In Reply Refer To:
Mail Stop 415

September 19, 2011

Memorandum

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2011.08

SUBJECT: Exposure time for ADCP moving-boat discharge measurements made during steady flow conditions

The purpose of this memorandum is to establish U.S. Geological Survey (USGS) policy regarding exposure time for discharge measurements from moving boats with acoustic Doppler current profilers (ADCPs) under steady flow conditions. Exposure time refers to the total amount of time spent sampling (or measuring) the flow during a discharge measurement and does not include time between transects nor time spent doing moving bed tests or other tasks. The policy established in this memorandum supersedes previous policy documented in OSW Technical Memoranda 2002.02 and 2005.04 and in Mueller and Wagner (2009). Previous policy (a) required the collection of 4 transects and the discharge for each transect to be within 5 percent of the mean or 8 transects if one or more of the original 4 transects exceeded 5 percent of the mean and (b) required 8 transects for StreamPro measurements having a mean velocity less than 0.8 feet per second. Policy for discharge measurements made during rapidly changing flow is unchanged.

Effective October 1, 2011, discharge measurements made from a moving boat under approximately steady flow conditions will consist of an even number of transects (at least 2) having a total exposure time of 720 seconds (s) or greater. An even number of transects with reciprocal courses is required to minimize directional biases in measured discharges. The exposure time for the discharge measurement should be at least 720 s (12 minutes), even if that requires the hydrographer to make more than 4 transects. This requirement applies to all ADCPs used for moving-boat discharge measurements and also applies when using differential GPS (GGA, VTG, and RTK) as a reference for boat velocity. The quality of each transect included in the average is important. Therefore the user should verify the data in the field and replace transects with identifiable problems (improper boat operation, significant loss of bottom track, another boat passed, etc.) with transects collected in the same direction.

This new policy (described above) means that it is possible for a transect discharge to be more than 5 percent different from the mean discharge of 2, 4, 6, …. n transects, even if the exposure time for the measurement is greater than 720 s. Analyses of data from Oberg and Mueller (2007) and Czuba and Oberg (2008) have confirmed that no other requirement is necessary. However, even if the exposure time for a measurement is 720 s or greater, it may still be necessary to make a check discharge measurement. The requirement for check measurements as described in Mueller and Wagner (2009) by Rantz and others (1982, p. 346), and Turnipseed and Sauer (2010, p. 81) is still valid.

"If the measurement does not plot within 5 percent (or other specified percentage) of the rating curve in use, or if it is not in line with the previous trend of measurements, try to find an explanation …. If a satisfactory explanation cannot be found, then make a check measurement."

BACKGROUND

Previous USGS policy required that at least four transects be averaged for a complete moving-boat ADCP discharge measurement, except in rapidly changing flow, according to OSW Technical Memorandum 2002.02 and Mueller and Wagner (2009, p. 21-22). When using an ADCP, a complete transect (single pass across the stream) can be made in less than 2 minutes. Therefore, it is possible to complete a discharge measurement using an ADCP with less than 8 minutes of exposure time.

Previous work (Oberg and Mueller, 2007a) suggested that the uncertainty of a moving boat ADCP discharge measurement under steady-flow conditions, is more dependent on exposure time, than on the number of transects collected. Oberg and Mueller's (2007a) results were based on 29 measurements made with Rio Grande ADCPs using bottom tracking as the boat velocity reference, with varying widths, depths, water speeds, and boat speeds. Subsequent work (Oberg and Mueller, 2007b; Czuba and Oberg, 2008) has validated the conclusions from Oberg and Mueller (2007a) for ADCP discharge measurements made with Rio Grande and StreamPro ADCPs. Czuba and Oberg (2008) made measurements at 4 sites with the goal of independently validating the exposure time concept using both Rio Grande and StreamPro ADCPs. Analysis of these validation measurements confirms that exposure time is a critical factor in reducing measurement uncertainty and is independent of stream width, depth, and range of boat speeds.

SUMMARY

Thus, work completed by the OSW to-date (2011) suggests that a 720 s exposure time with a minimum of two transects, is appropriate for moving boat ADCP discharge measurements under steady flow conditions. As additional evaluations of instruments are completed, we will confirm or revise this policy as needed. When measuring rapidly-changing flows, policies discussed in OSW Technical Memo 2002.02 and Mueller and Wagner (2009) still apply.

If you have any questions regarding this policy, please contact Kevin Oberg (kaoberg@usgs.gov) or the Hydroacoustics Work Group (hawg@simon.er.usgs.gov).

/signed/

Robert R. Mason
Acting Chief, Office of Surface Water

SELECTED REFERENCES

Czuba, J.A. and Oberg, K.A., 2008, Validation of Exposure Time for Discharge Measurements made with Two Bottom-Tracking Acoustic Doppler Current Profilers: Proceedings of the IEEE/OES/CMTC Ninth Working Conference on Current Measurement Technology, Charleston, SC, 2008, p 245-249. (available online at http://hydroacoustics.usgs.gov/publications/CMTC08-finalpaper.pdf)

Mueller, D.S., and Wagner, C.R., 2009, Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A–22, 72 p. (available online at http://pubs.water.usgs.gov/tm3a22)

