Before the EPA
Trans-Tasman Resources Ltd Ironsands Extraction Project

In the matter of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012

And

In the matter of a board appointed to consider a marine consent application made by Trans-Tasman Resources Ltd to undertake iron ore extraction and processing operations offshore in the South Taranaki Bight

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Statement of Evidence in Chief of Dr Dan McClary on behalf of Trans-Tasman Resources Ltd

17 February 2014

EXECUTIVE SUMMARY

1. TTRs proposal to extract, process and redeposit sediment in the South Taranaki Bight will have deleterious effects on the environment. These effects include the loss of habitat and biological communities on the seabed, displacement of pelagic organisms from the mining area and reduced primary productivity.

2. Understanding the relative scale and permanence of each of these effects is critical to the decision on whether to provide TTR with approval to operate in the PPA. To achieve this, TTR have commissioned extensive investigations into the local environment; in my evidence I rely on much of this work, as well as studies conducted overseas, to provide commentary on the relative importance of the major potential effects.

3. I used a risk assessment framework to evaluate the potential significance of the effects by calculating a risk score as the product of consequence and liklihood with values ranging from low to extreme. My assessment identified four moderate-high and 40 low risk effects; the moderate to high risk effects are as described below.

   (a) effects on benthic organisms within the direct extraction and deposition areas;

   (b) effects on benthic organsisms in the close vicinity of the extraction and deposition areas;

   (c) potential impacts on biogenic offshore habitats due the potential “choking” effect; and the

   (d) potential effects of unplanned events including biosecurity incursions and oil spills

4. There will be complete loss of all biota within the extraction zone. Approximately 3.5% of the habitat area between 20 and 40 m depth in the South Taranaki Bight will be directly affected in this manner. However, on an annualised basis just 0.25% of the habitat area will be affected; given that recolonisation and recovery will be a continual

process, I consider that the total amount of habitat that will be affected at any one time will be quite low.

5. In the close vicinity of the proposed activities, suspended sediments will have an effect on the local biota through shading of the water column and seabed. Due to the highly dynamic nature of the environment and the continually moving nature of the proposed activities as the area is progressivley mined, the long term effects of shading on primary production are considered to be relatively low.

6. I consider that the likely impacts on offshore biogenic habitats due to choking are relatively low. Mathematial modeling of plume dispersion and sedimentation suggests that the area falls outside the main zones of effect.

7. The effects of unplanned events, such as would arise through an accidental oil spill or inadvertent translocation of an invasive marine pest species to the area could be quite dramatic. These can, however, be avoided through the implementation of best management practices and it is recommended that approval of the application should be conditional on preparing and implementing such practices.

8. After examining the application documents and all of the ecologically relevant supporting evidence, it is my professional opinion as a marine scientist with over 25 years of experience that there is nothing within the scope of the proposed activities that should prevent approval of the application by the EPA. Uncertainties, where they exist, should be evaluated through a set of operating conditions, which include a phased programme of environmental monitoring to occur throughout the lifetime of the project.

Introduction

9. My name is Daniel Jay McClary. I hold Bachelor and Master of Science degrees in Biology from Mount Allison University, Canada and a Doctor of Philosophy (PhD) in Zoology and Marine Science from the University of Otago, New Zealand.

10. I am currently employed as Principal Scientist and Environmental Manager for Gardline Marine Sciences Pty Ltd, a wholly owned subsidiary of Gardline Marine Sciences Ltd, of Great Yarmouth, United Kingdom. From 2010 to 2012 I was the Marine Management Team Leader with Sinclair Knight Merz Pty Ltd in Perth, Australia and prior to that was based in Auckland as Principal Marine Scientist with Golder Associates (NZ) Ltd.

11. I am past Chairman of the Editorial Advisory Board of the New Zealand Journal of Marine and Freshwater Research and former President of the New Zealand Marine Sciences Society. I have had over 25 years of experience in marine environmental science research and consulting. My primary areas of expertise are in marine benthic ecology, environmental effects assessment and marine biosecurity science and management.

12. I, through Gardline Marine Sciences, was contracted to provide ecological advice to Trans Tasman Resource Ltd (TTR) in relation to their application to extract ore from the seabed in the South Taranaki Bight. The focus of my input was to provide an informed assessment of the effects of the proposed activities on the environment, notably with respect to benthic ecology, marine biosecurity (invasive species) and ecosystem-level effects. I drafted assessments that were incorporated in sections 12.2 to 12.7 of TTR's Impact Assessment.

Code of Conduct

13. I confirm that I have read the 'Code of Conduct for Expert Witnesses' as contained in Schedule 4 of the Judicature Act 1908 and the Environment Court Consolidated Practice Note 2011. I agree to comply with these Codes of Conduct. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

Scope of Evidence

14. My evidence focuses on matters pertaining to the effects of the proposed activities on the marine ecosystem of South Taranaki Bight. The areas upon which I provide comment are within my area of

expertise as a professional marine ecologist of more than 25 years experience. I also rely upon the Evidences in Chief of the following individuals: Dr. Anderson (Ecology) Dr. Beamsley (Oil Spill Modelling), Dr Grieve (Zooplankton), Dr Hadfield (sediment plume modelling) Mr Orpin (de-ored sediment particle sizes), Dr Pinkerton (optical effects), Dr. Vopel (water chemistry) and Mr Venus (environmental monitoring).

15. I was commissioned by TTR to evaluate the significance of the likely effects of the proposed activities on the environment. This requires consideration of a number of different lines of evidence, including the nature of the proposed activities, the spatial and temporal extent of the activities and their effects as well as the biological and physical processes that may be affected.

16. My evidence relates to consideration of the biological/ecological resources and processes that may be affected by the proposed activities. In considering these effects, I rely upon my personal experience and training and also upon the information provided by other specialists that had input to the Impact Assessment document.

17. In preparing my input to the Impact Assessment I reviewed all other relevant specialist reports, reviewed the outcome of a risk assessment workshop convened by TTR on 5-6 August 2013 and I met with NIWA and other specialists to discuss potential environmental effects on 30 January 2014. I also visited the sites of the Traps and Graham Bank in early February 2014.

Methodology and Limitations

18. In forming my opinions I have relied heavily upon the Evidences in Chief as noted in paragraph 6 above. In addition I provide a reference list at the end of my evidence, studies of which I have specifically cited within the text.

Risk Assessment Framework

19. I evaluated all available data as described in the paragraphs above. Following this review, I assessed ecological effects likely to arise across the entire project area from both routine operations and

unplanned events in terms of the nature, duration, scale and type of impacts.

20. I evaluated these effects in terms of a risk analysis based around a management protocol adapted from "AS/NZS ISO 31000:2009 Risk Management"[1], and a rationale set out in MFE (2011)[2], a report prepared for the Ministry for the Environment setting out the findings of an expert risk assessment of activities in the New Zealand exclusive economic zone and extended continental shelf.

21. In summary the approach adopted involved identification of ecological effects, consideration of the consequences of activities, the likelihood of that consequence occurring and the confidence with which the conclusion is reached. I subsequently derived a Risk Score calculated as the product of consequence and likelihood, with Risk scores expressed as:

(a) Low

(b) Moderate

(c) High

(d) Extreme

22. In my evaluation I gave consideration to effects in relation to the following ecological matters:

(a) Benthos

(b) Plankton

(c) Fish

(d) Birds

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[1] "AS/NZS ISO 31000:2009, Risk management - Principles and guidelines"

[2] MFE (2011) "Expert Risk Assessment of Activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf "NIWA Client Report No: WLG2011-39, September 2011, Published in May 2012 by the Ministry for the Environment, Publication No: CR 124.

(e) Habitat

(f) Water quality

(g) Ecosystems and biological diversity

OVERALL FINDINGS

23. My overall findings are set out in Table 25 of the IA (attached as Appendix A).

24. My assessment identified four moderate-high risk effects as described below. Primarily, these matters related to effects on benthic organisms in the vicinity of the direct extraction and deposition area, biosecurity, potential impacts on biogenic offshore habitats due the potential "choking" " effect, and the potential effects of unplanned events.

25. The following effect was considered to be of high environmental risk:

> *(1) Extraction of benthos at extraction site due to sand extraction, and smothering and burial from de-ored sand re-deposition. A particular effect was associated with direct impact on the habitat of the tubeworm Euchone sp. A.*

26. The following effects were considered to be of moderate environmental risk:

> *(2) Impact on near-field benthos due to de-ored sand deposition (same effect on Euchone sp. A – but at lower deposition rates across a wider area than the direct extraction and deposition zone).*
>
> *(3) Impact on offshore biogenic habitats due to "choking" – potential effect of elevated sediment loads in water column.*
>
> *(4) The potential for effects arising from Unplanned Events – including biofouling effects on native biodiversity through the incidental translocation of non-indigenous marine species to the project site and around New Zealand; and ecological effects from spills.*

27. My assessment also identified 40 effects which I considered to be of low environmental risk.

28. I address each of these moderate to high risk areas in the following sections of my evidence

EFFECTS ON BENTHIC ORGANISMS AND RECOLONISATION

29. There will be a direct impact on benthic organisms in the immediate area of TTR's extraction process. I have assumed that all sediment and sessile and sedentary benthic organisms will be entrained into the intake and pumped to the FPSO.

30. Initial screening will divert any hard bodied organisms (such as bivalves), but soft bodied organisms that have survived transit through the pump will be physically disrupted by the screening process, and 100% mortality of soft-bodied organisms is assumed. The remnants of these disrupted organisms will be returned to the sea-floor with the de-ored sediment stream.

31. It is my overall conclusion that the pumping and screening process is expected to result in complete mortality of organisms present in extracted seabed material. Re-deposition of de-ored sediment will also directly smother and result in the complete loss of any residual fauna remaining in pits after excavation.

32. The long-term environmental implications of extraction and deposition relate to, among other things, the rate with which the operational area will recover Biological recovery post-extraction and re-deposition will occur through natural processes of recolonisation of available habitats; I address these mechanisms in detail in the following paragraphs of my evidence.

33. Recovery of de-ored sediment (and near and far field areas) will be influenced by numerous factors, including the following:

    (a) Prevailing energy regime / hydrodynamics

    (b) Spatial scale and pattern of the disturbance;

    (c) Latitude;

    (d) Sediment type;

    (e) Depth of deposited sediments;

(f) Timing and frequency of the disturbance.

Each of these elements as they relate to the TTR proposal are addressed in the subsequent sections of my Evidence.

34. When compared to investigations conducted overseas (see Appendix B), relatively few studies have been undertaken into recolonisation of dredged sediments by marine macro-organisms in New Zealand. Notable studies have, however, been undertaken near Auckland, Nelson, Christchurch and Dunedin.

Prevailing Energy Regime

35. In a review of research conducted over nearly twenty years, Newell (2013) indicates that that the scientific consensus is that recovery of both substrate composition and biological community composition is relatively fast in high energy environments characterised by sands and colonised by fast growing, opportunistic species.

36. Recovery of dredged habitats in the UK was slowest in ‘low energy' environments (e.g., low tidal flows) where biological communities typically comprised of slow growing, long lived species and required many years to reach pre-dredge abundance and biomass (MESL 2002).

