Report on Current Meter Record Dec18/06 to Jan 9/07 off Port Mouton Island

1 Background

This is a report on currents measured with a recording current meter by Dominator Marine Servicers for Aqua Fish Farms in the vicinity of the proposed salmon aquaculture site near Port Mouton Island. These data on currents are applied to test the hypothesis that dissolved, suspended or floating material from this proposed salmon aquaculture site off Port Mouton Island could reach nearby shores as a result of currents. Experienced fishermen advised us that this site, as well as the nearby Spectacle Island site, are depositional areas except in times of strong winds, and that northeast winds, in particular, would be most effective for transporting accumulated material.

In earlier reports (Friends of Port Mouton Bay, March 2007) we presented near-surface drogue tracks over a semi-diurnal tidal cycle on a day of light winds which showed that current speeds were low and the waters re-circulated – supporting the hypothesis of deposition in Port Mouton Bay. Then followed reports on the transport of seabed drifters to shore under persistent northeast winds and their retrieval by volunteer shore patrols in and near the Kejimkujik National Park, and later on protected Carter's Beach. The data for the present report are complementary to the near-surface drogue data and the seabed drifter data. Whereas the drogue data tracked the actual current trajectory in space and time, it was limited to just one tidal cycle. The seabed drifters provided the release and retrieval locations and inferred trajectories during the elapsed time period, but not the positions in that period. This current meter data, supplied courtesy of Aqua Fish Farms, DFO and NS Fisheries and Aquaculture, provides time coverage at 15-minute intervals, at two depths, from a single location. The question is: does it bear out the pattern described by the fishermen?

December, 2006, was the time both when this current meter mooring was installed and when Friends of Port Mouton Bay were active with their seabed drifters trials. Based on the fishermens' advice, Friends were watching and waiting for a northeasterly-winds-event to be forecast and experienced. Such a forecast was received for January 8th and some seabed drifters were released that day but strong NE winds did not materialize at that time, and not until mid-April was the significant northeasterly event experienced. Unfortunately, this current meter coverage, December 18, 2006 to January 9, 2007, did not include a significant northeasterly winds event.

2 Approach

The current meter data pertain to water motions at two depths at the position of the current meter mooring, Our analysis is based mainly on graphs of the inferred drift trajectory patterns and histograms of current speeds. For inferred drift trajectories, the current meter data are displayed as cumulative drift distances. The series of velocity readings at 15 minute intervals is multiplied by the number of seconds in the data interval (900 seconds) to obtain a series of drift distances, each associated with a measured direction of flow. The successive drift distance vectors are plotted ‘tail-to-head’, repeated, to obtain an inferred drift pattern, albeit based on measurements at a single location.

The purpose here is to identify when currents are weak or strong, and either steady in direction or re-circulating. From strong currents, steady in one direction, we would infer large drift distances over one tide cycle so that exchange of waters is occurring around the mooring site. Currents that exhibit slow speeds and vary in direction would suggest that weak local dispersion or recirculation rather than exchange of waters is occurring. Near-surface drogues give good records of actual current patterns, either of exchange or recirculation, though we have only one tide-cycle measured by near-surface drogues – on March 13th 2007 . In contrast, this current meter record gives forty-two tide cycles coverage though the spatial pattern has to be inferred and is subject to some distortion.

3 Results

The key results appear in the diagrams; first the position of the current meter (Figure 3.1), then the histograms of speeds at two locations and two depths (Figures 3.2 to 3.4), followed by residual drift trajectories inferred from the current meter data apart from the effect of the tides (Figures 3.5 and 3.7, and finally the drift with tides included (Figures 3.8 to 3.14).

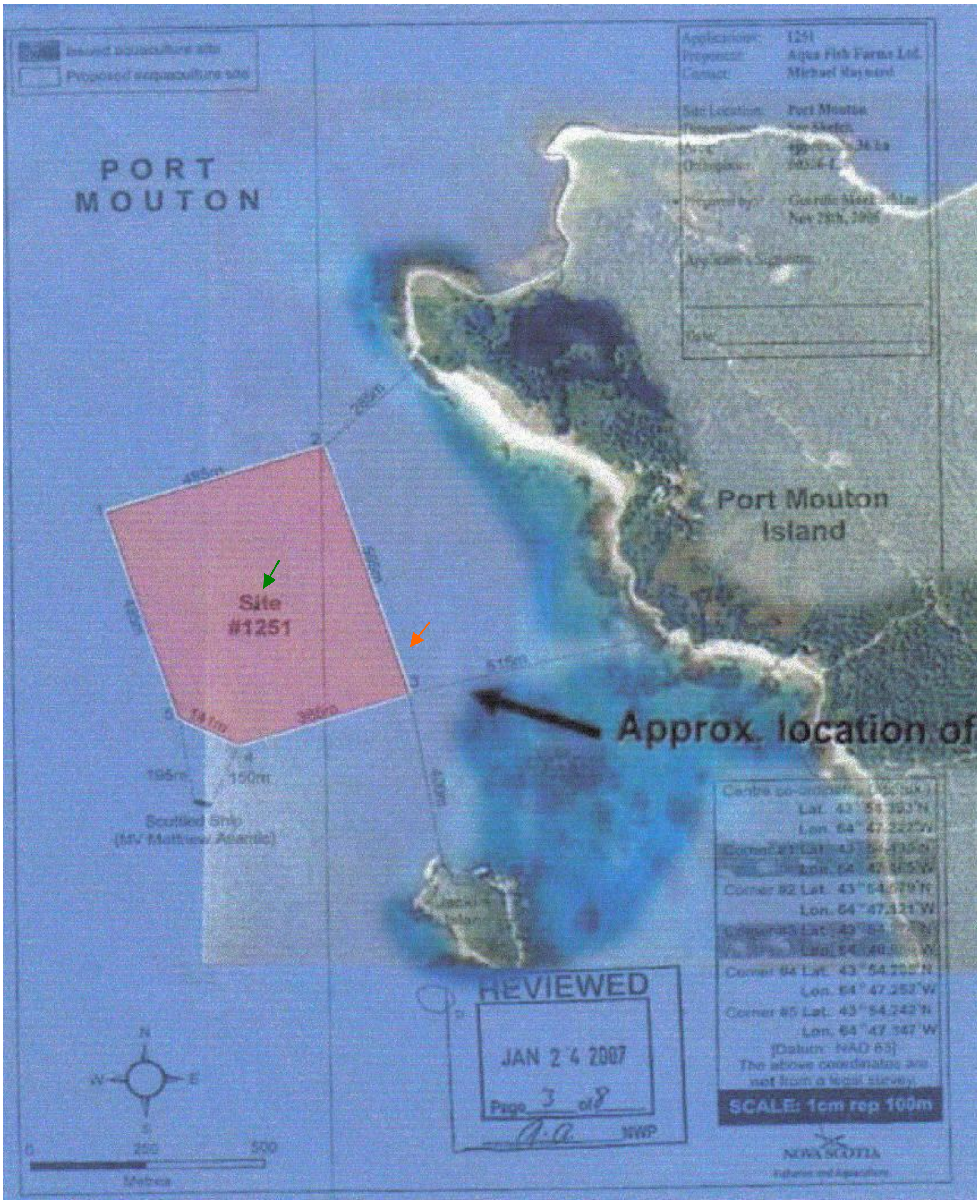


Figure 3.1. Locations of current meter moorings for three days in January February 2002 (orange arrowhead) and for three weeks in December 2006 –January 2007 (green arrowhead).

