STREAM DISCHARGE MEASUREMENT REPORT

Woman Lake Chain of Lakes

Cass County, Minnesota

This report summarizes instantaneous discharge measurements collected by Northeast Technical Services, Inc. (NTS) on August 19, 2026 at three locations on the Woman Lake chain. The locations were provided by Mr. Jeff Davis of Woman Lake Action. A field report with supporting files and photographs is attached to this report as Appendix A. Due to equipment connectivity issues, one discharge file could not be obtained from the device; photographs of that discharge measurement and summary from the device are included in the field report. The instrument file was improperly named Child Lake Dam at the time of collection.

1. Locations

- Culvert-CR5 Inflow — Boy River inflow at Cass County Road 5.
- Blackwater River Inflow — connecting channel from Blackwater Lake into Woman Lake at Cass County Road 11.
- Girl Lake Outflow — discharge from Girl Lake to Boy River near Minnesota State Highway 84. (improperly named Child Lake Dam on flow tracker file)

2. Reported Results

Results are presented in Table 1. Positive values indicate flow in the expected direction for that site.

Table 1. Instantaneous discharge measurements, 19 August 2026

#	Location	Role	Discharge (cfs)
1	CR5 Inflow	Inflow to Woman Lake	**1.57**
2	Blackwater River inflow	Inflow to Woman Lake	**−0.01**
3	Girl Lake fish ladder outflow	Outflow from Girl Lake	**4.57**

Notes: cfs = cubic feet per second.

3. Technology & Methodology

Measurements were collected with a SonTek FlowTracker2 Handheld Acoustic Doppler Velocimeter (ADV). The instrument transmits a short acoustic pulse and records the Doppler shift of sound scattered back from particles and bubbles in a small sampling volume offset from the probe. Additional information is available from the manufacturer. Discharge was computed using the mid-section (area-velocity) method described by NTS' QM-305 Flow Measurements SOP (Appendix B).

Appendix A

Field Report Cover Sheet

Environmental Science & Engineering

NORTHEAST TECHNICAL SERVICES, INC.
526 CHESTNUT STREET
VIRGINIA, MINNESOTA 55792
218-741-4290 FAX 218-741-4291
E-mail: nts@netechnical.com

Project: 23644 - Women Lake Chain Flows
Project Number: 23644

Client: Jeff Davis
Project Manager: Kurt Doran

Location: Women Lake Chain
Date: (yyyy-mm-dd) 2026-08-19

Prep/Unload/Report Time: 0630 - 0725 (Prep) 1642 - 1815 (Unload/Report) **Total** ~2.50 hrs
Weather/Temp: High 77°F, Partly Cloudy, Light winds

Site Time: 1005 (Arrive) 1440 (Depart) **Total** ~4.50 hrs
COC#: N/A

Travel Time: 0725 - 1005 (To) 1440 - 1642 (From) **Total** ~4.50 hrs

Vehicle #: 63 | 229 **Miles Driven**

Total Field Time Entered: 11.75 hrs

Summary of Technical and / or Engineering Services Performed

Flow measurement equipment was prepared at the NTS Office for the Women Lake Chain Flows event. Stream flow measurements were obtained at three locations with the SonTek Flow Tracker 2 Flow Meter. Measurements were recorded at the downstream side of the culvert on the Boy River at County Road 5, at the mouth of the culvert on the upstream side of the Blackwater River*, and downstream of the Girl Lake Dam. Some beaver activity was noted at the Boy River - County Road 5 culvert. All flow measurements occured following NTS SOP. Photos were taken at each location. See the attached documents for further detail.

* Addendum 8/25/26 Blackwater River flow measurement is negative, meaning effectively zero.

Site Sketch

Please Indicate North

Field Test Data are Estimated Pending Final Laboratory Results.

Attach *other documents* as defined by the Project Manager.

Field Scientist: Logan Yuretich
Approved by: [signature]

Date: 8/24/26
Page 1 **of** 1

Fill out and hand in field sheet on a real-time basis. Any questions or comments, contact your project manager.

Location Women Lake Chain   Date 8/19/26

Project / Client   Page 1 of 2

Project: 23644

Personnel: L. Yuretich

Wether: High 77°F Partly Cloudy, Light Winds

Equipment: VT63 (229 miles) E2-06E

0630 Arrive at NTS Office, Prep, Load Truck

0725 Depart NTS Office

0955 Meet with Client

1005 Culvert - County Rd 5 - Boy River Inflow

* Flow Recorded with SonTek Flow Tracker 2 - photos obtained. Flow performed on downstream side of culvert, beaver activity present at both ends

1200 Blackwater River

* Flow recorded with SonTek Flow Tracker 2 - photos obtained. Flow performed at mouth of the upstream side of the culvert

* Addendum 8/25/26: SonTek Flow Tracker 2 file is accessible on the handheld but fails to transfer onto the ~~computer~~ computer. The value is −0.0052 cf/s which means effectively zero flow.

LY 8/25/26

$\boxed{\text{NEXT PAGE}}$

Discharge Measurement Summary

File Information

File name	20260819_Culvert-CR5.ft
Start date and time	8/19/2026 9:57 AM
Calculations engine	FlowTracker2
Data collection mode	Discharge

Discharge Summary

Start time	8/19/2026 9:59:32 AM	End time	8/19/2026 11:13:45 AM
# Stations	35	Avg interval	40
Mean depth	1.263 ft		
Mean velocity	0.0692 ft/s	Total width	18.000 ft
Mean SNR	33 dB	Total area	22.7400 ft²
Mean temp	70.835 °F	Total discharge	1.5733 ft³/s

System Information

Sensor type	Top Setting
Handheld serial number	FT2H1807014
Probe serial number	FT2P1810021
Probe firmware	1.23
Handheld software	1.4

Site Details

Site name	Culvert-CR5
Site number	23644
Operator(s)	LY
Comment	

Discharge Uncertainty

Category	ISO	IVE
Accuracy	1.0%	1.0%
Depth	0.1%	2.4%
Velocity	0.3%	3.7%
Width	0.1%	0.1%
Method	1.2%	
# Stations	1.5%	
Overall	2.2%	4.5%

Discharge Settings

Discharge equation	Mid Section
Discharge uncertainty	IVE
Discharge reference	Rated

Station Warning Settings

Station discharge caution	5.00	%
Station discharge warning	10.00	%
Maximum depth change	50.00	%
Maximum spacing change	100.00	%

Summary overview

No changes were made to this file
Quality control warnings

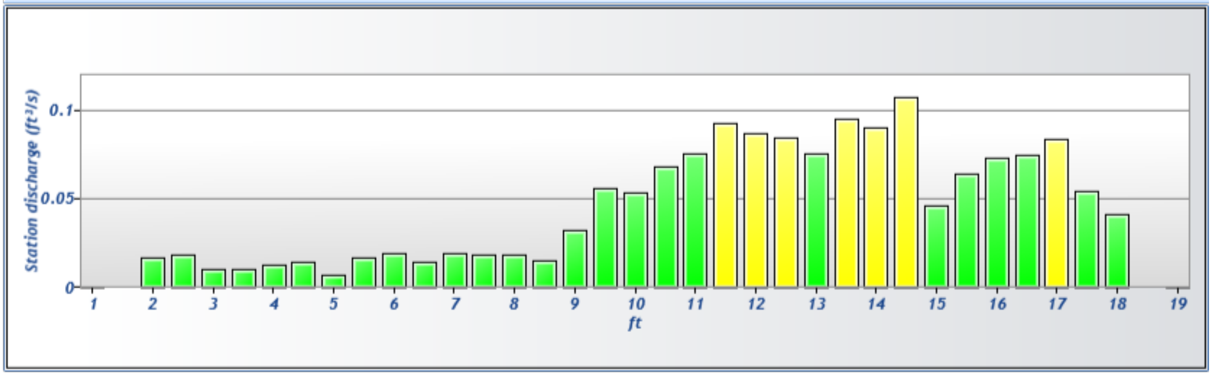
Data Collection Settings

Salinity	0.000	PSS-78
Temperature		°F
Sound speed		ft/s
Mounting correction	0.00	%

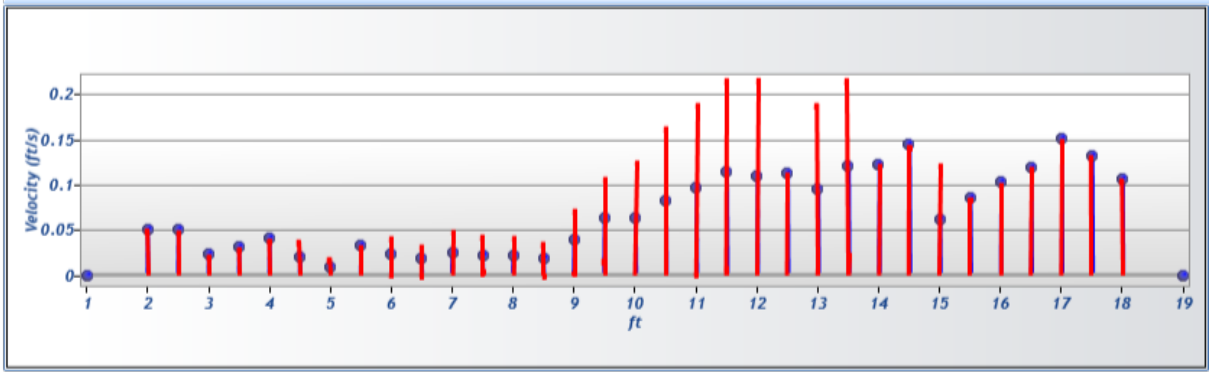
Quality Control Settings

SNR threshold	10	dB
Standard error threshold	0.0328	ft/s
Spike threshold	10.00	%
Maximum velocity angle	20.0	deg
Maximum tilt angle	5.0	deg

