Irrigation Training and Research Center

California Polytechnic State University
San Luis Obispo

Flow Measurement Update
by Dr. Stuart Styles

26 January 2012

- Introduction
- USBR water management plan update
- “Accuracy” defined
- Devices
- Documentation requirements
- Other agencies and new guidelines
- Summary

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moving water in new directions

Flow Measurement Update

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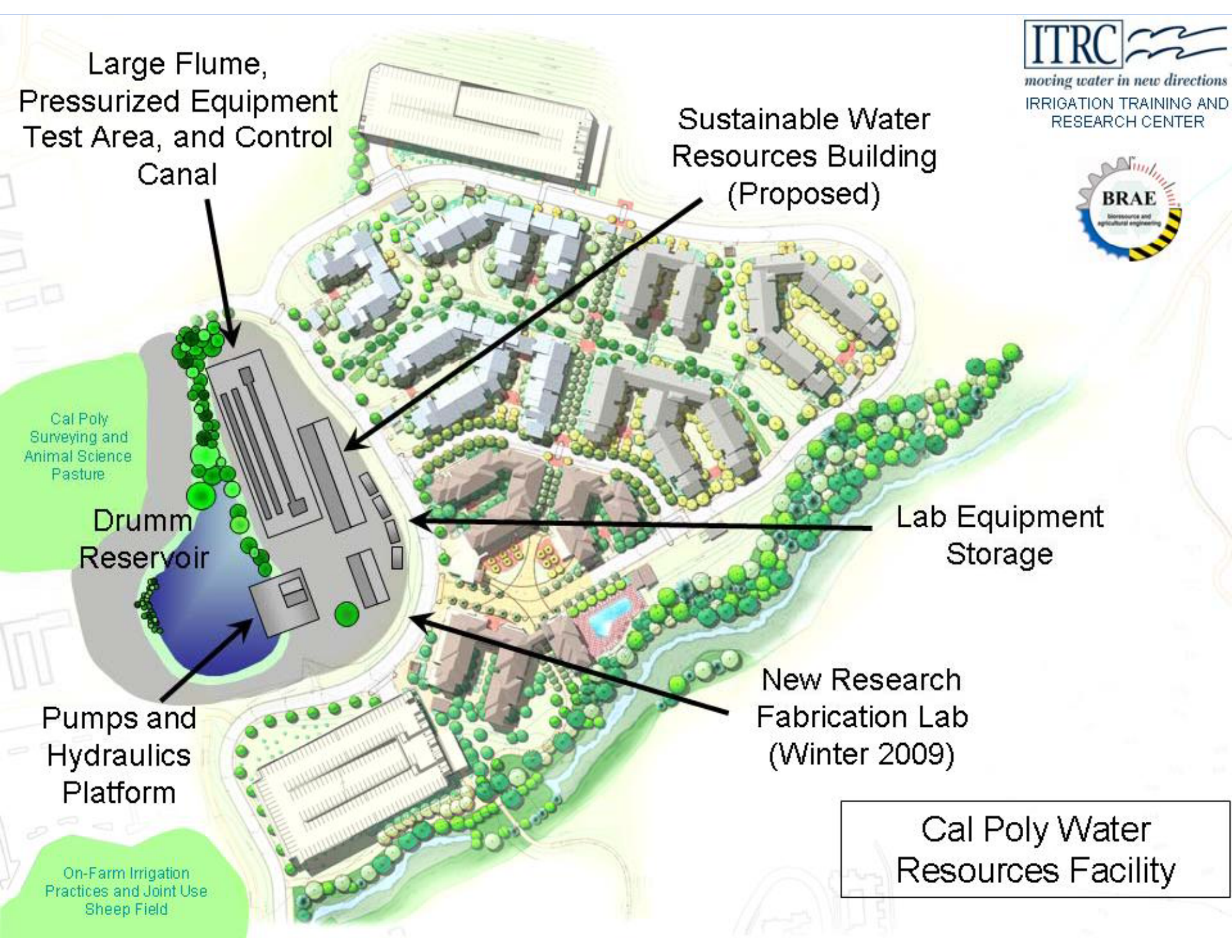
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IRRIGATION TRAINING AND RESEARCH CENTER
BRAE
Large Flume, Pressurized Equipment Test Area, and Control Canal
Sustainable Water Resources Building (Proposed)
Cal Poly Surveying and Animal Science Pasture
Drumm Reservoir
Lab Equipment Storage
Pumps and Hydraulics Platform
New Research Fabrication Lab (Winter 2009)
On-Farm Irrigation Practices and Joint Use Sheep Field
Cal Poly Water Resources Facility

Cal Poly Water Resource Facility

New Hydraulic Equipment
NIST Traceable Weigh Tank

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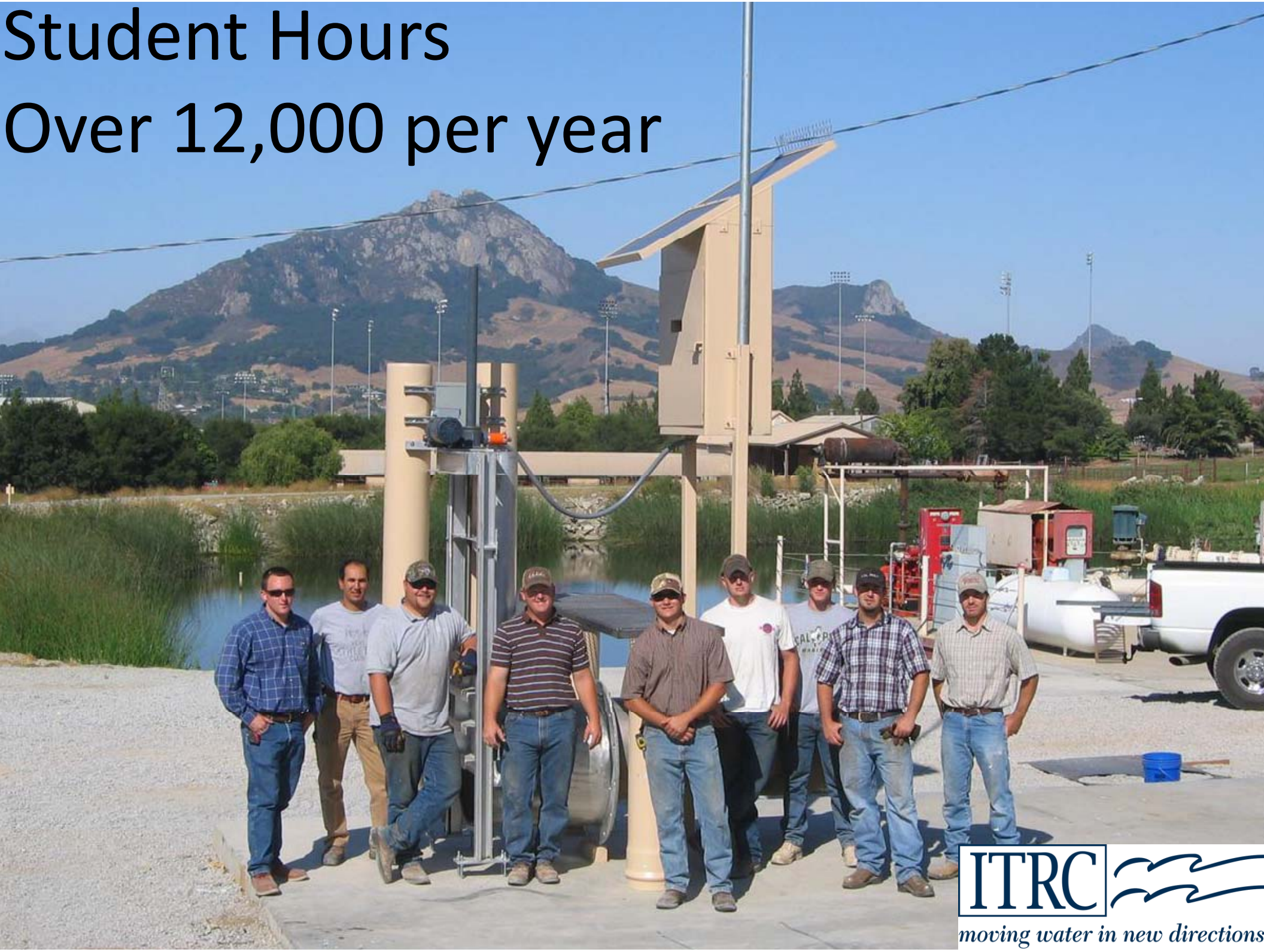
Student Hours
Over 12,000 per year



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RECLAMATION

Managing Water in the West

Water Conservation Standard Criteria for Evaluating Water Management Plans

Reference:
http://www.usbr.gov/mp/watershare/documents/Water_mgmt/Working%20documents/2011%20Presentation%20for%20public.pdf

U.S. Department of the Interior
Bureau of Reclamation

USBR – New Guidelines

- **Water measurement –documentation in support of verifying measurement accuracy (e.g. +/-6%) must be submitted**

- **Note: "Documentation is what is the new item. The +/-6% has been in place for 20+ years.**

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Accuracy

The percent shall be calculated as:

100 x (measured value – actual value) / actual value

Example: Metergate reading – 10.3 CFS
Current meter reading – 10.6 CFS

Flow Rate Accuracy =

100 x (10.3 – 10.6)/10.6 = -2.8%

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Accuracy

Flow Rate Accuracy is not the same as Volumetric Accuracy

Volumetric Accuracy must take into account the **time** that water was delivered using one of 2 options:

- Propeller meters (or any meter with a totalizer)
- Any calibrated measurement device equipped to make flow rate measurements at frequent intervals

Gas Station 5-Gallon Accuracy
+/-0.5%

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ITRC Weigh Tank – Accuracy +/-0.1%
NIST Traceable

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USBR: BMP Language

Measure the volume of water delivered by the Contractor to each customer with devices that are operated and maintained to a reasonable degree of accuracy, under most conditions, to +/- 6 percent.

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Accuracy

		Potential Flow Rate Accuracy Assuming Proper Installation and Maintenance				
Device Category	Example Types	USBR - Lab (Flow Rate)	ILRI20 - Lab (Flow Rate)	Reference & Notes (See footnotes for links to references)	ITRC - Field (Flow rate)	Reference & Notes
Pipelines		(%)			(%)	
Propeller meters		2%	5%	USBR - Section 14-4, Pg. 14-12. ILRI20 -Table 3.1, Section 9.7. Must have at least 8-10 diameters upstream and 4 diameters downstream. Meters must be maintained and checked for accuracy at least every 5 years. See the link below from the USBR-MPR for the maintenance and protocol requirements. ITRC note: It is possible to place customized flow conditioning upstream that minimizes errors due to rotating flow and non-symmetric flow. Propeller meters are sensitive to trash accumulation. Some models have serious bearing problems with sand/silt.	5%	Estimated by ITRC
Magnetic meters						
	Full bore	1%	---	USBR - Section 14-6, Pg. 14-18. Recommended to have at least 2 diameters upstream and 1 diameter downstream. Major differences between manufacturers. Some have built-in flow conditioning. One of the most accurate flow measurement devices.	3%	Estimated by ITRC
	Insert	---	---	ITRC notes: Insert meters must have an excellent straight section of pipe upstream and downstream; accuracy is limited. Not recommended for turnouts.	?	
Acoustic Meters						
	Transit-Time	2%	---	USBR - Section 11-1, Pg. 11-3. ITRC notes: Results with "dry" transducers can be variable.	5%	Estimated by ITRC
	Doppler	2%	---	USBR - Section 11-8, Pg. 11-15. Highly dependent on the canal section to obtain good accuracy. ITRC note: There are huge differences in quality among the manufacturers. Some are excellent; some are very undependable and have been abandoned by irrigation districts.	5%	Estimated by ITRC
Differential head meters						
	Venturi	1%	---	USBR - Section 14-3	5%	Estimated by ITRC
	Orifice	1%	---	USBR - Section 14-3. ITRC notes: Few orifice meters used in agricultural irrigation turnouts because of narrow range of flow rate accuracy, head loss, and difficulty in measuring the difference in head. Not recommended for turnouts	?	
Electricity KWH meter				ITRC notes: Not recommended. Some users will use a flow rate from a pump test and extrapolate a value for AF/KWH. This approach is very inaccurate.	50+%	Estimated by ITRC
Open Channel						
Metergates		2.5%	6%	USBR - Section 9-14, Pg. 9-23. ILRI20 - Table 3.1, Section 8.6. Main issue is that the standard conditions used to create the flow tables must be met. In addition, the following specific conditions must be met: "Zero" height is when the gate starts to leak and must be verified for each gate. Always pull up on shaft to take a reading. Keep the bottom of the gate entrance clean/clear to maintaing a constant flow characteristic. A water level in the downstream pool is not same as a properly set stilling well 12-in behind the gate. Eddies or vortexing at the gate entrance will generally cause an overestimation of the flow rate. The accuracy is poor if the gate is more than 70% open. If installed according to a manufacturer's specifications, with a well-calibrated chart provided by the manufacturer, results can be good.	5%	Estimated by ITRC

