NIWA
Taihoro Nukurangi

1 March 2011

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Dear Lincoln

Project Next Generation: Currents and circulation at the offshore A0 disposal area

This letter outlines the background to determining current velocity fields to support plume modelling for the A0 disposal area and how that work ties in with recent current-meter measurements at A0 by MetOcean Solutions Ltd. from 19 October to 5 December 2010.

Background
NIWA has provided what we consider to be fit-for-purpose modelling to Port Otago Ltd to underpin the AEE for the Project. Offshore modelling of currents was undertaken in late 2008 using a 3-dimensional (3-layer) finite-element model (DHI MIKE-3 FM) of the Otago Shelf, that was driven on the offshore boundaries by tides, winds (taken from Taiaroa Head) and a mean velocity for the Southland Current over a 2008 field period (extracted from another larger-domain ocean model developed by NIWA). The latter was applied with different spatial distributions of input flow discharge along the southern boundary of the offshore model, concentrated more at the main shelf break, until a good match was obtained with residual (net) currents over 2.5 months from ADCP measurements at a nearby site A1 (3 km WSW from A0). The details can be found in Chapters 10 & 11 in the NIWA/MetOcean 2009 Modelling Report that was lodged with the Consents Application.

Peer Reviews
Port Otago Ltd engaged Tonkin & Taylor (T & T) to carry out an independent peer review of the NIWA/MetOcean modelling technical report. The review is contained in a T & T letter dated 3 August 2010.

Overall, the T & T review stated that the study of effects on hydrodynamics, sediment transport and wave climate was comprehensive. The peer review acknowledged that simulating seabed disturbance, sediment discharges and sediment transport is not a precise science, but noted the authors have chosen to be conservative or bracket model parameters where in doubt.

The modelling was assessed as being robust and fit-for-purpose, with no further or more detailed studies being necessary. Although the T&T peer review suggested that alternative models and methodologies could have been used, they also state that the final conclusions are likely to be similar to those given in the NIWA/MetOcean modeling report. Finally, T & T appraised the modelling results and conclusions drawn from them to be sound.

In a letter to you, dated 9 August 2010, your will recall that I responded to the specific matters raised by the T & T review in the context of the environmental assessment phase of the Project.

A further independent peer review was undertaken by Dr Ross Vennell of the Department of Marine Sciences, Otago University at the request of the Otago Regional Council. The review is contained in a PDF document dated 16 August 2010.

In terms of the offshore hydrodynamic modelling, Dr Vennell noted the following main points:

- The 3-D modelling did not include the effects of water density, but he concluded that the neglect of water density inshore e.g., 30 m depth, was reasonable.
- The Southland Current was kept constant in the 3-D offshore model. Dr Vennell questions what effects a variable current would have and whether the chosen value is a true average or a conservatively high value.
- The offshore model didn't explicitly include Otago Harbour – rather it was substituted in the offshore model as a tidal flow boundary condition at the Harbour Entrance. Dr Vennell comments that this is a reasonable approach.
- Dr Vennell commented on the very good comparison of modelled currents and field measurements at site A1.
- He also noted that no current measurements were undertaken at the proposed disposal area A0 and suggested that direct measurements at A0 would increase the confidence in the model, particularly as the Southland Current is variable.

Recent current measurements at A0

As a result of the last suggestion by Dr Vennell, Port Otago Ltd. contracted MetOcean Solutions Ltd. to deploy a current meter near the bed at site A0 (within 50 m of the disposal area centroid 45.7358°S and 170.799°E).

A 47-day deployment of a single-point InterOcean S4 current-meter was undertaken from 19 October to 5 December 2010, set at approximately 4 m above the seabed. The results are documented in a report by MetOcean Solutions Ltd (2011).[1]

The main results from the deployment are:

- the mean current speed was 13.7 cm/s, with a maximum of 50 cm/s
- strongest currents were to the NNE and SSE sectors
- tidal currents make up a relatively small percentage of the total variance (energy) in the measured currents, with 15% for the N-S component (compared to 14% at A1 in 2008) and 18.7% for the E-W component (37% at A1 in 2008–higher due to the inshore eddy off Taiaroa Head)
- a residual (net) current for the entire period was to the east
- the directional distribution of currents for this period does not necessarily reflect the long-term distribution, and it is notable that the strongest currents were directed towards SSE and SE coinciding with persistent strong northeasterly winds.

