Irrigation Metering System

RSA Environmental, Inc.
Patent Pending

Goal:

Identify water usage and misusage to direct managers efforts to improve the low performers in the District. This in the long run will save water.

How:

By meeting the requirements of SBx7-7 with an effective on-farm measuring system at a reasonable cost.

What:

A designed metering system that will provide volume delivery accurate to better than +/- 5%.

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Features

Base system design includes:

- Prepared pipe with proprietary inlet flow conditioning elements
- Calculated lengths of diameter of pipe to further condition flow
- In pipe mounted reverse propeller flow meter
- Calculated length of exit pipe for final flow conditioning
- Battery powered totalizer with readouts showing instantaneous flow and volume delivery
- Protective cover for flow meter and cable
- Exclusive arrangement with McCrometer
- Installation
- USA design and fabrication

Features (cont.)

Advanced system design includes:

- Communications that are compatible with SCADA systems

NOTE: All systems are component designed from basic to advanced:

1) Retrofit flow conditioned pipe with flow meter using battery powered totalizer at site;
2) Added powered/manually operated control gate through solar panel at site with constant flow feedback between flow meter and gate actuator;
3) Linked to SCADA system that records historical volume usage for each customer in district office computer and allows remote real-time monitoring and operational remote control;
4) Full automation among all gates in system (i.e. check and turnout gates)

Physical Benefits

- Systems are stand-alone or remotely-monitored and controlled.

- Systems may be installed in the District's Canal or in the Farmer's Field or Ditch.

- Systems may be manually operated or electronically actuated.

- Basic design with control gate increases the effective use of the applied water to meet the water demand of the crop at the right time and for the right duration.

Benefits to Districts

Instituting the RSA Irrigation Metering System

Benefits to the District Standpoint

1. Stabilizes the delivery in the lateral.

With RSA software at each gate to maintain constant delivery (having the flow meter automatically set the gate position) the Ditch Tender sets the system once during the entire delivery time. The advantage is independent stable delivery to every user. Right now the users have no control of over or under deliveries due to lateral fluctuations. Usually this problem increases further downstream the lateral line.

2. Assures billing equity. The Farmer pays only for what is accurately measured and delivered. The District no longer has to over deliver to assure user satisfaction. - thereby wasting water.

3. Generates a conservation transfer with efficiency upgrades – produces excess water compared to today.

Benefits to Farmers

Benefits to the Farmer's Standpoint

1. Assurance of equitable delivery – delivers what was purchased.

2. May allow the Farmer operator to trim deliveries with assurance that it will lower water cost.

3. Responds to sloping border or furrow irrigation systems. Which are the majority of the surface irrigation systems in California. This gives the Farmer the ability to match application rates to soil intake rates to improve uniformity of application.

4. Metering of the turn out costs will not be borne by Farmers as the District will pay for systems.

SYSTEM CAPABILITIES

CANAL WATER METERING SYSTEM

Size in	Q cfs	velocity ft/s	V^2/2g ft	Headloss inches
30	25	5.1	0.403	8.7
	23	4.36	0.341	7.3**
	15	**3.1***	0.145	3.1
24	25	7.5	0.985	21
	20	6.4	0.630	14
	15	4.8	0.354	7.7**
	10	**3.1***	0.158	3.4
16	10	7.1	0.797	17
	6.5	4.7	0.336	7.3**
	5	3.6	0.199	4.3
	4.5	**3.2***	0.165	3.6
12	5.0	6.4	0.630	14.0
	4.0	5.1	0.403	9.7
	3.5	4.5	0.309	6.8**
	3	3.8	0.227	5
	2.5	**3.2***	0.158	3.5

3.0* --Suggested minimum velocity to discourage sedimentation

7.0** --Suggested minimum headloss

Installation at Merced Irrigation District

Early May, 2011

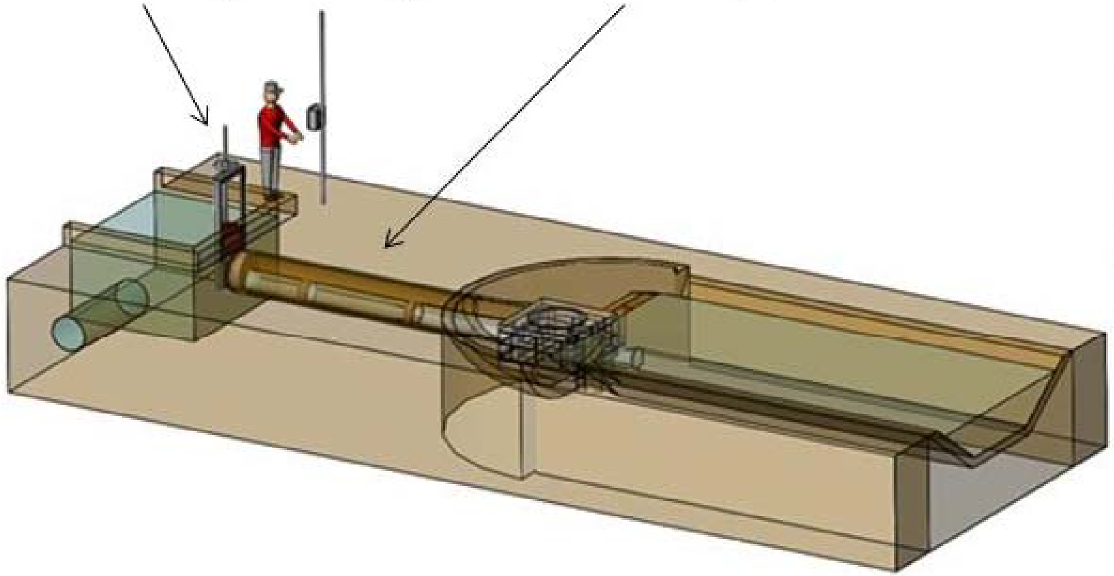
RSA ENVIRONMENTAL FLOW CONDITIONED PIPE METER\
Base Model – Minimum requirement to meet SBx7-7
Flows from 2.5 to 3.5 cfs - 12” pipe

