ADCP Survey of Half Moon Cover – 16 May 2008.

Jim Irish for Free Flow energy – 5 June 2008 Final Draft

INTRODUCTION:

To evaluate the Half Moon Cove entrance near Eastport, ME as a potential tidal power energy site, a survey was conducted using an RD Instruments 1200 kHz ADCP (Acoustic Doppler Current Profiler) with bottom tracking capability. This instrument measures the Doppler shift from suspended particulates moving with the water to make profiles of water velocity at 0.5 m vertical increments from about 1 m below the surface to about 0.5 m above the bottom. The ADCP also measures the "speed of the bottom" with the bottom tracking, and subtracts that from the water velocity profile observations relative to the ship to obtain velocity profiles relative to the bottom. A number of profiles are averaged together for presentation to reduce the random uncertainty in the velocity observations. A Garmin WAAS (Wide Area Augmented System) enabled GPS was used to determine the position of the observations to better than 3 m.

The ADCP was mounted on the survey vessel (Fig. 1) on a pole over the side. This allowed the ADCP to be positioned close to the surface, yet keeping the transducers in the water for proper operation. The mount also allowed the ADCP to be swung up out of the water for rapid transit to and from the survey area. The ADCP and GPS data were logged on a notebook computer for later processing. The whole system was powered from an absorbed glass mat lead acid battery and a 700 Watt DC to 110 v AC converter.

Figure 1. The RD Instruments ADCP mounted on the side of the survey vessel in Eastport Harbor, ME. The GPS receiver is located on top of the pole holding the ADCP. Pete Feeney is seen on deck. The computer logging was done in the ship's cabin.

HALF MOON COVE SITE:

Half Moon Cove (Fig. 2) is located North and West of Eastport Maine. The road running through Mitchell Point and Carlow is the main road into Eastport. The international line between the US and Canada is the magenta dashed line on the upper right of the chart. Half Moon Cove has a narrow entrance channel into Cobscook Bay which is connected to the Gulf of Maine around the North end of Campobello Island, and through Lubec Narrows. Most of the survey work was done between the two magenta lines marking out the overhead power cable crossing area. The large, shallow area that is flooded by the tides, and flushed through the narrow inlet is what gives the high velocities here that are for interest to potential tidal power generation here.

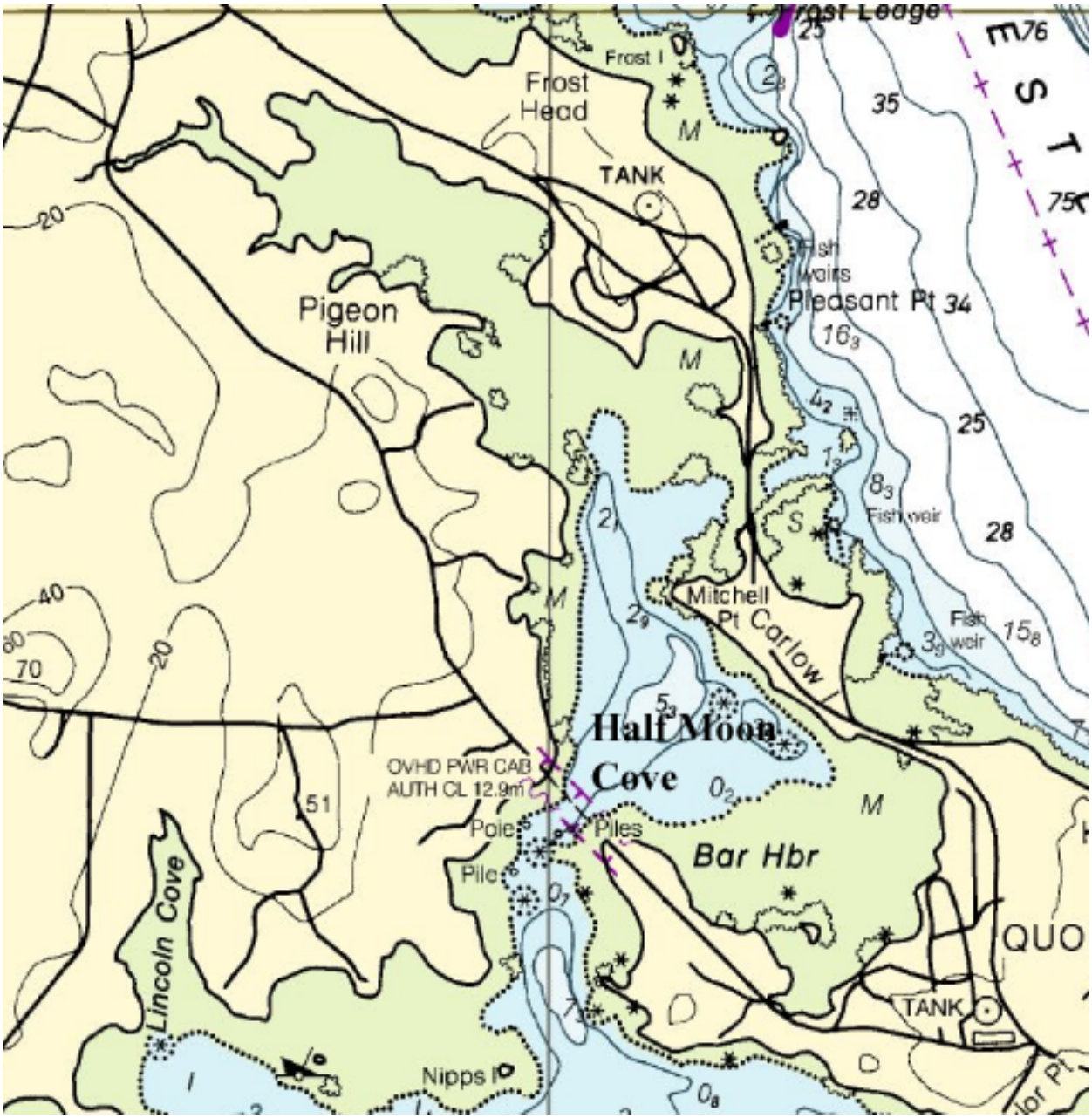


Figure 2. A section from NOAA Chart13394 showing the Half Moon Cover site

TIDES IN THE REGION:

Eastport, Maine is located in the Bay of Fundy at the US Canadian border. Eastport is protected from waves by Campobello Island, which blocks direct access of waves from the Gulf of Maine. The Bay of Fundy-Gulf of Maine system is a resonance basin for frequencies just under the Semidiurnal tide. This creates the very large tidal amplitudes (~8 m) seen at Eastport. This extreme tidal range has the potential to create large tidal currents as areas are flooded and drained each tidal cycle. Half Moon Cover is such an area, hence the interest in this survey.

NOAA/NOS/CO-OPS (National Oceanic and Atmospheric Administration/National Ocean Survey/Center for Operational Oceanographic Products and Services) maintains a tide station (Number 8410140) in Eastport (Fig 3). This station includes meteorological as well as water level information. It is available in near-real time, and from archives on the CO-OPS web site.

Figure 3. NOAA/NOS/CO-OPS tide gauge 8410140 in Eastport, Maine. The instrumentation is housed in the white shack toward the end of the pier/breakwater. The two anemometers for wind speed are on a pole to the right of the shack. The tower on the shack holds solar panels to power the tide gauge and the GOES antenna for sending data back to NOAA. The white pipe to the left of the shack is the tide stilling well which extends down into the water, has a hydraulic filter to reduce wave effects and an acoustic sounder to determine water level.

The predicted tide record for Eastport, ME for May 2008 (Fig. 4) shows the water level elevation changes due to the tides in meters. The predicted tide is the result of the analysis of a year's observations at that station and represents the tidal part of the sea level changes. There are additional sea level changes due to river run-off, storm/wind driven sea level effects, etc. These latter changes are on the order of ¼ m (Fig. 5), and with the tidal range at Eastport, are negligible. The predicted Spring tide for May 2008 has a tidal range of 7.5 meters and occurs about 6 May 2008. The Neap tides during May 2008 occur on 14 and 26 May. The time

available for people and equipment for the survey of Half Moon Cove was 16 and 17 May 2008 (see red stars in Figs. 4 and 5). The tidal range at the time of the survey was 6.0 meters. As this was near the neap tidal range, we expect the survey results to represent a "low flow" condition, with Spring tides producing velocities about 1.25 times as large as reported below.

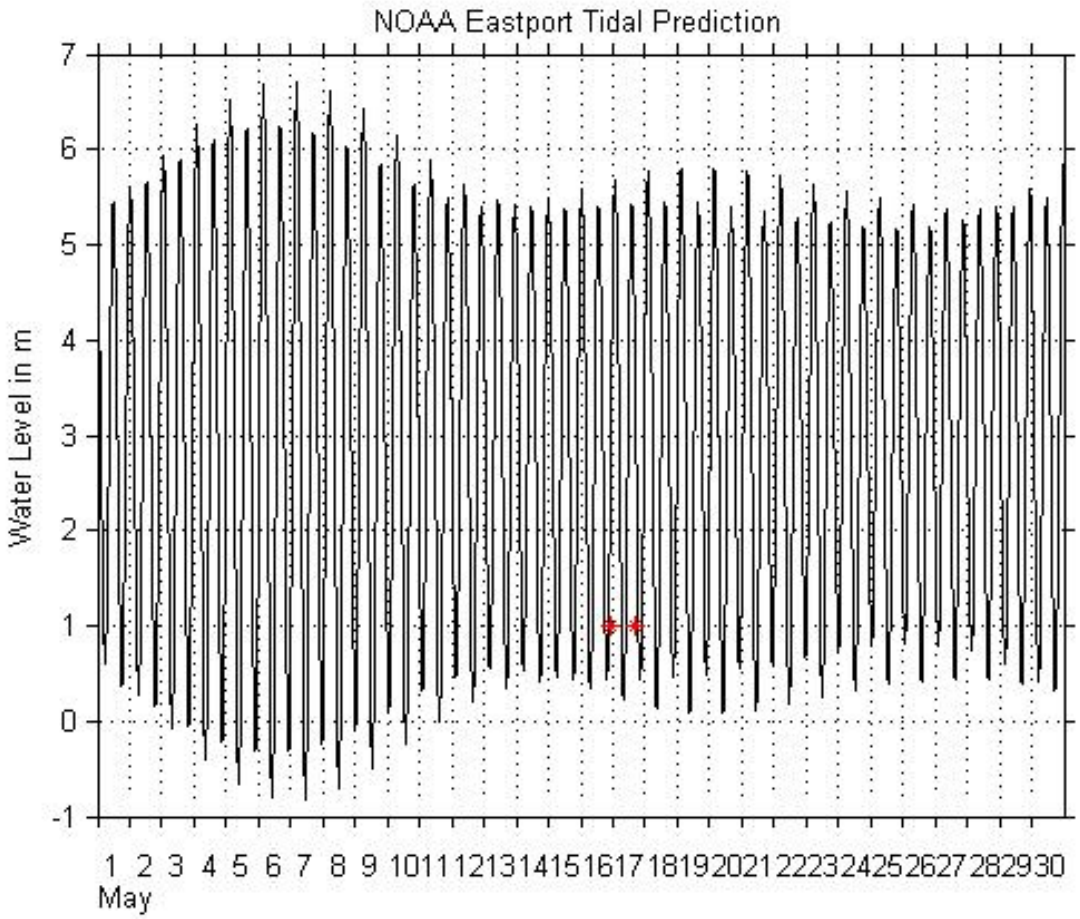


*Figure 4. The NOAA/NOS/CO-OPS prediction for tide gauge 8410140 in Eastport Maine for the month of May, 2008. The elevation is reported relative to MLLW. The times of the flood and ebb tidal surveys are shown by the red *.*

The observed tidal elevations from 16 and 17 May 2008 are shown in Fig. 5. The weather forced signal (the difference between the observed and the predicted sea level) is shown as the blue line. The times of the survey were selected to be about mid-tide as shown by the red * in Fig. 5.

