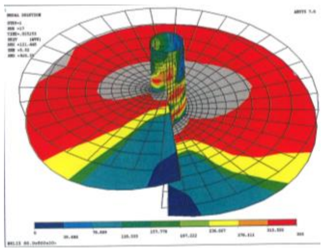
NEW ZEALAND KING SALMON

ENGINEERING FEASIBILITY OF THE PROPOSED SALMON FARM AT TIO POINT TORY CHANNEL



October 2016

by

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EXECUTIVE SUMMARY

The purpose of this document is to report on the engineering feasibility study of the proposed Tio Point salmon farm at the entrance to Oyster Bay off Tory Channel. The work, commissioned by New Zealand King Salmon Company Limited (King Salmon) in consultation with Te Atiawa and carried out by OCEL Consultants NZ Limited (OCEL), encompassed a preliminary structural design and mooring analysis as part of determining the engineering feasibility of the proposal.

The Tio Point site is located in 18 - 44 m water depth in a region of moderate to strong tidal currents – maximum tidal current velocity ranging up to 0.5 m/sec during spring tide events.

The design of the floating farm structure is based on offshore engineering principles adapted to account for the flexible nature of the marine farm structures and suspended nets. As part of the confirmation of the theoretical approach a hydrodynamic force monitoring program will be implemented – the same as has been done for the other King Salmon farms in the Tory Channel high current area – to check the actual loads experienced by the structure. The dimensions of the proposed farm are several multiples of the incident wave lengths for locally generated wind waves so the net or global wave induced force on the farm structure is close to zero. Tidal current induced hydrodynamic loading dominates and produces the forces the mooring system must resist. The mooring system is designed to achieve a factor of safety of 5 for the mooring line elements.

The farm will be anchored by screw anchors. These are lightweight and efficient and can be installed with a high degree of accuracy. They can also be installed diverless. Screw anchors cause minimal disturbance to the seabed during installation. The connecting warp is the only evidence of their presence at seabed level. Monitoring the installation torque provides a good indication of the anchor pullout capacity. A pullout test will also be performed on a representative anchor to check screw anchor capacity and to confirm the relationship between installation torque and pullout capacity. The mooring lines will incorporate elastic Marine Flex units both to accommodate the tidal range in Tory Channel and to eliminate snatch loading in the mooring system under wave loading from both locally generated waves and Cook Strait ferry wash.

The proposed salmon farm at Tio Point is fully feasible from a mooring and structural safety standpoint and has as precedents the already established farms in Tory Channel at Te Pangu, Clay Point and Ngamahau. The current speeds at Tio Point are less than at these other locations. The Tio Point farm will use existing proven technology, based on experience with the Te Pangu and Clay Point farms and will benefit from King Salmon's ongoing development and refinement work to ensure a safe secure structure with known factors of safety.

1.0 INTRODUCTION

It is proposed to build a new salmon farm site at Tio Point in the entrance to Oyster Bay off Tory Channel. This report reviews the suitability of the proposed site based on engineering considerations and identifies a design for the location.

The farm design will be closely similar to the existing proven King Salmon salmon farms on Tory Channel, in strong tidal current locations at Ngamahau, Te Pangu and at Clay Point. The farm is well away from the Cook Strait entrance to Tory Channel and not affected by relatively long period ocean swell. It is subject to short period seastates characteristic of the Sounds. The farm structure will be the same as the structure of the other Tory Channel farms, continuous pipe flotation/structural elements defining pens. The nets are suspended from the tubular elements. The mooring lines attach to strong points on the structure where the tube elements join, at corners or tee intersections. The whole structure will be subject to finite element analysis, using the ANSYS® program to ensure that the stresses induced in the structure remain within the stress limits of the NZ Steel Structures Code.

The design of the floating farm structure is based on offshore engineering principles, however, the calculation methods need to be adapted to account for the flexible nature of the marine farm structures and suspended nets. As part of the confirmation of the theoretical approach a hydrodynamic force monitoring program has been put in place to check the actual loads experienced by existing farm structures. This is part of the King Salmon policy of ensuring the safety and security of the company's farm structures. For the proposed new location the same policy will be implemented. The self recording (and real time readout) load cell devices used to monitor the relatively steady slow fluctuating tidal current loads on the moorings will be complemented by load cell devices that can monitor higher frequency wave loads. The farm components, structural and mooring, will have a known factor of safety.

2.0 LOCATION

The proposed new salmon farm at Tio Point in the entrance to Oyster Bay off Tory Channel is in a region of moderate to strong tidal currents. In that regard the new farm will be similar to the existing King Salmon salmon farms in strong tidal current locations in Tory Channel, at Te Pangu, Ngamahau and at Clay Point.

The tidal current speeds at the Tio Point are similar to, but less than, the currents experienced at Te Pangu in that the farm is located in tidal current eddies at the entrance to Oyster Bay. The flood tide shears off across the mouth of Oyster Bay to the southwest the ebb tide current is directed out of the Bay to the northwest. The longitudinal axis of the farm is at roughly 45° to both the ebb and flood tidal flows.