Reverse Propeller Flow Meter

Battery Powered Totalizer

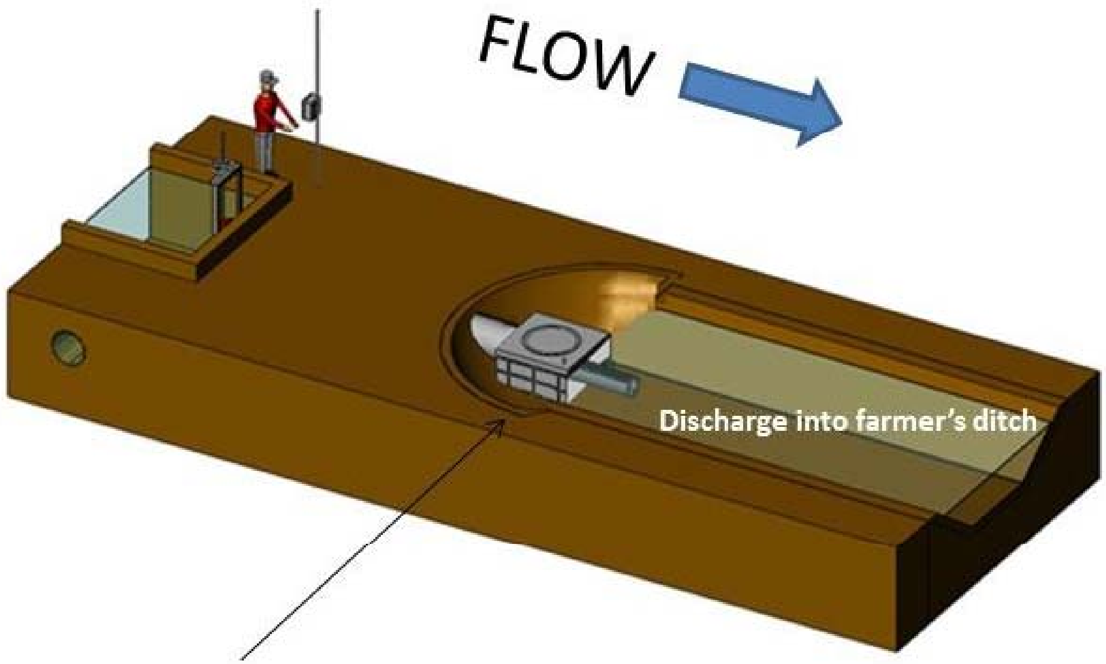
Use existing control gate

RSA pipe inserted into existing District pipe



Farmer or Ditch Tender opens gate then reads battery powered totalizer

FLOW

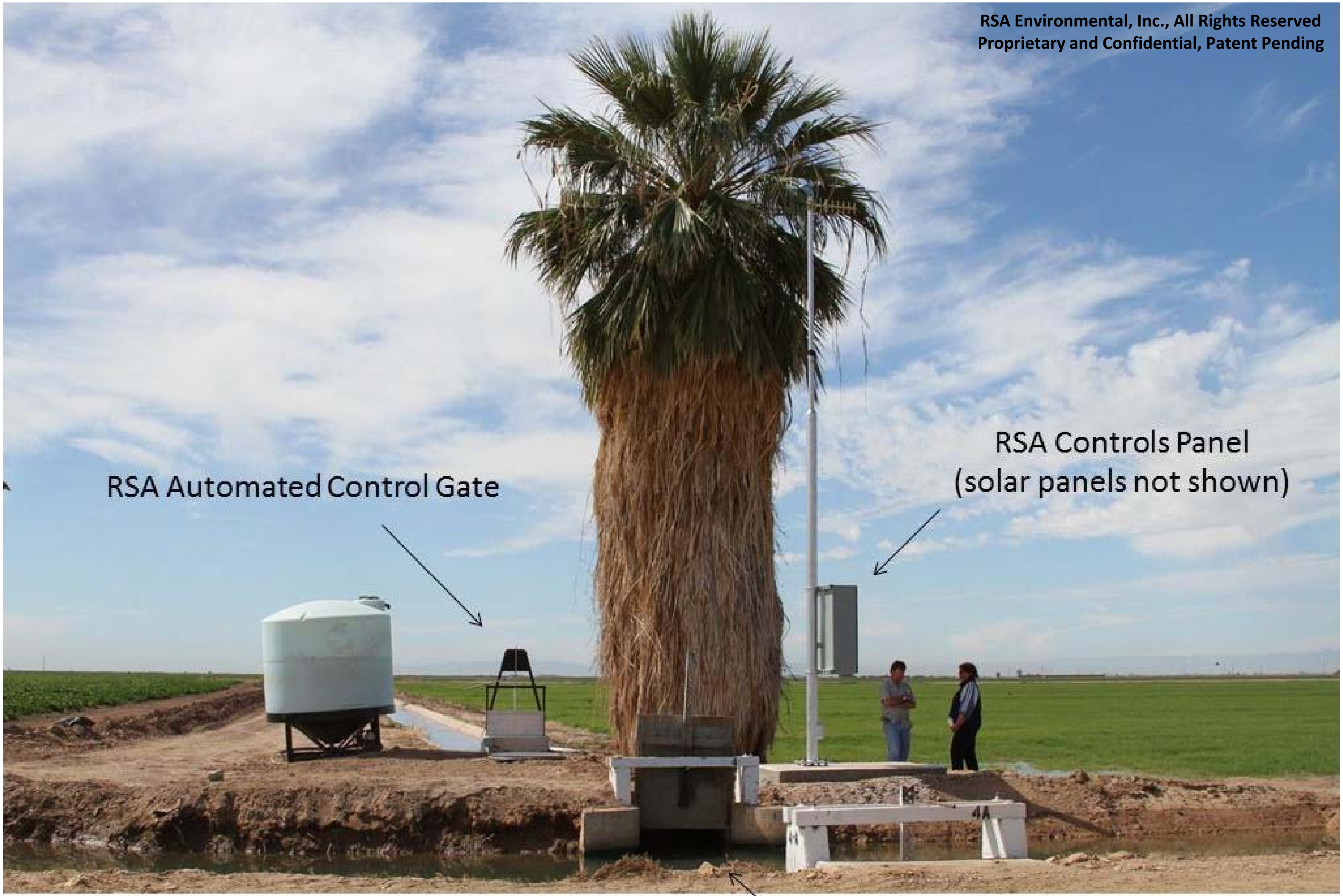


Installation at Merced ID May , 2011

Access to propeller meter

Installation at Imperial Irrigation District

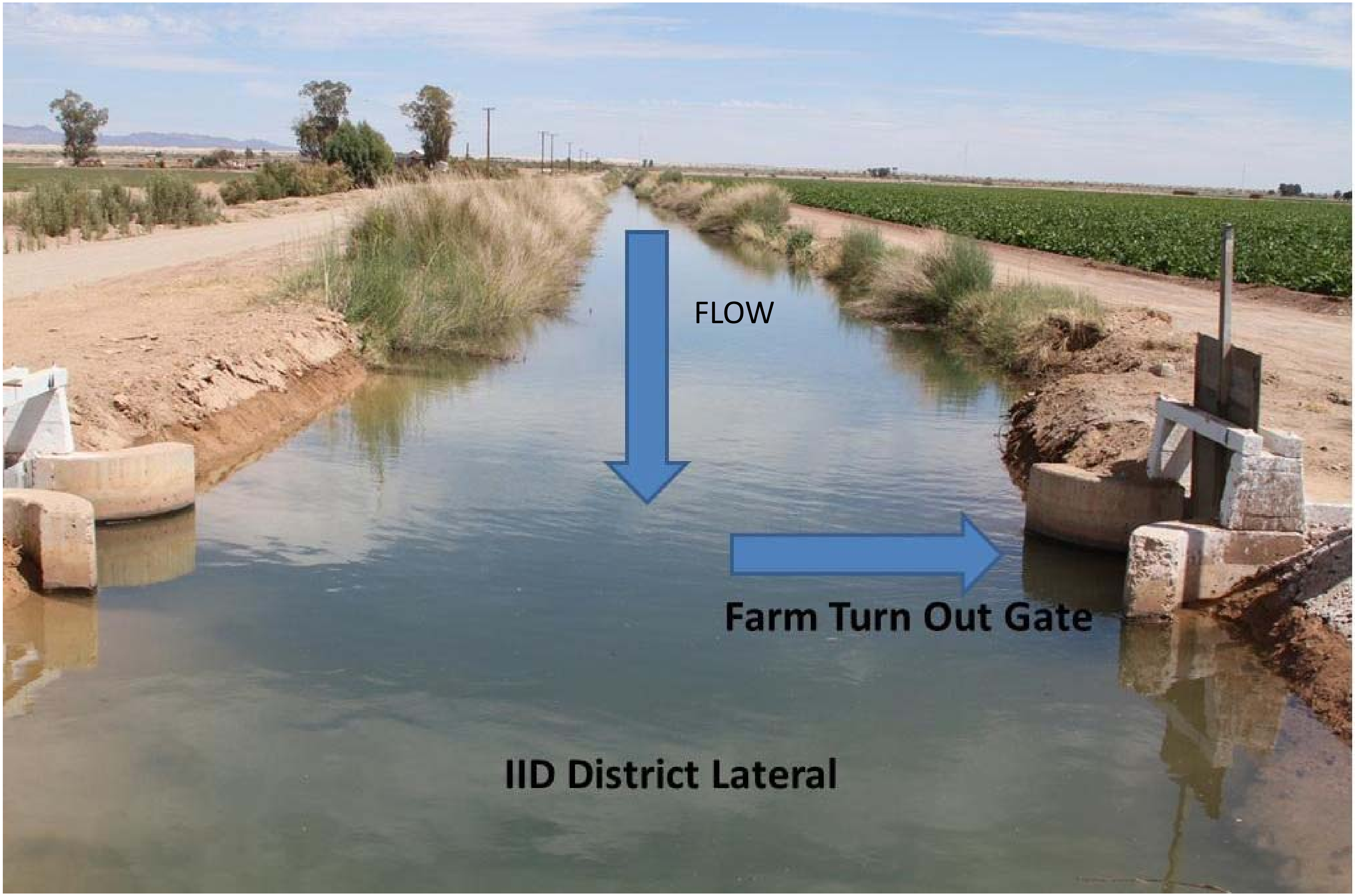
3/31/11



Existing turn out
(full open)

12 cfs – 24” pipe

RSA Installation at IID 3 31 2011


FLOW
Farm Turn Out Gate
IID District Lateral

Existing site prior to RSA installation

NOTE: 24’ of existing Farm Ditch removed as RSA pipe is installed and backfilled over with soil

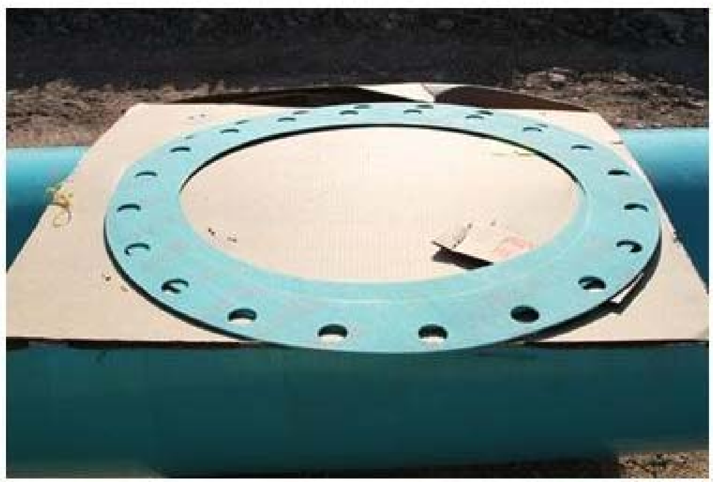
Ditch Tender uses manual crow bar to move gate.
Then writes values onto blue paper.

RSA system meters the flow inside flow conditioned pipe.