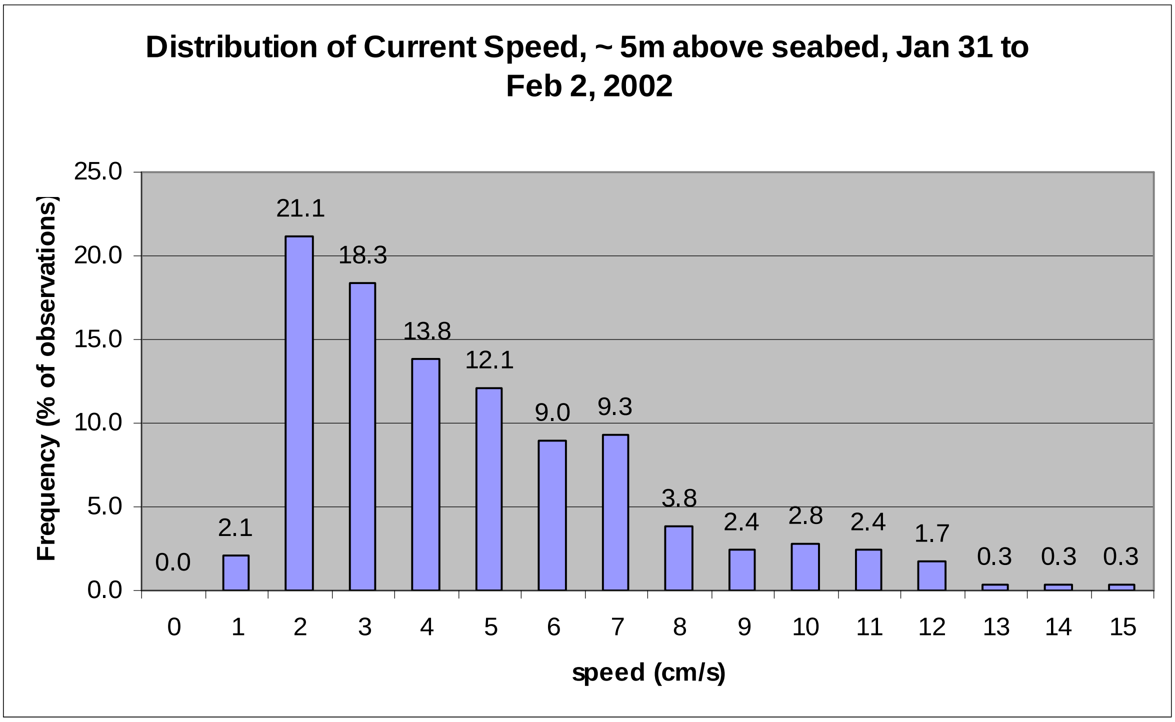
3.1 Positions of Moorings

Figure 3.1 below shows the approximate positions of the current meter moorings , an earlier three-day mooring, January 31 to February 2, 2002 (orange arrowhead) and this recent three-week mooring, December 18, 2006, to January 9, 2007 (green arrowhead). The more recent mooring was approximately 400 m closer to the channel than the earlier one, and in 13 m depth (at low water) rather than 10 m. The assumed location of the proposed aquaculture expansion is shown as the larger, clipped rectangle. The December 06 – January 07 current meter was an acoustic Doppler current profiler which provided data at 15-minute intervals at two depths,1.8 m above the seabed and 6.9 m above the seabed.

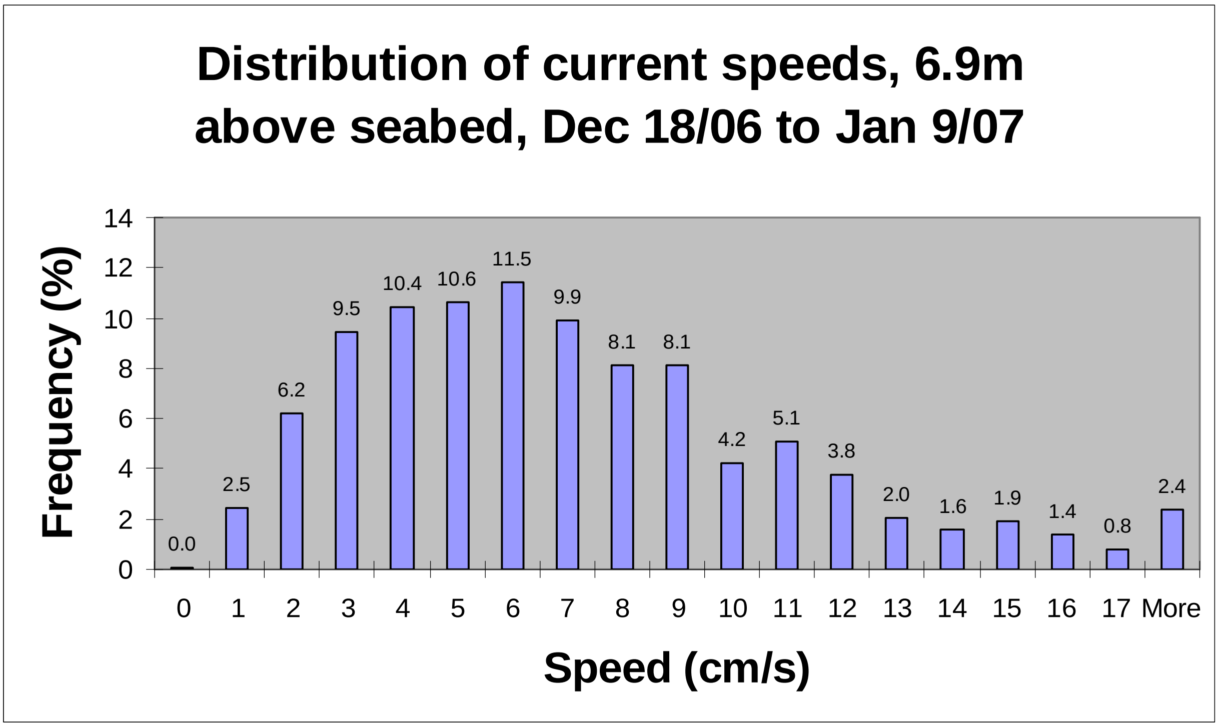
What was not measured was a significant northeasterly-winds event which is noted by fishermen as the wind direction of greatest effect for transport and exchange of waters in the channel off Port Mouton Island. In 2007, the first such event of the year did not occur until mid-April.

