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COMPARISON BETWEEN SBX7-7 AND ORIFICE MEASUREMENT METHODOLOGY AT THE FARM-GATE LEVEL

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ABSTRACT

As part of a program to improve upstream water level water control and farm delivery steadiness, Reclamation District No. 108 (RD 108, District) recently replaced certain existing weir board check structures in selected District laterals with long crested weirs. The existing weir board checks had been used by operators for flow measurement, including estimation of farm delivery flows by computing differences between flows at checks upstream and downstream of farm delivery gates. After reviewing several options to provide an alternative means of farm delivery measurement with the existing structures removed and new long-crested weirs installed, the District selected a hybrid approach featuring direct measurement at individual farm delivery gates complemented by Acoustic Doppler measurements at key locations in the canal system. As part of its evaluation, the District conducted 60 verification flow measurements at existing farm delivery gates during the 2008 and 2009 irrigation seasons. The gates had a submerged orifice configuration and ranged from 18 to 48 inches in diameter. Farm delivery gate measurement errors were computed regarding the verification measurement as the standard. The errors were then compared to pending farm delivery measurement standards being developed by the California Department of Water Resources (CDWR). This paper describes the verification flow measurement procedure, summarizes the results of the error analysis and discusses implications relative to the pending CDWR regulations.

INTRODUCTION

As part of a program to improve upstream water level water control and farm delivery steadiness, Reclamation District No. 108 (RD 108, District) recently replaced certain existing weir board check structures in selected District laterals with long crested weirs (LCW). The existing weir board checks had been used by operators for flow measurement, including estimation of farm delivery flows by computing differences between flows at checks upstream and downstream of farm delivery gates. After reviewing several options to provide an alternative means of farm delivery measurement with the existing structures removed and new long-crested weirs installed, the District selected a hybrid approach featuring direct measurement at individual farm-gates

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complemented by Acoustic Doppler measurements at key locations in the canal system. As part of its evaluation, the District conducted 60 verification flow measurements at existing farm delivery gates during the 2008 and 2009 irrigation seasons. The gates had a submerged orifice configuration and ranged from 18 to 48 inches in diameter (Figure 1). The verification measurements were performed downstream of the farm delivery gate approximately at the location of Section A.

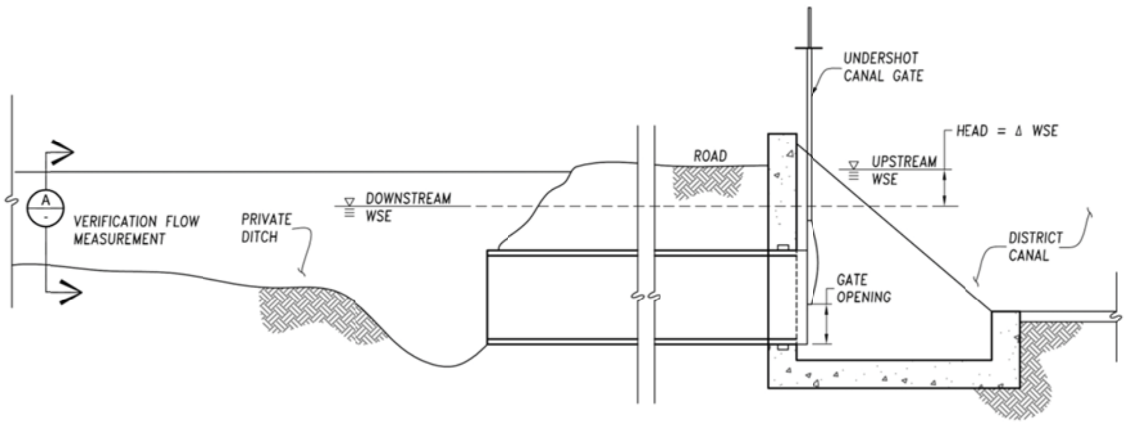

Figure 1. Typical Farm Delivery Cross-Section

FARM-GATE VERIFICATION FLOW MEASUREMENTS

Farm-gate verification flow measurements were performed by the conventional USGS mid-section current-meter method (Rantz 1982). Accordingly, the calculated discharge (Q) from a current-meter measurement is the sum of the products of the subsection areas (A) in a stream cross section and their respective average velocities (V) (Equation 1). Point velocity measurements used within the mid-section method were made by a SonTek FlowTracker Acoustic Doppler Velocimeter (Rehmel 2007). Due to limited water depths (generally less than 1.5 feet), the six-tenths-depth method was used to determine average velocity for each vertical subsection (Bureau of Reclamation 2001).

$$Q = \sum V * A \quad (1)$$

Figure 2 illustrates how station and depth information at incremental stations are used to determine A and Q for each location where V is measured.

