TOWNSVILLE PORT EXPANSION PROJECT

Additional Information to the Environmental Impact Statement

APPENDIX A3

Consideration of the PEP Design Refinement on Wave Climate at the Port of Townsville; Wave Analysis

TOWNSVILLE PORT EXPANSION PROJECT

AECOM BMT WBM

Port of Townsville Limited
01-Oct-2016

Consideration of the PEP Design Refinement on wave climate at the Port of Townsville

Wave Analysis

Consideration of the PEP Design Refinement on wave climate at the Port of Townsville

Wave Analysis

Client: Port of Townsville Limited

Prepared by

AECOM Australia Pty Ltd
Level 8, 540 Wickham Street, PO Box 1307, Fortitude Valley QLD 4006, Australia
T +61 7 3553 2000 F +61 7 3553 2050 www.aecom.com
ABN 20 093 846 925

01-Oct-2016

Quality Information

Document	Consideration of the PEP Design Refinement on wave climate at the Port of Townsville
Ref	60161996
Date	01-Oct-2016
Prepared by	Sam Knight
Reviewed by	Stuart Bettington

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	10-Feb-2016	For POTL review	Rouven Lau Project Manager	
2	01-Apr-2016	Final Issue	Rouven Lau Project Manager	Original previously signed
3	01-Oct-2016	Final Issue	Rouven Lau Project Manager	

Table of Contents

1.0 Introduction

In response to comments received around the Port Expansion Project (PEP) Environmental Impact Statement (EIS) a revised channel design has been adopted. The refined design involves widening of the channel to a width of 180 m at channel marker P16 tapering to a width of 135 m at channel markers P1/P2, and only partial deepening of the channel to an average design depth of -12.8 m chart datum (CD). In comparison the EIS reference design considered a channel width of 92 m (the existing channel width), widening to 130 m at channel markers P11/P12. The partial channel deepening involved in the revised reference design represents a reduction from the design depth of -13.7 m CD considered in the EIS.

This report presents the results of Boussinesq wave modelling and assessment of the probable impacts of the changes in the reference design on the wave climate leeward of the channel. The Boussinesq model used in this study is a phase resolving model that represents the interaction of the waves and steep dredged slopes. This modelling supplements the spectral wave modelling undertaken previously to provide greater insight into the interactions of waves with the dredged channel.

In undertaking this assessment, a particular focus has been on the transmitted waves. These waves ultimately progress to foreshores on the western side of the channel, such as The Strand and Rowes Bay, and bays on Magnetic Island.

2.0 Partial channel deepening

A deeper channel can influence the degree of wave refraction as the waves pass over the dredge faces. Previous work undertaken for the Port of Townsville examined the impact of the approach channel on wave fields propagating across Cleveland Bay using Boussinesq wave modelling. This work (Knight & Bettington, 2012) was verified against recorded wave data in and around Platypus Channel. It was found that Snell's law provides a reliable first principle assessment of the impacts of the channel on waves in Cleveland Bay. Thus for this review the impact of changes in channel depth has been assessed using Snell's law. In developing the study methodology previous research into wave interactions with dredge channels was referenced (Cruickshank *et al*. 2008; Grey *et al*. 2010; Misra *et al*. 2008; Nielsen, Bonner & Berthot. 2012; Tao & Long. 2001; Zwamborn and Grieve. 1974).

Snell's law is used in the following form to describe the wave refraction processes occurring at dredged channels,

$$\alpha_r = cos^{-1}\left(cos(\alpha_i) \times \frac{C_r}{C_i}\right) \quad (1)$$

where C_i is the incident wave celerity, α_i is the incident wave angle, C_r is the refracted wave celerity, and α_r is the refracted wave angle.

The incident wave direction that results in the refracted wave running parallel to the edge of the channel is known as the critical angle, α_c. Waves that approach the channel from angles less than the critical angle will be internally reflected by the dredged slope and prevented from crossing into the channel. Such occurrences can be identified using Eq. 1.

For longer period waves, for which the wave celerity within the channel is dependent on the water depth, deepening of the channel will result in an increase in wave celerity within the channel. This increase in wave celerity will result in a change in the refracted wave direction and therefore the critical angle, as described by Snell's Law. For shorter period waves, where the wave celerity within the channel is not impacted by the water depth, the channel deepening will not impact the refracted wave direction.

Wave celerity is known to be dependent on water depth for relative water depths (h/L, where *h* is the water depth and *L* is the wave length) less than 0.5. Based on this criterion, wave celerity within the Refined Design channel (-12.8 m CD) will be dependent on the channel depth for waves with periods greater than approximately 4 seconds. Therefore, the change in channel depth will only impact wave refraction for waves with periods longer than 4 seconds.

Snell's law was used to assess the change in critical angle resulting from refined channel depth. Figures 1 to 3 show the variation of critical angle with wave period for wave reflection off the Platypus Channel for the PEP EIS design channel depth (-13.7 m CD) and refined PEP Additional Information to the Environmental Impact Statement (AEIS) design channel depth (-12.8 m CD), estimated using Snell's Law. The graphs also include 5 months of incident wave period and direction data recorded from September 2009 to February 2010 by an ADCP (Acoustic Doppler Current Profiler) located on the South-Eastern edge of the Platypus channel near channel marker P10. The changes in critical angle are small over the range of wave periods recorded on site, ranging from no change for a 2 second wave, up to 0.8^o for a 10 second wave.

The Platypus Channel is orientated approximately perpendicular to the sea bed contours, and longer period waves refract to become more aligned with the channel. As a result, the longer period waves, for which wave refraction is impacted by the water depth in the channel, approach the channel from less than critical angle and are reflected off the channel for both the previous design and refined design scenarios. Therefore, the reduction in channel depth from -13.7 m CD in the PEP EIS design, to -12.8 m CD in the refined PEP AEIS design, is considered to have little impact on the transmitted wave climate.

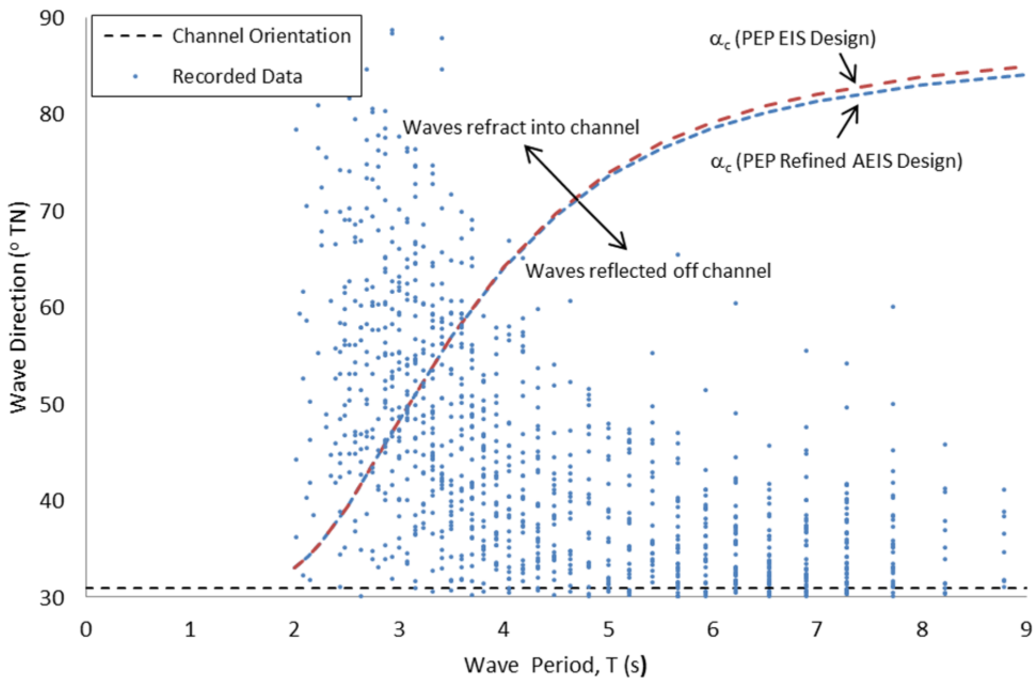

Figure 1 Theoretical assessment of impact of the change in channel depth on the critical angle for a water level of +0.00 CD m (LAT)

