Before the Independent Hearing Panel
Appointed by the Southland Regional Council

Under	the Resource Management Act 1991 (**RMA**)
In the matter of	an application by **South Port NZ Limited** to dredge parts of the Bluff Harbour

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Statement of evidence of Gary Teear

29 March 2022

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Qualifications and experience

1 My full name is Gary Charles Teear. I am the managing director of OCEL, OCEL being an acronym for Offshore & Coastal Engineering Limited, an engineering consultancy firm specialising in the marine field.

2 OCEL works throughout New Zealand and has also worked on projects in Australia and Papua New Guinea, principally on submarine pipelines and ocean outfalls. Clients include port companies, national civil and marine contractors, international marine contractors and aquaculture companies and Councils.

3 I hold the qualifications of Bachelor of Engineering (1st Class Honours) and Master of Commerce (Hons.) from the University of Canterbury. I also completed Professor Kirk's Masters level Coastal Processes paper offered by the Geography Department at Canterbury University.

4 I am a Chartered Professional Engineer (CPEng., PE (Int)) with 50 years experience in marine related work., a member of Engineering New Zealand and a member of the International Society of Explosive Engineers (ISEE).

5 I have extensive experience in the engineering and design of coastal and offshore structures including offshore platforms, wharf and jetty structures, fixed and floating, submarine pipelines and ocean outfalls and marine anchor design, screw and High Holding Power.

6 I am a qualified diver, to mixed gas and saturation level, and have previously carried out much of the physical subsea soil investigation work required for marine farms , salmon and mussel, and submarine pipelines throughout NZ, myself using water jet probes and in situ soil strength testing gear.

7 I am experienced and qualified in the use of explosives and qualified as an RNZE demolition instructor during army service. I have a professional interest in the use of explosives, hold current civilian blasting certificates. and have done specialist blasting jobs both within NZ and internationally throughout my career, the latest being the scuttling of the fire damaged Korean deep sea trawler Dong Won 701 offshore Dunedin in 2021

8 I have experience in geotechnical analysis and investigation work, above and below water and have designed both diver and diverless operated subsea drilling equipment for geotechnical investigation work prior to the deployment of jackup drill rigs.

9 OCEL has a strong practical ethos. Four of the engineers have commercial diver training and the company has its own survey boats and oceanographic equipment - turbidity meter, wave buoy and current meter - to collect environmental data for the investigation of coastal processes as part of coastal development and dredging studies.

10 I started work as an engineer for the Lyttelton Harbour Board in 1971 and worked for an OCEL predecessor practice before leaving NZ to work internationally in 1977. I worked overseas as an Engineering Manager, Project Manager, Barge Superintendent and Project Engineer/Diver for an international offshore contractor, COMEX, now Subsea 7, in South East Asia, the Middle East, North Sea, Gulf of Mexico and Australia. I have been back in New Zealand and at OCEL (and its predecessor company) since 1989, but continued as a consultant for COMEX/Acergy until 2011, working on projects in Indonesia, Argentina, Norway/UK, France and Canada.

11 For five and a half years of my time overseas I was the engineering manager for COMEX Norway at a time when offshore technology was rapidly evolving and engineers and operators were learning by trial and error. COMEX demonstrated the ability to dive and perform hyperbaric welds at 300 m depth and subsequently pioneered diverless techniques.

12 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of evidence

13 I have been asked to prepare evidence in relation to the following topics

(a) Harbour Entrance Blasting – Effects of Underwater Explosions

(b) Drilling, Blasting & Dredging Methodology

(c) Coastal Processes Assessment

Executive summaries

Harbour Entrance Blasting & Effects of Underwater Explosions

14 South Port NZ Ltd.’s (Southport) proposed Capital dredging operation is to increase the depth of Bluff Harbour by 0.75-1 m. The deepening exercise would not be a uniform depth increase for the whole channel width and length more a trimming operation both to create a uniform straight edge to

the channel and give a constant navigable width and to remove isolated seamount rock type features from the channel. The depth of the swinging basin will also be increased to match the depth of the entrance channel.

15 The bulk of the material to be removed in the channel is high quality norite rock, the plutonic/intrusive equivalent of volcanic basalt, dense and strong, that has to be blasted to fragment it so that the material can be easily dredged by an excavator. The nature of the rock suits the use of explosives – it can't easily be dredged any other way - because it is easily shattered by an intense shock.

16 Both to increase the efficiency of the blast, minimising the weight of explosive used per cubic metre, and to minimise environmental impact the drill and blast technique will be used. Placing the explosive charges directly in drilled holes in the rock to be removed ensures that the bulk of the blast energy is absorbed in the rock and not radiated out as it would be in an unconfined or open water blast.

17 Detonation delays will be used between individual charges both to increase the efficiency of the blasts and to reduce the environmental impact of the blasting.

18 The detonation of explosions in air and water creates noise, vibration and blast wave effects. The OCEL report that I authored documents the effects and environmental impact of underwater explosions and how these will be predicted, controlled, monitored and mitigated.

19 The potential effects of the underwater blasts on the workboats undertaking the drilling are also identified along with the required pull back distance prior to any blast.

20 Two characteristics of the underwater shock wave from an explosion are commonly used as a measure of its severity, the peak pressure P_{max}, decibels/kPa, and the impulse I. The peak pressure and impulse developed by a known charge of weight W, freely suspended in water, at a range R can be calculated using empirical, well proven equations. W is the charge weight per delay, taken for the Bluff Harbour Entrance blasting work as a maximum of 25 kg.

21 Placing the charges in drilled boreholes reduces the peak pressure of the underwater shockwave to 10-14% of its value for a freely suspended charge in water. The minimum distances to the permanent injury thresholds are set by the peak pressure/noise parameter not the Impulse parameter.

22 The effect of air pressure waves from the blasting and other airborne noise is covered by the Styles report. The exclusion zone radii for marine mammals for the underwater blasts were also set/modelled by the Styles Group.

23 For the proposed underwater blasting in the Bluff harbour entrance the depth of water – ≥ 9m – plus the use of detonating delays and placing the charges in drilled holes make excessive airblast very unlikely. Only a muffled thump is expected following detonation. Sound level meters will be used to monitor airblast to confirm that the noise levels are within NZS 6803.

24 While the blast wave effects differ markedly between explosions in air and explosions in water vibration effects are the same irrespective of the medium. Detonating an explosive charge in a drilled hole produces vibration waves.

25 A simple empirical power law formula is used to relate the weight of the explosive charge set off per delay and the distance or range from the detonation point to the location of interest to calculate the Peak Particle Velocity (PPV) and thus assess the potential for structure damage.

26 Of the four parameters used to measure the magnitude of the seismic or vibration waves – displacement, velocity, acceleration and frequency - the peak particle velocity (PPV) correlates best with structural damage and PPV limits on vibrations are used to limit damage to structures.

27 The German Standard DIN 4150-3 1999 is widely used in NZ as a guideline to preventing structural damage from vibrations. The Standard recognizes that commercial buildings can withstand higher vibration levels than residential and historic buildings. Figure no.1 in Appendix B to my evidence is an excerpt from DIN 4150-3 and shows PPV limits for various building types.

28 The general form of the equation to predict the PPV, V is: $V = K \cdot W^{m} \cdot R^{-n}$, Where K is the ground transmission constant, W is the charge weight per delay and m & n are empirical constants based primarily on the geology. Typical values based on a large number of field measurements on a range of sites are $K = 410$, $n = -1.6$, $m = n/2$ giving

$$V = 410 \cdot (R/\sqrt{W})^{-1.6}$$

29 The predicted vibration/Peak Particle velocity using this equation is, PPV = 0.53 mm/sec for a maximum charge weight of 30 kg/delay for the houses

nearest (350 m) to the closest blast location. This PPV value is well within DIN 4150 guidelines – 5-15 mm/sec for f = 10-50Hz, line 2 for dwellings. All blasts will be monitored by seismographs placed adjacent to the nearest structure to the blast – minimum 350 m for houses. The PPV for a 25 kg maximum charge at 350 m radius is .046 mm/sec.

