BEFORE THE OTAGO REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of an application for resource consents for Project Next Generation
BY	**PORT OTAGO LIMITED**
	Applicant

STATEMENT OF EVIDENCE OF MARTIN BERNARD SINGLE ON BEHALF OF PORT OTAGO LIMITED
6 April 2011

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INTRODUCTION, QUALIFICATIONS & EXPERIENCE

1. My name is Martin Bernard Single. I am an environmental consultant with 20 years of experience. I hold a Ph.D. in Geography, which investigates coastal processes and geomorphological change. I am a director and principal consultant for Shore Processes and Management Limited, specialising in the science, management and planning of coastal lands and waters.

2. I am an associate member of the Institute of Professional Engineers of New Zealand, a member of the International Coastal Navigation Association PIANC, and a member of the New Zealand Coastal Society. I also hold a position as a Senior Fellow in the Geography Department, University of Canterbury.

3. I have authored or co-authored over ninety reports dealing with coastal geomorphology and management in New Zealand, Scotland and Fiji, including hazard assessment and mitigation measures, nearshore, beach and estuarine sediment transport, dredge spoil dispersal, beach nourishment, beach management prescriptions, and planning and audit control of consents for coastal protection structures and lake shoreline change.

4. My areas of specialisation are coastal processes and coastal management of New Zealand ocean beaches, lakeshores and harbours.

5. My work on harbours and sedimentation has included hazard assessment, beach management, nearshore and beach sediment movement and where necessary the development of management and monitoring prescriptions for:

    a. Port Otago Limited (**POL**), sedimentation studies off Otago Harbour, beach management at Te Rauone Beach and Shelly Beach;

    b. Tranz Rail Limited (**TRL**) sedimentation and shore management at Clifford Bay, vessel wake effect in Marlborough Sounds;

c. MWH at Whangarei Harbour;

d. URS at Tauranga Harbour;

e. Beca Infrastructure (**Beca**) reviewing sedimentation aspects of dredging for Ports of Auckland, and

f. Thames Coromandel District Council (**TCDC**), at Tairua and Whangamata Harbours.

6. I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Consolidated Practice Note 2006 and I agree to comply with it. I confirm that I have complied with it in the preparation of this statement of evidence.

BACKGROUND INFORMATION

7. I have worked on assessment of the effects of dredged material disposal for POL since 1994, including preparation of reports with Professor R M Kirk on the effects of dredge spoil disposal in 1994 and 2003, management of erosion at Shelly Beach using placement of sand dredged from the lower harbour channel (1998). I have also supervised a masters thesis in Geography at the University of Canterbury that examined the changes to Shelly Beach and the entrance to Otago Harbour (Leon 2005).

8. In 2007 I was asked by POL to prepare an assessment of the feasibility of deepening the Otago Harbour channel. I have also been the advisor on the physical coastal environment and processes to the POL project team since 2007. In that regard, I have prepared and/or co-written a number of reports on the physical coastal environment of Otago Harbour and Blueskin Bay, details of which are included in the bibliography of the Assessment of Environmental Effects ("**AEE**") for the project.

9. I have read the evidence of Mr Coe, Dr Bell, and Dr James, and have also reviewed the section 42A officer's report and conditions and Environmental Management Plan proposed by POL and Otago Regional Council (**ORC**).

SCOPE OF EVIDENCE

10. I have been asked by POL to prepare evidence relating to the physical coastal environment of Otago Harbour and Blueskin Bay for Project Next Generation. In my evidence I will:

    a. describe the harbour bed sediment structure and materials projected to be encountered in dredging,

    b. discuss the effects on the physical coastal processes of the Harbour and offshore in the vicinity of the disposal areas,

    c. discuss the effects of wake from vessels using the deeper channel, and

    d. discuss the effects of the proposal on the beaches and shoreline of the harbour and Blueskin Bay.

11. By way of explanation, the effects of the proposal on physical coastal processes are dependent on the nature of the sediments present and the natural processes that influence their distribution (which I discuss in my evidence), together with the antecedent wave and current regime (which are described by Dr Bell). In that regard, I adopt the evidence of Dr Bell.

EXECUTIVE SUMMARY

12. As is also explained by Dr Bell, Blueskin Bay between Taiaroa Head and Karitane Peninsula is subject to high-energy waves, strong tidal and oceanic currents and large volumes of sediment transfer on the continental shelf and nearshore seabed. The wave and current energy gradient promotes northerly transport of sediment under southerly swell and storm conditions, and south-westerly transport under north-easterly storm conditions. Northward sediment transport dominates.

13. Currents in Blueskin Bay are a function of the state of the tide, wind direction and strength and the strength of the southern current, moving northward and as a gyre within the wider bay area. The net current drift is to the north. Near the entrance to Otago Harbour, wave and tidal currents combine to transport

sediment inshore and east along Aramoana Beach, offshore around Heyward Point, and inshore north of Heyward Point.

14. The Harbour and Blueskin Bay beach sands are sourced offshore, having moved north along the nearshore seabed and continental shelf. Most of the sediment is fine sand, with textural characteristics remaining constant over time. Sand from within the Harbour has the same characteristics as the offshore and Blueskin Bay beach sands.

15. Otago Harbour is flood tide dominated, and sediment will naturally move into the Harbour resulting in the Harbour being a sink of sediment and infilling. The construction of the Mole has stabilised the position of the Harbour entrance while dredging of the channel maintains the depth. The dredging of the Lower Harbour and entrance channel, and deposition to maintenance disposal sites acts to bypass the capture of sediment within the Jarbour, slowing the rate of infilling, but enhancing the natural northward and inshore transport of sediment along the coast.

16. The hydrological modelling described by Dr Bell shows that the effects of the project on the tidal range, tidal phasing and current will be very small. These changes would not result in changes to sediment transport within the Harbour due to tidal currents, nor would they affect boating conditions. The effects of the deeper channel on the tidal hydrodynamics of the Harbour would be similar for different wind and tide combinations.

17. Based on Dr Bell's analysis, the placement of sediment at the disposal site(s) would not result in significant changes to the wave dynamics. Any changes to the waves as they crossed the disposal site(s) will have no persistent effects at the shoreline. There will be no noticeable effect on surfing conditions and there will be no changes to existing patterns of beach response to the wave environment.

18. Fine sediments will disperse from the disposal site(s) but in my opinion will not settle on the shores of Blueskin Bay or further afield. Natural sand movement on the seabed will continue

across the disposal site(s), and sand will be deposited on the site(s) and will be winnowed from the site(s).

19. Waves crossing the deeper channel within Otago Harbour will not be significantly modified. Wake waves from existing vessels using the deeper channel are likely to be smaller than at present. For all but the largest of vessels (~6000 TEU) in the deeper channel, the effects at shores at a distance from the sailing line is likely to be reduced from the present effect.

20. Apart from the physical change to the seabed topography, I consider that the effects on the physical coastal environment of the dredging and deposition of dredged sediment will be minor, and of magnitudes within the variability of the natural environment.

THE PROPOSAL

21. My evidence relates to the Project Next Generation proposal to:

    a. deepen, widen and dredge the Otago Harbour channel, swinging areas and berths,

    b. dispose of dredge material at sea.

EVIDENCE

Background

22. My evidence presents the findings of investigations carried out in assessing the effects of the proposed dredging and disposal activity and the resulting deeper channel on the physical coastal environment. In assessing the effects, I have used an approach consistent with international practice such as put forward by the international navigation congress PIANC.

23. The coastal areas at the focus of my evidence are the Otago Harbour and the offshore area between Taiaroa Head and Karitane Peninsula. This area of open coast is often referred to as Blueskin Bay, a name also used for the estuary southwest of Warrington. In my evidence, the estuary will always be referred to as Blueskin Bay Estuary, while the general open

coast area will be referred to as Blueskin Bay. I have also considered the coastal environment to the south of Taiaroa Head, but because of the strong south to north currents and associated sediment flows, such areas will be entirely unaffected by the proposal. As such, I do not refer to them further in my evidence.