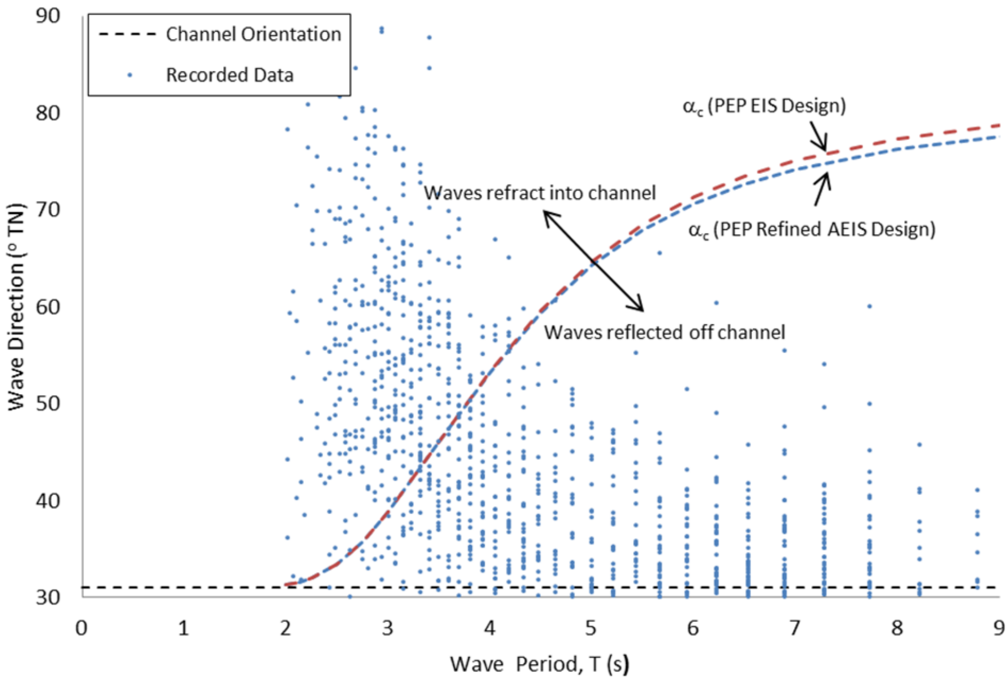

Figure 2 **Theoretical assessment of impact of channel change in channel depth on the critical angle for a water level of +1.94 CD m (MSL)**

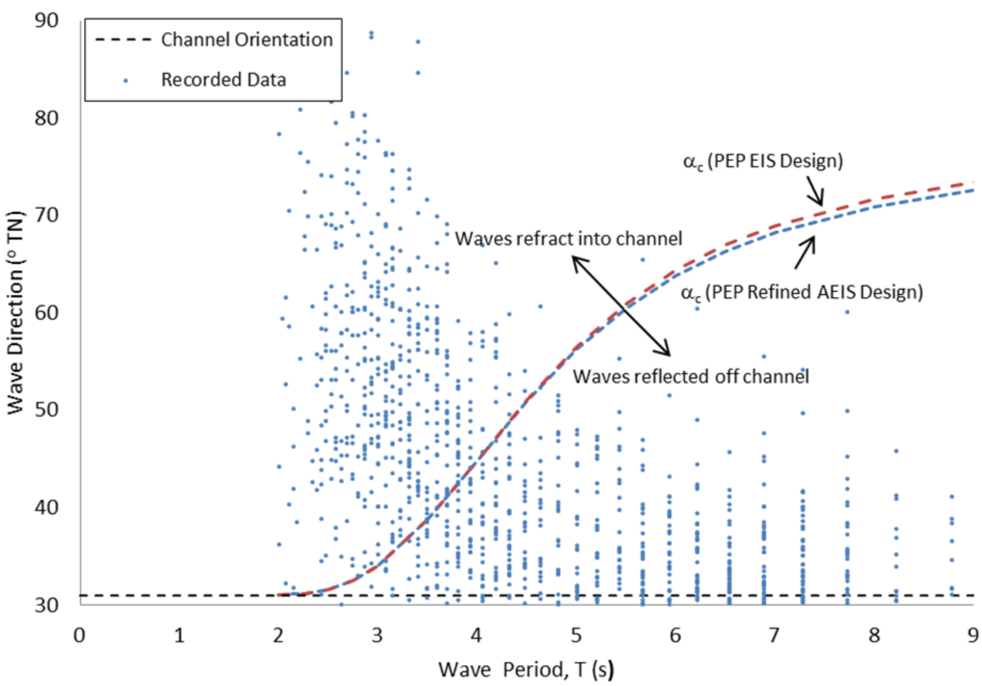

Figure 3 **Theoretical assessment of impact of channel change in channel depth on the critical angle for a water level of +4.11 CDm (HAT)**

3.0 Channel widening

The potential impact of the Design Refinement channel widening has been considered using the DHI MIKE21 BW modelling suite. MIKE21 BW is a phase resolving numerical model that is capable of accurately reproducing the wave transformation processes associated with abrupt changes in water depth, such as dredged channels.

3.1 Model setup

An existing Boussinesq model of Townsville Port and its approach channel was updated to include the proposed PEP AEIS reclamation and used to assess the impact of the Refined Design on the transmitted wave climate. The existing model had been set up to assess the wave climate within Townsville Port harbour, and the model results of interest for this study (i.e. the transmitted waves north of Townsville Port) were impacted by boundary effects (refer Section 3.3). The offshore model extents were therefore expanded to provide a larger area north of the channel not impacted by boundary effects (refer Section 3.3).

Figures 1 to 3 indicate that longer period waves approach the channel from directions that are less than critical angle relative the channel and are therefore reflected off the channel slope. As this assessment is primarily concerned with the impacts of the Design Refinement on the wave climate west of the channel, modelling needs to consider waves that pass over the channel. Modelling has therefore been performed using a wave period of 4 seconds, which allows for modelling of scenarios captured within the 5 months of recorded wave data at incident angles less than the critical angle.

The Boussinesq model has limitations on the relative water depth (h/L) and the ratio of wave length to spatial resolution ($L/\Delta x$) which limit simulation of shorter period waves. The maximum water depth (water depth in the channel) was consequently decreased to a hypothetical 7.5 m CD for the purpose of considering the channel widening to allow modelling of these shorter period waves. The modelling therefore does not incorporate changes in channel depth, which have been assessed separately in Section 2.0.

Wave inputs were generated using unidirectional, JONSWAP frequency spectra and input into the model using internal wave generation lines. As MIKE21 BW requires the water depth to be constant along the internal wave generation line, an artificial slope was incorporated into the model bathymetry to create a boundary with a constant water depth.

