that allows the user to input simple control variables. For example, the user can input variables such as the ramp time (how quickly an RPM change can be made), minimum RPM, maximum RPM, and frequency of actions. They commonly provide for a pressure transducer input so that a pump discharge pressure can be automatically measured and then maintained at a target value.

Irrigation district applications are often more complex than maintaining a pressure in a pipeline. Automation may be desired to maintain a water level in a canal, or in a reservoir. With a canal, there are other considerations such as time lag and the resonance of the canal itself – inappropriate speed changes can cause instability, with the formation of damaging waves moving up and down the canal.

To automate pumps for complex canal operation, an additional programmable logic controller is needed. The PIF (Proportional Integral with Filter) is an effective control algorithm if it is tuned properly. That tuning is done with an unsteady canal simulation program. A complete description of the PIF algorithm and the tuning is beyond the scope of this presentation. However, the specific way that pump control fits in is described as follows:

1. A canal pool that a pumping station supplies is simulated to define resonance characteristics, plus how a flow rate imbalance (into versus out of the pool) appears in the form of a water level change.
2. These two pieces of information are placed into a separate algorithm tuning program for PIF variables.
3. The result in the field is that at every control timestep, the PIF control algorithm computes if there should be a change in flow rate and its magnitude. Such a change is based on whether the water level is high or low, by how much, the direction of water level movement, and resonance characteristics of the pool.

The important point is that the control algorithm computes a required change in flow rate from the pumps. Two ways to do this are:

1. Use a flow rate meter input, and change a pump speed until the correct new flow rate is established. A problem is that most of the electronic flow meters need to average values for several minutes, whereas the control timestep is usually only one or two minutes. In other words, there is too much lag time and uncertainty.
2. Use the knowledge of the pump curves and system curves to define the relationship between a change

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## IRRIGATION DISTRICT PUMPING WITH VFDS

(Continued)

in RPM and a change in flow rate ( $dRPM/dQ$ ). Then compute the RPM change that is needed to produce the desired change in flow rate (Q).

$$\text{Change in RPM needed} = (\text{Desired change in } Q) \times (dRPM/dQ)$$

The value ( $dRPM/dQ$ ) is not constant – it will vary depending upon the pump RPM. So an equation for ( $dRPM/dQ$ ) is needed. RPM (or speed, Hz) is an output variable from the VFD controller, and it is easy to change with a PLC output to the VFD controller.

One procedure to develop the relationship of  $dRPM/dQ$  as a function of RPM is as follows:

- Looking at Figure 2 as an example, one can make a table of the flow rates (from the system curve) that will be obtained at different RPMs. Those values can then be plotted as seen below.

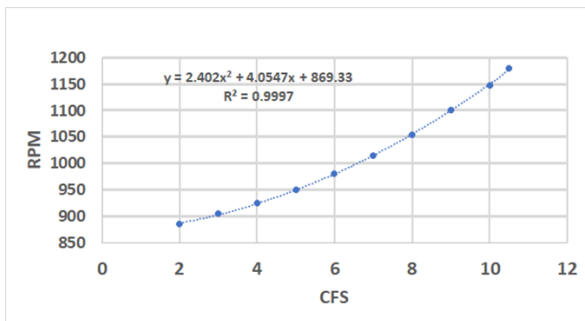


Figure 5. Relationship between RPM and flow rate of a pump with a specific system curve.

- Take the derivative of the equation in Figure 5 above.

$$dRPM/dCFS = 4.804 \times CFS + 4.0547$$

- Combine (1) and (2) to make a table with 3 columns as follows:

CFS	$dRPM/dCFS$	RPM
1	8.9	876
2	13.7	887
3	18.5	903
4	23.3	924
5	28.1	950
6	32.9	980
7	37.7	1015
8	42.5	1055
9	47.3	1100
10	52.1	1150
10.5	54.5	1177

Table 1. CFS,  $dRPM/dCFS$ , and RPM

- Plot the 2 right columns above and determine the best-fit polynomial equation.

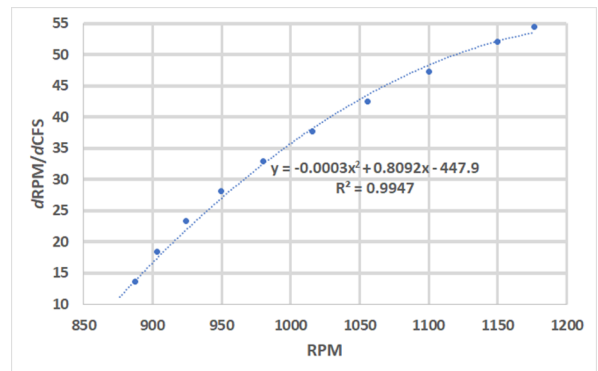


Figure 6.  $dRPM/dCFS$  as a function of RPM

- If the present pump RPM is 1000.  
 $dRPM/dCFS = -.0003(1000)^2 + .8092(1000) - 447.9$   
 $= 61.3$

If the PIF algorithm computed that a flow rate change of +0.2 CFS is needed, the required change in pump RPM will be:

$$\begin{aligned} \text{Req'd change in RPM} &= dRPM/dCFS \times (\text{Req'd change in CFS}) \\ &= 61.3 \times 0.2 \text{ CFS} \\ &= 12.3 \text{ RPM} \end{aligned}$$

The required change in RPM for a pump depends upon the RPM of the pump at the moment – just as a required movement for a cross regulator (check structure) gate depends upon position of that gate opening.