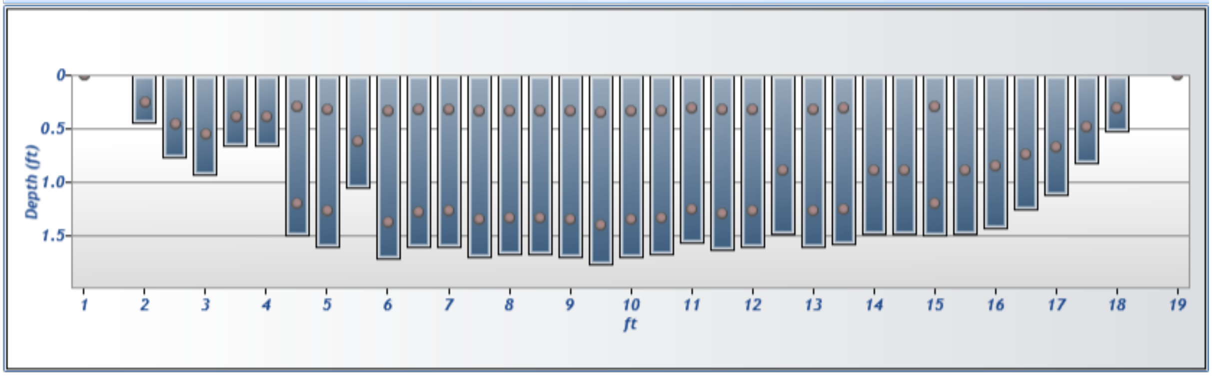
Discharge chart



Velocity chart



Depth chart



Measurement results

St#	Time	Location (ft)	Method	Depth (ft)	%Depth	Measured Depth (ft)	Samples	Velocity (ft/s)	Correction	Mean Velocity (ft/s)	Area (ft²)	Flow (ft³/s)	%Q	
0	9:59 AM	1.000	None	0.000	0.0000	0.000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	✓
1	9:59 AM	2.000	0.6	0.440	0.6000	0.264	80	0.0509	1.0000	0.0509	0.3300	0.0168	1.07	✓
2	10:01 AM	2.500	0.6	0.760	0.6000	0.456	80	0.0497	1.0000	0.0497	0.3800	0.0189	1.20	✓
3	10:03 AM	3.000	0.6	0.930	0.6000	0.558	80	0.0224	1.0000	0.0224	0.4650	0.0104	0.66	✓
4	10:05 AM	3.500	0.6	0.660	0.6000	0.396	80	0.0309	1.0000	0.0309	0.3300	0.0102	0.65	✓
5	10:06 AM	4.000	0.6	0.660	0.6000	0.396	80	0.0400	1.0000	0.0400	0.3300	0.0132	0.84	✓
6	10:07 AM	4.500	0.2/0.8	1.500	0.2000	0.300	80	0.0386	1.0000	0.0196	0.7500	0.0147	0.93	✓
6	10:07 AM	4.500	0.2/0.8	1.500	0.8000	1.200	80	0.0005	1.0000	0.0196	0.7500	0.0147	0.93	✓
7	10:10 AM	5.000	0.2/0.8	1.600	0.2000	0.320	80	0.0198	1.0000	0.0096	0.8000	0.0077	0.49	✓
7	10:10 AM	5.000	0.2/0.8	1.600	0.8000	1.280	80	-0.0006	1.0000	0.0096	0.8000	0.0077	0.49	✓
8	10:17 AM	5.500	0.6	1.050	0.6000	0.630	80	0.0329	1.0000	0.0329	0.5250	0.0173	1.10	✓
9	10:18 AM	6.000	0.2/0.8	1.720	0.2000	0.344	80	0.0430	1.0000	0.0230	0.8600	0.0198	1.26	✓
9	10:18 AM	6.000	0.2/0.8	1.720	0.8000	1.376	80	0.0030	1.0000	0.0230	0.8600	0.0198	1.26	✓
10	10:22 AM	6.500	0.2/0.8	1.610	0.2000	0.322	80	0.0338	1.0000	0.0179	0.8050	0.0144	0.92	✓
10	10:22 AM	6.500	0.2/0.8	1.610	0.8000	1.288	80	0.0021	1.0000	0.0179	0.8050	0.0144	0.92	✓
11	10:24 AM	7.000	0.2/0.8	1.600	0.2000	0.320	80	0.0492	1.0000	0.0249	0.8000	0.0199	1.26	✓
11	10:24 AM	7.000	0.2/0.8	1.600	0.8000	1.280	80	0.0006	1.0000	0.0249	0.8000	0.0199	1.26	✓
12	10:27 AM	7.500	0.2/0.8	1.700	0.2000	0.340	80	0.0449	1.0000	0.0217	0.8500	0.0185	1.17	✓
12	10:27 AM	7.500	0.2/0.8	1.700	0.8000	1.360	80	-0.0015	1.0000	0.0217	0.8500	0.0185	1.17	✓
13	10:29 AM	8.000	0.2/0.8	1.680	0.2000	0.336	80	0.0433	1.0000	0.0221	0.8400	0.0185	1.18	✓
13	10:29 AM	8.000	0.2/0.8	1.680	0.8000	1.344	80	0.0009	1.0000	0.0221	0.8400	0.0185	1.18	✓
14	10:32 AM	8.500	0.2/0.8	1.680	0.2000	0.336	80	0.0362	1.0000	0.0188	0.8400	0.0158	1.00	✓
14	10:32 AM	8.500	0.2/0.8	1.680	0.8000	1.344	80	0.0013	1.0000	0.0188	0.8400	0.0158	1.00	✓
15	10:34 AM	9.000	0.2/0.8	1.700	0.2000	0.340	80	0.0727	1.0000	0.0385	0.8500	0.0327	2.08	✓
15	10:34 AM	9.000	0.2/0.8	1.700	0.8000	1.360	80	0.0043	1.0000	0.0385	0.8500	0.0327	2.08	✓
16	10:37 AM	9.500	0.2/0.8	1.770	0.2000	0.354	80	0.1089	1.0000	0.0633	0.8850	0.0560	3.56	✓
16	10:37 AM	9.500	0.2/0.8	1.770	0.8000	1.416	80	0.0177	1.0000	0.0633	0.8850	0.0560	3.56	✓
17	10:40 AM	10.000	0.2/0.8	1.700	0.2000	0.340	80	0.1258	1.0000	0.0630	0.8500	0.0535	3.40	✓
17	10:40 AM	10.000	0.2/0.8	1.700	0.8000	1.360	80	0.0001	1.0000	0.0630	0.8500	0.0535	3.40	✓
18	10:42 AM	10.500	0.2/0.8	1.670	0.2000	0.334	80	0.1643	1.0000	0.0820	0.8350	0.0685	4.35	✓
18	10:42 AM	10.500	0.2/0.8	1.670	0.8000	1.336	80	-0.0002	1.0000	0.0820	0.8350	0.0685	4.35	✓
19	10:45 AM	11.000	0.2/0.8	1.570	0.2000	0.314	80	0.1897	1.0000	0.0963	0.7850	0.0756	4.80	✓
19	10:45 AM	11.000	0.2/0.8	1.570	0.8000	1.256	80	0.0028	1.0000	0.0963	0.7850	0.0756	4.80	✓
20	10:47 AM	11.500	0.2/0.8	1.630	0.2000	0.326	80	0.2172	1.0000	0.1136	0.8150	0.0926	5.89	✓
20	10:47 AM	11.500	0.2/0.8	1.630	0.8000	1.304	80	0.0101	1.0000	0.1136	0.8150	0.0926	5.89	✓
21	10:52 AM	12.000	0.2/0.8	1.600	0.2000	0.320	80	0.2176	1.0000	0.1088	0.8000	0.0870	5.53	✓
21	10:52 AM	12.000	0.2/0.8	1.600	0.8000	1.280	80	0.0000	1.0000	0.1088	0.8000	0.0870	5.53	✓
22	10:54 AM	12.500	0.6	1.490	0.6000	0.894	80	0.1132	1.0000	0.1132	0.7450	0.0843	5.36	✓
23	10:55 AM	13.000	0.2/0.8	1.600	0.2000	0.320	80	0.1898	1.0000	0.0943	0.8000	0.0755	4.80	✓
23	10:55 AM	13.000	0.2/0.8	1.600	0.8000	1.280	80	-0.0011	1.0000	0.0943	0.8000	0.0755	4.80	✓
24	10:58 AM	13.500	0.2/0.8	1.580	0.2000	0.316	80	0.2173	1.0000	0.1210	0.7900	0.0956	6.08	✓
24	10:58 AM	13.500	0.2/0.8	1.580	0.8000	1.264	80	0.0248	1.0000	0.1210	0.7900	0.0956	6.08	✓
25	11:00 AM	14.000	0.6	1.480	0.6000	0.888	80	0.1227	1.0000	0.1227	0.7400	0.0908	5.77	✓
26	11:01 AM	14.500	0.6	1.490	0.6000	0.894	80	0.1439	1.0000	0.1439	0.7450	0.1072	6.82	✓
27	11:03 AM	15.000	0.2/0.8	1.500	0.2000	0.300	80	0.1229	1.0000	0.0615	0.7500	0.0461	2.93	✓
27	11:03 AM	15.000	0.2/0.8	1.500	0.8000	1.200	80	0.0001	1.0000	0.0615	0.7500	0.0461	2.93	✓
28	11:05 AM	15.500	0.6	1.490	0.6000	0.894	80	0.0861	1.0000	0.0861	0.7450	0.0642	4.08	✓
29	11:06 AM	16.000	0.6	1.430	0.6000	0.858	80	0.1023	1.0000	0.1023	0.7150	0.0732	4.65	✓
30	11:08 AM	16.500	0.6	1.250	0.6000	0.750	80	0.1194	1.0000	0.1194	0.6250	0.0746	4.74	✓
31	11:09 AM	17.000	0.6	1.120	0.6000	0.672	80	0.1502	1.0000	0.1502	0.5600	0.0841	5.35	✓
32	11:11 AM	17.500	0.6	0.820	0.6000	0.492	80	0.1324	1.0000	0.1324	0.4100	0.0543	3.45	✓
33	11:12 AM	18.000	0.6	0.520	0.6000	0.312	80	0.1064	1.0000	0.1064	0.3900	0.0415	2.64	✓
34	11:13 AM	19.000	None	0.000	0.0000	0.000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	✓