Three model bathymetries were created. The first has a constant channel width of 92 m. This is representative of the current channel width and the channel width over much of the channel within the PEP EIS design, as channel widening was only proposed for the stretch of channel between the port and channel markers P11/P12 in the PEP EIS design. The second model bathymetry is representative of the PEP EIS design and has a channel width of 92 m increasing to 130 m at channel marker P11/P12. This model bathymetry was used to assess the localised impact of the abrupt increase in channel with at channel markers P11/P12. The third bathymetry represents the refined PEP AEIS design and has a channel width of 180 m at channel marker P16 tapering to 135 m at channel markers P1/P2.

Figures 4 to 6 display the three model bathymetries and indicate where the internal wave generation line was located and where the transmitted wave climate was extracted. Waves entering the channel at the wave generation line impacted the results over much of the northern part of the model domain (refer Section 3.3). The transmitted wave extraction line was therefore located to avoid these impacts as much as possible.

Bottom friction has been included in the modelling, with a Chezy number of 65 being adopted (Manning's n of approximately 0.02).

This model setup is considered to be appropriate for considering the PEP AEIS Design Refinement changes.

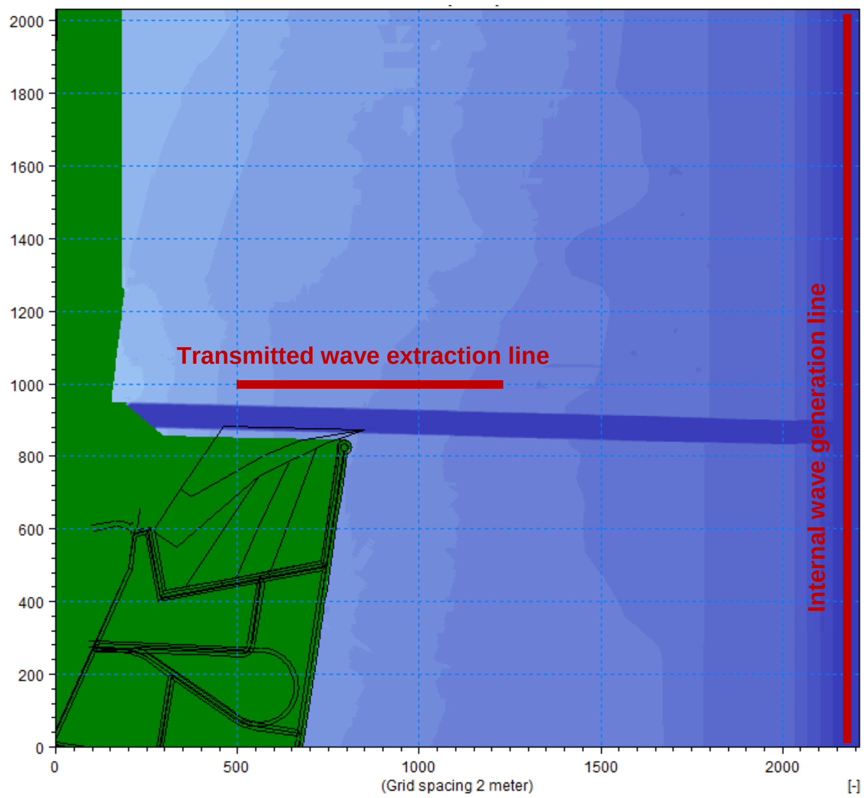

Figure 4 Model bathymetry with existing channel configuration (constant channel width of 92 m), indicating the location of the internal wave generation and transmitted wave extraction lines

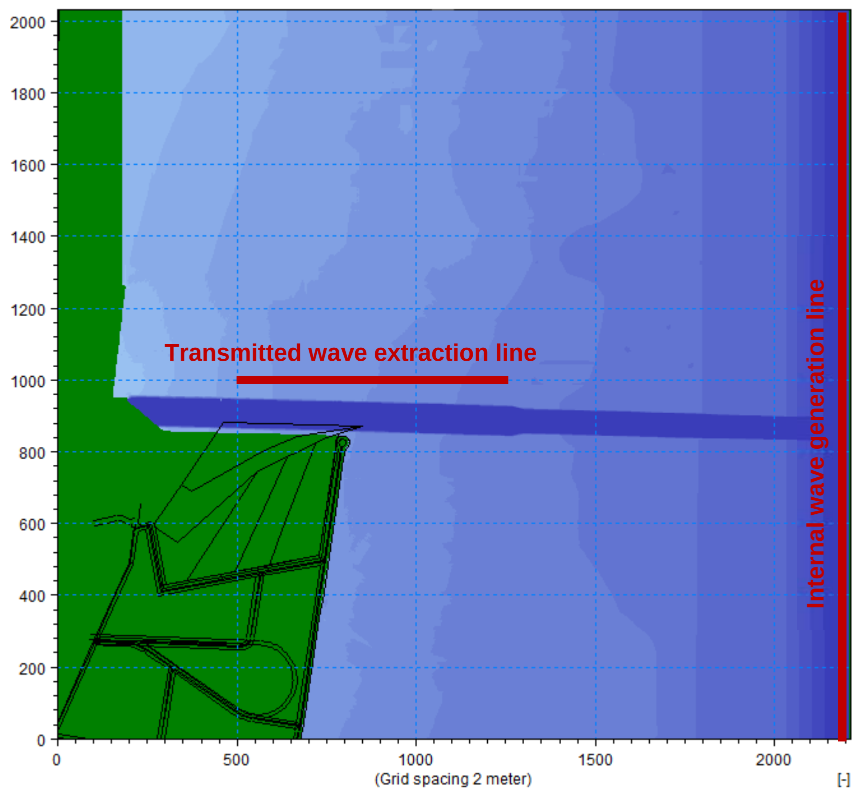

Figure 5 PEP EIS design model bathymetry with 92m wide channel increasing to 130 m wide at channel markers P11 and P12, indicating the location of the internal wave generation and transmitted wave extraction lines

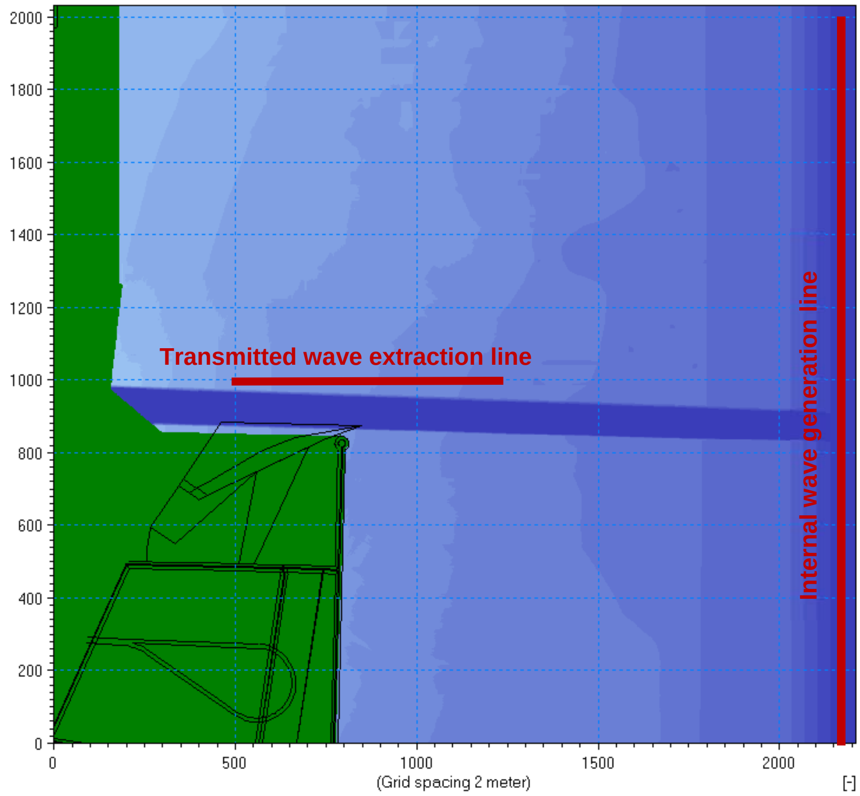

Figure 6 PEP Refined AEIS design model bathymetry with 180 m wide channel at channel marker P16 tapering to 135 m at channel markers P1/P2, indicating the location of the internal wave generation and transmitted wave extraction lines

