OCEAN BEACH RESTORATION PROJECT: SEDIMENT REPORT

REPORT FOR
Dunedin City Council

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112 DCC 1153 Ocean Beach

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SUMMARY

This report presents present all the available information on characteristics of the native sediment found in the nearshore, foreshore and dune environments at Ocean Beach, sand placed on the foreshore and dunes during the 2007 emergency works, and potential other sources of renourishment sand both from within Otago Harbour and from a quarry at Blackhead. The report concludes with recommendations on the suitably of these potential sources of renourishment sand.

Results from Cawthron (2002) and Ryder (2003) indicate that 99% of the nearshore sediments in Ocean Beach are in the medium to fine sand size class (e.g. 0.5 to 0.125 mm dia), however no breakdown of the distribution within these size classes are given. These results are consistent with the description of nearshore seabed sediment given in Carter *et a*l (1985), in which the inner shelf sediment is described as being fine grey silicate sand primarily sourced from Schist in the Clutha and Taieri catchments since sea level stabilised some 6500 years ago.

Sampling undertaken for this investigation indicates that the apart from having a higher percentage of finer sand in the western corner of the beach, the sediment found on the foreshore at Ocean Beach is very homogenises, being a well sorted mixture of pre-dominantly medium sized sand (60-70%) and fine sand (30-40%) with a mean grain size in the order of 0.27 mm. The only longshore variation was found to be at the western end of St. Clair, where there was as increased presence of finer material (80%), which was considered to be due to reduced wave energy at this end of the beach.

Dune sands were found to have a similar narrow range of well sorted grain sizes as the beach, but with higher percentage of fine sand being 50-70%, and a finer mean grain size of 0.25 mm. Sediment trace metal analysis undertaken by Hills Laboratories on the dune samples found that the concentrations of all metals were well under the Interim Sediment Quality Guidelines Low Trigger value specified in ANZECC (2000), indicating that the dune sediments are uncontaminated, even where fill material has been exposed.

Of the sand placed during the 2007 emergency works, the material from the Green Island Bush Road quarry had a comparable size distribution to the native beach sands, hence was the most appropriate to use to cover the exposed sand sausages at St. Clair. The harbour sands placed during 2007 were generally finer than the native dune sands, hence had less resistance to wave and wind processes. However, sources of supply were limited, and there was no option of finding an alternative source at short notice. The material has proved to be adequate for placement in the dune environments, but is rapidly transported when exposed to wave run-up processes. Neither of the sand sources used in the 2007 emergency works showed any evidence of heavy metals contaminant.

Ten areas within Otago Harbour were sampled to determine potential long-term renourishment sources. Of these, only two, Cross channel and Tayler's Point, had size distributions approaching those found on the native beach, with the percentage of medium sized sand being in the order 60 -65% and a mean grain size of 0.27 mm. Sand from the remainder of the Harbour dredge sites was finer than found in the Ocean beach dune system, with percentages of fine sand being in the order 80% to 95% and mean grain sizes in the range 0.17-0.21 mm. All of the harbour samples were found to be very well or well sorted, which is similar to the native beach sediment, and no sites were found to have any heavy metal contamination.

Samples from a second quarry at Blackhead (Billington's) showed a similar grain size distribution as the nearby Green Island Bush Rd quarry, and is very comparable to the native beach sediment, having 62% medium sand and a mean grain sand of 0.26 mm.

Based on the grain size distributions, the most desirable sources of long-term renourishment sand are dredging from Cross-channel and Tayler's Point in the Harbour, or from either of the Blackhead quarries. It is unknown how much sand may be available from any of these sites. The use the finer sand from the other sources in the harbour for renourishment on the beach would require in the order of two to four times the amount of volume as from the above sources to achieve a beach berm of the same width. There would also be larger and more frequent maintenance requirements if using this finer material on the beach. However, material from these sites would be appropriate for increasing dune bulk, and could be made more sustainable for placement on the beach by filtering to remove some of the fines, or mixing with a coarser stock to obtain comparable distributions to the native beach.

1.0 Introduction

This report forms part of the investigations stage of the Dunedin City Council Ocean Beach Restoration Project. The purpose of the report is present all the available information on characteristics of the following sediment:

- Native sediment found in the nearshore, foreshore and dune environments at Ocean Beach.
- Material placed on the foreshore and dunes at Ocean Beach during the 2007 emergency works from a private quarry in Green Island Bush Road and Otago Harbour.
- Potential other sources of renourishment sand from within Otago Harbour.
- Potential other sources of renourishment sand from an alternative quarry at Blackhead.

The report concludes with recommendations on the suitably of the potential sources of renourishment sand.

1.1 Data Sources and Sampling Methods

1.1.1 Native Ocean Beach Sediment

Data on nearshore sediments was obtained from reports by Cawthron (2002) and Ryder (2003), who undertook sediment sampling as part of ecological investigations for the Tahuna wastewater outfall consents. The Cawthron (2002) investigation involved 6 grab samples of 0.1 m^2 of seabed in the Tahuna and Lawyers Head area at water depths between 15 m and 32 m. Ryder (2003) collected 13 samples using an 85 mm diameter core inserted 250 mm into the surface of the seabed along a transect parallel to, and 1100 m offshore from the beach. Samples were located at various distances up to 2 km east and west along a transect away from the proposed Tahuna outfall site. Water depths at the sample sites were generally in the order of 20 m, except for the most western two sites which were shallower at 16.7 m (1 km west) and 9.4 m (2 km west). The locations of all of the nearshore sampling sites are shown in Figure 1. Information on sediment on the middle and outer continental shelf is presented in Carter *et al* (1985).

Sediment grain size from the Cawthron (2002) samples was gravimetrically determined at Cawthron after wet sieving and drying. Results are presented as percentage in each of the gravel, sand, and mud classes. The samples were also analysed for total organic carbon, nutrients, and trace metals by Hills Laboratories. Ryder (2003) states that the divers taking the samples noted the immediate characteristics of the seabed, but does not indicate whether any grain size analysis was carried out on the samples.

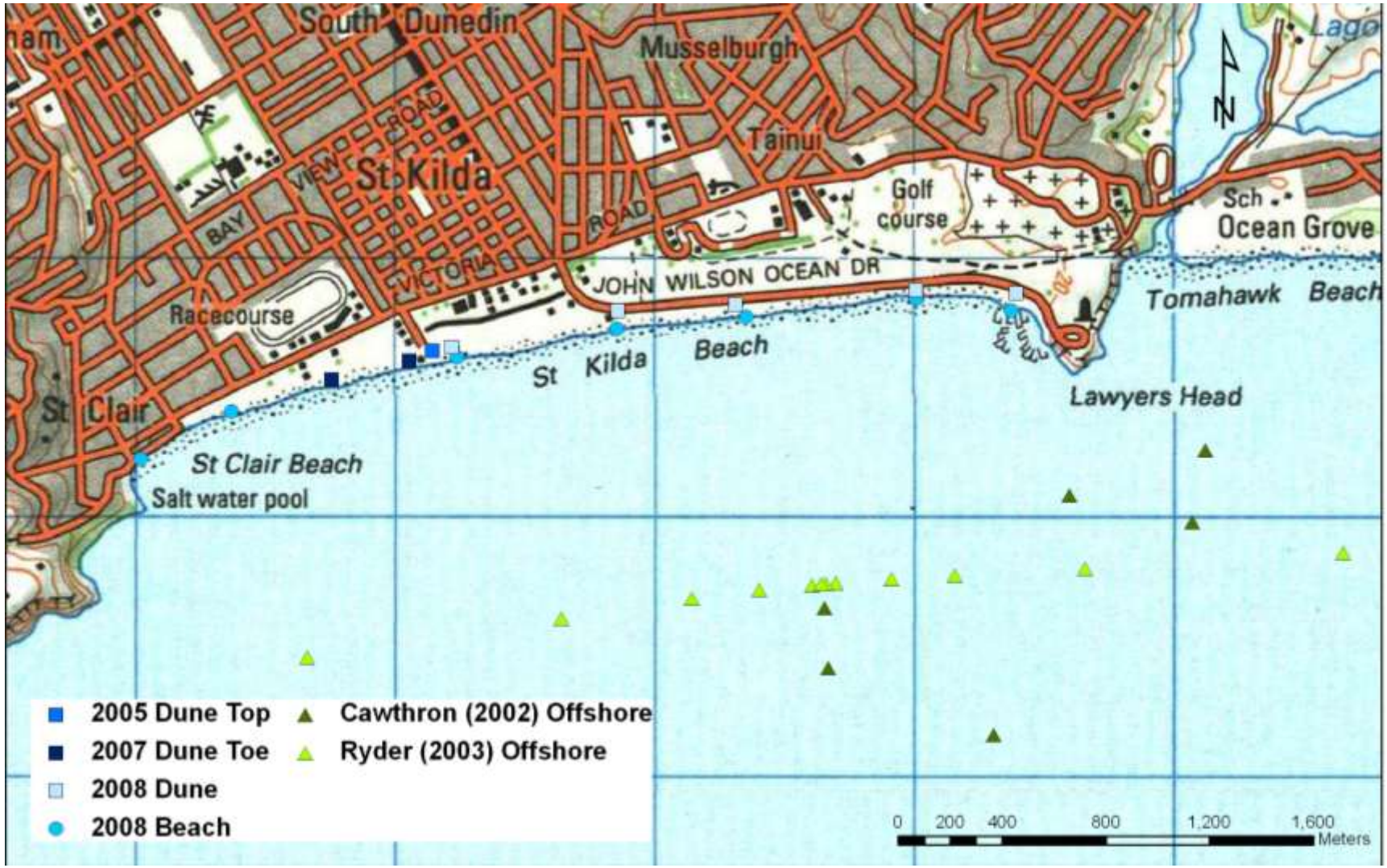


Figure 1: Location of sediment sample sites at Ocean Beach

The results presented describe the characteristics of the substrate but do not include any size breakdown, which suggests that size analysis was not undertaken. The samples were however analysed for benthic fauna and trace metals.