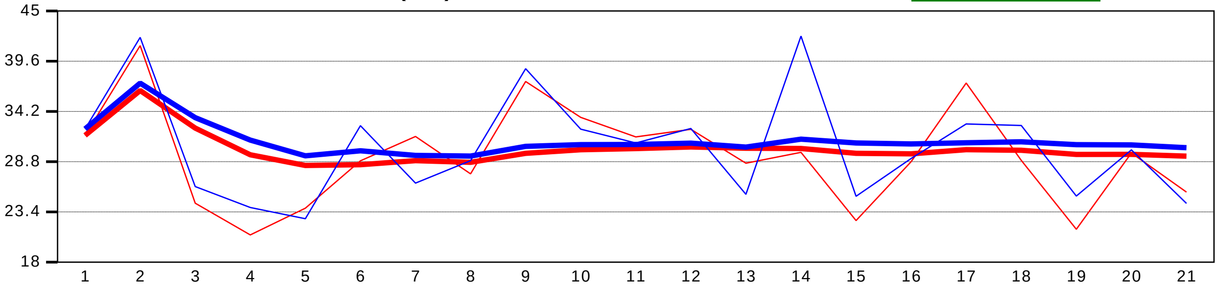
Quality control warnings

St#	Time	Location (ft)	Method	Depth (ft)	%Depth	Measured Depth (ft)	Warnings
1	9:59 AM	2.000	0.6	0.440	0.6000	0.264	Large SNR Variation
2	10:01 AM	2.500	0.6	0.760	0.6000	0.456	Large SNR Variation
3	10:03 AM	3.000	0.6	0.930	0.6000	0.558	Beam SNRs Not Similar,Large SNR Variation,SNR Threshold Variation
4	10:05 AM	3.500	0.6	0.660	0.6000	0.396	Large SNR Variation
6	10:07 AM	4.500	0.2/0.8	1.500	0.2000	0.300	SNR Threshold Variation,High % Spikes
6	10:07 AM	4.500	0.2/0.8	1.500	0.8000	1.200	SNR Threshold Variation,High % Spikes
7	10:10 AM	5.000	0.2/0.8	1.600	0.2000	0.320	Boundary Interference,SNR Threshold Variation
7	10:10 AM	5.000	0.2/0.8	1.600	0.8000	1.280	Boundary Interference,SNR Threshold Variation
9	10:18 AM	6.000	0.2/0.8	1.720	0.2000	0.344	Large SNR Variation,SNR Threshold Variation
9	10:18 AM	6.000	0.2/0.8	1.720	0.8000	1.376	Large SNR Variation,SNR Threshold Variation
10	10:22 AM	6.500	0.2/0.8	1.610	0.2000	0.322	Boundary Interference,Low SNR,SNR Threshold Variation,High % Spikes
10	10:22 AM	6.500	0.2/0.8	1.610	0.8000	1.288	Boundary Interference,Low SNR,SNR Threshold Variation,High % Spikes
11	10:24 AM	7.000	0.2/0.8	1.600	0.2000	0.320	Boundary Interference,SNR Threshold Variation
11	10:24 AM	7.000	0.2/0.8	1.600	0.8000	1.280	Boundary Interference,SNR Threshold Variation
12	10:27 AM	7.500	0.2/0.8	1.700	0.2000	0.340	Boundary Interference
12	10:27 AM	7.500	0.2/0.8	1.700	0.8000	1.360	Boundary Interference
13	10:29 AM	8.000	0.2/0.8	1.680	0.2000	0.336	Boundary Interference,SNR Threshold Variation
13	10:29 AM	8.000	0.2/0.8	1.680	0.8000	1.344	Boundary Interference,SNR Threshold Variation
14	10:32 AM	8.500	0.2/0.8	1.680	0.2000	0.336	Boundary Interference,Approaching Low SNR,Beam SNRs Not Similar,SNR Threshold Variation
14	10:32 AM	8.500	0.2/0.8	1.680	0.8000	1.344	Boundary Interference,Approaching Low SNR,Beam SNRs Not Similar,SNR Threshold Variation
15	10:34 AM	9.000	0.2/0.8	1.700	0.2000	0.340	Boundary Interference,Beam SNRs Not Similar
15	10:34 AM	9.000	0.2/0.8	1.700	0.8000	1.360	Boundary Interference,Beam SNRs Not Similar
16	10:37 AM	9.500	0.2/0.8	1.770	0.2000	0.354	Large SNR Variation
16	10:37 AM	9.500	0.2/0.8	1.770	0.8000	1.416	Large SNR Variation
17	10:40 AM	10.000	0.2/0.8	1.700	0.2000	0.340	SNR Threshold Variation
17	10:40 AM	10.000	0.2/0.8	1.700	0.8000	1.360	SNR Threshold Variation
18	10:42 AM	10.500	0.2/0.8	1.670	0.2000	0.334	High % Spikes
18	10:42 AM	10.500	0.2/0.8	1.670	0.8000	1.336	High % Spikes
19	10:45 AM	11.000	0.2/0.8	1.570	0.2000	0.314	Boundary Interference
19	10:45 AM	11.000	0.2/0.8	1.570	0.8000	1.256	Boundary Interference
20	10:47 AM	11.500	0.2/0.8	1.630	0.2000	0.326	Boundary Interference,Large SNR Variation
20	10:47 AM	11.500	0.2/0.8	1.630	0.8000	1.304	Boundary Interference,Large SNR Variation
21	10:52 AM	12.000	0.2/0.8	1.600	0.2000	0.320	SNR Threshold Variation
21	10:52 AM	12.000	0.2/0.8	1.600	0.8000	1.280	SNR Threshold Variation
23	10:55 AM	13.000	0.2/0.8	1.600	0.2000	0.320	Boundary Interference
23	10:55 AM	13.000	0.2/0.8	1.600	0.8000	1.280	Boundary Interference
27	11:03 AM	15.000	0.2/0.8	1.500	0.2000	0.300	SNR Threshold Variation
27	11:03 AM	15.000	0.2/0.8	1.500	0.8000	1.200	SNR Threshold Variation
28	11:05 AM	15.500	0.6	1.490	0.6000	0.894	Boundary Interference

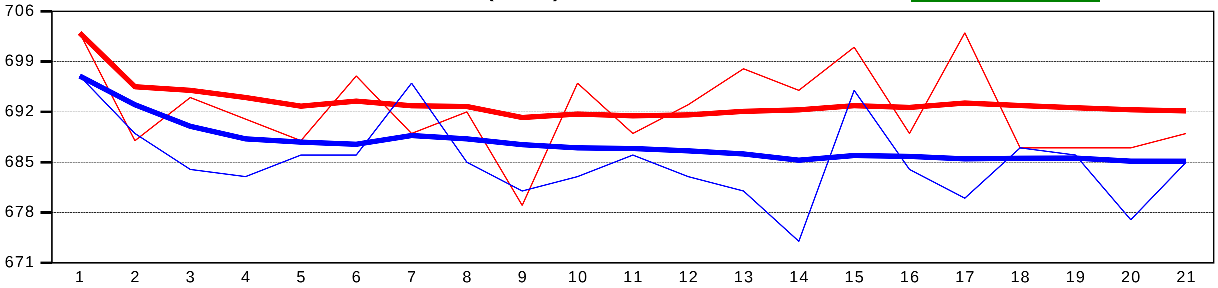
8/19/2026 5:29:21 PM

Automated beam check Start time 8/19/2026 9:59:00 AM

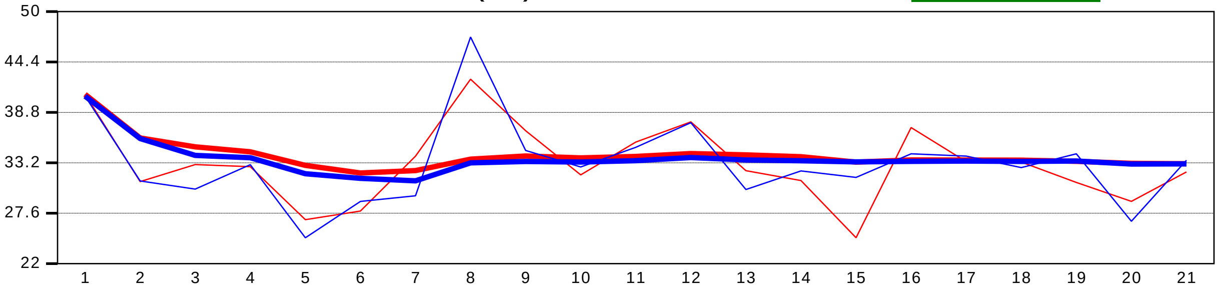
Automated beam check SNR(dB) PASS



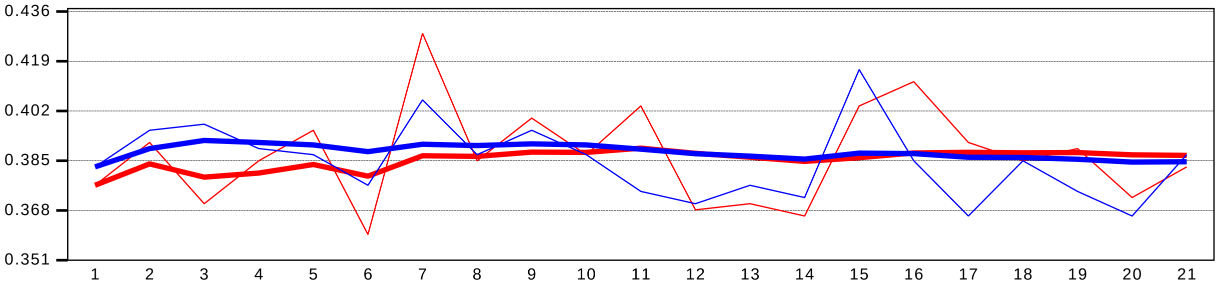
Automated beam check Noise level(cnts) PASS



Automated beam check Peak level(dB) PASS



Automated beam check Peak position(ft) PASS



Automated beam check Quality control warnings

No quality control warnings

FlowTracker2

Discharge Measurement Summary

File Information

File name	20260819_Child Lake Dam.ft
Start date and time	8/19/2026 1:00 PM
Calculations engine	FlowTracker2
Data collection mode	Discharge

Discharge Summary

Start time	8/19/2026 1:01:54 PM	End time	8/19/2026 2:03:04 PM
# Stations	42	Avg interval	40
Mean depth	0.570 ft		
Mean velocity	0.2006 ft/s	Total width	40.000 ft
Mean SNR	29 dB	Total area	22.8025 ft²
Mean temp	74.132 °F	Total discharge	4.5742 ft³/s

System Information

Sensor type	Top Setting
Handheld serial number	FT2H1807014
Probe serial number	FT2P1810021
Probe firmware	1.23
Handheld software	1.4

Site Details

Site name	Child Lake Dam
Site number	23644
Operator(s)	LY
Comment	

Discharge Uncertainty

Category	ISO	IVE
Accuracy	1.0%	1.0%
Depth	0.3%	3.4%
Velocity	0.7%	10.0%
Width	0.1%	0.1%
Method	1.5%	
# Stations	1.2%	
Overall	2.3%	10.6%

Discharge Settings

Discharge equation	Mid Section
Discharge uncertainty	IVE
Discharge reference	Rated

Station Warning Settings

Station discharge caution	5.00	%
Station discharge warning	10.00	%
Maximum depth change	50.00	%
Maximum spacing change	100.00	%

Summary overview

No changes were made to this file
Quality control warnings

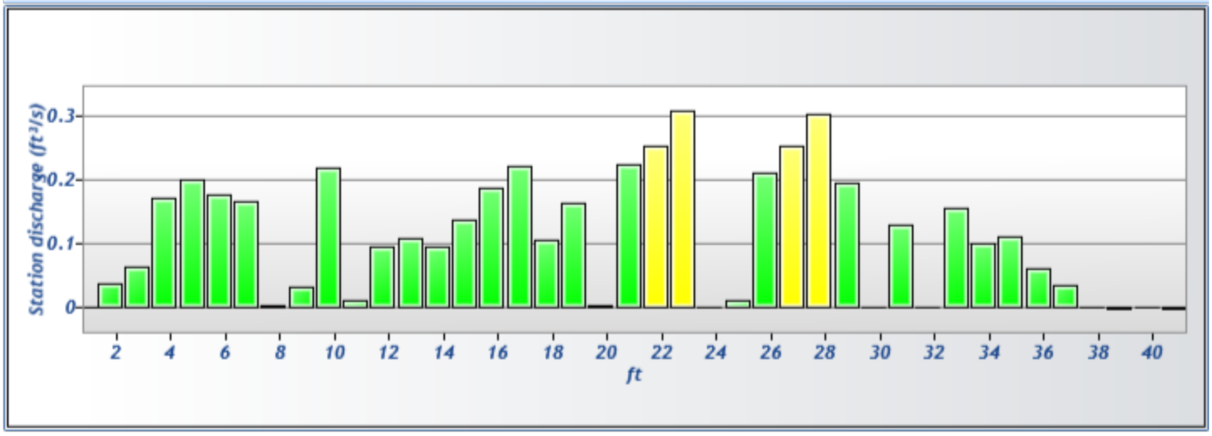
Data Collection Settings

Salinity	0.000	PSS-78
Temperature		°F
Sound speed		ft/s
Mounting correction	0.00	%

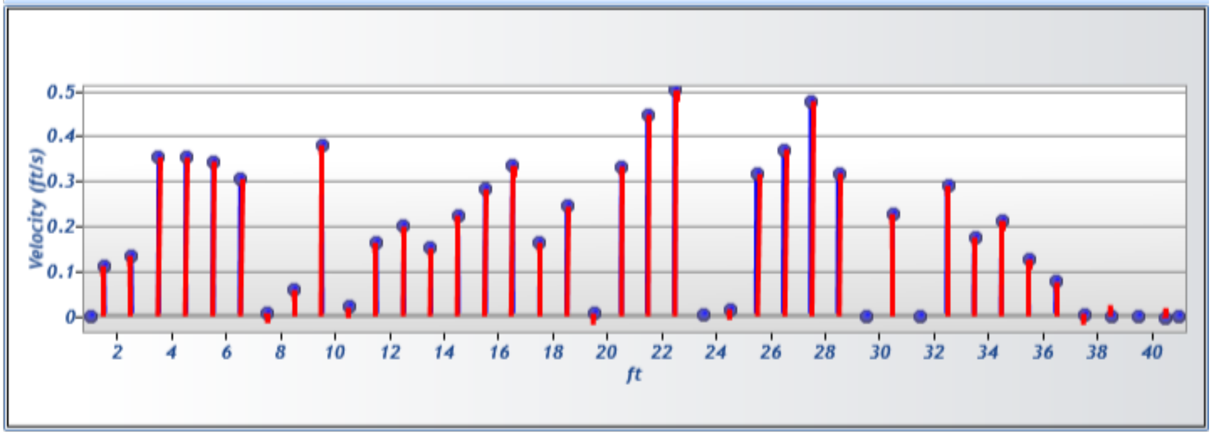
Quality Control Settings

SNR threshold	10	dB
Standard error threshold	0.0328	ft/s
Spike threshold	10.00	%
Maximum velocity angle	20.0	deg
Maximum tilt angle	5.0	deg

