Acoustic Doppler Current Profile Measurements in Government Highline Canal, Collected near Grand Junction, Colorado

Prepared for: Kevin Moran, Western Colorado Area Office - Northern Division

Prepared by: Tracy B. Vermeyen and Connie DeMoyer, Hydraulic Engineers,
Water Resources Research Laboratory

Peer Reviewed by: Brent Mefford, Technical Specialist, Water Resources Research Laboratory

Copies to: Brent Mefford (D-8560), D-8560 (files)

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Purpose: To measure current profile transects in the Government Highline Canal. Velocities were measured to determine if the flow distribution is uniform at the proposed fish screen location in this reach of the Government Highline Canal. Tracy Vermeyen from Reclamation's Water Resources Research Laboratory in Denver, Colorado collected the current profile data with a RD Instruments 1200 kHz Rio Grande Acoustic Doppler Current Profiler (ADCP).

ADCP Setup: A RD Instruments 1200 kHz Rio Grande Acoustic Doppler Current Profiler (ADCP) was mounted to a small pontoon raft (figure 1). The raft was moved across the canal using hand lines from each bank (figure 2). The ADCP was powered using a marine-grade 12-volt battery. A handheld Garmin GPS system was used to mark the starting positions of the ADCP transects. A laptop computer was used to operate the ADCP, monitor the real time data, and collect and store the data. The ADCP was set up for velocity measurements by checking the compass calibration and measuring the transducer's draft.

Data Collection: Nineteen ADCP transects were collected at 8 cross sections. The individual discharge measurements are summarized in table 1. The velocity measurements were made between 13:00 and 14:30 on August 28, 2002. A typical ADCP transect took 2 minutes to collect. Sites were named GHC, GHC1, GHC1A, GHC2, GHC3, GHC3A, GHC4, and GHC5 from upstream to downstream (figure 3). When stopped at a bank, the ADCP was positioned approximately three feet from the waterline. The raft was pulled slowly across the canal while continuous current profiles were collected (figure 2). GPS waypoints were marked at the left bank at each measurement cross section (see table 2). The ADCP's bottom tracking feature resolved raft velocity from the water velocity. However, there was no effort to determine if there was a moving bed caused by bedload transport. A moving bed can significantly affect the discharge computation because the boat velocity is accurately measured. The ADCP was configured to collect velocity profiles with a vertical resolution of 10 inches (25 cm). The first velocity measurement was collected at a depth of 2.0 ft. Two or more transects were made at each site to ensure good data quality. When two discharge measurements were in close agreement, we moved the raft downstream to the next cross section.

Figure 1. Photograph of ADCP mounted on a small pontoon raft.

Figure 2. Photograph of raft being pulled across the canal. The ADCP is mounted on the front of the raft, which is facing upstream.

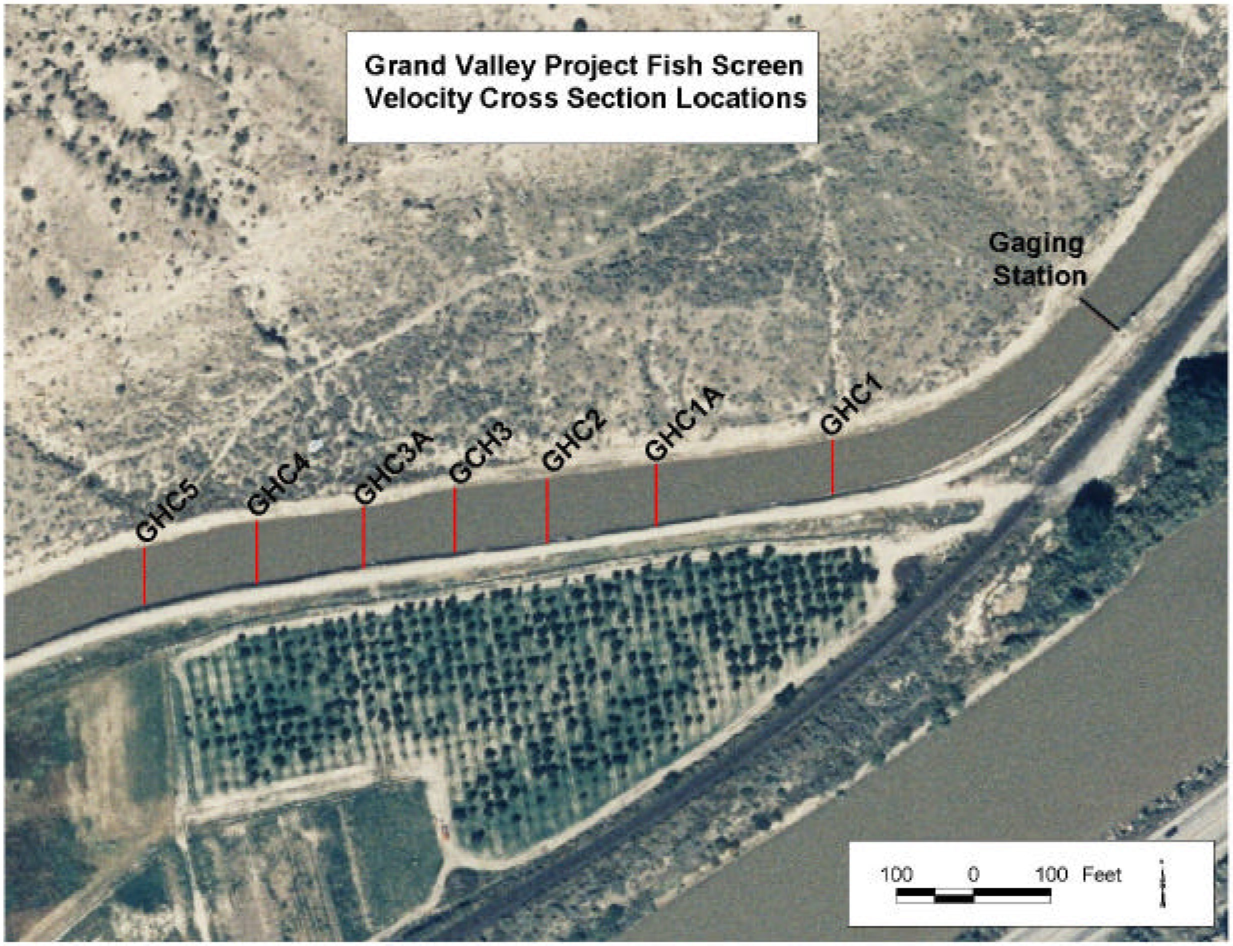


Figure 3. Site map of Government Highline Canal and the ADCP Transect Locations. The canal has a concrete lining on the left bank, but how far it extends across the channel was not known. The channel lining terminates between cross sections GHC1 and GHC1A.

Data Processing: ADCP data were processed to generate cross sectional velocity profiles. The cross sections are plotted from the left to right bank, as if looking downstream. Figures 4 – 11 show the cross sectional current profiles and the depth-averaged velocity vectors along the raft's path (ship track). Velocity contours represent the magnitude of the horizontal velocity in ft/sec. Missing velocity contours near the banks occur when the depth is too shallow to accurately measure velocity data. The heavy black line on the cross sectional velocity contour plots represents the channel bottom. The lighter black line represents the depth where velocities may be corrupt because of side-lobe interference. Side-lobe interference is when a secondary acoustic pulse reflects from the bottom and interferes with reflections from the primary acoustic pulse returning from particles near the bottom. As a result, velocities affected by side-lobe interference are not used in the discharge computations. Velocities near the surface are not measured by the ADCP because the transducer needs to be submerged and the instrument requires a blanking distance to allow the acoustic transmitters to change into acoustic receivers.