# Application of Hard Armor Geomembrane Backed Geosynthetic Cementitious Composite Mats (GCCMs) Canal Liner to Reduce Water Loss and Prevent Erosion in Existing Earthen Irrigation Canal

Nathan Ivy<sup>1</sup>

## ABSTRACT

Irrigation districts are comprised of a network of canals constructed of materials from geomembranes to concrete to shotcrete and simply earthen canals. As water scarcity and population increase, so does the need to protect water resources. This is particularly important across the western states where rainfall can average as little as 13 inches per year. Earthen canals are subject to damage from wind and water erosion in addition to burrowing animals which can compromise a containment structure. This paper reviews the application of a thermally bonded geomembrane backed Geosynthetic Cementitious Composite Mats (GCCMs) as a low permeability liner for irrigation canals to mitigate water loss and damage. GCCMs are a well-established material technology within storm-water drainage and erosion control applications. Irrigation canals require a more robust solution to provide the level of impermeability and protection that is required for these applications. GCCM rolls were typically narrow and may not include a geomembrane backing. Because concrete alone is porous and subject to cracking; a GCCM with a geomembrane backing that could be thermally bonded was necessary to not only prevent water from permeating through the GCCM itself but to also minimize permeation through the seams. GCCMs are defined by ASTM D4439–20 ‘Standard Terminology for Geosynthetics’ as factory-assembled geosynthetic composites consisting of a cementitious material contained within a layer or layers of geosynthetic materials that becomes hardened when hydrated. This paper explores key material characteristics of GCCMs pertinent to the lining of irrigation canals including the accommodation of differential ground movement, damage from burrowing animals and the importance of conformance to ASTM standards and the determination of permeability to liquids of a thermally bonded GCCM with a polymeric backing. Specifically, this paper provides analysis of a hard armour canal lining for the Middle Rio Grande Conservancy District (MRGCD). The total earthen canal section being lined in this phase is about 6,800’ of of the Socorro Main Canal near Albuquerque, NM. The original section was lined with 6” reinforced shotcrete. For the new section they decided to line half – 3,424 lf – with traditional 6” reinforced concrete and half with geomembrane backed GCCM. The paper also covers general installation processes of GCCMs versus

traditional membrane and shotcrete solutions and reviews financial and time savings realized by using GCCM in place of conventional shotcrete lining.

## INTRODUCTION

Albuquerque NM averages less than 9” of rainfall annually. The MGRCD is responsible for constructing and maintaining a large network made up primarily of earthen canals. The water transported by these canals is vital for the local agricultural land – growing crops and raising livestock – and for human existence within any environment. Irrigation canals have played an important role in maintaining and transporting water through arid regions for thousands of years. The ancient Romans constructed aqueducts to transport water from where it was to where it was needed. Since that time, there have been significant advancements in canal construction, but largely, they remain unlined, earthen canals. The first material used to line canals was concrete, whether pour-in-place or shotcrete. This material was very strong, but also very brittle; in some cases, the concrete would be cracked and seeping only a few years after it was constructed. Concrete alone is susceptible to differential settlement resulting in cracking and eventual water loss and undermining. The next advancement in canal construction was geomembranes. These materials were flexible and water tight, but susceptible to damage from animals, debris and storms. Both products are effective, at least initially, in protecting water resources, but both are susceptible to damage and seepage losses, especially when used independently of each other. The USBR published the results of their 25-year durability report on a variety of canal lining solutions<sup>1</sup>. The study concludes that a geomembrane overlain by concrete provides the longest lasting protection. This paper discusses geomembrane backed GCCMs that impart both a geomembrane – that can be thermally bonded – and a high strength concrete layer into a single product to provide an estimated lifespan in excess of 50 years when

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*Continued on next page*

## Application of Hard Armor Geomembrane Backed Geosynthetic Cementitious Composite Mats (GCCMs) Canal Liner to Reduce Water Loss and Prevent Erosion in Existing Earthen Irrigation Canal (Continued)

designed and installed properly. It will provide a brief history of the current ASTM standards that are available for specifying GCCM and will focus on a case study of a canal over 1/2 mile long where it was successfully installed and greatly reduced water losses and canal damage at less than half the cost of what conventional concrete would have cost and installed in half of the time.

### HISTORY OF GCCMs

The newest class of geosynthetics, now known as GCCMs, were first developed in the UK in 2005. Their initial use was as emergency humanitarian aid shelters. As the manufacturing process evolved, mass production began in 2009 for use in erosion control applications. Because they are a new class of geosynthetics, many existing ASTM test standards were not appropriate to test material that, as installed, is pliable, but ends up hardened after it is hydrated and cured. Much work has been done since those early days to develop test standards to support specifying this material. ASTM D8364 “Standard Specification for Geosynthetic Cementitious Composite Mat (GCCM) Materials” is the overarching test standard (Table 1). The standard defines three types of GCCM, Type I, II and III. They vary by compressive strength and required values for the prescriptive test properties. The application (weed suppression, erosion control, water conveyance) and site-specific conditions (soil type, slope angle, water velocity) determine the best type of material to use for a specific project. The standard recommends that a Type II GCCM be used for water conveyance applications. Each type of GCCM is further defined by flexural strength and tensile strength among other important characteristics. Currently this is the only recognized test standard for specifying GCCM so it is important to ensure any GCCM used on a project meets or exceeds all of these requirements. ASTM D8173 “Standard Guide for Site Preparation, Layout, Installation and Hydration of GCCMs” is also available to guide first time specifiers in how to ensure a quality installation. Additionally, there are various training resources online from a variety of manufacturers.

Property	Test Method	State of GCCM	Minimum Values		
			Type I	Type II	Type III
Thickness	D5199	uncured	4.5 mm	7.0 mm	
Mass per Area	D5993	uncured	6.5 kg/m <sup>2</sup>	10.5 kg/m <sup>2</sup>	
Density	D5993	uncured	1250 kg/m <sup>3</sup>		
Flexural Strength (cured 24 hr)	D8058	initial load	625 N/m	1500 N/m	3450 N/m
		initial flex strength	3.5 MPa		
		final flex strength	4.0 MPa		
Compressive strength	D8329	cured 28 days	40 MPa	50 MPa	60 MPa
Pyramid Puncture	D5494	cured 28 days	2 kN	3.5 kN	4.5 kN
Abrasion	C1353	cured 28 days	0.3 mm		
Tensile Strength	D4885	uncured	8 kN/m		
		cured 28 days	3.5 kN/m	6.5 kN/m	9 kN/m
		cured 28 days	10 kN/m	19 kN/m	
Freeze-Thaw	C1185	cured 28 days	>80%		

