USCID

U.S. Committee on Irrigation and Drainage

The U.S. Society for Irrigation and Drainage Professionals

President's Message

Dear USCID Members,

I would like to thank each of you for your continued support of USCID and our shared mission of advancing irrigation, drainage, and water management practices throughout the United States and beyond. I am grateful for the many ways you contribute to our community.

This year is already shaping up to be an exciting one for USCID. Planning is underway for the 2026 USCID Conference, which will be held October 20–23, 2026, at the Eldorado Resort Casino in Reno, Nevada. The conference will provide opportunities to exchange ideas, learn about emerging technologies and research, discuss challenges facing our industry, and reconnect with colleagues from across the irrigation and drainage community.

Whether through presenting at the conference, participating in committees, contributing articles to the newsletter, or sharing your experiences with fellow members, your involvement helps strengthen our organization and enriches the professional community we have built together.

Thank you again for your dedication to USCID and to the advancement of irrigation and drainage practices. I look forward to seeing many of you in Reno this October and continuing our work together in support of sustainable water management.

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

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. We hope you can join us in Reno for conference activities that offer time for net-working and reconnecting with colleagues!

Spring 2026
Issue No. 1010

USCID is now on LinkedIn!

Follow our new page to stay up to date on USCID news, events, and insights from the irrigation and water management community.

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USCID

U.S. Committee on Irrigation and Drainage (USCID)

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In This Issue…

USCID Newsletter Advertisers - Spring 2026

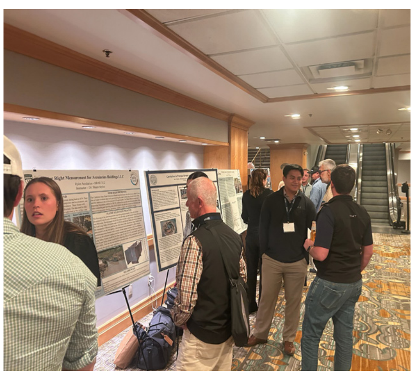
We would like to thank our advertisers for making this edition of the USCID newsletter possible!

2025 USCID Conference Recap:

The 15th International Conference on Irrigation and Drainage, hosted by the U.S. Committee on Irrigation and Drainage (USCID) was held October 21-24, 2025 in Reno Nevada. Centered around the theme of implementing sustainable management to balance water supply, the conference brought together professionals from across the water resources sector. The event featured a strong lineup of keynote speakers, technical sessions, panel sessions, workshops, and a field trip, addressing pressing challenges related to water supply and demand in the United States.

The field tour included stops at Topaz Reservoir, several key headworks sites operated by the Walker River Irrigation District (WRID), Jensen Precast Concrete Solutions, and other modernization projects.

Look ahead, USCID will host the 2026 conference, from October 20-23rd, in Reno. Please follow the USCID website - www.uscid.org/events as more details become available. This is an important conference for anyone involved in water resources, irrigation, or environmental management because it offers an unique opportunity to engage with the most current challenges and solutions in sustainable water use.



Cal Poly San Luis Obispo’s Hydraulic Students

Cal Poly continues to showcase the strength of its BioResource and Agricultural Engineering (BRAE) program. This year, three BRAE 312 students earned top-voted poster awards at major industry conferences, reflecting Cal Poly’s hands-on, industry-connected approach to engineering education.

Cassandra Richardson is a fourth-year BRAE student. Her poster was presented at the 2025 USCID Conference in Reno, Nevada. Her research assessed how various centrifugal intake reducers affected overall pump efficiency at a pump located at Cal Poly ITRC’s Water Resource Facility.

On campus, Cassandra is involved in the Agricultural Engineering Society as well as the Triathlon and Cycling clubs. After graduation, she plans to pursue a M.S. in Agriculture at Cal Poly, specializing in Water Engineering, with the goal of building a career focusing on water conveyance, technology and critical infrastructure.

Anna Reed is a third-year BRAE student. Her poster was presented at the 2026 CII Conference in Sacramento, California. The project explored the effect of fertilizer injection on magnetic flow meter accuracy in irrigation systems. It explained how changes in water conductivity from upstream chemical injection can cause inaccurate and unstable flow readings and highlights proper installation practices to ensure reliable measurement.

At Cal Poly, Anna is involved in the Agricultural Engineering Society and Farm Robotics. Growing up on a small family farm in Texas, Anna developed a strong appreciation for efficient irrigation systems. Through Cal Poly, she has developed a deeper understanding of irrigation principles and how engineering solutions support modern agricultural systems.

Tatiana Avila is a third-year BRAE student. Her poster, presented at the 2026 CAIA Conference in Tulare, California, highlighted the design and installation of an intake system for a booster pump at Nelson Reservoir.

She is actively involved in the Agricultural Engineering Society, the Quarter Scale Tractor Design Team, and Tractor Pull. She has worked at Cal Poly’s Irrigation Training and Research Center since her freshman year. Tatiana plans to pursue a career in water engineering with interests in pumps, hydraulics, and natural resources.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Understanding the Vertical Pump Industry: Lessons from William Beekman

A longtime Technical Director at Weir Floway Pumps, Bill Beekman spent decades shaping the agricultural irrigation and vertical pump industry. Over a career spanning more than 47 years, he worked extensively in vertical pump design, unique applications and new technology, while also contributing to the Hydraulic Institute beginning in 1969, where he chaired and served on many committees.

A legend in the irrigation design industry, Beekman emphasized the hands-on problem solving during his time at Floway, becoming one of the foremost vibration diagnostic people. Reflecting on his approach, he explained, “We trained our people to go out there, roll up their sleeves, and get right in there. These were problems that could be solved with simple, on-site things, and that’s the way we tackled it.”

Described as an “Engineer’s Engineer,” Beekman was awarded the Hydraulic Institute Lifetime Achievement Award in recognition of his sustained technical contributions and leadership. Throughout his career, he played a key role in advancing industry knowledge, including contributions to major resources such as *Improving Pumping System Performance: A Sourcebook for Industry*, developed by the U.S. Department of Energy’s Industrial Technologies Program in collaboration with the Hydraulic Institute.

In addition to his professional influence, Beekman made a lasting contribution to the next generation of agricultural engineers. As a 1960 Agricultural Engineer graduate, he donated his personal technical library to Cal Poly’s Irrigation Training and Research Center (ITRC). This collection represents decades of knowledge, experience, and industry evolution, a valuable resource for students and professionals alike.

The publication highlighted below comes from Beekman’s specialization in vertical pump design. He was able to develop the acronym “PMLV”- Precision Manufactured Low Vibration, to describe the many requirements for custom design and precision manufactured long life pumps, solving many problems with field vibrations, often caused by structural resonance.

RESONANT VIBRATIONS IN VERTICAL PUMPS

BILL BEEKMAN, P.E.[1]

ABSTRACT

Vertical pump and motor structures are particularly susceptible to a resonance condition created by the coincidence of the operating rpm with the Natural Reed Frequency (NRF) of the pump structure. Excessive resonant induced vibration occurs in a vertical pump when the natural frequency of the pump discharge head and vertical driver are the same as the speed of the pump and drive.
For custom engineered vertical pumps driven by a variable speed or constant speed driver, it is recommended that the pump discharge head and driver structure are evaluated for resonance

[1] *Former Technical Director at Weir Floway Inc. Retired in 2007. This article originally appeared in World Pumps magazine as “Resonant Vibrations in Vertical Pumps” by Bill Beekman (World Pumps, Issue 458, November 2004, pp. 18, 20–22).*

Continued on next page

conditions across the intended operating speed range. However, a pre-engineered standard constant speed vertical pump generally does not require individual job evaluation.

INDUSTRY DESIGN PRACTICE

Most vertical pump manufacturers have in-house technology to determine the NRF of their pumps. Within the vertical pump industry it is normal practice to design the drive support (discharge head) so that the NRF of the head and motor have a separation margin of either 20% above the maximum operating rpm or 20% below the minimum operating rpm.

When the desired rpm operating range is within the structure's NRF, it is necessary to alter the pump's discharge head and motor stiffness.

The most appropriate procedure in this situation is to select a fabricated discharge head that can be easily changed dimensionally rather than a cast discharge head that is usually difficult to structurally modify motor Reed reliably. Critical Frequency (RCF) data is required when computing the pump and motor's combined structural RCF. This is normally available from most manufacturers of vertical motors. It is worth noting that the motor's RCF will vary between different motor manufacturers and their style of motor construction. Often the pump manufacturer will select a specific motor manufacturer that can provide the optimum RCF required for the NRF of the head and motor.

Events can dictate that the pump's maximum synchronous speed must be increased or reduced; i.e. from 6 pole to 4 pole or 6 pole to 8 pole, in order to achieve the desired non-resonance operating range. As this could become costly, it is recommended that the specifying engineer consults with the pump manufacturer prior to specifying motor synchronous speeds and speed ranges when the vertical pump is driven by a variable speed driver.

MOUNTING FOUNDATIONS

The foundations on which the vertical pump is mounted do require consideration. As a rule, it is advisable to provide a foundation that represents less than 5% of the total deflection of the structural elements of the pump/drive. Typically a reinforced concrete foundation will comply with these criteria.

If the natural frequency is close to the maximum rpm operating range (Figure 1), the unit can be stiffened to make it more robust. However, there is a limit to the pump manufacturer's ability to add rigidity to the unit's structure and obtaining a vertical motor that has a high level of rigidity may not be feasible. Therefore, by providing a more robust motor support in the form of a fabricated discharge head, it may be possible to raise the pump's structural natural frequency above maximum operating speed.

