Appendix A Cardno Lawson Treloar - Long Wave Modelling Report

Our Ref LJ2689/L1859 :sjg

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28 May 2009

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AECOM
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Attention: Mr Lex Nielsen - Associate Director, Coastal

Dear Sir,

RE: PORT KEMBLA OUTER HARBOUR LONG WAVE MODELLING

This letter describes the outcomes of numerical long wave and tidal flushing modelling of Port Kembla Harbour undertaken as part of investigations into the proposed re-development of the Outer Harbour.

Previous work has involved a numerical long wave modelling exercise intended to investigate long wave propagation into the Outer Harbour and the extent and character of harbour seiching that may develop as a result of a number of land reclamation options. Investigations to date include field work and modelling investigations reported in MSB Sydney Ports Authority/Lawson and Treloar (1993). More recently modelling of harbour seiching during long wave events was completed (Cardno Lawson Treloar, 2008), including model verification against measured long wave events. Furthermore, analysis of some additional data from a wave/current meter moored north of the entrance to the Outer Harbour was undertaken. For further detail on model setup, verification and input long wave conditions, the reader is directed to the abovementioned studies.

The outcomes of the previous work resulted in a preferred optimum configuration of Outer Harbour for land reclamation that would maximise the available port-area land to provide for a maximum number of berths suitable for container handling and bulk trades. This round of modelling investigations considers a modified, developed Outer Harbour layout (Final Layout No.1) that includes a modified tug harbour layout and the examination of the response of the Inner Harbour to the proposed re-development of the Outer Harbour.

Long wave Modelling

Three long wave simulations were undertaken. They were:-

1. Existing Layout
2. Final Layout No.1
3. Final Layout No.1 with an alternative long-wave input spectrum

Input Spectrum

For harbour configuration investigations, a hypothetical, but physically representative, long wave spectrum was derived from available data. Analysis of all available data at the wave/current instrument location outside of and north of the Outer Harbour showed that the majority of those long wave spectra, especially under higher incident swell waves, were bi-modal in form. Peak periods range from approximately 140 to 240 seconds and 50 to 140 secs.

Wave heights (H_s) up to 0.35m were observed - whole of long wave energy band of the spectra.

In line with the observed data, a bimodal, long-wave frequency spectrum with peaks at 200 and 60 seconds was developed, based on the combination of two single peaked JONSWAP spectral shapes with peakedness parameters of 4. The lower frequency peak at 200 seconds contains the larger part of the energy; in line with observed water level signal measurements.

A second bimodal spectrum with peaks at 150 and 80 seconds was also developed from measured long-wave events to test the response of the re-developed harbour to a range of long-wave frequencies.

Existing Layout

Plan plots of wave coefficient and rms current results are provided in Figure 1.1. They show that there is amplification of the long wave height around the western and southern shoreline as well as the southern section of the eastern breakwater. The current plot is heavily influenced by the water depths in the Outer Harbour with high rms current speeds, greater than 0.1m/s, observed at shallower depths. This is to be expected and a result of the long wave energy being compressed over a shorter water column (shoaling) and reflection. This is not necessarily an indication of harbour resonance.

A full discussion of the existing Outer Harbour layout results is provided in Cardno Lawson Treloar (2008), however, the outcomes suggest that spectral amplifications occur at frequencies consistent with the resonant frequencies identified in previous physical model studies of the harbour basin (Foster, 1957).

The Inner Harbour, see Figure 1.2, shows very little response to the long wave energy with only minor amplification at the northern ends of the berthing areas where wave reflection occurs. Current speeds associated with long wave motion too are not significant except in these same areas.

Current speed roses have been produced at three berth locations, see Figure 1.3. These results show the predominant direction of the long wave caused currents and the magnitudes that are encountered during such events - generally these are low and in the order of 0.05-0.15m/s.

Final Layout No.1

Final Layout No.1 includes the reclamation of a significant area within the Outer Harbour involving the construction of a hard stand area to allow ship mooring and container handling. The entire length of the southern and western shoreline would be included in the reclamation and conversion to hardstand area, and it is therefore considered that the phenomenon of surf beat and long wave generation would not then occur along the western Outer Harbour shoreline - too deep (see Cardno Lawson Treloar (2008). A breakwater to create a protected tug harbour area to the north of No. 6 Jetty would be constructed. The proposed layout and model results can be seen in Figure 2.1. The Inner Harbour would remain unchanged and these model results are shown in Figure 2.2.

Output locations shown on Figures 2.1 refer to proposed ship berthing or boat mooring locations. Results at selected locations are compared to results from the Existing layout in Figures 2.3 and 2.4 in terms of long wave spectra. The spectral plots show that the long wave energy is concentrated around 220 seconds and between 50 and 60 seconds for this harbour layout. Generally the results show a decrease in long wave energy at these locations. Current roses at these locations are provided in Figures 2.5 and 2.6. A full set of wave spectra (Figures 2.7 and 2.8) and current rose (Figures 2.9 and 2.10) results are provided for the tug harbour also. These results show maximum current speeds of approximately 0.25m/s observed in the tug harbour (Tug 4).

Alternative Long Wave Spectrum

The alternative long wave input spectrum causes patterns of wave coefficients and current magnitudes that are similar to those for the previous long wave spectrum. Model results can be seen in Figures 3.1

and 3.2. When compared to the results from the original input spectrum, the Outer Harbour shows a slightly greater response, which is evident in the proposed tug harbour and near Loc 7. Conversely the Inner Harbour shows a reduced response to the long wave energy.

Results at ship berthing and boat mooring locations are compared to results from the Existing layout in terms of long wave spectra in Figures 3.3 and 3.4 and as current roses in Figures 3.5 and 3.6. Results for the proposed tug harbour are presented in Figures 3.7 to 3.10.

Tidal Flushing

In order to assess the relative tidal flushing performance of the re-developed Outer Harbour layout, and in particular the effect on tidal flushing in the Inner Harbour, hydrodynamic simulations of both layouts extending over a two weeks tidal cycle were undertaken using the Delft3D model system (in 3D - 7 layers). They were undertaken using an inert tracer having no density - simulating a dissolved contaminant. Initially the entire harbour (both Inner and Outer) was filled with this conservative tracer at concentration of 100.

Conservative tracer testing can provide a measure of the flushing rate of a particular section of a water-body (estuary, canal, enclosed harbour etc). A useful measure for quantification of the flushing time is to determine the e-folding time.

The e-folding time refers to the time taken for a tracer to reach 1/e or 0.3679 of its initial concentration. At any location within a partially enclosed water body subject to dynamic equilibrium forcing, the concentration of a particular tracer can be described by Equation 1.

$$
\begin{aligned}
&C_i = C_0 e^{-kt_i} \\
&where \\
&\quad C_i = \text{concentration at time i}, \\
&\quad C_0 = \text{initial concentration at time } 0, \\
&\quad t_i = \text{time i}, \\
&\quad k = \text{dispersion constant},
\end{aligned}
\qquad (1)
$$

Following-on from Equation 10.1, k can be calculated by Equation 2.

$$
k = \frac{\ln\left(\frac{C_i}{C_0}\right)}{-t_i} \qquad (2)
$$

The e-folding time is then the inverse of k shown in Equation 3.

$$
e - folding = \frac{1}{k} \qquad (3)
$$

The initial tracer concentration outside the Port Kembla harbour was defined to be zero. No catchment flows were supplied to the model, including those from Allans Creek; that is, the flushing times determined by these analyses are maxima because catchment flows reduce flushing times by causing a net transport through a region.

Results are presented in Figure 3.1 for both the Existing and Final No.1 Harbour Layouts. E-folding times differ greatly between the Inner and Outer harbours in both cases. In the Outer Harbour e-folding times of between 5 and 20 days have been estimated for both the Existing and Final No. 1 layouts. These times increase significantly through the “neck” to an e-folding time of around 100 days just north of this region. Maximum e-folding times in the Inner Harbour occur in the upper reaches, with e-folding times up to 400 days being estimated. It should be noted that this simulation includes no flow from Allans Creek and the significant depths in the Inner Harbour mean that there is a large initial mass of contaminant in the system, having been dosed through the whole water column. Therefore e-folding times would not be comparable to observed times in the field. They do, however, allow for an accurate comparison between layouts.

To estimate the influence of re-developing the Outer Harbour a comparative plot, in terms of percentage change in e-folding time, is presented in Figure 3.2. This shows very small changes in the Inner Harbour basin, with an increase in flushing in the most critical upper reaches and an increase in e-folding time through the "neck". Overall, however, these changes are small and it could be concluded that the development of the Outer Harbour will have little effect on flushing in the Inner Harbour.

Note that these results cannot be translated directly to water quality outcomes because this is a relative assessment. That is, a decrease in flushing will only be of concern should water quality contamination be sufficiently large to maintain elevated concentrations above any water quality objectives. Furthermore, this analysis is conservative when considering point source spills in that any actual spill would be more localised and disperse much more quickly than indicated by the model results; which describe a case where the whole harbour area is assumed to be contaminated.

Concluding Remarks

The purpose of these latest investigations has been to determine the nature of long wave activity within the Port Kembla Outer Harbour, with a particular focus on the effect at potential ship mooring locations, and also the effects of the proposed Outer Harbour re-development on the Inner Harbour basin. This was investigated in terms of long waves and tidal flushing.

It is intended that the results of the long wave modelling will be incorporated into a ship mooring simulation exercise to further assess the appropriateness and feasibility of the proposed Final No. 1 layout. Time series of water levels and current speeds from these simulations have been provided to AECOM for this task.

Tidal flushing investigations were also undertaken to compare the outcomes for the existing and developed harbour layouts and the change in flushing character of the inner harbour.

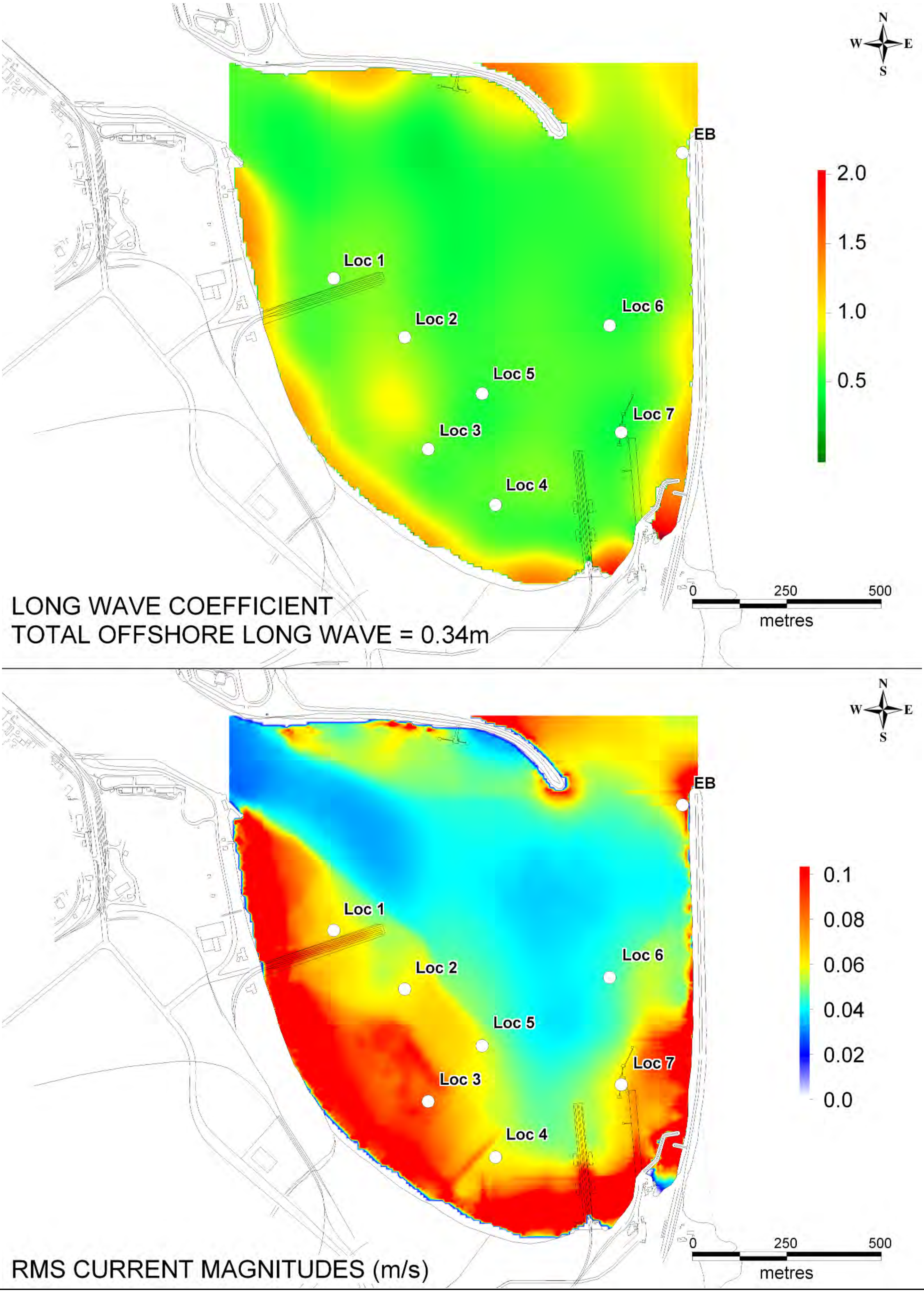
Yours faithfully,

P. D. Treloar

P D Treloar
for **Cardno Lawson Treloar**

References

Cardno Lawson Treloar (2008): Port Kembla Outer Harbour Masterplan. Numerical Long Wave Modelling. Report (LJ2689/R2439) Prepared for Maunsell Australia.