Oberg, K.A., and Mueller, D.S., 2007a, Validation of Streamflow Measurements Made with Acoustic Doppler Current Profilers: Journal of Hydraulic Engineering, v. 133, No. 12, p. 1421-1432. (available online at http://hydroacoustics.usgs.gov/publications/14-Oberg-Mueller.pdf)

Oberg, K.A., and Mueller, D.S., 2007b, Analysis of exposure time on streamflow measurements made with acoustic Doppler current profilers: Proceedings of the ASCE Hydraulic Measurements and Experimental Methods Conference, Lake Placid, NY, 2007, 6 p. (available online at http://hydroacoustics.usgs.gov/publicationsQmExposureTime-HMEM_rev4.pdf)

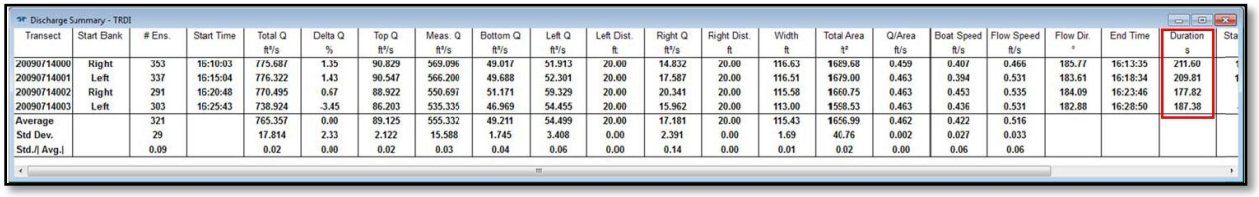
Rantz, S.E., and others, 1982, Measurement and computation of streamflow, volume 1, Measurement of discharge: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (Also available at http://pubs.usgs.gov/tm/tm3-a8/.)

EXPOSURE TIME FROM EXAMPLE MEASUREMENT DATA

Exposure time from WinRiver II Measurements

Exposure time for ADCP discharge measurements collected using Teledyne RD Instrument's WinRiver II software is computed by summing the values shown in the Duration column shown in the Discharge Summary Tabular view (F12). For the example below, the exposure time for this measurement is 789 sec (13 min and 7 sec).



Discharge Summary - TRDI

Transect	Start Bank	# Ens.	Start Time	Total Q ft³/s	Delta Q %	Top Q ft³/s	Meas. Q ft³/s	Bottom Q ft³/s	Left Q ft³/s	Left Dist. ft	Right Q ft³/s	Right Dist. ft	Width ft	Total Area ft²	Q/Area ft/s	Boat Speed ft/s	Flow Speed ft/s	Flow Dir. °	End Time	Duration s	Sta
20090714000	Right	353	16:10:03	775.687	1.35	90.829	569.096	49.017	51.913	20.00	14.832	20.00	116.63	1689.68	0.459	0.407	0.466	185.77	16:13:35	211.60	1
20090714001	Left	337	16:15:04	776.322	1.43	90.547	566.200	49.688	52.301	20.00	17.587	20.00	116.51	1679.00	0.463	0.394	0.531	183.61	16:18:34	209.81	1
20090714002	Right	291	16:20:48	770.495	0.67	88.922	550.697	51.171	59.329	20.00	20.341	20.00	115.58	1660.75	0.463	0.453	0.535	184.09	16:23:46	177.82	
20090714003	Left	303	16:25:43	738.924	-3.45	86.203	535.335	46.969	54.455	20.00	15.962	20.00	113.00	1558.53	0.463	0.436	0.531	182.88	16:28:50	187.38	
Average		321		765.357	0.00	89.125	555.332	49.211	54.499	20.00	17.181	20.00	115.43	1656.99	0.462	0.422	0.516				
Std Dev.		29		17.814	2.33	2.122	15.588	1.745	3.408	0.00	2.391	0.00	1.69	40.76	0.002	0.027	0.033				
Std./I Avg.I		0.09		0.02	0.00	0.02	0.03	0.04	0.06	0.00	0.14	0.00	0.01	0.02	0.00	0.06	0.06				

Do NOT use the total time shown in the *Q Measurement Summary* output as this is the total elapsed time from beginning to end of the measurement, and NOT the exposure time for the measurement.

Exposure time from RiverSurveyor Live Measurements

Exposure time for ADCP discharge measurements collected using SonTek/YSI's RiverSurveyor Live software is shown in the Discharge Measurement Summary output at the bottom of the Measurement Results table. In the example below the exposure time for the measurement was 1,419 sec (23 min and 39 sec).

Measurement Results

Tr		Time			Distance				Mean Vel		
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	
1	R	10:08:41 AM	0:05:39	54.1	1,264.03	1,164.39	1,268.39	21,512.5	3.729	4.298	6
2	L	10:14:30 AM	0:06:10	54.7	1,244.83	1,171.46	1,270.46	21,869.2	3.364	4.307	5
3	R	10:20:56 AM	0:06:30	54.1	1,379.67	1,176.04	1,269.04	21,704.6	3.538	4.569	5
4	L	10:27:38 AM	0:05:20	54.7	1,234.53	1,165.83	1,271.83	21,613.9	3.858	4.583	7
			Mean	54.4	1,280.76	1,169.43	1,269.93	21,675.1	3.622	4.439	6
			Std Dev	0.3	58.08	4.64	1.33	131.1	0.187	0.137	
			COV	0.0	0.045	0.004	0.001	0.006	0.052	0.031	

Exposure Time: 0:23:39