TARANAKI VTM PROJECT

RESPONSES ON BEHALF OF TRANS-TASMAN RESOURCES LIMITED TO REQUEST FOR INFORMATION 1 AND 2 IN MINUTE 13 OF THE EXPERT PANEL

17 November 2025

This response addresses the requests for information in Minute 13 of the Expert Panel, specifically items 1 and 2. The responses to item 1 (a)-(c) have been authored by Dr Collins and reviewed by Drs Dearnaley and MacDiarmid. The responses to item 2 have been authored by Dr Dearnaley.

In addition to the text responding to item 1, TTR refers the Panel to Dr Macdonald's 2024 evidence at [16]-[25], which provides an easy-to-read summary of model uncertainties.

1(a). Relevant model parameters relating to the model outputs presented, including model parameters discussed in the 2017 and 2014 JWSs. Relevant model parameters are those that are uncertain and that the model outputs are particularly sensitive to.

Parameters of the hydrodynamic model

Ocean circulation models or hydrodynamic models can be sensitive to the external data sets used to inform the model dynamics. These include external forcing fields and lateral boundary conditions.

External forcing fields refer to atmospheric parameters that modify the temperature, salinity or momentum in the upper ocean. The commonly used external forcing fields include surface air temperature, humidity, radiation, precipitation and wind. These parameters are usually obtained from global or regional atmospheric models. The ocean circulation model used in the sediment plume model uses wind from a regional ocean model but obtains all other external forcing parameters from a global atmospheric model. A comparison of preliminary model results with available current measurements indicated that the model generally underestimated the wind-driven variability. This underestimation indicates that either the wind speed from the regional atmospheric model is too low and/or that the drag coefficient used to estimate wind stress are too low for the wind and wave conditions in the coastal areas of South Taranaki Bight. The drag coefficient is a parameter that represents how strongly the ocean surface resists the motion of air flowing across it and can be calculated using different formulations. In order to get a better approximation of the wind-driven currents, the drag coefficient was multiplied by a factor of 1.4. The model sensitivity to wind data from another product was not explicitly tested nor were different formulations for the drag coefficient.

Lateral boundary conditions are model state parameters that are applied at the edges of a regional model domain. The typical boundary conditions required in a regional ocean model such as the one used for the sediment plume modelling are ocean temperature, salinity, meridional (north-south) velocity, zonal (east-west) velocity. Additional boundary conditions, such as SSC can also be prescribed at the model boundaries if these exist. The lateral boundary conditions for regional models are usually obtained from global or other regional ocean models. In most instances, these products will only contain the main model state parameters and not additional parameters such as SSC. For the sediment plume modelling, the model state parameters for the lateral boundaries were obtained from a medium-resolution (~10 km horizontal grid spacing) global ocean model that is constrained by satellite-derived and in-situ observations of temperature, salinity and ocean currents. The sensitivity of the ocean model used for the sediment plume modelling to lateral boundary conditions from a higher resolution (~5 km horizontal grid spacing) ocean model of the NZ EEZ was also tested. The sensitivity test indicated that the estimates of current, plume dispersion and transport were not sensitive to the source of the boundary data.

Parameters of the sediment plume model

In the sediment plume model, the different types of sediment that constitutes the sediment mixture (such as clay, sand, silt) encountered in the marine environment is distributed amongst different sediment classes each with its own set of prescribed characteristics that determines how it will behave. The different properties prescribed to each sediment class include settling velocity, critical bed shear stress, and erosion rate.

Settling velocity controls how quickly particles leave suspension and are deposited on the seafloor. Sediment classes with a lower settling velocity will stay in suspension for longer while sediment classes with a higher settling velocity will sink to the bottom faster and thus stay in suspension for shorter time periods.

Critical bed shear stress determines the minimum force needed from the combined action of flowing water and wave action to start moving sediment particles on the seabed. It marks the threshold between sediment remaining stable on the seafloor and sediment beginning to erode or be resuspended. Sediment classes with a higher critical bed shear stress will require more force to be resuspended compared to sediment classes with a lower critical bed shear stress.

The erosion rate describes how quickly sediment is removed from the seabed and put into suspension. It quantifies the mass of sediment eroded per unit area per unit time once the flow is strong enough to exceed the critical bed shear stress. This parameter was set to 0.0002 $kg/m^2/s$ for all sediment classes across all sediment simulations.