Table 1. ASTM D8364 Requirements<sup>2</sup>

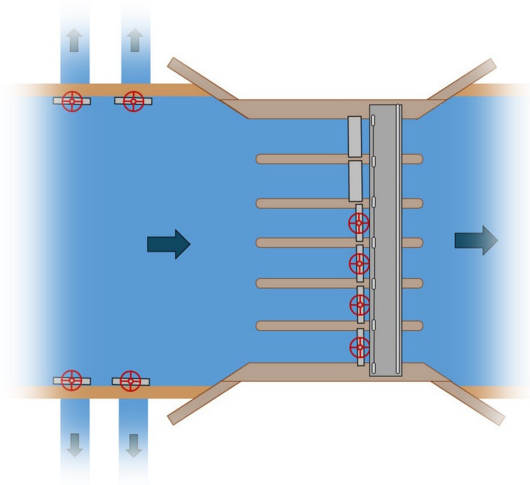
### JOINTING METHODS

There are different ways to join panels of GCCM. The best method depends on the project application and expectations. Far and away, the most common method is using stainless steel screws at 4-8” centers to join the seams. This joint is not meant to be impermeable, but is used for slope protection applications or for water conveyance applications where water is expected to be present only when flowing during storm events, for example. The water will be flowing over the seam and not back up into the seam. This method is also useful in areas of high hydrostatic uplift. In locations with high water tables, this approach allows seepage through the joints without exerting pressure on the joints which could cause damage to the joints or the material itself. This method also allows recharge by allowing water to seep from the channel back into the ground if that is desired.

For applications where the lowest permeability is required and hydrostatic uplift is not an issue, thermally bonded seams is the preferred jointing method. In areas where hydrostatic uplift is a concern, the engineer must consider a French drain system, weep holes, one way pop-up valves, or other means whereby to decrease the uplift pressure. If such pressure is allowed to build up under the system, it could compromise the system. With thermal bonding, the bottom of the top layer is bonded to the top of the bottom layer. This can be performed with standard thermal bonding equipment used for other types

*Continued on page 16*

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- Automated
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  - Flow control without level overrides
  - Flow control with level overrides
  - Lateral flow control

### Why use FLUID?

- Developed from decades of ITRC research and field experience with canal control.
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- A separate, future control package will include pump control. Look for that package in late 2025 or early 2026.

01/29/2025

### Contact

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**Application of Hard Armor Geomembrane Backed Geosynthetic Cementitious Composite Mats (GCCMs) Canal Liner to Reduce Water Loss and Prevent Erosion in Existing Earthen Irrigation Canal**  
(Continued)

of geosynthetics though an automated Leister Unidrive hot air welder is the preferred equipment to use. Although GCCMs are innovative, their installation and specification are similar to other conventional geosynthetics. The same stainless-steel screws are then used on the thermally bonded seams at 4” centers to account for any drying shrinkage and to provide the strongest, lowest permeability joint available.

**LOWER MIDDLE RIO GRANDE CONSERVANCY DISTRICT—SOCORROS CANAL SECTION (MRGCD) CASE STUDY**

In 1923 the New Mexico Legislature passed the Conservancy Act. At the time of its creation, the flow of the Rio Grande fluctuated dangerously and unpredictably. Sedimentation in the river caused it to flow wider and shallower than it had been. By 1935 they had 231 miles of canal in their system. Today, their system consists of 1,200 miles of water conveyance canals. Agricultural production resulting from water provided by the canal system is estimated to be as much as \$70,000,000 per year.<sup>3</sup>

Because this region is arid, agriculture would be very difficult without the water supplied by the irrigation district. Much of their existing canal infrastructure consists of earthen canals. The earthen canals demonstrate problems with seepage, erosion, vegetation growth, and burrowing animals, requiring significant ongoing maintenance activities.

Different options were considered for lining the canals. Among the options considered were 6” of reinforced shotcrete as used in the prior year’s construction and geomembrane backed GCCM. As with most irrigation districts, there is a relatively short window when such maintenance can be done. Normally maintenance is performed in the winter when agricultural production is minimal. The district was allowed to shut the canal down from late November to mid-February. Ultimately, a Type II GCCM was chosen for the rehabilitation of half of the existing earthen canal. The GCCM offered many advantages over the other options. The material was more cost effective than other alternatives, in part, because the district personnel could install the material themselves without the need for outside contractors. Using outside contractors would have added a level of complexity

for scheduling which meant the GCCM solution could be installed on a much tighter timeline and return the canal to operation more quickly. The GCCM that was chosen is able to withstand differential settlement of 12% or more without compromising the integrity of the containment solution, the 12 mil LLDPE geomembrane which provided the impermeability, would not be impacted by this level of settlement.

Table 2, is a summary of observed strain and tensile strength for CCX. When the layers above the LLDPE backing rupture, this indicates the point at which the LLDPE backing is compromised.

Product Type	Direction	Mean Geomembrane Failure Indicators	
		Final Failure Strain (%)	Ultimate Strength (lbf/in)
CCX-M™	MD	12.8	200
	CD	15	130

Table 2. Average strain and tensile strength for CCX-M.



Figure 1. Vegetation damage to the canal and condition of the canal prior to final earthwork preparation.

*Continued on next page*

## Application of Hard Armor Geomembrane Backed Geosynthetic Cementitious Composite Mats (GCCMs) Canal Liner to Reduce Water Loss and Prevent Erosion in Existing Earthen Irrigation Canal (Continued)



Figure 2: Subgrade being compacted and profiled for installation of GCCM and deployment of first rolls of GCCM into the canal.



Figure 3: Ladders were used on long slopes to allow construction personnel to safely thermally bond the material and install the screws.

As mentioned earlier, the USBR study indicated that a geomembrane overlain by concrete is the best solution for lining canals. This product offered a 2-in-1 solution – geomembrane and concrete. Another important consideration was the design life. While the MGRCD was struggling with maintenance issues, the expected design life of the GCCM that was chosen is in excess of 50 years.