37. Habitats with the most rapid recovery time in the UK were those which experienced high levels of natural disturbance (e.g., strong tidal flows). In the Bristol Channel, for instance, physical impacts disappeared within a few tidal cycles and community recovery occurred within 6 to 9 months (Newell et al 1998); while the scale of activities was much smaller than for the TTR project, the inherent processes are the same.

38. Locations that experience relatively frequent wave, wind, and current induced disturbances, are typically inhabited by benthic assemblages that can readily re-establish themselves under conditions of high frequency disturbances. Such assemblages frequently have relatively low-diversity and are dominated by relatively small, fast-growing, opportunistic species.

39. These communities are naturally held in relatively early successional stages by the continuously disturbed nature of the environment and therefore are able to recover more rapidly than communities in more stable, less-disturbed environments. Marine organisms living in high energy areas, such as STB, are thus generally adapted to high levels of sediment disturbance as a consequence of frequent storms that pass through the area.

40. A benthic community naturally dominated by early to intermediate successional stages is evident in the TTR extraction area. The key, disturbance- tolerant species found in benthic sediments being two polychaete worm genera (*Euchone* spp., *Aricidea* spp.) and cirolanid isopods of the genus *Pseudaega* spp. (Beaumont et al 2013).

41. These genera are identified in numerous studies as opportunistic early colonisers and invasive species of sediments in a variety of studies conducted overseas (Gallagher & Keay 1998; Gilkenson et al 2005; Hewitt & Campbell 2010; Munari 2013). On the basis of the known and inferred life-history characteristics of the dominant taxa present and the highly dynamic nature of the environment in the PPA, I therefore anticipate relatively rapid recolonisation by these species in the TTR Project area.

Spatial Scale – Extraction Area Effects

42. In determining the scale of effects, I consider it essential to understand the spatial context of the proposed activities. Although the direct footprint of extraction, for example, is less than the total proposed mining area (due to operational matters), for the purposes of my evidence I assume that the entire area will be mined.

43. The total application area is 65.76 km^2, falling into a broad band of between 20 and 40 m depth. The area of the South Taranaki Bight that falls between 20 and 40 m depth is approximately 1,860 km^2 (see Appendix C attached to my evidence), thus approximately 3.5% of the seabed of this type will be directly affected by extraction activities during the 20 year life of the Consent.

44. The TTR proposal will see a harvest of approximately 50 MMT per annum using a crawler having a throughput of approximately 8000 t per hour. At that rate, 50 MMT will be extracted within 6,250 hours or approximately 260 operational days per year.

45. The TTR proposal indicates that extraction from a single 300 m x 300 m block will be completed within 5 days. On that basis, 52 such blocks may be completed within a 260-day operational year for a total dredged area of 4.7 km^2, equating to 0.3% of the total available habitat area in the South Taranaki Bight between 20 and 40 m depth.

46. There have been extensive investigations of the effects of dredge-mining for marine aggregate material around the coast of the UK. These operations can result either in 8-10 m deep, saucer-shaped depressions or long, 2-3 m wide furrows in the seabed, depending on the type of equipment employed (Hill et al 2011).

47. During the peak harvest of marine aggregates in the UK, approximately 20 million metric tonnes (MMT) of material was harvested from the seafloor per annum. This material was extracted primarily using trailer suction dredges from a ‘worked’ area of approximately 141 km^2 (Hill et al 2011). The average rate of extraction therefore equated to 0.14 MMT per km^2 per annum.

48. As per the area calculations noted in Paragraphs 42 to 45 above, the average rate of extraction in the TTR proposal is thus approximately 10.6 MMT per km^2 per annum. However, the majority of this material is re-deposited to the seabed following ore extraction. The average (net) rate of extraction therefore equates to approximately 1 MMT per km^2 per annum.

Spatial Scale – Near Field Effects

49. Effects will also be likely outside the direct zone of extraction. Sediment processing and redeposition of the de-ored sediment onto the seabed will all result in the production of a plume of suspended sediment. The dispersal of this plume has been modelled by Dr Hadfield and he discusses this in his evidence, which I have reviewed.

50. Dr Hadfield's modelling of the plume dynamics may in one sense be considered to present a 'worse case' scenario of an immobile point source working the same location for a full year (two different locations were modelled), whereas the source will be continually moving throughout the year (at a rate of a single 300 m x 300 m block in 5 days). Despite this accepted limitation, Dr. Hadfield's evidence indicates that the dispersal of the sediment plume will be highly variable over time, such that the potential for sedimentation on the seabed and shading will be both spatially and temporally highly dynamic.

51. I have also reviewed Dr. Pinkerton's evidence on the effects of the sediment plume on optical qualities of the water column. Dr. Pinkerton notes that there is evidence from satellite imagery that suspended sediment concentrations in excess of 4000 mg/L may be transported over 30 km from the STB shoreline; thus the baseline condition for the area is one of extremely variable levels of suspended sediment.

52. Research on benthic communities affected by dredge-mining in other areas of the English Channel (Newell et al 2004) revealed an unexpected positive impact on benthic communities outside the dredged area, but within the boundaries of the sediment plume.

53. Species richness, population size, biomass and mean body size were all markedly elevated at sites affected by the dredge plume. This effect was particularly noted to result in enhancement of the 'downstream' populations of suspension feeding invertebrates, possibly due to increased levels of organic material in the water column.

54. A similar impact was noted in Moreton Bay, Queensland as part of a smaller project following dredging of the harbour approaches (Poiner & Kennedy 1984). This was attributed to a release of organic matter in the plume from sediments disturbed by dredging.

55. In a study of the effects of hydraulic dredging on seabed biological communities over two years, Gilkenson et. al (2005) focussed on sandy substrates in depths of 70 - 80 m, approximately 120 nm from shore on the Scotian Shelf in the North Atlantic Ocean. The authors described

the benthic assemblages over a three year period prior to and after a program of experimental dredging at the site.

56. The authors noted an increase in abundance in populations of suspension feeding polychaetes and small crustaceans in those areas immediately adjacent to the dredge footprint that were subject to 'secondary sedimentation' (from the resultant sediment plume) and direct burial.

57. Abundance of the polychaete *Euchone papillosa* was largely unaffected by dredging in samples collected immediately after dredging. In each of the two years following dredging, however, abundance of *Euchone* and another opportunistic polychaete, *Spiophanes bombyx* in these nearby areas had increased by over 100%.

58. The authors suggest that the mechanisms contributing towards this increased abundance could have included heightened reproductive activity within the dredged areas in response to disturbance as well as larger scale natural pulses of recruitment.

59. Given the highly dynamic physical environment at the PPA, the spatially variable nature of the plume and the potential for positive impacts in the near-field, I consider it unlikely that smothering of the seabed biota in nearby biological communities will have more than a transient and spatially restricted effect.

Spatial Patterns Affecting Recovery

60. Re-colonisation of de-faunated dredged areas will occur from adults migrating from adjacent relatively undisturbed areas, or from larval recruitment from adjacent areas, along with those more distant.

61. The spatial scale and pattern of the dredging or disposal area may proportionally influence recovery times, particularly in relation to the migration of nearby organisms to the disturbed area.

62. In some studies rapid recolonisation of unconsolidated sediments in dredged channels has been attributed to slumping of non-dredged

sediments into the dredged furrows, thus incidentally translocating entrained benthic infauna.

63. In particular, the ratio of the edge/surface area of the disturbance may be an important determinant of natural recolonisation. This ratio may thus be used as a predictor of relative rate of recolonisation (Newell 2013)

64. For small-scale disturbances, the edge/surface area ratio of the disturbed area is large relative to that for spatially more extensive disturbances. The greater the edge/surface area ratio, the greater the potential for recolonisation through adult immigration from surrounding undisturbed 'edges.'

65. One evaluation of 14 studies of recovery at dredging and disposal sites (Guerra-Garcia et al. 2003) demonstrated a log-linear relationship between recovery time and spatial scale. Recovery in small patches (1,000 m^2) took approximately 6 months, whereas recovery was projected to require over a year at spatial scales of 10,000 m^2 and above.

66. A pattern of numerous, relatively small areas of disturbance may thus facilitate more rapid recovery than for patterns of spatially extensive disturbance. Recolonisation of the central portions of larger disturbed areas is therefore increasingly reliant upon settlement from the water column, which will, in turn, be dependent on seasonal recruitment patterns and local hydrodynamics.

67. Overall the studies suggested that recovery of the benthos is facilitated through the use of a series of relatively small actively dredged zones. Such zones would be fully exploited then left to recover through natural processes (Newell 2013).

68. In the US, dredging sand for beach nourishment typically results in either the creation of relatively shallow borrow pits that are refilled by sand movement and are rapidly recolonised by opportunistic infauna, or the creation of deeper pits that become depositional areas where fine sediments accumulate and sand-associated assemblages are replaced by soft-bottom fauna. If borrow pits are deep enough that water

circulation is restricted, hypoxic or anoxic conditions may result in a depauperate infaunal community.

69. The TTR project involves infilling of extraction areas other than at the end of lanes and thus there will be minimal areas of residual pits. Over the broad extraction area, after initial infilling, it is expected that the residual seabed might be 1 m below its present level and over time this depression will fill. Given the highly dynamic wave-energy regime of the PPA, I have therefore concluded that the depressions in the seabed will not adversely impact on recolonisation.

70. TTRs extraction process involves use of a Crawler to cut 10 m ‘lanes’ and replacement of de-ored sediment into adjacent areas. This should facilitate recovery from areas in close proximity. The narrowness of these extraction and deposition ‘lanes’ will likely assist quicker recolonisation process than if for example extraction was undertaken over a large area, with de-ored sand disposal occurring some time later.

71. The proposed extraction methodology will also increase the opportunity for rapid recolonisation from nearby undisturbed habitat as a result of the cross-current orientation of the dredging “lanes”.

72. Individual “lanes” will be subject to continuous extraction and backfilling such that the maximum area of disturbance at any one time will generally be only 300 m x 300 m. Once the area is backfilled it will be immediately available for recolonisation and once recolonized, act as a source population for nearby disturbed habitats.

73. I have also evaluated the potential risk of Grade control drilling to be low. The surface area affected by grade control drilling will be no more than 0.05 m^2 per drill with the rig footprint occupying around 4 m^2. This area is minimal in comparison with the anticipated extraction area. Accordingly, I would anticipate no additional adverse effects in relation to grade control drilling.

74. Based upon the nature of benthos, spatial pattern and extent of activities within the PPA, I estimate that recolonisation would take place within a timeframe of 1-2 years.

Geographical Latitude

75. Relatively rapid recovery has been noted to occur in warm temperate and sub-tropical disposal areas, while longer recovery rates (up to several years) have been observed at higher latitudes. This may be related to temperature-dependent processes though other environmental factors are likely to also play a part; 'latitude' may be a surrogate measure for consideration that integrates several different environmental variables.

76. I have evaluated data for recovery in a Hauraki Gulf dredge spoil disposal site (located at a lower latitude than the STB) which indicated a rapid recovery characterised by re-establishment of a benthic community within timeframes of the order of months. Data for the Lyttleton Harbour (higher latitude than the STB) dredging programme indicates recovery post-disposal commenced rapidly, such that polychaetes become established within a year. Monitoring undertaken in Tasman Bay for the Port of Nelson (similar latitude to STB) dredging disposal programme indicates very rapid rates of recovery (of the order of 4-6 months).