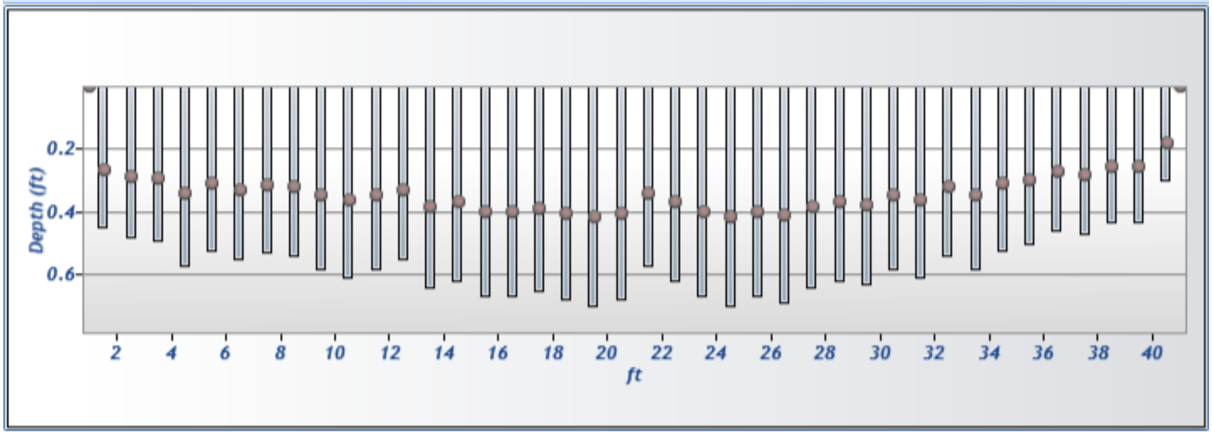
Discharge chart



Velocity chart



Depth chart



Measurement results

St#	Time	Location (ft)	Method	Depth (ft)	%Depth	Measured Depth (ft)	Samples	Velocity (ft/s)	Correction	Mean Velocity (ft/s)	Area (ft^2)	Flow (ft^3/s)	%Q	
0	1:01 PM	1.000	None	0.000	0.0000	0.000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	✓
1	1:02 PM	1.500	0.6	0.450	0.6000	0.270	80	0.1108	1.0000	0.1108	0.3375	0.0374	0.82	✓
2	1:03 PM	2.500	0.6	0.480	0.6000	0.288	80	0.1332	1.0000	0.1332	0.4800	0.0640	1.40	✓
3	1:04 PM	3.500	0.6	0.490	0.6000	0.294	80	0.3525	1.0000	0.3525	0.4900	0.1727	3.78	✓
4	1:06 PM	4.500	0.6	0.570	0.6000	0.342	80	0.3517	1.0000	0.3517	0.5700	0.2005	4.38	✓
5	1:07 PM	5.500	0.6	0.520	0.6000	0.312	80	0.3420	1.0000	0.3420	0.5200	0.1778	3.89	✓
6	1:08 PM	6.500	0.6	0.550	0.6000	0.330	80	0.3044	1.0000	0.3044	0.5500	0.1674	3.66	✓
7	1:10 PM	7.500	0.6	0.530	0.6000	0.318	80	0.0077	1.0000	0.0077	0.5300	0.0041	0.09	✓
8	1:12 PM	8.500	0.6	0.540	0.6000	0.324	80	0.0578	1.0000	0.0578	0.5400	0.0312	0.68	✓
9	1:13 PM	9.500	0.6	0.580	0.6000	0.348	80	0.3778	1.0000	0.3778	0.5800	0.2191	4.79	✓
10	1:15 PM	10.500	0.6	0.610	0.6000	0.366	80	0.0193	1.0000	0.0193	0.6100	0.0118	0.26	✓
11	1:16 PM	11.500	0.6	0.580	0.6000	0.348	80	0.1630	1.0000	0.1630	0.5800	0.0945	2.07	✓
12	1:17 PM	12.500	0.6	0.550	0.6000	0.330	80	0.1991	1.0000	0.1991	0.5500	0.1095	2.39	✓
13	1:19 PM	13.500	0.6	0.640	0.6000	0.384	80	0.1508	1.0000	0.1508	0.6400	0.0965	2.11	✓
14	1:21 PM	14.500	0.6	0.620	0.6000	0.372	80	0.2228	1.0000	0.2228	0.6200	0.1382	3.02	✓
15	1:23 PM	15.500	0.6	0.670	0.6000	0.402	80	0.2808	1.0000	0.2808	0.6700	0.1881	4.11	✓
16	1:24 PM	16.500	0.6	0.670	0.6000	0.402	80	0.3332	1.0000	0.3332	0.6700	0.2232	4.88	✓
17	1:25 PM	17.500	0.6	0.650	0.6000	0.390	80	0.1632	1.0000	0.1632	0.6500	0.1061	2.32	✓
18	1:26 PM	18.500	0.6	0.680	0.6000	0.408	80	0.2429	1.0000	0.2429	0.6800	0.1652	3.61	✓
19	1:28 PM	19.500	0.6	0.700	0.6000	0.420	80	0.0046	1.0000	0.0046	0.7000	0.0032	0.07	✓
20	1:29 PM	20.500	0.6	0.680	0.6000	0.408	80	0.3319	1.0000	0.3319	0.6800	0.2257	4.93	✓
21	1:30 PM	21.500	0.6	0.570	0.6000	0.342	80	0.4469	1.0000	0.4469	0.5700	0.2547	5.57	✓
22	1:32 PM	22.500	0.6	0.620	0.6000	0.372	80	0.5007	1.0000	0.5007	0.6200	0.3105	6.79	✓
23	1:33 PM	23.500	0.6	0.670	0.6000	0.402	80	0.0005	1.0000	0.0005	0.6700	0.0003	0.01	✓
24	1:35 PM	24.500	0.6	0.700	0.6000	0.420	80	0.0149	1.0000	0.0149	0.7000	0.0104	0.23	✓
25	1:36 PM	25.500	0.6	0.670	0.6000	0.402	80	0.3158	1.0000	0.3158	0.6700	0.2116	4.63	✓
26	1:38 PM	26.500	0.6	0.690	0.6000	0.414	80	0.3684	1.0000	0.3684	0.6900	0.2542	5.56	✓
27	1:39 PM	27.500	0.6	0.640	0.6000	0.384	80	0.4764	1.0000	0.4764	0.6400	0.3049	6.67	✓
28	1:40 PM	28.500	0.6	0.620	0.6000	0.372	80	0.3158	1.0000	0.3158	0.6200	0.1958	4.28	✓
29	1:42 PM	29.500	0.6	0.630	0.6000	0.378	80	0.0001	1.0000	0.0001	0.6300	0.0001	0.00	✓
30	1:44 PM	30.500	0.6	0.580	0.6000	0.348	80	0.2252	1.0000	0.2252	0.5800	0.1306	2.86	✓
31	1:46 PM	31.500	0.6	0.610	0.6000	0.366	80	0.0004	1.0000	0.0004	0.6100	0.0003	0.01	✓
32	1:48 PM	32.500	0.6	0.540	0.6000	0.324	80	0.2895	1.0000	0.2895	0.5400	0.1564	3.42	✓
33	1:49 PM	33.500	0.6	0.580	0.6000	0.348	80	0.1734	1.0000	0.1734	0.5800	0.1006	2.20	✓
34	1:51 PM	34.500	0.6	0.520	0.6000	0.312	80	0.2130	1.0000	0.2130	0.5200	0.1107	2.42	✓
35	1:52 PM	35.500	0.6	0.500	0.6000	0.300	80	0.1249	1.0000	0.1249	0.5000	0.0624	1.37	✓
36	1:53 PM	36.500	0.6	0.460	0.6000	0.276	80	0.0757	1.0000	0.0757	0.4600	0.0348	0.76	✓
37	1:55 PM	37.500	0.6	0.470	0.6000	0.282	80	0.0041	1.0000	0.0041	0.4700	0.0019	0.04	✓
38	1:56 PM	38.500	0.6	0.430	0.6000	0.258	80	-0.0028	1.0000	-0.0028	0.4300	-0.0012	-0.03	✓
39	1:58 PM	39.500	0.6	0.430	0.6000	0.258	80	0.0001	1.0000	0.0001	0.4300	0.0000	0.00	✓
40	2:00 PM	40.500	0.6	0.300	0.6000	0.180	80	-0.0049	1.0000	-0.0049	0.2250	-0.0011	-0.02	✓
41	2:03 PM	41.000	None	0.000	0.0000	0.000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	✓

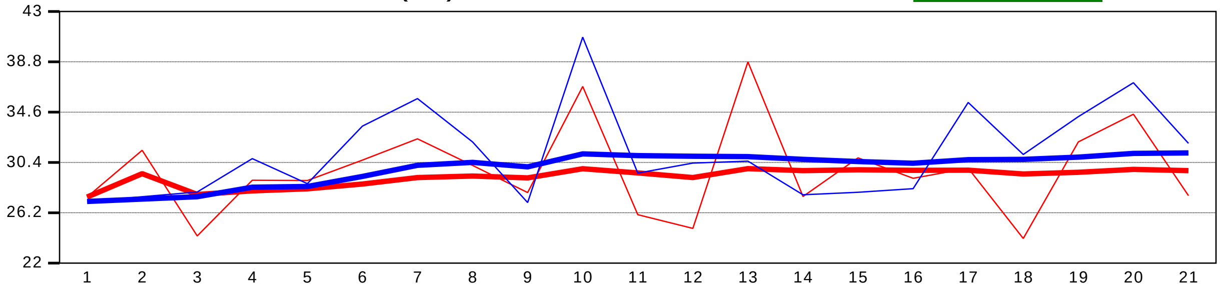
Quality control warnings

St#	Time	Location (ft)	Method	Depth (ft)	%Depth	Measured Depth (ft)	Warnings	
3	1:04 PM	3.500	0.6	0.490	0.6000	0.294	Boundary Interference	
7	1:10 PM	7.500	0.6	0.530	0.6000	0.318	Boundary Interference	
8	1:12 PM	8.500	0.6	0.540	0.6000	0.324	Large SNR Variation	
10	1:15 PM	10.500	0.6	0.610	0.6000	0.366	Boundary Interference,Large SNR Variation	
11	1:16 PM	11.500	0.6	0.580	0.6000	0.348	Boundary Interference	
16	1:24 PM	16.500	0.6	0.670	0.6000	0.402	Boundary Interference	
17	1:25 PM	17.500	0.6	0.650	0.6000	0.390	Boundary Interference,Large SNR Variation	
19	1:28 PM	19.500	0.6	0.700	0.6000	0.420	Large SNR Variation	
23	1:33 PM	23.500	0.6	0.670	0.6000	0.402	SNR Threshold Variation	
24	1:35 PM	24.500	0.6	0.700	0.6000	0.420	Large SNR Variation	
29	1:42 PM	29.500	0.6	0.630	0.6000	0.378	SNR Threshold Variation	
31	1:46 PM	31.500	0.6	0.610	0.6000	0.366	Large SNR Variation,SNR Threshold Variation	
37	1:55 PM	37.500	0.6	0.470	0.6000	0.282	Boundary Interference	
38	1:56 PM	38.500	0.6	0.430	0.6000	0.258	Beam SNRs Not Similar	
39	1:58 PM	39.500	0.6	0.430	0.6000	0.258	Beam SNRs Not Similar,SNR Threshold Variation	
40	2:00 PM	40.500	0.6	0.300	0.6000	0.180	Low SNR,SNR Threshold Variation,High % Spikes	