3.2 Histograms

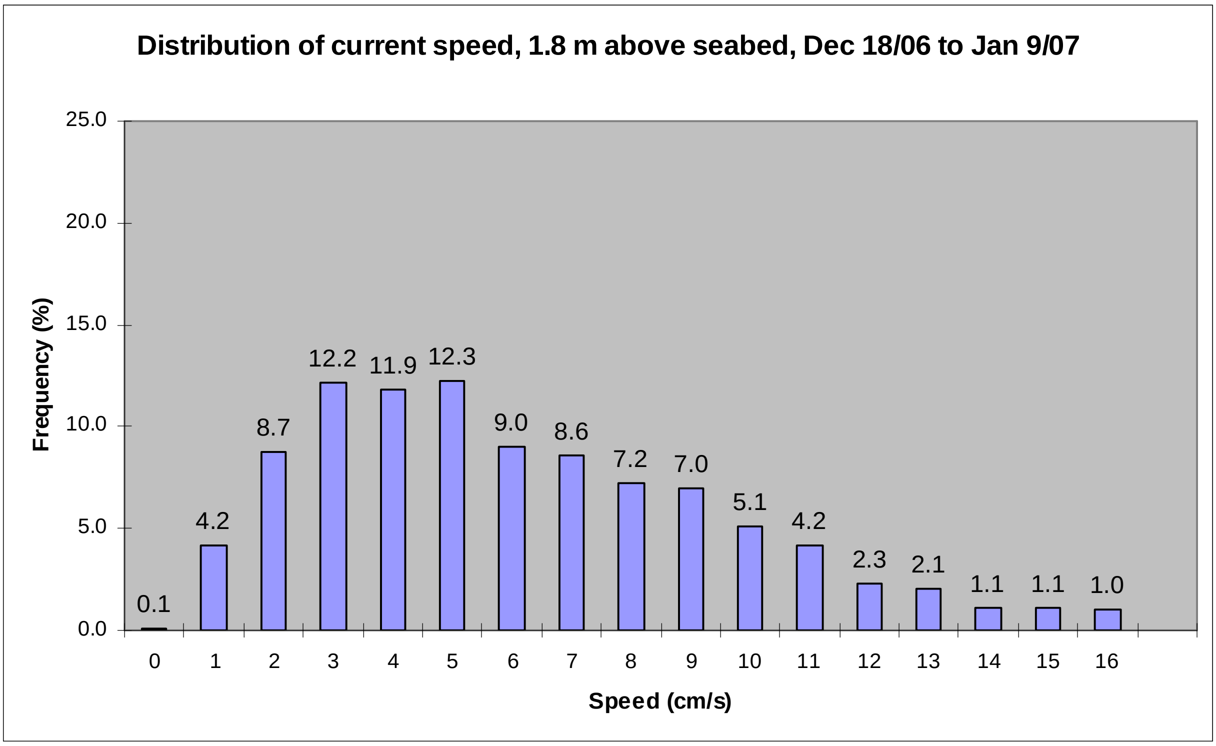
The histograms show the frequency of occurrence of various speeds in the data record.



Distribution of Current Speed, ~ 5m above seabed, Jan 31 to Feb 2, 2002
Frequency (% of observations)
25.0
20.0
15.0
10.0
5.0
0.0
0.0
2.1
21.1
18.3
13.8
12.1
9.0
9.3
3.8
2.4
2.8
2.4
1.7
0.3
0.3
0.3
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
speed (cm/s)



Distribution of current speeds, 6.9m above seabed, Dec 18/06 to Jan 9/07
Frequency (%)
14
12
10
8
6
4
2
0
0.0
2.5
6.2
9.5
10.4
10.6
11.5
9.9
8.1
8.1
4.2
5.1
3.8
2.0
1.6
1.9
1.4
0.8
2.4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 More
Speed (cm/s)



Figures 3.2, 3.3 and 3.4. Three histograms: Fig. 3.2 mid-depth in 2002; Fig. 3.3 mid-depth in 2006-7 and farther offshore than in 2002; and Fig. 3.4 near the seabed, farther offshore in 2007.

3.3 Residual Drift Patterns

Here, residual drift means the drift is portrayed 'as the crow flies' from the inferred position at the time of one high water to the inferred position at the time of the next high water. Detailed drift motions *within* a tide cycle are the focus of §3.4.