30 The empirical constants K, m and n will be determined from the initial trial blast of the blasting program using one charge by itself initially and simultaneously measuring the resulting PPVs on land at differing distances from the charge and plotting the results, PPV versus $R/\sqrt{W}$ on log-log paper. A straight regression line will be fitted to the data by means of a least squares analysis

31 The PPV equation presented above will be used as a first approach and checked against the actual PPVs recorded by the seismograph during the site test program. The initial test blast will enable fine tuning of the vibration equation for subsequent blasts.

32 I have read the proposed new condition defined in the S42A report for the blasting trial and find that is consistent with what was proposed by OCEL. The condition is acceptable. The site specific vibration parameters will be determined by the trial. The PPV prior to the trial blast will be predicted using the equation in #28 and checked that it is well within the limits of DIN 4150. The findings of the blast trial will be documented and reported to the Compliance Manager Environment Southland

33 Placing the charges in drilled holes and using delays is the best way of mitigating the effects of underwater blasts but it is also the most efficient/cost effective way of fragmenting the rock so considerations of minimising the effects and maximising efficiency converge.

34 An air bubble curtain can be used to reduce the peak pressure of the underwater shock wave but increases the duration to the extent that the impulse is unchanged. An air bubble curtain is best used around an isolated feature rather than for a large blasting pattern It would be unlikely to be used for the Bluff Harbour work the pressure reduction in relation to the cost incurred would not be worth it.

35 Monitoring of the underwater shock wave using a hydrophone, monitoring of the ground vibrations using seismographs and monitoring of the airblasts using a sound level meter will be undertaken to confirm that the effects are within acceptable limits avoiding either damage to structures or injuries to marine life. The recordings will also confirm the results of the calculations of the effects – PPV. P_{max} and I.

Drilling Blasting & Dredging Methodology

36 The dredging will likely be undertaken using a specialist backhoe dredging barge fitted with spud piles. This dredge would also be used for the rock drilling operation required - to drill holes to take the explosive charges used to fragment the rock - employing a hydraulic rock drill mounted on the excavator dipper arm.

37 The holes will be positioned in accordance with a predetermined drilling plan nominating each hole position in terms of DGPS coordinates. The depth of material to be removed to increase the available draft is generally low and the drilled holes required are correspondingly shallow at just over 1 m. The spacing between holes is then close to 1 m with the result that a large number of holes would need to be drilled. It is more efficient and economical to drill the holes deeper to a minimum depth of 2.5 m, irrespective of cut height, with a spacing between the holes increased to 2.2 m maximum.

38 Millisecond delay detonators or relays would be used to minimise vibration and underwater shock wave pressures the intensity of which is directly related to the amount of explosive detonated at any instant, not the total charge weight detonated in one blast.

39 An hydraulic rock breaker attached to the dipper arm of a backhoe excavator has also been considered, as an alternative method to the proposed drill and blast methodology however while that is quieter in terms of generalised noise subsea than the blasting operation it would go on for much longer.

40 The operator would be remote from the rock break location and would not be able to directly observe the rock breaker in action and exploit rock weaknesses or fractures. The hydraulic rock breaker would most likely be employed in a supplementary role to scale the rock face after the blast to remove loose rocks.

41 The drilling operation will be diverless and independent of the tidal currents. Placing the charges and connecting them up to a firing circuit will require some diver intervention using Surface Supplied Breathing Apparatus (SSBA) at slack water. The involvement of divers will be minimised where possible by automating the placement of the charges.

42 The drilled holes will likely be loaded with liquid bulk emulsion explosive using a hose from a tank on the surface support and an electronic detonator with its own primer or booster charge will be placed in the borehole. Each

detonator will be connected via its own wire to a blast computer on the surface support vessel that is in communication with all the electronic detonators and is used to set the individual delays and the blast pattern and fire the charges. Up to 30 holes will be fired per blast. The maximum charge weight used on any delay will be 25 kg.

43 This will not be the first time that explosives have been used to fragment the rock high points in the channel. There is a long history, in excess of 100 years, of blasting and dredging work in the Harbour entrance. Progress has generally been slow and incremental, slowed both by limitations imposed by the strong tidal currents in the entrance and the limitations of the marine support and drilling equipment in difficult conditions.

44 A variety of blasting techniques have been employed ranging from simple plaster charges through to shaped charges and drilling and blasting work carried out firing all the holes and charges simultaneously. Incorporating delays between charges increases the efficiency of the blasts and reduces the environmental impact. Some of the earlier blasting, in particular the plaster charging, was inefficient in terms of rock fragmentation and depth increase, and environmentally damaging but it was spectacular to see and is etched on the memories of the residents of Bluff.

45 Pro Dredging and Marine Consultants Pty. Ltd. (Pro-Dredging) were engaged by SouthPort to undertake an analysis of a historic Drill and Blast campaign in the entrance channel that was undertaken during 1979 and 1980 by the Southland Harbour Board. The results of the Pro-Dredging analysis indicate that a significant portion of the Channel area to be dredged as part of the capital dredging program may have already been fractured by the 1979-1980n campaign and may be able to be dredged by a backhoe dredging campaign without further drilling and blasting in the area concerned.

46 This would have to be proven by a dredging trial before any reduction in the scope of the proposed new drilling and blasting program was considered. Blasting and drilling will still be required for the capital dredging program.

47 The sophistication and capabilities of both blasting techniques and the marine support employed for the work - incorporating advanced dredging, drilling and positioning technologies - has advanced significantly since last century to the extent that the proposed drill, blast and dredging operation can be expected to be effective, efficient and unobtrusive, no drama.

Coastal Processes Assessment – Disposal of Dredged Material

48 The bulk of the material to be removed by the dredging operation in the swinging basin area is silt and sand, predominantly sand, with isolated rock high points. A TSHD (Trailing Suction Hopper Dredge) will dredge sand and silt in the turning area to achieve the desired draft increase. The TSHD will dispose of the sand and silt, dredged up during the capital dredging work, on the existing disposal location used for the maintenance dredging spoil.

49 This location has proved to be an excellent disposal location without significant adverse environmental effects over a 70 year period. The existing coastal processes will deal with the higher volumes to be dumped, the mobilisation of the sand by waves will increase because of temporary shallowing and the rate of sand movement away from the disposal site will increase because of the greater volumes of sand mobilised and available to be moved. The increased volumes will have a beneficial effect on the beach backing the disposal location, effectively the sand dump functions as beach nourishment.

50 The dredging in the entrance channel will be undertaken using a specialist backhoe dredging barge fitted with spud piles. The same dredge will also be used for the rock drilling operation required - to drill holes to take the explosive charges used to fragment the rock - employing a hydraulic rock drill mounted on the excavator dipper arm. The holes will be positioned in accordance with a predetermined drilling plan nominating each hole position in terms of DGPS coordinates.

51 Drilling and blasting will alternate with dredging using the barge’s long reach excavator and the dredged rock fragments will be placed into non-propelled split hopper barges and towed to a new dump location in 13-15 m water depth east of the existing disposal location. The rock fragments will stabilise to form a permanent low profile rock reef feature on the seabed. This will have no effect on the existing coastal processes.

52 I prepared the OCEL report assessing the effects of the Capital dredging operation on the existing coastal processes. The report considers the existing tidal currents and the wave energy environment - tidal currents and waves being the principal drivers of coastal processes - and concludes that the proposed deepening operation will have no noticeable effect on the existing coastal processes.

