NIWA

Taihoro Nukurangi

Assessment of sustainability issues related to marine farm development proposals by Marlborough Mussel Company

DRAFT

NIWA Client Report: CHC00/8
Project No.: MMU00501
January 2000

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prepared for

Marlborough Mussel Company

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Executive Summary

This report considers the sustainability issues associated with four marine farm developments proposed by Marlborough Mussel Company Ltd in Pelorus Sound. The study focuses on potential effects of the developments on neighbouring farms and does not address the wider issue of long term sustainability of cumulative farms in the Marlborough Sounds as a whole. The results of our analysis are summarised in the following points:

(1) Current flow at the Opani-aputa (Crail Bay) site is generally easterly (off-shore) during the outgoing tide and variable, tending on-shore, during the incoming tide. Current speeds are moderate (for this area) averaging 9.2 cm/s. The total flushing time of the farm is estimated to be between 19 and 56 minutes.

(2) The direction of current flow at the Sheep Pen Bay (Beatrix Bay) site is highly variable with no predominant direction of flow. The mean current speed of 6.8 cm/s is typical for Beatrix Bay. The total flushing rate of the proposed site is estimated to be 59 minutes.

(3) On farms of the size proposed (5 hectares or less) no studies have found detectable depletion outside the farm boundary. Some studies have found significant depletion inside the backbones of the longlines. Hence, there appears to be a rapid recovery in depleted water, due to mixing with undepleted water, as water flows through the farm.

(4) The maximum depletion rate of phytoplankton in water flowing through the Opani-aputa site is estimated to be between 0.9-2.6%. Due to the absence of neighbouring farms nearby, the off-shore direction of the prevailing flow, and the generally rapid recovery in depleted water due to mixing with undepleted water, we consider it very unlikely that the proposed site would impact on any other sites.

(5) The maximum depletion rate of phytoplankton in water flowing through the Sheep Pen Bay site is estimated to be approximately 2.7%. Given that the depletion is low, the flow is variable in direction, and that the recovery due to mixing with undepleted water is likely to be high for this size of farm (see above), we consider there is unlikely to be a significant impact at the neighbouring farm site to the west of the proposed farm.

(6) We have used conservative estimates of net current flow in the range of 50-100 m/hour for the Cape Horn (Port Ligar) and Pigeon Bay (Forsyth Bay) sites to estimate flushing and depletion rates. The estimated theoretical depletion rates at the Cape Horn site range from 6-30% depending on the assumed direction of flow in relation to neighbouring farms. At the Pigeon Bay site, the theoretical depletion rates have a similar range of 5-16%.

(7) At the Cape Horn site, the neighbouring farms are sufficiently far away that we consider any depletion that does occur in water flowing through the proposed site will recover by the time it takes this water to reach neighbouring farms (estimated to be at least four hours). At the Pigeon Bay site, the neighbouring farms are much closer and we can not reasonably conclude that there will be no effect - except that it is worth noting the lack of detected depletion outside a farm of this size in any published studies (see point 3 above).

1 INTRODUCTION

Marlborough Mussel Company Ltd has applied for coastal permits to farm greenshell mussels (*Perna canaliculus*) at four sites in Pelorus Sound. NIWA has been contracted to assess the sustainability of the proposed developments and their potential effects on adjacent marine farms. This report describes our assessment of sustainable production, particularly the possible effects on neighbouring farms of extraction of marine phytoplankton by the farmed mussels. The study does not address the wider issue of cumulative farms affecting the long-term sustainability of Pelorus Sound as a whole.

In this report we have defined sustainability as the level of production at which growth and condition of the stock are not adversely affected. This level will be determined by the mass flux of food to each farmed mussel and the stock density. The mass flux is the product of the flow rate and the food concentration.

If the flow is weak and the shellfish density is high enough, the mussels may extract food from water which has already had food partially extracted by neighbouring mussels, or by mussels on neighbouring farms. In situations where there are very low current velocities, this 're-filtration' may occur many times, resulting in a depleted food supply to the mussel. Conversely, if food concentration in the unfiltered water is high, limited re-filtration may not significantly affect the mussels. However at low food concentrations and high flow rates, re-filtration may be low but still significant because of the low ambient food levels.

In this report, we will consider the sustainable production issues both within the proposed developments and their potential effects on the sustainability of neighbouring farms. The proposed sites are located in Beatrix, Crail and Forsyth Bays and in Port Ligar.

2 BACKGROUND

2.1 Phytoplankton abaundance

Seasonal and long term variability in the abundance of phytoplankton and nutrients have been recorded by NIWA in Pelorus Sound, in Beatrix Bay and the Pelorus Channel at Tawero Point as part of Public Good Science Fund (PGSF) and related studies. A summary of phytoplankton abundance data, as measured by chlorophyll *a* pigment concentration, from previous studies in mid- and outer-Pelorus Sound is shown in Table 1.

Table 1. *Phytoplankton biomass as measured by chlorophyll* a *pigment concentration in the Marlborough Sounds (0-15 m water depth). No. = number of data points.*

Location	Dates	No.	Concentration range (µg Chl./l)
Main Pelorus Channel[1]	July 1981	2	7, 8
Northern Pelorus[2]	June 1986 – November 1987	6	0.6-1.0
Crail Bay –Northwest[3]	April 1984 – April 1985	161	0.5-2.9, Mean=1.3, median=1,1
Main Pelorus Channel[4]	August, December 1997	4	0.9-1.5
Tawhitinui Reach[4]	October 1997 – February 1998	76	0.5-2.8, mean=1.4, median=1.2
Beatrix west[5]	August 1995 – April 1999	186	0.3-4.5, mean = 1.4, median = 1.1
Beatrix east[5]	August 1995 – April 1999	187	0.2-11.2, mean = 1.4, median = 1.0
Tawero Point[5]	September 1997 – April 1999	126	0.3-4.7, mean = 1.5, median = 1.3

[1] From Bradford *et al.* 1987.
[2] From Mackenzie and Macintosh 1995, 0-15 m integrated depth – from zone "N".
[3] From Gibbs et al. 1988. Depth resolved samples from 1-32 m – mean depth = 9 m.
[4] Unpublished NIWA data from various depths from 0-30 m.
[5] Unpublished NIWA data, Ross *et al.* 1998a,b – from weekly 0-15 m integrated water samples collected by the Marlborough Sounds Shellfish Quality Programme.

These concentrations are likely to be reasonably representative of phytoplankton levels at the proposed sites. The concentrations are generally sub-optimal for mussel production. Hence, any reduction in phytoplankton abundance, for example as a consequence of a neighbouring farm extracting phytoplankton, can potentially affect the production capacity of the farm.

There are a number of factors that determine the abundance of phytoplankton in coastal waters. Perhaps the most important single factor in Pelorus Sound is the stratification of the water column. This is a particularly significant factor in Pelorus because it controls the extent of light limitation of phytoplankton growth in winter, and the extent of nutrient limitation in summer (Ross *et al.* 1998c – a summary and a discussion of the importance of stratification to phytoplankton production is given in Ross *et al.* 1998a). There is considerable variability in water column stratification on short and long term (inter-annual) time scales. Hence there is considerable natural variability in phytoplankton abundance.

Inter-farm effects on production as a consequence of depletion, therefore need to be seen in this context. A small level of depletion may not be greatly significant during normal phytoplankton conditions. However during periods of prolonged low phytoplankton abundance, slightly depleted water may make a bad production environment even worse.

2.2 Water currents

At two of the proposed sites, Opani-aputa and Sheep Pen Bay, current velocities were measured on 17 and 18 January 2000. At the other two sites current measurements were not made. For the first two sites, we will use the measured data to assess the flushing rate and the direction(s) in which potentially depleted water leaves the site. For the second two sites we will use conservatively estimated ranges of current velocities.

Current measurements were made using an Acoustic Doppler Profiler (ADP - SonTek, San Diego) attached to a moving vessel. This instrument measures currents remotely by calculating the acoustic Doppler shift of moving particles below the instrument. This method allows collection of velocity data for layers of the water column, and is hence equivalent to having a number of conventional current meters in a vertical array. The instrument is unable to measure the top 1.5 m and also the bottom 4 m of the water column due to acoustic interference from the bottom boundary.

The water column was divided into 4m layers, and current velocities measured in each of these layers over the period of the survey, (usually less than one hour). Currents were measured along transects which crossed the proposed site. The boat's velocity was measured using acoustic 'bottom-tracking' and the current velocity calculated by subtracting the velocity of the boat from the total measured velocity. The positions of the velocity measurements were recorded using a Lowrance GPS system integrated with the ADP. At each of the two sites, four repeat surveys were conducted over a 24-hour period.

