RECLAMATION

Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1041

Mace USA LLC Continuous Wave Doppler Flow Tests Oct 21, 2011

18” circular conduit and 1.5’ trapezoidal channel results

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

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Prepared: Bryan J. Heiner
Hydraulic Engineer, Hydraulic Investigations and Laboratory Services Group, 86-68460

Technical Approval: Robert F. Einhellig, P.E.
Manager, Hydraulic Investigations and Laboratory Services Group, 86-68460

Peer Review: Robert F. Einhellig, P.E. — 11/2/11 Date
Hydraulic Engineer, Hydraulic Investigations and Laboratory Services Group, 86-68460

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Introduction

This report summarizes the testing of the Mace Agriflow3 acoustic Doppler flow meter conducted at the Bureau of Reclamation's Hydraulics Laboratory in Denver, CO. The testing was funded by Mace USA LLC. Mathew A. Campbell and Tim Quinlan were present during the testing to witness the test facilities, setup the units and troubleshoot any problems that were encountered.

Test Facility

Testing was conducted in Reclamation's Hydraulics Laboratory located in Denver, CO USA. Two setup configurations were tested, a 18-in circular conduit (Figure 1) and a 1.5-ft trapezoidal channel (Figure 2) with side slopes of 1.5:1 (H:V). Both test setups were operated as open channels with discharge ranging from from 0-8 ft^3/sec. Flow was pumped into each setup using a 100-hp centrifugal pump. Reference flow rates were measured using calibrated[1] venturi meters accurate to 0.25 percent. Reference depth measurements were obtained using a point gauge accurate to 0.001 ft, and average reference velocities were determined by dividing the reference discharge by the cross sectional area calculated from the depth measurements.

[1] Every two years the Hydraulic Investigations and Laboratory Services group calibrates each venturi meter in place. Calibrations are performed using a weight vs time relationship derived from a permanent volumetric weight tank. Historical performance of all venturis have shown little if any deviation year to year. (Hydraulic Laboratory Techniques, Denver CO 1989 available online at: http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/HydraulicLabTech.pdf)