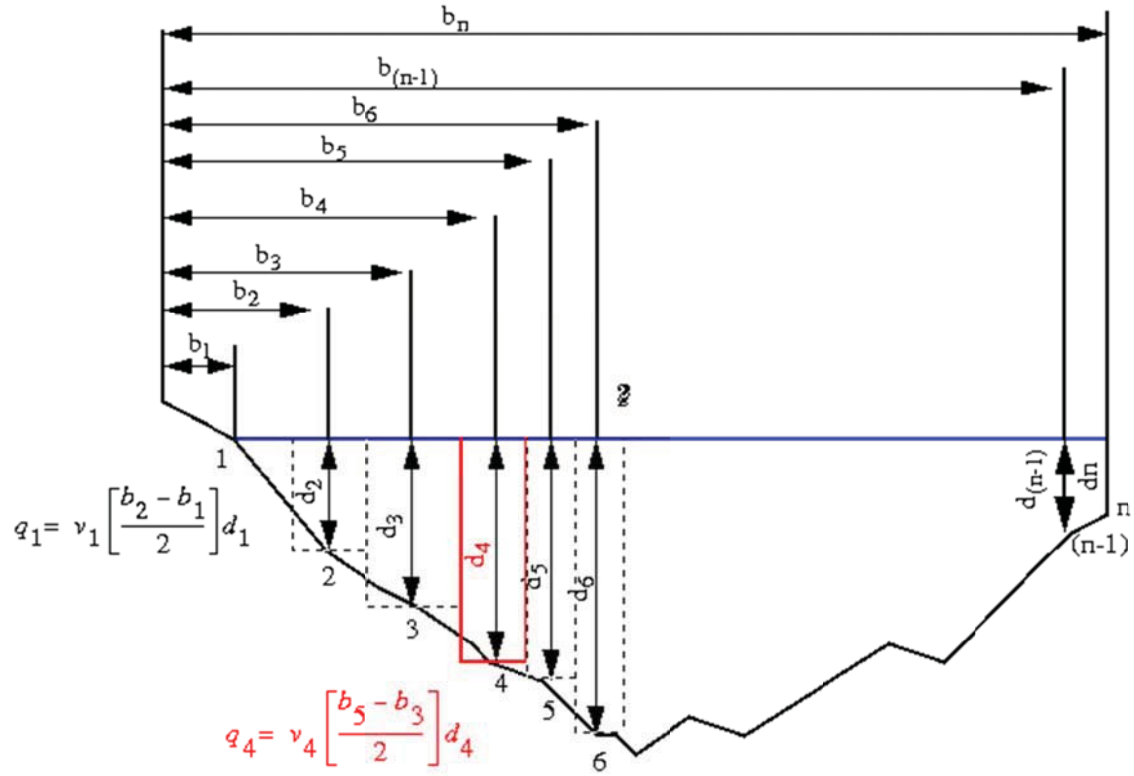

Figure 2. USGS Mid-Section Discharge Method (Rantz 1982)

Equation 2 was derived by combining Figure 2 and Equation 1, where x is the vertical station number, n is the total number of stations, b is perpendicular station and d is the water depth (Figure 3).

$$Q = \sum_{x=1}^{n} V_x * \left(\frac{b_{(x+1)} - b_{(x-1)}}{2}\right) * d_x \qquad (2)$$

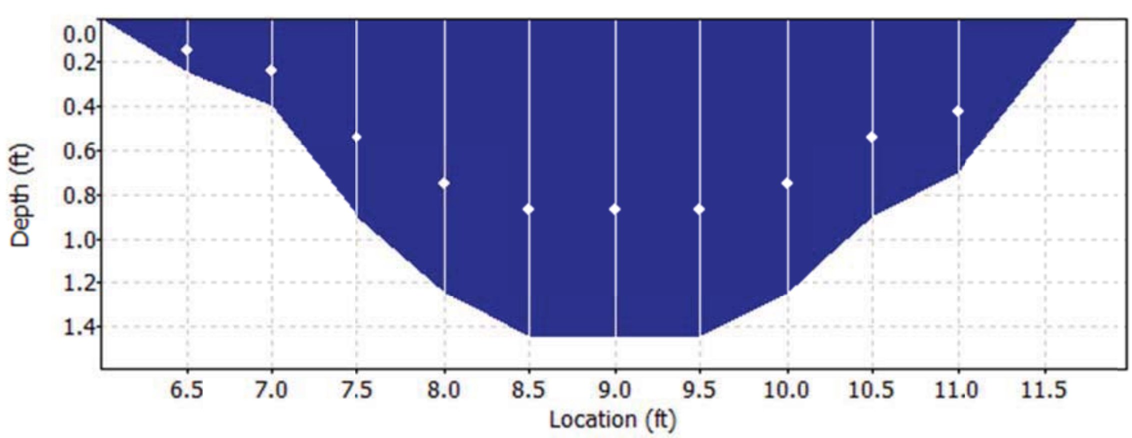

Figure 3. FlowTracker Cross Section for 121L Verification Measurement

The majority of verification flow measurements were performed in either concrete lined or earthen open channels (head ditches). Figure 4 illustrates flow measurement in a typical earthen head ditch, in this case with a maximum depth of 1.4 feet, top width of 6.7 feet and bottom width of 1.0 feet. Typically, velocity measurements were performed at 0.5 foot intervals with velocities averaged over a 40 second period.

Figure 4. Example Verification Measurement Setup

ORIFICE GATE FLOW MEASUREMENTS

Theoretical discharge through a submerged orifice can be solved from the Bernoulli Equation (Equation 3) where C is an empirical coefficient used to account for minor losses, flow contraction and velocity of approach (Bureau of Reclamation 2001), A is the cross section flow area, h is the headloss through the orifice and g is the gravitational constant.

$$Q = C * A * \sqrt{2 * g * h} \qquad (3)$$

Information necessary for computation of discharge (i.e. cross section area and headloss) through orifice gates upstream of the verification measurement cross section was gathered at the beginning and ending of each verification flow measurement. Information gathered included the (1) site name, (2) date and time, (3) gate size, (4) gate type, (5) full-stem, (6) dead-stem, (7) upstream water surface elevation (WSE) and (8) downstream WSE. WSE upstream and downstream of the orifice gate was recorded at a minimum of before and after the verification flow measurement. As shown in Figure 5, stem measurements were performed from the highest part of the ‘lift nut’ to the top of the gate stem. Dead-stem was defined as the amount of stem at the onset of flow when moving the gate from a closed to open position. Full-stem was defined as the stem measurement during the verification flow measurement. A term representing the actual gate opening called "good-stem" was then defined as the difference between full-stem and dead-stem (Equation 4).

$$Goodstem = (Fullstem) - (Deadstem) \tag{4}$$

Figure 5. Dead-Stem and Full-Stem Measurements

Waterman gate rating tables provide flow rates through orifice gates as a function of gate opening (good-stem) and head loss (head) for each gate size (Figure 6). Implicit within these rating tables is the empirically derived orifice coefficient in Equation 3 above. These 'factory' rating tables generally assume standard conditions exist in the field including measurement of downstream water surface elevation one foot downstream of the gate. In most cases encountered during this investigation, there was no access to the downstream water surface elevation one foot downstream of the gate because the gates typically discharge into a 20- to 25-foot long culvert pipe crossing under a farm road before emptying into a head ditch. Instead, most downstream water surface elevation measurements were taken at the culvert discharge into the ditch. At low flows, this procedure does not pose a significant error because the friction loss in the culvert is negligible. However, at higher flows culvert friction loss becomes significant and could introduce error into the orifice gate flow calculation if not taken into account.