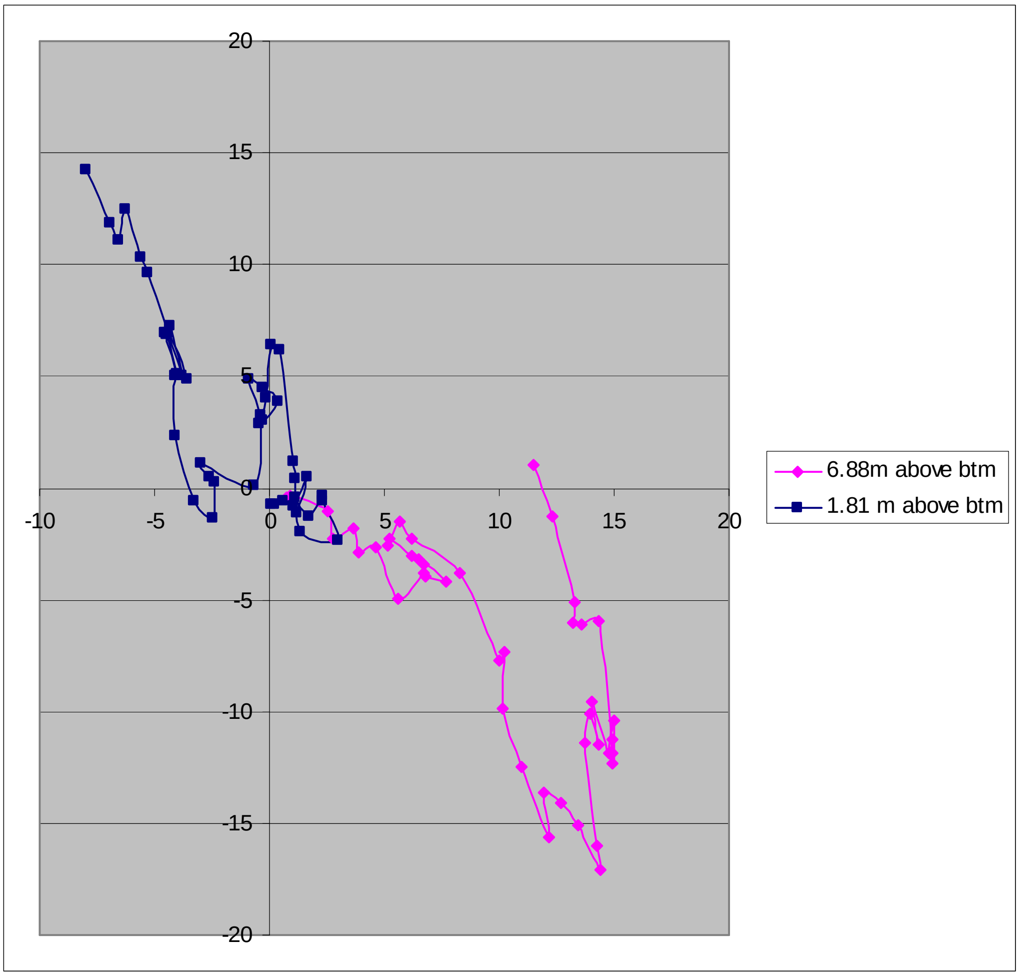


Figure 3.5 The 20-day residual current drift pattern for 1.8 m and 6.9 m above the seabed, summarized by the 'position' at high water for each ~12.5 hour tide cycle. Inferred position is calculated by summing the distance vectors at 15-minute intervals. The drift trajectory begins at the origin and concludes in the northwest for the 1.8 m record and in the east for the 6.9 , record. The scales are in kilometres.

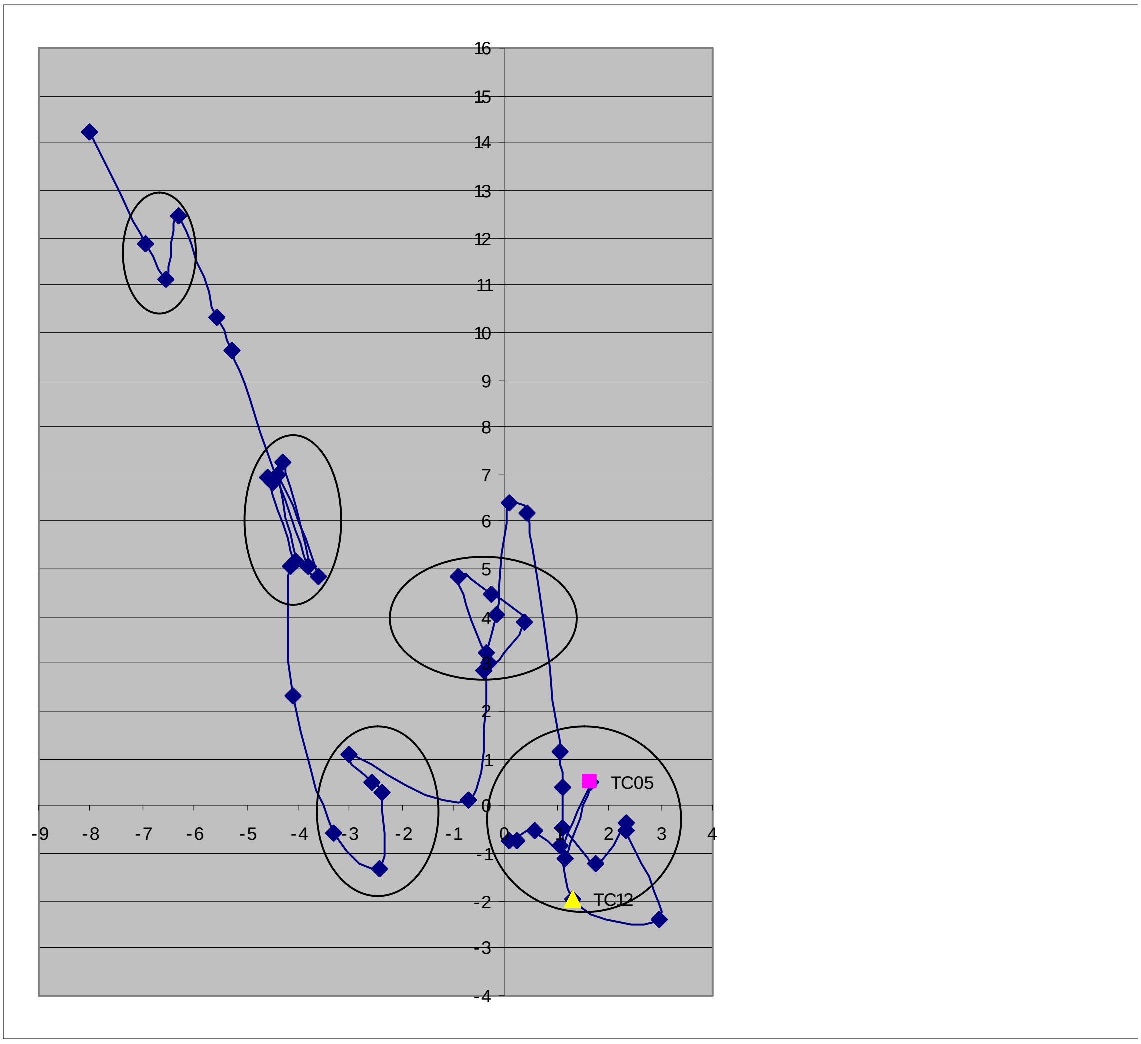


Figure 3.6. The inferred residual drift for 1.8 m above the seabed is shown with the periods of almost stagnation outlined with ovals.

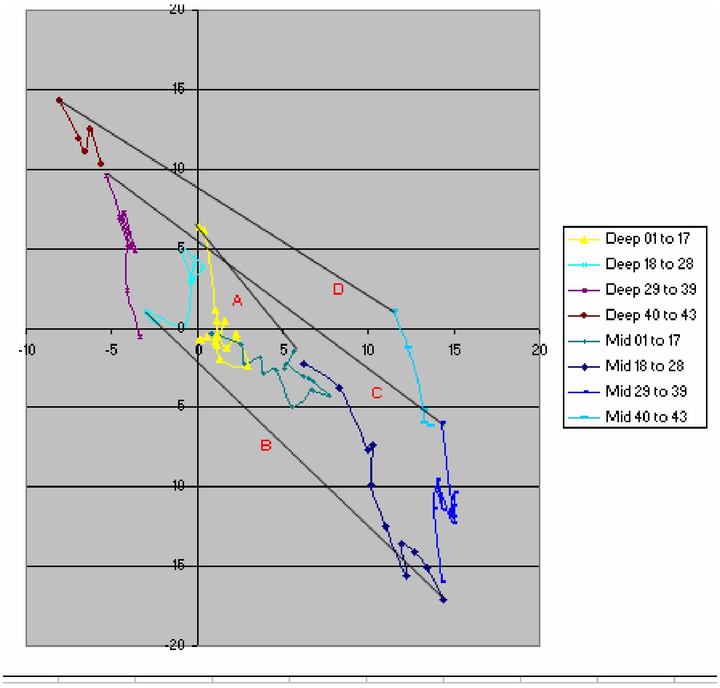


Figure 3.7 Another version of Fig. 3.5 with sequences of tide cycles color-coded starting with yellow for 1.8 m above bottom and blue-green for 6.9 m above the seabed, and lines linking the positions of near-bottom and mid-depth drifts after each sequence to reveal vertical shear – the difference in residual current near bottom and at mid-depth.

