Date:	March 26, 2021
To:	Anna Sutton – USBR Water Conservation
From:	Jack Evans and Stuart Styles, ITRC
Subject:	**Patterson Irrigation District**
	Field Evaluation of Non-Contact Flow Measurement Device

Summary

The Irrigation Training and Research Center (ITRC) has analyzed the data from several non-contact volumetric flow meter models under various conditions. This testing was done with support from technical services contracts with the California Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR).

In September 2018, a Teledyne ISCO LaserFlow non-contact flow meter was installed at Patterson Irrigation Districts (PID) Main Canal approximately 300 ft downstream of the discharge from Pumping Plant 1. The meter was mounted at midspan along a footbridge that crosses the throat of an ITRC designed subcritical contraction structure (see Figure 1). The LaserFlow was replaced with a Sommer RQ-30A non-contact meter in June 2019. An existing SonTek SL Acoustic Doppler Flow Meter (ADFM) was used as the standard device for comparing measurements from non-contact meters over the course of the study. The SonTek ADFM was installed on the side wall of the structure and positioned adjacent to the non-contact meter installation. During the second year of the study, ITRC periodically performed current metering using a SonTek RiverSurveyor M9 to evaluate the accuracy of SonTek ADFM.

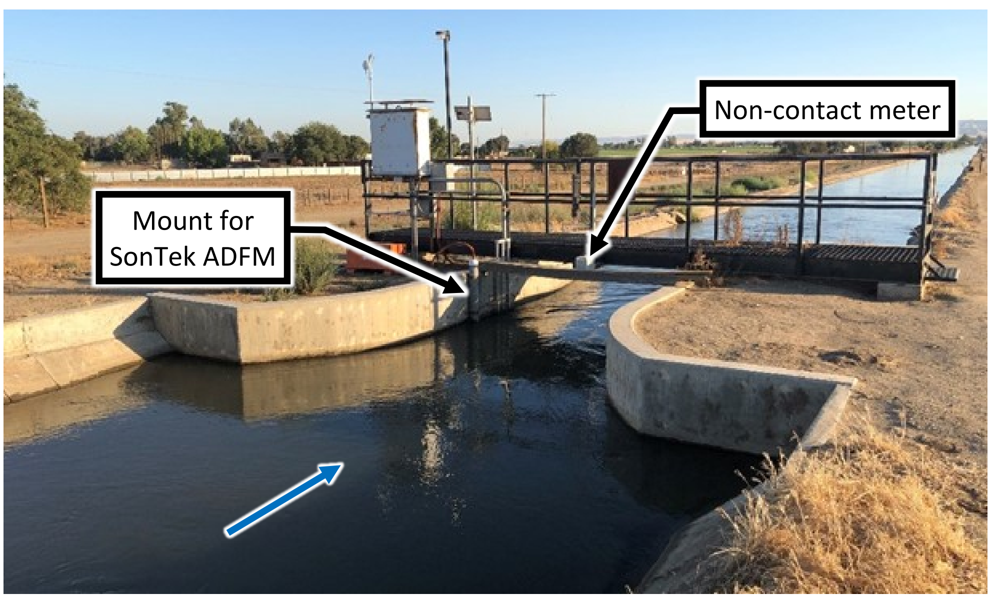

Figure 1.PID Main Canal subcritical contraction structure with non-contact meter installation and SonTek ADFM

The non-contact meter and SonTek ADFM data was collected over two irrigation seasons to assess the accuracy of the non-contact meters and the potential for implementing these models in open-channel flow measurement applications. The ranges of overlapping data available for the non-contact flow meters and the standard SonTek ADFM is listed in Table 1. Within these date ranges, there were periodic gaps in the data where the sensor(s) did not log measurements; these gaps were excluded from the analysis.

Table 1. Date ranges over which the non-contact flow meter data was analyzed

Device	Start Date	End Date
Teledyne ISCO LaserFlow	11-Sep-2018	18-Mar-2019
Sommer RQ-30A	4-Jun-2019	25-Mar-2021

One of the challenges of using flow measurement sensors in open-channel applications is the interference between environmental factors and device measurements. Open channel flow meters could be significantly affected by wind, rain, sediment, algal growth, or debris moving through a canal. To minimize the presence of such errors, each data set was filtered to eliminate erratic measurements. Additional data filtering was performed to eliminate data points when the canal water level or water velocity did not meet the manufacturer's minimum requirements for flow measurement.