The proposed farm site is located in water depths ranging from 18 m to 44 m. The seabed at the farm location is formed predominantly by soft sediment – sandy mud. A detailed bathymetric survey of the site was undertaken by the Cawthron research vessel Waihoe on 24 May 2016. That survey work showed the bathymetry to be deeper and more complicated than the bathymetry shown on the NZ Marine Chart for the area. The depth contours shown on the OCEL location plan drawing were taken from the Marine Chart and do not show the holes/depressions in the seabed identified by the Cawthron work. Figure No 1 shows the 2d bathymetric map generated by Cawthron for the new farm site, offshore of an existing marine farm site. Figure No 2 shows the 3d bathymetry. Note that the depths shown are depths relative to mean sea level (MSL). The marine chart depth contours are in terms of Chart Datum (CD). The maximum tidal range for Tory Channel is 1.3 m the MSL derived depths are approximately 0.65 m higher than the CD depths.

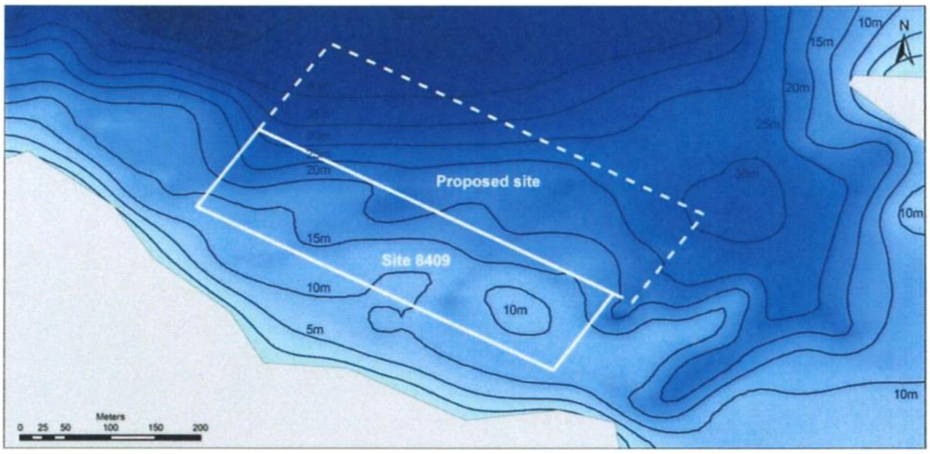

Figure No 1

Two dimensional bathymetry map for the area surrounding marine farm site 8409
and a proposed new site at Tio Point, Oyster Bay, Tory Channel.
Depths are in metres relative to mean sea level, as shown on the contour lines.

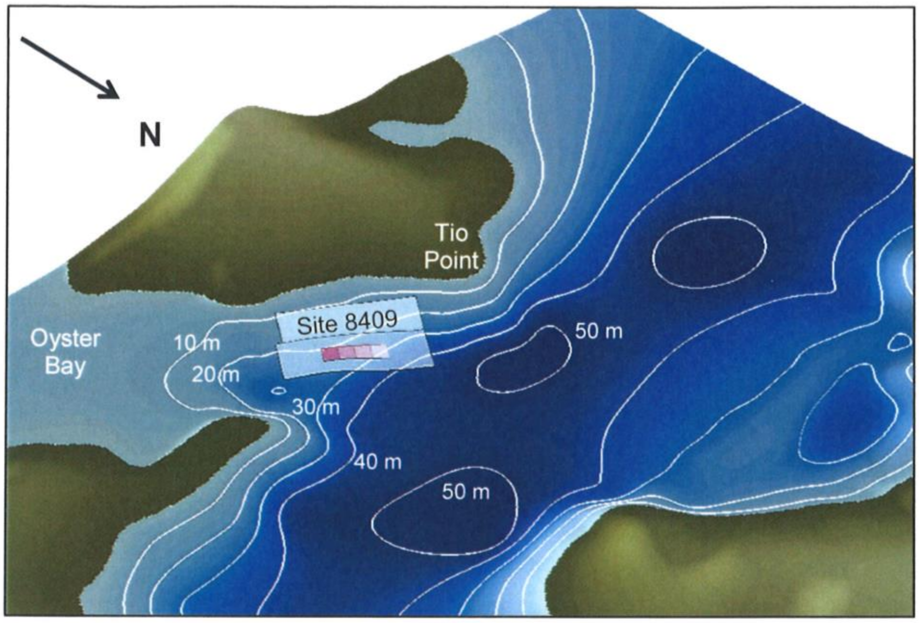

Figure No 2

Three dimensional bathymetry map for the area surrounding marine farm site 8409
and a proposed new site at Tio Point, Oyster Bay, Tory Channel.
Depths are in metres relative to mean sea level, as shown on the contour lines.

Tio Point acts as a control on the current direction forcing the flood tide west. The ebb current is weaker than the flood.

3.0 DEVELOPMENT

The Tio Point farm will be closely similar in concept and structure to the existing Te Pangu, Clay Point and Ngamahau farms which utilise continuous pipe flotation/structures. The structure will incorporate the lessons learnt through operational experience at the Te Pangu, Clay Point and Ngamahau farms.

The mooring design will benefit from the ongoing King Salmon research into quantifying hydrodynamic forces on marine farms.

Marine farming has essentially evolved in a trial and error, pioneering fashion, practical operational personnel developing practical solutions to problems as they arise. This has worked well for King Salmon.