Discharge measurements at the Colorado Division of Water Resources gaging station (GHC site) had average value of 1303 ft^3/sec over the data collection period (see table 1). The average ADCP discharge measurement and standard deviation were 1157 $\pm$30 ft^3/sec. The ADCP discharge was 11.2 percent lower than the average gaging station measurements. Individual ADCP measured discharges for each site are given in the figure captions and in Table 1. The difference in discharges is a concern, but does not affect the comparison of cross sectional velocity distributions throughout the canal reach. The discrepancies between DWR and ADCP discharges are consistent with a moving-bed in that the ADCP measured discharge is under predicted. To correct for a moving bed, differentially corrected GPS is used instead of the bottom tracking to get the boat's speed and direction.

To determine the flow distribution between the right and left sides of the cross section, I used RD Instrument's WinRiver software to determine the average velocity for right and left segments of the channel (based on cross sectional area). Table 3 contains a summary of cross sectional area for the GHC cross sections and average channel velocities in four segments of equal cross sectional area (total area divided by 4). Table 4 contains a summary of average channel velocities, velocity ratios, and cross sectional area for the GHC cross sections. The ratio of right to left average channel velocities (V_{right}/V_{left}) was computed for each canal cross section. Ratios less than one indicate the flow is skewed toward the left bank. The velocity ratios show that by GHC4 the distribution is nearly uniformly distributed across the channel. At cross section GHC5 the velocity distribution is skewed very slightly toward the right half of the channel.

Table 1. Summary of ADCP and DWR discharges for August 28, 2002.

Cross Section	Time	ADCP Flow (ft^3/sec)	ADCP V_{avg} (ft/sec)	DWR Flow (ft^3/sec)
Gaging Station (lb to rb)	13:00	1150	2.8	1310
Gaging Sta. (rb to lb)	13:09	1135	3.0	
Gaging Sta. (lb to rb)	13:12	1130	2.8	
Gaging Sta. (rb to lb)	13:16	1226	3.0	1310
Gaging Sta. (lb to rb)	13:20	1150	3.0	
GHC1 (rb to lb)	13:27	1148	2.5	
GHC1 (lb to rb)	13:30	1182	2.7	1300
GHC1 (rb to lb)	13:32	1172	2.5	
GHC1A (lb to rb)	13:37	1188	2.1	
GHC1A (rb to lb)	13:39	1184	2.2	
GHC2 (lb to rb)	13:44	1150	1.9	1300
GHC2 (rb to lb)	13:46	1204	2.0	
GHC3 (lb to rb)	13:51	1123	1.9	
GHC3 (rb to lb)	13:56	1115	1.9	
GHC3A (lb to rb)	13:59	1131	2.3	1300
GHC3A (rb to lb)	14:02	1162	2.2	
GHC4 (lb to rb)	14:16	1174	2.1	1300
GHC4 (rb to lb)	14:18	1141	2.1	
GHC5 (lb to rb)	14:22	1125	2.2	
GHC5 (rb to lb)	14:25	1148	2.3	1290
Average Flow (ft^3/sec)		1157		1301
Standard Deviation (ft^3/sec)		29		
Percent Diff. in Discharge (DWR-ADCP)/DWR*100		11.1%		

Table 2. GPS Positions for Left Bank Stations for GHC Transects

Cross Section	UTM Zone	Easting (m)	Northing(m)
DWR Gaging Station	12 S	734227	4340061
GHC1	12 S	734134	4340017
GHC1A	12 S	734062	4339999
GHC2	12 S	734017	4339993
GHC3	12 S	733980	4339987
GHC3A	12 S	733941	4339981
GHC4	12 S	733902	4339972
GHC5	12 S	733856	4339962

Table 3. Velocity distribution for ¼segments of the entire cross sectional area (ft/sec) (to get the flow in each segment multiply V by the area)

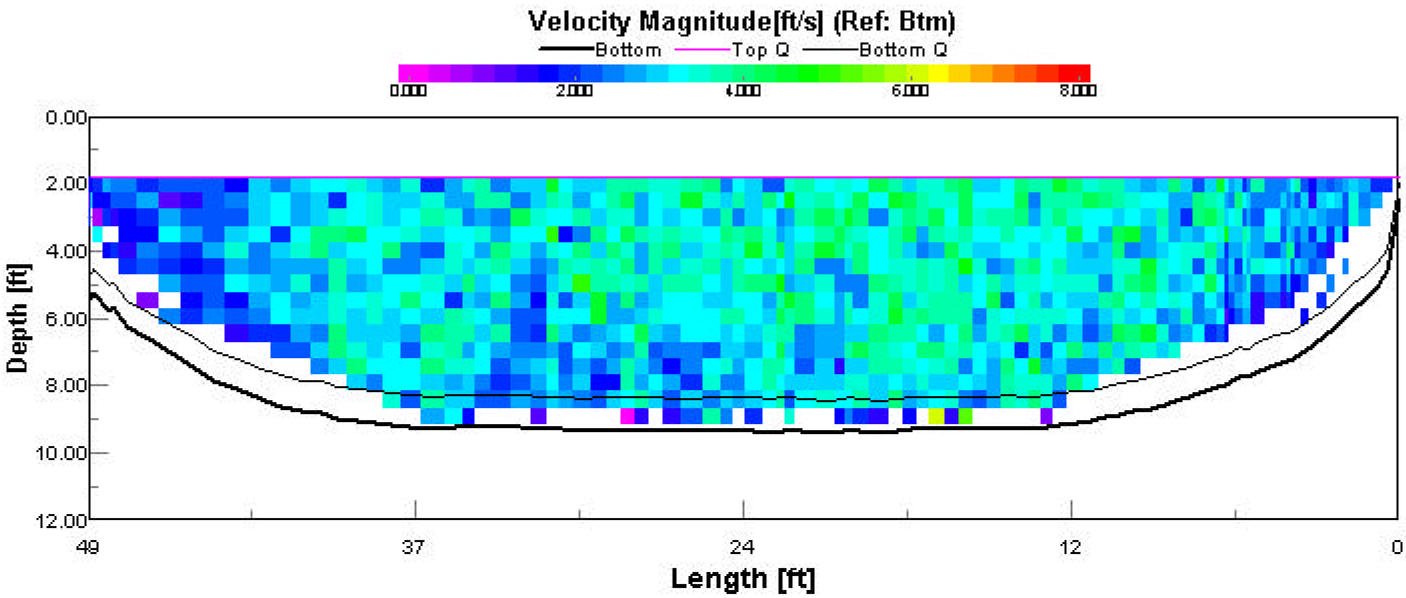
Canal Cross Section	¼of channel area (ft^2)	LB to ¼L	¼L to ½	½ to ¼R	¼R to RB
DWR Gaging Station	104	2.5	3.0	3.2	2.6
GHC1	127	2.5	2.6	2.3	1.7
GHC1A	155	2.1	2.5	2.0	1.1
GHC2	165	2.0	2.3	1.9	1.1
GHC3	161	1.9	2.3	2.0	1.1
GHC3A	137	2.2	2.4	2.3	1.6
GHC4	148	1.7	2.4	2.2	1.6
GHC5	138	1.8	2.5	2.3	1.7

Table 4. Summary of Velocity Distribution, Velocity Ratios, and Cross Sectional Areas