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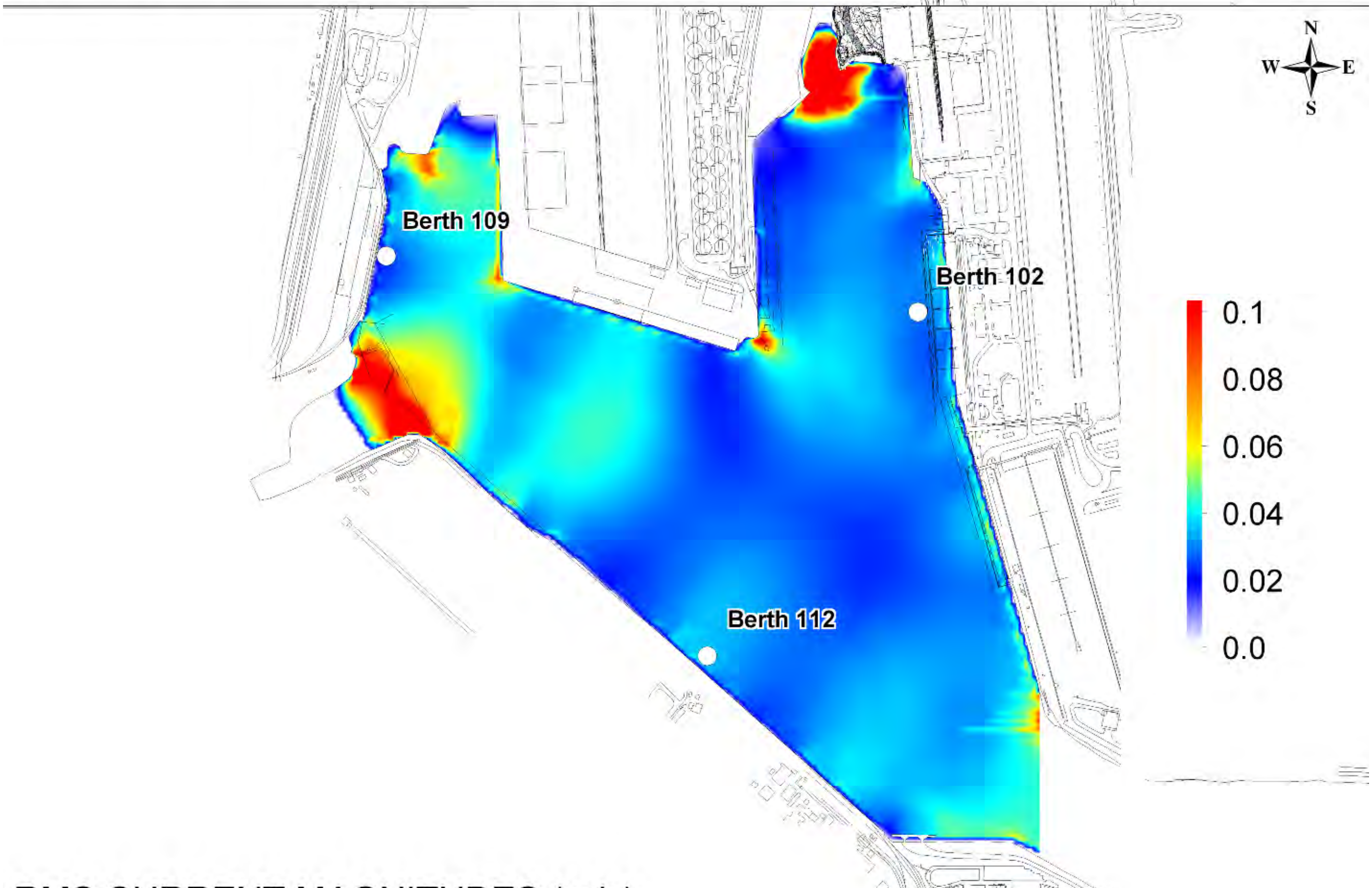
Port Kembla Outer Harbour – Long Wave Stage Modelling

LONG WAVE HEIGHT AND CURRENT MAGNITUDE DISTRIBUTIONS
EXISTING LAYOUT – OUTER HARBOUR

Figure 1.1

LONG WAVE COEFFICIENT
TOTAL OFFSHORE LONG WAVE = 0.34m



RMS CURRENT MAGNITUDES (m/s)

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Port Kembla Outer Harbour – Long Wave Stage Modelling

LONG WAVE HEIGHT AND CURRENT MAGNITUDE DISTRIBUTIONS
EXISTING LAYOUT – INNER HARBOUR

Figure 1.2

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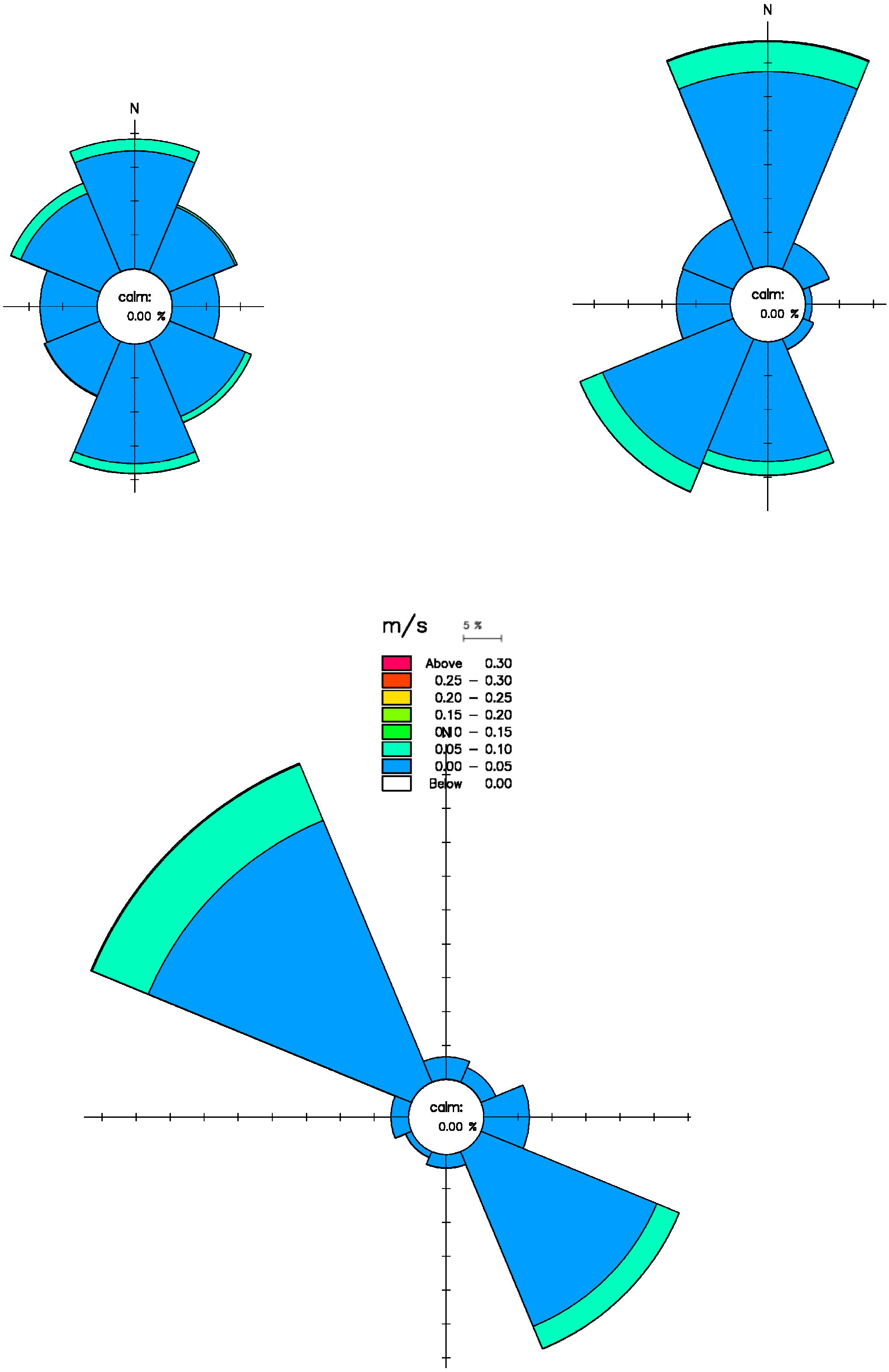

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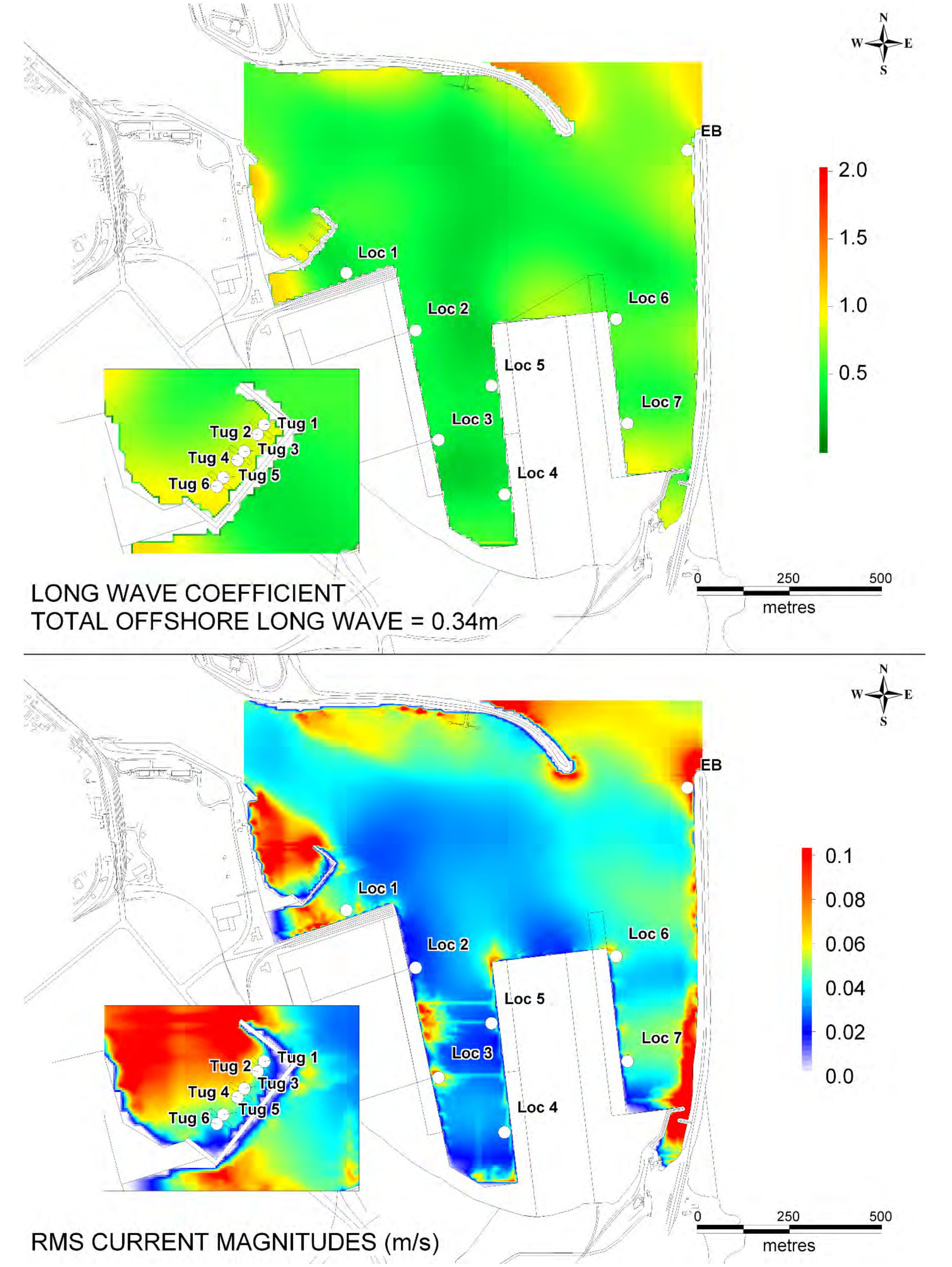
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS
EXISTING LAYOUT – INNER HARBOUR LOCATIONS

Figure 1.3



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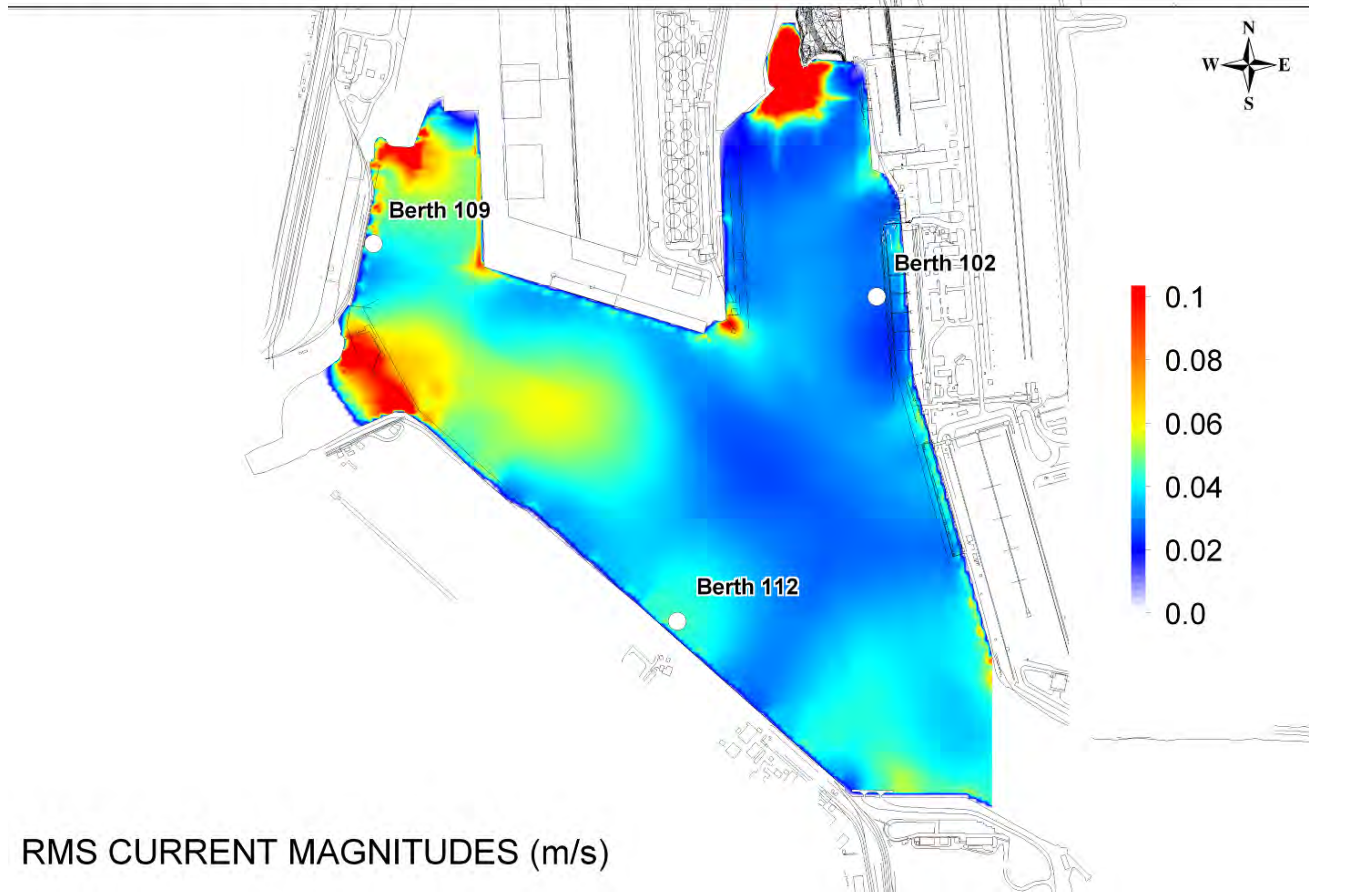
Port Kembla Outer Harbour – Long Wave Stage Modelling