53 There will be minor, barely detectable, reductions to current speeds based on small increases in the channel cross section area and minor reductions in the wave energy passing up the entrance channel into the harbour as a

result of refraction but these changes will not be noticeable let alone have any effect on existing coastal processes.

54 The latest (November 2021) revision of the report, Rev.4, addresses and incorporates responses to, the comments produced by Derek Todd, Principal Coastal and Hazards Scientist, Jacobs NZ, following his review of Rev.2 of this report and the AEE section of the Southport Dredging Disposal Consent Application.

Tidal Currents

55 Bluff is a large natural harbour inlet of about 5.5 Ha, with Bluff Harbour on the west side and includes Awarua Bay 10 km long and 3 km wide on the eastern side. Awarua Bay is shallow typically less than 5 m depth, with a tidal range from 1.5 m (neap tide) to 2.21 m (spring tide). It is part of the Awarua – Waituna Wetlands and is one of the largest remaining wetland complexes in New Zealand and is important for its biological diversity and cultural values.

56 Ocean Numerical (Oceanum) and Calypso Science were commissioned by South Port in 2020 to develop a a 3D hydrodynamic model of Bluff Harbour and data from an earlier University of Otago model was used to validate the model results.

57 The tidal currents are strongest in the constricted entrance throat and in the channel sweeping past the Tiwai wharf. The natural channel curves around to line up with the narrow entrance to Awarua Bay. The distance, the flow path length, from the harbour entrance to the entrance to Awarua Bay is of the order of 12 km.

58 The strong tidal flow through the constricted harbour entrance throat generates a tidal vortex reverse flow in the swinging basin as the harbour widens out because of the concentration of the flow along past the Tiwai wharf. The current speeds drop off with distance from the entrance. The tidal excursion distance, the distance a particle carried through the entrance on an incoming tide would travel before the tide turns and the particle is swept back out is probably less than the 12 km distance to the entrance to Awarua Bay. For incoming seawater to reach Awarua Bay to effect a tidal exchange would take several tidal cycles.

59 Slack water in the entrance channel is typically less than 1 hour. The outgoing tidal currents are, as shown by the Oceanum Calypso Science study, primarily concentrated in the harbour approach channel seaward of the entrance – the South channel - sweeping around the Bluff Hill shoreline.

The incoming tide does not show the same concentration of flow in the South Channel and has significant contributions from the North channel.

60 Figure nos.1 and 2, taken from OCEANUM and Calypso Science modelling and included in the Appendix to this evidence show the tidal current patterns for spring tides – maximum current speeds – in and either side of the harbour entrance, at mid tide, for both the ebb and the flood tides. The figures also show the existing disposal site for sediment dredged during maintenance dredging.

61 The maximum current speeds are 0.6 m/sec at 6 m depth and 0.2 m/sec at 15 m depth. These currents will move sediment mobilised either by wave action or by the speed of the currents themselves although the figures given above are for the maximum tidal velocities in a tidal cycle, the average velocities are much less. Wave action is the principal determinant of sediment mobility.

62 The ebb tide currents are stronger than the flood tide currents in the area of the dredged material disposal site as is evident by the mean tidal currents for the area in figure no.3. The mean tidal current is the net tidal current over the tidal cycle. The net direction a water particle would move in the region of the disposal site is in the direction of the ebb tide current - to the southwest.

63 The movement to the southwest of the ebb current flow, and any sediment entrained in the flow, is coincident with the ebb tide flow out of the harbour in the form of a tidal jet down the South channel. The sediment in the ebb tide flow across the disposal ground cannot enter the harbour but is swept away to the south west, as illustrated in figure no. 3.

64 Figure no.4 shows the wider picture of the mean tidal current in a tidal cycle covering the entrance to Bluff Harbour, demonstrating the asymmetry of the tidal flows. The tidal flow is stronger and more focused near Tiwai Point during the flood stage while the ebb tidal flow is dominated by the jet extending from the entrance down the South Channel. Within the harbour the tidal circulation is anticlockwise.

65 Figure no.4 illustrates tidal imbalances in the harbour entrance area and in the harbour itself. An understanding of the tidal circulation is important in avoiding recirculation of dredged material dumped in the disposal ground outside the harbour returning back into the harbour. This understanding dictates why fine sediment, predominantly sand and some silt, is only deposited at the disposal ground on the ebb tide.

66 Any sediment entrained in the flow will be swept to the southwest by the ebb flow out of Toetoes Bay then advected into the ebb flow jet coming out of the harbour down the South Channel and carried on out into Foveaux Strait.

Waves

67 There are two sources of wave data for the Bluff Harbour Entrance and Toetoes Bay areas. Wave data is available from a wave hindcast study undertaken by Ocean Currents Ltd. (OCL) for OCEL in 2005 and from a recent, 2021 study, undertaken by Oceanum, Ocean Numerical.

68 The Oceanum study produced specifically for Southport confirms and expands the findings of the OCL study with a much higher level of detail.

69 The wind, wave and current regime used for the Southland region was hindcast in a previous study by Oceanum for the Ministry of Primary Industries (MPI) in 2021. A 10 year period (2010-2019) was recreated at high resolution on an hour by hour basis considering the topographic and bathymetric influences on the local marine conditions.

70 Near the disposal ground the tidal and non -tidal currents were resolved to around 80 m, discretised on a triangular mesh. These data are of suitable scale and quality to characterise the hydrodynamic regime of the ground.

71 Waves however were resolved at 1 km scales which is too coarse to fully capture the complexity of the region and further downscaling was required. The SWAN (**S**imulating **WA**ves **N**earshore) spectral wave model was used to downscale waves from 1 km to 100 m resolution. The model includes formulations for wave growth, refraction, shoaling, nonlinear wave interactions and dissipation by white capping, bottom friction and depth-induced wave breaking.

72 The high resolution 10 year hindcast has been used by Oceanum to characterise the wave climate along the ocean beach adjacent to the Tiwai Smelter. Figure no.5 shows the maximum significant wave height from the 10 year hindcast.

73 The centre of the disposal ground is shown by the white dot. The sheltering influence of Dog Island is clear from the plot. These results are broadly in line with the earlier OCL report although the Oceanum report identified the prevalence of longer wave periods than the OCL report.

74 The centre of the disposal ground is shown by the white dot. The sheltering influence of Dog Island is clear from the plot. These results are broadly in line with the earlier OCL report although the Oceanum report identified the prevalence of longer wave periods then the OCL report. An analysis of the waves and currents at the centre of the disposal ground for the dredged material is presented in the Oceanum report.

75 The wave rose for the centre of the disposal ground is shown in figure no.6. The waves, swell, are almost exclusively from the south with a minor contribution from the southeast. The peak wave periods were also surprising, 33.9% are in the range 12-14 seconds and 29.4% are in the range 14-16 seconds. Long period low height waves from fetches far to the south.

76 The wave directions shown at the centre of the disposal ground incorporate wave refraction and diffraction effects because the SWAN program allows for these supplanting the need for refraction diagrams.

77 Sediment disturbed by wave action from the south, either as bedload or in suspension, can be moved by ebb tidal currents west into the tidal maw of the harbour entrance. Depending on the state of the tide sediment will either be sucked into and swept through the harbour entrance by flood tide currents or swept seawards down the south channel and out into Foveaux Strait.

78 When the ebb tide is running strongly the sediment carried by the tidal current will be swept west and advected with the strong ebb flow out of the harbour. This will occur for a much greater percentage of the time because of the imbalance in the tide off Tiwai Pont, the mean or net movement is strongly to the west.