The material was thermally bonded and the seams screwed together with stainless steel screws. Normally, the recommendation is to hydrate all material that is installed in one day at the end of the day's construction activities. Because this installation was performed in the winter in NM when nighttime temperature could fall below freezing for several hours, the

material was hydrated first thing in the morning and covered with clear plastic sheeting. The darkened color of the GCCM absorbed solar radiation which heated the material and allowed for proper curing to take place during the day. Care must be taken to ensure rainfall is not expected overnight, but winter conditions in NM were such that there was brilliant sunshine during the day and no precipitation at night. If partial pre-hydration were to occur, the upper most part of the concrete layer would cure, leaving concrete powder between the cured layer and the underlying geomembrane. While the entire layer would eventually cure, during that time, the GCCM would not exhibit the strength or durability of a fully hydrated and cured GCCM that was expected. This was a challenging installation. The slopes were long and in some cases steep. Much

*Continued on next page*



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# Application of Hard Armor Geomembrane Backed Geosynthetic Cementitious Composite Mats (GCCMs) Canal Liner to Reduce Water Loss and Prevent Erosion in Existing Earthen Irrigation Canal

(Continued)

of the thermal bonding had to be done from ladders to assure the safety of the construction personnel. These considerations caused construction to move more slowly in some areas. Even with these tough site conditions, a total of 215,000 SF of GCCM was installed from late December to early February. The installation rate averaged just over 6,000 SF per day.

## SEEPAGE TESTING

While seepage testing was not performed on this site, testing done at another site demonstrated that a reduce in seepage of more than 96% can be achieved using a thermally bonded GCCM. This results in significant saving to both the irrigation district and the end user.

## RESULTS AND DISCUSSION

The irrigation district realized immediate savings in water loss as a result of the hard armour, geomembrane backed GCCM installation. The chosen GCCM has been tested for resistance to burrowing animals and shown to be resistant to any damage including moles, rats, ground squirrels, beavers and badgers. The client had originally used 6" of shotcrete to line a section of the canal during the previous shut down from November 2023 to February 2024. They were anxious to give GCCM a try for the next section. Because it was a new technology, they split the second phase between 6" shotcrete previously used and the geomembrane backed GCCM. The client indicated that the GCCM section was completed at less than half the of the shotcrete section. In addition to financial benefits, the geomembrane backed GCCM section was installed in half the time.

## CONCLUSIONS

The District was faced with a problem of maintenance headaches and water loss from the earthen canals. This lost water represents lost revenue that could be gained from selling this water. They reached out to different vendors for a solution to their problem. They were constrained by installation window of the scheduled shut down as well as cost and ease of installation. This geomembrane backed GCCM solution provided both the durability of a concrete surface and the impermeability of a geomembrane backing. It allowed for faster installation and allowed them to stretch their available budget to line more of the canal for less money. The USBR decided a long time ago that a combina-


tion of geomembrane and concrete is the best long-term solution for canal lining – one that provides the longest life – up to 50 years in water conveyance application – resistance to burrowing animals, the lowest seepage and the best protection for water conveyance. The lining of canal assets protects residents and farmers from issues related to water scarcity.

## ACKNOWLEDGEMENTS


We appreciate the support of Angel Madera, Engineer I, MRGCD. He had this to say about the installation: "This is the first time the Middle Rio Grande Conservancy District (MRGCD) has used CCX-M® for a channel lining project of this magnitude. MRGCD is very pleased with the constructability and ease of installation of CCX-M®. MRGCD has a construction season open from November to the end of February, giving contractors limited time to complete construction projects. This 2024/2025 off-season our contractor was able to line around 3,424 feet of our Socorro main canal and we were able to return the canal to operational use in time for irrigation season. We are currently and will continue monitoring the CCX-M® sections as the irrigation season continues, but so far, the material is holding up well and looks great. MRGCD plans to continue to use the product to line more of our irrigation canals within the Middle Rio Grande. I would recommend other irrigation districts try out this material within their irrigation facilities"

## REFERENCES

- <sup>1</sup> Baumgarten, B. (2019). Canal Lining Demonstration Project – Year 25 Durability Report. US Department of the Interior Bureau of Reclamation
- <sup>2</sup> ASTM D8364-21, "Standard Specification for Geosynthetic Cementitious Composite Mat (GCCM) Materials", American Society of Testing and Materials
- <sup>3</sup> [www.mgrcd.com/history](http://www.mgrcd.com/history) website




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# Designing Suitable Ratio Feedback Control Systems to Control EBID Main Canal Reaches

Blair Stringam<sup>1</sup>

## ABSTRACT

A series of hydraulic models have been developed for the Elephant Butte Irrigation District (EBID) main canal to evaluate water feedback control methods for best water delivery performance. The goal of this work is to evaluate feedback control methods that deliver accurate water orders to the water users in the district. Ratio control has been investigated to evaluate the accuracy of water deliveries. In order to evaluate the ratio feedback method, adequate control gains must be determined for the controller designs. Two feedback control gain design methods were assessed in this paper Ziegler – Nichols and bump tuning. These two methods were evaluated based on their ability to adequately handle canal system changes and accurately deliver water orders as well as the time and ease at which these methods were implemented. It was determined that the Ziegler – Nichols method was better for selecting feedback gains for optimal performance but this method would take more time to determine in the field. Bump tuning would require less time to develop in the field but the feedback control gains were less optimal for system performance.

## INTRODUCTION

In the US and around the world irrigation districts and water supply organizations work to provide water at the right time and in the correct quantity for their water users. Many of these organizations use canals or river channels to provide the needed water which makes the delivery task difficult because of open channel travel time delays. Sediments and weed growth further complicate the delivery process by changing travel times.

Water managers are often under a great deal of pressure to make timely and satisfactory water deliveries to the water user. These managers frequently deal with delivery delay problems by sending more water than is required which wastes water. Considering that water is a limited resource in New Mexico and in many locations throughout the world, wasting the resource is not an acceptable option. A technology that helps water managers provide accurate water orders in a timely manner while limiting waste is

needed. Agriculture is the highest consumer of diverted water and reducing water losses will make more water available for irrigation as well as other water uses.