[1] MetOcean Solutions Ltd (2011). *Current measurements at A0 disposal ground: Field data report*. Prepared for Port Otago Ltd, January 2011, 12 p.

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The 2011 MetOcean report concludes that "the current regime at A0 appears to be predominantly influenced by regional-scale wind-driven flows. However, it is likely that the combined effects of bathymetric steering and the impingement of oceanic-scale flows will also be influential at this location."

Synthesis and interpretation of currents at A0

Putting all this information together, a more complete picture emerges of the variability of currents out at the proposed disposal site A0.

Firstly, the oceanography of the Otago Shelf is complex with the geostrophic Southland Current interacting with both regional and local winds and tides to a lesser degree. With very limited past measurements of currents on the Otago Shelf, it was quite a challenge to model all these processes operating together, besides including natural variability.

NIWA modelled the offshore area based on a 15 cm/s velocity for the Southland Current, which was the mean velocity computed by NIWA's larger ocean model of the wider Otago Shelf and abyss over the mid-March to May 2008 period that coincided with ADCP field measurements at site A1. The range for the Southland Current velocity simulated over this period was 7.5 cm/s up to 33 cm/s to the NNE at a location 31 km due south of Cape Saunders in ~130 m water depth. This range is within the 0 to 50 cm/s range cited by Dr Vennell from current measurements by Chiswell (1996)[2] off Nugget Point in 108 m water depth and a mean of 23.8 cm/s.

So the mean current of 15 cm/s used for the A0 plume modelling is on the lower end of the range. Use of the 15 cm/s as the basis for developing an inflow boundary produces a net residual current to the NNE, which matches with the pattern of seabed deposition shown in Fig 11.22 of the 2009 NIWA/MetOcean modelling report.

Modelling investigations carried out last week with different inflows on the southern boundary of the MIKE3 FM model show that increasing the Southland Current beyond 15 cm/s would orient the net current at A0 more offshore to the NE and persistently so. Therefore, higher Southland Current flows would be less conservative with regard to impingement of the edge of diluted sediment plumes on the Otago coastline. Also, a simulation was undertaken for the same mid-March to May 2008 period with no Southland Current (i.e., only winds and tides), which produced a much smaller net residual current (about 10% of that for the simulation used), which was to the north for the bottom and middle layers while the surface layer drift was to the NNE. However, there were periods in this additional simulation when the current drift was to the SE or East, particularly in the surface layer (probably from strong SW wind periods), but seldom onshore and even then only for short periods due to local winds (which are already included in the reported simulations).

Therefore in summary, the mean velocity used for the Southland Current is at the lower, more conservative end (with respect to any coastline effects). As far as simulating the effect of varying the strength of this current for plume simulations, it would have compounded the number of model combinations. It was deemed more important in terms of local variability to focus more on wind variability for the plume modelling rather than increasing and decreasing the Southland Current strength, which only makes slight differences in net residual current direction as it increases, more to the NE. The focus on building winds into the simulations used in the Modelling Report, taking into account their frequency of occurrence, is backed up

[2] Chiswell, S.M. (1996). Variability in the Southland Current, New Zealand. *NZ Journal of Marine & Freshwater Research 30*:1–17.

