BEFORE THE HAWKE'S BAY REGIONAL COUNCIL

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of Applications by Port of Napier Limited to the Hawke's Bay Regional Council for resource consents (CL180009E,Cl180010E,CL180011E and CL180012W) to undertake wharf expansion, associated capital and maintenance dredging, disposal of dredged material within the coastal marine area, and occupation of the coastal marine area for existing port activities and the proposed new wharf

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STATEMENT OF EVIDENCE OF PETER COWELL

INTRODUCTION

1. My name is Peter Cowell. I have held an appointment continuously since 1976 in geoscience with the University of Sydney, where I obtained my PhD in 1983. My current appointment is as an Honorary Associate but my evidence is provided in an independent capacity, not as a representative of the University.

2. I have been requested by Napier City Council to provide my opinion on:

   a. all the factors causing erosion in the Westshore beach littoral cell;

   b. what effect the dredging of the channel will have on that inshore sediment budget if the sediments are removed from the area; and

   c. why the deposition in the near shore is important in terms of mitigating those effects.

Qualifications and Experience

3. My evidence draws from professional and scientific expertise spanning 41 years in marine geosciences, including as Director, University of Sydney Institute of Marine Science, and as Head, School of Geosciences at the University of Sydney; and through membership since 1977 of the internationally recognised Coastal Research Group (formerly Coastal Studies Unit).

4. The emphasis on my research is on bridging the gap between sediment dynamics and Quaternary geology. Application of this research is directed at practical prediction in coastal management, including impacts of climate change, and for geological exploration. This approach to the science involves combined use of field data and computer modeling to yield information that is otherwise unattainable, along with the application of formal methods for managing uncertainty.

5. My research has been developed through multidisciplinary projects undertaken on four continents and islands in the Pacific and Indian Oceans in close collaboration with leading specialists from Australia, New Zealand, Europe and the Americas. General principles derived through this research are readily applicable to Westshore in Hawke Bay.

6. My research outputs are available in the international, peer-reviewed literature, reports to States and the Commonwealth Government in Australia, and have formed the basis of numerous commissions on coastal management that I have undertaken throughout my career. These have included the design and implementation of two beach

construction and nourishment projects, with both these beaches remaining intact without further intervention for 30 years. Both the Delft3D and MIKE21 have been in use by my research group at the University.

7. I have applied HR Wallingford model (Powell, 1990; Diserens and Coates, 1993) for gravel beaches. The Wallingford model is consistent with our published research on behaviour of reflective beaches where the beach face and step comprises coarse material and the nearshore comprises fine sand (Hughes and Cowell, 1986). These results concern response of such beaches to variations in wave energy.

8. My experience of particular relevance at Westshore draws from projects on three coasts: the Columbia River coast of the Pacific north west USA; the Tiber River Delta coast of Rome, Italy; and the SE East coast of Australia which shares with Hawke Bay similar climatic forcing of coastal processes.

9. The Columbia River coast contains a geological record of multiple events involving sudden changes in sea level by one or two metres as well as the effects of entrance-training wall installation (Columbia River and Grays Harbour) and effects of changes in sediment supply to the coast. Both types of disturbance were found to cause changes in coastal alignment that took many decades to complete the adjustments.

10. The multi-million dollar research project was undertaken by the US Geological Survey with the aim of testing limits on accuracy in measurement of geohistorical and contemporary coastal change. Involvement in this project occurred initially as independent science reviewer (along with Paul Komar and others) and subsequently as supervisor for PhD research based on project data, undertaken by one of the two project co-leaders. I also undertook data analysis and coastal change modeling in collaboration with other members of the project team.

11. The Tiber Delta coast and continental shelf of Rome similarly contains a high resolution depositional record of coastal change in response to variations in sediment supply from Tiber River as well as effects of coastal protection works at the River entrance. Research on the Tiber project involved computer modeling of coastal change in collaboration with staff from the Department of Earth Science at the University of Rome La Sapienza, exploiting the rich geogogical data set they had been compiled through intensive field investigations over the course of several decades.

12. As with US Columbia River project, the data and modeling from the Tiber coast revealed that responses to systematic disturbances of sediment supply and coastal engineering works ensued for many decades.

13. My evidence also draws from invaluable experienced gained from field reconnaissance of the Hawke Bay coast and hinterland in the company of Dr Jeremy Gibb who had been involved in investigation of coastal change in the region for many years. During the reconnaissance he provided detailed explanations of interpretations about coastal processes and coastal change at the range of sites throughout the region, and outlined competing ideas of other researchers that had worked in the area. This reconnaissance was undertaken (over two days in May 2004 and 2005, four days in April 2005, two days in February 2006, and two days in August 2011) in preparing reviews, for Napier City Council, of coastal hazard assessments in Hawke Bay formulated by others.

14. These reviews were successively compiled in 2002, 2004, 2005, 2006 and 2011 based on the field reconnaissance plus detailed review of available scientific literature on the Hawke Bay coast (journal articles, unpublished reports and research-student theses). The reviews also entailed undertaking analysis of survey quality aerial photograph history, beach profile survey data available at that time (HB and other series); and computer modeling of the coastal response to coseismic uplift together with effects of sediment displacements along the coast and between the beach and sea bed.

15. My earlier review of scientific literature on the Hawke Bay was augmented since 2015 through reference to the summary and interpretation of the literature compiled by Paul Komar (2005) and direct access to studies discussed therein, such as that of Kirk and Single (1999). I have also reanalysed data Hawke Bay reviewed by Komar and from other sources.

EVIDENCE

Factors causing erosion in the Westshore beach littoral cell

16. Data I have reanalysed from HB and other surveys show that short-term (acute) erosion episodes are of minor importance in terms temporary loses in the volume of beach sediments within and above the intertidal zone at Westshore, compared to more secular (chronic) erosion. Acute erosion episodes, due to individual storms or periods of increased storm intensity and frequency, are probably mitigated at Westshore through the wave-sheltering effects of the Port Breakwater, as noted in previous reviews undertaken for Port Napier by Kirk and Single (1999) and Komar (2005). The storm erosion evident in my reanalysis is significantly less than deduced by Komar.