This paper focuses on ratio feedback control to operate open channel water conveyance systems for accurate and timely water delivery. The control method is designed to provide downstream water level control. Ratio control is similar to proportional integral control which will be explained later.

Designing a controller that operates one or two reaches in series is not difficult, but the majority of canal supply networks are made up of multiple reaches in series. When multiple reaches are connected in series, the control difficulty increases. As water has to travel from reaches in the upstream end of the network down to the lower reaches, the system response time increases.

Numerous downstream control schemes have been developed for canal automation systems. A number of these schemes implement the use of proportional integral (PI) control methods. For example, Van Overloop et al. (2005) present a technique that can be used to tune PI controllers. This control method accounts for interactions between pools and changing flow conditions in the canal. Clemmens and Schuurmans (2004) also present a method for tuning downstream PI controllers. Clemmens and Wahlin (2004) examine the performance of PI controllers on the ASCE test canals. Baume et al. (1999) discuss optimization techniques for tuning PI canal controllers. Litrico et al. (2007) present a method called Auto Tune Variation (ATV), to automatically tune decentralized PI controllers for irrigation canal pools.

Burt and Piao (2002) discuss the difficulty of tuning PI controllers for irrigation canals using trial-and-error techniques. Basically, even when this process is done in a systematic manner, the process can take a long time. Interactions between canal pools require simultaneous tuning of all the controllers. Skertchly and Miles (1994) discuss a method for tuning proportional integral derivative controllers for irrigation canals using trial-and-error techniques as

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## Designing Suitable Ratio Feedback Control Systems to Control EBID Main Canal Reaches (Continued)

well.

Wahlin and Clemmens (2002) also used PI controllers to operate a series of canal reaches. The PI controller is tuned by using trial-and-error techniques for one reach, then an additional reach is added to the system. At this point, the controllers have to be adjusted so that they do not interfere with the operation of each other. This process continues as each additional reach is added. The task is time consuming and less-than-optimal gain constants usually result.

Many water supply organizations have invested in and installed automation equipment to limit water losses. This equipment mainly consists of water level sensors, gate position sensors, motor-powered gates, computer monitoring and communication equipment. This helps reduce water losses, but the control system has limited intelligence and provides little more than remote control operations. If a feedback control algorithm such as a ratio controller is programmed into the automation system, water can be monitored continuously, and timely changes can be executed that reduce water losses and conserve water.

In this work, ratio controllers are designed to maintain the downstream water level for a series of canal reaches that are modelled from the EBID main canal system. As with any control method, the controller design requires tuning to provide optimal behavior. Tuning can take considerable amounts of time to provide optimal behavior. This work will look at two tuning methods to evaluate their effectiveness for ideal control behavior. These methods are the Ziegler-Nichols (Ziegler and Nichols, 1942; Parr, 1989) and the bump tuning (Cooper, 2006) methods. These controllers will be designed to conduct local control on each canal reach.

Tailoring a controller design for a canal reach in the field is the most desirable, because the best optimal response is achieved when this is done. However, water travel time and control system noise can complicate the design process. This work will look at modelling the canal system and evaluate the feasibility of designing a controller in the field.

The ratio feedback control equation is derived and explained by Stringam and Wahl, (2015). The equation

takes the following form:

Where  $\Delta g_p$  = change in gate position;  $K_r$  is the ratio control gain;  $g_{pp}$  = present gate position;

$$\Delta g_p = K_r \left( \frac{p g p}{p w l} \right) e + K_i \Sigma e \quad (1)$$

and  $pwl$  = present water level;  $K_i$  integral gain;  $e$  = the control error or difference between the control setpoint and the present control variable value. It should be noted that this equation is similar to the proportional integral control equation except for the  $g_{pp}/pwl$  component. This component allows for the ratio gain portion of the control equation to adjust throughout operation range of the ratio controller. This component helps to speed system response (Stringam and Libbin, 2019).

When the bump tuning method is used for controller design, a small flow increase (bump) is sent down the canal reach. As the downstream depth responds to the bump a number of measurements are taken to tune the controller. Initially, a time constant ( $\tau_p$ ) must be derived. The following equation is used to determine the time constant:

Where  $\tau_p$  is the time constant;  $t_{63.2}$  is the time where the output value has reached 63.2 percent

$$\tau_p = t_{63.2} - t_{ystart} \quad (2)$$

of the output change;  $t_{ystart}$  is the initial start time of the output change. A second relationship is also required:

Where  $\theta_p$  is the system dead time;  $t_{Ustep}$  is controller output step or start time. An additional

$$\theta_p = t_{ystart} - t_{Ustep} \quad (3)$$

relationship is defined by the following equation: Where  $K_c$  is the steady state process gain;  $\Delta y$  is the change in the system output and  $\Delta u$  is the

$$K_c = \frac{\Delta y}{\Delta u} \quad (4)$$

*Continued on next page*

## Designing Suitable Ratio Feedback Control Systems to Control EBID Main Canal Reaches

(Continued)

change in the system input. The variables from the previously defined relationships in equations 2 through 4 are used in the following equation:

$$K_r = \left(\frac{1}{K_c}\right) \left(\frac{\tau_p}{\theta_p + \tau_c}\right) \quad (5)$$

This

equation helps to determine the ratio gain  $K_r$  and the factor  $\square_c$  is determined from the larger of  $0.1\square_p$  and  $0.80\theta_p$  (Cooper, 2006). The integral gain ( $K_i$ ) is determined by the following:

$$K_i = \frac{K_r}{\tau_p} \quad (6)$$

Figure 1 demonstrates how the bump tuning values are derived.