Canal Cross Section	Right Channel Velocity (ft/sec)	Left Channel Velocity (ft/sec)	Velocity Ratio (Right/Left)	Cross Sectional Area (ft^2)
DWR Gaging Station	2.9	2.7	1.1	414
GHC1	2.0	2.6	0.8	508
GHC1A	1.6	2.3	0.7	620
GHC2	1.6	2.2	0.7	658
GHC3	1.5	2.1	0.7	643
GHC3A	1.9	2.3	0.8	548
GHC4	2.0	2.0	1.0	590
GHC5	2.1	2.0	1.1	550

Conclusions:

- The ADCP was used to collect velocity distributions at 8 cross sections in the Government Highline Canal. Nineteen transects were completed in under 1.5 hours.
- Figures 4 through 9 show that the velocity distributions are skewed toward the outside of the bend (the left bank) as water flows from GHC1 to GHC3. At GHC4 and GHC5 (USBR property line) the flow distribution across the channel is recovered to a nearly uniform condition (see tables 3 and 4 and figures 10 and 11).
- The effects of a slightly skewed velocity distribution will most likely not significantly impact the performance of the proposed fish screen. However, for the design discharge the velocity skewness may extend further downstream. The proposed fish screen should be located as close to GHC4 and GHC5 as possible to limit the impacts of any skewness in the cross sectional velocity distribution.
- The 11.1 percent discrepancy between the ADCP discharge measurements (table 2) and the flow reported by the DWR Government Highline Canal gaging station is larger than expected given the accuracy of ADCP measurements. Generally, ADCP discharge measurements are within the same accuracy bounds as standard stream gaging techniques (±5%). However, given the possibility of sediment bedload in the canal, there is a potential for moving-bed errors in the bottom track velocity measurements that can be a significant source of discharge error.
- The difference in discharge measurements is a concern, but does not affect the comparison of cross sectional velocity distributions throughout the canal reach. A moving bottom can reduce the magnitude of the measured velocity by an amount equal to the bedload velocity, which is probably small. If future discharge measurements are required, a moving bottom test should be performed. If a moving-bed is detected, a differential GPS system will be required to account for the moving-bed.



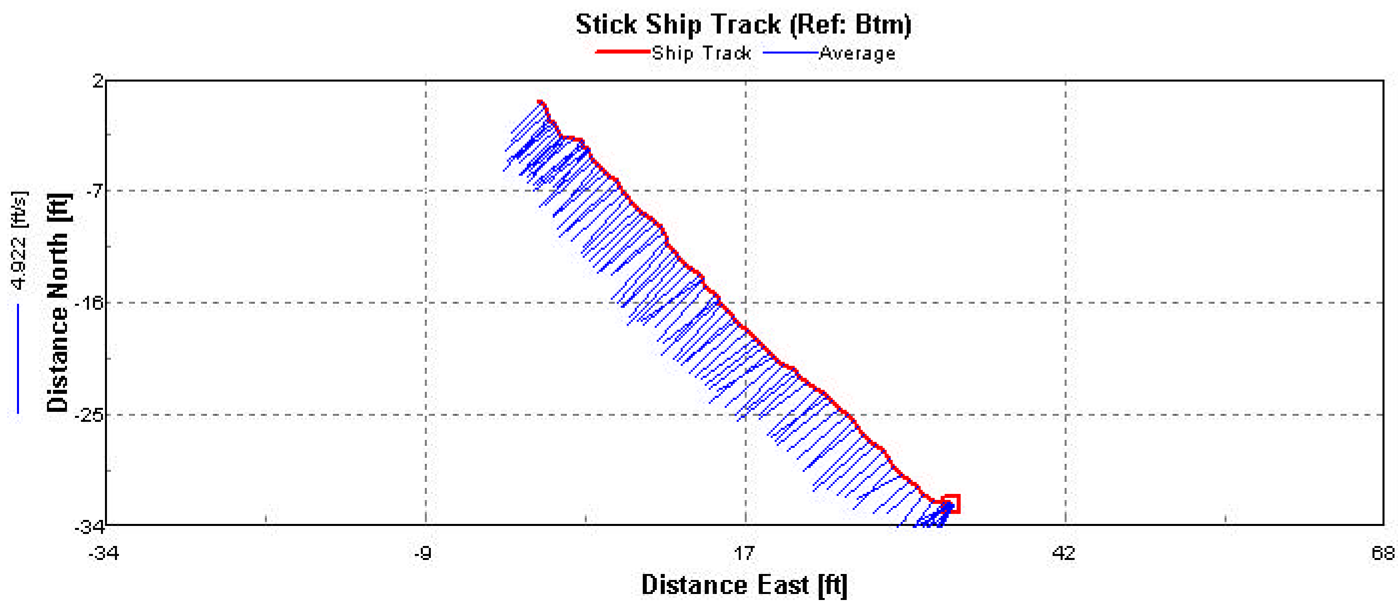
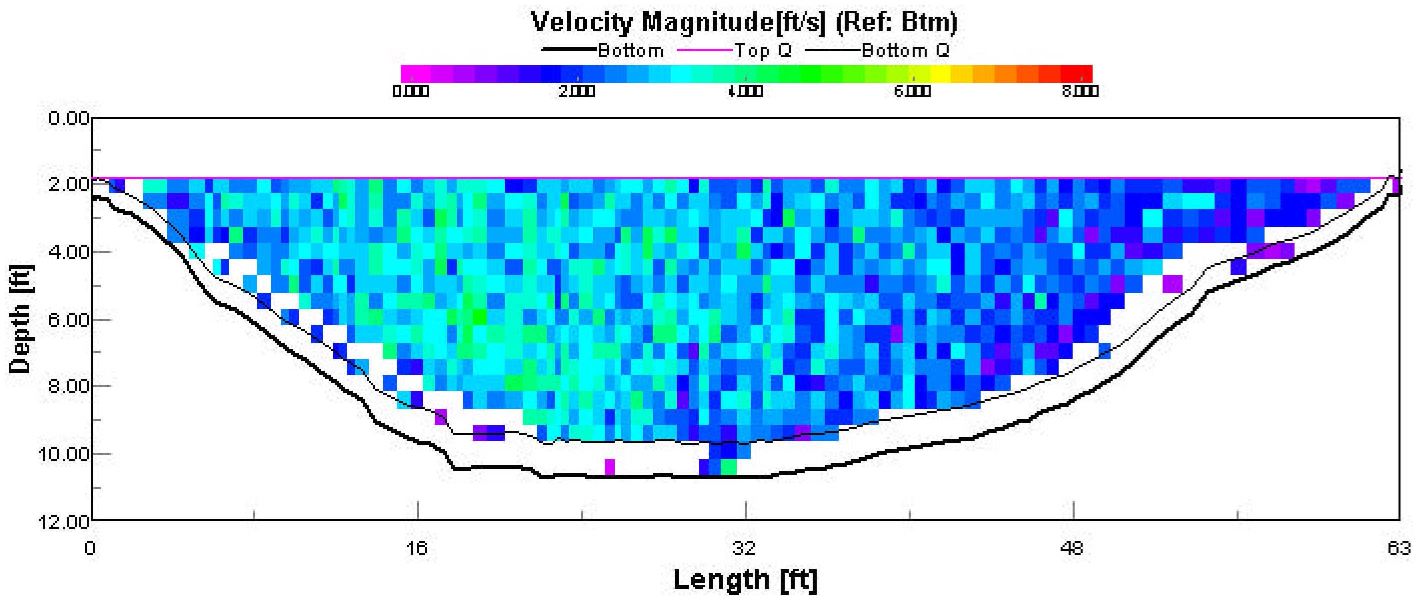


Figure 4 – DWR Gaging Station current profiles (GHC003r.000). ADCP measured discharge was 1130 ft^3/sec. Notice the velocities are uniformly distributed across the channel, and the depth-averaged velocity vectors are mostly perpendicular to the ship track. The velocity ratio of average velocity in the right and left sides of the cross section is 1.07.