The nearest current observations to Half Moon Cove, were made by the GoMOOS (Gulf of Maine Ocean Observing System) buoy J02 in Coobscook Bay 44° 53'24" N x 67° 00'45" W in 35 meters (114 feet) of water south of Half Moon Cove. This buoy (Fig. 6) has an aluminum frame and well, surrounded by a Surlyn foam flotation collar. The meteorological sensors (wind speed and direction, air temperature and barometric pressure, and visibility) are mounted on top of the buoy tower, and water observing sensors (temperature and salinity at 1 and 10 m) hung under the buoy on the mooring cable. Currents are measured by an Aanderaa RMC-9 current meter mounted in the mooring line at 2 meters depth (Fig. 6). An accelerometer in the buoy is used to measure the waves (significant wave height and dominate wave period).

The Aanderaa current meter data for the 16 and 17 May 2008 (Fig. 7), show current speeds peaking at 1.5 m/s (3 kts). However, this was for the higher tides which occurred during the night, and so were not safely observed in the survey. The lower of the two tides were the ones which we were able to survey. At these times, the GoMOOS buoys saw speeds of 1.25 m/s (2.5 kts). The direction shows the back and forth flow (300º or 120º) in the channel.

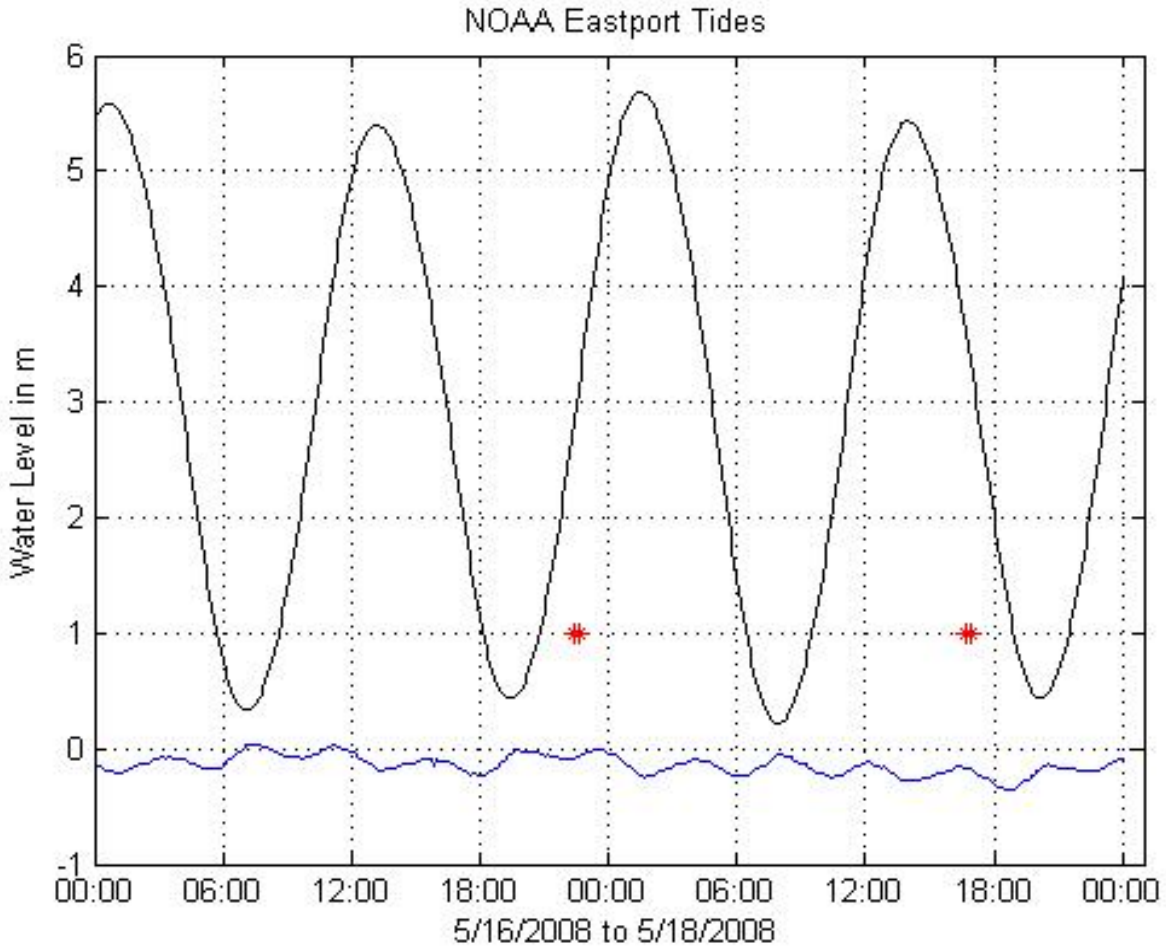


*Figure 5. . The NOAA/NOS/CO-OPS tide gauge 8410140 in Eastport Maine observed water level for the 16 and 17 May, 2008. The elevation is reported relative to MLLW. The times of the flood and ebb tidal surveys are shown by the red *. The blue line is the difference between the predicted tide and the observed water level*

SURVEY RESULTS: SURVEY 1 – FLOOD TIDE – 16 MAY 2008.

Two surveys were run in the entrance to Half Moon Cove (Fig. 2). The first survey was late in the afternoon of 16 May 2008 during a flood tide. The log made at the time of the survey is shown in Table 1. There are four surveys listed – 1 and 3 are of Half Moon Cove and 2 and 4 are for Lubec, Me (not presented here). Note that HMB### shown on the plots of the ADCP data is the program's file name convention for the surveys of Half Moon Cove. The Track number starts with 1 and continue through the survey. Not all tracks were good and these are not shown.

Figure 6. GoMOOS buoy J02 being retrieved for servicing by U. Maine, Ororno staff aboard the R/V Argo Maine. The meteorological sensors are on top of the tower. The sensor just below the buoy is the Aanderaa current meter at 2 m depth. The GoMOOS buoys are serviced at 6-month intervals, or when repair is need. Newly refurbished buoys are seen on either side of the deck, ready for deployment.

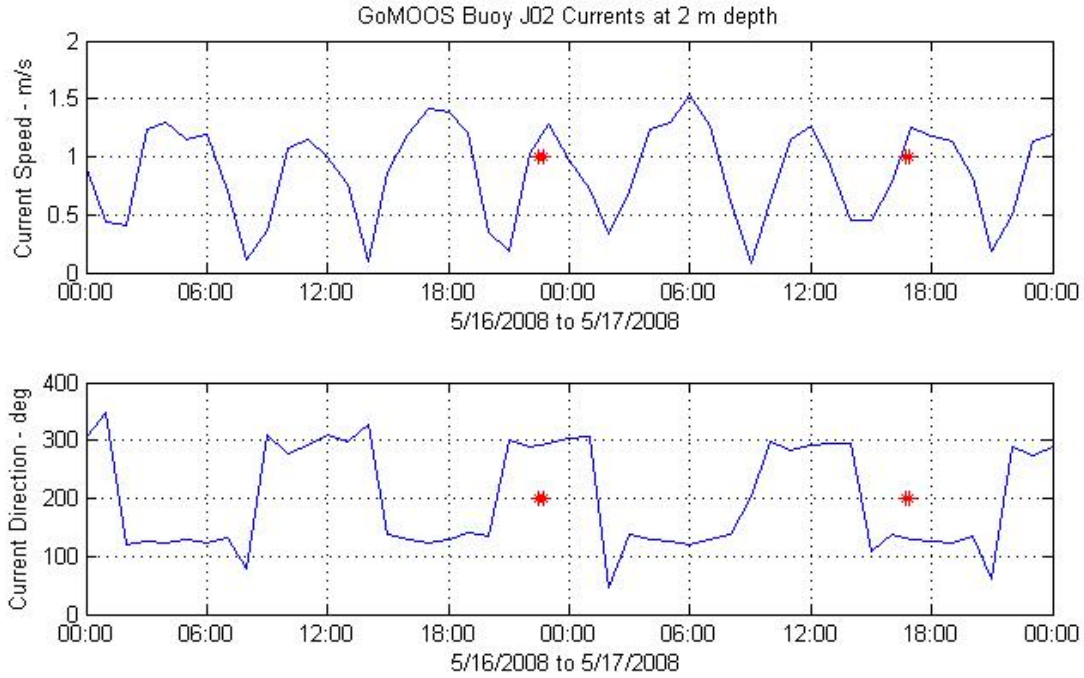


*Figure 7. GoMOOS Buoy J02 current speed and direction at 2 m depth. The red * are the times of the ADCP survey of Half Moon Cove.*

Table 1: ADCP Survey Log - Half Moon Cove, Eastport, ME.