The Physical Coastal Environment of Otago Harbour and Blueskin Bay

Regional Geology and Quaternary history

24. The rocks that outcrop along the Otago coast, including those around Dunedin represent four major stages of geological history. They are:

   a. The Basement rock - comprised of Tertiary schist;

   b. Two Tertiary sedimentary sequences;

   c. Three late Tertiary eruption phases of the Dunedin Volcano; and

   d. Glacial and inter-glacial deposits laid down approximately 15,000 to 10,000 years BP.

25. The attached Figure 1 presents a generalised regional map of the geological make-up of the study area and the wider hinterland, and shows the spatial extent of these four evolutional stages of geological history. From Figure 1 it can be seen that Otago Peninsula and the shoreline to the north to Blueskin Bay estuary is dominated by the Dunedin volcanic complex and modern alluvial deposits. The coastline north of the estuary to Karitane is characterised by Tertiary Sediments and remnants of the volcanic flows that now form the sea cliffs along this section of shore.

26. Otago Peninsula, Dunedin and Otago Harbour are located on what is thought to be the centre of the Dunedin Volcano. The volcano took several million years to develop, with successive lava flows progressively overlapping in the westward direction upon a surface of low relief that was created by the two Tertiary sedimentary sequences. Alluvium was laid down over the volcanic rocks during the Quaternary (last 1.8 million

years). Loess deposits are also present and are thought to have been sourced from what is now the seabed, during glacial periods when sea level was at a significantly lower elevation than today.

27. The glacial and interglacial periods that featured during the Late Quaternary through to the Holocene (from about 100,000 years ago) were the main controlling factors of the morphology of the Otago Shelf. The area has been subject to prolonged periods of sediment supply from offshore, and progradation of the shores. Areas of the margins of Otago Harbour now covered with dune sands were probably covered by seawater less than 6,000 years ago.

Seabed sediments

28. The quartz sands of the nearshore zone off Otago are derived from Otago Schists, with their ultimate source being the Clutha River and to a lesser extent the Taieri River. The mineral suite of these nearshore sediments is made up of quartz, sodic plagioclase, chlorite, epidote, zoisite, garnet, wollastonite, and biotite, many of which are signature minerals of the Haast Schist that the Clutha River transports to the littoral zone south of Otago Peninsula.

29. In 1986, Carter produced a sediment budget for the coast south of Otago Peninsula to Nugget Point. From this budget, he showed that the dominant source for the modern sediment (younger than 6,500 years) is the Clutha River, which delivers in the order of 3.14 million tonnes of sediment to this coastal system each year. In comparison, the much smaller Taieri River provides a mere 0.6 million tonnes per year, with the nearshore and biogenic productivity providing 0.4 and 0.25 million tonnes of sediment per year respectively. Carter also noted from his study that although suspended mud size particles make up over half of the modern sand input, little is retained on the Otago nearshore shelf. Carter proposed that of all the sand and gravel sized material delivered to the Otago coast by the Clutha River; approximately half is stored within the large nearshore sand-wedge, with approximately 1.1 million

tonnes per year transported north under the influence of wave processes and nearshore currents. That assessment remains valid.

30. Figure 2 illustrates the general shelf sediment facets off Otago. It can be seen that sediments are distributed as an inner shelf belt of modern terrigenous sand; a middle shelf belt of relict terrigenous sand and gravel; and an outer shelf zone of biogenic sand and gravel. Beyond the shelf, relict sandy muds line the submarine canyons and slope bottom. The distribution of modern sands and muds that lie close to the shore reflect the location of river mouths.

31. A submarine feature in the form of a submerged spit is situated off Otago Peninsula (commonly referred to as 'Peninsula Spit'). It is a product of the inner continental shelf sand-wedge. The submerged spit can be seen in Figure 3. It is approximately 25 kilometres long, tapering from 3 to 4 kilometres width where it abuts the northern shore of Cape Saunders and fades out northwards on the mid shelf off Karitane. Separate to this submarine feature, is the ebb-tide delta of Otago Harbour. The shipping channel truncates the ebb-tide delta. There is also a prominent accumulation of sediment immediately to the east of the shipping channel. This feature takes the form of a bar, trending north from Taiaroa Head for approximately 2km.

32. A nearshore sand-wedge blankets the inner-mid Otago continental shelf, where the deposition of up to 34 metres of Holocene sediment has accumulated. The wedge appears to have evolved in two main stages. The first being the still-stand between 9,600 and 8,800 years BP when mean sea level was approximately 24 to 27 metres below where it is today. Accumulation lessened with the re-commencement of the Holocene regression and when the sea level stabilised to its present position (about 6,500 years BP), the second stage of the evolution of this sand-wedge commenced with a deposition of modern sands over the lower wedge.

Wave environment of Blueskin Bay

33. Waves provide the energy that drives sediment transport on the seabed. The direction of the wave approach is important in governing the direction of sediment transport. However waves work in conjunction with ocean currents in determining the nature and direction of coastal and inner shelf sediment movement. In water deeper than about 15 to 16 m, wave energy and the motion of water particles under the wave can act to disturb sediment particles on the seabed, initiating movement that results in entrainment of the particle by a combination of wave, tidal and oceanic currents. In shallower water, incident waves play a very important role in short and long-term beach stability, beach form and evolution, and have a direct effect on nearshore processes that include sediment transport. In the nearshore, where depth is less than about 10 m, waves start to shoal and transform, changing shape and direction of travel. The energy of shoaling and breaking waves govern patterns of sediment transport to a considerably greater degree than tides and oceanic currents.

34. The depth of effect of wave-induced currents is a function of the wave length, determined by the wave period, such that longer period waves will ‘feel’ the seabed at greater depths than shorter period waves. In Blueskin Bay, this results in waves from the southerly quarter having an effect at greater depths than those from the northerly quarter, as wave periods are greater for waves from the south.

35. The most frequent wind directions for the area offshore of Otago Peninsula and Blueskin Bay are from the north / northeast and south / southwest. As a result of the local geography, the direction of wave propagation into the bay is modified such that waves approach predominantly from the northeast and southwest.

36. Many studies have shown that the East Coast of the South Island is dominated by oceanic southerly swell waves, with local waves playing a secondary role. The southerly swell component is generally a longer period wave when compared

to other waves that are generated locally. An assessment of sea state conditions at Taiaroa Head recorded over a 40-year period (1961 - 2001) showed that swell waves predominantly propagate from the northeast, and these waves are generally low in height. Southerly swell waves are the second most dominant wave, and are larger than those propagating from the northeast. The data also showed a seasonal trend with occasional large wave energy events with wave heights greater than five metres typically experienced during the autumn and winter months. Such waves propagate from the south and southeast and refract around Taiaroa Head into Blueskin Bay.

37. Dr Bell’s evidence sets out in detail the site-specific wave climate and currents of relevance to this proposal. For the purpose of my evidence the wave climate of Blueskin Bay can be summarised as being 'quieter' than the outer Otago shelf and those beaches south of Otago Peninsula, with the bimodality in local wind conditions being reflected also in the wave environment in Blueskin Bay. Of the waves that do enter the bay, strongly refracted southerly swell dominates but refraction lessens its intensity. The north-easterly locally generated waves are unimpeded within the bay, although they are generally less powerful than the southerlies affecting the outer-shelf. Overall the regime within Blueskin Bay can be described as a low energy coastal environment that experiences periodic high-energy storm waves propagating from the south.

Ocean and Tidal Currents

38. At a regional scale many reports have described the southern current that moves northwards up the East Coast of the South Island. Also well recognised is the disruption that Otago Peninsula has on this northward current, by forcing an anti-clockwise 'eddy' or gyre to form in its lee. This gyre, when considered together with the wind and wave processes has a direct effect on nearshore processes within the lee of Otago Peninsula in Blueskin Bay, as well as the coast south of Taiaroa Head to Cape Saunders. This gyre and its implications for this project are described by Dr Bell.