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Accuracy

Calibrated slide or sluice gates		2%	---	Estimated by ITRC. ITRC notes: Numerous conditions for calibration must be met, as with metergates. Standard textbook calibrations are rarely satisfactory. Calibration must correspond to the specific dimensions and inlet/outlet conditions. Must constantly be in either free flow or submerged conditions.	5%	Estimated by ITRC
Constant Head Orifice		3%	7%	USBR - Section 9-11-b, Pg. 9-14. ILRI20 - Table 3.1, Section 8.3. The poor accuracy reported by ILRI20 was based on information from the 1980s, and because of inherent dislike of CHOs that were inappropriately used in foreign projects. The 2nd gate simply maintains a submerged condition on the first gate. Same accuracy as calibrated slide or sluice gates.	5%	Estimated by ITRC
Weirs						
	Rectangular	1%	1%	USBR - Section 7-17. ILRI20 - Table 3.1, Section 5.1. ITRC notes: In general, there is insufficient head in California for widespread usage of these.	5%	Estimated by ITRC
	V-notch	1%	1%	USBR - Section 7-17; Section 7-11, Pg. 7-20. ILRI20 - Table 3.1, Section 5.2.ITRC notes: In general, there is insufficient head in California for widespread usage of these.	5%	Estimated by ITRC
	Cipoletti	1%	5%	USBR - Section 7-17. ILRI20 - Table 3.1, Section 5.3. ITRC notes: In general, there is insufficient head in California for widespread usage of these.	5%	Estimated by ITRC
Acoustic Meters						
	Transit Time	2%	---	USBR - Section 11-1, Pg. 11-3. Must be maintained and field verified weekly. ITRC note: Generally not applicable to turnouts.	5%	Estimated by ITRC
	Doppler	2%	---	USBR - Section 11-8, Pg. 11-15. Highly dependent on the canal section to obtain good accuracy. ITRC note: There are huge differences in quality among the manufacturers. Some are excellent; some are very undependable and have been abandoned by irrigation districts.	5%	Estimated by ITRC
	Doppler with control section	---	---	New structure design by ITRC. Uses a stucture to straighten the stream lines in combination with an uplooking Doppler. http://cedb.asce.org/cgi/WWWdisplay.cgi?267867. With a high quality of Doppler, this can be an excellent technique.	3%	Estimated by ITRC
Flumes						
	Parshall	2%	3%	USBR - Section 8.10, Pg. 8-21. Not recommended by USBR for new installations (Pg. 8-40). ILRI20 - Table 3.1, Section 7.4.	5%	Estimated by ITRC
	Replogle Flumes, aka "Ramp flume", "broadcrested weir"	2%	3%	USBR - Section 8.8.a, Pg. 8-21. ILRI20 - Table 3.1, Section 7.1. ITRC notes: These can be excellent if designed and maintained properly. Very sensitive to incorrect design, not using as-built dimension in rating tables, incorrect positioning of "zero" on staff gauge, and poor downstream conditions that cause submergence at high or low flows. Nevertheless, can be excellent in the correct situation.	3%	Estimated by ITRC
	Cutthroat flumes	-	-	ITRC note: Not recommended. Although they received considerable attention in Colorado, subsequent work indicates they have poor accuracy.		
Radial gate		---	5%	USBR - Section 9.13. Reported as complex to evaluate. ILRI20 - Table 3.1, Section 8.4. Rarely if ever used for turnouts.	5%	Estimated by ITRC

USBR Reference (9mB):

http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/wmm.html
Water Measurement Manual, A Water Resources Technical Publication\
US Department of the Interior, Bureau of Reclamation, Third Edition - 2001

ILRI 20 Reference (18.6 mB):

http://content.alterra.wur.nl/Internet/webdocs/ilri-publicaties/publicaties/Pub20/pub20.pdf
Discharge Measurement Structures (third edition), 1976/1989.
Note: Most of the accuracy values are from Table 3.1 - Column 14

USBR-MPR Maintenance and Protocol Requirements for Flow Rate Measurement:

http://www.usbr.gov/mp/watershare/documents/Water_mgmt/Planner/2008%20%289%29%20Calibration%20and%20Measurement.pdf

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USBR Turnout Devices

Category I

The first category includes devices with totalizers that measure volume. These devices might measure velocity, flow rate or volume directly. All of these devices will provide a direct volumetric reading. The devices in Category I include:

- Propeller meters
- Venturi meters with flow recorders
- Magnetic meters
- Acoustic meters

These have a high level of accuracy with proper installation and periodic maintenance and calibration.

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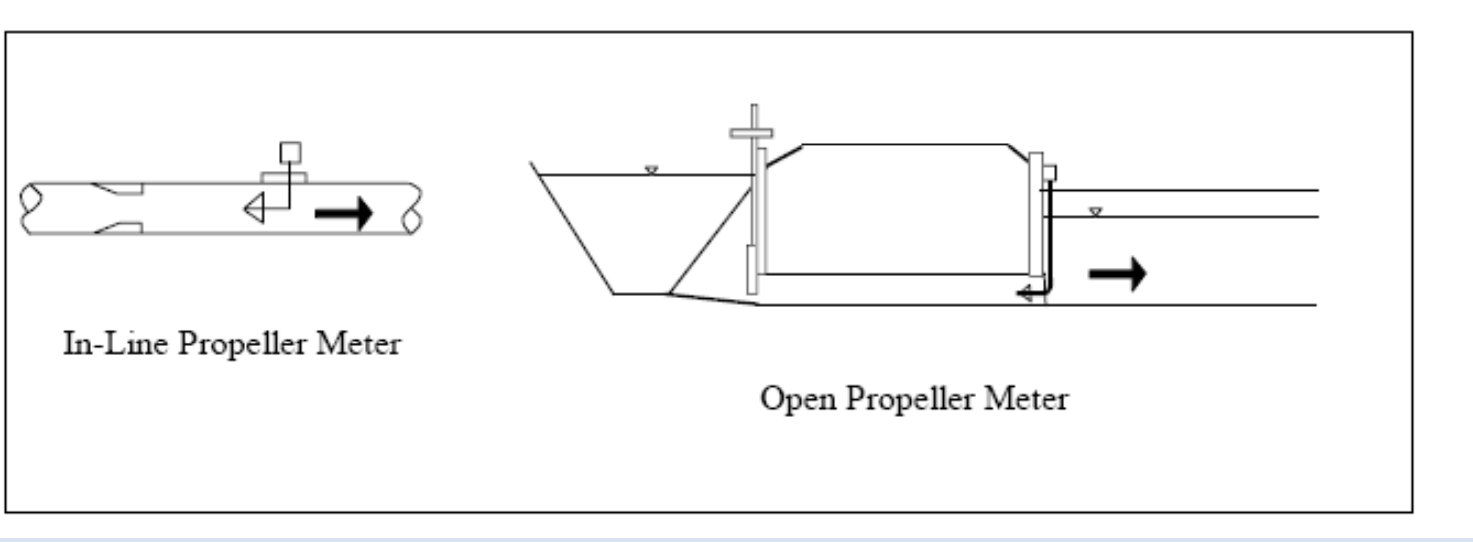
Traditional Flow Measurement Device for Pipelines:

Propeller Meters



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Propeller Meters

- Advantages
  - Easy to use
  - Relatively low cost

- Disadvantages
  - Sensitive to plugging
  - Sensitive to turbulence
  - Inaccurate at low velocity (less than 1 fps)

Most popular
Saddle-type Propeller Meter

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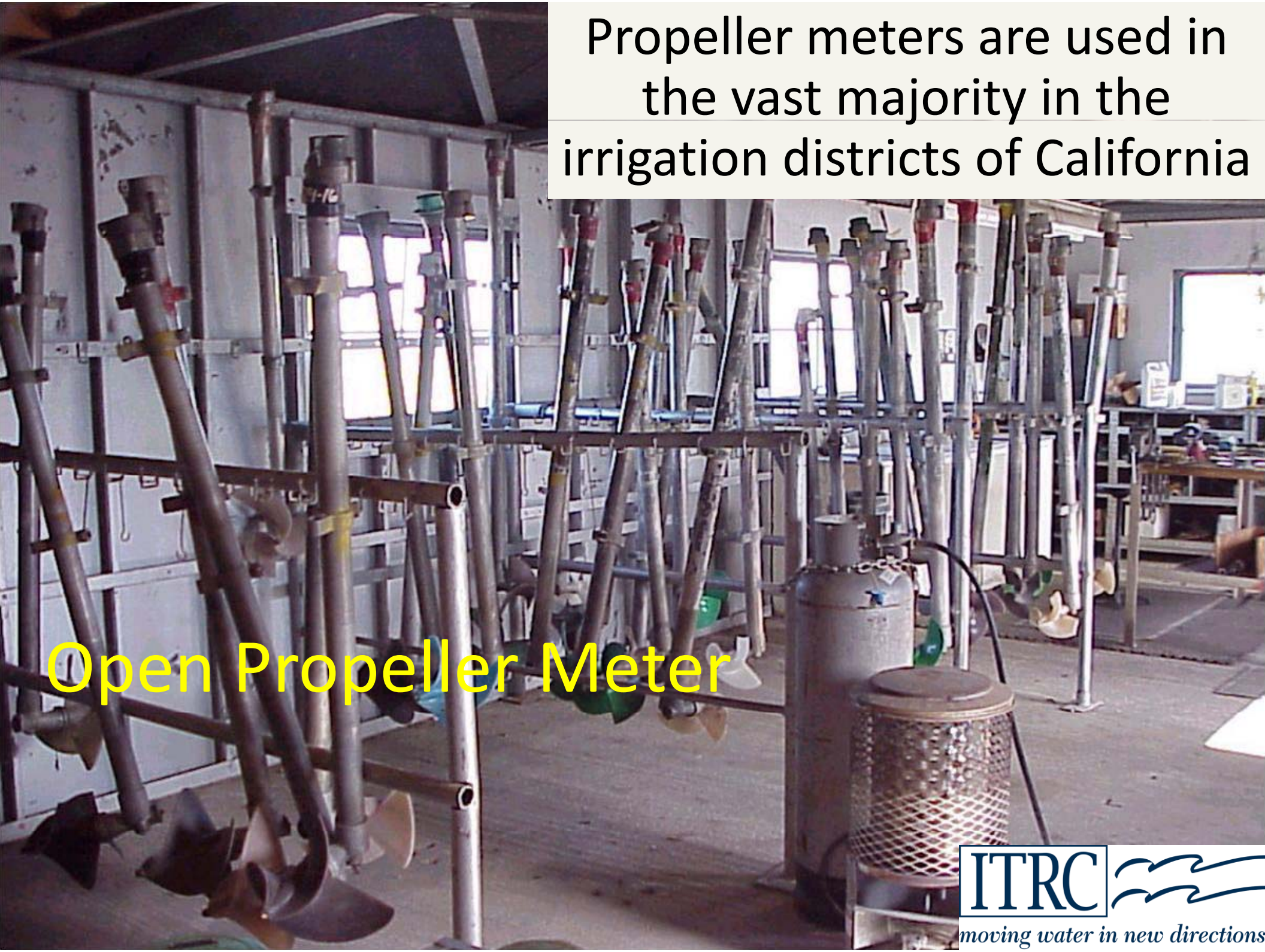
Propeller meters are used in the vast majority in the irrigation districts of California