Data on beach sediment size is presented by Hodgson (1966), Dyer (1994) and from samples collected as part of this investigation. Hodgson (1966) appears to have taken one sample from around St. Kilda at approximately 1.5 m below the high tide run-up level. Dyer (1994) indicates that sediment samples were collected and analysed using "Rapid Sediment Analysis" techniques, but the number and locations of the samples is not given. For the current investigations, samples of 200-400 g of beach sediment were collected from the mid tide swash zone on 30th October 2008 at seven locations along the foreshore as shown in Figure 1. For each sample, 100 g of sediment was dry sieved at the Geography Department, University of Canterbury following the methodology outlined in Lewis & McConchie (1994).

Data on dune sediments is from the following samples collected since 2005:

- 1 sample from top of the dune at Moana Rua collected in 2005
- 2 samples from base of the dunes west of Moana Rua collected following significant storm in June 2007
- 5 samples from the dune face at Lawyers Head, Tahuna, St; Kilda, and Moana Rua collected in October 2008 as part of the current investigations programme.

For all of these samples, representative sub samples were dry sieved at the Geography Department, University of Canterbury to determine grain size characteristics. The samples from the base of the dunes taken in 2007 were also analysed for trace metals by Hills Laboratories.

1.1.2 Material Placed during 2007 Emergency Works

This material was initially placed on the beach in early and mid July 2007 as emergency works following the damaging coastal storms from April to June. Around 13,000 m^3 of material from a private quarry in Green Island Bush Road in the Blackhead area, was placed over the exposed sand sausages to the east of the St. Clair seawall. One sample of this material was analysed by the Department, University of Canterbury to determine grain size characteristics and by Hills Laboratories to determine concentrations of trace metals.

Another 7,400 m^3 of material dredged from Otago Harbour was also placed over the dunes at Moana Rua in July and August 2007. Two samples of this material were taken, one from the initial placements in early July 2007, and one from placements in August 2007. Both of these samples were dry sieved at the Geography Department, University of Canterbury following the methods outlined in Lewis & McConchie (1994)

to determine grain size characteristics and analysed for trace metals by Hills Laboratories. Over the remainder of 2007 and in 2008 a further 13,500 m^3 of sand from the harbour has been either placed over the dune at Moana Rua, used to re-cover the sand sausages to the east of the St. Clair seawall, or placed in the dune stockpile by the Te Whanau Arohanui Marae. The volumes involved in the various placements and the dredging sites within the harbour are given in Appendix A.

1.1.3 Potential other sources of renourishment sand from within Otago Harbour

As part of this investigations programme, Port Otago undertook sampling from 10 locations within Otago Harbour in May 2008 to determine what site might provide the best source of sediments for potential future beach renourishment at Ocean Beach. The general locations of these sampling sites are shown in Figure 2. As indicated in Appendix A, sand from many of these sites has already been used in the emergency placements at Ocean Beach in 2007 and 2008. All of these samples were dry sieved at the Geography Department, University of Canterbury by the methods outlined in Lewis & McConchie (1994) to determine grain size characteristics and analysed for trace metals by Hills Laboratories.

1.1.4 Potential other sources of renourishment sand from an alternative quarry at Blackhead

As part of this investigations programme a sample of the sand from Billington's quarry in the Blackhead area was taken in December 2008 and analysed for grain size by dry sieving at the Geography Department, University of Canterbury by the methods outlined in Lewis & McConchie (1994). The location of Billington's quarry is very close to the location of the Green Island Bush Road quarry used in the July 2007 placements at St. Clair.

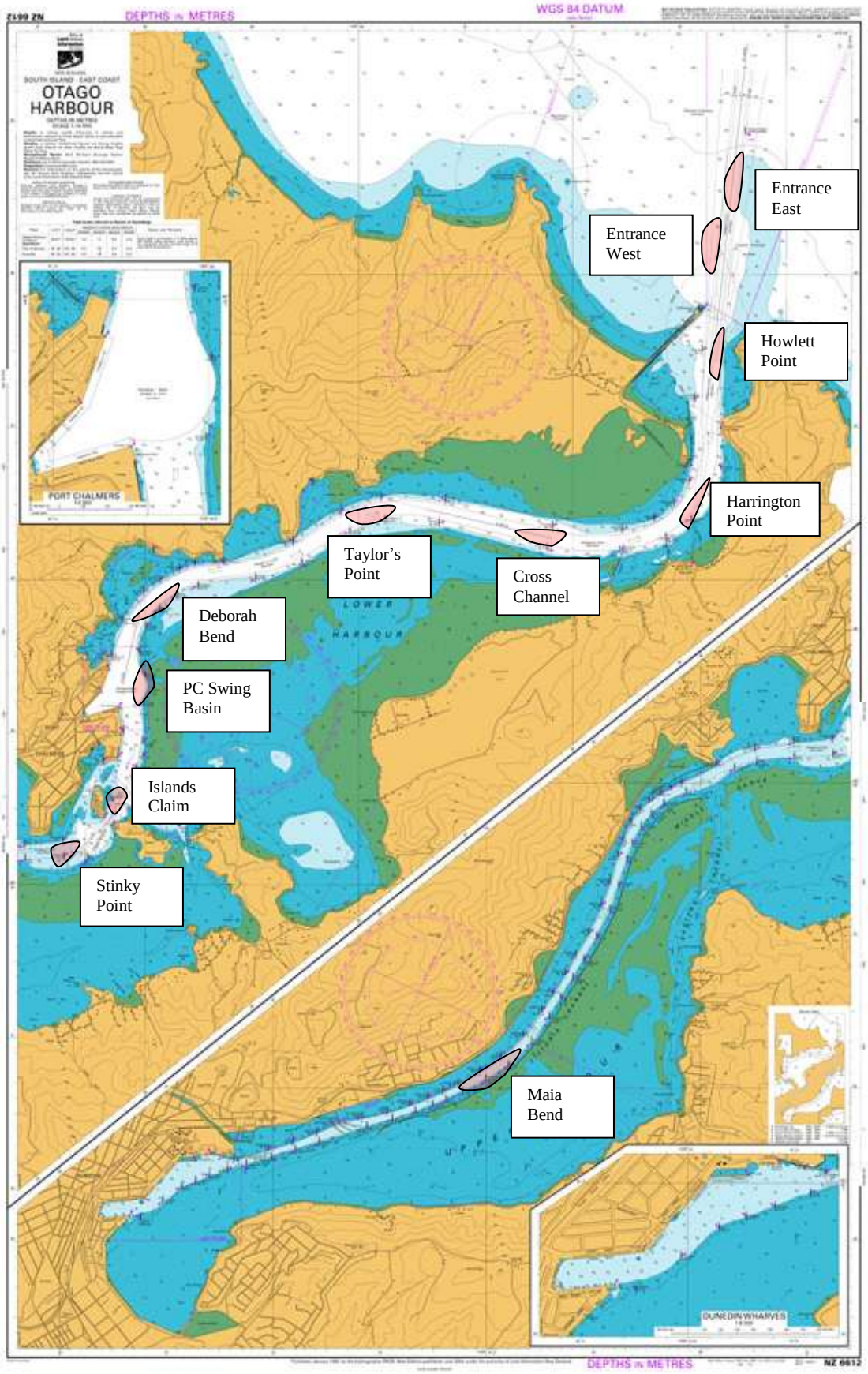


Figure 2: Location of sediment sample sites in Otago Harbour

2.0 Results

2.1 Native Ocean Beach Sediment

2.1.1 Nearshore Sediment

The results from Cawthron (2002) indicate that 99% of the nearshore sediments in Ocean Beach are in the sand size class, however no breakdown of the distribution within this size class is given other than that they are primarily in the fine-medium fraction. These results are consistent with the observations of Ryder (2003) who notes combinations of mobile sands, compact sands, and sand/reef/shells along a shore parallel nearshore profile. These results are also consistent with the description of nearshore seabed sediment given in Carter *et a*l (1985), in which the inner shelf sediment is described as being fine grey silicate sand primarily sourced from Schist in the Clutha and Taieri catchments since sea level stabilised some 6500 years ago. From the offshore profile presented in MWH (2002) these modern sands extend out to around the 40 m contour approximately 2.5 km from shore where they give way to relict gravels sourced from the Clutha catchment that are considered to have been deposited during a period of sea level standstill around 12,000 years BP (Carter *et al* 1985).