3.2 Modelled scenarios

Table 1 presents a summary of the scenarios modelled using the bathymetries displayed in Figures 4 to 6. Figure 7 shows the modelled scenarios compared to the 5 months of data recorded from September 2009 to February 2010 by an ADCP (Acoustic Doppler Current Profiler) located on the South-Eastern edge of the Platypus channel near channel marker P10. For all model runs the water level was constant at Mean Sea Level (MSL) equivalent to +1.94 CD m.

Table 1 Modelled scenarios

Design Scenario	Wave Height Hs (m)	Peak Period Tp (s)	Incident wave direction (^{o})
Existing channel configuration	1	4	40
			50
			60
PEP EIS Design*	1	4	50
Refined PEP AEIS Design	1	4	40
			50
			60

*Modelling was only undertaken for a wave direction of 50 degrees for the PEP EIS Design as the impact of the abrupt widening of the channel at channel markers P11/P12 was not captured along the wave extraction line for the other wave directions.

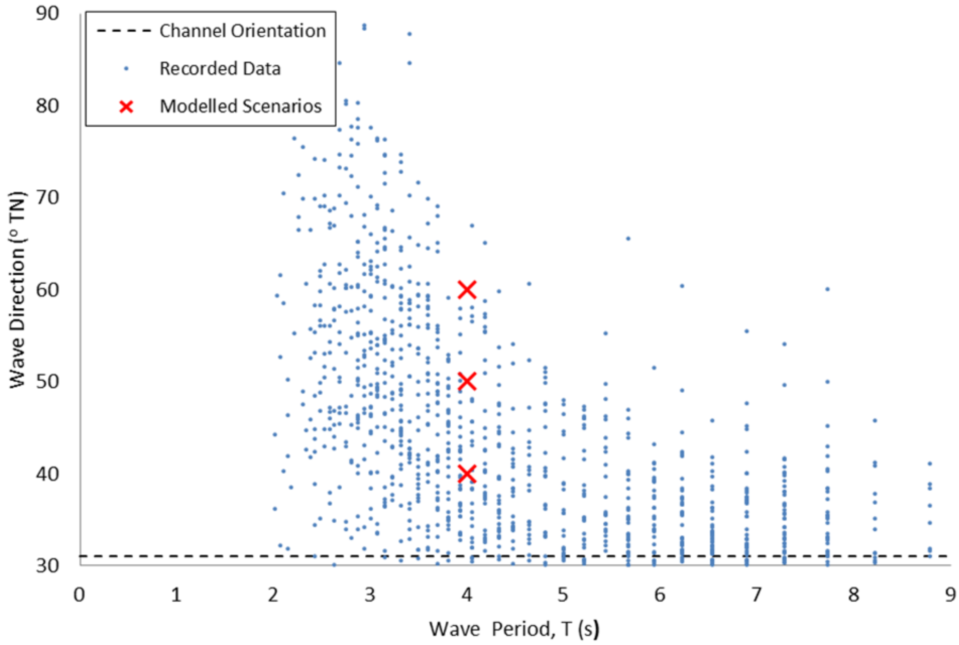

Figure 7 **Modelled wave scenarios compared to recorded data and theoretical estimates of the critical angle of wave reflection**

3.3 Results

Maps of the modelled wave heights for all model runs are displayed in Appendix A. The artificial slope required to achieve the constant water depth boundary for the internal wave generation results in waves entering the channel near the wave generation line, which impact the wave climate over the northern part of the model. The results of the model run for the 60° incident wave direction are also impacted by boundary effects from the bottom end of the wave generation line. The results should therefore not be relied upon in absolute terms.

The profiles of the transmitted significant wave height (H_s) along the extraction line for the model simulations considering the channel at the constant 92 m and the refined PEP AEIS design configuration of 135 m wide increasing to 180 m wide near the port are displayed in Figures 8 to 10. It is noted that significant wave height (H_s) is the average height of the 1/3 biggest waves in a wave field and is the common characteristic used to describe the wave height. The results indicate only very minor differences in the transmitted wave height for the change in channel width from the constant 92 m to the refined PEP AEIS design configuration of 135 m wide increasing to 180 m wide near the port.

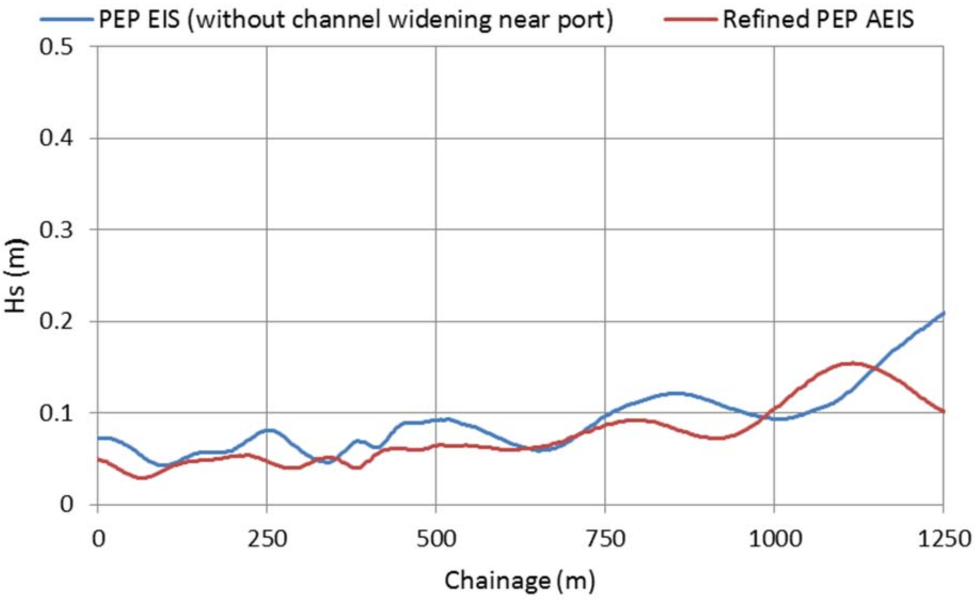

Figure 8 Impact of channel layout on the modelled transmitted wave climate, Tp = 4 seconds, Wave direction = 40^{o}