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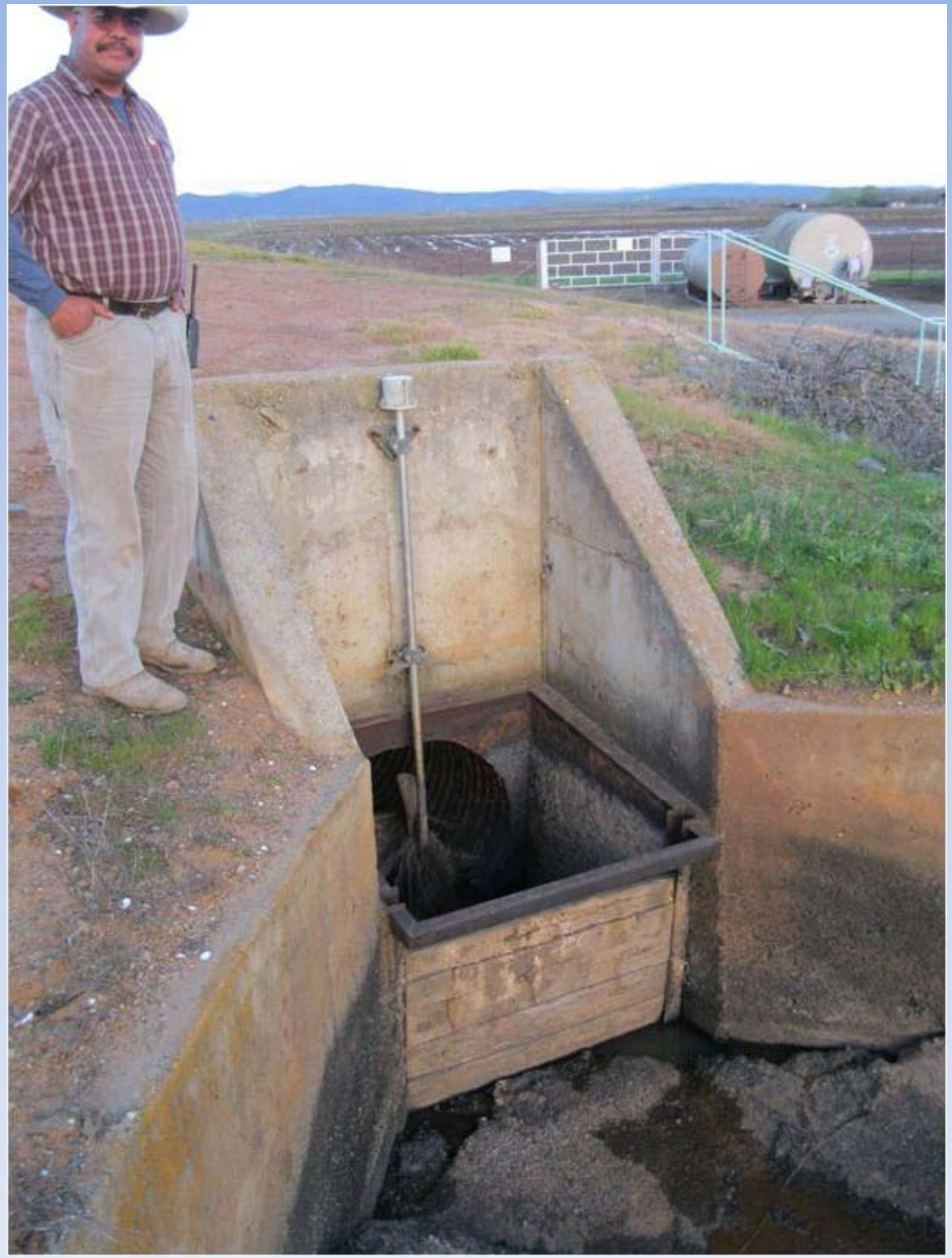

Propeller Meter with weir box

Cordua ID

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Trash Problem on a Open Propeller Meter

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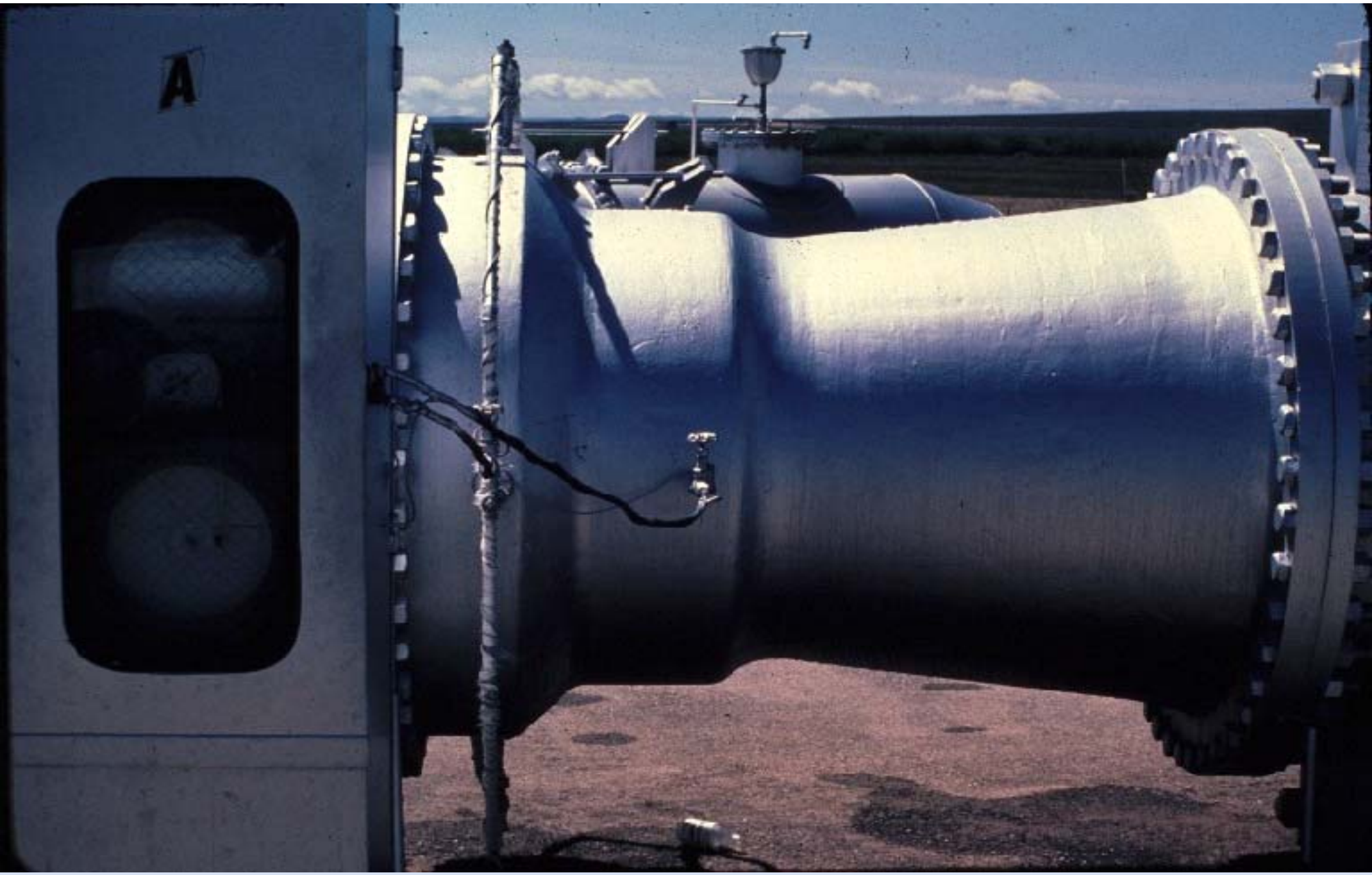

Venturi Meter

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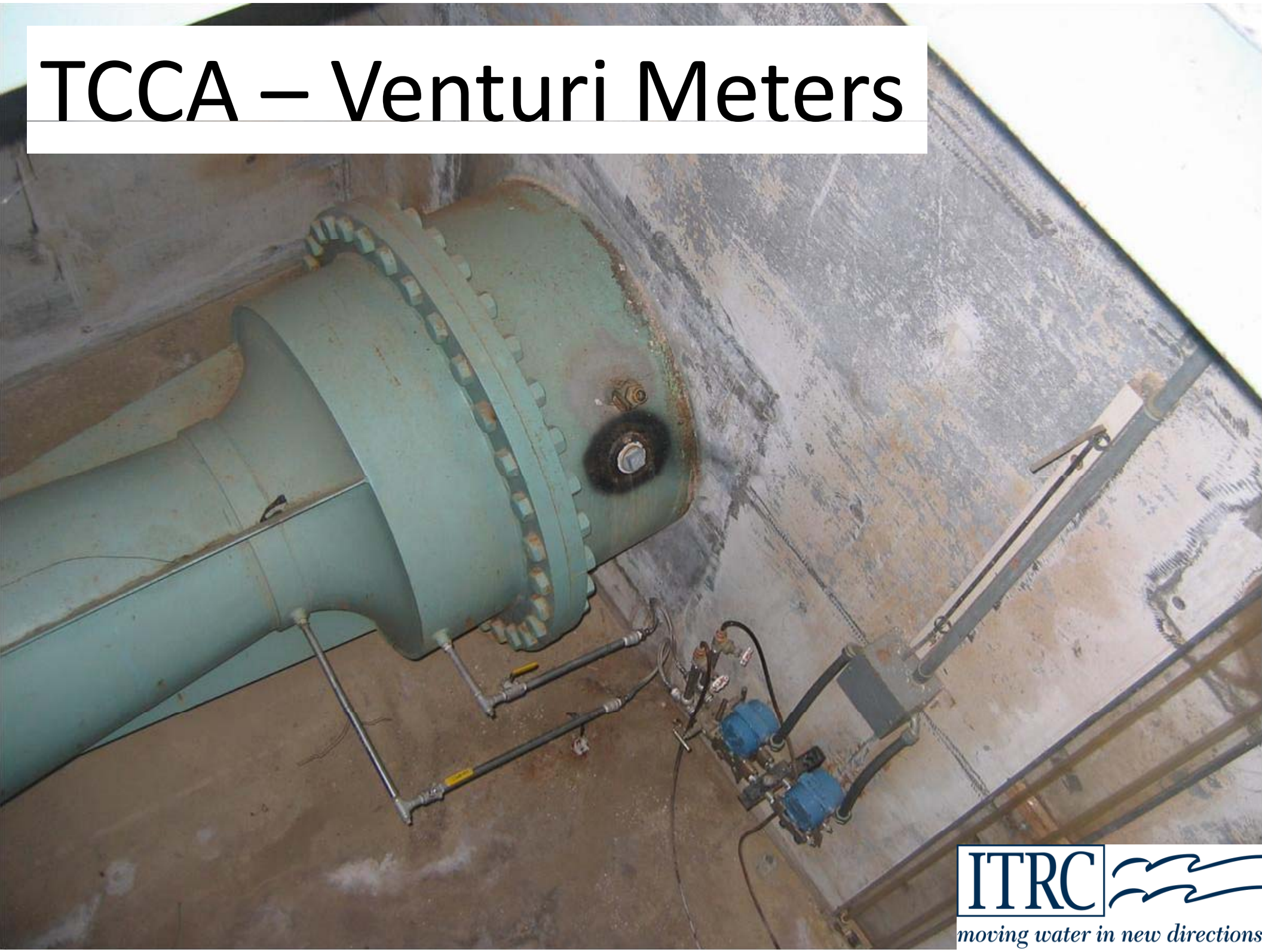
TCCA – Venturi Meters