As marine farms have moved out of sheltered environments into more challenging and productive areas subject to higher environmental loads, in particular tidal currents and wave action, engineering input is required to ensure that the farm structures remain safely moored. King Salmon have recognised this requirement and have engaged OCEL for mooring design and structural analysis work.

The engineering approach requires quantification of the environmental forces and the establishment of a safety factor – available resistance/force applied – for the farm. In order to establish a factor of safety for the farm as a whole it is necessary to know the tidal current and wave induced hydrodynamic forces acting on the farm.

Offshore engineering principles can be applied but the fish net cages are not readily amenable to the theoretical analysis of the hydrodynamic forces produced by tidal currents. The cage structures are relatively flexible and can deform and are partly transparent to water movement. Hydrodynamic coefficients are available for common fixed shapes, and have been established for net structures.

In the absence of readily applicable theory field measurement of the actual forces can supply the answers. King Salmon have instituted programs at the Te Pangu, Ngamahau and Clay Point farms to measure mooring line tensions using load cell devices connected in line in the mooring arrangement. The target maximum tension in any of the mooring lines is less than 5 tonne.f. Where monitoring shows that this load is being exceeded then the reasons for that are investigated, the cause identified and the situation rectified to bring the tension down to the desired maximum, consistent with keeping the factor of safety for the system at 5. The same policy will be followed for the proposed new farm location. The moorings will also be kept pretensioned, in conformance with King Salmon mooring practice, to spread the load evenly between the moorings.

Knowing the maximum force and the minimum breaking load (MBL) of each element in the mooring line assembly allows a factor of safety (FofS) to be established for the mooring line and ultimately for the whole farm. The target FofS is 5.

The wave loading on the farm structure from locally generated wind waves results in a very low net or overall mooring load on the farm because the length of the farm structure is several multiples of the short period wave length. The wave induced hydrodynamic force on the structure is forward, in the direction of wave advance, under the wave crest and backward under the trough. The forces cancel out over a complete wave length.

While the wave forces are localised and largely cancel out over structures longer than the wave length the structure must be flexible enough to ride the ferry wash wave profile.

An indicative farm structure layout, shown in drawing DR-160501-001 Rev 3 shows four 40 m x 40 m cage units in a single row configuration.

4.0 ENVIRONMENTAL CONDITIONS

4.1 Wind Conditions

The location is subject to high wind speeds however the wind loading on the farm structure is small in relation to the tidal current and wave loading, essentially only walkway handrailing and nets project any distance above water level. The wind loading is important for the independent barge moorings.

4.2 Wave climate

The location is subject only to locally generated wind waves in Tory Channel and Oyster Bay but the wave heights and periods are limited by available fetch lengths and their orientation. The wave lengths are less than the plan dimensions of the structure so the net force on the structure from wave action is zero. The largest waves experienced at the location are wake waves generated by Cook Strait ferry traffic in Tory Channel. The effect on the farm structure will be the same as on the existing Tory Channel farms the farm will ride the wake wave without over straining the moorings.

4.3 Tidal Currents

The dominant environmental force on the farm is the hydrodynamic drag exerted by the tidal currents in the Sound.

The tidal currents were measured at the Tio Point farm site by NIWA in 2013 using an RD instruments 3D Acoustic Doppler Current Profiler (ADCP) self recording directional current meter. An ADCP uses the Doppler shift to measure ocean currents. Data measuring full water column currents were collected every 10 minutes with varying bin sizes dependent on site characteristics. Each depth measured is referred to as a bin and the full column of bins is referred to as a profile. The ADCP was deployed close to the farm site in Oyster Bay in 36 m of water between 1 August 2013 and 13 September 2013. Spring tides occurred near to 10 August, 22 August and 6 September. A well known limitation of ADCP's is the loss of data near the surface due to the spreading of the acoustic beams on the instrument (~10% of water depth). Therefore each profile from an ADCP provides current measurements from close to the seabed to within the top 10% of water depth where the instrument was deployed.

Flow charts in the form of a current rose plot of current speed and directions for all bins and a plot of average direction and magnitude in each bin taken from the NIWA Site Assessment for Potential Fin Fish Site, Oyster Bay report are shown in Figure Nos 3 to 7. Note that the current rose plots indicate the direction the water is moving to not where the water has travelled from. The strongest current speeds were at the surface. Water level and current meter data cover three spring-neap cycles during August and September 2013. Mean current speeds were between 0.2 and 0.25 m/sec for the duration of the deployment with similar speeds throughout the water column.

For several days around the spring tides near to 10 August, 22 August and 6 September, current speed of around 0.45 m/sec were recorded. The timing of the faster flows was at two different times in the tidal cycle with 1) at low water when there was an abrupt shift in the flow direction from 310° to 260° and 2) at mid flood in the lower 20 m of the water column.

During neap tides current speeds ranged from 0.1 to 0.2 m/sec and oscillated between similar directions of 310° and 250°. The lowest speeds were presented at high water and for several hours of the ebb tide directed towards the southwest.

Five bins of data were extracted from the ADCP time series for more in depth analysis (see Appendix A). Current rose plots that combine speed and direction with percentage occurrences of these were generated for 5, 12, 20, 28 and 34 m water depths. The convention for ocean currents is that direction shows where the water is moving towards. Near surface current rose at 5 m (Figure No 3) shows ebb flows of up to 0.15 m/s^{-1} that were directed to the northwest (310°). Higher flows of 0.25 m/s^{-1} flowed towards the southwest (200° to 240°) during the flood tide. A similar response was observed at 12 m (Figure No 4). These top two bins showed a greater spread of both speeds and associated directions. This is most likely due to the shedding of tidal flows from the nearby headland.