DISCHARGE DATA 24" WATERMAN RED TOP CANAL GATES WITH METERING WELLS- Model C-10														
Head in Inches	Net Gate Opening In Inches Discharge in Feet Per Second													
	2	2½	3	3½	4	4½	5	5½	6	7	8	9	10	11
1	.71	.88	1.01	1.14	1.27	1.40	1.53	1.66	1.79	2.02	2.24	2.41	2.66	2.89
1¼	.80	.96	1.13	1.27	1.42	1.56	1.71	1.85	2.00	2.25	2.50	2.69	2.94	3.22
1½	.88	1.05	1.23	1.39	1.55	1.71	1.87	2.04	2.20	2.47	2.73	2.95	3.25	3.51
1¾	.95	1.14	1.34	1.56	1.69	1.86	2.04	2.21	2.38	2.68	2.97	3.11	3.49	3.80
2	1.00	1.22	1.43	1.61	1.79	1.98	2.17	2.35	2.53	2.84	3.15	3.40	3.74	4.07
2¼	1.07	1.29	1.52	1.72	1.91	2.10	2.30	2.49	2.68	3.02	3.35	3.62	3.96	4.31
2½	1.12	1.36	1.60	1.80	2.01	2.21	2.41	2.62	2.83	3.19	3.52	3.80	4.18	4.53
2¾	1.18	1.42	1.67	1.88	2.10	2.32	2.53	2.74	2.95	3.33	3.69	4.00	4.40	4.77
3	1.23	1.49	1.75	1.97	2.20	2.43	2.65	2.87	3.10	3.49	3.89	4.18	4.57	4.97
3¼	1.28	1.55	1.83	2.06	2.30	2.54	2.77	2.99	3.23	3.63	4.02	4.34	4.75	5.18
3½	1.33	1.61	1.89	2.14	2.38	2.62	2.87	3.11	3.35	3.78	4.19	4.51	4.92	5.35
3¾	1.38	1.67	1.96	2.21	2.47	2.72	2.97	3.22	3.48	3.91	4.32	4.67	5.11	5.53
4	1.42	1.72	2.02	2.28	2.55	2.79	3.03	3.31	3.59	4.02	4.45	4.82	5.29	5.73
4¼	1.47	1.77	2.08	2.35	2.63	2.85	3.08	3.39	3.70	4.08	4.60	4.99	5.44	5.90
4½	1.52	1.85	2.17	2.43	2.70	2.98	3.27	3.54	3.81	4.29	4.73	5.12	5.59	6.09
4¾	1.55	1.88	2.20	2.48	2.76	3.05	3.34	3.62	3.90	4.40	4.85	5.27	5.73	6.22
5	1.58	1.92	2.26	2.55	2.84	3.13	3.42	3.71	4.00	4.50	4.97	5.39	5.88	6.40
5½	1.67	2.02	2.37	2.67	2.98	3.28	3.58	3.88	4.18	4.62	5.21	5.65	6.18	6.71
6	1.74	2.10	2.47	2.79	3.10	3.42	3.75	4.06	4:38	4.95	5.48	5.90	6.44	7.00
6½	1.82	2.20	2.58	2.91	3.24	3.57	3.91	4.23	4.56	5.15	5.69	6.14	6.71	7.30
7	1.88	2.28	2.67	3.01	3.36	3.72	4.07	4.39	4.72	5.34	5.90	6.39	6.93	7.56
7½	1.95	2.35	2.76	3.06	3.49	3.85	4.21	4.56	4.92	5.55	6.12	6.60	7.20	7.82
8	2.02	2.43	2.85	3.19	3.60	3.96	4.33	4.70	5.08	5.71	6.30	6.80	7.45	8.07
8½	2.07	2.50	2.94	3.32	3.70	4.09	4.49	4.85	5.22	5.88	6.50	7.04	7.67	8.34
9	2.14	2.59	3.04	3.43	3.82	4.22	4.61	5.00	5.38	6.06	6.70	7.25	7.89	8.56
9½	2.19	2.65	3.11	3.51	3.91	4.31	4.72	5.11	5.51	6.23	6.89	7.45	8.11	8.80
10	2.25	2.72	3.20	3.60	4.01	4.43	4.85	5.25	5.65	6.39	7.05	7.63	8.34	9.02
11	2.35	2.85	3.35	3.77	4.20	4.65	5.10	5.53	5.95	6.70	7.40	8.00	8.71	9.46
12	2.47	2.98	3.50	3.95	4.41	4.87	5.33	5.77	6.22	7.00	7.75	8.40	9.11	9.87
13	2.57	3.12	3.67	4.13	4.60	5.08	5.55	6.03	6.50	7.30	8.10	8.75	9.46	10.26
14	2.67	3.22	3.78	4.26	4.75	5.26	5.78	6.24	6.70	7.60	8.40	9.05	9.80	10.65
15	2.76	3.34	3.91	4.41	4.91	5.43	5.95	6.45	6.95	7.82	8.70	9.30	10.16	11.02
16	2.85	3.45	4.05	4.57	5.09	5.62	6.15	6.65	7.15	8.10	8.90	9.65	10.49	11.35
17	2.93	3.51	4.08	4.65	5.23	5.76	6.30	6.85	7.40	8.30	9.20	9.90	10.78	11.74
18	3.02	3.75	4.30	4.85	5.40	5.95	6.51	7.05	7.60	8.55	9.50	10.20	11.17	12.00

Figure 6. Example Waterman Rating Table for 24" C-10 Canal Gate.