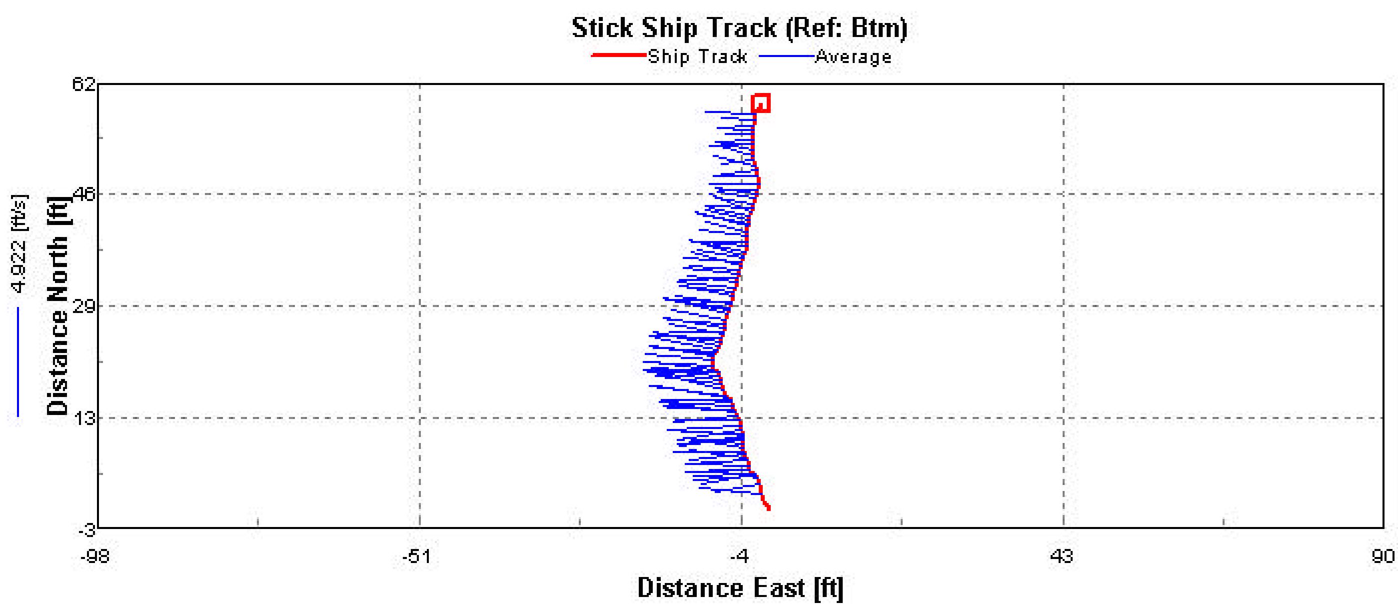
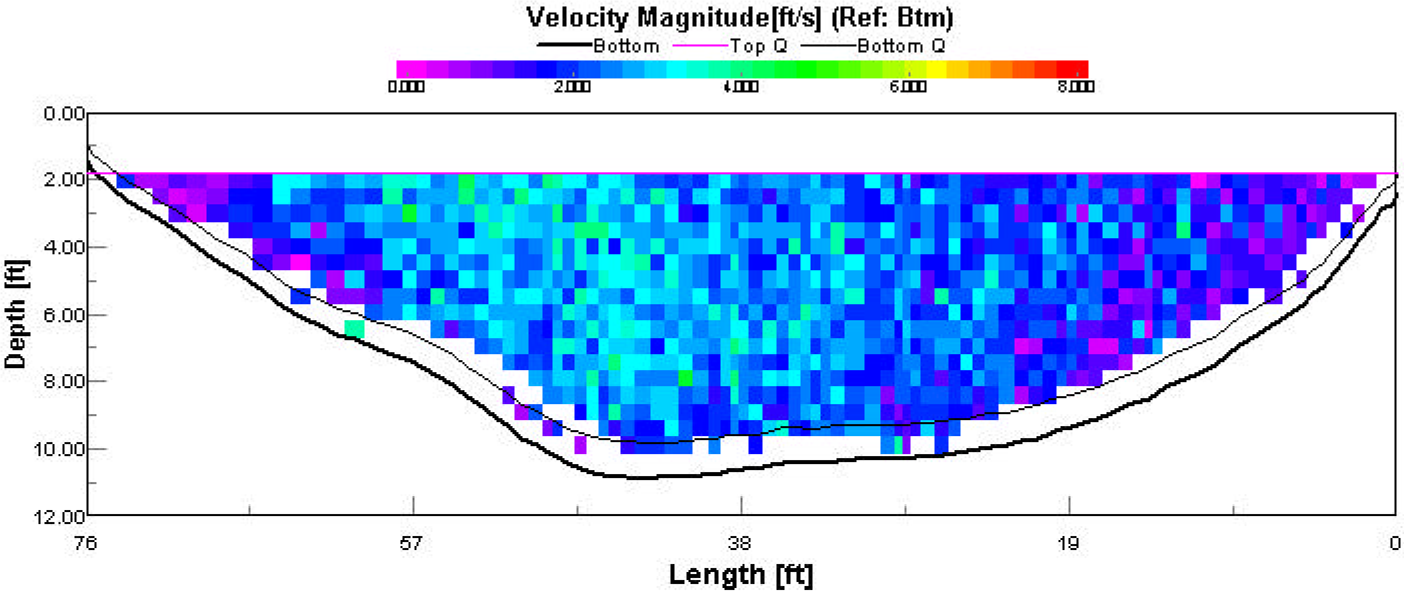


Figure 5 – Site GHC1 current profile (GHC006r.000). ADCP measured discharge was 1182 ft^3/sec. Notice that downstream from the bend the velocities are higher along the left bank. The velocity ratio (V_{right}/V_{left}) of average velocity in the right and left sides of the cross section is 0.76.