17. The dominant reason for chronic erosion at Westshore in my opinion, and in conclusions to studies reported by others (including Kirk and Single, although with different ideas on timing) stems from the misalignment of the beach and nearshore seabed resulting from

uplift that accompanied the 1931 earthquake. The misalignment involves a seaward displacement of the beach relative to a position it would have occupied before the earthquake, had it not been for other earlier factors, and a corresponding overly shallow subtidal seabed in the nearshore zone. Chronic erosion at Westshore also has been attributed to beach misalignment in studies reported by Worley (2002) and Beca (2007). The readjustment would have initiated immediately after the uplift, but at first would have manifest as coastal accretion, then a period of relative stability punctuated by episodes of acute erosion.

18. Chronic erosion at Westshore since about 1980 is an expression of the final phase of natural readjustment. This phase involved evolution of the alongshore beach alignment back toward its (theoretical) former more stable geometry: one in which the gradients in time-averaged, net, alongshore transport of sediments are uniform (or zero) along the coast. The former, more stable beach alignment entailed a tighter shoreline curvature located further landward at Westshore.

19. The parenthesised 'theoretical' reference is included because, before the earthquake, the natural alignment had already been displaced seaward due to the construction of the Ahuriri Harbour moles, in the late 1870s, which caused the flanks of the ebb-tide delta to collapse, as described in detail by Kirk and Single (1999). That is, the new Harbour moles isolated the lateral parts of the ebb-delta shoals from the out-flowing Ahuriri tidal jet. The jet was thereby no longer present to oppose the shoreward transport tendencies exerted by wind waves and swell on shoal sands. The shoals were consequently driven onshore where new land was temporarily created.

20. The town planning consequences of this are still problematic today, and in the context of The Port's present Application: the citizens of Napier too hastily exploited the newly emergent land. The Freezer Works were constructed on this new land, and new sub divisions (now partly lost to erosion) were formalised. The cadastre remains in force today.

21. Unbeknown to the citizens of the late 19th century, this bounty of new land following harbour mole construction was set a few decades at most. These coastal changes are evident in a rich collection of historical photographs held at Napier. The former ebb-tide delta shoals became progressively depleted as their sands were displaced landward to form beach deposits that steadily accreted. The resulting protrusion in the beach alignment, however, relative to the coastline further north in Hawke Bay, enhanced rates of wave driven alongshore transport of beach and nearshore sediments away from the protrusion (i.e., toward the north). This process of readjustment was the same as that

described above in relation to the post-uplift response: coastal processes tending to equilibrium through a progressive reduction in littoral transport gradients.

22. As long as the onshore feed from the collapsing ebb shoals was sufficient to offset the alongshore losses, beach accretion or stability prevailed. Eventually, however, the volume of onshore sand feed declined to rate less than that of the alongshore transport. Even after the shoals had become completely depleted, resulting in cessation of the onshore sand supply, the residual beach protrusion at Westshore would have caused the enhanced alongshore transport at Westshore to persist until the protrusion was removed, returning the beach alignment to its former more stable configuration.

23. The entire cycle of this ebb delta collapse and re-equilibration of the beach alignment was researched in detail in the USGS Columbia River coastal erosion project referred to above, where similar town planning consequences ensued. The spatial dimensions and sand volumes involved in the Columbia River case are an order of magnitude greater than in Hawke Bay. The entire cycle has been ongoing for more than a century. The time scale of the cycle was correspondingly shorter in Hawke Bay, although at Napier, completion of the cycle was eclipsed by the coseismic uplift in 1931.

24. This second enhanced disturbance of coastal alignment away from a stable equilibrium has also involved a multi-decadal adjustment back toward a stable equilibrium: the later part of this adjustment again has manifested itself as chronic coastal erosion. The present civil development at Westshore, however, is the ongoing legacy of the Ahuriri ebb delta collapse, a legacy that underpins the imperative of town planning decisions upon which the Westshore beach nourishment program is predicated and, thus, has bearing on the Port Napier Application before the Commission at present.

25. The multi-decadal time scale of re-adjustment is not exceptional. It is also evident in another rich data set from the coast of Rome at the Tiber River delta. We have worked on this data set compiled over several decades by colleagues from Earth Sciences at La Sapienza University (Rome), with whom we collaborated. Progressive dam construction in the Tiber drainage basin caused reduction in sand volumes supplied to the delta. The reduced sediment supply resulted in a gradual decline in deltaic protrusion of the coastline flanking the River mouth, which we have modelled. This adjustment toward a new equilibrium, in which net alongshore transport gradients are diminished, has taken several decades, as in the case at Napier.

26. In my opinion, the post-uplift readjustment at Westshore remains ongoing. Single has proffered the opinion that adjustment should have gone to completion by now (in Kirk and Single, 1999). As with the cycle of beach realignment after harbour mole

construction, the process of adjustment to uplift has probably also been eclipsed: in this case by the artificial beach nourishment program initiated at Westshore in the 1980s. The post-uplift misalignment of the intertidal and beach and berm has thereby been perpetuated through the nourishment program. The program is a beach-management intervention to protect assets and property behind the beach at Westshore, and in an attempt to maintain at least some beach amenity.

27. I base my opinion, that adjustment to the 1931 uplift is ongoing, mostly on the evidence that the sand surface of nearshore seabed off Westshore continues to deflate. This nearshore lowering is particularly evident in survey data from the sector toward the southern end of Westshore. The sub tidal seabed there has not been raised through sand nourishment with dredge spoil as has occurred at Site R.

28. I should note that both the Kirk-Single (1999) and Komar (2005) reason that the Westshore beach alignment has been in near equilibrium, with near zero net time averaged alongshore transport of sediments, in the 20 years or so before and at the time of their writing. This conclusion would imply that Westshore beach has largely re-equilibrated after the misalignment caused initially by ebb delta collapse and subsequently by earthquake uplift. Others, including Worley (2002) and Beca (2007) have provided opinion based on crude theoretical considerations that alongshore alignment of Westshore beach remains out of equilibrium.