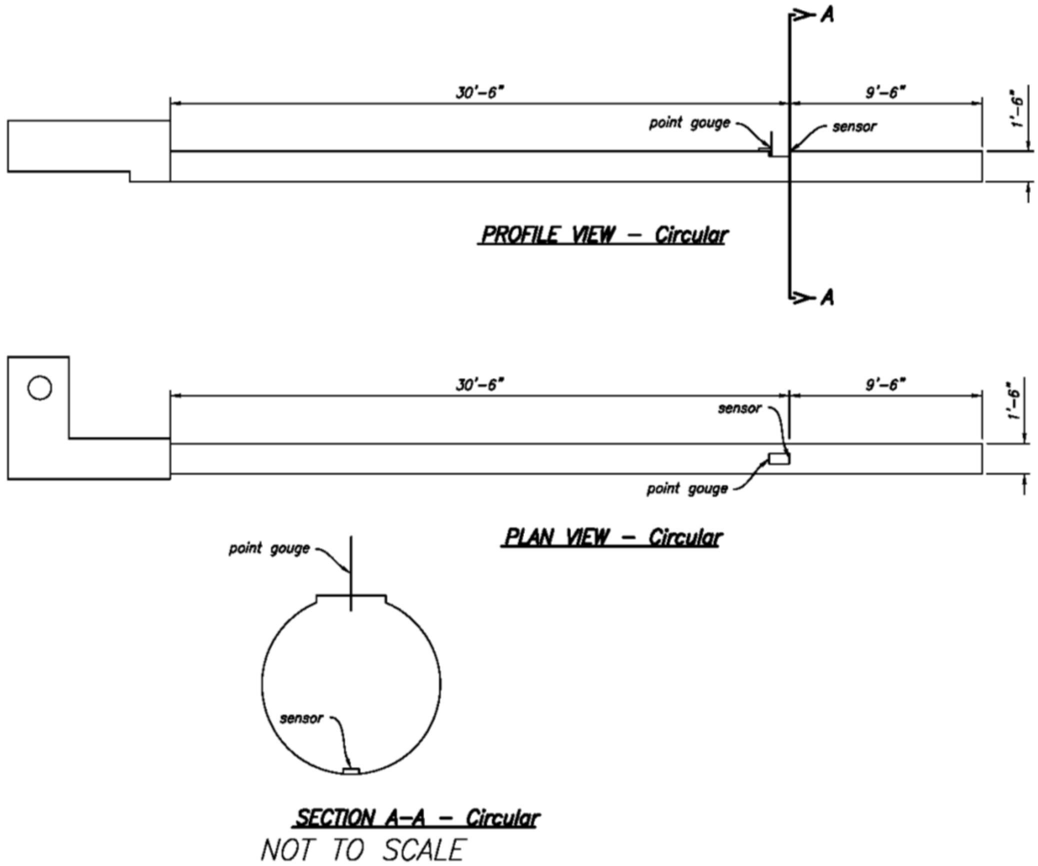

Figure 1 - 18-inch circular conduit test setup (flow is left to right)