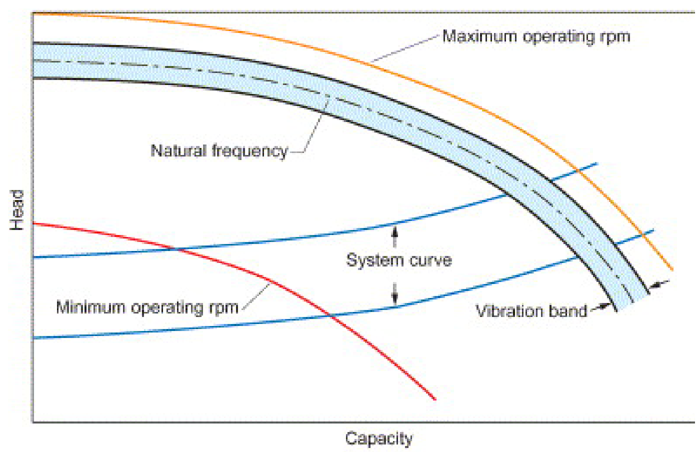

Figure 1. Natural frequency is close to the maximum range of operating rpm.

If the natural frequency is close to the minimum rpm operating range (Figure 2), the unit can be made more flexible. This has the effect of lowering the natural frequency below the operating range. During start-up and shutdown, the unit will pass through its natural frequency and vibration may occur. However, this vibration should not inflict any damage as it occurs for only a very short time.

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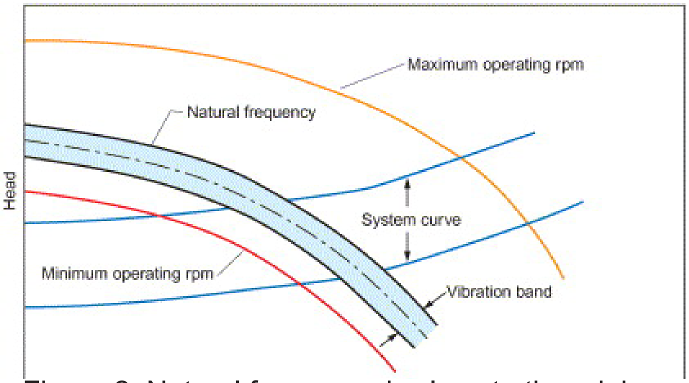

Figure 2. Natural frequency is close to the minimum range of operating rpm.

Excessive pump/motor vibration does occur when the variable speed driven pump and motor are run in the non continuous operation zone. Locking out the speed zone of operation on a motor controlled by a variable frequency drive may limit the pump's useful range of operation. Therefore, it is usually desirable to change the rigidity of the pump/motor structure in order to move the resonance band away from the desired operating zone (Figure 3).

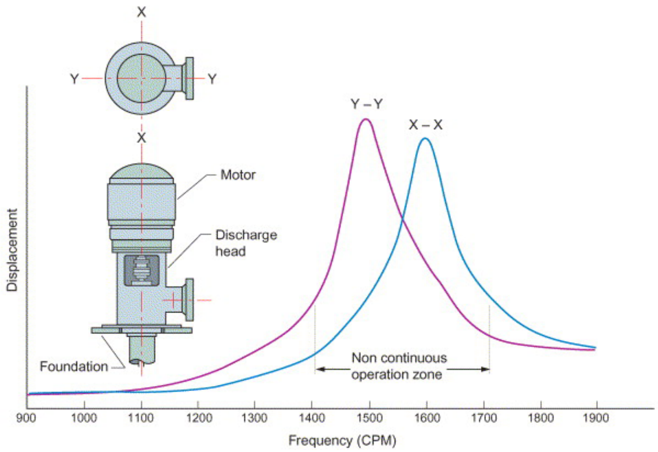

Figure 3. Typical vibration signature of discharge head/motor structure.

PART TWO: STOPPING AND STARTING VFDS OR VERTICAL TURBINE PUMPS

When it comes to the start and stop phases of operating vertical drive turbine pumps, consideration has to be given to those features that can be influenced when Soft Start/Soft Stop (SS/SS) or Variable Frequency Drives (VFD) are employed. Mix Flow and Axial flow pumps are particularly sensitive to starting and stopping where either VFDs or SS/SS driven motors are employed. This is because the horsepower curve rises towards shut-off head.

The water works industry provides good examples of the issues that need to be addressed.

DOWNSTREAM VALVES

Having a detailed knowledge of the types of valve technology lying downstream of the pump is important as all valves must be synchronized with the VFD & SS/SS motor controllers when starting and stopping a pump.

In a typical scenario, there may be combinations of the following valves beyond the pump's discharge point:
• Check Valve
• Flow Control Valve (FCV), Motorized Butterfly, Gate, Ball, etc. all with time adjustable opening and closure and no check valve.

Other types of valves may be used to control pump and system operations, but for the purpose of this article these types of valves are the focus of attention.

DRIVES AND MOTORS

Awareness of the ability of VFDs and SS/SS to control pump start-up and shut-down time is very important. VFDs are used to vary the motor speed in order to enable the pump to provide variable rates of flow to meet the system requirements. They have time adjustable ramp-up and ramp-down features for controlling motor acceleration and deceleration times. The controller can also be programmed to electrically disconnect the motor on signal to shut down.

SS/SS controllers are generally selected as motor

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drives for the purpose of reducing electrical in rush power during start-up and cushioning valves from system hydraulic transients (water hammer) during shut down. They feature programmable ramp-up and ramp-down times and may also be programmed to electrically disconnect the motor on signal to shut down.

SYNCHRONIZING START-UP AND SHUT-DOWN TIMES

It is essential to recognize that there is a need to ensure the correct timing adjustment of all components prior to first start-up. Serious pump and motor failure have been recorded simply because synchronizing controls with valves was not accomplished.

CHECK VALVES

When a check valve is used in the piping system the opportunity for back flow from the piping system interrupting pump start-up or shut down is removed. When shutting down longer, deeper setting, pumps the water column in the pump rushes down through the pumping bowl assembly to the standing water level and the reverse flow creating backspin torque on the pumpshaft. If the motor is programmed to decelerate it is still trying to drive the pump forward. When this adverse condition occurs, the pump's drive shaft and motor are subjected to a significant torque overload. To prevent this occurrence at shut down, a device that electrically disconnects the motor is required. The types of valves located downstream of the pump have very little effect on the severity of this occurrence.

With the presence of only a check valve in the piping system down stream of the pump, there is little chance of motor overload occurring during starting ramp-up of Turbine, Mix Flow and Axial Flow pumps. However, it advisable to have an electrical disconnect to the motor on pump shut down.

START UP WITHOUT CHECK VALVES

Where flow control valves do not incorporate a check valve, pump start up time must be carefully synchronized with the valve opening to prevent system backflow into the pump prior to the pump attaining full speed. Thus a very short ramp-up time, ideally less than five seconds, is desired. It is essential that the flow control valve should not begin to open prior to the pump attaining full speed as the pumpshaft and motor will be subjected to considerable torque overload if this synchronization is not followed.

When starting high specific speed pumps, such as Mix Flow or Axial Flow types, with high shut-off horsepower, synchronization of the valve opening time with the pump ramp-up time is particularly important must and be carefully planned with qualified personnel.

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RESONANT VIBRATIONS IN VERTICAL PUMPS

(Continued)

PUMP SHUT-DOWN

Timing of the flow control valve closure must also be carefully synchronized with pump shut down in order to prevent system backflow into the pump prior to the motor being electrically disconnected.

If the flow control valve is used to dampen pipeline surge on shutdown, it must close prior to the pump being shut down. This means the pump operates at shut-off head before electrical disconnection.

Pump shut-down can occur only when the motorized valve is fully closed. The signal to shut down will activate the motorized valve and start it closing and once fully closed, the motor must be electrically disconnected. Under no circumstances should the VFD or Soft Stop controller be allowed to run down the motor with out the valve being fully closed.

SUMMARY

Usually pump ramp-up time to full speed should be as short as possible. A five second ramp-up time is recommended for the following reasons. On wet pit type VTP, MF and AF pumps that have product lubricated line shaft bearings that are not pre-lubricated, it is advisable to wet the bearings from pumped fluid as soon as possible. Pump acceleration time must not, however, be delayed.

It is also recommended that where liquid levels are in excess of 50ft. depth below the surface, deeper setting pumps are pre-lubricated prior to start-up.

Generally vertical pumps must pass through their structural critical speed on ramp-up to full speed. The start-up time for full voltage, across line start induction motors to full speed is approximately one second.

The pass through the structural critical speed is so fast that there is no notice able vibration increase. However, a VFD or SS/SS driven motor/pump can build up significant vibration when ramping excessively slowly through its structural critical speed range.

On occasions VFD's and SS/SS controllers are used to reduce electrical in-rush surges to motors during start-up by extending the ramp-up time to full speed. Five second acceleration to full speed is usually long enough to accomplish the reduced in-rush with common squirrel cage induction motors.

Vertical pumps of the wet pit type (figure 4) will backspin on shut down when the water rushes downwards in the pump's vertical column pipe. If it is not feasible to use a non-reverse ratchet in this motor, a time delay to prevent pump restart during a backspin is recommended. On long length deep setting pumps, backspin duration can range between four and five minutes. However, on the normal wet pit pumps, with less than 50 ft to the standing water level, the backspin time rarely exceeds two minutes.

Figure 4. Floway 2500 HP - 900 RPM High Service Pump - Rigid Structure with 1st RCF above 1150 CPM.