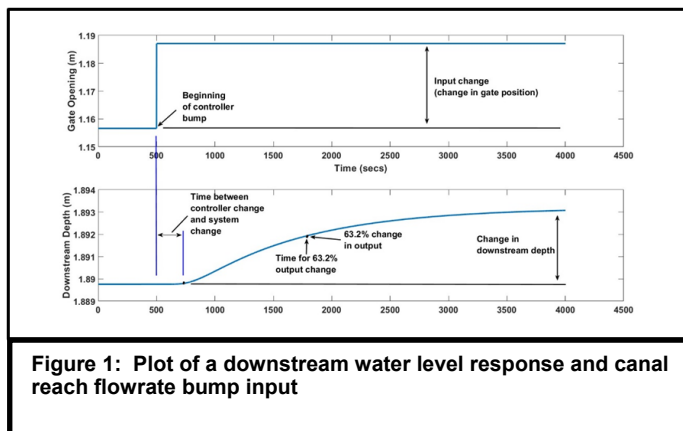


Figure 1: Plot of a downstream water level response and canal reach flowrate bump input

Ziegler and Nichols (1942) describe a tuning method that provides optimal gains for a PI controller, but in this case the method is used to provide gains for a ratio controller. This is accomplished by turning off the  $K_i$  gain and adjusting the ratio gain until the system is forced to oscillate at a resonant frequency (Figure 2). When resonance is achieved, the corresponding gain is called the ultimate gain ( $K_u$ ). The time between oscillation peaks is measured to determine the ultimate time period ( $T_u$ ).  $K_u$  is multiplied by 0.45 to determine the ratio gain  $K_r$ . The integral gain is determined by dividing  $K_u$  by the ultimate time period and multiplying the result by 0.54.

## METHODS

As mentioned before, canal reaches have long delay times and designing a feedback control system for a canal in the field can take a lot of time and produce unacceptable fluctuations. So, the canal reaches were modelled using an explicit differencing method that is reported by Akon (2006). These canal systems were programmed and modeled in Matlab. Multi-reach models were created for the EBID main canal. The modeling parameters for the EBID canal are reported in table 1. The feedback control gains that were determined for the models, were programed into the model and tested for their performance.

Table 1. Dimensions for the 8 reaches of the Elephant Butte Irrigation supply canal.

	Length (meters)	Roughness	Side slope	Bottom width (meters)	Slope
Reach 1	1023	0.026	1.5	7.6	0.0005
Reach 2	1951	0.026	1.5	10.7	0.00026
Reach 3	1223	0.026	1.5	7.9	0.00026
Reach 4	1205	0.026	1.5	6.4	0.00026
Reach 5	1200	0.026	1.5	5.2	0.00026
Reach 6	3659	0.026	1.5	6.1	0.00026
Reach 7	1968	0.026	1.5	5.1	0.00026
Reach 8	1223	0.026	1.5	5.1	0.00026

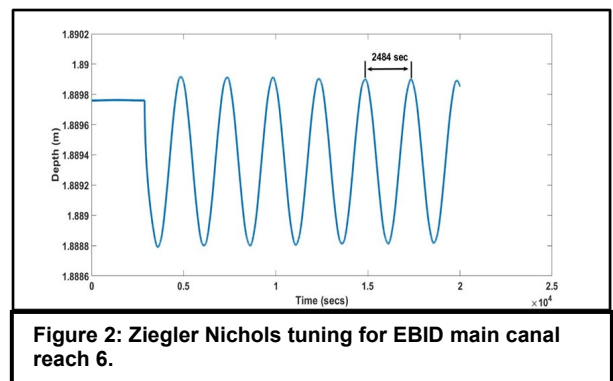


Figure 2: Ziegler Nichols tuning for EBID main canal reach 6.

It should be noted that the gains for the EBID canals were determined for a high flow where the discharge into the first reach is  $10.19\text{ m}^3/\text{s}$  (360 cfs). All of the reaches in the model used a downstream depth of 1.89 m (6.2 ft) for a control setpoint. If the design flowrates of the canal reaches or the water depths changed, these design gains would be less optimum. This is especially true with PI controllers but the

Continued on page 24

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## Designing Suitable Ratio Feedback Control Systems to Control EBID Main Canal Reaches (Continued)

(pgp/pwl) component in ratio controllers provide an adjustment if control parameters change. No matter what controller is used, a good controller design at the least, requires a review of the upper and lower operation ranges to make sure the controller provides acceptable performance throughout the operation range. A flowrate of 4.53 m<sup>3</sup>/s was diverted into the first reach for the low flowrate test.

Both bump tuning and Ziegler – Nichols methods provide a design technique that helps to reduce the time it takes to tune the controllers so that near optimal performance can be realized. The K<sub>r</sub> and K<sub>i</sub> gains for both tuning methods for the first 8 reaches of the EBID main canal are recorded in Table 2. As the gains for both bump and Ziegler – Nichols tuning were compared, bump tuning tends to have less aggressive values for the ratio as well as the integral gains. The EBID high flowrate model was programmed with the feed back control gains and subjected to a water offtake schedule shown in Table 3. A EBID low flowrate model was also programmed and subjected to the offtake schedule reported in Table 4.

Table 2. Initial Bump Tuning and Ziegler Nichols gains for the EBID canal model.

	Bump Tuning		Ziegler Nichols Tuning	
	Ratio Gain	Integral Gain	Ratio Gain	Integral Gain
Reach 1	6.83	0.0059	5.13	0.004
Reach 2	3.93	0.002	9.18	0.0055
Reach 3	2.17	0.0025	8.55	0.0069
Reach 4	0.54	0.00142	10.44	0.0081
Reach 5	1.56	0.0025	9.9	0.008
Reach 6	4.62	0.0019	17.91	0.0087
Reach 7	2.26	0.002	13.77	0.0089
Reach 8	0.37	0.0011	10.4	0.0081

Table 3. Reach inflows and offtake discharges for the EBID main canal high flow test.