79 Waves from the south approach at an angle to the coast to the east of Tiwai Point in Toetoes Bay and the resulting littoral drift will drive sediment west toward Tiwai Point. Toetoes Bay is in the shelter of Bluff Hill and waves from the west do not have much effect on the bay but east of the bay will develop a littoral drift to the east.

Sedimentation

80 A much earlier report in 1984 on sedimentation for the Southland Harbour Board by the OCEL predecessor practice R. W. Morris and Associates (RWMA) identified a large ebb tide delta seaward of the harbour entrance. The surface of the delta lies in depths of less than 6 metres and the seaward face slopes steeply down to depths in excess of 16 metres.

81 Prominent tidal current channels occur along both coastal margins of the delta – the South channel along the western flank of the delta adjacent to Bluff, and the North channel, a broader channel leading from the harbour entrance eastward along the shore of the Tiwai Peninsula.

82 The principal features of the morphology are a constricted entrance throat and to seaward a large ebb-tide delta with a steep outer face on which strong currents and breaking waves interact. The circulations of water and sediment in the constricted entrance throat of the harbour and the harbour itself are primarily driven by the tides rather than by river flow or by meteorological disturbances. It is a known feature of tidal hydraulics that tide-dominated estuaries having unconsolidated boundaries tend to have a stable relationship between the entrance cross sectional area in the narrowest part of the throat and the tidal prism or compartment.

83 From an examination of the geometries of sixteen New Zealand inlets Heath 1975 proposed the following relationship between the tidal prism, V_p, and the cross sectional area, $A – V_{p.} = A^{0.98} \times 10^{4.21}$. V_p for a spring tide for Bluff Harbour was calculated at 97.0×10^6 m^3 which is a large volume to flow through the entrance in one tidal cycle and implies strong currents and significant potential for sediment transport.

84 If the cross section area is less than that required to give stability the inlet entrance becomes unstable and the entrance section will scour. If the entrance section area is larger than required to satisfy the relationship the inlet will infill to reduce the cross section area. At the time of the original study, 1984, the harbour entrance plotted near the ‘erosional’ side of the relationship established by Heath. This indicates that the entrance is self scouring and high sediment transport rates could occur through it, both into and out of the harbour basin.

85 The seabed inside the harbour entrance in the swinging basin area and the port area itself is predominantly sand (reference E3 Scientific), 25% silt content including berths, 4% in the turning basin area alone and a maximum of 50% silt in berths 5 & 6 in the harbour basin, a sheltered area not swept by strong tidal currents.

86 Sand and silt sediment, primarily fine sand, dredged up in periodic maintenance dredging campaigns in the swinging basin area and in the harbour berth areas is deposited in an existing dredged material disposal site in shallow water adjacent to Tiwai Peninsula. The dumped material does not remain at the dump location but is widely dispersed onto the Toetoes Bay beach and on the tidal ebb delta, indicating long term stability

of the bathymetry and active coastal processes maintaining a dynamic equilibrium.

Existing Disposal Ground for the Dredged Material

87 South Port has undertaken maintenance dredging in the entrance channel and the berthing areas since 1883 and has utilised a site for the disposal of the spoil within a defined part of the coastal marine environment adjacent to Tiwai Peninsula for over 70 years. That area has been used as a disposal site for dredged material for that length of time without creating any adverse environmental effects.

88 The sediment to be dropped on the existing disposal ground contains a relatively small percentage (≈25%) of silt material which can create a turbidity plume when dropped through the water column. Condition 13A proposed in the s42A Report covers the monitoring of turbidity at the edge of both disposal sites. This is unlikely to be necessary for the new rock disposal site because the channel is a high current area and silt is not found there but monitoring is an acceptable condition for the existing disposal site. Turbidity is not expected to be significant at the existing disposal site because material is dropped there only on an ebb tide. Any turbidity plumes will be moved westward by the prevailing ebb tidal currents in Toetoes Bay and advected into, and rapidly dispersed in, the strong ebb flow out of the harbour down the south channel out into Foveaux Strait. Precautionary monitoring will be needed to confirm the rapid dispersal of turbidity plumes.

89 New conditions proposed following Condition 12 in the s42A Report cover bathymetric surveying of the existing disposal site – a baseline bathymetric survey, a bathymetric survey immediately post disposal and surveys every 6 months until such time as the surveys show that seabed in the disposal area has returned to the base elevation. The bathymetry is expected to revert back to close to the equilibrium baseline depths relatively quickly given the persistence of long period swell reaching the location and mobilising the seabed sediment. The condition is acceptable.

Mobilisation by Tidal Currents

90 Incipient sediment motion for sand subject to current action, approximated as steady flow, occurs when the flow velocity exceeds a threshold current speed. For steady flow (tidal current) conditions this critical velocity U_{cr} is calculated using the equation (Soulsby - Dynamics of Marine Sands 1977) in my Coastal Processes Report. For fine sand, taking D_{50} at 0.15 mm, the critical velocity U_{cr} = 0.41 m/sec.

91 U_{cr} = 0.41 m/sec. is a relatively high speed for the existing disposal area and little mobilisation of the sand will be achieved by the tidal current speed alone.

Mobilisation by Wave Action

92 The threshold of motion for sand exposed to wave action depends on the bottom orbital velocity amplitude, the wave period and the grain diameter and density. The threshold orbital velocity U_{wcr} can be determined from the equations of Komar and Miller:

93 For T = 10 secs. and fine sand, D_{50} = 0.15 mm, U_{wcr} = 0.17 m/sec.

94 Wave action is more effective at mobilising sediment because the wave induced water particle velocity required to mobilise the sediment is less than the current speed required to mobilise the equivalent grain diameter.

95 Using OCEL's 7th Order Stream Function Wave theory software the wave water particle velocity induced at seabed level, 7 m depth, by a 10 sec. period H_s = 0.35 m significant wave height is 0.192 m/sec. This wave particle velocity is in excess of the threshold orbital velocity for sand of 0.17 m/sec. The significant wave height of H_s = 0.35 m is then the lower wave height limit for a 10 second period wave to mobilise/disturb sand.

96 From figure no.9 in the OCEL Coastal Processes Assessment report significant wave heights off the Tiwai Peninsula for wave periods > 7.5 secs. are in excess of H_s = 0.35 m for 90% of the time. From Table 2 in the OCEL report it is apparent that peak wave periods $T_p \leq 10$ secs occur only 10% of the time, while peak periods in the range of 12-16 seconds occur 63% of the time.

97 When the wave induced water particle velocity exceeds the incipient motion threshold velocity, U_{cr}, the sand sediment on the existing dump site is mobilised by wave action. It does not require a large wave height for this to occur, from the calculation H_s = 0.35 m is the lower limit for this to occur for T_p = 10 sec. period waves. For a 16 sec period wave Hs ≈ 0.3 m is the lower limit to mobilise sand particles. Once mobilised the sand can move with the tidal current and the littoral current although the latter is only really significant within the surf zone and rapidly drops off seaward of the surf zone.

98 The maximum wave orbital velocity figures given in the Stream Function output are the maximum horizontal velocities under the crest of the wave. For long period (16 sec. plus), low height swell waves in shallow water –

relative to the depth of the water, 7 m in this case for a wavelength of 130 m – the maximum orbital velocity under the trough - -0.157 m/sec. - is less than the maximum velocity under the crest – 0.180 m/sec. - and is directed offshore. The net movement of the sand caused by swell action is then towards the beach in wave heights ≈ 0.3 m.

99 D. Todd in his comment on sand mobilisation in this section noted that he doubts that the combination of a 0.35 m significant wave height with 10 second period occurs in nature. It does, typically where ocean swell penetrates through the processes of refraction and diffraction into sheltered areas and is much attenuated in the process so is difficult to pick up visually because of the long wave length and low height. In this case the height was derived as the lower limit for seabed disturbance in 7 m water depth.