RESULTS

Verification flow measurements and corresponding gate flow estimates based on the Waterman gate rating tables were plotted on an x-y plot (Figure 7). Figure 7 contains a sample size of 60 and includes all the flow measurement data for all gate sizes measured (18", 24", 30", 36", 42" and 48" diameters). Table 1 contains a tabular summary of the data from Figure 7. A least-squares linear regression was performed to determine the relationship between these two variables (Davis 2002). Forcing a y-intercept value of zero, the linear regression yielded Equation 5 after substituting orifice gate for 'y' and verification for 'x'. The R^2, or goodness of fit, for Equation 5 was 0.951. This means that roughly 95 percent of the variability in the orifice gate flow estimates is explained by the variability in verification flow measurements. It follows that, on average, the orifice gate estimates were 6 percent lower than the actual flow rate as defined by the verification measurements.

$$orifice\ flow\ estimate = 0.941 * verification\ flow\ measurement \qquad (5)$$

Gate Size (in)	Datetime	Full Stem (in.)	Dead Stem (in.)	Good Stem (in)	Head (ft)	Q Orifice (cfs)	Q Verification (cfs)	Residual (cfs)	% Difference
18	9/1/09 13:45	19 4/8	1 4/8	18	0.10	2.99	3.11	-0.13	-4%
18	9/1/09 14:15	4 4/8	1 2/8	3 2/8	1.88	3.81	3.82	-0.01	0%
18	6/2/09 12:40	6 6/8	2 6/8	4	2.66	5.50	4.68	0.83	18%
18	6/29/09 10:05	5 2/8	3 1/8	2 1/8	3.72	3.58	3.80	-0.22	-6%
24	6/29/09 9:10	20 6/8	2 4/8	18 2/8	1.18	15.69	15.80	-0.11	-1%
24	6/10/09 10:15	16 5/8	1	15 5/8	0.37	8.19	5.95	2.23	38%
24	6/29/09 7:00	3 5/8	1	2 5/8	1.26	3.41	4.26	-0.85	-20%
24	6/29/09 7:00	6 2/8	2 5/8	3 5/8	0.50	2.91	3.53	-0.62	-17%
24	5/18/09 8:08	7 1/8	4 4/8	2 5/8	5.18	6.91	6.76	0.15	2%
24	6/2/09 8:56	6 3/8	4 4/8	1 7/8	4.70	4.69	5.68	-0.99	-17%
24	6/10/09 8:40	6	4 4/8	1 4/8	6.23	4.41	5.41	-1.00	-19%
24	6/29/09 9:30	7 6/8	4 4/8	3 2/8	6.40	9.40	9.14	0.26	3%
24	8/14/09 9:30	7 7/8	4 4/8	3 3/8	1.15	4.13	4.23	-0.10	-2%
24	6/29/09 8:30	2 5/8	7/8	1 6/8	3.16	3.65	3.38	0.27	8%
24	6/29/09 7:00	2 6/8	1 4/8	1 2/8	1.08	1.53	1.98	-0.45	-23%
24	6/29/09 12:20	3 5/8	1 1/8	2 4/8	3.96	5.76	6.60	-0.83	-13%
24	8/4/09 10:42	3	1 1/8	1 7/8	4.23	4.51	4.83	-0.31	-6%
24	8/12/09 16:36	2 2/8	1 1/8	1 1/8	4.36	2.78	3.94	-1.16	-29%
24	6/2/09 12:40	6 4/8	1 6/8	4 6/8	1.80	7.10	6.18	0.92	15%
24	5/18/09 14:44	7	2 4/8	4 4/8	0.28	2.66	3.41	-0.74	-22%
24	5/18/09 14:44	4 4/8	3 7/8	5/8	3.16	1.33	3.41	-2.08	-61%
24	6/29/09 14:35	12 7/8	3 6/8	9 1/8	0.69	7.73	8.64	-0.92	-11%
24	8/26/09 10:00	7 2/8	3 6/8	3 4/8	1.62	5.07	5.26	-0.19	-4%
24	5/20/09 11:45	4 3/8	2 5/8	1 6/8	1.34	2.37	2.65	-0.27	-10%
24	7/16/09 11:58	4 4/8	2 5/8	1 7/8	1.44	2.63	2.13	0.50	23%
24	6/10/09 12:00	4 2/8	1 7/8	2 3/8	0.91	2.63	3.01	-0.38	-13%
24	8/26/09 14:45	12 4/8	4 5/8	7 7/8	0.71	6.95	7.75	-0.80	-10%
24	5/7/09 16:20	3 7/8	2	1 7/8	2.00	3.10	3.28	-0.18	-5%
24	6/2/09 14:05	4 5/8	1 6/8	2 7/8	1.42	3.94	4.79	-0.84	-18%
24	8/26/09 13:20	4 4/8	1 6/8	2 6/8	1.33	3.66	4.21	-0.55	-13%
24	6/29/09 13:45	5	7/8	4 1/8	0.73	3.97	4.00	-0.03	-1%
24	6/29/09 11:00	5 4/8	2 4/8	3	1.94	4.80	3.68	1.12	31%
24	7/21/09 13:23	8 3/8	3 2/8	5 1/8	0.51	4.05	4.17	-0.12	-3%
30	5/7/09 15:21	4 6/8	1	3 6/8	0.83	4.91	4.99	-0.08	-2%
30	5/18/09 15:33	17 1/8	2 3/8	14 6/8	1.43	21.26	22.32	-1.06	-5%
30	9/1/09 13:00	4 2/8	1	3 2/8	1.98	6.62	6.94	-0.32	-5%
30	5/7/09 17:10	10	6/8	9 2/8	0.45	8.24	8.27	-0.03	0%
30	8/4/09 13:35	6 3/8	6/8	5 5/8	0.15	3.06	2.78	0.28	10%
30	8/12/08 14:13	12	6/8	11 2/8	0.53	10.52	11.00	-0.48	-4%
30	8/12/08 14:42	9	6/8	8 2/8	0.57	8.35	9.28	-0.93	-10%
30	8/12/08 15:07	7	6/8	6 2/8	0.77	7.62	7.90	-0.28	-4%
30	8/12/08 15:32	5	6/8	4 2/8	0.88	5.70	5.75	-0.05	-1%
30	8/12/08 15:57	3	6/8	2 2/8	1.30	3.76	3.18	0.58	18%
30	5/20/09 12:45	3 5/8	2 3/8	1 2/8	2.01	2.63	2.13	0.50	23%
30	7/16/09 13:00	3 3/8	2 3/8	1	2.58	2.39	2.14	0.25	12%
30	7/16/09 14:22	9	4 2/8	4 6/8	0.59	5.18	4.30	0.88	20%
30	7/21/09 11:00	8 2/8	4 2/8	4	0.54	4.21	3.75	0.46	12%
30	5/14/09 15:32	5	2	3	1.65	5.60	4.72	0.87	19%
30	5/14/09 14:09	7	3 1/8	3 7/8	1.72	7.30	6.66	0.64	10%
30	6/2/09 10:55	8	4 1/8	3 7/8	0.95	5.42	5.34	0.09	2%
30	9/1/09 15:37	6 5/8	4 1/8	1 4/8	0.71	1.87	3.72	-1.85	-50%
30	6/2/09 10:55	2 6/8	7/8	1 7/8	0.67	2.26	2.48	-0.22	-9%
36	6/10/09 14:35	7 3/8	3	4 3/8	1.40	8.92	9.42	-0.51	-5%
36	8/4/09 10:08	7 3/8	3	4 3/8	1.37	8.82	8.94	-0.12	-1%
36	8/12/09 16:12	4 3/8	3	1 3/8	1.86	3.34	3.13	0.21	7%
36	6/2/09 9:50	3	1 1/8	1 7/8	1.88	4.55	3.33	1.23	37%
42	8/26/09 11:20	4 4/8	2 2/8	2 2/8	2.85	7.80	7.90	-0.10	-1%
48	5/7/09 8:20	1 4/8	1	4/8	0.65	0.97	2.61	-1.65	-63%
48	5/7/09 10:58	3 4/8	1	2 4/8	0.65	4.74	5.99	-1.25	-21%
48	5/14/09 11:19	10 4/8	1	9 4/8	0.89	19.51	23.64	-4.13	-17%