Deeper in the water column at 20 and 26 m (Figure No 5), currents flowed in the same two main directions of 310° and approximately 240° for the ebb and flood tides, respectively. Of interest for material transport was the higher southwest flows observed on the mid flood in the lower water column. These current speeds ranged from 0.25 to 0.4 m/s^{-1} depending on the stage of the spring neap cycle. The near bed current rose (Figure No 7) showed slowed currents toward the northwest during the ebb, but similar speeds of 0.3 to 0.4 m/s^{-1} towards 240° persisted during the flood tides.

By way of comparison the maximum current speed at the Clay Point site was .93 cm/sec (close to 2 knots).

5.0 MARINE FARM STRUCTURE AND LAYOUT

5.1 Farm Structure

The farm structure will be similar to the structure of the Te Pangu Bay, Clay Point and Ngamahau farms, continuous pipe flotation/structural elements defining pens. The nets are suspended from the tubular elements. The mooring lines attach to strong points on the structure where the tube elements join, at corners or the intersections. The whole structure will be subject to finite element analysis using ANSYS® program, to ensure that the stresses induced in the structure remain within the stress limits of the NZ Steel Structures code.

5.2 Mooring Arrangement

The indicative mooring arrangement is shown in drawing DR-160501-001 Rev 2. The mooring lines are pre-tensioned to 10 kN to ensure an even distribution of the total load on the farm to the mooring lines. The mooring lines are pretensioned using a hydraulic ram to take up on the mooring line. Once the desired pretension is reached the line is shackled off. Each mooring line will consist of a 40 mm diameter polypropylene rope strop connected directly to the anchor at one end and to a chain tail at the top end. The purpose of the chain tail is to allow fine adjustment of the line length and thus mooring line tension. The chain is connected via a shackle to the anchor padeyes on the farm structure. The ends of the polypropylene strops terminate in spliced eyes with hard thimbles and the connection to the anchor and the chain is via shackles. This eliminates the need for knots which can significantly reduce the strength of the polypropylene line below the minimum breaking load (MBL). The use of spliced eyes and thimbles with connecting shackles keeps the strength of the mooring line close to the MBL of the polypropylene rope. Drift algae may attach to the moorings but the additional drag is not significant and will not compromise the moorings or have an impact on the factor of safety.

A MarineFlex elastic mooring unit will be incorporated in each mooring line to accommodate the tidal range in Tory Channel and to reduce any shock loading. The mooring lines are relatively steep to keep the farm within the consented seabed footprint and the polypropylene rope is relatively inflexible. The MarineFlex units provide the elastic extension to accommodate the change in mooring line length required and the elastic element prevents snap loading of the mooring lines.

5.3 Anchors

The farm will be anchored by screw anchors. The seabed sediment at the proposed farm location is suited for the use of screw anchors based on experience elsewhere in the Sounds. The diameter of the screw anchor plate used is tailored to the strength of the seabed sediment at the location to achieve the desired pullout resistance. Screw anchors are a particularly efficient way to anchor marine farms. They are lightweight in relation to the holding power or pull out resistance developed and do not require heavy marine plant for their installation and can be installed diverless. They can also be installed with a high degree of accuracy using a Differential Global Positioning System (DGPS) receiver positioned vertically above, and on, the installation axis. The diverless feature is important for the Tio Point farm given the water depth on the outside boundary, 44 m MSL which is close to the limit for air diving. The particular type of screw anchor used for the Horseshoe Bay farm will be shaftless screw anchors.

Another advantage of screw anchors is that the installation process causes very little disturbance to the seabed. The anchors screw in like a wood screw only the soil in the helix described by the anchor as it screws into the soil is disturbed. This is why close to full pullout strength is obtained immediately after installation. The soil shear strength on the circumference of the cylinder of soil directly above the screw anchor auger plate in its as installed position is virtually undisturbed. Once the screw anchor is in only the shaft or rope projecting above the seabed is evidence of its presence.

The standard screw anchor, as used on mussel farms in the Marlborough Sounds, features the use of an 800 mm diameter steel auger/anchor plate at the end of a 6 m long shaft. Such an anchor is excellent for resisting vertical pullout loads but the principal hydrodynamic forces exerted on farm structures by waves and tidal currents are lateral or horizontal loads. In a Sounds type application the screw anchors resist lateral forces by bending above the anchor plate into approximate line with the applied load. The bending is a permanent or plastic deformation – indicated by slotting in the seabed – which is acceptable if the anchor is not subject to load reversals and the level of strain is limited. Load reversals are a constant of a strong tidal environment, the anchors must be provided with a means of resisting the lateral load. Shaftless screw anchors avoid the need to provide for separate lateral earth pressure resistance. They are installed using a temporary shaft threaded over the top of the polypropylene rope connected to the anchor. Once the anchor has been screwed down to depth the shaft is withdrawn. Inclined loads cause the anchor to rotate into line with the applied load, there is no yielding or bending of a shaft.