Start of Operations on 16 May 2008
Survey 1: Flood Tide - Sunny and Calm

ADCP time 6 seconds fast (ahead) of GPS time

UTC
2120 – HMB019: running around in mouth of HMC
2145 – end HMB019
2225 - GPS log on "hmcgps.txt"
222645 – HMB020: Track #1 – start W to E section
223006 – end HMB020
223040 – HMB021: Track #2 – start E to W section - Just south of power lines
223240 – end HMB021
223310 – HMB022: Track #3 – start W to E section
223455 – end HMB022
223522 – HMB023: Track #4 – start E to W section - Seaward of power lines
223750 – end HMB023
223818 – HMB024: Track #5 – start W to E section
224128 – end HMB024
224543 – HMB025: Track #6 – in middle of channel
224722 – Boiling water
224538 – under lines – North of boiling water
225746 – North of power lines
225406 – end HMB025

End operations for May 16

Start of Operations on May 17
Survey 3: Ebb Tide - Raining and Windy

ADCP is 8 seconds fast (ahead) of GPS

UTC
162857 – GPS log on
164011 – HMB029: Track #10
164050 – Start of Run
164347 – end HMB029 – transducer out of water – 100 yds in front of power lines
164702 – Start HMB030: Track #11
165022 – End HMB030
165048 – Start HMB031: Track #12
165256 – End HMB031
165332 – Start HMB032: Track #13 – right under power lines
165538 – End HMB031
165631 – Start HMB033: Track #14 – just north of power lines
165744 – Start along section
165953 – End HMB033 – under last wire of power line - going out of Cove
170147 – End HMB034
170655 – Start HMB035: Track #16 – under wires
170834 – End HMB035

End operations for May 17 – End of Survey

The data from the flood tide survey is shown in Figs. 8 through 13. The top panel on each figure is the GPS track for the whole survey with the track for the ADCP data shown in red. The ADCP section is shown in the bottom panel. The scale of the GPS sections is the same for both Surveys, and the depth and speed scales are the same for all ADCP sections. The horizontal scale is adjusted so the survey extends across the page. The length of the section is shown at the bottom of each section plot. These sections are used to determine the transport of a river, and so the velocities shown are normal to the section. Therefore a section along the channel appears to have low velocities, when in fact it only see one component of the flow.

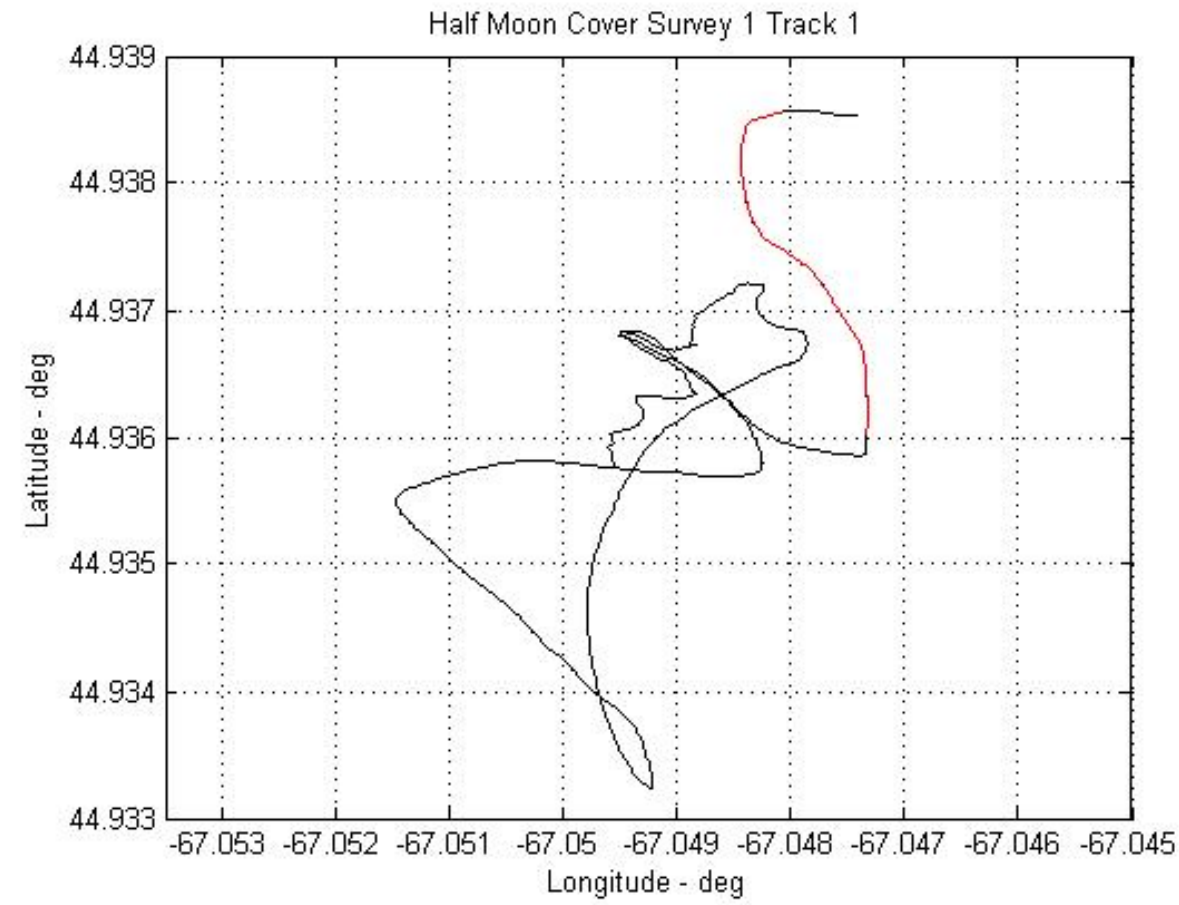
The direction traveled is always from left to right on the section, even when we run back over the same line (Figs. 9 and 10). The heavy black line at the bottom of the section is the bottom as seen by the ADCP. The lighter line above it the maximum depth of good data as determined by the ADCP. The data are displayed with the 0.5 m vertical resolution. The data are averaged in the horizontal direction (about 5 times longer than seen in real-time on the computer when we were doing the survey). This averaging reduces the uncertainty in the velocity estimate, and so is less noisy.

Summary of results from Survey 1:

- Fig 8 shows the current after it has made its way into Half Moon Cove. It's maximum is located in the deep part of the main channel inside the Cove from the overhead wires. The velocity on each side of the channel is negligible.
- Figs. 9 and 10 are under the wires and are a run back and forth across the channel at nearly the same place. The low currents in the shallow waters to the east are seen clearly in Fig. 9. In both figures, the maximum currents are toward the west of the deep channel. This is up in the shallower regions and probably relates to the flow coming into the mouth of Half Moon Cove from the south having to turn toward the northeast. This pattern is also seen in Figure 13 where we ran back through this area with a jog going over the same places as the west end of Figs 9 and 10. All these survey lines show maximum currents of 2.2 m/s (4.4 kts) in these shallower regions.
- When you get out side of Half Moon Cove (Figures 11 and 12) the channel is not as well defined and the velocities are lower.

SURVEY RESULTS: SURVEY 3 – EBB TIDE – 17 MAY 2008.

The second survey was run mid-day of 17 May 2008 over the same region of the narrow entrance to Half Moon Cover. Some of the lines were occupied. Plots similar to those for Survey 1 were generated and given in Figs. 14 to 19. A comparison of the tracks of the two surveys is given in Fig. 20.



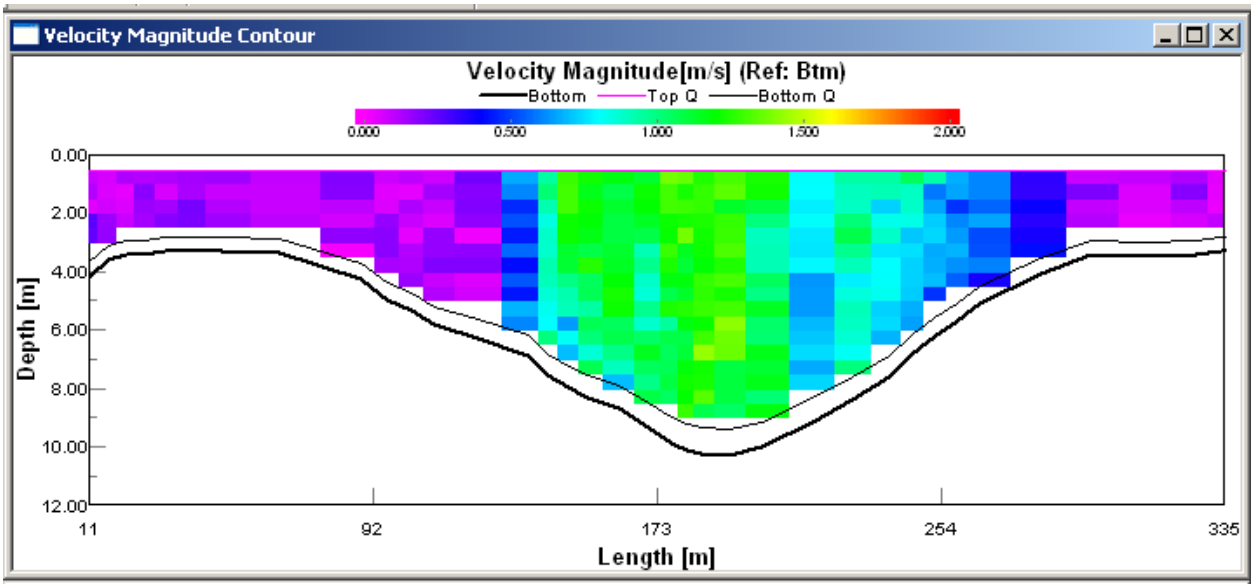


Figure 8: Track 1 HMB20 – traveling from North to South (top) and left to right (bottom). Maximum velocity is about 1.4 m/s (2.8 kts) in the middle of channel. Most of water transport is in middle of channel. This section is inside Half Moon Cove from the power lines, and looks like a reasonable place to deploy a turbine in the middle of the channel.