The data on nearshore sediment sizes presented in Cawthron (2002) and Ryder (2003) is presented in Appendix B.

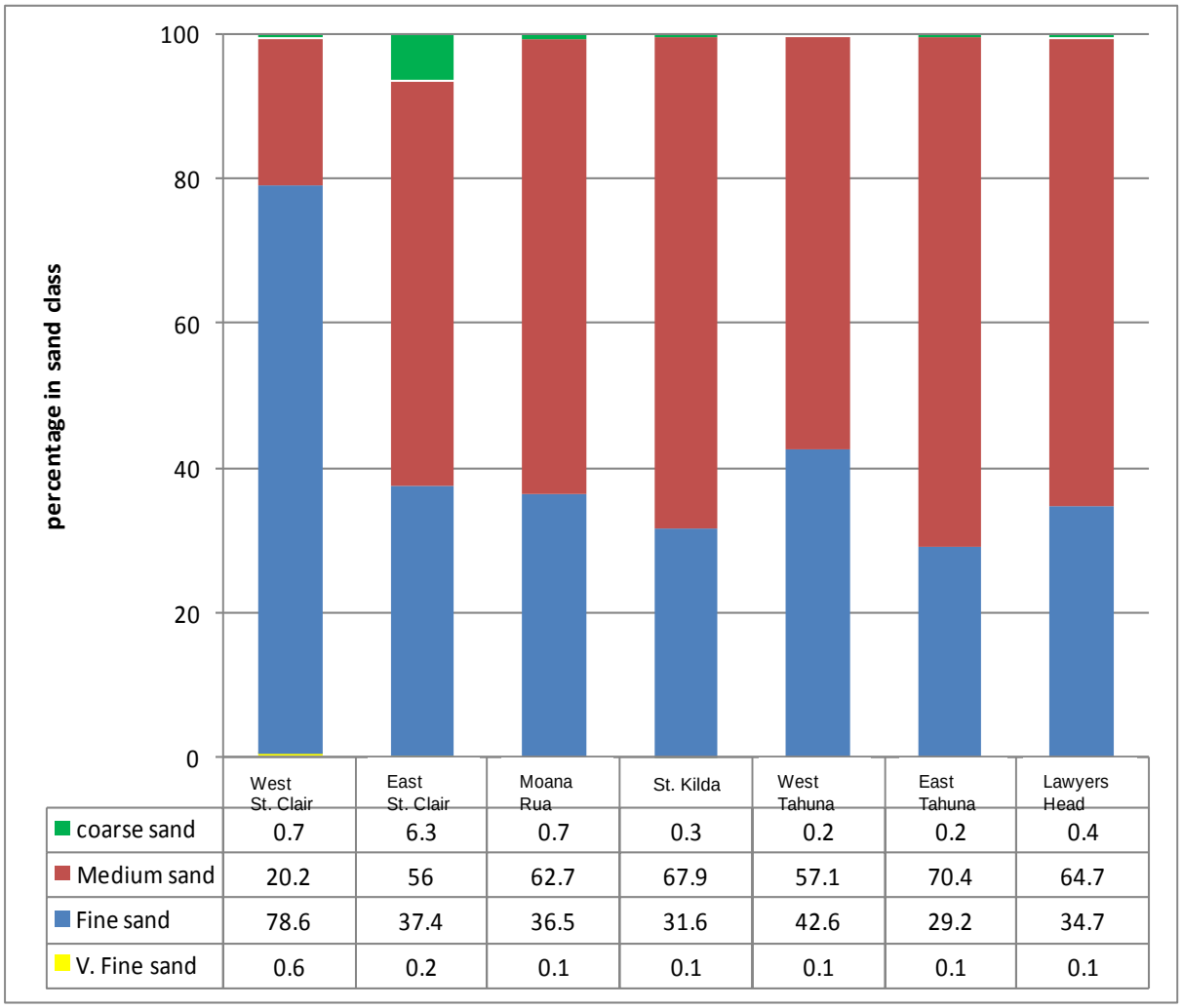
The sediment trace metal analysis undertaken by both Cawthron (2002) and Ryder (2003) found that that the concentrations of all metals were considerably lower than the Interim Sediment Quality Guidelines Low Trigger value specified in ANZECC (2000), above which further investigations is required. These results indicate that the nearshore sediments are uncontaminated, and as stated by Ryder (2003) are "*consistent with those reported for relatively "clean" coastal material environments in New Zealand*".

2.1.2 Beach Sediment

The results from the October 2008 beach samples are presented in Appendix C. These results and Figure 3 show that the beach sand is predominantly comprised of well sorted fine to medium sand (99%), which are similar grain sizes to the nearshore sediment reported by Cawthron (2002). It is therefore concluded that this narrow band of sediment sizes found on the beach is a response to the narrow ranges of sizes available to be transported to the shore, rather than due to size selection by the wave transport processes.

However, there appears to be a difference in the size distribution of the sediment at the western end from the reminder of the beach. For the majority of the beach length, the dominant grain size is medium sand (0.25 to 0.5 mm dia), comprising

between 60-70% of the total, and resulting in a mean grain size of in the range of 0.26-0.29 mm. This is similar to the mean grain sands for Ocean Beach reported by Hodgson (1966) of 0.26 mm and Dyer (1994) of 0.3 mm. In contrast, the sample from the western end of St. Clair revealed a much lower percentage of medium sand (20%) and a corresponding higher percentage (78%) of fine sands (0.125 to 0.25 mm dia), resulting in a mean grain size in the fine sand class (0.21 mm). This pattern suggests that the sands at the western end of St. Clair are more mobile that at the remainder of the beach to the east, and possibility exposed to a smaller wave energy environment.



	West St. Clair	East St. Clair	Moana Rua	St. Kilda	West Tahuna	East Tahuna	Lawyers Head
coarse sand	0.7	6.3	0.7	0.3	0.2	0.2	0.4
Medium sand	20.2	56	62.7	67.9	57.1	70.4	64.7
Fine sand	78.6	37.4	36.5	31.6	42.6	29.2	34.7
V. Fine sand	0.6	0.2	0.1	0.1	0.1	0.1	0.1

Figure 3: Beach sediment size distribution from samples collected in October 2008

The only other exception to the homogenises natural of the beach sediment was the higher proportion of coarse sand in the east St. Clair sample (6.5%) than the other locations, which were less than 1%. While the presence of this coarser sand could be due to the close proximity of this sample site to the placed sediment over the exposed sand sausages, the results of the size analysis for this material don't indicate that this was the case (see section 2.2.1). As shown by the results in

Appendix C, the presence of this coarse sand results in this sample being only moderately well sorted compared to well sorted (e.g. very narrow range of grain sizes present) for the other samples.