Table 1. Summary Data Table

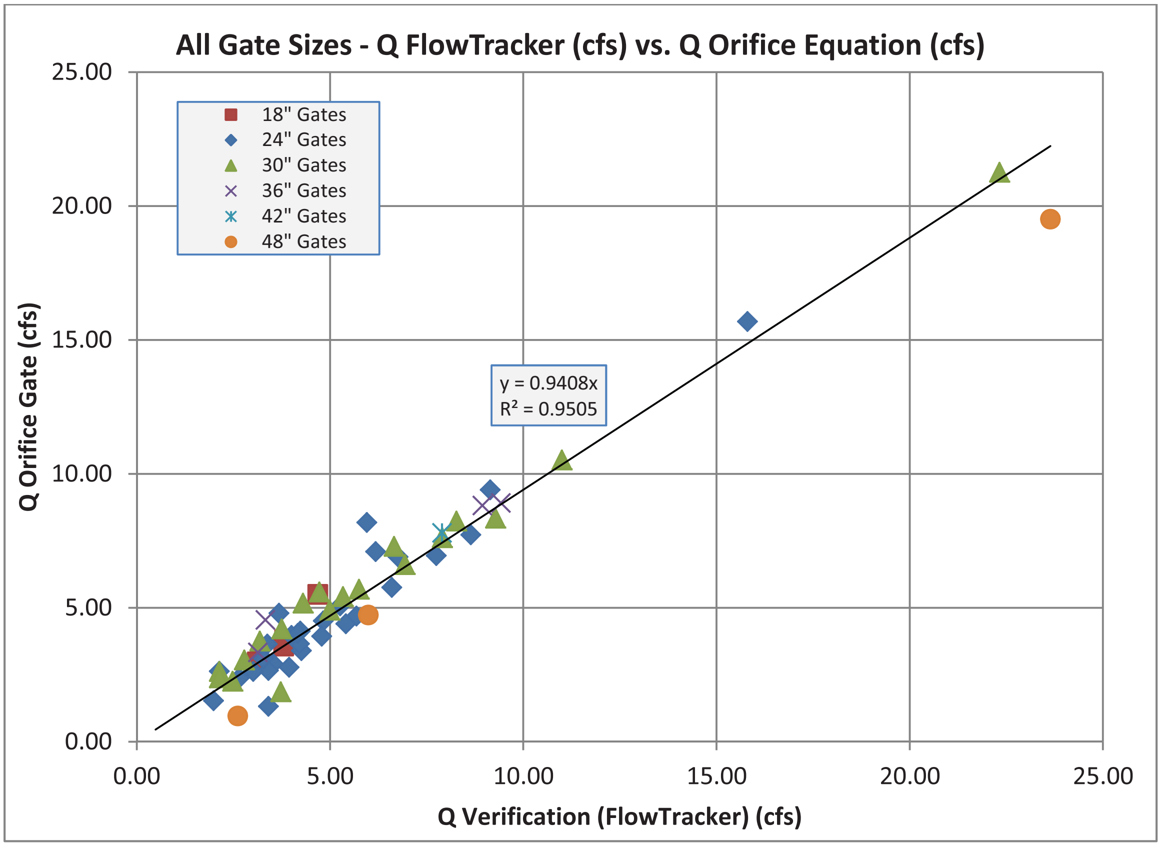

Figure 7. Estimated Q Orifice Gate vs. Measures Q Verification for Full Sample

Considering that most of the samples had flow rates of less than 12 cfs and that the 48" gates operating at low flow rates are extremely sensitive to error in the determinations of full-stem, dead-stem and good-stem, the analysis was repeated for a sample excluding all gates larger than 36" and any gate with a verification flow of 12 cfs or higher. Six gates were excluded leaving a sample of 54. A least-squares linear regression was performed to determine the relationship between the estimated and measured flows (Equation 6, Figure 8) (Davis 2002). The R^2 for Equation 6 was 0.888. This means that about 89 percent of the variability in estimated gate flow is explained by variability in the measured flow. This value is lower than the R^2 for Figure 7 and illustrates that, in addition to the error of the data points included in the regression, R^2 values are also sensitive to sample size delineations. It follows that, on average, for this sample the orifice gate flow estimates were 2.6 percent lower than the actual flow rates determined by the verification measurements.

