1. New Era Plume Modelling Report (Bell & Reeve 2010)
2. NIWA Letter re T&T Peer Review
3. T&T Peer Review
4. NIWA Letter re Additional Current Data and Link with Modelling.
5. MetOcean Solutions 2010 Ltd – Additional Current Data at A0
6. Ross Vennel Peer Review

Sediment plume dispersion modelling: Comparison of a larger dredger and the *New Era*

NIWA Client Report: HAM2010-119
December 2010

NIWA Project: POL11201

Sediment plume dispersion modelling: Comparison of a larger dredger and the *New Era*

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Prepared for

Port Otago Ltd

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Executive Summary

As part of assessing environmental effects for Project Next Generation, Port Otago Ltd. commissioned NIWA in 2008 to carry out a comprehensive hydrodynamic, dispersion and sediment transport modelling investigation, which was reported by Bell et al. (2009). The 2009 report was submitted in 2010 to Otago Regional Council as a Technical Appendix to the Assessment of Environmental Effects (AEE) that accompanied the consents application.

As outlined in the Port Otago Ltd. applications and AEE, Port Otago will use their own small trailing suction hopper dredger *New Era*, for undertaking a substantial portion of the capital works dredging in Otago Harbour in the form of incremental dredging, progressively working towards the target depth over a longer period of time.

The 2009 NIWA report covered modelling simulations for the worst-case dredging operations, based around the use of a larger trailing suction hopper dredger (TSHD) of 10,800 m^3 capacity. In comparison, the capacity of the *New Era* is only 600 m^3.

This supplementary report compares the suspended-sediment concentrations (SSC) that would be generated during the dredging and disposal phases using the smaller *New Era* with previous model simulations for a larger TSHD. In the Harbour, the 14-day simulations for suspended sediment concentration and sediment deposition (Section 7.5 of the 2009 NIWA report) were all repeated based on the *New Era*, discharging conservatively at 1/13.3 times the larger TSHD sediment discharge rate but overflowing onto the water surface (rather than 5 m depth). Offshore, at the disposal area at A0, the repeated sediment plume simulations for the *New Era* were only undertaken for the scenarios where a hopper load of predominantly-silt dredged material is released at the landward side of the A0 disposal area offshore and at a higher elevation in the water column than the larger TSHD.

Harbour plume modelling (New Era)

Depth-averaged SSC in Otago Harbour for the repeated model simulations was then averaged over a 2 week spring-neap tide cycle to directly compare with the previous 2009 model simulations for a larger TSHD. Monitoring requirements for overseas dredging projects tend to also be expressed as a 2-week moving-average (covering a spring-neap tide cycle).

All simulations for *New Era*, based on a conservative 24/7 operation, show that 2-week average SSC in the main harbour channel reaches only 20–50 mg/L above background concentrations, with smaller patches from 50–100 mg/L where the dredge operates. On the intertidal areas, mostly the average SSC is predicted to only reach 20 mg/L with some limited areas adjacent to the channels of up to 50 mg/L. These concentrations are at least ten times less than those simulated for the larger TSHD.

Considering the silt component of discharges produced by *New Era* from either predominantly-silt versus predominantly-sand[1] areas, there is little difference in the spatial extent of the areas affected by the silt plumes from either dredging source. The SSC are only slightly higher in most cases for the longer overflows when dredging "sand" sources.

Virtually all of the eastern side of the Lower Harbour from Te Rauone Beach through to the eastern side of Portobello Bay would be largely unaffected by turbidity generated by *New Era*, with only a few small patches of SSC up to 10 mg/L above background. Similarly, the eastern side of the Upper Harbour from Grassy Point to Dunedin would be also largely unaffected.

Accumulated seabed deposition over each 14-day plume simulation is presented in mass of sediment per unit area of seabed (kg/m^2). These deposition values are generally conservative as no subsequent resuspension by competent tidal currents or wind-wave stirring was included in the plume model simulations, which will act to further spread and disperse some of the initially-settled material. The deposition plots show the following key results for seabed deposition over a 14-day neap/spring tide cycle with varying winds:

- deposition at or above a nominal 5 kg/m^2 upper level, or approximately 3.8 mm silt accumulation over a fortnightly period at a rate of 0.3 mm/day, is very confined to the immediate vicinity of the main shipping channel where *New Era* dredges. This is in contrast to the larger TSHD, where the same deposition level or rate occurred throughout the main shipping channel (from all discharge sources), and several other areas of the harbour

- most of the eastern parts of the Lower and Upper Harbours would be subject to negligible or no deposition, apart from the reach west of Latham Bay for discharges from the eastern side of the Turning Basin, where deposition may reach 0.5 kg/m^2 (0.4 mm) over 2 weeks or an accumulation rate of 0.03 mm/day)

- flanking mid-harbour intertidal flats, where most of the non-channel deposition will occur, will be at substantially lower deposition rates using *New Era* compared with the larger TSHD by about 10 times less, from 2–5 kg/m^2 (0.1–0.3 mm/day) down to 0.2–0.5 kg/m^2 (0.01–0.03 mm/day) for similar areas.

Offshore plume modelling (New Era)

The maximum excess SSC in the general vicinity of disposal area A0 using *New Era* will only be about 5–7% of the maximum SSC produced by a larger TSHD, based on three wind scenarios (light and moderate WSW winds at 7 and 14 m/s respectively and a light 3 m/s NNE wind). At the disposal area, the <u>near-surface layer</u> SSC concentrations for all silt classes from *New Era* are predicted to be in the range 7–11 mg/L (highest during the light NNE wind) above background concentrations. In the

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[1] Where a small 2% fraction of silt has been assumed in the sands

more concentrated bottom layer, predicted SSC in the vicinity of A0 will be in the range 47–57 mg/L above background concentrations (highest for the moderate WSW wind).

The fringes of sediment plumes from the smaller *New Era* will reach the coastline north of Cornish Head, but the excess SSC combining all silt-size classes will be no higher than 0.05 mg/L for the different wind simulations (highest during light WSW winds). This is around ten times less than for the larger TSHD. During light NNE winds, the fringes of the sediment plumes will also reach Otago Heads, where the excess SSC for all silt classes will be no more than 0.6 mg/L.

The extent of the area influenced by the offshore sediment plume is similar for both dredge sizes during offshore-directed winds (WSW), but minor differences occur for the onshore or offshore fringes of the area affected, particularly to the north of the disposal area. In any case, the excess SSC in the fringes of the plume will be very low.

1. Introduction

1.1 Project Next Generation

Project Next Generation is an initiative by Port Otago Ltd. (POL) to expand the capability of Port Chalmers to handle larger container vessels of up to 8000 TEU capacity[2] through a substantial channel deepening capital works project. The main Harbour channel from Port Chalmers to Harington Bend (Figure 1.2) would need to be dredged to 15 m below Chart Datum to accommodate such vessels, but would need to be deepened to 17.5 m below Chart Datum in the offshore approach channel to accommodate vessel motions arising from a combination of waves, swell and currents.

As part of assessing environmental effects for Project Next Generation, Port Otago Ltd. commissioned NIWA in 2008 to carry out a comprehensive hydrodynamic, dispersion and sediment transport modelling investigation, which was reported by Bell et al. (2009). The modelling provides quantitative or comparative before-and-after information to underpin the assessments of the possible effects of dredging and disposal operations on both Otago Harbour and offshore-shelf environments. The 2009 report was submitted in 2010 to Otago Regional Council as a Technical Appendix to the Assessment of Environmental Effects (AEE) that accompanied the consents application.

1.2 This report

POL will use their own small trailing suction hopper dredge *New Era* (Figure 1.1), for undertaking the initial portions of the capital works dredging in Otago Harbour. This would be done over a much longer period of years (rather than months) to incrementally increase the draught of the channel. POL also wish to retain the flexibility to contract a larger dredge for part of the capital dredging project if the demand for larger TEU vessels rapidly increases in the future and the capital works require completion in a period of months.

The 2009 NIWA report covered modelling simulations for the worst-case dredging operations, based around the use of a trailing suction hopper dredger (TSHD) of 10,800 m^3 capacity. In comparison, the capacity of the *New Era* is much smaller at only 600 m^3 or 1/18 of the hopper capacity of the larger TSHD. Consequently, a number of plume-model simulations for harbour dredging and offshore disposal were

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[2] Twenty-foot Equivalent Unit (or TEU) is an inexact unit of cargo capacity often used to describe the capacity of container vessels. It is based on the volume of a standard-size 20-foot (~6 m) long shipping container.

repeated using the smaller-scale discharges from *New Era*. This provides a quantitative comparison with the environmental effects that were extensively assessed for the larger TSHD.

This supplementary report compares the suspended-sediment concentrations that will be generated during the dredging and disposal operations using the smaller *New Era* with similar model simulations reported by Bell et al. (2009) for the larger TSHD. Accumulated deposition was also compared for the harbour modelling.

The 14-day harbour simulations repeat those carried out in the 2009 NIWA report (see Figures 7.4 to 7.13 of Bell et al., 2009) for all five representative source areas (see Figure 7.2, Bell et al., 2009). The outputs include plots of the spatial distribution of 2-week average suspended-sediment concentrations and the accumulated sediment deposition.

For the harbour modelling, a very conservative case was simulated with *New Era* working continuously (24/7). However, in reality this very unlikely to occur on a sustained and ongoing basis due to down-time or non-productive time the vessel may be dredging at other ports. In addition, a two-crew operation of *New Era* would only yield approximately 50% of this dredging intensity being available 90 hours per week out of 168 hours for 24/7 (Lincoln Coe, POL, pers. comm.)

Offshore, the simulations for both types of dredger assume the worst-case, where a hopper load of <u>predominantly-silt</u> dredged material is released at the landward side of the A0 disposal area offshore (see Figure 11.4 of Bell et al., 2009).

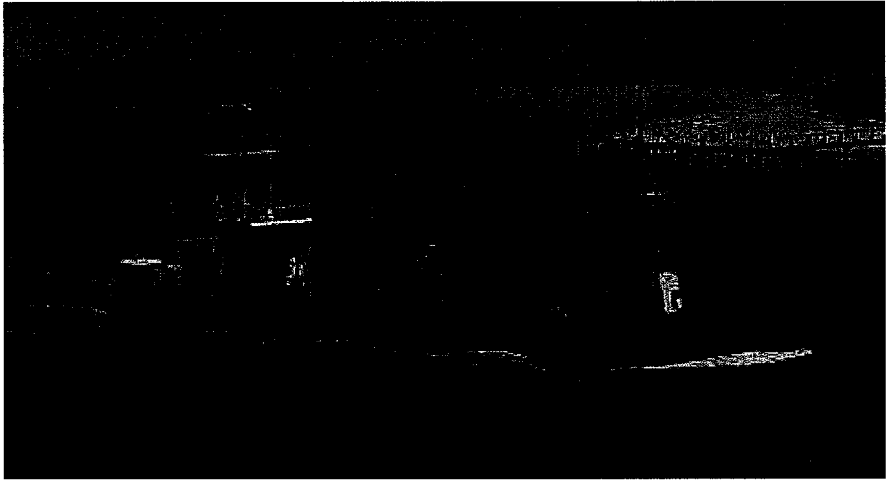

Figure 1.1: *New Era* passing Spit Jetty fully laden on passage to an offshore disposal site.

For ease of determining various Otago Harbour locations mentioned in this Report, Figure 1.1 from the 2009 NIWA report is reproduced in Figure 1.2.

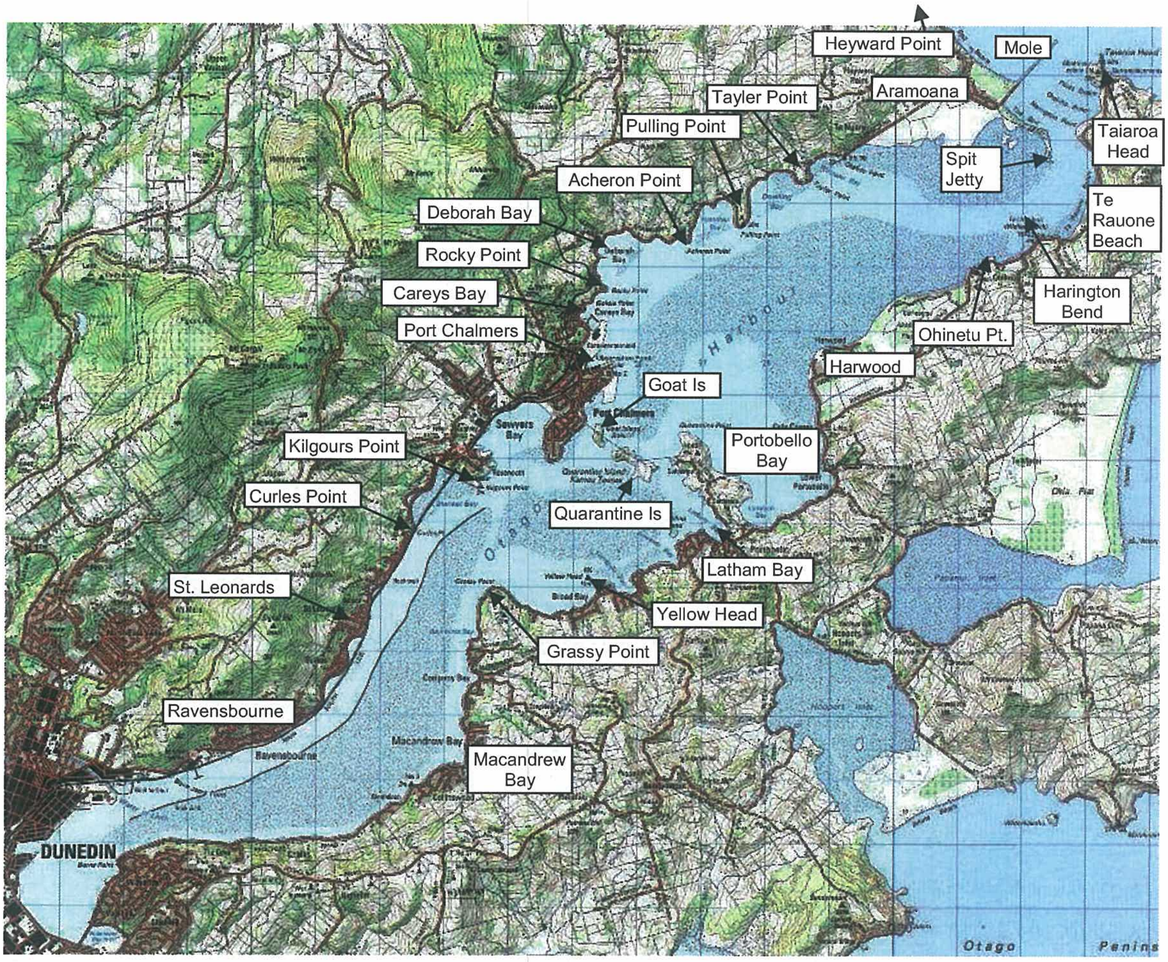

Figure 1.2: Geographical sites in Otago Harbour [*Source:* ©LINZ 1:50,000 topographic maps].

2. Set up of *New Era* simulations

2.1 Harbour sediment plume modelling

Sediment plume modelling in Otago Harbour for a larger TSHD was previously carried out using MIKE-21, which is a 2D (depth-averaged) hydrodynamic model setup on a regular square model grid of 30 m cells, and the MIKE PA module for the plume dispersion, which is 3D "particle-tracking" dispersion model with gravitational settling. In all, ten sets of 14-day sediment plume simulations were undertaken for dredging based at five representative source areas (Figure 2.1) and at each source area, for dredging predominantly-sand sediments (with a 2% silt content) and predominantly-silt sediments (with a distribution of silt size ranges based on seabed samples).

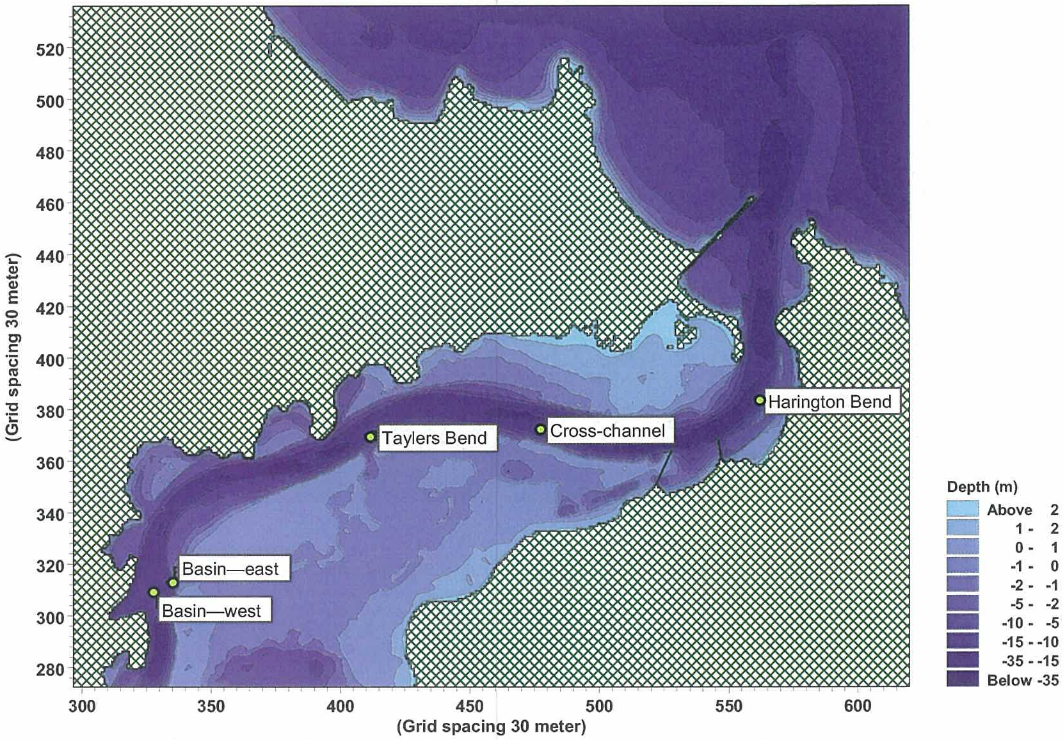

Figure 2.1: The five representative channel source-area sites used as the discharge source locations for dredged-cycle suspended-sediment plume simulations inside Otago Harbour.

These ten simulations were repeated using the smaller-scale *New Era* dredge. The model parameters used to set the sediment discharge rates and their depths for the *New Era* are listed in Table 2.1 (which can be compared with Table 7.1 in the 2009 NIWA report for the larger TSHD). The main differences are the sediment discharge rates are about 1/15th of the larger TSHD modelled previously, the overflow for sands starts earlier at 10 minutes into the dredging cycle (20 minutes for the larger TSHD)*, and the overflow from *New Era* discharges directly onto the water surface (compared with 5 m depth for the larger TSHD).

Table 2.1: Source discharge rates for silt sizes to be used for the *New Era* for both near-bed suction-head disturbances and hopper overflow sources, time windows for these sources ($t = 0$ minutes at the start of pumping) for each sediment-source type. [*Source:* Lincoln Coe, POL].

Sediment source	Discharge height	Silt discharge rate (kg/s)	Timing (min)
"Sand" claims (2% silt)	1 m above bed	2	0–80 min
	0 m below surface	4	10–80 min
"Silt" claims	1 m above bed	2	0–24 min
	0 m below surface	75	20–24 min

*Note: the plots for predominantly-sand simulations in the 2009 NIWA report (bottom panels of Figs. 7.4 to 7.13) were mistakenly done for an overflow for the final 20 minutes of the 80 minute dredge cycle. These previous larger-TSHD simulations were repeated for the correct timing of the overflow starting 20 minutes after the start of the cycle and are displayed in Section 3 of this Report for comparison with the *New Era* simulations. The predominantly-silt simulations (top panels) were correct in the 2009 NIWA report. For assessing the effect of the revised predominantly-sand simulations on seabed deposition, compared to the earlier simulations in the 2009 NIWA report, see the comparison plots in Appendix A.

The dredge cycle times including turn-around times for *New Era* were left the same as for the previous simulations as listed in Table 7.2 of the 2009 NIWA report, including a conservative assumption of a 24/7 continuous dredging operation (which in reality will not occur on a sustained and ongoing basis due to downtime and non-productive time outside of the port). All other parameters, including settling velocity were also held to the same values as previously used.

Results are provided in plot showing the spatial distribution of a 2-week average of suspended-sediment concentrations in kg/m^3 (depth averaged and saturated-weight[3]

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[3] Normally suspended-sediment concentrations are expressed in dry-weight of sediment, so these higher results based on saturated-weight will be more conservative.

basis as previously) and the accumulated sediment deposition after 2 weeks in kg per square metre of seabed. To convert to metres of deposition, these results would need to be divided by a conservative wet bulk sediment density of 1300 kg/m^3. The additional complex step of apportioning the deposition to several sub-areas of Otago Harbour (see Figure 7.3 of the 2009 NIWA report) and reporting on statistics was not re-done for this supplementary work, given the potentially long time of a few years that would be required to complete the dredging using *New Era*. However, the overall 14-day deposition plots show the main areas where sediments would preferentially settle under *New Era* dredging (with a surface overflow) compared to the larger TSHD overflowing at a greater depth.

2.2 Previous offshore sediment plume modelling

Previous modelling offshore for plume dispersal from the disposal site A0 was based on MIKE3-FM, which is a 3D layered hydrodynamic model on a flexible triangular mesh, and the MIKE3 PT module, which is a 3D "particle-tracking" dispersion model with gravitational settling (Bell et al., 2009).

The following plume model parameters were previously implemented in Bell et al. (2009) for the offshore disposal ground as described in Section 11.1.1 of that Report:

- sediment classes - Four sediment size fractions were simulated by "particles" in the discharge with their respective average settling velocity:
    - *Class 1* - fine silt with grain sizes of <0.00625 mm.
    - *Class 2* - medium silt with grain sizes between 0.00625 and 0.02 mm.
    - *Class 3* - coarse silt with grain sizes between 0.02 and 0.0625 mm.
    - *Class 4* - fine sand with grain sizes of >0.0625 mm.
- discharge height from bottom of hopper - set to 5 m below the water surface at the time, which is applicable to a larger trailing suction hopper dredger (TSHD)
- discharge sequence - based on an analysis of dredging operations by POL, the discharge at the disposal site was simulated as a 10-minute slug of sediment with a 2-hour turn-around window before the next disposal commenced and so on
- discharge location – the most landward sub-site #1 within the 2 km diameter A0 disposal area (see Figure 2.2 below)

- dredge hopper composition and discharge rates - two variants on the likely sediment composition of a hopper were simulated with their associated discharge rates in kg/s for each sediment class listed in Table 11.1 of Bell et al. (2009). The wet bulk density of sand in the hopper was assumed to be packed at 1800 kg/m^3 and for silts 1600 kg/m^3 based on dredging experience (Lincoln Coe, pers. comm.). The majority of the plume model runs in Bell et al. (2009) used an overall average sand/silt hopper composition, based on a dredging analysis by Port Otago Ltd. that incorporated geotechnical findings and sediment size grading curves. In terms of ascertaining peak suspended-sediment concentrations at the disposal site and surrounding area, some simulations were also performed for a hopper of predominantly silt (e.g., sourced from the Hamilton Bay reach between Beacons 18 and 20). It is these simulations for predominantly-silt hopper loads that are compared with using the *New Era* in this present Report.

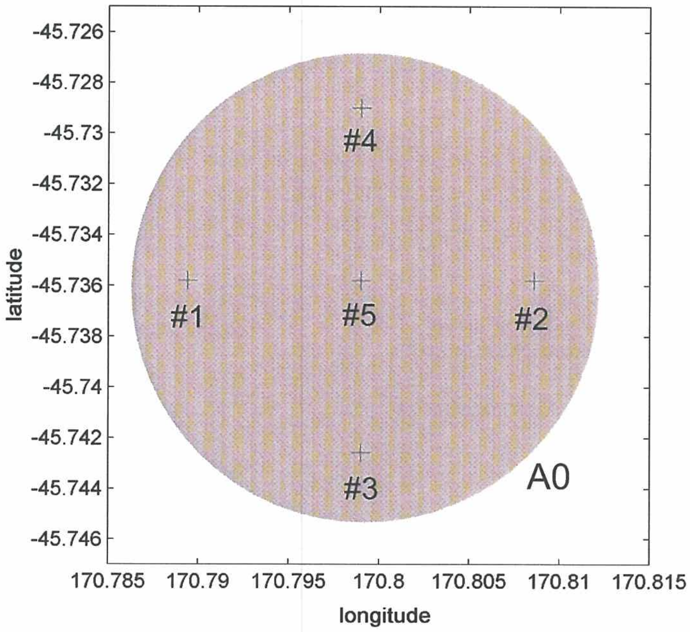

Figure 2.2: Relative location of the 5 sub-sites used as hopper-release locations within a 2-km diameter disposal site at A0 (central sub-site #5 is at –45.7358°N and 170.799°E).

2.3 *New Era* offshore plume simulations

The equivalent parameters for the *New Era* sediment-plume modelling runs were:

- *sediment classes* – used the same four sediment classes and settling velocities

- *discharge height* – the bottom of the hopper for the *New Era* when laden is 3.5 m below the water surface and 1.5 m when empty, so the sediment discharge height has been set at 2.0 m below the surface, slightly below the laden/empty average

- *discharge sequence* – the turnaround time of 2 hours is set the same as the larger TSHD but the discharge time is set at 4 minutes compared with 10 minutes for a larger TSHD

- *discharge location* – same as before

- *hopper composition and discharge rates* – the *New Era* hopper capacity is only 600 m^3 compared with 10,800 m^3 for the larger TSHD, otherwise the loading factors and wet bulk densities are assumed to be the same. Therefore the sediment volumes discharged from the *New Era* hopper are 5.56% of those for the larger TSHD (i.e., 600/10,800 = 0.0556), but the discharge time is only 4 minutes compared with 10 minutes for the larger TSHD so a factor of 10/4 has been applied to the volumes to determine the *New Era* discharge rates. A comparison of the sediment discharge rates for both TSHD is shown in Table 2.1.

Table 2.1: Sediment discharge rates (kg/s) on a saturated-weight basis used for the dredge hopper scenarios for each sediment size class covering a predominantly-silt hopper composition using a larger TSHD (10,800 m^3 capacity) compared with the *New Era* (600 m^3).

Hopper load scenarios (predominantly silt load)‡	**Larger TSHD**	***New Era***
Sediment-class discharge (kg/s)		
Class 1 (fine silt)	2,326	323
Class 2 (medium silt)	3,034	422
Class 3 (coarse silt)	3,236	450
Class 4 (fine sand)	1,517	211

‡Predominantly-silt hopper load for the larger TSHD dredge would be 3,790 m^3 assuming a lower hopper loading factor of 0.35 for mostly silts. The same loading factor was applied to the *New Era*. The lower loading factor arises from early cessation of dredging when the hopper starts to overflow and silts don't readily settle in the hopper like sands. A bulk density of 1600 kg/m^3 is assumed for both TSHD dredgers.

3. Results for the harbour plume modelling

The results are presented as a series of two sets of paired plots on facing pages of both the 2-week average SSC and the 2-week accumulated deposition.

The left-hand pages are the previous results from the larger TSHD shown in Figures 7.4 to 7.13 of the NIWA 2009 report (apart from the predominantly-sand simulations in the bottom panel which were re-run for an overflow starting 20 minutes into the dredging cycle). The right-hand pages are the equivalent simulations using the smaller *New Era*.

The same spatial coverage and the same suspended-sediment concentration or deposition scale palettes have been used in the plots, as those used in the 2009 NIWA report, to provide a ready comparison of the differences in average SSC and the 2-week accumulated deposition between using a larger dredger and the *New Era*.

Harbour sites mentioned are shown in Figure 1.2.

3.1 Comparisons for the 2-week average suspended-sediment concentrations

Suspended-sediment concentration (SSC) averaged over each 14-day plume simulation was calculated for each model grid cell (30 m × 30 m) and plotted in Figure 3.1 to Figure 3.10 for each of the five discharge sources. Concentrations are presented in kg/m^3, where 1 kg/m^3 is equivalent to 1000 mg/L and 0.1 kg/m^3 is equivalent to 100 mg/L. Average SSC over 2 weeks are provided to directly compare with the previous 2009 model simulations for a larger TSHD and monitoring requirements for overseas dredging projects tend to be expressed as a 2-week moving-average (covering a spring-neap tide cycle). Note: the modelled SSC excludes any background concentrations, which can vary considerably each day and throughout a tide cycle. So SSC is expressed as an excess concentration due to the dredging over and above any background concentration.

Concentrations from the MIKE-21 PA plume model are averaged over the entire depth of the water column at the time of calculation, so the 14-day SSC averages shown in the plots are also averages over the water depth (mid-tide to seabed level). However, because the sediments are discharged at depth and they preferentially settle (even though there will be some upwards vertical dispersion), the SSC will be distributed unevenly through the water column, skewed towards much higher-than-average SSC near the seabed compared to a lower-than-average SSC at the water surface. This skewed distribution also occurs naturally with tidal current or wave stirring of bottom sediments, where the SSC is far greater just above the seabed than at the surface - more so the deeper the water column and the larger the grain size.

The plots (Figures 3.1–3.10) show the following key results:

- all simulations for a 24/7 operation based on *New Era* show that 2-week average SSC in the main channel reaches only 20–50 mg/L above background concentrations, with smaller patches from 50–100 mg/L where the dredge operates. On the intertidal areas, mostly the average SSC is predicted to only reach 20 mg/L with some limited areas up to 50 mg/L. These concentrations are at least ten times less than those simulated for the larger TSHD

- the *New Era* discharges in the Turning Basin (Figures 3.2 & 3.4) and Taylers Bend (Figure 3.6) would have the most influence on raising average SSC above background levels in the Upper Harbour. Outside the main channels, SSC would be up to 50 mg/L in small areas (mainly west of Portobello Peninsula for dredging in the eastern Turning Basin), and mostly below 10 mg/L above background concentrations

- the highest depth-average SSC values of up to 100 mg/L will occur in small patches in the main shipping channel where the *New Era* is operating. In subsidiary side channel north of Quarantine Island through to Portobello Peninsula (Figure 3.4), there will be patches with SSC up to 50 mg/L when the dredge is working the eastern Turning Basin

- considering the silt component of discharges produced by *New Era* from predominantly-silt (top panels) versus predominantly-sand[4] areas (bottom panels), there is little difference in the spatial extent of the areas affected by the respective silt plumes. The SSC are only slightly higher in most cases for the longer overflows when dredging predominantly-sand areas

- while there is only a short distance separating the two Turning Basin source locations (east and west on Figures 3.2 & 3.4), there will be a substantial divergence in areas affected by suspended-sediment plumes due to the strong flow divergence at Quarantine Island. From the "west" source location, discharge plumes would be transported up the Victoria Channel partway into the Upper Harbour (Figure 3.2), while plumes from the "east" source location (Figure 3.4) would be preferentially transported and dispersed to areas around

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[4] Where a small 2% fraction of silt has been assumed in the sands

the Portobello Peninsula and into the Latham Bay to Yellow Head area of the Upper Harbour, predominantly only in the SSC range 5–10 mg/L above background but there are small patches with SSC up to 50 mg/L (for locations see Figure 1.1 of Bell et al., 2009)

- virtually all of the eastern side of the Lower Harbour from Te Rauone Beach through to the eastern side of Portobello Bay would be largely unaffected by turbidity generated by *New Era*, with only a few small patches of SSC up to 10 mg/L (Figure 3.10)

- the eastern side of the Upper Harbour from Grassy Point to Dunedin would be also largely unaffected by sediment discharges from *New Era*

- the 14-day average SSC will be negligible in the indistinct plume that emanates from the Mole to Taiaroa Head channel section for dredging claims in the Turning Basin, but will gradually increase up to a depth-average SSC of 10–20 mg/L for dredging at Harington Bend. These average SSC levels offshore from the Mole would reduce somewhat as the dredger works the Howlett claim (between Harington Point and the Mole) and further reduce in the Outer Channel claim as the silt content of the sandy seabed sediments reduces considerably to be negligible.

Also pertinent to these results on 2-week averages is the finding in the NIWA 2009 Report (Bell et al., 2009) that the % of time that the excess SSC is negligible is quite high outside the main channels—often 80% of the time or more. This occurs because the dredging discharges are not continuous, but cyclic with gaps of up to 1.8 hours and the tidal flows reverse every 6 to 6.5 hours, providing lengthy periods at "upstream" sites for silt-sized material to settle out.