LONG WAVE HEIGHT AND CURRENT MAGNITUDE DISTRIBUTIONS
FINAL LAYOUT No. 1– OUTER HARBOUR

Figure 2.1



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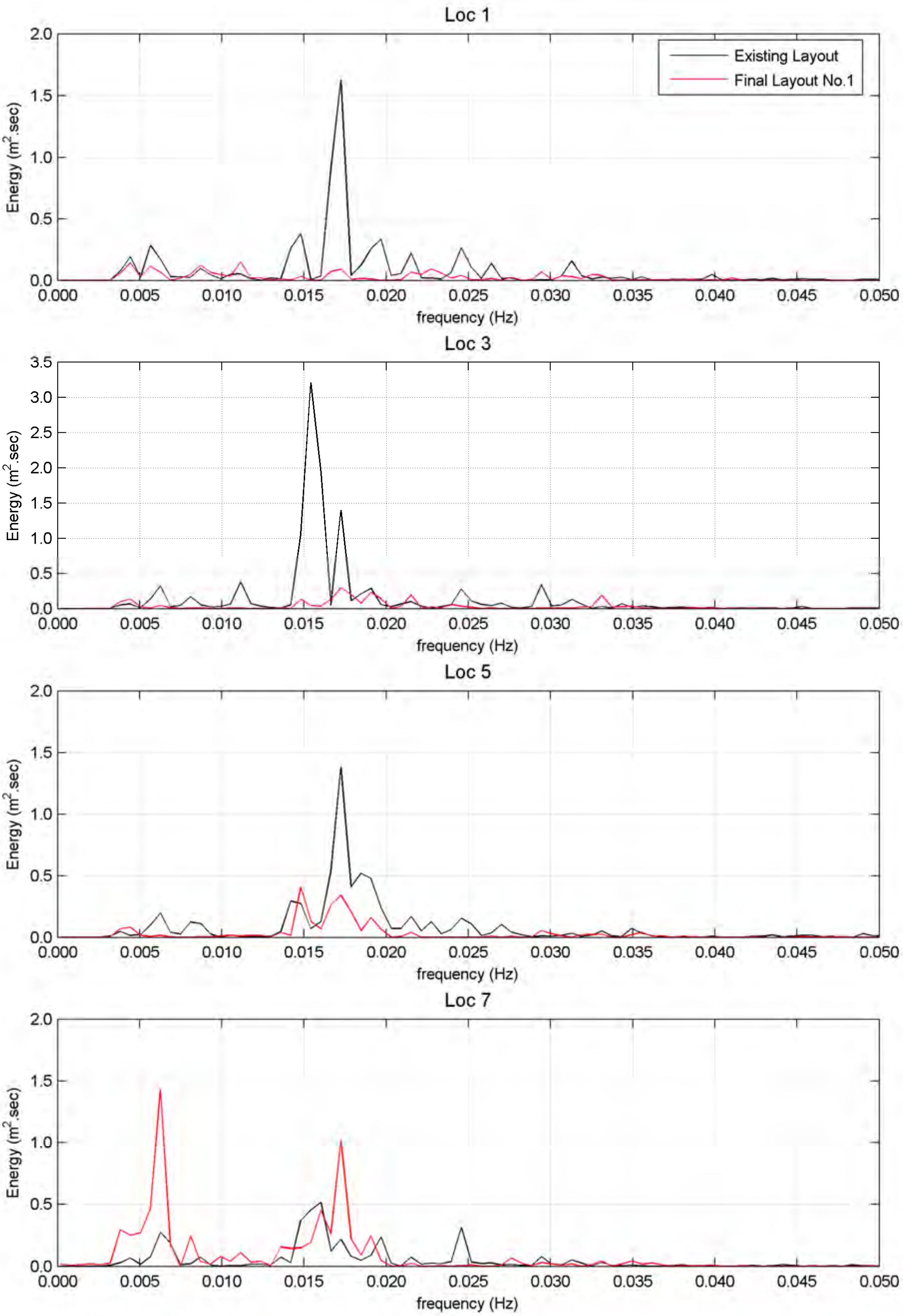
Port Kembla Outer Harbour – Long Wave Stage Modelling

LONG WAVE HEIGHT AND CURRENT MAGNITUDE DISTRIBUTIONS
FINAL LAYOUT No. 1– INNER HARBOUR

Figure 2.2



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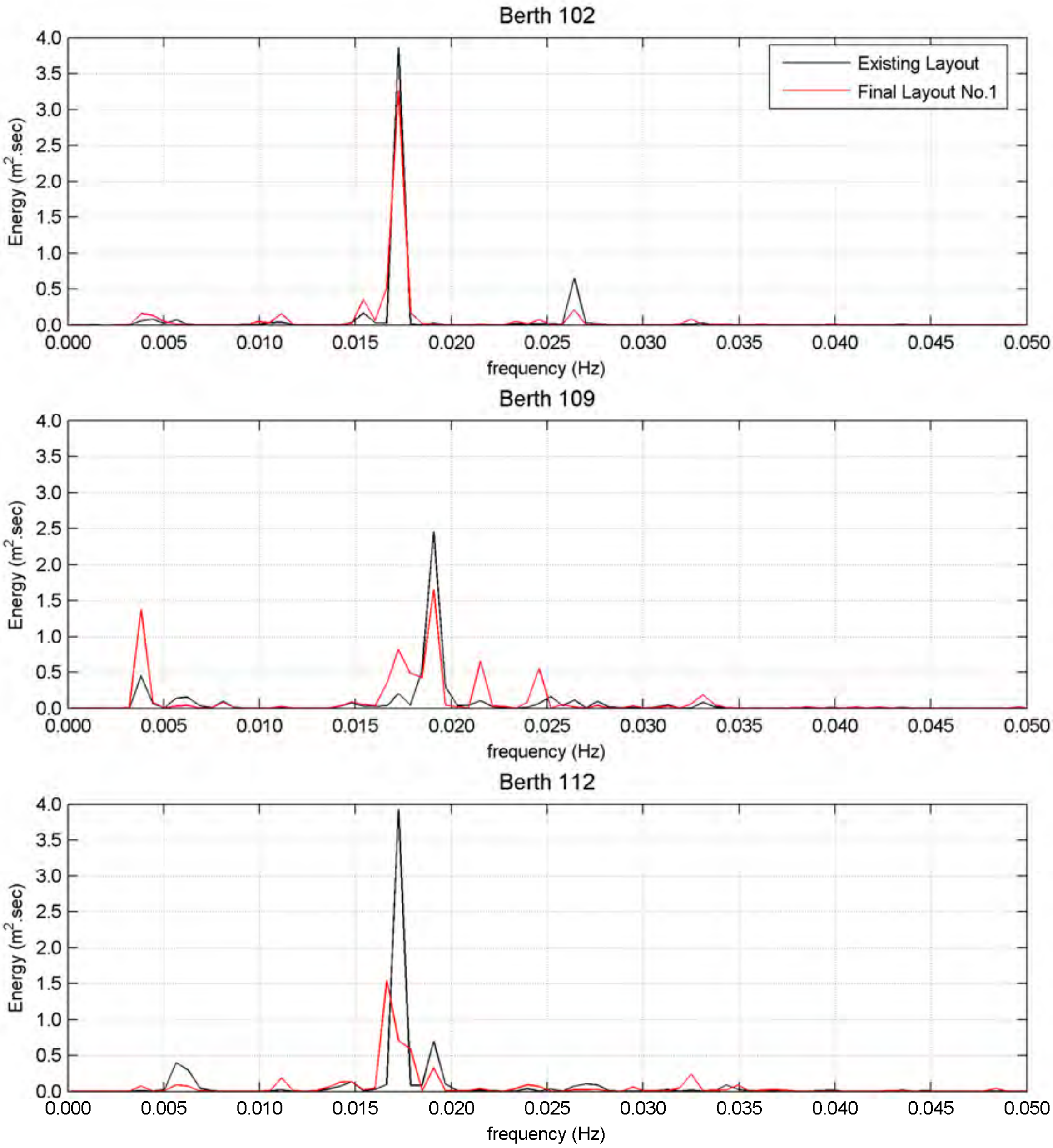
Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS
FINAL LAYOUT No. 1 – OUTER HARBOUR LOCATIONS

Figure 2.3



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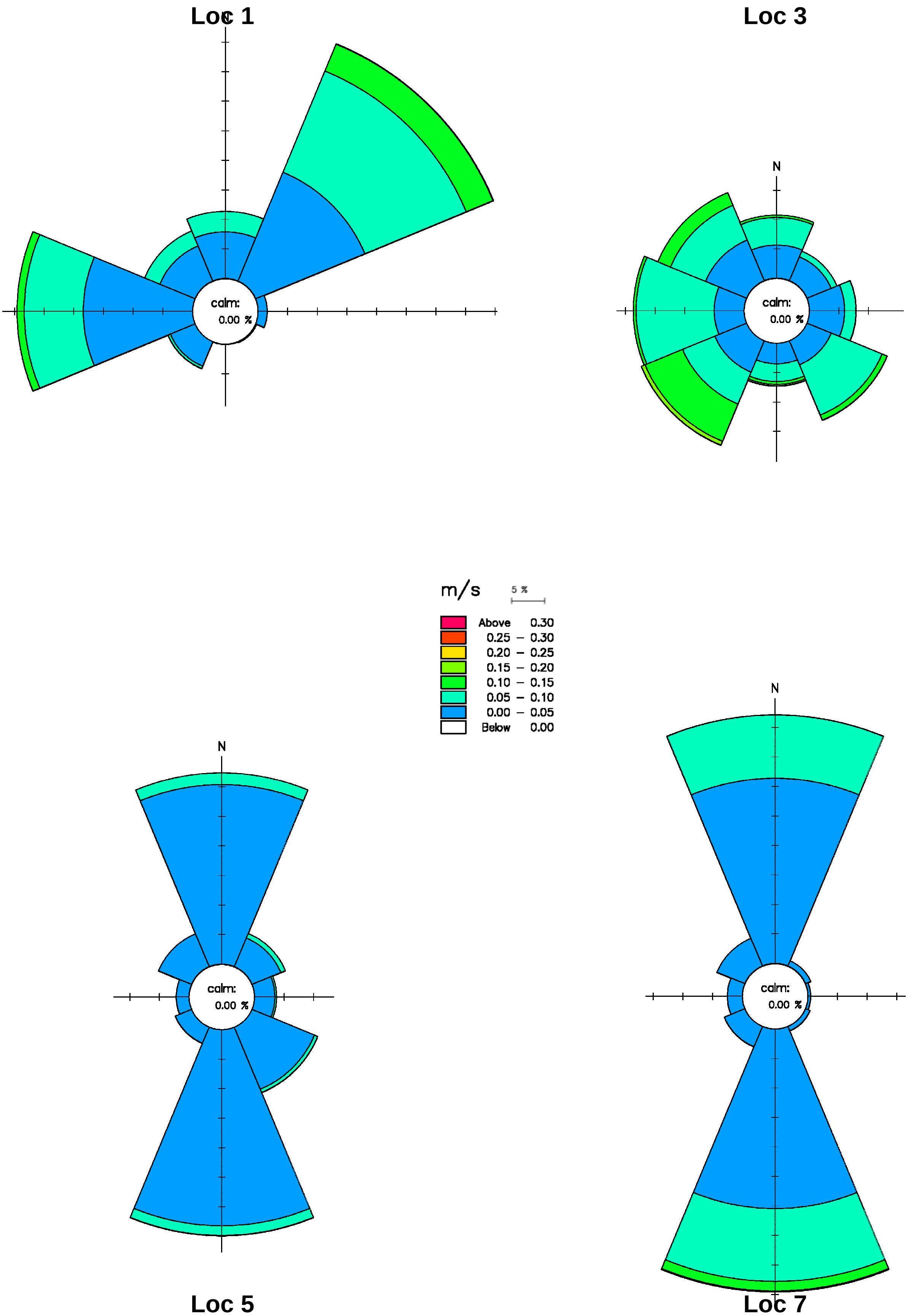
Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS
FINAL LAYOUT No. 1 – INNER HARBOUR LOCATIONS