100 The sand mobilisation wave height limit at 0.35 m for 10 sec period waves is low which means the seabed sand is readily mobilised a high percentage of the time. What is surprising at the disposal ground location is that the wave periods are unusually high and long period swell waves – T_p ≥12 secs. – are the primary source of energy with the oscillatory motion of the near bed wave orbital velocities typically exceeding the critical shear stress threshold for sediment entrainment on a daily basis.

Sand Movement away from the Disposal Location

101 The seabed levels at the disposal location have remained stable and have not changed significantly over time – as is evident from the results of the most recent bathymetric survey undertaken for Southport by Fugro in 2020.

102 Sediment dropped on the location has evidently been completely dispersed in the period between hydrographic surveys and the seabed has returned to a state of equilibrium. Considering the maximum volume allowed per annum by the existing consent as uniformly distributed over the full consent area gives an average depth of sediment equivalent to 0.3 m.

103 The nature of the sediment – predominantly fine sand - dropped on the location is the same as the natural seabed material. The disposal location is relatively shallow and the sediment can be easily mobilised by wave action. Once mobilised the sand can either move onshore under low height swell wave action to build up the beach and the sand dunes backing the beach or be moved West/South West around the end of the Tiwai Peninsula to build the ebb tide delta out seawards.

104 The coastal processes operating at the existing dredge spoil disposal area, in particular the long period background swell reaching the location, are

very efficient at dispersing the sediment dropped on the location. Dropping fine sand on the disposal location which is in shallow water close inshore qualifies as a form of beach nourishment.

105 A significant proportion of the sand will either end up on the beach or in the sand dunes backing the beach. The sand dunes act as a storm erosion buffer protecting the hinterland, losing sand offshore from the beach in high energy storm wave conditions then regaining it in calmer low height swell wave conditions which put the sand back on the beach.

Capital Dredging Disposal

106 The material dredged during the Capital dredging operation will be disposed of at two separate disposal sites. The choice of disposal site will be dependent on the nature of the material to be disposed of. Sand and silt will be disposed of at the existing disposal location used for the maintenance dredging operation. Rock fragments recovered from the entrance channel will be disposed of at a new designated site further east in Toetoes Bay, in 13-15 m water depth.

107 The sediment is the same as disposed for the maintenance dredging operation – silt and sand, predominantly fine sand - and indistinguishable from the natural seabed material. The total volume of material disposed – 120,000 m^3 - will be much higher than for the maintenance dredging operation but the rate of deposition, in terms of cubic metres/week, will be close to the same as for the maintenance dredging operation because it is likely that the same size TSHD, if not the same vessel, as used for the maintenance dredging will be used for the Capital dredging.

108 Typically, much larger dredges are used for capital dredging. Capital dredges utilise the same principle of operation as smaller maintenance dredges but are much larger vessels with much higher hopper capacities and dredging productivity. Such vessels are not available in New Zealand and have to be mobilised from overseas. The total volume to be dredged, 120,000 m^3, is not that high in terms of capital dredging volumes and could be handled by the maintenance dredge that serves most NZ ports.

109 Because the sediment, predominantly sand, is discharged off the Toetoes Bay shoreline in relatively shallow water within the reach of the wave energy environment it can be considered as beach nourishment. Sand will be mobilised by waves and moved by the existing coastal processes onshore and alongshore. The sand moved onshore by swell action will buildup the beach and the sand dunes backing the beach. This will counter beach

retreat consequent on Sea Level Rise (SLR) and increase resilience against storm events.

110 The dredged sediment disposed on the seabed will be dispersed by the existing coastal processes, mobilised by waves moved by a combination of waves and currents – onshore/offshore by wave action, and moved alongshore by currents out beyond the beach surf zone and by wave induced littoral drift inside the surf zone. The deposition of sediment will have minimal effect on the tidal currents but shallowing resulting from the dumping will increase the wave induced mobilisation rate of the sand. The capital dredging volume of 120,000 m^3 is equivalent to a uniform depth of 0.9 m across the consented disposal area.

111 A significant wave height of 0.35 m and 10 sec. period swell induces a maximum wave particle horizontal velocity of 0.192 m/sec at the seabed under the wave crest in 7 m depth of water. This is in excess of the threshold orbital velocity, 0.17 m/sec. for wave induced sediment motion. The H_s = 0.35 m is the lower wave height limit for a 10 second period wave to be able to mobilise seabed sand.

112 From figure no.9 in the OCEL report swell wave heights for wave periods > 7.5 secs. are greater than this 90% of the time. The same wave, H_s = 0.35 m, induces a maximum water particle velocity of 0.215 m/sec in 6 m water depth. The increased water particle velocity means both that the same size wave can increase the rate of sand mobilisation in shallower water and even smaller wave heights can mobilise the seabed sediment. The sand dispersion rate increases as the depth reduces, a form of automatic compensation or ramp up of the coastal processes to deal with increased volumes.

113 The shape of the disposal area is a long narrow parallelogram parallel to the beach. This is an effective/efficient shape for sand nourishment of the beach but not an efficient shape for the formation of a surf reef. If the sediment is uniformly disposed of over the disposal ground area it is unlikely to cause sufficient wave refraction to concentrate wave attack on particular beach areas resulting in local erosion for example.

114 Surf reefs function analogously to lenses refracting light to focus it on set distances. The sediment needs to form convex lens shapes on the seabed to focus waves at a point. Loose sand dropped through water to the seabed does not form other than very gentle slopes and any differences that do occur in sand levels are erased/levelled out by wave action. Seabed shallowing does have an effect on the incident waves, it causes shoaling of

the waves, the wave heights increase to the point that they become unstable and break. The breaking increases turbulence and sand mobilisation.

115 Rock fragments recovered from the entrance channel will be disposed of at a designated site further east in Toetoes Bay, in 13-15 m water depth. The rock fragments will form a natural rock reef feature on the seabed. The rock fragments will sort themselves under wave action into a stable matrix, the larger fragments sheltering smaller elements and being mutually supported by them, forming a permanent, low height rock reef structure.

116 The hydraulic stability of the rock fragments dumped on the seabed at the rock disposal site has been checked for a significant wave height of H_s = 3m and wave period T_p = 12 secs. based on the incipient motion or Shield's critical shear concept.

117 The calculation shows that particles characterised by D_{50} = 0.14 m and above are stable once wave action has flattened out peaks or bed form roughness. Turbulence resulting from wave and current flow around the boundaries of the reef will cause localised scouring and rock will drop into the scour holes sealing them off. This will produce a transition of buried or partly buried rocks into the sand seabed.

118 The volume of rock fragments allowed for, 40,000 m^3, will be disposed of over an area of 13 hectare equating to an average deposit depth of 0.3 m. The deposition over the area will not be uniform to that extent but the projection of the disposed material above seabed level could be expected to be of the order of 1 m maximum after the levelling effects of wave action on isolated mounds have occurred. In 13 -15 m water depth, Chart Datum (CD) that amount of bottom variability will not cause any discernible effects on wave height and focussing.

119 It would not function as a surf reef unless it was shaped in to a lens type shape in an optical lens type analogy. The deposit will not be entirely uniform there will be some variation which will produce minor random refraction effects.

Alternative Disposal Site Locations

120 The dredged sediment and rock fragments could be discharged into deep water offshore beyond the 12 nautical mile limit, out of sight and out of mind but that would not be a sensible use of a resource in this situation for three reasons.

121 Firstly the sand material, and it is predominantly sand, dredged up is a valuable resource in coastal engineering terms and should be kept within the coastal system. The disposal location is so close to shore that disposing sand at this location constitutes a form of beach nourishment and as such will help compensate for SLR and provide a buffer against erosion.