The chart of residual drift, Figure 3.6, shows that there are 'clusters' of several tidal cycles during which the residual drift over a 12.5 hour tidal-cycle is relatively small, indicating that velocities are either weak or recirculating, and that these clusters are interspersed or separated with one or two tidal cycles showing higher speeds.

3.4 Drift Patterns In Detail

The figures in this section show the current meter records in full detail throughout the tide cycle – not summarized using tidal cycle totals. –

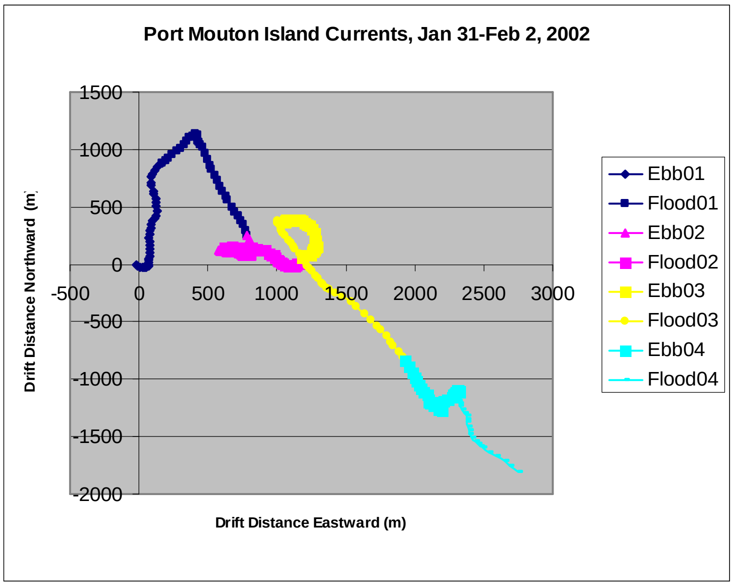


Figure 3.8 Inferred drift over four tide cycles in 2002, approximately 5 m above seabed.

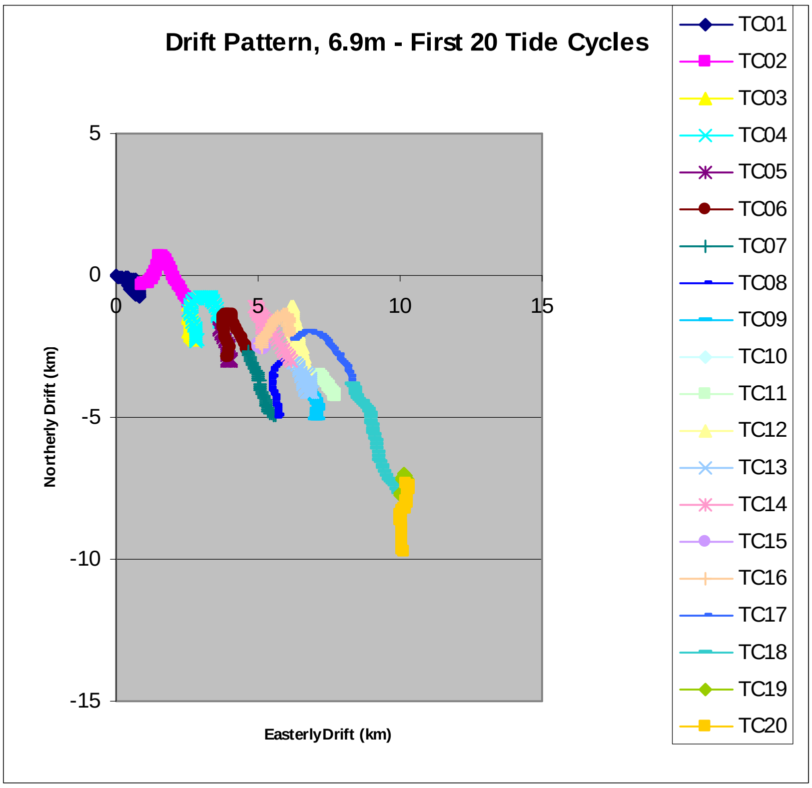


Figure 3.9 Inferred drift over twenty tide cycles in 2006-7, approximately 6.9 m above seabed.

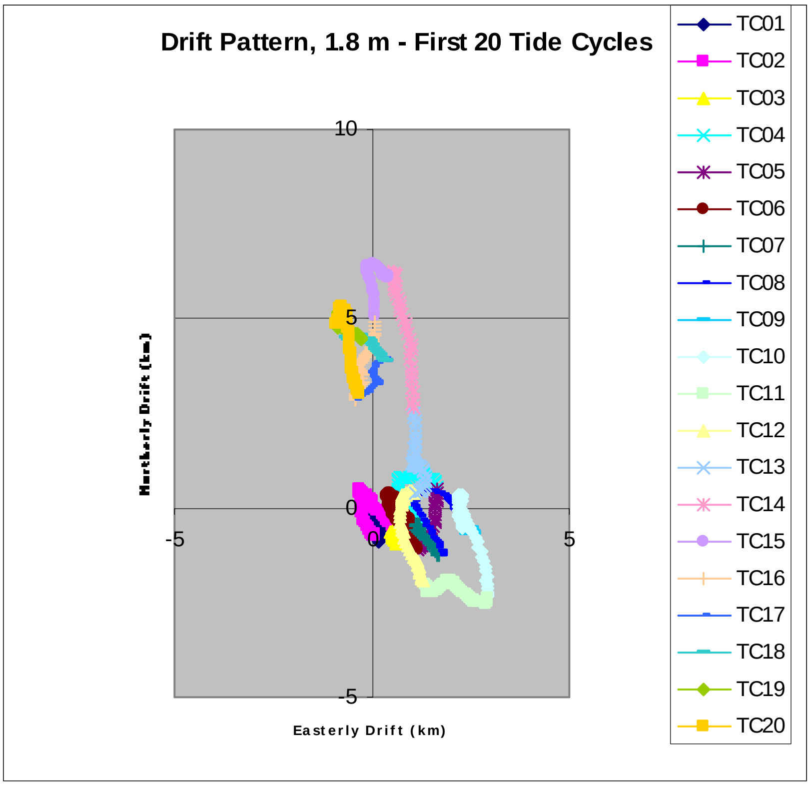


Figure 3.10 Inferred drift over twenty tide cycles in 2006-7, approximately 1.8 m above seabed.