THE MODERN IRRIGATION DISTRICT RESPONDING TO GROWING WATER SCARCITY

PETER MOLLER[1], DANIELE ZACCARIA, PASQUALE STEDUTO[3]

ABSTRACT

Agricultural water efficiency potential can be realized by transforming manually operated reticulation networks (e.g. canals), also referred to as gravity-fed water delivery systems into a modernized and automated on-demand supply (i.e. water orders of flexible duration, flexible timing, and variable flow) and the subsequent enabling of efficient on-farm application methods (e.g. micro, sprinkler, and advanced surface irrigation).

For example, The Pacific Institute, indicate that there is significant untapped agricultural water efficiency potential in California (Cooley et al., 2009), as irrigation water is predominantly delivered through canals designed and constructed in the early and middle of the 20th century. Nearly 80% of these water systems fail to provide water on-demand, which is a necessary precondition for many on-farm water efficiency improvements (Cooley et al., 2009).

Accurate metering and flow control at the delivery turnouts are an important element of:
• Delivering an automated on-demand supply that matches crop consumptive water use
• Leveraging the investment made by irrigators in on-farm efficient irrigation system and practices
• Ensuring the accurate management of an irrigator's water allocation (a growing asset of an irrigation enterprise)

INTRODUCTION

FAO has used the term "water requirement ratio" (FAO-AQUASTAT, 2017) when referring to the ratio between irrigation water requirement and the amount of water withdrawn for irrigation at national level. In the USA, the Surface Water Requirement ratio (efficiency) for the storage-based water released from reservoirs and supplied by these gravity-fed water delivery networks, less than 50% of the water diverted is finally used for crop consumptive use (FAO_ AQUASTAT 2007, 2019). The water volume that would otherwise not require to be diverted is due to, in part aging infrastructure and antiquated, manual and restrictive operating practices, forcing inefficiencies on to the farm level.

Data from USDA (USDA 2017 Irrigation Water Use Census) indicates that irrigation farms supplied by manually operated gravity-fed water delivery networks use 75% more water per acre than those with access to an on-demand supply.

By retaining in upstream reservoirs, this water not required to be diverted, can be stored and allocated for strategic uses and provide for:
• secure agricultural production with a future of changing and variable climate
• reduced pressure associated with excessive groundwater extraction
• allocation for environmental water and base flows
• transferred to urban use
• other water policy options

The modernization of gravity-fed water delivery networks and pipelines using improved flow measurement and flow control ensures higher water productivity, with the volume of water needed by the crops being close to the volume of water released from the reservoir. This is evident with the conveyance efficiency (Econv) for fully modernized irrigation districts like Murrumbidgee Irrigation Ltd, (95.6%), Goulburn-Murray Water (91.4%) and Coleambally Irrigation Co-operative Limited (95.9%) which publishes conveyance efficiency (Econv) in their annual reports (with water data usually reviewed by

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[1] *Business Development Manager, Rubicon Water, Imperial, CA 92251 USA*
Email: peter.moller@rubiconwater.com
[2] *Professor and Agricultural Water Management Specialist, Department of Land, Air, and Water Resources, University of California, Davis, CA 95616 USA*
Email: dzaccaria@ucdavis.edu
[3] *Senior Visiting Water Scientist, Department of Land, Air, and Water Resources, University of California, Davis, CA 95616 USA*
Email: psteduto@ucdavis.edu

a certified third party and within the approved +/- 5% as per the Australian Metrological Assurance Framework 2) (DAWE. 2021) for system-wide distribution efficiencies, from diversion through to delivery to the farm gate or turnout (interface between irrigation district and the farm).

A near on-demand supply system (Cooley et al., 2009) can readily respond to the optimal needs of a crop which are now being measured with high precision at a farm level.

Growers are responding to the increasingly stressed water resource by investing in technology at a farm level that not only efficiently apply irrigation water (e.g. micro irrigation, mechanized sprinkler, advanced surface irrigation) to achieve Farm Efficiency (Efarm) and Application Efficiency (Eappl), but also determine how much, when, and how to apply this water (Cooley et al., 2014), with homogeneous or variable rate modes. These modern and efficient irrigated agricultural practices also need enabling conditions, i.e. a matching agile, reliable, and efficient gravity-fed water delivery system to enable them achieve their desired performance.

A tighter managed on-demand gravity-fed water delivery system that reflects the true value of the resource will encourage continued on-farm investment (Bluefield Research 2026), to achieve the highest possible return from one of farming's highest valued inputs, irrigation water, as water scarcity is intensifying irrigation costs.
Growers will want to ensure their share of the water resource, which is an increasingly valued asset within their enterprise, is accurately measured and accounted for. This measurement occurs at the delivery point to the farm and is also a critical element of an on-demand supply system and service. As with most other utilities there is an opportunity to employ smart meter technology within irrigation districts that ensures the appropriate level of integration between on-farm operations and off-farm gravity-fed water supply and delivery systems. Accuracy, adequacy, dependability, and flexibility of water supply will eliminate current practices associated with manually operated systems of over-ordering water that exceeds to the requirements at the farm level.

This water has high economic value as a valuable agricultural sector input for crop irrigation (Brown et al 2025), and clearly justifies the investment in achieving these savings, as irrigation is forecast to play a key and growing role in US food production and security.

The Challenges and Clear Opportunities for the Irrigation Industry

Irrigated agriculture plays a key role in feeding the world's population with irrigation accounting for 40% of global agricultural production from 20% of the land that is farmed (FAO, 2011). The reliance on food produced from irrigated agriculture is forecast to grow. It is estimated that agricultural production will need to increase with a projected 50 – 60 percent increase in total global food demand by 2050 (Falcon et al., 2022) and upwards to more than 70% (World Bank 2022) driving an urgent need for smarter Agricultural Water Management (AWM) systems.

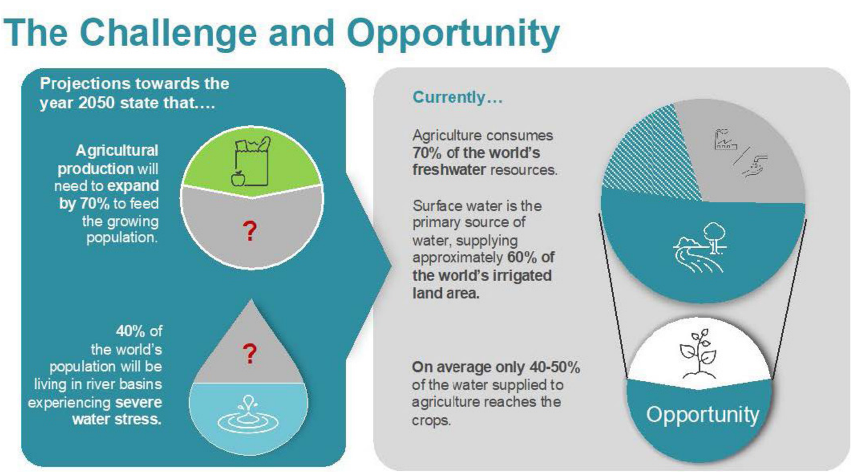

Figure 1: Projections for agricultural production to meet 2050 demands and current agricultural water statistics.

A changing climate is impacting irrigated agriculture in several ways. Greater variability and uncertainty in the available volume in storage across seasons, more than often leading to a reduction in allocations (Jalilov 2025). Dryland or rainfed agriculture will become a less reliable source for food and place greater pressure on irrigated agriculture, to meet what is an overall growing demand

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for food and food security.

On average, irrigated agriculture is already at least twice as productive per unit of land as rainfed agriculture (World Bank 2022). The value of irrigation water is being established in mature irrigation markets such as Australia and the USA. Current USA water pricing ranges an economic value of water of $300 per acre feet per annum (sale price based on USBR fallow price, and IID QSA), with recent long term price ranging up to $800 USD AF/yr (USBR).

The economic value of irrigation water is beginning to reflect the true productive value of land having secure access to a water resource. For example, access to water sources significantly influenced farmland values (Porse et al 2025) in Central Valley California. The value of this water is growing as its importance to secure food production begins to grow in a world of changing climate.

The FAO (AQUASTAT 2019) lists the total area of USA irrigated agriculture as 70 Mac comprising:
- **Surface Water** being approximately 25 Mac (portion of the equipped for irrigation area that is irrigated from rivers or lakes, reservoirs, pumping or diversion)
- **Groundwater** being approximately 45 Mac (portion of the area equipped for irrigation that is irrigated from wells, shallow wells and deep tube wells or springs)

FAO (AQUASTAT Glossary, FAO, 2019 - Irrigation Water Withdrawal) states:
"The amount of water withdrawn for irrigation by far exceeds the consumptive use of irrigation because of water lost in its distribution from its source to the crops.

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The term "water requirement ratio" (irrigation efficiency) is irrigation water requirement necessary to compensate for the potential evapotranspiration, effective precipitation over the growing period of the crop, and change in soil moisture), and the amount of water withdrawn for irrigation including the losses.

At the scheme level, water requirement ratio values can vary from less than 20 percent to more than 80 percent".

The FAO (AQUASTAT 2019) lists the following water data for the USA:
1. Total Irrigation Water Withdrawal: .... 144 MAF/yr
2. Irrigation Water Requirement (consumptive use): .... 88.4 Mac/yr
3. Resulting in a Water Requirement Ratio (efficiency): 61%

It is estimated that the consumptive water use derives for 31 MAF/yr from surface water and for 57 MAF/yr from Groundwater. These figures for consumptive use per acre are the same for surface and groundwater sourced irrigation water (FAO AQUASTAT 2019).

Assuming a value of 80% for the Groundwater Requirement ratio (efficiency), on the basis that a high proportion of groundwater use in the USA is center pivots pumping directly from aquifers with a distribution component from aquifer to pump close to 100% and the application efficiency around 80% for pivots, (being a conservative estimate), then the Surface Water Requirement ratio (efficiency) is 43% (FAO AQUASTAT 2019).