29. I too disagree with conclusions of Kirk-Single (1999) and Komar (2005) that the gravel-beach alignment had reattained near equilibrium several decades ago, although I cannot say whether the misalignment is a vestige of the 1931 uplift, or solely due to the gravel-nourishment program. I base my conclusion, that beach alignment is out of equilibrium, on the overwhelming evidence of the need for recurrent artificial nourishment of the beach with gravel. The nourishment program remains necessary because depletion of the beach volume is ongoing, as recorded in survey data. The question arises as to the fate of this lost gravel: where is it? Gibb (2003) and others have reported a corresponding accretion of the beach north of Westshore in the vicinity of Bayview, and speculate that this likely to be the gravel lost from Westshore. There is no evidence that gravel is lost permanently offshore from the Westshore Beach. Nor can abrasion explain the loss, because such an explanation would require a higher rate of abrasion at Westshore than further north where the chronic erosion of the beach is not in evidence. All technical specialists agree that Westshore is subject to significantly lower levels of wave energy than further north toward Bayview. From this it is reasonable to conclude that abrasion rates at Westshore would be correspondingly lower.

30. Focus in previous studies reviewed by Komar (2005) has been exclusively on the gravel beach of the intertidal zone and above. To date, the rationale for the beach nourishment program at Westshore has been to add gravel to this upper part of the beach. Some attention has shifted to the role of the sub tidal nearshore seabed in recent years, starting with Gibb in 2003. The nearshore gained attention when disposal of spoil from maintenance dredging was initiated at Dump Ground 'R', located off the northern segment of Westshore Beach. The effect of dredge spoil disposal at this site seems to have temporarily ameliorated the erosion trend according to NCC and HBRC staff and their technical advisers, and is evident in beach-monitoring surveys. Nourishment of the nearshore with fine sand thus provides a benefit to beach stability at intertidal elevations and above. Recurrent nourishing of the nearshore with fine sand thus offers a means of supplementing recurrent nourishment of the beach face and berm with gravel.

31. Scientific knowledge of mixed sand and gravel beaches is not as advanced as for sand beaches, although even for the latter knowledge is far from definitive. Nevertheless, sufficient international research results are available on the behaviour of reflective beaches composed of mixed sediments to understand that a coupled behaviour exists for the beach face and nearshore seabed. Our group published quantitative results on this in the 1980s, confirmed subsequently by work in the UK on mixed sand-gravel beaches.

32. Given the tight relation between waves and nearshore water depths, it is reasonable to conclude that nearshore seabed elevations averaged over time will have a strong relation to the wave regime (time average wave conditions) as function as distance from the beach face (systematically increasing water depths with distance offshore). The time averaged stable morphology (other factors excluded) is expressed through application of principles formulated largely by RG Dean and his colleagues for dependence of beach and nearshore profile morphology on sediment size.

33. These principles are applied piece-wise to account for effects of variation of sediment sizes across the beach and nearshore: an approach that is routinely exploited in the design of artificial nourishment projects to ensure greater morphological stability by selecting a nourishment fill that is coarser than the native sediments. In practice, this is possibly only if coarser sediments are available: if not nourishment-overfill is applied to achieve a temporary increase in beach volume on the understanding that nourishment applications will need to be recurrent: with larger overfill volumes allowing longer periods between renourishment applications.

34. Westshore appears to exhibit a systematic trend in lowering of the fine sand surface of the sub tidal seabed over time. This lowering can be regarded as a counterpart to a landward retreat of nearshore seabed (technically known as the shoreface, of which the intertidal beach face forms the upper segment of this surface: Cowell et al., 1991). The theory for this behaviour of coasts (shoreface kinematics) is well developed (e.g., Moore and Murray's 2018) and widely applied in coastal management. For example, Tonkin Taylor have applied the most common, yet crude rendition of these principles (the kinematic Bruun Rule) to obtain estimates of beach retreat due to forecast sea level rise in preparing coastal hazard lines for the mixed sand and gravel beaches Hawke Bay.

35. Progressive lowering of the nearshore seabed off Westshore therefore can be interpreted as a landward retreat of the shoreface, including the beach face. By using gravel to artificially enhance the volume of intertidal beach and berm through the Napier beach nourishment program, the landward retreat of the shoreface means that progressively larger volumes of gravel will be required to hold the line. The rate of gravel loss alongshore can be expected to progressively increase as well, for reasons given further below.

Effect the dredging of the channel will have on that inshore sediment budget

36. The perceived benefit of previous disposal of dredge spoil at site R may be explained with reference to the principles outlined above. That is, the disposal offsets and temporarily reverses the nearshore lowering responsible for beach profile retreat. Wave action can be expected to redistribute the dumped material in the nearshore to produce a naturally stable morphology. Application of sand directly from dredge to the nearshore in beach nourishment programs is now common place throughout the world.

37. The beneficial effects can be expected to persist at Westshore until the dumped material is displaced from the nearshore seabed at Westshore to elsewhere. Such displacement and loss of dredge spoil from Site R at Westshore will likely result from the same nearshore transport regime responsible for lowering the nearshore seabed over recent decades. This loss is also consistent with expectations that the nearshore seabed has been too shallow to retain its sediments, following the effects of the 1931 uplift. Kirk and Single provide a description of how the uplift of beach and nearshore differed in outcome from other parts of the Napier coast, primarily because the nearshore was significantly shallower at Westshore than elsewhere. This condition can be explained by the presence of the Ahuriri ebb tide delta, which was present then (as now), albeit in reduced extent after the previous collapse of its flanking shoals due to construction of the Inner Harbour moles.

38. An accelerated loss of nearshore sands can be expected due to the artificial creation of additional sediment sinks through dredging of navigation channels in both the Inner Harbour and the approaches to Port Napier. The coastal area modeling undertaken by Advision, like earlier numerical modeling, provides insight into possible sediment dispersal patterns involved in these losses. The historical need for maintenance dredging provides field evidence that the dredged channels act as sediment sinks.