Bathymetry

39. Figures 3 and 4 show the bathymetry of the area offshore from Otago Harbour.

40. The width of the continental shelf out from Taiaroa Head is approximately 30km. The seabed slopes gently to depths of 100-250m at the edge of the shelf. A series of drowned Quaternary shorelines have been identified across the shelf. The seabed of Blueskin Bay slopes to a depth of 30m at a distance of about 17km from Warrington Spit. The contour at 30m forms a near straight line from south to north starting from about 5.5km offshore of Taiaroa Head. The 'Peninsula Spit' is located landward of the 30m contour (shown clearly on the right side of Figure 3). The crest of the 'spit' slopes from a depth of about 20m at the southern end to a depth of 30m at the distal end. The depth inshore of the 'spit' is about 30m in an area northeast of the dredged channel.

41. POL propose to locate an additional dredged sediment placement site for the Capital dredging project at a location around the distal end of the 'Peninsula Spit', centred at or about Latitude 45.735S, Longitude 170.80E, about 6.3km northeast of Taiaroa Head. This site is referred to as site A0.

42. The existing consented disposal grounds for maintenance dredged sediment, at Heyward Point and Aramoana, form small sand-hills on the general seabed topography. The maintenance disposal site at Shelly Beach provides sand that nourishes the narrow beach and spit. Investigations of the bathymetry of the maintenance dredge spoil disposal grounds show that in 2010 the crest of the Heyward Disposal site was about 8m below Mean Sea Level (MSL), sloping north to the general surrounding seabed level of about 11m depths. The crest of the mound at the Spit Disposal site in 2004 was 5.7m below MSL, sloping gently to the general seabed level of 9m below MSL. By 2010 there was no discernible mound at the disposal site. Accumulation of sediment at the existing maintenance disposal sites includes placed sediment and sediment passing through the area naturally due to nearshore

sediment transport processes, but does not include sediment moving inshore of the site and possibly increasing the beach volume.

Sediment Characteristics

43. The textural characteristics of the nearshore sediments (size, shape and arrangements) can be described as medium to fine sand, with a mean diameter between 0.125mm and 0.14mm, well to very well sorted, and strongly positively (finely) skewed. The sediments of Blueskin Bay are generally well consolidated. The textural nature of the nearshore is homogeneous in that especially close inshore, there is no discernible textural trend.

44. The only exception to this textural trend is that of the ebb tide delta situated at the harbour entrance. This local area is very coarsely skewed. The relatively homogenous nature is consistent with a single dominant source for the material.

45. The sediments present on the inner shelf have important implications with regard to the type of material found at the beaches of Blueskin Bay, as the source of the beach sediments is almost entirely from offshore. As shown in Figures 5 and 6, although fine sands dominate the area, very fine sands and silts dominate the central region of the bay, with slightly coarser fine sand dominating sediments in shallower parts of the bay.

46. The sediment of the nearshore is predominantly very well sorted, although sorting values range from very well sorted to moderately sorted. The spread of values is indicative of varying degrees of energies acting upon the shoreline between Karitane and Taiaroa Head, with anomalies away from the general trend of very well sorted sediment confined to localised areas.

47. The sediments of the beaches and nearshore between Taiaroa Head and Karitane range from 0.15mm to 0.33mm in diameter, corresponding to descriptive classifications of fine sand to medium sand respectively. A large proportion (85% of all

samples) of the sediments are fine sand size (0.17mm to 0.24mm).

48. The textural characteristics of the sediments compare well between studies that span 44 years. It can therefore be concluded that the physical nature of the sediments of the coastal system between Taiaroa Head and Heyward Point have not changed significantly over the period since the first descriptions in 1958. Studies carried out for POL also show that the disposal of the sediment dredged from the shipping channel of Otago Harbour offshore at the Shelly, Aramoana, and Heyward Point has not changed the textural nature of the beach and nearshore sediments. These areas do not appear to stand out as anomalies from the surrounding seabed.

49. The textural characteristics of the beaches and seabed within Blueskin Bay aid the understanding of the processes responsible for the deposition and transportation of the sediments. This section of the Otago coastline possesses a relatively homogeneous size range of fine sand. This is likely to be a direct effect of two dominant factors. The first is that the main contemporary source of sediment to the coastal system is from one dominant source, the Clutha River. The second is that a relatively consistent and narrow range of energy is received in the nearshore and at the shore. Moreover, the finely skewed samples obtained between Heyward Point and Karitane indicate that small streams and the Blueskin Bay Estuary are responsible for the supply of fines to this section of shore. These are additional to the main dominant sediment source. This is also reflected in the slightly less well-sorted nature of the sediments north of Heyward Point.

Sediment Transport Paths

50. Work for previous maintenance dredged sediment disposal consents determined sources, sinks and transport routes of the nearshore and beach sediments from Taiaroa Head to Heyward Point using a concept of “rollability”. This method considers the sediment from the whole environment in a relative manner. Sinks and sources of sediment can be

identified. These indicate where sediment is travelling to and from, respectively. The results of the rollability analysis for sediments sampled in 2002 are shown in Figure 7 This method can be used to infer transport pathways but not rates or volumes of sediment movement. The inferred transport pathways of sediment are from ‘sources’ to ‘sinks’.

51. Sediments collected by NIWA in 2008 were also analysed in the Geography Department, University of Canterbury, using the same rollability method as used in earlier studies. The inferred transport pathways are shown in Figure 8.

52. The results of the studies from 1980 through to 2008 are relatively consistent in that the main sources and sinks of sediment and major pathways show the same pattern for all studies. The main sediment source areas identified are the shelf south of Taiaroa Head, and areas around Mapoutahi Point (between Purakanui Bay and Blueskin Bay Estuary), Warrington Spit and Potato Point (north end of Long Beach). There are two secondary source areas of sediment. These are the area offshore and the beach at Karitane and the offshore area between Warrington Spit and Brinns Point. The main sink areas are the entrance channel and nearshore area off Aramoana Beach, and the distal end of the Peninsula Spit.

53. Rollability analysis of nearshore and beach samples showed two separate nearshore coastal compartments. Sediment sources dominate the nearshore between Heyward Point and Karitane Peninsula (the northern compartment). The implied sediment transport direction for the area is movement onshore and alongshore from Karitane to Warrington Spit and also south toward Heyward Point. Where Warrington Spit abuts the hinterland a source area is present. From here a strong gradient exists along the length of the spit to a dominant sink at the inlet channel.

54. Sediment sinks dominate the coastal area south of Heyward Point to Taiaroa Head, including the entrance to Otago Harbour. Two strong sink areas exist, one being located between Heyward Point and the Heyward Point dredge

placement site, and the other north of Taiaroa Head, east of the harbour channel. This latter sink is likely to be the product of sediment being deposited as part of the general northward transport of sediment and the deposition of sediment that has been flushed out from Otago Harbour by the ebb tide. The rollability analysis also indicates that longshore transport of sediment is dominant over onshore or offshore transport.

55. The relative role of the northern compartment acting as a source of sediment for the southern compartment between Taiaroa Head and Heyward Point is also indicated from other descriptive sediment characteristics. An increase in sorting, and gradual increase in positive skewness values in a southerly direction was found in the sediment samples.

56. Overall, both rollability and the sediment textural characteristics show that the northern coastal compartment acts as a source of sediment to the southern compartment, together with the southern current that delivers sediment up the east coast. The three existing dredged sediment receiving areas (Heyward Point, Aramoana and Shelly Beach) do not appear to supply sediment north into Blueskin Bay Estuary, nor do they appear to supply sediment back into the entrance channel. However an oversupply of sediment to Shelly Beach could result in some material finding its way back into the channel.

57. The rollability assessment is consistent with the findings from analysis of current and wave measurements and modelling.

Shores of Blueskin Bay

58. The volcanic rock that abuts the shoreline north of Otago Harbour forms a contemporary back-beach cliff at Aramoana, Kaikai, Murdering, and Long beaches. The presence of well water-weathered, rounded basalt cobble ridges at the foot of these cliffs suggests that the initial source of beach sediment to the coastal system was direct wave attack upon these high basalt cliffs. The beaches between Taiaroa Head and Karitane are modern (in geologic time) depositional features made up of quartz sands sourced and deposited onshore directly from the

Otago shelf. This was confirmed by analysis of Maori artefacts from excavations at the foot of the fossil seacliffs in the 1950s.