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Magmeters

- Various sizes available
- Range up to 100:1
- Accurate (+/- .5%)

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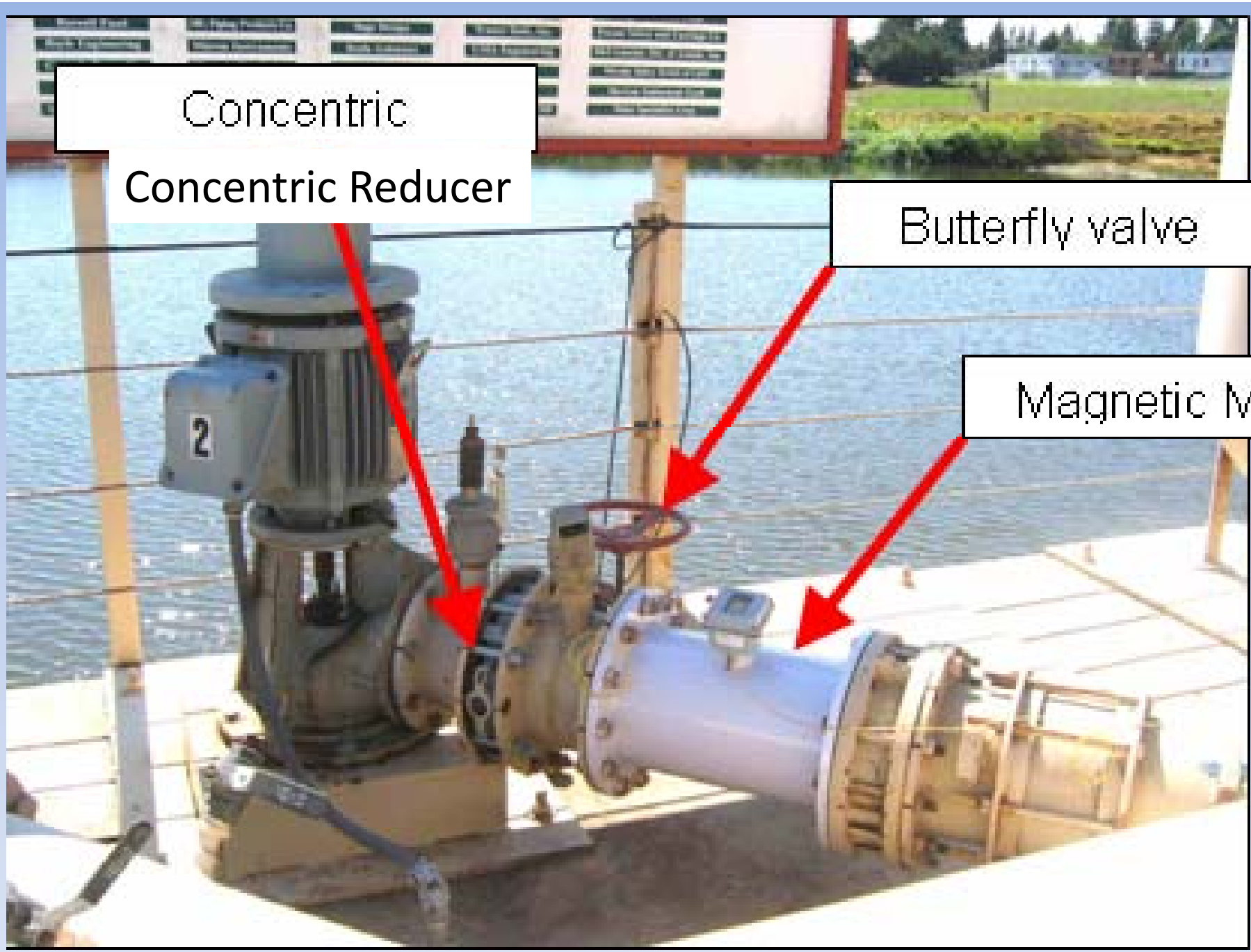
Advantages of Magmeters

- No moving parts
- Good for highly erosive and corrosive fluids
- Not impacted by sand, sediment, algae

Full Bore Magmeter



ITRC Testing in Poor Hydraulic Conditions

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Magnetic meters in Patterson Irrigation District

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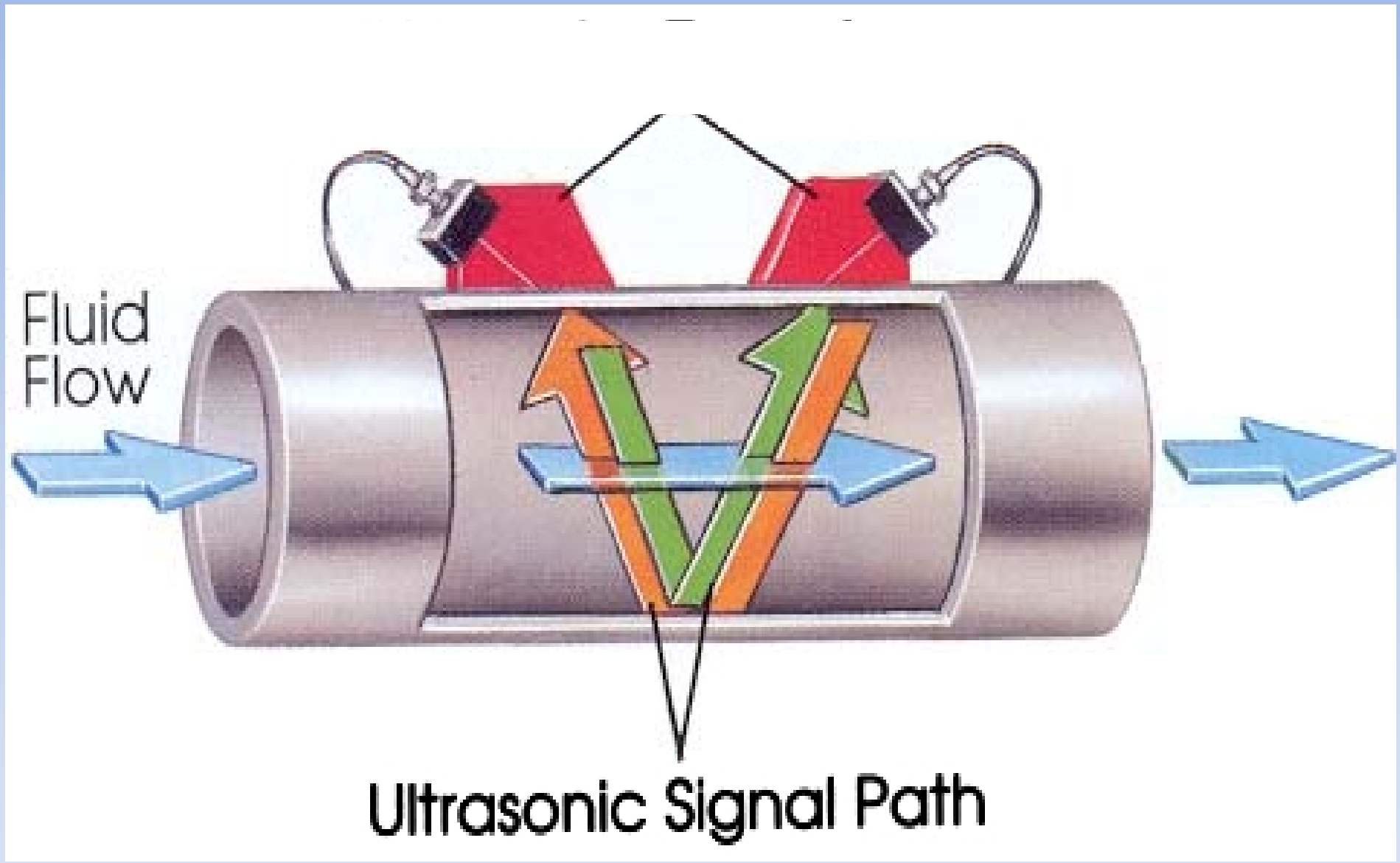
Acoustic Meters

- Transit Time
- Doppler

Transit Time Acoustic Meter



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RD108
Transit Time Acoustic Meter
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TCCA, DEID – Sontek SW Doppler Meter

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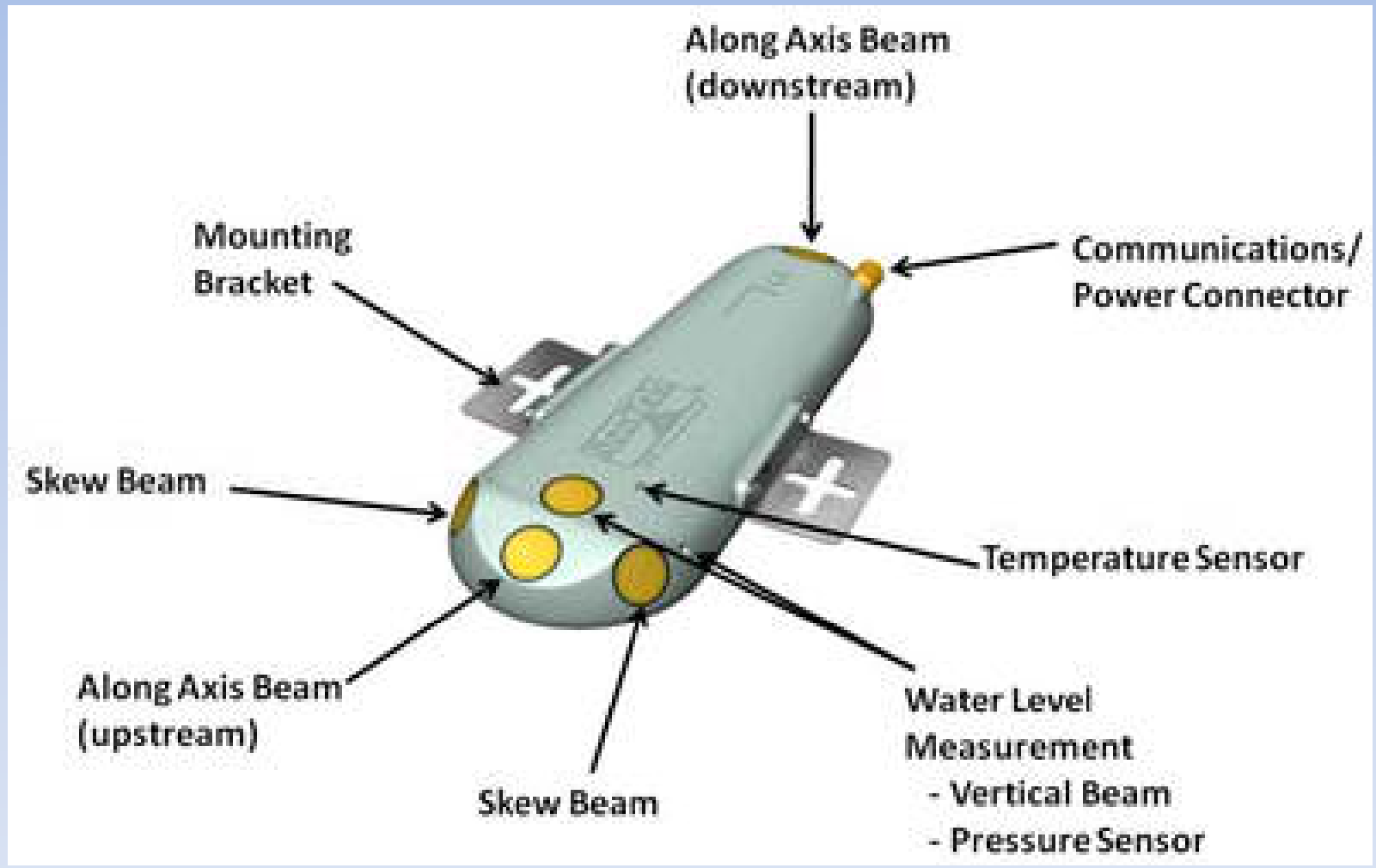
New Sontek IQ Doppler Meter



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Trash Problems on Dopplers

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USBR Turnout Measurement

Category II

The second category involves devices used for open channels. The second category includes:

1. Standard flow measurement devices that measure flow rate and also require accurate measurements (hourly or more frequently) of water level **or,**
2. The same standard devices combined with excellent canal water level control using positive means such as flap gates, long-crested weirs, or properly designed PLC-controlled water level control gates.