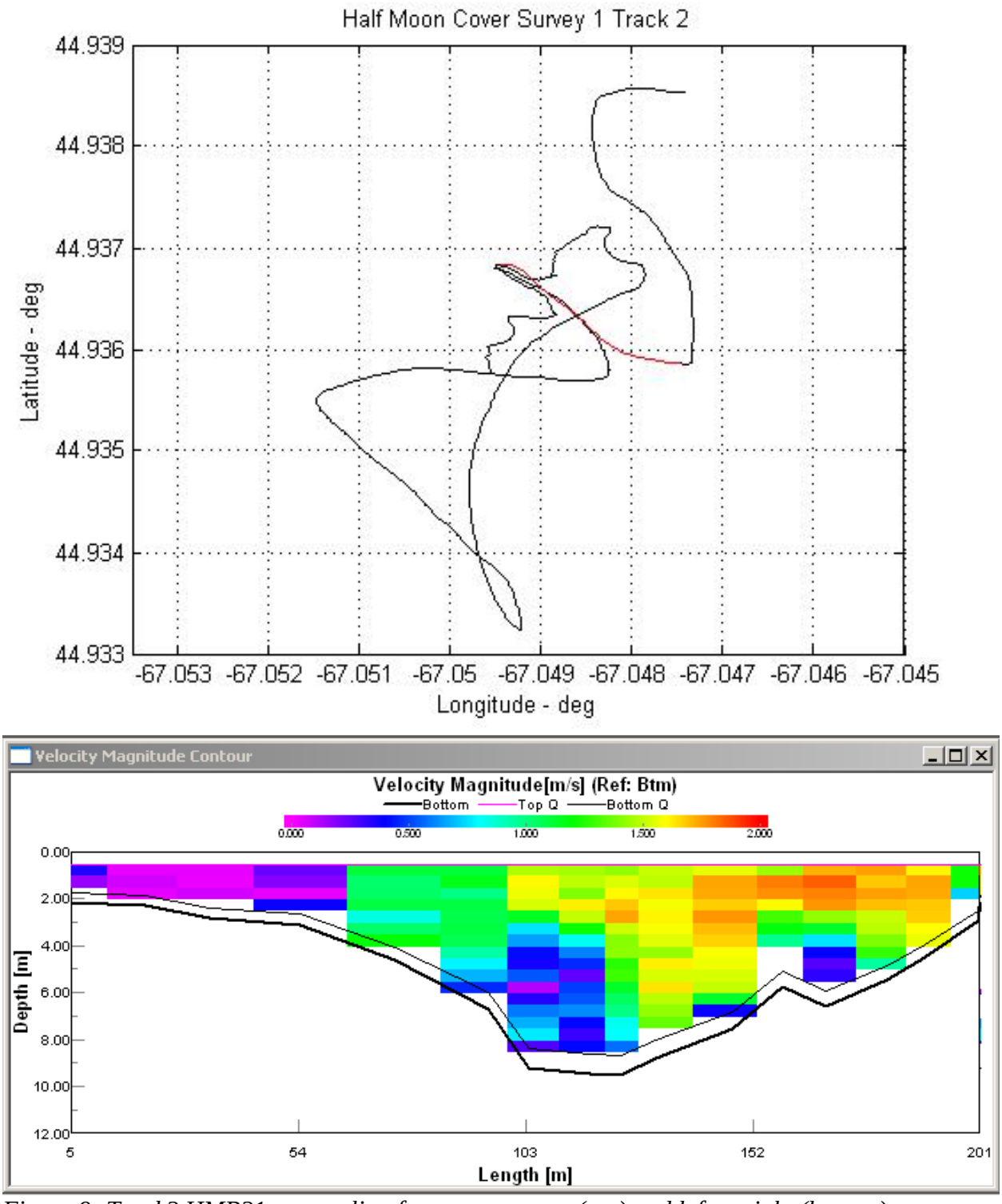


Figure 9: Track2 HMB21 – traveling from east to west (top) and left to right (bottom). Maximum velocity about 1.8 m/s (3.6 kts) toward the west of the main channel. This section is taken crossing under the power lines, and is repeated going the opposite direction in Fig. 10.

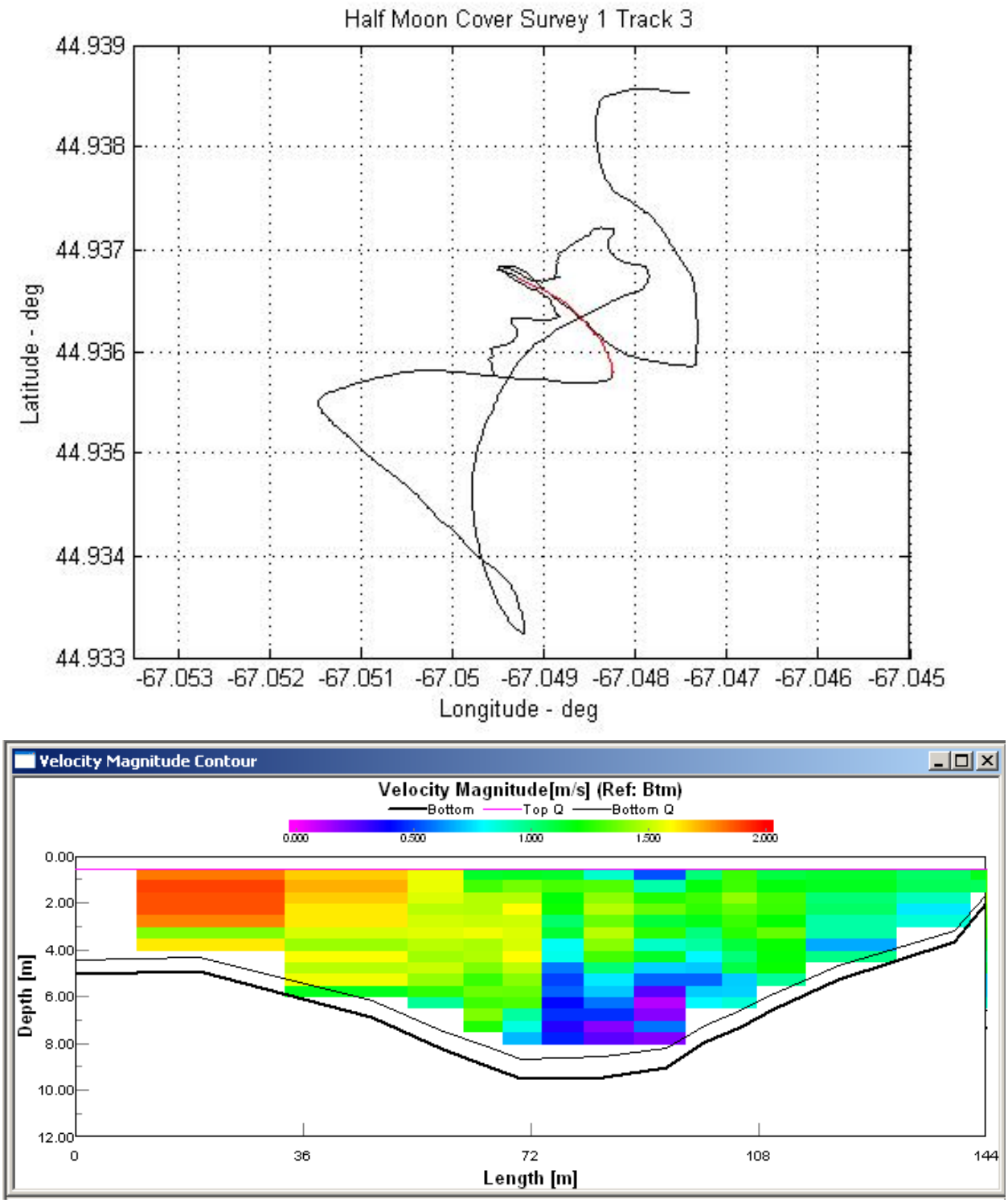


Figure 10: Track3 HMB22 – traveling from west to east (top) and left to right (bottom). Maximum velocity about 1.9 m/s (3.8 kts) toward the west of the main channel. This section is also under the power lines, and a repeat of the section shown in Fig. 9.

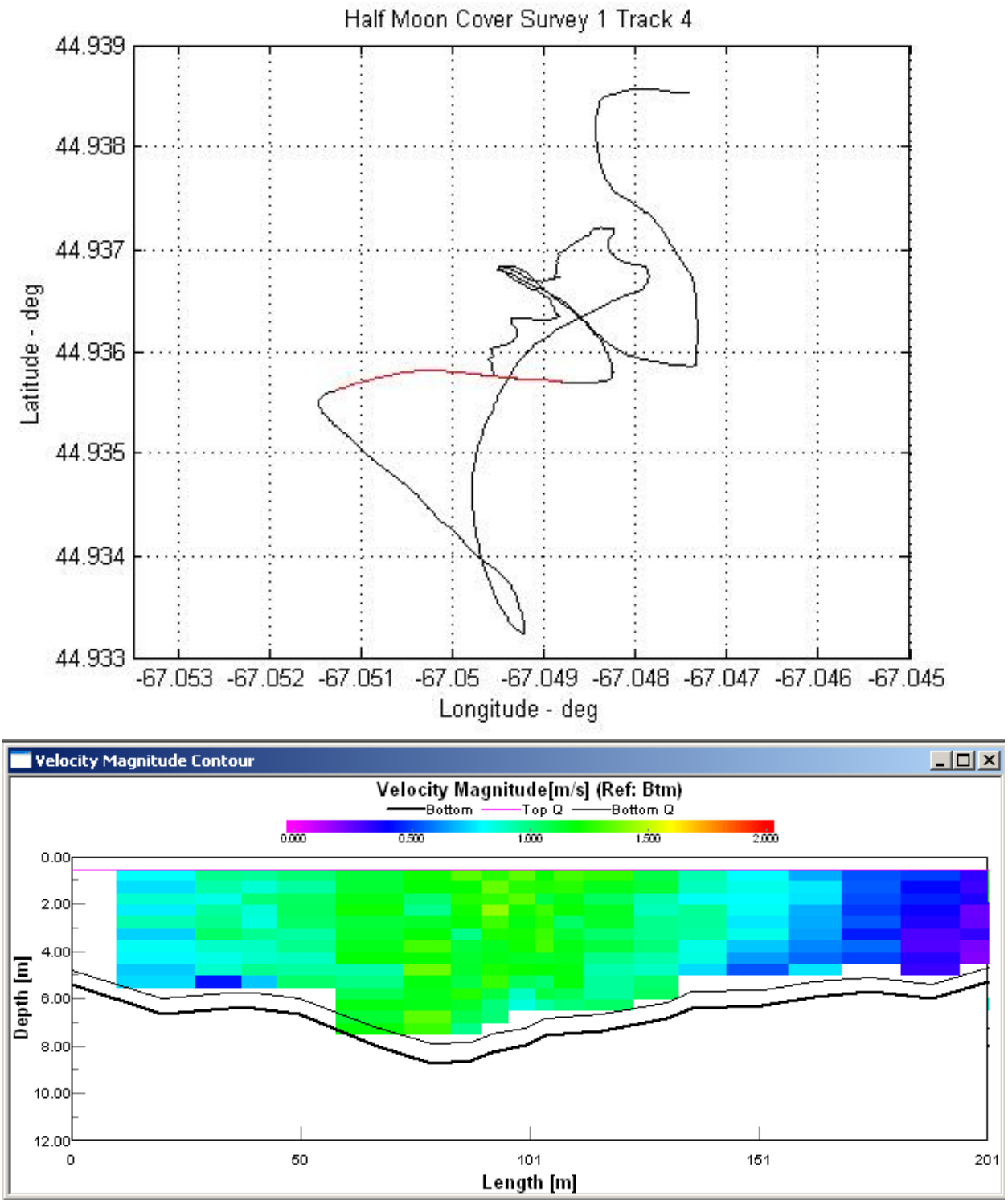


Figure 11: Track 4 HMB23 – traveling from east to west (top) and left to right (bottom). Maximum velocity about 1.4 m/s (2.8 kts) again centered on deepest part of the channel. This section is run from the east side under the power lines, somewhat along the channel to the west.