The different iterations of the sediment plume modelling parameterized the background and mining-derived sediments in slightly different ways. The changes to the sediment-related parameters were either based on new information that became available or on conclusions from the 2017 and 2014 JWSs. Here we only describe the parameters for the sediment plume modelling presented in Hadfield and Macdonald (2015) and Macdonald and Hadfield (2017) as these model simulations supersede any previous sediment plume modelling.

The sediment plume modelling includes sediment from two main ‘sources’: background sediment consisting of sediment entering the coastal zone from rivers (i.e. river-derived sediments) and sediments on the seafloor; and mining derived sediment. For the latter, two different sediment categories are considered: sediment that will be released into suspension upon release (assumed to be sediments with grain sizes <38μm), and sediment that will sink to the seafloor shortly after release (assumed to be sediments with grain sizes >90μm).

Background sediments

In the sediment plume modelling, the background sediment (i.e. sediment derived from natural sources such as river runoff) is represented using seven different sediment classes. Two of these classes represented sediments that are discharged nto the coastal zone by rivers. The two classes used to describe river-derived sediments were coarse silt (16-63μm) and fine silt/clay

(<16μm), each contributing an equal proportion (50%) to the total river-derived sediments. The 50/50 split between the two sediment classes were based on particle distribution data from some SSC measurements obtained from a single river, the Whanganui River, during flood conditions. While this split is a reasonable assumption for flood conditions, it likely overestimates the contribution of coarse silt during low-flow conditions. This, however, was not considered to be of major concern because most of the sediment input from rivers to the marine environment occurs during flood conditions.

The sediments present on the seafloor were described using five different sediment classes that ranged from coarse sand (500 -1000μm) to fine silt (4-16μm). The composition of the sediment on the seafloor at the start of the model simulation were as follows: 20% coarse sand (500 – 1000μm), 72% medium sand (128 – 500 μm), 6% very fine sand (63 -128 μm), 1.5% coarse silt (16-63 μm) and 0.5% fine silt (4-16 μm). These proportions were based on particle size distribution data from sediments collected from the seafloor within the mining area, but the fraction of fine sediment was adjusted after analysis of an initial simulation to achieve a better approximation of the surface suspended sediment concentrations observed in the near-shore area. The composition of seafloor sediment was assumed to be spatially uniform across the entire model domain.

Table 1. Sediment classes and properties used to represent the river-derived and seafloor sediment composition in Hadfield and Macdonald (2015).

Sediment class	**Fraction**	**Nominal size range (μm)**	**Settling velocity (mm/s)**	**Critical Stress (Pa)**
		River-derived sediments		
Coarse silt	50%	16-63	0.63	0.200
Fine silt/clay	50%	4-16	0.01	0.200
		Seafloor sediments		
Coarse sand	20%	500-1000	103	0.431
Medium sand	72%	128-500	38	0.219
Very find sand	6%	63-128	6.3	0.200
Coarse silt	1.5%	16-63	0.76	0.200
Fine silt	0.5%	4-16	0.01	0.200

The grain size ranges of the different sediment classes were based on the grain size classification used by the GRADISTAT analysis program (Blott and Pye, 2001) – a program created for the rapid analysis of grain size statistics.

Hadfield and Macdonald (2015) used a lower settling velocity for fine silt (4-16μm) sediment class compared to Hadfield (2014) to more accurately represent a tail of very slowly settling fines that had been observed in the laboratory tests.

Mining-derived sediment

The sediment plume modelling considered two different sediment categories: sediment that will be released into suspension upon release (assumed to be sediments with grain sizes <38μm), and sediment that will settle on the bottom shortly after release and then be buried with the de-ored sand (assumed to be mainly fine-medium sand (125-500μm) with some finer material). The parameterization for the former is described below under the heading suspended sediment source while that for the latter is described under the heading patch source.

A major change for the sediment plume modelling of the mining-derived sediment in Hadfield and Macdonald (2015) compared to Hadfield (2014) is the switch from a grain-size-based classification for the sediment classes used to represent the mining-derived sediment to a settling-velocity-based classification. At the time this was considered a major advancement as it provides a more realistic representation of the settling behaviour of the mining-derived sediment.

Suspended sediment source

The parameters used for the suspended sediment source in Hadfield and Macdonald (2015) were based on laboratory tests of sediment samples. The laboratory tests were carried out to assess the settling velocity, flocculation, and critical stress for deposition and erosion of various fractions of the proposed mining-derived sediment. Particle size distribution analysis of the sediment samples was also carried out to determine the fractions of different sediment classes. The parameters for the suspended sediments from the mining activity are presented in Table 2.