The FAO analysis lists the volume of water withdrawn from the source through to the volume of water consumed by the crop, whereas the USDA data (USDA 2017 Irrigation Water Use Census) details the volume of water used at on-farm level per acre, based on which water source supplied the farm, under the following three classifications:

i. Ground water is water from a well or wells located on this farm.

ii. On-farm surface supply is water from a surface source not controlled by a water supply organization. It includes sources such as streams, drainage ditches, lakes, ponds, reservoirs, on or adjacent to the operated land.

iii. Off-farm surface supply is water from off-farm water suppliers, such as the U.S. Bureau of Reclamation; irrigation districts; mutual, private, cooperative, or neighborhood ditches; commercial companies; or community water systems.

Both (i.) and (ii.) access their water from sources on or close to the farm and by definition will have access to an on-demand supply, typically via a pump. Off-farm surface water supply (iii.) are supplied by gravity-fed reticulation networks (e.g. canals, pipelines) and it is assumed these networks are predominately manually operated (Cooley et al., 2009).
A detailed analysis of the irrigation water used at a farm level is found in the USDA 2017 Census definition of Water Sources (B - 36 Appendix B):

	GROUNDWATER*	ON-FARM SURFACE*	OFF-FARM SURFACE	TOTAL
AREA (M ACRES)	36.16	6.29	15.92	55.94
VOLUME (MAF)	41.50	8.27	33.56	83.38
ACRE-FEET/ACRE	1.1	1.4	2.1	1.5
COMBINED AF/AC*	1.2			

Figure 2: Farms supplied by Groundwater and On-Farm Surface Water assumed to have access to an on-demand supply. The Combined AF/AC of 1.2 for Groundwater and On-Farm Surface water was derived using data from Table 4 USDA Census.[(41.50 + 8.27)MAF / (36.16 + 6.29)Mac]

The USDA census also provides the average volume of water supplied to a farm per acre under irrigation. The figures for the three classifications are as follows:
I. Groundwater.................................. 1.1 Acre-Feet/Acre
II.On-Farm Surface Water................ 1.4 Acre-Feet/Acre
III. Off-Farm Surface Water .... 2.1 Acre-Feet/Acre

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More water is supplied to farms that have a manually operated gravity-fed water delivery network (iii) than those with access to an on-demand supply (i & ii). On average farms supplied via manually operated gravity-fed water delivery networks (Cooley et al., 2009) use 75% more water per acre (0.9 Acre-Feet/Acre) than those with access to an on-demand supply (USDA, 2017), further highlighting the opportunity for additional water not required to be diverted, with the surface irrigation delivery systems within the USA.

Assuming the definition of USDA Off-Farm Surface Water applies to the potential scope for automating surface irrigation delivery systems, then the potential area of 15.9 million Acres is 64.5% of the FAO Surface Water data. Resulting in the potential area for modernization solutions of gravity-fed surface water deliveries. Therefore the Annual Total Potential Water Savings is 64.5% of 40.82 MAF/yr (FAO) which is calculated at 26.3 MAF/yr.

It is assumed one quarter (25%) of the total potential savings could be attributed to the modernization of gravity-fed water delivery networks. The potential savings, therefore, are estimated to be 6.6 MAF/yr.

Estimates of the annual economic value of water that is not required to be diverted, in the USA if using automate the gravity-fed water delivery networks of canals and pipelines is approximately $2.0 billion per year (at $300 per acre feet per annum). From experience with similar large-scale projects, the cost of this infrastructure would be approximately $5.2 billion.

Total Cost to Automate/Modernize for 15.9 MHa:
15.9 MA x $329/Acre = $5.24 Billion

The volume of water that could potentially reduce water diversion (6.6 MAF/yr) by this investment would fill Lake Mead in under five years. Such an investment in modernizing and automating the gravity-fed surface water infrastructure would have a payback period of less than three years and deliver sizeable efficiency gains for US irrigated agriculture amidst growing water scarcity, increasingly variable water supply and food security concerns.

Automation of gravity-fed water delivery infrastructure ranks as one of the better returns on investment in achieving water savings in the global water industry (compared to Desalination) and ensures the modern irrigation district can respond to growing water scarcity.

The following estimated figures summarize the findings of the potential surface water not required to be diverted, and the investment in a modernized gravity-fed water delivery network (combining FAO and USDA data and associated definitions):

1. Surface Water Area:........................15.9 Million Acres
2. Annual Total Potential Surface Water not diverted: ....26.3 MAF per annum
3. Annual Distribution System of water not diverted: ....6.6 MAF per annum
4. Annual Value of Distribution System of water not diverted:.. $2.0 B per annum
5. Present Value of Distribution System of water not diverted:..$33 B
6. Total Cost to Automate/Modernize:...............$5.24 B
7. Investment Payback Period:...........................2.7 years

EFFICIENT OFF-FARM SURFACE WATER NETWORKS

Most of the water volume that would otherwise not be required to be diverted, via off-farm surface networks is spilt from canals and at the farm level (e.g. tailwater). Modern automated gravity-fed water delivery networks that provide an on-demand supply service and eliminate canal tailwater spills are having a major impact globally resulting from the ability to retain this surplus water in upstream reservoirs.

Recent experience with the modernization of water delivery networks (off-farm), especially in Australia, shows that there has been a shift in distribution efficiency from 70% (before) to 90% as is evident with Murrumbidgee Irrigation Ltd, (95.6%), Goulburn-Murray Water (91.4%) and Coleambally Irrigation

Continued on next page

Co-operative Limited (95.9%), as published in their annual reports (water data usually reviewed by a certified third party and within the approved +/- 5% as per the Australian Metrological Assurance Framework 2) (DAWE. 2021) for system-wide distribution efficiencies.

University and Academic Research (Smith et al., 2009, Smith et al., 2016 and Gillies et al., 2010) have demonstrated that it is feasible to transform inefficient manually operated flood irrigation systems and achieve results of 85-95% application efficiency using Advanced Surface Irrigation systems and in many cases crop yield were also increased, significantly improving the ratio of crop production/applied water, in some cases doubling the dry matter production per acre foot of applied water.

Therefore, the Agricultural water efficiency potential

is a combination of 90% for off-farm distribution efficiency and an 85% on-farm application efficiency, resulting in a 77%+ reservoir to crop Surface Water Requirement ratio (efficiency) from the reservoir (Wvo), to the farm gate (Wfg), then to the root zone (Wrz) (Hsiao, T.C., Steduto, P. and Fereres, E., 2007).

This compares to the Surface Water Requirement ratio (efficiency) of 43% (FAO AQUASTAT 2019) for US supply and delivery canal systems with aging infrastructure and antiquated, manual and restrictive operating practices, through to the manually operated inefficient surface irrigation systems at the farm level.

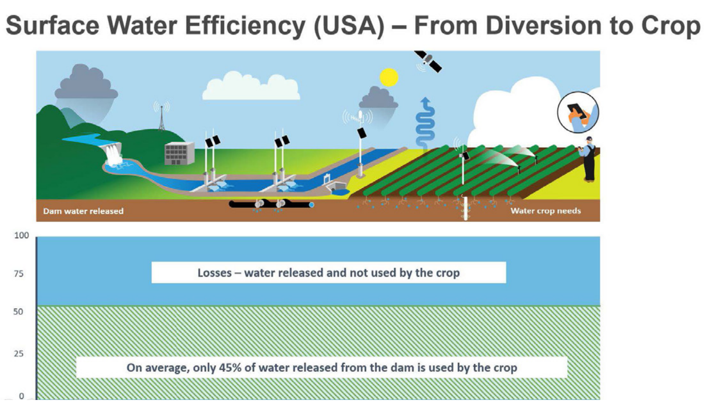

Figure 3: Surface water withdrawals in the USA versus. aggregated consumptive crop water use

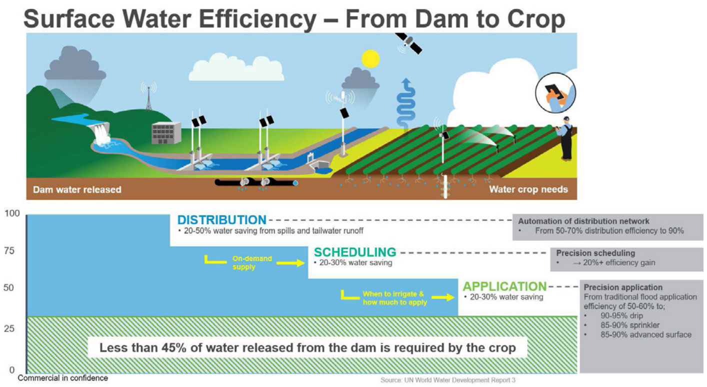

Figure 4: Quantifiable off-farm/on-farm methods to match water supply with crop water demand and uses

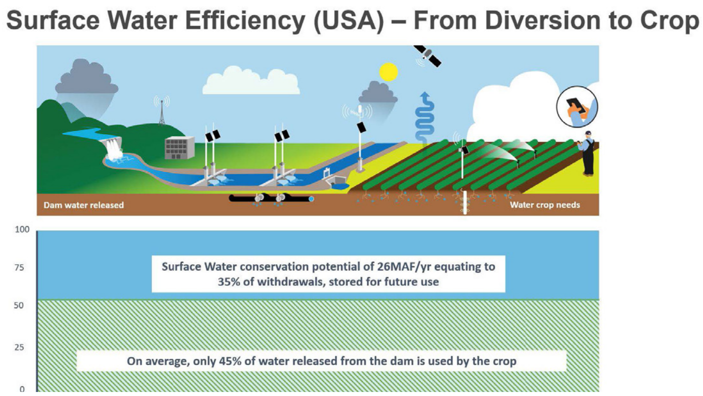

Figure 5: Potential yearly surface water reductions in diverted water across the United States following uptake of distribution and application upgrades

The opportunity for reductions in diverted water, is the water which is not used by the crop or for crop production practices. For many reasons, it is best that this water remains in the upstream reservoir and then is strategically allocated and managed, rather than on an ad-hoc access to it by downstream users.