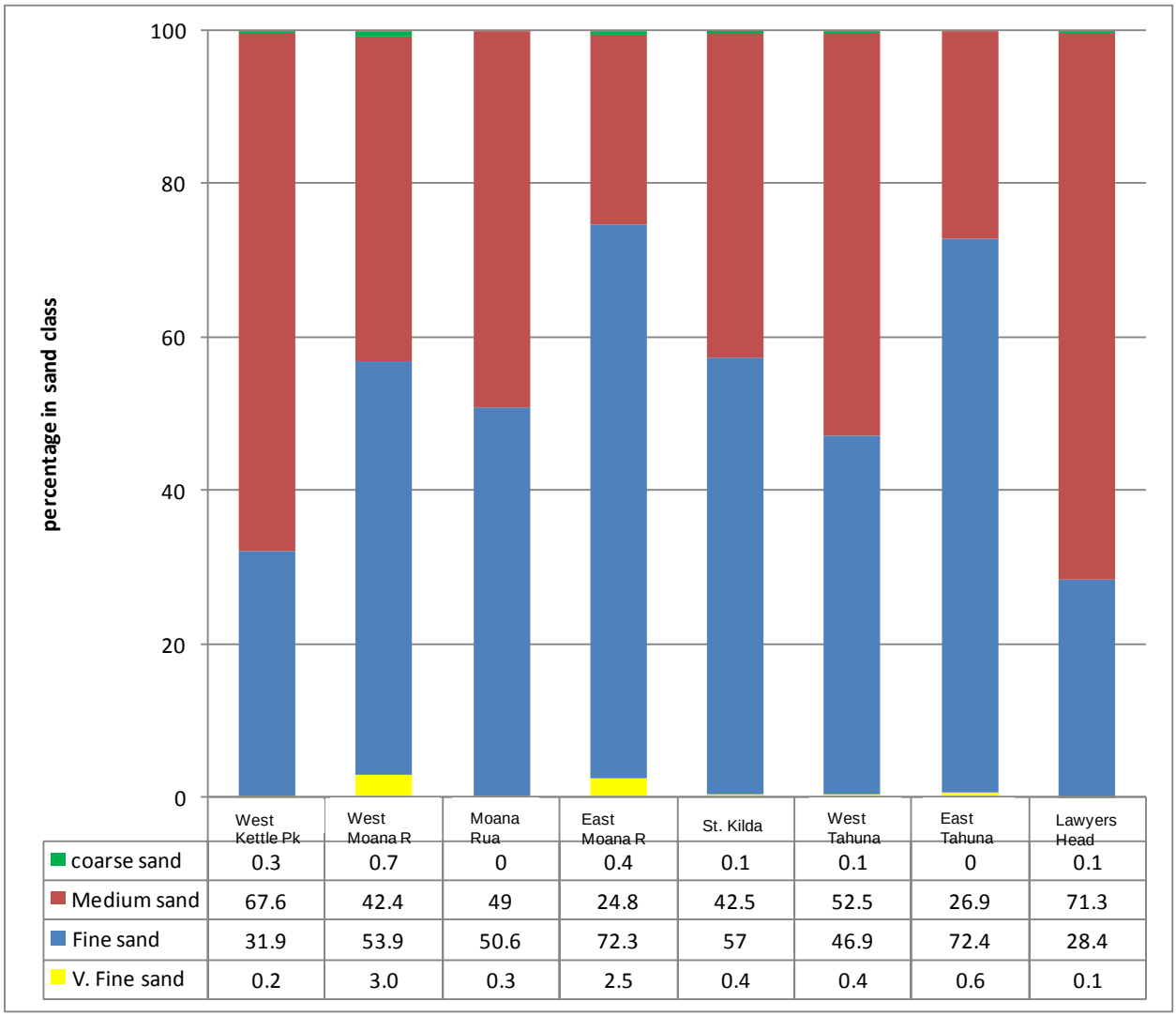
The other results in Appendix C show that all of the samples except the eastern two are have near symmetrical distributions, indicating that the mean and medium grain sizes are the same, while the eastern two sites are very slightly fine skewed. All samples are mesokurtic, indicating that the grain size distribution is very close to a normal distribution curve with the sorting in the tails and the central portion of the distribution being very similar.

In conclusion the sampling indicates that the apart from having a higher percentage of finer sand in the western corner of the beach, the sediment found on the foreshore at Ocean Beach is very homogenises, being a well sorted mixture of pre-dominantly medium sized sand (60-70%) and fine sand (30-40%) with a mean grain size in the order of 0.27 mm.

2.1.3 Dune Sediment

The results from all of the dune samples (2005, 2007, 2008) are presented in Appendix D. These results and Figure 4 show that as with the beach sand, the dune is predominantly comprised of well sorted fine to medium sand (96-99%). As with the beach sediment, this narrow band of sediment sizes is a response to the narrow ranges of sizes available to be transported to the dunes from the shore. However, as shown in Figure 4, there is generally a higher percentage of fine sand in the dune samples, being 50-70% compared to 30-40% for the beach samples. This pattern is as expected, due to the higher percentage of time that wind can transport fine sand into the dune environment compared to medium sand. The exception to this distribution pattern is for the most western and eastern samples, both which have lower percentages of fine sand, more in line with what is found on the beach. There is no logical reason which the distributions are different at these sites, as wind exposure should be similar at all sites, and based on the results from the other samples, the elevation of the sample on the dune does not appear to be a factor, and all samples were from areas of bare sand away from vegetation.

The higher percentage of very fine sand (3%) found in the 2007 sample from the dune toe west of Moana Rua is considered to be residue from the presence of large volumes of soil/clay fill material in this area. The higher percentage (2.5%) of this size material in the 2008 sample from the dune top east of Moana Rua is considered to be residue from the initial 2007 placement of Otago Harbour sand at Moana Rua, (see section 2.2.2)



	West Kettle Pk	West Moana R	Moana Rua	East Moana R	St. Kilda	West Tahuna	East Tahuna	Lawyers Head
coarse sand	0.3	0.7	0	0.4	0.1	0.1	0	0.1
Medium sand	67.6	42.4	49	24.8	42.5	52.5	26.9	71.3
Fine sand	31.9	53.9	50.6	72.3	57	46.9	72.4	28.4
V. Fine sand	0.2	3.0	0.3	2.5	0.4	0.4	0.6	0.1

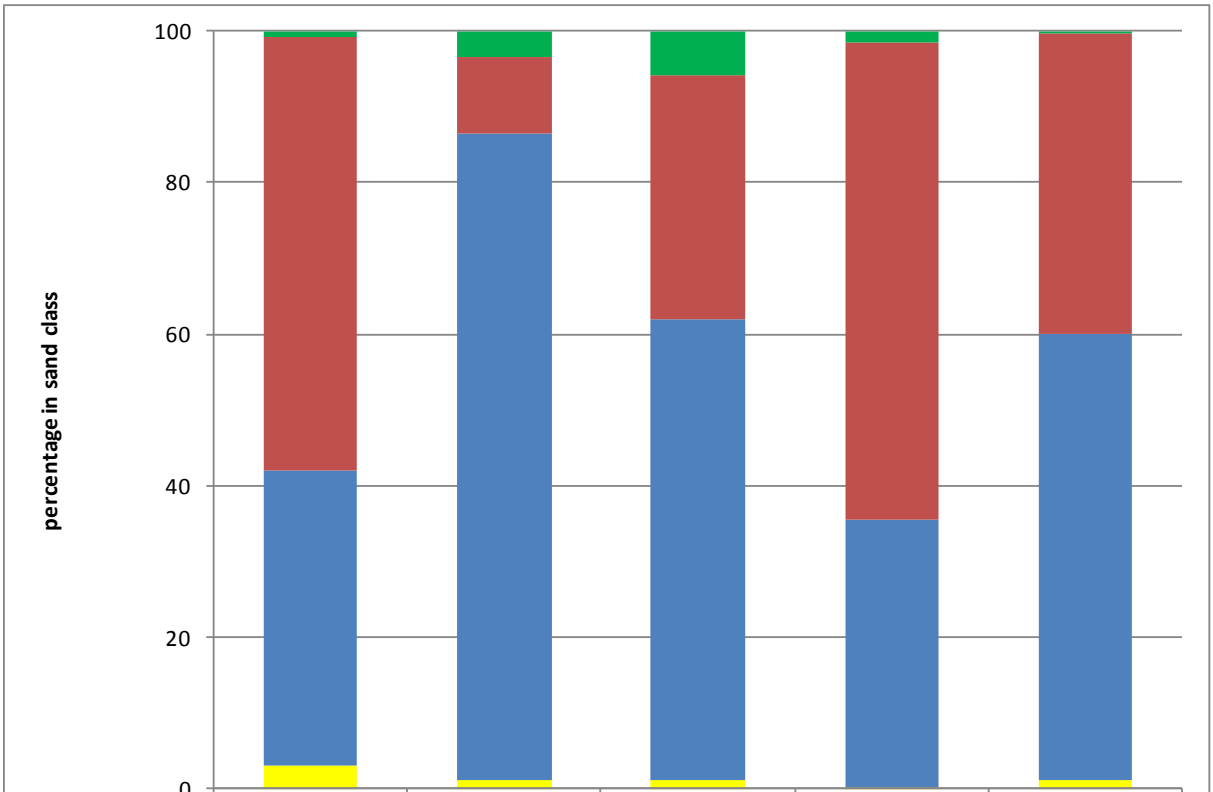
Figure 4: Dune sediment size distribution from samples collected in 2005, 2006, 2007 and 2008

Due to the higher percentage of fine sands in the dunes, the mean grain size of the dune samples was slightly smaller than for the beach samples, being in the order of 0.25 mm, which is the boundary between fine and medium sand classes. All the samples except one were well sorted, the majority were near symmetrical distributions, (e.g. mean and medium grain sizes very similar) and mesokurtic, (e.g. grain size distribution is very close to a normal distribution curve with the sorting in the tails and the central portion of the distribution being very similar).

The sediment trace metal analysis undertaken by Hills Laboratories on the 2007 samples from the base of dune at Middle Beach are presented in Appendix F. This analysis found that the concentrations of all metals were well under the Interim Sediment Quality Guidelines Low Trigger value specified in ANZECC (2000), above which further investigations is required. These results indicate that the dune sediments are uncontaminated, even where fill material has been exposed.

2.2 2007 Sand Placements

The results from samples of sand placed at Ocean Beach as part of the 2007 emergency works are presented in Appendix E. The percentages of the samples in each sand size class compared to an average for the natural beach and dune sands are presented in Figure 5.