$$orifice\ gate\ flow\ estimate = 0.974 * verification\ flow\ measurement \qquad (6)$$

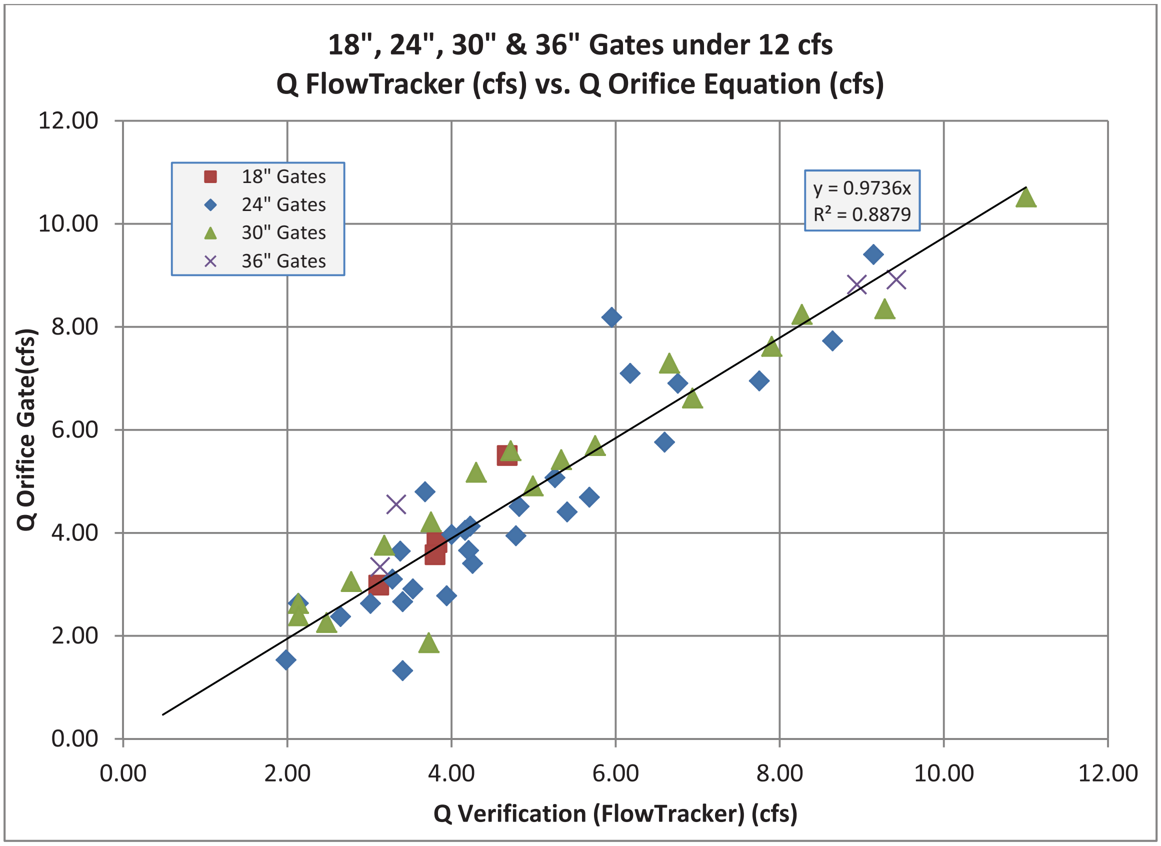

Figure 8. Estimated Q Orifice Gate vs. Measures Q Verification for Partial Sample

Additional analysis was performed on gates that had multiple verification measurements in an attempt to refine the characterization of the dead-stem values for these gates. The objective was to determine whether the verification flow data could be used to empirically calculate the dead-stem value. In other words, what would the dead-stem need to be in order for the orifice gate to be the same as the verification measurement? Figure 9 shows the percent difference in dead-stem for the sites with multiple verification measurements. If the percent difference in empirically derived dead-stem versus measured dead-stems remained consistent across multiple measurements, than it could be concluded that the dead-stem should be revised per this empirical approach. However, as illustrated in Figure 9, there was no consistent relationship in percent differences. This indicates that the empirically based dead-stem determination is unlikely to be a valid solution to the complications arising from accurately quantifying dead-stem values.