Two metrics were used to report the results of the non-contact meter testing:

1) The average and average absolute error of the hourly flow measurements.
2) The average and average absolute error of the hourly measurements weighted by the flow rate. This is indicative of the volumetric error of each meter.

The results for each of the non-contact meters tested in comparison to the SonTek ADFM are listed in Table 2 and Table 3.

Table 2. Summary of hourly flow measurement accuracy results from non-contact meter testing at GCID

Device	Average Error (%)	Standard Deviation (%)	Average Absolute Error (%)
Teledyne ISCO LaserFlow	+3.6	75.8	59.6
Sommer RQ-30A	+14.7	18.6	17.2

Table 3. Summary of non-contact meter error weighted by flow rate

Device	Average Error (%)	Average Absolute Error (%)
Teledyne ISCO LaserFlow	-16.1	56.5
Sommer RQ-30A	+12.6	14.7

Non-Contact Flow Meters

Non-contact flow meters are often used to measure flows in municipal pipelines with well-defined cross-sections, however, the potential for using these devices in open channel flow measurement applications has not been extensively researched. One of the advantages of using non-invasive flow measurement devices is the ability to access and perform maintenance on the sensors year-round. Periodically retrieving and cleaning submersible sensors can be time consuming and costly for irrigation districts.

ITRC acquired two non-contact flow meters to evaluate the accuracy of these meters in comparison to an existing SonTek ADFM installed at PID. The manufacturer specifications for the non-contact meters tested are listed in Table 4.

Table 4. Manufacturer specifications for the non-contact meters installed at PID

Manufacturer	Teledyne ISCO	Sommer
Model	LaserFlow	RQ-30A
Power supply	8 to 26 VDC	6 to 30V DC
Velocity method	Doppler laser	Doppler radar
Velocity measurement location	Subsurface	Water surface
Maximum water velocity	±15 ft/s	±49 ft/s
Minimum water velocity	±0.5 ft/s	±0.3 ft/s
Water level method	Ultrasonic	Radar
Water level range	0-10 ft	0-50 ft
Flow measurement accuracy	±4%	±5%
SCADA integration (Y/N)	No	Yes

Site Overview

The non-contact meters were installed at the PID Main Canal, approximately 300 ft downstream from the discharge of Pumping Plant 1. Because the Main Canal is operated on a downstream water level control scheme, there is minimal water level fluctuation at this site and there can be large fluctuations in flow over short periods. The sensors were mounted midway across a suspended walkway that crosses the throat of an ITRC designed subcritical contraction structure. Subcritical contraction structures are specifically designed to improve the accuracy of ADFM sensors by creating a uniform velocity profile at the throat of the contraction. The SonTek ADFM was mounted to the side wall of the contraction throat, directly adjacent to the non-contact meter location. There was a straight reach of canal both upstream and downstream of the sensor's location. An aerial map view of the PID Main Canal non-contact meter installation location is shown in Figure 2. The configuration of the two sensors on the subcritical contraction structure is shown in Figure 3.