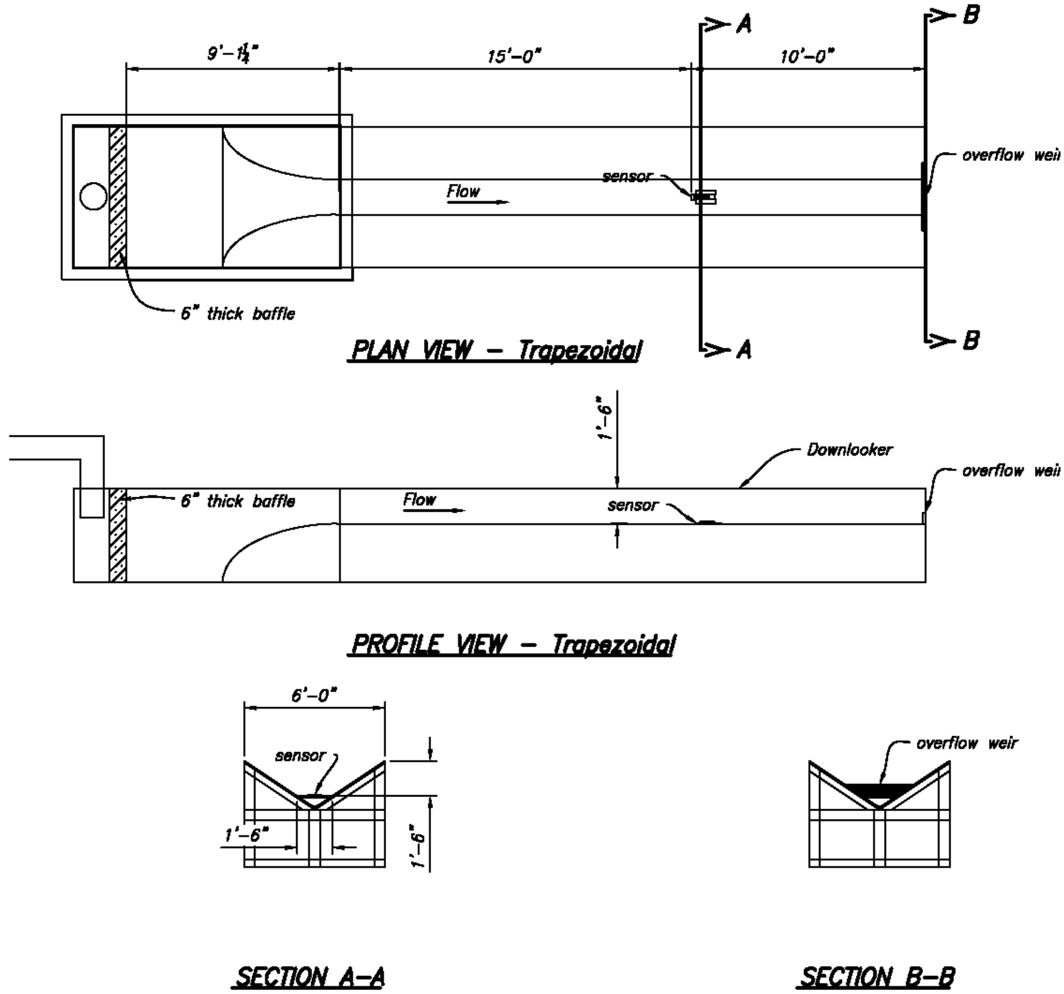

Figure 2 - 1.5-foot trapezoidal channel test setup (flow is left to right)

Test Procedure and Results

Testing procedures were the same for each setup. After a specific flow rate was set it was allowed to stabilize for 10 minutes to ensure that equilibrium conditions had been reached. Once stabilized, flow, velocity and stage were logged using the Mace Agriflo 3 over a 10-15 minute interval at 1 minute increments. Laboratory (reference) flow rates were determined by continuously averaging the differential pressure from the venturi meter over the same 10-15 minute period. Reference depths were monitored and recorded manually for each stable flow rate. Bounces in the water surface during some flows (primarily in the 18-in conduit) added a small amount of uncertainty to the depth measurements. Once flows and depths were recorded the flow rate was changed and the process was repeated.

Table 1 and Figure 3 provide the data for the 4 test runs completed in the 18-in circular conduit. Tests were conducted at flows of 1.00, 2.99, 5.50 and 8.00 ft^3/sec. Percent deviations in the Agriflow3 measurements were calculated by dividing the difference of the measured and reference values by the reference. For all flows tested in the 18-in circular conduit the minimum deviation of flow (-7.7%) occurred at 8 ft^3/sec, and the maximum deviation of flow (16.2%) occurred at 2.99 ft^3/sec. During the testing the most accurate measurement was at 1.0 ft^3/sec with 2.0 percent deviation from the laboratory reference flow rate.

Table 2 and Figure 4 provide the data for the 6 test runs completed in the 1.5-ft trapezoidal channel. Tests were conducted at flows of 0.54, 1.00, 3.00, 5.03, and 7.97 ft^3/sec. As with the circular conduit tests, percent deviations were calculated by dividing the difference of the measured and reference values by the reference. For all flows tested in the 1.5-ft trapezoidal channel the minimum deviation of flow (-2.2%) occurred at 0.53 ft^3/sec, and the maximum deviation of flow (3.1%) occurred at 7.97 ft^3/sec. During the testing the most accurate measurement was at 5.03 ft^3/sec with 1.0 percent deviation from the laboratory reference flow rate. The 7.97 ft^3/sec flow rate was tested twice, once with and once without a tailboard in place to vary the depths in the model which provided different velocities to be compared.

Discussion

Possible reasons the 18-in culvert tests did not meet recommended design specifications provided by Mace USA LLC is that the pipe was a corrugated HDPE plastic pipe that is commonly used in irrigation and drainage facilities. Although the pipe is considered a smooth wall pipe, slight ridges are present along the smooth interior surface of the pipe that could disrupt flow boundaries and cause the velocities in the pipe to fluctuate slightly from rib to trough (approximately 2 inches apart). It should also be noted that the 18-in pipe used for the testing was also about 1/4-3/8-inch out of round (egg shaped). This occurrence is not uncommon of pipes installed in the field and no attempt was made to remedy the pipe shape. It should also be noted that for some of the flow rates tested the comparison between reference and measured depths varied significantly due to bulking and standing waves that were caused by the sensor being installed in the pipe.