	Green Island Bush Rd Quarry	Port July Placement	Port August Placement	Average Beach sand	Average Dune sand
coarse sand	0.7	3.3	5.7	1.4	0.2
Medium sand	57.4	10.1	32.2	63.1	39.7
Fine sand	39.0	85.5	61.0	35.3	58.9
V. Fine sand	2.9	1.1	1.0	0.1	1.2

Figure 5: Sediment size distribution from samples of sand placed on Ocean Beach in 2007, compared to average distribution from native beach and dune samples

For beach renourishment the most desirable sand is that which replicates the distribution, or is slightly coarser, than the native beach sands, as this material will have a similar or higher resistance to erosion processes while not greatly altering the physical characteristics of the beach (except possibly colour). However, it is recognised that at the time of the initial placements there were other considerations of speed and availability of supply to consider.

As can be seen from Figure 5, of the sand used in the initial placements, the size distribution of the sand from Green Island Bush Rd quarry was the most comparable with the native beach sand, with mean grain size and sorting also being similar. This

sand also had the highest proportion of medium sand (57%), therefore was the most desirable of the initial sources. Around 13,000 m^3 of this material was placed over the exposed sand sausages to the east of the St. Clair seawall between the 3rd and 9th July, with some being to replace losses in high seas of 5th & 6th.

The initial July placement by Port Otago was considerably finer, and had a higher proportion of fine sand (85%) than either the native beach or dune sand. Therefore, this sand would be less resistant to transport by both wave and wind processes that the native beach, hence is an inferior source of renourishment material. Also, the coarse sand in the sample was found to be derived from shell, which has a lower specific weight than the same size grains derived from rock, so also has a lower resistance to transport processes. From Appendix A, this sand was most likely obtained from the Stinky Point dredging area (see Figure 2), which notes from Port Otago indicate has a supply of clean sand that is quick to load at times. Around 2,500 m^3 of the 4,500 m^3 of Harbour sand placed over the dune at Middle Beach during the initial placement from 4th to 12th July 2007 was from this source, with losses occurring during high seas on 5-6th and 13-14th July (which resulted in a further 800 m^3 placement on 18th July).

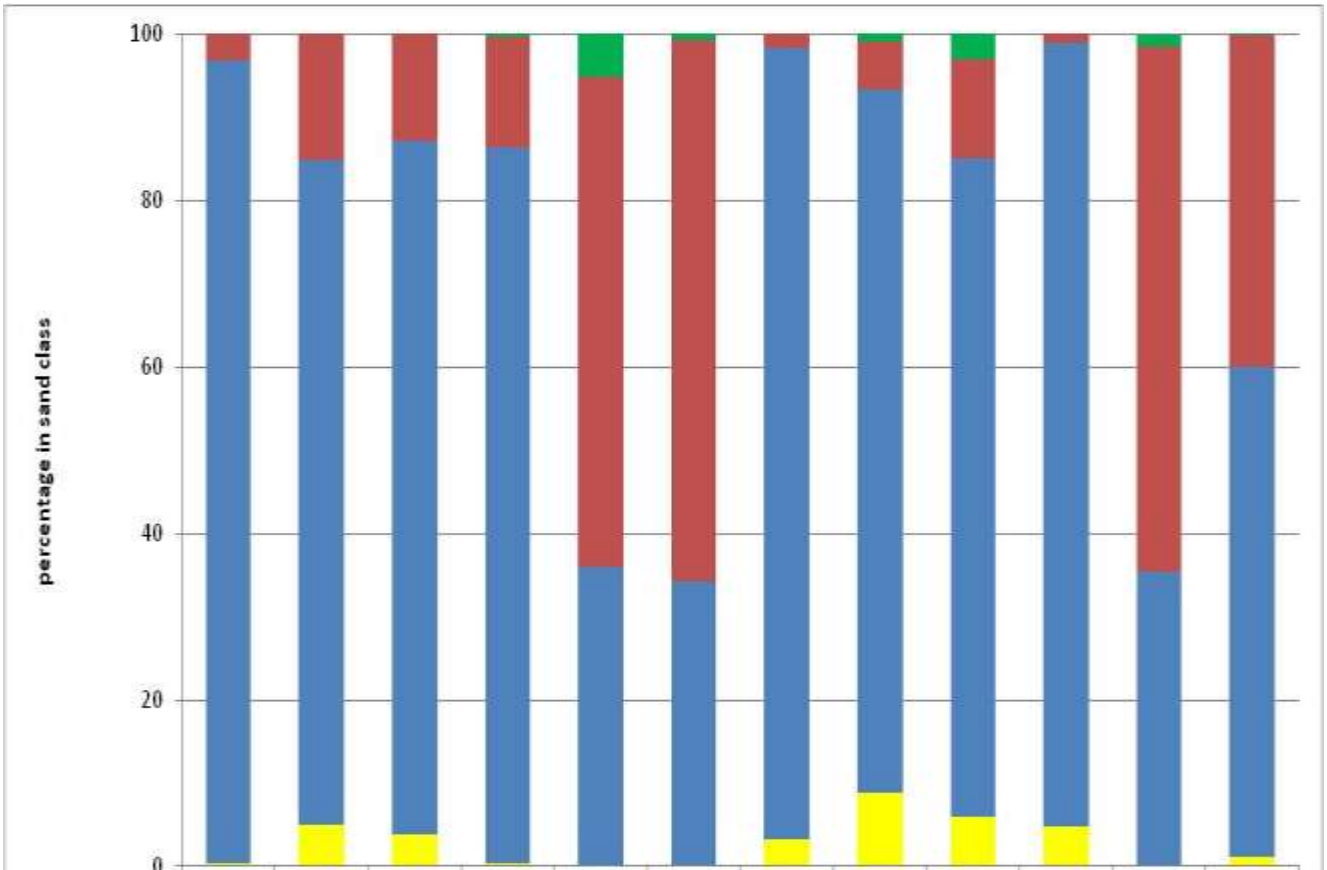
Appendix A indicates that a further 2,000 m^3 of dredged harbour sand was placed over the dunes at Middle Beach during August 2007, the majority of which (1,200 m^3) was dredged from the Howlett Point area. The Port Otago dredging notes indicate that sand from this area is clean and quick to load, but as shown on Map 2, it is a further haul distance to discharge at the down town wharfs. Figure 5 and Appendix E show that this material had higher percentage of medium sands (32%) than the initial port placements, and that the size distribution was very compatible to the native dune sands. However, the proportion of medium sand in the sample was still below that found in the native beach samples, and the relatively high percentage of coarse sand in the sample was again found to be derived from shell, which has a lower specific weight than for the same size grains derived from rock. Therefore, this sand would also be less resistant to transport by both wave and wind processes than the native beach material. A further 4,000 m^3 of harbour sand was deposited over the dunes at Middle Beach in the October to December 2007 period, of which around half was sourced from the Howlett Point dredge area.

Trace metal analysis was undertaken by Hills Laboratories on the samples from Green Island Bush Road quarry and the initial July placements from Otago Harbour. The results from this analysis are presented in Appendix F, and show that the concentrations of all metals were considerably lower than the Interim Sediment Quality Guidelines Low Trigger value specified in ANZECC (2000). Hence there were no issues with potential contamination of the sand placed on the dunes in the initial placements.

2.3 Potential Other On-going Sand Sources

2.3.1 Otago Harbour

The results of the grain size analysis for the samples from the 10 dredging sites within the harbour are presented in Appendix E, and a plot of the size distributions compared to the average native beach and dune distribution is shown in Figure 6.



	Ent East	Ent West	Howlett	Harington	X Channel	Tayler's	Deborah	PC Basin	Islands	Maia	Avg Beach	Avg Dune
coarse sand	0.2	0.1	0	0.4	5.2	0.8	0	0.9	3.1	0	1.4	0.2
Medium sand	3.3	15.2	12.9	13.3	59.0	65.1	1.8	5.8	11.9	1.2	63.1	39.7
Fine sand	96.3	79.8	83.3	86.0	35.7	34.0	95.0	84.5	79.1	94.0	35.3	58.9
V. Fine sand	0.4	5.0	3.8	0.3	0.2	0.2	3.3	8.8	5.9	4.8	0.1	1.2

Figure 6: Sediment size distribution from samples obtained from dredging areas in Otago Harbour, compared to average distribution from native beach and dune samples.