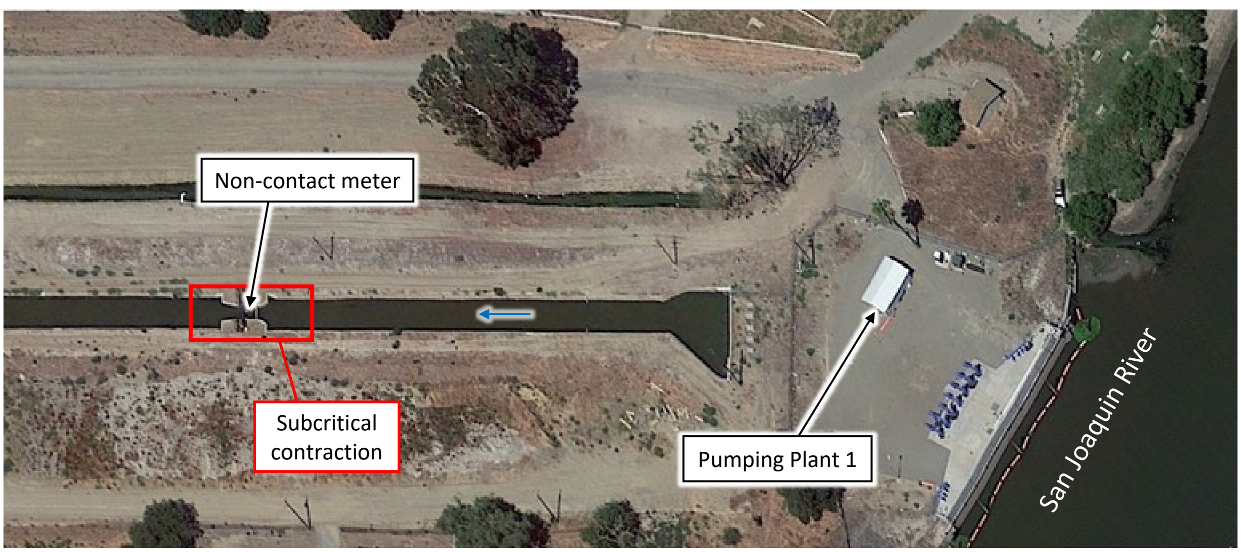

Figure 2. Aerial map view of PID Main Canal and non-contact meter installation

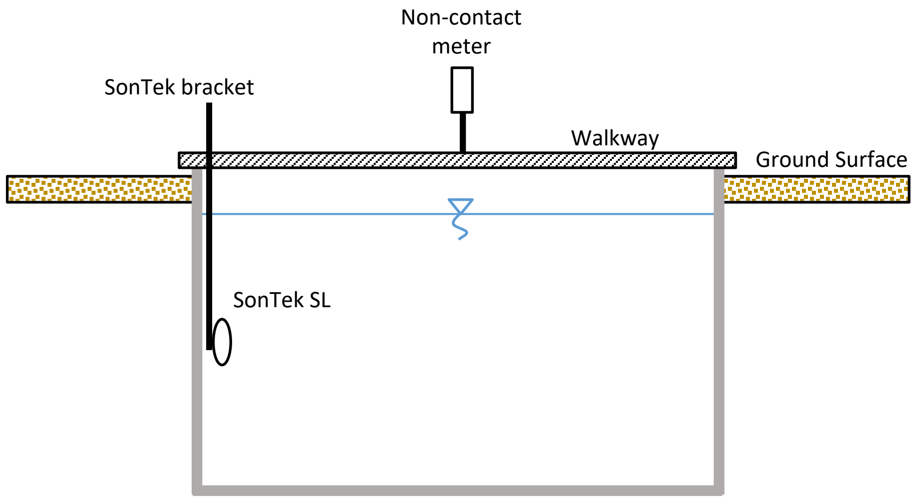

Figure 3. Cross-section view of the subcritical contraction structure showing the positions of the measurement devices, looking downstream

In the second year of the study, ITRC performed six stationary discharge measurements (current metering) at the site using a SonTek M9 acoustic Doppler profiler. These measurements were used to evaluate the accuracy of the existing SonTek ADFM and gauge its suitability for use as a standard device for comparing the non-contact meter measurements[1]. Table 5 lists the results of each discharge measurement, the average flow recoded by the SonTek ADFM over the discharge measurement period, and the percent error of the SonTek ADFM for each discharge measurement performed.

Table 5. Summary of current metering data collected to evaluate the accuracy of the SonTek ADFM

Site Visit Date	SonTek M9	SonTek ADFM	
	Flow Rate (CFS)	Flow Rate (CFS)	Error (%)
7/25/2019	133.1	123.1	-7.5
7/25/2019	100.9	103.9	+2.9
4/16/2020	101.6	101.4	-0.1
7/23/2020	112.1	116.6	+4.1
8/21/2020	121.1	110.3	-8.9
10/16/2020	91.8	91.6	-0.2

Average Field Device Error	-1.6
Standard Deviation	5.4

Data Filtering

Several filters were applied to the raw data to eliminate instances where erratic measurements were observed from the standard device, and to ensure that the site conditions met the test meter manufacturer minimum requirements for accurate flow measurement.