Table 1 - 18-in circular conduit data 10-21-2011

Mace – AgriFlo3 - 18in circular conduit (10-21-2011)								
Stage (ft)			**Velocity (ft/sec)**			**Discharge (ft^3/sec)**		
Reference	Measured ±SD	% Deviation	Reference	Measured ±SD	% Deviation	Reference	Measured ±SD	% Deviation
0.40	0.39 ± 0.002	-2.9%	2.62	2.78 ± 0.021	6.4%	1.00	1.02 ± 0.012	2.0%
0.57	0.67 ± 0.006	17.4%	4.81	4.52 ± 0.036	-6.0%	2.99	3.48 ± 0.052	16.2%
0.82	0.89 ± 0.007	9.1%	5.60	5.28 ± 0.03	-5.7%	5.50	5.76 ± 0.052	4.8%
1.20	1.21 ± 0.011	1.2%	5.29	4.83 ± 0.038	-8.8%	8.00	7.39 ± 0.062	-7.7%

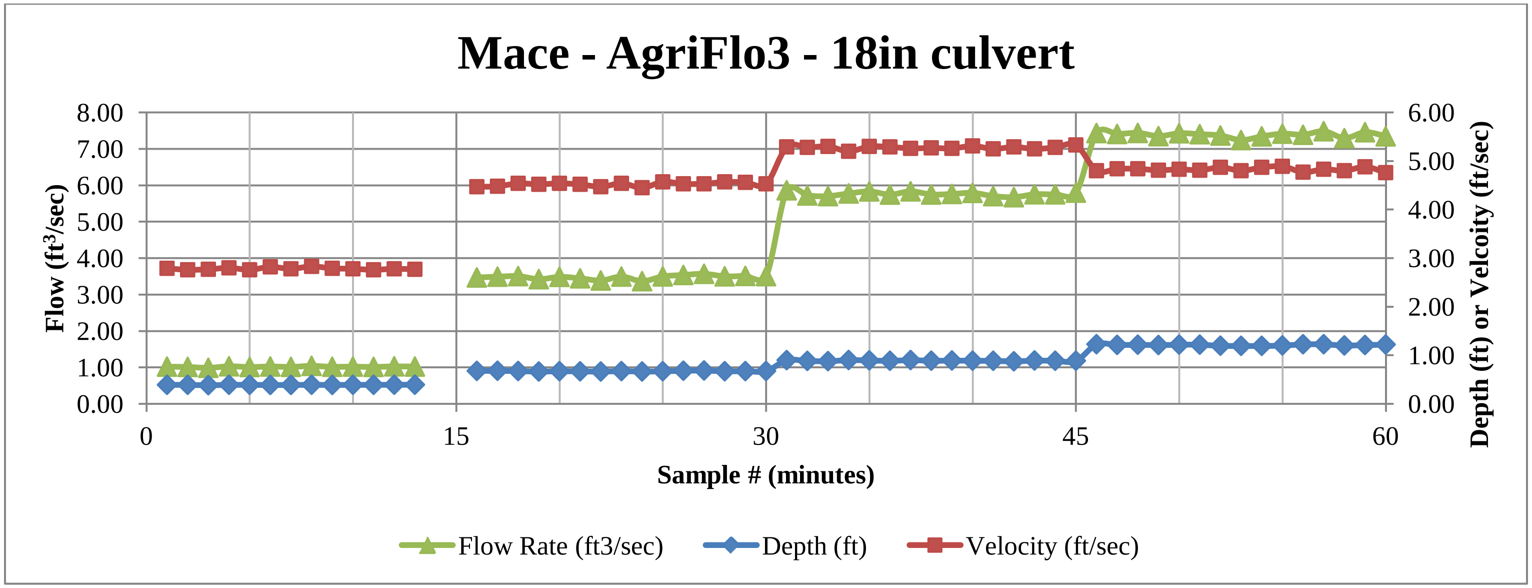

Figure 3 - 18-in circular conduit data 10-21-2011

Table 2 - 1.5-ft trapezoidal channel data (10-21-2011)