Table 2. The three sediment classes and properties used to represent the mining-derived suspended sediment in Hadfield and Macdonald (2015).

Sediment class	Nominal size range (μm)	Settling velocity (mm/s)	Critical Stress (Pa)	Source rate (kg/s)
Coarse silt	16-38	1.0	0.200	1.7
Medium silt	8-16	0.10	0.200	14.35
Fine-very fine silt	< 8	0.01	0.200	6.85

Patch source

For the sediment plume modelling, the de-ored sand that will settle on the bottom after release is considered to comprise mainly of fine-medium sand (125-500um) with some finer material. The finer material was taken into account in the modelling-derived suspended sediment described above. However, a proportion of the fraction of fine sediment that will become trapped in the mining pit can be resuspended, and this is taken into consideration with the rest of the patch source material. Three sediment classes were used to describe the fine-medium sand within the patch source with an additional three sediment classes used to represent the trapped fine sediment. The fraction of the different sediment classes and the settling velocity prescribed to each are provided in Table 3.

Table 3. The sediment classes and properties used to represent the mining-derived sediment for the patch source in Hadfield and Macdonald (2015).

Sediment class	Fraction	Nominal size range (um)	Settling velocity (mm/s)
Coarse sand	19.7%	500-1000	103
Fine-medium sand	70.8%	128-500	38
Very fine sand	5.9	63-128	6.3
Fine sediment class 1	2.6%		10
Fine sediment class 2	0.8%		1
Fine sediment class 3	0.3%		0.01

1(b). A description of the temporal nature of predicted sediment distributions presented, including the likely frequency and duration of suspended sediment increases and sediment deposition at different locations and, if applicable, the likely duration of pauses between subsequent increases. Where statistics are used to reflect these factors and dynamics, provide lay descriptions that relate statistics to real-world conditions.

The sediment distributions predicted are based on an illustrative scenario where the mining release point is kept fixed for the entire simulation. This helps to illustrate the variability in time and space associated with the processes influencing the plume. However, in reality the source of the plume will be moving over several kilometres during the time scale of the simulation and this process is not included in the modelling.

The temporal nature of predicted suspended sediment concentrations at different locations are presented in Figures 4.1 – 4.6 and Figures 4.10-4.13 of Hadfield and Macdonald (2015) along with observed suspended sediment concentrations at the same locations. These figures show that the SSCs at different locations are highly variable, and this variability will be determined by a number of processes at both local (e.g. winds, waves and tides) and regional scales (e.g. large-scale currents, sediment input from rivers).

The temporal nature of the predicted sediment plume is illustrated (to some extent) by Figures 5.1 – 5.7 and Figures 5.19 – 5.24 of Hadfield and Macdonald (2015). These figures show the spatial distribution of the mining derived sediment plume under different wind and wave conditions. The main take away from these figures is that the spatial distribution or extent of the predicted sediment plume is highly variable. This is because under certain conditions, such as weak winds and waves, the spatial distribution of the plume is more confined around the release location compared to an extensive plume that forms under high wind and wave conditions.

Figures 3.2 – 3.5 of Macdonald and Hadfield (2017) presents time-series of predicted suspended sediment concentrations from the sediment plume model of Hadfield and Macdonald (2015) and from the worst-case scenario for different locations to those presented in Figures 4.1 – 4.6 and Figures 4.10-4.13 of Hadfield and Macdonald (2015). These time-series plots show that a number of increases in SSC occur over the course of the 180-day time-period displayed. It also shows a number of periods of low SSC that varies in duration.

Figures 3.6 – 3.15 of Macdonald and Hadfield (2017) presents time-series of high-frequency predicted SSC from the worst-case scenario at a number of locations of interest. The statistics indicated on these figures are the maximum SSC value, the SSC value that occur 1% of the time (99^{th} percentile), the SSC value that occurs 5% of the time (95^{th} percentile) and the SSC value that occurs 50% of the time (the median). As with the other time-series plots, these also indicate that the SSC is highly variable in time and space.