Compared to dryland agriculture, irrigated agriculture provides security in seasonal planning and management of investment risks associated with crop planting, both with annual and longer-term permanent crop systems. A key benefit of irrigated agriculture is the ability to plant and grow crops with confidence.

Retaining water in storage reservoirs ensures equal

Continued on page 21

FLUID + PRIME

Comprehensive irrigation structure and pump control packages
Advanced automation for gate control, pump control, and flow management

Cal Poly Irrigation Training & Research Center

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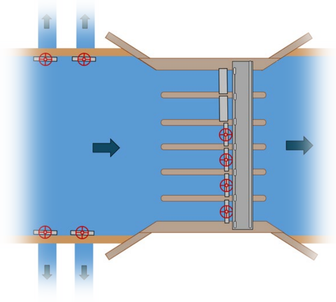
FLUID: Canal Gate Structures



FLUID is a comprehensive control package for **canal gate structures**. It was built for the Schneider Electric SCADAPack RemoteConnect platform and can control:

- Up to 6 main check structure gates
  - Undershot Gates (radial gates, sluice gates)
  - Overshot Gates (tilt, Langemann)
- Up to 4 lateral gates

Control Modes:

- Remote Manual
  - Gate position control
- Automated
  - Upstream water level control
  - Downstream water level control
  - Flow control without level overrides
  - Flow control with level overrides
  - Lateral flow control

PRIME: Pump Stations

PRIME is a comprehensive control package for **pump stations**. It was built for the Schneider Electric SCADAPack RemoteConnect platform and can control:

- Single speed and VFD pumps
- In-line canal pump stations
- Reservoir pump stations, including sites with gate structures for gravity flow in or out

Control Modes:

- Remote Manual
  - Pump speed control
- Automated
  - Upstream water level control
  - Downstream water level control
  - Flow control
  - Discharge pipeline pressure control

Why use FLUID and PRIME?

- Developed from decades of ITRC canal control research and field experience.
- Multiple control modes that can be changed on-the-fly via the site OIT or HMI
- Integrate with new or existing SCADA systems
- Provides accurate flow totalization
- Includes comprehensive alarms for power, intrusion, equipment failure, and sensors
- Supports role-based access for operators and supervisors

Implementation Process

- Modernization Plan/Rapid Appraisal
- Survey & analysis
- ITRC optimization routines for control constants
- Streamline code
- Coordinate with implementation team
- Site commissioning
- Maintenance support (long-term)

Contact: Sierra Layous, P.E., Director, Irrigation Training & Research Center
California Polytechnic State University | San Luis Obispo, California 93407
(805) 748-0721 | slayous@calpoly.edu | www.itrc.org

06/01/2026

and secure access by all users (agriculture, urban, environment, recreation), whether they are up-stream or down-stream along the supply network.

The reduction in operational and tailwater losses associated with better on-farm efficiencies, will also lead to reduced agricultural runoff, leach-outs, and associated pollutants.

Changing climate is making the retention of water in storage more of an imperative. The net effect being the need to produce more with less - with tighter management and minimizing the diversion of excess water in the supply chain – from reservoirs to crop.

There is also evidence that irrigated farms are exploiting groundwater options even when they have access to canal water, due to mis-matches between water delivery and on-farm water needs, which result from manually operated gravity-fed water delivery networks not providing on-demand service or the flexibility required to irrigate crops. This in turn is leading often leads to over extraction of groundwater.

A clear benefit of surface supply water is the low energy cost in its delivery (especially compared to groundwater supply). Solutions now exist to modernize gravity-fed infrastructure (canals and pipes) to provide an on-demand supply with minimal losses, which are also predominately solar powered.

ALLOCATING SCARCE WATER TO IRRIGATORS WILL HELP DRIVE EFFICIENCIES

Security of supply is typically associated with access to water in storage. (e.g. reservoir or groundwater aquifer). The formal entitlement to water in storage with its security of supply and its allocation to irrigation farms is key to the productive output of these enterprises.

Water is becoming one of the most valuable inputs to irrigated agriculture, and in many instances surpasses the value of land, and as such the management of its allocation becomes critical. (PV of ~ $5,000 per acre-foot. Assuming on average 1.5 acre-feet applied would imply a water value of approximately $7,500 per acre).

The only way to manage an irrigator's allocation in the reservoir is to deduct (debited from their water account) what volume is used at farm level. This demands accurate measurement, which is not only required for billing purposes, but more importantly to enable the efficient use of a scarce but highly valuable resource.

Tightly managed allocations are also a precursor to driving water efficiency gains, both on-farm and off-farm. Irrigators are rewarded for running an efficient farm by having the rights to any on-farm savings retained in the reservoir. In some areas of the world this asset can be traded (to other agriculture users or to urban, environmental, or recreational uses), and therefore growers can realize the true market value of their water asset and separate to that of their land.

PRECISION IRRIGATION – DELIVERING THE EXACT VOLUME WHEN THE CROP NEEDS IT

Increasingly irrigation growers will be demanding high efficiency and performance with the distribution of water that complements their investment in improved application techniques at field and farm level. They will want to preserve their valuable entitlement and ensure it is used for the productive output and the consumptive use of the crop.

Accurate flow measurement and variable flow control at the delivery turnout to the farm are key to achieving on-farm efficiencies. They are necessary for micro, sprinkler, and advanced surface irrigation in responding to optimal soil moisture needs of the crop.

A supply system that is close to on-demand can respond to the variable demands of the crop across the growing season. The dynamic crop responses to varying weather conditions (e.g., evapotranspiration, precipitation, heat waves) and the crop growth stage means the efficient irrigator can accurately assess when to irrigate and how much water to apply on a daily, if not on a shorter timeframe.

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In the cases of specialty crop systems (vegetables, fruit and nut orchards crops, and vineyards) managers often implement mild-to-moderate deficit irrigation strategies in some stages of the crop growing season for yield and market-demanded fruit composition targets.

Modern water delivery systems should enable not only to meet the crop consumptive water use (ETc) but should also allow the necessary flexibility to enable specialty crop growers to follow regulated deficit irrigation (RDI) practices (as well as fertigation practices). Flexible, on-demand delivery systems will enable the application of water with accuracy and precision necessary to achieve these deficit irrigation strategies.

The variable demand is reflected in both the timing of each irrigation and the volume required by the crop. The modern science of irrigation scheduling can precisely determine these parameters but is of little benefit if the water is not delivered to the farm with the proper timing, frequency, and flow rate required. Similarly, it is of little benefit investing in field and farm application efficiency (e.g., micro, sprinkler, advanced surface irrigation) if there is not the matching flexibility of supply.

The modern irrigation farmer now has access to technology that can:

i. Spatially determine soil moisture across a field using satellite or proximal sensing techniques
ii. Assess soil moisture profiles and root penetration using soil moisture sensors
iii. Monitor crop stress using plant sensors or thermal imaging to guide the optimal time to irrigate
iv. Predict weather data and atmospheric water demand (ETo) with 1-day to 7-day leads with good accuracy to enable prospective irrigation scheduling

The water delivery system needs to be capable of supporting these developments that are occurring in the irrigation industry. On-demand supply is readily available when water is directly sourced from groundwater or diverted from a river but is not possible with manually operating reticulation networks supplied by an upstream reservoir.

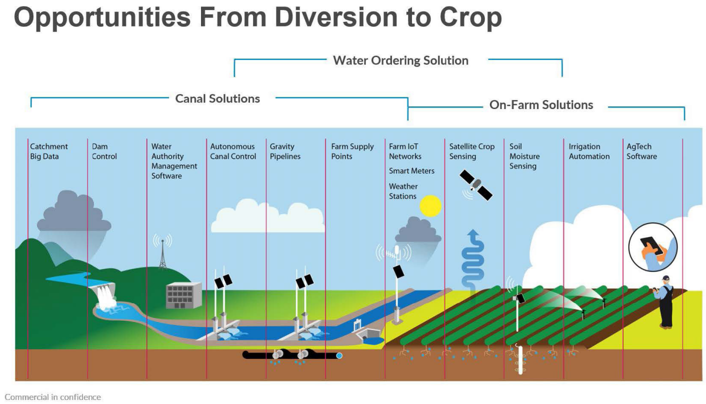

Figure 6: Modernized canal water delivery networks and innovation with on-farm irrigation application systems and scheduling, ensure an on-demand supply of water to meet the crops' consumptive water use.

The limitation with manually operated systems is that operational staff can only be in one place at a time and there is usually lengthy travel required between water flow regulation control structures. Whereas on-demand supply requires frequent and continuous flow control actions at all water regulation structures and can achieve autonomous responses to changing conditions with very small-time intervals.

To accommodate these limitations, manually operated systems are typically constrained by a formal water delivery schedule which has rigid rules under which water can be ordered and delivered at certain intervals and flows. An example being specific times during a day when an irrigation supply can start or finish to coincide with manual operations, which in turn confines the supply to a fixed volume for a fixed duration and with an order required to be placed day(s) in advance.

The uncertainty associated with flow measurement inaccuracy and with fixed ordering rules results in irrigators often over-ordering to avoid any shortfall in water needed for the irrigation. This operating regime also discourages on-farm water saving initiatives if the

Continued on next page

supply lacks the flexibility required.