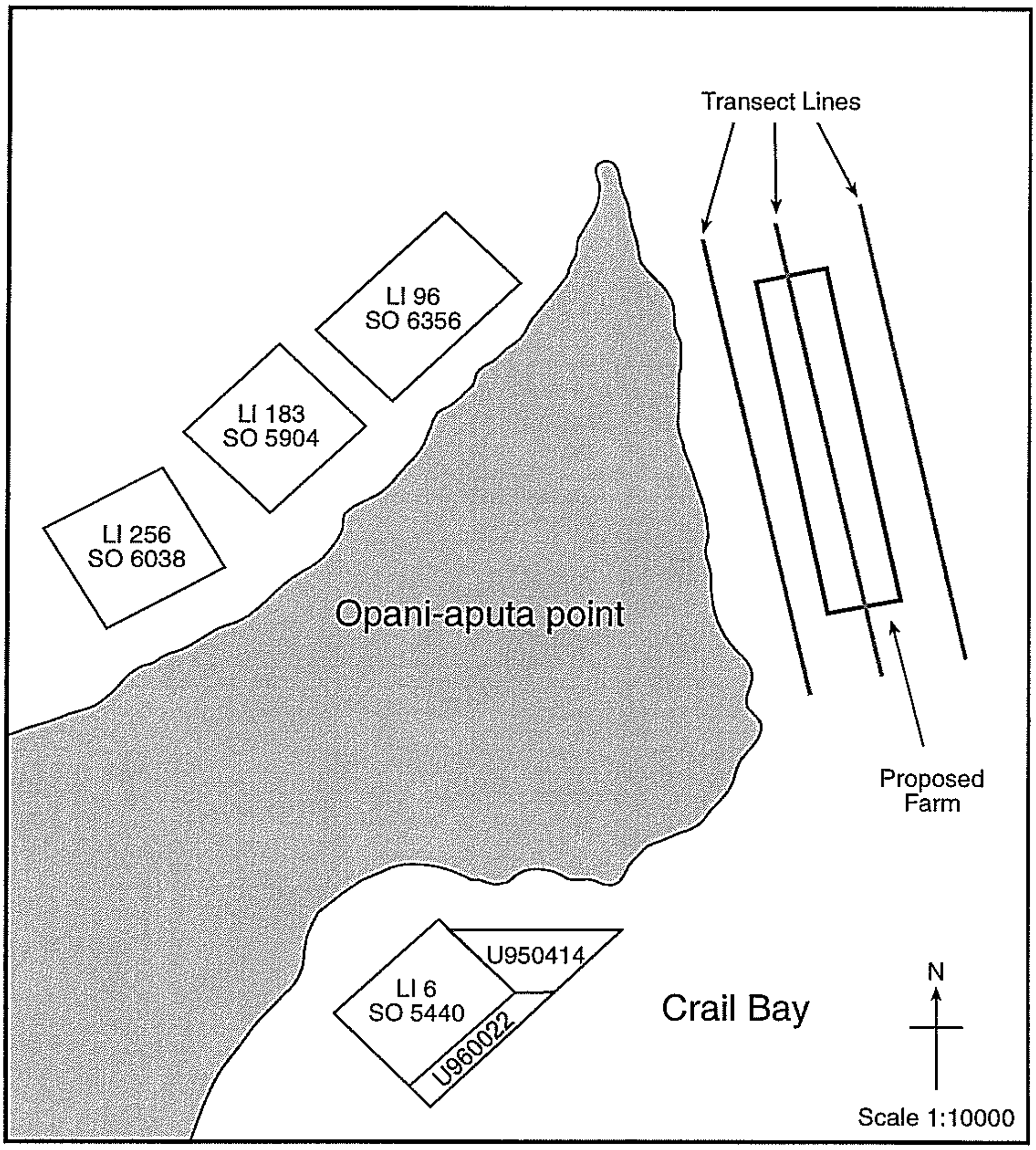
Current vectors have been averaged over 30 second periods, with each period containing 24-25 separate estimates. The vectors have been plotted (In Figures 2.2-2.5 & 2.7-2.10) using the appropriate latitude and longitude. The mid-point of each vector corresponds to the latitude and longitude of the boat at the mid-point of this averaging period. These positions are plotted relative to the proposed development. Note that the scale of the vectors in Figures 2.2-2.5 differ from the scale in Figures 2.7-2.10, but is the same for all the plots that relate to each site. Tide times are model generated for each specific site.

2.2.1 Opani-aputa Point (Crail Bay)

The transect lines, over which the current surveys were conducted, are shown in Figure 2.1. During the first survey on 17 January, the current flow at the proposed site was predominantly in an easterly, offshore, direction (Fig. 2.2). This was during a period of 1-2 hours after high water when we might expect water to be flowing out of Crail Bay. The following morning, a second survey was conducted 3-4 hours after high water (Fig. 2.3). There was a very pronounced easterly flow, although current speed was weaker than during the first survey. A third survey was conducted immediately before low water. The direction of flow was found to be highly variable with what appeared to be smaller eddy behaviour over the site (Figure 2.4). This situation had largely persisted during a fourth survey that was conducted approximately three hours later. There was slightly more indication of on-shore flow during this last survey.

On the evidence of these four surveys, current flow appears to be easterly on the outgoing tide, and perhaps westerly - but highly variable - on the incoming tide. The mean current speed across the three transects and over the four surveys was 9.2 cm/s.

Figure 2.1. *Transect lines across the proposed site over which current measurements were made.*



Due to the influence of wind on the vessel direction and the need to keep vessel speed low, the actual survey lines may not be an exact match to these lines.

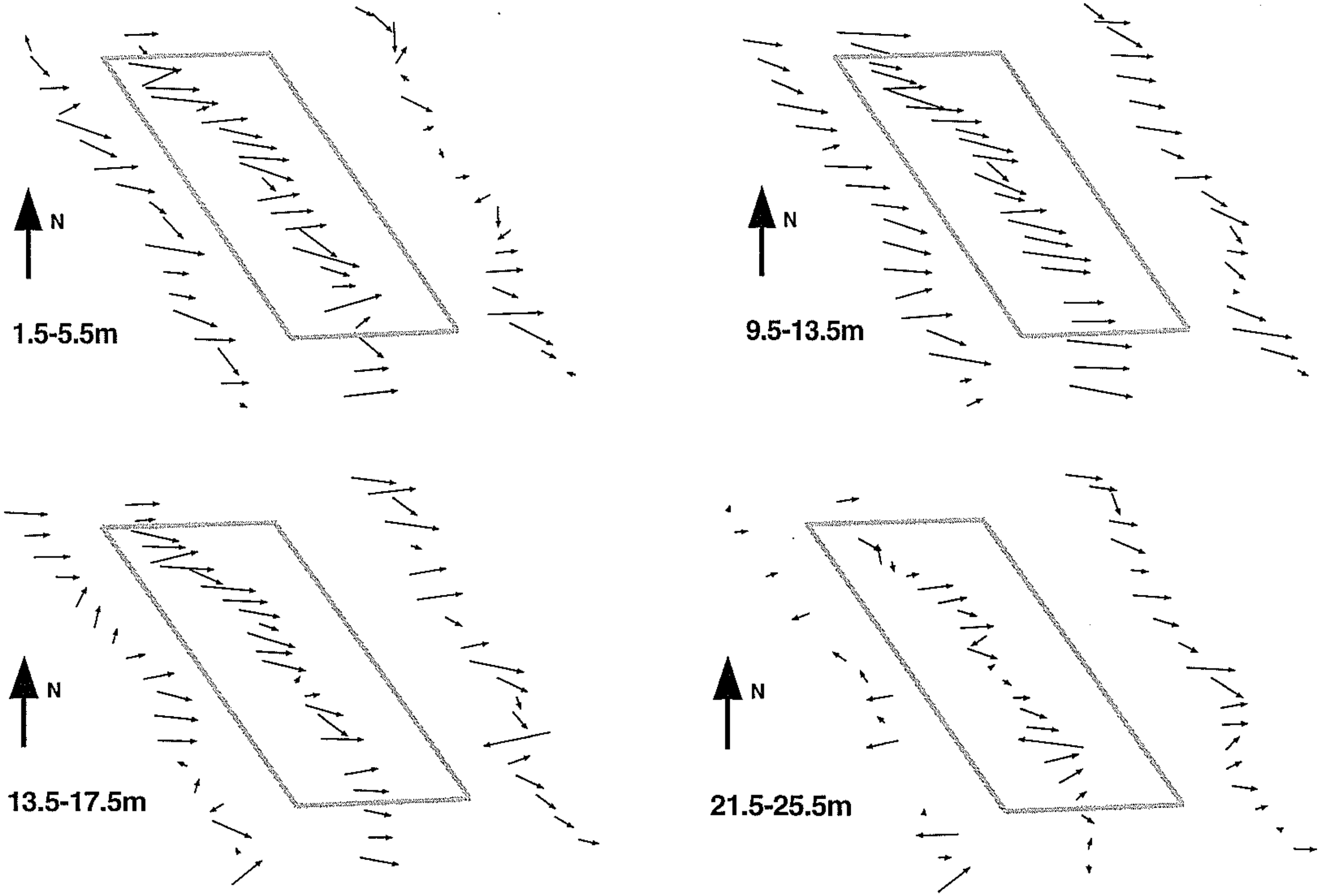


Figure 2.2 *Current flow around the proposed Opani-aputa site on 17 January 2000 from a survey conducted between 19:07-19:42 (NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.1 km/hr. The average current speeds were 10.2, 12.2, 9.9, and 8.5 cm/s at the respective depth intervals (1.5-5.5m -> 21.5-25.5m). High water was ~17:30 PM.*