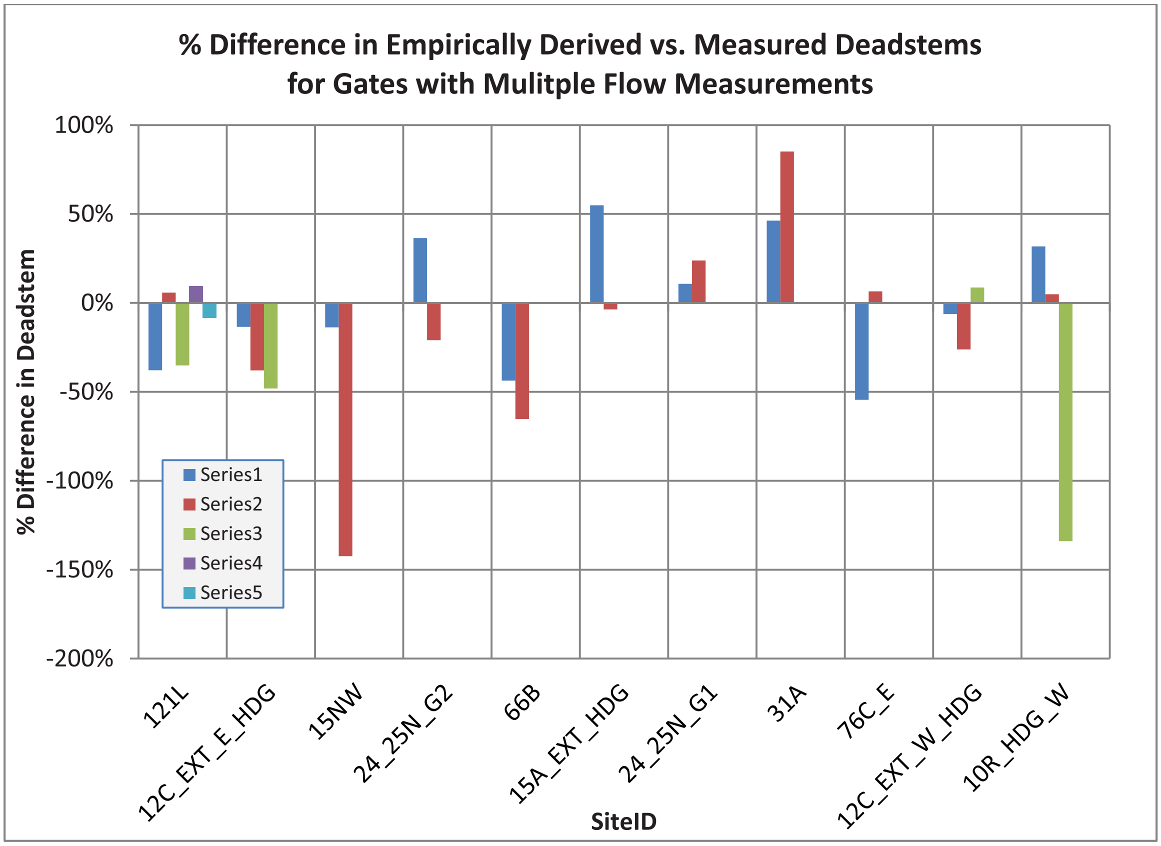

Figure 9.

IMPLICATIONS RELATIVE TO CALIFORNIA'S PENDING FARM DELIVERY GATE MEASUREMENT REGULATIONS

The Comprehensive Water Package passed by the California State legislature in November 2009 consists of four policy bills and an $11.14 billion water bond. One of the policy bills (SBx7-7) addresses both urban and agricultural water conservation and, with respect to agriculture, includes new requirements for agricultural water suppliers (over certain acreage thresholds) with respect to farm delivery measurement. RD 108 is over the specified threshold and is therefore subject to the new regulation. CWDR is responsible for developing and adopting regulations pursuant to SBx7-7, a process that was formally launched in July 2010 with respect to the agricultural aspects of the law and is ongoing as of this writing.

SBx7-7 requires that on or before July 31, 2012, agricultural water suppliers subject to the law shall measure the volume of water delivered to customers with sufficient accuracy to:

(1) Enable reporting of aggregated farm-gate delivery data to the state and

(2) Adopt a pricing structure for water customers based at least in part on the quantity of water delivered.

The presumed purpose of the requirement to report aggregated farm deliveries is to provide information that the state and others can use to better understand agricultural water use in California. New requirements for volumetric pricing, again presumably, are to induce on-farm conservation through water pricing.

During the latter half of 2010 and first half of 2011, CDWR developed its draft regulation with the input and involvement of an Agricultural Stakeholder Committee comprised primarily of staff from agricultural water supplier staff and environmental advocacy organizations, plus some academics and consultants.

CDWR's emergency regulation adopted on July 5, 2011 requires that existing farm delivery gates like those in RD 108 have a measurement accuracy of ±12% by volume, meaning that the measured volume of water delivered at each farm delivery point must be no greater than 12% more, or 12% less than the actual volume. The regulation requires that accuracy certification be performed by either: (1) field testing of a random and statistically representative sample of existing gates, or (2) field inspections and analysis of every existing delivery gate, with the testing or inspections documented by a registered engineer.

Although the original intent of RD 108's measurement verification program was not related to the pending regulation, the data provides insight into the likely implication of the regulation if adopted as drafted. It is noted that the regulation applies to the *volume* of water delivery whereas the verification measurements are for *flow rate*. For purposes here, it is assumed that flow rate accuracy as determined through RD 108's verification measurements is representative of volume accuracy. The implied assumption is that no additional error would occur in integrating observed farm delivery gate flow rates over time to estimate delivered water volumes.

The relative (%) error of each data pair was calculated as the difference between the measured and actual flow values divided by the measured value (Equation 7), where the flows estimated using the rating table are regarded as the measured flows and the flows measured using the FlowTracker are regarded as the actual flows. This definition of accuracy is consistent with the draft regulation.

$$\%\,error = (measured\ flow\ rate - actual\ flow\ rate)/\ actual\ flow\ rate \qquad (7)$$

The distribution of relative error among the full population of 60 gate measurements is illustrated in Figure 10. Just 33 gates, or 55% of the sample, would satisfy the ±12% accuracy standard in the CDWR emergency regulation, with the remaining 45% of the gates falling outside the standard. The emergency regulation states that if more than 25% of a sample of existing measuring device falls outside of the ±12% accuracy standard, a plan to test an additional 10% of the population[4] must be developed and submitted as part of the District's Agricultural Water Management Plan. Thus, if this sample of measurements was used for compliance with the new regulation, the District would be

[4] The regulation states that the 10% of the population selected for the second round of field-testing should be no less than 5 and no greater than 100.