77. The studies referred to in the preceding paragraph of my Evidence refer to recovery and recolonisation in a variety of different environments. While none may be completely applicable to the TTR proposal in the South Taranaki Bight, the range of studies is used to set a broad range of conditions within which recolonisation has occurred.

78. The South Taranaki Bight is located in the warm-temperate waters of the Tasman Sea. Solely on a latitudinal basis alone, recovery of the benthos might thus be expected to fall within the broad range recorded to date in the temperate latitudes of New Zealand. Other environmental factors will, however, affect the recovery rate; these are discussed in subsequent sections of my evidence.

Sediment Type

79. Rapid recolonisation of soft-bottom benthic habitats is frequently associated with either unconsolidated fine grain sediments or the rapid dispersion of fine-grained dredged material by currents. Typical

recovery times of 1-3 years have been documented for coarser sand and gravel substrata (Newell et al 1998).

80. In relation to the Port of Otago dredging project James et al. (2009) predicted that the highly mobile sand habitat near the harbour entrance would likely recover from dredging disturbance through dispersion of larvae and bed transport.

81. James et al. (2009) commented that, in relation to the Port of Otago dredging's disposal site, recovery was fastest when dredged and spoil sediments are well matched (i.e., similar grain size). Once disposal ceases, recovery could take up to a year for early pioneering species and several years for large animals. In sandy locations of the dredging area, recovery was thus considered likely to occur over the medium term (1-5 years).

82. Monitoring undertaken in Tasman Bay for the Port of Nelson dredging disposal programme indicates that the site has been permanently altered to a sandier substrate and very rapid rates of recovery have been observed (4-6 months) (R Sneddon, Cawthron Institute unpubl. data)

83. Existing surficial sediments in the TTR extraction area are typically medium to fine sands (150-500 µm). Finer material has been "winnowed" out because of re-working by wave activity.

84. The sediments in the STB area are fine-medium sands with little coarse sand or gravel, thus the general rate of recolonisation should be relatively rapid.

85. TTR's extraction process collects all sediments, processes it to remove the ore and then passes residual sediments through hydro-cyclones to strip out fine particles (most of which arise from the milling process on the FPSO). The de-ored sand deposited back to the seabed will have a similar particle size distribution to that present on the seabed surface prior to extraction (refer to Dr. Orpin's Evidence), therefore change in particle size should not in itself pose an impediment to recolonisation.

Depth of Deposited Sediments

86. Some benthic organisms such as burrowing polychaetes, amphipods and molluscs can colonise newly deposited sediments through vertical migration. If deposited sediment depths are within the vertical migration capacity of these organisms (20-30 cm), recovery rates may, therefore, be more rapid than if colonisation is dependent upon the lateral migration of juveniles and adults from adjacent areas and larval settlement.

87. Successful vertical migration through 15 cm of sediments occurred for benthic infauna in Auckland (Roberts et al 1988), and mud snails in Delaware Bay (Miller et al 2002). Successful movements through up to 32 cm have been documented for polychaetes (Mauer et al 1982) and bivalves (Mauer et al 1981). The amount of the deposit and the frequency of deposition are interactive factors affecting vertical migration for nematodes.

88. Vertical migration of juveniles and adults through the deposited sediments is also thought to contribute to relatively quick recovery rates in areas with shallow deposits. While such vertical migration would not be relevant where de-ored sediment is returned to the seabed, it would be a factor to consider in the area affected by deposition from the dredge plume.

89. The nature of deposited sediments can also have a bearing on ability for recolonisation. For example experiments with clay deposits in an Auckland estuary demonstrated that clay layers as thin as 0.3 to 0.7 cm had some impact on macrofauna, but were relatively short-term (Berkenbusch et al 2009). Conversely, rapid accumulations of thicker layers of fine sediments (> 2 cm of clay) were found to smother entire benthic communities.

90. In these situations (which will differ on a case-by-case basis), recovery of sediment properties and benthic communities was found to take a few months for opportunistic species like many polychaete worms and several months to a few years for larger taxa like some gastropod molluscs.

91. The re-deposited de-ored sands from the TTR project will not contain clays such as those noted above; these sediments will have a very similar particle size distribution to the ambient seabed, with the removal of iron being the only significant difference. Accordingly, recovery should begin very quickly and be well advanced (in the absence of any other disturbance, for example by bottom trawling) within timeframes of months to a years.

92. In the immediate deposition area the thickness of de-ored sand will be of the order of 4-5 m, so vertical movement of biota is unlikely to occur. However, the deposition of material offsite in the nearfield and farfield areas (i.e. not within the dredge footprint or away from the operational area) has been modelled by NIWA to be in the order of a few mm per year.

93. Hewitt et al (2003) tested the effects of a range of suspended sediment concentrations on the behaviour, 'condition' and mortality of 5 common marine invertebrates in the Auckland region: the scallop *Pecten novaezealandiae*, the tube worm *Boccardia* sp., the snail *Zeacumantus* sp., the wedge shell *Macomona* sp. and the heart urchin *Echinocardium* sp. This scallop and the heart urchin are both found within the potentially affected area so can be used as a direct comparison; the tube worm, snail and wedge shell can offer other potentially useful surrogates for similar species found near the project area (Beaumont et al 2013).

94. The authors found that the effects of different concentrations of suspended sediment, ranging from 50 mg/L (control) to 850 mg/L, had variable impacts on the species tested. The greatest effects were seen in the heart urchin and wedge shell, in which mortality rates increased as the level of suspended sediments in the water column increased, while in the scallop and tube worm the overall condition and feeding rates declined and no effect on the snail was observed even at the highest sediment concentrations tested.

95. Szostek et al (2013) recently found that the scallop *Pecten maximus* was able to tolerate levels up to 100 mg/L of suspended sediment as well as survive burial by coarse to medium sands. Growth rates did,

however, decline under conditions of elevated suspended sediments and the test animals were not able to survive burial by fine sediments.

96. In response to mass mortalities of coastal bivalve species, Angioni et al (2010) tested the effects of suspended sediments (250-500 mg/L; 750-2,000 mg/L; 2,250-2,500 mg/L) on shallow subtidal (5-10 m depth) clams (*Chamelea gallina*) in Italy. The authors recorded no correlation between adult mortality and the level of suspended sediments present in the test chambers, indicating that for this species at least, even very high levels of suspended sediment can be tolerated by nearshore/coastal bivalve taxa.

97. Modelling by Hadfield (2013) suggests that the median level of sediment that will be accumulate in some areas of the STB deposited in a given 5 day period will be generally less than 1 mm more than a few km away from the source. Median suspended sediment concentrations near the surface will increase by 5 mg/L near the source, and 99% of the time will be less than 20 mg/L near the source; near-seabed suspended sediment concentrations are expected to normally be less than 20 mg/L (median) and 99% of the time will be less than 100 mg/L near the source.

98. Overall, I conclude from these studies that the effects upon benthic communities in the ‘near-field’ are likely to be minimal. These near-field communities will therefore provide an on-going source of propagules for recolonisation of the surficial layers of the immediate deposition area.

Timing of disturbance activities

99. For the Port Otago dredging project, James et al. (2009) suggested that populations might be less vulnerable if dredging took place in winter as although there may be continual or pulses of recruitment during the year the majority of benthic recruits are more likely to settle in the warmer months (spring/summer) (Roper et al. 1992, NIWA, unpublished data).

100. TTR’s anticipated excavation rate is around 4-5 hours for each 300 m x 10 m excavation “lane” will mean that the extraction and deposition

impact at each site will be of very short duration, meaning that there will be on-going opportunity for recovery on a continuous basis throughout the year. The timing of extraction and redeposition activities should not, therefore, have any major effect upon the processes of recruitment and recolonisation of the seabed in the PPA.

Consideration of TTR Effects on Potential Larval Settlement Behaviour

101. Recolonisation of disturbed sediments by benthic invertebrates is dependent, as discussed above, on a variety of factors, including the nature and extent of nearby communities (potential source populations), the physical structure of the seabed and environmental factors such as light, temperature and currents, among others.

102. The seabed within the TTR extraction and re-deposition area is considered to be a dynamic environment in which populations of organisms living within this environment must be either fully mobile or, if not, capable of rapid recolonisation following disturbance. As noted in paragraph 40 above, the main sessile species that are present in the TTR extraction and re-deposition area are opportunistic taxa, frequently among the first organisms to colonise a disturbed area.

103. A number of generalisations may be made which describe the key environmental drivers of settlement and recolonisation in the TTR area. Typically, macroinvertebrate larvae preferentially select appropriate chemical cues present on the substrates on which to settle and grow. Such cues may be comprised of the metabolites of extant species in the area, specific bacterial flora or simply the presence of foodstuffs (either grazed or prey species), among other things.

104. The processes involved in extracting the ore from the seabed and dewatering the sands will likely result in the modification of much of the existing chemical cue-structure upon which benthic macro-organisms settle. It is expected, however, that organic material (remnants of the disrupted organisms) will remain in the de-ored sediment and process water.

105. The dewatered sand that is deposited into the furrows on the seabed will, however, be subject to the same natural processes of succession

that govern colonisation of any artificial structure or surface in the marine environment. These general processes may be summarised as follows:

(a) Deposition of the dewatered sand into the dredge furrows;

(b) Rapid colonisation of the surficial sediments by bacteria, microphytobenthos and mobile epifauna (e.g. errant polychaete worms, epibenthic/demersal fish); this will begin almost immediately upon settling of the sediments on the seafloor;

(c) Continued winnowing of the surficial sediments by the extant physical processes (currents, waves, storm events);

(d) Colonisation of winnowed sediments by short lived, opportunistic species living in the vicinity; this will typically occur within 1-2 generations (on a scale of months to years, depending upon the taxa involved);

(e) Continued colonisation by opportunists with increasing levels of larval settlement by longer lived species; and,

(f) Displacement of the opportunistic species by longer lived taxa if they occur in the area (and in the absence of further significant disturbance)

106. As discussed in paragraphs 52 to 58 of my Evidence, there is also the possibility that suspension feeding communities downstream of the dredge plume and outside the directly affected dredge footprint are enhanced through additional nutrient availability in the water column.

107. In general, after an initial disturbance to seabeds such as in the STB, "pioneering" organisms, such as small, tube-dwelling polychaetes and small bivalves colonise the surficial sediments. These opportunistic taxa occur in relatively high abundances and low diversity.

108. The benthic biological communities present within the TTR extraction and re-deposition area are dominated by short lived, opportunistic species; the locally abundant polychaete genus *Euchone* and others including *Aricidea* and also a number of syllid and photid polychaetes

are known as early colonizing, relatively short lived genera. The relative absence of longer-lived taxa in the benthic samples is indicative of a highly disturbed environment.

109. The de-ored sand discharged back to the seabed will have a similar particle size distribution to that present on the seabed prior to extraction; the de-ored sands will not contain clays which have been found elsewhere to inhibit re-colonisation. I therefore do not consider that changes in grain size will pose any impediments to recolonisation of the seabed.