Upper layer (6.88 m) data and lower layer (1.81 m) data are color-coded by tide-cycle with corresponding colors, thus they can be compared, tide-cycle by tide-cycle. Figure 3.9 for the first twenty tidal-cycles (ten days) of this current-meter record at 6.9 m (above seabed) indicates drift to be a residual current to the southeast at approximately 1 km/day, overlain by recirculation loops (of scale up to 2 kms) in each tide-cycle. At 1.8 m (above seabed) the instrument indicates two stationary clusters of slow speeds and some recirculation, separated by a 5 km exchange northward. Currents at these two depths are sometimes drifting in the same direction and at other times in opposite directions.

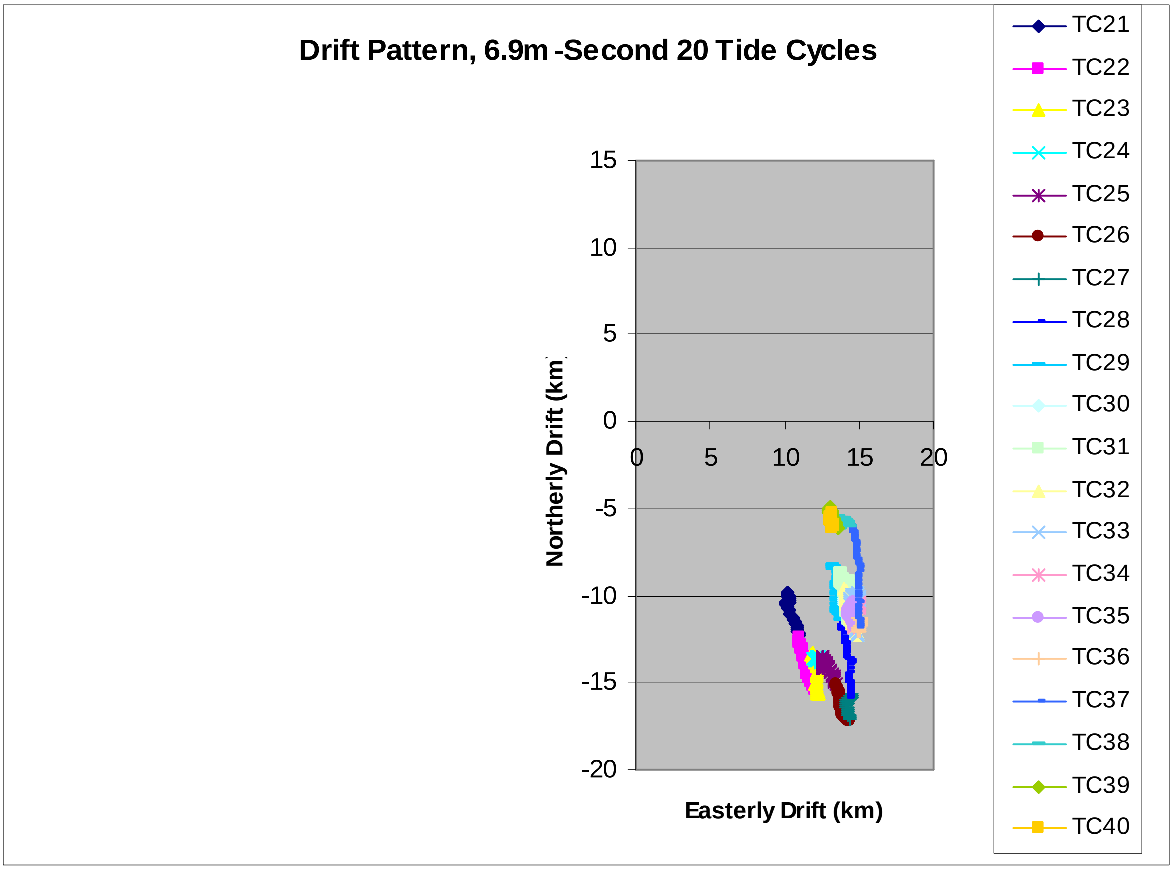


Figure 3.11 Inferred drift over the second twenty tide cycles in 2006-7, approximately 6.9 m above seabed.

