Lyttelton
Port of
Christchurch

9 March 2015

Canterbury Regional Council
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Dear Bianca Sullivan

RE: Additional information – effects of reclamation only scenario

As per our discussions at recent meetings, ECAN LRPR team has requested LPC provide further clarity and interpretation regarding the reclamation only scenario (i.e reclamation development in Te Awaparahi Bay in absence of major port channel deepening via capital dredging development.

Our original package of information included a detailed hydrodynamics assessment of the reclamation only scenario (Appendix 13, Section 4.3), but the changes were not covered in detail in other experts reports. We also understand that due to the balancing effect on current speeds of the reclamation and capital dredge projects, unless the reclamation only effects are better understood and not significant, you are considering a planning framework within the LPRP that couples these projects in some way. This coupling has the potential to cause programming and sequencing issues for the port which may reduce the effective and timely recovery.

Consequently, LPC understand it is essential to provide information that enables the assessment of effects for these major projects both as stand alone and cumulatively. Our experts have undertaken further analysis of the 'reclamation only' scenario to aid in the understanding of the reclamation only effects. The purpose of this information is to demonstrate both the nature and scale of the potential effects of undertaking the reclamation without the enlarged shipping channel in place (i.e. the capital dredging project).

Our hydrodynamics, marine ecology, Mahinga Kai and sedimentation experts have undertaken further review of the reclamation only scenario and their conclusions are summarised in the following sections.

A telephone conference with our experts and your team may also be useful to further discuss and resolve the matters discussed below.

WAVES AND TIDAL CURRENTS

The original report included detailed information about the effects on tidal currents and waves for a reclamation only scenario (Appendix 13, Section 4.3). This concluded the following:

- Reclamation without capital dredging only has an effect on waves in the immediate vicinity of the reclamation, and this effect is only a very minor decrease in wave height.
- Outside the immediate vicinity of the reclamation the effect on waves is insignificant.
- The effect on waves for the combined scenario is due to increased waves refraction along the deepened channel, not the reclamation.

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- The reclamation only scenario shows a marked increase in current velocities in the mid and upper harbor, particularly in the existing areas of greater current velocity i.e. bedside the reclamation, at Naval Point and south west of Quail Island.
- The increased velocities result from reclamation narrowing the mid harbor. As the tidal volumes stays the same, the tidal currents must increase to maintain the same flow of water during the tidal cycle. This results in higher current speeds which propagate into the Head of the Bay in the upper harbor.
- The quantum of the change in tidal velocity is small in absolute terms. For example at the Quail Island North point (point 11, figure 3.2.6, page 28, Appendix 13) an increase in actual velocity of 0.084 m/s or 0.3 km/hour is predicted. In percentage terms this equals a 30.8% increase in velocity in a mid-ebb tide.
- To further investigate the potential effect on the changes in current velocity might have on the movement of sediment, the model was run to generate five flow trajectories for neutrally buoyant particles. This showed increases in movement of sediment from higher velocity areas of the upper harbor (i.e. south west and north of Quail Island) out towards the mid harbour (i.e. to around Cashin Quay) could be expected under the reclamation only scenario. This is shown in Figure 1 below, note that the important characteristic is not the end position of the particle, rather that the particles in the higher current areas (dark blue and pink) travel over greater distances in the reclamation only scenario. This transported sediment would most likely be deposited in the shipping channel. Arguably this sediment removal would be a positive effect as the build-up of sediment in the upper harbor is generally accepted to be undesirable.