59. There are three types of shoreline in Blueskin Bay. These are:

a. Bay-Head Beaches;

b. Spit Complexes; and

c. Sea Cliffs.

60. Kaikai Beach, Murdering Beach, Long Beach, and Karitane Beach are all bay-head beaches. The morphology of all four of these beaches is very similar. At the southern locations, a sand beach fronts a now fossil, sea-cut cliff. Karitane has a bay-head beach formed in alluvial deposits flanking Karitane Peninsula. Warrington Spit, Purakanui Beach, Aramoana and Shelly Beach at the entrance of Otago Harbour are all sand-spit complexes. Sea cliffs, the third shore type, make up the Headlands of Taiaroa Head, the shore from Warrington to Green Point, and Karitane Peninsula.

61. The nearshore processes of Blueskin Bay are predominantly low energy with respect to the outer Otago shelf. As a result the bay is a depositional environment, acting as a re-entry trap to catch the northeast sediment drift along the Otago shelf.

62. Once within the coastal system of Blueskin Bay, the sands are reworked by a variety of Iocal processes and transported into the smaller bays and onto the beaches. Within the beaches immediately north of Otago Peninsula, longshore drift occurs in both directions along the shore (northward during southerlies and southward in north-easterlies), with site specific variations near the shore due to cell circulation and return currents south of Heyward Point. Although the net direction of drift is not large, it is in a northward direction.

63. The coastline north of Otago Peninsula displays active and rapid progradation. Superimposed on this long-term trend are short-term periods of erosion and deposition, a feature that is typical of sand beaches. With the aid of shoreline surveys and aerial photographs, rates of shoreline change were calculated. Long Beach and Purakanui Spit prograded over the period

from 1863 and 1979. Between 1975 and 1997 progradation was nearly zero and these beaches appear to now be in a state of relative stability.

64. Table 1 shows the long-term net change to the shoreline position. Long Beach has advanced seaward by about 206 metres since 1863, at a long-term rate of 1.83 metres per year. The seaward face of Purakanui Spit has moved seaward by about 360 metres, at a rate of about 2.7 metres per year. It can also be seen from Table 1 that there appears to be a decline in this rate of shoreline advance in a southeastward direction towards the harbour entrance where Kaikai Beach presents a long-term near-stable beach state, and Murdering Beach is moderately erosional, retreating approximately 173 metres since 1863. These measured rates of change indicate that varying amounts of sediment are supplied to adjacent beaches, and different wave energies are spent on the beaches.

65. Warrington Spit advanced approximately 97 metres between 1967 and 1997 at a rate of about 3.23 metres per year. However this shoreline eroded 28 metres between 1975 and 1997. Some sections of the shore between Warrington and Karitane are known to be erosional, with past erosion at Karitane presenting hazard to a roadway and Karitane School.

Table 1 Summary of net rates of shoreline change at Warrington Spit, Purakanui, Long, Murdering, and Kaikai Beaches, 1863 to 1997 (adapted from Nicholson 1979 and Bunting *et al.* 2003a).

LOCATION	NET SHORELINE CHANGE (m)	RATE OF CHANGE (m/yr)
Warrington Spit (1967-97)	+97.03	+3.23
Purakanui	+358.8	+2.68
Long Beach	+206.3	+1.54
Murdering Beach	-173.5	-1.29
Kaikai Beach	-18.6	-0.13

NB: + denotes shoreline advance, - denotes shoreline retreat.

66. Data from an analysis of beach profile surveys carried out at Aramoana, Murdering Beach, Long Beach, Purakanui, Warrington Spit and Karitane between 1990 and 2003 was assessed for POL maintenance dredging consents in 2003. Storm incidence and onshore winds result in short-term changes to the beach profiles in the form of erosion and accretion. Over that time period dune and upper foreshore growth had occurred on all of the beaches except Karitane.

Human Induced Modifications to the Offshore Physical Environment

67. Human activities have modified the offshore physical coastal environment and approaches to Otago Harbour in three main ways:

a. By modification of the harbour inlet form and stability through construction of the Mole and Long Mac, and by dredging of the harbour channel,

b. Disposal of dredged sediment at the Heyward and Spit sites,

c. Disposal of dredged sediment at Shelly Beach.

68. Between 1846 and 1994, shoreline position and sediment transport at Aramoana was significantly altered by coastal engineering structures. Progradation of Aramoana Beach after

the Mole construction (from 1884) indicates sediment has accumulated on the updrift side. The beach area between the mole and Harington Point (Shelly, or Spit Beach) retreated rapidly after the construction of the Mole, indicating the beach is on the downdrift side of the Mole and starved of sediment. The position of the channel has remained effectively fixed because of the training works.

69. Maintenance and development dredging of the shipping channel in Otago Harbour has been carried out since 1865. Approximately 33.7 million m^3 of sediment has been dredged from the harbour. Prior to 1930, approximately 7.4 million m^3 of dredged sediment was used in reclamations around the harbour, and some (possibly up to 1.5 million “hopper yards”) was placed in the vicinity of Te Rauone Beach. Sediment dredged from the channel and port areas has been deposited offshore at the Heyward site since 1930 but has been regularly used since 1974, the Aramoana (Spit) site since 1983, and the Shelly Beach site since 1987.

70. The total dredged sediment placed at the Heyward site from 1974 to the end of 2009 is about 3,269,000 m^3, the total dredged sediment placed at the Aramoana (Spit) site from 1983 to the end of 2009 is about 3,000,120 m^3, and the total dredged sediment placed at the Shelly Beach site from 1987 to the end of 2009 is about 613,900 m^3.

71. In addition to sediment disposal from the maintenance dredging, about 3.9 million m^3 of sediment was disposed of in the vicinity of Heyward Point as a result of capital dredging of the lower harbour in 1976 and 1977.

72. Sediment placed at the Heyward site disperses quickly from the main location of placement (usually in the southeast corner of the site), and there is no direct relationship between the volume of sediment placed at the site and changes to the volume of sediment at the site over time.

73. Sediment accumulation at the Aramoana (Spit) site initially occurred within the site, but sediment does move shoreward in

response to changes in the wave environment. It is likely that the position of accumulation in any year is related to the position of placement, as dispersal from the placement area is relatively slow. Analysis of historical data shows that Aramoana Beach has been accreting since the construction of the mole. Accumulation of sediment on the disposal site and the nearshore has also occurred during years when no dredged sediment has been placed there. It is likely that a combination of natural and human sediment inputs are occurring at Aramoana.

74. At Shelly Beach, sediment placement has been carried out to provide sand as nourishment to the eroding beach. A significant erosion hazard was identified for this beach in the early 1990s. Retention of placed dredged sediment on Shelly Beach and in the nearshore south of the Mole has assisted in mitigating the erosion hazard to the beach.

Sediments in the Lower Harbour

75. Opus International Consultants (Opus [Reports 16 and 17]) carried out detailed geotechnical investigations of the sediment composition of the Lower Harbour to determine the nature of the materials to be dredged as part of the present POL proposal. This work yielded similar results to past studies. Sand was found to be the dominant fraction of sediment in the Entrance section of the Lower Harbour and towards Taylers Bend, with silts and some clay being present at depths greater than 12 m up-harbour towards Port Chalmers.

76. Sediments in Otago Harbour range from silt to coarse sand containing shell fragments. Finer grained sediments including mud and silts can be found with the fine sand in the Upper Harbour, while coarser sand sizes are found with the fine sand in the Lower Harbour.

77. The two main objectives of the Opus geotechnical investigation were to characterise in detail the sediments to be dredged and to determine whether or not the dredged sediment would be contaminated.