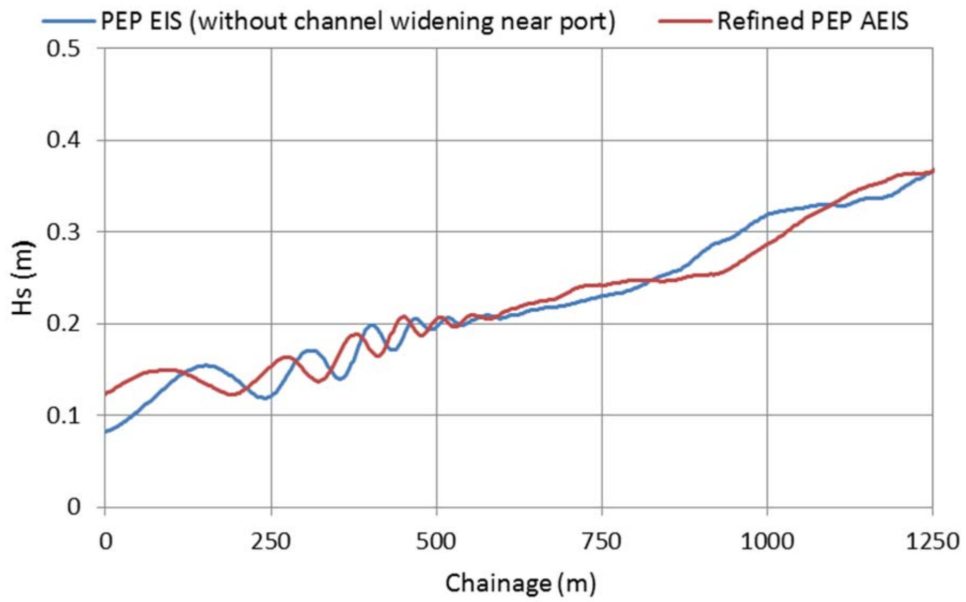

Figure 9 Impact of channel layout on the modelled transmitted wave climate, Tp = 4 seconds, Wave direction = 50^{o}

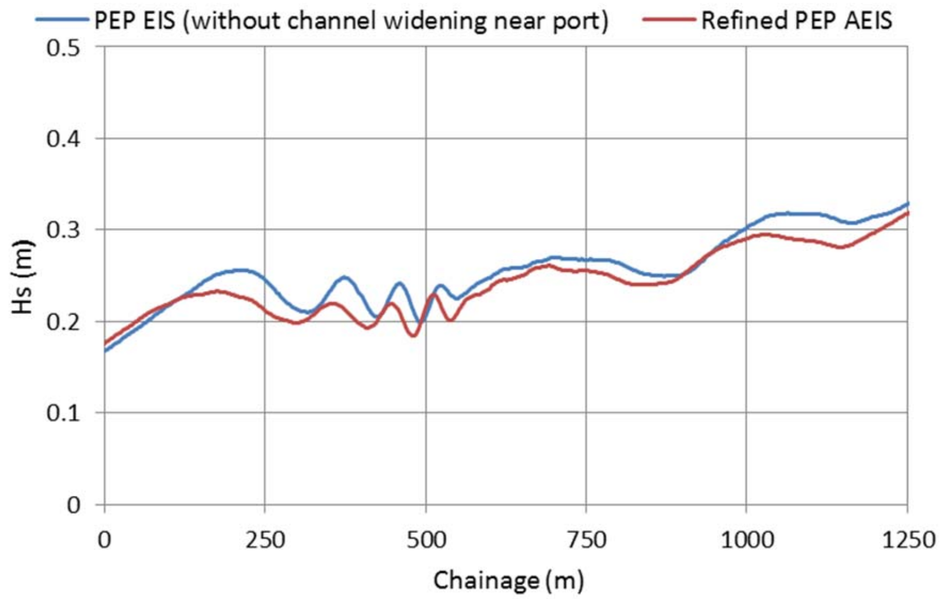

Figure 10 Impact of channel layout on the modelled transmitted wave climate, Tp = 4 seconds, Wave direction = 60°

The profile of the transmitted significant wave height (H_s) along the extraction line for the model simulation that includes the increase in channel width at the P11/P12 channel is compared against that for the refined PEP AEIS design configuration of 135 m wide increasing to 180 m wide near the port in Figure 11. The results indicate that the abrupt increase in channel width at channel markers P11/P12 in the PEP EIS design may result in a minor, localised redistribution of wave energy west of channel markers P11/P12. As the refined PEP AEIS uses a gradual increase in channel width this localised redistribution of wave energy does not occur.

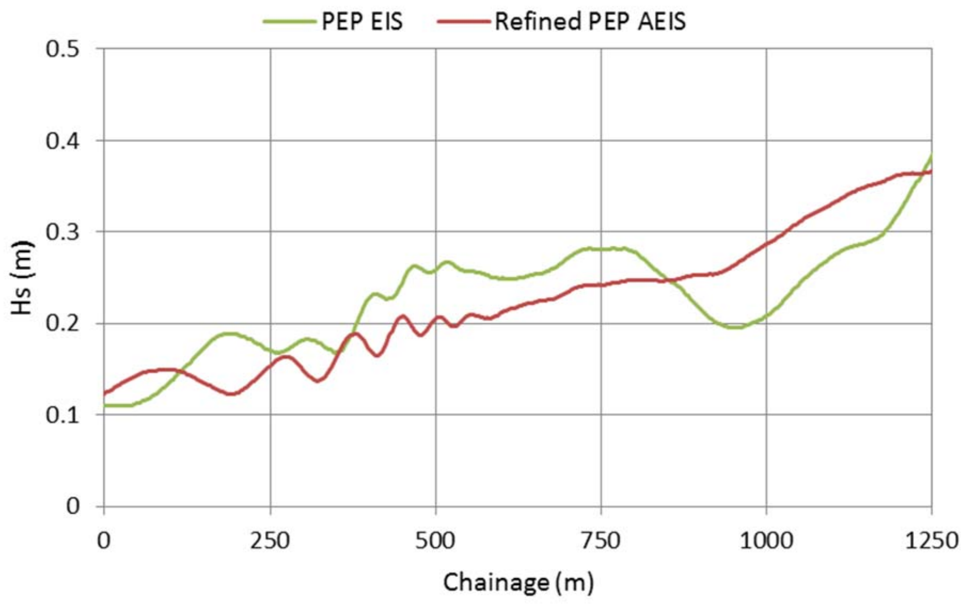

Figure 11 Impact of abrupt increase in channel width at channel marker P11/P12 on transmitted wave climate, Wave direction = 50°

4.0 Summary

The impact of changing the channel depth on wave interaction with the channel slope has been assessed using first principles. This assessment indicated that changes in channel depth would have minimal impact on wave interactions for the shorter period waves passing over the channel. The change in channel depth was found to have a minor impact on longer period waves, however these swell waves approach from offshore and encounter the channel from much less than the critical angles of wave reflection. Thus swell waves currently and will continue to reflect off the channel under both the PEP EIS and refined PEP AEIS design layout. Therefore the proposed changes in channel depth will have minimal impact on the wave climate in Cleveland Bay.

The impact of changes to the channel layout on the transmitted wave climate, including reduced energy dissipation due to bottom friction, has been assessed using a Boussinesq numerical model. The results indicate that widening the channel has a minimal impact of the transmitted wave climate. Whilst the modelling shows that the PEP EIS design may result in a minor redistribution of wave energy west of the increase in channel width at channel markers P11/P12, the gradual increase in channel width in the refined PEP AEIS design does not result in this localised effect.