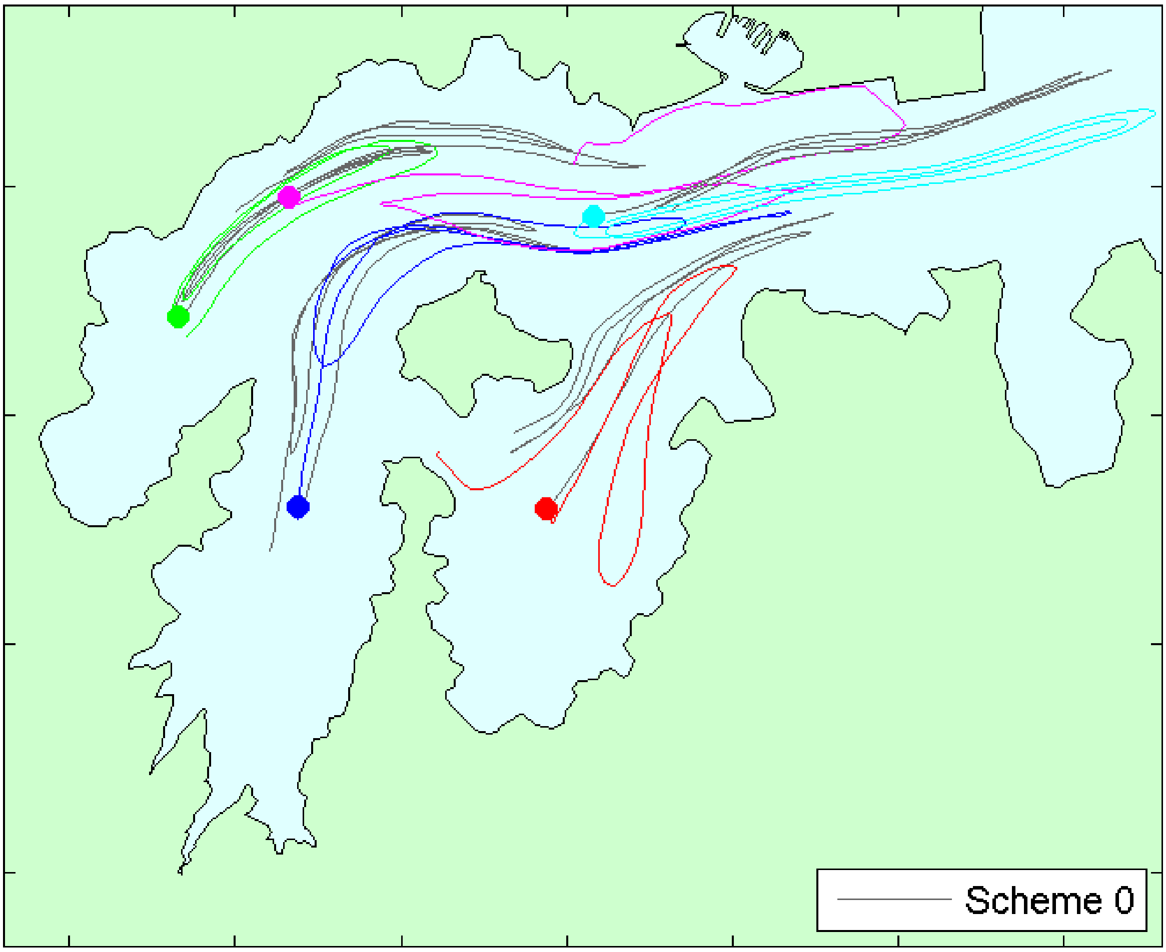

Figure 1 Neutrally buoyant particle trajectories (reclamation only is coloured, underlying grey is reclamation plus capital dredging)

SEDIMENTATION

For the reclamation only scenario the increases in current velocity in the upper harbour - particularly in the existing areas of greater current velocity (beside the reclamation, at Naval Point and south west of Quail Island) - do not have a significant impact on sediment entrainment in the upper harbour. This is because the increases start from a low base speed for the existing situation. The existing current speeds are low, generally less than the erosion velocity threshold for silt which is of the order of .3 m/sec. For example at the Quail Island North point (point 11, figure 3.2.6, page 28, Appendix 13) a 30.8% increase in velocity is expected in a mid-ebb tide. The existing current speed for the mid-ebb tide is 0.273 m/sec, the 30.8% increase in actual velocity is only 0.084 m/s to give an equivalent current speed for the no reclamation scenario of .357 m/sec.