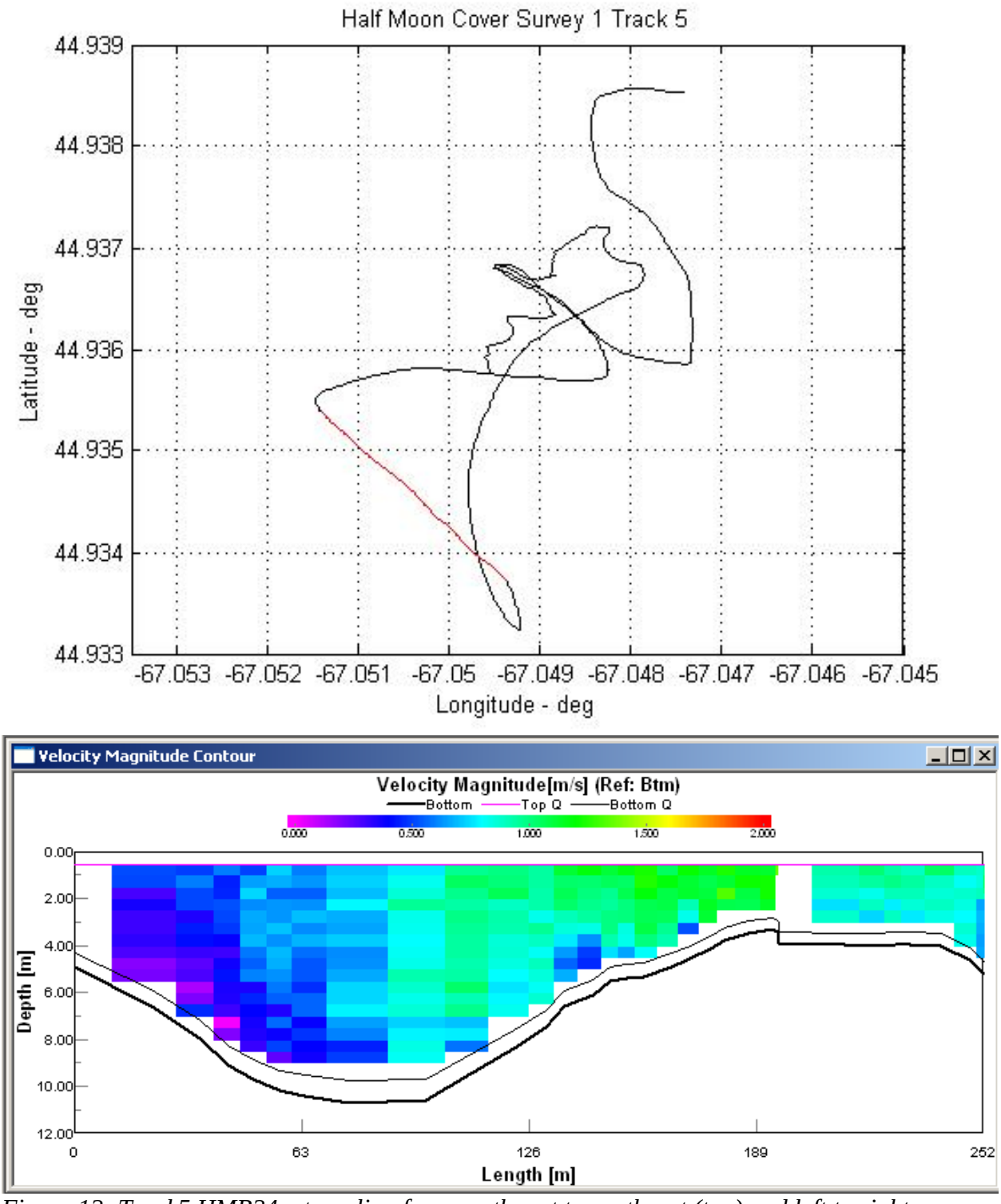
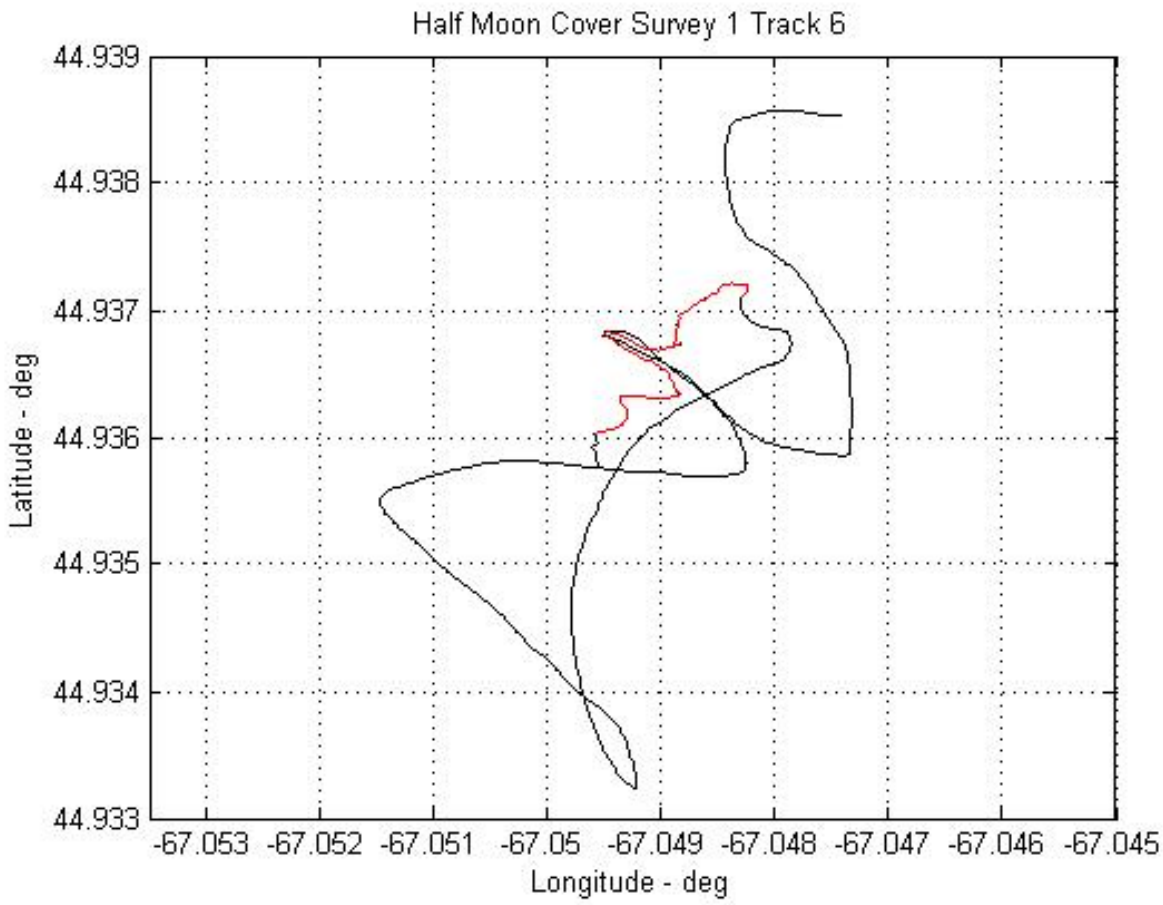


Figure 12: Track5 HMB24 – traveling from northwest to southeast (top) and left to right (bottom). Maximum velocity about 1.2 m/s (2.4 kts) toward the southeast of the main channel. This section is outside of Half Moon Cover from the power lines. This track was reoccupied on the Ebb tide in Survey 3 Track 11 (Fig. 15).



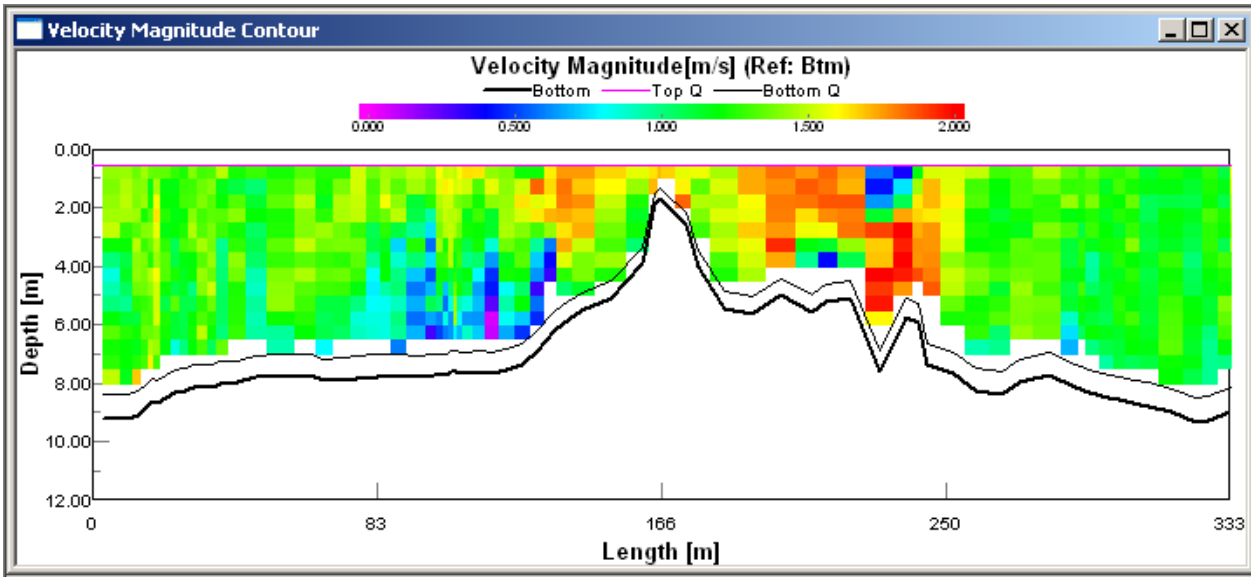


Figure 13. Track6 HMB25– traveling sort of along channel (top) with a little jog to the northwest and left to right (bottom). Maximum velocity about 2.2 m/s (4.4 kts) in the region of the jog which is just to the west of the main channel and is the region of most rapid velocities in Fig 9 and 10. This implies that under the power lies, and during the flood, the highest velocities are found out of the deepest part of the channel on the west side.