122 Marine sand is a valuable and diminishing resource NZ wide and should not be thrown away. In 70 years of use of the existing disposal site there have been no adverse environmental effects and it is close to the port. There is no pressing need for an alternative disposal location either on economic or environmental grounds.

123 Secondly a recent coastal erosion mapping exercise as part of the Resilience to Natures Challenges (RNC2) National Science Challenge at the University of Auckland has exposed an erosion issue in front of the storage site for toxic Spent Cell Liner (SCL) waste at Tiwai Point. This site is 1.5 km east of the smelter and sits behind the dunes 100 m from the beach.

124 The record of shoreline change at Tiwai Point, as derived from a study and comparison of aerial photographs and satellite imagery, shows a complicated pattern of alternating accretion and erosion of sections of the beach which are generally more pronounced east of the smelter. The shoreline in front of the SCL storage site accreted by 30 m from 1951 to 2013 then has eroded since and is now a few metres closer to the waste facility than it would have been in 1951. Given this erosion it would make sense to use the sand as beach nourishment to mitigate the problem.

125 Thirdly, a disposal location 12 nautical miles out from shore puts the location out in Foveaux Strait, a notoriously rough stretch of water which will impose operational limits on the dredges and hopper barges employed for the work. In the case of the 'Albatross' the TSHD used for maintenance dredging around NZ the operating limits under its load line exemption certificate are subject to the following conditions: Wind speeds not exceeding 35 knots, Significant wave height H_s = 2.5 m maximum.

126 These limits are regularly exceeded in the strait and would impose vessel downtime on small TSHD maintenance dredges. Transiting to and from the disposal location would increase costs and waste fuel for no perceptible benefit.

127 The alternative site for the disposal of the rock fragments could be onshore but there would have to be a requirement or use for them to justify the

transfer and handling costs, otherwise better to use the rock for an artificial reef as proposed.

Dredging Effect on Coastal Processes

128 The result of the dredging will be to achieve a relatively small but economically significant increase in draft. The changes to the channel cross section areas will be minor, less than 5% considering the channel cross section alone, and even less, less than 2.5%, if the whole submerged width of the entrance, including those areas either side of the channel are taken into account.

129 If the total width of the entrance section is included the increase in area decreases to < 2.5% of the existing cross section area. That is not a uniform increase in cross section, just an increase at one section. Many of the areas to be removed are seamount type features, the current speed decrease is likely to be close to undetectable, it will be localised rather than general.

130 The roughness and hydraulic resistance of the channel sides and bottom will be as before so the only factor affecting the flow and the flow speed will be the increase in channel cross section area ΔA. The tidal prism - the volume of water V flowing into and out of the harbour with the flood and ebb of the tide, plus any freshwater inflow - will be unchanged so the only change will be a very minor and hard to detect reduction in tidal current flow speeds u, $\Delta u = V/ A - V/(\Delta A.+ A)$. The effect on tidal current velocities as a result of dredging in the swinging basin area will also be negligible. For a maximum current speed of 6 knots the localised decrease could be $.025 \times 6 \approx .15$ knot $\approx .075$ m/sec.

131 The effect on incident waves consequent on channel deepening will be a very minor, close to undetectable, increase in wave refraction. That part of the wave front passing up the entrance channel in deep water will advance faster than those parts of the wave front in shallow water either side of the channel. The wave front will bend and the wave orthogonals, notional lines perpendicular to the wave front, will diverge reflecting a reduction in wave energy/m of the wave front or crest. That applies only if the seabed is of uniform slope, not an irregular seabed with rough features, seamounts, hollows.

132 The wave energy flux is taken as constant between orthogonals so if the orthogonals diverge the same amount of wave energy is distributed over a greater length of wave front and wave height decreases. This effect will not be noticeable in the channel entrance.

133 The amount of wave energy penetrating into the harbour will be unchanged and existing coastal processes unaffected. The wave energy environment in the harbour entrance is relatively low and wave energy penetration into the harbour is not high in any case. Minor deepening of the harbour will not change this.

134 Climate change and the associated SLR and increase in storm event frequency and intensity will increase the energy of the wave environment outside the harbour. This will further energise the wave driven coastal processes, increasing the strength of the littoral drift and beach erosion in storm events. The effects will only impact on the beaches to the east of the harbour entrance, the rock shorelines to the west will be unaffected. The effects on the beaches will be countered by the beach nourishment effect of disposing of the dredged material in the existing disposal site off the Tiwai Peninsula.

Conclusion

135 The proposed dredging work in the Bluff Harbour entrance channel will have no noticeable/significant effect on the existing coastal processes – neither currents nor waves - and no further hydrodynamic modelling will be necessary on that account. The sand and silt volumes dredged up during the Capital dredging are much higher at 120,000 m^3 than the normal maintenance dredging volumes dumped at the existing disposal site. This will result in greater temporary shallowing at the location but the existing coastal processes can handle this and scale up.

136 As a result of the shallowing the wave heights necessary to mobilise the sand will decrease and the mobilisation rate of the sand will increase – the seabed will be disturbed by wave action more often - to allow a greater volume of sand to be transported away.

137 Because the sediment is dropped in shallow water the beach onshore of the disposal site will end up being nourished by the sand and will become more resilient to storm erosion. The backing sand dunes will also gain height and volume and be better placed to adjust to SLR.

138 The fine sand recovered by the dredging constitutes a resource and should not be removed from the coastal zone. Disposing of the sand offshore out of the reach of waves beyond the 12 nautical mile limit would be a waste of a valuable resource.

139 An understanding of the coastal processes at work and their drivers, waves and tidal currents, will guide the disposal of dredged sediment to ensure

that the small proportion of fine sediment in the dredged material will not affect water quality within the harbour

140 The Capital dredging program will be short at around 6 weeks duration and any dredged material containing a significant percentage of silt, from berth areas within the port, will only be dumped on the outgoing tide.

141 The disposal of the rock fragments at a new dump location in deeper water - 13-15 m below CD - east of the existing disposal location will also have no discernible effect on the existing coastal processes. The rock fragments will be stable and organize themselves in a self supporting matrix as a permanent rock feature. There will be no discernible change either to the waves or the tidal currents. There will be localised scouring and scour holes around the edges of the reef into which the fragments will drop sealing off future scouring.