The entrainment of fine sediment is a complex process. The silt particles are so small that electrochemical force and viscosity become significant. The current speed required to erode consolidated silt and clay material is higher than for fine sand because of the cohesion exhibited by the fine particles and the smoothness of the seabed. The fine sediment, predominantly silt sized sediment, characteristic of the harbour seabed is susceptible to disturbance by wave or current action. Wave action dominates the entrainment process. Long period swell entrains seabed sediment in the relatively deep water of the outer harbour while short period locally generated waves are the dominant sediment entrainment mechanism in the shallow areas in the upper harbour. Once entrained the suspended sediment is almost solely moved by the tidal currents.

The most important hydrodynamic property of waves and currents for sediment transport/disturbance purposes is the bed shear stress they produce. The bed shear stress is a function of the square of the water particle velocity irrespective of whether the water particle velocity results from wave or current action or the vector addition of the two. The waves and currents differ in their effectiveness in entraining sediment even if the current speeds have reached or exceeded the erosion velocity threshold, because of boundary layer effects. For a smooth seabed and relatively small wave particle velocities the boundary layer may be laminar, but more often in cases where sediment is in motion it will be turbulent. The boundary layer - in which the water particle velocity rapidly decreases to zero at bed level - is only a few millimetres or centimetres thick for waves but can be of the order of metres thick for steady currents. This has the effect of producing a much larger velocity shear in the wave boundary layer which in turn causes the bed shear stress produced by a wave with orbital velocity U_w to be much larger than the bed shear stress developed by a steady current U_c of equal speed. Waves are consequently much more effective in stirring the seabed than tidal currents.

In the relatively high current area south west of Quail Island the wave climate is low energy. There is a very limited wave fetch to the south west and Quail Island provides shelter from short period locally generated waves from the north east. Swell waves are much attenuated by bottom friction and diffraction effects by the time they reach this location and are ineffective at entraining sediment. While the current speeds increase by up to 0.2 m/sec in this area this will not have a significant effect on increasing seabed erosion in the area because the wave effects are limited. This area is also characterized by sandy mud with some gravel and shell and the seabed is adjusted to higher current velocities than elsewhere.

The impact of the increased speeds is much less in their erosion potential and much more in the consequent greater travel or excursion distance for neutrally buoyant particles entrained in the flow over the course of a tidal cycle. The potential effect changes in current velocity might have on the movement of sediment, were investigated by using the hydrodynamic model to generate flow trajectories for neutrally buoyant particles. The model runs showed that increases in movement of entrained suspended sediment from the higher velocity areas of the upper harbor out towards the mid harbor, to the deeper water off Cashin Quay, could be expected under the reclamation only scenario. This is shown in Figure 1 above. The important characteristic is not the end position of the particle, rather that the particles in the higher current areas (dark blue and pink) travel over greater distances in the reclamation only scenario. Some of the transported sediment would most likely be deposited in the sediment sink represented by the shipping channel.

Work currently being undertaken by OCEL on turbidity in the harbor and offshore during a period of relatively low swell wave energy has shown that the turbidity levels, - represented as NTU values, suspended sediment concentrations (SSC) and Secchi disk monitoring depths – are highest (lowest in the case of the Secchi disk measurements) in the upper harbor and decrease with distance towards the entrance. The turbidity is lowest outside the harbor and turbid water is being slowly flushed out of the harbor improving the water quality. This can change in the course of a high energy swell wave event which will disturb the seabed in the harbor and offshore generating high turbidity levels in Pegasus Bay and the outer harbor but the general effect of the increased velocities is to effectively expand the upper harbor tidal compartment and bring the entrained sediment into deeper water. Over a long time period (i.e. tens of years) this could assist with flushing accumulated sediment out of the upper harbor but the effect would be small.