Figure 2.4



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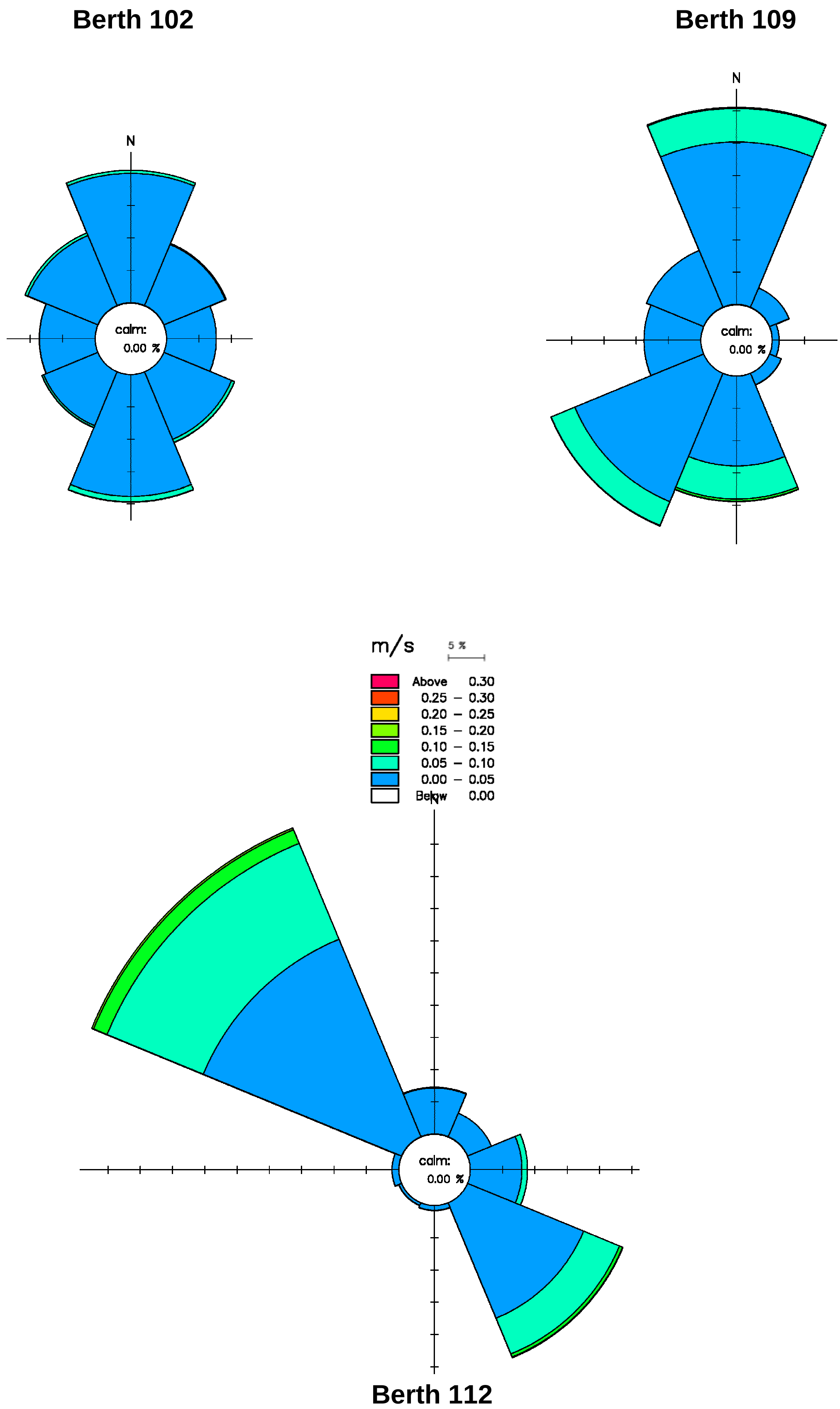
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS

FINAL LAYOUT No. 1 – OUTER HARBOUR LOCATIONS

Figure 2.5



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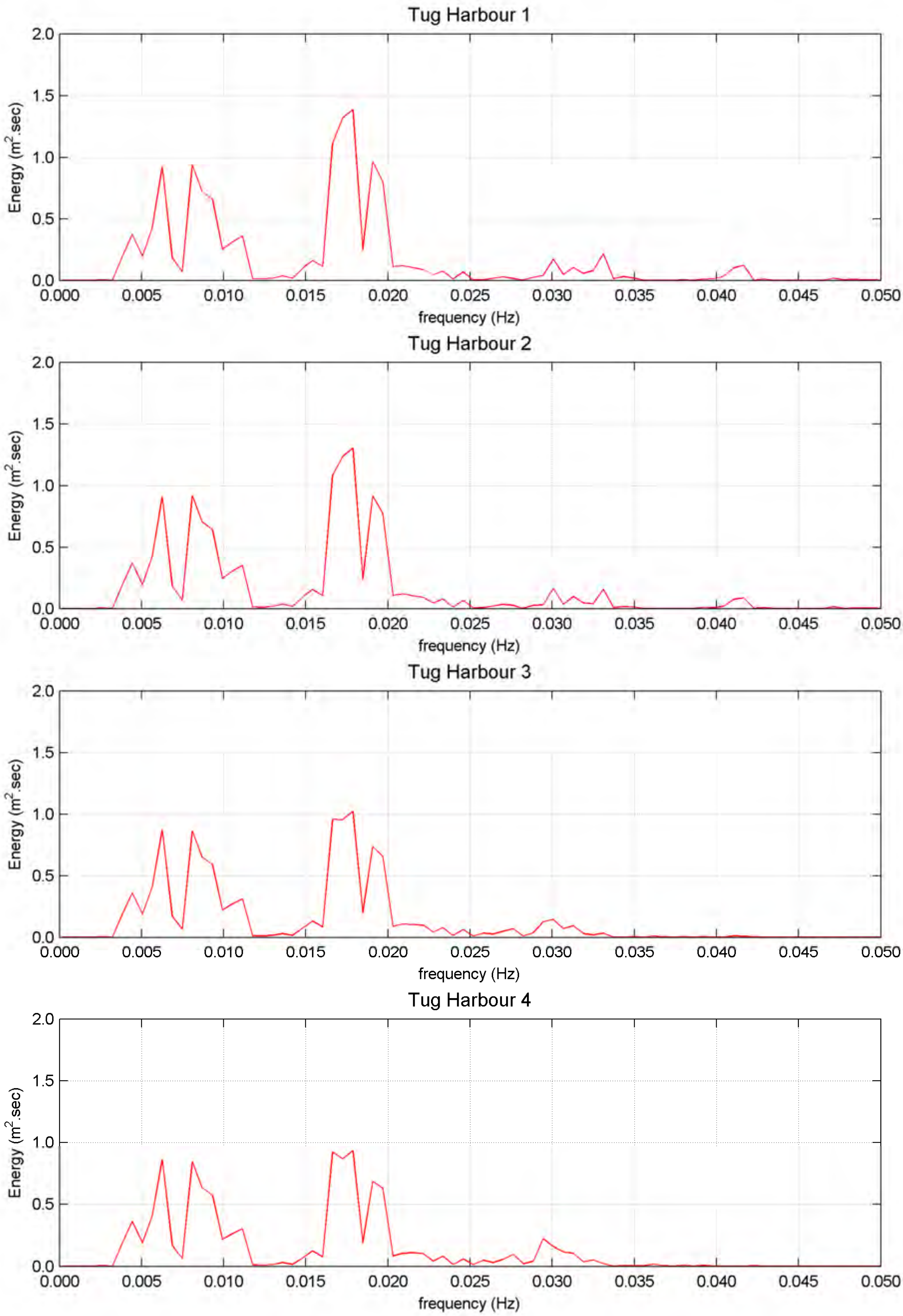
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS

FINAL LAYOUT No. 1 – INNER HARBOUR LOCATIONS

Figure 2.6



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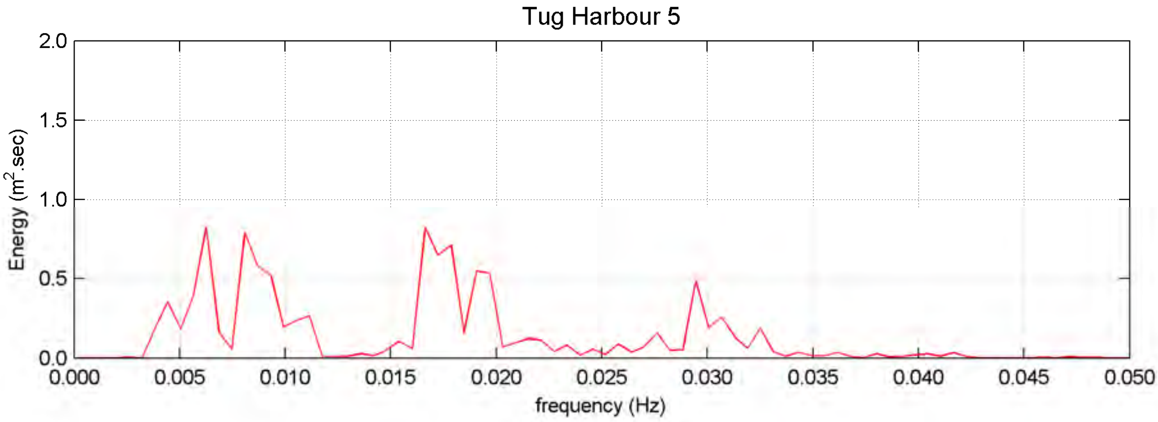
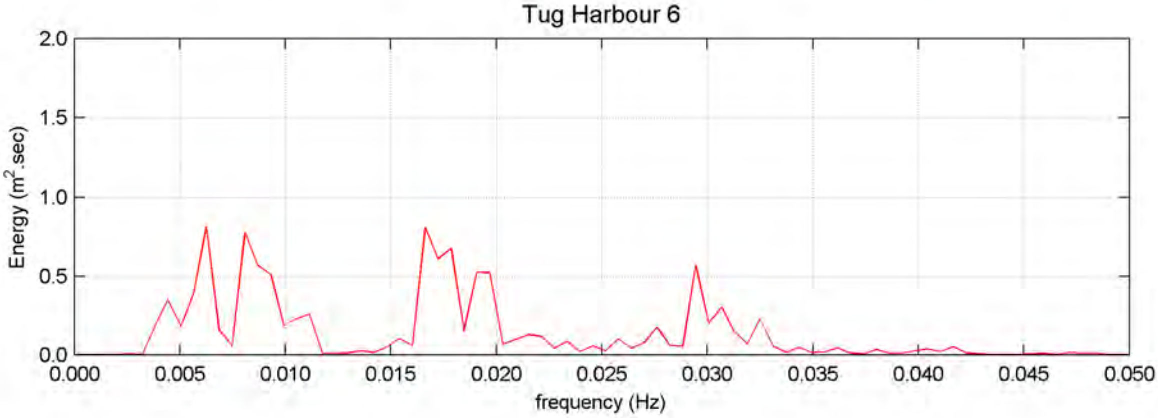
Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS

Figure 2.7





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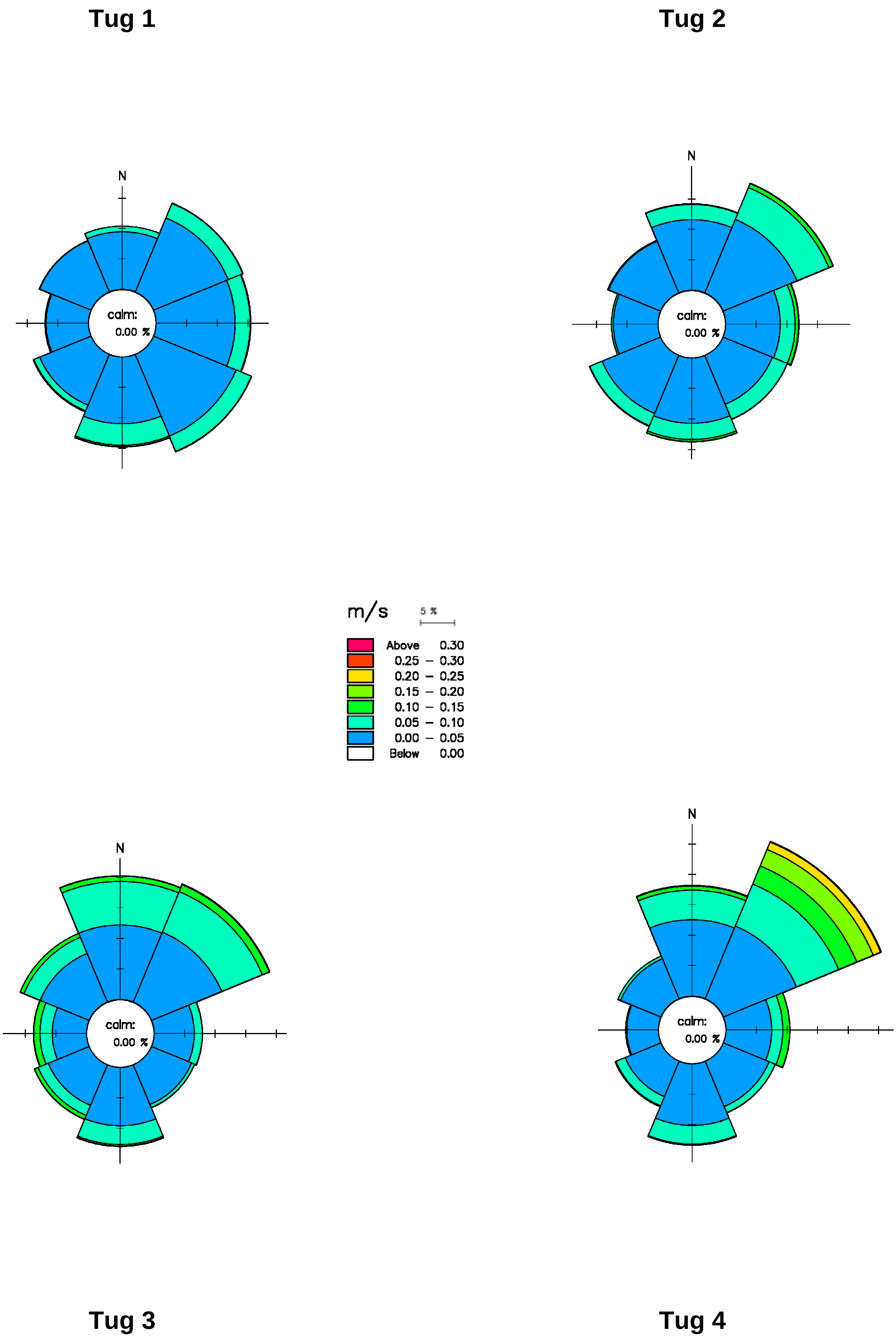
Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS

Figure 2.8



Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS

FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS

Figure 2.9

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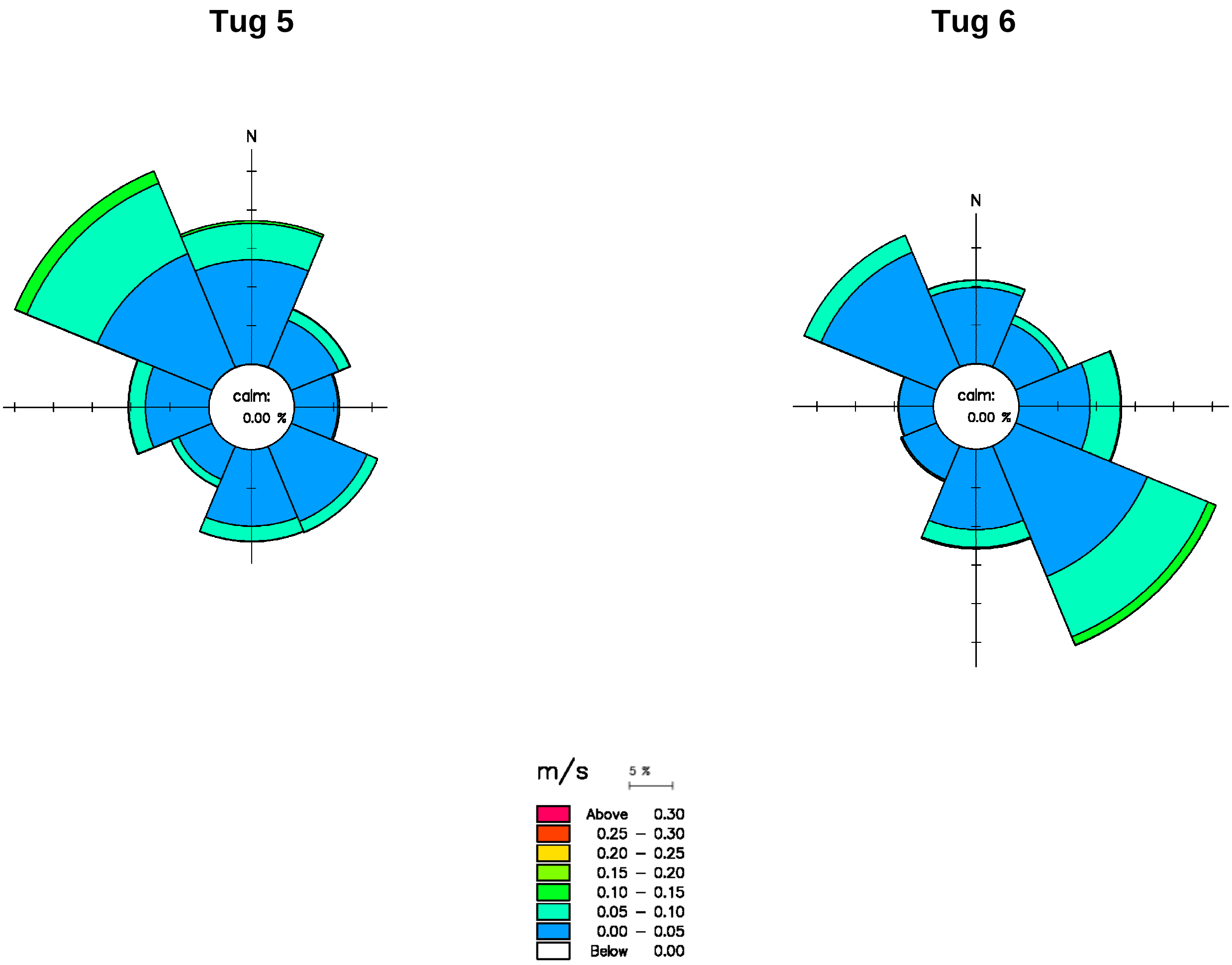

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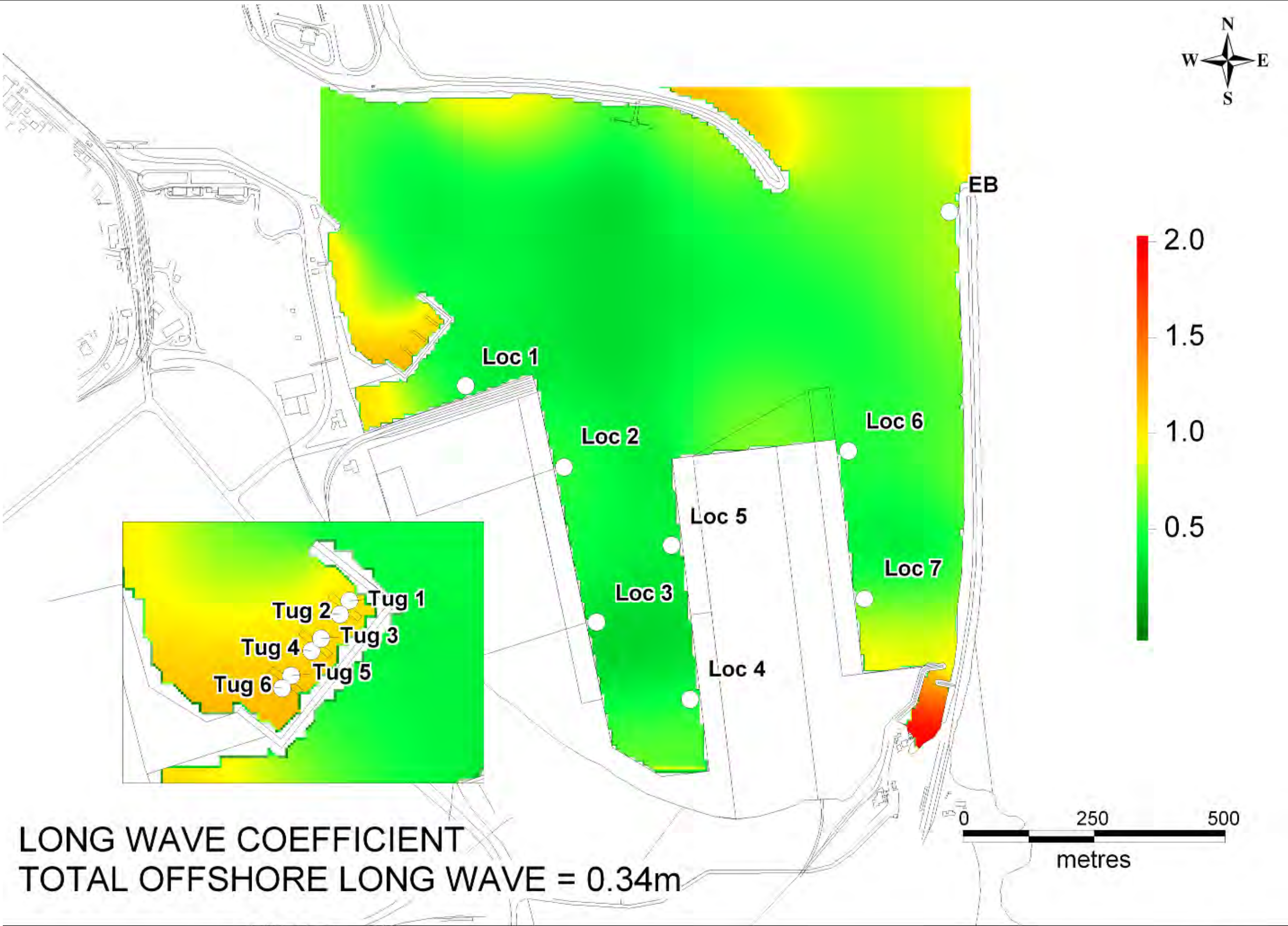
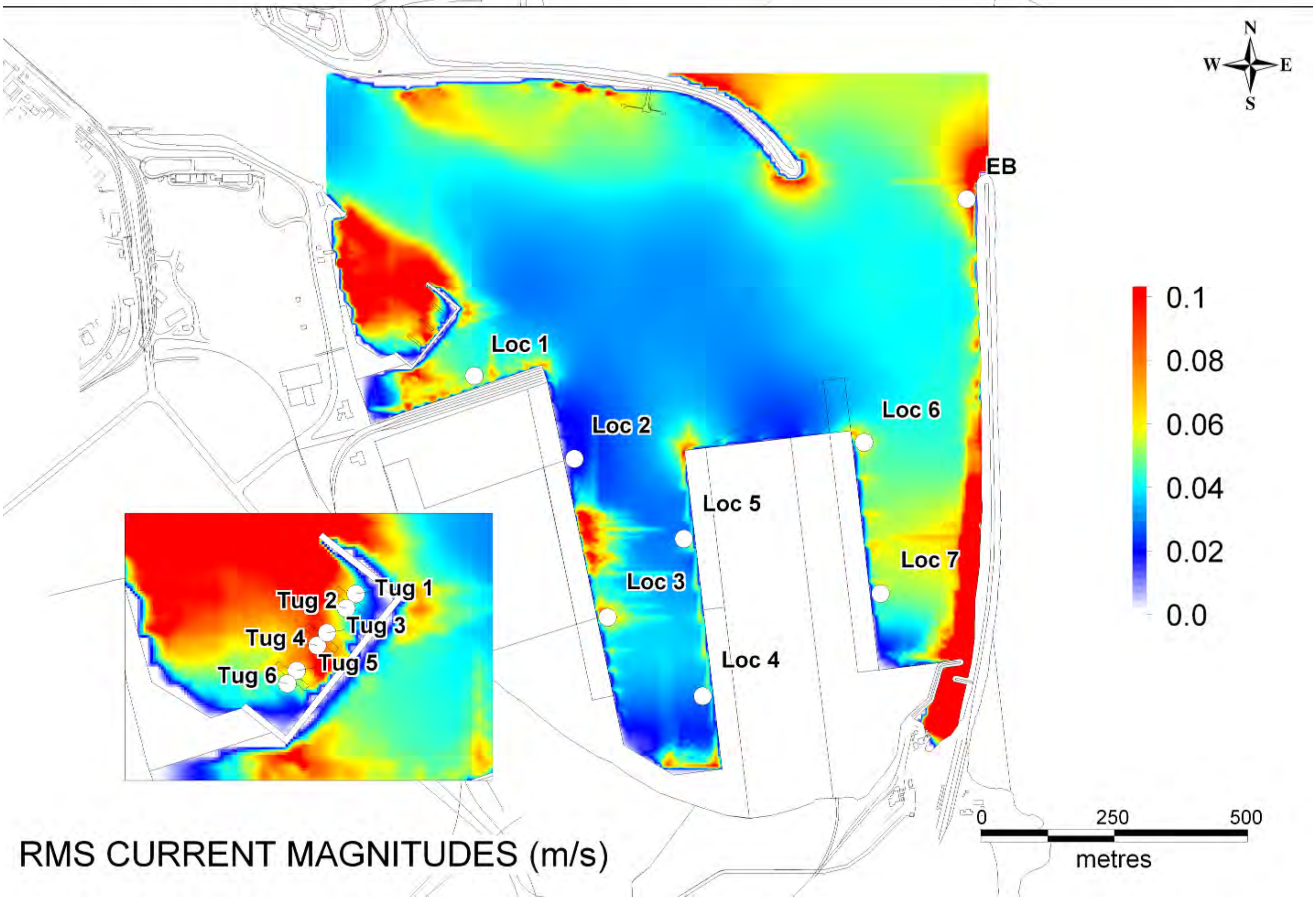
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS
Figure 2.10





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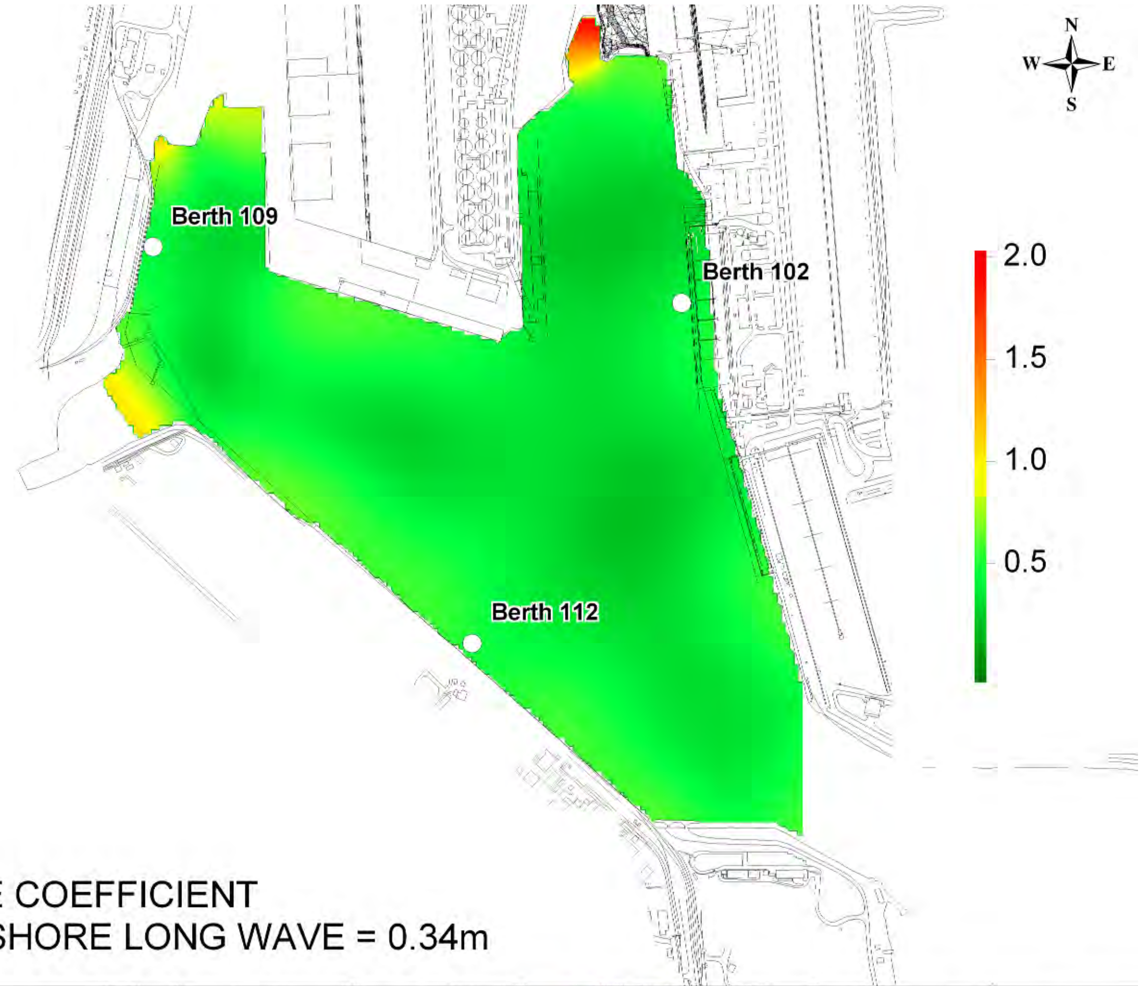
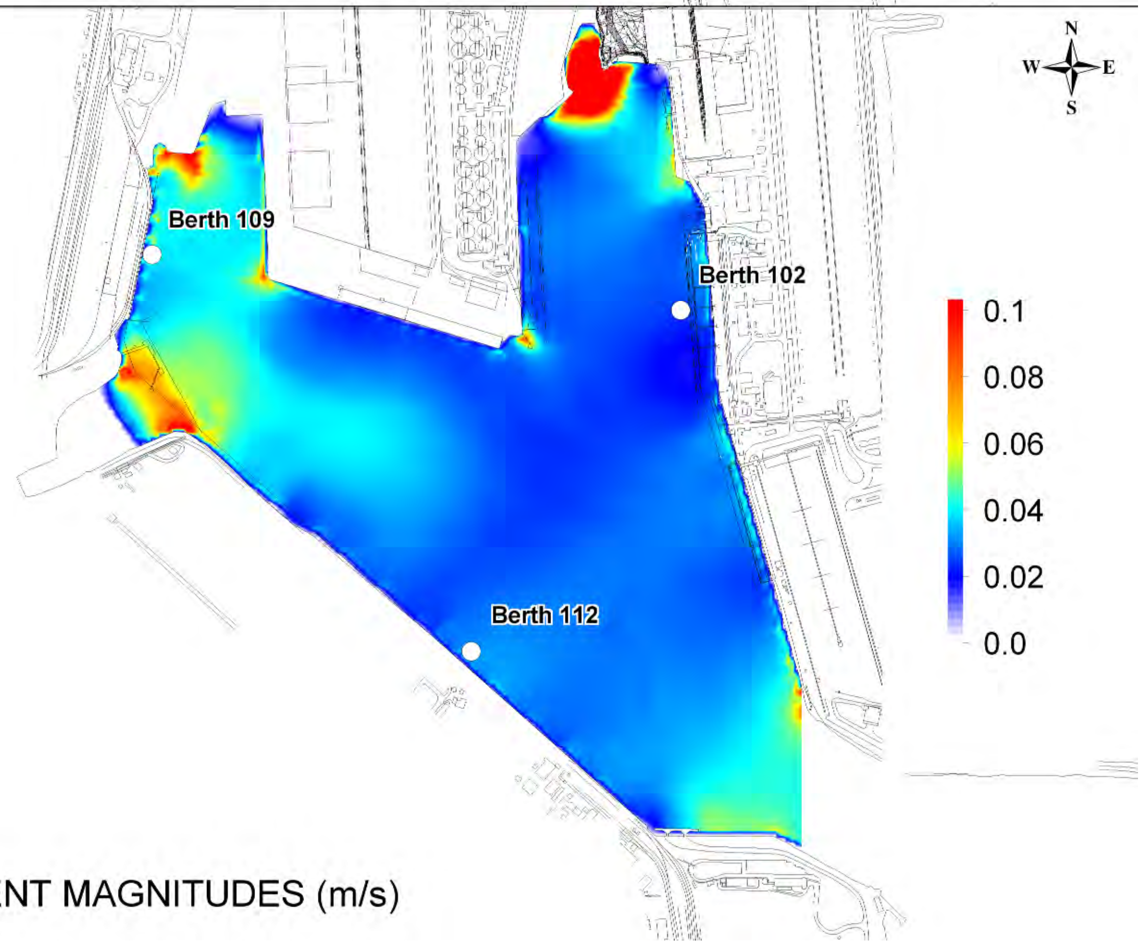
Port Kembla Outer Harbour – Long Wave Stage Modelling