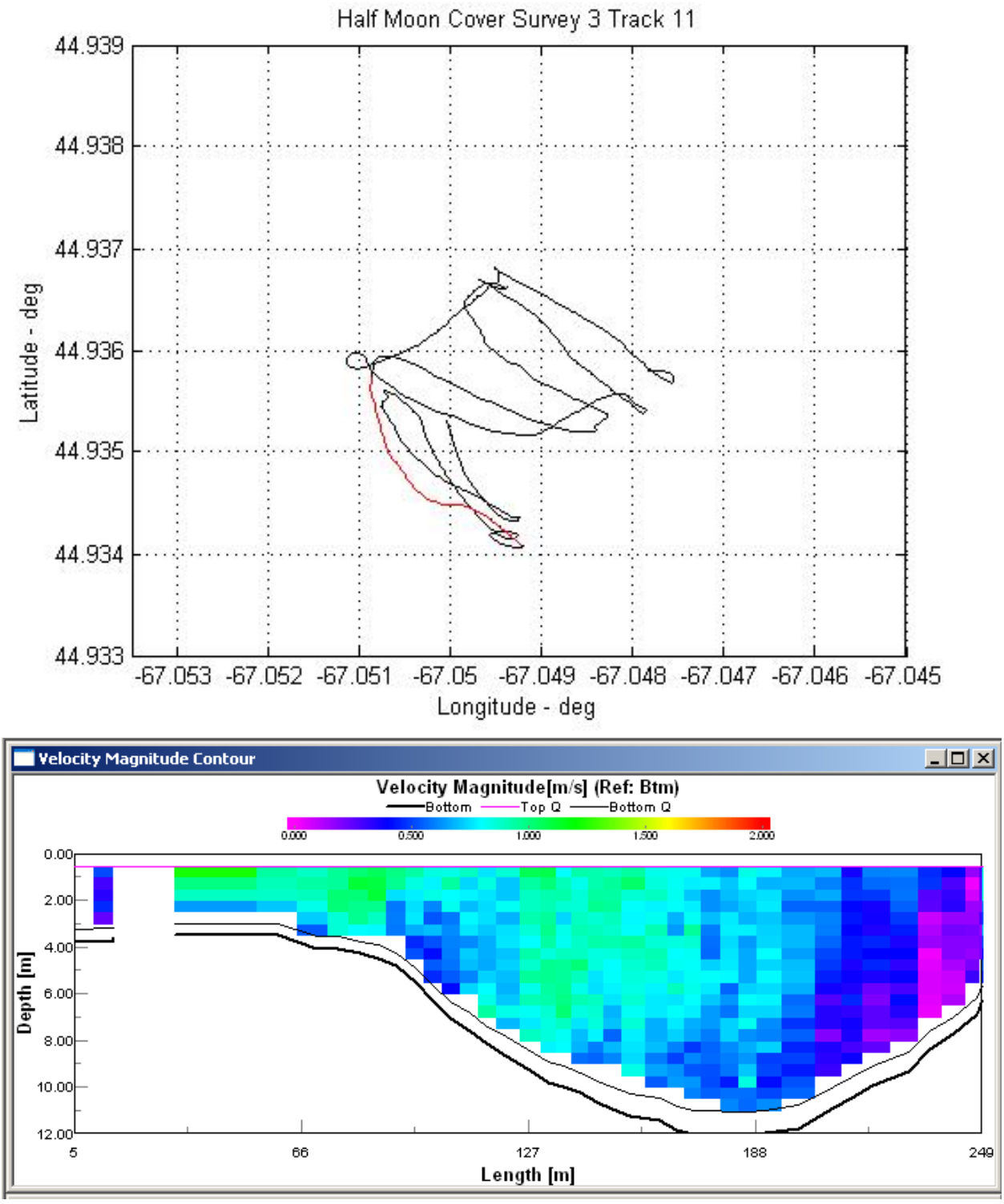


Figure 14: Track11 HMB30 – traveling from southeast to northwest (top) and left to right (bottom). Maximum velocity about 1.0 m/s (2.0 kts) located just to the southeast side of the main channel. This transect is located nearly on the Section 1 Track 5 (Fig. 12) 100 m in front of power line. On both of these sections on the Ebb and Flood, the maximum current is found on the southeast side of the deepest part of the channel.

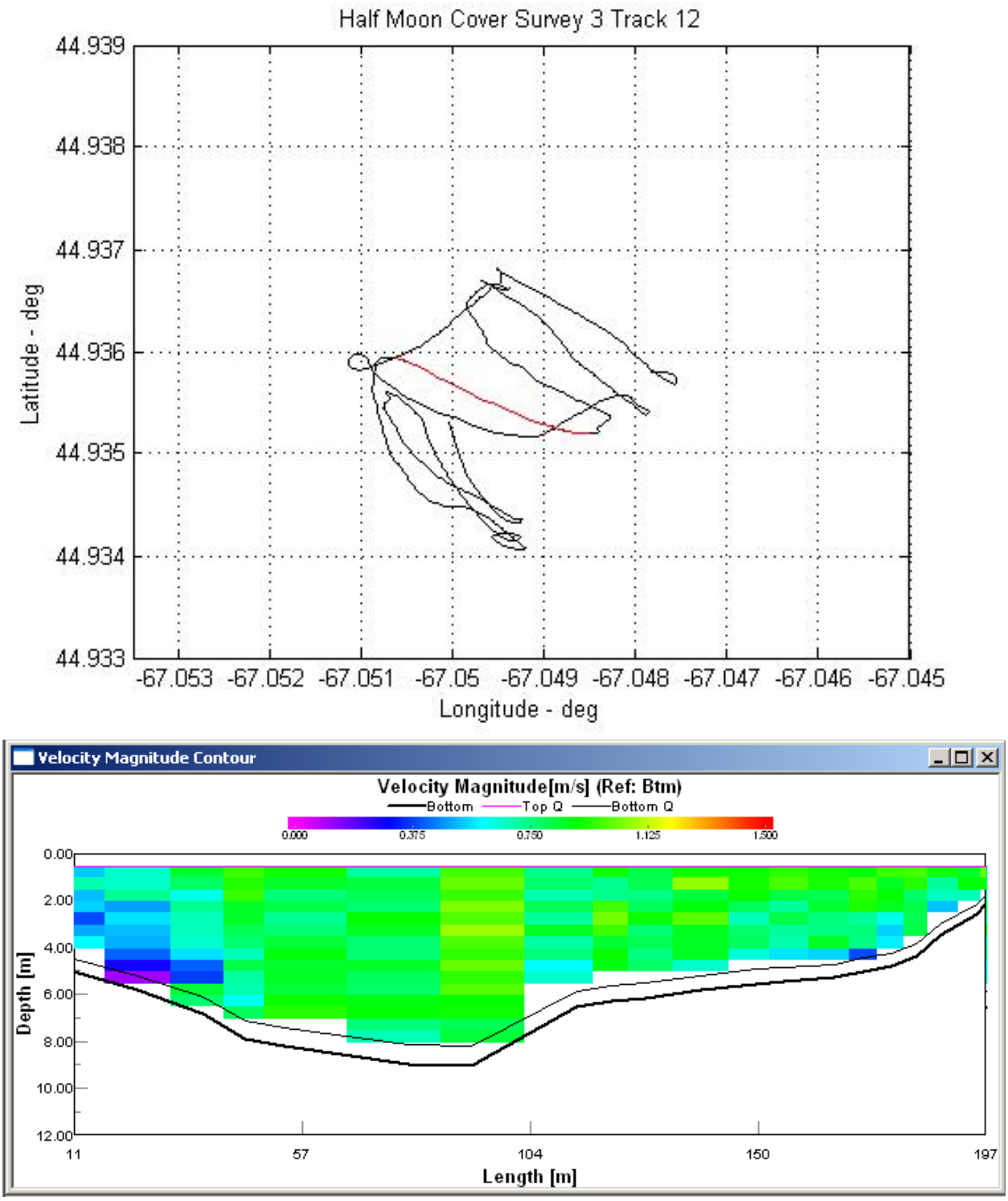


Figure 15: Track12 HMB31 – traveling from northwest to southeeast (top) and left to right (bottom). Maximum velocity is about 1.1 m/s (2.2 kts) and located on the southeast side of the main channel.

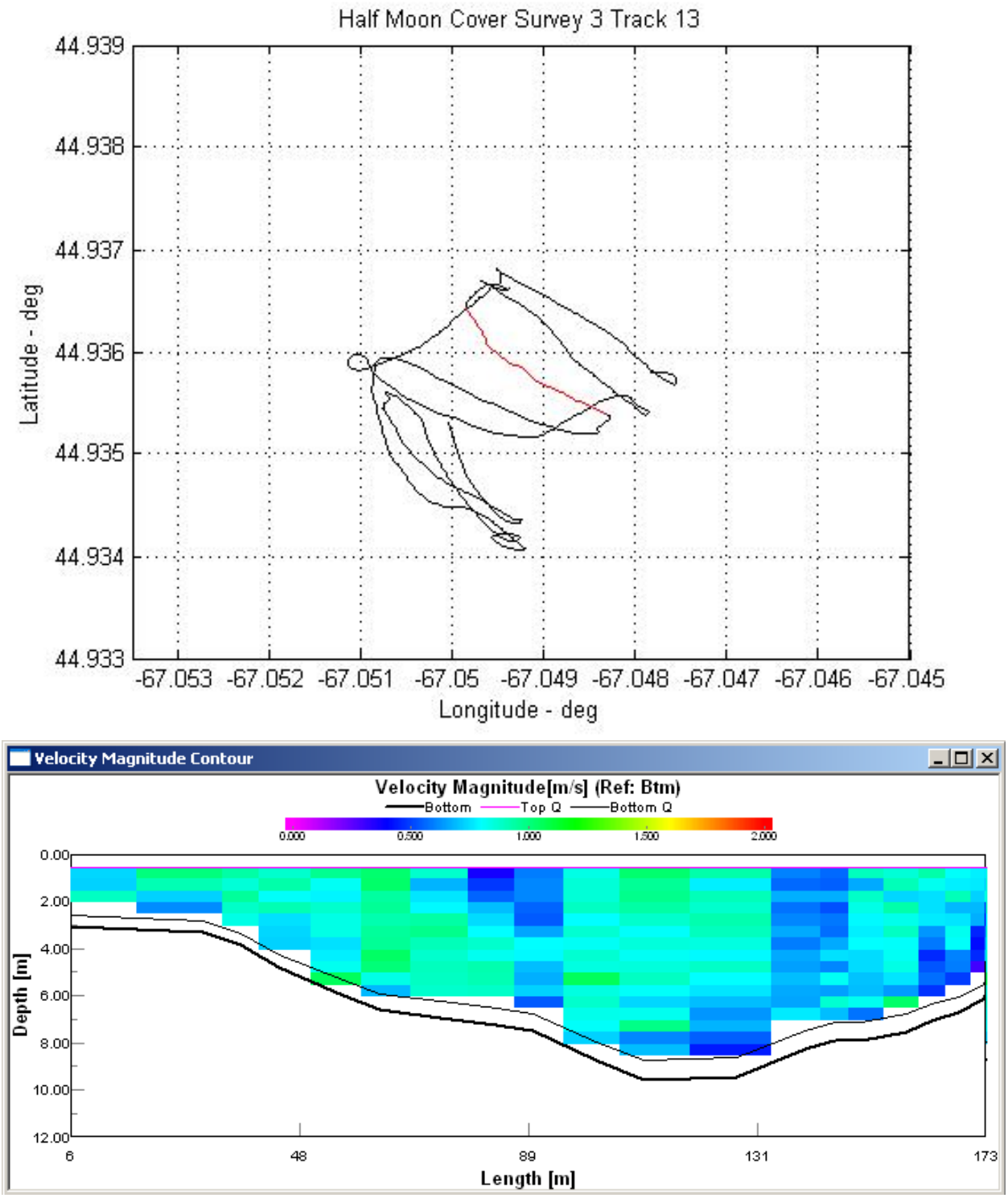


Figure 16: Track13 HMB32 – traveling from southest to northwest (top) and left to right (bottom). Maximum velocity is about 1.0 m/s (2.0 kts) and located on the southeast side of the main channel, but is more general in location. Track is located under power lines?