Assessment of the impact of both the change in channel depth and channel width on the transmitted wave climate have been undertaken, and found to not have a significant impact. The combined channel deepening and widening together indicate that the design refinement will have a negligible change on transmitted waves which is not anticipated to be physically measurable beyond the channel edge and therefore is not expected to materially alter the transmitted waves that may ultimately progress to foreshores on the western side of the channel, such as The Strand, Rowes Bay and bays on Magnetic Island.

5.0 References

Cruickshank, I.C., Beresford, P., Grey, S.M, Tozer, N.P. (2008). Innovative techniques to reduce or remove the need for a breakwater, Proceedings of the 7th International Conference on Coastal and Port Engineering in Developing Countries, Dubai, Paper 11.

Grey, S.M., Cruickshank, I.C., Beresford, P.J. and Tozer, N.P. (2010). The impact of navigation channels on berth protection, Proceedings of the ICE – Civil Engineering, Vol. 163

Knight, S.J.F., Bettington, S.H., (2013), “Wave Interactions with Dredged Areas”, Coasts and Ports 2013: 21st Australasian Coastal and Ocean Engineering Conference and the 14th Australasian Ports and Harbours Conference, September 2013

Misra, S.K, Driscoll, A.M., Kirby, J.T., Cornet, A., Lomonaco, P., Sayao, O. and Yavary, M. (2008). Surface gravity wave interactions with deep-draft navigation channels – Physical and numerical modelling case studies, Proceedings of the 31st International Conference on Coastal Engineering, Hamberg, Vol. 3, pp. 2786-2798

Nielsen, A.F., Bonner, R.I. and Berthot, A. (2011). Wave energy reflection off dredged channels, Proceedings of the 20th Australasian Coastal Ocean Engineering conference and the 13th Australasian Ports and Harbour Conference, pp 535-539

Tao, J. and Long, W. (2001). The critical angle of wave refraction and multiple refraction by harbour approach channels and basins, Proceedings of the 29th IAHR Congress, Cardiff, pp 472 – 478

Zwamborn, J.A. and Grieve, G. (1974). Wave attenuation and concentration associated with harbour channels, Proceedings of the 14th International Conference on Coastal Engineering, Copenhagen, pp 2068-2085

6.0 Appendix A

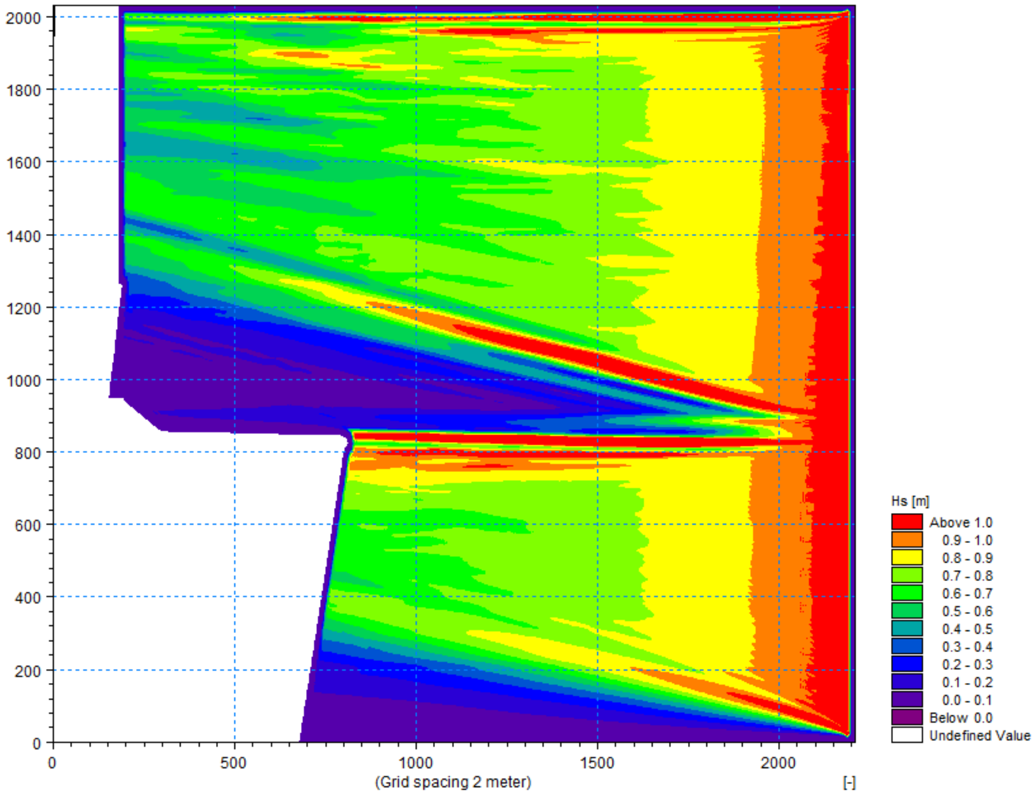

Figure A 1 Boussinesq model results for PEP EIS design with a channel width of 92 m, Tp = 4 seconds, Wav direction = 40°

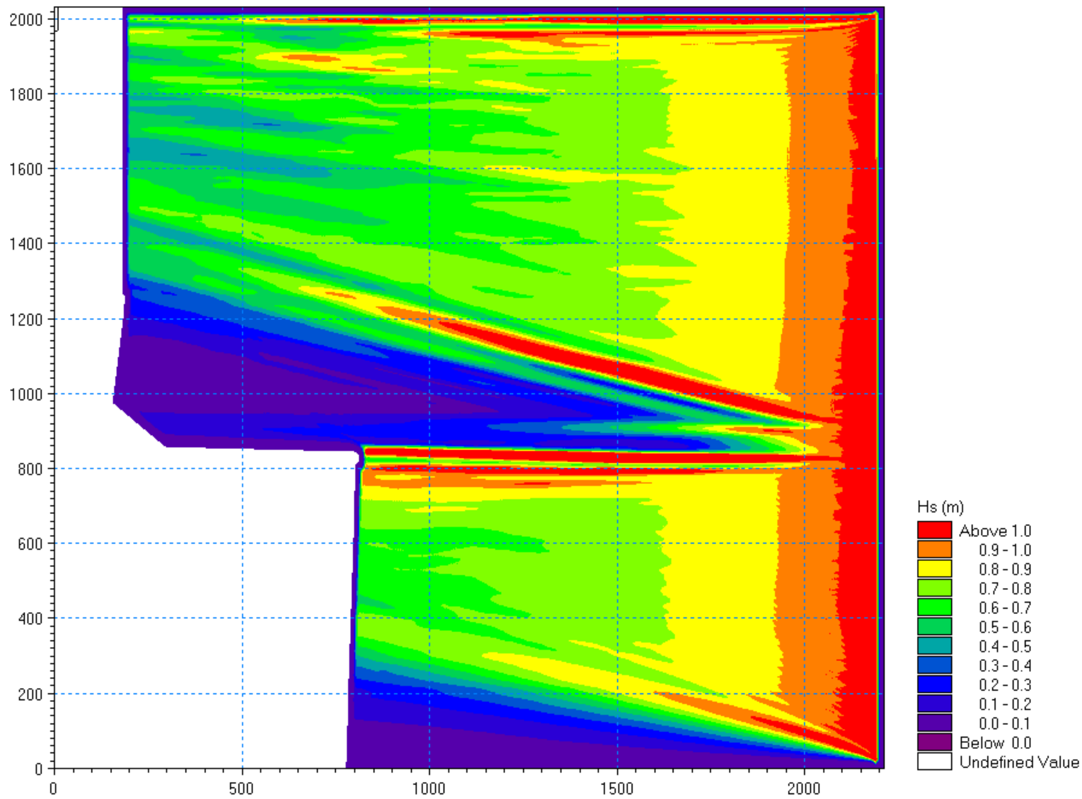

Figure A 2 Boussinesq model results for refined PEP AEIS design, Tp = 4 seconds, Wav direction = 40°