Actuated downstream gate controls flow in conjunction with meter reading to offer constant discharge through RSA system.

Flow conditioned pipe and control gate concrete box

Installation into existing farmer's lined ditch

Excavate ditch for pipe/gate installation



Assembling 24’ long flow conditioned pipe with propeller meter

McCrometer Reverse Propeller Flow Meter mounted inside RSA Flow Conditioned Pipe

Install flow conditioned/metered pipe

Prepare exit end of existing pipe

Install concrete drop box

McCrometer Reverse Propeller Meter
Saddle Installation

NOTE: Area backfilled with soil over RSA metered pipe

Partially Assembled System

Gate Installed

Manhole access to McCrometer Reverse Propeller Meter


RSA Actuated Control Gate
with Manual Crank Override

System running 12 cfs


View looking downstream

Electrical Enclosure mast with solar panels (not shown)

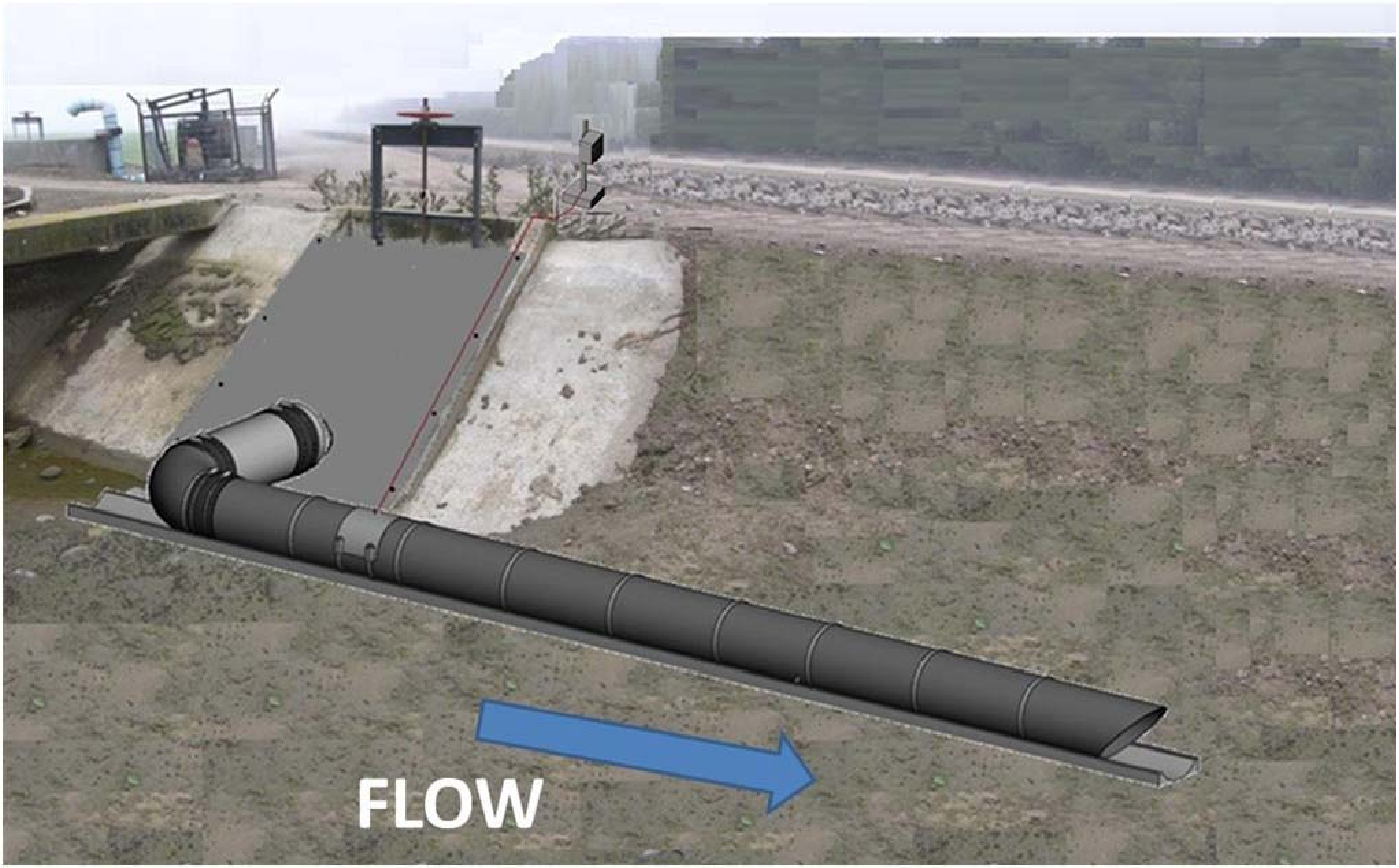
RSA Controls Panel
(solar panels not shown)