Evidence of over-ordering can be seen in the USDA census data where farms supplied by manually operated canal water delivery networks use 75% more water per acre (0.9 Acre-Feet/Acre) than those with access to an on-demand supply.

The difference, presumably, can only be attributed to over-ordering. Nationally this equates to some 14 MAF/yr. or close to twice the estimated surface water saving from the FAO data (6.6 MAF/yr.).

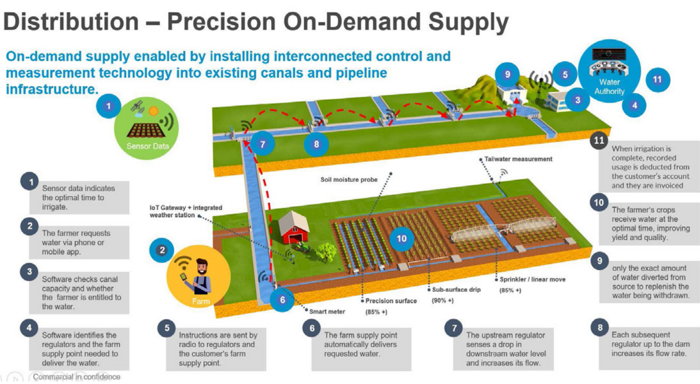

Figure 7: Illustration of on-demand delivery system to support on-farm technology investments by matching water supply with crop demand.

FLOW MEASUREMENT AND FLOW CONTROL IS KEY TO ACHIEVING EFFICIENCIES

The farm delivery turnout, as the point of management change, from the water supplier to the water user, is an important component of the gravity-fed water delivery network (dam to crop) and is central to achieving highly efficient irrigation management for crop production. Accurate flow measurement and flexible flow control at the delivery turnout supports the following functions:

i. Metering for billing purposes
ii. Maintenance of the status of a farmer's available allocation held in storage
iii. Provide the real-time demand input to an automatic control system that can precisely respond/react to this demand
iv. Interface with on-farm application systems – micro, sprinkler, advanced surface irrigation

Like most utilities (e.g. power, gas, municipal water) smart meters are increasingly becoming important elements of the supply infrastructure and distribution. They provide a seamless link between the point of demand and use through the source of supply.

Accurate billing and allocation management requires accurate volumetric measurement of water use at the farm delivery turnout. Accurate volumetric measurement requires:

i. Accurate flow measurement
   1. Independently certified to industry standards
   2. High/low flow range
ii. Near continuous flow measurement
   1. Not periodic sampling
   2. Maximum measurement intervals and frequencies need to be defined
iii. Low power consumption to support the remote low power (solar) requirements of the irrigation industry

The modern irrigation district is implementing a new operational regime as it moves from a manual to a precision operation in pursuit of efficiencies and service levels being demanded by the crop production industry.

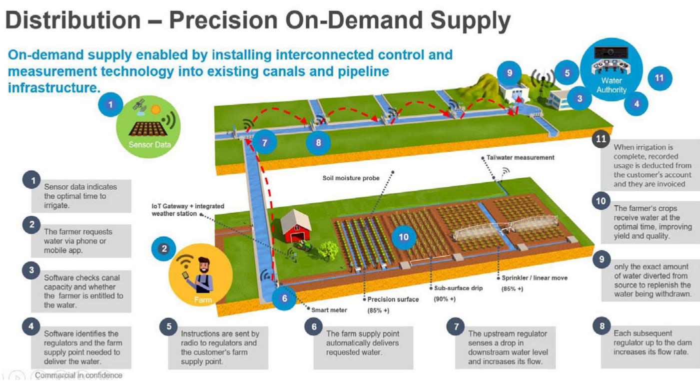

Figure 8: Illustration of current manually operated surface water delivery system, resulting in mismatch between water supply and crop consumptive water use.

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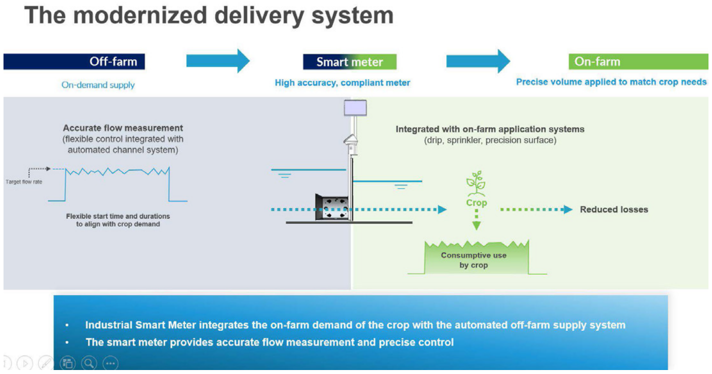

Figure 9: Illustration of improved surface water delivery system with on-farm metering, offering growers the flexibility to adjust irrigation timing and frequency, duration, and flow rates, to match water supply with specific crop needs. Resulting in more water banked for future use.

SUMMARY

In the USA, the Surface Water Requirement ratio (efficiency) for storage-based water released from reservoirs and supplied by gravity-fed water delivery networks, less than 50% of the water diverted is finally used for crop consumptive use (FAO_AQUASTAT 2007, 2019). The water volume that would otherwise not require to be diverted is due to, in part with aging infrastructure and antiquated, manual and restrictive operating practices, forcing inefficiencies on to the farm level.

USDA data (USDA 2017 Irrigation Water Use Census) indicates that irrigation farms supplied by manually operated gravity-fed water delivery networks use 75% more water per acre than those with access to an on-demand supply.

By retaining the amount of water not required to be diverted, in upstream reservoirs, it can be allocated for strategic uses and provide for secure agricultural production with the ongoing and future changing climate and more frequent occurrence of weather extremes (droughts, heat waves, wild fires, etc.). The modernization of the gravity-fed and piped water delivery networks using improved flow measurement and flow control ensures that the water needed by crops and for advanced farming and irrigation practices is close to that being released from the reservoir. A near on-demand supply system can readily respond to the optimal crop water use which are now being measured and managed with high precision at a farm level.

Growers are responding to the increasingly stressed water resources by investing in technology at farm level that can not only efficiently apply irrigation water (e.g. micro, mechanized sprinkler, advanced surface irrigation), but also determine how much, when, and how to apply water along with agrochemicals and fertilizers. These modern and efficient irrigated agricultural practices also need, as a prerequisite, a matching agile, reliable, and efficient water delivery system in order that they can achieve their desired performance.

A tighter managed on-demand gravity-fed water delivery system that reflects the true value of the resource will encourage continued on-farm investment (Bluefield Research 2026), to achieve the highest possible return from one of farming's highest valued inputs, irrigation water, as water scarcity is intensifying irrigation costs

Growers will want to ensure their share of the water resource, which is an increasingly valued asset within their enterprise, is accurately measured, managed, and accounted for. This measurement occurs at the delivery point to the farm and is also a critical element of an on-demand gravity-fed water supply and distribution network. As with most other utilities, there is an opportunity to employ smart meter technology within irrigation districts that ensures the appropriate level of integration between on-farm operations and off-farm supply systems. Accuracy, adequacy, dependability, and flexibility of supply will eliminate current practices associated with manually operated systems of over-ordering and over-using water that is excess to the requirements at the farm level.

Estimates of the annual economic value of water that would otherwise not require to be diverted

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in the USA from modernizing and automating the gravity fed water and pressurized delivery networks is approximately $2.0 billion per year, at an average economic value of water of $300 per acre feet per annum (sale price based on USBR fallow price, and IID QSA), with recent long term price ranging up to $800 USD AF/yr.

From experience with similar large-scale projects, the cost of this infrastructure would be approximately $5.2 billion. The volume of water that could potentially not be diverted (6.6 MAF/yr) by this investment would fill Lake Mead in under five years, based on its elevation of 1221.4ft., it contains 28,945,000 acre-feet. Such an investment in upgrading and automating the gravity-fed water delivery infrastructures would have a payback period of less than three years and deliver sizeable resource-efficiency gains for US irrigated agriculture amidst growing water scarcity, increasingly unreliable water supplies, and food security concerns.

The dominant water saving opportunities with irrigation in the USA are with modernizing manually operated reticulation networks (e.g. canals). The water savings are realized via an automated on-demand supply (i.e. flexible duration, flexible timing, adjustable frequency, and variable flow) and the subsequent enabling of efficient on-farm water application methods (e.g. micro, sprinkler, and advanced surface irrigation). Accurate metering and flow control at the delivery turnouts are an important element of:

- Delivering an automated on-demand supply that match crop consumptive use and growers' needs (for optimizing labor, energy, inputs, and operational efficiency, etc.)
- Leveraging the investment made by growers in on-farm efficient irrigation methods
- Ensuring the accurate management of grower's water allocation (a growing asset of a farming enterprise)

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There are sizeable opportunities for agricultural water efficiency potential that can be realized in gravity-fed water delivery networks within the USA. This water has high economic value and clearly justifies the investment in achieving these savings as irrigation is forecast to play a key and growing role in US food production and food security.