Mace - Agriflo3 - 1.5ft Trapezoidal Channel								
Stage (ft)			Velocity (ft/sec)			Discharge (ft^3/sec)		
Reference	Measured ±SD	% Deviation	Reference	Measured ±SD	% Deviation	Reference	Measured ±SD	% Deviation
0.59	0.6 ± 0.002	1.9%	0.38	0.37 ± 0.007	-5.0%	0.54	0.53 ± 0.01	-2.2%
0.65	0.67 ± 0.002	3.2%	0.62	0.59 ± 0.011	-5.5%	1.00	0.99 ± 0.02	-1.1%
0.83	0.85 ± 0.002	2.3%	1.32	1.3 ± 0.022	-2.0%	3.00	3.04 ± 0.053	1.4%
0.96	0.97 ± 0.002	1.6%	1.79	1.77 ± 0.012	-1.4%	5.03	5.08 ± 0.042	1.0%
1.10	1.1 ± 0.001	0.5%	2.31	2.36 ± 0.009	2.3%	7.97	8.21 ± 0.027	3.1%
0.82	0.82 ± 0.002	-0.4%	3.54	3.6 ± 0.007	1.6%	7.97	8.05 ± 0.043	1.1%

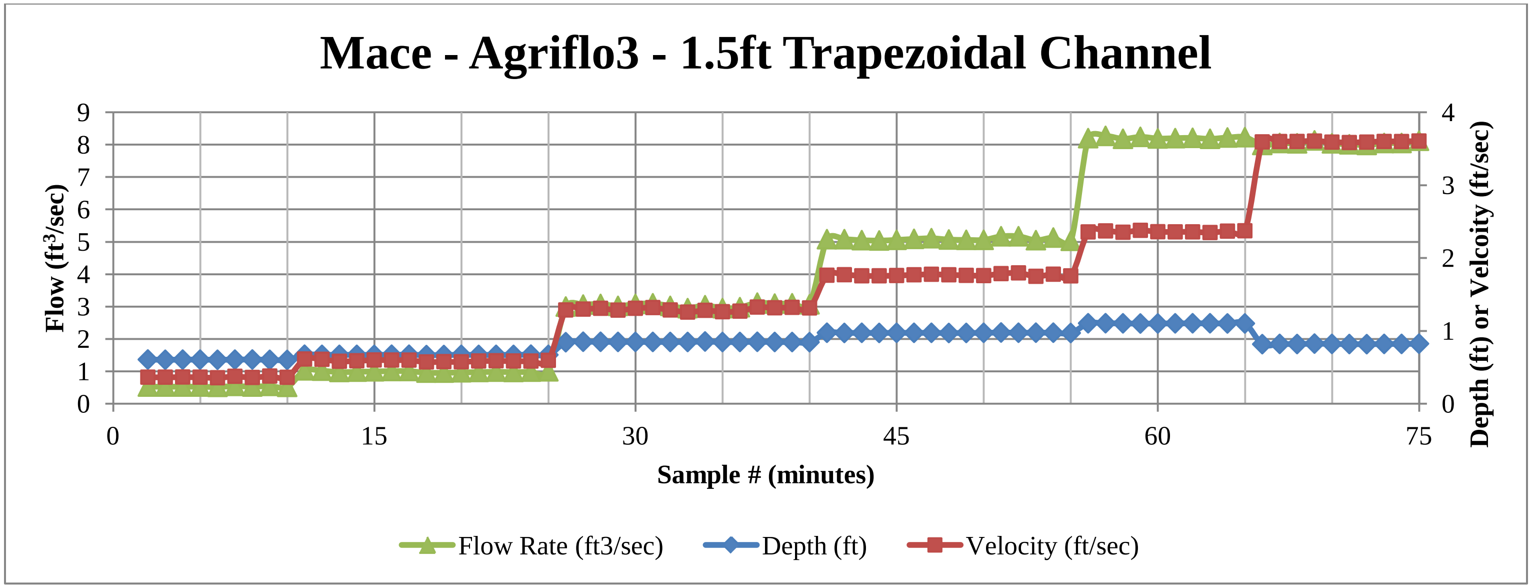

Figure 4 - 1.5-ft trapezoidal channel data (10-21-2011)