Data Display Shows:

1. Height of Gate Opening
2. Instantaneous cfs
3. Average cfs
4. Acre Feet delivered – real time totalized
5. Historical Billing Information from each Irrigation Cycle stored and accessible (not shown)

Proposed installations inside District Canal

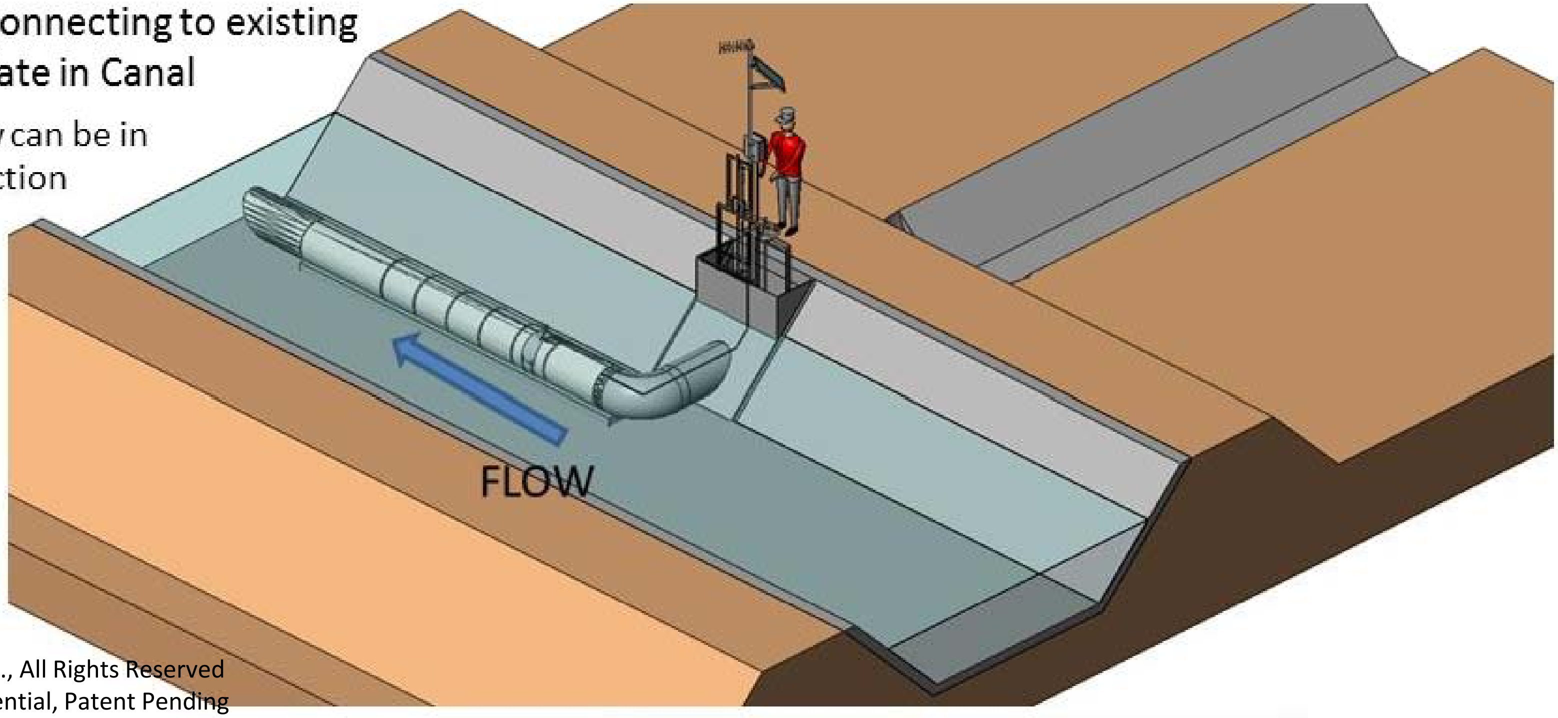
Installation inside District Canal

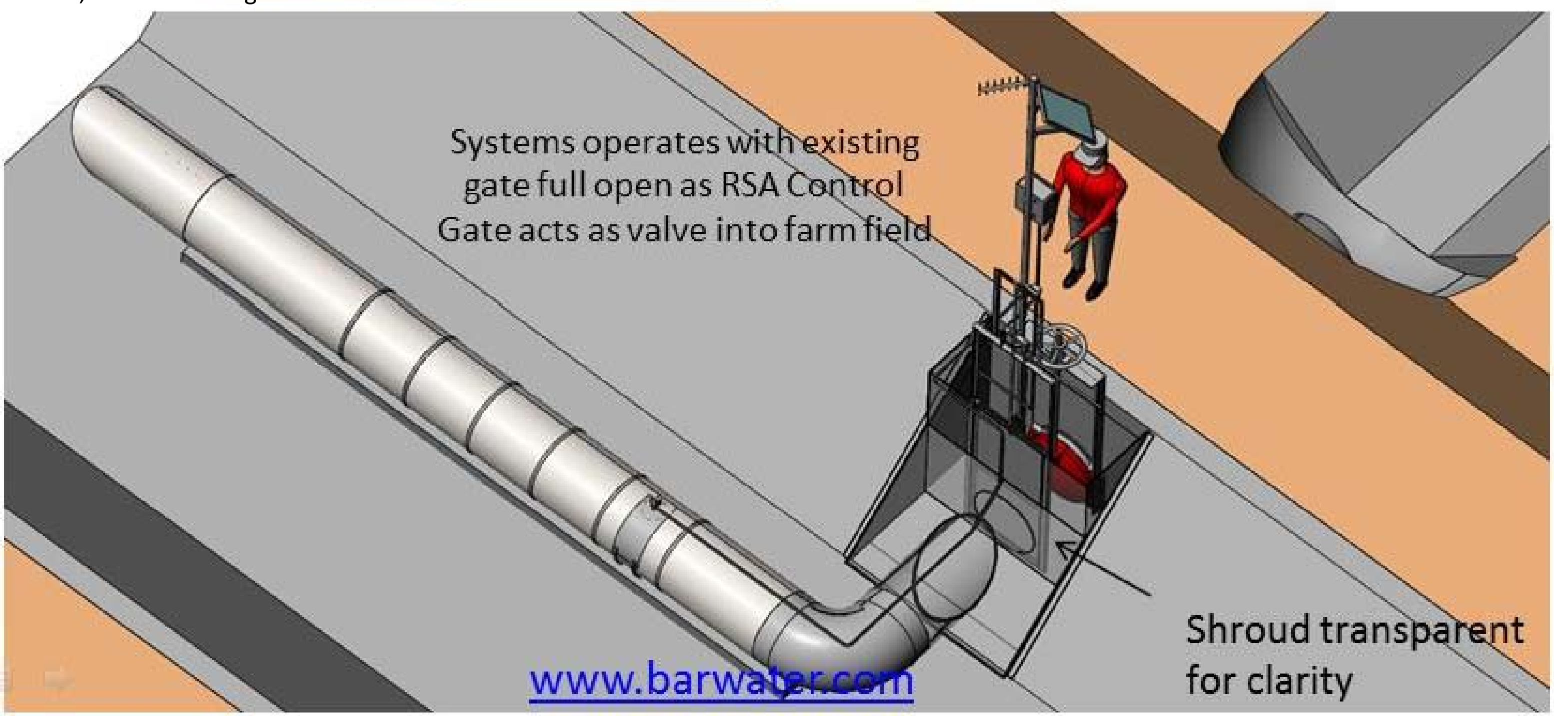


Base Model – Minimum requirement to meet SBx7-7

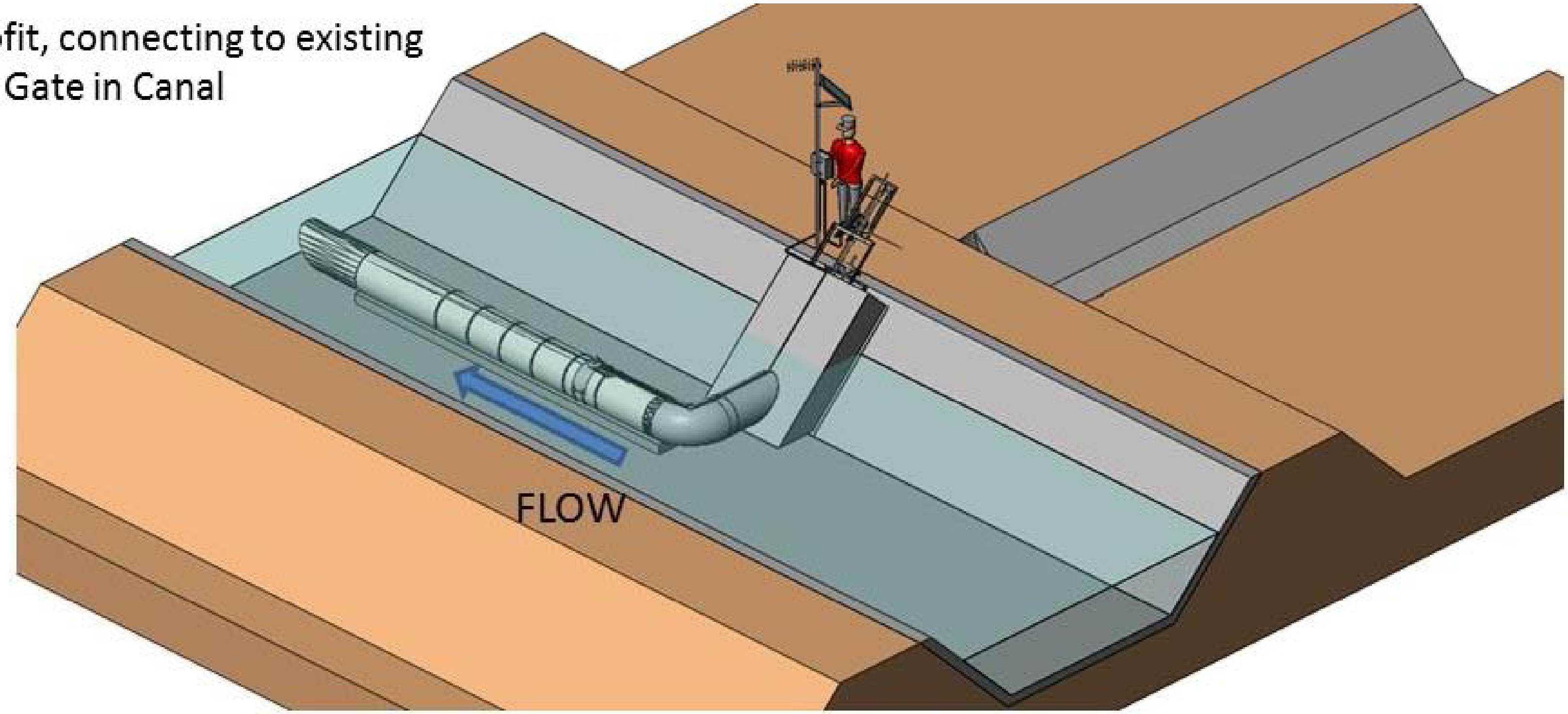
Retrofit, connecting to existing Vertical Gate in Canal