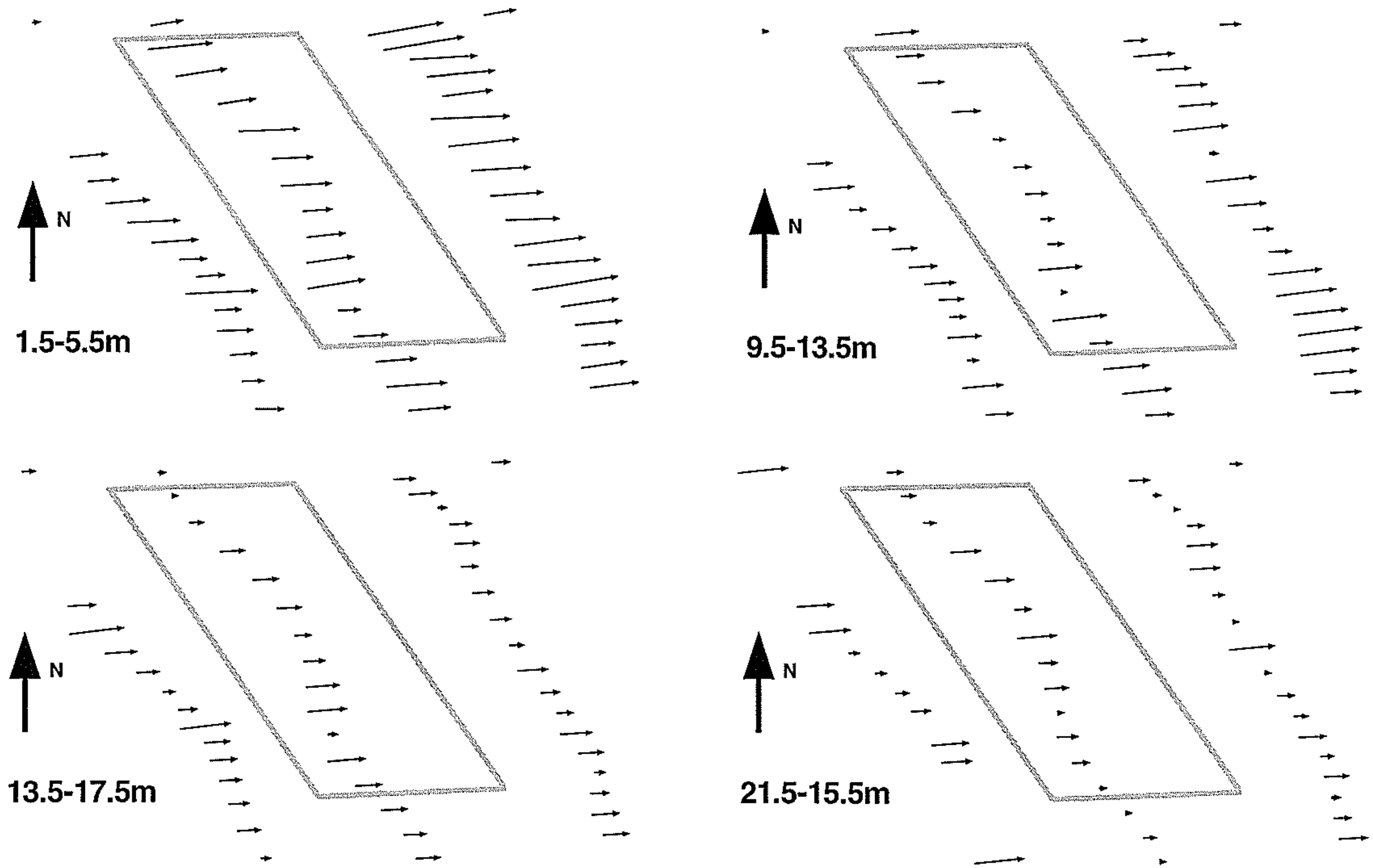


Figure 2.3 *Current flow around the proposed Opani-aputa site on 18 January 2000 from a survey conducted between 09:48-10:20 (NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.5 km/hr.* The average current speeds were *9.8, 7.6, 5.4, and 5.9 cm/s at the respective depth intervals (1.5-5.5m -> 21.5-25.5m). High water was ~6:30 AM.*

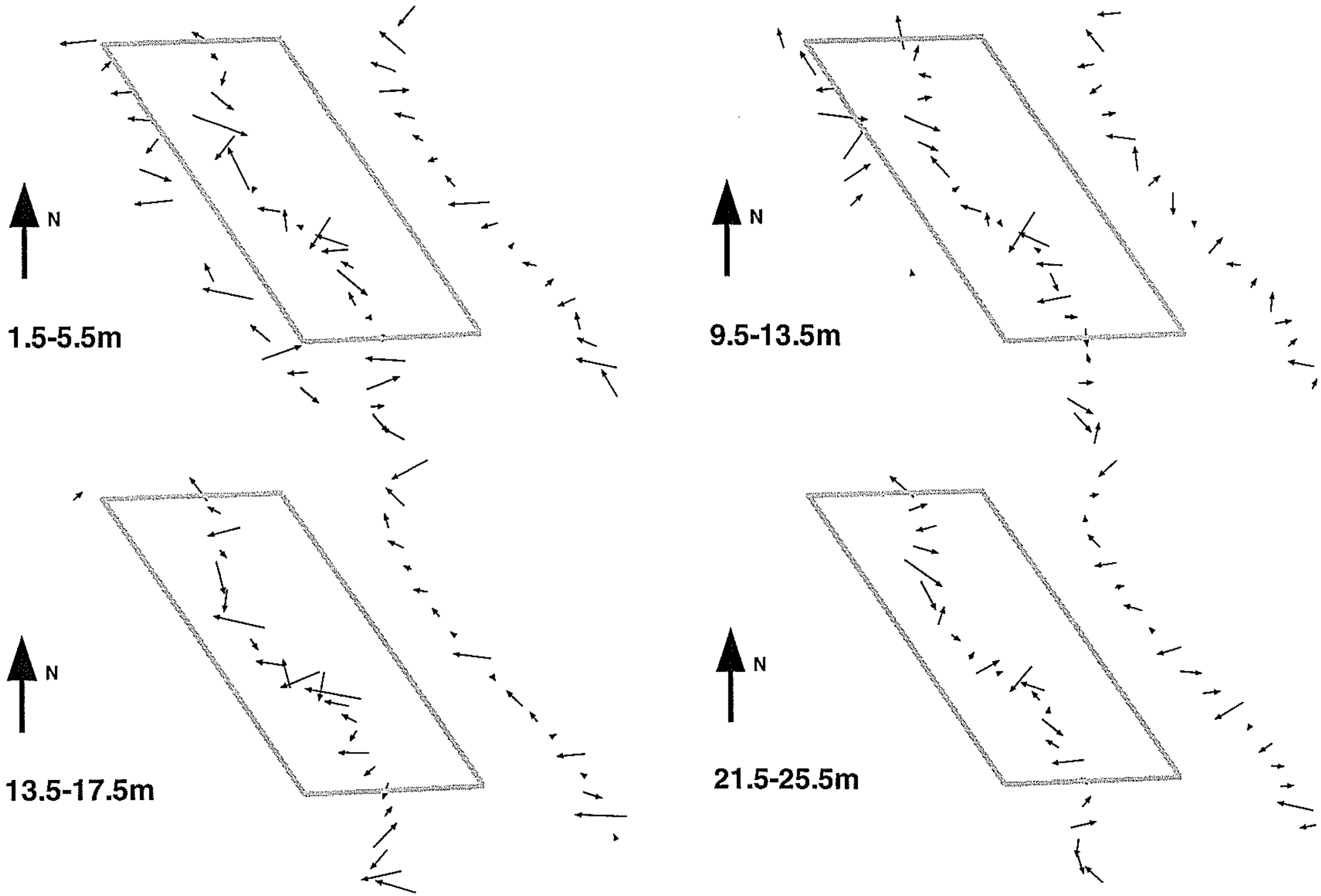


Figure 2.4 *Current flow around the proposed Opani-aputa site on 18 January 2000 from a survey conducted between 11:49-12:23(NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.5 km/hr. The average current speeds were 8.1, 6.0, 6.2, and 7.7 cm/s at the respective depth intervals (1.5-5.5m -> 21.5-25.5m). Low water was ~12:30 PM.*