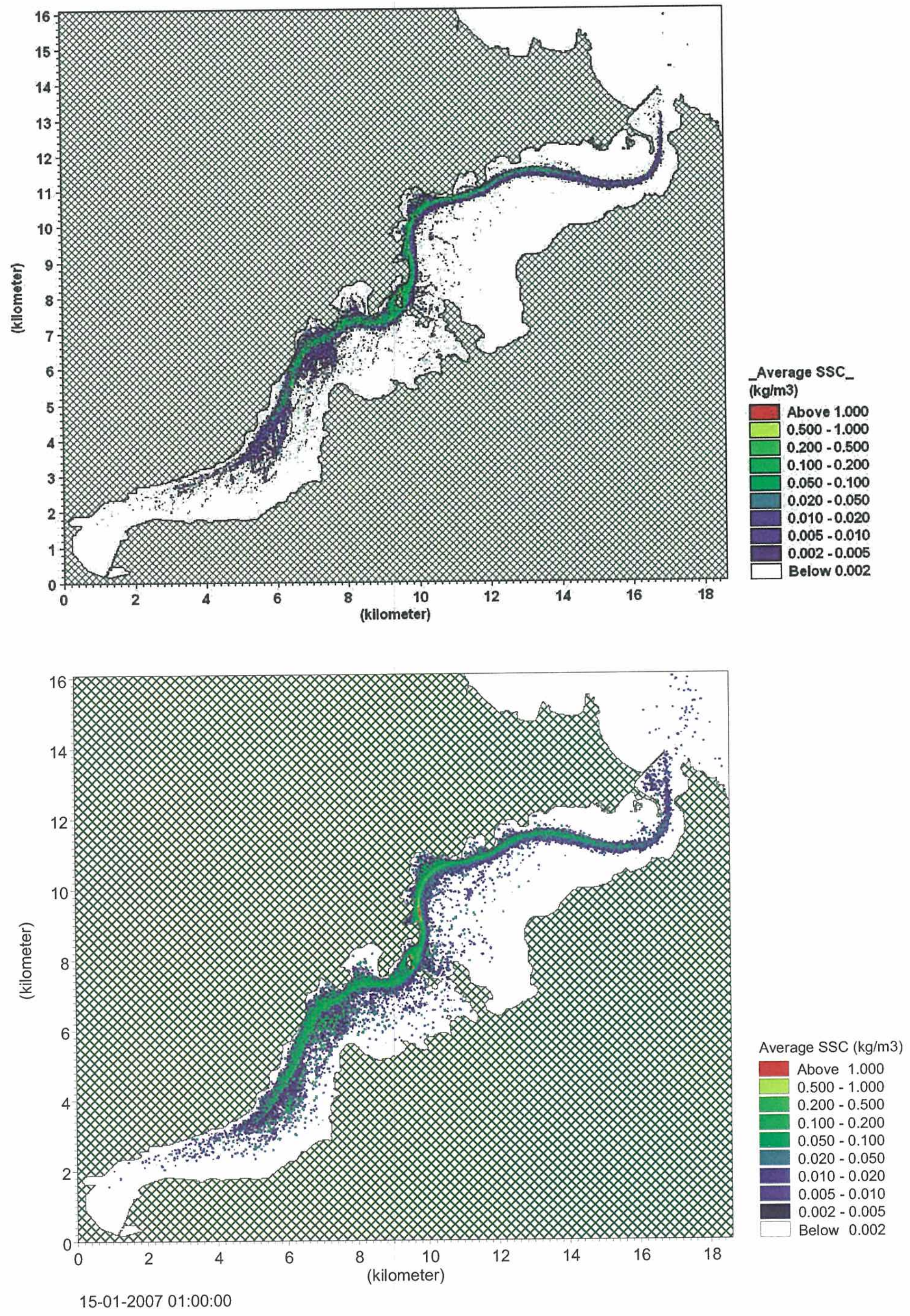

Figure 3.1: 14-day average SSC in kg/m^3 for a Basin–west discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

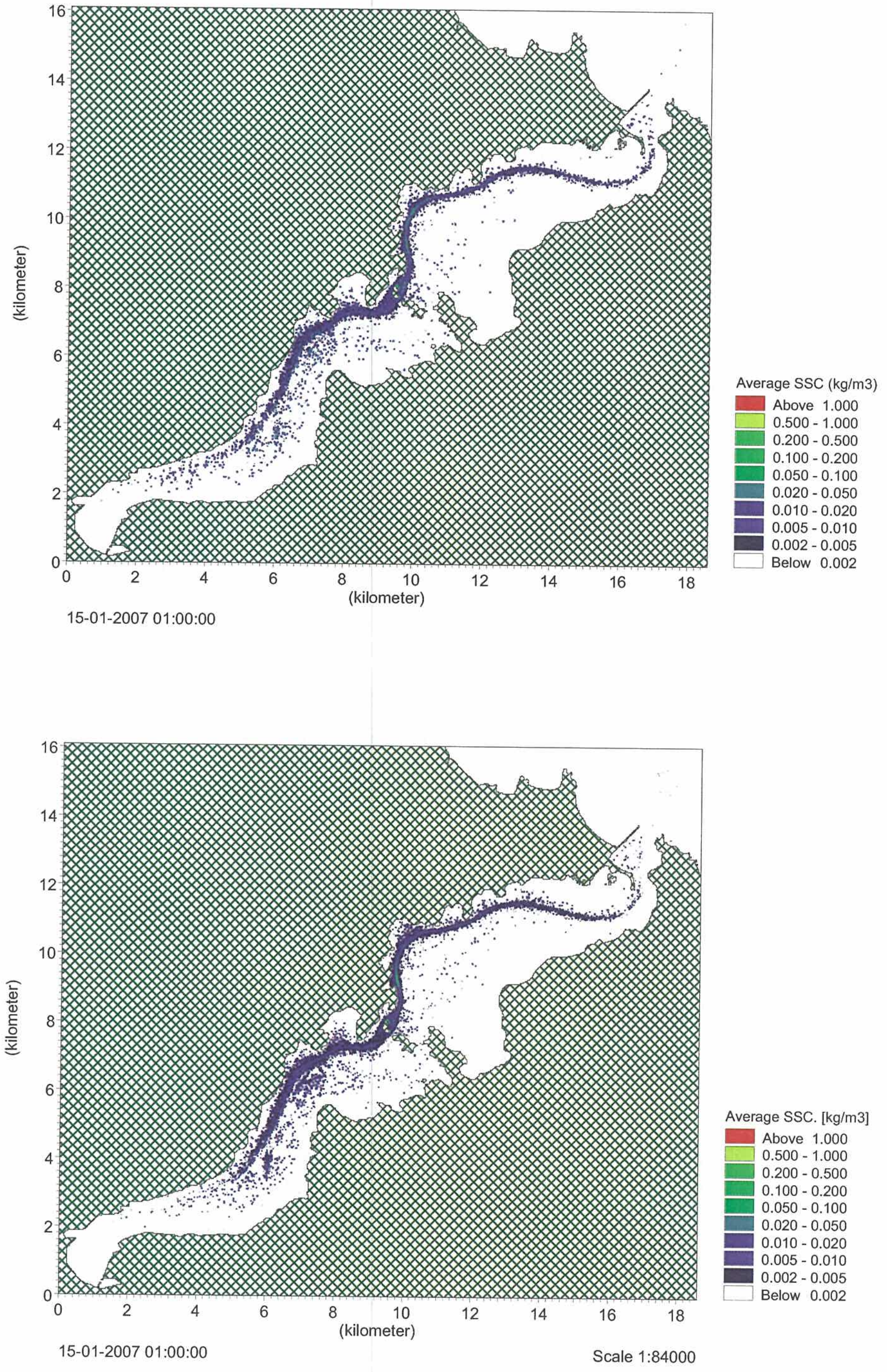

Figure 3.2: 14-day average SSC in kg/m^3 for a Basin–west discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

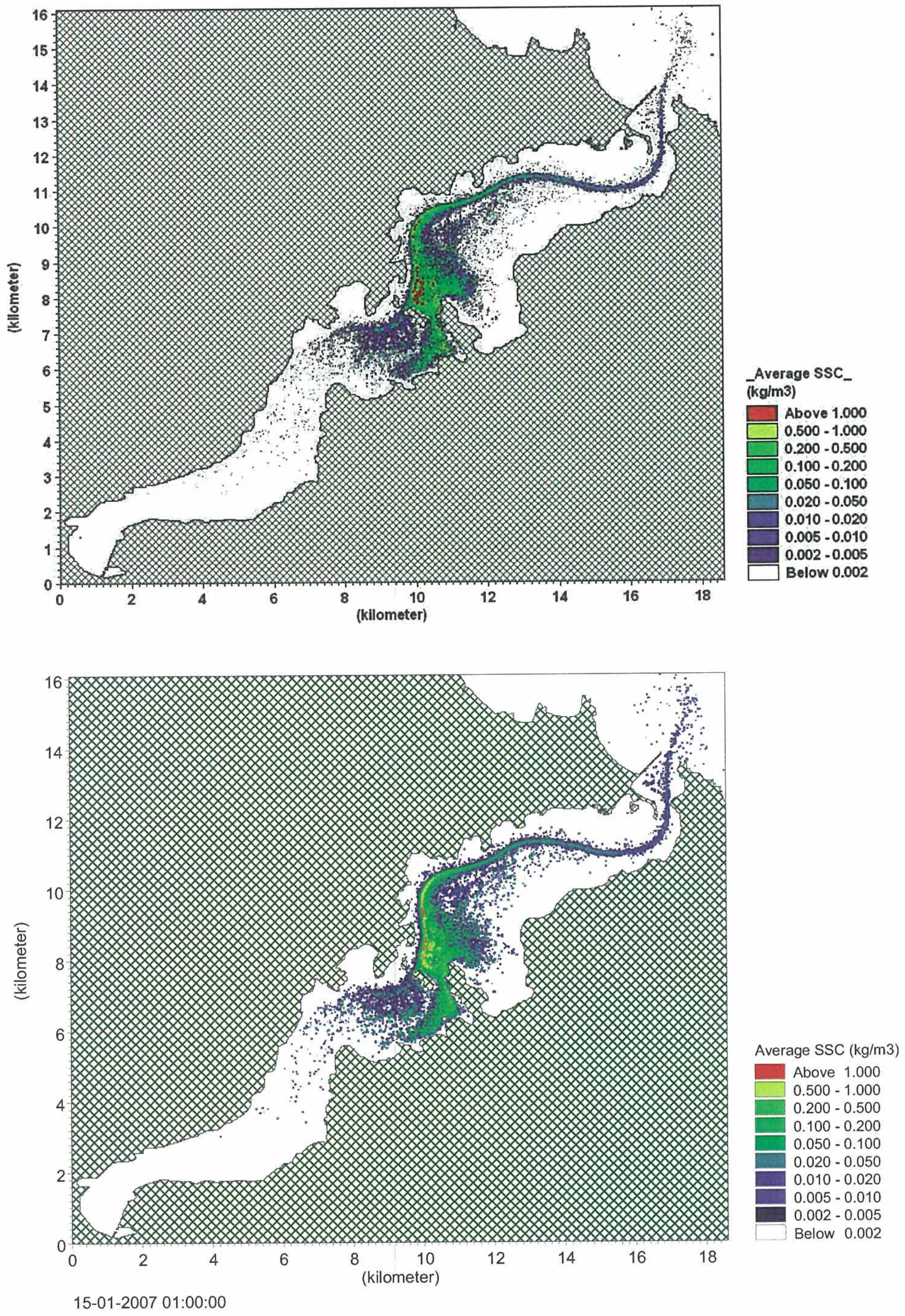

Figure 3.3: 14-day average SSC in kg/m^3 a Basin–east discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

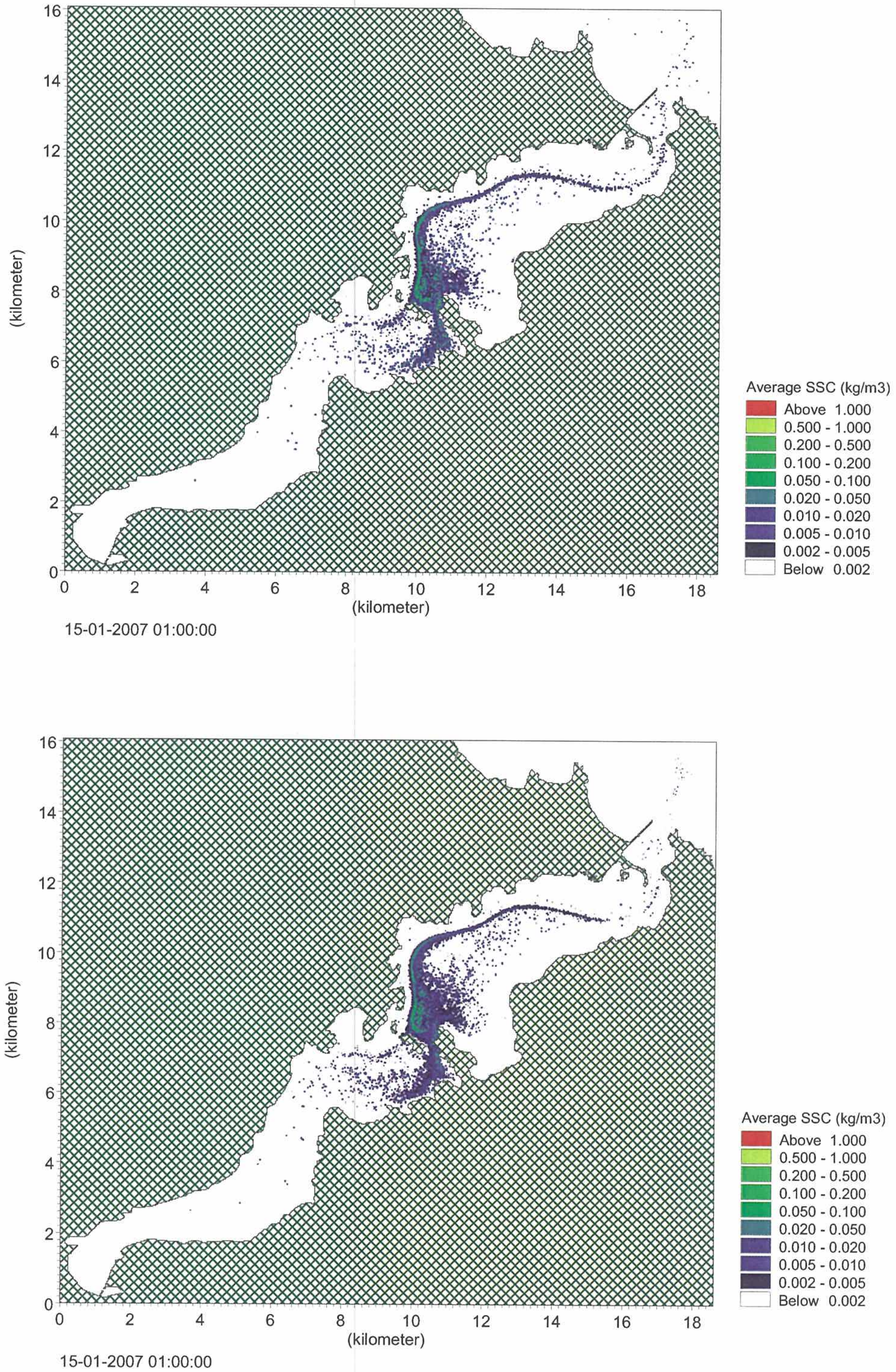

Figure 3.4: 14-day average SSC in kg/m^3 for a Basin–east discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

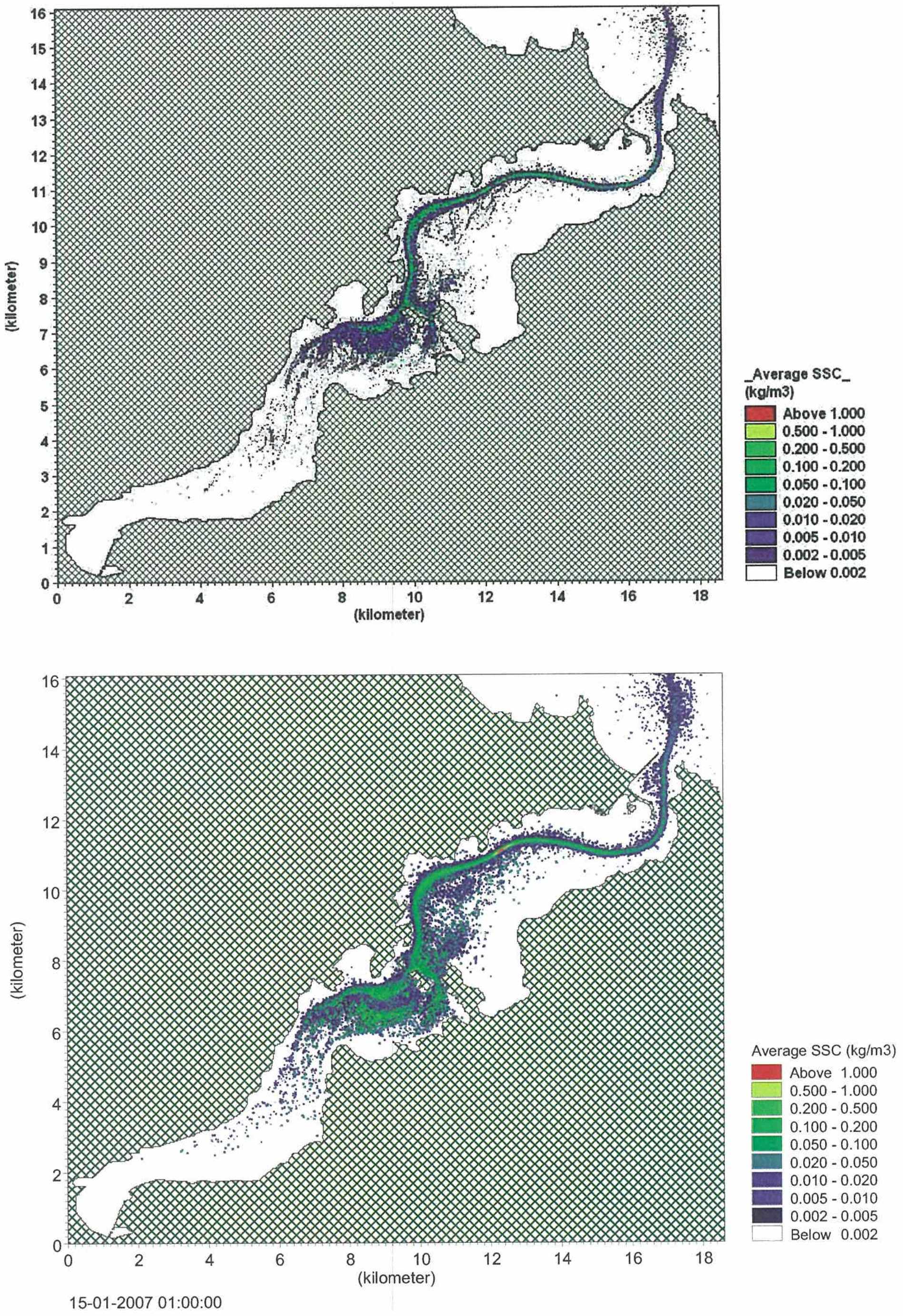

Figure 3.5: 14-day average SSC in kg/m^3 for a Taylers Bend discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

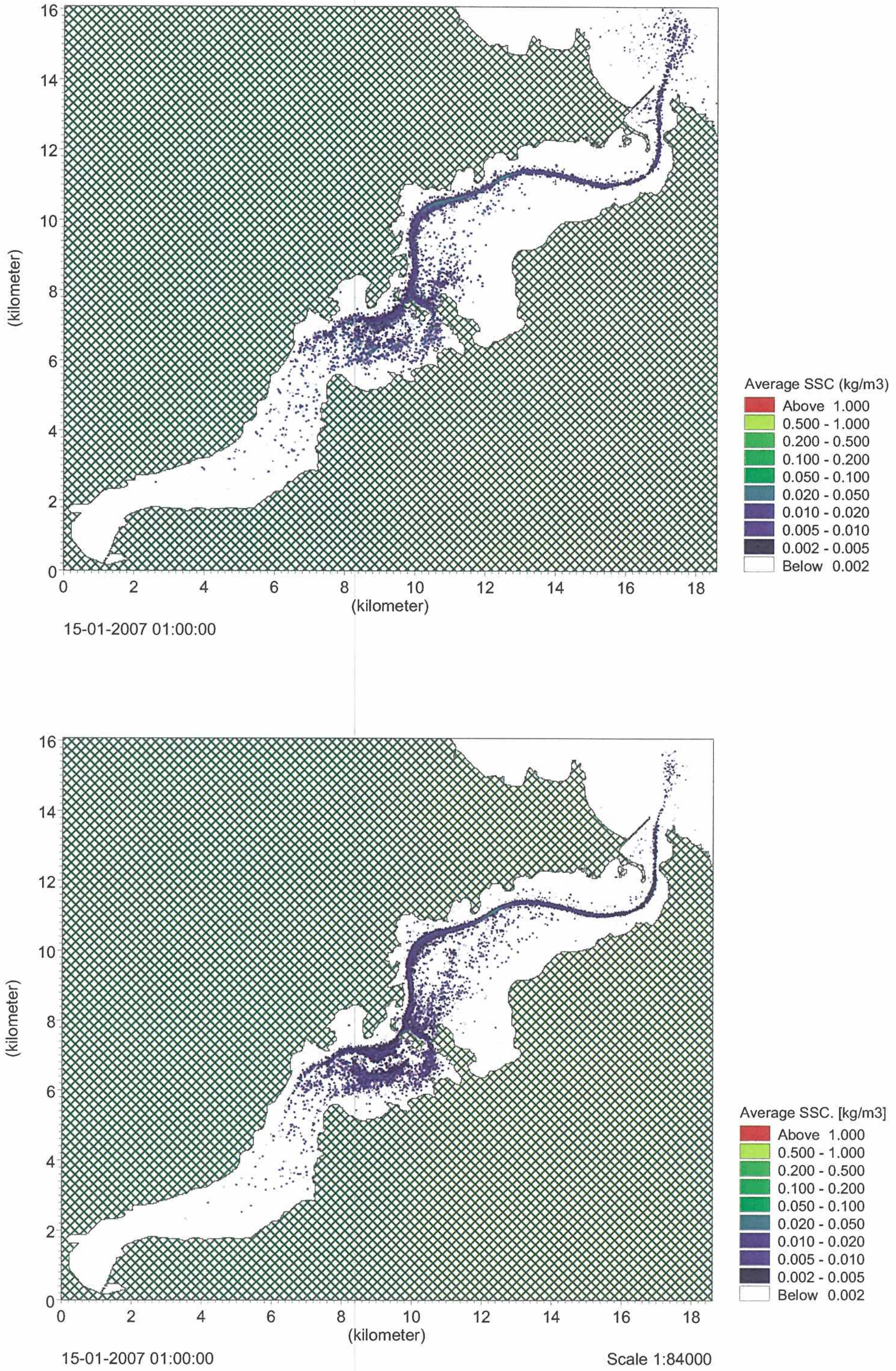

Figure 3.6: 14-day average SSC in kg/m^3 for a Taylers Bend discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

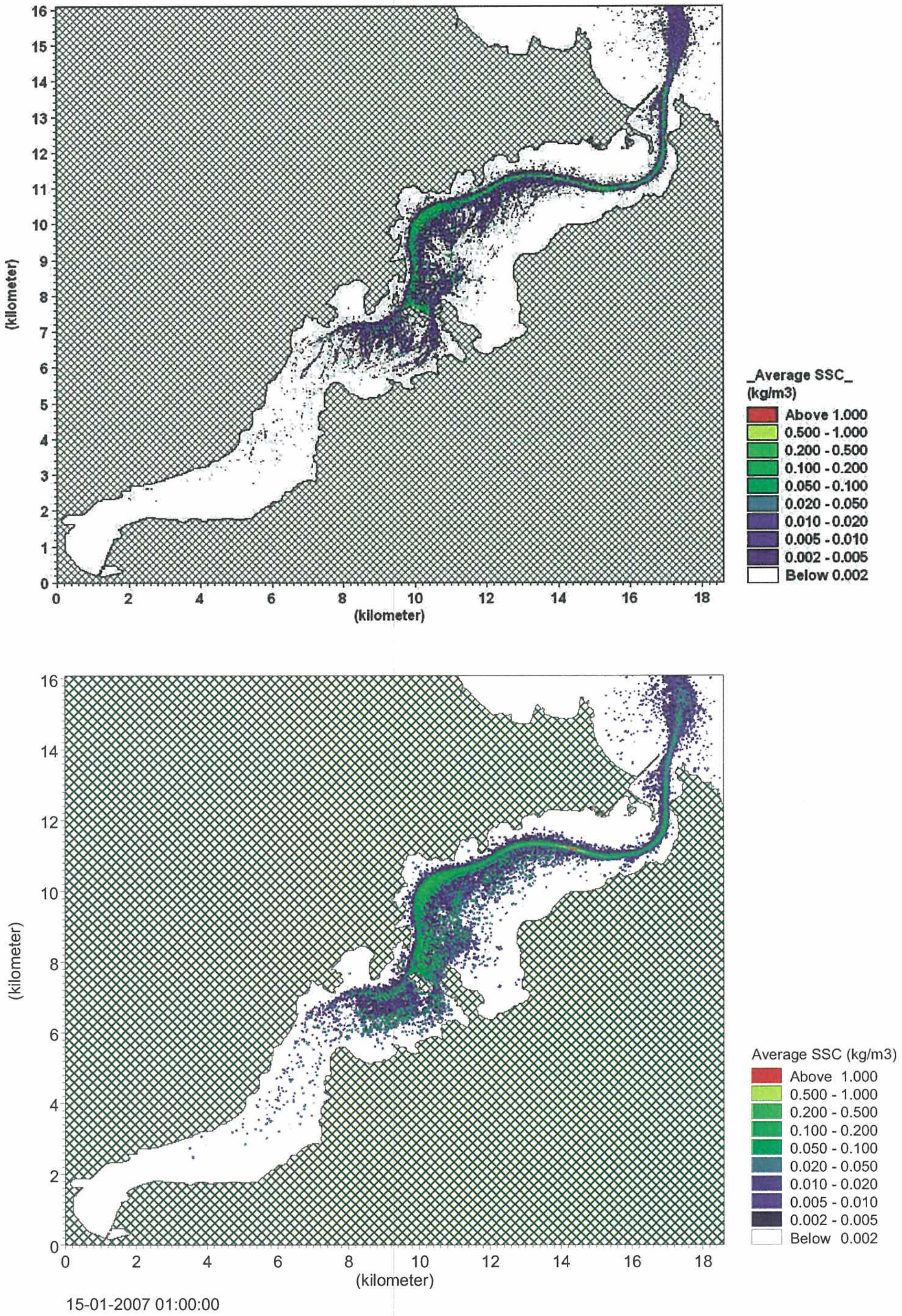

Figure 3.7: 14-day average SSC in kg/m^3 for a Cross-channel discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

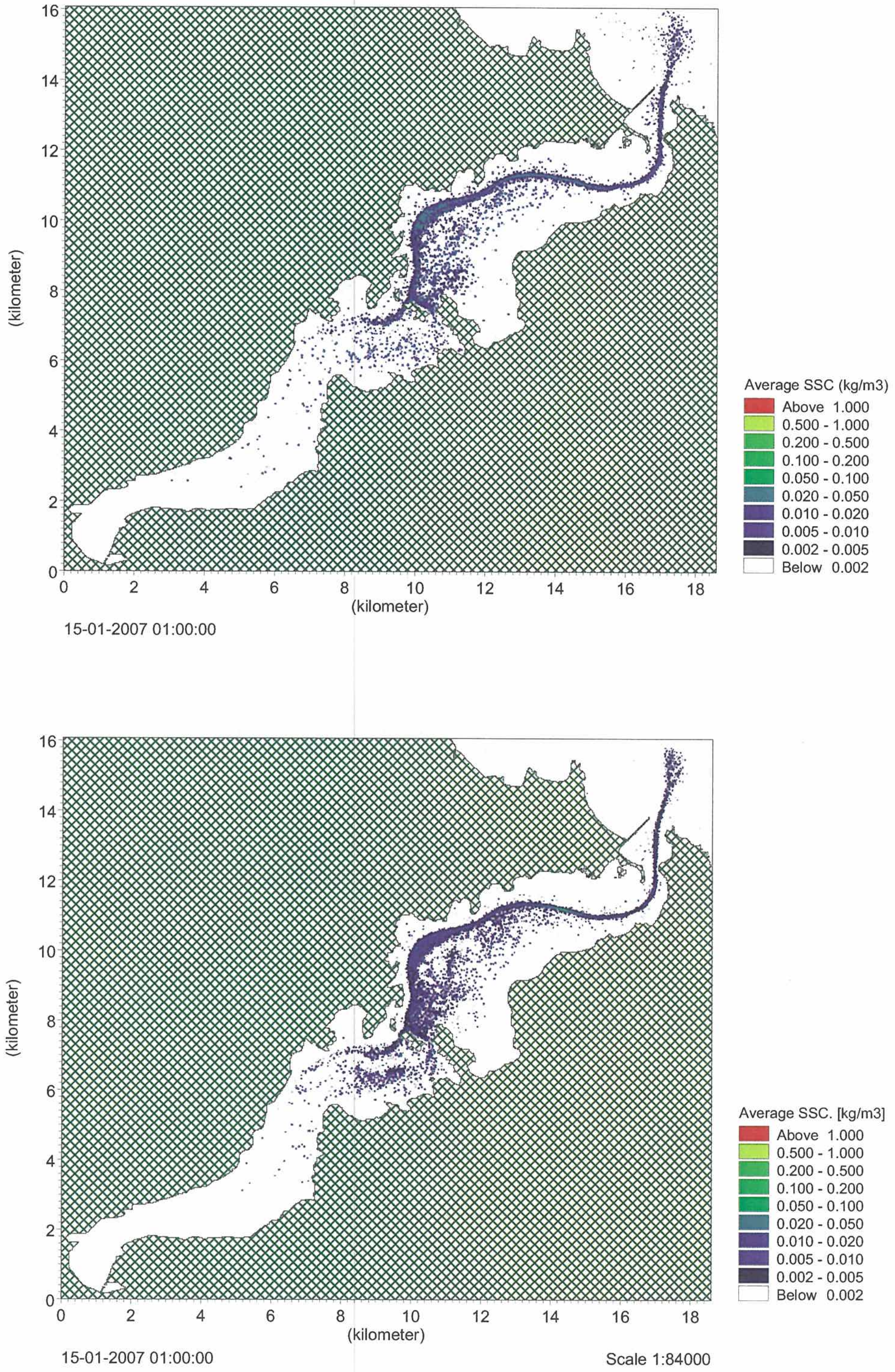

Figure 3.8: 14-day average SSC in kg/m^3 for a Cross-channel discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

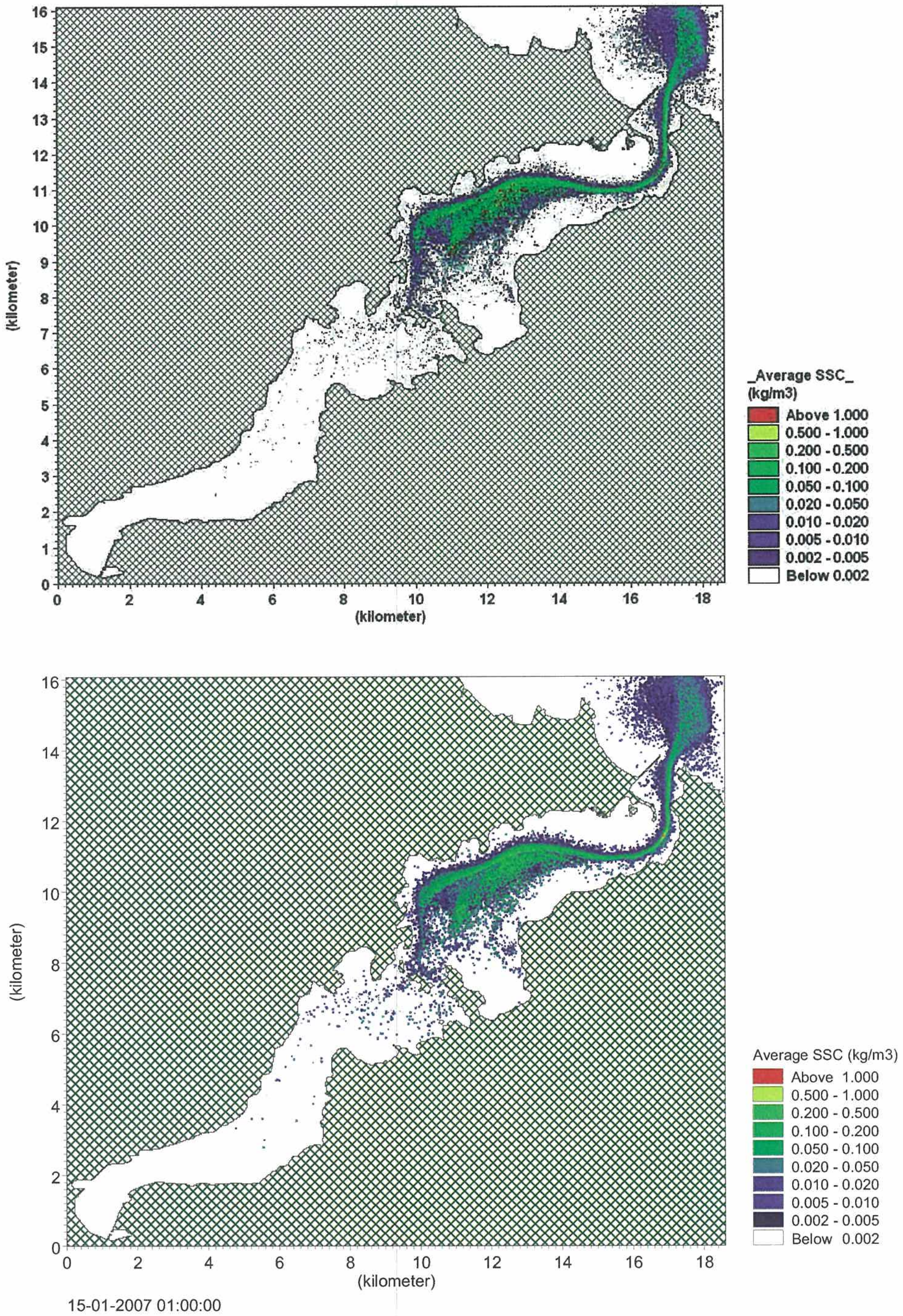

Figure 3.9: 14-day average SSC in kg/m^3 for a Harington Bend discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