1(c). A description of uncertainties associated with the model outputs presented, providing as much specificity and real-world analogies as possible. If statistics are used to describe uncertainties, provide lay explanations of the statistics to support readers' understanding of uncertainties in the information presented

Compared to satellite derived data and in-situ measurements of suspended sediment concentrations (SSC), the near-shore (within a kilometre or two from the shore) modelled background SSC may be double that of the observations. The most likely source of this uncertainty is the SSC from rivers for which data was only available for a single river and the concentrations for all other rivers were estimated based on the assumption that SSC is directly proportional to river flow. Complex bedforms and bio-stabilisation by benthic organisms influence resuspension of the sediments on the seafloor. Thus, the large differences observed between modelled and observed near-bed sediment concentrations are likely due to the absence of these features in the model. The lack of complex bed forms in the model likely results in an underestimation of the erosion and transport rates of sediments deposited on the sea floor.

In addition, the offshore modelled background SSC is lower compared to satellite derived measurements of Total Suspended Solids (TSS) which includes organic and inorganic suspended matter. The lower background SSC in the model compared to TSS are likely due to the absence of organic suspended matter in the model and a lack of sediment input from the open ocean boundaries of the model domain.

In situ measurements of background SSC are necessarily only available from a limited number of sample locations within the model domain while satellite estimates are available over the whole domain, albeit at a coarser scale. While all available data were used to calibrate and validate the model, the number of observations limits any further refinement of the model.

2. Worst-case model scenario

Modelling undertaken by MacDonald & Hadfield (2017) incorporated a "worst-case scenario". For a specific location, the intensity of impact from a sediment plume is determined by a range of plume characteristics, including its spatial extent, shape, amount of sediment being dispersed, and temporal dynamics. Therefore, a worst-case scenario plume for one location may not be a worst-case scenario for another location. In this context, what type of impact does the worst-case model scenario represent?

The far-field plume modelling undertaken represents mining activity being undertaken at a fixed point for the entire duration of the simulation. This means that the full sequence of hydrodynamic conditions that might occur over an 800 day period are simulated and thereby the full extent of the area that could be influenced by the plume released from a fixed location are identified through the simulation. In reality the mining activity will move by several kilometres over time during the simulation period and accordingly the hydrodynamic conditions whilst mining in one area will be a subset of those simulated. The statistical plots should not be confused with a snap-shot of what the plume would look like at any point in time. They represent the statistical likelihood of the plume influencing all locations over the period of the simulations. The entire plume simulation is available as an animation and this is the best way of understanding the spatial and temporal influence of the plume.

The worst-case scenario was modelled in the same way as the original case and included for an increased source term from the discharge from the IMV. It did not consider relocating the release point from the mining activity or making it move during the simulation. The results of the worst-case scenario provide an indication of how much the original results could increase as a result of an alternative larger source term. The original scenario includes for a source term (1.6% ultra fines) that exceeds the source term condition and is therefore a credible position from which to inform the environmental assessment. The worst case scenario further exceeds these conditions.

Specifically, to what extent does the worst-case scenario reflect the likely maximum intensity impact on habitats (benthic and water column) near the mining area, habitats located in different directions from the mining area, and habitats located in the far field?

The far-field modelling of the worst-case includes for release of the plume from a fixed point for a full simulation period (800 days). It includes for time varying currents and wave conditions and therefore shows the full envelope of how the plume released from a fixed point would vary over time (in all directions).

The simulation thus covers combinations of hydrodynamic forcing that might reasonably occur whilst mining at one location. In reality the mining activity will move in space over time. By considering a static point of release the predictions of maximum impact can be considered worst-case for mining activity at the location simulated.

The variation in spatial impact in relation to the point of generation of the plume can also be broadly inferred by considering superimposing the envelopes of predicted SSC centred on other locations where mining activity could occur. Noting that if the plume were being generated at different fixed locations, or moving around over locations that might be mined sequentially over an 800 day period the predicted envelope of effect would be subtly different as a result of relative changes to the flow and wave conditions and to the seabed bathymetry between the points simulated and other locations.

For locations (in all directions) which are more than 3km away from any potential mining activity the worst-case plume results presented are informative to give an indication of the worst-case variation in suspended sediment concentrations or deposition that could be expected in regions of the plume at relative different distances from the mining site centred broadly along the longitudinal and lateral dimensions of the envelope of the plume. This is particularly the case for the extreme results 95%, 99% and maximum results. For the median concentration result because the point of release of the plume from the mining activity will vary spatially by several kilometres over a period of 800 days the envelope of the predicted plume already represents a narrower and more elevated distribution of median concentrations than will occur in reality.

For locations within 3km of potential mining activity then the relative proximity to the point of plume release becomes much more important and is less well informed by the results presented in the far-field modelling and the results of the near-field monitoring should also be considered.