LONG WAVE HEIGHT AND CURRENT MAGNITUDE DISTRIBUTIONS
FINAL LAYOUT No. 1 – OUTER HARBOUR – ALTERNATE SPECTRA

Figure 3.1



LONG WAVE COEFFICIENT
TOTAL OFFSHORE LONG WAVE = 0.34m



RMS CURRENT MAGNITUDES (m/s)

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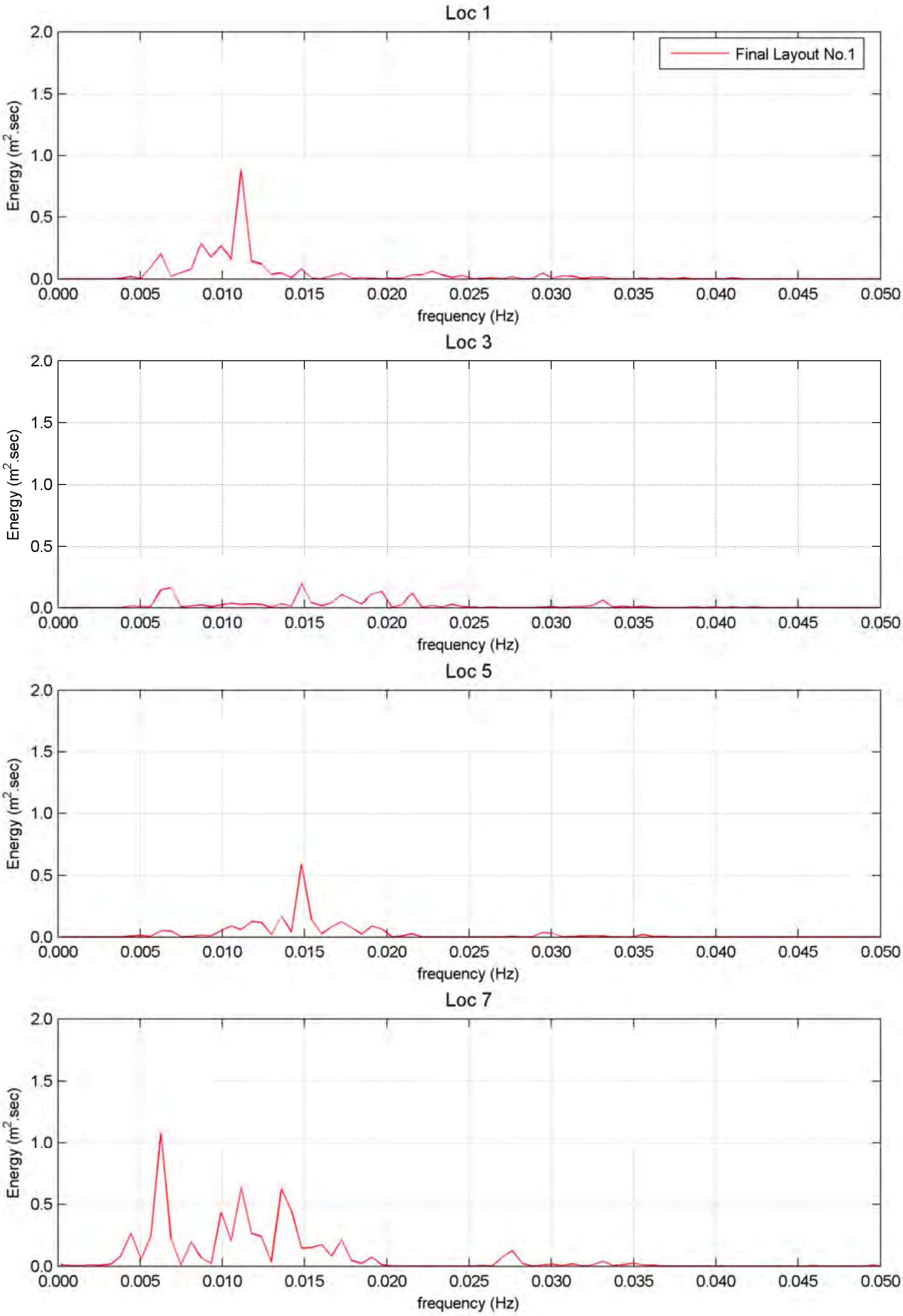
Port Kembla Outer Harbour – Long Wave Stage Modelling

LONG WAVE HEIGHT AND CURRENT MAGNITUDE DISTRIBUTIONS
FINAL LAYOUT No. 1 – INNER HARBOUR – ALTERNATE SPECTRA

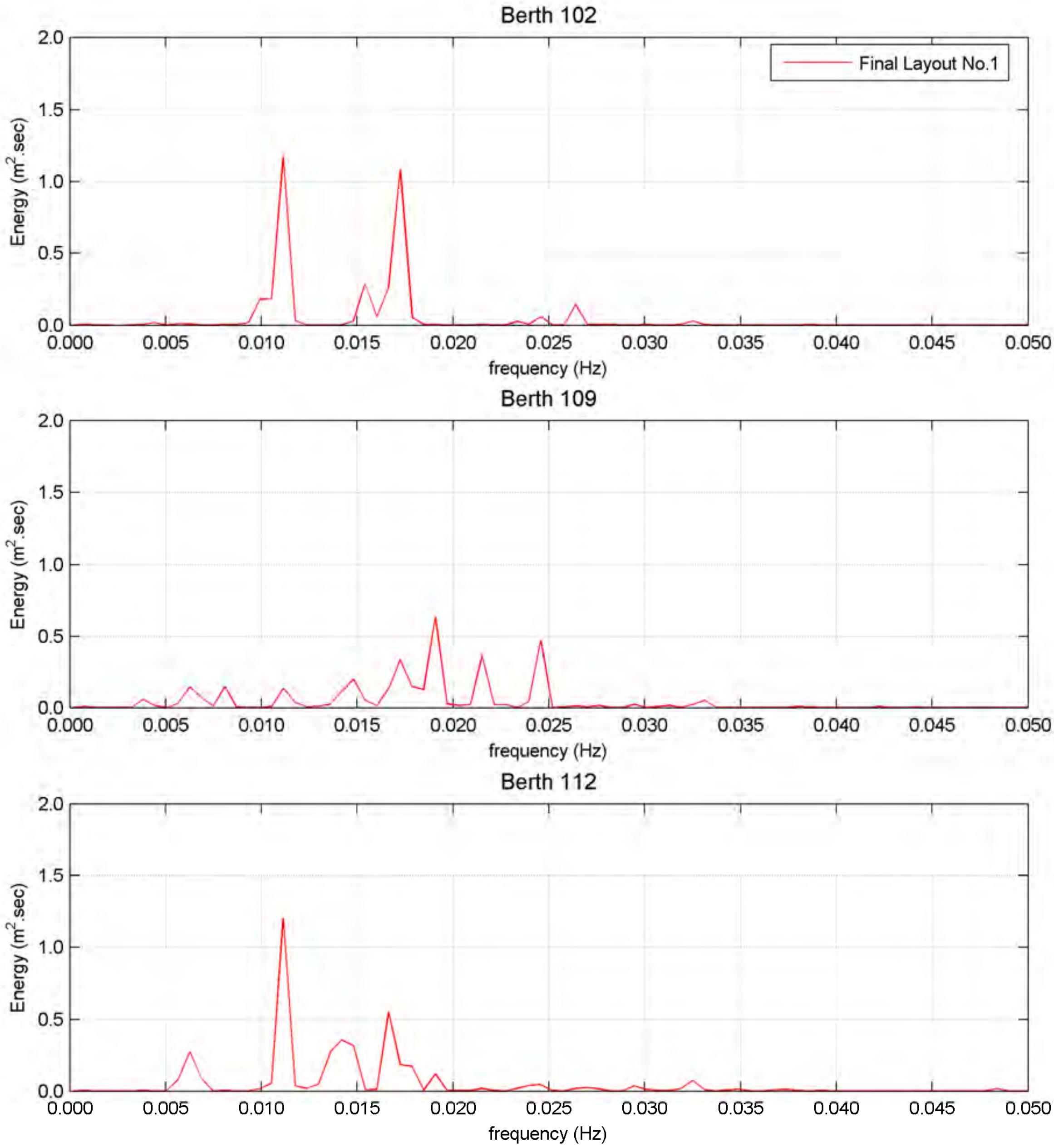
Figure 3.2



Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – OUTER HARBOUR LOCATIONS

Figure 3.3



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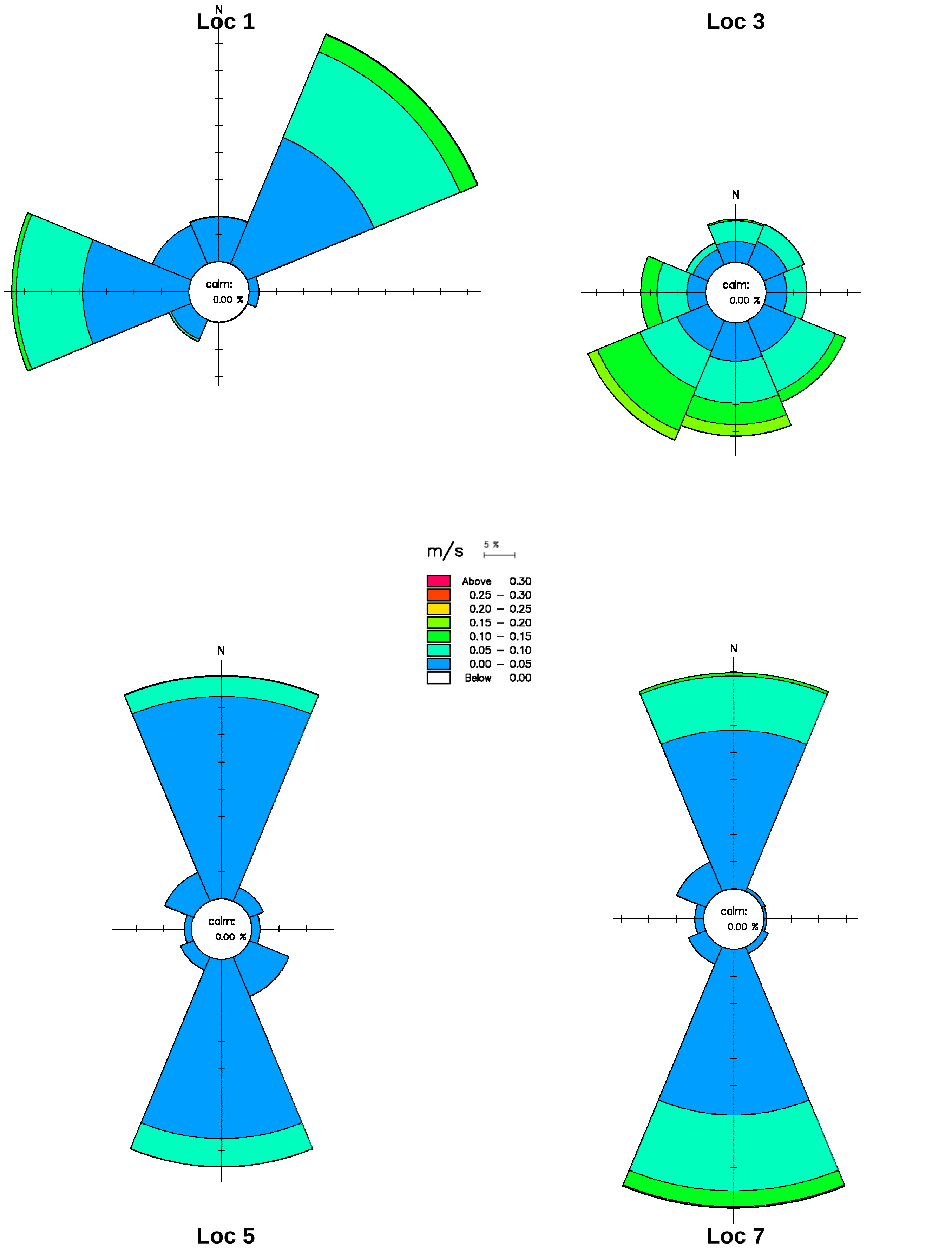
Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – INNER HARBOUR LOCATIONS