Weirs

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TCID - Rectangular Weir

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RD 1004 - ITRC Weir Stick

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Replogle Flumes

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Turlock Irrigation District
2,100 CFS

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Firebaugh Canal Water District
100 CFS – Redwood Flume

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Westlands Water District

Small Flumes

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WinFlume

USBR-Denver

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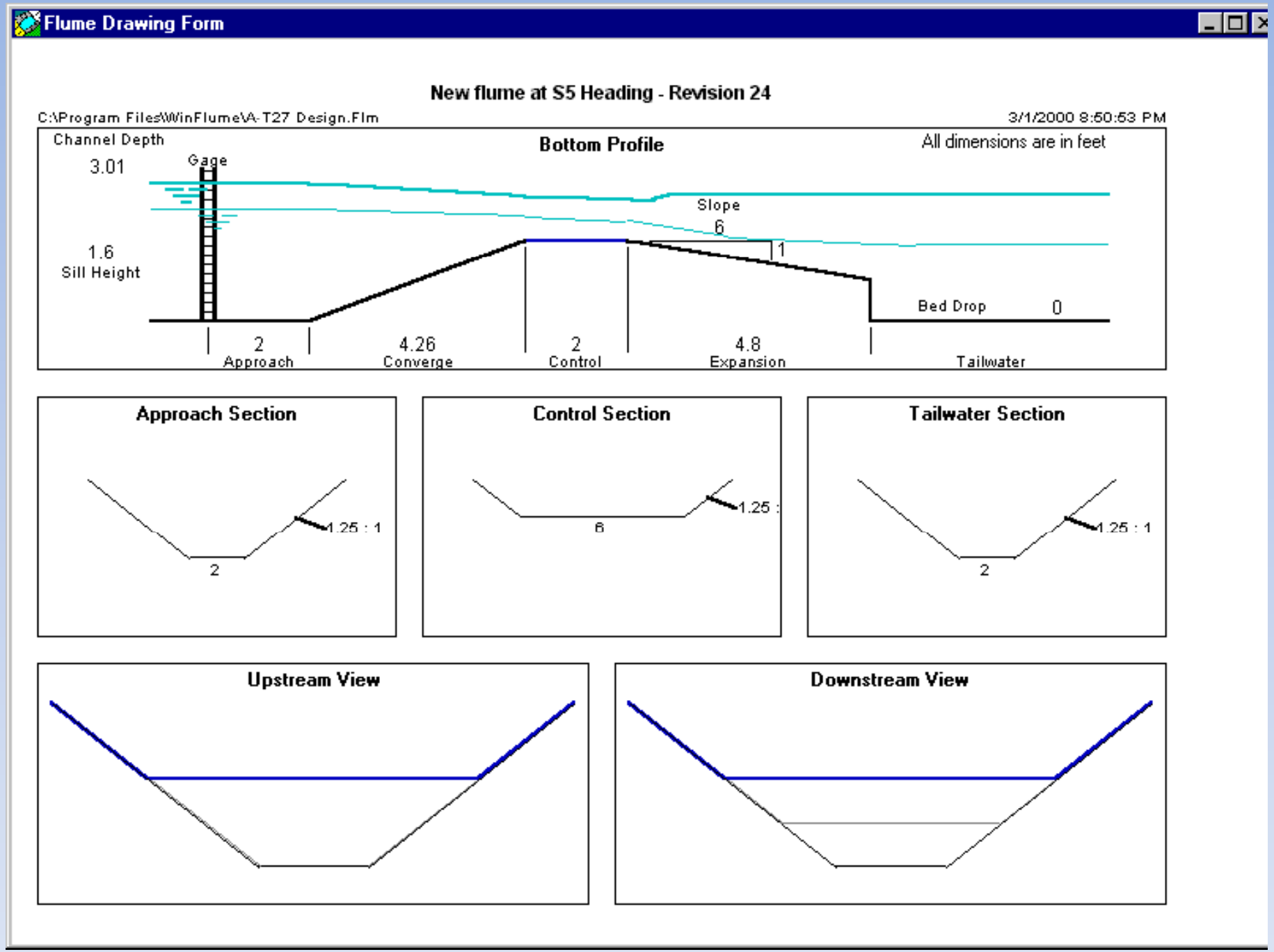

WinFlume Set-up Screen

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Maps News Shopping Gmail more
yuma, az
Search Maps
Show search options
Find businesses, addresses and places of interest. Learn more.
More...
Replogle Flume at
Gila Gravity Main Canal
McKinley Rd
Senator Wash Rd
Imperial Rd
Imperial Dam Rd
E Laguna Rd
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Maps
yuma, az
Search Maps
Show search options
Find businesses, addresses and places of interest. Learn more.
Mor
Replogle Flume at
Gila Gravity Main Canal
Imperial Dam Rd
Imperial Dam Rd
Imperial Dam Rd
Imperial Dam Rd
Yuma Proving Ground
Imperial Dam R
Imperial Da
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New Device by ITRC
Subcritical Contraction with Doppler

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USBR Turnout Measurement

Category III

The third category includes non-standard, individually calibrated flow measurement devices. These are often special measurement devices developed by an irrigation project. Typically, there are no published standard dimensions or flow tables for such devices. Requirements for acceptability would include:

- Consistent dimensions and installations
- Accurate determination of delivery time
- Local calibration and a verification of accuracy, based on a representative sample number of devices measured over time (see guidelines later in this document)
- A proposed schedule for maintenance and calibration

USBR Turnout Measurement

Category III

Devices in this category also require:

- Accurate measurements of water level (taken hourly or more frequently), or
- Excellent water level control using positive means such as flap gates, long-crested weirs, or properly designed PLC-controlled water level control gates, along with delivery time to determine volumes, or
- Adequate delivery pools for accurate deliveries (demonstrated with a verification procedure)

This category also includes calibrated pumps in cases where the suction-side water level fluctuation is small when compared to the total lift (+/- 5 percent) and the discharge pressure does not change with time.

Metergate

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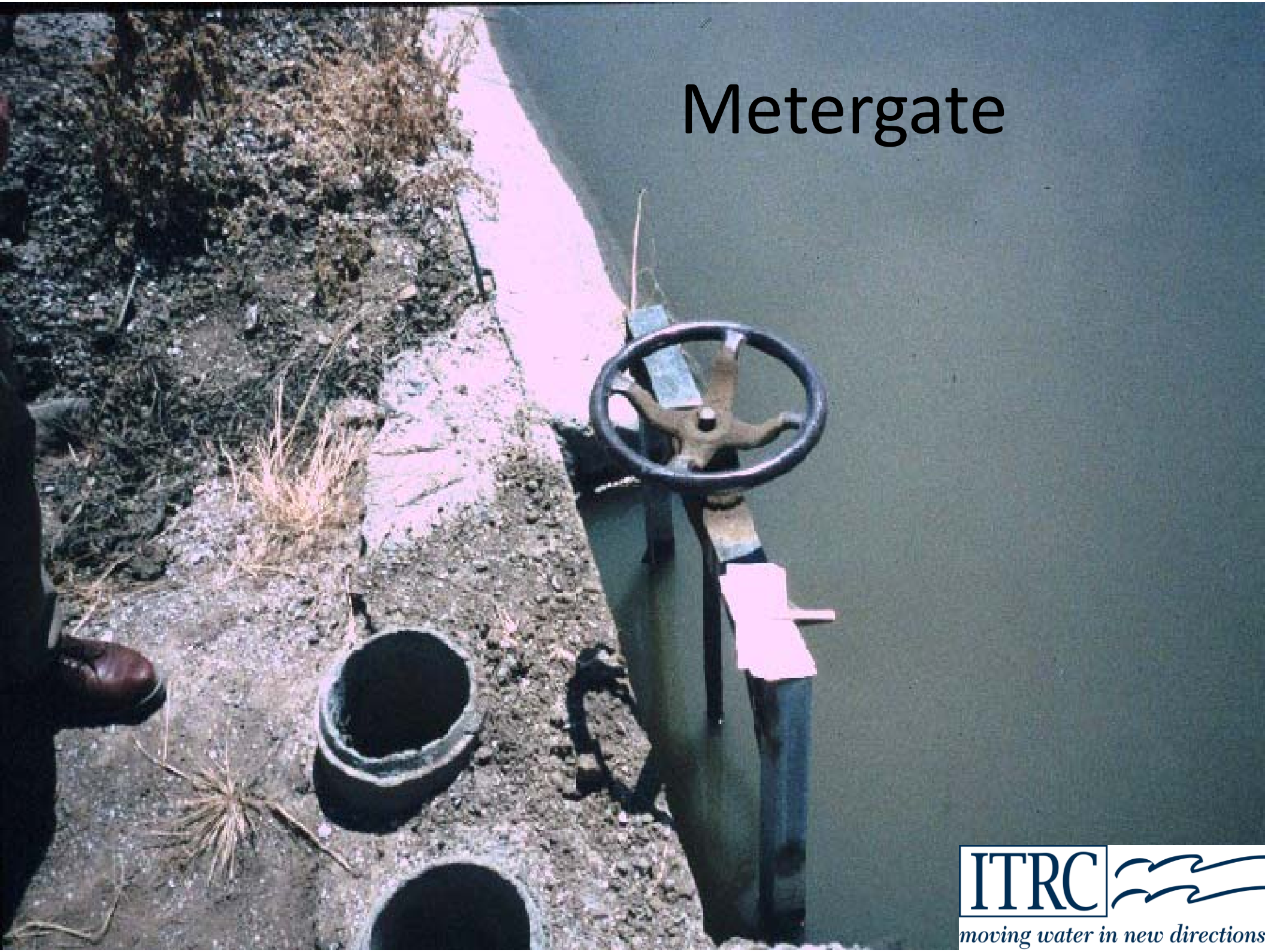