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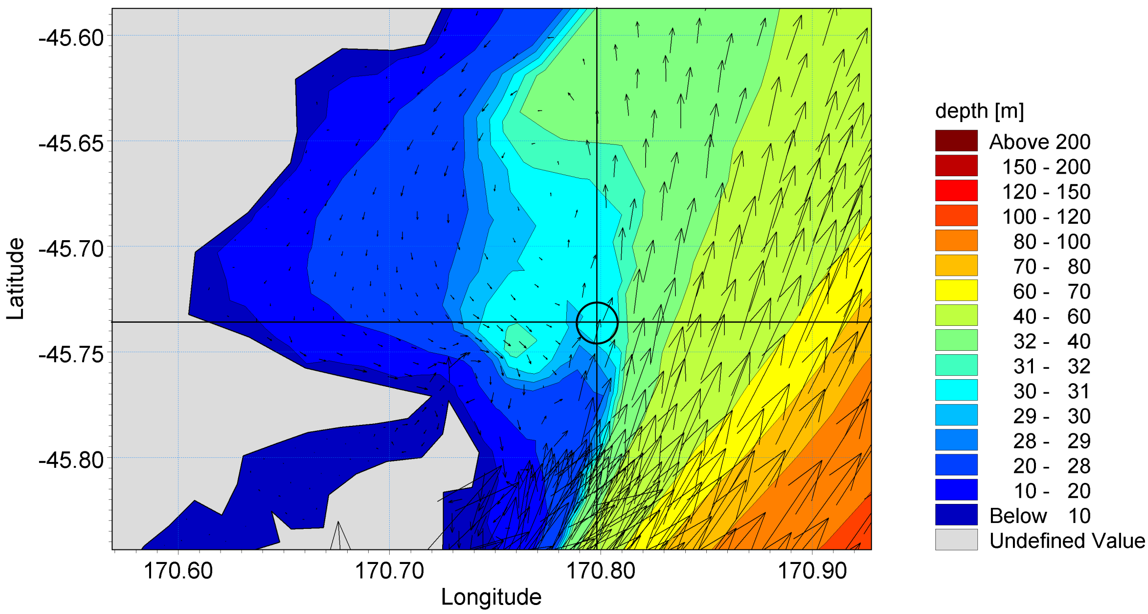
by the recent measurements, even though they don't show a consistent influence from the Southland Current.

The plot below shows the overall residual current pattern for the bottom layer (akin to the deployment depth for the recent current-meter) from the long simulation used in the NIWA/MetOcean Modelling Report. The centroid of the A0 area (shown by cross-hairs) is at the landward edge of the influence of the Southland Current offshore, which has its strongest expression further offshore at the main shelf break in depths of 100–500 m. Given its location in this east-west transition zone, the A0 site is likely to experience variations in currents that over the long-term are dominated by the NNE shelf flow at the edge of the Southland Current influence, but there will also be periods when it is more influenced by the East to ESE flow arising from the outer extension of the Blueskin Bay eddy and/or regional/local wind effects. This variability is also confirmed from larger-domain ocean model simulations by NIWA oceanographers that show in-and-out movements of the landward edge of Southland Current flowstream in the vicinity of A0 at periods of days subject to regional wind patterns.



Consequently, the recent current-meter measurements at the centroid of A0 with an overall residual current to the East for the 47-day deployment confirms that this area is indeed a variable transition zone between regional/local wind effects and the influence of a varying Southland Current flowstream. Mostly currents were either to the N, NE, or SE (particularly during two persistent NE wind periods). It is not known what the strength and variability of the Southland Current at offshore locations was during this field deployment, although it is not critically important to know this in the context of A0 currents to be able draw my conclusions below.

Taken together, with the modelling, the key points that arise out of these investigations with respect to the A0 disposal area are:

a) based on the 2010 measurements and the modelling with a zero Southland Current, the current at A0 is very seldom directed onshore

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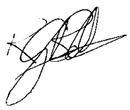
b) while it has been confirmed there will be periods of days and weeks when the residual current is more directed to the east (including brief periods of 1-3 days when the current is more to the SE), these residual currents will transport sediment plumes offshore, where after a short travel distance (particularly if the current is to the SE) they will quickly encounter the Southland Current and be transported in a general NNE or NE direction, depending on the strength of the Southland Current at the time

c) the 2008 hydrodynamic model simulations don't include this eastwards (offshore-directed) residual at A0, so these model results tend to show the plume closer to the coast and be more conservative for the Otago coastline, than if an easterly (offshore-directed) residual is included

d) at the very long timescales, the offshore submergent spit on which A0 has been placed shows a strikingly consistent North to NNE orientation, which will enhance topographic steering of currents to some degree but is also indicative of a long-term net residual current that has shaped this large sedimentary body

I trust this synthesis helps place the previous hydrodynamic modelling and the recent field measurements into the overall context of what it means for dredged-material disposal at A0.

Yours sincerely



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