39. Advision appropriately presents the modelled results more as heuristic indicators of net movement than definitive measures of net transport rates. This heuristic characterisation is shown in **Figure 8-7** of the Advision report **(Appendix D of the Application)** as conceptual transport pathways. The diagram contains six smaller panels showing modelled current vectors under different selected wind conditions. These panels feature reversals in direction for simulation experiments of steady-state conditions. In nature, waves, winds, tides and other agents contributing to sediment transport change (evolve) continuously.

40. No assessment was given, in the Advision reports, on implications of conceptualised sediment movements in terms of cumulative effects over centuries or millennia. The modeling is of a largely natural coastal environment, and the general assumption is that the Port constructions have not introduced a disturbance that dominates coastal sedimentation processes in the Napier-Hawke Bay environment. The sediment transport field, that modeling aims to characterise, can be assumed to have persisted, with minor effects due to the Port, over these longer time scales, in the absence evidence on significant changes wave climate and wind regime.

41. The expectation to be inferred from Advision's concept diagram, for net fine sand advection with wind driven currents, is for long-term displacement of this sand toward the east, beyond the Breakwater, and ultimately to the nearshore seabed along the stretch of coast south of The Bluff. From this it might be reasonable to anticipate the presence of lobes containing fine sand extending into deeper water off The Bluff. In addition, the nearshore seabed south of The Bluff and extending along the coast toward Awatoto, should be filled with fine sand to a much greater thickness than north of The Bluff, and nearshore water depths should be much less than north of The Bluff, depending on comparative substrate depths.

42. Evidence of a long-term accumulation of fine sand extending seaward of The Bluff may exist in the form of the 'salient' mapped in **Figure 2.5 of Appendix G** of the Application. The base of this fine-sand salient appears to extend from the nearshore further north

than the conceptual transport pathways for fine sand shown in **Figure 8.7 of Appendix D** of the Statement, interpreted from the model results.

43. If however the fate of fine sand, implicit in the **Figure 8.7**, was the dominant component of up-scaled implications for depositional evidence, then there would be no expectation of the preponderance of fine sand accumulation in the nearshore zone at Westshore. Instead, a thin veneer and traces of fine sand could be anticipated to characterise nearshore deposits. Such ephemeral deposits of fine sand would be indicative of this material being in transit to the permanent sink offshore from and south of The Bluff. Yet the nearshore sediment body off Westshore is characterised from field data to comprise predominantly fine sand.

44. A geological accumulation, like the 'salient' referred to above, because of its size, provides the most coherent evidence for actual net sediment displacements (*e.g.*, the accreted beach and dune deposits on the central Netherlands coast referred to above). These features constitute natural integrators of the signal relevant to morphological change, with the noise created by weather-forced transport variability filtered out. Nevertheless, more localised accumulations also provide evidence of sediment sources and sinks.

45. The need for recurrent maintenance dredging demonstrates that the Napier navigation channels are areas of sediment accumulation (*i.e.*, sediment sinks). The dredged volumes provide a measure of the rate at which this sink operates. The Port undoubtedly has a wealth of hydrographic survey data that could indicate whether one side accumulated sediment faster than the other, which would provide evidence on asymmetry in the sediment transport field over time.

46. The only hydrographic plot I have seen is one circulated by Cr Dallimore from NCC. That plot shows an asymmetry in the channel cross section, with a ramp from the channel floor sloping up to the top of what is reported (Dallimore per comm.) to be the eastern side the navigation channel. The asymmetry of the channel cross section might indicate a sediment wedge accumulating from sand entering from the offshore direction.

47. Such an interpretation is consistent with the conceptual pathways in **Figures 8-3 and 8-7 of the Advision report (Appendix D of the Application).** These diagrams depict modeling results that indicate potential for fine to medium sand bypassing from south of The Bluff and around the Breakwater. **Figure 8-3** indicates that the navigation channel interrupts a possible net sand flux that otherwise seems likely to form a potential supply to the nearshore seabed off the beach at Westshore. The interpretation is also consistent with previous studies summarised by Komar (2005), and Komar's assessment of them,

that a sand supply to Westshore had existed from sources south of The Bluff at some time in the past. (Komar's review concludes that the Tukituki River is the overwhelmingly dominant source of sediments to the coast in the southern half of Hawke Bay.)

48. Unfortunately Cr Dallimore's sonar record stands in isolation. If Napier Port Ltd holds a series of survey records of the navigation channels, these would likely be of greater detail due to better spatial and temporal coverage. Such records would also be afforded a more formal status, and would provide useful field data for validation of sediment-transport pathway interpretations drawn from the Advision modeling.

49. One of objectives of the sediment transport modeling, stated in **Appendix F** of the Application, was to assess the possibility that sand from the inshore dredge-spoil disposal Site R re-enters the dredged navigation channel. From the results of the modeling, the conclusion is drawn in **Appendix F** that this possibility is confirmed. I agree with this conclusion: that the dredged channel forms a probable sink for nearshore sand from Westshore. This conclusion holds with or without the addition of dredge spoil at Site R. That is, the navigation channels (including the entrance to Ahuriri) are likely sinks for subtidal sand from Westshore beach, and thus contribute to the deficit in the Westshore sediment budget. More specifically, this component of the deficit is evident in the progressive lowering of the sub tidal nearshore and surface.

50. While the presence of the navigation channels contributes to the deficit in Westshore sediment budget, the nearshore sands off Westshore will likely continue as a contributing factor in the need for maintenance dredging of the channels, even if disposal of dredge spoil at Site R ceases. A key question then becomes, would disposal of dredge spoil at Site R significantly increase the rate of channel shoaling and thus costs to the Port of recurrent dredging. I am of the opinion that the marginal increase in contribution to channel shoaling is likely to be significantly less than might be anticipated from the model results of the wind-driven transport taken in isolation. My opinion is based on two issues:

    a. the relative size of sand accumulations reviewed by Komar (2005) for the east (offshore) versus west (shoreward) side of the northern navigation channel; and

    b. limitations of in the simplified design of the model experiments reported in Appendices D and F concerning wind advection of sand stirred by waves.