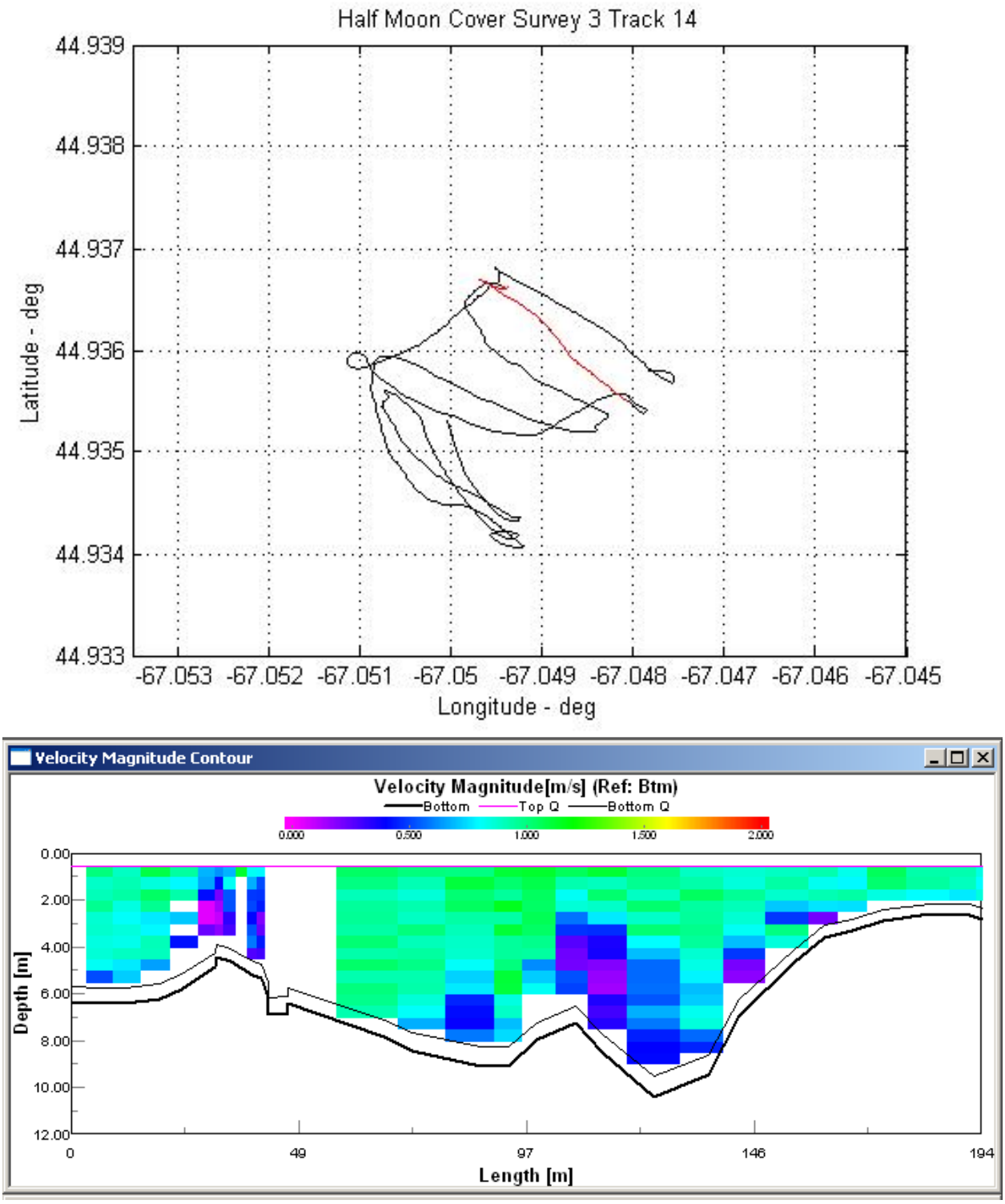
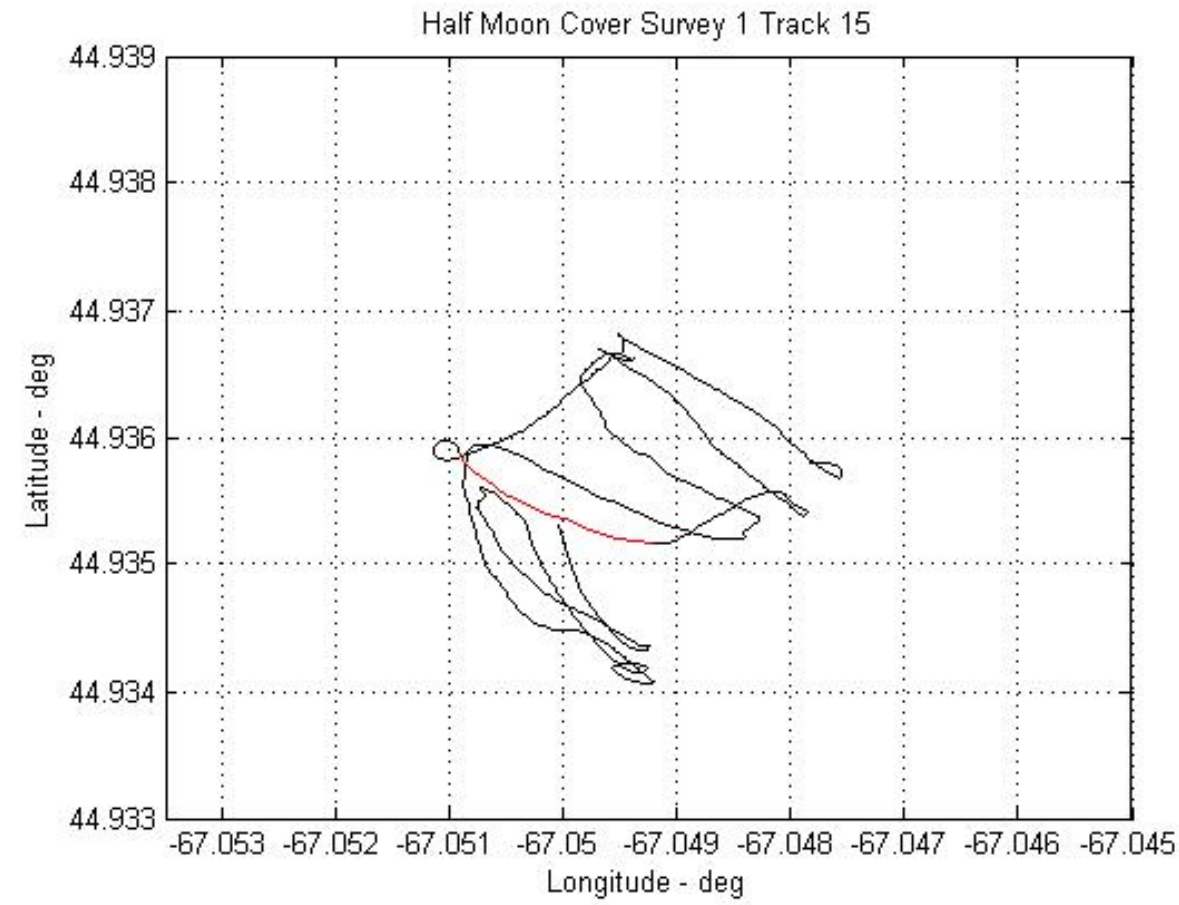


Figure 17: Track14 HMB33 – traveling from northwest to southeast (top) and left to right (bottom). Note that the first bit of the section on the left of the bottom panel is a retrace of the track. Maximum velocity is about 1.1 m/s (2.2 kts) and located on the northwest side of the main channel, but again is not as concentrated as in the flood. Track is just north of power lines.



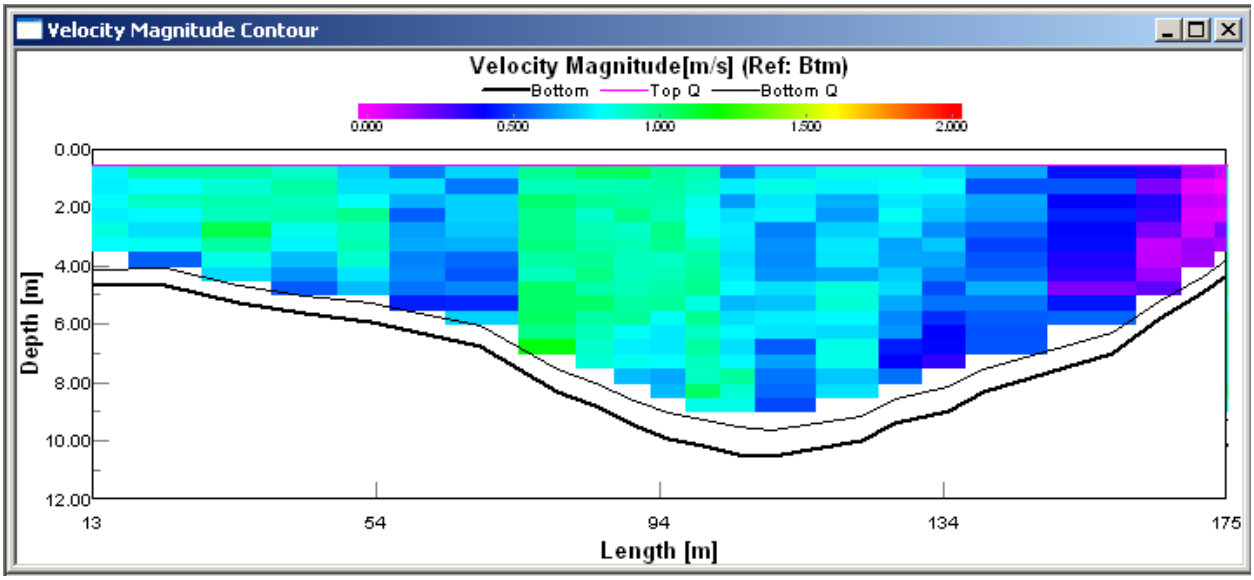


Figure 18: Track15 HMB34 – traveling from southeast to northwest (top) and left to right (bottom). Maximum velocity is about 1.2 m/s (2.4 kts) and located on the southeast side of the main channel. This track is under the wires.