78. Subsurface samples were taken in order to achieve these objectives. Figure 9 shows the location of the sites. The sites are within the area proposed for dredging. Two different methods were used to extract the sediments for description and testing for contaminants. They were:

a. Vibrocoring - This is used for investigations for dredging works and involves vibrating a tube into soft sediments to obtain a fully cored sample. The maximum core length was limited to 3m, so the use of this method was restricted to locations within the existing channel. A total of 37 vibrocore holes were completed to an average depth of 2.7m below the seabed, with minimum and maximum depths of 0.65 and 3.16m, respectively.

b. Rotary Borehole Drilling – This was used in locations where materials of interest had a thickness greater than ~ 3m, such as on the margins of the existing channel, where the channel would be widened, or where rock was expected. A total of 6 rotary-drilled boreholes were completed to an average depth of 8.6m below the seabed, with minimum and maximum depths of 2.5 and 12.1m, respectively.

79. Figure 10 shows a description of the sub-seabed sediments in relation to the location of the cores along the channel. The starboard and port notations are relative to inbound travel along the channel, so the Starboard Side refers to locations nearest Rocky Point, the Aramoana tidal flats and the Spit, while the Port Side refers to sites adjacent to the mid-harbour inter-tidal flats. Section names for the channel are also denoted on Figure 18. Blue lines for different sections of the channel show the proposed dredged depth.

80. The geological description based on logging of cores received from all 43 locations is presented in Table 2. Results are summarised according to the channel sections where each hole was located (as shown in Figure 9).

81. Sand is most commonly encountered in the channel sections near the entrance to the Harbour and beyond, namely from the Harington Bend to the Entrance sections. The laboratory analysis found that sand was generally loosely packed in cores and had a water content between ~ 20 – 30%.

82. Clayey silt is most prominent from the Swinging Basin to the Cross Channel sections. The behaviour of this material is dominated by the high silt content. These sediments were generally soft to very soft and non-plastic. Water content was between ~ 30 – 40% and had a measured shear strength between 14 – 24kPa.

83. Silty clay was the least common sediment type encountered and is most prominent in the area around Acheron Head. The silty clay had a relatively high clay content and sediments were generally soft to very soft, had a high plasticity and water content ~ 60%. The shear strength of these materials was measured to be between 12 – 22kPa.

84. Rock was only encountered at Rocky Point and Acheron Head, and consisted of completely weathered basalt (cobbles and boulders) near the seabed and moderately weathered basalt at depth. At borehole (B5) off Pulling Point, basalt cobbles were found but the borehole had to be terminated due to bad weather. Rock strength ranged from extremely weak to weak within the upper 2 to 4m and became moderately strong to very strong below this. Laboratory testing returned uni-axial rock strength values of 101 and 62MPa for sites B3 and B4, respectively.

85. Table 3 presents a summary of the proportions of different sediment types to be dredged. The information has been derived from the work in Opus.

86. It can be seen that the sediment to be dredged is predominantly fine sand, with a secondary modal volume of clayey silt. From Figure 10 and Table 3, it can be seen that there are areas and depths at which the sediment types are relatively uniform and other areas where there are a mix of sediments. In his evidence, Mr Coe discusses the implications

of this for dredging methodology and for the effects of the dredging activity in detail.

Table 2 Overview of geological description of materials found in borehole grouped by channel section (After OPUS 2008)

Section Name	**Geological Description of Materials**	**Boreholes & Vibrocores in Section**
Swinging Basin	Grey, sandy SILT and fine SAND. Silt is soft to very soft and non- plastic. Sand is loosely packed	B1, B2, VC1, VC1c, VC5, VC6, VC8
Deborah Bend with Rocky Point	SILT in the southern part close to Carey's Bay and silty CLAY closer to Acheron Head. Sediments soft to very soft and plastic where clay present. Completely to moderately weathered basalt in borehole 3 along the north side of the existing channel.	B3, VC9, VC10, VC12 - 14
Hamilton Bend with Acheron Head and Pulling Point	Clayey SILT with some sand, soft to very soft, non-plastic to slightly plastic. Silty CLAY, soft to very soft and plastic close to Acheron Head. Completely to moderately weathered basalt in boreholes 4 at Acheron Head. Basalt cobbles at Pulling Point	B4, B5, VC15, VC17, VC18, VC21, VC22
Taylers Bend	Clayey SILT at Dowling Bay end of section and sandy SILT at Waipuna Bay, soft to very Soft, plastic where clay content is high.	VC23, VC26, VC27, VC29, VC32
Cross Channel	Clayey SILT, soft to very soft, slightly plastic sand content increasing toward eastern end of section.	VC34, VC36, VC39
Harington Bend	Fine SAND near Otakou changing to clayey SILT near Harrington Point and the Spit.	B6, VC41, VC42, VC44 - 46
Howletts	Fine SAND with some Silt near the eastern side around Pilot Beach.	VC47 - 50
Entrance	Fine SAND	VC54, VC56, VC57, VC59

Table 3 Approximate dredged quantities of materials for the different channel sections (Source: Port Otago Ltd 2009). Note that the quantities shown are in-situ and hence will have a bulking factor of about 20% when dredged.

No.	Claim	Rock (m^3)	Sand (m^3)	Silt (m^3)	Clay (m^3)	Total (m^3)
1	Entrance	0	1,366,330	0	0	1,366,330
2	Howletts Point	0	588,637	37,573	0	626,210
3	Harington Bend	0	724,139	340,771	0	1,064,910
4	Cross Channel	0	502,613	270,638	0	773,251
5	Taylors Bend	0	137,961	613,158	15,329	766,448
6	Pulling Point	0	7,476	19,224	0	26,700
7	Hamilton Bay	0	26,284	123,908	225,288	375,480
8	Acheron Head	19,593	21,871	3,190	911	45,565
9	Deborah	0	180,979	370,787	67,259	619,025
10	Rocky Point	5,571	4,178	7,312	348	17,409
11	Basin	0	880,664	574,884	0	1,455,548
	Sub-total	**25,164**	**4,441,132**	**2,361,445**	**293,806**	**7,121,547**
	%age of Total	*1%*	*62%*	*33%*	*4%*	*100%*

87. At the pre-application stage, laboratory testing was completed by OPUS to determine the mechanical and chemical properties of the sediments.

Human modifications within the Lower Otago Harbour

88. The Harbour has been substantially modified by human activity through reclamation, causeway and jetty construction, dredging and channel stabilisation, catchment modification and lining the harbour shoreline with seawalls. Reclamation has resulted in reduction of the harbour tidal compartment. Studies in 1989 (Wilson 1989) found that MSL at Dunedin had decreased 40mm since 1888 due solely to channel deepening. It was suggested that if the channel had not been deepened, MSL rise over the last century would probably be about 1.4 $mm.y^{-1}$ rather than 1.0 $mm.y^{-1}$ as was previously accepted.

89. Inflows from modified urban and rural catchments have resulted in changes to the sediment supply and chemistry in parts of the Harbour. Investigations of sediment contaminants

and sedimentation within the Upper Harbour found that sediment texture was influential on infaunal organisms and absorption of pollutants. Researchers also found that the amount of heavy metals was low and well within typical levels for other New Zealand inlets. Most trace metal pollutants were sourced to stormwater runoff from the Leith River (Baird 1997, Purdie and Smith 1994, Stevenson 1998).

90. There are sections of natural shore in the Lower Harbour with sandy beaches. The largest expanses of sand shore are at Aramoana and Te Rauone. Although subject to modifications along the harbour side of the spit, the harbour shore at Aramoana is relatively stable. The shore at Te Rauone is more dynamic and has undergone periods of accretion and erosion.

91. I have carried out work for POL and the Te Rauone residents to describe the coastal process environment, shoreline changes at Te Rauone Beach and a summary of the findings of previous studies (Single 2007). This work shows that Te Rauone Beach is sensitive to many process factors. Shoreline changes there, are a result of changes to sediment supply due to the modification of the Harbour entrance, the addition of ad-hoc human modifications to the shoreline in front of private property, the natural wave environment and, to a lesser extent vessel wash at the shore.