Screw anchors fail by pulling out, either the soil fails or the anchor itself fails. The anchors are designed so that failure occurs in the soil not the anchor itself. They do not drag like gravity block anchors.

Screw anchors will be used for all the Tio Point farm moorings. A combination of screw anchors and gravity blocks is problematic because when the gravity anchors fail by dragging the load previously taken by the anchor block is transferred to the adjacent screw anchors resulting in the failure of the mooring lines and a cascade failure effect as successive mooring lines fail following load transfer caused by anchor dragging. The target pullout capacity for the anchor is the same or higher than the MBL of the polypropylene anchor rope and shackle connectors to achieve a factor of safety equal to 5.

The amount of torque used to install the anchor gives a good indication of the pullout capacity through a simple linear relationship of the form P (pullout capacity) = k (constant) x T (torque). Standard soil mechanics solutions exist to determine the pullout capacity of screw anchors if the seabed soil strength parameters are known. For the case of the Tio Point location the seabed soil strength parameters are not known. A pullout test will be carried out to determine the screw anchor capacity and from the results of this test the relationship between installation torque and pullout capacity will be known. The pullout capacity of all the anchors installed on the site can then be accurately predicted.

6.0 CONCLUSION

The proposed salmon farm at Tio Point is fully feasible from a mooring and structural safety standpoint. It will use existing proven technology, based on experience with the existing Te Pangu Bay, Ngamahau and Clay Point farms, and will benefit from King Salmon's ongoing development and refinement work to ensure a safe secure structure with known factors of safety. Screw anchors will be used to moor the farm structure and a level of redundancy provided. Test pullout loading of a representative anchor will be carried out to confirm the anchor pullout capacity.

The long axis of the structure will be at a 45° angle to the flood and ebb tidal vectors rather than directly in line to minimize the mooring forces because of its location in the entrance of Oyster Bay. The mooring lines have been designed to take the higher side loadings that occur because of the 45° angle however, the current speeds are lower than for the other farms in Tory Channel.

Monitoring of the actual hydrodynamic forces exerted on the farm by tidal currents and waves will be undertaken, the same as is done for the other Tory Channel farm structures, to confirm that the loadings are within the design loads used. The cause of any load exceedance will be investigated and rectified.

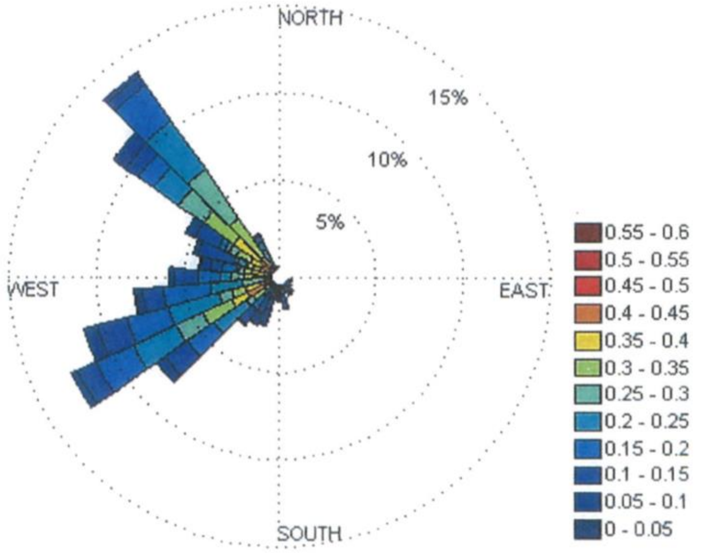

Figure No 3
Current roses showing percentage distribution of speeds and direction at 5 m in the water column

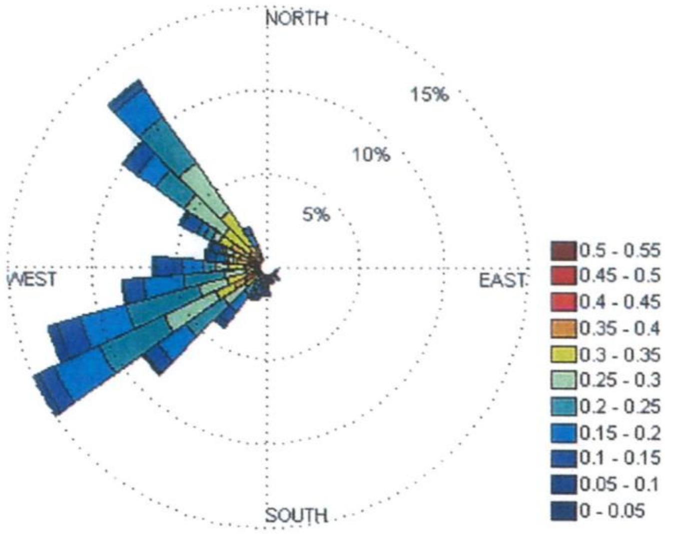

Figure No 4
Current roses showing percentage distribution of speeds and direction at 12 m in the water column