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Metergate
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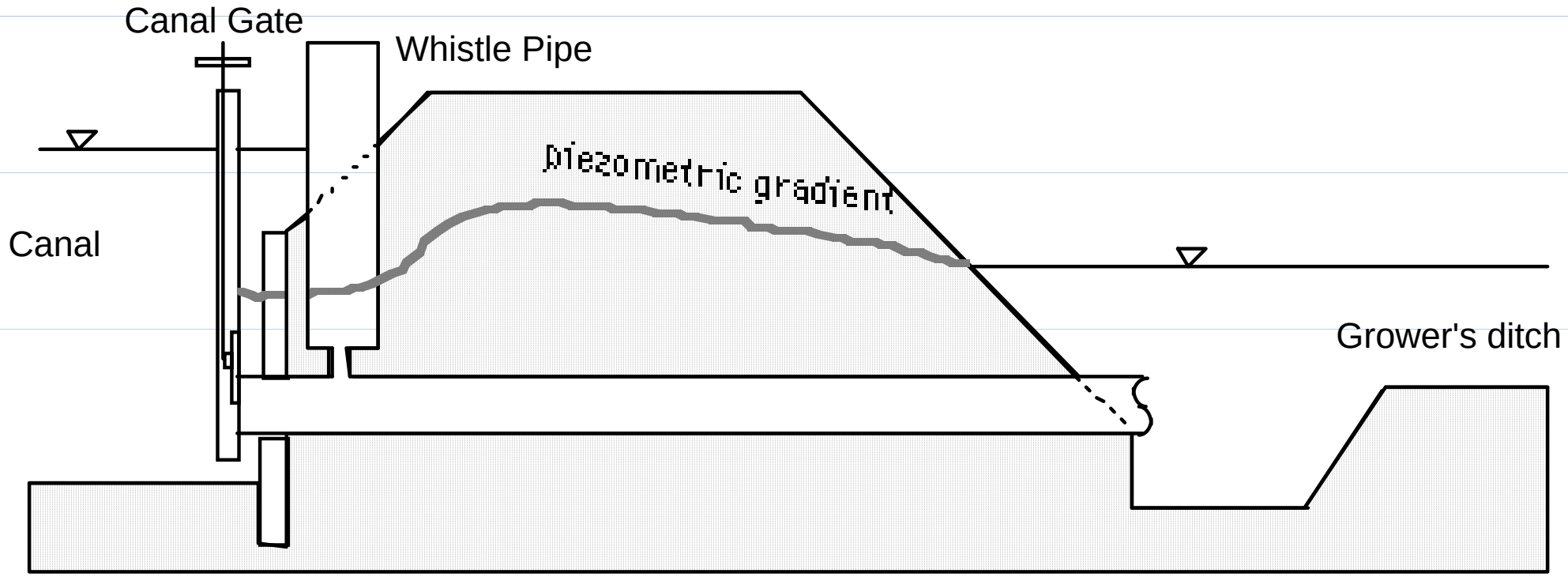
Metergate



Key:
Location of the differential head measurement

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8" Armco Metergate - Model 101

Head (mm)	Net Gate Opening (mm)														
	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
30	0.33	0.38	0.42	0.46	0.49	0.52	0.56	0.59	0.61	0.63	0.65	0.67	0.68	0.69	0.69
35	0.36	0.41	0.45	0.49	0.53	0.56	0.61	0.64	0.66	0.68	0.70	0.72	0.74	0.75	0.75
40	0.38	0.43	0.48	0.52	0.57	0.60	0.65	0.69	0.71	0.73	0.76	0.78	0.79	0.80	0.80
45	0.40	0.46	0.51	0.55	0.60	0.64	0.69	0.73	0.76	0.78	0.80	0.82	0.84	0.84	0.85
50	0.42	0.48	0.53	0.58	0.63	0.67	0.72	0.76	0.79	0.82	0.84	0.86	0.88	0.89	0.90
55	0.43	0.49	0.55	0.60	0.65	0.70	0.75	0.80	0.83	0.86	0.88	0.91	0.93	0.94	0.95
60	0.45	0.51	0.57	0.63	0.68	0.72	0.78	0.83	0.86	0.89	0.92	0.95	0.97	0.98	0.99
65	0.47	0.54	0.60	0.65	0.71	0.75	0.81	0.87	0.90	0.93	0.96	0.99	1.01	1.02	1.03
70	0.49	0.56	0.62	0.67	0.73	0.78	0.84	0.89	0.93	0.96	1.00	1.02	1.04	1.06	1.07
75	0.50	0.57	0.64	0.69	0.75	0.81	0.87	0.92	0.96	1.00	1.03	1.06	1.08	1.10	1.11
80	0.52	0.59	0.65	0.71	0.77	0.83	0.89	0.95	1.00	1.03	1.07	1.10	1.12	1.13	1.14
85	0.53	0.61	0.67	0.74	0.80	0.85	0.92	0.98	1.03	1.07	1.10	1.13	1.15	1.17	1.18
90	0.55	0.62	0.69	0.76	0.82	0.88	0.95	1.01	1.06	1.10	1.13	1.16	1.19	1.21	1.22
95	0.56	0.64	0.71	0.78	0.84	0.90	0.97	1.03	1.08	1.13	1.16	1.19	1.22	1.24	1.25
100	0.57	0.65	0.73	0.79	0.86	0.92	0.99	1.06	1.11	1.16	1.19	1.23	1.25	1.27	1.28
105	0.58	0.67	0.75	0.81	0.88	0.95	1.02	1.08	1.14	1.19	1.23	1.26	1.29	1.31	1.32
110	0.60	0.68	0.76	0.83	0.90	0.97	1.04	1.11	1.16	1.22	1.26	1.29	1.32	1.34	1.35
115	0.61	0.70	0.78	0.85	0.92	0.99	1.06	1.13	1.19	1.24	1.28	1.32	1.35	1.37	1.38
120	0.62	0.71	0.79	0.86	0.94	1.01	1.08	1.16	1.22	1.27	1.32	1.35	1.38	1.40	1.41
125	0.63	0.72	0.80	0.88	0.95	1.03	1.11	1.18	1.24	1.30	1.34	1.38	1.41	1.43	1.44
130	0.65	0.73	0.82	0.89	0.97	1.04	1.13	1.20	1.27	1.32	1.37	1.41	1.44	1.46	1.47
135	0.66	0.75	0.83	0.91	0.99	1.06	1.15	1.22	1.29	1.34	1.39	1.43	1.47	1.49	1.51
140	0.67	0.76	0.84	0.92	1.00	1.08	1.17	1.24	1.31	1.37	1.42	1.46	1.50	1.52	1.54
145	0.68	0.77	0.85	0.94	1.02	1.10	1.19	1.26	1.33	1.39	1.44	1.48	1.52	1.54	1.56
155	0.69	0.79	0.88	0.97	1.05	1.13	1.23	1.30	1.37	1.44	1.49	1.53	1.57	1.59	1.61
160	0.70	0.80	0.89	0.98	1.07	1.15	1.24	1.32	1.40	1.46	1.51	1.56	1.59	1.62	1.64
165	0.71	0.81	0.90	0.99	1.07	1.16	1.25	1.33	1.41	1.47	1.52	1.57	1.60	1.63	1.65
170	0.72	0.82	0.92	1.01	1.10	1.18	1.28	1.36	1.44	1.50	1.56	1.60	1.64	1.67	1.69
175	0.73	0.83	0.93	1.02	1.11	1.20	1.30	1.38	1.46	1.52	1.58	1.63	1.66	1.70	1.72
180	0.74	0.84	0.95	1.04	1.13	1.22	1.32	1.40	1.48	1.55	1.60	1.65	1.69	1.72	1.74
185	0.75	0.86	0.96	1.05	1.15	1.24	1.34	1.42	1.51	1.57	1.63	1.67	1.71	1.74	1.77
190	0.76	0.86	0.97	1.06	1.16	1.25	1.35	1.44	1.52	1.58	1.64	1.69	1.72	1.76	1.78
195	0.77	0.88	0.99	1.08	1.18	1.27	1.38	1.46	1.55	1.61	1.67	1.72	1.76	1.79	1.81
200	0.78	0.89	1.00	1.09	1.19	1.29	1.39	1.48	1.57	1.63	1.69	1.74	1.78	1.81	1.84
205	0.79	0.90	1.01	1.11	1.21	1.30	1.41	1.50	1.59	1.65	1.71	1.76	1.80	1.84	1.86
210	0.80	0.91	1.02	1.12	1.22	1.32	1.43	1.52	1.60	1.67	1.73	1.78	1.82	1.86	1.88
215	0.80	0.92	1.03	1.13	1.23	1.33	1.44	1.53	1.61	1.68	1.74	1.79	1.84	1.87	1.90
220	0.82	0.93	1.05	1.15	1.25	1.35	1.46	1.56	1.64	1.71	1.77	1.82	1.86	1.90	1.93
225	0.82	0.94	1.06	1.16	1.26	1.36	1.48	1.57	1.66	1.73	1.79	1.84	1.88	1.92	1.95
230	0.83	0.95	1.07	1.17	1.28	1.38	1.49	1.59	1.68	1.75	1.81	1.86	1.90	1.94	1.97
235	0.84	0.96	1.08	1.18	1.29	1.39	1.51	1.61	1.70	1.77	1.83	1.88	1.92	1.96	1.99
240	0.85	0.97	1.09	1.19	1.30	1.40	1.52	1.62	1.71	1.78	1.85	1.90	1.94	1.98	2.00

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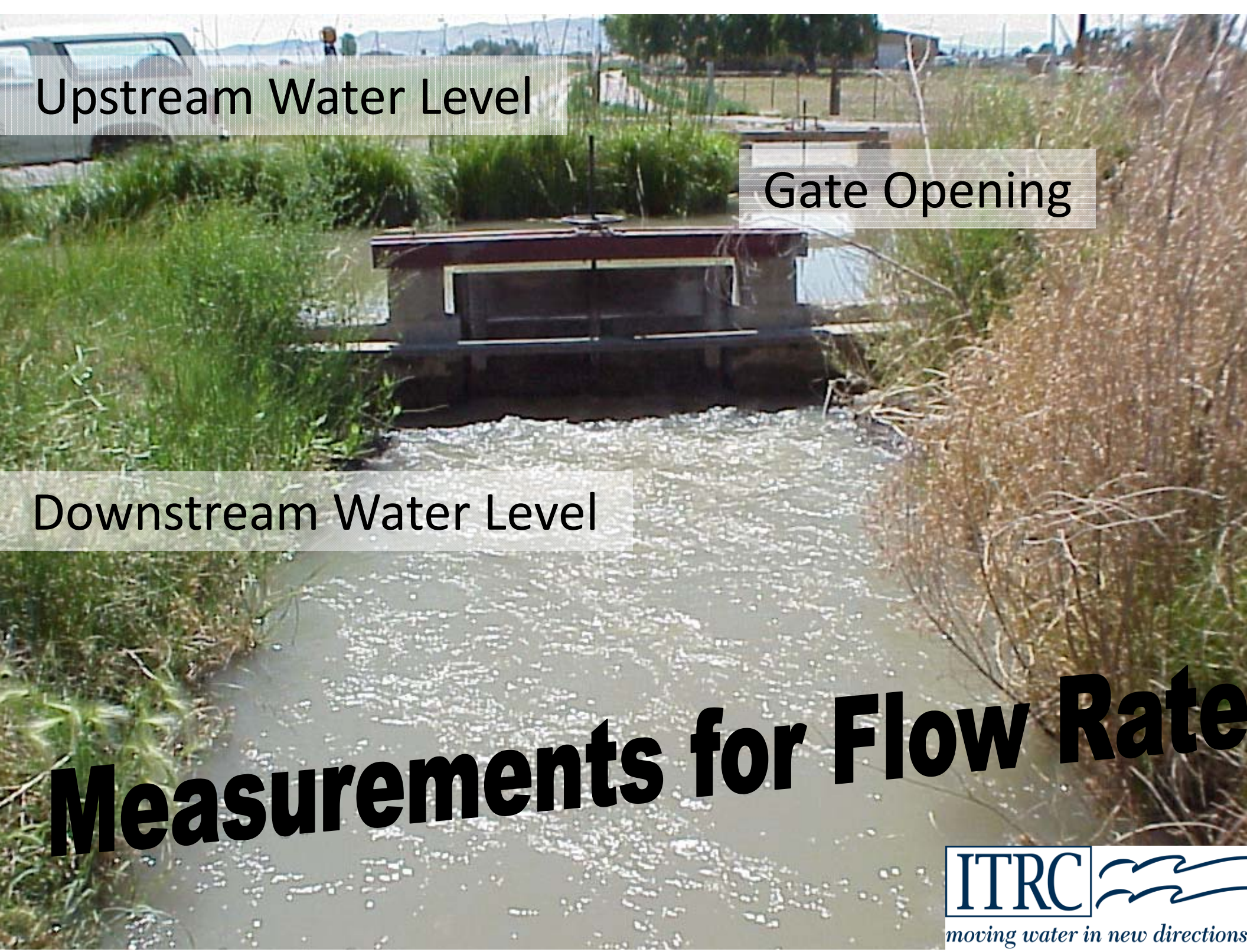
Submerged Orifice