110. Although TTR plans to extract year round, timing in relation to larval recruitment is not expected to be significant due to the scale of the Project area relative to the broader STB and the long term nature of the Project. TTR's anticipated excavation rate is around 4-5 hours for each 300 m x 10 m excavation "lane", followed by deposition over a similar timeframe, albeit separated by approximately 5-10 days.

111. Overall impacts due to extraction and deposition activities at each site will be of relatively short duration, meaning that there will be ongoing opportunity for natural recruitment and recovery on a near-continuous basis throughout the year.

112. Offsite deposition of material (nearfield and farfield) has been predicted to be in the order of 1 mm. As a consequence I consider that negative impacts on benthic communities away from the extraction area and immediate deposition area therefore likely to be minimal (and as discussed in Paragraphs 52 to 58 above, may be positive in nature). The remaining/regenerating communities thus present an on-going source of propagules for recolonisation of the surficial layers of the impact zone.

113. Given expected patterns of natural recruitment and recolonisation of the seabed following disturbance I consider that the dredged area will be 'devoid' of life for only a very short time following re-deposition of the de-ored sediment.

114. The ongoing removal of the natural biota of the area will, as discussed above, have a negative impact on biological assemblages in the

dredged footprint. These effects will, however be both localised and transient in nature.

115. To put this statement in context, the area to be dredged per year is approximately 4.7 km^2 (see paragraph 45 above) over a period of 20 years. As a gross comparison, the total coastal area in the STB that falls between 20 and 40 m depth is approximately 1850 km^2 (see Appendix C attached to my evidence).

116. If this may be considered approximately equivalent habitat to the TTR Project area (Dr Anderson indicates in her Evidence that benthic assemblages at sites within the TTR project area did not differ significantly from other areas she examined within the South Taranaki Bight), then just 0.25% of this habitat is affected annually by the proposed activities. Should full recovery of the seabed ecology in disturbed areas take as long as three years (I consider this to be a 'worst-case' scenario), then less than 0.8% of the total habitat area in the STB will be affected at any one time once operations are underway.

117. In addition, the potential increase in abundance and biomass in areas within and downstream of the dredge plume (see discussion in Paragraphs 43 to 58 above) may offset any localised and transient reduction in recruitment pressure in the dredge footprint.

118. Given this relatively small area is being taken out of active production of larvae for a relatively short time, I consider that the cumulative effects on invertebrate recruitment processes will be negligible. Based on my evaluation of species present, it is my opinion that larval settlement and recruitment processes onto the dewatered sand that is deposited into the furrows will occur in a similar fashion and timescale as on the natural seabed.

119. In my opinion, the cumulative impacts on the coastal ecology of STB will not, on this basis, be excessive, nor even detectable at an ecosystem scale.

Summary -recovery of the seabed biota

120. The extant benthic communities within the TTR extraction and re-deposition area are dominated by both sessile suspension and motile deposit feeding polychaetes, with just 5 taxa (of over 200 collected in epifaunal cores) comprising over 40% of individual abundance in the collected samples.

121. Currently the timing and frequency of natural reproduction and recruitment by these numerically dominant benthic taxa, primarily polychaetes (including *Euchone* spp, *Aricidea* spp., syllids, para syllids and photids) is unknown. ‘Early to mid-stage successional taxa such as these, however, typically colonise disturbed environments, generally have short generation times and multiple reproductive periods per life cycle, facilitating rapid recruitment.

122. Although these organisms will be removed from the processed sediments, the approach to extraction in 10 m wide lanes, with re-deposition of de-ored sediment, will provide undisturbed source populations in very close proximity, permitting rapid natural recolonisation within a few generations. It is expected that the mobile organisms will immediately begin to re-colonise the disturbed area following re-deposition of the de-ored sediment.

123. In addition and given the natural disturbance history of the seabed in this high energy environment, it is considered that nearby populations of benthic organisms will serve as sources for new recruits, both through natural movements/migration of mobile adults and reproductive processes. It is expected that the mobile polychaetes and isopod populations will relatively rapidly redistribute themselves across the deposited sediments.

124. Recolonisation of the seabed post disturbance is thus expected to be relatively rapid. Mobile organisms (e.g. Opalfish, Scallops, and some polychaete worms) will be capable of moving back into the area immediately post-disturbance. These species of benthic dwelling organisms are adapted to a sediment environment such as that which will arise outside the immediate deposition zone.

125. Defaunation of the entire project area for the duration of the project life will not occur. The pattern of disturbance (numerous small areas sequentially mined) will permit relatively rapid regeneration through natural processes. As discussed in Paragraph 116 of my evidence, I consider that the detectably affected area will not exceed 0.8% of the total habitat area between 20 and 40 m in the STB once activities are in progress.

126. Overall, recolonisation of the project area, including the re-deposited, de-ored sediments by local organisms is expected to occur very rapidly, with full recovery expected on a scale of months to years.

Effects on *Euchone*-dominated habitat

127. Beaumont et al (2013) provide a detailed description of the benthic ecological communities present within and adjacent to the PPA; infaunal assemblages (those organisms living within the seabed sediment) were investigated by collecting 15 cm thick samples and identifying and counting all organisms present. In her evidence, Dr. Anderson provides a detailed statistical treatment of the seabed benthic assemblages in the uppermost 5 cm of these sediment samples; Beaumont et al (2013) noted that the entire 15 cm thick sample could not be evaluated using these multivariate analyses due to methodological limitations in sample collection.

128. While this necessary analytical bias excludes from consideration some important components of the seabed assemblages that are under-represented in the uppermost 5 cm of each sample, I consider that the conclusions surrounding the relative importance of the different species present is largely accurate and reflects the broader nature of the infaunal communities present.

129. In her evidence, Dr. Anderson details the relative importance of the 'wormfield' communities in the PPA, numerically dominated by the presence of the sabellid polychaete *Euchone* sp. A. This genus of tube-dwelling worm is known from temperate sediments world-wide and has been reported in a number of studies of the effects of dredging on benthic assemblages. I have discussed the effects of dredging on

members of this genus already in my Evidence, referring to an investigation of the positive impacts of hydraulic dredging on the genus (Gilkenson et al 2005; paragraphs 55-58 of my Evidence).

130. The genus has also been recorded in Boston harbour (Gallagher and Keay (1998), San Francisco (Thompson et al 2000) and at several temperate ports in Australia where it is recorded as an invasive species (Hewitt & Campbell 2010). Parry et al 1997 indicated that a previously unidentified species of *Euchone* was the only invasive species within Portland harbour to be sufficiently abundant to cause a significant ecological effect on the seabed environment. Within New Zealand the genus has been recorded in invasive species surveys at the Ports of Gisborne (Inglis et al 2005), Timaru (Inglis et al 2006, 2008a), Nelson (Inglis et al 2008b) and Taranaki (Inglis et al 2008c).

131. While populations of *Euchone* within the PPA will definitely be affected by the dredging, the overall impact on this organism in the South Taranaki Bight is considered relatively low. As Dr. Anderson reports in her evidence, the organism is found outside the dredge footprint (albeit in lower numbers) and retrospective evaluation of samples from previous investigations in the area (e.g. within the Kupe pipeline corridor; Page et al 1992) suggests that it has been present within the STB for some time.

132. The exact distribution of this animal within the STB and the wider New Zealand region is as yet unknown, but there is no reason to suspect that it is restricted to the area thus far studied. Indeed, given the well documented ability of the genus to rapidly colonise new areas, I consider it likely that it will be found in similar exposed, relatively disturbed coastal habitats throughout the country.

Effects on Offshore Biogenic Habitats

133. Benthic habitats offshore from the TTR extraction and re-deposition area are comprised of bryozoan dominated communities and shellfish dominated communities. Both these communities are characterised by the presence of shell debris and other potentially biogenic (produced or brought about by living organisms) material.

134. Offshore 'bryozoan rubble' habitats are found predominantly in waters of greater than 60 m depth, whereas the 'bivalve rubble' habitats (dominated by shells of the dog cockle *Tucetona laticostata*) are found primarily in shallower waters (Beaumonth et al 2013).

135. The spatial location of the *Tucetona* bivalve populations appears to be temporally stable, and along with considerable shell debris forms a dominant biogenic habitat above 60 m depth; this biogenic debris (the 'bivalve rubble') supports a range of early successional stage colonisers. This is indicative of a high energy habitat.

136. In contrast, the shell debris below 60 m (the 'bryozoan rubble') is heavily encrusted with late stage colonisers, dominated by branching bryozoans. These, along with a wide variety of other sessile suspension-feeding invertebrates, collectively bind and stabilise the shell debris, providing further structural refuge for a diverse array of motile species (Beaumont et al 2013).

137. Total abundance and species richness were both significantly higher in these deeper biogenic habitats, than in the comparatively depauperate mid-shelf (TTR extraction and re-deposition area and adjacent areas) and inner shelf habitats - with the exception of rocky outcrops. Total abundance and species richness was also higher in the later-stage bryozoan/rubble habitat compared to the more poorly colonised shell debris of the bivalve beds; further offshore (>80 m), the biogenic zone became less abundant.

138. The potential for the TTR Project to affect communities offshore of the Project area depends upon the likelihood of the sediments disturbed by the activities to be redistributed over those offshore areas. Examination of the seabed imagery reported by Beaumont et al (2013) suggests that the environment in this offshore biogenic habitat is much more 'depositional' than in the shallower waters of the PPA; relatively minor increases in SSC and deposition are considered unlikely to have a marked effect upon the benthic communities present, as they are already adapted to a depositional environment

139. From my review of Hadfield (2013), I would expect that suspended solids concentrations (SSC) in the offshore biogenic region near the water's surface of less than approximately 5 mg/L and less than 60 mg/L near the seabed. In neither source scenario does the expected SSC change markedly over the areas occupied by the biogenic habitats when compared to baseline conditions.

140. Deposition modelling similarly predicts that the potential for accumulation of sediments on the seabed to be less than 0.1 mm per year over the biogenic habitats. All these predicted values are very low and not different than under baseline (no mining) conditions and in my opinion would not adversely affect the offshore biogenic habitats

141. Higher than anticipated SSC over the biogenic habitats could potentially have an effect on the seabed biota. Such effects could include smothering and direct mortality of the seabed biota and/or, clogging of the feeding/respiratory structures, resulting in reduced fitness or condition.

142. The organisms present in these habitats, however, appear to be relatively tolerant of suspended sediments. The major groups recorded by Beaumont et al 2013 (refer to Figure 12) include fish (seaperch and triplefins), echinoderms (brittle stars and sea cucumbers), bivalves (*Talochlamys*, *Tucetona*) and a mixed assemblage of sponges and branching bryozoans. The latter group, generally occurring in the deeper waters sampled, would be least tolerant of increased suspended sediment loads and sedimentation on the seabed.

143. Given, however the very dynamic nature of the environment, I consider that the sediment loads would need to be very high and both spatially and temporally persistent to have any detectable effect. Dr Hadfield's modelling, as presented in his Evidence, clearly indicates that the sediment plume from extraction and deposition activities is highly variable in space and time; the model, run over a 300 day period, suggests that frequency with which the plume impinges on the offshore biogenic habitats is very low.

144. Overall I conclude that the potential for effects on the offshore biogenic habitats in relation to TTRs activities to be very low.