As can be seen from the above plot, only samples from Cross channel and Tayler's Point had size distributions approaching those found on the native beach, with the percentage of medium sized sand being in the order 60 -65%. The mean grain size for samples from these two sites was 0.27 mm, the same as the average of the native beach samples (excluding west St. Clair). Sand from the remainder of the Harbour dredge sites was finer than even found in the Ocean beach dune system,

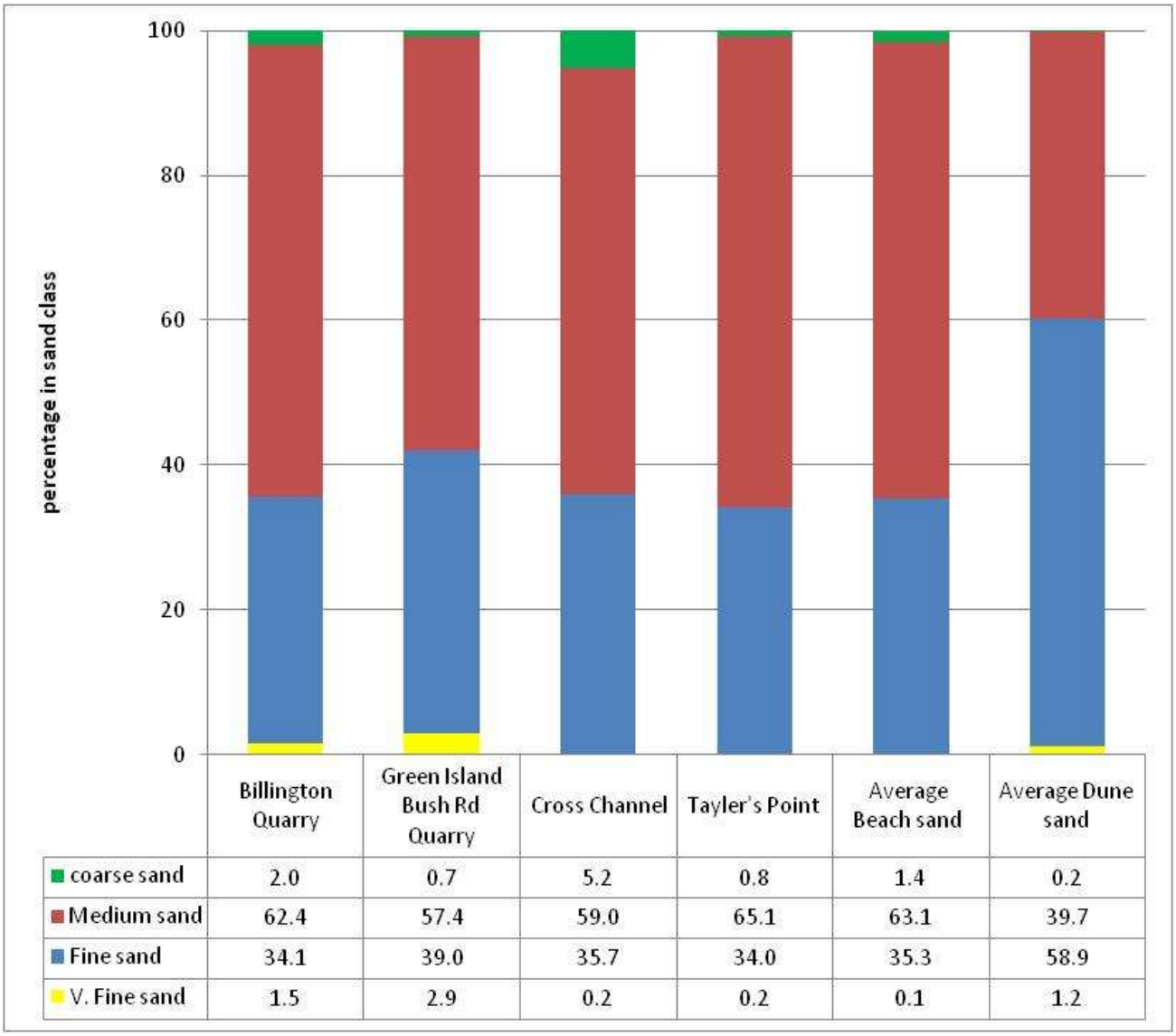
with percentages of fine sand being in the order 80% to 95% and mean grain sizes in the range 0.17-0.21 mm. All of the harbour samples were found to be very well or well sorted, which is similar to the native beach sediment. Based on the grain size distributions, Cross-channel and Tayler's Point are the most desirable harbour sources of long-term renourishment sand. It is unknown how much sand may be available from these dredge sites on a regular basis, however the break down in Appendix A indicates that to date none has been used at Ocean Beach. The Port Otago dredging notes indicate that sand from these sites is clean, but is slow to load.

It is notable that the sample from Howletts Point was considerably finer than the August 2007 placement sample, which was assumed to be sourced from this dredge area. This is considered to be due to some loss of fine sand in suspension while the placement material was draining on the wharf for 12 hours before being transported to the beach. If this was the case, the desirably of the harbour sand for renourishment purposes improves if this method of placement is used.

The results of the trace metal analysis undertaken by Hills Laboratories on all of the harbour samples are presented in Appendix F. The results show that the levels of trace metals were at least an order of magnitude below the maximum of the low effects range specified in ANZECC (2000), except Arsenic, which were predominantly less than 50% of the low trigger value for further investigations. Except for the higher results for Arsenic (e.g. those above 2 mg/kg dry wt), the results are comparable with the heavy metal concentrations found previously in the nature dune sands and used in the previous placements. It is notable that the sites with the best sized material for beach and dune renourishment, Cross Channel and Tayler's Point, had among the highest levels for Arsenic, however they are still very comfortably below the low trigger value specified in ANZECC (2000).

2.3.2 Billington's Quarry, Blackhead

The results of the grain size analysis for the sample from Billington's quarry, Blackhead is presented in Appendix E, and in figure 7 the size distributions is compared to the Green Island Bush Rd quarry, the best two sites from the harbour, and average native beach and dune distributions. As can be seen from the results, as expected the size distribution is very similar to that from the nearby Green Island Bush Rd quarry, and is very comparable to the native beach sediment, having 62% medium sand and a mean grain sand of 0.26 mm. Figure 7 therefore infers that the usefulness of this sediment for beach renourishment at Ocean Beach is similar to that of the best sediment dredged from Otago Harbour. As this stage it is unknown how much sand is available in the Billington quarry.



	Billington Quarry	Green Island Bush Rd Quarry	Cross Channel	Tayler's Point	Average Beach sand	Average Dune sand
coarse sand	2.0	0.7	5.2	0.8	1.4	0.2
Medium sand	62.4	57.4	59.0	65.1	63.1	39.7
Fine sand	34.1	39.0	35.7	34.0	35.3	58.9
V. Fine sand	1.5	2.9	0.2	0.2	0.1	1.2

Figure 7: Sediment size distribution from sample obtained from Billington's quarry, Blackhead, compared to other potential sources of renourishment sand and the average distribution from native beach and dune samples.

No trace metal analysis was undertaken on the sample from Billington's quarry. However it is assumed that it would be similar to from the Green Island Bush Rd quarry, and therefore have no issues with contamination.

3.0 Discussion on Suitably of Potential Sources for Renourishment

The analysis clearly shows that sand from Cross channel and Tayler's Point in the harbour, and from either of the quarries in the Blackhead area are the most desirable for use for long-term renourishment purposes at Ocean Beach. This is not to say that sand from the other dredge area within Otago Harbour cannot be used. However, the sustainably of this sand from these sources will depend on how it was used. Although it appears to be slightly finer that the native dune sand, it would be suitable for placement in these areas to increase dune bulk. As with the native dune sands, it would need to be extensively covered with appropriate dune vegetation to prevent wind erosion.

However, for placement on the beach to increase the buffer against dune erosion (or to increase dry sand for recreation), the finer grain size of this material would result in flatter beach and nearshore slopes, with greater volumes of sediment likely to be moved to the nearshore, and therefore more renourishment volume would be required to achieve the desired beach width. The effect of sediment size on renourishment volume required to establish a given width of dry beach can be calculated by the formula presented by Dean (2002). Applying the appropriate input parameters for Dunedin, these formula indicate that using the finer harbour material to establish a 20 m wide dry beach berm at the toe of the dunes would require around 2.5 times more volume than if the coarser material from Tayler's Point, Cross channel, or the Blackhead quarries was used. If the required renourishment berm width is decreased to 10m, this difference in volume requirement increases to 3.5 times. These calculations are detailed in Appendix G.

The use of the finer material on the beach would also likely to result in more rapid longshore volume losses due to plan shape considerations, and greater offshore volume losses during high wave energy and water level events. Therefore the use of the finer material in renourishment on the beach would require larger and more frequent maintenance volumes to retain the desired beach widths. Hence, the choice of sand source will have a significant impact on both the initial volumes and the long-term maintenance requirements.

The long-term use of sand for beach renourishment from dredge sites within the harbour other than from Tayler's Point or Cross channel, could be made more sustainable by filtering the sediment to remove some of the fines, or mixing with a coarser stock to obtain comparable distributions to the native beach.