Upstream Water Level
Gate Opening
Downstream Water Level
Measurements for Flow Rate
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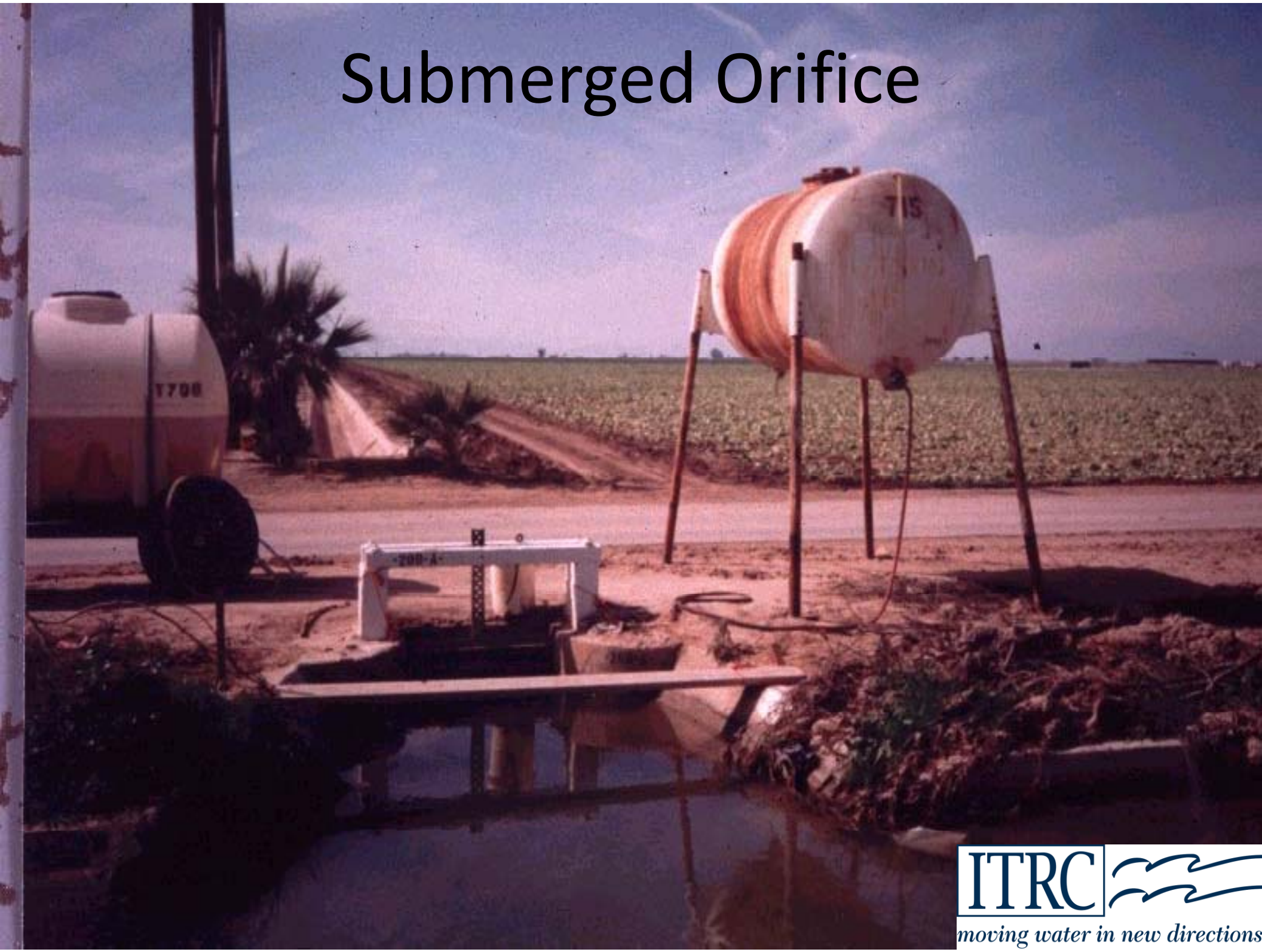
Submerged Orifice



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USBR Turnout Measurement

Category IV

A fourth category includes using rough estimates of flow rate or volume, such as flow-rate estimates at check structures or the sum of siphon tubes (or other methods of measurement not specified here). These approaches are NOT acceptable since they do not provide a documented reasonable degree of accuracy.

Flow Measurement Update

- Introduction
- USBR water management plan update
- “Accuracy” defined
- Devices
- **Documentation requirements**
- Other agencies and new guidelines
- Summary

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USBR – Documentation

1. Turnout calibration equations

If all similar turnouts (such as meter gates of a specific size) use the same equation of discharge, provide a description of all such similar groups along with their discharge equations and calibration coefficients.

If turnouts have been individually calibrated, provide a list of turnouts and locations and the equations and various calibration coefficients that have been developed.

USBR – Documentation

2. Standardization of inlet and valve conditions

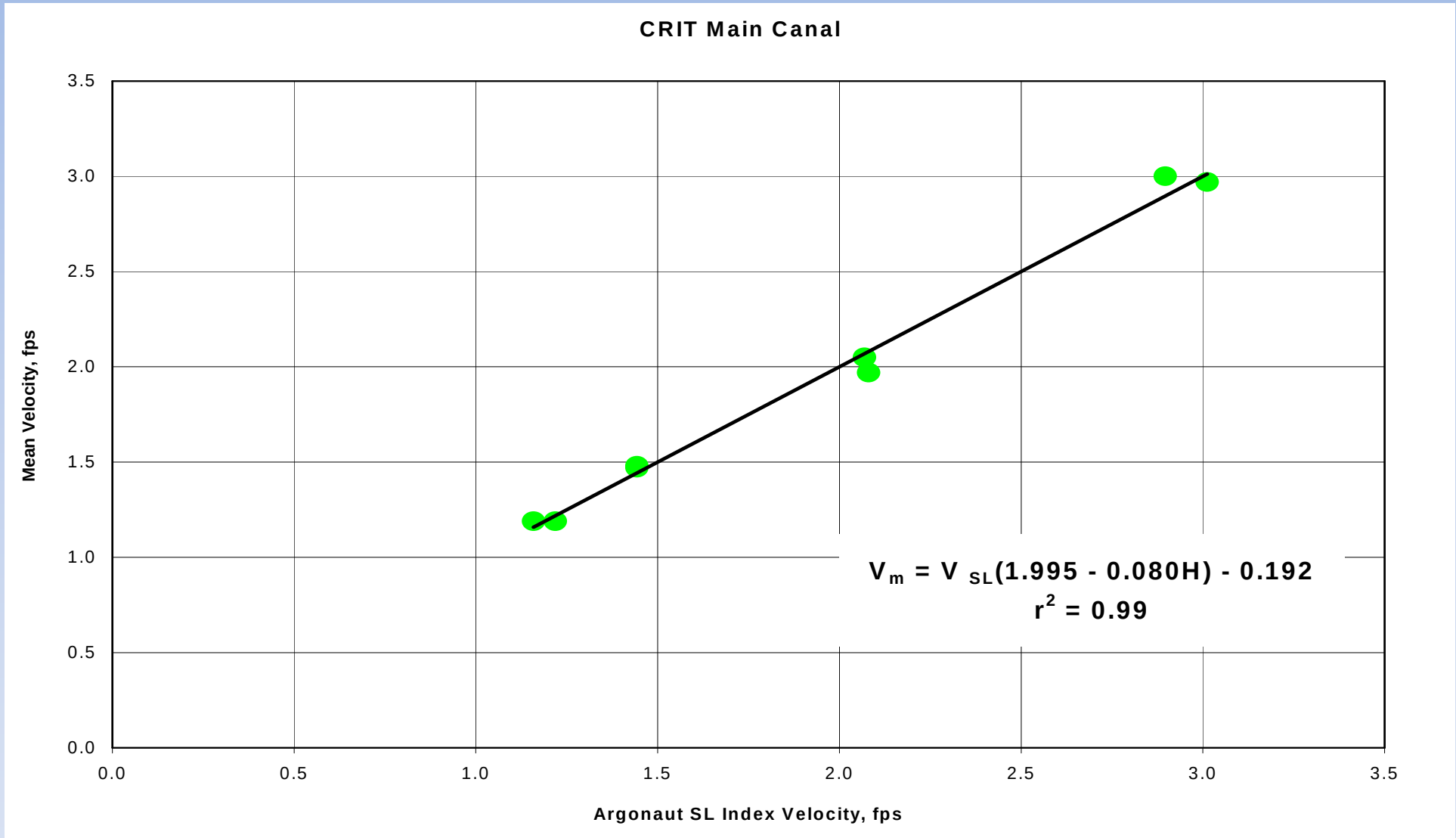
Provide photos of at least 10 devices of each of the same design showing verification that the inlet, valve placement, etc. conditions are the same within each group (e.g., if there are four different designs (not sizes), there would be four groups of photos, each group with 10 turnouts).

USBR – Documentation

3. Procedures and equipment for flow rate verification

Provide documentation of field procedures and equipment used to verify instantaneous flow rates for discharge equation calibration purposes, through at least 15 turnouts that span the range of possible designs and conditions of turnouts in the district. This verification procedure has to be conducted with accurate flow measurement verification equipment to avoid errors.

Calibration



10 Points using multiple regression required for +/-5% accuracy

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Calibration

Uncertainty Based on:

1 Standard Deviation

“Excellent” means ≤ 2%

“Good” means ≤ 5%

“Fair” means ≤ 8%

“Poor” means ≥ 8%

Current Meters

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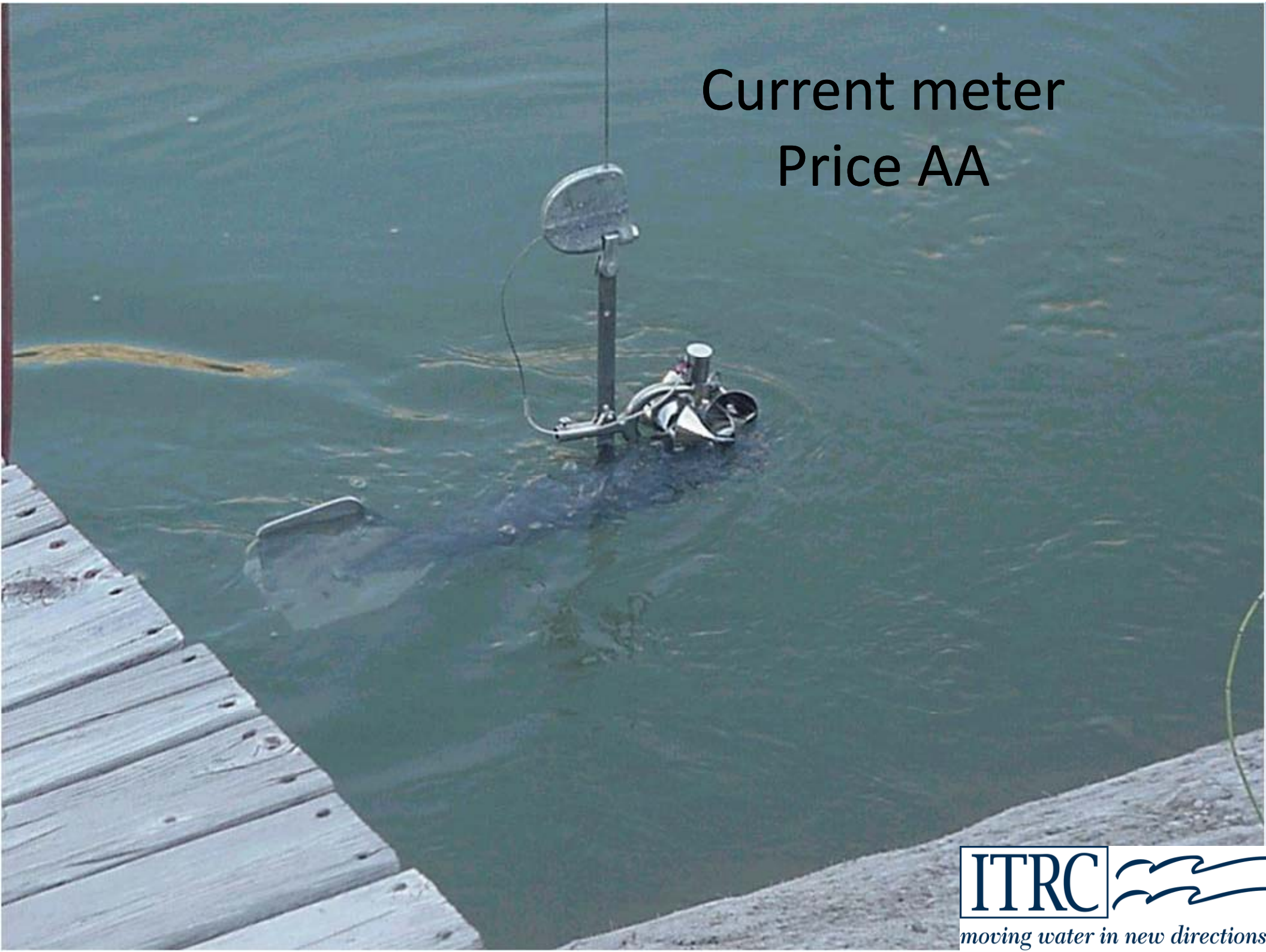