Effects on the North and South Traps and Graham Bank

145. Observations of the seabed were made at several sites at the North and South Traps and Graham Bank, in order to help characterise the seabed communities and natural values that might potentially be affected by the proposed activities. Visual surveys of the seabed habitats in these areas were conducted in early February 2014 by diver and drop camera, with high definition video files retained as a record.

146. The North and South Traps sites as surveyed by divers were characterised by classic 'urchin barrens' communities (e.g., Shears & Babcock 2004, with rocky outcrops and ridges dominated by sea urchins *Evechinus chloroticus* and low growing red and brown macroalgae; a few isolated *Ecklonia* sporophytes were present and the conspicuous fish species noted included Leatherjackets (*Parika scaber*), Blue Cod (*Parapercis* colias), Red Moki (*Cheilodactylus spectabilis*) and Blue Maomao (*Scorpis violacea*). Unconsolidated seabed sediments within the Traps were generally less than 10 mm thick and were underlain by a hard rock basement.

147. A bathymetric and video survey of the Traps was also conducted by ASR Ltd. For the Taranaki Regional Council to produce habitat maps of the area (See Appendix D attached to my evidence). They recorded similar features as were noted in the present survey with the addition of patchily dense stands of *Ecklonia radiata.*

148. Observations made on and just shoreward of Graham Bank revealed rippled, very coarse sandy/shelly to pebbly substrate on the seabed with occasional scallops (*Pectin novaezealandiae*) and pagurid hermit crabs present.

149. Two drop camera stations on Whenuakura Spur revealed a rippled coarse sandy substrates. An additional drop camera station along the westward periphery of the North Traps revealed rocky outcrops several Blue Cod, John Dory (*Zeus faber*) and small schools of Leatherjackets.

150. No rare or vulnerable ecosystems or habitats of threatened species have been identified as being potentially affected by the TTR Project including at the North and South Traps and Graham Bank. The nature of the seabed and fish communities present suggests that they are relatively disturbance-tolerant.

151. The results of modelling as provided by Dr. Hadfield in his Evidence suggests that mining derived sediments will not accumulate at the Traps, while Graham Bank may receive (99th percentile) up to 10 mm of sediment per year. The models also suggest that in the baseline condition, both the Traps and Graham Bank experience near bottom suspended sediment concentrations of between 100 and 300 mg/L (99th percentile); mining activities would thus only increase this by less than 10 to 20 mg/L per year.

152. Overall, Dr. Hadfield's modelling as presented in his evidence indicates that the sediment plume generated by TTR project activities would rarely be distinguishable from the baseline conditions at both the Traps and at Graham Bank. On this basis and observations made on site, it is my opinion that activities within the TTR project area would be unlikely to have any detectable effect upon the biological resources present at these locations.

EFFECTS ON PRIMARY PRODUCTION

153. Modelling of the optical properties of the suspended sediment plume suggests that dredging may, in some areas and under certain conditions, cause the depth of the euphotic zone (the uppermost layer of the ocean in which net primary production can occur) to rise above the depth of the seabed. The effect will be particularly pronounced near the actively mined sites during operations.

154. Some submitters have suggested that this will have considerable and long lasting effects on coastal benthic and pelagic productivity and as a consequence the wider ecosystem of the South Taranaki Bight. In my opinion this will not be the case, which I will address in the following sections of my evidence.

Benthic Productivity

155. As a unit of measure, several studies have suggested that the euphotic zone is equivalent to the depth to which ambient light drops to 1% of surface irradiation; most benthic macroalgae can in fact survive at light levels below this 1% light threshold and some hard coral algal endosymbionts can survive surface irradiance of 0.15%; it is well understood that macroalgae can adapt to changes in the light regime (e.g., intensity, wavelength) through physiological and/or morphological changes over both short and longer terms to suit ambient environmental conditions (Algarra & Neil 1990).

156. Rather than referring to the relatively generic term 'euphotic zone', a more specific phrase to use is the 'compensation point'. This is the point or depth at which the rate of carbon fixation by photosynthesis is balanced by the rate of carbon use by respiration.

157. The compensation point is specific to the algal/plant species in question; that for a brown algae such as *Ecklonia*, for example, occurs at a much shallower depth than that for many coralline red algae. In the study of the benthic flora and fauna off Patea Shoals (Beaumont et al 2013), for example, only red coralline algae were found in the deepest, offshore sites.

158. The modelling of potential optical effects (Gall et al 2013) is based on modelled plume dispersion from a single point source (Site 'A' in Hadfield 2013). TTR's activities will not, however, be restricted to a single location within the proposed area but will cover a broad area (over the operational lifetime) and the plume itself is spatially dynamic over time. As a consequence, the physical location of the plume will vary markedly as extraction activities move from block to block, as well as due to natural physical forcing (tides, currents, storm events).

159. Thus while it is accepted that a temporary rise in the euphotic depth, as the operational plume affects a given area, will constrain any growth of the algae in the affected seabed, such a rise does not result in instantaneous mortality. When the euphotic depth again descends as

the disturbance moves on, net carbon fixation will resume and the algae will again be capable of growth and reproduction.

160. Similar responses have been noted in benthic primary producers affected by the extensive dredging programs that have occurred, particularly on the northwest shelf of Australia but also other locations globally over the last decade. In a review of the published literature of 89 reef building corals, Erftemeijer et al (2012) reports that some sensitive species, for example, can tolerate short term exposure (days) to highly turbid water while tolerant species can survive for weeks at very low ambient light levels; similarly, some corals could tolerate less than 10 mg/L of suspended sediment, while others can survive extended periods of 1000 mg/L

161. Several submissions have also questioned whether the level of sedimentation predicted by the mathematical modelling (Hadfield 2013) will have a lasting negative impact on benthic primary production, particularly at the North and South Traps and at Graham Bank. Overall the cumulative level of sedimentation in these areas is estimated by the model at approximately 1 mm per year.

162. In order to construct the sedimentation model limits must be placed on the geographic extents. Thus while the model describes possible conditions within a spatially constrained area, the STB is not constrained as such- materials will flow into and out of the system and it is considered that the modelled sediment accumulation will not persist over the long term.

163. In addition, the coastal macroalgal communities in the region are well adapted to periodic high levels of suspended sediments (refer to Dr Pinkerton's evidence) and sedimentation, as can occur during extreme weather events. On balance, it is considered that the effects of mining derived sedimentation will be virtually indistinguishable from baseline conditions.

164. On these bases, I consider that any effects on benthic primary productivity due to shading and sedimentation will be both transient and highly localised.

Pelagic Productivity

165. The modelling of optical properties has, as discussed in Paragraphs 50 and 51 above and in Dr. Pinkerton's evidence, indicated that there will be transient and localised areas where the thickness (or depth) of the euphotic zone will be reduced due to the activities of the extraction and re-deposition of de-ored sediment. Submitters have suggested that this will result in negative long term ecosystem impacts. It is my opinion that this will not be the case.

166. The sediment dispersal and optical properties modelling provided by Dr.s Hadfield and Pinkerton in their evidence indicates that changes to the depth of the euphotic zone will be highly variable and dependent on local hydrodynamic processes. Thus the depth of light penetration into the water column will be both spatially and temporally highly variable, not unlike the baseline conditions within the STB.

167. While highly variable, the plume will on occasion potentially affect optical properties in as much as 15% of the STB as indicated by Dr. Pinkerton in his evidence. When, however, considering the different factors affecting primary productivity in the water column, the thickness of the euphotic zone explains a relatively low proportion of the overall variance (Behrenfeld & Falkowski 1997)

168. Much of this variance is apparently due to the types of phytoplankton present in a particular area and the nutrient state. There is broad evidence that phytoplankton within the STB are not light limited and thus the depth of the euphotic zone will not be a major factor in determining total primary production:

(a) Chlorophyll levels within the STB are generally higher in winter than summer months, when the levels of natural surface irradiance are lower

(b) The nutrients that fuel phytoplankton blooms are derived predominantly from 'upstream' of the STB given the predominant wind-driven currents affecting the area (Walters et al 2010)

169. Overall, a reduction in the depth of the euphotic zone may cause transient and localised effects on primary productivity. Any ‘shading’ or reduction in light penetration produced by the plume is not, however, restricted to a single spatial location and also does not occupy the entire water column; the effect on primary production by phytoplankton at and near the sea surface is considered likely to be negligible.

Effects on Fish

170. Adverse effects on fish can potentially arise from direct entrainment into the extraction pipeline, loss of benthic feeding areas, changes to water chemistry, the suspended sediment regime, the underwater noise regime and changes in the pattern of commercial fishing. I address each of these matters in turn as follows.

Effects on Fish - Direct Entrainment

171. Fish at the periphery of the intake zone may be able to avoid entrainment into the intake pump but the intake water velocity of the Crawler pump (up to 6 m/sec) exceeds the likely burst swimming velocity of smaller coastal fish and entrainment of occasional? fish along with non-mobile benthic organisms is expected. Initial screening will divert any fish, but soft bodied organisms that have survived transit through the pump will be physically disrupted by the screening process, and 100% mortality of soft-bodied organisms including fish entrained into the intake pipe is predicted.

172. Fish located further away from the direct influence of the intake head would be able to swim away from the areas of disturbance. In my opinion, given the observed low abundance of fish in the direct project area any such losses would not be ecologically significant.

173. Any sediment extraction associated with grade control drilling will pose no risk to fish.

Effects on Fish - Loss of Benthic Feeding Areas

174. The loss of benthic feeding area is in my opinion, not likely to be significant as the extraction process operates in a sequential harvesting

manner with recolonisation over time as discussed previously in my evidence. Overall, given there are no endangered species in the region and that the region does not support fish nursery or extensive feeding grounds, it is my opinion that the effects are likely to be negligible.

Effects on Fish - Changes in the Sediment Regime

175. Earlier in my evidence I addressed the effects of the sediment plume on sedentary benthic organisms. I have also given consideration to the effects of the sediment plume on mobile organisms such as fish, both in the immediate deposition area and further afield.

176. Dr. Hadfield's evidence indicates that suspended sediment levels in the immediate area of redeposition will range from 20-40 mg/L (near surface) within a few km of the source to 130-260 mg/L near the seabed while seabed levels at the source are higher (approximately 288 mg/L). At most locations near the shoreline the levels of surface suspended sediment derived from mining activities are within the range of values that are naturally experienced.

177. Fish in the region say 2-3 km from the immediate deposition area will thus be subject to elevated levels of suspended sediments and thus potentially be displaced (or remove themselves) from the affected areas if not capable of tolerating these higher levels.

178. I have given consideration to the effects of suspended sediments in respect of potential for choking fish in areas offshore from, near to and inshore from the active Project area. I have concluded based, on my evaluation of plume modelling data presented by Dr Hadfield, that the offshore area will not be adversely affected as levels will not be elevated.

179. In the mid-shore to nearshore areas the risk of fish choking was scored as low-moderate risk with high confidence as the midshore and nearshore habitats are already characterised by turbid conditions and the modelling suggests that this will not be significantly worsened.