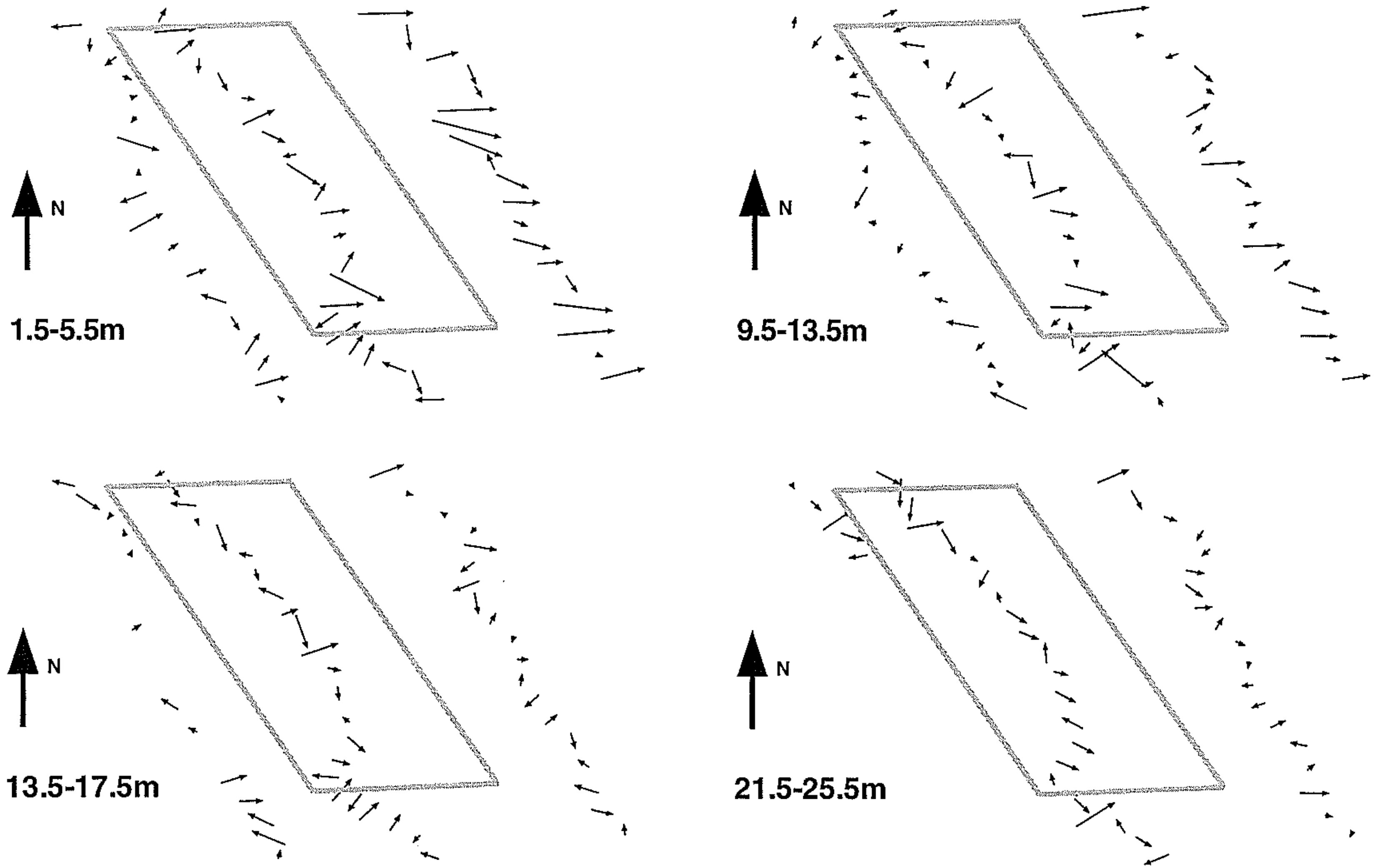


Figure 2.5 *Current flow around the proposed Opani-aputa site on 18 January 2000 from a survey conducted between 14:35-15:10(NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.3 km/hr. The average current speeds were 9.2, 9.3, 11.4, and 10.3 cm/s at the respective depth intervals (1.5-5.5m -> 21.5-25.5m). Low water was ~12:30 PM.*

2.2.2 Sheep Pen Bay (Beatrix Bay)

Circulation in Beatrix Bay is generally clockwise (Mark Hadfield, pers. comm., Sutton and Hadfield 1997), suggesting that Sheep Pen Bay is most likely influenced by water from eastern Beatrix Bay.

The transect lines over which the current surveys were conducted are shown in Figure 2.6. During the first survey on 17 January, immediately after high water, the current flow through the site was variable but generally southwesterly (Fig. 2.7). Deeper water was flowing into Sheep Pen Bay and surface waters at the bay entrance appeared to be highly variable.

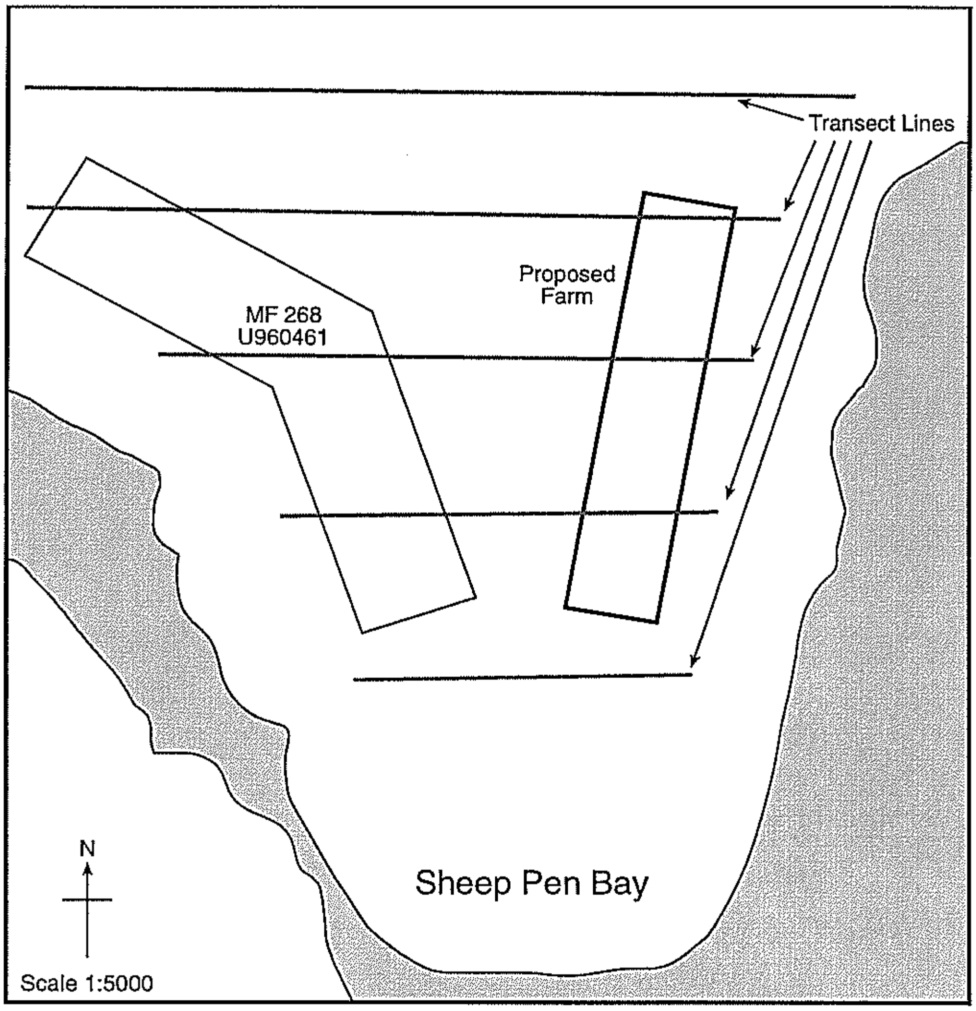


Figure 2.6 *Transect lines across the proposed Sheep Pen Bay site over which current measurements were made. Due to the influence of wind on the vessel direction, and the need to keep vessel speed low, the actual survey lines may not be an exact match to these lines.*