[1] The discharge measurements were performed after the LaserFlow non-contact meter was removed from the site.

For the SonTek ADFM (standard meter) measurements, filters were applied to ensure that the non-contact meter measurements were only compared against reliable flow data from the standard device. Data points were omitted if:

- 24-hour continuous data was not available prior to the measurement. If the sensor failed to record measurements, the subsequent measurements were omitted until 24-hours of continuous data had been recorded. This filter was applied to eliminate measurements that coincided with periods when the sensor was not operating properly or consistently.
- The measurement significantly deviated from the adjacent measurements. The maximum allowable deviation in flow rate was set to 10 percent of the 90th percentile of all recorded flow rates. This corresponded with flow changes greater than ±11 CFS over a 1-hour interval. This filter was applied to eliminate erratic data when sudden increases/decreases in flow were recorded.
- The logged flow rate was less than 20 CFS.

The criteria for the maximum percent deviations were selected based on the estimated maximum possible change in flow that could occur at this site over the one-hour interval on which the sensors logged data.

For the test meters, data points were omitted if:

- The standard meter mean canal water velocity did not meet the non-contact meter manufactures minimum requirements. The manufacturers minimum velocity requirements vary between the meters tested and are listed in Table 4 (above).
- The distance between the water surface and the non-contact meter exceeds the manufacturers specified range. The specifications for the maximum distance between the sensor and the water surface vary between the meters tested and are listed in Table 4 (above).
- The flow rate logged was 0 CFS.

Table 6 below summarizes the data filters used, the data sets to which they were applied, and the percentage of the total data that was filtered out for each device.

Table 6. Data filters applied to the raw SonTek and non-contact meter data

Data Filter Applied	SonTek ADFM	LaserFlow	RQ-30A
Omit values when the flow rate logged was zero		X	X
Omit values when the flow rate logged was less than 20 CFS	X		
If 24 hours of continuous data is not available prior to the logged flow, omit the data point	X		
Omit values when flow changes of greater than ±11 CFS occur within 1-hour	X		
Canal water velocity did not meet manufacturer specifications		X	X
Distance from sensor to water level did not meet manufacturers specifications		X	X
Percent of total data that was omitted	35[2]	70[2]	24

[2] A large portion of the SonTek ADFM and LaserFlow data was filtered out because the canal flow was below 20 CFS between 15-Nov-2018 and 18-Mar-2019.

Results

The results of the study show that both non-contact meters experienced significant fluctuations in measurements over short time intervals and consistently overestimated the flow. The LaserFlow had and average error of +3.6% with a standard deviation of 75.8%, and an average absolute error of 59.6%. The high standard deviation and average absolute error indicate that there was significant variability in the LaserFlow's flow measurement accuracy. The RQ-30A performed slightly better with an average error of +14.7%, a standard deviation of 18.6%, and an average absolute error of 17.2% for the cumulative, unadjusted data. The hourly and weighted by flow average percent error and average absolute percent error for each of the non-contact meters tested in comparison to the SonTek ADFM are shown in Figure 4. The performance of each meter is analyzed separately in the following sections.