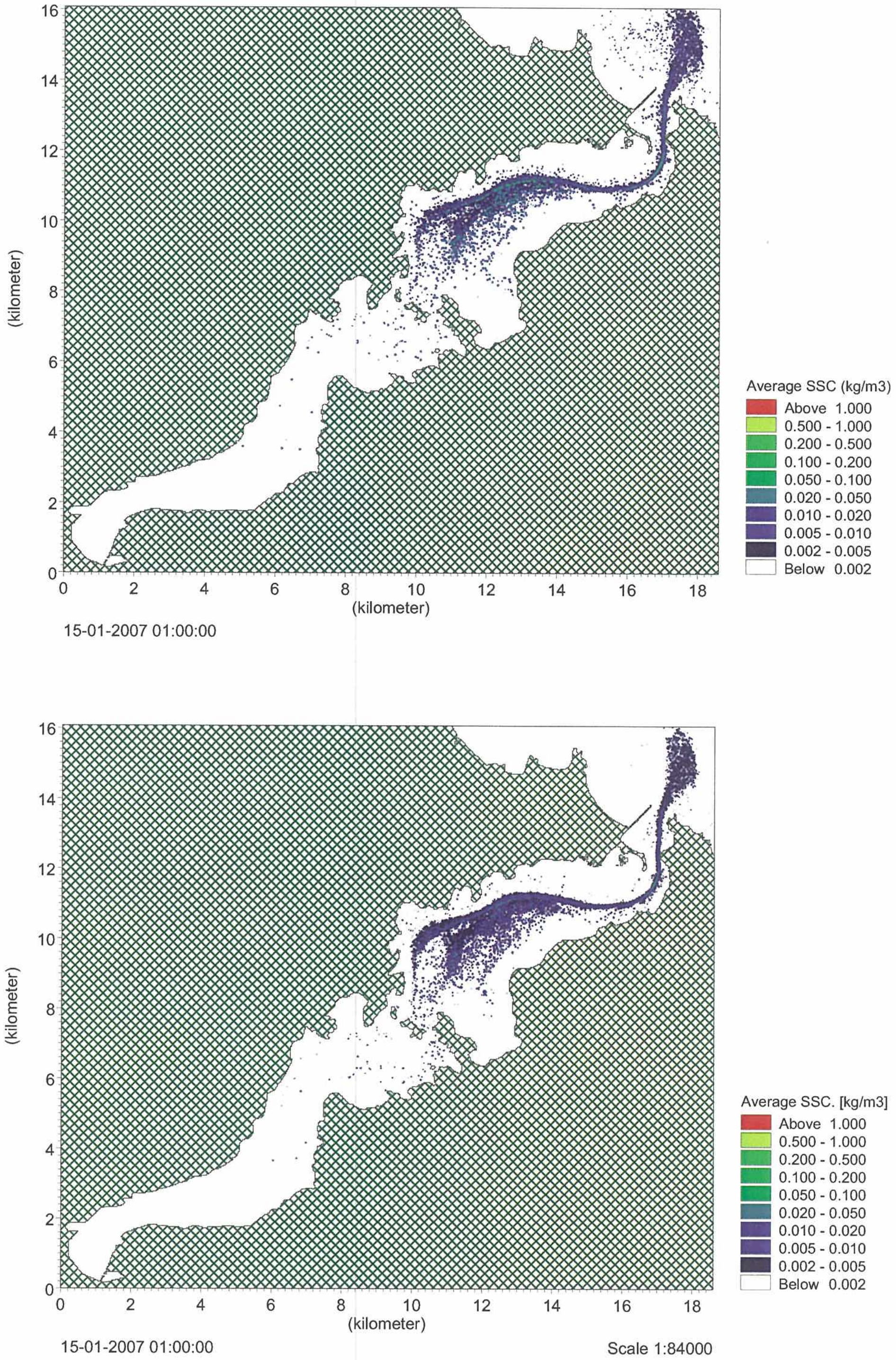

Figure 3.10: 14-day average SSC in kg/m^3 for a Harington Bend discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

3.2 Comparisons for the 2-week accumulated seabed deposition

A similar sequence of plots is shown below (Figures 3.11 to 3.20) for the 2-week accumulated sediment deposition. Results are discussed at the end of the plots.

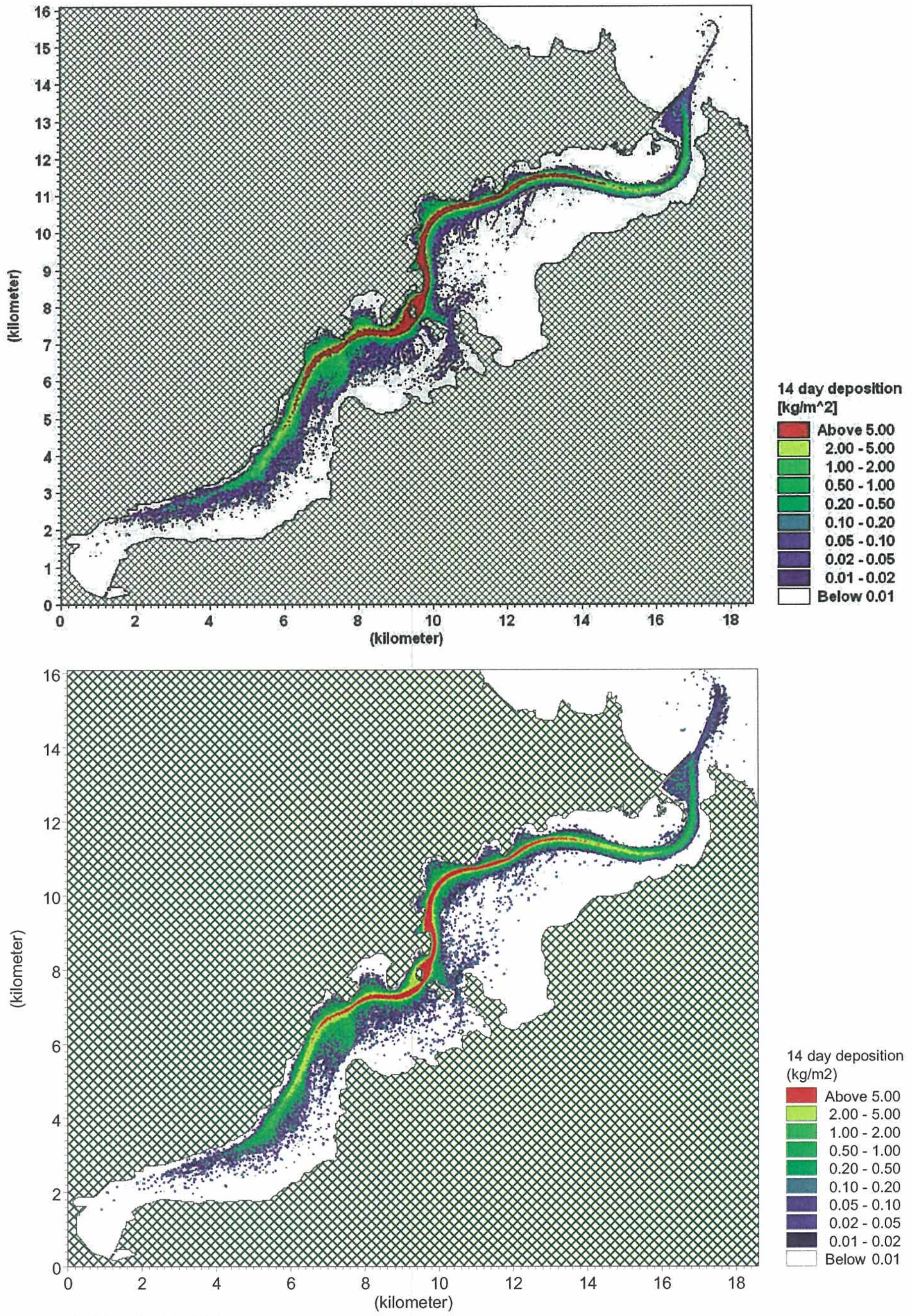

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Figure 3.11: 14-day accumulated seabed deposition in kg/m^2 for a Basin–west discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

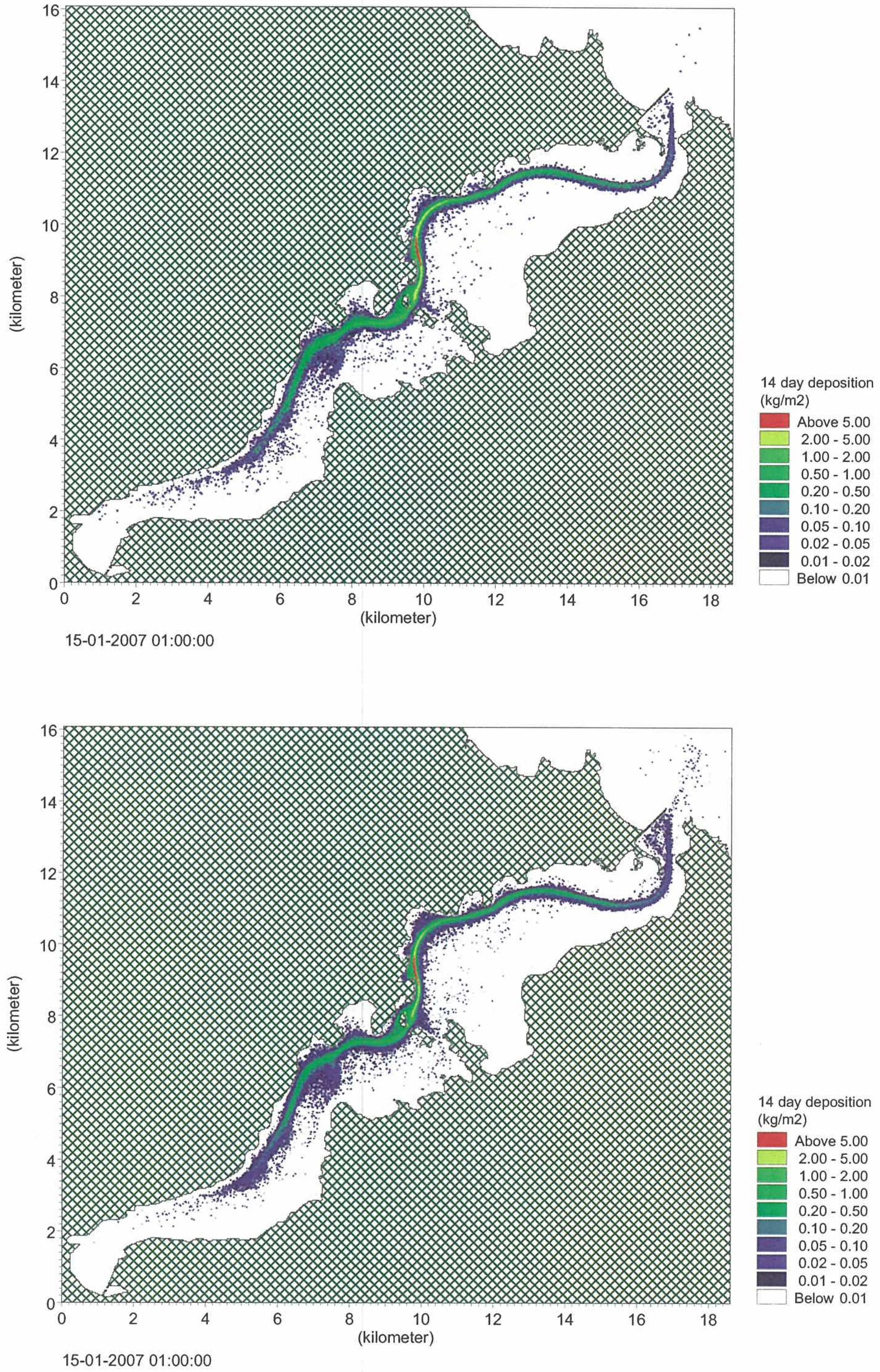

Figure 3.12: 14-day accumulated seabed deposition in kg/m^2 for a Basin–west discharge from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

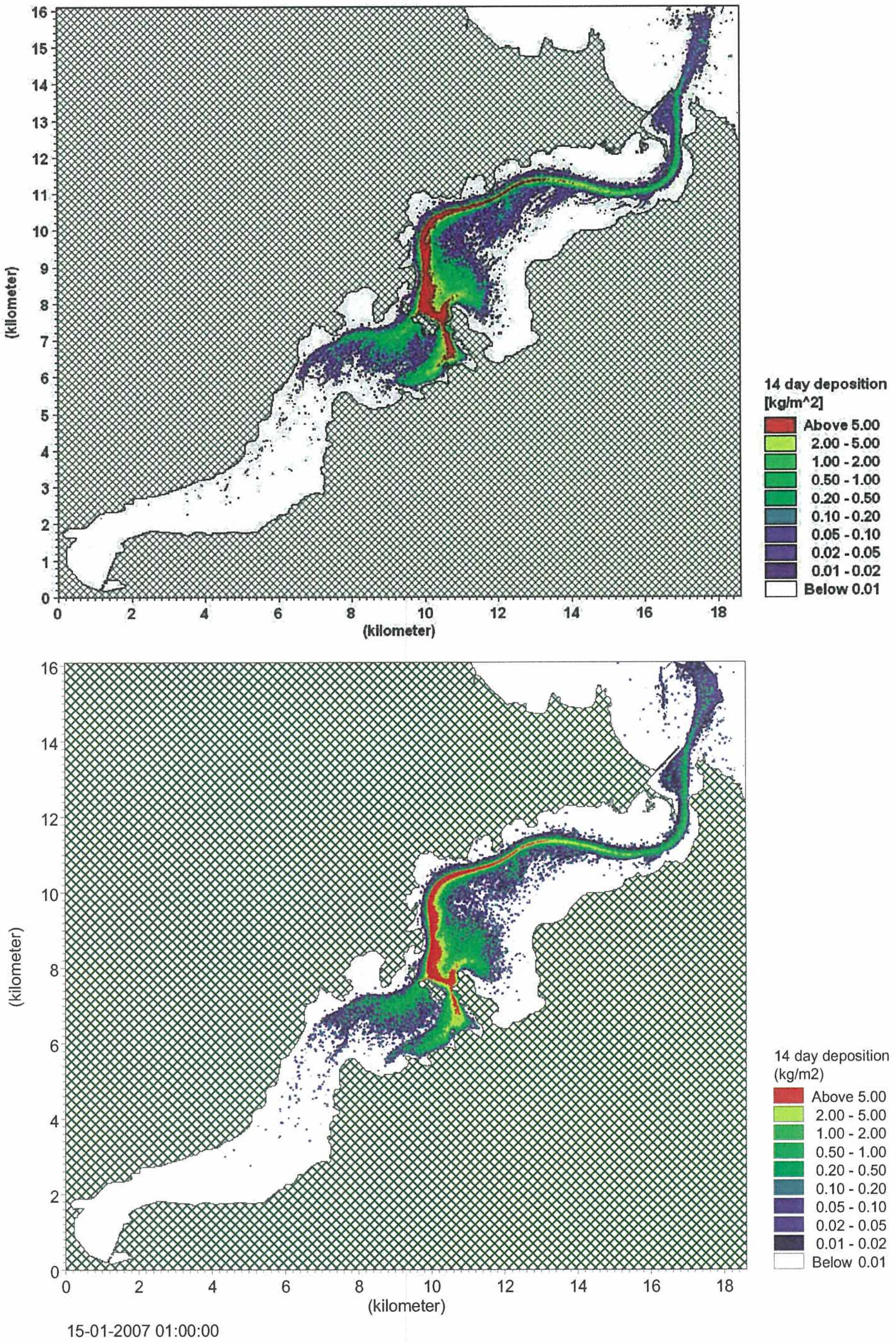

Figure 3.13: 14-day accumulated seabed deposition in kg/m^2 for a Basin–east discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

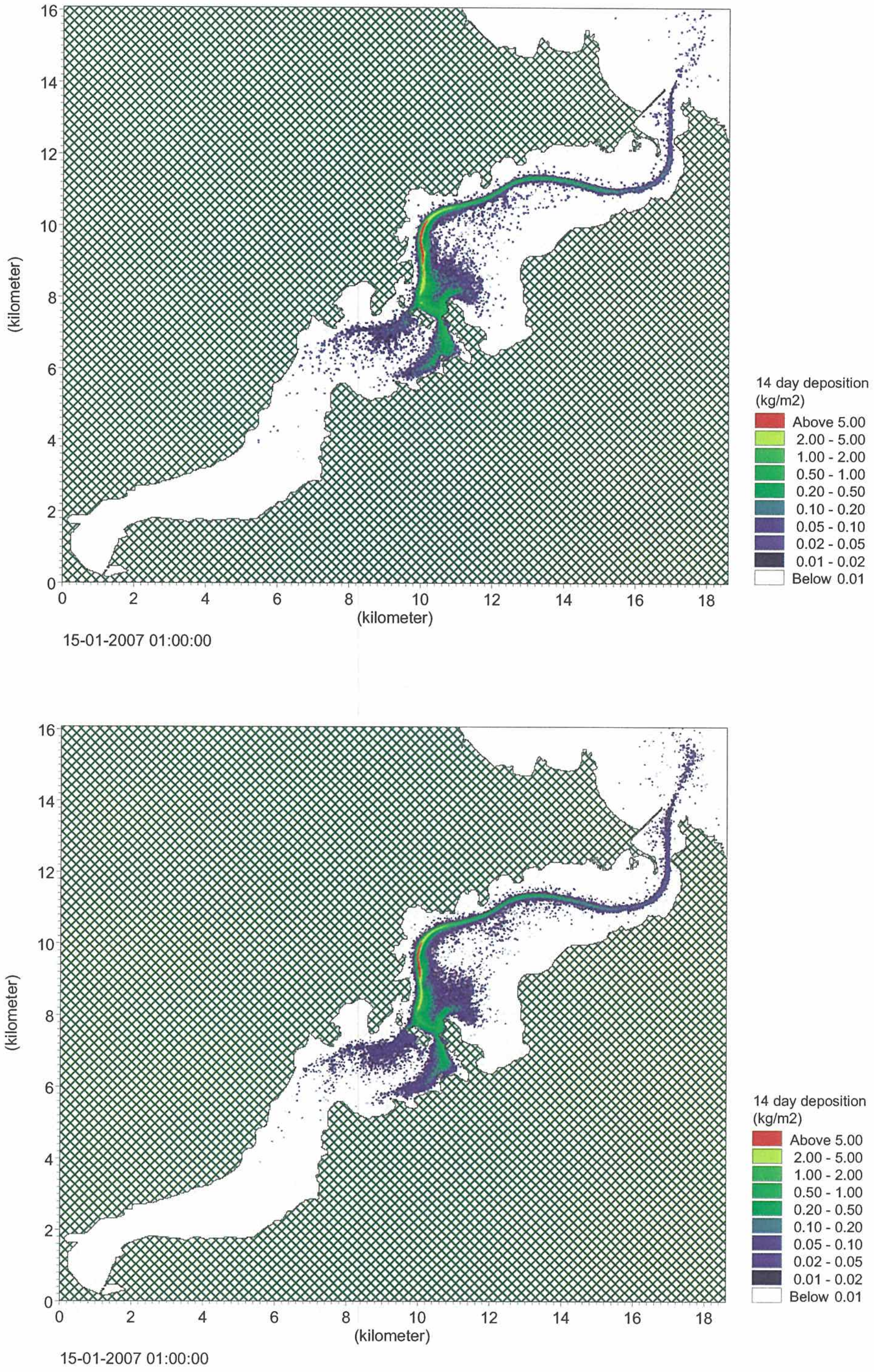

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Figure 3.14: 14-day accumulated seabed deposition in kg/m^2 for a Basin–east discharge from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

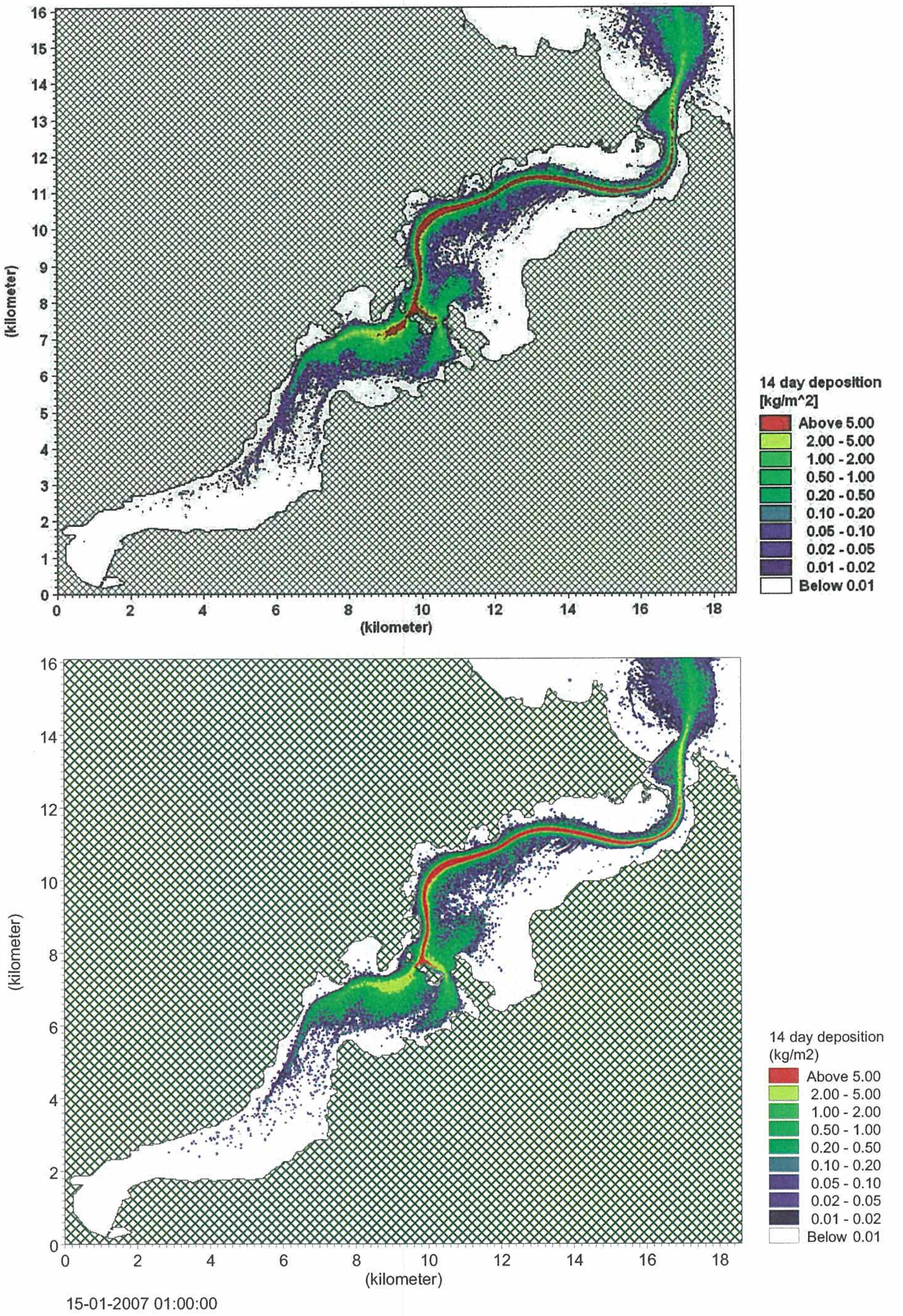


Figure 3.15: 14-day accumulated seabed deposition in kg/m^2 for a Taylers Bend discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

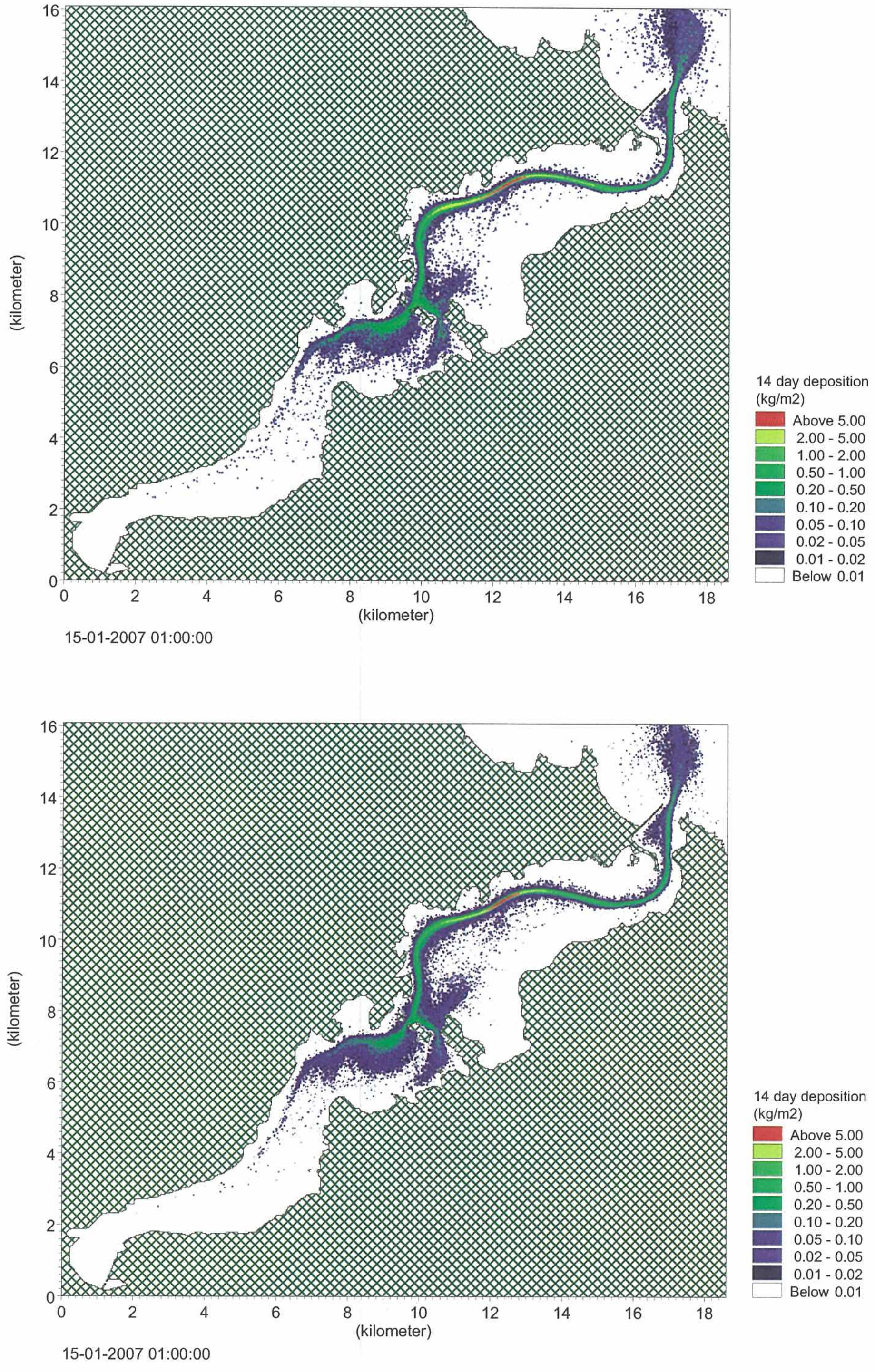


Figure 3.16: 14-day accumulated seabed deposition in kg/m^2 for a Taylers Bend discharge source from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

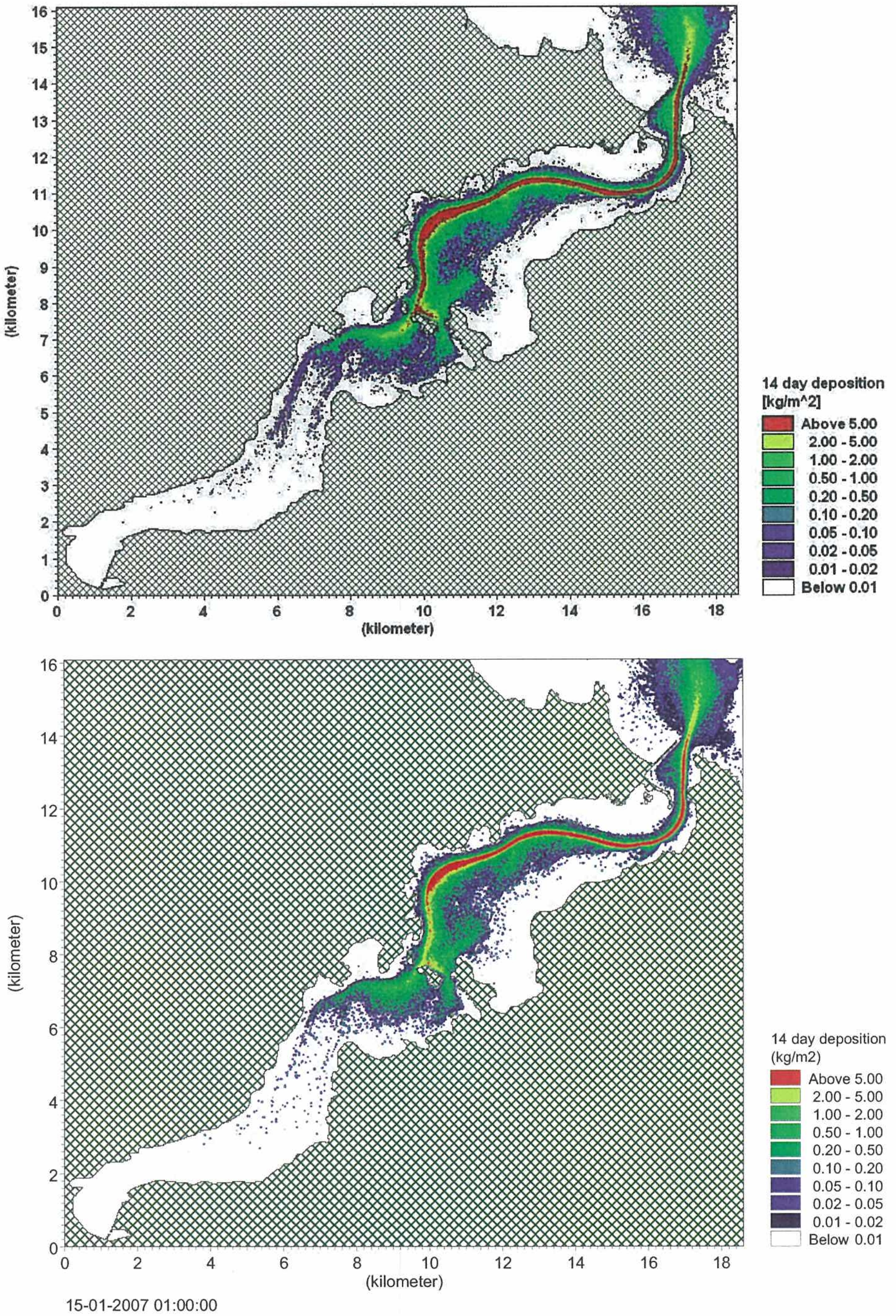


Figure 3.17: 14-day accumulated seabed deposition in kg/m^2 for a Cross-channel discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