Gary Charles Teear

APPENDIX A

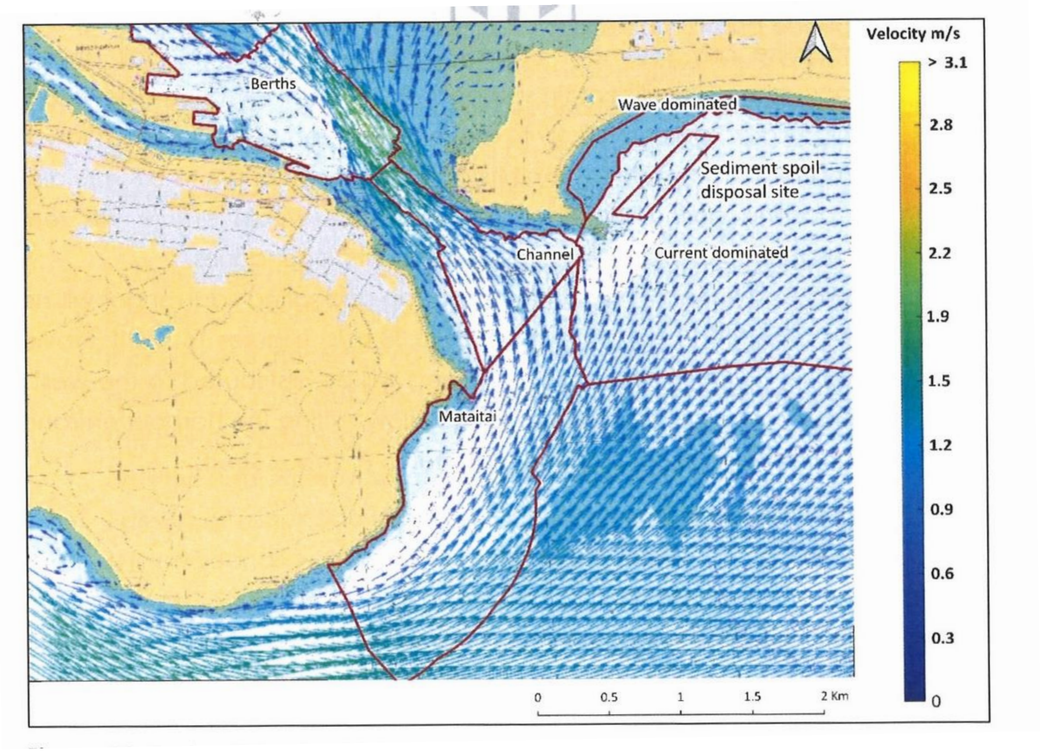


Figure no.1

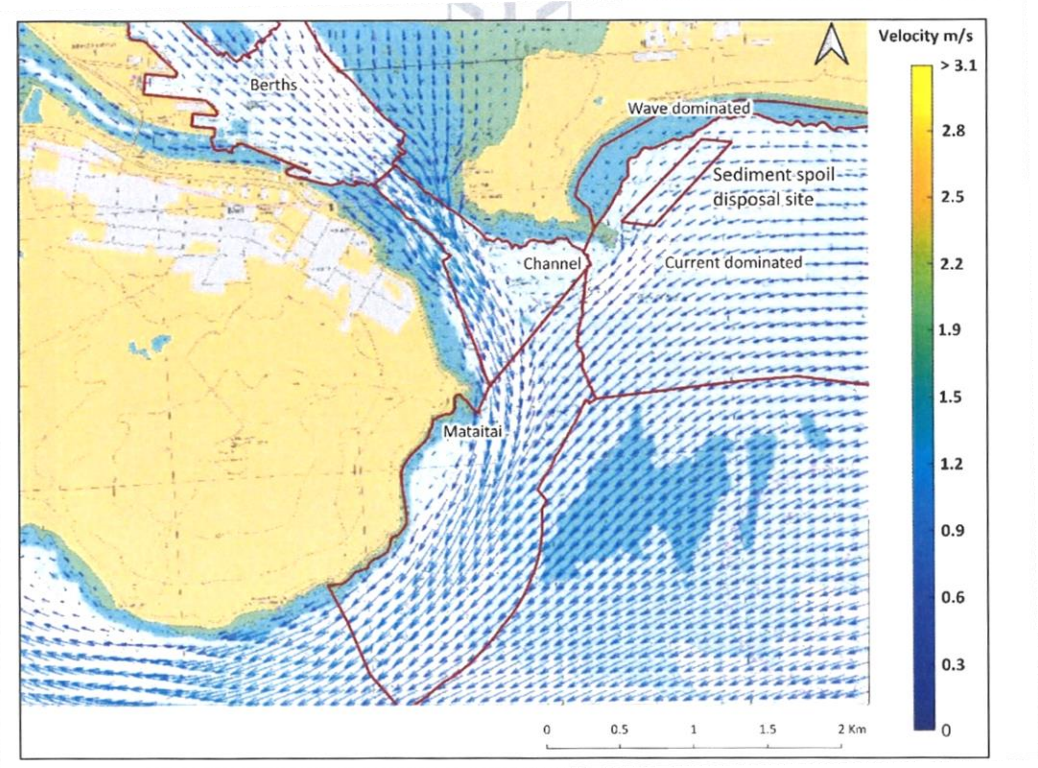
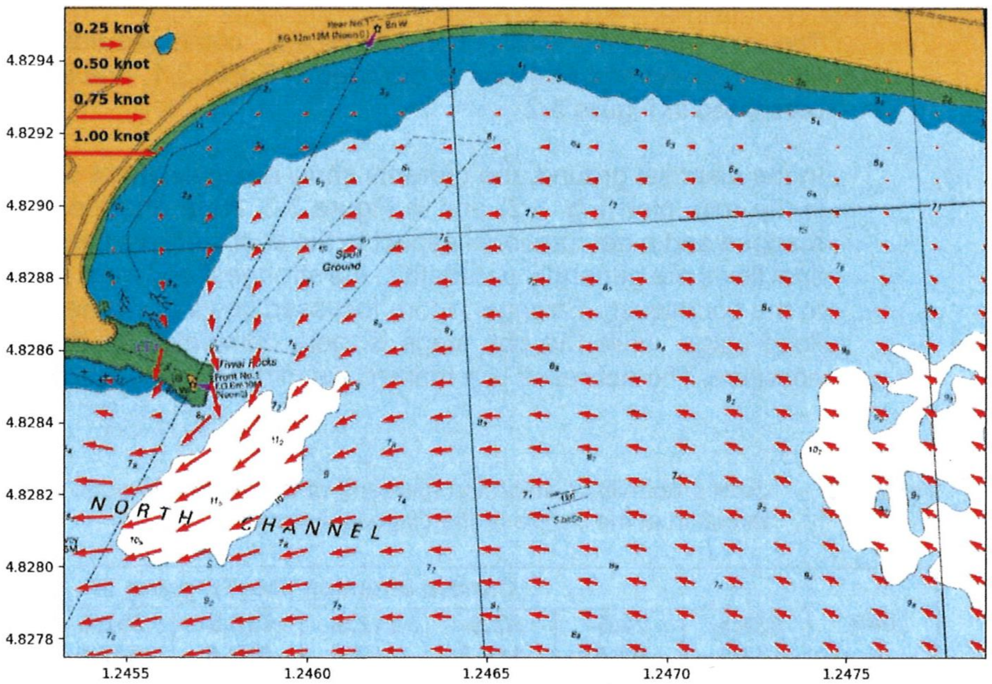


Figure no.2



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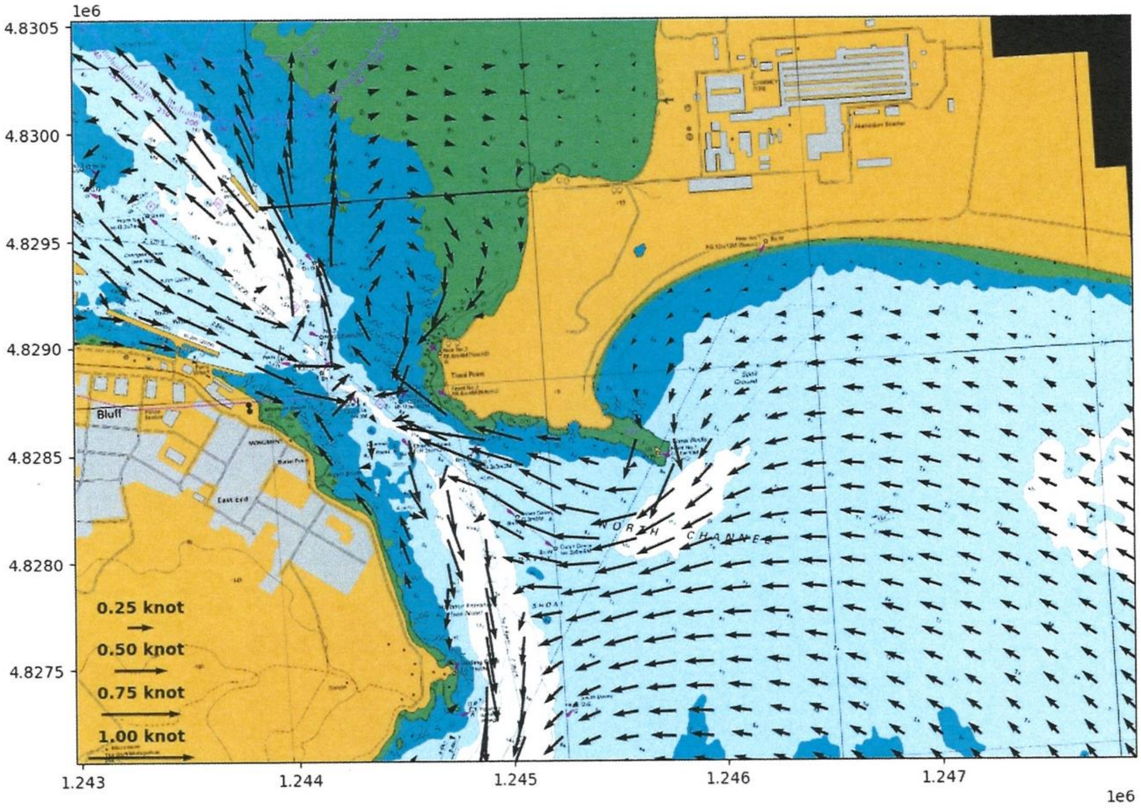