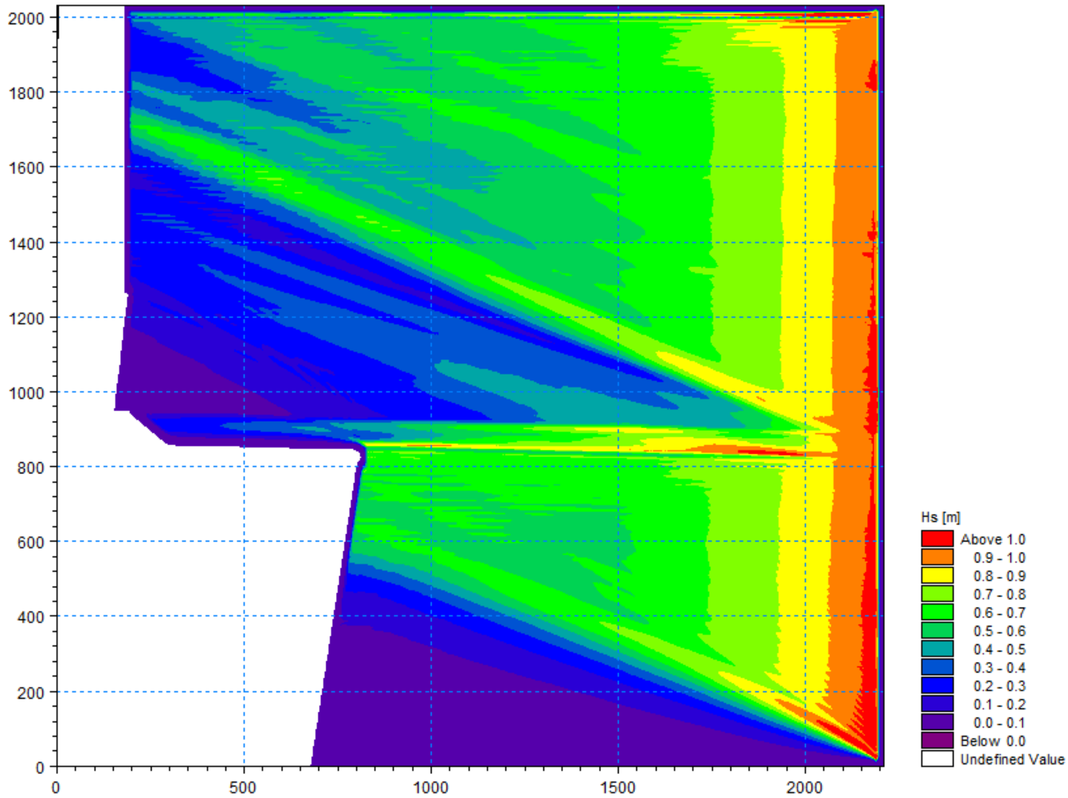

Figure A 3 Boussinesq model results for PEP EIS design with a channel width of 92 m, Tp = 4 seconds, Wav direction = 50°

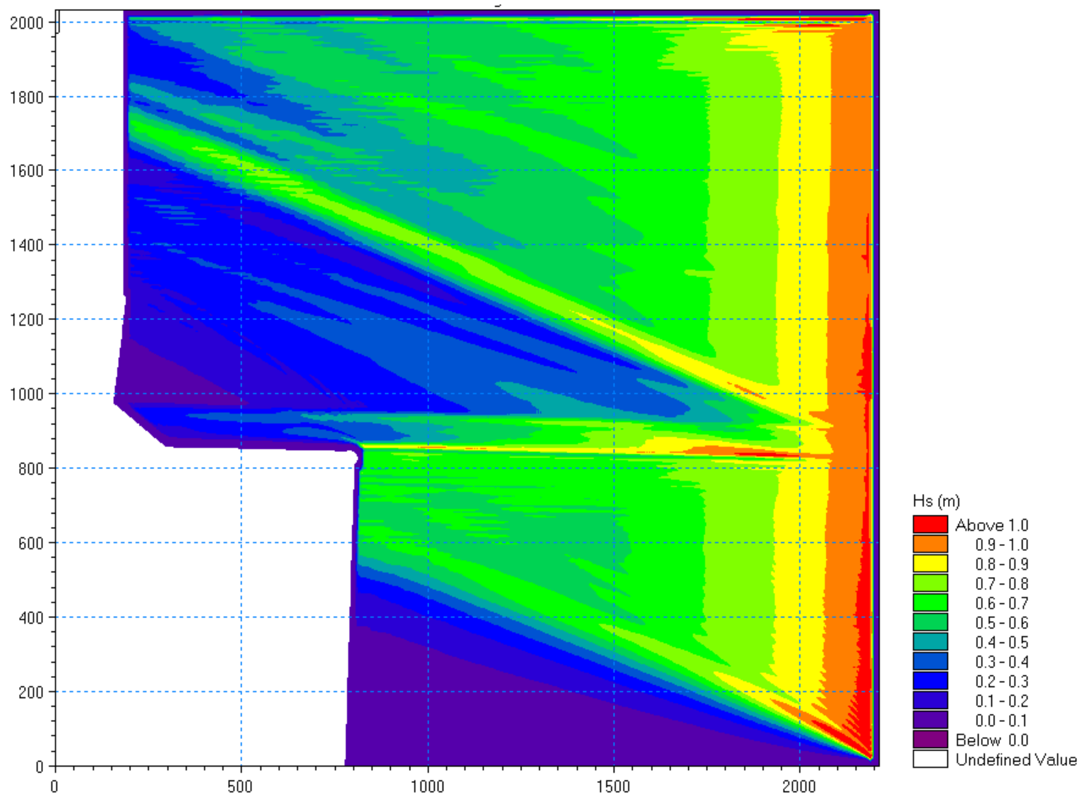

Figure A 4 Boussinesq model results for refined PEP AEIS, Tp = 4 seconds, Wav direction = 50°