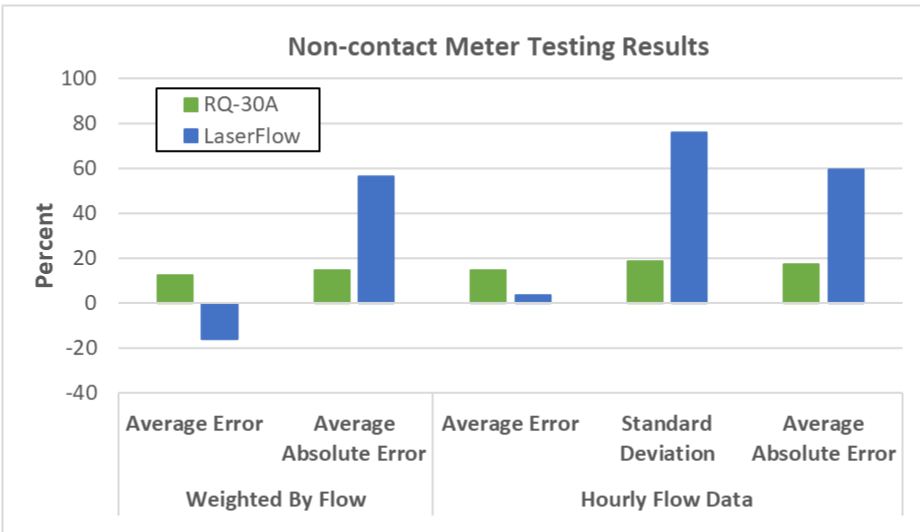

Figure 4. Results of non-contact meter testing at PID

Teledyne ISCO LaserFlow Results

Figure 5 shows the time series of the quality controlled SonTek ADFM and the filtered LaserFlow flow data over the course of the study. The data between November 2018 and March 2019 was filtered out because the canal flow was less than 20 CFS. The visible noise in the data indicates large fluctuations in flow measurements over a short period of time.

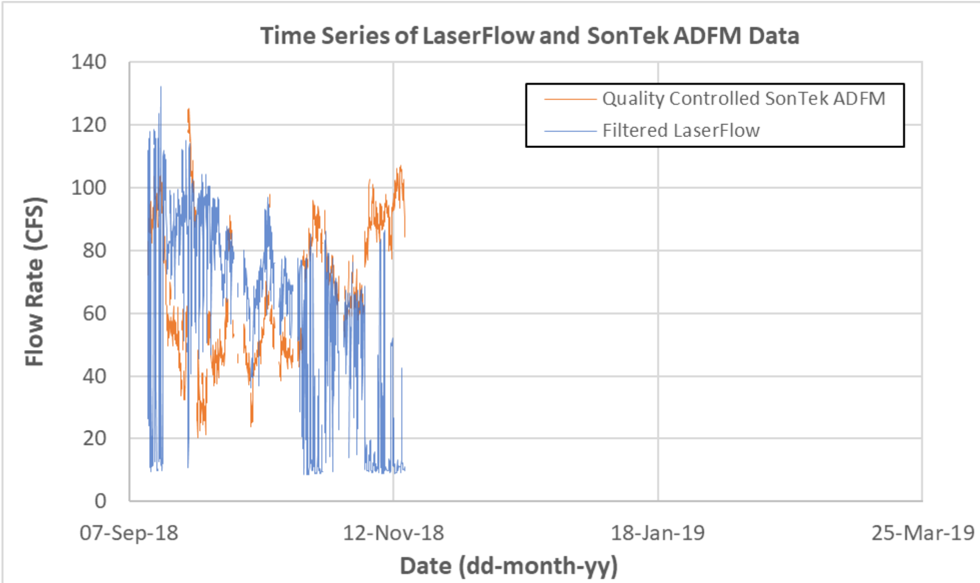

Figure 5. Hourly LaserFlow and SonTek ADFM flow rate data

The chart in Figure 6 shows a comparison between the filtered LaserFlow measurements and the quality-controlled ADFM measurements. There is no evidence of a correlation between the two sensors measurements.