Effects on Fish – Spawning Areas

180. Snapper and a range of other fish might use the STB for spawning, but the area is not reported as a high value snapper spawning area. Any effects on spawning by snapper (or other demersal fish) would be likely to be minor, given the relatively small scale of TTR's activities in the context of the broader area of the STB. [Refer to Section 6.10.7 of the IA]

181. Although nothing is known of the use of the STB by diadromous (freshwater migratory) fish such as lamprey, eels and whitebait, these fish are adapted to living in turbid freshwater systems and it is considered unlikely that the SSC elevations arising from TTR's operations would adversely affect such fish – either in the adult form or the larval form.

PROTECTION OF BIOLOGICAL DIVERSITY INCLUDING RARE/VULNERABLE ECOSYSTEMS

182. TTR's operations will affect a relatively small area of the seabed within the STB. On an annual basis TTR's extraction operations will disturb around 5% of the 65.76 km^2 extraction area or 3.23 km^2 (assuming a 20 year project life). This equates to less than 0.1% of the area of the STB out to 18 nm from the shore.

183. Given these ratios, the TTR operation is not considered to present any issues in respect of protection of biological diversity in the broader STB area notwithstanding localised effects in the extraction and immediate deposition areas.

184. No rare or vulnerable ecosystems or habitats of threatened species have been identified as being potentially affected by the TTR Project.

IMPACT OF UNPLANNED EFFECTS

185. Potential effects of unplanned events may arise from ballast water and biofouling (introduction of non-indigenous species) and from fuel/lubricant spills. I review the ecological implications of each as follows.

Non-Indigenous Species

186. Vessel biofouling refers to those organisms that are carried by vessels on both the external surfaces of their hull(s) and also within their internal seawater systems. Vessel ballast waters can also carry organisms that may be translocated and released into the environment. These organisms can be problematic if introduced to new ecosystems and may be referred to as non-indigenous species (NIS).

187. If NIS successfully become established by colonising the marine environment after release in New Zealand waters, and subsequently developing to form viable self-sustaining populations, they can spread domestically, both by natural dispersal mechanisms and by anthropogenic transport pathways such as vessel movements and aquaculture transfers among regions.

188. After establishment, some NIS can proliferate in new environments, and may cause (or be perceived to cause) adverse effects; such species tend to be described as “marine pests”. The issue of marine pest introduction and spread is generally regarded as an important one, not only because of the range of values at risk, but also because, once introduced, NIS usually become permanently established; unlike the case with most contaminant spills, the effects are generally irreversible.

189. The colonisation and growth of biofouling organisms is typically controlled through both the application of fouling control or release coatings (‘antifouling paints’) to the external surfaces of the vessel as well as a variety of ‘approved’ active and passive systems for controlling fouling of internal systems. The Marine Environmental Protection Committee (MEPC) of the International Maritime Organisation (IMO) has prepared a set of guidelines for managing biofouling to reduce the transfer of invasive aquatic species.[3]

[3] IMO 2011: Guidelines for the Control and Management of Ship’s Biofouling to Minimize the Transfer of Aquatic Invasive Species. MEPC Resolution 207(62)

190. The movement of ballast waters, on the other hand, are considered by the IMO Ballast Water Management Convention[4] and the Ministry of Primary Industry's Import Health Standard for ballast water; although this Convention and also the Biofouling Guidelines are not in force, a condition of the consent which requires adherence to this guidance will limit the potential for spread of invasive species in ballast waters.

191. TTR proposes to mitigate potential biofouling effects by use of appropriate biofouling management measures and manage the ballast water risk through adherence to the IMO Convention to which I refer above. This is discussed by Mr Venus in his evidence.

192. I consider that these management measures will be appropriate to mitigate ecological risks associated with biofouling.

Oil Spill

193. Accidental release of lubricating or fuel oils could have significant deleterious effects on the environment; the accidental release of heavy fuel oil from the grounding of the MV Rena in the Bay of Plenty has illustrated the potential effects on seabirds and other marine life in New Zealand. Potential effects on the shoreline biota could include mortality of seabirds and benthic invertebrates within the intertidal zone. I have reviewed Dr. Beamsley's evidence and consider his conclusions relating to likely dispersion of a contaminant spill to be accurate; this, however, is ameliorated by the very low likelihood of such an unplanned release.

194. Appropriate industry standard safety and environmental management systems on board the TTR vessels would prevent such spills from occurring and in my view should be a condition of Approval. The system should include development of an oil and contaminant spill response plan in order to effectively respond to such unplanned events. On this basis, the potential for effects relating to oil or contaminant spill is considered to be low.

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[4] International Maritime Organization 2004: International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM). International Maritime Organization. Adopted 13 February 2004

Response to Section 42 Requests by the EPA

The North and South Traps and Impact Thresholds

195. A discussion of the values and potential impacts of mining on the North and South Traps is presented in my evidence in Paragraphs 145 to 152. Overall I consider the potential for effects on these areas to be moderately low.

196. Evaluation of potential impact thresholds is problematic. Within my evidence I have discussed factors that will affect marine ecological communities but unfortunately the specific information required to formulate thresholds of impact for the different species assemblages is either absent or minimal in nature.

197. In terms of the likely effects on biological systems, the key organismal sensitivities relate to direct removal (during extraction), smothering and shading (during processing and redeposition) to the seabed and competition/predation pressure (due to invasive species).

198. Impact thresholds are difficult to assign as we are limited in terms of the level of information available upon which to formulate such levels. This information includes such things as

(a) tolerance of benthic organisms to differing levels of suspended and sediment,

(b) ability to burrow or migrate upwards through deposited sediment,

(c) physiological tolerance to reduced light limits

(d) competitive ability

(e) anti-predation defences

199. As specific information of these sensitivities/abilities is for the most part lacking for the species present within the STB, taxa from other areas for which relevant information is available must be used as surrogates. A few studies have, however, been conducted in New Zealand and elsewhere which have investigated the potential effects of

sedimentation and burial (e.g. Hewitt et al 2003); these could potentially form the basis of organismal-specific impact thresholds, but considerable further investigation would be required to test their validity

200. Impact thresholds have been prepared for reef-building hard corals in Australia, notably in relation to large scale dredging projects in the north-west of that country. The thresholds are based on decades of extensive research (see review by Erftemeijer et al 2012) into the sensitivities of different coral species to such dredging-related impacts as shading, suspended sediments and sedimentation.

201. In the absence of this extensive body of research for the organisms affected by TTRs proposed activities in the STB, species-specific impact thresholds (e.g., the effect of sedimentation on the *Euchone* tube worms) are impossible to prepare. Thresholds which focus on community-level responses to anthropogenic impact are, however, possible to prepare and have been the basis for environmental management and monitoring in New Zealand for many decades; such community or habitat-based thresholds should be the focus of any Conditions placed on the activities should the proposal be approved.

Sensitivities of benthos to mining induced changes

202. Discussion of the potential sensitivities to the benthos to mining induced changes are provided throughout my evidence, notably Paragraphs 101 to 119 (effects on benthic recolonisation), Paragraphs 127 – 132 (effects on *Euchone* spp), Paragraphs 133 to 144 (offshore biogenic habitats) and Paragraphs 155 to 164 (effects on benthic macroalgae).

203. Overall the proposed activities will have relatively transient effects on the seabed benthos. The de-ored material placed back on the seabed will be devoid of macrofauna for only a relatively short time before natural recolonisation processes occur and shading effects on benthic macroalgae will be transient due to natural hydrodynamics and the continually varying mining location

The impact of changes in PSD on the benthic community.

204. The potential effects on changes in particle size distribution on the benthic communities within the affected area is discussed briefly in Paragraph 78 of my evidence. It is anticipated that the redeposited sediments will be broadly similar in nature to that of the extracted sediment.

205. Any increase in very fine material arising from milling the ore may, however, have an effect on benthic communities in the near field when operations are underway. As operations move away from any area the deposited fines would be subject to natural winnowing and resuspension and as such have no lasting impact on the particle size distribution of the seabed.

Smothering of benthos in newly colonised areas

206. The potential implications of sediment deposition arising from sediment plumes are discussed in Paragraphs 78 to 90. In brief, deposition of de-ored sediment on the seabed will result in the smothering of any remaining organisms present in the mined furrows. Deposition of materials in the near field arising from sediment plumes may result in some smothering of benthos though upward migration of benthos through levels of less than a few mm has been demonstrated for some marine benthos from New Zealand (see Paragraphs 78 to 90 in my evidence). On this basis I do not consider that smothering of newly colonised areas (in the absence of any other disturbance) will play an important role in ecological recovery of the seabed.

Response to Public Submissions

207. Analysis of the public submissions has indicated that concerns over effects on the local ecology were raised by nearly 40 people and organisations. These concerns are addressed in this section of my evidence based on the main issues raised; these issues are summarised below:

(a) Generic Effects

(i) Temperature

(ii) Salinity

(iii) Light

(iv) Contaminants (metals and hydrocarbon spills)

(v) Mooring anchors

(vi) Suspended sediments/turbidity

(vii) Sedimentation

(b) Effects on specific locations/organisms

(i) North & South Traps

(ii) Graham Banks

(iii) Inshore reefs

(iv) Euchone habitat

(v) Marine megafauna

(c) Ecosystem-level effects

(i) Primary production (benthic and pelagic)

(ii) Recolonisation & seabed recovery

(iii) Biosecurity and invasive species

(iv) Cumulative effects

Generic Effects

208. Changes to the ambient seawater temperature due to operating machinery regimes is likely to be undetectable more than a few m away

from the operations and as such I consider the potential effects to be negligible. Changes in salinity relating to the discharge of desalination brine are likewise considered to be undetectable outside a reasonable mixing zone.

209. The effects of changes to light intensity as related to the potential for shading of phytoplankton and macroalgae and a concomitant reduction in primary production are discussed in paragraphs 137 to 153 of my evidence. Conversely, submitters have also expressed concern that the additional light at night arising from 24h operations will have a significant effect on macrofauna. While additional feeding opportunities may be presented to visual predators in the immediate vicinity of operations, the potential for negative effects is in my opinion limited due to the highly localised (and continually moving) scale of operations.

210. Effects related to the potential release of contaminants, either through accidental oil spills or liberated to the water column from mining activities are discussed in the evidences of Drs Beamsley and Vopel, respectively. The oil spill risk is considered manageable through good practice and Dr Vopel's evidence indicates that discharges will be within ANZECC/ARMCANZ water quality guidelines within a reasonable mixing zone and as such I do not consider these effects to be of significant concern.

211. The anchor deployment for the FPSO involves installation of 4 standard Stevpris-type anchors, each attached by anchor chain and 90 mm diameter, tensioned steel cables directly to the FPSO; the anchors are moved in the course of the Crawler extraction programme, but other than the direct disturbance caused by the anchor placement, removal and re-deployment, the anchor system will have only a limited range of sweep when used in extraction mode and will have lesser environmental effect than conventional anchoring with 360 degree sweep. Furthermore anchor deployment will be largely on areas which will be or have been subject to extraction and re-deposition so that effects of anchoring will be minor relative to the impact of those activities.

212. Overall, I consider that the effects related to the use of these anchors are spatially and temporally restricted and thus unlikely to be significant.

213. Effects relating to suspended sediments are discussed in a number of sections of my evidence - these effects are related to shading of the water column and seabed and clogging/smothering of benthic biota. I consider that effects relating to shading, as discussed in paragraphs 137 to 153, will be relatively transient in nature.