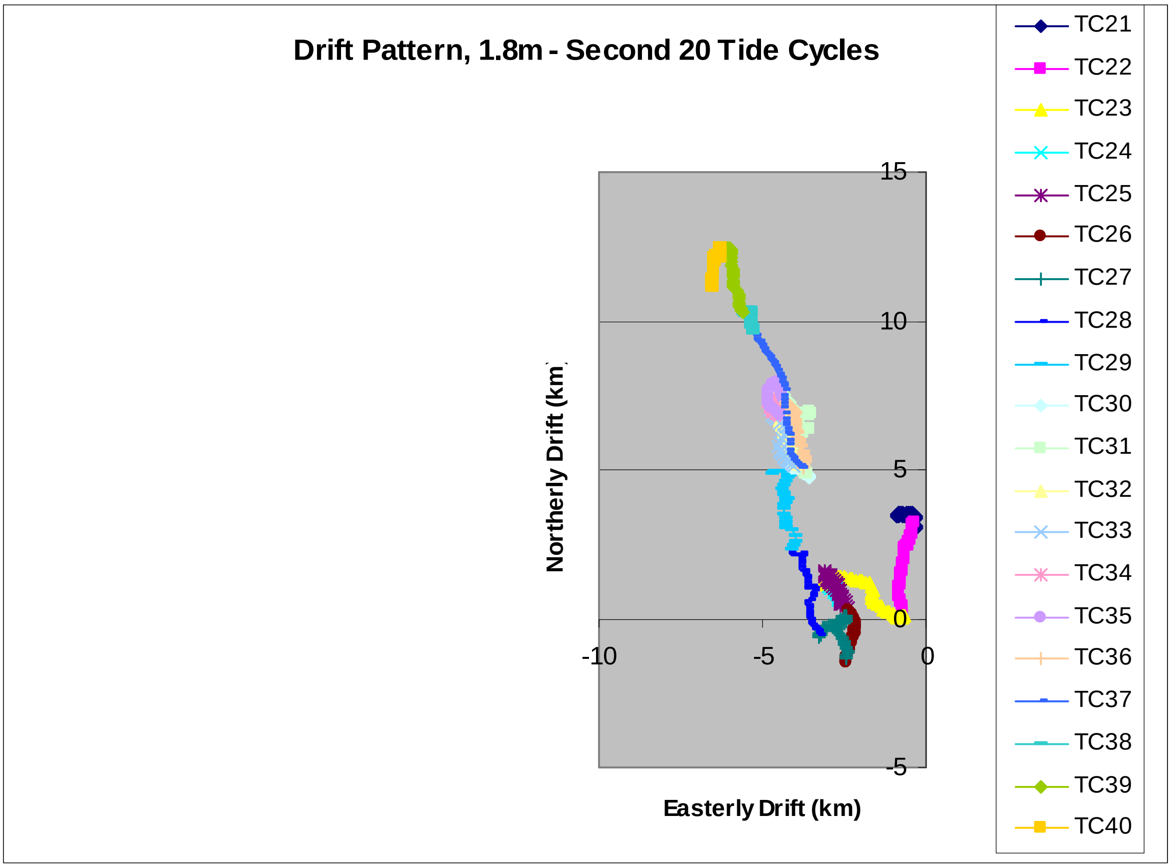


Figure 3.12 Inferred drift over the second twenty tide cycles in 2006-7, approximately 1.8 m above seabed., e.g., from December 28th to January 7th.

For these second twenty cycles, the 6.9 m (above seabed) data indicated a drift to the south-southeast during tide-cycles 21 to 26, shifting to north northwest during tidal cycles 27 to 39. The 1.8 m (above seabed) indicated weak currents with recirculation during tide cycles 24 to 27, a drift north during cycles 28 and 29, another weak current / recirculation period from cycles 30 to 36, and drift northwest during cycles 37 and 39.

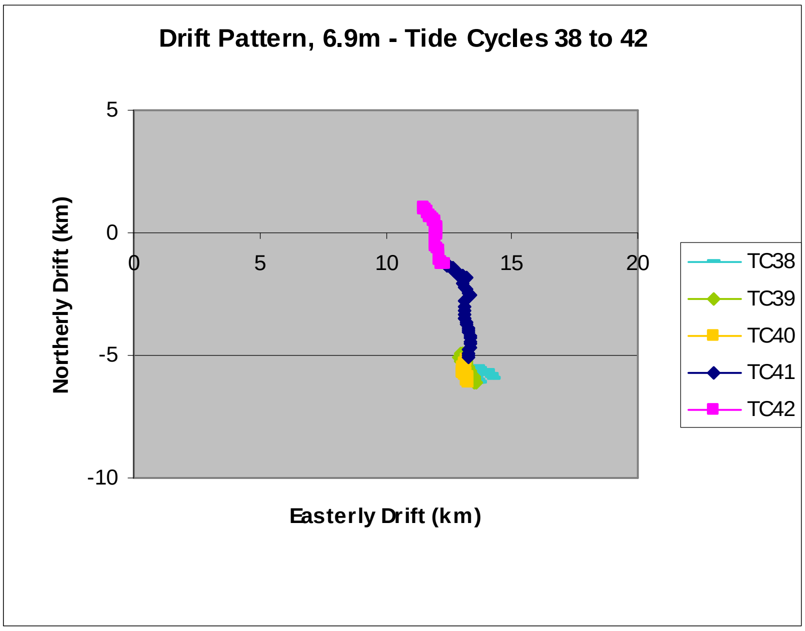


Figure 3.13 Drift pattern for mid-depth, the final two and one-half days of record.

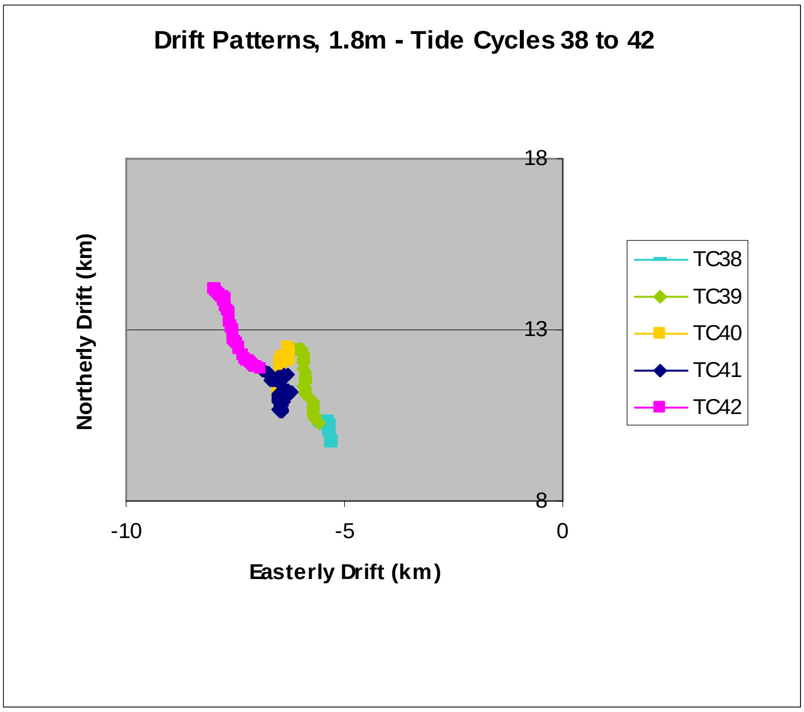


Figure 3.14 Drift pattern for near the seabed, the final two and one-half days of record.

4 Interpretation

4.1 Positions

The current meter mooring in 2007 was approximately 400 m further offshore from Port Mouton Island than the current meter mooring in 2002, and in deeper water, nearer to the channel. As a result, stronger currents as shown in the 2006-7 histograms are not surprising.

4.2 Histograms

Figure 3.2 for 2002, and 3.3 and 3.4 for 2006-7 both pertain to mid-column currents, though at locations separated by some 400 m, with the 2006-7 mooring being further offshore. The histogram for 2002 shows a high percentage of speed readings at 2 cm/s or less. The histogram for 2006-7 does not have a high percentage of speed readings at 2 cm/s or less; the overall shape is shifted to higher speeds., likely because the instrument was positioned further offshore from Port Mouton Island.

Comparing Figures 3.3 and 3.4, two histograms for the same place and time period but at different depths, higher speeds occur more frequently at 6.9 m above seabed than at 1.8 m above the seabed.

Comparing winds with these December-January currents showed that strong wind components, aligned with the channel, drove currents there. Since winds are generally lighter in summer than in winter, one would expect that the histograms of current speeds in summer would show slow currents to be more frequent. Summer currents have not as yet been measured. [1]

The next section involves current direction as well as speed.

4.3 Residual Drift Patterns

The residual drift patterns have the tide cycle effectively removed, revealing the displacement distance for each tide cycle - whether large or small. In Figure 3.3.1, near the seabed (blue) and at mid-depth (fuschia), both inferred trajectories begin at the 0 km east, 0 km north origin and drift from there. The near-bottom trajectory shows small drift distances for many early tide cycles, then moves in a northwesterly direction in ‘fits and starts’. The ‘fits’ are interludes of very slow drift and the ‘starts’ are episodes when larger speeds and distances are inferred. This same pattern of fits and starts can be seen in the mid-depth record (Figure 3.3.1, fuschia). At this depth the drift moves off to the *southeast* before reversing and returning.