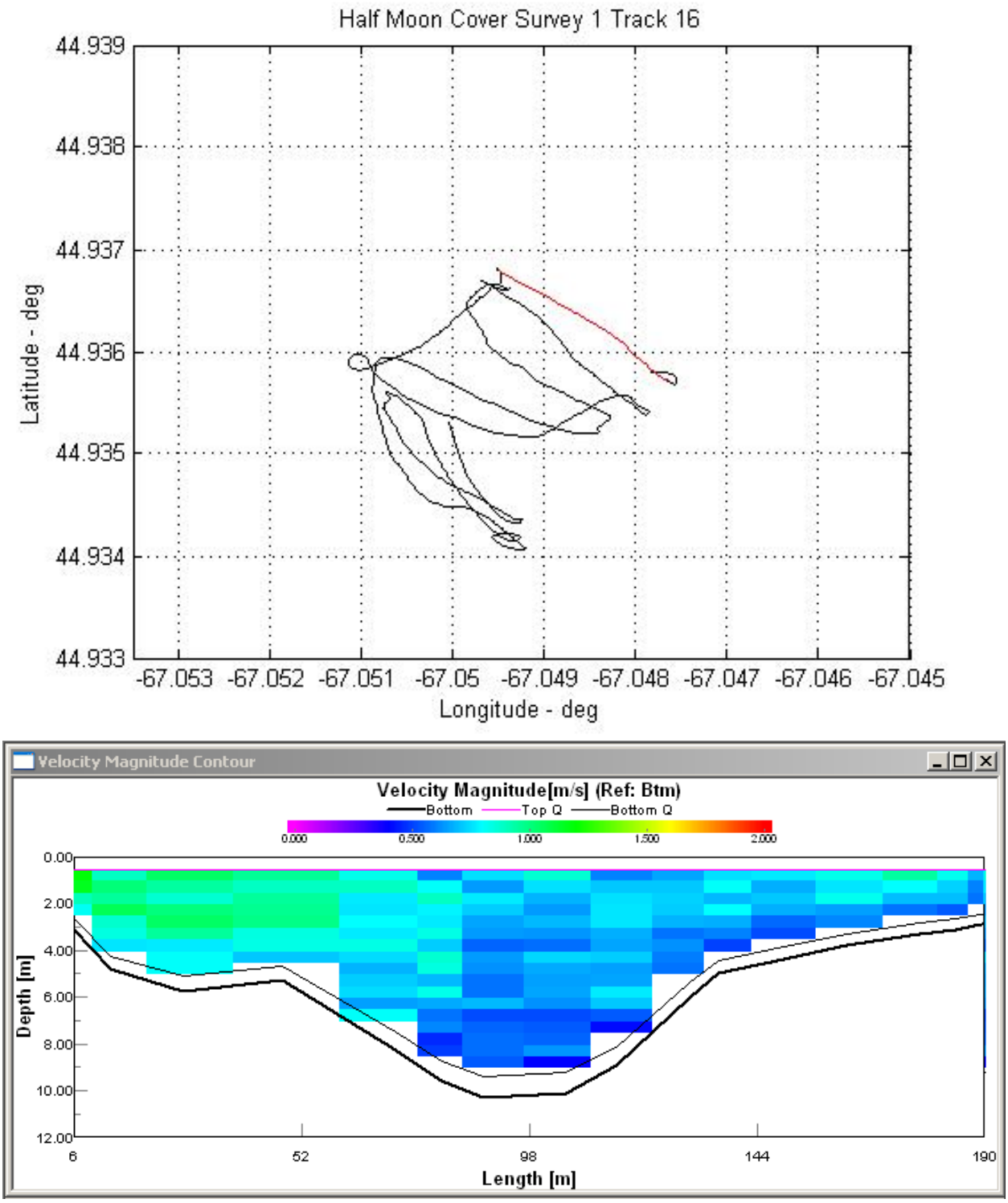


Figure 19: Track16 HMB35 – traveling from northwest to southeast (top) and left to right (bottom). Note that the firs bit of the section on the left of the bottom panel is a retrace of the track. Maximum velocity is about 1.0 m/s (2.0 kts) and located on the northwest side of the main channel.

Summary of Survey 2:

- In tracks 11 to 16 (Fig. 15 to 20), there is a general trend for the maximum current to be on the western side of the deepest part of the channel. As the survey doesn't extend farther into or out of the entrance to Half Moon cover than our survey on the Flood tide, these results are consistent with them, and the fact that the maximum current is not found in the deepest part of the channel.
- The maximum ebb currents are not as large as the observed flood currents the day before.

Comparison of the two Surveys:

In order to more clearly slow the survey results, Fig. 14 shows the surveys during the flood and during the ebb tide plotted on top of one another, so that the repeated lines can be more easily selected and compared.

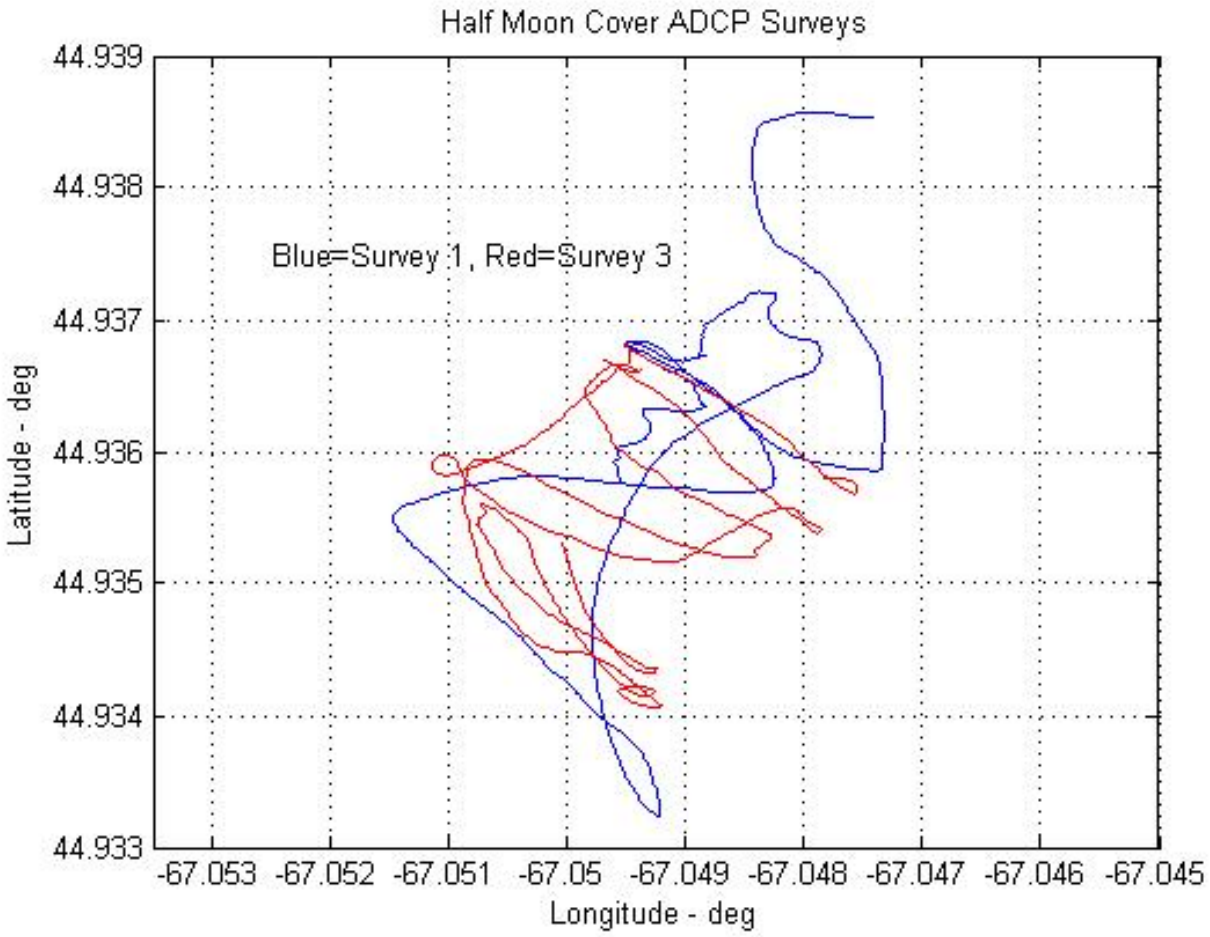


Figure 14. Both Survey 1 (blue) on the Flood Tide and Survey 3 (red) on the Ebb Tide are shown for comparison.

Comparison of similarities in reoccupied survey lines:

- There is only one good overlap in both surveys with the tracks under the power lines. Track 2 and Track 3 from Survey 1 (Figs. 9 and 10) and Track 16 from Survey 3 (Fig. 20). The results from both surveys show that the high velocity under the power lines is located to the west of the central channel in shallower water, and must be related to the bathymetry of the region and the accelerating flow around the corner going in and out of Half moon Cove.
- Track 5 (Fig 12) and Track 11 (Fig 15) taken on the outside Half Moon Cover from the power lines. Here the maximum flow is now located to the Southeast side of the deepest part of the channel on both the ebb and flood.

The maximum transport of water in and out of the Half Moon Cove is estimated by the RD Instruments WinRiver software used to make the section plots. For our survey, the inflow on the flood was about 950 to 1000 m^3/s and the outflow on the ebb was about 840 to 950 m^3/s. As the tidal range show in Fig. 5 for the flood and the ebb is about the same, and the current speeds observed at buoy J02 (Fig. 6) are about the same, it is surprising that the flood and ebb are not more similar. The major error in this technique is that the data doesn't extend from the top to the bottom and from one side to the other. The program does extrapolate the data, but this is only an estimate as seen in Table 2 where the estimated discharge is ~30% of the total. Therefore, these numbers are to be used with a bit of caution, but are a ball park estimate for consideration.

Table 2. WinRiver Discharge estimates for Track 3 HMB22 section under the wires.

Discharge Standard Tabular

Discharge (Btm) Left to Right		
Good Bins	2	
Top Q	**100.715**	[m^3/s]
Measured Q	**721.510**	[m^3/s]
Bottom Q	**192.837**	[m^3/s]
Left Q	**0.000**	[m^3/s]
Right Q	**0.000**	[m^3/s]
Total Q	**1015.062**	[m^3/s]