214. Submitters suggest that elevated suspended sediment will have deleterious effects on fish, benthic invertebrates and also inshore macroalgae. The effects on each of these groups is discussed in the paragraphs that follow.

215. Lowe (2014) suggests that fish in general are directly affected by elevated sediment levels in the water column through reduced visual acuity for foraging and through clogging of gills. Being fully motile, fish have the ability to select their preferred habitat and thus there is thus a possibility that some species (those which prefer waters of high clarity) will avoid areas with high loads of suspended sediment (e.g., nearest the site of mining activities).

216. In addition many of the species present in the area are tolerant of occasionally turbid water as would naturally occur during storm events. In my opinion the timing and extent of any displacement will be transient and highly variable due to the continually varying nature of the proposed activities, the predicted sediment plume and the naturally dynamic environment.

217. The potential effects of additional suspended sediment on benthic invertebrates is discussed in paragraphs 93 to 98 of my evidence. In this I conclude that the expected levels of suspended sediments in the near field are unlikely to have any detectable effect upon benthic invertebrates.

218. The potential effects of suspended sediments due to shading on benthic macroalgae is discussed in part in paragraphs 155 to 164. I consider also that any effects related to deposition of these sediments

upon reef-dwelling algae would be transient due to the dynamic nature of the environment.

219. Shiel et al. (2006) indicate that low levels of sediment can inhibit recruitment of macroalgae on rocky reefs; the species present on rocky reefs in the area are, however, already well adapted to occasionally high loads of suspended sediment that naturally arise during storm events, thus I expect the effects on benthic macroalgae to be limited.

Effects on specific locations and species

220. The North and South Traps and Graham Banks have been noted by submitters as ecologically significant areas that will be negatively affected by the proposed activities. These areas are discussed in paragraphs 145 to 152. Overall the effects on these areas will in my opinion be relatively minor in nature.

221. The sediment plume dispersion modelling presented by Dr. Hadfield in his evidence clearly illustrates that the dredge plume will not appreciably result in reduced underwater visibility or sedimentation in the nearshore rocky reef areas when compared to baseline conditions. Overall I anticipate that the effects on these inshore areas will be minor.

222. I have discussed the potential effects of the proposed activities on the *Euchone* dominated habitat specifically in paragraphs 127 to 132 of my evidence; in addition, I refer to the effects of dredging on other *Euchone* species in paragraph 57; in a study that reported no effect on *E. papillosa* adjacent to the dredged area. Overall I consider that the effects will be restricted predominantly to the dredge footprint [and that E is widespread and will recolonise rapidly?].

223. The effects on marine megafauna (seabirds, marine mammals) is discussed in the evidences presented by Dr Thompson and Mr Cawthorn. I concur with their assessments that there will be no discernable effects on these charismatic megafauna.

Ecosystem-level effects

224. The main ecosystem-level effects of concern to submitters relate to potential impacts on primary production due to shading, recolonisation of the seabed biota, biosecurity and invasive species and cumulative impacts of extended dredging. I have addressed the effects on primary production (paragraphs 153 to 169) and recolonisation (paragraphs 29 to **Error! Reference source not found.**) already in my evidence.

225. Introduction to an area of non-indigenous marine species can, as pointed out by submitters, have dramatic and permanent effects on the environment. The potential for effects, however, can be well reduced by the strict implementation of a comprehensive biosecurity management plan (BMP) for all vessels that are to be involved in the TTR project.

226. Risks associated with the discharge of ballast water from international vessels can be effectively managed through adoption of the procedures nominated in the IMO's Ballast Water Management Convention and through compliance with the Ministry for Primary Industry's Import Health Standard for ballast water.

227. Risks due to the unintentional presence of biofouling on the hulls and in the internal systems of ships can also be mitigated through conducting a biosecurity risk assessment of each vessel prior to arrival at the site (and regularly for resident vessels). Only low risk vessels would be permitted onsite; those that are nominated as of 'uncertain' risk would require further investigation (e.g., visual inspection) before being permitted to site, while high risk vessels would require some level of intervention (e.g. hull cleaning or internal sterilisation) prior to site permission.

228. Submitters have raised concern that potential cumulative effects of the proposed activities could relate to changes in long term sedimentation rates (affecting the survival of benthic organisms), reduced levels of primary production (affecting trophic interactions) and also habitat loss of important benthic food resources. Potential effects related to sedimentation and primary production are as noted above in this section of my evidence.

229. The potential loss of food-resources for benthic-feeding fish would relate to the biota that are removed through sand extraction. The overall effect of this will be relatively small, as the operational area per year is small compared to the size of the STB and recolonisation of the seabed will be a continual/ongoing process. On this basis I consider that there is a very low likelihood that the proposed activities will have any detectable effects at the ecosystem level.

Huber & Probst review of benthic ecological effects

230. As provided for by Section 44 of the EEZ Act, the EPA commissioned several independent reviews of TTRs application to operate. I will comment herein on the review conducted by Huber & Probst (2013) on the effects on benthic ecology.

231. The authors concur with TTRs Application that there are no differences between benthic communities in the PPA and those in similar habitats in adjacent areas. The key areas of concern noted by the reviewers related to uncertainty around potential effects on the North and South Traps, water chemistry and their opinion that the impact assessment did not adequately link potential effects with the sensitivities of the affected fauna to develop impact thresholds.

232. As indicated above, information of the communities present at the Traps and Graham Banks has now been provided. Matters relating to water quality (particularly metals in the water column) have been addressed by Dr Vopel and I consider that the ANZECC/ARMCANZ water quality guidelines will be satisfactorily met during operations.

233. I have also discussed the problems relating to organism-specific impact thresholds in paragraphs 196 to 173 of my evidence. In the absence of detailed information on organismal sensitivity, impact thresholds would be restricted to consideration of community-level responses and I consider this to be an appropriate focus for environmental monitoring should the application be approved.

CLOSING

234. TTR have commissioned an extensive suite of investigations of the marine environment of the South Taranaki Bight area in support of their application for approval to extract and process iron ore from the seabed. These studies have markedly extended the body of knowledge on marine ecosystem composition and function in the area; this is not to say that our knowledge of the area is complete, but rather that the level of information now available should permit an appropriately informed decision by the EPA

235. After examining the application documents and all of the ecologically relevant supporting evidence, it is my professional opinion as a marine scientist with over 25 years of experience that there is nothing within the scope of the proposed activities that should prevent approval of the application by the EPA. Uncertainties, where they exist, should be evaluated through a set of operating conditions which include a phased programme of environmental monitoring to occur throughout the lifetime of the project.

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Dan McClary

17 February 2014

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Appendix A: Ecological Assessment: Iron sand mining - Pre-Mitigation. Levels of consequence, likelihood, risk and confidence associated with TTR's activities are listed (a, b, c, etc.) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted.

		Recovery period				Key species				Protected species/ sensitive environments				Ecosystem functional impact				Proportion of habitat affected			
Activity	Effects	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
a. Antifouling	Impact on pelagic organisms and coastal ecosystem function	2	1	2	2b	3	1	3	2b	2	1	2	2b	3	1	3	2b	0	1	0	2b
b. Mooring blocks and structures	Impact on benthos	1	6	6	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b
c. Extraction of sand from the seabed, including grade control drilling	Impact on benthos	2	6	12	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b
	Impact on demersal fish	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b
d. De-ored sand re-deposition & hydro-cyclone overflow sediment	Impact on benthos at mining site due to processing and re-deposition of sediment	2	6	12	2b	2	6	12	2b	2	6	12	2b	2	6	12	2b	2	6	12	2b
	Impact on near-field benthos due to re-deposition	2	6	12	2b	2	6	12	2b	2	6	12	2b	2	6	12	2b	3	6	18	2b
	Impact on rocky reef benthos due to re-deposition	0	6	0	2b	0	6	0	2b	0	4	0	2b	0	6	6	2a	0	6	0	2a
	Impact on rock reefs due to choking	1	6	6	2b	1	6	6	2b	1	6	6	2b	2	3	6	2a	1	3	3	2b
	Impact on rocky reefs due to light reduction	1	2	1	2b	2	0	0	2b	1	4	4	2b	4	0	0	2b	1		0	2b
	Impact on nearshore sand due to re-deposition	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2a	0	6	0	2a
	Impact on nearshore sand due to choking	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2a	0	6	0	2a
	Impact on benthic algae	0	5	0	2b	0	5	0	2b	0	5	0	2b	0	5	0	2b	0	0	0	2b
	Impact on offshore biogenic habitat due to re-deposition	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	5	5	2b
	Impact on offshore biogenic habitats due to choking	2	6	12	2b	2	6	12	2b	2	6	12	2b	2	6	12	2b	2	6	12	2b
	Impact on algae in offshore biogenic habitats due to light reduction	0	5	0	2b	0	5	0	2b	0	5	0	2b	0	5	0	2b	0	0	0	2b
	Change in water chemistry	0	5	0	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	5	5	2b
	Change in pore water	0	5	0	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	5	5	2b
	Offshore shading effects	0	5	0	2a	0	5	0	2a	0	5	0	2a	0	5	0	2b	0	5	0	2b
	Offshore u/w visibility effects	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b
	Offshore effect on aerial predators	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b
	Offshore choking	1	6	6	2b	1	6	6	2b	0	6	0	2b	1	6	0	2b	1	6	6	2b
	Midshore shading effects	1	6	6	2a	1	6	6	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
	Midshore u/w visibility effects	1	6	6	2a	1	6	6	2a	0	6	0	2a	1	6	6	2a	0	0	0	2a
	Midshore effect on aerial predators	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b
	Midshore choking	0	6	0	2c	0	6	0	1c	0	6	0	1c	0	6	0	1c			0	2a
	Nearshore shading effects	0	6	0	2c			0		0	6	0	2a			0				0	2a
	Nearshore u/w visibility effects	0	6	0	2c			0		0	6	0	2a			0				0	2a
	Nearshore effect on aerial predators	0	6	0	2c			0				0				6				0	2a
	Nearshore choking	0	6	0	2c	0	6	0	2c	0	6	0	2c	0	6	0	2c	0	6	0	2c
e. Effects of FPSO operations – u/water noise and vibrations	Acoustic impact on marine mammals, reptiles, fish and invertebrates	1	4	4	2c	1	4	4	2c	1	4	4	2c	1	4	4	2c	1	4	4	2c
f. Release of dissolved material ex pore water	Impact on pelagic organisms	1	3	3	2b	1	3	3	2b	1	3	3	2b	1	3	3	2b	1	3	3	2b

Appendix A (contd.): Ecological Assessment: Iron sand mining - Pre-Mitigation. Levels of consequence, likelihood, risk and confidence associated with TTR's activities are listed (a, b, c, etc.) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted.