MARINE ECOLOGY

Water quality

It is important to remember that the construction of the reclamation will not result in a change to the tidal prism of the upper Harbour. Therefore, the net transport of waterborne constituents such as nutrients or dissolved oxygen into and out of the upper Harbour compartment will not change with locally increased currents. Harbours and estuaries usually have higher nutrient status than the waters outside, especially those with developed catchments. Dissolved oxygen levels at the seabed could increase with greater current velocity, but only if the increased currents disrupt (by increased vertical mixing) stratification in the water column which may otherwise occur. This is unlikely within Lyttelton Harbour due to the effectively flat seabed, especially for shallow areas of the upper Habour. In shallow harbours, oxygen uptake from the atmosphere is more affected by wave disturbance of surface waters than by relatively small tidal currents.

Since the resuspension of fine sediments will still be dominated by the wave climate in shallow areas, general levels of turbidity would not be expected to change.

Substrate, habitats and benthic communities

Examination of sediment texture maps in light of the modelling outputs indicates that the coarseness of benthic sediments is to an extent explained by current speeds. In predicting changes to benthic habitats arising from increased current speeds, it is useful first to examine areas within the Harbour where this set of conditions presently occurs. The areas north and west of Quail Island, where increased current velocities are predicted, vary in depth from 1 – 6 m relative to mean sea level. These areas are characterized by soft mud in the deeper areas to the north and sandy mud with some gravel and shell in the shallower areas near and to the south-west of Quail Island (Hart *et al.* 2008).

For the modelled zones of increased current speeds to the north and north-west of Quail Island and directly north of Diamond Harbour, the only areas of presently similar current speeds (≥0.35 m/s) in similar water depths appear to be very small areas around Shag Reef and the Cashin Quay breakwater. However, only limited or no data regarding substrate and benthic communities is available for these sites. Hart *et al.* (2008) defined the area north of Shag Reef as being muddy (25-49%) gravel/shell-hash. A second area of this type was located west of Pauaohinekotau Head (west of Diamond Harbour) where the benthic community was dominated by the mud crab *Macrophthalmus hirtipes* and polychaete worms (*Owenia* sp. dominant).

There is an area of intertidal muddy sand (sand >50%) on the western side of Head of the Bay which corresponds to the greatest currents modelled for the Harbour's present configuration (Scenario 0; Fig. 4.11, Goring 2014). It is reasonable to expect that, with the enlargement of this area of relatively higher currents under the reclamation-only scenario, this area of sandier substrate (mapped by Hart *et al.* 2008) will also expand spatially in similar water depths.

Data collected by Bolton-Ritchie (2013) for intertidal areas of Governors Bay, Head of the Bay and Charteris Bay was in general agreement with that of Hart *et al.* (2008). From analysis of correlations between individual taxa and sediment texture, it was found that the abundance of seven of the eleven most abundant fauna was influenced by sediment grain size.

> *"<u>Notoacmea helmsi</u>, cockles, <u>Turbonilla</u> sp. and Isopod sp are more abundant in the coarser grained gravel/sand sediment than the fine grained silt and clay sediment. <u>Arthritica bifurca</u>, <u>Nicon aestuariensis</u> and <u>Austrohelice crassa</u> are more abundant in the fine grained silt and clay sediment than the coarser grained gravel/sand sediment."*

However, of the key species occurring, a number of polychaete worms were identified that are tolerant of a very wide range of sediment texture (chiefly silt content). Polychaete worms are among the most abundant and diverse taxa within Lyttelton Harbour benthic communities.

In general, Bolton-Ritchie (2013) found that the abundance of snails and other shellfish at a given site was influenced by the fraction of gravel-sized particulates in the sediment with greater numbers occurring with increasing gravel content. Bolton-Ritchie (2013) cited an optimum range for cockles as 5-10% mud (Gibbs & Hewitt 2004), concluding that "*The environment of upper Lyttelton Harbour/Whakaraupō is not conducive to the settlement and/or survival of cockle recruits and their growth to adult size*."