4.0 Conclusions

The sampling undertaken for this and previous investigations shows that the distribution of grain sizes in the nearshore, beach and dune environments are similar, being dominated by well sorted material in the medium and fine sand size classes. This reflects the limited range of source material transported to Ocean Beach. The only indication of cross-shore variation is a slight fining of the dune sands, where fine sand is the dominant class compared to medium sand being dominant on the beach. This is considered to be due to the turbulence in the swash zone limiting fine sand deposition, and fine sand being able to be transported into the dunes easier by wind. The only indication of an alongshore trend was the increased presence of finer material on the beach at the western end of St. Clair, which was considered to be due to reduced wave energy at this end of the beach.

Green Island Bush Road quarry sand placed during emergency works of 2007 had a comparable size distribution to the native beach sands, hence was the most appropriate to use to cover the exposed sand sausages at St. Clair. The harbour sands placed during 2007 were generally finer than the native dune sands, hence had less resistance to wave and wind processes. However, sources of supply were limited, and there was no option of finding an alternative source at short notice. The material has proved to be adequate for placement in the dune environments, but is rapidly transported when exposed to wave run-up processes. Neither of the sand sources used in the 2007 emergency works showed any evidence of heavy metals contaminant.

Of the ten areas sampled within Otago Harbour to determine potential long-term renourishment sources, only two, Cross channel and Tayler's Point, had size distributions approaching those found on the native beach, with the percentage of medium sized sand being in the order 60 -65% and a mean grain size of 0.27 mm. Sand from the remainder of the Harbour dredge sites was finer than even found in the Ocean beach dune system, with percentages of fine sand being in the order 80% to 95% and mean grain sizes in the range 0.17-0.21 mm. All of the harbour samples were found to be very well or well sorted, which is similar to the native beach sediment, and no sites were found to have any heavy metal contamination.

Samples from a second quarry at Blackhead (Billington's) showed a similar grain size distribution as the nearby Green Island Bush Rd quarry, and is very comparable to the native beach sediment, having 62% medium sand and a mean grain sand of 0.26 mm.

Based on the grain size distributions, the most desirable sources of long-term renourishment sand are dredging from Cross-channel and Tayler's Point in the Harbour, or from either of the Blackhead quarries. It is unknown how much sand may be available from any of these sites. The use the finer sand from the other sources in the harbour for renourishment on the beach would require in the order of

two to four times the amount of volume as from the above sources to achieve a beach berm of the same width. There would also be larger and more frequent maintenance requirements if using this finer material on the beach. However, material from these sites would be appropriate for increasing dune bulk, and could be made more sustainable for placement on the beach by filtering to remove some of the fines, or mixing with a coarser stock to obtain comparable distributions to the native beach.

5.0 References

Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Australian and New Zealand guidelines for fresh and marine water quality.

Volume 2, Aquatic Ecosystems.Carter R.M., Carter L., Williams J.J., Landis C.A. 1985: Modern and relict sedimentation on the South Otago Continental Shelf, New Zealand. NZ Oceanographic Institute Memoir 93. 43pps.

Cawthron Institute 2002: Tahuna Wastewater Plant Upgrade: Baseline Ecological Study. Report for DCC. Cawthron Report No. 733. 20pps + appendices

Dean R.G. 2002 Beach renourishment Theory and Practice. Advanced Series on Ocean engineering Vol 18. World Scientific Publishing. 399 pps.

Dyer M. J. 1994: Beach profile change at St. Clair Beach, Dunedin. Unpublished MSc thesis (Geography), University of Canterbury. 229pps

Hodgson W.A. 1966: Coastal processes around the Otago Peninsula. NZ Jl of Geology & Geophysics 9: 76-90

Lewis, D.W. and McConchie, D. 1994. Analytical Sedimentology. Chapman and Hall: New York, 197p.

MWH New Zealand Ltd 2002: Tahuna Wastewater Treatment Plant Upgrade: Assessment of Effects on the Environment including Resource Consent Applications. Prepared for DCC. 132pps + appendices

Ryder Consulting Ltd 2003 Tahuna WWTP proposed offshore outfall: Offshore sediment survey December 2002. Report for DCC. 43pps

Disclaimer

This report has been prepared for the benefit of Dunedin City Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

DTec Consulting Ltd
Environmental & Coastal Consulting

Report written by: Report Reviewed by:

..... ……..
Derek Todd

5 August, 2013
sediment report

APPENDIX A

Source and Volumes of Sand Placements from Otago Harbour in 2007-2008.

2007 Calender Year			
Month	**Day**	**Dredge Claim**	**Qty (m3)**
July	4	Stinky	250
	4	Stinky	325
	5	Stinky	375
	5	Stinky	387
	6	Stinky	451
	6	Maia	387
	9	Stinky	350
	9	Islands	425
	10	Stinky	387
	10	Maia	387
	11	Maia	400
	11	Islands	400
	16	Islands	425
	16	Maia	413
July		**TOTAL**	**5,362**
August	8	Howlett	413
	9	Entrance	350
	10	Howlett	425
	13	Stinky	425
	14	Howlett	400
August		**TOTAL**	**2,013**
October	30	Entrance	360
	31	Entrance	425
November	1	Howlett	388
Oct/Nov		**TOTAL**	**1,173**
December	5	Howlett	450
	6	Entrance	560
	7	Stinky	550
	10	Howlett	482
	12	Howlett	465
	13	Howlett	473
December		**TOTAL**	**2,980**
2007		**TOTAL**	**11,528**

2008 Calender Year			
Month	**Day**	**Dredge Claim**	**Qty (m3)**
May	8	Howlett	519
	9	Entrance (west)	532
	12	Stinky	525
	13	Howlett	520
	14	Howlett	520
	15	Entrance	530
	16	Entrance	533
May		**TOTAL**	**3679**
June	9	Howlett	513
	10	Entrance	525
	11	Howlett	525
	12	Entrance	530
June		**TOTAL**	**2093**
July	10	Stinky	530
	11	Stinky	525
	14	Stinky	515
	15	Entrance	520
	21	Islands	515
	22	Stinky	520
	25	Cross Channel	525
July		**TOTAL**	**3650**
2008		**TOTAL**	**4,688**

APPENDIX B

Nearshore Sediment Size Information

From Cawthron (2002)

Site	Location		Depth(m)	Sediment Grain size (%w/w dry)		
	Latitude	Longitude		Gravel	Sand	Mud
1a	45 55.214	170 31.331	26	<0.10	99.30	0.70
1b	45 55.339	170.31.338	30	<0.10	99.60	0.40
1c	45 55.488	170 31.824	32	<0.10	99.20	0.80
2a	45 54 994	170 32.070	17	0.10	98.40	0.60
2b	45 54.909	170 32.480	18	<0.10	99.90	<0.10
2c	45 55.058	170 32.434	16	0.10	99.40	0.50

From Ryder (2003)

Location[(1)]	Depth (m)	Substrate
2000E	21.0	Compact sand
1000E	20.5	Sands/Shells
500E	21.0	Mobile Sands
250E	20.5	Mobile Sands
50E	22.0	Sand/reef
10E	20.6	Sand/reef
Outfall site	21.0	Compact sand
10W	21.0	Sand/reef
50W	20.8	Sand/reef/shells
250W	19.8	Sand/reef/shells
500W	20.2	Mobile Sands
1000W	16.7	Mobile Sands
2000W	9.4	Mobile Sands

(1) Location is distance east (E) or west (W) from Tahuna wastewater outfall site, along transect 1100m from the shore as per Figure 1.

APPENDIX C

Beach Sediment Size Information from Samples Collected October 2008

	NZMG Co-ordinates		% in size class				Mean Gain Size		Sorting		Skewness		Kurtosis	
Descriptive location	Easting	Northing	V. Fine sand	Fine sand	Medium sand	coarse & V.C sand	(mm)	Class	Value	Class	Value	Class	Value	Class
Beach Rd, west end St Clair seawall	2315014	5474231	0.6	78.6	20.2	0.7	0.21	Fn Sand	0.42	Well sorted	-0.04	Near symmetrical	1.19	Mesokurtic
East end of St. Clair seawall	2315364	5474415	0.2	37.4	56	6.3	0.29	Md Sand	0.55	Mod well sorted	-0.05	Near symmetrical	0.98	Mesokurtic
East of Moana Rua	2316233	5474624	0.1	36.5	62.7	0.7	0.27	Md Sand	0.4	Well sorted	0.04	Near symmetrical	0.96	Mesokurtic
St. Kilda surf club	2316849	5474732	0.1	31.6	67.9	0.3	0.27	Md Sand	0.4	Well sorted	0.09	Near symmetrical	1.02	Mesokurtic
200m west of Tahuna wastewater pier	2317349	5474779	0.1	42.6	57.1	0.2	0.26	Md Sand	0.41	Well sorted	0.07	Near symmetrical	0.96	Mesokurtic
400m east of wastewater pier	2318002	5474848	0.1	29.2	70.4	0.2	0.27	Md Sand	0.38	Well sorted	0.1	Fine Skewed	1.09	Mesokurtic
East end of beach at Lawyers Head	2318369	5474803	0.1	34.7	64.7	0.4	0.27	Md Sand	0.39	Well sorted	0.11	Fine Skewed	1	Mesokurtic