Figure 3.4



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Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – OUTER HARBOUR LOCATIONS

Figure 3.5

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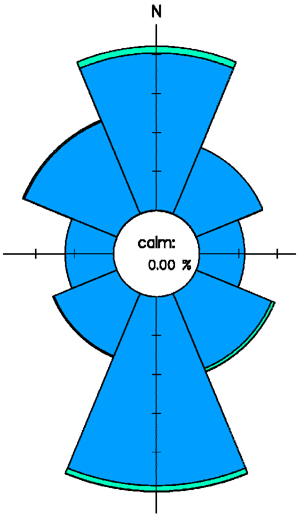

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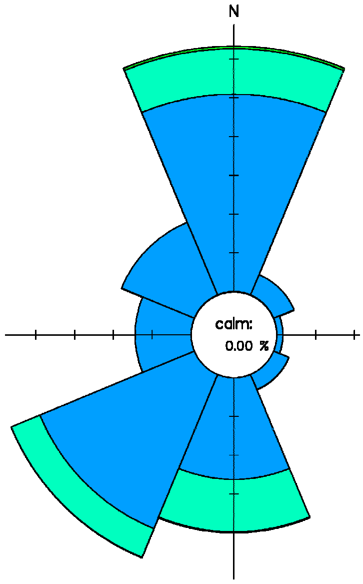

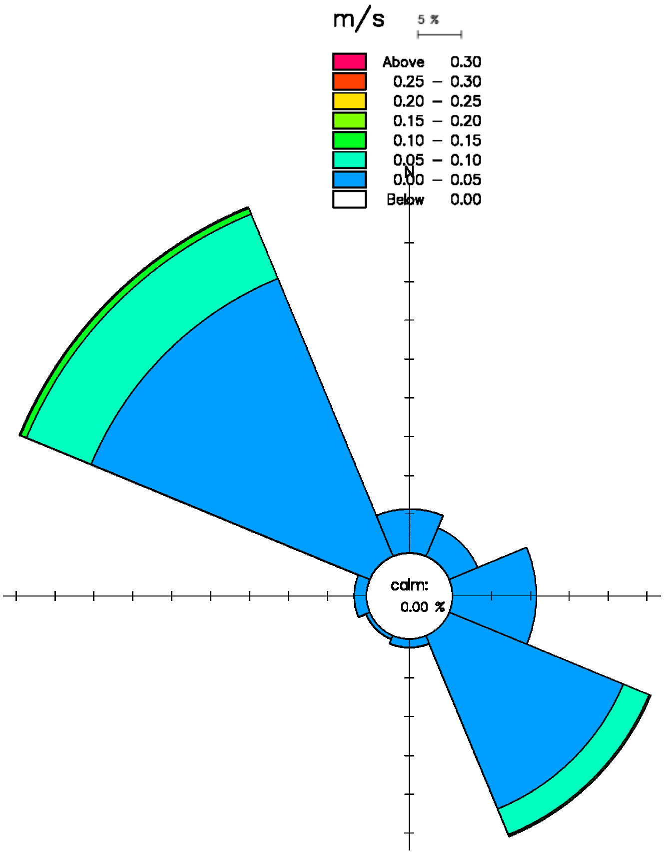

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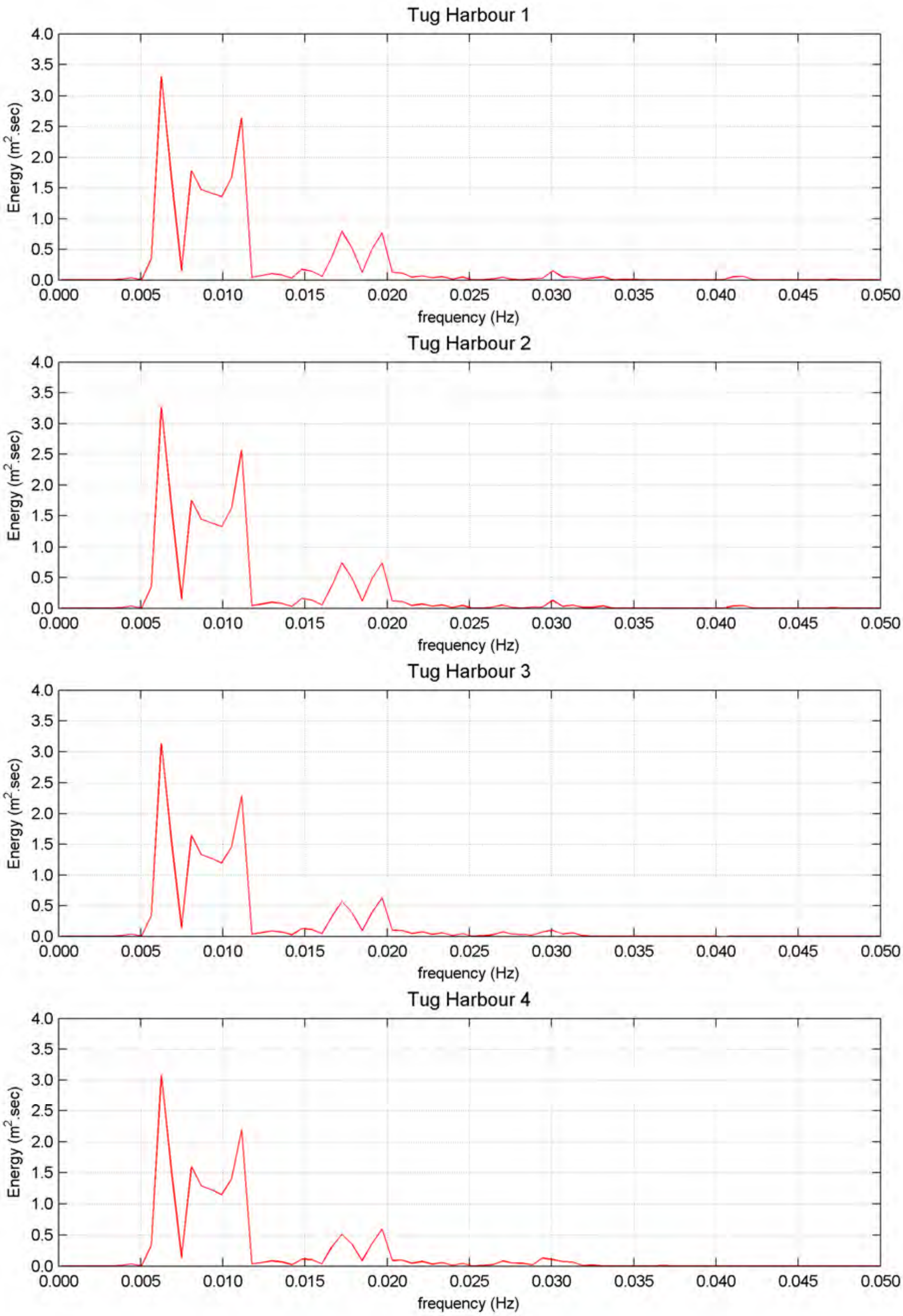
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – INNER HARBOUR LOCATIONS

Figure 3.6



Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS

Figure 3.7

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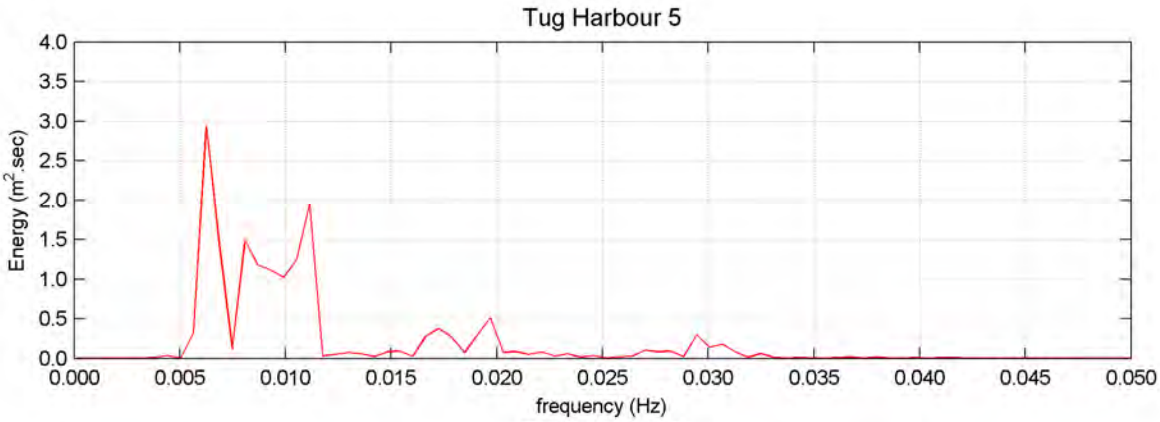

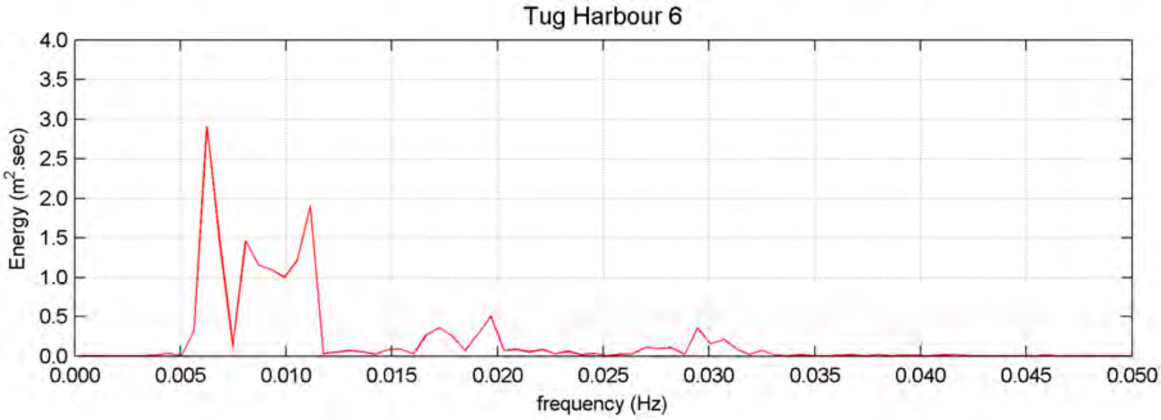

Port Kembla Outer Harbour – Long Wave Stage Modelling

OUTPUT SPECTRA RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS

Figure 3.8

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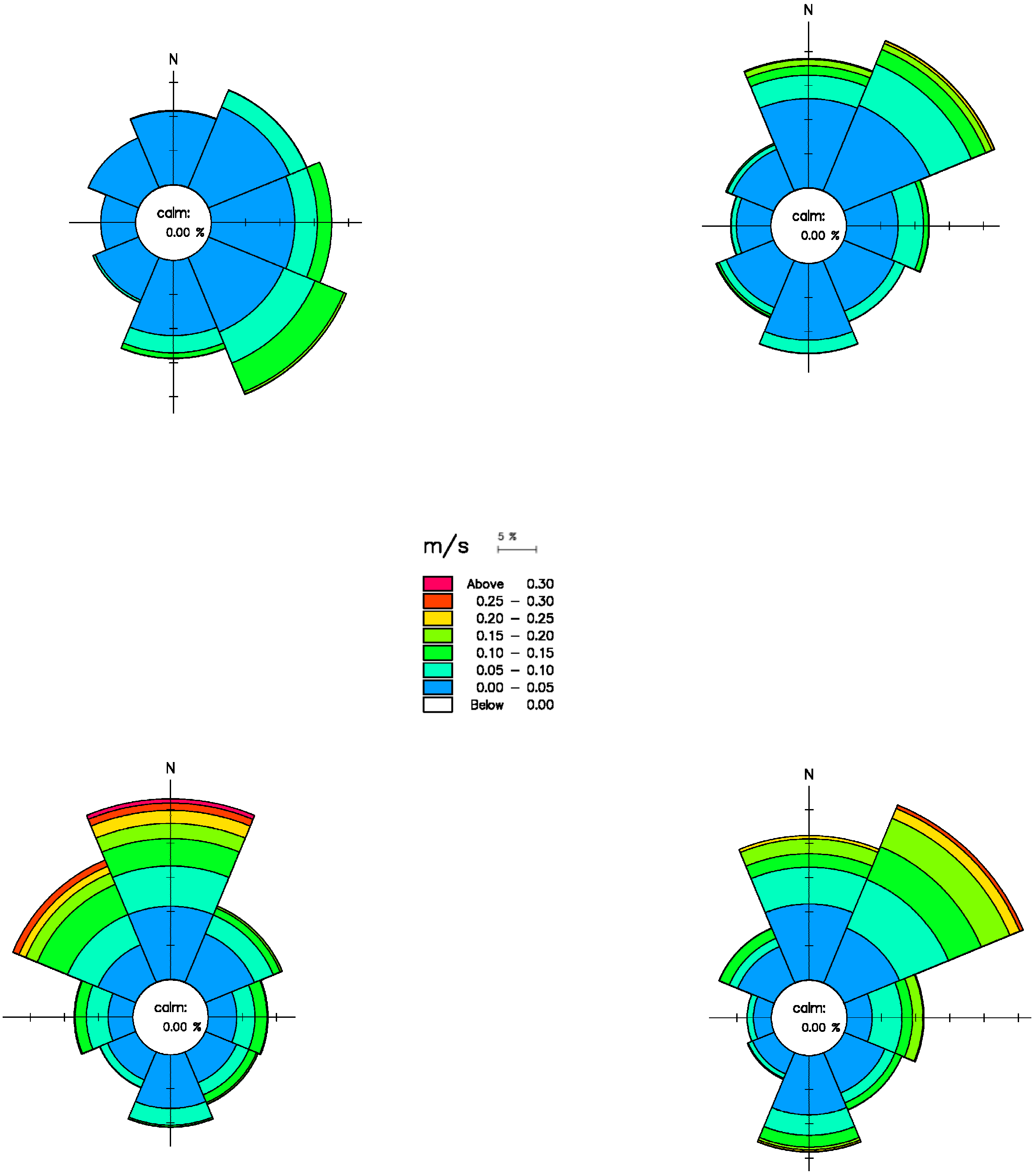
Tug 1 Tug 2