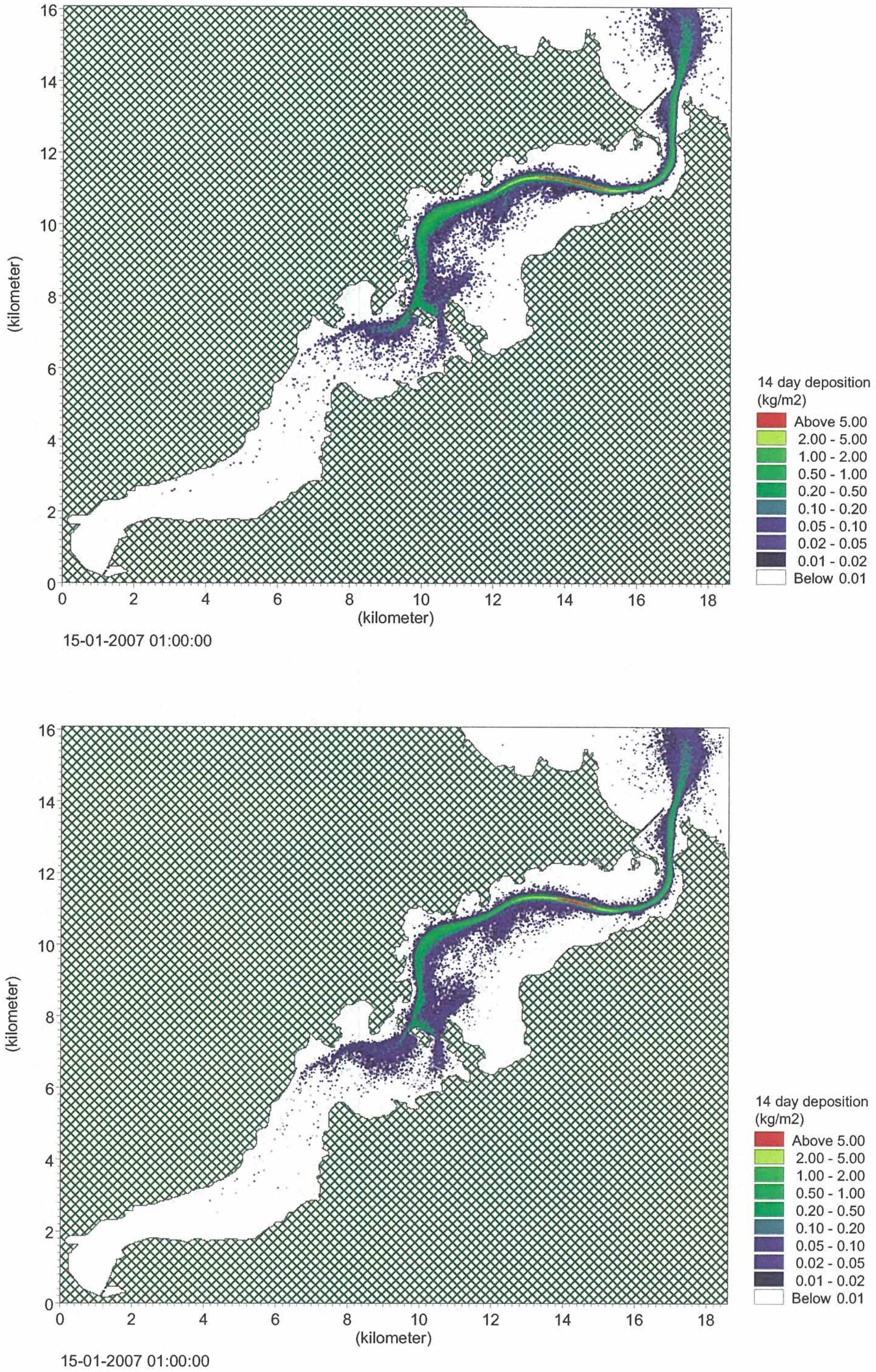


Figure 3.18: 14-day accumulated seabed deposition in kg/m^2 for a Cross-channel discharge source from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

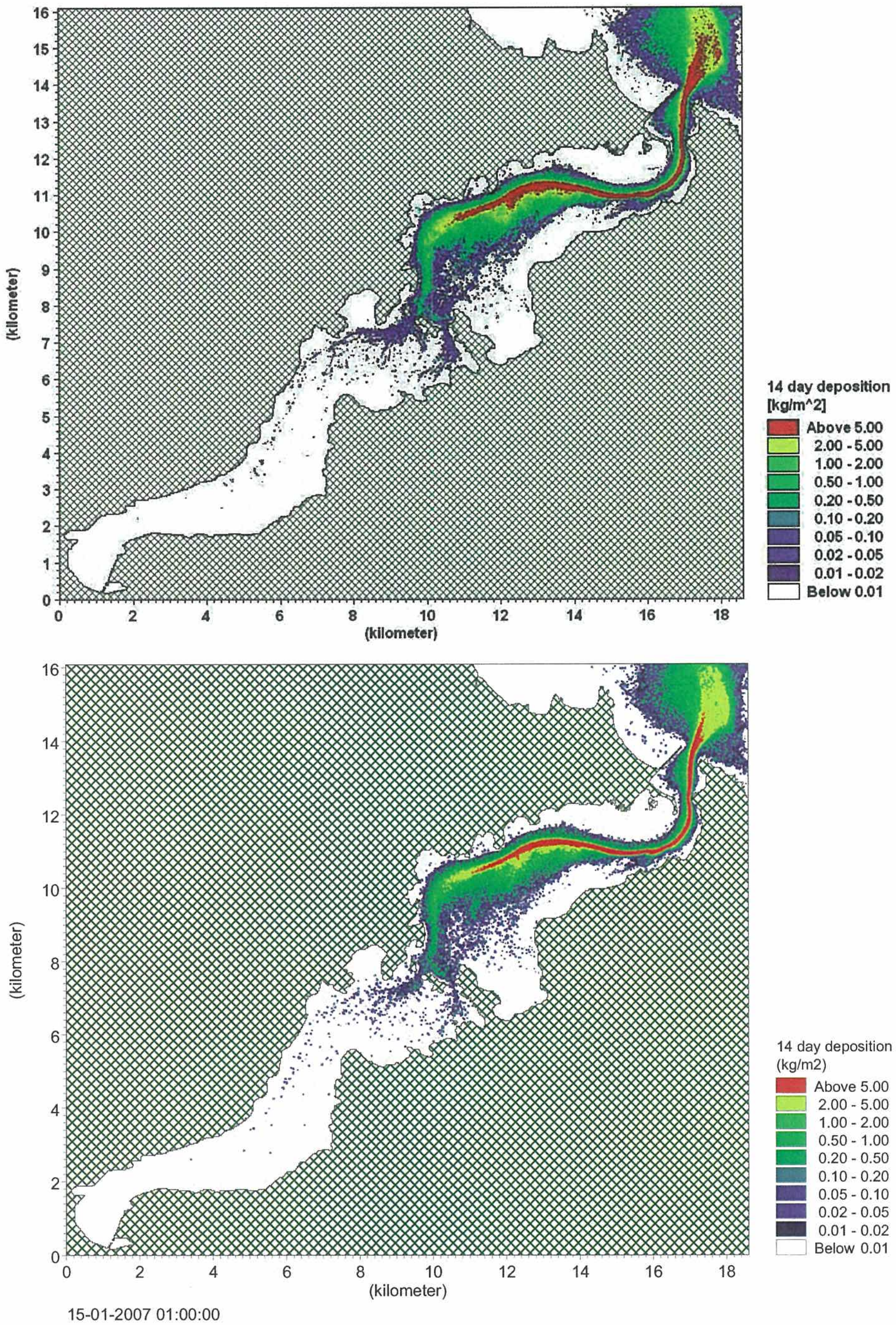


Figure 3.19: 14-day accumulated seabed deposition in kg/m^2 for a Harington Bend discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

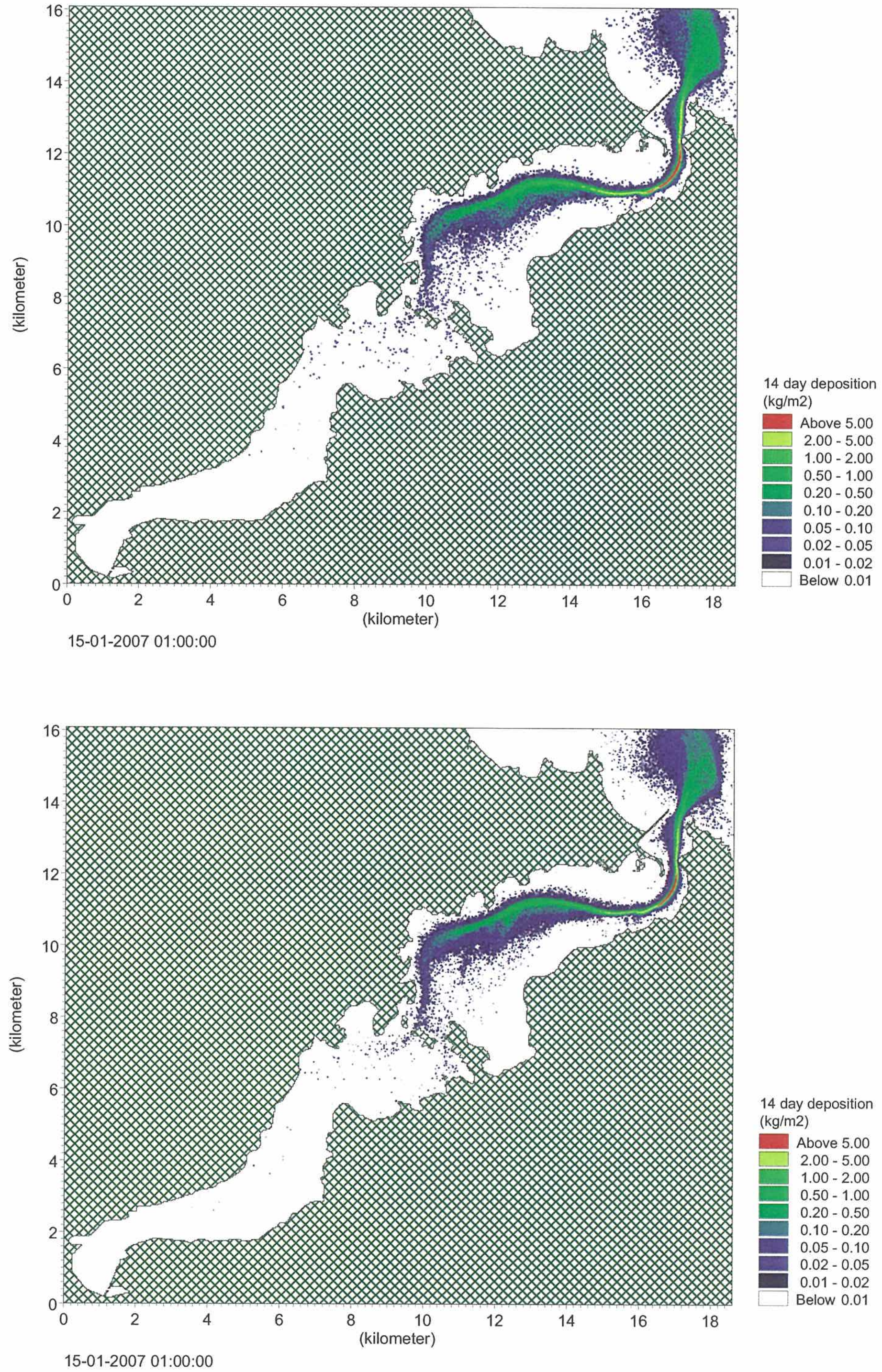


Figure 3.20: 14-day accumulated seabed deposition in kg/m^2 for a Harington Bend discharge source from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

Accumulated seabed deposition over each 14-day plume simulation is presented in mass of sediment per unit area of seabed (kg/m^2). These deposition values are generally conservative as no subsequent resuspension by competent tidal currents or wind-wave stirring was included in the plume model simulations, which will act to further spread and disperse some of the initially-settled material.

To convert to the predicted thickness of deposition (mm), a settled wet bulk density has to be assumed. A wet bulk density for recently-settled sediments was assumed to be around 1300 kg/m^3 as used in the 2009 NIWA report. Consequently, the highest band of deposition above 5 kg/m^2 (red) in Figures 3.11–3.20 equates to a 3.8 mm thickness (dividing 5 by the density 1300) that would be accumulated over the 14-day simulation period, which converts to a rate of 0.3 mm per day.

The plots show the following key results for seabed deposition over a 14-day neap/spring tide cycle with varying winds:

- deposition at or above 5 kg/m^2 (red) or approximately 3.8 mm over a fortnightly period is very confined to the immediate vicinity of the main shipping channel where *New Era* dredges. This is in contrast to the larger TSHD, where the same deposition level occurred throughout the main shipping channel (all discharge sources), the subsidiary channel to the east from Quarantine Island, around Goat Island and up Victoria Channel to opposite St. Leonards for a discharge source at Turning Basin–west, and some of the flanking intertidal flats to these channels

- discharges from predominantly-silt claims (top panels in Figures 3.11–3.20) cause very similar deposition thicknesses (and daily deposition rates) to those from predominantly-sand claims (bottom panels)

- the Upper Harbour will have virtually no discernable seabed deposition arising from discharge sources at Harington Bend and further seaward (Fig. 3.20)

- most of the eastern parts of the Lower and Upper Harbours would be subject to negligible or no deposition, apart from the reach west of Latham Bay for discharges from the eastern side of the Turning Basin, where deposition may reach 0.5 kg/m^2 (0.4 mm) over 2 weeks or an accumulation rate of 0.03 mm/day)

- mid-harbour intertidal flats will have substantially lower deposition rates and extent of deposition using *New Era* compared with the larger TSHD by about 10 times less, from 2–5 kg/m^2 to 0.2–0.5 kg/m^2 for similar areas. With *New Era*, the main areas affected by up to accumulation of 0.5 kg/m^2 in 2 weeks or a rate of 0.03 mm/day will be: a) mid-harbour intertidal flats opposite Tayler and Pulling Points from dredging at Harington Bend; b) mid-harbour intertidal flats opposite Port Chalmers to Quarantine Island from dredging the eastern Turning Basin; and c) the inter-tidal bank south-west of Quarantine Island adjacent to the Victoria Channel from dredging Taylers Bend area.

4. Results for the offshore plume modelling

The results are presented as a series of paired plots of the envelopes of maximum suspended-sediment concentrations predicted at each location at any time during a 48-hour cycle of disposal from the larger TSHD (top plots) versus the *New Era* (bottom plots). These simulations cover the more conservative light-wind conditions simulated for the larger dredger and reported in Section 11.4.3 of Bell et al. (2009).

The same spatial coverage and concentration palette have been used in the plots to provide a true comparison of the differences in maximum suspended concentration between using a larger dredger and the *New Era.*

4.1 Light WSW winds

Figures 4.1a–c show the composites of maximum excess suspended-sediment concentration (SSC) during 48-hour periods for each of the smaller three size classes (excluding fine sand) in the bottom layer for wind scenario 1 (light WSW wind of 7 m/s). Figures 4.2a-c show the equivalent comparisons for the near-surface layer for the same wind scenario. Note: SSC from each of the three finer sediment classes is additive to get the total SSC leaving aside fine sand that settles much more quickly.

The top plot in each case shows the result from the predominantly-silt hopper load from a larger TSHD, and the bottom plot is the equivalent result for the *New Era.* Results are only for discharges at the most landward sub-site #1 in A0 (Figure 2.2).

The maximum SSC in the disposal area in the bottom layer using *New Era* will be about 6–7% of the maximum simulated SSC for a larger TSHD that was reported in Bell et al. (2009). For this light WSW wind condition, adding the maximum SSC in the disposal area from the three silt-size classes, the bottom layer will reach a maximum of 47 mg/L and the near-surface layer 8 mg/L using the *New Era.*

When the edge of the plume reaches the coastline north of Cornish Head, the excess SSC is very low reaching no higher than 0.5 mg/L (adding all 3 silt-size classes) in the bottom layer for the larger dredger under these wind conditions, while the *New Era* would produce concentrations of ten times less (<0.05 mg/L).

The extent of influence from the sediment plumes is similar for both sizes of dredge, with subtle differences, especially in the spread offshore for this light WSW wind scenario. These arise from differences in the hopper discharge depth.

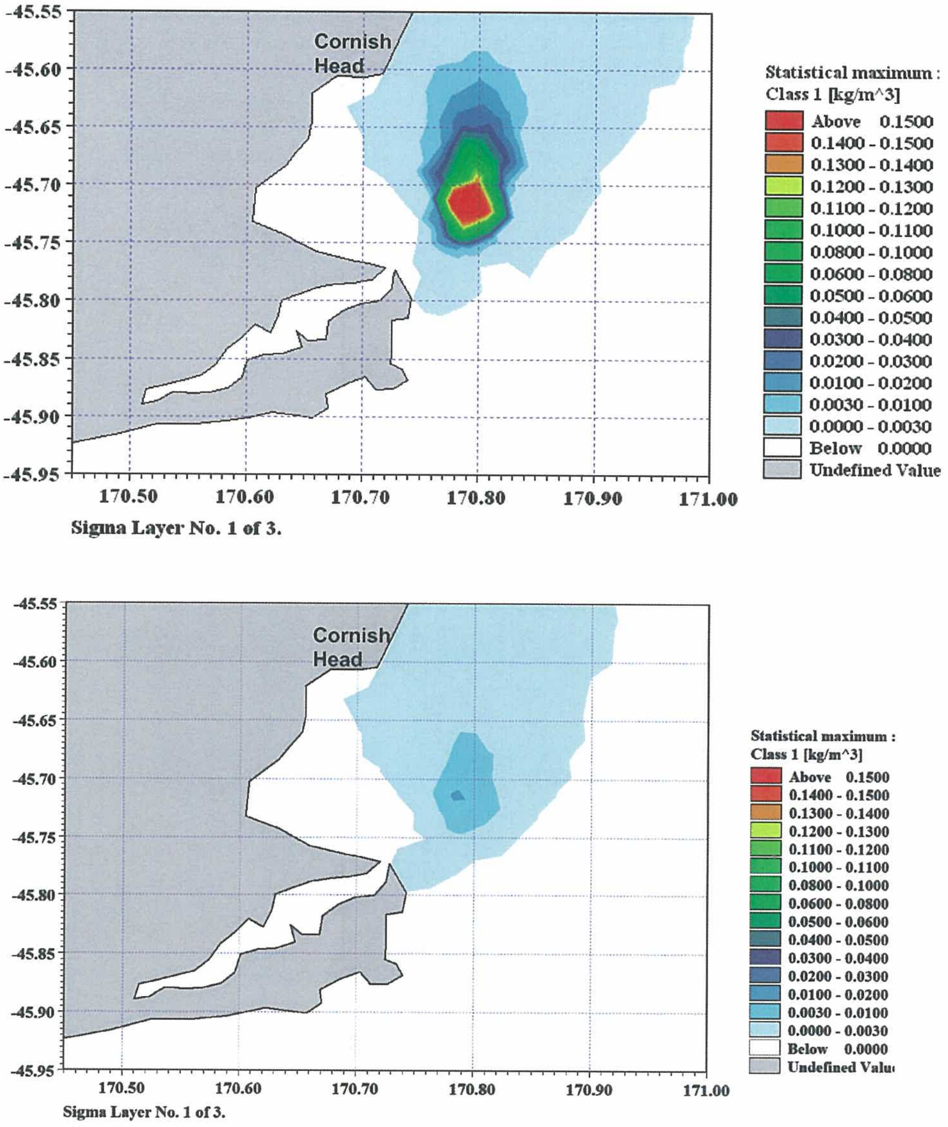
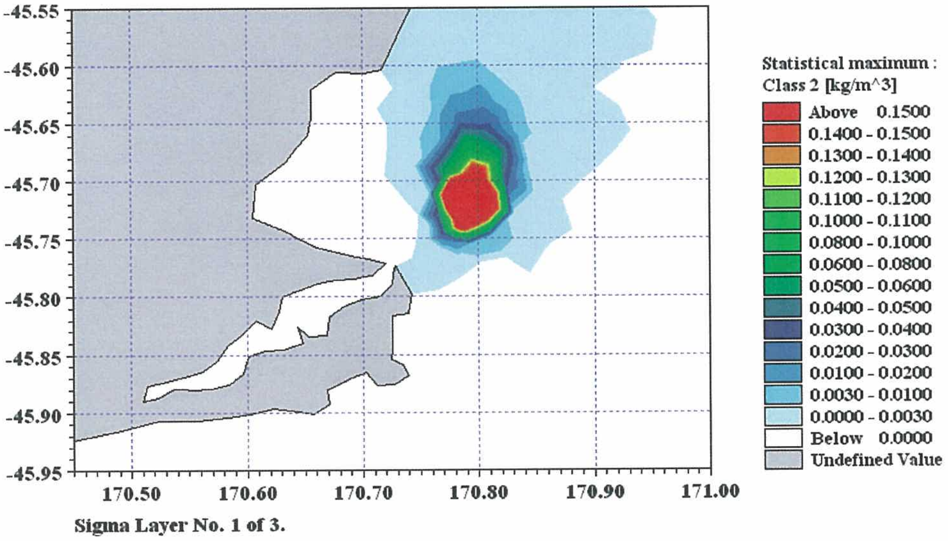


Figure 4.1a: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the bottom layer (L1) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 160 mg/L and 11 mg/L (7%) and for coast north of Cornish Head, SSC will be 0.2–0.4 mg/L and 0.015–0.03 mg/L respectively.



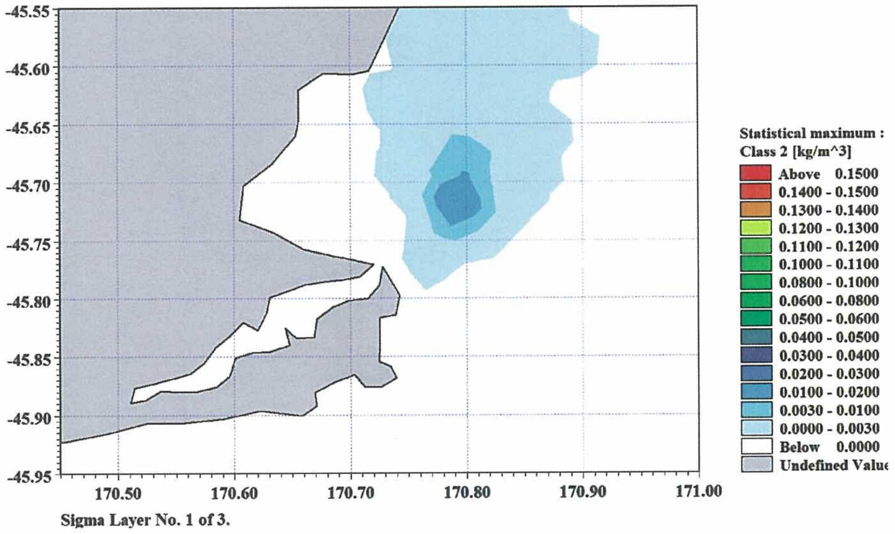


Figure 4.1b: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 2 in the bottom layer (L1) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 280 mg/L and 17 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.002–0.04 mg/L and 0.002–0.01 mg/L respectively.

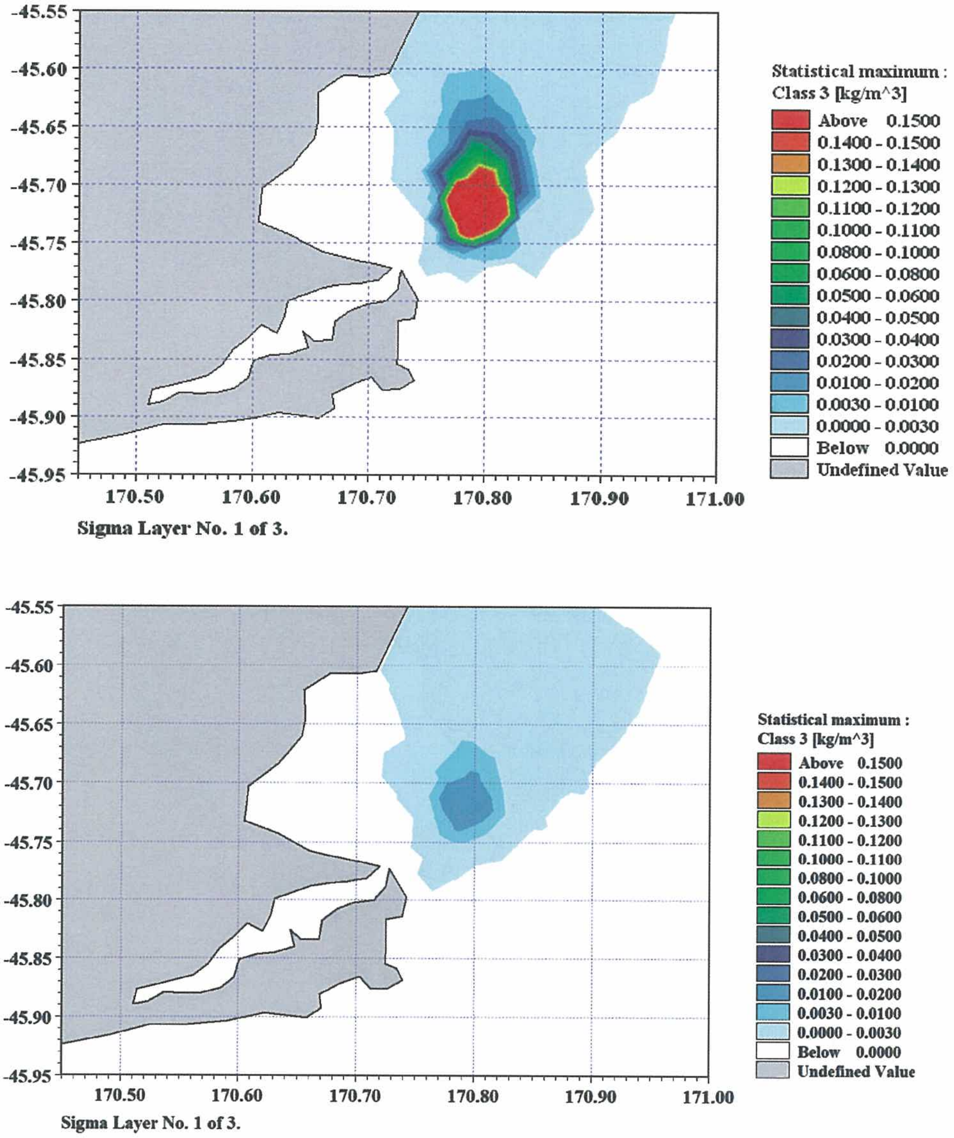


Figure 4.1c: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 3 in the bottom layer (L1) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 320 mg/L and 19 mg/L (6%) and for coast north of Cornish Head, SSC will be <0.011 mg/L and 0.001–0.003 mg/L respectively.

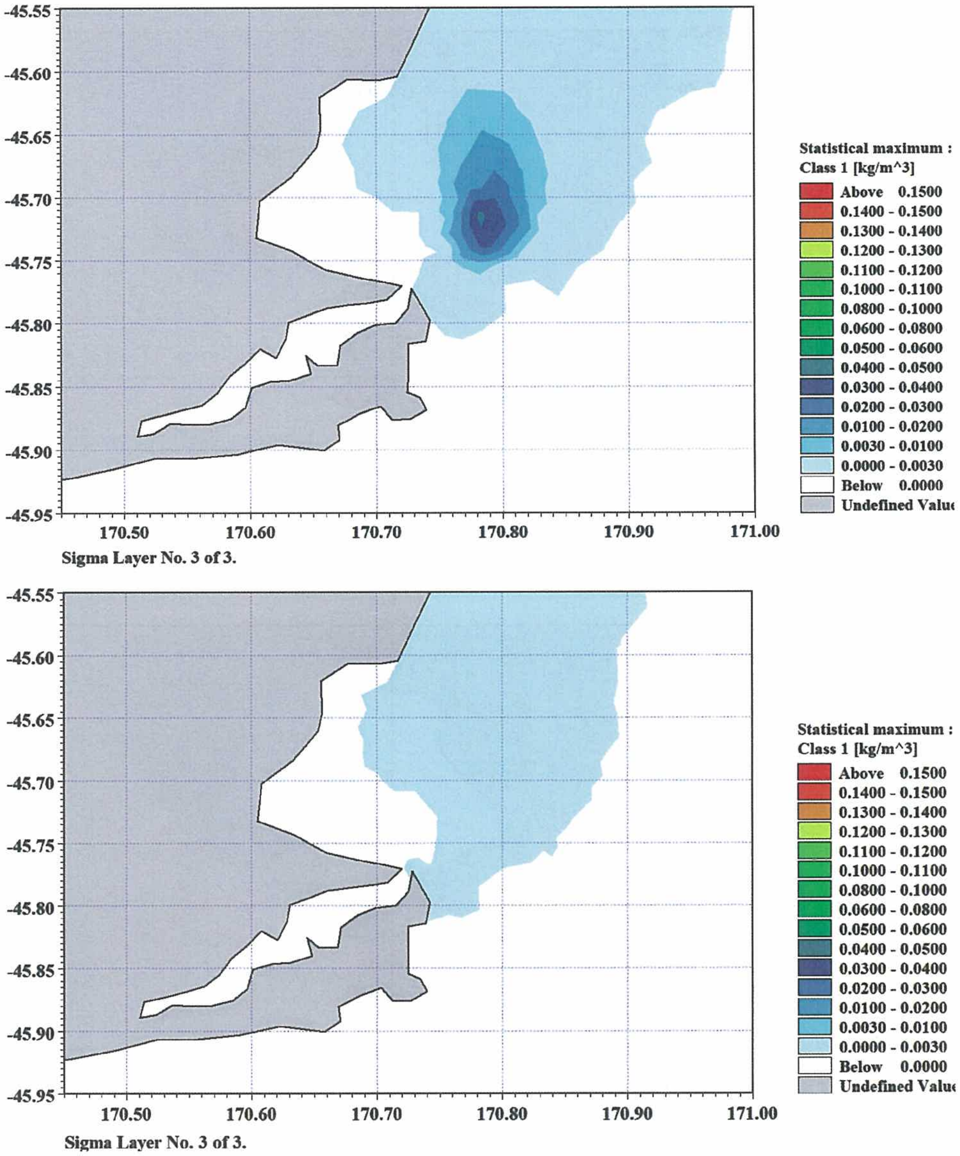


Figure 4.2a: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 42 mg/L and 2.5 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.02–0.2 mg/L and 0.007–0.03 mg/L respectively.

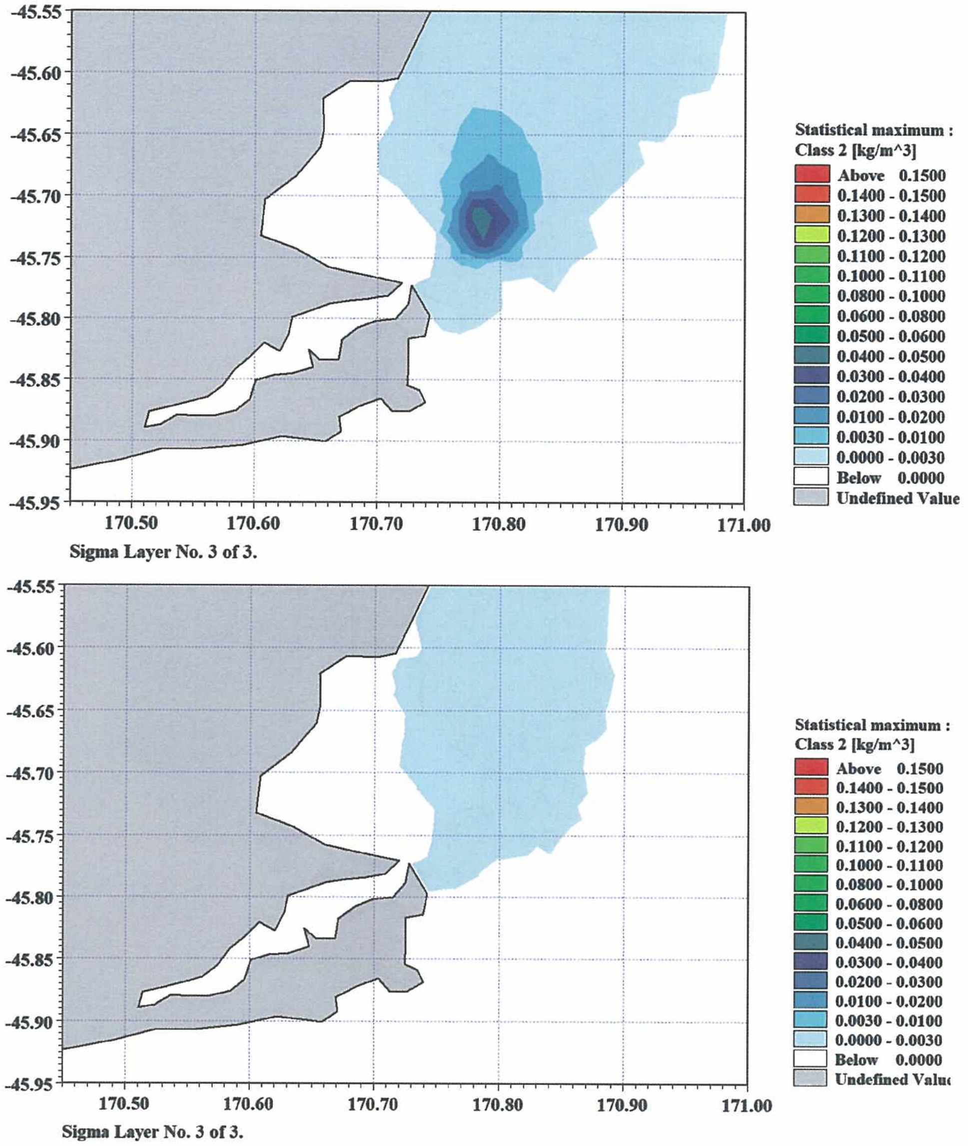


Figure 4.2b: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 2 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 46 mg/L and 2.7 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.01–0.03 mg/L and 0.001–0.005 mg/L respectively.