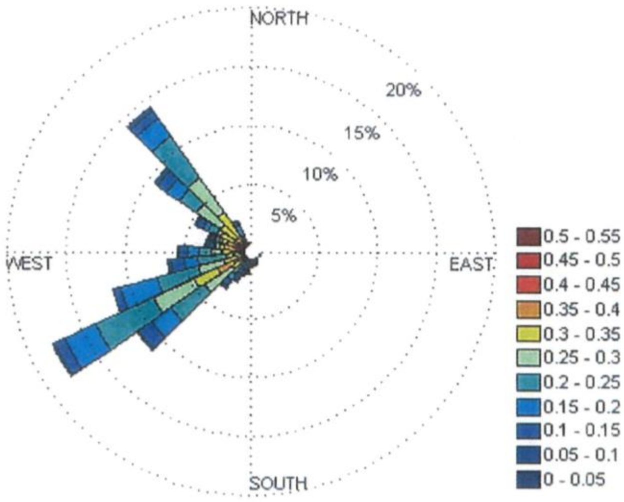

Figure No 5
Current roses showing percentage distribution of speeds and direction at 20 m in the water column

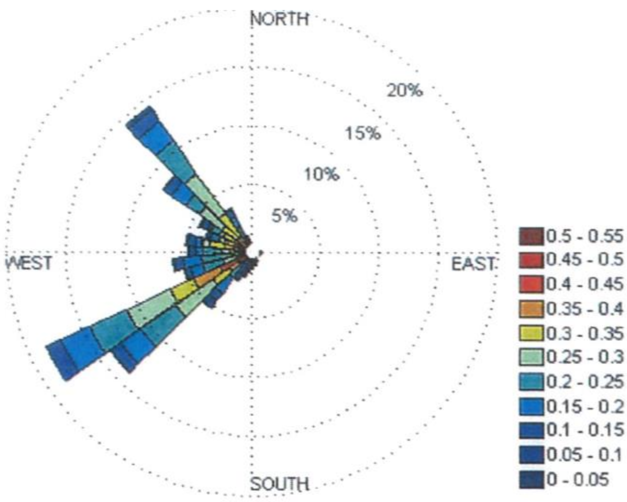

Figure No 6
Current roses showing percentage of speeds and direction at 26 m in the water column

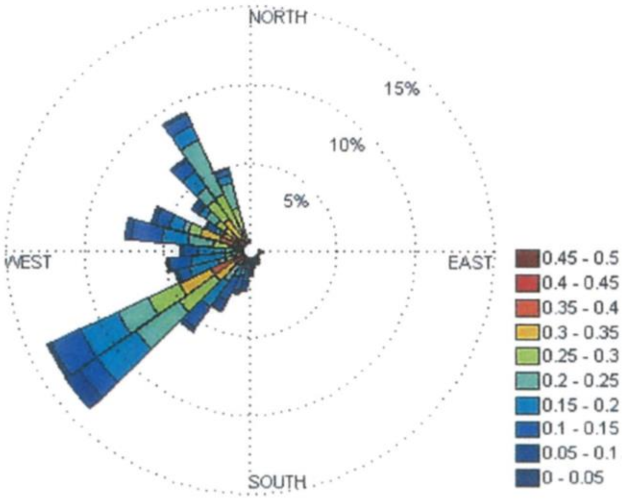

Figure No 7
Current roses showing percentage distribution of speeds and direction at 34 m in the water column

APPENDIX No A

Time series plots ADCP observations

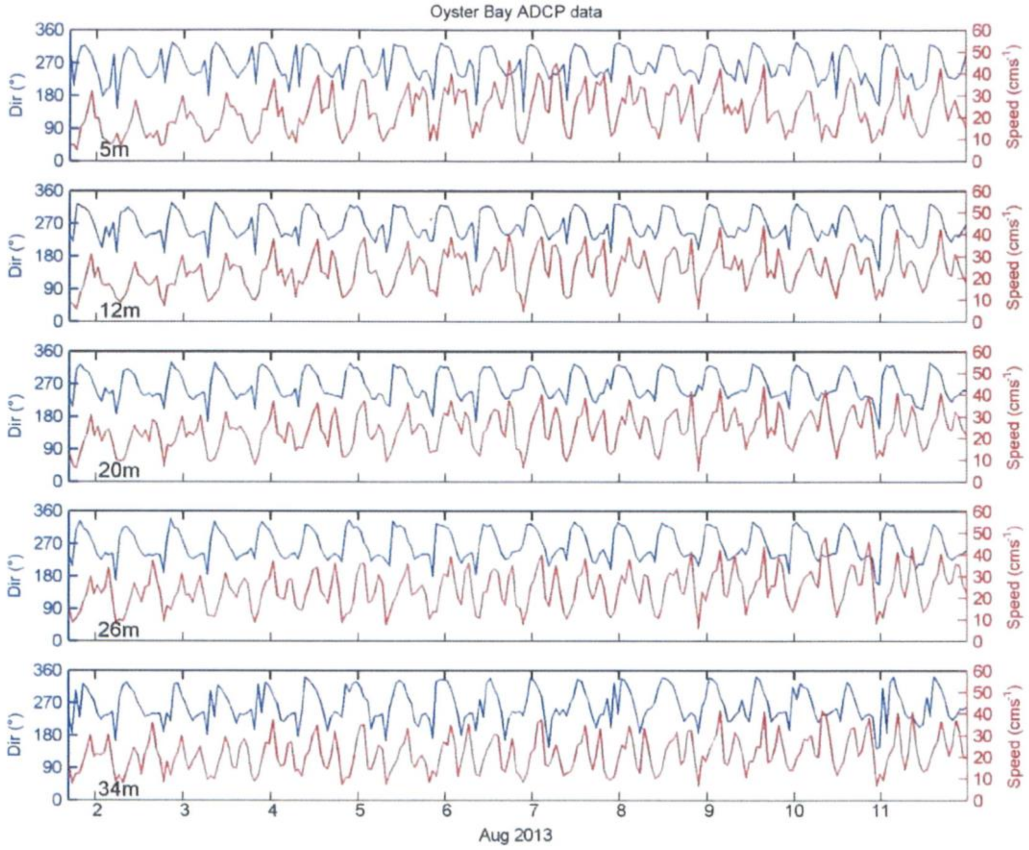

Figure No 8
Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from 1 to 12 August 2013