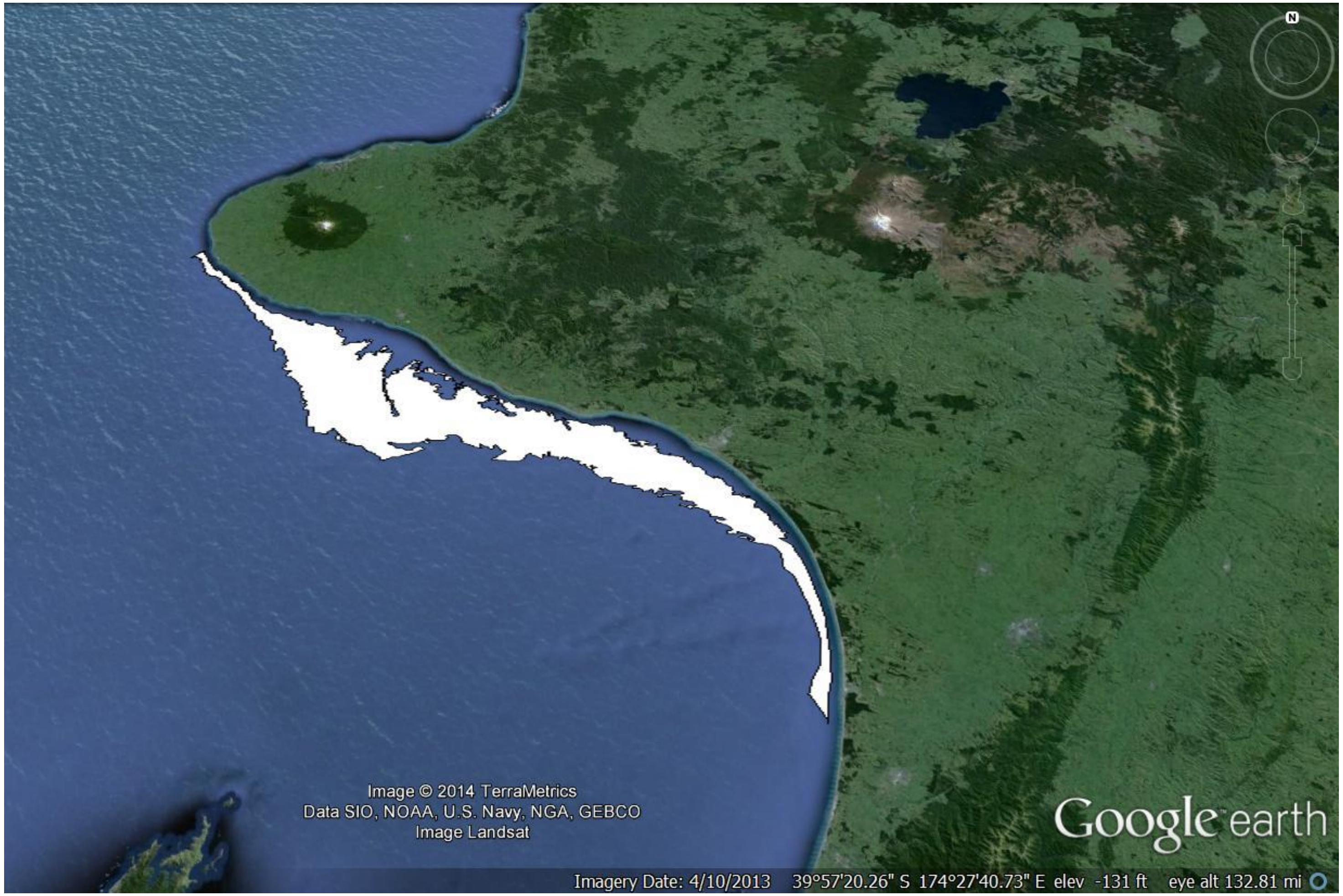
		Recovery period				Key species				Protected species/ sensitive environments				Ecosystem functional impact				Proportion of habitat affected			
Activity	Effects	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
g. Ship-to-ship ore transfer	Impact of normal operation on pelagic organisms	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
	Impact of normal operation on benthos	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
h. Ship-to-ship fuel transfer	Impact of normal operation on pelagic organisms	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
	Impact of normal operation on benthos	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
i. RO brine in hydro-cyclone flow	Impact on pelagic organisms	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
j. Hydro-cyclone overflow (sea water with fines sediment, particulate and dissolved organic matter	Impact on pelagic organisms	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
k. Reverse osmosis chemical discharge	Impact on pelagic organisms	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
l. Discharge from hyperbaric filters that de-water the concentrate on-board the FSO.	Impact on pelagic organisms	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
m. Other discharges from ships (such as sewage)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n. Discharge to air	Impact on pelagic organisms	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
o. Ship's deck lighting (shielded)	Seabird attraction, disturbance, collision	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
	Effects on squid	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
	Effects on fish	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a	0	6	0	2a
p. Other- Vessel exclusion	Impact of displaced fishing on fish stocks	1	3	3	2c	1	3	3	2c	0	1	0	2c	0	1	0	2c	0	1	0	2c
q. Vessel movements	Ship strikes on marine mammals	3	1	3	2a	0	6	0	2a	3	1	3	2a	0	6	0	2a	0	6	0	2a
r. Unplanned Events	Effects on native biodiversity through the incidental translocation of non-indigenous marine species; Effects of spills	3	4	12	2c	3	4	12	2c	3	4	12	2c	3	4	12	2c	3	4	12	2c

Appendix B: Studies in which benthic macrofaunal recovery rates were reported (from Wilber & Clarke 2007)

	Site	Region	Depth(m)	Sediment Type	CH[1]	Mech[2]	Recovery Time[3]	Metric[4]	Reference
Open Water Disposal Sites	New S. Wales, Australia	Temperate	6	Fine sand	N	A	3 months	U/M	Smith & Rule 2001
	Gulfport, MS, US	Temperate	3	Silt and clay	Y	A	1 year	U/M	Wilber et al. in press
	Corpus Christi, TX, US	Temperate	3	Silt and clay	N	L/A	< 1 year	U/M	Ray & Clarke 1999
	South Carolina, US	Temperate	13	Fine sand	Y	Un	N/A	U/M	Zimmerman et al. 2003
	Coastal Louisiana, US	Temperate	3	Silt and clay	N	Un	5 months	U/M	Flemer et al. 1997
	Sewee Bay, SC, US	Temperate	3	Silt and clay	Y	A	6 months	U/M	Van Dolah et al. 1979
	Dawho River, SC, US	Temperate	<5	Silt and clay	Y	A	3 months	U/M	Van Dolah et al. 1984
	Delaware Bay, US	Temperate	Shallow	Silt and clay	N	Un	>5 months	U	Leathem et al. 1973
	Queensland, Australia	Sub-Tropical	11	Silt and clay	Y	A	3 months	U/M	Cruz-Motta & Collins 2004
	New S. Wales, Australia	Temperate	Shallow	Silt, clay, sand	N	A	1 month	U	Jones 1986
	Mobile Bay, AL, US	Temperate	3	Mud	N	A	3 months	U	Clarke & Miller-Way 1992
	Oregon, US	Temperate	8	Silt and clay	N	A	1 month	U	McCauley et al. 1977
	Mirs Bay, Hong Kong	Sub-Tropical	19	Sand and gravel	Y	Un	< 2 years	U/M	Valente et al. 1999
	Quebec, Canada	Cold	55	Fine sand	Y	L/A	> 2 years	U/M	Harvey et al. 1998
	Port Valdez, Alaska	Cold	15-23	Mud	N	L	> 2.5 years	U/M	Blanchard & Feder 2003
	Puget Sound, WA	Cold	60	Silt, clay, sand	N	A	> 9 months	U	Bingham 1978
	Western Baltic Sea	Cold	19	Fine sand	N	A	< 2 years	U/M	Powilleit et al. 2006
	Liverpool Bay, UK	Cold	10	Sand and mud	N	Un	N/A	U/M	Rees et al. 1992
	Weser estuary, Germany	Cold	16	Silt and sand	Y	Un	> 8 months	U/M	Witt et al. 2004
	James River, VA	Temperate	3	Fluid mud	N	L/A	3 months	U	Diaz & Boesch 1977, Diaz 1994
	Columbia River, OR	Cold	Shallow	Fine sand, clay	N	L/A	>10 months	U	Richardson et al. 1977
	Southern Brazil	Temperate	19	Silt, clay, fine sand	Y	A	< 9 months	U/M	Angonesi et al. 2006
Dredging - Site Channels	Sewee Bay, SC, US	Temperate	4	Silt and clay	Y	A	6 months	U/M	Van Dolah et al. 1979
	Dawho River, SC, US	Temperate	4	Silt and clay	N	A	3 months	U	Van Dolah et al. 1984
	Georgia, US	Temperate	Shallow	Silt and clay	N	A	3 months	U	Stickney & Perlmutter 1975
	Oregon, US	Temperate	11	Silt and clay	N	A	1 month	U	McCauley et al. 1977
	Delaware Bay, US	Temperate	Shallow	Silt and clay	N	Un	>5 months	U	Leathem et al. 1973
	Sardinia, Italy	Temperate	15-20	Silt and clay	N	A	~ 6 months	U	Pagliai et al. 1985
	Ceuta, North Africa	Temperate	3	Silt and clay	Y	L/A	6 months	U/M	Guerra-Garcia et al. 2003
	New South Wales, Australia	Temperate	Shallow	Silt, clay, sand	N	A	1 month	U	Jones 1986
	Queensland, Australia	Temperate	17	Medium/fine sand	N	Un	N/A	U	Poiner & Kennedy 1984
	Southwest Finland	Cold	9	Mud	N	L/A	2-5 years	U	Bonsdorff 1980, 1983
	Long Island, NY	Temperate	2	Sand, silt, clay	Y	A	> 11 months	U	Kaplan et al. 1975
	Algeciras Bay, Spain	Temperate	5,15,30	Fine sand	N	L/A	4 years	U/M	Sanchez-Moyano et al. 2004

	Yaquina Bay, OR	Cold	6-11	Fine sand, silt	Y	L/A	1 year	U/M	Swartz et al. 1980
	North Sea, UK	Cold	9	Silt and clay	N	A	> 3 months	U/M	Quigley & Hall 1999
	Southern Brazil	Temperate	3-18	Silt, clay, sand	Y	Un	> 3 months	U/M	Bemvenuti et al. 2005
Dredging Site - Aggregate Mining	Nome, AK	Cold	9-20	Sand, cobble	Y	Un	4 years	U/M	Jewett et al. 1999
	Southeast coast, England	Cold	27-35	Sand, gravel	Y	L	2-4 years	U/M	Boyd et al. 2004
	South coast of U.K.	Cold	10-20	Sand, mud, gravel	N	Un	2-3 years	U/M	Newell et al. 2004
	Eastern English Channel	Cold	15	Gravel	Y	Un	> 28 months	U	Desprez 2000
	Southern Baltic Sea	Cold	10-14	Sand	Y	Un	> 10 years	U/M	Szymelfenig et al. 2006.
	Southern North Sea	Cold	25	Sand, gravel	Y	L	> 2 years	U/M	Kenny and Rees 1996
	Botany Bay, Australia	Temperate	14-18	Mud	Y	L	> 1 year	U/M	Fraser et al. 2006
Capping	Hong Kong, China	Sub-Tropical	5-6	Mud	N	L	3 years	U/M	Qian et al. 2003

Appendix C: South Taranaki Bight displaying the area located between the 20 m and 40 m bathymetric contours



Appendix D: Habitat map of the North and South Traps produced by ASR Ltd (2005).