Figure 3.3.2 shows just the drift pattern 1.8 m above the seabed. Here the ‘fits’ are marked with ovals while in-between these‘fits’, larger drift distances occur at higher speeds, illustrating the pattern of ‘fits and starts’, or more deposition and less deposition.

Figure 3.3.3, for vertical shear, with both drift trajectories starting at the origin, shows, via line A, that after the first 17 tide cycles, the water at mid-depth has moved some 5 kms to the east while the water near the seabed has moved some 5 kms to the north. After another 11 tidal cycles (almost 6 days) have elapsed, line B indicates that the water at mid-depth has moved

[1] Although it is known that a (geostrophic) coastal current flows southwest along the Scotian Shelf, stronger in winter (600,000 m^3 per second) and weaker in summer (150,000 m^3 per second) (Sutcliffe et al., 1976; Drinkwater et al., 1978), no connection to this current record can be resolved at this time.

about 15 kms to the southeast while the water near bottom has returned to the origin. Line C, after another almost 6 days indicates that current speeds were the same at both depths. Line D, after another 2 days to the end of the record, indicates that current speeds remained about the same at both depths – no vertical shear, 15 kms total in 8 days, from Line B to D, apparently in response to sustained southwest winds.

Similar to the comment for the histograms, one would expect that since the faster currents are associated with heavy winds and since winds are generally lighter in summer than in winter, these drift patterns would show smaller displacements – weaker exchanges of water – due to weaker currents in summer, if these had been measured.

4.4 Detailed Drift Patterns

Examining the currents plotted at 15 minute intervals, the lower layer is of most interest because it is the layer of the water column where the load of waste particles accumulates and either settles out, or drifts off site. If it drifts offsite, the water either re-circulates back onto the farm site later and receives another load of waste, or flows away in a constant direction and be replaced with 'new' water. Figure 3.4.1 illustrates the detailed drift patterns – notice the curves and the crowded superposition of the tidal cycles. Then too notice the relatively-straight-line tidal cycles (aqua). It is a pattern of 'fits and starts' at the detailed level too – recirculation and weak exchanges which can persist for more than a week, interspersed with periods of stronger exchanges.

The current meter record indicates interludes of weak currents, recirculation and dispersion on a scale of ~2 kilometres interspersed by 'transport events', associated with winds, during which water is transported three to four kilometres in one direction during a tide-cycle. Variability due to spring tides (tide cycles 8, 10, 31, 33) and neap tides (tide cycles 20, 43) is not apparent. This is consistent with part of the pattern described by the fishermen and corroborated by the near-surface drogue trials (Friends of Port Mouton Bay, March 2007). The other aspect of their description is the less frequent, extreme-transport-event, driven by strong northeasterly winds. During these events, particles of fish farm waste which accumulated during the recirculation / dispersion / weak exchange phase, such as depicted in this current meter record, are likely mobilized and transported, in this case towards shore. This type of mobilizing event occurred in mid-April, 2007. Seabed drifters, which presumably had lain practically dormant since being released in January, were found washed up on shore in the days immediately following the April northeaster – our first recoveries after weeks of shore patrols. The current meter deployment, on behalf of Aqua Fish Farms, was concluded in January, 2007; there is no current meter record of a northeasterly winds mobilization event.

Port Mouton Bay appears to exhibit an unfortunate combination of factors in relation to fish farm wastes – enough recirculation to carry the waste materials beyond the proposed farm site into the far-field and back again, but not enough energy to in these excursions to disperse wastes widely.. The pattern recognized by fishermen at the proposed site off Port Mouton Island – periods of collection and deposition of materials there, interrupted by episodes of transport and dispersal away from the site associated with northeasterly winds – is, so far, supported by three other sets of data. The AquaFish 2002 current meter data showed low average speeds consistent with recirculation and deposition. The drogue tidal cycle study which we conducted on a calm day, March 13th, 2007 indicated low speeds and recirculation through a tidal cycle rather than exchange of waters. The seabed drifter results suggest accumulation of non-buoyant materials at the site for an extended period, then mobilization and transport during northeast winds. The situation at the proposed Port Mouton Island salmon aquaculture site appears to be this: periods of deposition - of salmon aquaculture particulates - interrupted sporadically by wind-drift events which transport material to nearby shores. The area of the proposed Port Mouton Island farm site has been characterized as depositional and deposition model DEPOMOD typically predicts drifts of one to three kilometres for materials resuspended (e.g., by storm waves) from salmon farms (B. Hargrave, pers. comm.).

5 Conclusions

The record in 2006-7 relates to a position approximately 400 m further offshore and closer to the channel than that of 2002 and shows stronger currents.

This current meter record is for twenty-two winter days in 2006-7. Since winds as well as tides are a significant driving force in this area, the currents in summer are likely to be weaker than in this record because of lighter winds, and also because of a weaker coastal current.

The winter drift patterns show periods of weak currents, periods of recirculation and tide cycles when the inferred drift is practically steady in one direction.

Based on the consistent evidence - the pattern observed by fishermen over long experience, our analysis of the 2002 moored current meter data and of this December / January 2007 current meter data, our March 2007 near-surface tidal-cycle drogue observations which re-circulated, and the April 2007 to June 2007 seabed drifter recoveries ashore which began only after the mid-April northeasterly storm, it is concluded that fish farm wastes would be likely deposited outside, as well as within, a salmon farm lease area, where they would accumulate over time, and later be shifted to shores by particular storms. The likelihood is strong that this settled waste material and nutrients will be re-suspended in a northeasterly storm and transported at least a few kilometres from the proposed site to the nearby national park and protected beach.

The Port Mouton Island site appears to fall into that mid-zone of worst circumstances with enough energy in the currents to move wastes off the farm-site into the far-field, and yet not enough energy to continually disperse this material so widely that habitat and nearby sensitive shores will escape being degraded. Evidence for this is that the seabed drifters remained in the area for approximately one hundred winter days before washing ashore with a northeast storm. Accumulations of wastes will likely do the same.

References

Drinkwater, K., B. Petrie and W.H. Sutcliffe,Jr. 1978. Seasonal Geostrophic Volume Transports Along the Scotian Shelf. Estuarine and Coastal Marine Science 9, 17-27.

W.H. Sutcliffe, Jr., R.H. Loucks and K.F. Drinkwater. 1976. Coastal Circulation and Physical Oceanography of the Scotian Shelf and the Gulf of Maine.Vol.33, No.1, 98-115.