92. In my work I also identified options for coastal management for the area. These options include engineering works and artificial beach nourishment and include consideration of the effects of wake and surge conditions that result from shipping movements in the harbour channel as well as the natural wave environment and sediment loss and supply.

Shelly Beach

93. Shelly Beach was formed as a result of constraint of movement of the harbour entrance with the construction of the Mole and the Long Mac groyne. The beach is at the head of the embayment between the two structures. Erosion of this beach has been an issue for many years, and has been the subject of

studies to determine the processes at work and potential solutions to the erosion through coastal management.

94. The present solution to the erosion is the placement of maintenance dredging sand onto the nearshore seabed within the Shelly Beach embayment. This solution has been very successful. However dune management is required in order to maintain a healthy dune system between Shelly Beach and the Harbour. These dunes provide protection of the Aramoana saltmarsh area. A Coast Care group such as has been formed for other New Zealand coastal areas (for example in communities in the Bay of Plenty) would facilitate management of the dunes. Port Otago Ltd is at present investigating the establishment of such a group for Shelly Beach.

The Environmental Effects of the Proposal

95. The changes to the physical coastal environment due to the proposed dredging activity, disposal of dredged sediment and the deeper shipping channel in Otago Harbour have been assessed with regard to the following areas:

a. The potential effects of the dredging operation on the hydrodynamics of Otago Harbour and the area offshore of Otago Peninsula between Taiaroa Head and Karitane Point as a result of the proposed dredging operation. These are addressed by Dr Bell

b. The potential effects of changes to the wave environment on the physical coastal environment of Otago Harbour and the area offshore of Otago Peninsula between Taiaroa Head and Karitane Point as a result of the proposed dredging operation.

c. The potential effects of the dredging operation and placement of dredged sediment on the sedimentation processes of Otago Harbour and the area offshore of Otago Peninsula between Taiaroa Head and Karitane Point.

Effects on the present pattern of maintenance dredging

96. The design of the channel sides and batter slopes replicates the existing slopes to minimise adjustment of the channel and margins after the capital-dredging programme is complete. I would not expect there to be any increased sedimentation arising from scouring of the channel margins or from erosion of the intertidal banks, as confirmed by Dr Bell's analysis.

97. Sediment will not move from the A0 receiving ground back towards the Harbour Entrance. However the deeper channel across the ebb-tide delta is likely to result in additional capture of sand in the entrance channel and will possibly result in an increase of maintenance dredging demand seaward of Harington Bend. The quantity and the duration of this increase are unknown, but it is my opinion that this effect will stabilise over time to a situation similar to the present maintenance dredging demand.

The effects of wake from vessels using the deeper channel

98. The POL proposal will expand the capacity to service large container ships of 6000 TEU (twenty-foot equivalent units). These ships have 50% more capacity and are longer and wider than existing ships (4100 TEU) that come to the harbour.

99. Identification and assessment of the effects of larger vessels using the proposed deeper channel on the physical coastal environment has been carried out using an approach consistent with international practice, for example guidelines from the International Navigation Congress (PIANC), the requirements of the RMA and NZCPS (2010).

100. The largest vessel currently calling at Port Chalmers is the 4100 TEU weekly Maersk service. The 4100 vessel fleet, Albatross Class, is generally 281m LOA, 32.2m beam and design draft of up to 12.60m. All departures have a deeper draft than on arrival due to Port Chalmers being predominantly an export port. There is also seasonal variability in the draft with a larger variation between arrival and departure drafts

during the export meat season, which starts in November and finishes between January and May.

101. Even though the 4100 TEU vessels are currently the largest in terms of displacement tonnage to call at Port Chalmers there are also a number of other smaller commercial vessels using the Lower Otago Harbour channel. A large percentage (approximately 40%) of additional vessel calls are smaller container ships used as either feeder vessels for the 4100 weekly call or deep-sea vessels in their own right. These smaller container vessels typically range from 180 to 225m long with drafts between 9.0 and 11.0m

102. The increased channel depth and altered alignment will enable ships of greater tonnage to call at Port Chalmers on a regular basis albeit with some tidal restrictions at deeper drafts. This is covered off in more detail in evidence from Mr Coe. Table 4 provides examples of vessels expected to be capable of navigating the proposed channel and for comparison an example of the current Maersk vessel calling at Port Chalmers. It is unlikely that there will be increases in the size of other types of vessels such as LPG and oil tankers, bulk carriers such as fertiliser, log and chip carriers or cruise ships.

Table 4 Design vessels for Port Chalmers

Nominal Size	Design Draft	LOA	Beam	Displacement Tonnage	Typical Ship
4100 TEU	12.5m	281m	32.2m	53,081	*Maersk Damascus*
6000 TEU	14.0m	318m	42.8m	84,900	*Maersk Karlskrona*
6000 TEU	14.5m	300m	40.0m	84,771	*Maersk Kendal*

103. Mr Coe has described the discrete steps in dredging required to meet the anticipated increases in container ship size.

104. The increase in vessel size and the changes to the harbour bathymetry are likely to result in changes to the vessel generated waves associated with ship passage along the channel. The potential environmental effects include those resulting from waves generated by vessels such as wake and

Bernoulli waves, seabed scour and any potential safety impacts. However the size and effects of the wake waves is dependent on a large number of variables such as vessel speed, length, climatic conditions and water depth.

Areal extent of wake related effects

105. The area potentially affected by waves associated with vessel movements along the proposed channel in relation to this application is limited to the Lower Otago Harbour and seaward of the entry point of the vessel to Harington Bend.

106. Any effects are likely to be within 500 m of the channel. However the potential effects of wake waves through the entrance Channel to Harington Bend and at Te Rauone Beach were examined in more detail in the assessment of wake effects. These areas are the most dynamic in terms of coastal environment and exhibit greater sensitivity to environmental and climatic change in addition to being adjacent and closer to the channel edge in an area of higher vessel speed.

Wake waves

107. The magnitude of wake generated by the passage of a vessel is a combination of the following factors:

   a Vessel speed;
   b Hull form;
   c Vessel size - length and draft;
   d Vessel displacement – load and trim;
   e Vessel course - distance from shore (sailing line), straight or turning;
   f Channel size and water depth, i.e. bathymetry.

108. Due to the number of dependent factors for the generation of wake, it is highly unlikely any two vessels will produce the same height of wave for the passage of the same channel. Additionally the effects of climate, current and antecedent wave conditions also affect wake generation and in turn wave energy dissipation.

109. When travelling within the Otago Harbour channel, wake generated by the same vessel generally varies with each

transit depending on a multitude of factors. Vessel speed is one of the dominant factors and was considered for the large container vessels that use or could use Port Otago. The current maximum speed in the Lower Harbour is restricted to 12 knots with vessel speed approaching the Swinging Basin progressively reducing from 12 knots at Cross Channel down to 6 knots at Acheron Point for berthing at Port Chalmers. The changes in speed for the inbound vessel are shown in Table .

Table 5 Vessel speed in Lower Otago Harbour navigation channel (Data from Port Otago Ltd 2009)

Channel Reach	Vessel Speed (knots)
Harington Bend	12
Tayler Bend	10
Pulling Point	8
Acheron Point	6

110. These speeds have been determined from years of experience within the Lower Harbour by the Pilots Group at Port Otago and are applied to maintain safety requirements whilst maintaining vessel control and manoeuvrability.

111. Depending on the state of the tide and wave conditions it may be necessary, at the Pilots discretion, to increase vessel speeds passing through the channel entrance, both inward and outward, to enable safe navigation through those sections of the channel. For example vessel speeds past the Mole End may need to be greater than 12 knots for arrival of the 4100 Class vessel during mid spring ebb tide to “punch” through the current.

112. Following extensive vessel simulation at Devonport Naval Base it was determined that vessel speed for the proposed channel would not be any greater than the speeds shown in Table 5, irrespective of vessel size.

Existing wave climate and vessel wake generation

113. From an examination of the Spit tide gauge tracing, it was found that the wake pattern generated by vessel passage was noticeable on the trace recorded by the data logger.