APPENDIX D

Dune Sediment Size Information from Samples Collected 2005, 2007 and 2008

	NZMG Co-ordinates		% in size class				Mean Gain Size		Sorting		Skewness		Kurtosis	
Descriptive location	Easting	Northing	V. Fine sand	Fine sand	Medium sand	coarse & V.C sand	(mm)	Class	Value	Class	Value	Class	Value	Class
2007 dune toe west Kettle park	2315752	547435	0.2	31.9	67.6	0.3	0.28	Md Sand	0.35	Well sorted	0.04	Near symmetrical	0.99	Mesokurtic
2007 dune toe west of Moana Rua	2316077	5474598	3.0	53.9	42.4	0.7	0.24	Fn Sand	0.37	Well sorted	0.01	Near symmetrical	1.17	Leptokurtic
2005 dune top at Moana Rua	2316135	5474610	0.3	50.6	49	0	0.25	Fn Sand	0.39	Well sorted	0.07	Near symmetrical	0.89	Platykurtic
2008 dune top east of Moana Rua	2316213	5474662	2.5	72.3	24.8	0.4	0.2	Fn Sand	0.5	Mod well sorted	-0.14	Coarse Skewed	0.96	Mesokurtic
2008 dune top at St. Kilda surf club	2316854	5474803	0.4	57	42.5	0.1	0.24	Fn Sand	0.39	Well sorted	0.02	Near symmetrical	0.9	Mesokurtic
2008 dune face 200m west of Tahuna outfall	2318002	5474882	0.4	46.9	52.5	0.1	0.25	Md Sand	0.4	Well sorted	0.13	Fine Skewed	0.91	Mesokurtic
2008 dune face 400m east of Tahuna outfall	2317306	5474827	0.6	72.4	26.9	0	0.22	Fn Sand	0.39	Well sorted	-0.04	Near symmetrical	1.13	Leptokurtic
2008 dune face east of Lawyers Head	2318387	5474869	0.1	28.4	71.3	0.1	0.27	Md Sand	0.35	Well sorted	0.14	Fine Skewed	1.11	Mesokurtic

APPENDIX E

Sediment Size Information from Samples of Sand Placed at Ocean Beach 2007 and Potential Other Sources of Renourishment Sand

	% in size class				Mean Gain Size		Sorting		Skewness		Kurtosis	
Descriptive location	V. Fine sand	Fine sand	Medium sand	coarse & V.C sand	(mm)	Class	Value	Class	Value	Class	Value	Class
2007 Placement Samples												
Green Island Bush Rd Quarry	2.9	39.0	57.4	0.7	0.26	Md Sand	0.37	Well sorted	0.16	Fine skewed	1.13	Lepokurtic
Port July Placement (Stinky Pt)	1.1	85.5	10.1	3.3	0.20	Fn Sand	0.30	V Well sorted	-0.05	Near symmetrical	0.95	Mesokurtic
Port August Placement (Howlett)	1.0	61.0	32.2	5.7	0.24	Fn Sand	0.49	Well sorted	-0.20	Coarse skewed	1.37	Lepokurtic
2008 Potential Port Otago Supply Sites Samples												
Entrance East	0.4	96.3	3.3	0.2	0.20	Fn Sand	0.22	V Well sorted	0.06	Near symmetrical	0.89	Platykurtic
Entrance West	5.0	79.8	15.2	0.1	0.19	Fn Sand	0.37	Well sorted	-0.07	Near symmetrical	0.87	Platykurtic
Howlett Point	3.8	83.3	12.9	0	0.19	Fn Sand	0.34	V Well sorted	-0.09	Near symmetrical	0.97	Mesokurtic
Harington Point	0.3	86.0	13.3	0.4	0.21	Fn Sand	0.27	V Well sorted	-0.05	Near symmetrical	1.06	Mesokurtic
Cross Channel	0.2	35.7	59.0	5.2	0.27	Md Sand	0.38	Well sorted	-0.16	Coarse skewed	1.26	Lepokurtic
Tayler's Point	0.2	34.0	65.1	0.8	0.27	Md Sand	0.32	V Well sorted	0.02	Near symmetrical	1.06	Mesokurtic
Deborah Bend	3.3	95.0	1.8	0	0.18	Fn Sand	0.27	V Well sorted	-0.03	Near symmetrical	0.97	Mesokurtic
PC Swing Basin	8.8	84.5	5.8	0.9	0.17	Fn Sand	0.36	Well sorted	-0.07	Near symmetrical	1.4	Lepokurtic
Islands Claim	5.9	79.1	11.9	3.1	0.20	Fn Sand	0.53	Mod Well sorted	0.22	Fine skewed	2.23	V Lepokurtic
Maia Bend	4.8	94.0	1.2	0	0.18	Fn Sand	0.27	V Well sorted	-0.05	Near symmetrical	1.06	Mesokurtic
Other Potential Supply Sites												
Billington Quarry, Blackhead	1.5	34.1	62.4	2.0	0.26	Md Sand	0.75	Mod sorted	0.43	S. fine skewed	2.47	V Lepokurtic

APPENDIX F

Results of trace metal testing by Hills Laboratories

All concentrations in mg/kg dry weight

Metals	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
ANZECC (2000) Low Effects guidelines for sea disposal of waste	**8.2**	**1.5**	**80**	**65**	**21**	**50**	**200**
2007 Dune Samples							
West Kettle Park	<2	<0.1	2	<2	1.1	<2	5
West Moana Rua	<2	<0.1	2	<2	2	2	6
2007 Sand Placement Samples							
Green Island Bush Rd	<2	<0.1	2	<2	0.8	<2	6
Initial Port Otago Placement	<2	<0.1	3	<2	1.5	3	6
2008 Otago Harbour Potential Sand Source Samples							
East Entrance Channel	2.3	<0.010	1.3	0.67	0.62	1.6	5.7
West Entrance channel	2.2	<0.010	2.3	1.1	0.82	2.4	8.7
Howlett Point	2.8	<0.010	2.0	1.0	0.87	2.4	8.5
Harington Point	1.6	<0.010	1.7	0.73	0.65	1.6	6.5
Cross Channel	3.6	<0.010	2.8	0.98	1.1	3.4	7.2
Tayler's Point	4.2	<0.010	3.1	1.1	1.5	2.7	8.2
Deborah Bend	1.4	<0.010	1.8	0.90	0.78	1.9	8.3
PC Swing Basin	2.7	<0.010	2.8	0.99	0.82	2.7	11
Islands Claim	4.6	<0.010	3.7	1.1	1.4	2.8	10
Maia Bend	1.8	<0.010	2.4	0.86	0.96	2.0	10

APPENDIX G

Renourishment volumes calculations from Dean (2002) for Harbour grain sizes

Definitions

A_N: Native Beach mean sediment grain size

A_F: Renourishment Fill mean sediment size

h: Closure Depth, the seaward limit of effective seasonal profile fluctuations;
$h=1.57H_e$, where H_e is the wave heights exceeded 12 hours per year

W: Offshore distance to closure depth; $W=(h/A_n)^{3/2}$

B: Berm height

V: Renourishment volume per unit length of beach (e.g. m^3/m)

Δy_o: change in cross shore distance with renourishment

H_e: Wave heights exceeded 12 hours per year

Calculation of closure depth (h) and distance to closure depth (W)

From now cast wave heights at St. Clair beach since September 2007, H_e is in the order of 2.5 m, hence h has been taken to be 4m.

So, for A_N at Ocean Beach of 0.27mm, W=57 m.

Renourishment profile form

From Dean (2002), for situation where $A_F \leq A_N$, the renourishment profile and native profile will be non-intersecting at the closure depth h. From equation 5.5 (pg 81), for non-intersecting profiles, the non-dimensional volume V_1 is expressed as:

$$V_1/BW=(\Delta y_o/W)+0.6(h/B)(((\Delta y_o/W)+(A_N/A_F)^{1.5})^{5/3}-(A_N/A_F)^{1.5})$$

So, to renourish to obtain a 20 m wide berm (e.g. $\Delta y_o=20$) at the elevation of the dune toe (e.g. B=3) would require the following:

1. 108 m^3/m using $A_F=0.27$ mm for harbour sand from Cross-channel or Tayler's point, or the Blackhead quarries; or
2. 276 m^3/m using $A_F=0.20$ mm for harbour sand from the other dredging sites.

Hence, ratio of sand required is 2.6.

And to renourish to obtain a 10 m wide berm (e.g. $\Delta y_o=10$) at the elevation of the dune toe (e.g. B=3) would require the following:

1. 54 m^3/m using $A_F=0.27$ mm for harbour sand from Cross-channel or Tayler's point, or the Blackhead quarries; or
2. 184 m^3/m using $A_F=0.20$ mm for harbour sand from the other dredging sites.

Hence, ratio of sand required is 3.4.