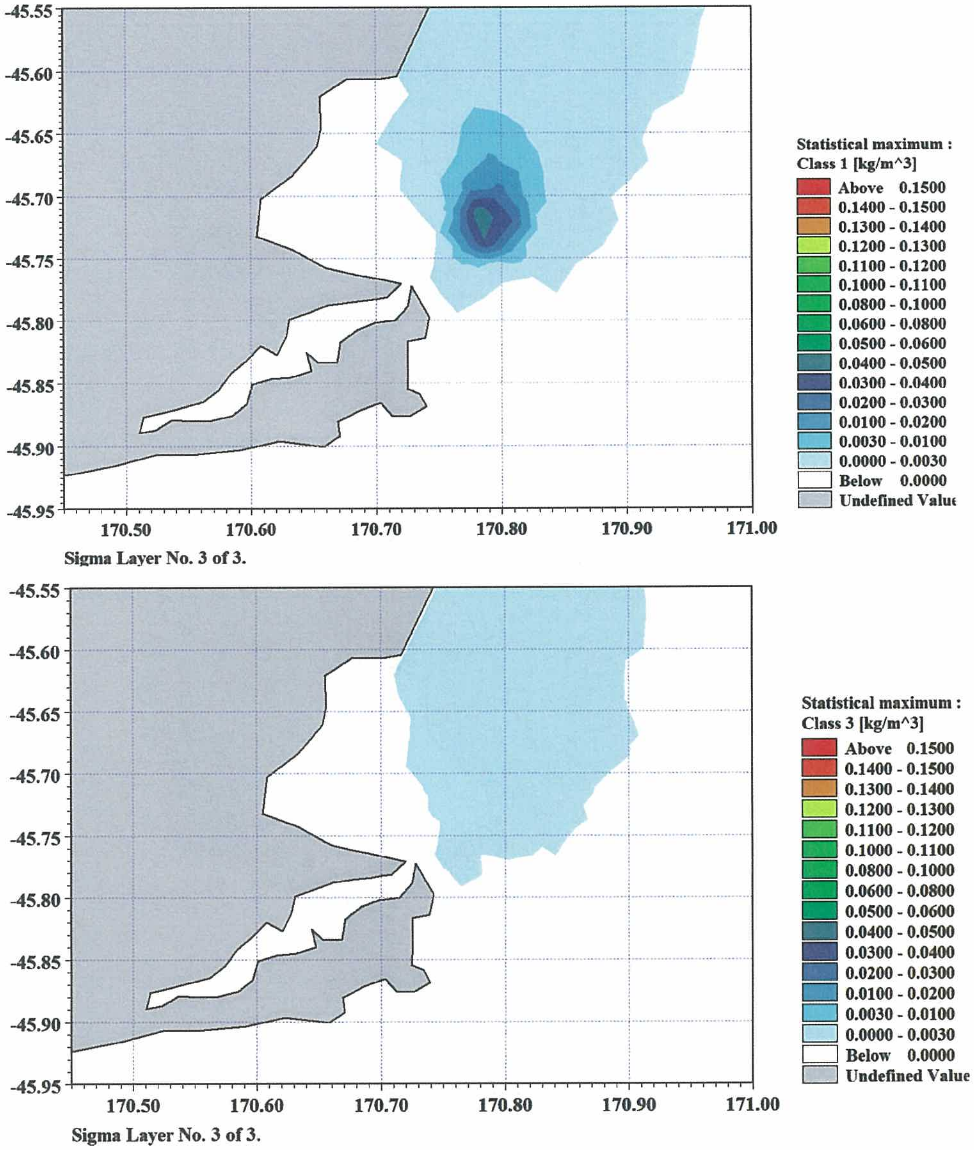


Figure 4.2c: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 3 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 46 mg/L and 2.7 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.002–0.02 mg/L and 0.001–0.004 mg/L respectively.

4.2 Moderate WSW wind

Figure 4.3 shows a comparison of the composites of maximum excess suspended-sediment concentration (SSC) during 48-hour periods for just the finest silt-size class in the bottom layer for wind scenario 2 (moderate WSW wind of 14 m/s). Figure 4.4 shows the medium and coarse silt composites in the bottom layer for just the *New Era* simulations.

Figure 4.5 shows the equivalent comparison for fine silts between the larger TSHD and *New Era* for the near-surface layer for the same wind scenario. Figure 4.6 shows the maximum SSC composites for medium and coarse silts for just the *New Era*.

The top plot in Figures 4.3 & 4.5 show the result from the predominantly-silt hopper load from a larger TSHD, and the bottom plot is the equivalent result for the *New Era*. Results are only for discharges at the most landward sub-site #1 within the A0 disposal area (Figure 2.2).

The maximum SSC considering only fine silts (class 1) in the disposal area in the bottom layer using *New Era* will be about 5–6% of the maximum simulated SSC for a larger TSHD (Figure 4.3). If the edge of the plume reaches the coastline north of Cornish Head, the excess SSC for fine silts will be very low reaching no higher than 0.18 mg/L in the bottom layer for the larger dredger under these wind conditions. In comparison, the *New Era* would produce somewhat lower concentrations in the surface layer and ten time lower in the bottom layer.

Looking at all three silt fractions (and excluding fine sands that settle quickly), the maximum excess SSC in the bottom layer from *New Era* will be around 57 mg/L at the disposal area and along the coastline north of Cornish Head the maximum on the fringe of the plumes will be around 0.003–0.01 mg/L, with coarse silts not reaching the coast (Figure 4.4). In the near-surface layer, the maximum SSC from all silt classes would be 7 mg/L at the disposal area and no more than 0.01 mg/L along the coast north of Cornish Head, with medium and coarse silt plumes not reaching the coast (Figure 4.6).

The extent of influence from the sediment plumes is similar for both sizes of dredge (Figures 4.3 & 4.5), with only subtle differences due to the different hopper discharge depths.

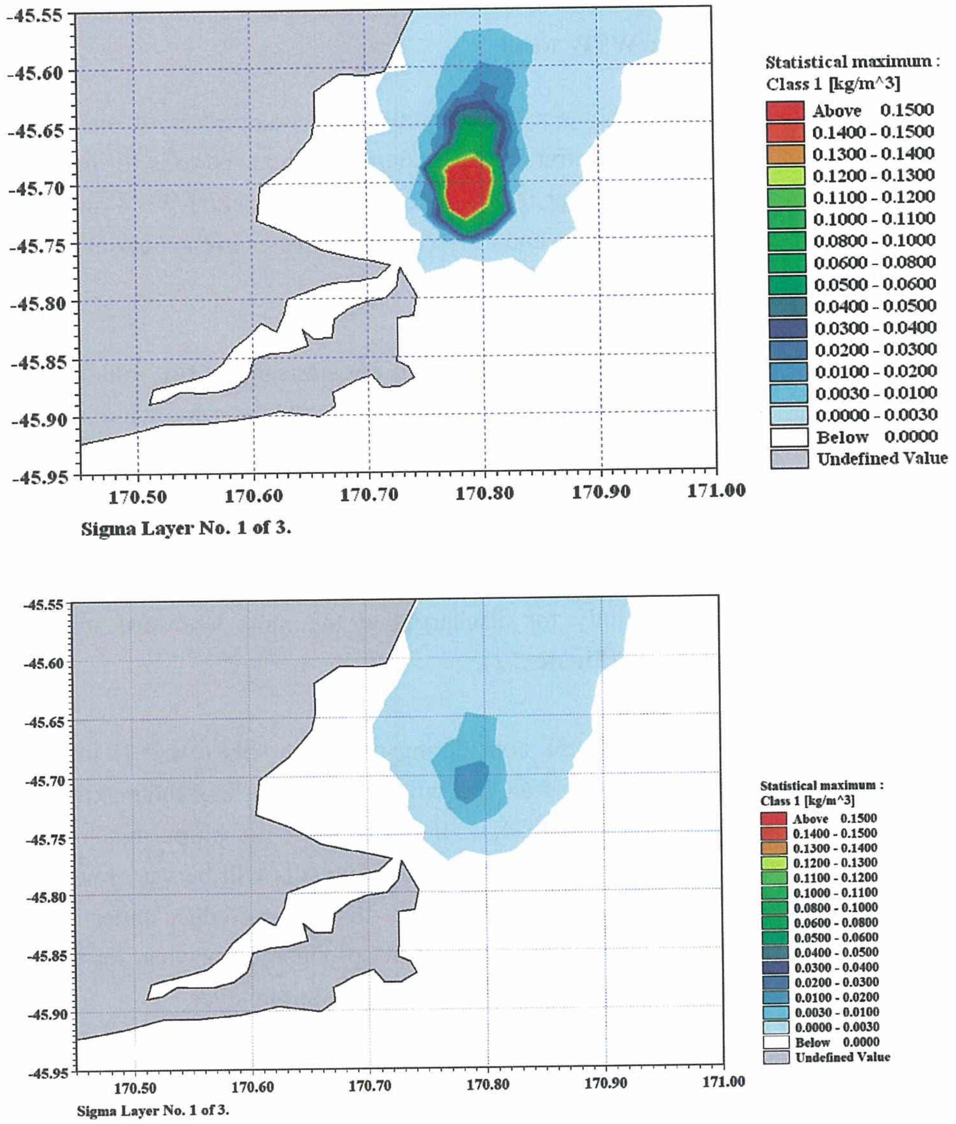


Figure 4.3: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for sediment size class 1 in the bottom layer (L1) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 260 mg/L and 14 mg/L (5%) and for coast north of Cornish Head, SSC will be 0.03–0.18 mg/L and 0.002–0.01 mg/L respectively.

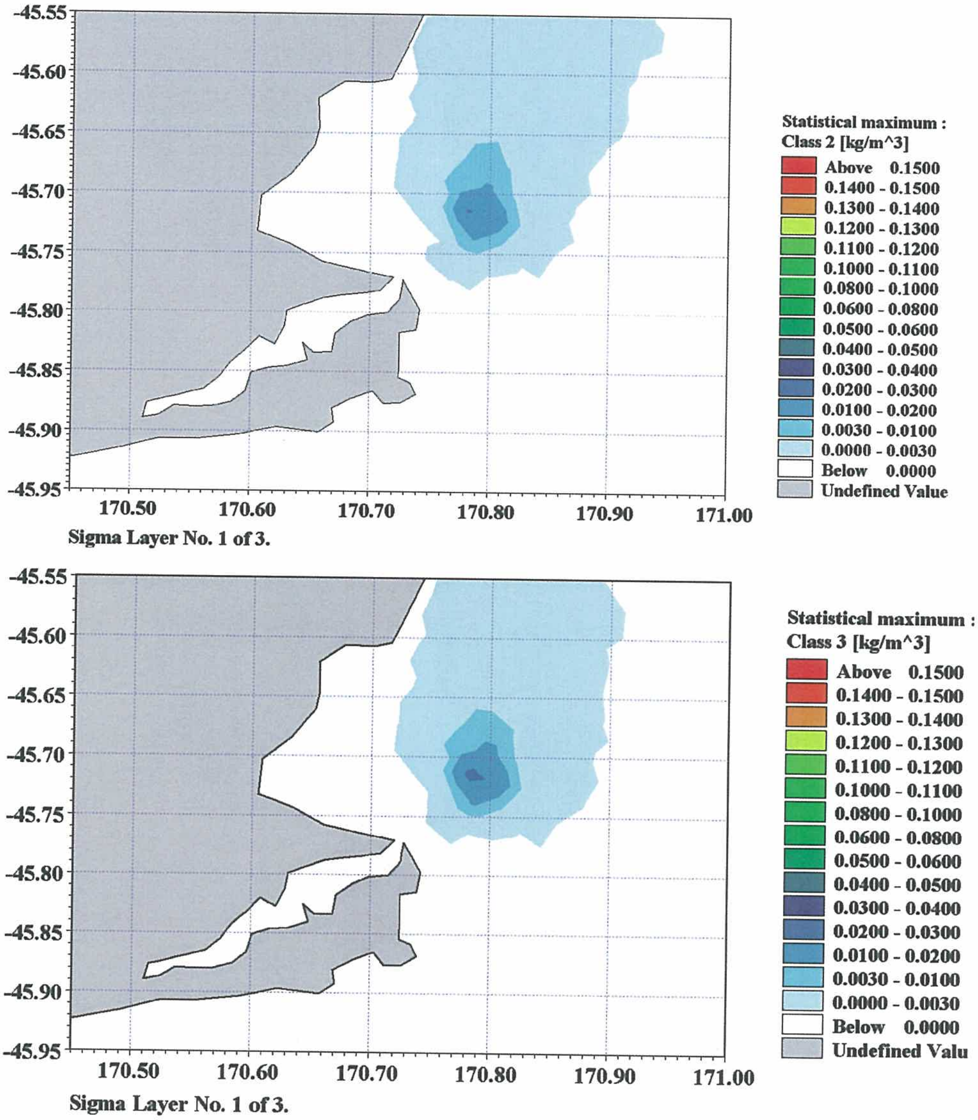


Figure 4.4: Max. SSC composite envelopes for just the *New Era* hopper discharges for medium silt (top) and coarse silt (bottom) in the bottom layer (L1) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 21 mg/L (medium silts) and 22 mg/L (coarse silts) and for coast north of Cornish Head, SSC will be ≤0.001 mg/L (medium silts) and 0 mg/L (coarse silts).

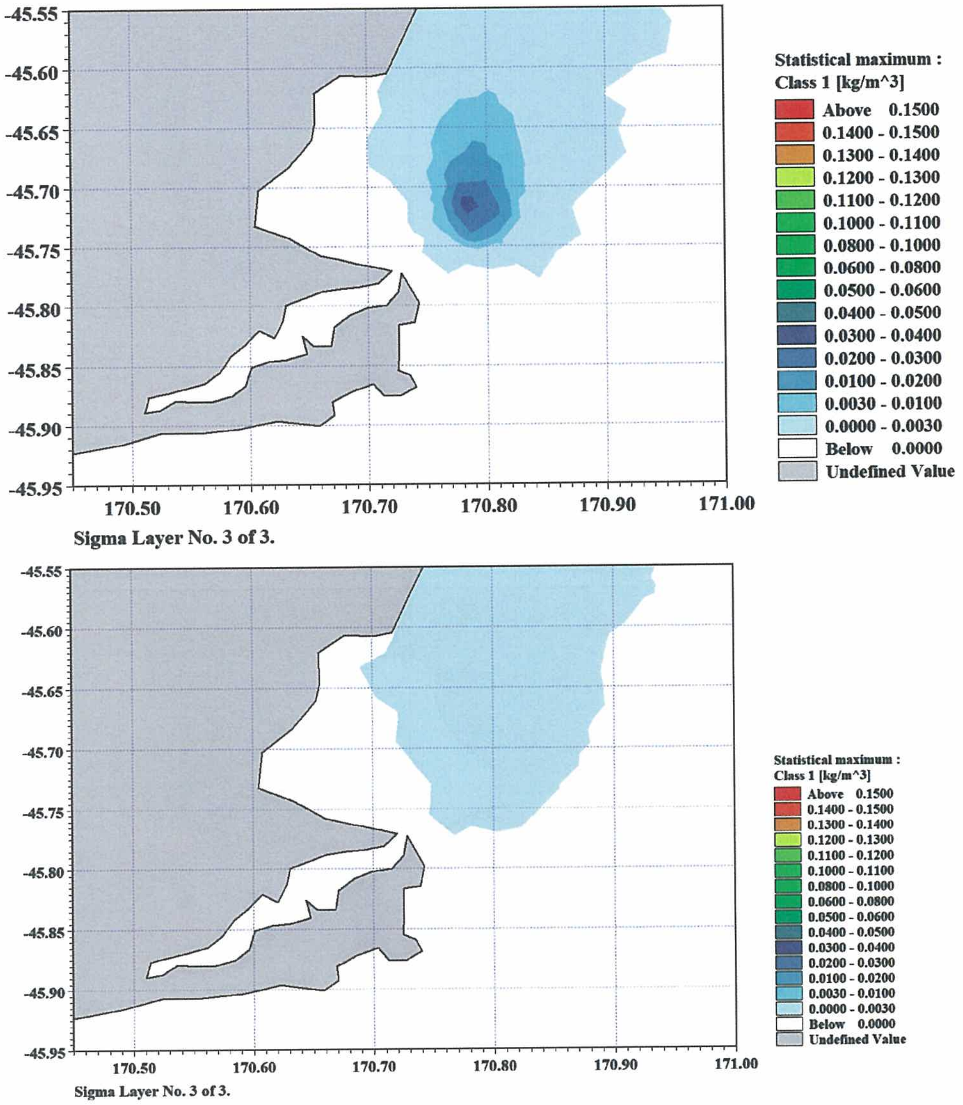


Figure 4.5: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for sediment size class 1 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 35 mg/L and 2 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.003–0.05 mg/L and 0.002–0.02 mg/L respectively.

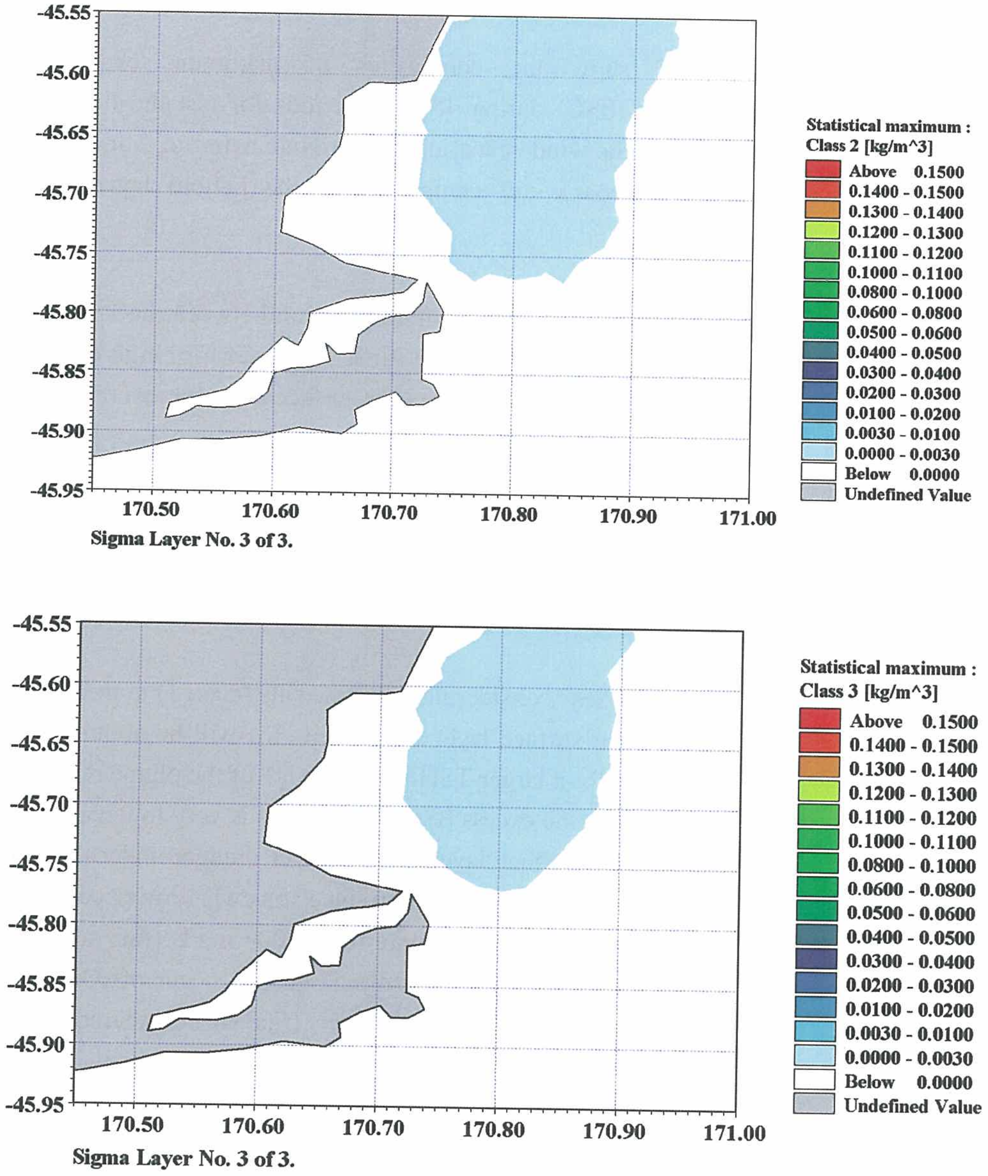


Figure 4.6: Max. SSC composite envelopes for just the *New Era* hopper discharges for medium silts (top) and coarse silts (bottom) in the near-surface layer (L3) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 2.2 mg/L (medium silt) and 2.3 mg/L (coarse silt) and for coast north of Cornish Head, the excess SSC will be nil.

4.3 Light NNE winds

Figure 4.7 show the composites of maximum excess suspended-sediment concentration (SSC) during 48-hour periods for just the finest silt-size class in the bottom layer for wind scenario 4 (light NNE wind of 3 m/s). Figure 4.8 shows the medium and coarse silt composites in the bottom layer for just the *New Era* simulations.

Figure 4.9 shows the equivalent comparison between the larger TSHD and *New Era* for the near-surface layer for the same wind scenario. Figure 4.10 shows the medium and coarse silt composites in the near-surface layer for just the *New Era* simulations.

The top plot in Figures 4.7 & 4.9 show the result from the predominantly-silt hopper load from a larger TSHD, and the bottom plot is the equivalent result for the *New Era*. Results are only for discharges at the most landward sub-site #1 within the A0 disposal area (Figure 2.2).

The maximum SSC considering only fine silts (class 1) in the disposal area in both the bottom and near-surface layer using *New Era* will be about 5–6% of the maximum simulated SSC for a larger TSHD. If the edge of the plume reaches the coastline north of Cornish Head, the excess SSC for fine silts is very low reaching no higher than 0.1 mg/L in the near-surface layer for the larger dredger under these wind conditions. In comparison, the *New Era* would produce somewhat lower concentrations in the near-surface or bottom layer at no more than 0.004 mg/L (fine silts). A similar pattern of decreased SSC from a *New Era* discharge will occur off Otago Heads, with excess concentrations of no more than 0.3 mg/L (fine silt) compared with a maximum of 1.2 mg/L (fine silt) for the larger TSHD.

Across all three silt fractions (excluding fine sands that settle quickly), the maximum in the bottom layer from *New Era* will be around 50 mg/L at the disposal area. Along the coastline north of Cornish Head the maximum excess SSC on the fringe of the plumes from all silt classes will be ≤0.008 mg/L and along Otago Heads, ≤0.6 mg/L above background. In the near-surface layer, the maximum SSC from all silt classes would be 11 mg/L at the disposal area and no more than 0.03 mg/L along the coast north of Cornish Head, and along Otago Heads, ≤0.6 mg/L above background.

The extent of influence from the sediment plumes for both sizes of dredge shows subtle differences due to the different hopper discharge depths, which interacts with the 3-dimensional structure of the combined Southland Current flow and onshore NNE winds. The main difference is the reduced lateral spread of the plumes (both onshore and offshore) to the north for the *New Era* discharges.

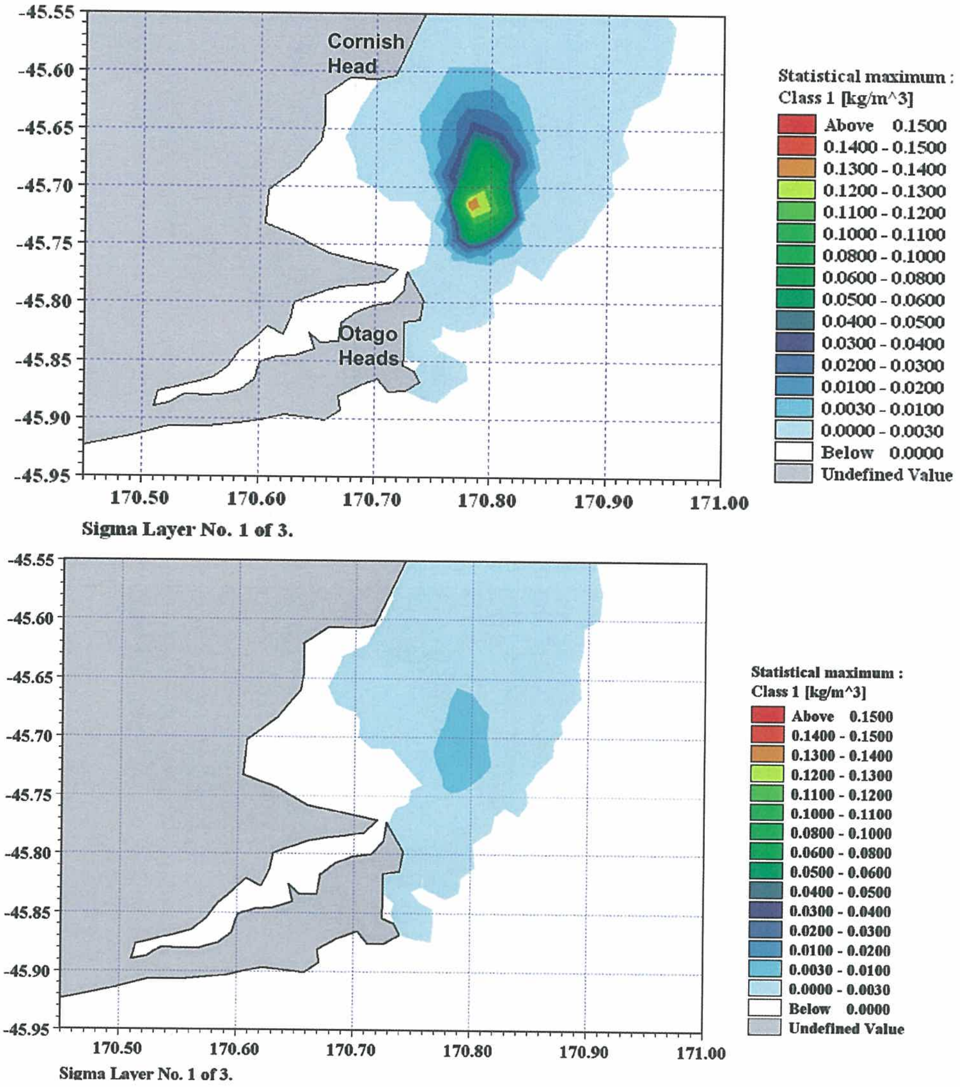


Figure 4.7: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the bottom layer (L1) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 140 mg/L and 7 mg/L (5%). For the coast north of Cornish Head, SSC is predicted to be 0.01–0.06 mg/L compared with 0.001–0.004 mg/L (*New Era*) and off Otago Heads, 0.15–1 mg/L compared with 0.02–0.3 mg/L (*New Era*).

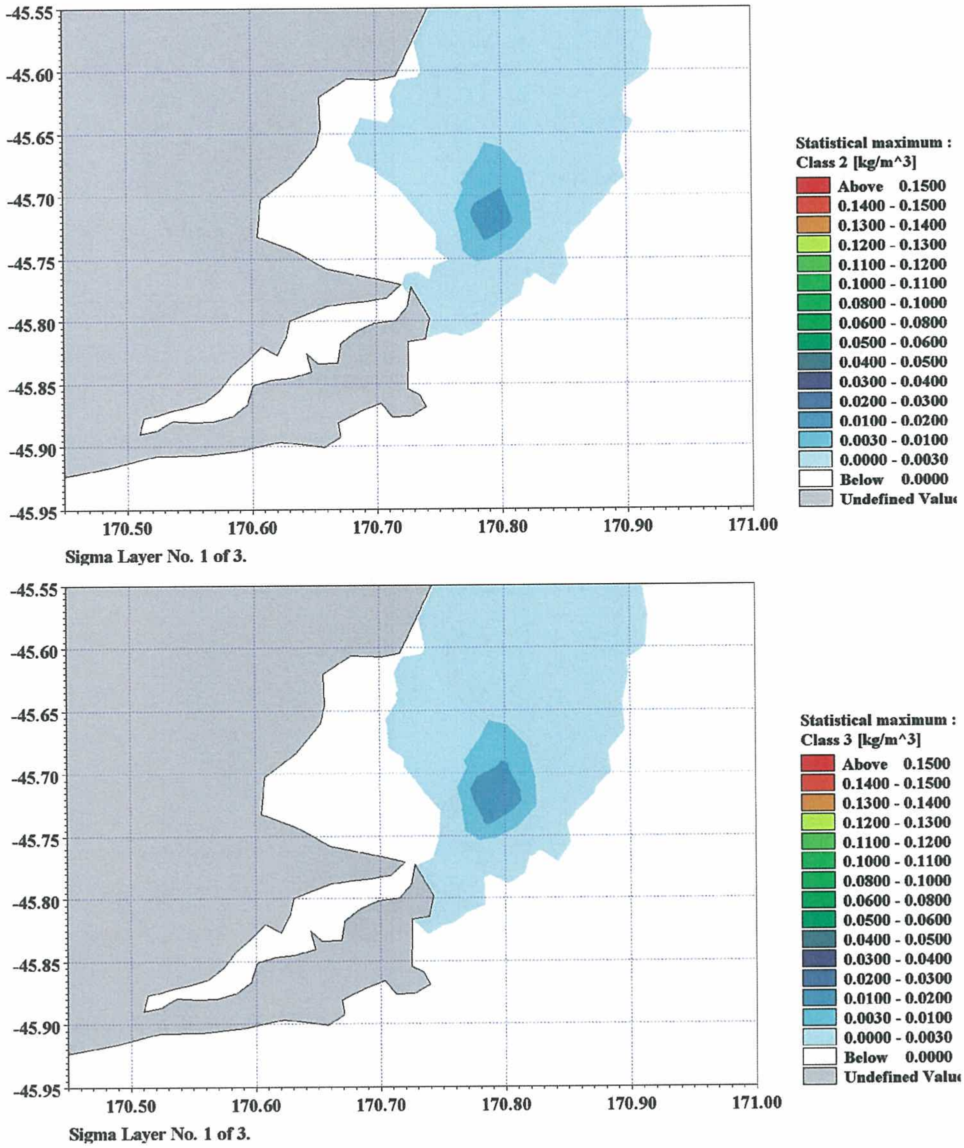


Figure 4.8: Max. SSC composite envelopes for just *New Era* hopper loads for medium silt (top) and coarse silt (bottom) in the bottom layer (L1) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 13 mg/L (medium silts) and 16 mg/L (coarse silts). For the coast north of Cornish Head, SSC is predicted to be ≤0.002 mg/L (medium and coarse silts) and off Otago Heads, 0.01–0.05 mg/L (medium silts) and 0.02–0.26 mg/L (coarse silts).