    Komar wrote: *"...dredged spoils dumped at site G to the immediate west of the Fairway apparently have been transported back into the Fairway, where it has accumulated along its western shoulder at an average rate of about 11,000* m^3*/year" (p.7-34); and "...accumulation of fine sand along the eastern shoulder* *of the channel, with its rate of accumulation estimated by dredging records to be* about 25,000 m^3/year" (p.7-33).

51. The comparison indicates that sand supplied from south of The Bluff, which the sand bypasses before being intercepted by the channel, bears more than twice the responsibility then attributable to sand from seabed off Westshore. The two accumulations also illustrate that the sand would slosh to and fro (seaward and landward), if not intercepted by the channel: indicative of the relentless churning in sediment dispersal patterns that characterise *sediment-sharing systems* in coastal geomorphology.

52. The volume ratios for the two sets of channel-shoulder accumulations, however, provide evidence that the net (time averaged) transport of sand is toward Westshore rather than from Westshore toward the navigation channel. This asymmetry in net transport is more consistent with the wave-driven transport modeling presented in **Appendix D (Fig. 8-3)** of the Application, than with the "mean-annual total load" patterns derived from modelled wind-driven, wave-stirred scenarios **(Appendix D, Fig. 8-8)**. The reason for greater consistency with field evidence exhibited by the modelled wave-driven transport relates to the second of the two issues identified above.

53. This second issue (b) relates to the significance of details in the physics of sand transport under waves and currents that can be lost in the cause of simplification. An explanation of the physical principles relevant to this issue is given in the following paragraphs. The explanation forms the basis for my opinion that wave-dominated drivers of sand transport most likely causes a portion of the deficit in the nearshore sand budget off Westshore, Such losses would, in my opinion, occur in concert with gravel losses in that direction. The alongshore sand losses can be attributed to the same fundamental reason as applies to the gravel. That is, as discussed above, both the beach face and the nearshore at Westshore are overfilled with sediment. (The time averaged probability of remobilisation exceeds that of deposition.) The annual average wave-driven transports **(Fig. 8-3, Appendix D)**, and depositional evidence from the respective shoulders of the navigation channel, indicate that net migration out of the nearshore to seaward does not occur, except for losses to the channel. This leaves only transport to the north as unopposed by any strong counter tendencies in the net, wave-driven transport vectors. I elaborate upon this in the final paragraphs further below. These wave-driven sediment dispersal patterns are consistent with the Westshore net-transport budget derived by Mead *et al.* (2001).

54. Concerning details in the physics of sediment transport, simplification is a necessary practicality in modeling coastal flow and sediment-transport fields that, in nature, feature a high degree of temporal and spatial variability. Such conditions are virtually universal, and remain the subject of much attention on how to synthesise results from either data-drive or model driven investigations of natural coastal environments. Should the driving factors (weather) be averaged or simplified before undertaking the modeling, or should they be retained and the outputs averaged? Which details of the problem can be ignored for practical purposes?

55. These issues need to be understood to avoid false confidence leading to seemingly definitive conclusions that preclude other factors that may be of equal or greater significance in governing morphological behaviour. The simulation design adopted for the Application gives emphasis to use of 'representative' wave and weather conditions as model inputs. The representative conditions selected for the modeling, and the decision to emphasis wind driven advection of sediments mobilised by waves is of particular relevance. Use of this simplified excess-shear stress approach to wave current transport (Baillard-Inman concept) is not uncommon, and driven by a practical imperative.

56. Emphasis is given in the Napier simulations to offshore wind conditions as inputs as the overwhelmingly dominant drivers. Generally, coastal researchers and coastal dwellers normally think about conditions prevailing during onshore-wind events as dominating formative processes in coastal geomorphology. There is no question that predominating weather of SE Australia and east coast New Zealand entails so-called zonal winds that blow offshore (away) from the coast. Even so, most of us are more inclined to attribute weather events with onshore-directed winds as the dominant drivers of flows governing coastal morphology, even for coastal dune formation in most cases.

57. The modelled outputs in the Application **(Figures 5-5 to 5-8 in Appendix F)** give a fair sense of the complexity in the transport field based on a limited selection of wind-input conditions. Delft3D and Mike21 software suites both also have the capacity to simulate continuous change in the forcing, albeit in discrete time steps. For example, time series of measured winds, waves and predicted tides can be used to drive these models, with outputs of the wave-current velocity field extracted at selected time intervals (hourly or several times a day). These types of simulations, not presented by Advision, demonstrate even greater complexity and variability in the velocity fields, for both waves and currents. Synthesising outputs from such modelled time series is as challenging as it is for time series data measured and observed in nature.

58. The spatial and temporal complexity would be further evident if simulated output for a selected range of wave-driven transport fields, like those showing annual averages in **Figure 8-3 of Appendix D** of the Application. The influence of variations through time in tidal velocities would add yet another layer of variability and complexity had it been included in the plots presented. While tidal currents are reported as weak throughout Hawke Bay at large, importance of their contribution to the velocity field in the vicinity of the tidal inlets is probably significant. The ebb-tide delta shoals that form part of the nearshore sand deposit, especially off the southern end of the beach at Westshore, is the morphological product of tides and waves acting in concert, as well described by Kirk and Single (1999).

59. So in focusing on modelled wind-driven transports, how representative are these results of the actual sand transport field off Westshore? The results for modelled wind-driven transport predominate over the model output plots given in the Appendices of the Statement (*e.g.*, **Figures 8-7 to 8-9 of Appendix D**; and **Figures 5-5 to 5-8 in Appendix F**). Only two summary diagrams of transport field vectors are given in each **Appendices D and F** to characterise the vector field for potential wave-driven transport under baseline conditions and predicted after the proposed enlargement of the Port navigation channel.