114. Tide height readings are recorded at 1-minute time intervals and provide the opportunity to carry out a statistical analysis of the readings from the Spit tide gauge. The maximum 1 minute deviation in the water level trace was + / - 110mm with 99% of the discernable events being less than 40mm deviation.

115. Information was assessed for the 6-month period from 1st January to 30th June 2008. The aim of the analysis was to identify any correlation between commercial vessel visits and recorded wake events and also to put the magnitude and duration of these events into context with background natural meteorological events.

116. Deviations in water level about the tidal curve were identified as event signatures. During the six months of data examined, there were 683 events observed. The times of known commercial vessel passages past the Spit tide gauge were also available and were assessed against the observed events. There were 298 events (44% of the total) that corresponded with commercial vessel visits over the 6-month period. It was inferred that the observed events that coincided with vessel passages were related to wake waves from the vessel. This means that over 50% of the events observed are likely to have been created by other users of the harbour, either vessels such as the *Monarch* scenic cruises, non-piloted fishing vessels, the dredge *New Era* and the *Aramoana* pilot vessel or by background natural events.

117. Of the large wakes events observed, 37% came from the 4100 TEU Container ships, while 51% of large wake events came from smaller container vessels. The analysis of ship visits also showed that there were 162 commercial visits (35% of the total over the 6 months) that were not identified on the tide trace due to either high background “noise” on the trace, or no discernable deviation from the smooth tidal curve during the time when the vessels passed the Spit gauge.

Vessel wake observation programme

118. A visual observation programme was carried out to provide further background information on vessel-generated effects away from the shipping channel, and at the shore. The observation programme did not include instrumented measurements. However detailed observations were carried out at Te Rauone Beach between 17th August 2009 and 19th October 2009. Twenty-two vessel passages were observed. Estimates of wake wave heights were made, and the time of wake onset after the vessel had passed the beach, and the duration of the wake event was recorded. The field observation programme also included recording a number of features relating to the vessel transit, the state of the wave environment prior to the wake, and the observed effect of the wake waves at the beach. Further information about the state of the tide and the vessel loading were added to the recorded notes following the field observations.

119. An assessment of the relationship between wake height and a number of variables was carried out. There was no clear relationship between vessel speed and wake height for the data set.

120. However there were six occasions when the wake reached the dune face at Te Rauone Beach. On each of these occasions the vessel transits were at, or near, high tide with the water level already at a level near the base of the dunes. Sand was put in motion at the dune face as a result of wake on one occasion.

121. In addition, complex wave patterns between the shore and the shipping channel were observed when wake waves reflected off the shore (or shore structures) and interacted with subsequent incoming wake. These observations and discussion with local residents confirmed that this complex wave pattern does not occur on all passages, but is very much dependent on the vessel, the climatic conditions, the tide height and the state of tidal flow.

Determination of vessel wake generation with a deeper channel

122. Empirical vessel speed studies carried out as part of the Channel Deepening Project (CDP) for Port of Melbourne Corporation by Maunsell Australia were examined in order to provide comparative information to the observations in Port Otago.

123. Conclusions from this comparison indicate that a deeper draft (14m) vessel in the proposed channel will create slightly smaller waves, approximately 5 – 10% reduction, than the 12.1m draft vessels in the existing channel. The reasons for the reduction is explained as being due to the increased water depth and cross sectional area of the new channel being the dominant factor rather than the deeper vessel draft.

124. It is expected that the wake and wave effects of all existing vessels using the proposed deeper channel in Otago Harbour will be reduced due to the deeper and wider channel. The proposed channel provides a larger cross sectional area with a reduction in blockage ratio (size of vessel cross-section in relation to channel cross-section) for existing size vessels. A fully loaded 4100 TEU vessel could be expected to produce a wake of around 205mm in the current channel configuration which would be reduced to 187mm in the new channel, a reduction of 9%. A similar reduction could be expected to apply to all vessels currently using the channel. This agrees with the findings from Melbourne and studies by the US Army Corps of Engineers.

125. There is an expected increase in the order of 10 to 15% from the current observed wake heights from the 4100 TEU vessels (ranging from no discernable effect to Class 3 wake events) for the passage of 6000 TEU vessels under similar conditions. The relative increase in wave height between the 4100TEU and 6000TEU vessels will be very small and well within the natural variability of the existing wave environment. As such, it is my opinion that the utilisation of the deepened shipping channel by larger vessels will have effects that cannot be discriminated from those which exist naturally at present.

Effects on Sandbank and Beach Stability

126. The sandbanks of the Lower Otago Harbour are relatively stable sedimentary units. There has been some accretion of sediment in areas of Aramoana and south of the shipping channel opposite Aramoana. However the main secondary channels on the eastern side of the harbour towards Omate Beach and Te Rauone have been stable in location and in depth. There is no indication that there has been an effect of wake waves modifying the sandbanks or disturbing the ecology and habitats of the inter-tidal areas. Surveys of the cross-section of the dredged channel also show that there has been little change to the stability of the channel sides.

127. The minor changes expected in the magnitude of the wake waves from larger vessels using the deeper channel are not likely to have any additional effect on the sandbanks or channel sides.

128. The beaches potentially directly affected by wake waves due to close proximity are Te Rauone Beach, the harbour side of Aramoana Spit / Shelly Beach, small pocket "low-tide" beaches and along Omate Beach. As the wake wave is likely to be smaller for the existing vessels and for all but the largest vessels (>6000 TEU) in the deeper channel, the effects at shores at a distance from the shipping channel is likely to be reduced from the present effect.

Seabed Scour

129. Suspension and redistribution of seabed material, or seabed scour, is a common phenomenon associated with the passage of vessels in close proximity to the seabed. It is a function of the return of water to an at rest state following the passage of the vessel with the extent of scour largely influenced by the return velocity of the displaced water.

130. The return water velocity is dependent on a number of factors including underkeel clearance, shape and size of channel, vessel blockage ratio and vessel speed. There is also scour generated by the action of the propeller jet. High return velocities and scour are prevalent when the underkeel

clearance is very low or there is a high blockage ratio (large vessel in a small channel).

131. The critical velocity for sand entrainment in locations where higher vessel speeds will occur is estimated to be about 0.5m/s. It is likely there is suspension already occurring under the present channel conditions through passage of the 4100 TEU vessels. However, the rate of sediment entrainment and scour may be higher in the proposed channel with the passage of the 6000 TEU vessels due to slightly greater return velocities.

132. Sediment suspension and transport also occurs naturally within the channel under tidal flows. The result of the combined processes of tides and the passage of ships acting on the seabed in the proposed deeper channel will not change the potential mobility of the sediments to a large degree.

Wake Management

133. Wake will almost always be an effect of the passage of vessels using the navigable channel of the Otago Harbour. These effects cannot be avoided due to the requirement to maintain vessel speed to ensure safe navigation of the channel. Physically there is little that can be done to reduce the magnitude of vessel wake instead options for the awareness and management of the effects would be more realistic.

134. The physical occurrence of wake cannot be eliminated. However, management measures recommended during and following channel deepening and widening can improve personal safety by increasing the community awareness and educating the general public and users of the harbour to the effects of vessel traffic even though most of these effects are likely to be reduced. Likely methods of increasing awareness may be through media promotion, signs and continued communication with user groups.

The effects of the proposal on the beaches and shoreline of the Otago Harbour and Blueskin Bay

Within the harbour

135. The shoreline within the Harbour contains expanses of inter-tidal sand with expansive sandy beaches at Te Rauone, Harwood and Aramoana. Smaller pocket beaches are located along the western shore of the lower harbour between Port Chalmers and Aramoana.

136. As explained by Dr Bell, the dredging operations may result in some fine sediments being distributed into the water column and settling temporarily on the beaches of the Harbour. The sediment will be readily re-entrained into suspension with wave action, and will not be significantly different in character to sediments already in motion within the Harbour, particularly as a result of natural events.