Reach	Reach Inlet Discharge	Offtake Discharge	Offtake Discharge 4 hours	Offtake Discharge 12 hours
1	10.19 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s
2	10.19 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
3	9.63 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
4	9.06 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s
5	8.5 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
6	7.93 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.85 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
7	7.93 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s
8	7.65 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.85 m <sup>3</sup> /s	0.85 m <sup>3</sup> /s

## RESULTS

The EBID high flowrate test (Figure 3) shows the response for both the bump and the Ziegler – Nichols tuned examples. It should be noted that initially the bump tuned model K<sub>r</sub> values were not large enough for a desired response so the K<sub>r</sub> values for each reach were increased by a value of 10. On the other hand, the K<sub>i</sub> values for the Ziegler – Nichols controllers were too large and were divided by a value of 12.

Table 4. Reach inflows and offtake discharges for the EBID main canal low flowrate test.

Reach	Reach Inlet Discharge	Offtake Discharge	Offtake Discharge 4 hrs	Offtake Discharge 12 hrs
1	4.53 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s
2	4.53 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s
3	3.96 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
4	3.96 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
5	3.68 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
6	3.40 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s
7	3.40 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s
8	3.11 m <sup>3</sup> /s	0.57 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s	0.28 m <sup>3</sup> /s

Even though there is some additional adjustments to the control gains, the bump tuned controller exhibits slightly larger fluctuations. This is an indication that some or all of the K<sub>r</sub> gains should be adjusted. The Ziegler – Nichols controller shows a longer time for returning all the way to setpoint. The controller for reach 6 seems to have the greatest difficulty to return to setpoint. In this case, the K<sub>i</sub> gain likely needs additional adjustment.

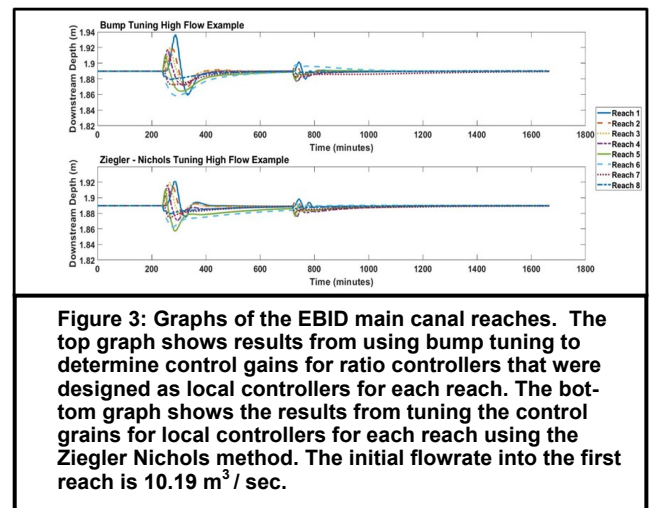


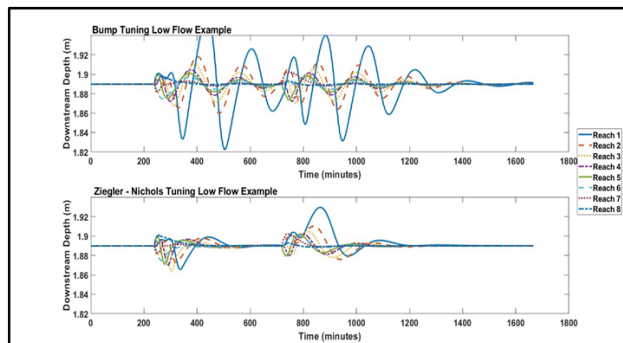
Figure 3: Graphs of the EBID main canal reaches. The top graph shows results from using bump tuning to determine control gains for ratio controllers that were designed as local controllers for each reach. The bottom graph shows the results from tuning the control gains for local controllers for each reach using the Ziegler Nichols method. The initial flowrate into the first reach is 10.19 m<sup>3</sup>/sec.

Continued on next page

## Designing Suitable Ratio Feedback Control Systems to Control EBID Main Canal Reaches (Continued)

The low flowrate condition was tested using the gains that were determined for the high flowrate canal model. The results indicate that the control system is not responding as desired (Figure 4). The bump tuned controllers are showing more of an oscillatory response while the response from the Ziegler – Nichols controllers is more acceptable. The Ziegler – Nichols tuned controllers do exhibit larger deviations when compared to the high flowrate test. Considering that the gains are for different operational conditions (high flow), for both controllers, this behavior is expected.

Bearing in mind the responses from the high flowrate and low flowrate tests, a control designer would likely make adjustments to the  $K_r$  and  $K_i$  gains that is a compromise for both operation conditions. Considering that the bump tuning method had poor  $K_r$  performance while the Ziegler – Nichols method had poor  $K_i$  performance, a model was constructed that used the  $K_r$  values from Ziegler – Nichols and the  $K_i$  values from bump tuning (Figure 5).

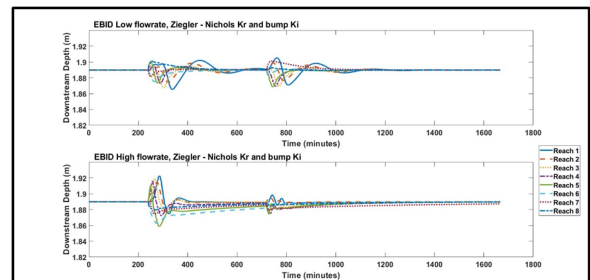


**Figure 4: Graphs of the EBID main canal reaches. The top graph are results from using bump tuning to determine control gains for ratio controllers that were designed as local controllers for each reach. The bottom graph shows the results from tuning the control grains for local controllers for each reach using the Ziegler Nichols method. The initial flowrate into the first reach is 4.53 m<sup>3</sup> / sec.**

happened with the low flowrate test similar to the low flowrate response in Figure 4. It was determined that the  $K_i$  values were too aggressive and they were all reduced by 50%. Once this was done, the response was more acceptable for the high and low flowrate tests. The high flowrate test demonstrates that once the controllers pull the water level close to the set point it has difficulty bringing the water levels all the way to setpoint. This would require some additional adjustment to the  $K_i$  values to make sure that the control response was acceptable for both the high and low flowrates and subsequently all the flowrates in between these two values.