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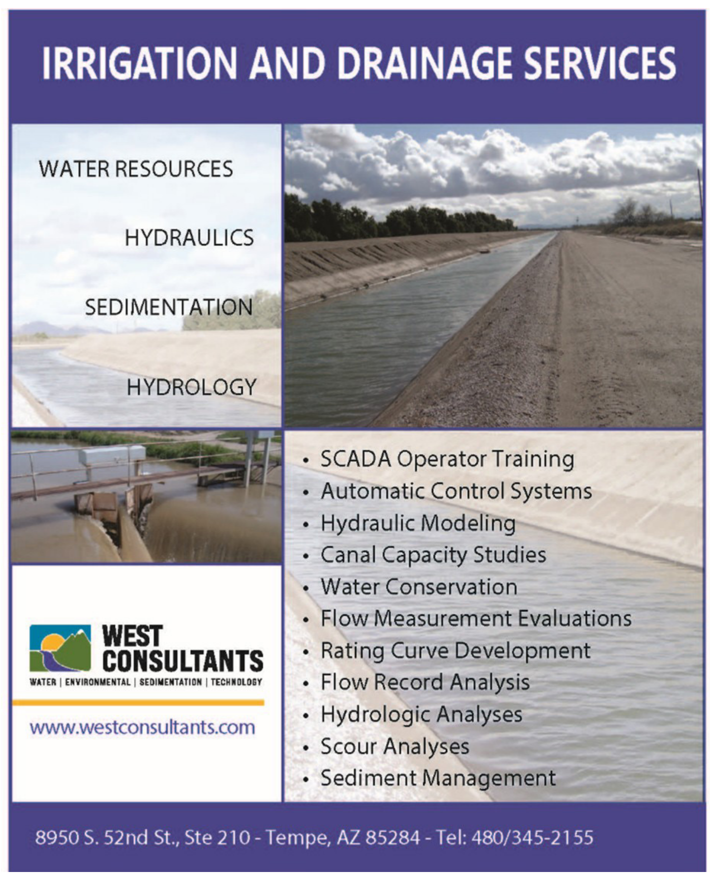
For employment inquiries contact
linneman@summerseng.com



A Blast From the Past:

TOOLS FOR DESIGN, CALIBRATION, CONSTRUCTION AND USE OF LONG-THROATED FLUMES AND BROAD-CRESTED WEIRS

TONY L. WAHL[1], ALBERT J. CLEMMENS[2], MARINUS G. BOS[3], JOHN A. REPLOGLE[4]

ABSTRACT

Long-throated flumes and broad-crested weirs provide a practical, low-cost, flexible means of measuring open-channel flows in new and existing irrigation systems and have distinct advantages over other flume and weir devices. Application of these flumes and weirs has been greatly facilitated by the 1999 release of the WinFlume software used to design and calibrate these structures, and the recent publication of Water Measurement with Flumes and Weirs, a text providing comprehensive information on design, calibration, construction, and operation issues. The primary advantages of these flumes and weirs are that they can be custom-designed to satisfy unique operational and site requirements, and they can be computer calibrated without the need for laboratory testing. In addition, these devices are easily and economically constructed, and a number of commercially built, pre-calibrated devices are available. This paper and accompanying poster describe the use of the WinFlume software and present examples to illustrate application to a range of situations, including various flow rates, channel types, and construction techniques.

INTRODUCTION

The term long-throated flume describes a broad family of critical-flow flumes and broad-crested weirs used to measure open-channel flows. A variety of specific configurations are possible (Fig. 1). Bos et al. (1984) described the theory for determining discharge through these flumes. WinFlume is the most recent in a series of computer programs used to design and calibrate these structures. Water Measurement with Flumes and Weirs (Clemmens et al. 2001) presents updated hydraulic theory, design procedures, application and construction examples, and detailed instructions for using the WinFlume software.

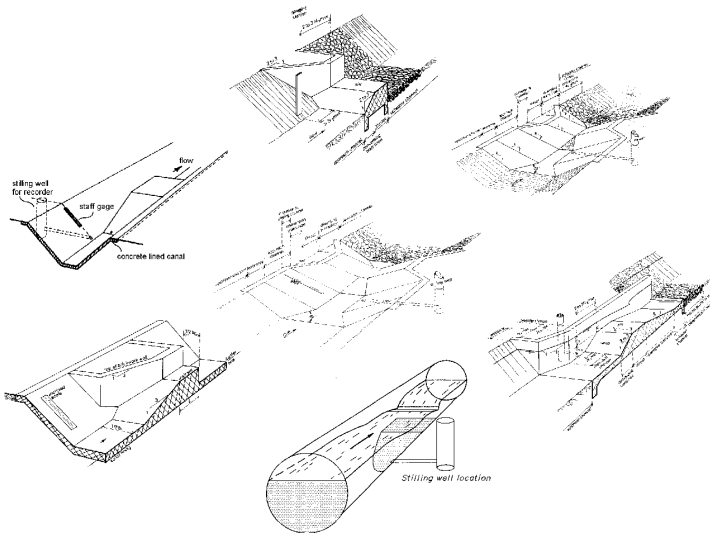


Figure 1. — Examples of Long-Throated Flumes and Broad-Crested Weirs.

Long-throated flumes are the measurement device of choice for most open channel applications, having significant advantages over Parshall flumes and other traditional devices. These older devices were laboratory-calibrated, because the flow through their control sections is curvilinear. In contrast, streamlines are essentially parallel in the control sections of long-throated flumes, making them ratable using straightforward hydraulic theory. Significant

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[1] Hydraulic Engineer, U.S. Bureau of Reclamation, Water Resources Research Laboratory, D-8560, P.O. Box 25007, Denver, CO 80225, phone 303-4452155, twahl@do.usbr.gov

[2] Laboratory Director and Supervisory Research Hydraulic Engineer, USDA ARS, U. S. Water Conservation Laboratory (USWCL), 4331 E. Broadway Rd., Phoenix, AZ 85040, phone 602-437-1702 x-269, bclemmens@uswcl.ars.ag.gov

[3] Senior Irrigation Adviser, International Institute for Land Reclamation and Improvement, PO Box 45, 6700 AA Wageningen, The Netherlands, phone +(31) 317 400144, M.G.Bos@Alterra.wag-ur.nl

[4] Research Hydraulic Engineer & Chief Scientist, USDA-ARS, USWCL, phone 602-437-1702 x-246, jreplogle@uswcl.ars.ag.go

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advantages of long throated flumes include:
• Rating table uncertainty of ±2% or better in the computed discharge.
• Choice of throat shapes allows a wide range of discharges to be measured with good precision.
• Minimal head loss needed to maintain critical flow conditions in the throat of the flume.
• Ability to make field modifications and perform computer calibrations using as-built dimensions.
• Economical construction and adaptability to varying site conditions.

Adaptability of these structures is a primary advantage, with the range of applications demonstrated by design and construction examples provided in Clemmens et al. (2001). Structures meeting the criteria for analysis as long throated flumes can be small or large, permanent or temporary, fixed or portable, and may serve as either simple flow measurement devices or as combined measurement and control or flow division structures.

PERMANENT STRUCTURES FOR FLOW MEASUREMENT

Permanent flumes and weirs form the backbone of many water measurement networks for open-channel irrigation and drainage systems. In concrete-lined canal sections the most common structures are of the broad-crested weir type, consisting essentially of a sill that spans the full width of the existing lined channel. The resulting shape of the throat section of the flume (the control section) may be trapezoidal, rectangular, or one of several complex shapes such as a sill in a circle or sill in a parabola. The side walls of the existing lined channel form the side walls of the throat section, so construction is generally straightforward.

Figures 2-4 illustrate several possible construction methods. In Figure 2 an earthfill core is constructed, and a concrete shell is then placed over the earthfill to form the converging ramp and the control section. Drain pipes through the structure eliminate

Continued on next page

TOOLS FOR DESIGN, CALIBRATION, CONSTRUCTION AND USE OF LONG-THROATED FLUMES AND BROAD-CRESTED WEIRS

(Continued)

undesirable standing water upstream from the flume during the off-season. When flow is initiated, the underlying earthfill is washed out, leaving a concrete shell structure.

Figure 2. — Construction of a Broad-Crested Weir in a Concrete-Lined Trapezoidal Channel.

Figure 3 shows the installation of pre-cast concrete sections of a broad-crested weir for a lined trapezoidal channel. This construction technique is useful when many weirs of exactly the same design are needed for installation at several locations in a canal system. Similar weirs can also be constructed with pre fabricated metal ramp and sill sections.

Figure 3. — Placing Pre-Cast Weir Sections in a Lined Trapezoidal Canal.

Figure 4 shows the construction of a large permanent flume with a trapezoidal throat section. In this case, a length of the existing earth canal was fully lined to create the sidewalls of the control section. The most important aspect of construction is maintaining a level sill in the throat section (level in the flow direction is most important).

Figure 4. — Construction of a Large Broad-Crested Weir in an Earthen Channel.

A common flume design used for earth-lined canals is illustrated in Figure 5. The throat section is rectangular, which often simplifies construction, since sloped side walls do not have to be constructed in the throat section. The vertical side walls are constructed from concrete block and mortar. Erosion protection is provided downstream from the flume in the channel bottom and on the side walls.

In natural channels where a very large range of flows may need to be measured, flumes with a triangular-shaped control section are often used. These flumes offer good measurement accuracy at low flows, while passing flood flows without an unacceptably large flow depth upstream from the structure. Figure 6 shows a triangular-shaped flume constructed in Florida.

Figure 5. — A Rectangular-Throated Flume in India.

Continued on next page

Figure 6. — Triangular-Throated Flume in Florida.

PORTABLE AND TEMPORARY FLUMES

Long-throated flumes and broad-crested weirs are very useful for portable and temporary applications. Such devices can be very economical to build, while still providing highly accurate flow measurement capability. The RBC family of 5 small trapezoidal-throated flumes is suitable for flow survey work.

These flumes can be constructed from sheet metal using drawings provided in Clemmens et al. (2001), or commercially pre-fabricated flumes are also available, such as the fiberglass models shown in the right hand photograph in Figure 7.