Expected effects of current changes

Tidal current velocities in Lyttelton Harbour are relatively small compared to many other inlets of similar size, and this will remain the case with the predicted increases under the reclamation-only scenario. The subtidal Harbour bed is largely depositional in nature and this is consistent with the prevalence of deposit-feeding taxa relative to filter feeders. While the locally increased currents may be of some benefit to benthic filter feeders, the changes are not considered to be great enough to change this pattern of dominance. While any change in substrate will affect the benthic communities supported, it is important to stress that the change in substrate, where it occurs, will be relatively subtle and gradual. Where a measurable change in substrate occurs, it is unlikely to be noticeable to the majority of Harbour users.

Hart *et al.* (2008) described benthic communities within upper Lyttelton Harbour as being a continuum of overlapping communities (associated with the mud crab *Macrophthalmus hirtipes*). This is distinct from some harbours (such as Whangarei or Otago) where a patchwork or mosaic of distinct benthic habitats exists as a result of discontinuities in bathymetry and shoreline morphology. While this is not expected to change under the reclamation-only scenario, there will be a spatial re-distribution within the existing spectrum of communities, but largely as a result of consequent substrate changes rather than as a direct result of current velocity. With no distinct physical boundaries to benthic habitats, such community changes as do occur with the construction of the reclamation will be relatively fluid and there will be no effective lag relative to the rate of change in sediment texture.

The depositional nature of the upper Harbour means that any subsequent decrease in these locally raised current velocities (as a result of the later deepening of the Harbour Channel and swing basin) will result in a gradual return towards the earlier harbour bed condition and community. That is to say, the response of benthic communities to sediment changes will be dynamic and reversible.

The model results do not appear to show significant differences in current speed for shoreline areas although it is accepted that these shallow margins may not be well characterized by hydrodynamic models. Siltation of shoreline hard substrates is presently prevented or limited by wave action rather than currents. Changes in current speeds are not expected to be great enough to produce measureable changes in intertidal communities except perhaps at the tips of adjacent headlands, where such changes will nonetheless be relatively subtle.

MAHINGA KAI

Mahinga kai in the wave zone

Given the information above, that the reclamation without capital dredging only has an effect on waves in the immediate vicinity of the reclamation area, and that this effect would be minor (from Appendix 13, Section 4.3) it is likewise expected that effects, if any, on mahinga kai within the wave zone would also be minor. The reclamation construction would create an entirely new intertidal area, and the considered inclusion of substrates and habitats that are conducive to mahinga kai settlement and residence (as described in ‘Effects on Mahinga Kai’, LPC Information Package, Appendix 17,Section 5) would enhance these species.

Subtidal mahinga kai

The modelling showed that the reclamation construction would cause an increase in water current speeds in the areas to the north and north-west of Quail Island. The mahinga kai species most likely to be in these areas is the tuaki (cockle, *Astrovenus stuchburyi*). If the higher water current speeds were to cause a subtle change in the substrate to coarser materials such as sand, as discussed above, this could create conditions that are more suitable for tuaki, that might underpin part of the spatial redistribution of existing species that is also described above. It is also worth noting that because tuaki are filter-feeders, the higher water current speeds would be expected to bring more food per unit time, which could enhance the scope for growth for this species.

In this scenario, it is useful to use tuaki as an indicator species, but with limited available information on the other mahinga kai species that are likely to be in the areas of increased water current speeds, it is difficult to extend this discussion beyond tuaki.

As for the benthic ecologies discussed above, any subtle changes in the mahinga kai species would be reversible once the channel deepening is implemented.

References

Bolton-Ritchie L. 2013. Sediments and invertebrate biota of the intertidal mudflats of upper Lyttelton Harbour / Whakaraupō. Technical Report No. R13/77. Environment Canterbury. 44p plus appendices.

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Gibbs, M. and Hewitt, J. 2004. Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. Auckland Regional Council Technical Publication No 264. 48 pp.

Yours sincerely

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1. Waves and tidal currents prepared by: Derek Goring, Mulgor Consulting Ltd
2. Sedimentation prepared by: Gary Teear, OCEL Consultants Ltd
3. Marine Ecology prepared by: Ross Sneddon, Cawthron Institute Ltd
4. Mahinga Kai prepared by: Dr Shaun Ogilvie, Tonkin &Taylor Ltd