### CONCLUSIONS

The original goal of this work was to consider if ratio feedback gains could be determined on a canal system in the field. One of the requirements would be that the feedback control gains are derived in a reasonable period of time. Bump tuning makes sense because all that is required is sending a bump in flowrate down the



**Figure 5: Low and high flow test using ratio gains from Ziegler – Nichols tuning and integral gains from bump tuning.**

canal and the collection of data as the water level responds to the change. If the canal reach is around 4000 m long or less, about 2 to 3 hours is required to collect the data. However, for the canal that is modelled in this paper, bump tuning produces  $K_r$  gains that are small and the control response is less than optimal. Bump tuning did produce  $K_i$  gains that were more suitable, but they still required adjustment.

Ziegler – Nichols tuning produced more optimal  $K_r$  gains but the  $K_i$  gains were at least 10 times larger than they needed to be. Also, if the gains

Initially, the  $K_r$  and  $K_i$  values worked well for the high flowrate test (Figure 5), but an oscillatory response

*Continued on next page*

## Designing Suitable Ratio Feedback Control Systems to Control EBID Main Canal Reaches (Continued)

were determined in the field it would take hours to turn up the gain until resonance was achieved. In addition, wind and system noise would likely make the determination of the gain values difficult. Another issue that is concerning is turning the  $K_r$  gain up to the point that the water level achieves resonant behavior. This is not a desirable for an earth lined canal even if the deviation in depth is not large. As these methods are considered for tuning a controller, it is concluded that placing a reasonable effort in collecting physical dimension data from the canal reach and modelling the reach is likely the best. There are open channel modelling software that is available where a canal reach can be programmed in 2 to 3 hours and control gains can be derived in about an hour. Once the gains are determined, the entire canal system will need to be modelled to make sure there is no interference between individual reach controllers. Once this is done, the control gains can be programmed into the field controllers. Over time, these gains may need adjustment.

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**Winter 2026**

<p><b>ITRC</b> <b>Flow Measurement – January 2026 February 2026</b> (8 am - 5 pm) <b>Sponsor: USBR California-Great Basin Region</b></p> <p>ITRC is providing several training and educational opportunities for staff, engineers, and water operators of agricultural irrigation districts. These classes utilize the excellent indoor and outdoor facilities at ITRC.</p>	<p><b>Chico</b> <b>Flow Measurement – February 2026</b> (9 am - 4 pm) <b>Sponsor: USBR California-Great Basin Region</b></p> <p>Provided in cooperation with Chico Farm, this annual flow measurement and canal operation training covers topics including: flow measurement details such as how to properly use a meter gate, how to get more water through various structures, and an introduction to SCADA.</p>
<p><b>ITRC</b> <b>Pumps (for Irrigation Districts) – February 2026</b> (8 am – 5 pm) <b>Sponsor: USBR California-Great Basin Region</b></p> <p>Pumps topics covered include types; terms; curves; pumps in series and parallel; system curves; TDH computations; efficiency; WHP, BHP, input HP; pump selection; common pump questions and answers.</p>	<p><b>ITRC</b> <b>SCADA (for Irrigation Districts) – 2026</b> (8 am - 5 pm) <b>Sponsor: USBR California-Great Basin Region</b></p> <p>This course provides an overview of SCADA systems, starting with electric and electronic fundamentals and moving on to typical technician role and responsibilities.</p>

**Spring and Summer 2026**

<p><b>ITRC</b> <b>Certified Irrigator Program</b> <i>Training for ITRC Certified Irrigator</i> (8 am - 5 pm) <b>Sponsor: CDFW WETA</b></p> <p><b>Certified Irrigator I</b> Focuses on the basics of irrigation. Certified Irrigator I (English and Spanish) TBD Winter 2026</p> <p><b>Certified Irrigator II</b> Covers basic pipeline hydraulics, irrigation efficiency, salinity management for drip/micro and drainage and freeze protection. Certified Irrigator II (English and Spanish) TBD Winter 2026</p> <p><i>Exam administered after class.</i></p>	<p><b>ITRC</b> <b>Designer/Manager School of Irrigation</b> (8 am - 5 pm)</p> <p>The Designer/Manger School is a comprehensive educational program offering a variety of classes designed for agricultural irrigation professionals. See <a href="http://www.itrc.org/classes/desmgr.htm">http://www.itrc.org/classes/desmgr.htm</a> for details.</p> <p><b>Irrigation Scheduling</b> <span style="float: right;"><b>TBD 2026</b></span> <i>Training for IA Certified Ag Irrigation Specialist</i> Soil texture and structure, water holding capacity, retention, intake rates, evaporation, transpiration, soil classification, measurement of soil moisture and tension, ETo and crop coefficients. <i>Exam administered after class.</i></p> <p><b>Pipeline Hydraulics</b> <span style="float: right;"><b>TBD 2026</b></span> Pipe material &amp; sizes, energy equation, friction, elevation changes, and basic spreadsheet operations.</p> <p><b>Pumps</b> <span style="float: right;"><b>TBD 2026</b></span> Pumps topics covered include types; terms; curves; pumps in series and parallel; system curves; TDH computations; efficiency; WHP, BHP, input HP; pump selection; trimming impellers; common pump questions and answers.</p> <p><b>Row Crop Drip Irrigation</b> <span style="float: right;"><b>TBD 2026</b></span> Design layouts, flushing, fittings, how design relates to management, hose installation, retrieval.</p> <p><b>Drip/Micro Irrigation Design</b> <span style="float: right;"><b>TBD 2026</b></span> <i>Training for IA Certified Irrigation Designer</i> Filtration, step-by-step design procedure of hardware selection and hydraulics, drip/micro system design, SDI for trees and vines, plugging prevention. <i>Exam administered after class.</i></p>
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<p><b>CHICO</b> <b>Ag Irrigation System Evaluation</b> <i>Training for ITRC Certified Evaluator</i> <b>2026 (9 am - 4 pm)</b> <b>Sponsor: DWR</b></p> <p>This comprehensive 3-day class combines classroom (50%) and outdoor laboratory (50%) activities. The techniques and programs covered are the standard used for DWR-funded evaluation projects throughout California.</p>	

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