Figure 7. — Portable RBC Flumes Measure Flow in Drains and Furrows.

Continued on next page

TOOLS FOR DESIGN, CALIBRATION, CONSTRUCTION AND USE OF LONG-THROATED FLUMES AND BROAD-CRESTED WEIRS

(Continued)

Portable flumes with rectangular throat sections are shown in Figure 8. These can be constructed from wood, metal, or fiberglass. Temporary flumes for lined trapezoidal canals can be constructed from plywood (Figure 9).

Figure 8. — Rectangular-Throated Portable Flumes.

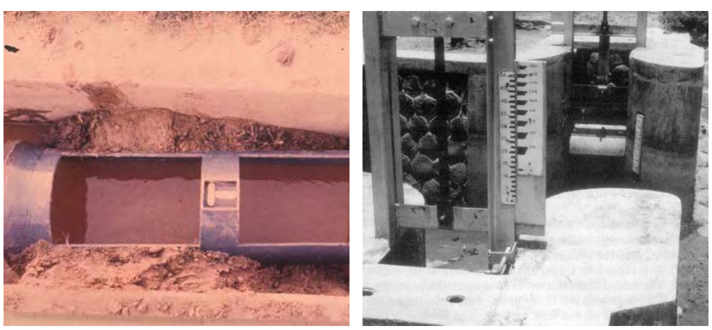

Figure 9. — Temporary Flumes for Lined Trapezoidal Channels.

Portable flumes can also be constructed by installing a sill into a circular or semicircular pipe section. If the pipe section is small enough, these flumes can be easily transported to different measurement sites. Leveling bubbles shown on the flume in Figure 10 help the user to achieve a good installation.

Figure 10. — Portable Flume Constructed in a Section of Circular Pipe.

FLUMES AND WEIRS FOR FLOW DIVISION AND CONTROL

In addition to flow measurement, flumes and weirs can facilitate regulation of deliveries and accurate division of flows. For regulation of deliveries, weirs with a vertically movable crest are used. Such weirs can be constructed in sizes up to about 4 m wide. These weirs are installed at offtakes where the supply water level is steady, and the weir elevation is varied to change the delivered flow rate. Figure 11 shows a pair of vertically movable weirs and the flow registration system used to directly indicate the flow rate.

Figure 11. — Movable-Crest Weirs and Flow Registration Scales.

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TOOLS FOR DESIGN, CALIBRATION, CONSTRUCTION AND USE OF LONG-THROATED FLUMES AND BROAD-CRESTED WEIRS

(Continued)

Broad-crested weirs with a rectangular throat section can be used to accurately divide flows among two downstream users or districts. A vertical division board is installed just downstream from the control section. The division board may be fixed or movable. Such structures are useful on projects where different users are entitled to a percentage of the available water supply, rather than a fixed quantity of water. Figure 12 shows an adjustable flow division structure in Argentina.

Figure 12. — Flow Division Structure with a Movable Divisor.

PRECOMPUTED FLUME DESIGNS AND RATINGS

Two basic approaches can be taken to the problem of flume design. Custom designs may be developed with the WinFlume software described later, or precomputed flume designs can be selected from tables provided in Clemmens et al. (2001). Precomputed designs are available for trapezoidal-throated structures to be installed in lined canals, rectangular-throated structures for installation in lined or earthen channels, triangular-throated structures for natural channels and drains experiencing a wide range of flows, and for sills installed in circular conduits. Tables provide discharge and head ranges, minimum head loss requirements, structure dimensions, and rating equation parameters. Precomputed designs are available for typical small to medium-size channels; for large structures, analysis with WinFlume is recommended to achieve an optimum design. Each precomputed design has been developed to satisfy criteria related to approach channel Froude number and flow measurement accuracy. The user is responsible for verifying that a selected design will satisfy upstream freeboard requirements and operate in a free flow condition (i.e., that enough head loss is available at the site to avoid submergence of the flume by the existing tailwater conditions). Clemmens et al. (2001) provides numerous design examples to illustrate the use of the tables.

WINFLUME SOFTWARE

Custom flume ratings and designs to satisfy nearly any application can be developed with the WinFlume software (Figure 13), available for free download on the Internet at www.usbr.gov/tsc/techreferences/computer%20software/software/winflume. The software operates on all Windows-based computers. An online help system is integrated into the program, and a printable user's manual is distributed electronically with the software. A helpful flume wizard is available to assist new users with basic data entry.

Continued on next page

TOOLS FOR DESIGN, CALIBRATION, CONSTRUCTION AND USE OF LONG-THROATED FLUMES AND BROAD-CRESTED WEIRS

(Continued)

Flume ratings for existing structures can be developed from as-built dimensions, provided that the throat section is horizontal in the flow direction and there is a smooth transition from the approach channel into the throat section. The software will generate head-discharge tables, rating curves, rating equations, and flow graduated wall gages. Wall gages can be printed at full scale on Windows compatible plotters and printers and provided to a fabricator for construction of durable field-quality staff gages (Figure 14). Additional optional parameters provided in WinFlume's rating tables include the required head loss and modular limit (i.e., maximum allowable submergence ratio).

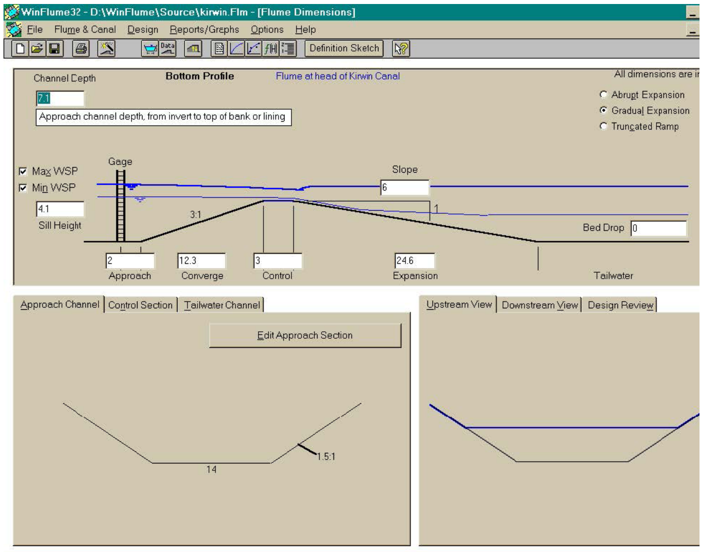

Figure 13. — Entering Flume Dimensions into the WinFlume Software

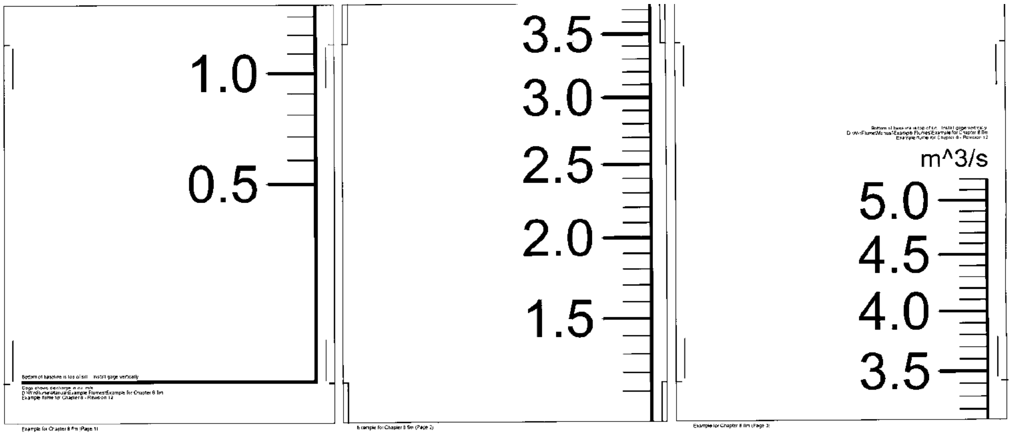

Figure 14. — A 3-Section Flume Wall Gage Produced by WinFlume.

Design of new flumes can be accomplished either by trial or with the assistance of WinFlume's automated design evaluation routines. To develop a design by trial, the user enters the flume dimensions and design requirements (e.g., desired freeboard, discharge range, tailwater conditions, accuracy requirements), and then performs a design review. The design review report will indicate deficiencies in the design and suggest alternatives to improve the design. The initial design task is to determine the proper amount of contraction in

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the throat section (narrowing of the channel width or raising of the sill) needed to produce critical depth flow over the full range of flows to be measured. Once this is accomplished, the length of flume components is fine-tuned so that the structure meets the requirements for performance as a long-throated flume.

To develop a design using the design evaluation routines, the user again provides starting flume dimensions and design requirements, then executes the design evaluation routine. WinFlume builds a family of virtual flume designs derived from the initial design and evaluates each against the primary design criteria. The alternative designs are created by changing the amount of contraction in the throat section of the structure, for example by raising or lowering the sill. Acceptable designs are listed in a report and the user can then select a design from the list. This approach allows the user to see the range of acceptable designs (since there is not normally just one acceptable design) and the performance tradeoffs to be considered in selecting a final design. These tradeoffs usually involve maintaining acceptable upstream freeboard while minimizing the possibility of flume submergence if tailwater levels should be higher than expected. An intermediate design that provides acceptable freeboard and operates somewhat above the modular limit condition is often the best final design choice.

CONCLUSION

The release of the WinFlume software and publication of Water Measurement with Flumes and Weirs has greatly advanced the application of long-throated flumes and broad-crested weirs for open-channel flow measurement. The flexibility of these structures and the simplicity of developing, calibrating, and constructing effective, economical designs make them the best structure for most open-channel flow measurement applications.

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