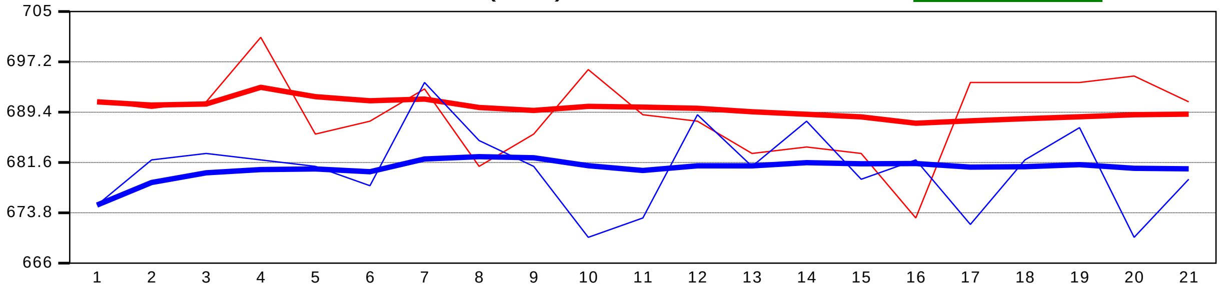
8/19/2026 5:28:24 PM

Automated beam check Start time 8/19/2026 1:01:21 PM

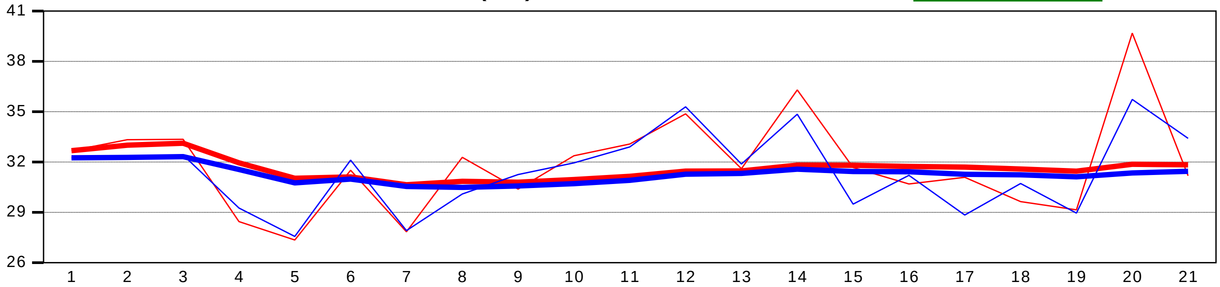
Automated beam check SNR(dB) PASS



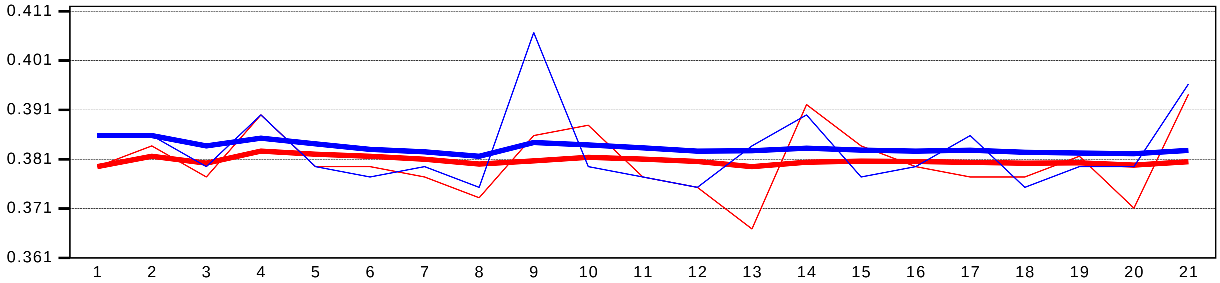
Automated beam check Noise level(cnts) PASS



Automated beam check Peak level(dB) PASS



Automated beam check Peak position(ft) PASS



Automated beam check Quality control warnings
No quality control warnings

Location Women Lake Chain Date 8/19/26

Project / Client Page 2 of 2

Project: 23644
Personnel: L. Yuretich

1305 Girl Lake Dam
Flow recorded with SonTek Flow Tracker 2 - photos obtained
Flow performed downstream of Dam

1440 Depart Girl Lake Dam to return to NTS Office

1642 Return to NTS Office, Unload, Report

[signature]
8/19/26

LY
8/19/26

Environmental Science & Engineering

Northeast Technical Services, Inc.
Daily Vehicle Inspection

Driver's Name: Logan Yuretich **Date:** 8/19/26 **Time:** 0715

Odometer Reading: 144954 **Vehicle #:** 63

Place a √ (check) next to each item inspected

Driver/Passenger Side

External Side Mirrors (Right and Left): X
Tires (Properly inflated, adequate tread): X Windows: (Clean, free of cracks): X

COMMENTS: ______

Inside of Vehicle

Truck is clean inside: X Gauges: X
Windshield wipers and fluid: X Seatbelts: (working condition) X
Check horn: X Check parking brake reset/release: X Oil change current: X
Brakes: X Check inside mirrors, rearview: X Check oil level weekly X

COMMENTS: ______

Front and Rear of Vehicle

Tail lights: X Head Lights: X Bumpers: X Fluid leaks: X
License plates (Tags Current): X Exterior damage to body: X Turn signals: X

COMMENTS: ______

General/Safety

Insurance Card/Operator's Manual: X Wheel chocks: X First Aid Kit: X
Strobe light: X Buggy whip ______ (If needed)

COMMENTS: ______

Deficiencies Corrected: ______

Signature: Logan Yuretich Date: 8/19/26

New form 6/11/15

NTS Environmental Science & Engineering

Daily Tailgate Safety

Project: 23644 **Date:** 8/19/26

Work Site Hazard Assessment Worksheet

- ☑ PPE Required (List): Hi-Viz Vest, Waders, Safety Boots Level* D
- ☑ Weather Conditions (List): High 77°F, Partly Cloudy, Light Winds
- ☑ Vehicular Traffic
- ☐ Communications
- ☐ Noise
- ☐ Equipment/Tools
- ☐ Housekeeping
- ☐ Other Site Hazards**

☐ I have examined the work place named and found no hazards
☑ I have examined the work place named and hazards found are listed below with corrective action taken

Hazards Identified/Safety Items Discussed:

Slips/Trips/Falls
Highway Traffic
Unfamiliar Flow Locations - Rivers/Streams

Corrective Actions Taken:

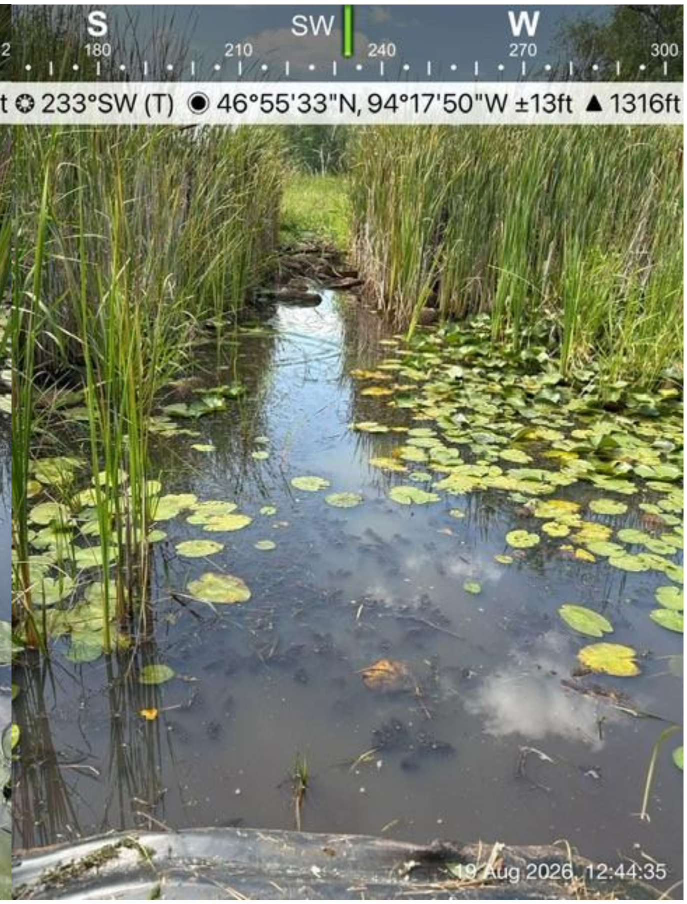
Take careful steps
Be cautious when roadside, use hazard lights when necessary
Properly inspect flow site conditions before entering the water

Participants in Safety Discussion:

	Print Name	Signature
1.	Logan Yuretich	Logan Yuretich
2.		
3.		
4.		
5.		

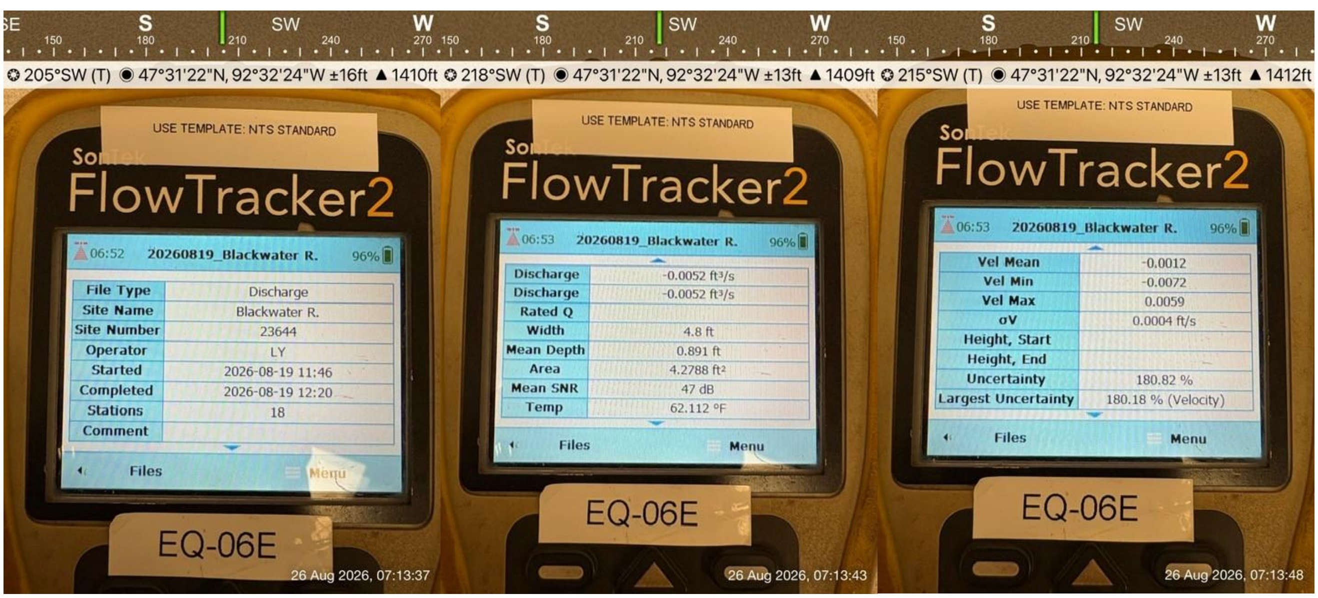
Signature of Site Supervisor/Examiner: Logan Yuretich Date: 8/19/26

*Level D, C, B or A
**Examples: Heavy Equipment, Air Quality, Flammable materials, Wildlife, Work Site Security, Confined Space