In Blueskin Bay

137. As explained by Dr Bell, the position of Site A0 is such that the beaches of Blueskin Bay and the rocky shoreline south of Taiaroa Head, and north of Warrington will not receive any appreciable amounts of fine sediments that have been put into suspension during the dredge disposal operation or from sediment re-suspended from the dredge disposal site A0.

138. Waves propagating across the deepened channel seaward of Harington Point will be modified by the change in depth. Waves from the easterly quarter may alter along the crest length with slight changes in direction or focussing of wave energy. MetOcean Services Ltd investigations and modelling of these processes suggest that the surfability of the waves will be unchanged or possibly improved, and there will not be any adverse effects at the shore due to the changes in energy distribution along the wave crest.

RESPONSE TO SUBMISSIONS

139. The main themes from the submissions related to my area of expertise and experience are as follows:

a Sand and finer sediments will adversely affect the beaches of Blueskin Bay and the shore north to Karitane.

b The surfing waves at Aramoana would change, resulting in loss of the nationally significant surf break.

c The Harbour shoreline of the Aramoana ecological area will be adversely affected by the change in channel depth and width.

d Wake waves will cause erosion and adversely affect other harbour users.

Sediment on the shores of Blueskin Bay

140. The shores of Blueskin Bay and north to Karitane are subject to high-energy waves from the northeast through to the south-southwest quarters. Fine sediment, including sands and muds, mantle the continental shelf in this area. These sediments are highly mobile and are put into suspension during storms. The dominant direction of sediment transport is northward in the outer bay area, with a southern and anti-clockwise movement in the gyre within Blueskin Bay. There is also onshore and offshore movement of sediment along the total shoreline.

141. The sediment available for transport varies depending on the energy environment (waves and currents) and the volume and size of the sediment on the seabed. The POL proposal will not change the energy levels, but will add to the sediment volume available for transport on the seabed at Site A0 (the amount varying as a function of the type of dredging activity undertaken, major or incremental capital).

142. The nature of the sediments will be similar to that naturally present in the offshore environment. The amount of fine sediment is of a similar order of magnitude to that put into the coastal system by major floods in the Clutha River.

143. The modelling results presented by Dr Bell show that the amount of redistribution of sediment from the disposal site A0 will be relatively small and result in a very thin layer of deposition except for the area in the immediate vicinity of the site. Any fine sediment that reaches the shore will be readily re-suspended and will be indistinguishable from the fine sediments already present in the nearshore environment. Sand is unlikely to reach the shores. These volumes are also a function on the type or mix of major and incremental dredging undertaken. Accordingly, in my view the submitters can be satisfied that sand and finer sediments will not adversely affect the beaches of Blueskin Bay and the shore north to Karitane.

Surfing waves

144. The 2010 New Zealand Coastal Policy Statement notes the surf break at Aramoana as Nationally Significant. The break is a result of the combined effects of the natural offshore wave environment and the modified nearshore topography resulting from the construction of the Mole and placement of maintenance dredged sand at the Spit disposal site.

145. Modelling by MetOcean Solutions Ltd, that I adopt, has shown that the placement of dredged sediment at site A0 will not significantly modify the offshore wave environment. Waves from the east and southeast, crossing the deeper harbour channel offshore of the end of the Mole, may be modified to a minor degree due to the deeper, wider channel configuration. The modelling results indicate that the surfability of the wave at Aramoana will not be compromised.

146. Changes to the sediment volume in the Spit disposal area have been investigated with regard to the disposal of sediment dredged during maintenance of the harbour channel. The changes to the nearshore topography are a combination of variations in the wave environment moving sediment on and offshore and along the shore, and the volumes of sediment deposited at the site each year. Between 2004 and 2010, volumes deposited were less than the long-term average due to a perceived build up of a mound at the site between 2002

and 2003. Recent work has shown that the perceived build-up of sediment volume at the Aramoana site was part of long-term variability to the seabed topography, and not as a result of oversupply with placed dredged sediment.

Aramoana ecological Area shoreline

147. Submitters noted concern that the margin of the Aramoana ecological Area would be eroded due to subsidence from the deeper channel margin, and from the effects of wake waves. The design of the proposed deeper channel does bring the northern edge of the channel closer to the tidal flats but does not result in loss of the inter-tidal sands.

148. Existing erosion of the north-western, inner margin of the inter-tidal sands will not be exacerbated by changes to the channel depth and width.

149. Wake waves are likely to be smaller for existing vessels that use Otago Harbour with a deeper channel, and the findings of the Port of Melbourne studies concluded that the wake from larger vessels should not be significantly larger than the wake of the existing large container vessels. Therefore there should be no increase erosion of the Aramoana Ecological Area due to the effects of the POL proposal.

150. Due to the biological sensitivity of the area, it is proposed below that the area is included in monitoring of the Lower Harbour shoreline.

Wake

151. The effects of vessel passage following widening and deepening of the existing navigable channel will be similar or less than that currently existing other than for a comparatively small number of larger vessels when these are brought into service. In my opinion, there will be no change in the effect of wake on the shoreline of the Lower Harbour, or on other users of the Harbour.

MONITORING

152. The proposed dredging and deeper channel will result in small changes to the physical process environment of Otago Harbour and the Blueskin Bay area. However modification of the shape and depth of the channel, and the deposit of the mound of sediment at the disposal site will physically change the seabed topography.

153. The requirements of the existing Port Otago maintenance disposal consent include seabed surveying of the channel and the disposal grounds off Heyward Point, Aramoana and Spit Beach. This type of monitoring is useful in that it provides information on the dredging demand and on the retention of sediment at the disposal sites. POL has acknowledged in the Environmental Management Plan that it would do this work.

154. Monitoring of the effects of the proposed dredging operation and the deeper channel on the physical coastal environment should be of the same methodology, with annual surveys of the seafloor and intertidal flats within the Lower Harbour, plus a survey of the disposal mound at A0 before and after deposition from Major Capital works, before incremental capital works and at least annually during deposition from Incremental Capital works.

155. There is potential for ship wakes to have a different effect at Te Rauone Beach than at present. This beach is in an erosional state, and is subject to locally generated storm waves, swell penetrating into the Harbour, and ship wake. The beach requires management to provide a sustainable coastal resource for the area. POL is at present actively involve in investigations and management planning for Te Rauone Beach.

MATTERS RAISED IN THE OFFICERS' REPORT

156. I have read the officer's report and recommendations prepared by ORC (dated 16 March 2011). There are no matters arising requiring my comment.

CONCLUSIONS

157. Otago Harbour is a robust, dynamic environment subject to variable wave energy and sediment supply, and to a history of human modification to the shores, the main channel and the entrance configuration. The area of Blueskin Bay between Taiaroa Head and Karitane Peninsula is subject to high-energy waves, strong tidal and oceanic currents, and a large but variable volume of sediment transfer on the continental shelf and nearshore seabed.

158. Feasibility studies were carried out on the proposal to deepen the shipping channel through the Lower Otago Harbour, and to identify the most suitable method of sediment disposal and the offshore disposal site with the least adverse effect.

159. The main considerations for the effects on the physical coastal processes were:

    a Potential changes to the hydrodynamics of the Harbour and the entrance channel,

    b Potential changes to the wave environment of the Harbour, the entrance channel and the disposal site,

    c Changes to patterns of sedimentation within the Harbour, the entrance channel and the wider Blueskin Bay area, and

    d The dispersal of fine sediments due to the dredging operation.

160. Studies carried out to investigate these effects have shown that they are mostly negligible, and of magnitudes within the variability of the natural environment.

161. With regard to the effects of the proposal on wake waves, it is likely that the proposed deepening and widening of the Lower Otago Harbour channel will result in a reduction in the magnitude of wake generated by commercial vessels currently transiting the channel, and no change in the overall effect of wake waves on the shore and beaches of the Lower Harbour, or on other users.

162. Apart from the physical change to the seabed topography in and along the margins of the channel, and at the disposal site, I consider that the effects of the dredging operation on the physical coastal environment are minor.

Martin Bernard Single

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