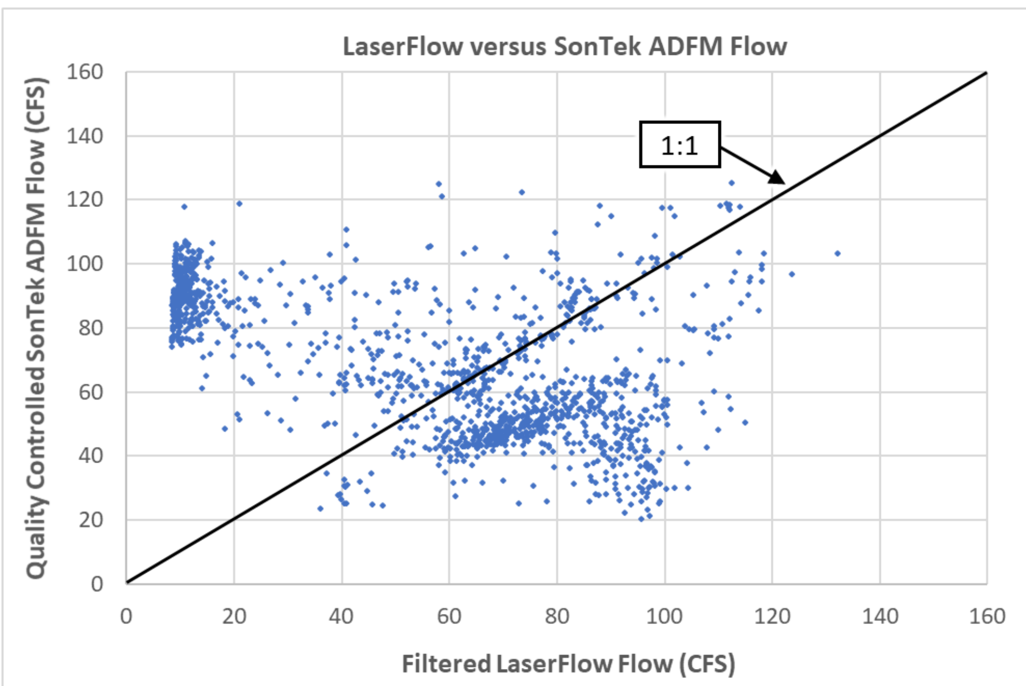

Figure 6. Comparison of filtered LaserFlow flow rate to quality controlled SonTek ADFM flow rate

Sommer RQ-30A Results

The Sommer RQ-30A data also exhibited significant measurement variability over short durations. On July 30th, 2019, the RQ-30A meter was configured with 15-minute averaging to minimize the noise in the data. The average slightly reduced the measurement variability but did not have a significant impact on improving the overall accuracy of the sensor. Figure 7 shows the time series of the SonTek ADFM and RQ-30A flow data, and the SonTek M9 discharge measurements over the course of the study.

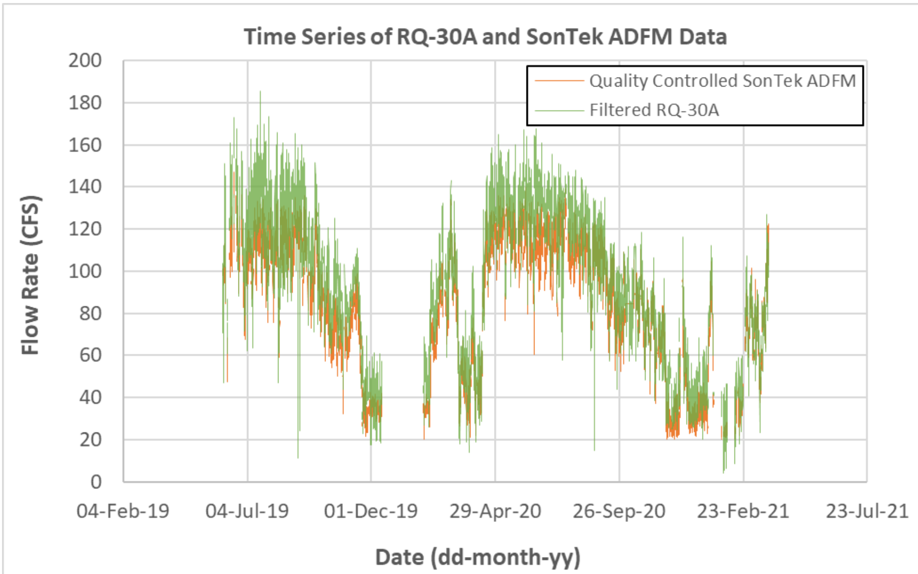

Figure 7. Hourly RQ-30A and SonTek ADFM flow rate data

The chart in Figure 8 shows a comparison between the filtered RQ-30A measurements and the quality controlled ADFM measurements. On average, the RQ-30A slightly overestimates the flow.