Blackwater River Inflow Cross Section

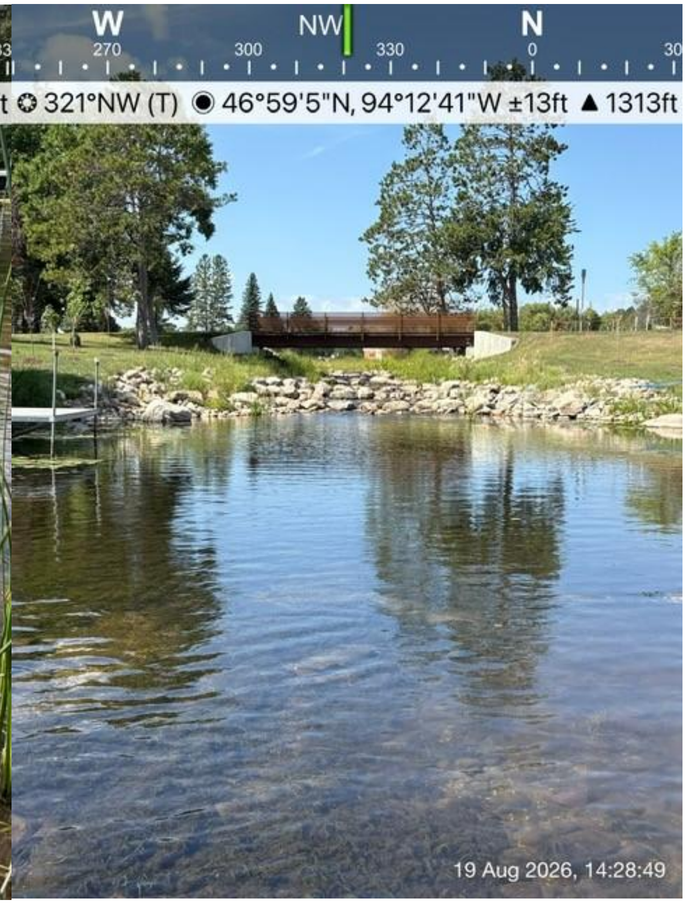
Blackwater River Inflow Upstream



Blackwater River Inflow Discharge Summary

Boy River Inflow Cross Section

Boy River Inflow Downstream



Girl Lake Outflow Cross Section

Girl Lake Outflow Upstream

Appendix B

FLOW MEASUREMENT

QM-305

Rev 1

Initial Draft by
Craig Douglas on June 6th, 2024 3:26 pm CDT

Team Lead Approved by
Katrina Davis on June 11th, 2024 8:09 am CDT

Approved - Effective - 3 - Stage by
Craig Douglas on June 11th, 2024 8:14 am CDT

Full Approval Records
https://app.isolocity.com/documents/113/revisions/129

Table of Contents

1.0 Purpose

This standard operating procedure (SOP) describes procedures that will be used to obtain water flow measurements in streams, culverts, pipes, sharp-crested weirs, and bucket and stopwatch methods. The overall goal is to obtain a practical flow estimate within 10% of the actual flow. There are many different flow measurement techniques and equipment that may be used depending on the specific application (e.g., open-channel or closed conduit, in-place or portable equipment, continuous or instantaneous measurement). This SOP only details common flow measurements performed by Northeast Technical Services, Inc. (NTS). Refer to equipment manuals, reference documents, or equipment manufacturers for flow measurement details that are not included in this SOP. Deviations from this SOP should be documented according to NTS SOP QM-201.

Best professional judgment and an understanding of project requirements are required when obtaining any flow measurement as each situation is unique. An exceptional level of care should be taken when monitoring flow at stream gaging stations.

2.0 Responsibilities

Any NTS staff collecting flow measurements shall follow this SOP.

3.0 Health and Safety

Life preservers should be worn if there is a risk of drowning. Always check site ice conditions before working on ice. Follow procedures in the MnDOT Temporary Traffic Control Field Manual when performing work near roadways.

4.0 Equipment

The most common flow measurement equipment utilized by NTS is described below:

1. Electromagnetic current meter (ECM) – Measures flow velocity using electromagnetic induction:
   <u>Marsh-McBirney Model 2000</u>
   Range: -0.5 to 20 ft/s
   Accuracy: ± 2% of measured velocity plus 0.05 ft/s
   Min. Water Depth: 0.1 ft
   <u>Hach FH950</u>
   Range: -0.5 to 20 ft/s
   Accuracy: ± 2% of measured velocity plus 0.05 ft/s (0 to 10 ft/s)
   Min. Water Depth: 0.1 ft

2. Acoustic Doppler Velocimeter (ADV) – Measures flow velocity using Doppler shift:
   <u>SonTek FlowTracker2</u>
   Range: -13 to 13 ft/s
   Accuracy: ± 1% of measured velocity plus 0.008 ft/s
   Min. Water Depth: 0.07 ft

3. USGS top setting wading rod – Measures water depth and positions velocity probe at set depth:
   Depth Range: 0.1 to 10 ft
   Graduations: 0.1 ft

5.0 Stream Flow Procedures

Stream Gaging Station Midsection Method with Wading Rod

Stream flow can be measured using a variety of techniques depending on site conditions, available equipment, and data quality objectives. Stream gaging stations require a high level of measurement accuracy and quality control because they are used to calibrate a stage-discharge rating curve. This procedure describes the midsection method for measuring stream flow at a stream gaging station using a wading rod and an electromagnetic current meter (ECM) or acoustic Doppler velocimeter (ADV). See the simplified stream flow method described later in this SOP if project data quality requirements are less stringent. Reference the note at the end of this document if there is ice cover. The midsection method calculations are not incorporated in the NTS field data collection software.

Figure 1 illustrates the midsection flow measurement method. Flow, or discharge, is calculated as the product of the area and the velocity. The stream cross-section is divided into segments, and the depth and mean velocity are measured at the vertical step in each segment. The mean velocity is determined by measuring the velocity at one or more points in each vertical step. The cross-sectional area for a segment extends laterally from half the distance from the preceding vertical step to half the distance to the next vertical step, and vertically, from the water surface to the streambed depth.

The following conditions are ideal when identifying the stream flow measurement location, but it is usually not possible to satisfy all conditions:

1. Cross-section lies within a straight reach, and streamlines are parallel to each other.
2. Velocities are greater than 0.5 ft/s and depths are greater than 0.5 ft.
3. The streambed is relatively uniform and free of numerous boulders and heavy aquatic growth.
4. Flow is relatively uniform and free of eddies, slack water, and excessive turbulence.
5. The measurement section is relatively close to the gaging-station control.

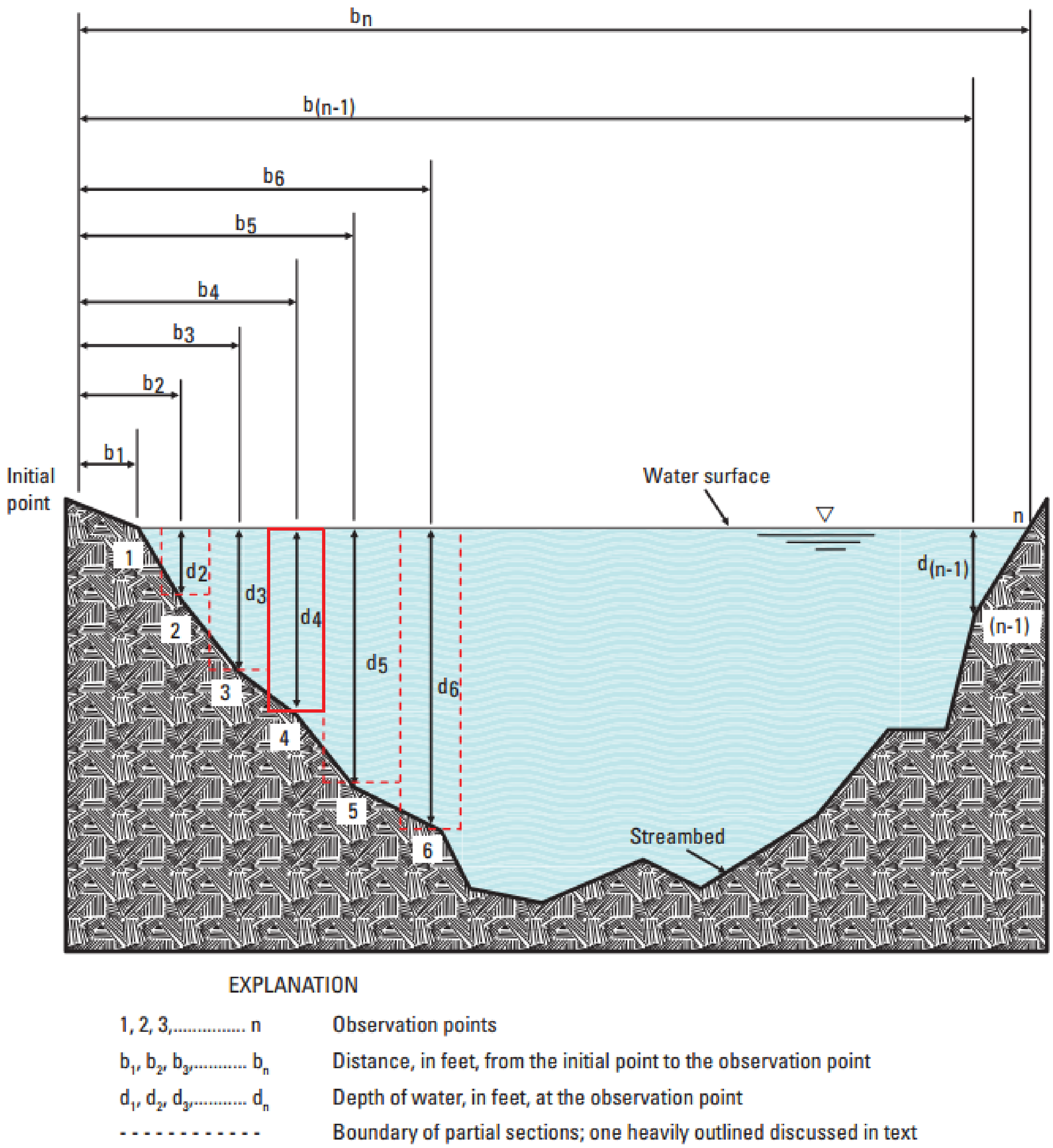


Figure 1. Illustration of the stream flow measurement method.

At the designated stream flow location, the following steps are required:

1. Determine the stream width.
    a. String a measuring tape so it is taught across the cross-section and perpendicular to the direction of flow. Avoid leaving footprints in the streambed cross-section.
    b. Document how the tape increments increase (e.g., increasing graduations from left-to-right facing upstream) and if the tape begins at zero or another mark.
    c. Document where the edges of the water begin and end by aligning and plumbing the wading rod to the measuring tape at the water's edge.
2. Determine the spacing of the vertical steps.
    a. The spacing can typically be set at a standard step size for a particular stream gaging location unless there are abnormally high or low flow conditions.
    b. The ideal step size is one in which no partial section has more than 5% of the total discharge, which usually requires at least 25 steps.
    c. Using equally-sized step spacing is preferred to allow for easier flow calculation, but it is not required. Step widths may need to be unequal to avoid obstructions in the cross-section.
3. Measure the depth and mean velocity at each vertical step.
    a. The wading rod should be aligned and plumbed to the measuring tape at each step. Document each step position to the nearest 0.1 ft.
    b. Stand in a position that least affects the velocity of water passing by the sensor. Stand out of the water if possible or stand 1.5 feet away from the wading rod while facing the bank. Do not stand in close proximity to the ADV sampling volume (Figure 2).