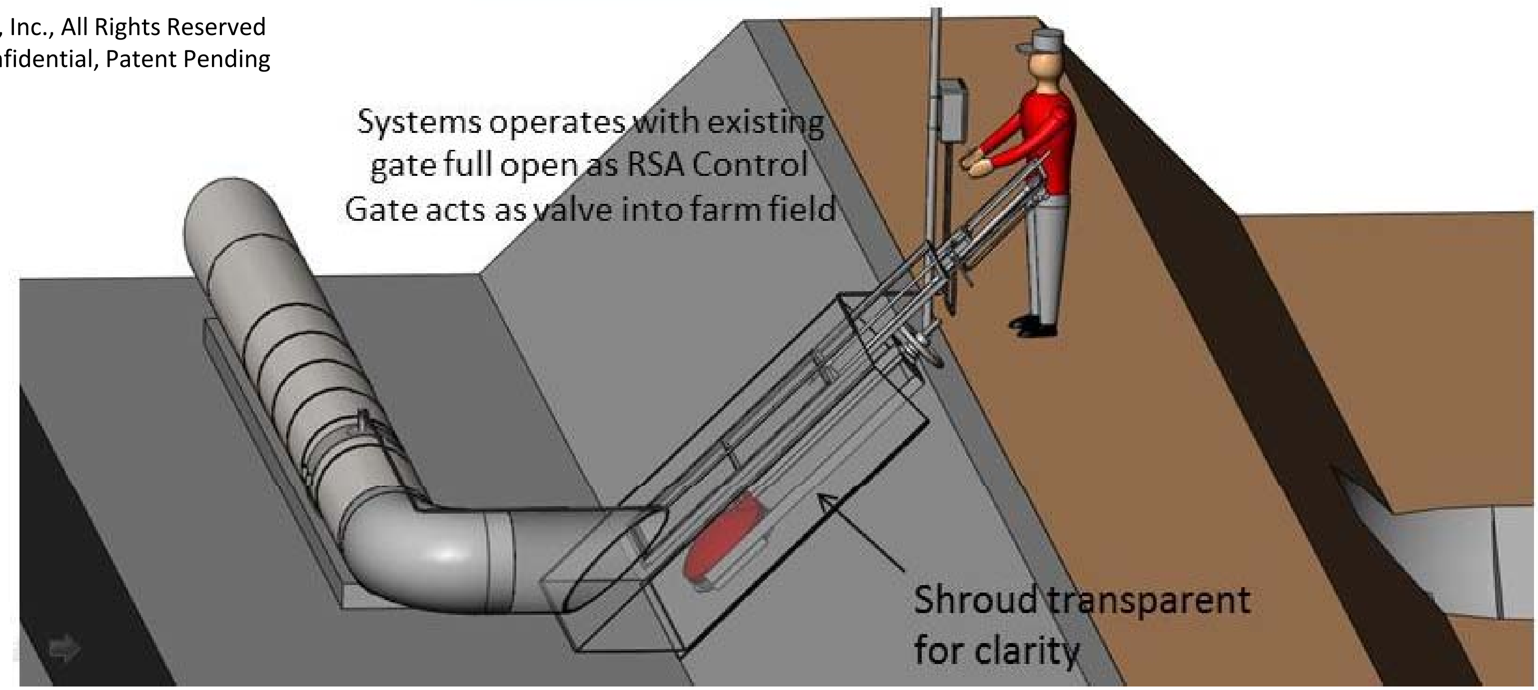
NOTE: Flow can be in either direction





Retrofit, connecting to existing Slant Gate in Canal





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Practical technologies for irrigation flow control and measurement

JOHN A. REPLOGLE
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Accepted 7 April 1997

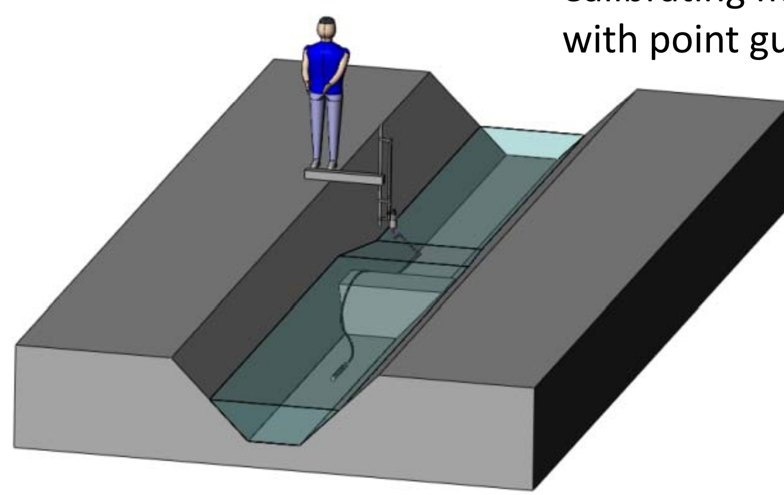
Abstract. Practical technologies can encourage farmers to adopt practices that support sustainable irrigated agriculture. Important among these are convenient water measurement and control techniques. Many simple constructions or operating procedures are available that can bring considerable convenience to farmers and irrigation delivery system operators. Some are new technologies and some are improvements on older technologies. Many can be implemented with small expense. Some are superior replacements for current practices. The techniques and devices discussed included: (a) accurate and convenient zero setting for weirs and flumes (b) pressure-transducer field checks, (c) easy-to-use scales for orifice and Venturi meters, (d) flow-profile improvers to assist accurate meter operations in irrigation pipelines, (e) floor sills and wave suppressors for canals that usually flow at variable depths of flow, (f) water surface slope measurements–based on static-pressure tubes, and (g) field checks of flow velocity profiles to evaluate flow conditioning using rising-bubble techniques for flow-profile visualization. Many of the concepts are demonstrated in a summary illustration showing several items in a typical stilling well and broad-crested weir (long-throated flume) that need attention, and offers suggestions for correcting the deficiencies.

RSA has means to field verify laboratory accuracy of flow meter with RSA's Chief Scientist, John Replogle, Ph.D.

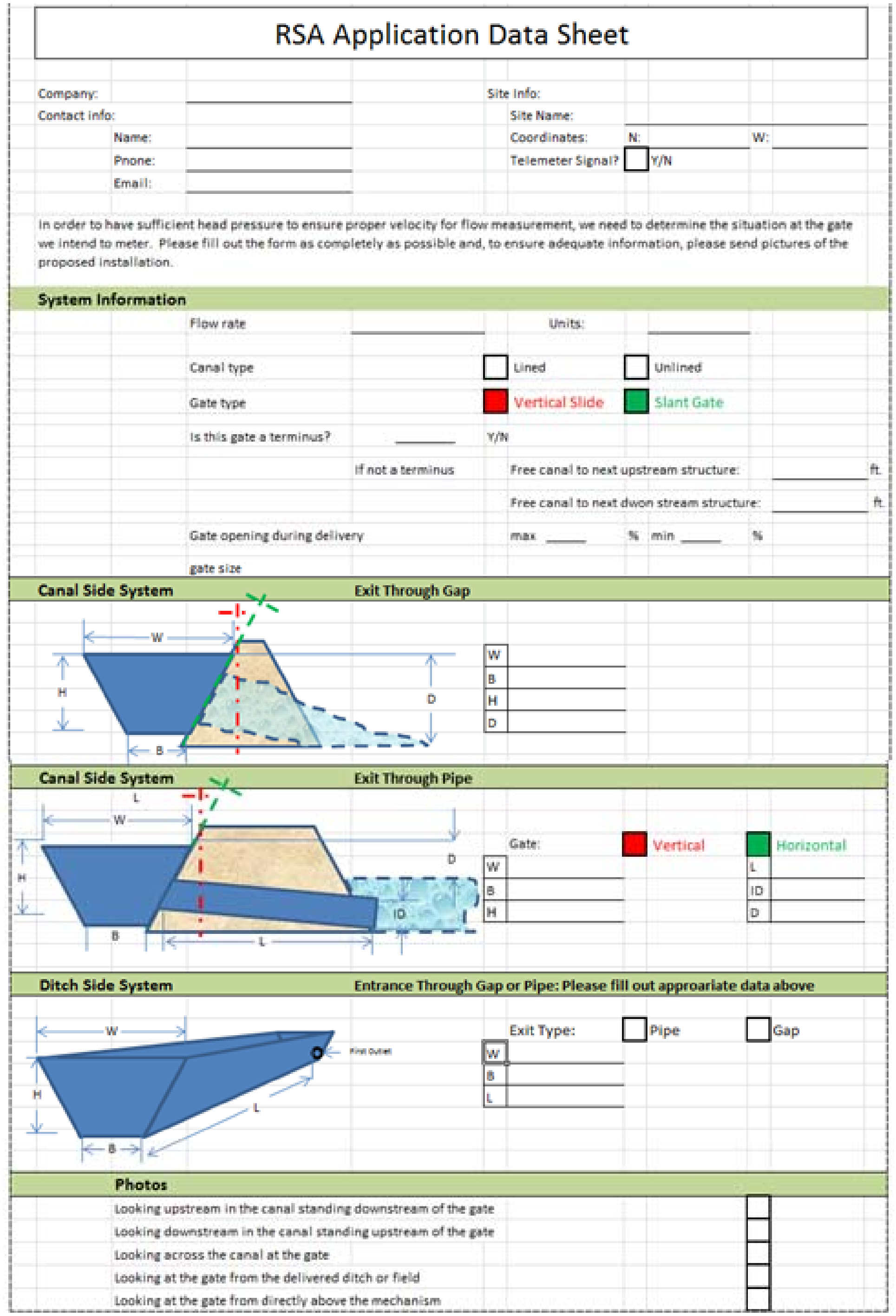
Figure 2. Method to zero-reference a flume or weir in flowing water.