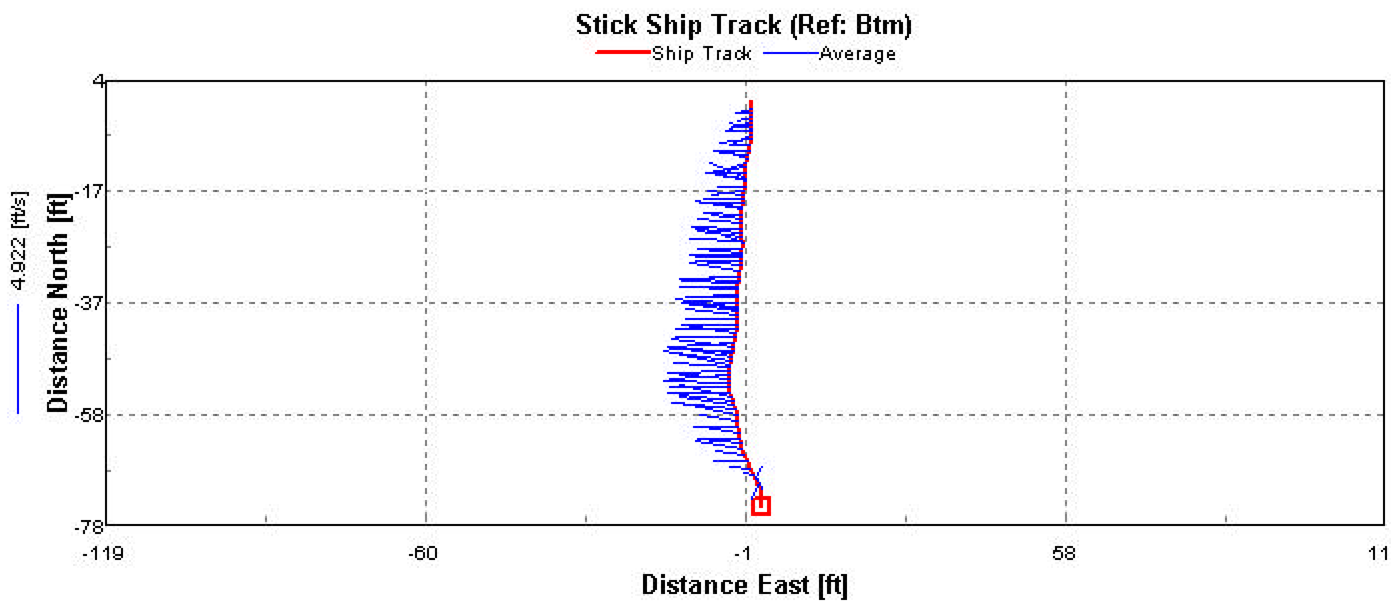
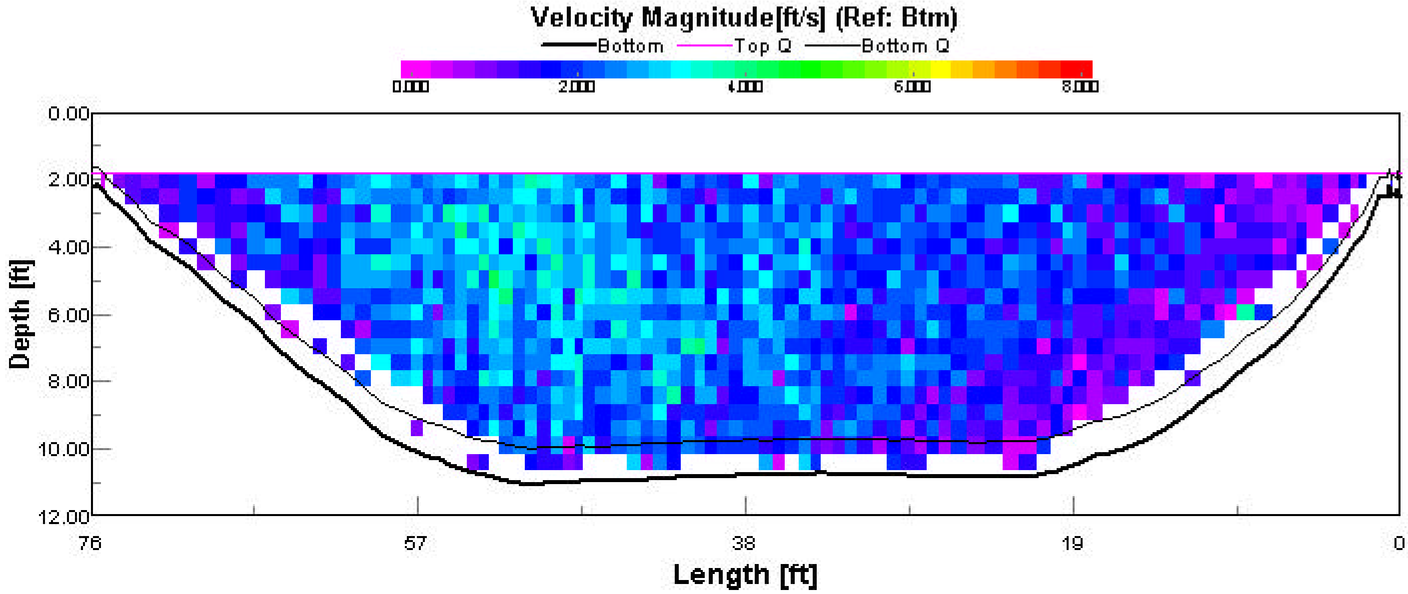


Figure 6 – Site GHC1A current profile (GHC009r.000). ADCP measured discharge was 1184 ft^3/sec. Notice that the velocities are higher along the left bank -the outside of the bend. The velocity ratio (V_{right}/V_{left}) for this cross section is 0.67.



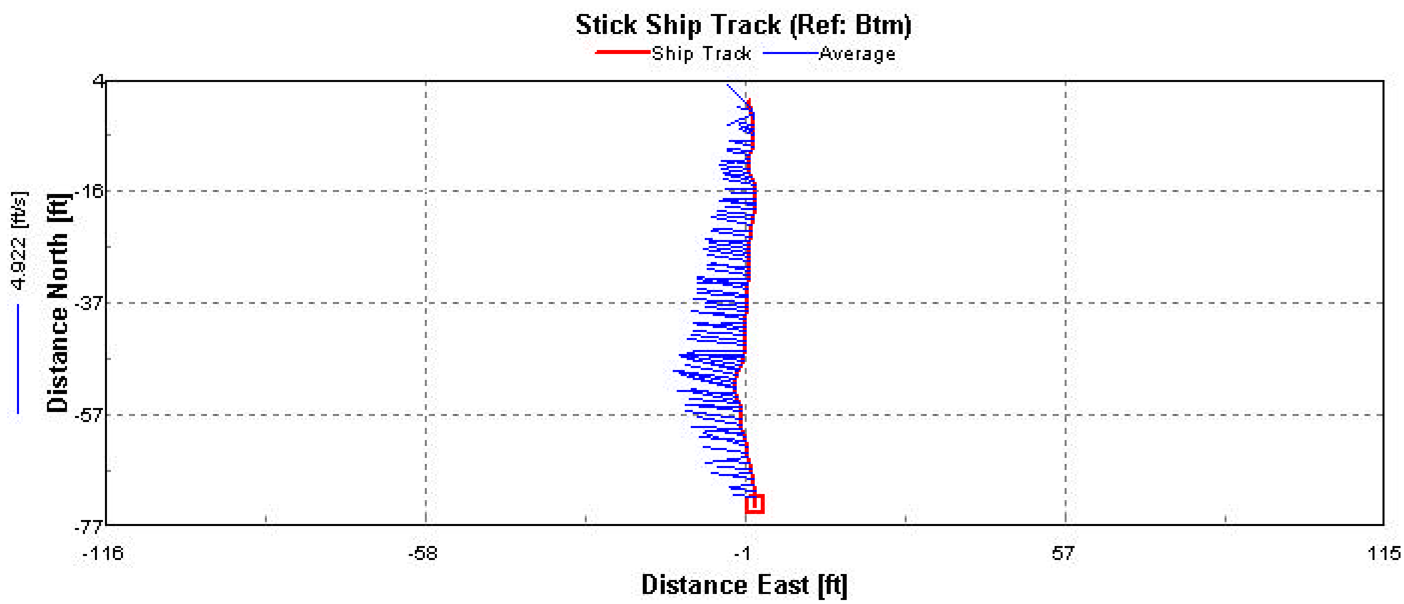
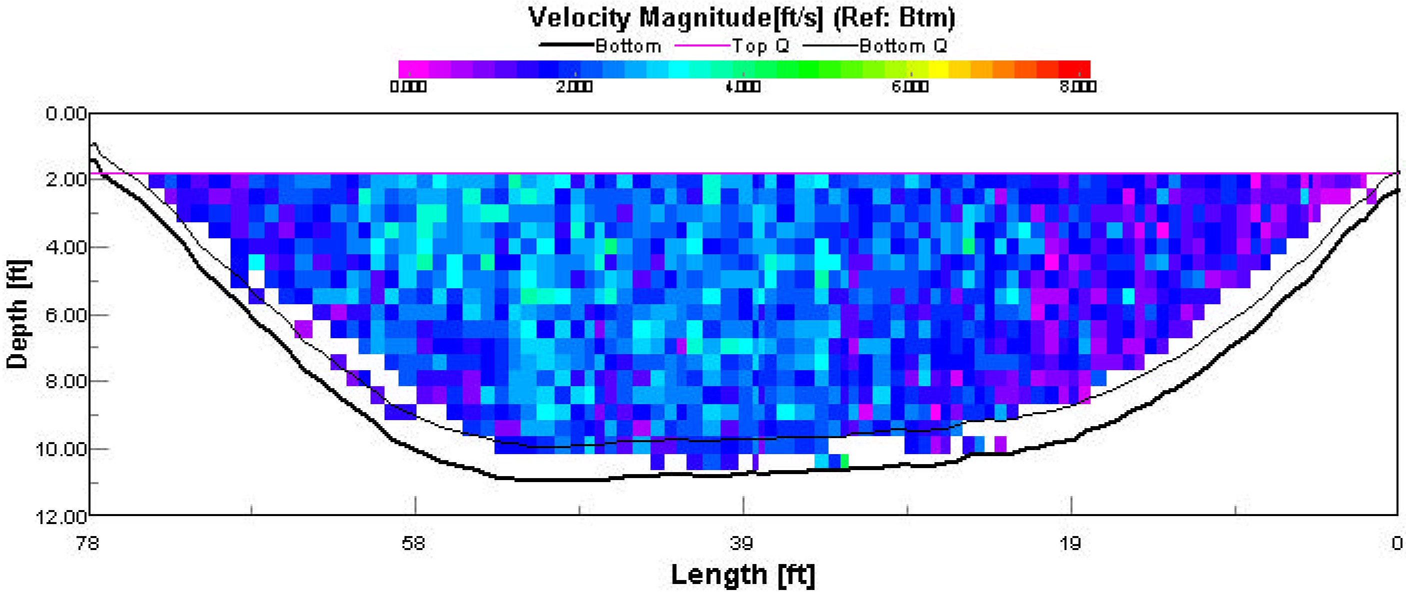