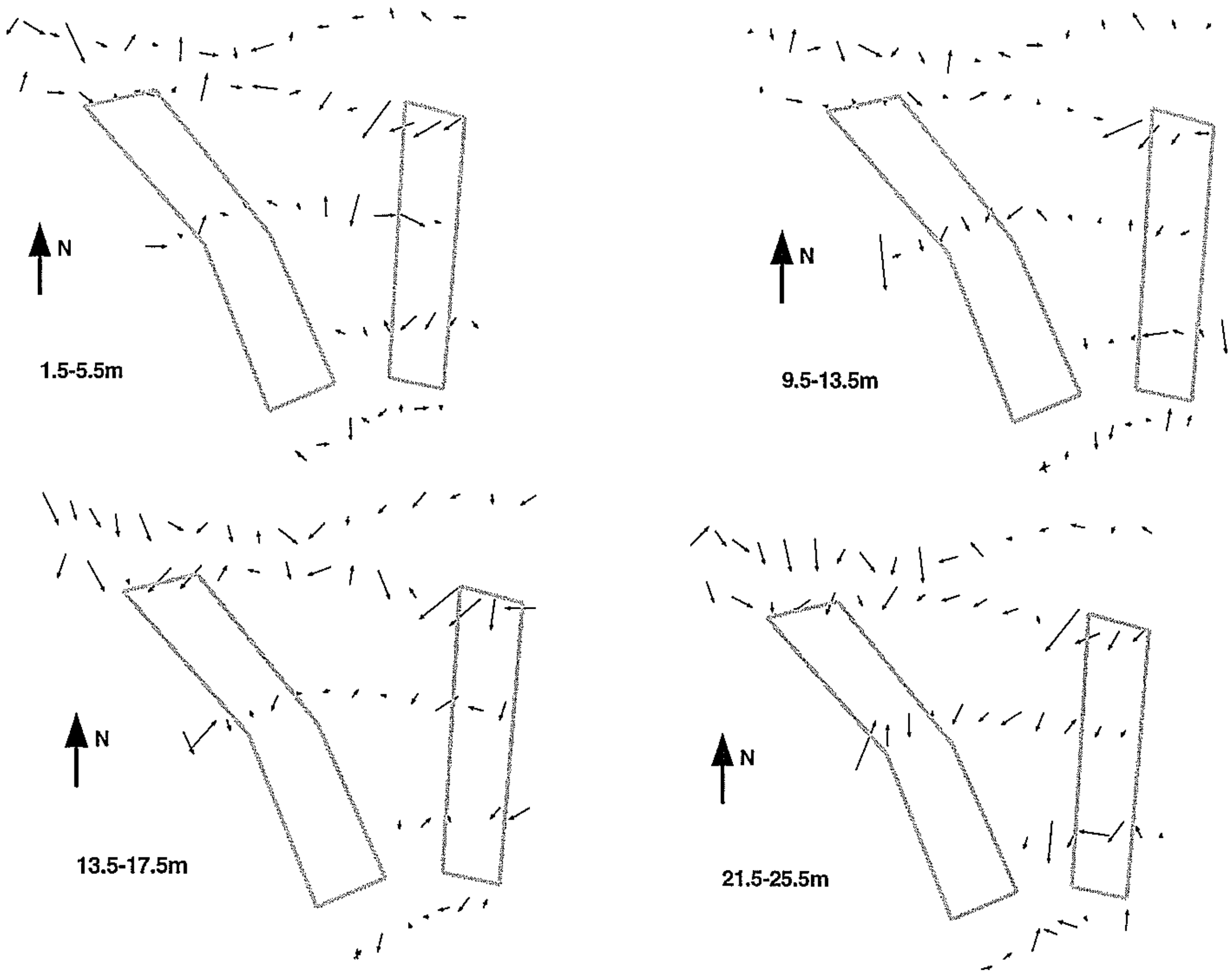


Figure 2.7 *Current flow around the proposed Sheep Pen Bay site on 17 January 2000 from a survey conducted between 17:42-18:25(NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.1 km/hr. The average current speeds were 6.7, 5.3, 7.1, and 8.5 cm/s at the respective depth intervals (1.5-5.5m -> 21.5-25.5m) High water was ~ 17:30 PM.*

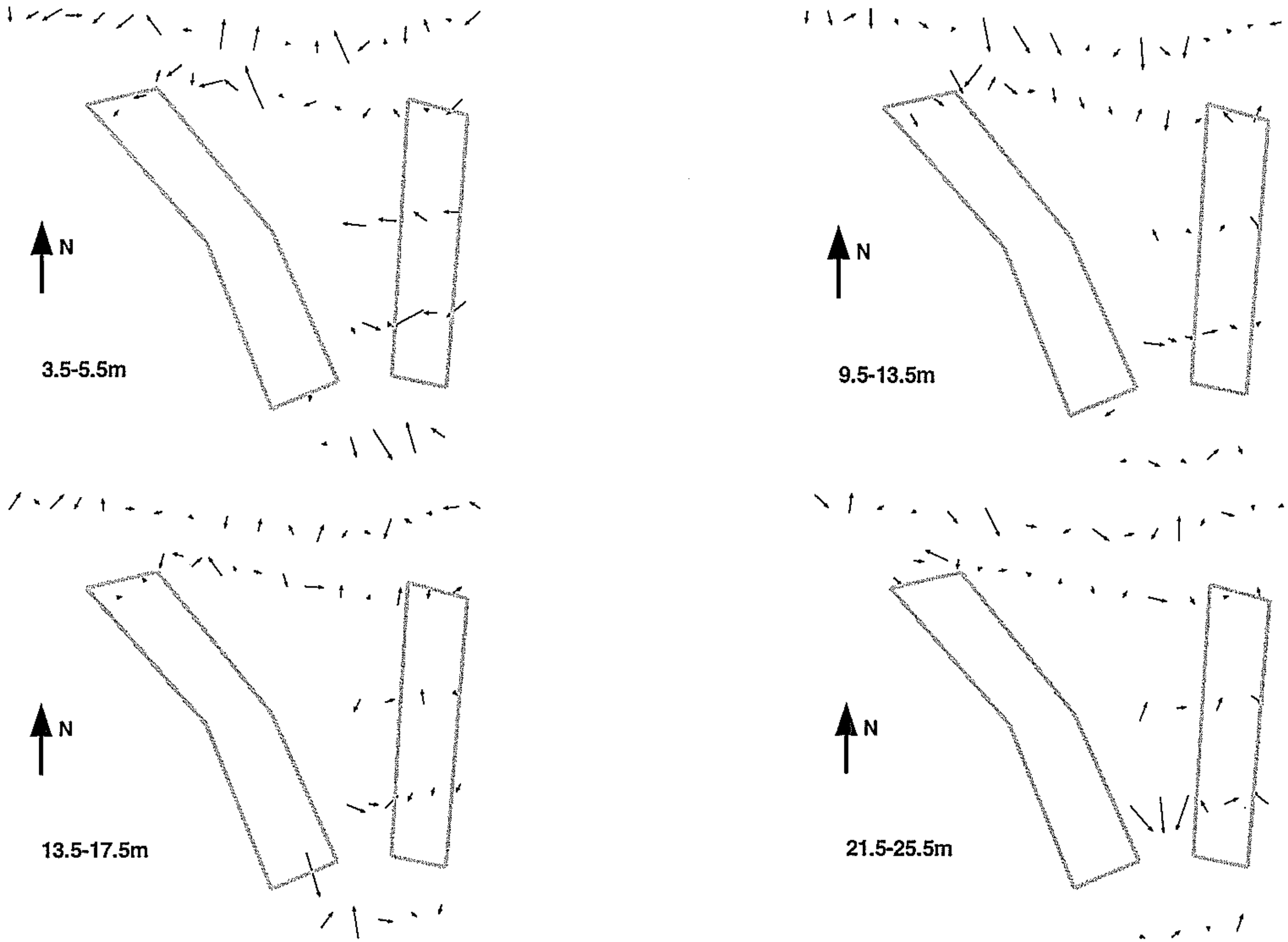


Figure 2.8. *Current flow around the proposed Sheep Pen Bay site on 18 January 2000 from a survey conducted between 08:45-09:27 (NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.3 km/hr. The average current speeds were 6.8, 5.0, 5.0, and 6.2 cm/s at the respective depth intervals (1.5-5.5 m -> 21.5-25.5m). High water was ~ 6:30 AM.*