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Truckee-Carson Irrigation District

Discharge Measurement Notes			
Station	L1-8-4-T1 Gary Busboom		
Date	7/7/99	Party	Watkins
Discharge	25.73		

Gage Readings				
Time		Recorder	Inside	Outside
11:19	Bay reference @ L1-8			0.88
12:15	"			0.88
11:21	L1-8 stem overall			1.70
12:16	"			1.70
11:30	Bay reference @ L1-8-4			2.52
12:11	"			2.54
11:31	L1-8-4 stem overall			3.74
12:12	"			3.74
Weighted M.G.H.				
G.H. correction				
Correct M.G.H.				

Water Order #

Meter # 784 Flomate 2000

Remarks

L1-8 headgate measurement

U-2.40, D-3.00, G-3.65, S-4.97, L-5.10 = 29.28

cfs.

O.T.B. @ the check next to the L1-8 headgate

U-.92, B-1.98, L-7.05 = 26.93 cfs.

The bay at the L1-8-4 headgate was up to the top of the structure. There was water going over the top of the L1-8 spill flashboards, as well as the L1-8-T10 gate.

Angle coef Orient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in second	Velocity At point	Velocity Mean in vertical	Adjusted for hor angle or _____	Area	Discharge
	1.0		0.00								
	1.2	.50	2.94				1.61	1.61		1.47	2.37
							1.61				
	2.0	.90	2.98				1.68	1.83		2.68	4.91
							1.98				
	3.0	1.00	3.00				2.13	1.94		3.00	5.82
							1.75				
	4.0	1.00	3.02				1.82	1.93		3.02	5.83
							2.04				
	5.0	.85	2.85				2.00	1.94		2.42	4.70
							1.88				
	5.7	.45	2.80				1.56	1.68		1.26	2.11
							1.79				
	5.9										

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Doppler on a boat

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New ITRC Portable Calibration Device

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USBR – Documentation

4. Equations for flow measurement verification

Provide well-explained computations and equations used for verification of flow measurement accuracy for each type of turnout (e.g., what % accuracy, on what percentage of delivered volumes).

USBR – Required Documentation

KEY

Combine the flow rate accuracy with the inaccuracy in volume measurement that is inherent with varying canal water levels or pipeline pressures to compute the overall accuracy of the volumetric measurements of the district. Show all equations and values in a neatly organized, well-explained procedure.

Volumetric Accuracy

Average error in volume measurement, %								
Initial Head across the turnout, ft.	AVERAGE **rise** in the pool water level after the initial flow measurement, ft.							
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
0.1	**32.0**	**44.3**	**55.2**	**65.1**	**74.1**	**82.5**	**90.4**	**97.8**
0.2	**17.6**	**25.1**	**32.0**	**38.3**	**44.3**	**49.9**	**55.2**	**60.2**
0.3	**12.2**	**17.6**	**22.7**	**27.4**	**32.0**	**36.2**	**40.3**	**44.3**
0.4	**9.3**	**13.6**	**17.6**	**21.4**	**25.1**	**28.6**	**32.0**	**35.2**
0.5	**7.6**	**11.1**	**14.4**	**17.6**	**20.7**	**23.6**	**26.5**	**29.3**
0.6	**6.4**	**9.3**	**12.2**	**14.9**	**17.6**	**20.2**	**22.7**	**25.1**
0.7	**5.5**	**8.1**	**10.6**	**13.0**	**15.3**	**17.6**	**19.8**	**22.0**
0.8	**4.8**	**7.1**	**9.3**	**11.5**	**13.6**	**15.6**	**17.6**	**19.5**
0.9	**4.3**	**6.4**	**8.4**	**10.3**	**12.2**	**14.0**	**15.8**	**17.6**
1	**3.9**	**5.7**	**7.6**	**9.3**	**11.1**	**12.8**	**14.4**	**16.0**
1.2	**3.3**	**4.8**	**6.4**	**7.9**	**9.3**	**10.8**	**12.2**	**13.6**
1.4	**2.8**	**4.2**	**5.5**	**6.8**	**8.1**	**9.3**	**10.6**	**11.8**
1.6	**2.5**	**3.6**	**4.8**	**6.0**	**7.1**	**8.2**	**9.3**	**10.4**
1.8	**2.2**	**3.3**	**4.3**	**5.3**	**6.4**	**7.4**	**8.4**	**9.3**
2	**2.0**	**2.9**	**3.9**	**4.8**	**5.7**	**6.7**	**7.6**	**8.5**
2.5	**1.6**	**2.4**	**3.1**	**3.9**	**4.6**	**5.4**	**6.1**	**6.8**
3	**1.3**	**2.0**	**2.6**	**3.3**	**3.9**	**4.5**	**5.1**	**5.7**

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Volumetric Accuracy

Example: Metergate reading – 10.3 CFS
Current meter reading – 10.6 CFS

Flow Rate Accuracy =
100 x (10.3 – 10.6)/10.6 = -2.8%

Volumetric Accuracy =
Table value for 3 ft drop and 0.25ft fluctuation = -3.3%

$$\text{Combined \% error} = \sqrt{(\text{\% flow meas. error})^2 + (\text{\% volumetric error})^2}$$

Combined Accuracy = $(2.8^2 + 3.3^2)^{0.5} = 4.3\%$

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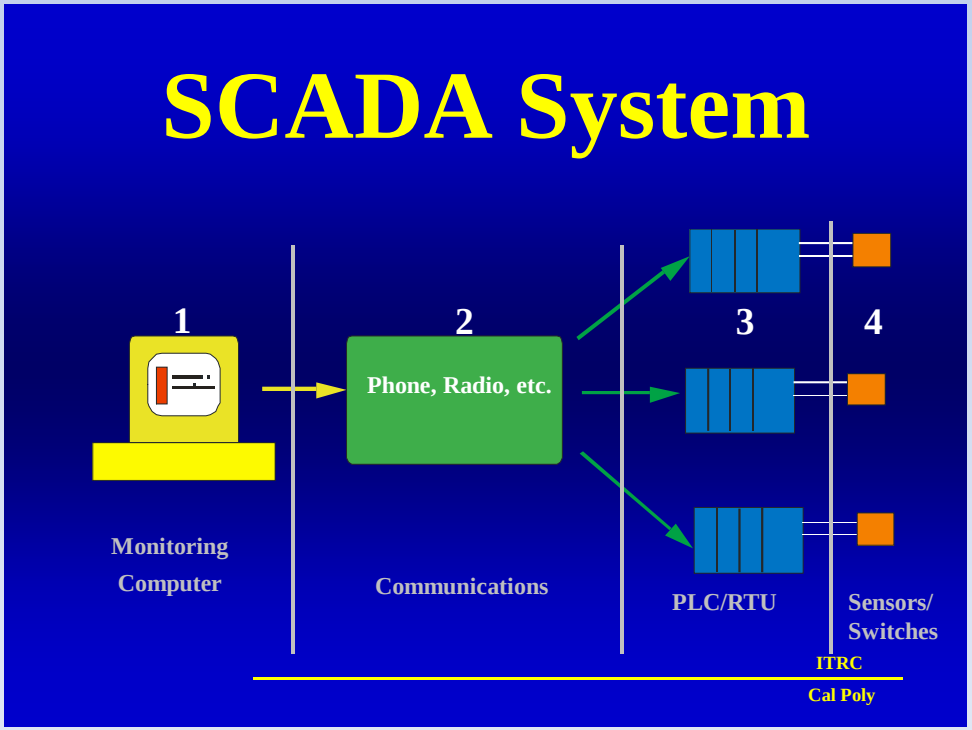
Volumetric Accuracy

- Strong link between Volumetric Accuracy and Modernization
- Automation and SCADA = constant pools



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USBR-TCID Agreement
75% of the delivered volume to be measured within +/-10%

Truckee Carson Irrigation District
50 CFS

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DWR – New Guidelines
SB7x7

- **Ag plans accepted by USBR also comply with State Water Management Plan requirements**

- **Note: Not approved as of 26 January 2012**

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DWR – New Guidelines

1) An existing measurement device shall be certified to be accurate to within **±12% by volume**.

2) A new or replacement measurement device shall be certified to be accurate to within:

A) **±5% by volume** in the laboratory if using a laboratory certification;

B) **±10% by volume** in the field if using a non-laboratory certification.

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SWRCB – New Guidelines

State Water Resources Control Board

NOTICE OF OPPORTUNITY TO COMMENT
GUIDANCE FOR COMPLYING WITH WATER DIVERSION MEASUREMENT REQUIREMENTS FOR STATEMENT HOLDERS

- Starting January 1, 2012, all diverters of surface water or pumped groundwater from a known subterranean stream must measure their water and submit a monthly report

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SWRCB

Examples of Alternative Measurement Methods

- **Propeller Meter/Turbine Meter:** A device that uses an internal propeller or turbine to determine the inline flow rate.
  - www.mccrometer.com
  - www.netafimusa.com/agriculture
  - www.watermeters.com
- **Acoustic Meter:** A device that uses a sensor to transmit an ultrasonic sound signal into a pipe.
  - www.mccrometer.com
  - www.elsteramcowater.com
  - www.macemeters.com
  - www.usabluebook.com
- **Flow Totalizer:** A device that totalizes measured flow through a flow meter.
  - www.mccrometer.com
  - www.netafimusa.com/agriculture
- **Slide/Sluice Gate:** A gate valve opening that has been calibrated to measure flow.
  - www.watermanusa.com
- **Weir:** An overflow dam with a designed edge or notch.
  - www.water.siemens.com

http://www.swrcb.ca.gov/waterrights/water_issues/programs/diversion_use/wm_vendors.shtml

SWRCB

Examples of Alternative Measurement Methods

http://www.swrcb.ca.gov/waterrights/water_issues/programs/diversion_use/wm_alt_mthds.shtml

All methods discussed below require that a daily log book or other recording device be maintained.

Electricity Records Dedicated to the Pump

Total Facility Records minus Estimated Non-Pump Electricity

Staff Gage and Storage-Capacity Curve

Pressure Transducer and Storage Capacity Curve

Power Generation Estimates

Remote Satellite Imaging

Crop Duty Estimates/Consumptive Use Estimates

Other Water Duty Estimates Other than for Crops

Pipe/Trajectory Method

Modeled/Estimated Flows

Bucket and Stopwatch

Engine Fuel Use

Staff Gage and Floodable Acreage

Float and Stopwatch

Note: There is **no** accuracy requirement with the new guidelines from the SWRCB (yet)

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Flow Measurement Update

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