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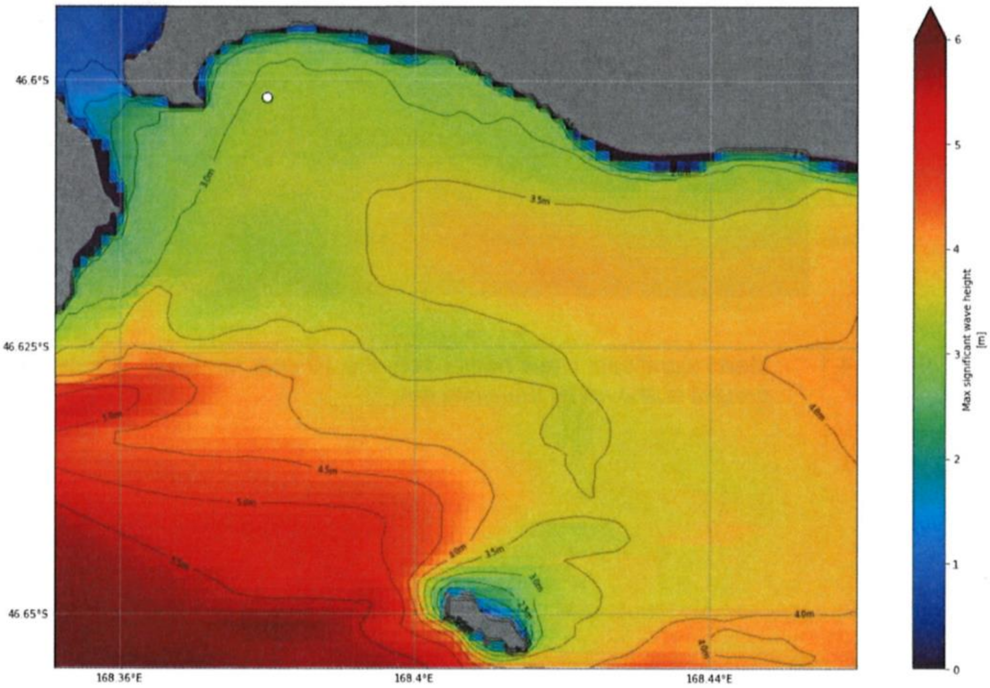

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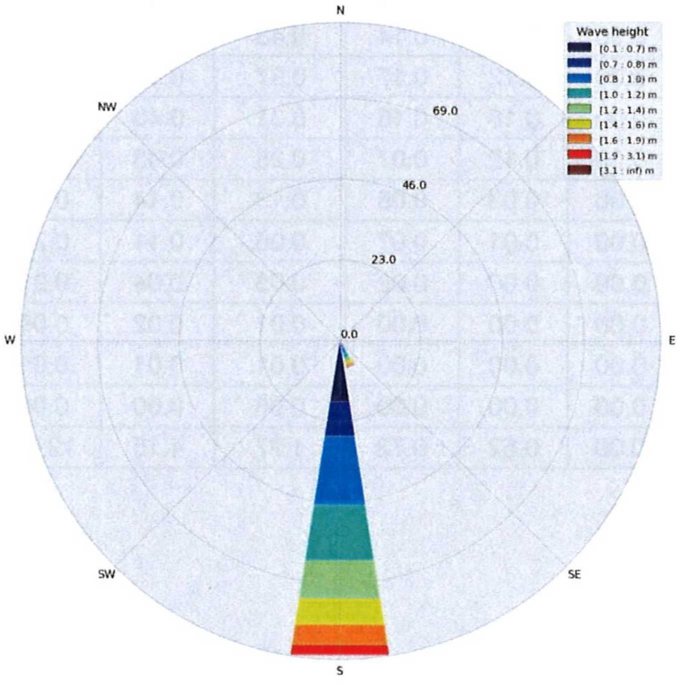

Figure no.6

APPENDIX B

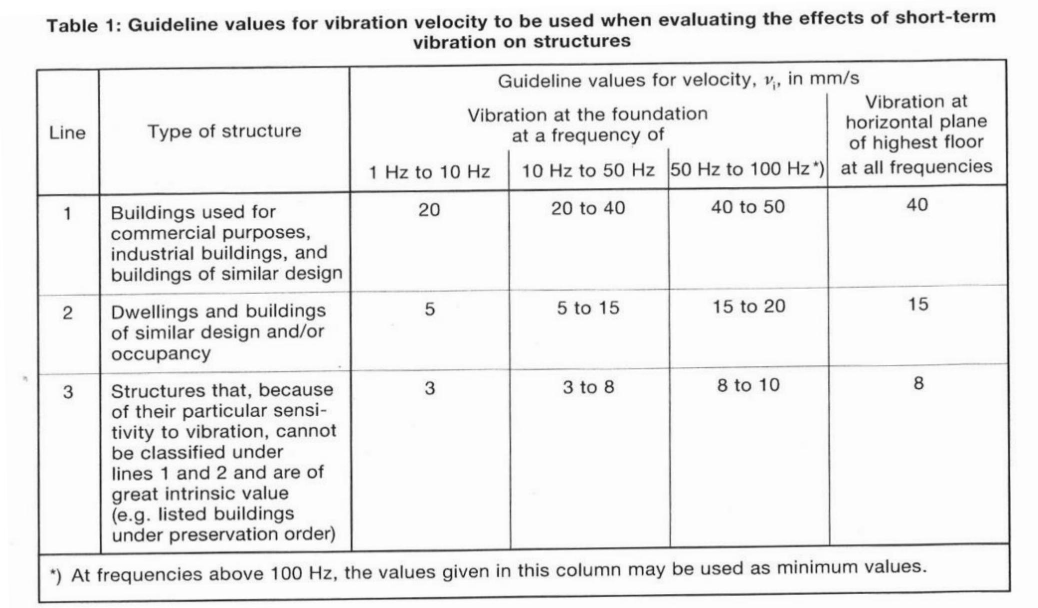

Table 1: Guideline values for vibration velocity to be used when evaluating the effects of short-term vibration on structures

Line	Type of structure	Guideline values for velocity, v_i, in mm/s			
		Vibration at the foundation at a frequency of			Vibration at horizontal plane of highest floor
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz *)	at all frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	3	3 to 8	8 to 10	8

*) At frequencies above 100 Hz, the values given in this column may be used as minimum values.