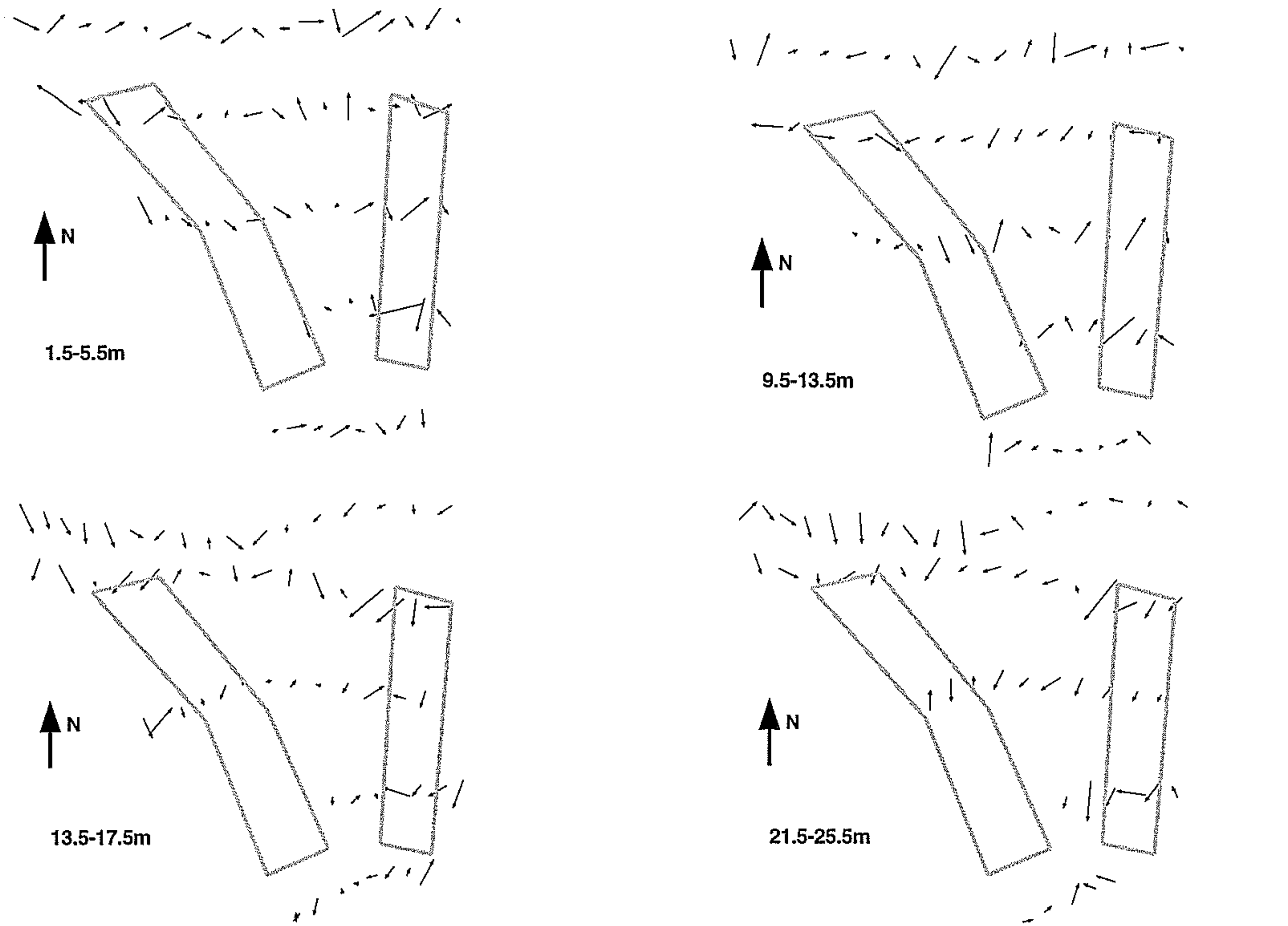


Figure 2.9 *Current flow around the proposed Sheep Pen Bay site on 18 January 2000 from a survey conducted between 10:40-11:24 (NZST). Current velocities are averages recorded in bins of 4m depth, over 30 second intervals, from a vessel moving at an average speed of 4.3 km/hr. The average current speeds were 8.4, 7.3, 8.1, and 9.5 cm/s at the respective depth intervals (1.5-5.5 m -> 21.5-25.5 m). Low water was ~12:30 PM.*

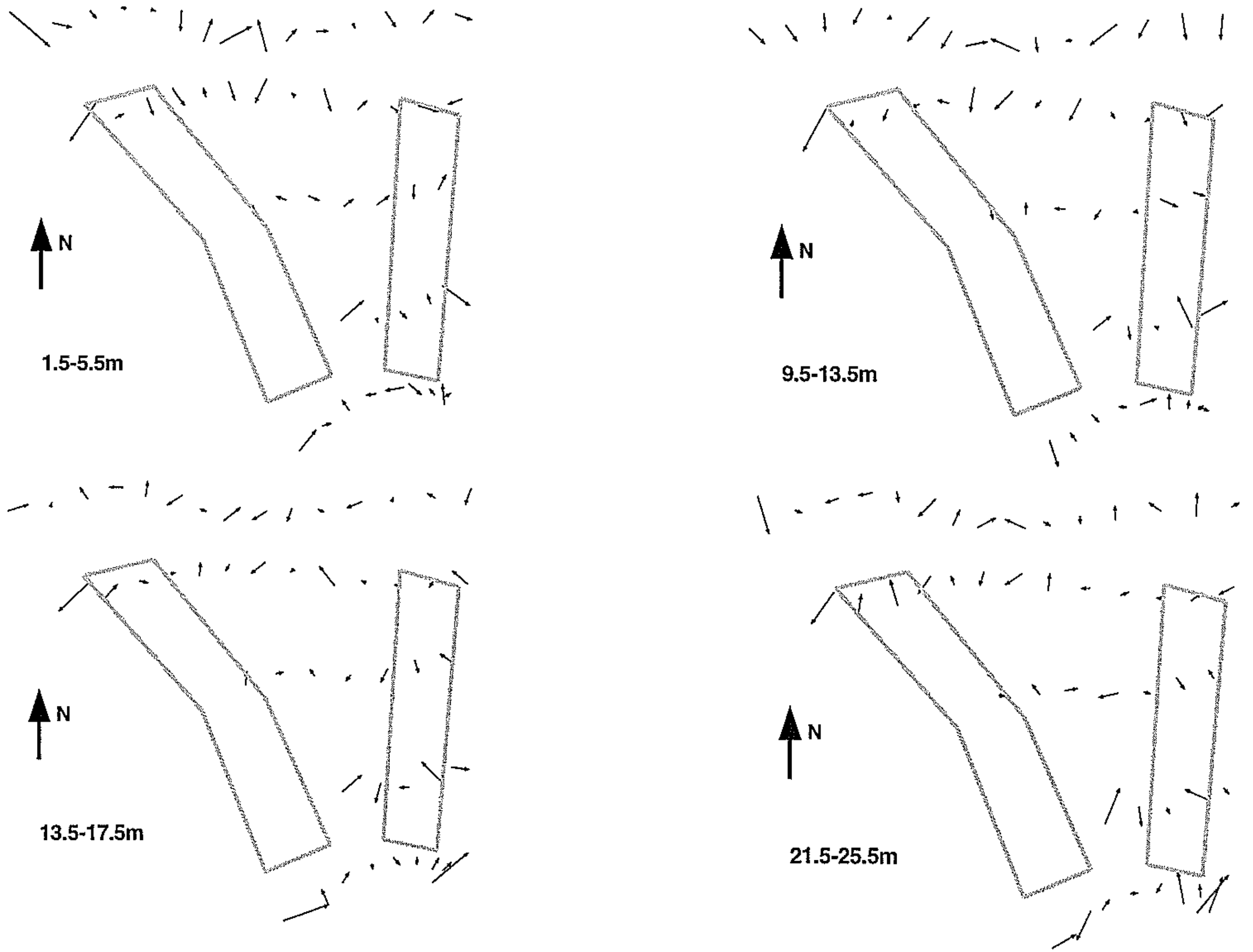


Figure 2.10 *Current flow around the proposed Sheep Pen Bay site on 18 January 2000 from a survey conducted between 13:11-14:20 (NZST). Current velocities are averages recorded in bins of 4 m depth,over 30 second intervals, from a vessel moving at an average speed of 4.6 km/hr. The average current speeds were 7.4, 6.9, 6.4, & 7.1 cm/s at the respective depth intervals (1.5-5.5 m -> 21.5-25.5m). Low water was ~12:30PM.*