For flowing water situations, a static pressure tube (see discussion below describing these tubes) is placed in the flow. The sensing holes of the static pressure tube should be placed upstream at about the same distance as the stilling well tap. The output is read with a point gage in a cup suspended above the reference elevation, Figure 2 (Bos et al. 1991). The head reading is the difference between the water surface in the cup and the top of the sill as illustrated in Figure 2. This value is set on the recorder. If possible, check another flow level to assure that mistakes are eliminated. A common mistake with chart recorders is that the technician sets the physical reading of h_1 on the chart instead of the gear-reduced chart value of h_1.

Calibrating flume with point guage



Data Sheet collects design parameters to minimize design costs.


RSA Application Data Sheet

Company: ______ Site Info:
Contact info: Site Name: ______
Name: ______ Coordinates: N: ______ W: ______
Pnone: ______ Telemeter Signal? ☐ Y/N
Email: ______

In order to have sufficient head pressure to ensure proper velocity for flow measurement, we need to determine the situation at the gate we intend to meter. Please fill out the form as completely as possible and, to ensure adequate information, please send pictures of the proposed installation.

System Information

Flow rate ______ Units: ______
Canal type ☐ Lined ☐ Unlined
Gate type ☐ Vertical Slide ☐ Slant Gate
Is this gate a terminus? ______ Y/N
If not a terminus Free canal to next upstream structure: ______ ft.
Free canal to next dwon stream structure: ______ ft.
Gate opening during delivery max ______ % min ______ %
gate size

Canal Side System **Exit Through Gap**

W	
B	
H	
D	

Canal Side System **Exit Through Pipe**

Gate: ☐ Vertical ☐ Horizontal

W		L	
B		ID	
H		D	

Ditch Side System **Entrance Through Gap or Pipe: Please fill out appropriate data above**

Exit Type: ☐ Pipe ☐ Gap

W	
B	
L	

Photos

Looking upstream in the canal standing downstream of the gate ☐
Looking downstream in the canal standing upstream of the gate ☐
Looking across the canal at the gate ☐
Looking at the gate from the delivered ditch or field ☐
Looking at the gate from directly above the mechanism ☐

In Support of Volume-Only Accuracy Limits and Water Control to Maximize Water Use Efficiency

By John Replogle, Ph.D., P.E., Clay Rosson, EIT, John Bischoff

SBx7-7 seeks to maximize the efficient use of water in California. Two factors are necessary to achieve this goal – accurate volume-only measurements and accurate water control capability.

The instant bill indicates that the reporting shall be in terms of **volume**. This renders considerations of competing approaches other than volume cumbersome and unnecessary.

Volume Accuracy Standards:

Volume is a static thing. **Flow** on the other hand can relate to **flow-rate** or **flow-velocity**, or both. To obtain the key measure (**volume**) flow-rate is time dependent and flow-velocity is area dependent. Meters are calibrated in a hydraulic laboratory to achieve certain flow accuracy. It is important to relate Flow and Volume as interchangeable and assume the accuracy of each parameter to be equivalent. In order to do this, one must assume that the time variable is highly accurate and does not contribute to the overall statistical error of the **Volume** or **Flow** calculation. Once velocity-limits are defined, then area limits need to be carefully defined with measurements like channel width, depth, shape and surface roughness.

For example:

Velocity is distance per unit time.

Area requires the integration of canal width, depth, shape and the like.

Thus volume accuracy within +/- 6 % could nearly be satisfied by an area-accuracy within +/- 10% when combined with a velocity-accuracy of +/-½ %. Of course other combinations of area and velocity accuracy can also achieve the desired +/- 6% volume accuracy. Thus, simply leaving the requirement as an accuracy-limit on volume allows many approaches to compliance without further complications.

Volume-only on-site Accuracy Limit is at about +/- 6% is further supported by the following:

As a former guidance standard from USBR for measuring by volume at the farmer turnout.

Very tolerant limits may preclude identifying low-end users and high-end users.

A level of +/- 6% appears accurate enough to accomplish the goal of improving water use efficiency for high-end users, but much larger margins may not.

The water-conservation advantages of this identification ability are numerous. Low-efficiency users could be offered assistance (for example from Extension and Natural Resources Conservation Service.) This would raise their production-unit efficiencies and provide economic advantages for themselves and their communities.

High-efficiency users could serve as model operations and qualify for financial rewards through lower pricing, tax or fee waivers, water credits for other uses or the like. While the usual concern of economist and policy makers, conservation engineering and water management interests might be better served by incentives rather than penalties.

The purpose of the meter survey was to determine Best Available Technology (BAT) for a reasonable cost. Virtually all meters listed in the document have been shown by ITRC and CIT to have an on-site inaccuracy of +/-5%. Thus there is no practical or economic policy rationale to *double* volume accuracy standard to +/- 10% - simply to accommodate a single outlier meter product.

While **flow meter accuracy** at the farmer turnout forms the foundation of irrigation system modernization **flow control** is required to fully achieve the goals of SBx7-7. The higher the accuracy, the less likely a district will spill water because water operations managers can more accurately determine the flows that enter the distribution system.

Value of Water Control:

Meter accuracy at the farm turnout forms the foundation of irrigation system modernization envisioned by SBx7-7. For example, the higher the accuracy, the less likely a district will spill water because water operations managers can more accurately determine the flows that enter the distribution system.

However, as many Ag committee members have commented, measurement accuracy alone will not maximize water use efficiency. To meet the goals of SBx7-7 fully other variables must be considered. Crops must receive water at the right time and for the right duration. Crop water demand is more effectively met by matching shutoff times to 6-hour, 12-hour or 24-hour duration intervals. Knowledgeable users with special soils knowledge (like monitoring soil moisture sensors) may be needed. Currently water is wasted since most farmers order plenty and run tail water to assure completion.

This in its worst form produces excessive infiltration and surface runoff, which can contaminate both groundwater and stream flows with pesticides and leached fertilizer.