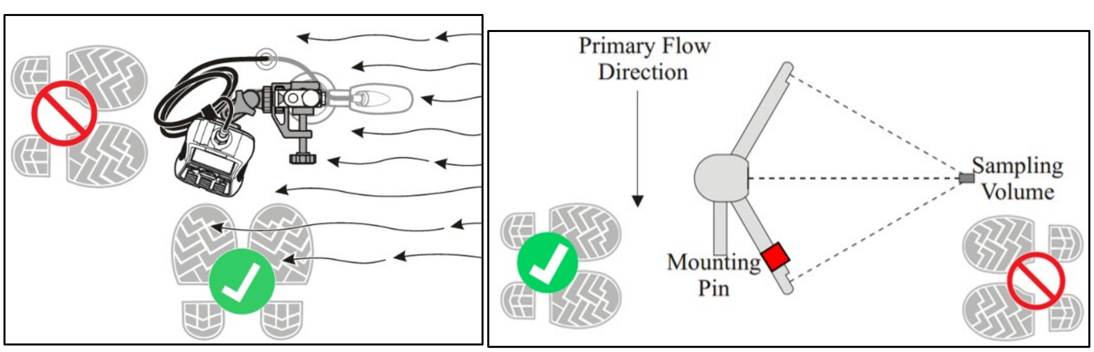


Figure 2. Positioning while obtaining velocity measurements.

    c. Avoid leaving footprints in the streambed cross-section.

d. In soft streambeds, be careful not to allow the wading rod to sink into the streambed. This may require supporting the weight of the wading rod.

e. Avoid positioning steps where obstructions (e.g., boulders, vegetation) may impact velocity readings, and document if obstructions are present.

f. Measure depth using the wading rod.

   i. Depth should be measured using the wading rod graduations and estimated to the nearest 0.01 ft.

   ii. In high velocities, there will be a velocity-head build-up of water on the wading rod (i.e., mounding effect), and the depth should be based on where the surface of the stream intersects the wading rod, not on the top of the velocity-head build-up.

g. Measure velocity using the ECM or ADV.

   i. The ADV should be used if stream velocities are less than 0.5 ft/s. The ECM is less accurate at low velocities.

   ii. Position the ECM sensor parallel to the flow direction. Position the ADV sensor perpendicular to the flow direction. Reference Figure 3.

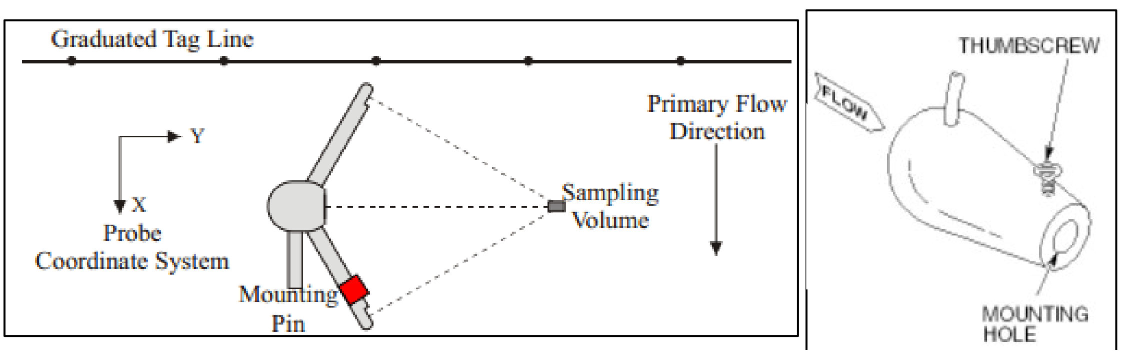


Figure 3. ADV orientation (left) and ECM orientation (right) relative to flow direction.

   iii. Measure the velocity at 60% below the water surface if the water depth is less than 1.5 ft. Reference Figure 4.

      1. To set the sensor at the correct depth, align the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod such that it reads the desired water depth.

   iv. Measure the velocity at 20% and 80% below the water surface if the water depth is 1.5 ft or greater. Calculate the average of the two measurements to estimate mean velocity.

      1. To set the sensor at 20% of the depth, multiply the total depth by two and repeat Step 3.g.iii.1.

2. To set the sensor at 80% of the depth, divide the total depth by two and repeat Step. 3.g.iii.1.

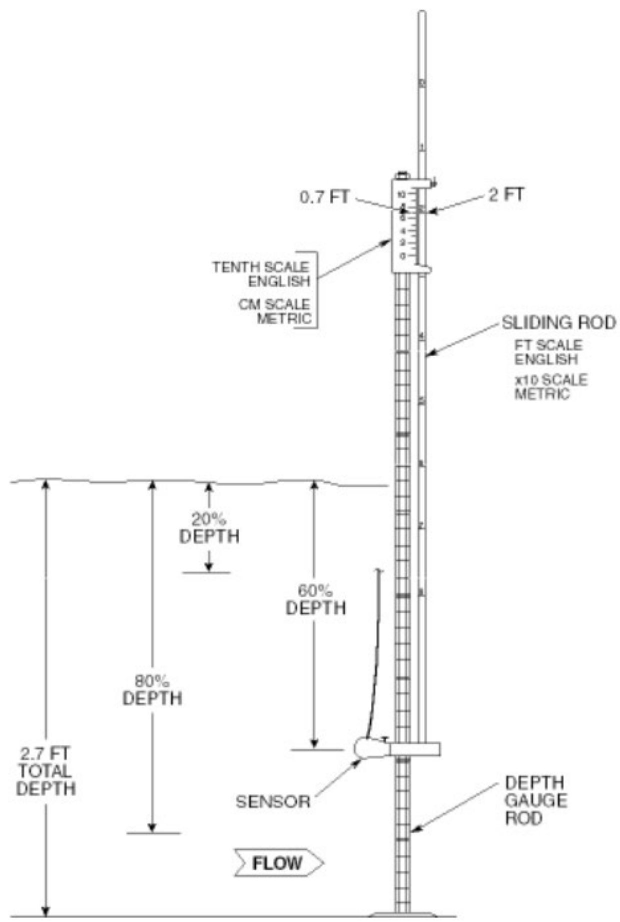


Figure 4. Top setting wading rod sensor positioning.

v. After the meter is set at the proper depth, allow it to adjust to the current prior to starting the velocity observation. It will take longer to stabilize in slow moving water. Once the current has stabilized, begin measuring velocity. The ADV requires 40-60 seconds to obtain each reading. The ECM can give continuous velocity readings but allow a minimum of 30 seconds before recording the velocity reading to ensure readings have stabilized. Readings may not completely stabilize in turbulent water.

vi. If the sensor reports negative velocities in an eddy, record the negative velocity (i.e., do not record negative readings as 0 ft/s).

4. Calculate the discharge percentage of each partial section prior to leaving the site to ensure all steps are less than 5%. If any steps are greater than 5%, repeat Steps 2 and 3.
5. Document the site conditions.
   a. Describe the geomorphology of the cross section (e.g., sand, clay, cobble, etc.).
   b. Document any obstructions, aquatic vegetation, or undercut banks in the cross section.
   c. Document the flow measurement equipment used (i.e., ECM or ADV).

Simplified Velocity-Area Method with Wading Rod

Stream flow can be measured using a variety of techniques depending on site conditions, available equipment, and data quality objectives. A simplified method is commonly used when projects do not require the rigorous data quality needed at stream gaging stations. This procedure describes a simplified velocity-area method for measuring stream flow using a wading rod and an electromagnetic current meter (ECM) or acoustic Doppler velocimeter (ADV). Most steps in this procedure are the same as those found in the steam gaging station procedure described earlier in this SOP but require fewer and less precise field measurements. The velocity-area method calculations are incorporated in the NTS field data collection software. Reference the note at the end of this document if there is ice cover.

Figure 1 provides an illustration of the velocity-area flow measurement method. Flow, or discharge, is calculated as the product of the area and the velocity. The stream cross-section is divided into segments, and the depth and mean velocity are measured at the vertical step in each segment. The mean velocity is determined by measuring the velocity at one or more points in each vertical step. The cross-sectional area for a segment extends laterally from half the distance from the preceding vertical step (or from the water's edge) to half the distance to the next vertical step (or to the water's edge), and vertically, from the water surface to the streambed depth.

The following conditions are ideal when identifying the stream flow measurement location, but it is usually not possible to satisfy all conditions:

1. Cross-section lies within a straight reach and streamlines are parallel to each other.
2. Velocities are greater than 0.5 ft/s and depths are greater than 0.5 ft.
3. The streambed is relatively uniform and free of numerous boulders and heavy aquatic growth.

4. Flow is relatively uniform and free of eddies, slack water, and excessive turbulence.
5. The measurement section is relatively close to the defined monitoring location.

At the designated stream flow location, the following steps are required:

1. Determine the stream width.
    a. Measure the stream width using a tape measure. Avoid leaving footprints in the streambed cross-section.
2. Determine the spacing of the vertical steps.
    a. The minimum number of steps is defined by project objectives. If not defined explicitly, a minimum of 4 steps is utilized.
    b. Using equally-sized step spacing, except at the first and last step, is required if the flow is calculated using NTS field data collection software.
3. Measure the depth and mean velocity at each vertical step.
    a. The wading rod should be aligned and plumbed to the measuring tape at each step. Document each step position to the nearest 0.1 ft.
    b. Stand in a position that least affects the velocity of water passing by the sensor. Stand out of the water if possible or stand 1.5 feet away from the wading rod while facing the bank (Figure 2).
    c. Avoid leaving footprints in the streambed cross-section.
    d. In soft streambeds, be careful not to allow the wading rod to sink into the streambed. This may require supporting the weight of the wading rod.
    e. Document if obstructions (e.g., boulders, vegetation) are present.
    f. Measure depth using the wading rod.
        i. Depth should be measured using the wading rod graduations and estimated to the nearest 0.05 ft.
        ii. In high velocities, there will be a velocity-head build-up of water on the wading rod (i.e., mounding effect), and the depth should be based on where the surface of the stream intersects the wading rod, not on the top of the velocity-head build-up.
    g. Measure velocity using the ECM or ADV.
        i. The ECM is used unless the ADV is required by project objectives.
        ii. Position the ECM sensor parallel to the flow direction. Position the ADV sensor perpendicular to the flow direction. Reference Figure 3.

iii. Measure the velocity at 60% below the water surface if the water depth is less than 1.5 ft. Reference Figure 4.

1. To set the sensor at the correct depth, align the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod such that it reads the desired water depth.

iv. Measure the velocity at 20% and 80% below the water surface if the water depth is 1.5 ft or greater. Calculate the average of the two measurements to estimate mean velocity.

1. To set the sensor at 20% of the depth, multiply the total depth by two and repeat Step 3.g.iii.1.
2. To set the sensor at 80% of the depth, divide the total depth by two and repeat Step. 3.g.iii.1.

v. After the meter is set at the proper depth, allow it to adjust to the current prior to starting the velocity observation. It will take longer to stabilize in slow moving water. Once the current has stabilized, begin measuring velocity. The ADV requires 40-60 seconds to obtain each reading. The ECM can give continuous velocity readings but allow a minimum of 10 seconds before recording the velocity reading to ensure readings have stabilized. Readings may not completely stabilize in turbulent water.

vi. If the sensor reports negative velocities in an eddy, record the negative velocity (i.e., do not record negative readings as 0 ft/s).

4. Document the site conditions.
   a. Document any obstructions, aquatic vegetation, or undercut banks in the cross section.
   b. Document the flow measurement equipment used (i.e., ECM or ADV).

6.0 Bucket and Stopwatch Method Procedure

The bucket and stopwatch methods are particularly useful for low flow conditions when water can be collected in a calibrated container. The bucket and stopwatch method calculations are incorporated into the NTS field data collection software. Flow is calculated by dividing the volume of water collected by the fill time.

The following conditions are ideal when determining if the bucket and stopwatch method is applicable:

1. The entire flow to be measured can be collected by gravity free flow into a single container.
2. Flow velocity will not cause water to splash outside of the container.

At the designated flow location, the following steps are required:

1. Use a stopwatch and record the time it takes to fill a calibrated container (bottle, bucket, etc.) to a known volume. A minimum of 10 seconds to fill the container is recommended.
2. Repeat Step 1 two more times for a total of three consecutive measurements. Average the three fill times to obtain an average fill time.
3. Document the site conditions.
   a. Document any conditions that may influence accurate flow measurement.
   b. Document the flow measurement equipment used (i.e., type of calibrated container).