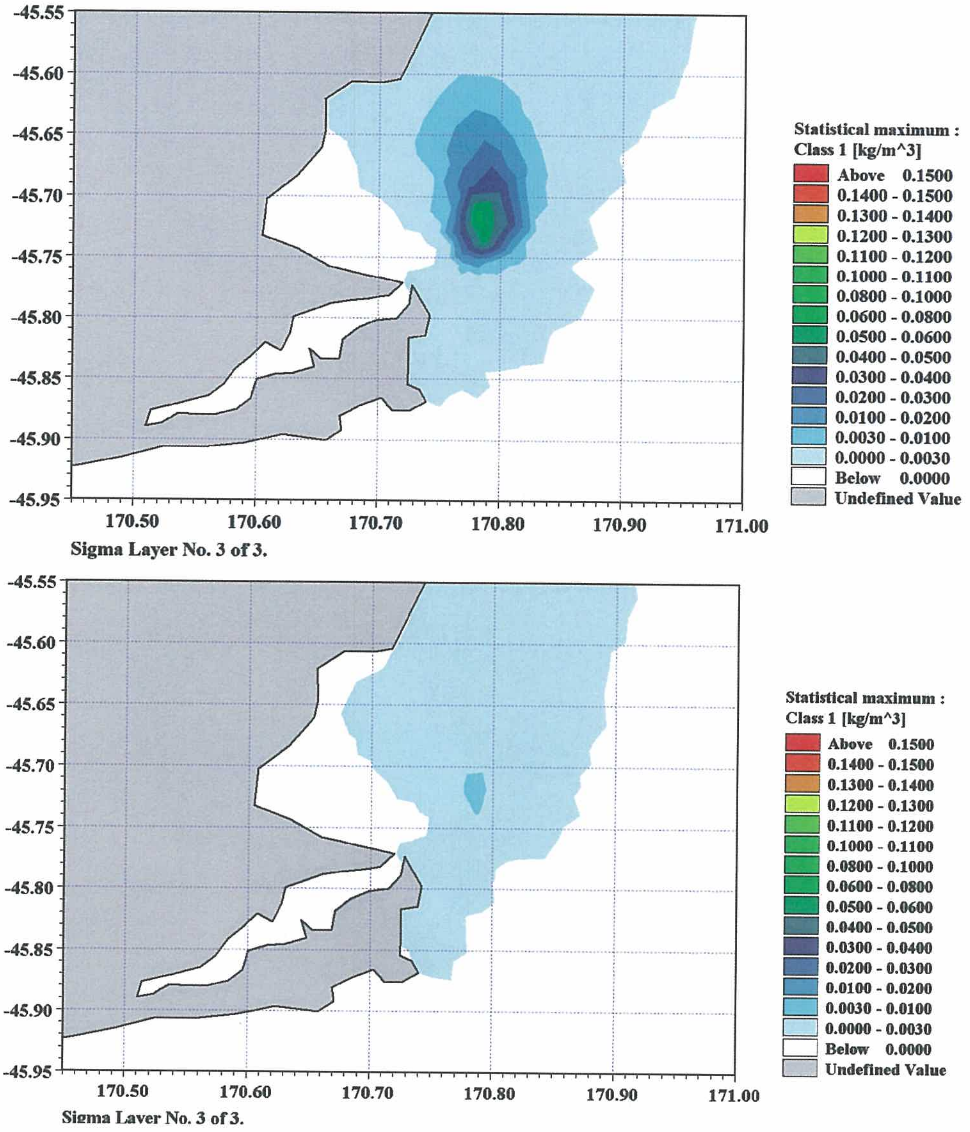


Figure 4.9: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 63 mg/L and 3.7 mg/L (6%). For the coast north of Cornish Head, SSC is predicted to be 0.04–0.1 mg/L compared with 0.001–0.003 mg/L (*New Era*) and off Otago Heads, 0.2–1.2 mg/L compared with 0.01–0.2 mg/L (*New Era*).

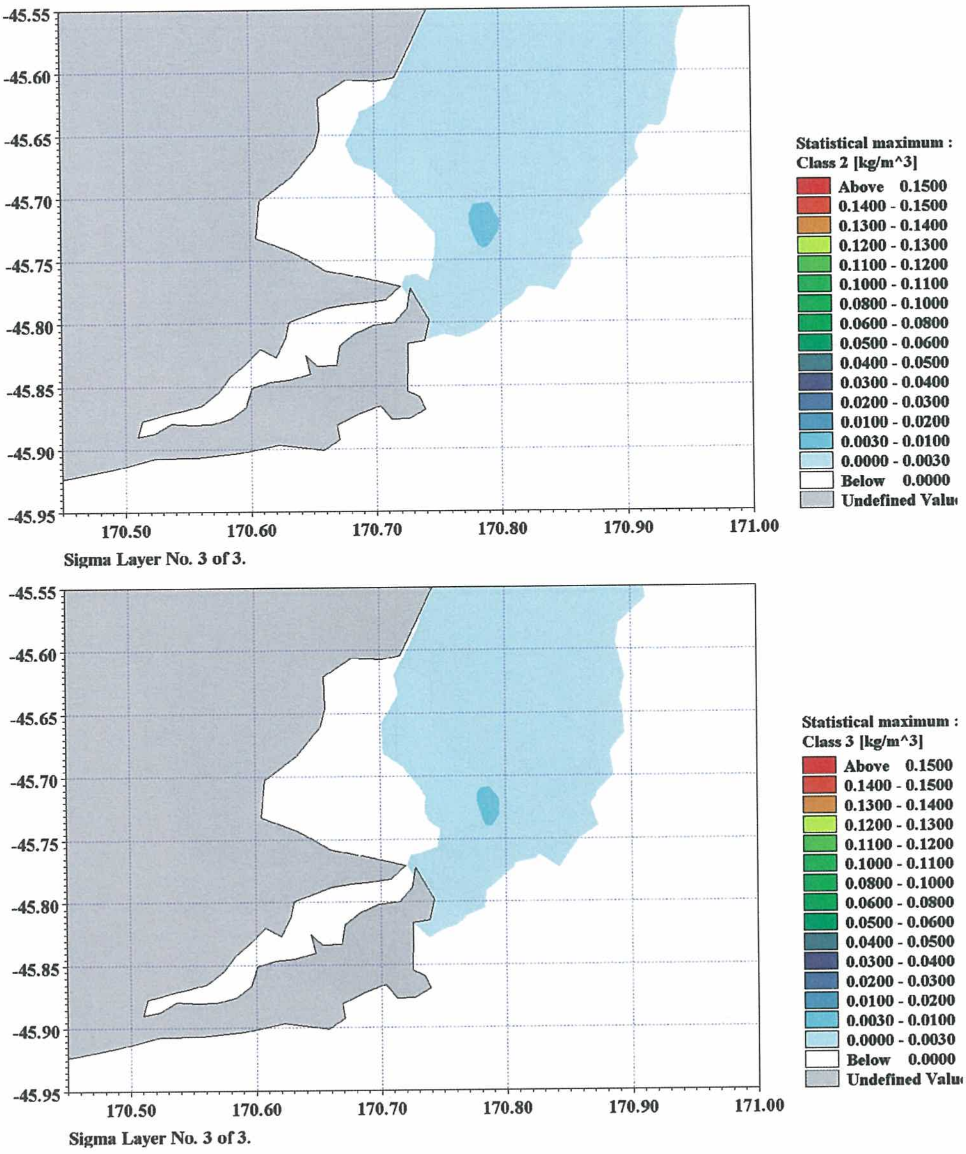


Figure 4.10: Max. SSC composite envelopes for just *New Era* hopper loads for medium silt (top) and coarse silt (bottom) in the near-surface layer (L3) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 4 mg/L (medium silts) and 15 mg/L (coarse silts). For the coast north of Cornish Head, SSC is predicted to be ≤0.014 mg/L (medium and coarse silts) and off Otago Heads, 0.01–0.024 mg/L (medium silts) and 0.02–0.18 mg/L (coarse silts).

5. Conclusions

In summary, this supplementary report, based on further comparable modelling of conservative scenarios previously presented in the lodged Technical AEE Report for the smaller New Era dredge shows that:

- harbour suspended sediment concentrations and deposition rates will be around ten times less using *New Era* than a larger dredge (on which the previous modelling was based)

- offshore, the silt concentrations in the plume generated during disposal in the vicinity of A0 would be around 5–7% of those predicted for the larger dredge. On the fringes of the sediment plumes where the intersect the coast, *New Era* would produce much lower concentrations and in some cases ten times lower than the larger dredge.

5.1 Harbour plume modelling

Sediment plume modelling in Otago Harbour for a larger TSHD was previously carried out by NIWA in 2009 using MIKE-21 PA module which is depth-averaged (2D) model comprising a regular square grid. These ten sets of 14-day plume simulations were re-run for the case where the much smaller *New Era* undertakes the capital dredging, based on five representative source areas and at each source area, for dredging predominantly-sand sediments and predominantly-silt sediments.

5.1.1 2-week average SSC

Average SSC over 2 weeks are provided to directly compare with the previous 2009 model simulations for a larger TSHD and monitoring requirements for overseas dredging projects tend to be expressed as a 2-week moving-average (covering a spring-neap tide cycle). Concentrations from the MIKE-21 PA plume model are averaged over the entire depth of the water column at the time of calculation, so the 14-day SSC averages shown in the plots are also averages over the water depth (mid-tide to seabed level).

All simulations for a 24/7 operation based on *New Era* show that 2-week average SSC in the main channel reaches only 20–50 mg/L above background concentrations, with smaller patches from 50–100 mg/L where the dredge operates. On the intertidal areas, mostly the average SSC is predicted to only reach 20 mg/L with some limited areas up to 50 mg/L. These concentrations are at least ten times less than those simulated for the larger TSHD.

Those *New Era* discharges in the Turning Basin and at Taylers Bend would have the most influence on raising average SSC above background levels in the Upper Harbour. Outside the main channels, SSC would be up to 50 mg/L in small areas (mainly west of Portobello Peninsula for dredging in the eastern Turning Basin), and mostly below 10 mg/L above background concentrations.

Considering silt discharges produced by *New Era* from predominantly-silt versus predominantly-sand[5] areas, there is little difference in the spatial extent of the areas affected by the silt plumes from either source. The SSC are only slightly higher in most cases for the longer predominantly-sand dredging cycles.

Virtually all of the eastern side of the Lower Harbour from Te Rauone Beach through to the eastern side of Portobello Bay would be largely unaffected by turbidity generated directly by *New Era*, with only a few small patches of SSC up to 10 mg/L above background levels. Similarly, the eastern side of the Upper Harbour from Grassy Point to Dunedin would be also largely unaffected by the direct transport and dispersion of suspended-sediment plumes generated by *New Era*.

The 14-day average SSC will be negligible in the indistinct plume that emanates from the Mole to Taiaroa Head channel section for dredging claims in the Turning Basin, but will gradually increase up to a depth-average SSC of only 10–20 mg/L for dredging at Harington Bend.

5.1.2 2-week accumulated deposition

Accumulated seabed deposition over each 14-day plume simulation is presented in mass of sediment per unit area of seabed (kg/m^2). These deposition values are generally conservative as no subsequent resuspension by competent tidal currents or wind-wave stirring was included in the plume model simulations, which will act to further spread and disperse some of the initially-settled material.

To convert to the predicted thickness of deposition (mm), the same settled wet bulk density of 1300 kg/m^3 was assumed, as used in the 2009 NIWA report.

The deposition plots show the following key results for seabed deposition over a 14-day neap/spring tide cycle with varying winds:

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[5] Where a small 2% fraction of silt has been assumed in the sands

- deposition at or above 5 kg/m^2 or approximately 3.8 mm over a fortnightly period (0.3 mm/day) is very confined to the immediate vicinity of the main shipping channel where *New Era* dredges. This is in contrast to the larger TSHD, where the same deposition level or rate occurred throughout the main shipping channel (all discharge sources), the subsidiary channel to the east from Quarantine Island, around Goat Island and up Victoria Channel to opposite St. Leonards for a discharge source at Turning Basin–west, and some of the flanking intertidal flats to these channels

- discharges from predominantly-silt claims cause very similar deposition thicknesses (and daily deposition rates) to those from predominantly-sand claims

- the Upper Harbour will have virtually no discernable seabed deposition arising from discharge sources at Harington Bend and further seaward

- most of the eastern parts of the Lower and Upper Harbours would be subject to negligible or no deposition, apart from the reach west of Latham Bay for discharges from the eastern side of the Turning Basin, where deposition may reach 0.5 kg/m^2 (0.4 mm) over 2 weeks or an accumulation rate of 0.03 mm/day)

- flanking mid-harbour intertidal flats, where most of the non-channel deposition will occur, will be at substantially lower deposition rates using *New Era* compared with the larger TSHD by about 10 times less, from 2–5 kg/m^2 (0.1–0.3 mm/day) down to 0.2–0.5 kg/m^2 (0.01–0.03 mm/day) for similar areas.

5.2 Offshore plume modelling

Simulations for offshore disposal were undertaken for a more conservative predominantly-silt hopper load during light and moderate WSW winds of 7 m/s and 14 m/s respectively and a light 3 m/s NNE wind, when the very low concentration fringes of sediment plumes are most likely to reach the coast. The disposal in these simulations pertains to the landward side of the disposal area at A0.

SSC concentrations offshore during disposal operations for these scenarios will be substantially lower using the *New Era*. Generally, maximum SSC from the *New Era* in the general vicinity of 1–2 km around the disposal area will be around 5–7% of the maximum SSC produced by a larger TSHD.

At the disposal area, the near-surface layer SSC concentrations for all silt classes from *New Era*, for the three wind conditions simulated, are predicted to be in the range 7–11 mg/L (highest during the light NNE wind) above background concentrations. In the more concentrated bottom layer, predicted SSC will the range 47–57 mg/L above background concentrations (highest for the moderate 14 m/s WSW wind).

The fringes of sediment plumes from the smaller *New Era* will reach the coastline north of Cornish Head, but the excess SSC combining all silt-size classes will be no higher than 0.05 mg/L for the different wind simulations (highest during light WSW winds). During light NNE winds, the fringes of the sediment plumes will also reach Otago Heads, where the excess SSC for all silt classes will be no more than 0.6 mg/L. No contact with the Otago Heads coastline will occur for stronger NNE winds (see Figure 11.10b; Bell, et al., 2009).

In comparison with the larger TSHD, *New Era* would produce much lower concentrations and in most cases ten times lower on the fringes of the sediment plumes when they do intersect with the coast. These substantial reductions arise from a commensurate reduction in sediment loads from *New Era* compared with a larger TSHD. Concentrations simulated in the receiving waters are generally proportional to the rate of sediment volume discharged given the same disposal location and release height in the water column.

Patterns of plume dispersion and areal extent of influence are broadly similar between the two sizes of dredger. This is expected as the sediment material is released at the same location, from which the same environmental processes e.g., tides, winds, currents, turbulent eddies govern the dispersal characteristics of the plume. There are however subtle differences in the extent of influence, especially along the onshore and offshore fringes of the plumes. These differences arise from the shallower discharge (2 m depth) from the *New Era* compared with the larger TSHD (5 m depth), which means the plume from the *New Era* is initially influenced by near-surface water processes for a slightly longer period while sediment settles through the 3 m discharge height difference. The differences in extent of the plume are a little more noticeable for light onshore NNE winds.

6. References

Bell, R.G.; Oldman, J.W.; Beamsley, B.; Green, M.O.; Pritchard, M.; Johnson, D.; McComb, P.; Hancock, N.; Grant, D.; Zyngfogel, R. (2009). Port of Otago dredging project: Harbour and offshore modelling. *NIWA Client Report HAM2008-179*, prepared for the Port Otago Ltd.

7. Appendix A: Ratio of seabed deposition for larger TSHD between 20-minute and a 60 minute overflow simulations for "sand" claims

The predominantly-sand plots in the 2009 NIWA report (bottom panels of Figs. 7.4 to 7.13) were mistakenly done for an overflow for the final 20 minutes of the 80 minute dredge cycle. These previous larger-TSHD simulations for "sand" claims were repeated in this present report (see Section 3) for the correct timing of the overflow starting 20 minutes after the start of the cycle for a 60-minute overflow.

For assessing the effect of the revised "sand" simulations on seabed deposition for the larger TSHD, compared to the earlier results in the 2009 NIWA report, the following plots show the ratio of the revised 14-day deposition to the earlier simulations with a 20-minute overflow e.g., a ratio of 2.0 means the longer 60-minute overflow simulations produce twice the deposition as the shorter 20-minute overflow for dredging "sand" areas.

In the main channel, the ratio is up to twice the deposition, while on the intertidal flanks of the channels, the ratio in places is up to three times higher for dredging in the critical swinging basin areas. This applies only to dredging by a larger TSHD in "sand" areas.

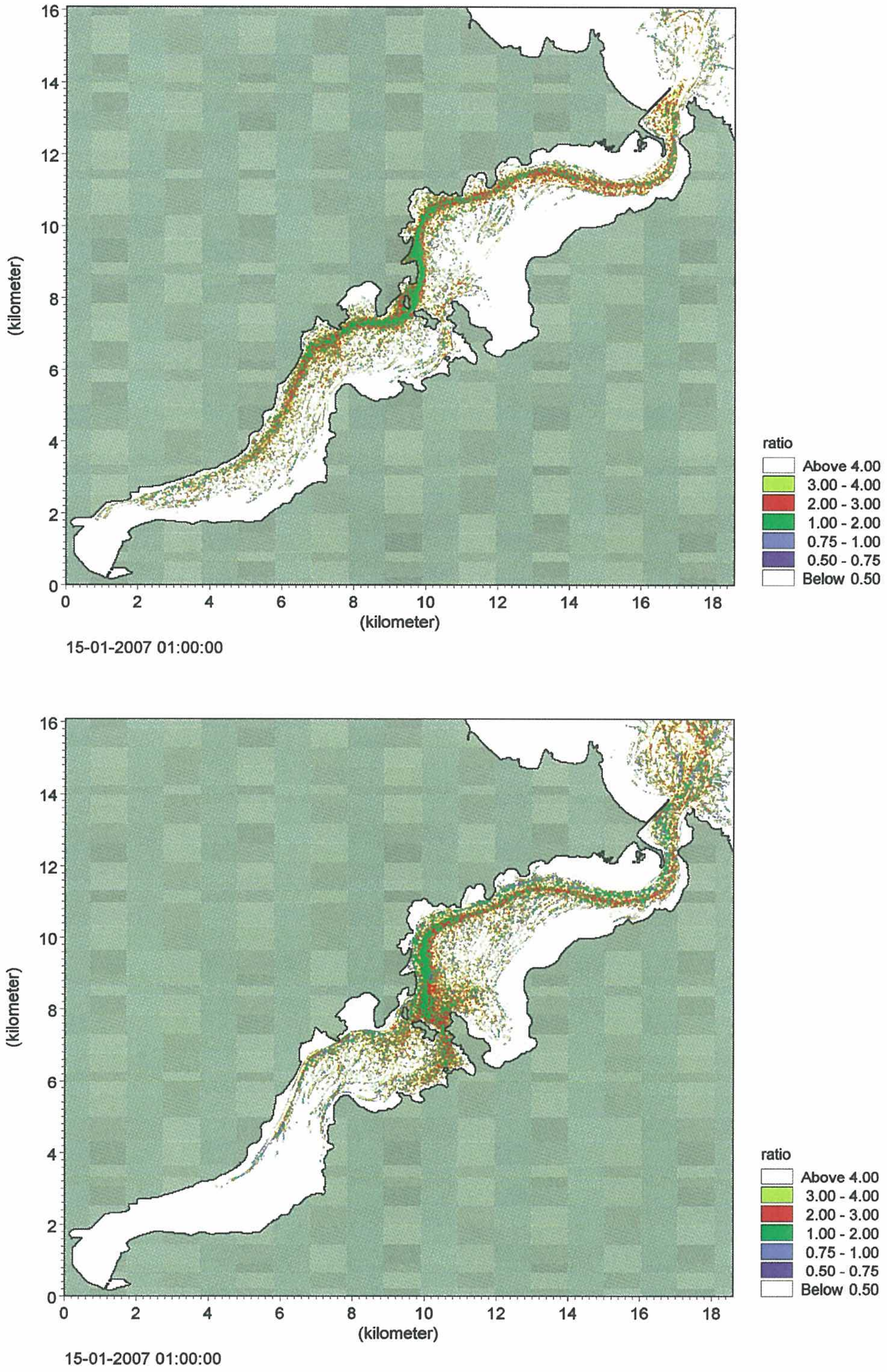

Figure A.1: Plots of the ratio of the seabed deposition for the longer 60-minute overflow to the previous 20-minute overflow simulations in the 2009 NIWA report for largely "sand" dredging in the swing basin–west (TOP) and swinging basin–east (BOTTOM) using the larger TSHD.

NIWA
Taihoro Nukurangi

9 August 2010

Mr Lincoln Coe
Technical Services Manager
Port Otago Ltd
PO Box 8
Port Chalmers 9023

Dear Lincoln

Review of Technical Report: Port of Otago Dredging Project: Harbour and Offshore Modelling

I confirm I have received the Tonkin & Taylor (T & T) peer review of the NIWA/MetOcean technical report that you sent to me on Wednesday 3 August.

Overall, the review stated that the study of effects on hydrodynamics, sediment transport and wave climate was comprehensive. The peer review acknowledged that simulating seabed disturbance, sediment discharges and sediment transport is not a precise science, but noted the authors have chosen to be conservative or bracket model parameters where in doubt.

The modelling was assessed as being robust and fit-for-purpose, with no further or more detailed studies being necessary. Although the T&T peer review suggested that alternative models and methodologies could have been used, they also state that the final conclusions are likely to be similar to those given in the NIWA / MetOcean report. Finally, T & T appraised the modelling results and conclusions drawn from them to be sound.

I have outlined below some responses to the specific comments raised in the T & T review, categorising them into broad topics.

1) Editorial comments

Several suggestions were raised about the structure, style and composition of the Report:

- Decision on not proceeding with an Executive Summary was made by the Project Team, given the range and complexity of the investigations–instead a more comprehensive Summary & Conclusions section was provided at the end.
- Various comments on how the style of the text, cross-referencing and Figures (e.g., Fig. 4.26, Fig. 5.4) could be improved.
- White areas on Fig 5.4 to 5.6 are intertidal areas where the bed is dry for part of the tide cycle. Therefore tide amplitude (half-range) and timing (phasing) of low and high tide can't be extracted from the model results as the tidal processing module can only be done for sites that are continuously inundated by the tide. Note: It doesn't mean these areas are any less accurate than those model cells that don't dry out.

2) Linkages to other reports (that weren't reviewed by T & T)

Several comments related to how results flowed through to other assessments on water clarity and ecological effects for instance. It should be recognised that this report is one of many streams of work supporting a wider Assessment of Environmental Effects (AEE). Ecological matters are picked up, assessed and discussed in detail in the report by James et al., 2009, and wider considerations of physical coastal processes are provided by Single et al., 2009. The integrated effects of the project's various activities are further assessed in the AEE document.

Field data for the present investigations is contained in a separate technical report (with its Executive Summary appended to AEE), while existing field and environmental information was covered in the Shore Processes & Management report (Single, & Benn, 2007). Our approach was to focus on those specific field datasets used to drive the models or used to calibrate or verify the model performance, but in the context of a wider body of field data summarised in Sections 2.2–2.4.

3) Types and resolution of models

The modelling for the project was undertaken in a sequence starting with preliminary scoping modelling inside the Harbour in 2007 (see Exec Summary of January 2008 NIWA report) and ending with the offshore modelling in 2008/09. In 2007, the Flexible Mesh DHI models were just coming into consideration in the market, so a decision was made to continue modelling with the regular-grid MIKE21 model for the Harbour and moving later to the flexible-mesh approach for the offshore modelling. Therefore, in a regular-grid model there are trade-offs in a lower resolution of specific areas of narrow channels (which can readily be resolved in a flexible-mesh model) versus overall run-times for 1-month simulations. In hindsight, persisting with the regular-grid MIKE21 model was warranted as the DHI Particle-Tracking module (used to simulate the sediment plumes) for flexible-mesh model grids struggles to work reliably in intertidal harbours (but alright offshore where it was used for this Project) and it doesn't readily output sediment deposition thicknesses (but the MIKE21 module does).

Swell penetration into the Harbour is minimal, limited to the area around the entrance and northward of Te Rauone Beach and does not extend appreciably past Harington Bend. The wind-wave modelling inside the Harbour was carried out to characterise the wave climate from different wind directions to assess effects on ship handling and for assessment of physical sediment processes in the Harbour. Deepening the main channel would have little effect on wave heights in the Harbour.

Resolution of the model in the area of the offshore disposal ground (A0) was assessed. The velocity field in the area of A0 changes gradually with distance across it. Therefore with the Particle-Tracking module using interpolation of these velocity fields from the hydrodynamic model, the resolution was seen as sufficient to characterise the flows over the disposal ground.

Inclusion of the Harbour Entrance in the offshore model was a compromise between including the tidal flow in and out of the Harbour (but only through a single model cell) and the run-time of the model for the duration of field measurement periods, knowing that the tidal jet doesn't influence flows further offshore e.g., at site A0. It also served its purpose in assessing potential disposal closer to shore off Taiaroa Heads and coming to a decision that disposal would need to occur further offshore. So the implementation of the model was fit-for-purpose in that regard. However, further resolution of the Harbour Entrance would have been undertaken if any inshore disposal sites had looked favourable in terms of effects.

The DHI sand transport module was assessed on previous sand-transport projects that NIWA had used it for, but we didn't have the confidence that it would produce sound results for predicting the longer-term changes in the disposal site mound. Instead, NIWA adopted a more fundamental approach based on sediment-transport physics, based on actual current-meter measurements for the 3 month field period. This fundamental approach was undertaken by sediment-transport experts in NIWA, which bracketed the potential deflation of the seabed mound using two different, but internationally recognized, sediment-transport formulae (viz. Rouse and Nielsen formulations). The results were also assessed within the context of the local geomorphology of the offshore submergent sand spit.

4) Model calibration

- Regarding the comment about the inverse Manning's n (Section 4.2.2), two values were tried 32 (the default value) and 38, but this change made little difference to the results – it is the form drag of the larger channel-bank-island features that predominantly govern flows rather than the bed roughness.

- The Braystoke current velocity used (p. 34) was averaged down the depth profile measurements, so can be compared with the model depth-averaged velocity. Comparing velocities measured at a single point with a model result will never match exactly as the model calculates an average over a model grid cell of 30×30 m or 900 m^2 area, so some discrepancies will be expected.

- Depth adjustments were made to match the mean tide level from the S4 current meters with the mean tide level from the model. The key here was to look at how well the model is performing in predicting the measured tidal range and timing of high and low tides rather than assessing absolute mean-tide levels during the mooring period (which are a function of climate and weather effects).

- The Macandrew Bay current meter site (Fig 4.22) was on the end of the intertidal bank on a sharp turn in the channel. On the flood tide, the current locally accelerates across that site (Beacon 'N') more than is shown by the averaged current velocity over a 30×30 m model cell. A higher resolution of cells in this area would have improved this match, but in terms of the overall result, the suspended sediment concentrations at Macandrew Bay would be slightly less in reality because the modelled flow hasn't cut the corner.

- The Jan-Feb 2007 period chosen for the hydrodynamic modelling runs was based simply on taking a period of recent measurements (at the time the Harbour modelling commenced in 2007 with freshly measured bathymetry data) that also included a higher spring–tide range and two complete neap-spring tide cycles.

- The modelled suspended-sediment concentration (SSC) was an average over the depth. Again a flexible-mesh 3-dimensional model was not available to NIWA (as outlined above), but given sources of sediment from a dredger occur at both the sea-bed and further up in the water column from the overflow, depth averaging is not too much of a constraint in terms of assessing in-water ecological effects. Depth-averaged results will also be more conservative for the visible surface SSC, as sediments start to settle and most of the discharges are below the water surface.

The above comments encapsulate the themes raised in the T&T peer review and I trust that this provides the clarification and context for the review.

Yours sincerely

Robert Bell
Project Leader

Tonkin & Taylor

T&T Ref: 27436
03 August 2010

Port Otago Limited
PO Box 8
Port Chalmers

Attention: Lincoln Coe

Dear Lincoln

Review of Port of Otago Dredging Project: Harbour and Offshore Modelling

1 Context

Tonkin & Taylor (T&T) were asked to provide an independent high level review of the NIWA Report HAM2008-179, Port of Otago Dredging Project: Harbour and Offshore Modelling, for Port Otago Limited. The report was obtained from the website (http://www.portotago.co.nz/10/3.html). The report combines two separate contractual pieces of work, i.e. wave modelling undertaken by MetOcean and the hydrodynamic/sediment transport modelling by NIWA. The review makes comment on both of these separate studies.

Specifically, this high level review provides comment on:

a The general robustness of the modelling approach in relation to a fit-for-purpose appraisal of the likely physical environmental effects and available field data

b The appropriateness of the tools and techniques used and how they compare with international best practice

c Whether the recommendations and findings from the study are soundly based and reasonable given the uncertainties.

2 Summary

This modelling study of proposed dredging of the main shipping channel to 15 m below Chart Datum is a comprehensive study of the hydrodynamics, sediment transport and wave climate within Otago Harbour. Simulating the transport of sediment released from both the active dredging head and subsequent release at the disposal site, is an in-exact art rather than a precise science. There are a number of sediment and hydrodynamic properties which cannot be accurately measured in a practical manner. The authors have chosen to be conservative where in doubt and bracket the results using reasonable high and low estimates for some of the major parameters.

a The modelling approach generally appears to be robust and fit for the purpose of predicting changes to coastal physical process, due to the proposed works, as per the reported design. The methodology used, and level of analysis, is appropriate given the magnitude of the Project Next Generation.

b The modelling packages used (Mike21, Mike3, the PA module, and SWAN) are well established and industry accepted coastal modelling tools. These modelling packages appear to have been correctly and professionally used. This includes calibration and validation of the models. T&T suggest that the vertical profile of suspended sediment concentration could have been simulated if Mike3 had been used within the Harbour Model. T&T acknowledge the increase in computational time required and the limitations of Mike3 Regular Grid in shallow tidal environments. T&T also suggest that an increase in grid resolution may improve the model results. In particular, this applies to the constrictions near Goat Island (Harbour Model) and the entrance to the Harbour (Offshore Model). These are detailed further in the comments below. T&T suggest that Mike3 FM and the Mud Transport module may have been used as an alternative model for the Harbour Model. The use of Mike3FM would have allowed for increased resolution in particular areas. The use of the Mud Transport Model may have avoided some the difficulties experienced with the PA module.

The modelling of long-term evolution of the deposited sand mound is particularly difficult to simulate. The authors have developed a methodology to estimate this long-term change. This method has not been peer reviewed or accepted by industry. While the basis of this method appears sound, this high level review has not reviewed this methodology in depth.

While T&T would have used different DHI modules and a different methodology for this modelling study, the final conclusions are likely to be similar to those given in the NIWA / MetOcean Report.

c The modelling results obtained appear to be sound with no unexpected or unexplained predictions. The conclusions drawn from the results and the recommendations are sound.

A few typographical errors, consistency errors and suggestions for clarity of reading were found during this review. As a high level review, these are not reported here but can be made available to the authors on request.

3 Recommendations

The following are general recommendations or queries regarding the content of the Report made during the review. Page numbers or Figure numbers are used to identify the relevant part of the Report.

T&T suggest that as a Project Report of over 300 pages and 13 Chapters, an Executive Summary would be useful.

P 15. When discussing the wind climate, a wind rose from Taiaroa Head would be useful. (Refer Fig 9.2)

P25. When discussing the cell grid size, it is useful to mention the typical size of important hydrodynamic features, such as the width of the main channel. The gap between Port Chalmers, Goat Island and Quarantine Island is approximately 120 m, or only 4 cells wide. The model would be improved by using a higher grid resolution in this area. It would be useful to explain why the Flexible Mesh model was not used for the Harbour modelling.

Quite a comprehensive volume of field data has been measured within Otago Harbour from various sources. A literature review of published works on Otago Harbour would be useful. A summary table or map of all the field data available and used in this study would also be useful (locations, dates, data type recorded etc), with a description of how the data was used in this study (i.e. model boundary conditions, calibration, verification).

P34. The report states that a new Mannings n value of 32 was tried, but no significant improvement was found so the original values were used. The original (and therefore final) values are not given in the report and should be included.

P34. Model results were configured to produce velocities at the Braystoke locations. The report should clarify if the depth-average model results were transformed in the vertical to point velocities.

P34 and Fig 4.5. The difference in ebb tide u velocity at approximately 10:15 between measured (-0.68 m/s) and modelled (-0.42 m/s) is quite high. This should be commented on, mentioning that the modelled result is slower and therefore conservative in terms of sediment advection.

Fig 4.6 and Fig 4.7. Figure 4.6 is from midnight to 2pm. Is the analysis in Fig 4.7 also from midnight to 2pm? This regression should be done over an integer number of tidal cycles to avoid a bias towards one part of the tidal cycle.

P. 40. T&T would question the text "by tuning the resistance parameter". The report would indicate that a value of Mannings was tried, but no improvement was made, so the original value was used. T&T disagrees that this constitutes 'tuning' the resistance parameter. Suggest that a spatially varying resistance parameter (shallow and main channel areas) may improve the calibration. Similarly p56 states "the model tuning parameters, principally the bed resistance coefficient" implies that other parameters were tuned as part of the calibration process. The report needs to clearly state which other parameters where adjusted and what values were used.

P41. Explain how does the adjustment of modelled elevation (3.08 m etc) compares to the local gradients over the 30 m cell (i.e. does the bed level in this cell vary by more than 3m?). Explain why pressure calibration of the S4 was not done and what error can be attributed to this.

Fig 4.22. T&T would expect a better comparison with ebb tide velocities than shown here. Please explain the discrepancy between modelled and measured (on p50) and comment on the consequences of the model under predicting ebb tidal velocities.