60. Moreover, the Application gives emphasis to conclusions about sand transport drawn from the wind-related transport. I am of the opinion, however, that the wave-driven transport, of the type characterised in **Figure 8-3 of Appendix D** in the Application, are likely to be more relevant to sand dispersal processes in the nearshore region on the Westshore coast. I base this opinion on well-established principles on physics of sand transport under waves and currents.

61. These well-established principles, or various versions of them, have been incorporated into sediment-transport algorithms included in coastal area models like Delft3D and Mike21. Even so, as **Appendix F** of the Application points out in Section 4.1, significant uncertainty is inherent in sediment-transport modeling (Davies *et al.*, 2002). Simulation design in application of these models to particular cases is also relevant to uncertainty and interpretations. Advision therefore properly present results qualitatively on potential sediment transport fields from which they draw their main conclusions.

62. The assumption stated for the wind-driven sediment-transport simulations was that occurrence of wave events and wind-driven currents are poorly correlated. This is to be expected when including offshore winds and waves in the correlation because the former are fetch limited on a windward shore and thus generally do not generate waves of

relevance nearshore processes. In east-coast swell-wave environments (Davies classification), such as in SE Australia and E coast NZ, the occurrence of swell on days with offshore winds is independent of the local wind, except to the extent that opposing form drag of strong offshore winds attenuates swell arriving from distance sources.

63. Sand tends to be transported within the thin wave boundary layer. This is not only the case for bedload, but also for suspended sand. The suspension concentrations are highest, and often fully contained within the thin wave boundary layer (typically the bottom 20cm of the water column). Wind driven surface currents thus have little influence within proximity of the bed. Certainly, depth average currents are not of much relevance there: the much greater thickness of boundary layers for steady currents means that velocities of these currents near the bed are negligible. This is especially the case under offshore winds with swell, because strong white capping is absent; and these are the predominant conditions simulated for the Application.

64. Onshore wind events in east-coast swell environments are typically associated with atmospheric fronts and low-pressure systems over the coast and out to sea. The most intensive low-pressure systems can deepen into mid latitude cyclones, or southerly tracking vestiges of tropical cyclones. Storm waves generated by these systems, combined with the destabilising effects on waves of form drag exerted by a following-wind behind crests, results in significant wave breaking in intermediate water depths. Laboratory experiments on wave breaking shows that turbulence from white capping is injected into the water column. Under these circumstances, that turbulence can result in suspended-sand concentrations, normally contained within the thin wave boundary layer, escaping much higher into the water column. Under these circumstances, the wind driven currents higher in the water column are more likely to have a similar influence on sand transport as with suspended silt and clay.

65. Although use of the simplified excess-shear stress approach to wave current transport is not uncommon, it does not take into account the phase shifts between the occurrence of wave orbital-velocity, shear-stress and suspension-concentration maxima within the wave boundary layer. These phase shifts are even more problematic in the presence of sharp crested bed ripples. With swell waves accompanying offshore winds, the presence of sharp-crested, wave-generated sand-bed ripples in intermediate water depths is the norm rather than the exception.

66. Because of this, I am of the opinion that the wave-driven sediment transport modeling undertaken by Advision (e.g., **Fig. 8-3, Appendix D**) is probably much more instructive, regarding sand transport, than the supplementary wave-current modeling they also present. The latter modeling approach is more relevant to the fate of silts and clays that, once mobilised, maintain concentrations, further up in the water column. The concentration of this fine fraction of sediments varies slowly on the time scale of wave periods. Whereas sand concentrations in the wave boundary layer have been shown in laboratory and field measurements to vary significantly within each wave cycle due to the phase differences referred to above. Thus there can be no confidence that the sand will go in the direction of the weak current superimposed on the wave orbital-velocity field, especially for waves and currents that share significant codirectional or counter-directional components.

67. The asymmetric near bed orbital velocities under shoaling waves in the intermediate water depths of the nearshore have a potential transport bias in the shoreward direction (**Fig. 8-5, Appendix D of the Application**). This is the standard concept behind wave-driven sediment transport. The wave boundary layer effects described above, however, can mean that sand may not go in the direction of wave propagation. Nevertheless, as noted on **Section 8.4.1 of the Appendix D**, transport of sand in the direction of wave motion is generally anticipated, although more on the grounds of *conventional wisdom* rather than a definitive principle, given that the complications stemming from wave boundary layer effects are also well established.

68. On balance, however, the results of the wave-driven transport are just as, if not more, telling than the wind-related transport patterns. The anecdotal depositional evidence of Cr Dallimore's sonar record across the navigation channel, that is suggestive of fill entering the channel from the seaward side, is consistent with the potential transport indicated in **Figure 8-3 in Appendix D** of the Application. I find it inconceivable that sand is not bypassed from south to north around The Bluff, based on the Komar's (2005) review of sediment sources between Cape Kidnappers and Napier, and the unequivocal net littoral transport to the north, consistent with Advision model results **(Fig. 8-3)**. I also note in his review of previous studies, Komar wrote:

> *"The fine sand is most abundant in the nearshore zone off Westshore Beach where its percentage increases toward the beach (reaching 70% just seaward from the beach), in the vicinity of dump sites in shallower water, and immediately to the north and east of the Port's breakwater where it forms a distinct tongue that achieves concentrations of 70% fine sand (Hume et al., 1989; Figure 4.6). This tongue gives the distinct impression of its having arrived from the south,*

> *moving along the breakwater's arm and then entering the Fairway. Its arrival in the Fairway builds out an accumulation of fine sand along the eastern shoulder of the channel, with its rate of accumulation estimated by dredging records to be about 25,000 m^3/year. ...The accumulation of the fine sand in the Fairway to the Outer Harbour has had to be removed by periodic dredging, as have the sediments causing the shoaling of the Ahuriri Inner Harbour." (Komar, 2005, p.7-33/34.)*

69. The Advision plots of modelled annual-average sediment transport magnitudes and vectors **(Fig. 8-3)** indicate that a supply of fine sand from south of the Bluff to the subtidal seabed off Westshore would likely be possible, if not interrupted by the sediment sink formed by the Port navigation channel. This sink is therefore likely to contribute toward the nearshore sediment deficit off the beach at Westshore in two ways:

    a. interception of a nearshore sand supply from the south of The Bluff that might otherwise feed the Westshore subtidal area; and

    b. losses from the Westshore subtidal sand body into the navigation channel when weather and sea conditions prevail conducive to seaward transport of sand.