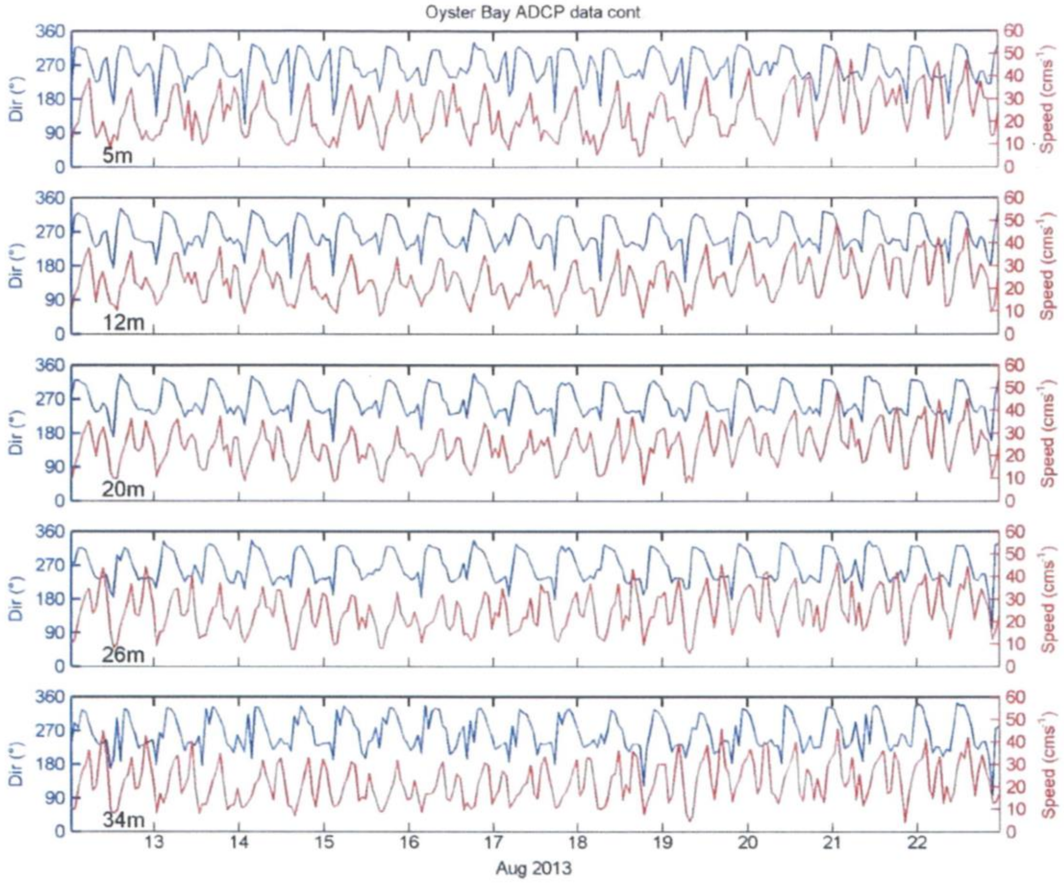

Figure No 9
Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from 12 to 23 August 2013