7.0 Circular Pipe or Culvert Flow – Velocity-Area Method Procedure

Pipe or culvert flow can be measured using a variety of techniques depending on site conditions, available equipment, and data quality objectives. This procedure describes a simplified velocity-area method for measuring circular pipe or culvert flow using a wading rod and an electromagnetic current meter (ECM) or acoustic Doppler velocimeter (ADV). The circular pipe or culvert velocity-area method calculations are incorporated in the NTS field data collection software. Reference the note at the end of this document if there is ice cover.

Figure 5 illustrates the circular pipe or culvert velocity-area flow measurement method. Flow is calculated as the product of the cross-sectional area and the average velocity.

The following conditions are ideal when determining if the simplified velocity-area method with a velocity meter is applicable to measure pipe or culvert flow:

1. The pipe or culvert is circular (i.e., not rectangular or oval-shaped) and clean (i.e., there is no sediment or debris buildup). If the pipe or culvert is not circular and clear of sediment, use the stream flow method instead.
2. The water depth is not fluctuating and there is no immediate upstream bends or obstructions.
3. The flow can be measured at a discrete pipe or culvert cross-section (e.g., at the inlet or discharge).

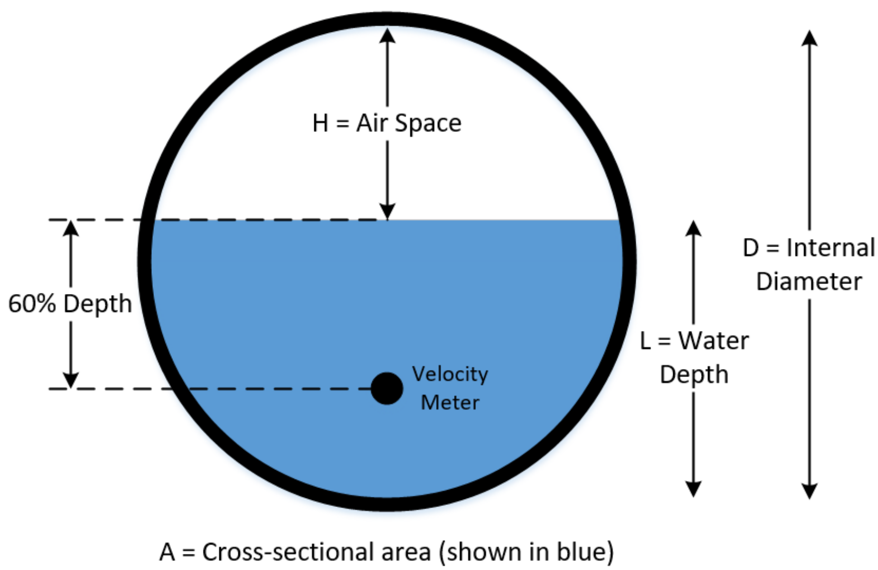


Figure 5. Circular pipe or culvert flow measurement method.

At the designated flow location, the following steps are required:

1. Measure the pipe or culvert internal diameter using a ruler or wading rod.
2. Measure water depth using the wading rod.
   a. Depth should be measured using the wading rod graduations and estimated to the nearest 0.05 ft.
   b. In high velocities, there will be a velocity-head build-up of water on the wading rod (i.e., mounding effect), and the depth should be based on where the surface of the stream intersects the wading rod, not on the top of the velocity-head build-up. The water depth can also be calculated by subtracting the air space from the internal diameter (i.e., L = D - H).
3. Measure velocity using the ECM or ADV.
   a. The ECM is used unless the ADV is required by project objectives.
   b. Position the ECM sensor parallel with the flow direction. Position the ADV sensor perpendicular to the flow direction. Reference Figure 3.
   c. Measure the velocity at 60% below the water surface if the water depth is less than 1.5 ft. Reference Figure 4.
      i. To set the sensor at the correct depth, line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod such that it reads the desired water depth.

d. Measure the velocity at 20% and 80% below the water surface if the water depth is 1.5 ft or greater. Calculate the average of the two measurements to estimate mean velocity.

   i. To set the sensor at 20% of the depth, multiply the total depth by two and repeat Step 3.c.i.

   ii. To set the sensor at 80% of the depth, divide the total depth by two and repeat Step. 3.c.i.

e. After the meter is set at the proper depth, allow it to adjust to the current prior to starting the velocity observation. It will take longer to stabilize in slow moving water. Once the current has stabilized, begin measuring velocity. The ADV requires 40-60 seconds to obtain each reading. The ECM can give continuous velocity readings but allow a minimum of 10 seconds before recording the velocity reading to ensure readings have stabilized. Readings may not completely stabilize in turbulent water.

4. Repeat Step 3 two more times for a total of three consecutive velocity measurements. Average the three velocity measurements to obtain an average velocity.

5. Document the site conditions.

   a. Document any conditions that may influence accurate flow measurement (e.g., fluctuating water level, damaged culvert, etc.).

   b. Document the flow measurement equipment used (i.e., ECM or ADV).

8.0 Sharp-Crested Weir Flow Procedure

Sharp-crested weir flow measurements consist of measuring the head relative to the weir crest. Tables or equations for the specific type and size of weir use the measured head to calculate flow. This procedure is not specific to any weir type but describes the general weir flow principles that apply to sharp-crested weirs. Flow calculations for several sharp-crested rectangular and V-notch weirs are incorporated in the NTS field data collection software.

Figure 6 illustrates a sharp-crested rectangular weir.

The following conditions are required for accurate sharp-crested weir flow measurements:

1. The weir plate should be plumb, smooth, level, and perpendicular to the flow direction.
2. The weir plate crest and side thicknesses should be less than 0.08 inches.
3. Maximum downstream water surface level should be at least 0.2 feet below crest elevation. Water downstream should not back up into the weir crest.
4. The overflow sheet of water (i.e., nappe) should only touch the upstream face of the weir plate and should not cling to the weir.
5. The head measurement should be obtained upstream from the weir at a distance of at least four times the maximum weir head. The head measurement device should be clear of ice.
6. The weir crest and approach to the weir should be free of debris and obstructions.

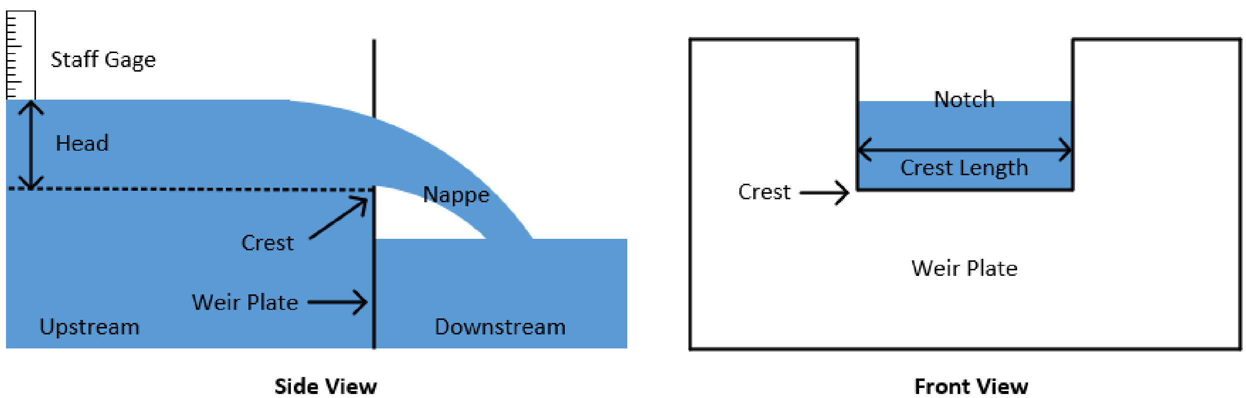


Figure 6. Sharp-crested rectangular weir schematic.

At the designated flow location, the following steps are required:

1. Measure the head above the weir crest in the upstream pool. This should be done by using a staff gage that has been surveyed and set relative to the weir crest.
   a. If possible, avoid measuring the head by placing a ruler in the weir notch because the head measurement will be influenced by the approach velocity.
2. Document the site conditions.
   a. Document any conditions that may contribute to inaccurate flow measurement (e.g., head measurement taken in the weir crest, nappe clinging to the weir instead of forming an air gap, downstream water backed up into the weir crest, water bypassing the weir, damaged or uneven weir plate, obstruction in the weir, ice cover, etc.).

b. Document the weir size and type.

9.0 Note Regarding Ice Cover

Measuring flow under ice cover is not ideal and should be avoided if possible due to measurement inaccuracies. The effective water depth is the total depth of the water minus the distance from the water surface to the bottom of the ice (Figure 7). The 20%, 60%, and 80% depth settings for the velocity sensor should be calculated as shown in Figure 7.

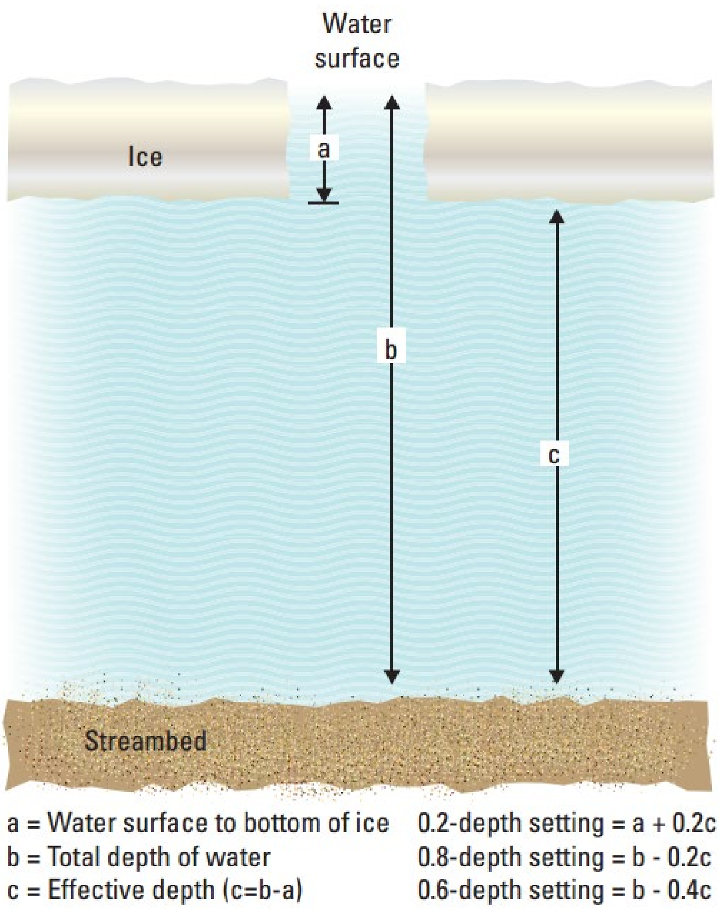


Figure 7. Top setting wading rod sensor positioning.

10.0 References

1. Discharge Measurement at Gaging Stations, Techniques and Methods 3-A8, *U.S. Geological Survey, U.S. Department of the Interior.*

2. Open Channel Profiling Handbook, *Marsh-McBirney, Inc.*
3. Measurement and Computation of Streamflow: Volume 1, Measurement of Stage and Discharge, *U.S. Geological Survey*.
4. Water Measurement Manual, *U.S. Department of the Interior*.
5. Operating Procedure for Wastewater Flow Measurement, LSASDPROC-109-R5, *Environmental Protection Agency*.

11.0 Revision History

Revision	Revision Description	Revised By
0	All revised, new SOP format	Jonathan Novak
1	Formatting	Craig S. Douglas