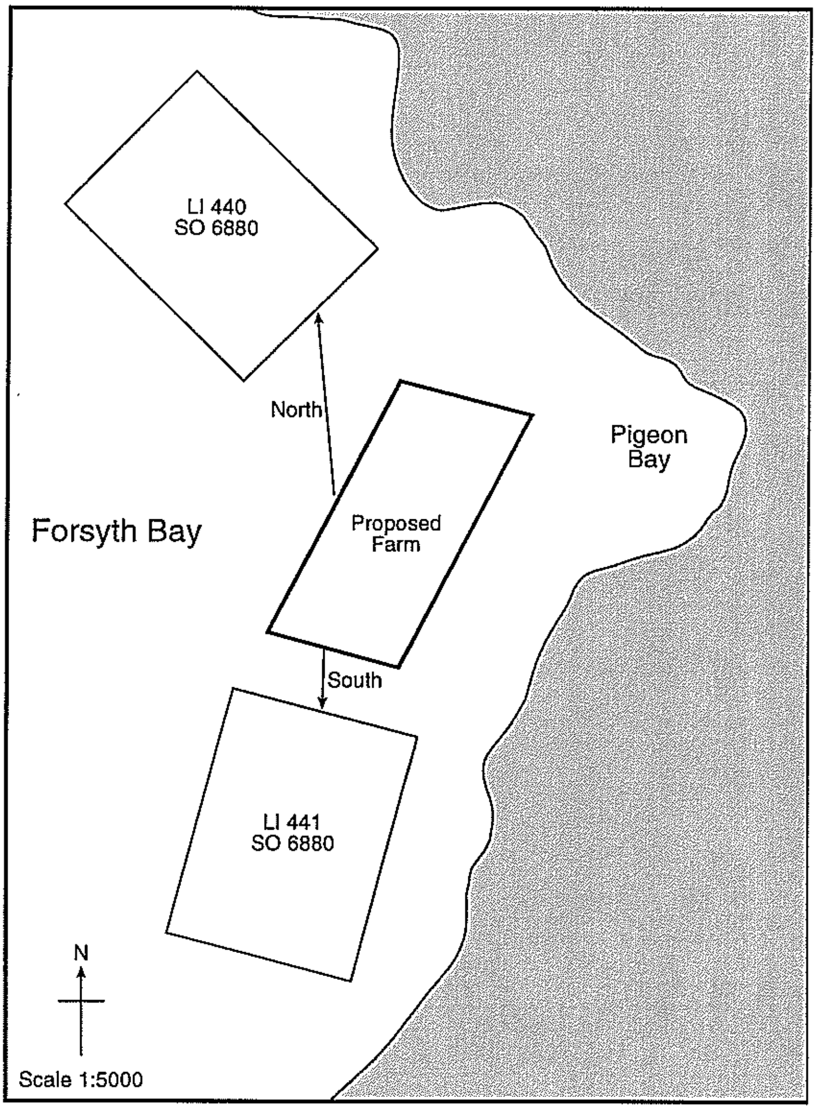


Figure 2.11. *The proposed site at Pigeon Bay, Forsyth Bay, showing the directions of the neighbouring farms to the north and south.*

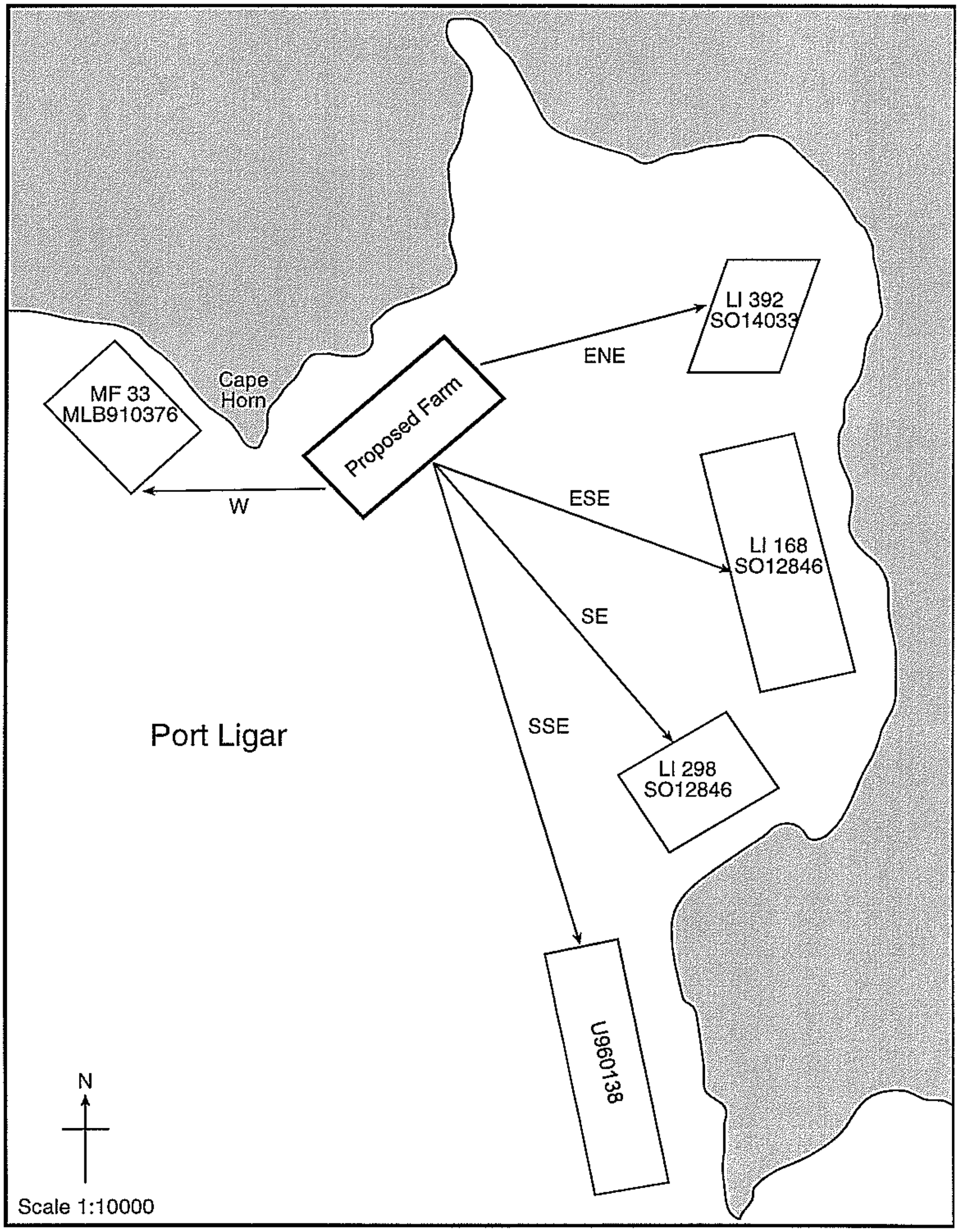


Figure 2.12. The proposed site at Cape Horn, Port Ligar, showing the directions of the neighbouring farms to the east, south and west.

During the second survey some 2-3 hours after high water on 18 January, the current flow was again highly variable both horizontally and vertically (Figure 2.8). There was no discernible pattern over the proposed site, or indeed over the whole bay. Very similar results were observed during the third and fourth surveys conducted 1-2 hours before and after low water respectively.

On the evidence of these four surveys, current flow appears to be highly variable in Sheep Pen Bay. There does not appear to be any persistent direction for water leaving the proposed site. The mean current speed in the vicinity of the site over the four surveys was 6.8 cm/s.

2.2.3 Cape Horn and Pigeon Bay

No current measurements have been made at Cape Horn or Pigeon Bay. For these sites we use conservative estimates of current speed and direction for assessing the potential influence of the proposed developments on neighbouring sites. We have assumed current directions that would result in water leaving the proposed site, travelling directly to each neighbouring farm (see arrows in Figures 2.11 & 2.12). Our assessment is based on net current flows of 50-100 m/hour, which we consider to be conservative estimates of maximum and minimum mean levels for these sites based on previous current measurements in similar areas of Pelorus Sound.

3 FLUSHING RATES AND PHYTOPLANKTON DEPLETION

Likely filtration rates (m^3/hour water filtered by mussels in a farm) have been calculated for each proposed development according to information on stocking densities provided by the client, standard farming practise, and measurements of size-specific filtration rate conducted by NIWA as part of PGSF research. These rates are determined independently of how much seawater is actually available to mussels at a given site. Water available to filter by the mussels depends on water currents at the site. If it is assumed that all the plankton in water passing through the mussels' filtering apparatus is retained by the mussels – generally a good assumption - then the ratio of filtration rate to the total flow of seawater (m^3/hour) passing through the development is equivalent to the fraction of plankton removed by the mussels, i.e., the depletion ratio. Results of calculations and the relevant data are summarised for each development in the tables below. In practice, we have used an average travel time (the time for water to pass from the middle of a development to its boundary, rather than from one end to the other) in the calculations, as being representative of conditions experienced on average by plankton traversing a development. At the other two sites, conservative estimates of the flushing rates have been made based on our experience of current measurements in similar areas of Pelorus Sound. Since for these latter two sites the direction of flow is unknown, we have assumed a worst case scenario in relation to each neighbouring farm — i.e. that the flow from the proposed site will be directly towards that farm.

3.1 Opani-aputa

We have estimated the total flushing time of this site in two ways:

1 A short total flushing time when the flow is west -> east as in Figures 2.2 and 2.3. The total flushing rate is calculated as the cross-sectional area perpendicular to the flow times the mean current speed. The flushing time is estimated to be 19 minutes.