Figure 7 – Site GHC2 current profile (GHC011r.000). ADCP measured discharge was 1204 ft^3/sec. Notice that the skewness in the velocities is starting to diminish. The velocity ratio (V_{right}/V_{left}) for this cross section is 0.67.



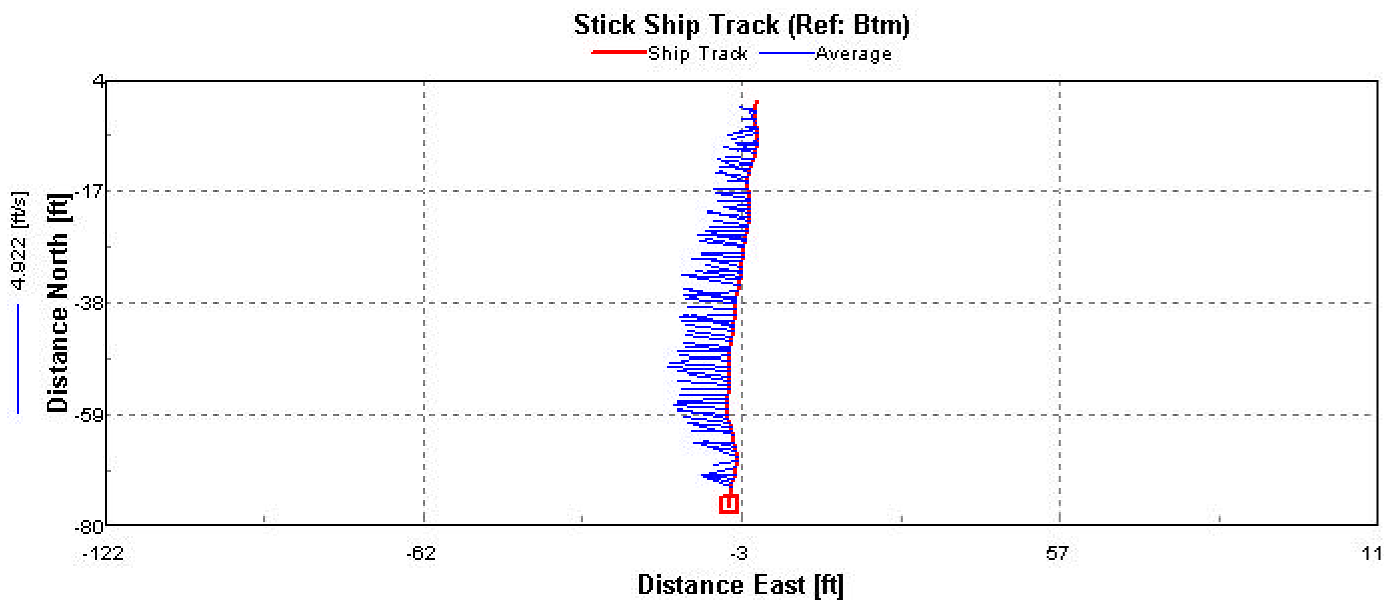
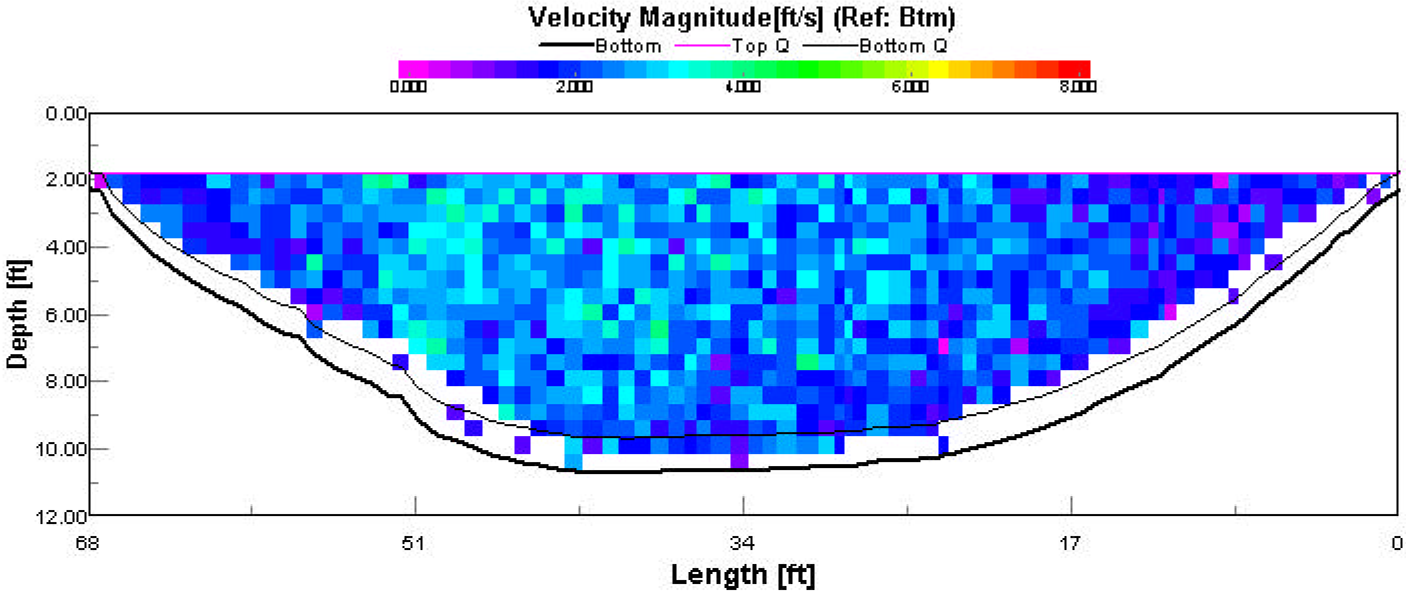


Figure 8 – Site GHC3 current profile (GHC013r.000). ADCP measured discharge was 1115 ft^3/sec. Notice that the velocities are still somewhat higher along the left bank. The velocity ratio (V_{right}/V_{left}) for this cross section is 0.73.