P 56. With regard to the comment "comparing apples with oranges". In such a comprehensive study it does not seem appropriate to conclude that like is not compared with like, implying that the incorrect method has been used. This issue would indicate that the resolution in this area needs to be increased to adequately represent the local bathymetry. To achieve better resolution we suggest the use of the Flexible Mesh version of M21.

P56. The ADCP "shows a good visual match". This is difficult to see in the fig 4.26 (suggest a bigger colour difference in vectors?) Can a quantitative match be made with the ADCP? Particularly as the ADCP is the best measurement of currents in the main channel, which is the strongest advection of sediment. See Fig 12.

P 57. Please clarify why 1 January to 5 February 2007 selected.

Fig 5.4a and others. Please clarify the value of the "white" area in the middle of the harbour.

P 83. The 'predominantly "sand source" ' is difficult to understand until the rest of the chapter is read. We suggest providing a context for this earlier in the Chapter.

Fig 6.4 – It would be useful to label discharge point on this plot

P 108. "Channel velocities generally slow down" – this is not conservative, in regard to sediment advection. A comment on this would be useful.

P110. It would be useful to make some quantitative assessment on the profile of SSC. Similarly, it would be useful to give a comment (or reference to companion report) on the ecological effect of the potentially much high SSC than reported, which may occur within a layer of the water column. This section suggests that a three dimensional model is required, such as Mike3.

P111. In the second bullet point, please clarify what these results mean in relation to a) the visual plume, b) ecology.

P 119. Explain where the wet bulk density of 1300 kg/m^{3}was obtained from.

P186. The harbour wave model just assumes wind waves. Please explain if swell penetration into the harbour is relevant and needs to be taken into account.

P193/194; Fig 10.1 or 10.2. Suggest make bigger and show locations of disposal sites. My concern is that Site A0 may not have a high enough resolution. In the DHI grid generator, you can define an area of higher grid resolution (cf text "...but more highly resolved in the area of interest ..." This does not seem to be shown in Fig 10.2.)

Also in Fig 10.2. The entrance from the Harbour appears to be only 1 cell wide. The approach used, of inserting a volume source in the Harbour entrance to account for the tidal flux is sound, however care is required at the entrance to ensure that the momentum flux of this flow stream is properly represented. This will depend on the location of the source point (not shown in Fig 10.2), the depth at the entrance, and the orientation of the entrance. In particular, the depth of the entrance cell (Fig10.2) appears to be below zero, i.e. very shallow. This may simulate unrealistic velocities exiting from the Harbour. These velocities will, in part, drive the circulation observed outside of the entrance (see Fig 10.4). Thus the circulation may be quite sensitive to grid resolution and the Harbour entrance. Much of the analysis of Site A1 was based on this flow circulation (top of Page 198 and others).

P198, S 10.3. Confirm that the residual current over the 61 days was over an integer number of tidal cycles.

P201. It would useful to explain why the DHI PA model was selected over the MT module. Use of the MT module would enable direct output of sediment deposition on the seabed (p202).

P 202, Para 2. Note, Wind is not an output of Mike3.

P202. "and assuming all particles ... would contribute to the total deposition". Clarify what is meant by "contribute". Are you saying that all particles in suspension at the end of the simulation in any cell are assumed to be deposited on the seabed?

P203. Wet bulk density is assumed to be 1600 kg/m3. Cf this with deposited wet density on P119. Explain difference (due to packing within hold??)

P243. 2nd bullet pt. Please explain what the consequences of this are in terms of the visual plume and ecology. Need to explain that this is assessed in companion report. Similarly, on P253 it states that James et al assesses the deposition rates on ecology, but no mention of SSC effects is given. Please confirm if SSC are also assessed in James et al.

P262. A comment on the choice of the long-term sediment transport method explained in Appendix 2, over use of the DHI sand transport model would be useful.

P265, Fig 12.1. This figure would provide a good validation of the Mike3 model. T&T suggest that this should be used in Section 4.3.

P 306. A plot to compare simulated results at A1 and A0 would be useful to back up the assumption that measured currents at A0 will also apply at A0.

P313. "Sediment plume modelling ... lower towards the surface". The harbour model was only 2D and therefore cannot predict vertical profiles of SSC. T&T recommend that this text be corrected.

P315, last para re environmental effects – this should also be said in the Intro or Exec Summary.

4 Applicability

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

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

Dr Alastair Senior
Senior Engineer
Coasts and Hydrodynamics

Richard Reinen-Hamill
Project Director

4-Aug-10
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NIWA
Taihoro Nukurangi

1 March 2011

Mr Lincoln Coe
Technical Services Manager
Port Otago Ltd
PO Box 8
Port Chalmers 9023

Dear Lincoln

Project Next Generation: Currents and circulation at the offshore A0 disposal area

This letter outlines the background to determining current velocity fields to support plume modelling for the A0 disposal area and how that work ties in with recent current-meter measurements at A0 by MetOcean Solutions Ltd. from 19 October to 5 December 2010.

Background

NIWA has provided what we consider to be fit-for-purpose modelling to Port Otago Ltd to underpin the AEE for the Project. Offshore modelling of currents was undertaken in late 2008 using a 3-dimensional (3-layer) finite-element model (DHI MIKE-3 FM) of the Otago Shelf, that was driven on the offshore boundaries by tides, winds (taken from Taiaroa Head) and a mean velocity for the Southland Current over a 2008 field period (extracted from another larger-domain ocean model developed by NIWA). The latter was applied with different spatial distributions of input flow discharge along the southern boundary of the offshore model, concentrated more at the main shelf break, until a good match was obtained with residual (net) currents over 2.5 months from ADCP measurements at a nearby site A1 (3 km WSW from A0). The details can be found in Chapters 10 & 11 in the NIWA/MetOcean 2009 Modelling Report that was lodged with the Consents Application.

Peer Reviews

Port Otago Ltd engaged Tonkin & Taylor (T & T) to carry out an independent peer review of the NIWA/MetOcean modelling technical report. The review is contained in a T & T letter dated 3 August 2010.

Overall, the T & T review stated that the study of effects on hydrodynamics, sediment transport and wave climate was comprehensive. The peer review acknowledged that simulating seabed disturbance, sediment discharges and sediment transport is not a precise science, but noted the authors have chosen to be conservative or bracket model parameters where in doubt.

The modelling was assessed as being robust and fit-for-purpose, with no further or more detailed studies being necessary. Although the T&T peer review suggested that alternative models and methodologies could have been used, they also state that the final conclusions are likely to be similar to those given in the NIWA/MetOcean modeling report. Finally, T & T appraised the modelling results and conclusions drawn from them to be sound.

In a letter to you, dated 9 August 2010, your will recall that I responded to the specific matters raised by the T & T review in the context of the environmental assessment phase of the Project.

A further independent peer review was undertaken by Dr Ross Vennell of the Department of Marine Sciences, Otago University at the request of the Otago Regional Council. The review is contained in a PDF document dated 16 August 2010.

In terms of the offshore hydrodynamic modelling, Dr Vennell noted the following main points:

- The 3-D modelling did not include the effects of water density, but he concluded that the neglect of water density inshore e.g., 30 m depth, was reasonable.
- The Southland Current was kept constant in the 3-D offshore model. Dr Vennell questions what effects a variable current would have and whether the chosen value is a true average or a conservatively high value.
- The offshore model didn't explicitly include Otago Harbour – rather it was substituted in the offshore model as a tidal flow boundary condition at the Harbour Entrance. Dr Vennell comments that this is a reasonable approach.
- Dr Vennell commented on the very good comparison of modelled currents and field measurements at site A1.
- He also noted that no current measurements were undertaken at the proposed disposal area A0 and suggested that direct measurements at A0 would increase the confidence in the model, particularly as the Southland Current is variable.

Recent current measurements at A0

As a result of the last suggestion by Dr Vennell, Port Otago Ltd. contracted MetOcean Solutions Ltd. to deploy a current meter near the bed at site A0 (within 50 m of the disposal area centroid 45.7358°S and 170.799°E).

A 47-day deployment of a single-point InterOcean S4 current-meter was undertaken from 19 October to 5 December 2010, set at approximately 4 m above the seabed. The results are documented in a report by MetOcean Solutions Ltd (2011).[1]

The main results from the deployment are:

- the mean current speed was 13.7 cm/s, with a maximum of 50 cm/s
- strongest currents were to the NNE and SSE sectors
- tidal currents make up a relatively small percentage of the total variance (energy) in the measured currents, with 15% for the N-S component (compared to 14% at A1 in 2008) and 18.7% for the E-W component (37% at A1 in 2008–higher due to the inshore eddy off Taiaroa Head)
- a residual (net) current for the entire period was to the east
- the directional distribution of currents for this period does not necessarily reflect the long-term distribution, and it is notable that the strongest currents were directed towards SSE and SE coinciding with persistent strong northeasterly winds.

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[1] MetOcean Solutions Ltd (2011). *Current measurements at A0 disposal ground: Field data report*. Prepared for Port Otago Ltd, January 2011, 12 p.

The 2011 MetOcean report concludes that "the current regime at A0 appears to be predominantly influenced by regional-scale wind-driven flows. However, it is likely that the combined effects of bathymetric steering and the impingement of oceanic-scale flows will also be influential at this location."

Synthesis and interpretation of currents at A0

Putting all this information together, a more complete picture emerges of the variability of currents out at the proposed disposal site A0.

Firstly, the oceanography of the Otago Shelf is complex with the geostrophic Southland Current interacting with both regional and local winds and tides to a lesser degree. With very limited past measurements of currents on the Otago Shelf, it was quite a challenge to model all these processes operating together, besides including natural variability.

NIWA modelled the offshore area based on a 15 cm/s velocity for the Southland Current, which was the mean velocity computed by NIWA's larger ocean model of the wider Otago Shelf and abyss over the mid-March to May 2008 period that coincided with ADCP field measurements at site A1. The range for the Southland Current velocity simulated over this period was 7.5 cm/s up to 33 cm/s to the NNE at a location 31 km due south of Cape Saunders in ~130 m water depth. This range is within the 0 to 50 cm/s range cited by Dr Vennell from current measurements by Chiswell (1996)[2] off Nugget Point in 108 m water depth and a mean of 23.8 cm/s.

So the mean current of 15 cm/s used for the A0 plume modelling is on the lower end of the range. Use of the 15 cm/s as the basis for developing an inflow boundary produces a net residual current to the NNE, which matches with the pattern of seabed deposition shown in Fig 11.22 of the 2009 NIWA/MetOcean modelling report.

Modelling investigations carried out last week with different inflows on the southern boundary of the MIKE3 FM model show that increasing the Southland Current beyond 15 cm/s would orient the net current at A0 more offshore to the NE and persistently so. Therefore, higher Southland Current flows would be less conservative with regard to impingement of the edge of diluted sediment plumes on the Otago coastline. Also, a simulation was undertaken for the same mid-March to May 2008 period with no Southland Current (i.e., only winds and tides), which produced a much smaller net residual current (about 10% of that for the simulation used), which was to the north for the bottom and middle layers while the surface layer drift was to the NNE. However, there were periods in this additional simulation when the current drift was to the SE or East, particularly in the surface layer (probably from strong SW wind periods), but seldom onshore and even then only for short periods due to local winds (which are already included in the reported simulations).

Therefore in summary, the mean velocity used for the Southland Current is at the lower, more conservative end (with respect to any coastline effects). As far as simulating the effect of varying the strength of this current for plume simulations, it would have compounded the number of model combinations. It was deemed more important in terms of local variability to focus more on wind variability for the plume modelling rather than increasing and decreasing the Southland Current strength, which only makes slight differences in net residual current direction as it increases, more to the NE. The focus on building winds into the simulations used in the Modelling Report, taking into account their frequency of occurrence, is backed up

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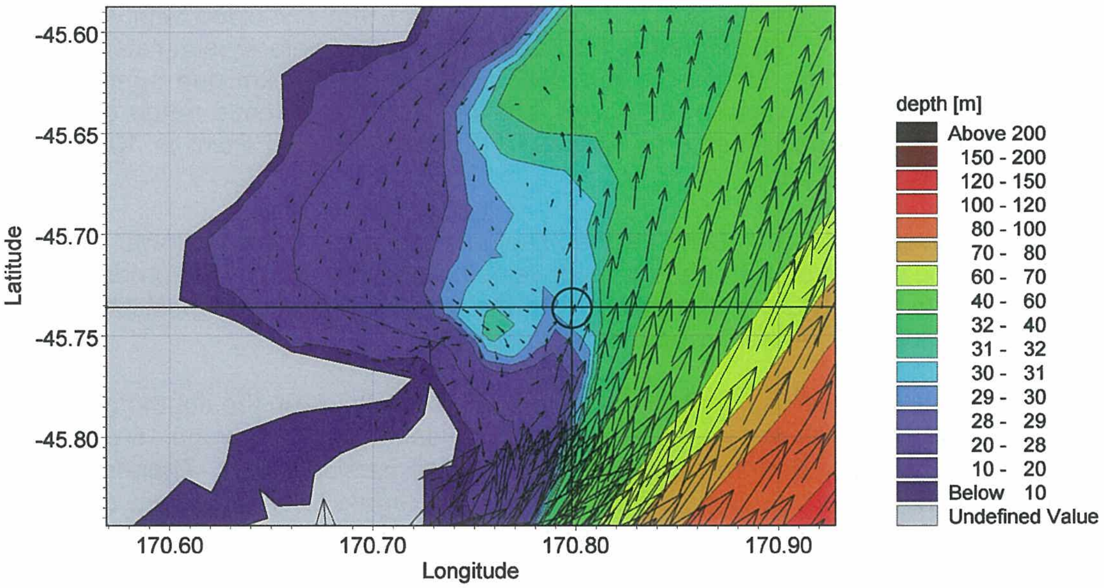
[2] Chiswell, S.M. (1996). Variability in the Southland Current, New Zealand. *NZ Journal of Marine & Freshwater Research 30*:1–17.

by the recent measurements, even though they don't show a consistent influence from the Southland Current.

The plot below shows the overall residual current pattern for the bottom layer (akin to the deployment depth for the recent current-meter) from the long simulation used in the NIWA/MetOcean Modelling Report. The centroid of the A0 area (shown by cross-hairs) is at the landward edge of the influence of the Southland Current offshore, which has its strongest expression further offshore at the main shelf break in depths of 100–500 m. Given its location in this east-west transition zone, the A0 site is likely to experience variations in currents that over the long-term are dominated by the NNE shelf flow at the edge of the Southland Current influence, but there will also be periods when it is more influenced by the East to ESE flow arising from the outer extension of the Blueskin Bay eddy and/or regional/local wind effects. This variability is also confirmed from larger-domain ocean model simulations by NIWA oceanographers that show in-and-out movements of the landward edge of Southland Current flowstream in the vicinity of A0 at periods of days subject to regional wind patterns.



Consequently, the recent current-meter measurements at the centroid of A0 with an overall residual current to the East for the 47-day deployment confirms that this area is indeed a variable transition zone between regional/local wind effects and the influence of a varying Southland Current flowstream. Mostly currents were either to the N, NE, or SE (particularly during two persistent NE wind periods). It is not known what the strength and variability of the Southland Current at offshore locations was during this field deployment, although it is not critically important to know this in the context of A0 currents to be able draw my conclusions below.

Taken together, with the modelling, the key points that arise out of these investigations with respect to the A0 disposal area are:

a) based on the 2010 measurements and the modelling with a zero Southland Current, the current at A0 is very seldom directed onshore

b) while it has been confirmed there will be periods of days and weeks when the residual current is more directed to the east (including brief periods of 1-3 days when the current is more to the SE), these residual currents will transport sediment plumes offshore, where after a short travel distance (particularly if the current is to the SE) they will quickly encounter the Southland Current and be transported in a general NNE or NE direction, depending on the strength of the Southland Current at the time

c) the 2008 hydrodynamic model simulations don't include this eastwards (offshore-directed) residual at A0, so these model results tend to show the plume closer to the coast and be more conservative for the Otago coastline, than if an easterly (offshore-directed) residual is included

d) at the very long timescales, the offshore submergent spit on which A0 has been placed shows a strikingly consistent North to NNE orientation, which will enhance topographic steering of currents to some degree but is also indicative of a long-term net residual current that has shaped this large sedimentary body

I trust this synthesis helps place the previous hydrodynamic modelling and the recent field measurements into the overall context of what it means for dredged-material disposal at A0.

Yours sincerely

Robert Bell
Project Manager

CURRENT MEASUREMENTS AT A0 DISPOSAL GROUND

Field Data Report

Prepared for Port Otago Ltd

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MetOcean Solutions Ltd: Report 0068-01
January 2011

Report status

Version	Date	Status	Approved by
RevA	11/01/2011	Draft for internal review	McComb
RevB	11/01/2011	Approved for client review	Beamsley
Rev0	12/01/2011	Approved for release	McComb

It is the responsibility of the reader to verify the currency of the version number of this report.

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1. INTRODUCTION

The Next Generation project at Port Otago involves the deepening of the approaches to Port Chalmers and the associated disposal of dredged material. A significant amount of modelling work has been undertaken to support this project, along with an oceanographic data collection program in 2008. The selection of a disposal ground (site A0) was based on the modelling outcomes, without specific measurements from the A0 location. A peer review of the Next Generation modelling work was undertaken in 2010. One of the recommendations of the review was that measurement of currents at site A0 would be beneficial; providing increased confidence in the modelling with respect to the dispersal of the sediments from the disposal ground.

This report provides details on a 47-day current measurement program that was conducted at the A0 disposal site from 19 October 2010 to 5 December 2010. The measurement program was undertaken by MetOcean Solutions Ltd, with assistance from staff at the Department of Marine Science at the University of Otago. The University research vessel *Polaris II* (Fig. 1.1) was used for deployment and recovery operations, and Skipper Bill Dickson and crew are gratefully acknowledged for their role in ensuring the safe and successful execution of the program.

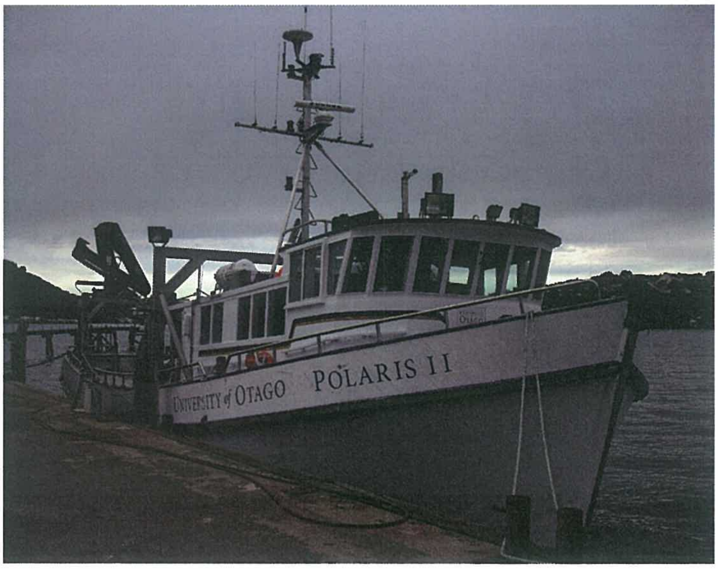

Figure 1.1 The RV Polaris II used for deployment and recovery operations.

2. METHODOLOGY

2.1. Instrumentation and mooring

An InterOcean S4 current meter was used to measure point source current speeds and directions. The S4 meter samples at 2 Hz frequency and was programmed to record a 5-minute mean at 30 minute intervals.

The meter was deployed on a taut-wire mooring, positioning the sensors at 4.2 m above seabed using a 160 kg buoyancy set attached to the current meter (Fig. 2.1). A schematic of the mooring is presented Figure 2.2.

Figure 2.1 The S4 current meter (right) and the 160 kg buoyancy set.

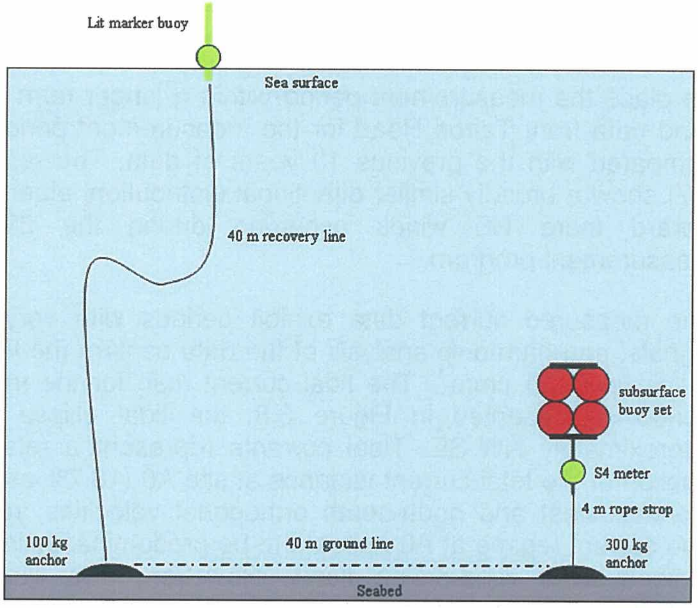

Figure 2.2 Schematic of the mooring.

3. RESULTS

The time series of the measured current speeds and directions are presented in Figures 3.1 and 3.2, respectively. Note the directions are provided in the 'going to' convention, and have been corrected for the local magnetic variance (24.97°). These data are also provided as a joint probability distribution of speed and direction in Table 3.1, and as a current rose plot in Figure 3.3.

The highest recorded current speed was 50.1 $cm.s^{-1}$ directed to the SE, while the mean current speed over the 47 days was 13.7 $cm.s^{-1}$. It is notable that relatively strong currents (i.e. > 35 $cm.s^{-1}$) were observed for all octants except E, W and SW. However, the strongest flows were all directed toward the NNE and SSE sectors. A progressive vector plot of the measured currents is provided in Figure 3.4.

The directional distribution of currents from this 47-day program does not necessarily reflect the long term distribution, and it is notable that the strongest current event was directed toward the SSE and SE and coinciding with persistent northeasterly wind conditions. This event can be seen on the progressive vector plot (Fig. 3.4) starting at 30/10/2010. The co-temporal relationship between wind and current vector is illustrated in Figures 3.5 and 3.6, showing the timeseries of orthogonal wind and current vectors. Wind data from the Tairoa Head recording station were used in this plot. In particular, the north-south vector timeseries (Fig. 3.6) exhibit a clear correlation between wind velocity and current velocity. These observations imply the regional wind stress has a significant influence on the local current regime at A0.

To place the measurement period within a longer term context, the wind data from Tairoa Head for the measurement period has been compared with the previous 10 years of data. The results (Figure 3.7) show a broadly similar directional distribution, albeit with a bias toward more NE winds occurring during the 2010 current measurement program.

The measured current data exhibit periods with very clear tidal signals, and harmonic analysis of the data confirm the tidal currents reach up to 11 $cm.s^{-1}$. The tidal current rose for the measurement period is presented in Figure 3.8; the tidal ellipse is oriented approximately NW-SE. Tidal currents represent a relatively small fraction of the total current variance at site A0 (18.7% and 15.0 % of the east-west and north-south orthogonal velocities, respectively). The current regime at A0 appears to be predominantly influenced by regional-scale wind-driven flows. However, it is likely that the combined effects of bathymetric steering and the impingement of oceanic-scale flows will also be influential at this location.

Table 3.1 Joint probability distribution (parts-per-thousand) of current speed and direction (going to) over the measurement period in late 2010.

Current speed (cm.s^{-1})	**Current direction (degT) 'going to'**								
	337.5 - 22.5	**22.5 - 67.5**	**67.5 - 112.5**	**112.5 - 157.5**	**157.5 - 202.5**	**202.5 - 247.5**	**247.5 - 292.5**	**292.5 - 337.5**	**Total**
> 0 <= 5	16.5	20.4	20.4	17.8	9.1	10.4	7.8	9.6	112
> 5 <= 10	31.3	38.7	50.4	49.6	33	18.7	16.1	19.1	256.9
> 10 <= 15	30	42.6	60.9	63.5	28.3	17.4	8.7	25.2	276.6
> 15 <= 20	19.1	11.7	42.6	45.7	14.8	5.7	8.7	20.4	168.7
> 20 <= 25	15.7	10.4	23.9	18.3	2.6	0.9	10	8.7	90.5
> 25 <= 30	9.1	10	9.1	13	1.3	0	2.2	3.9	48.6
> 30 <= 35	3.5	9.1	2.2	10	1.7	0	0.9	0.9	28.3
> 35 <= 40	2.2	1.3	0	8.3	2.6	0	0	0.4	14.8
> 40 <= 45	0.4	0	0	1.7	0.9	0	0	0	3
> 45 <= 50	0	0	0	0	0	0	0	0	0
Total	127.8	144.2	209.5	227.9	94.3	53.1	54.4	88.2	1000

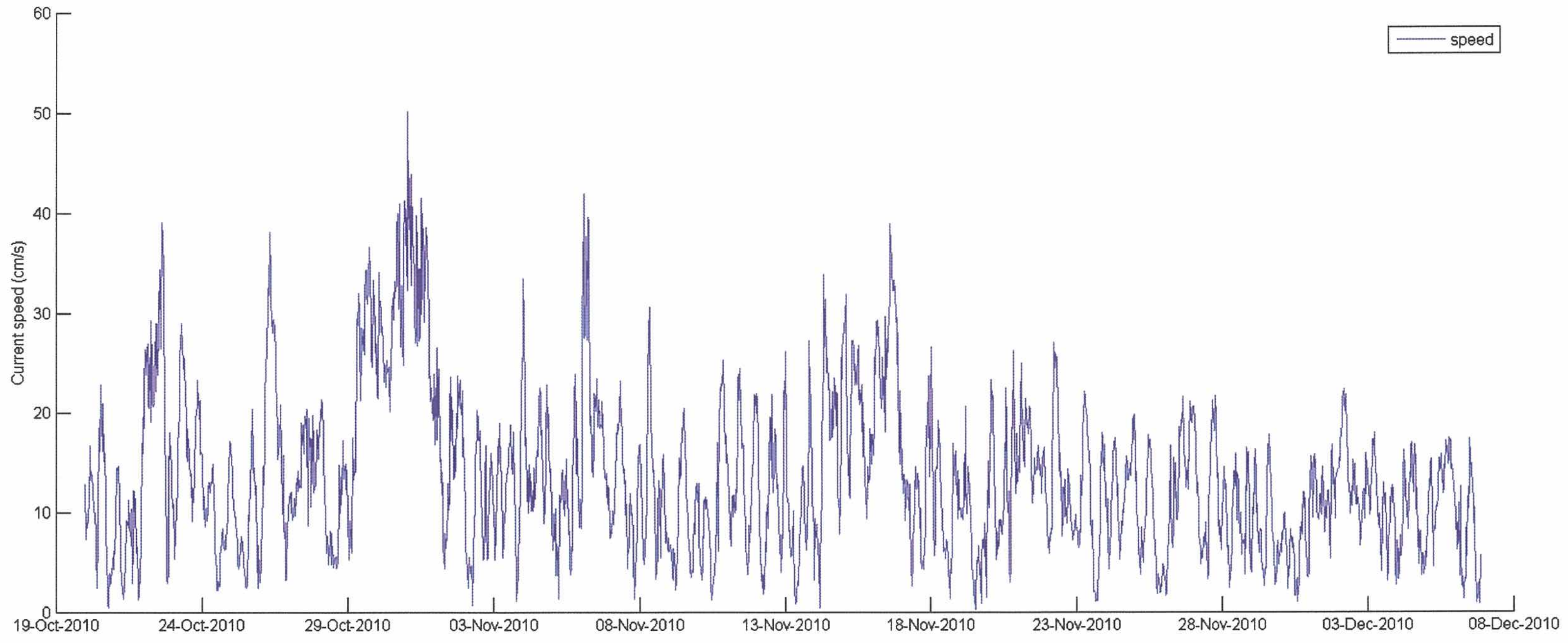

Figure 3.1 Measured current speeds at site A0.

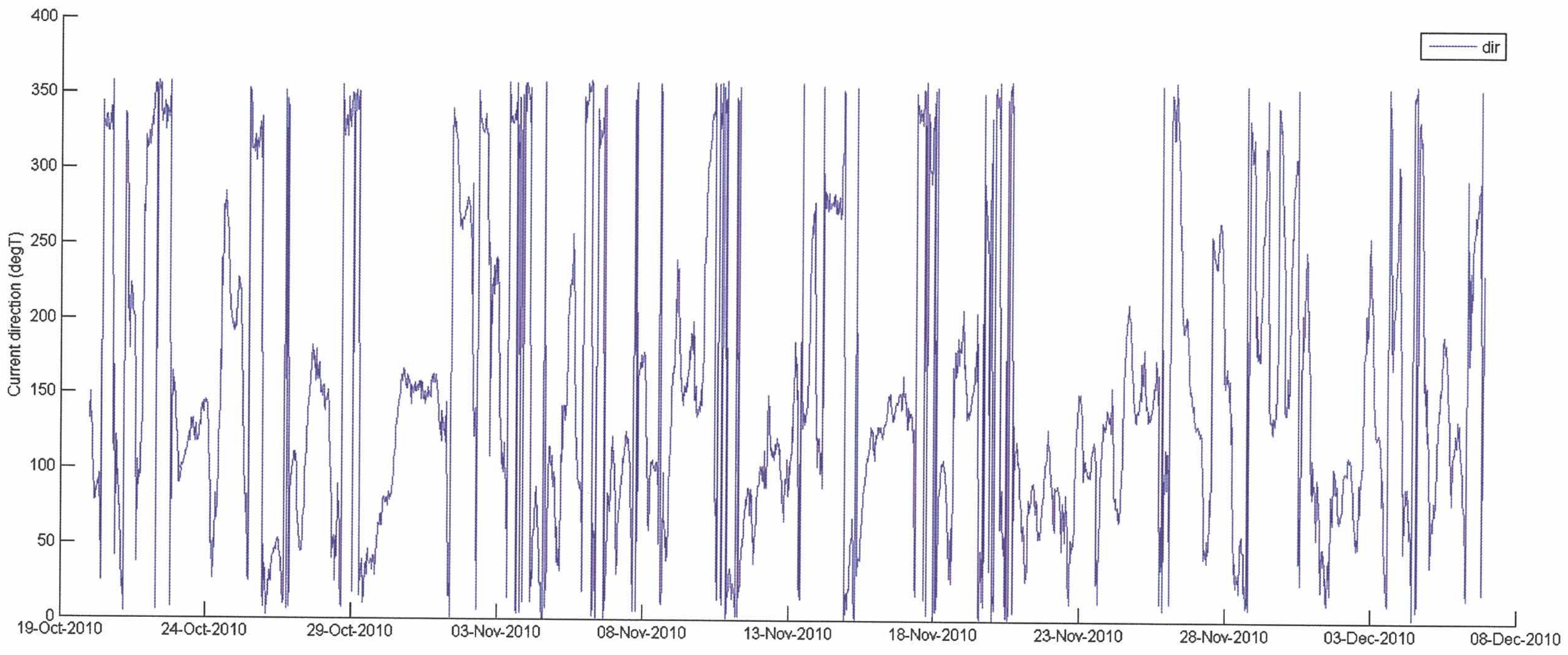

Figure 3.2 Measured current directions at site A0.

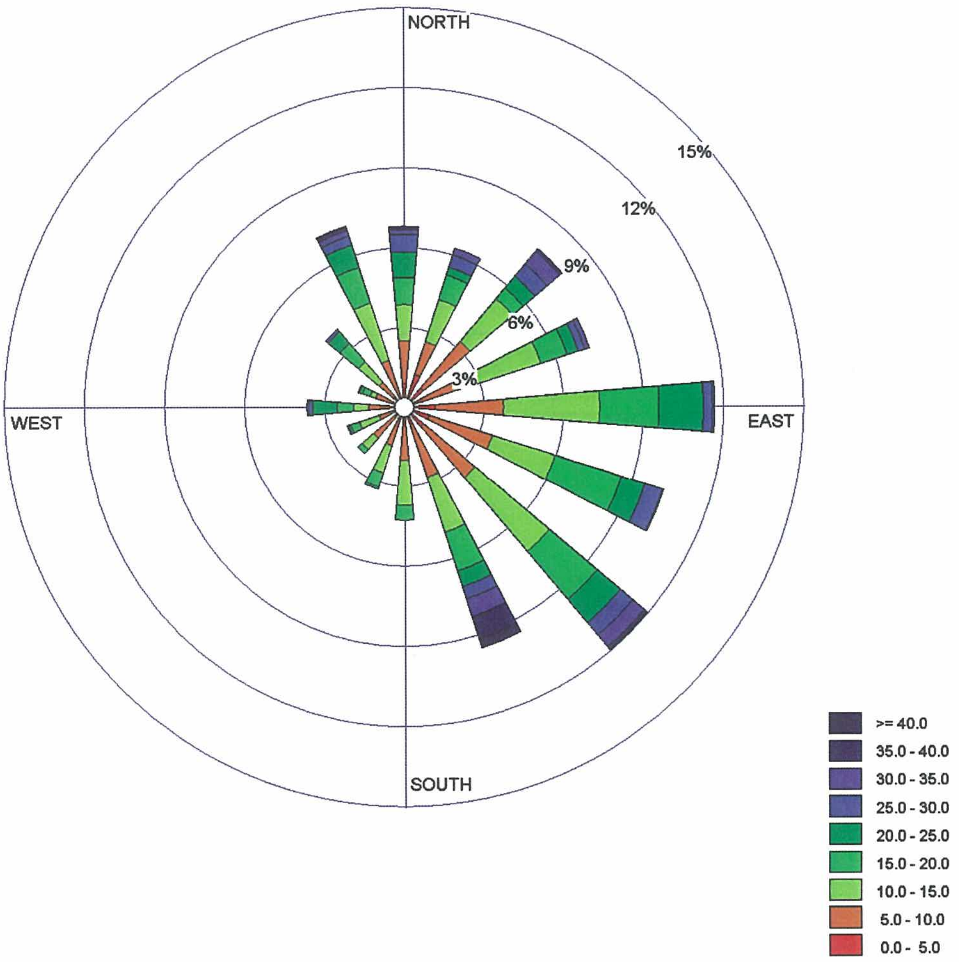

Figure 3.3 Current rose plot for the measurement period in late 2010.