The farm operators conceivably will wish to have control over duration if they will be charged by volume. In cases where the district's ability to satisfy the user in controlling duration become apparent, a control gate can be incorporated with the meter. In many situations, farm operators have the authority to open and close their own gates at the turnouts. However, full automation or even the luxury of allowing variable shutoff without notice is hard to handle without special canal freeboard availability or construction of strategic storage reservoirs. The higher the accuracy and the better the control, the less likely a district will spill water because water operations managers can more quickly respond to distribution variations from farm operator duration changes.

A Discussion of the Water Level Sensors with Slide Gate System Approach at Farmer Turnout

By John Replogle, Ph.D. P.E., Clay Rosson, EIT, and John Bischoff

Main Point: A slide gate (variable orifice) as a flow measuring device is highly questionable because of difficulties in accurate differential-head detection and in orifice opening detection and accurate accounting for a variable discharge coefficient.

Orifices respond to the mathematical relationship:

$$V = C_d (h_2 - h_1)^{0.5}$$

Or in terms of discharge rate, **Q:**

$$Q = C_d (A)(h_2 - h_1)^{0.5}$$

Where:

V = Average velocity through the orifice opening.

A = Area of orifice opening. In the orifice gate under consideration, this is a fixed width and variable height of a rectangular opening.

h_2-h_1 = The head difference across the orifice. These are usually obtained in stilling wells at the gate. Many depth level sensors have been tried, from pressure transducers and bubblers to ultrasonic level sensors. Most have failed to "turn on next spring." Problems involved here include vortex formation that makes the upstream side of the orifice difficult to detect accurately, and bypassing flow perpendicular to the gate that affect both the head detection and the discharge coefficient, **C_d.** Double orifice-gate systems are in use that are more reliable because they can be manually adjusted to pond a downstream-side level for more accurate detection but the upstream side is still subject to waves, etc. This is the so-called "constant head orifice" method.

C_d = The Coefficient of discharge for the orifice. This can vary over a wide range depending on the orifice gate opening, the **h_2-h_1** range, and entrance and exit conditions of the orifice and edge fouling with seasonal algae and weed problems. The entrance side contractions probably have the least effect on this but the floor and lip edges influence the value from installation to installation.

This is why the orifice gate is considered to be a 10 to 15 % flow estimator at best. Efforts to individually calibrate each site to assure higher confidence are not usually practical.

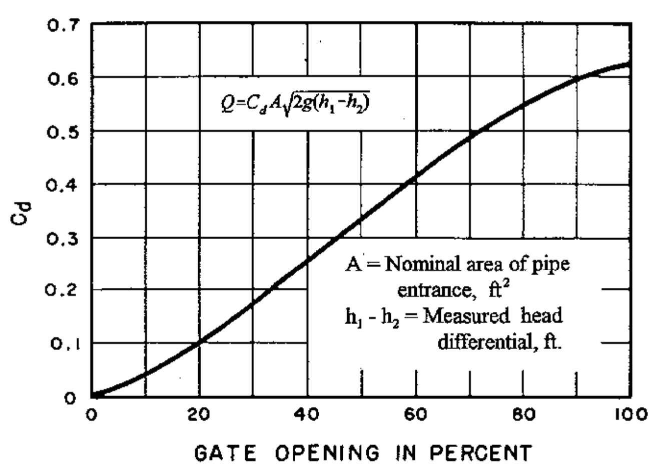
More details are presented below.

Typical commercially available upstream/downstream water level sensors located in the open channels of the downstream side and upstream side of an actuated turnout gate are an adequate solution for most Irrigation Districts. One task is to meter the turnouts to a certain standard of accuracy. Most meters available on the market have an onsite inaccuracy of +/-5% if according to manufacturer's specifications. Tony L. Wahl, from his technical paper, **Issues and Problems with Calibration of Canal Gates** describes the limitation of using slide gates as a metering gate here:

In contrast to flumes and weirs for which there is a one-to-one relationship between measured head and computed discharge, for orifice-type check gates (i.e. slide gates) there are three independent variables, upstream head, downstream head, and gate opening, and the relationships between discharge and net head are extremely non-linear in the transition zone. Thus, it may not be possible to develop simple relationships that could be programmed into a computationally weak RTU.

Basis of Measurement for the Slide Gate Opening

An orifice (opening of the slide gate) can be used for measuring the rate of fluid flow. It uses the same principle as a Venturi nozzle, namely Bernoulli's principle that states that there is a relationship between the pressure of the fluid and the velocity of the fluid. When the velocity increases, the pressure decreases and vice versa. If you do not have a meter that calculates velocity through the gate opening, the slide gate's changing undershot orifice relies on a coefficient of discharge "**C_d". ** The coefficient changes as the orifice or "opening" increases **or** decreases as shown in the figure below from the "USBR Water Measurement Manual, Chapter 9 - Submerged Orifices."



Factors reducing the flow accuracy of the slide gate are summarized as:

- The entrance conditions (geometry of side walls and floor) are not uniform from site to site, and change temporally as algae and trash build up.

- The water level within the canal is not accurate because the open farmer turnout can form a variable vortex causing a detection error in the true water level.

- Other meter manufacturers propose to place water level meters in the open channels of the canal and farmer ditch. In the best case scenario, the orifice would be installed in a pipe with a stilling well at some distance on each side of the orifice so the entrance and exit conditions are controlled and the stilling wells are not subjected to vortex (entrance) and submerged hydraulic jumps (exit). Even if the sensors accurately measure the water levels, they do not account error in sensing the gate opening or the change in gate edge or floor conditions, over the season.

- The actuator, even if highly accurate on slide gate may give a precise orifice opening but may not be able to account for floor buildup over the season or with debris and algae effects on the orifice edges.

- .A highly accurate actuator is much more expensive than the actuator that RSA currently utilizes and could reduce the error associated with the gate opening error, but not debris effects.

- When there is an open field on the other side of the turnout rather than a farmer ditch where do you locate the downstream water level sensor? The device depends on a submerged orifice, or else a different format must be available.

<u>Conclusion</u>

Typical commercially available upstream/downstream water level sensors which are placed in the canal on the upstream side of the canal and in the farmer ditch on the downstream side will be an inadequate solution. Incorrectly, some manufacturers do not utilize the placement of the meter/sensor into a velocity-profile-conditioning pipe as recommended by Dr. John Replogle.

In the situation when there is a farmer concrete-lined canal, it is practical for RSA's Chief Scientist to install a temporary Long-Throated Flume (Replogle Flume) in the farm canal that when properly equipped with laboratory point gages. or the equivalent, can determine spot flow rates to accuracies of about +/- 2%. (Refer to The USBR webside for WinFLume). Thus, it is possible that the Slide gate with level sensors could be field verified for a range of flow rates at particular sites, if the other manufacturer still feels that their proposal has merit.

Slidegate/Water level sensors in the field are reasonably expected to have an inaccuracy considerably higher than +/-6% tentatively proposed to the state law SBx7-7. Field installed water level sensors across the slide gate as proposed is unlikely to reach this level of accuracy with a pressure differential across a slide gate (undershot-orifice gate).