Tug 3 Tug 4

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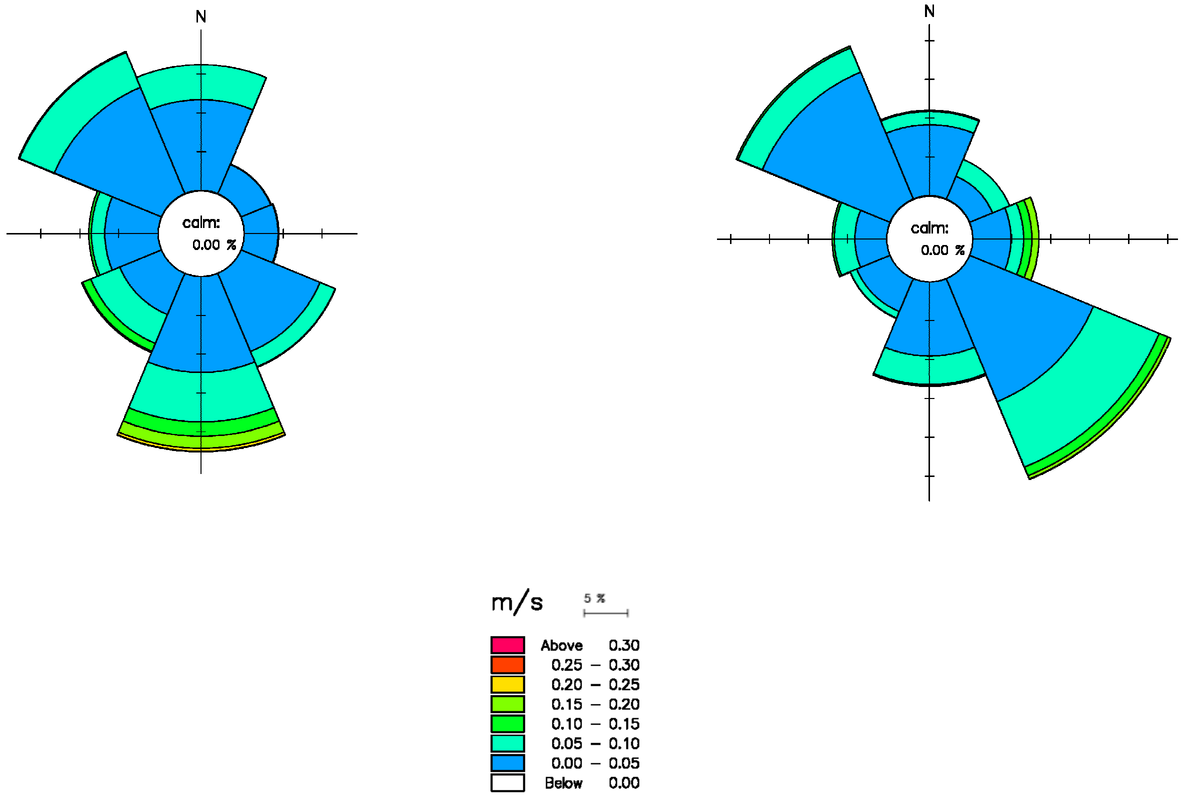
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS

Figure 3.9

Tug 5

Tug 6



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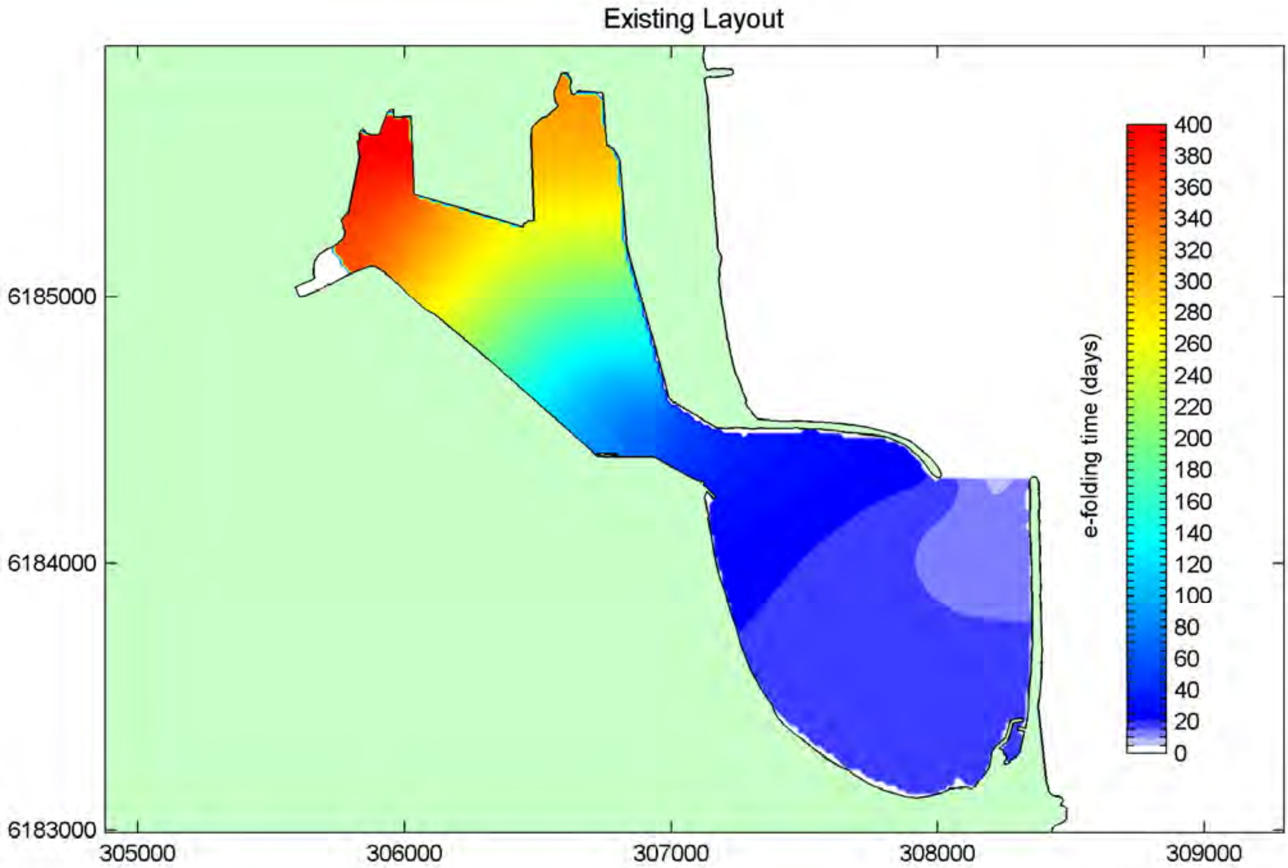
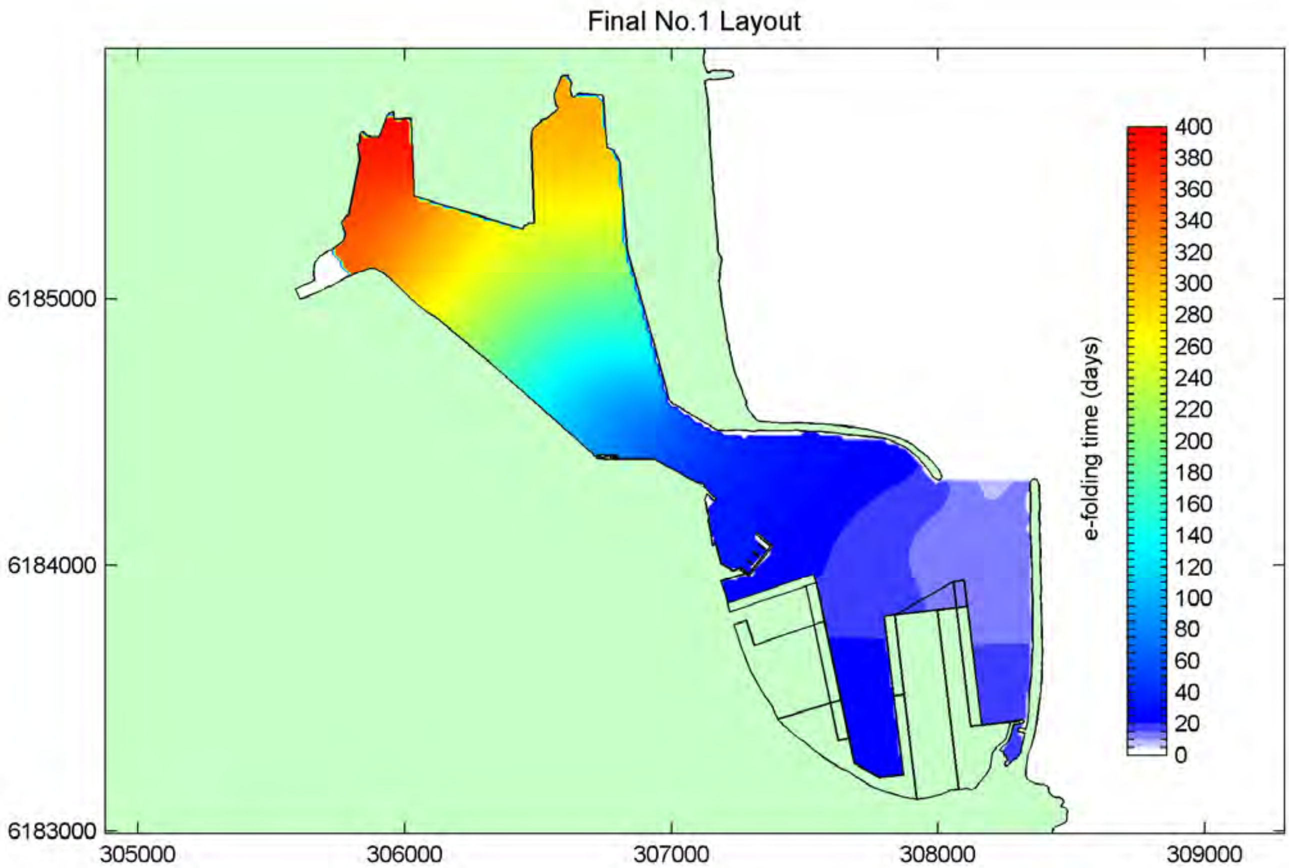
Port Kembla Outer Harbour – Long Wave Stage Modelling

CURRENT ROSE RESULTS – ALTERNATE SPECTRA
FINAL LAYOUT No. 1 – TUG HARBOUR LOCATIONS
Figure 3.10





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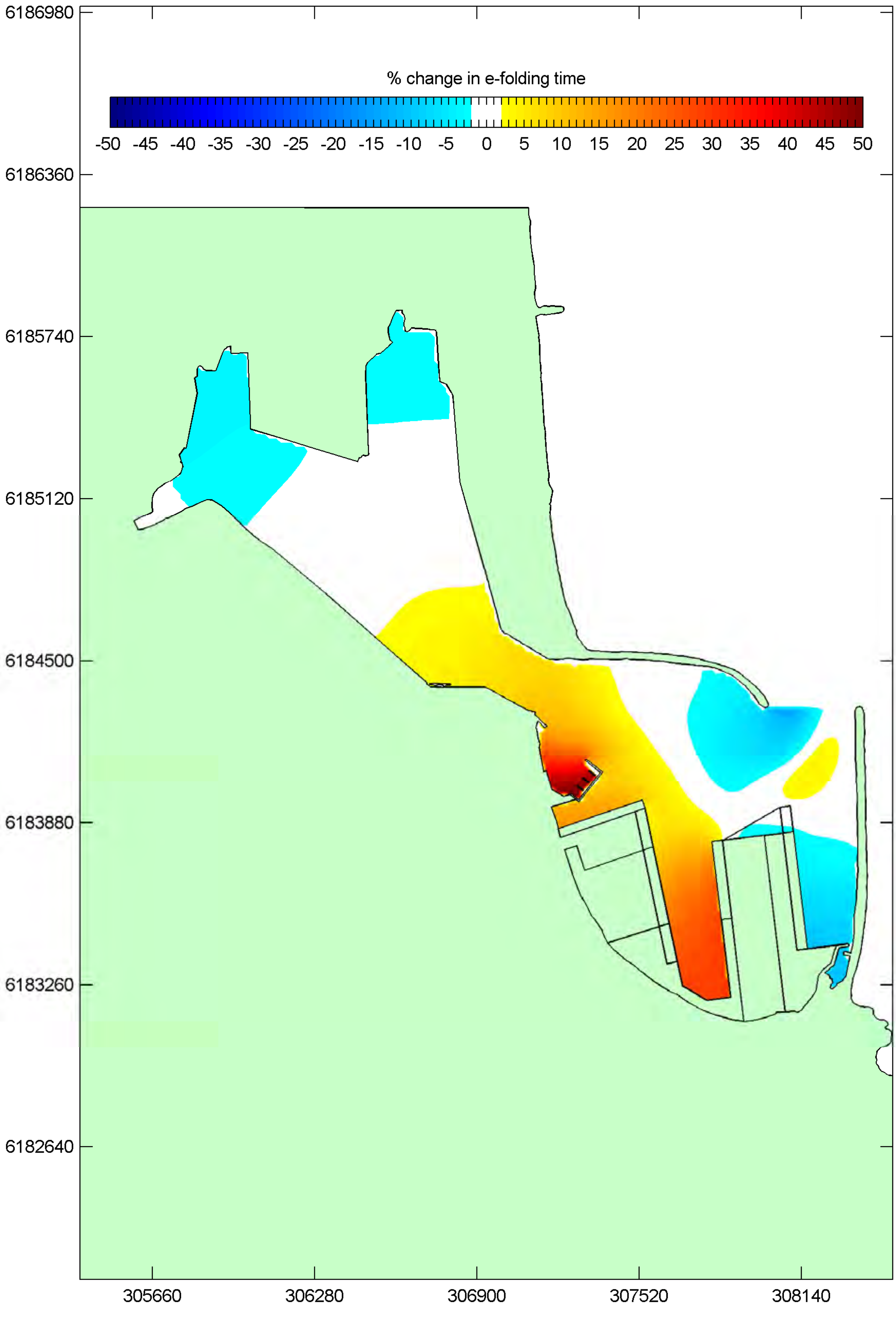
File: J:\CM\LJ2689\Figures\Curr_Rose_Scen3.png

Port Kembla Outer Harbour – Long Wave Stage Modelling

HARBOUR FLUSHING PRE- AND POST- DEVELOPMENT
E-FOLDING TIME DISTRIBUTION

Figure 4.1



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File: J:\CM\LJ2689\Figures\Curr_Rose_Scen3.png

Port Kembla Outer Harbour – Long Wave Stage Modelling

CHANGE IN HARBOUR FLUSHING
E-FOLDING TIME DISTRIBUTION

Figure 4.2