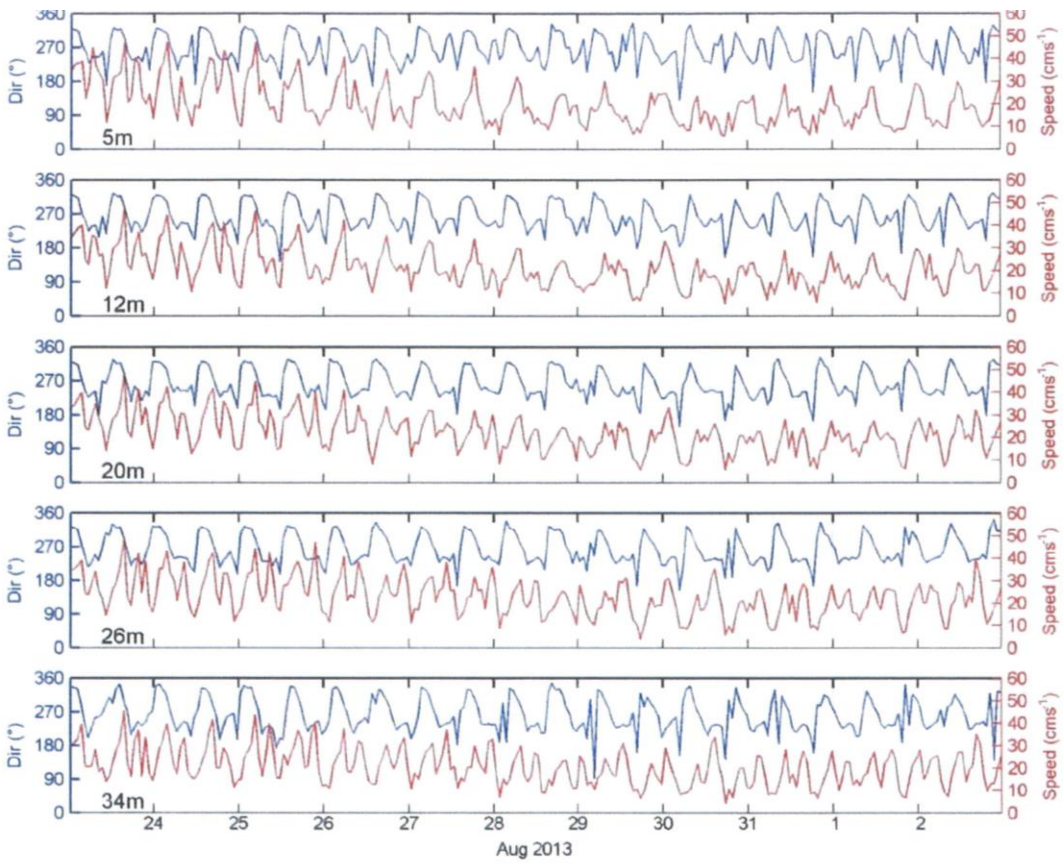

Figure No 10
Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 25 and 34 m from 23 August to 3 September 2013

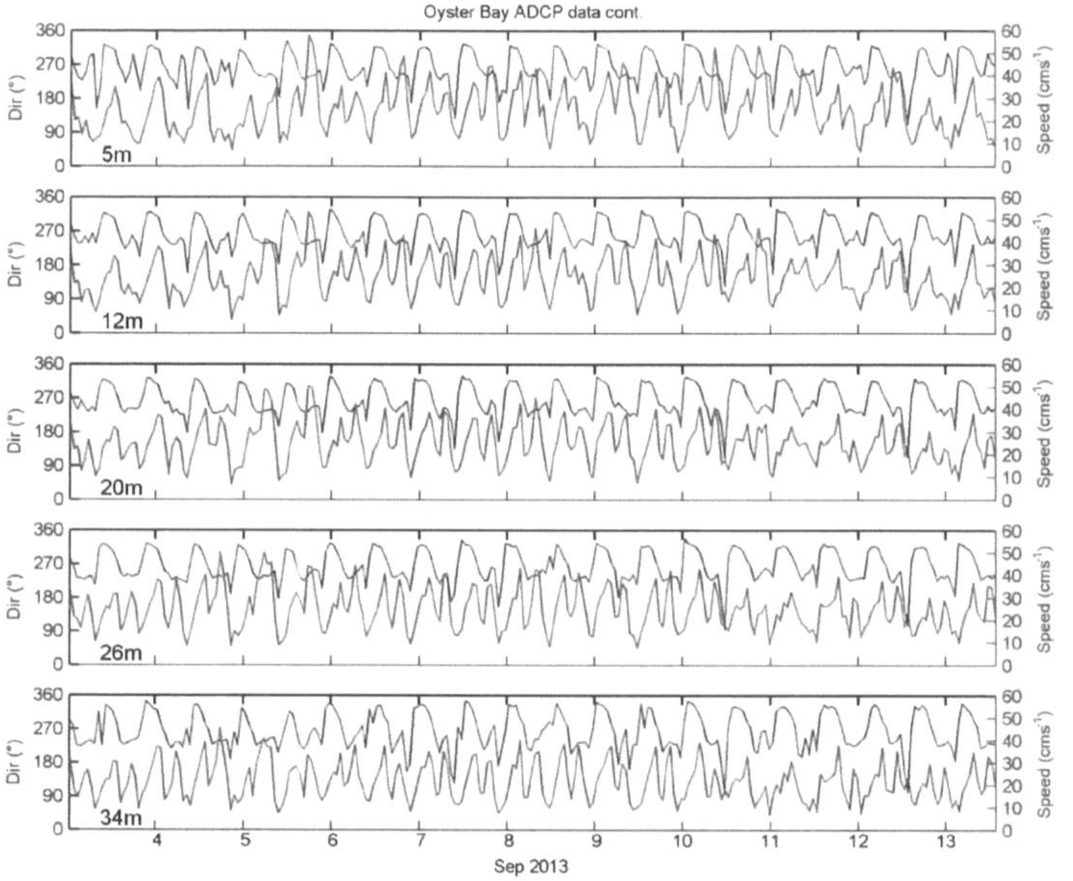

Figure No 11
Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from 3 to 13 September 2013


TORY CHANNEL
Tio Point
Motukina Point
Oyster Bay
SCHEDULE OF COORDINATES
NZTM2000
WGS84
LEGEND:
NOTE:
PRELIMINARY
TOTARANUI LIMITED
PROPOSED MARINE FARM SITE
OYSTER BAY, TORY CHANNEL
DR-160501-001
Scale 1:5000
DO NOT SCALE FROM DRAWING
CONSULTANTS NZ LIMITED