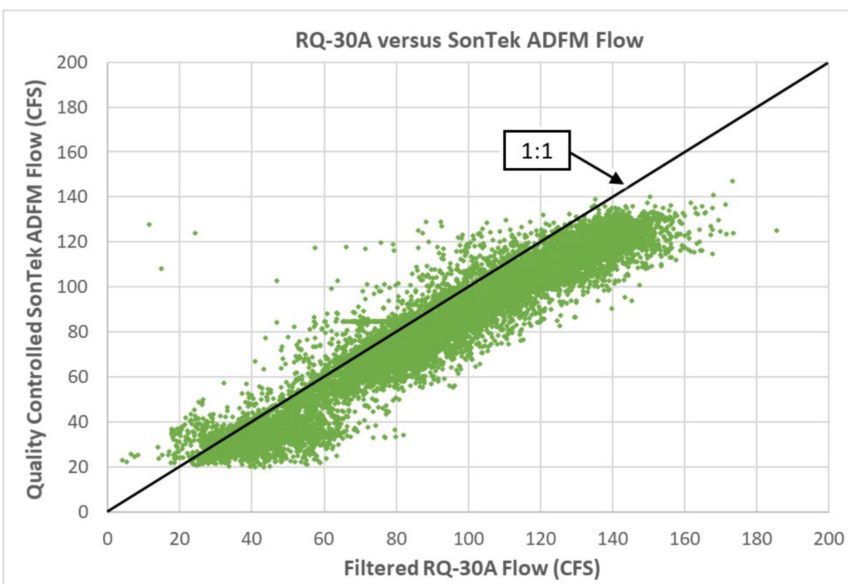

Figure 8. Comparison of filtered RQ-30A flow rate to quality controlled SonTek ADFM flow rate

Discussion

Wind Analysis

Because the non-contact meters measure the velocity at the top of the water surface, there was a concern that the local wind speed could affect the readings of the meter and artificially increase the error of the device. Wind speed data was collected from the nearest CIMIS station (Station 71) approximately 9 miles away and compared to the absolute errors of the non-contact meters. Figure 9 and Figure 10 show the average absolute error of each non-contact meter for each wind direction and wind speed. For both meters, there was no significant correlation between wind direction and meter accuracy. However, there RQ-30A average absolute error increased consistently with increasing wind speeds. There was no significant correlation between wind speed and average absolute error for the LaserFlow.

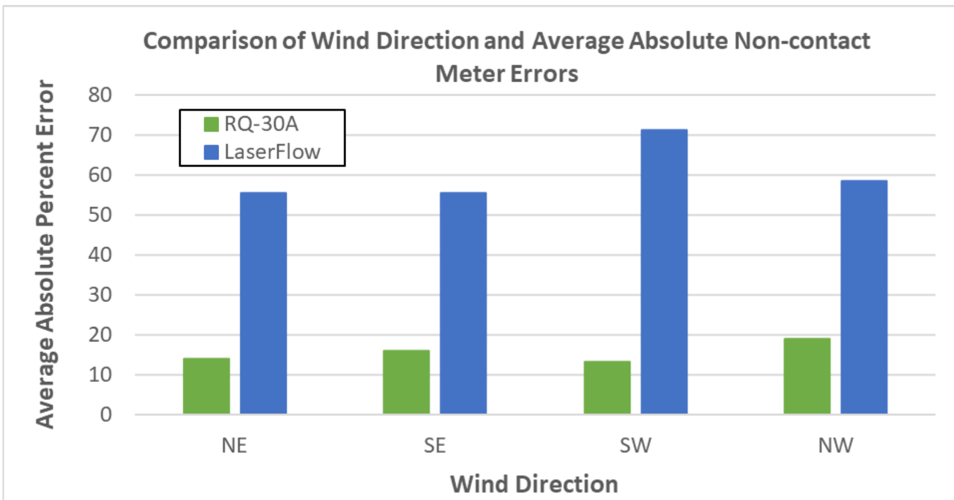

Figure 9. Non-contact meter average absolute percent errors for each wind direction