2 A moderate total flushing time applicable when the flow is highly variable (Figs. 2.4 and 2.5). In this case we have assumed that the magnitude of the net current flow is one third of the average of current speeds (i.e the scalar average of magnitudes of velocities, regardless of direction). This factor is typical for other current datasets we have collected in Pelorus Sound. This gives a maximum flushing time of 56 minutes in an east-west direction.

The percentage depletion is calculated using the estimated average flushing time, which is half the maximum estimated flushing time. Using the two different flushing rate estimates above, we estimate the percentage of phytoplankton depleted in water flowing through the proposed Opani-aputa site to be 0.9% during strong easterly flow, and 2.6% during variable flow conditions. These calculations are summarised in Table 3.1.

3.2 Sheep Pen Bay

For the Sheep Pen Bay site, the current direction is highly variable (Figs. 2.7-2.10). Hence we have used an estimate of the magnitude of net current flow equal to one third of the mean current speed. In this case the flushing rate in the direction of the neighbouring farm to the west is 59 minutes. From this we estimate that the percentage depletions rate will be 2.7% for water flowing in a westerly direction. These calculations are summarised in Table 3.2.

Table 3.1. *Opani-aputa estimated flushing and depletion rates.*

Characteristic	Easterly flow	Variable flow
Filtration rate of mussels (m^3/hour)	42,337	42,337
Volume of site	772,000	772,000
Min. distance to adjacent site (m)	Not applicable	Not applicable
Max length of site to be flushed (m)	103	103
Mean current speed (m/hour)	330	110
Maximum flushing time (hours)	0.31	0.94
Mean flushing time (hours)	0.16	0.47
% depletion (using mean flushing)	0.9%	2.6%

Table 3.2. *Sheep Pen Bay estimated flushing and depletion rates.*

Characteristic	Flow to west (MF268)
Filtration rate of mussels (m^3/hour)	19,540
Volume of site	357,000
Minimum distance to adjacent site (m)	70
Maximum length of site to be flushed (m)	72
Mean current speed (m/hour)	73
Maximum flushing time (hours)	0.99
Mean flushing time (hours)	0.49
% depletion (using mean flushing)	2.7%

3.3 Cape Horn and Pigeon Bay

For these two sites we have estimated several flushing times, one for each direction appropriate to water flowing towards each neighbouring farm. For Cape Horn there are five neighbouring farms so there are five estimates of flushing time. For Pigeon Bay there are two neighbouring farms and hence there are two flushing rate estimates. The flushing rates and depletions rates in each case are given as ranges appropriate to an assumed net current speed range of 50-100 m/hour. We consider that the mean net current flow is unlikely to be outside this range, based on our experience of estimating net current flow from long term moored current records. The depletion estimates for these two sites, together with the other characteristics used to estimate the depletion rates are shown in Tables 3.3 and 3.4.

The estimated depletion rates are higher for the Cape Horn (6-30%) and Pigeon Bay (5-16%) sites than for the Opani-aputa or Sheep Pen Bay sites. This is largely due to the necessity of using very conservative estimates of flushing for Cape Horn & Pigeon Bay since there are no current data available. In practise, the depletion rates are likely to be less than this.

Table 3.3 *Pigeon Bay estimated flushing and depletion rates.*

Characteristic	Flow to NNW (LI 440)	Flow to SSW (LI441)
Filtration rate of mussels (m^3/hour)	26390	26390
Volume of site	354,450	354,450
Minimum distance to adjacent site (m)	117.5m	50
Maximum length of site to be flushed (m)	140	215
Mean current speed (m/hour)	50-100	50-100
Maximum flushing time (hours)	1.4-2.8	2.1-4.2
Mean flushing time (hours)	0.7-1.4	1.1.-2.2
% depletion (using mean flushing)	5.2-10.4%	8-16%

Table 3.4 Cape Horn estimated flushing and depletion rates.

Characteristic	Flow ENE (LI 392)	Flow to ES E (LI 168)	Flow to SE (LI 298)	Flow to SSE (U960138)	Flow to W* (MF 33)
Filtration rate of mussels (m^3/hour)	56700	56700	56700	56700	56700
Volume of site	630,000	630,000	630,000	630,000	630,000
Minimum distance to adjacent site (m)	320	380	580	825	200**
Maximum length of site to be flushed (m)	330	160	140	155	210
Mean current speed (m/hour)	50-100	50-100	50-100	50-100	50-100
Maximum flushing time (hours)	3.3-6.6	1.6-3.2	1.4-2.8	1.55-3.1	2.1-4.2
Mean flushing time (hours)	1.65-3.3	0.8-1.6	0.7-1.4	0.8-1.6	1.05.-2.1
% depletion (using mean flushing)	15-30%	7-14%	6.5-13	7-14%	9.5-19%

***Only a small part of the farm to the west is 'visible' from the proposed site.**

4 EFFECTS ON NEIGHBOURING FARMS

4.1 Background

The effects of depletion from large-scale developments are unknown, but there is information on the influence of 3-hectare farms on the depletion of phytoplankton. Murdoch and Oliver (1995) found no significant difference between phytoplankton abundance as estimated by chlorophyll abundance inside and outside farms. Other studies have shown little difference between inside and outside farms (S. Ogilvie, pers. comm.) when the inside farm measurement is between the longlines. However, when the inside measurements are made within the backbones of the long-line, there can be significant differences.

Ogilvie *et al* (1999) have shown that there are significant differences between the outside of the farm and within the backbones of the longline of up to 80%. However, the depletion inside the backbone was usually found to be less than this.

Overall there is little evidence of detectable depletion outside the backbone of the longlines. This implies that the recovery rate of the water due to mixing with undepleted water is sufficiently rapid to make detection of depletion difficult. Hence it can be argued there are unlikely to be significant effects of one farm on another for the size of the proposed farms.

However there is always a theoretical possibility that the flow regime at a particular site may give rise to a depletion problem. For example, depletion may occur when a longline is orientated parrellel with the flow and is close to a neighbouring farm. To assess the risk of depletion affecting a neighbouring site, we need to consider a number of factors:

(1) the direction of the flow as it leaves the proposed site,

(2) the extent of the phytoplankton depletion in water flowing through the proposed site, and

(3) the distance from the proposed site to a neighbouring site.

These issues are related to each of the proposed sites below.

4.2 Opani-aputa

At the Opani-aputa site, there are no near neighbouring farms so the issue of the effect of depletion on neighbouring farms is somewhat academic. Although there are farms on either side of Opani-aputa point, these are very unlikely to be affected by the proposed development due to the speed and direction of flow at the site and the low phytoplankton depletion estimated in section 3 above.

4.3 Sheep Pen Bay

At Sheep Pen Bay there is an existing farm to the west, which at the closest point is about 70 m from the proposed site. There is no prevailing current flow direction as water leaves the proposed site (Section 2.2.2). Hence we can conclude that the neighbouring site is no more likely to be affected than other surrounding water masses. Given that the depletion is low, the flow direction is variable, and that the recovery due to mixing with undepleted water is likely to be high for this size of farm (see above), we consider there is unlikely to be a significant impact at the neighbouring farm.

4.4 Pigeon Bay and Cape Horn

The calculated depletion rates (Tables 3.3 and 3.4) for these sites may suggest a depletion problem. However, as discussed in section 3 above, these rates are heavily influenced by the conservative assumptions behind the calculations due to the absence of current data. The actual depletion rates are likely to be significantly lower - probably much less than 5% based on previous measurements. At the Cape Horn site, the neighbouring farms are some distance away ~200-800 m at the closest point. The time it takes for water leaving the proposed site to reach these neighbouring sites is likely to be upwards of four hours. Any depletion caused by water flowing though the proposed site is likely to recover due to mixing with undepleted water by the time it takes to reach the neighbouring farms.

At Pigeon Bay, the two neighbouring farms are closer than at Cape Horn (50, 120 m at the closest point). Hence at this site it is more likely that depleted water could affect the neighbouring sites under certain flow regimes – i.e. when the water is being carried directly onto the neighbouring farm. However, it is worth considering that there have been no published records of depletion outside a farm of this size, as discussed in Section 4.1 above.

5 MONITORING

At present there are no requirements to monitor the sustainability of marine farms or the general health of the ecosystem. However, it is in the interest of marine farm management to monitor the performance of farms in relation to environmental variation.

It is in the marine farming industry's interest to demonstrate that no adverse effects arise from the proposed development by monitoring before and for a period after the development begins. Few industries depend so heavily on environmental variation as marine shellfish farming - all production is ultimately driven by phytoplankton production. Therefore it would be prudent to systematically monitor at least the growth and condition of stock in relation to phytoplankton abundance.

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