70. The above extract from Komar also indicates that hydrographic data are available to the Port that would provide details on the sediment sink characteristics of the navigation channel in relation to the relative location of sediment sources connected to it.

71. The seeming contradiction involving losses due to sand transport in opposite directions simply reflects the variable nature, the complexity, of sediment transport through time. That is, the Westshore coast is best understood as part of *sediment sharing system.* As in all such systems, morphological change over time involves transfer of sediment from sources to sinks (Stive *et al.*, 2002; Cowell *et al.*, 2003a,b; Stive, 2004). In the case of the subtidal seabed off Westshore, this area constitutes a source zone because of legacy effects from the 1931 uplift, as discussed above.

72. The existing navigation channel Port therefore most probably contributes to the Westshore subtidal sediment deficit. The magnitude of this contribution to the deficit can be estimated indicatively (roughly) from the ratio for volumes accumulating on the respective shoulders of the navigation channel reported by Komar (2005, p. 7-33/34), as outlined further above. The supply would occur at an indicative rate of 14,000 m^3/year if the if the navigation channel were absent. This quantity therefore provides an estimate for the contribution to the deficit in the nearshore sediment off Westshore that can be attributed to the interception of sand by the navigation channel.

73. The likelihood is that extension and deepening of the navigation channel will enhance the sink capacity for Westshore sediments. The consequence would be to further ensure sand, that may have fed the subtidal nearshore supplied from south of The Bluff, is intercepted before reaching Westshore.

74. I am of the opinion that disposal of suitable sand material at Site R goes some way to ameliorating the contribution of the Port navigation channel to the nearshore sediment deficit. This remedial effect is potentially even greater if suitable dredge spoil were also dumped within the southern extension of Site R. I base my opinion on apparent gravel beach stability conferred during previous periods of a well plenished subtidal seabed at Westshore, and from established principles for beaches and shorefaces.

75. The tendency to confer a stabilising effect on the gravel beach by nourishing the subtidal nearshore with fine sand appears to have been demonstrated through previous use of Site R for disposal of maintenance dredge spoil. Komar (2005, p.7-34) reports on this in his review. The stabilising effects on the gravel berm conferred by shallow nearshore sand deposits at Westshore are also evident from the two decades following the 1931 uplift during which beach time beach accretion at Westshore predominated (Kirk and Single, 1999). During this period, the subtidal seabed off Westshore was exceptionally shallow due to the uplift.

76. Improved stability of gravel nourishment fill at Westshore is apparent from past disposal of dredge spoil from the navigation channel at Site R. This provides useful confirmation that material dumped at Site R is suitable for nearshore nourishment consistent with the overall strategy for artificial nourishment to protect property, assets and maintain beach amenity at Westshore.

77. The strategy is already predicated on the understanding that renourishment is required regularly, because nourishment fill is progressively lost over time. The loss occurs because the beach, like the nearshore, is in disequilibrium due to historical accidents that have meant both the beach face and the nearshore at Westshore are overfilled with sediment. For this reason, application of overfill principles applied in beach nourishment design are of diminished relevance.

78. The suitability of channel-dredge spoil for nourishing the subtidal seabed off Westshore relates to the similarity of the grain size distributions of the dredge material and native nearshore sediments. Komar (2005, p. p.7-33) provides a useful summary of findings from surface sediments sampled by Terry Hume and his colleagues:

> *"They found that the offshore seabed sediments are instead dominantly fine (0.125-0.25 mm) to very-fine (0.0625-0.125 mm) sand, making up to 80 to 100% of most samples, the remainder primarily being mud. The fine sand is most abundant in the nearshore zone off Westshore Beach where its percentage increases toward the beach (reaching 70% just seaward from the beach), in the vicinity of dump sites in shallower water, and immediately to the north and east of the Port's breakwater… …The distribution of the very-fine sand (0.0625-0.125 mm) is in effect the inverse of the fine sand (0.125-0.25 mm). Seaward from Westshore, the very-fine sand represents only 10% of the sediment near the beach but rapidly increases offshore, reaching 50% at about the 7-metre depth contour. It is patchy through the central bay, but beyond the 15-metre depth contour it exceeds 70% of the bottom sediment…. The dredged sediments from the Fairway consist of muddy fine and very-fine sand,…"*

79. The description by Komar is consistent with analysis of samples taken from vibrocores, for which grain size distributions are plotted in Figure 4-1 in Appendix F of the Application. The distributions show that many of the samples have sediment compositions with a maximum of 10 percent less than 0.0625 mm (mud). This is less than the silt and mud content reported for subtidal seabed sediments offshore, summarised by Komar, in which silt and clay ("mud") comprise up to 20 percent of sediments in some samples.

80. The criterion for suitability of dredge spoil applied in nearshore nourishment can therefore be put at a maximum of 10 percent sediment with size less than 0.0625 mm. Areas to be dredged have already been mapped in respect of size distributions of sediments, which facilitates identification borrow ares areas from which obtain material for nearshore nourishment.

81. From this mapping, areas to be dredged in which sediments conform to this criterion can be identified as being north of line 719600 in respect of maintenance dredging, and in Area A for capital dredging, delineated in the Application. Data on loss of mud component of sediments during dredge uplift with trailer hopper suction dredges, provided by the operator of the Albatross dredge, indicate that about 77 percent of sediments less than 0.063 mm is not retained. The suitability of dredge spoil for nourishment of the nearshore is accordingly enhanced.