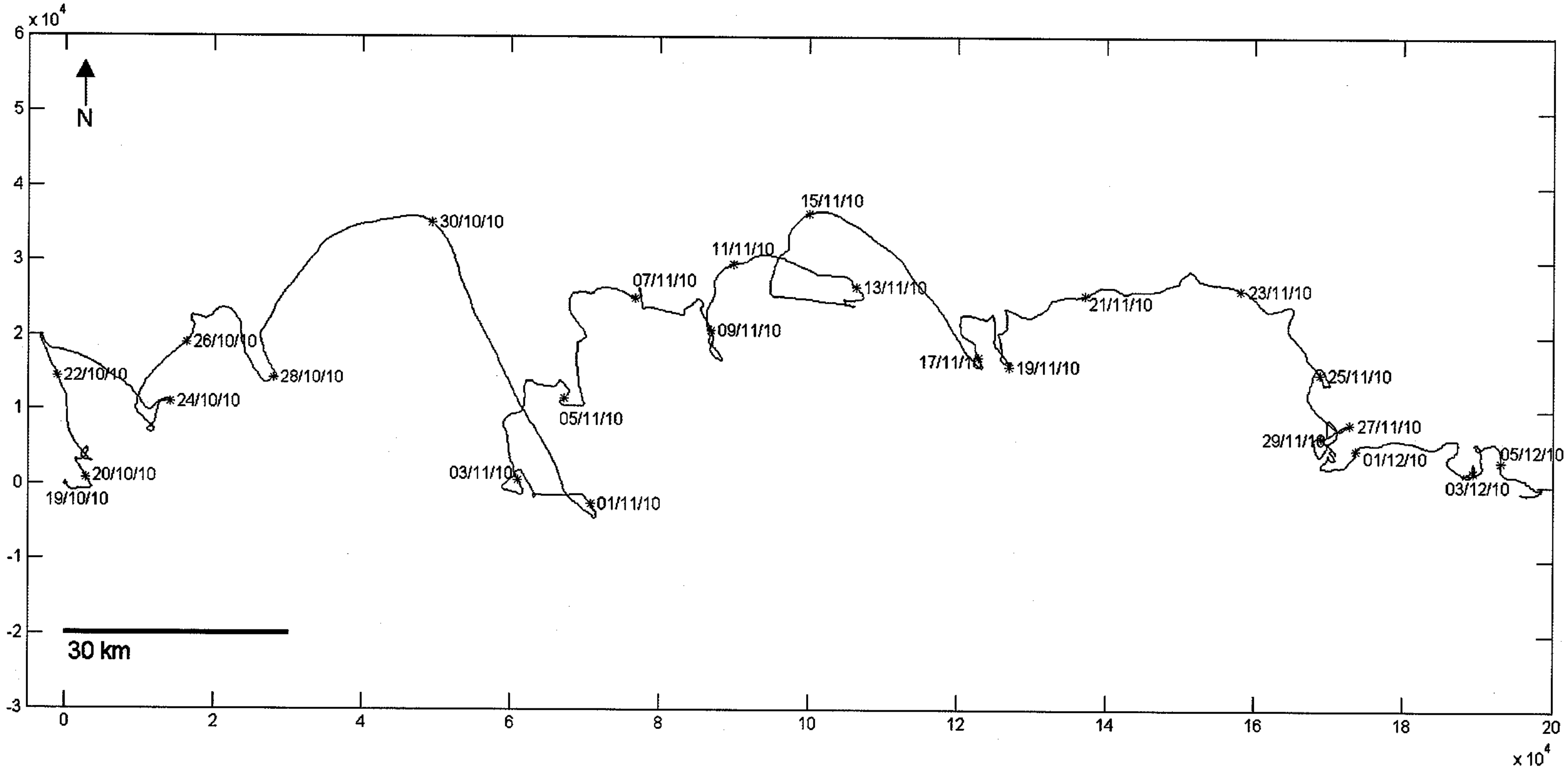

Figure 3.4 Progressive vector plot for the measurement period in late 2010.

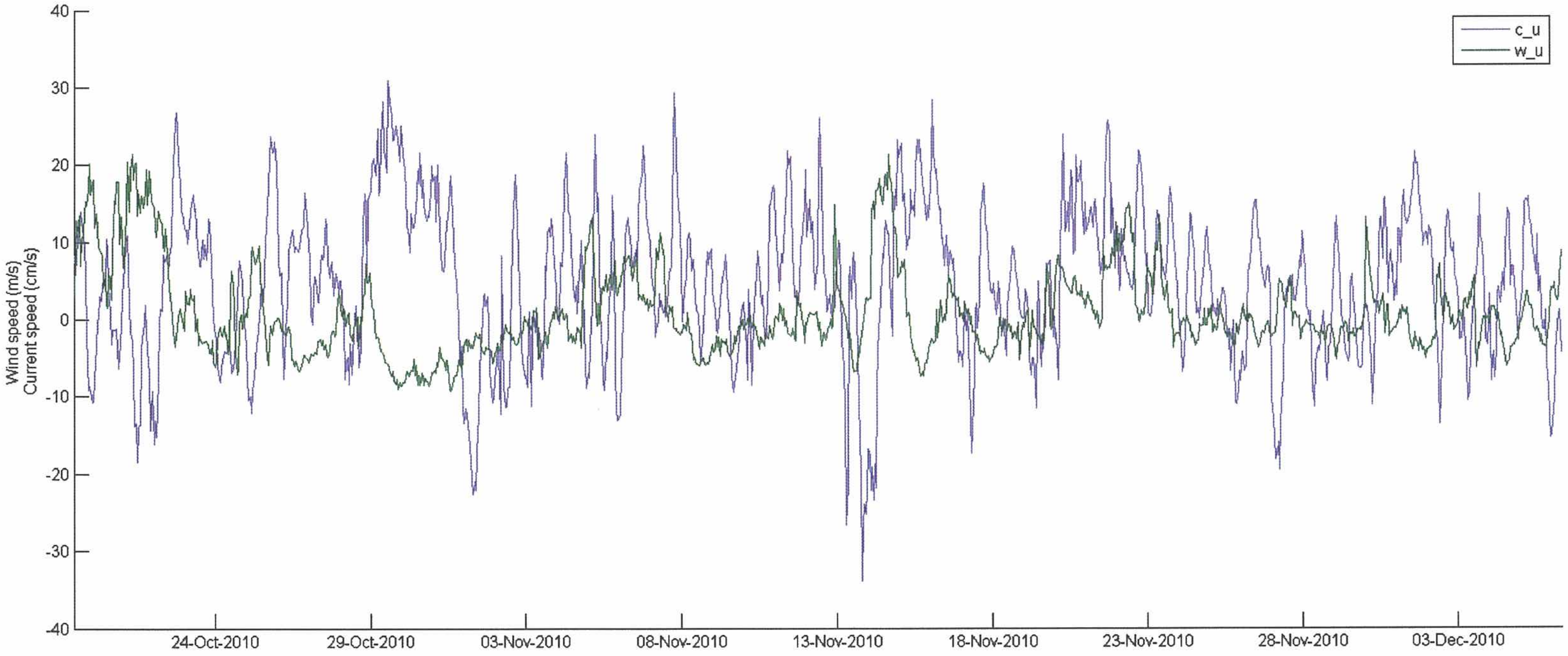

Figure 3.5 Timeseries plot showing the east-west (u) orthogonal vectors for measured wind speed (green) and current speed (blue).

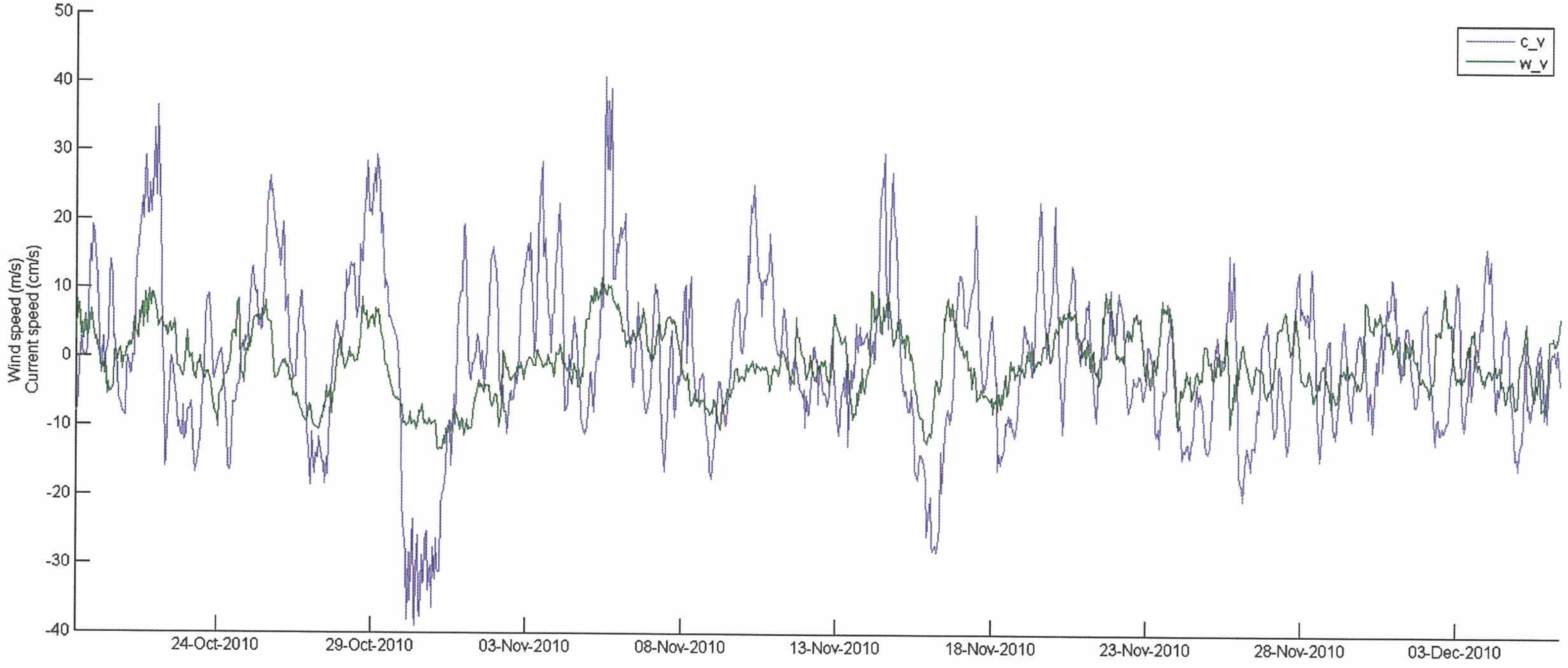

Figure 3.6 Timeseries plot showing the north-south (v) orthogonal vectors for measured wind speed (green) and current speed (blue).

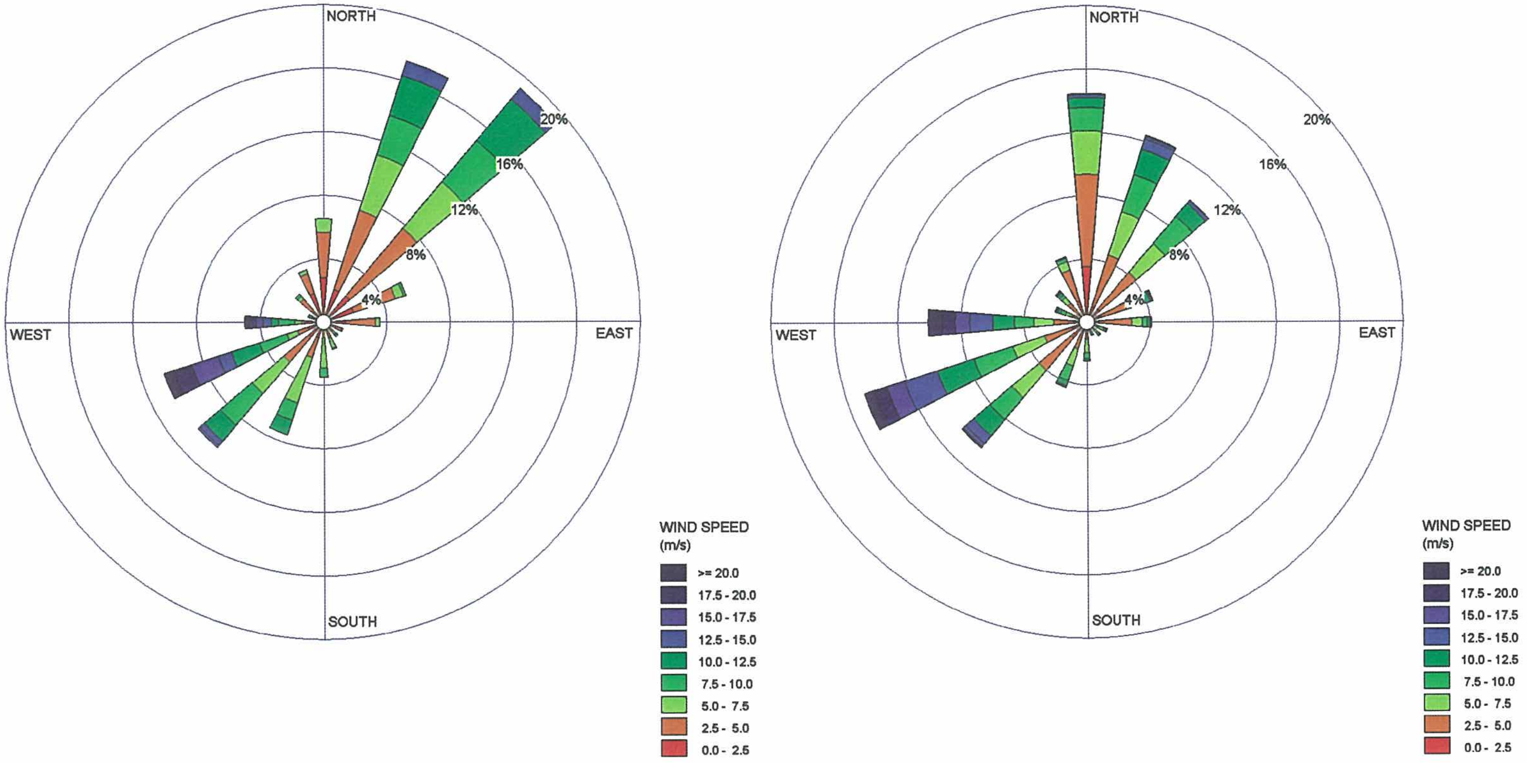

Figure 3.7 Wind rose plots for Tairoa Head over the current measurement period (left) and the previous 10 years (right).

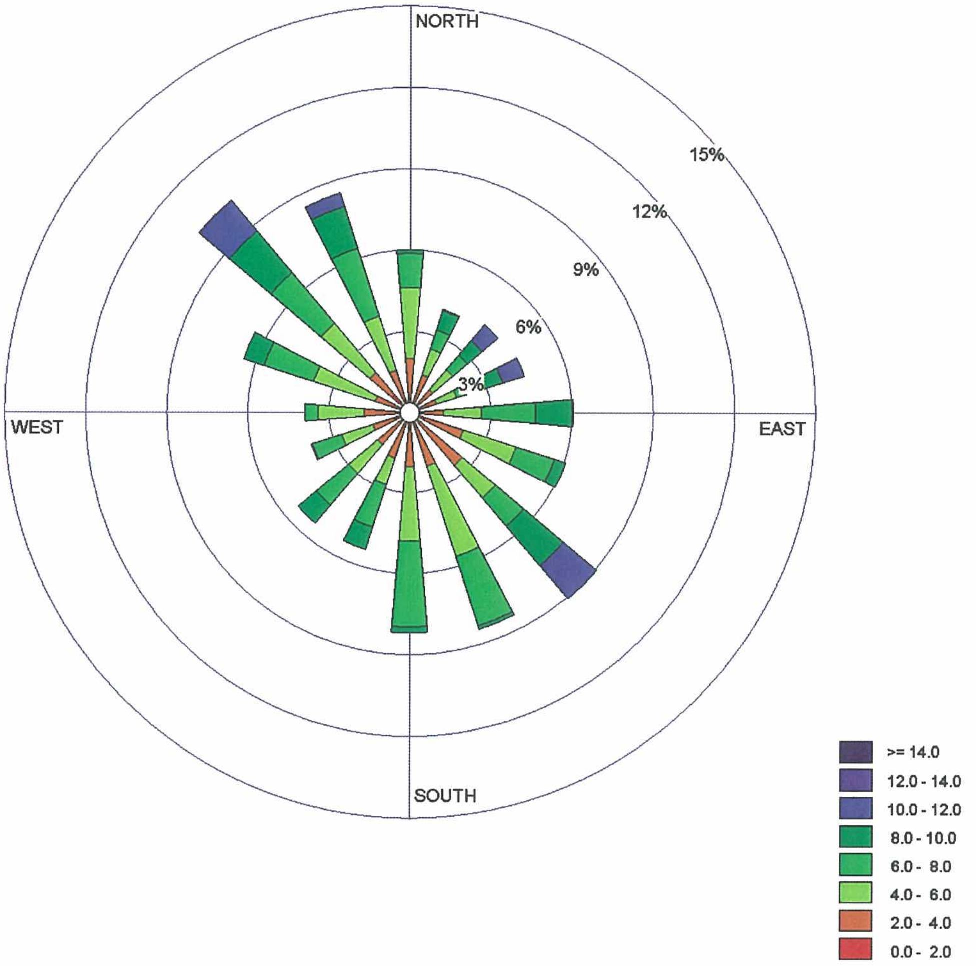

Figure 3.8 Tidal current rose plot for the measurement period in late 2010.

Review of: NIWA Client Report HAM2008-179

Port of Otago Dredging Project: Harbour and Offshore Modelling

by NIWA and MetOcean Solutions Limited

Part of Port Otago's Project Next Generation Channel Deeping
Resource Consent Application 2010

Reviewed by Ross Vennell
BE (Eng. Science), Auckland,
PhD (Physical Oceanography) Massachusetts Inst. Technology & Woods Hole Oceanographic Inst.
Dept Marine Science, University of Otago

August 16th 2010

Scope of Review

This independent review covers the physical numerical modeling undertaken to support Port Otago's resource consent application. The review is limited to the appropriateness of the methods and the robustness of the modeling detailed in the report HAM2008-179. It does not include a review of the results obtained or of the biological or other impacts of the proposed dredging program.

Modeling Aims and Approach

The modeling work aims to estimate the effects of the channel deepening on tides within Otago Harbour as well as the extent of the spread of sediment stirred by dredging and the spread of material from the proposed spoil dumping site. The hydrodynamic and wave modeling contains the elements you would expect to see to address the issues of

i) effects on tidal heights and currents within Otago Harbour
ii) the spread of fine material stirred up by the dredging within the Harbour
iii) the spread of fine material released during dumping
iv) the longer term dispersal of coarse material from the dump site

There are essentially two modeling elements

- A Harbour tidal model extending out to Landfall Tower outside the Harbour entrance, with a separate model for wind generated waves within the Harbour
- An offshore tidal and current model extending out to the steep edge of the continental shelf, with a separate wave and swell model extending over much of the area around the South Island

Computer Modeling Tools

Software from the MIKE suite developed by Danish international research and consultancy group DHI, was used to investigate the spatial extent of plumes from the dredging program. This suite of software has been used by many consultancy groups for engineering projects worldwide for decades and is continually being tested and improved. The MIKE-21 and MIKE-3 programs used in this work to model tides and currents are as close as its gets to industry standard software in the specialized field of hydrodynamic ocean modeling.

MIKE-21 which was used for the harbour models is a depth averaged model, i.e. is two dimensional which is reasonable for shallow well mixed areas like Otago Harbour. MIKE-3 is a three dimensional model, which was used here for the offshore model with three layers (i.e. the water depth was broken down into three horizontal layers).

For both the harbour and offshore models sediment transport was modeled using the MIKE Particle Tracking model (PA). This model releases large numbers of virtual particles (up to 100,000) into the modeled currents and traces their path through time and enables statistics to be developed about the fate of the virtual sediment particles. Particles are tracked horizontally and vertically (even in MIKE-21) as determined by currents and the settling speeds to estimate where they end up.

Wave modeling for the work was done using the University of Delft's SWAN wave model. SWAN (Simulating Waves Near-shore) is a third generation wave model specially developed for coastal areas. This freely available software is also close to the engineering standard for modeling waves, used extensively word wide for many years. It is also continually being improved and developed. SWAN propagates waves across the modeled area by allowing for wave refraction (changes in the direction of wave propagation due to the sea floor bathymetry). SWAN also allows for wind generation of waves within the area modeled, for propagation of waves and swell through offshore boundaries of the model, for wave energy losses due to breaking and bottom fiction, as well as for the effects that currents have on waves.

Harbour Hydro-dynamic Model, MIKE-21

Numerical models need calibration. In this case adjusting a single coefficient related to the bed roughness, the Mannings "n" value, for the whole model was done to give the best overall comparison with all the historical Braystoke measurements from the main channel. These 1988 measurements used now archaic instruments, so are only moderately accurate and only covered single tidal cycles. The model was then used to make predictions for the currents at the locations of three longer term 2008 S4 current meter deployed at sites within the Harbour (Table 4). The comparison is used to "validate " or check the calibration. Despite calibration being done against the relatively short term (13 hour) cruder older data the model's predictions for 2008 agree well with these new 10-14 day modern currentmeter measurements.

The S4's were also deployed outside the main channel where no historical data were available giving additional confidence in the model's performance in some of the shallower areas of the Harbour. Further S4 measurements would improve confidence in the model, but the important areas which are most likely to be impacted by fine sediments from the outer harbour channel, e.g. Portobello Peninsula and the outer parts of the shallow upper harbour, are covered. Visual comparison with the detailed 1999- 2000 moving vessel data was good, but detailed comparison at representative locations could provide further confidence in the model's performance.

Changes in Tidal Heights and Currents within the Harbour

Deepening parts of the channel will alter tidal heights and currents within the Harbour. To assess any changes model runs were carried out for pre- dredging and post-dredging channel water depths for an average tidal cycle and for a representative 14 day spring-neap cycle. The volume being dredged is relatively small in comparison to the total volume of water in the Harbour so, as would be expected, the effects are small, around the 1-2% level for tidal currents with small associated changes in heights and timings of the tidal water levels.

The volume fluxes across three transects near the entrance (the amount of water crossing the three lines in cubic meters per second) also show almost imperceptible changes as the result of channel deepening. The two outer transects (Fig 5.9) are close to the outer boundary of the Harbour model at Landfall Tower. The jet forming during ebb tides almost extends to Landfall Tower, thus the outer boundary would ideally be further offshore. This may have some impact on the volume fluxes across the outer two transects (#2 and #3) but is unlikely to affect the most important transect (#1) across the channel at Spit Wharf, which changes by only around 1%. Given the focus is on changes in volume flux due to dredging the effects of the proximity of the model's boundary on transects #2 and #3 is not likely to be a significant issue.

Harbour Plume Model

The extent to which the fine sediment plume is spread around the Harbour by tidal currents and wind driven currents is modeled using the MIKE 21 PA model. This uses the currents from the MIKE 21 model. From this statistics about how many particles end up settling in each of the 30m boxes which make up the model's grid can be compiled. The particle model is passive, i.e. assumes the sediment does not affect the density of the fluid mixture enough to cause density driven currents. This is reasonable for the generally low concentrations of fine sediment expected outside of the immediate vicinity of any discharges. The particle model requires choosing horizontal and vertical dispersion coefficients, which allow for small random motions within the model's 30m grid. Ideally these dispersion coefficients would be measured within Harbour using dye tracing experiments or by other means. The report however shows that for a variety of wind scenarios the extent of the plume after 14 days is insensitive to the value of these coefficients within a reasonable range of values, and reasonably opts for mid range coefficients.

The likely discharges over a dredge cycle from both sand and silt sources are used as input for the plume model. This is an area of uncertainty. Ideally measurements of discharges due to overflows or stirring by the suction head would be made. However, not knowing which particular dredge will be used and how much this particular dredge would disturb the sediments present in Otago Harbour, means that these discharges must be estimated. The report takes a conservative approach to several aspects of these discharges which are likely to overestimate the sediment inputs due to the dredge. Some of these are

1) The drag head disturbance rate of 30kg/s is higher than that found in other areas dredging silty sediments.
2) The way the sediment concentrations are reported.
3) Using the shorter distance to the original offshore dump site A1 rather than the now proposed A0 which is further offshore. This gives a higher rate of discharge.
4) Not allowing sediment to be re-suspended by waves or subsequent tidal currents within the typical 14 day modeling cycle once they settle to the bottom. This results in the model over estimating sediment thickness accumulating nearer the discharge.

The plume modeling covers five representative dredging sites, and is careful to include both eastern and western sites from the Port Chalmers turning basin, which give significantly different results. This is the area most likely to give significant differences in the extent of the sediment plume for a relatively small change in location of dredging due to the Portobello side channel at the Halfway Islands.

The suspended sediment concentrations are reported in terms of depth averaged values, which are likely to be higher near the bottom, particularly near the dredge. Thus more work may be needed to quantify near bottom concentrations experienced by benthic organisms. This does not affect how the amounts of sediments settling on the bottom and where they accumulate are reported.

Offshore Hydro-dynamic Model

The Mike 3 model used for the offshore tide and current model did not include the effects of water density on the flows. The effects of density on currents are important offshore, but given that the water column is well mixed in the area of focus (water depths less than 30m) the neglect of density for the inshore circulation is reasonable. The Southland current at the southern boundary was derived from a much larger ocean model of the NZ region. Tides were included but these produce weak currents in the area of interest. The circulation is dominated by the effects of wind and the northward flowing Southland Current. The Southland Current was kept constant in the offshore model. It is not clear what value was chosen, but the nearest long term current measurements in the Southland Current (at Nugget Point, Chiswell 1996) show strong variability from 0 to 0.5m/s over 5-10 day periods associated with weather patterns over the ocean to the south of the South Island. It is not clear if the constant Southland Current set at the model's southern boundary was an average value or a conservatively high value. Given that plume dispersion from the proposed site appears mostly due to the Southland Current, with some wind effects it would be useful to clarify this. If an average Southland Current was used then it would be useful explore the sensitivity of the results to a reasonable range of Southland Current speeds.

The offshore model does not include a detailed Otago Harbour, other than as a source of fluid to a coastal ocean. Given the small size of the Harbour compared to the area modeled this is a reasonable approach. The comparison of the modeled currents with the measured currents at A1 is very good, giving reasonable confidence in the model's performance, particularly as measured currents at A1 show almost exclusively south east flows. A1 sits on the shoreward side of a small eddy, a couple of kilometers in diameter, which forms in the lee of Tairoa Head due to the northward flowing Southland Current. This small eddy has not been documented before. On the bigger scale the model shows the expected much larger weak circulating eddy within Blueskin Bay creating weak south westward flow but mainly confined to water depths more than 20m.

The initial proposed dumping site, A1, lies on the shoreward side of the small eddy in the lee of Tairoa Head. The eddy is seen in both measured currents and modeled currents. The eddy causes generally southwards flow at this site, opposite to the northwards flow of the Southland Current further offshore. As a result a plume from dumping at A1 may contact the shore line, particularly if it interacts with the Harbour's ebb tidal jet. Thus a new site A0, further offshore, became the proposed dump site. This site sits within the northward flowing Southland Current, leading to a more extensive northward dispersal of the plume, which only under some wind conditions results in low concentrations of sediment at the shoreline to the north of Blueskin Bay. A1 lies on a small natural underwater ridge or spur. The spur extends to the north east of A1 and was likely formed by sediment from the south being transported past Otago Peninsular.

There are no current measurements at the proposed site A0, and none of the of sites where current measurements were made lie within the Southland Current. The Southland Current has a significant impact on dispersal from A0. Thus direct measurements of currents and waves at the proposed A0 site would increase confidence in the results, particularly as the Southland Current is so variable.

The modeling approach uses a number of weak, medium and strong wind scenarios from two directions and a range of sediment class sizes to look at the extent of dispersal of material fine enough to remain in the water column after dumping. Like the Harbour model, plume modeling in the offshore model is conservative in its approach. For example not allowing re-suspension of sediment means modeled accumulations are likely to be overestimated near the dump site. Re-suspension of sediments by waves is likely to spread material further, with smaller accumulations over a wider area.

Offshore Wave Model

The offshore wave model utilizes the standard SWAN model in a typical nested model approach. Models of a larger area are run to give information at boundaries of finer models of areas within the larger coarse model. This allows the fine model to have very detailed water depth information to bend or refract waves and swell as they propagate. In this case the wave model was tested against long-term wave data from the North Island for the outermost coarse grid and tested against shorter wave data records from Tahuna, Dunedin. The wave model reproduced the Tahuna record well (Fig 8.4) giving confidence in its results, with a tendency to overestimate the larger wave heights.

The effects on wave heights over the mounds created by dumping are very small, i.e.0.05m for typical wave heights on 0.8-1m. The effects on typical wave heights are localized to the mounds and to the north and east. (Fig 8.9). The mounds do not appear to affect wave heights at the coast, except for a small increase in maximum wave heights of 0.02m near Heyward Point under the extreme conditions of over 2.0m maximum waves at the coast (Fig 8.10).

Dredging of a deeper channel outside the Harbour has a slight effect on the propagation of waves and swell across the channel. Locally it reduces typical 0.5m wave heights at Aramoana by around 0.01m and by 0.02-0.04m at Shelly beach (Fig 8.9). Maximum wave heights are reduced by around 0.05m for the 2.0m maximum waves which occur near the inshore end of the Mole at the eastern end of Aramoana Beach (Fig 8.10). These reductions in wave heights occur before the waves grow and break at the shore, i.e. are reductions in wave heights outside the surf zone.

The offshore wave model was used to estimate re-suspension of coarse material from the dump site and its subsequent spread by currents. There are no direct measurements of sediment dispersal from the site to calibrate the model with. The model used 10 years of model wave data to estimate the times when water movements near the sea bed due to waves and swells are capable of stirring material off the bottom. On their own currents are rarely capable of re-suspending the material, but will move it once waves have stirred it off the bottom. The results show that sediment spread along the natural spur or spit formed downstream by sediment moving northwards along the Otago coast carried by the Southland Current (Fig 12.24) . This gives some confidence in the model's ability to predict the dominant direction of dispersal from the site. The rate at which this dispersal occurs has a wide range of uncertainty, with bounds given in Table 12.15.

Summary

The modeling approach used here is reasonable to address the aims of the work and has the elements you would expect for such a study. The work uses engineering standard software tools with a best practice application of these tools to estimate the extent of sediment dispersal and effects on tides within the Harbour. The models are used to simulate many scenarios for winds, waves etc., in a careful comprehensive approach to the modeling.

The biggest uncertainties lie in the amounts of fine sediments disturbed by the dredge, lost due to overflowing from the dredge within the Harbour and in the amounts of fine sediment which remain in the water column immediately after dumping. To address these uncertainties the approach taken has been to be conservative on several aspects of the modeled discharges, such as the volumes and rates of fine sediment discharge, as well as the behavior of the sediments once released. One example is in not allowing fine sediments to be re-suspended by waves or currents once they fall to the bottom. As a result sediment net accumulations are likely to be overestimated in the extent of the plumes shown by the model. Smaller accumulations over wider areas are more likely.

There are additional aspects which would further enhance confidence in the model's robustness. For example the proposed dumpsite lies on the edge of the northward flowing Southland Current. The highly variable Southland Current plays a significant role, probably more significant than wind or tides, in the short term dispersal of fine material from the dump site, as well as the long term dispersal of coarse material. Long term wave and current measurements at this site and/or drifter studies from this site would further enhance confidence in the findings.