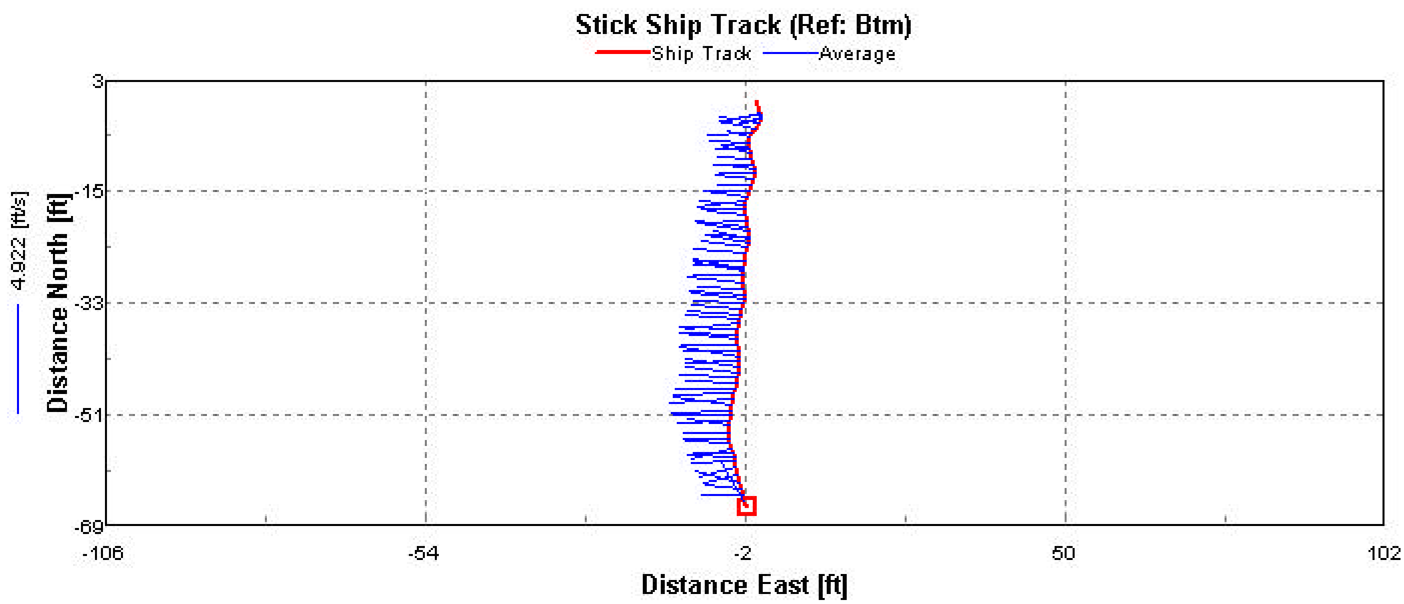
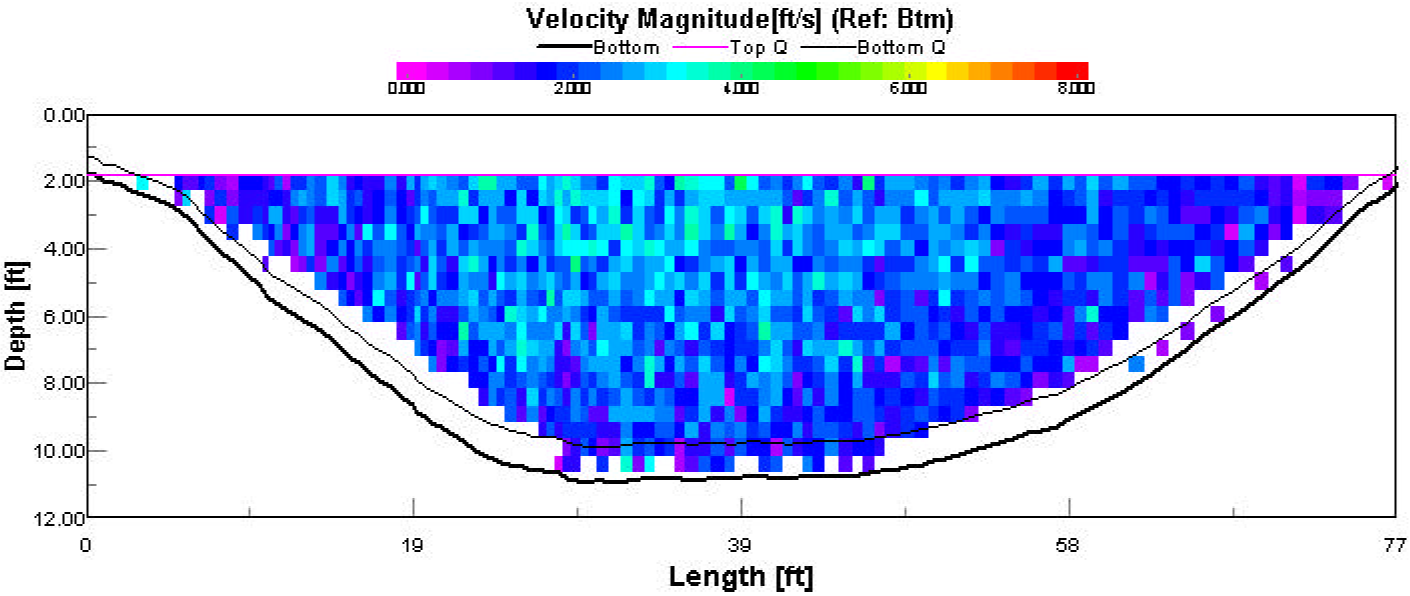


Figure 9 – Site GHC3A current profile (GHC015r.000). ADCP measured discharge was 1162 ft^3/sec. Notice that the velocities are somewhat higher along the left half of the channel. The velocity ratio (V_{right}/V_{left}) for this cross section is 0.81.