82. As discussed in the Joint Witness Statement following caucusing of Coastal experts, I consider that the southerly extension of the near coast deposition area R has potential benefits regarding nearshore sand placed closer to the southern end of Westshore, but

also negative potential effects regarding inundation of reef, impacts on the surf quality and increased sedimentation of Ahuriri Lagoon. None of these effects have been considered or quantified although deposition of dredged material has been occurring in this location for some time and the benefits identified through the surveyed beach profiles.

83. Previous studies conclude that coastline and associated seabed probably retain residual disequilibrium effects of 1931 uplift. Previous applications of fine to very fine sand within Dump zone R are generally thought to have had a stabilising effect on beachface in the vicinity of this disposal site. However, the placed material is expected to move from the placed location over time.

84. The effects of further seaward deposition locations haven't been assessed, would be more costly and takes sand out of the system which is already in disequilibrium and has a sediment budget deficit.

85. As noted in the Joint Witness Statement following caucusing of Coastal experts, witness for the Applicant agree that dredged sand deposited within southerly extension of R will add volume to *nearshore beach system but consider there remains considerable uncertainty on the longevity (and* therefore potential benefit) of any nourishment placed at Westshore due to the measured incompatibility of sediment grain size distributions of the dredged and native material.

86. I concur with experts for the Hawke's Bay Regional council that nourishment overfill principles are of diminished applicability under these circumstances because the sub tidal nearshore will continue to deflate, with negative consequences for the beachface even if nourishment is not applied to the fine-sand nearshore region.

87. As already noted, the ideal criterion for suitability of dredge spoil applied in nearshore nourishment can therefore be put at a maximum of 10 percent sediment with size less than 0.0625 mm. If identifying such material is seen by the Applicant as problematic, the reality is that any material of any grain size placed in Dump zone R will mitigate the effects of both the natural loss of sediments and the effects, agreed by all parties to the expert caucusing, of removing both the existing dredge volumes and any increased dredge volumes from the littoral system.

Why the deposition in the nearshore is important

88. The physical rationale for the dependence of alongshore-transport rates for gravel on the geometry of the sand bed fronting the gravel beach face is consistent with principles

about the behaviour of mixed sand and gravel beaches. These principles involve systematic changes in reflective beaches in general, and gravel beaches in particular, with variation in wave conditions (Hughes and Cowell, 1986; Powell, 1990; Diserens and Coates, 1993). More specifically, water depths immediately offshore from the beach face, and thus the height of the beach step at the base of the beach face, increase markedly with wave energy. This increase involves a lowering of the nearshore seabed, without the formation of offshore sandbars. Accompanying these changes, the beach face stretches horizontally such that the beach step extends seaward, while the upper beach face retreats landward by transferring sediment to the extending step. Differentiation of sediment sizes above and below the beach step (sorting) also increases.

89. The changes are quantitatively well correlated, and occur surprisingly quickly compared to responses of sand beaches to changes in wave conditions (Hughes and Cowell, 1986; Powell, 1990; van Rijn, 1998). The most remarkable aspect, in my opinion, is the speed with which the subtidal seabed lowers as wave energy increases, without the formation of offshore sandbars. (This first drew my attention to the phenomenon because of the threat it posed to my current metres and pressure transducers during field experiments on reflective beaches during field research toward my PhD.)

90. Conversely therefore, during periods of low wave conditions, water depths over the sand immediately seaward of the beach face decrease as the nearshore seabed builds back up. The height of the beach step accordingly becomes more subdued, as does the sediment size differentiation across the step. Under these conditions, the step relief may become negligible, and the lower half of the inter-tidal zone becomes increasingly dominated by sand. These conditions are often evident on the Westshore beach, and I have seen many photographs, showing what I describe, being circulated by coastal managers and the community during deliberations over the Application before this Hearing, and over management of the beach at Westshore more generally.

91. From these principles, we know that when the subtidal sand bed becomes lower in elevation, a corresponding increase occurs in the surface area and duration of gravel exposed to wave-breaking processes, including littoral drift. This behaviour has implications for a trend toward nearshore sand depletion at Westshore. The increased exposure of gravel to wave action can be expected to cause a corresponding increase in alongshore transport to the north of gravel used to nourish the beach. From this, the demand for increased gravel-nourishment volumes can be anticipated, and probably also a shorter interval between nourishment applications. The cost of maintaining the line at Westshore through use of gravel alone, accordingly, can be expected to increase over time.

92. For this reason I expressed the view at a public presentation, given at the request of NCC in 2017 on the erosion problem at Westshore, that supplementary nourishment of the nearshore with sand may provide a cheaper more efficient means of maintaining the coastal management objectives at Westshore. I am of the opinion for this reason, and the reasons given throughout this evidence, that disposal of suitable dredge spoil at Site R is a golden opportunity. This opportunity would be maximised in respect of benefits to Westshore if disposal includes the southern extension of Site R.

93. From the principles outlined in the preceding few paragraphs, it is possible to elaborate upon my opinion given above concerning loss of sand through northward littoral drift. As explained above, to the extent that this process contributes to the deficit in the nearshore sand budget, a corresponding reduction exists in nearshore sand re-entering the navigation channel. The elaboration is, that during periods of low wave conditions, much intermingling occurs of nearshore sand with beach face gravel in the lower half of the inter-tidal beach face and in the beach step.

94. Under these circumstances, the northward littoral drift that unequivocally occurs for gravel, also must occur for sand. During the rising phase of a storm conditions, as the mixed sediments are remobilised in the lower beach face and step, in accordance with the principles enshrined in the HR Wallingford model, a period of intense transport can occur for a limited period of time (several hours). From this it reasonably can be inferred that the risk of fine sand from dredge spoil disposed of at Site R is significantly less than might be concluded from the excess-shear stress wind driven sand transport results presented in **Appendices D and F** of The Application.

95. If continued nearshore sand loss is allowed to continue, without nourishment of the subtidal seabed off Westshore, sand loss rates can be expected to decline over time. This declining rate of sand loss alongshore, however, will likely occur at the expense of increased rates of gravel loss alongshore, as outlined above. That is, as the time average elevation of the nearshore sand surface decreases, the lower intertidal beach and step will become predominantly composed of gravel.

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