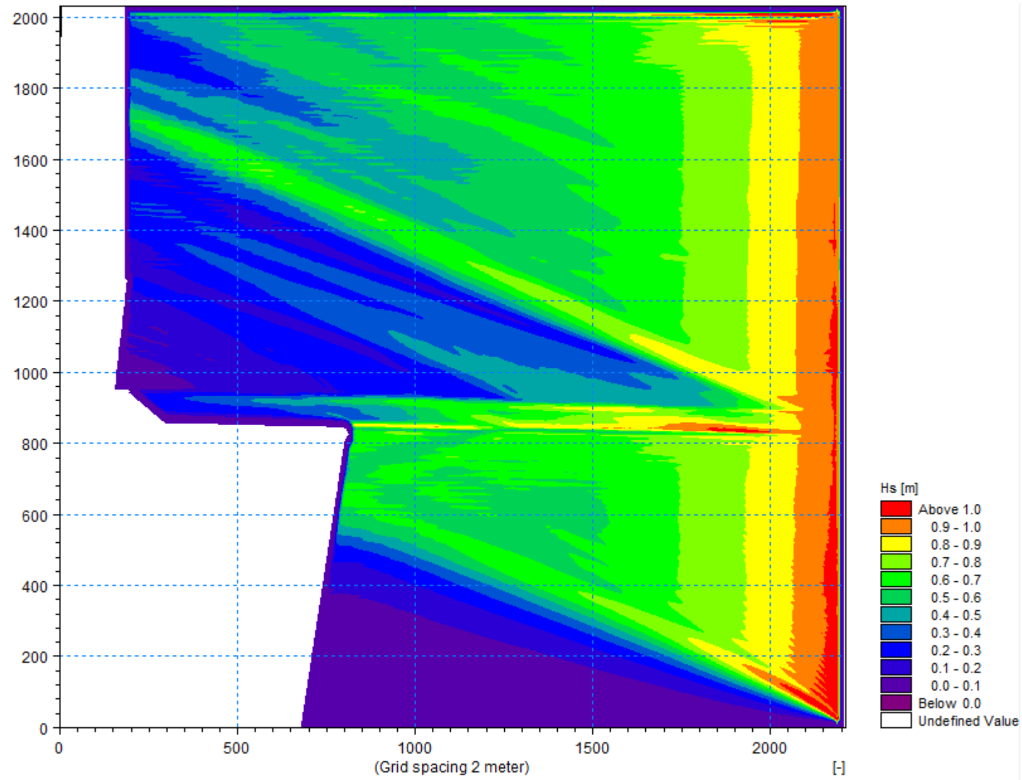

Figure A 5 Boussinesq model results for PEP EIS design with a channel width of 92 m, increasing to 130 m at channel markers P11/P12, Tp = 4 seconds, Wav direction = 50°

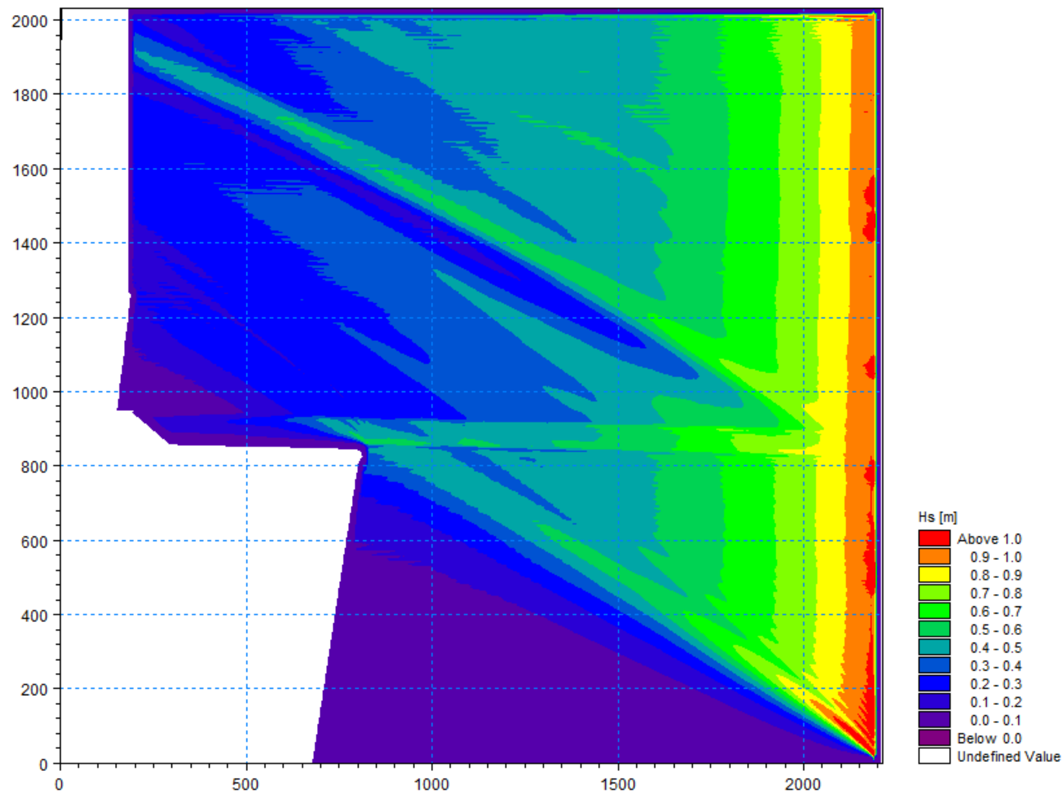

Figure A 6 Boussinesq model results for PEP EIS design with a channel width of 92 m, Tp = 4 seconds, Wav direction = 60°

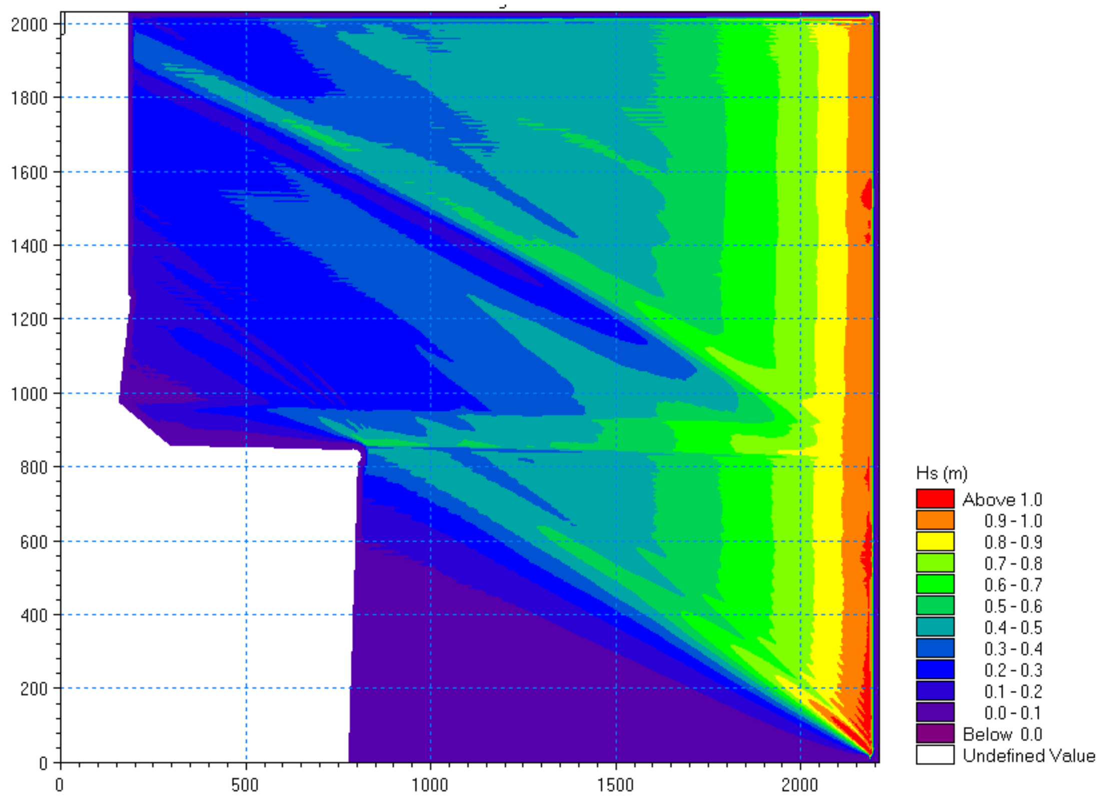

Figure A 7 Boussinesq model results for refined PEP AEIS design, Tp = 4 seconds, Wav direction = 60°