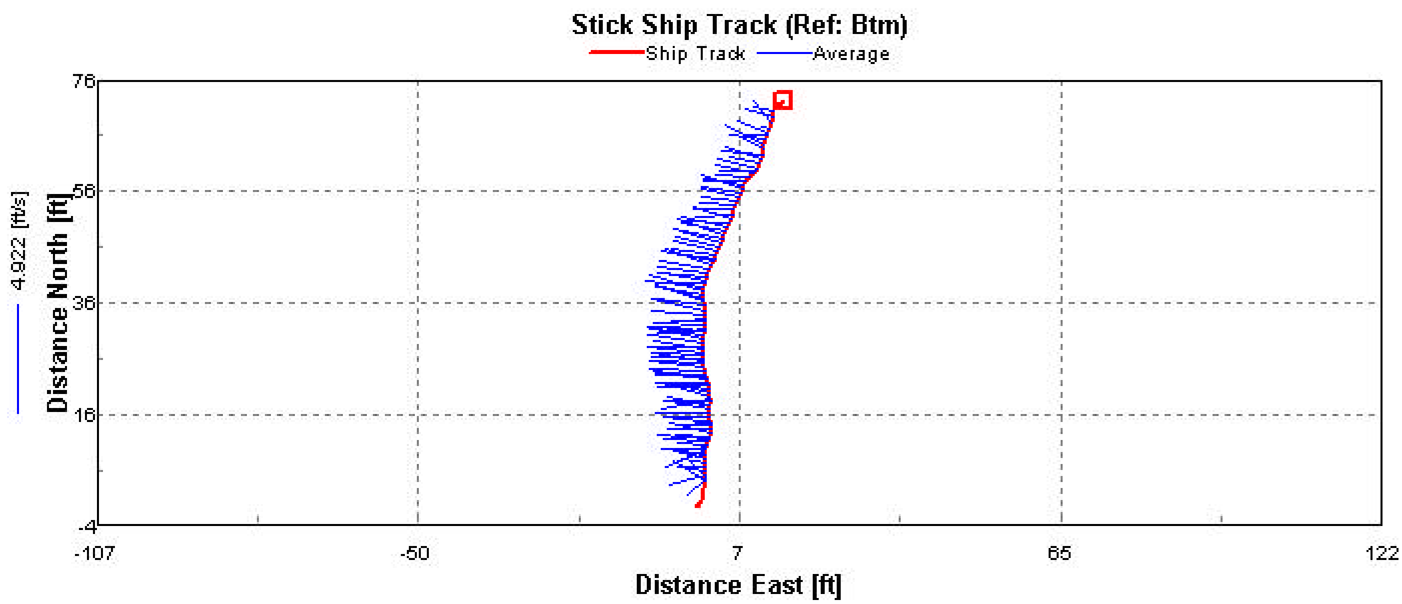
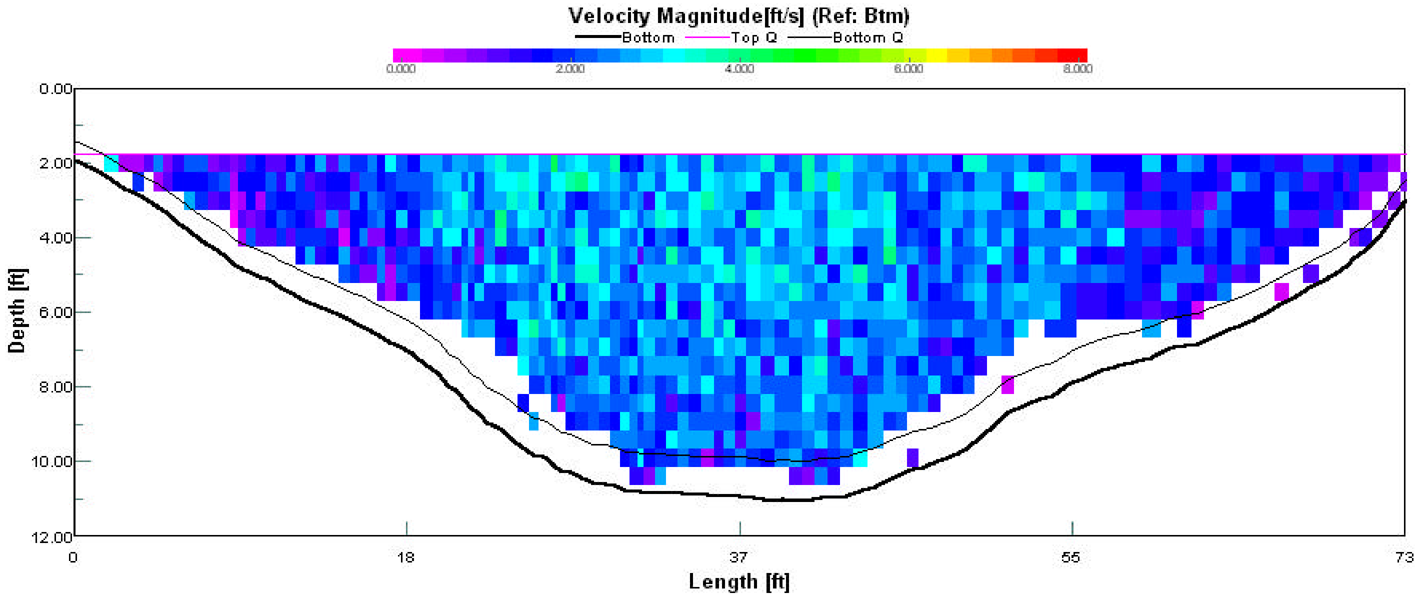


Figure 10 – Site GHC4 current profile (GHC016r.000). ADCP measured discharge was 1174 ft^3/sec. Notice that the velocity distribution is nearly recovered to a uniform condition. The velocity ratio (V_{right}/V_{left}) for this cross section is 0.97.



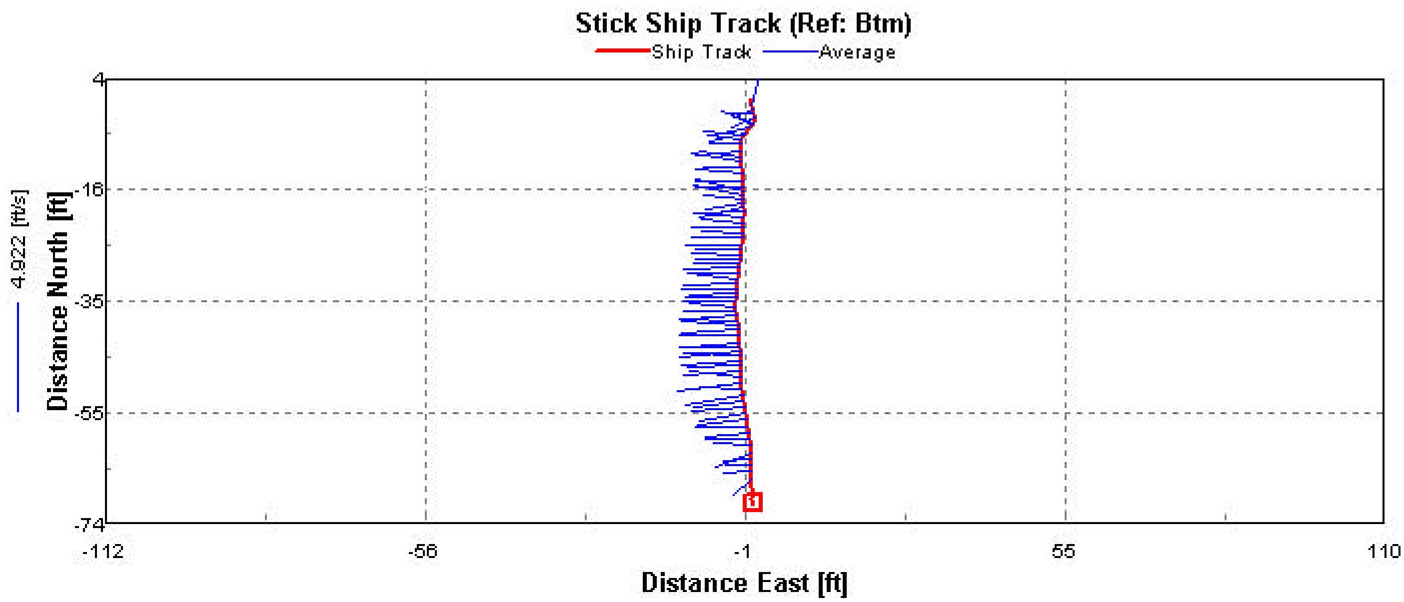


Figure 11 – Site GHC5 (Property Line) current profile (GHC018r.000). ADCP measured discharge was 1125 ft^3/sec. Notice that the velocity skewness is gone and the velocity distribution is nearly uniform. The velocity ratio (V_{right}/V_{left}) for this cross section is 1.03.