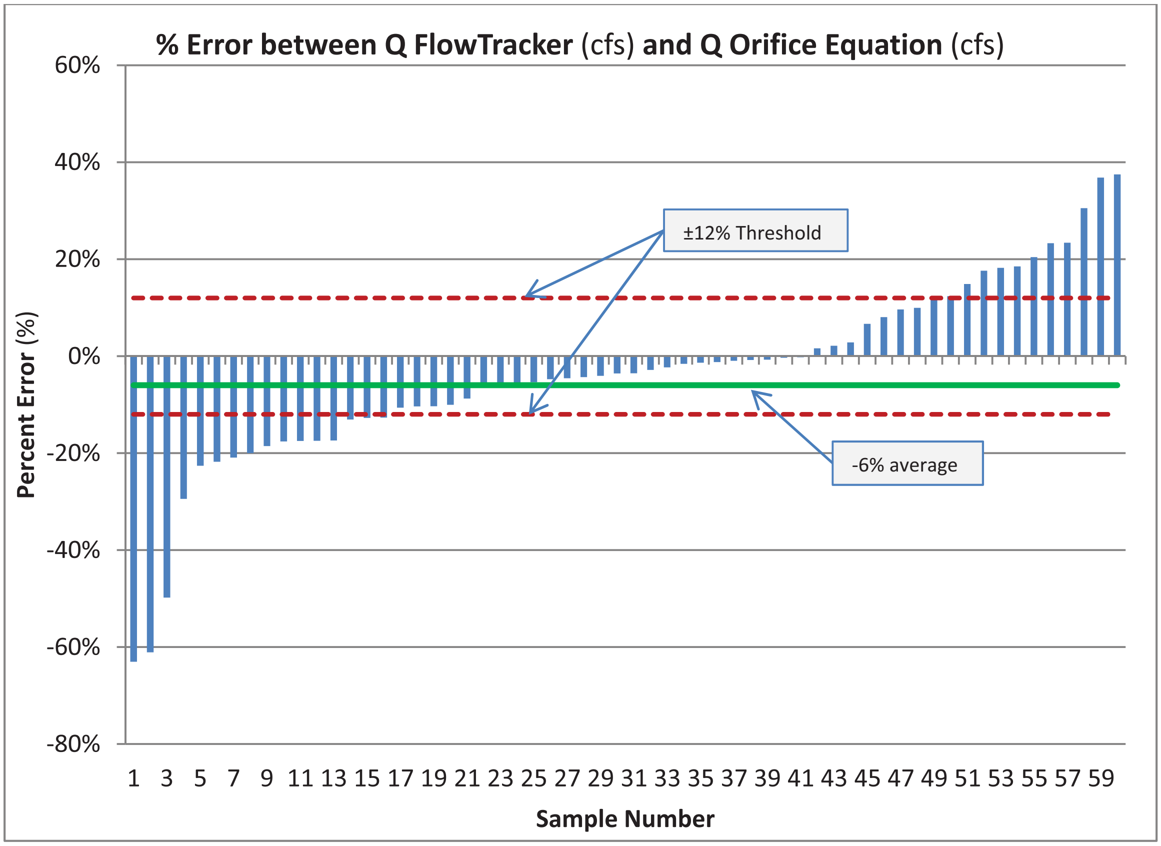

Figure 10. Percent Error between Measured Flows and Flows Estimated with the Gate Rating Table

required to conduct additional testing because more than 25% of the sample falls outside the standard. According to the regulation, the additional testing and corrective actions need to be completed within a three year period of the initial field-testing[5]. Options for bringing gates into compliance include: correcting non-standard hydraulic conditions where they can be identified; developing custom, gate-specific rating tables; reducing slack and hysteresis in gate stem measurements; and installation of improved measurement devices. All of these are expensive options.

It is interesting to note that the distribution of error is somewhat random, meaning that the positive and negative errors tend to cancel out. As noted above, the average error among this sample of gate measurements was just -6%; however, the draft regulation does not have a standard that applies to the average error for a population of gates, which, ironically, is important for purposes of aggregate reporting. The assumption implicit to the draft regulation is that, if a population of measure devices complies with the ±12% standard, the average error for all gates will probably be acceptable.

[5] The emergency regulation is not clear with regard to the implication of the initial or second round of field-testing or inspection verification approaches. In either case, if accuracy deficiencies are discovered, it is not clear whether just the outliers within the sample would need to be corrected, or whether all non-compliant gates must be included in the second round of field-testing.

Review of the RD 108 test data relative to the draft accuracy regulation reveals important philosophical questions, the main one being the role of government in regulating the relationship between agricultural water suppliers and their customers, in this case the accuracy of water delivery measurement. In this context, it is worth noting that water suppliers are in most cases are non-profit local government agencies formed and governed by the landowners they serve. Given this dynamic, is it state government's role to develop and enforce regulations to address an issue that would inevitably be dealt with locally between landowners and their district to mutual satisfaction?

Ironically, in the case of RD 108, the accuracy of existing measurement devices appears to be sufficient for purposes of reporting aggregate farm deliveries to the state, one of the expressed purposes of SBx7-7, but, again, the regulation is silent in this regard. Instead, the draft regulation focuses on individual device accuracy and proposes numeric standards that could have costly implication to RD 108 operations with questionable water management benefits.

CONCLUSION

Sixty orifice gate flow measurements were analyzed for this investigation. The measurement error at individual gates ranged from -63 to 38 percent relative to independent flow measurements made with a SonTek FlowTracker Acoustic Doppler Velocimeter (ADV) using the open channel, mid-section current metering methodology. The error distribution was nearly random, such that the positive and negative errors tended to cancel out. On average, orifice gate measurements were about 6 percent lower than the independent flow measurement.

Just 33 gates, or 55% of the sample, would satisfy the ±12% measurement accuracy standard in the CDWR emergency regulation adopted July 5, 2011, with the remaining 45% of the gates falling outside the standard. Therefore, in order to comply with the regulation, RD 108 could be faced with the prospect of having to perform a second round of field-testing and to implement corrective actions within a three year period of the initial field-testing, even though the average error among gates is just -6%. Any expenditures to improve gate measurement accuracy will provide questionable benefits and delay planned investments in other water management facilities and programs.

ACKNOWLEDGEMENTS

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