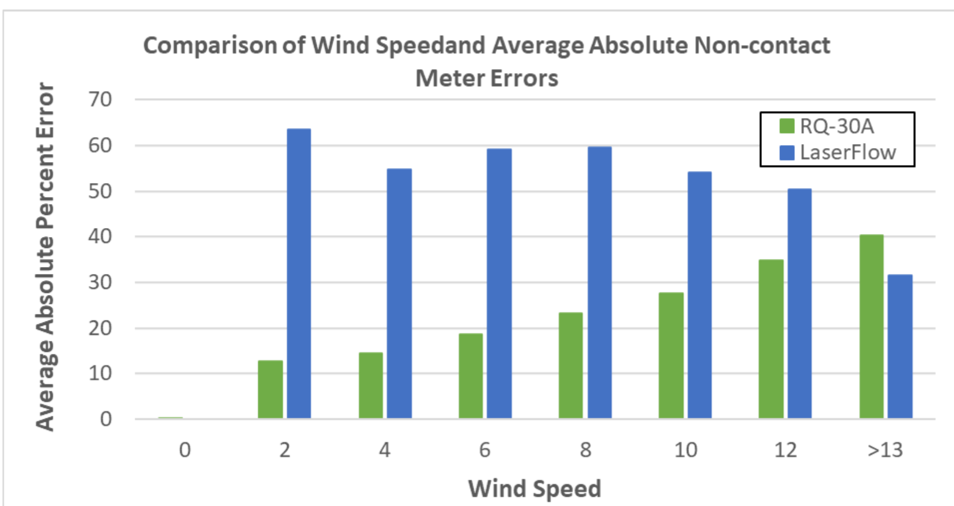

Figure 10. Non-contact meter average absolute percent errors for each wind speed

Water Level

An additional analysis was performed to determine if the non-contact meter errors could be attributed to be attributed to the velocity measurements. For each non-contact meter, a linear best fit relationship was derived to relate the non-contact meter water level measurements to the ADFM flow rate measurements. This relationship was used to determine if the non-contact meter water level was a more accurate indicator of canal flow than the internally computed non-contact meter flow measurements. The results of this analysis are shown in Figure 11.

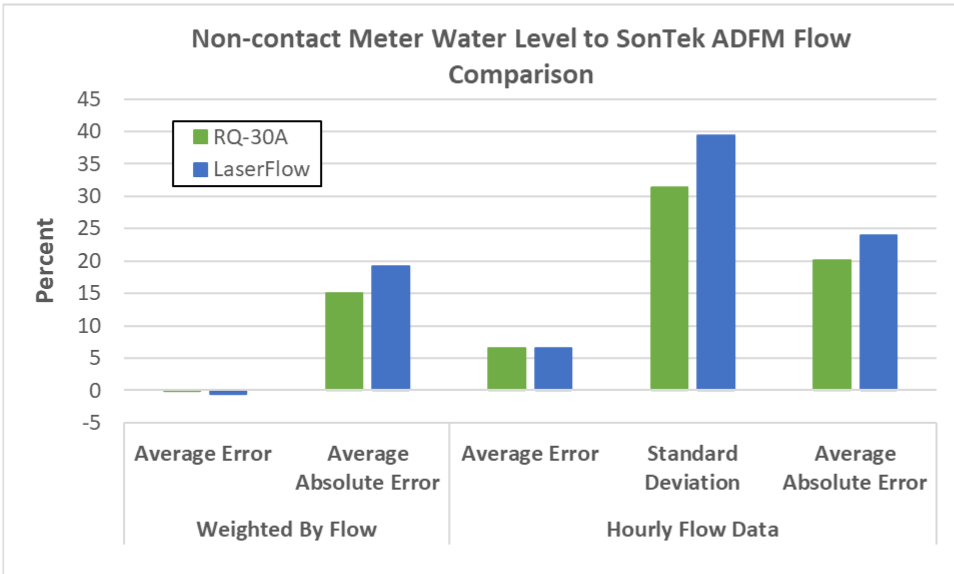

Figure 11. Results of using the non-contact meter water level measurement to predict the flow

For the RQ-30A, the water level computed flow rate decreased the average error but increased the average absolute error. For the LaserFlow, the water level computed flow rate improved both the average error and absolute average error or the sensor. This indicates that the velocity measurements are likely contributing to the large errors observed from the LaserFlow sensor.