APOLLO BAY, VICTORIA, WAVE CLIMATE STUDY

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01 Introduction

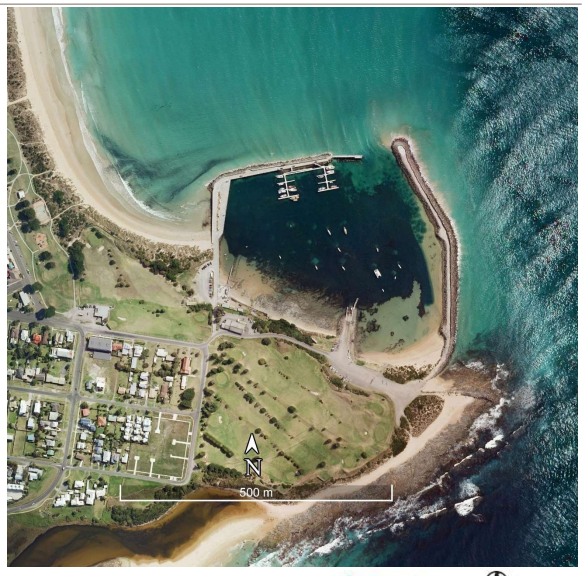
- The marina berths within Apollo Bay Harbour in south-western Victoria suffered damage from wave activity and required rehabilitation.
- Cardno now Stantec were engaged by International Marina Consultants (IMC) undertake a wave climate study of the harbour and provide design wave and water level criteria for the extension and improvement of facilities within the Apollo Bay Harbour.

01 Summary

> Cardno modelled the wave climate of the area applying numerical models. This included an offshore global wave model that was transferred inshore to the harbour entrance using SWAN, and then from the harbour entrance to berth areas using SWASH model.

> Model results were further calibrated and validated with measurements in the area.

> Based on design wave and water levels calculated, wave models were then updated to investigate modifications to the harbor infrastructure in attenuating wave energy at the marina.



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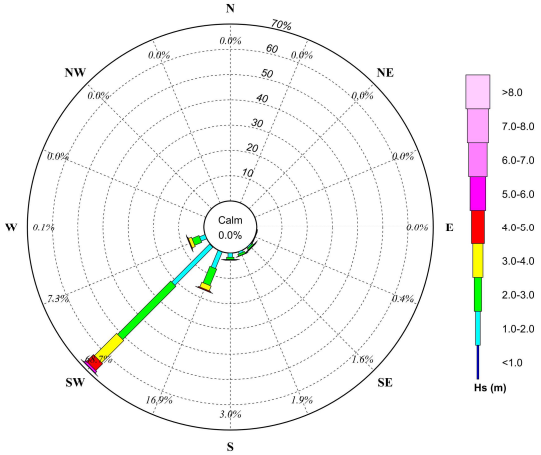
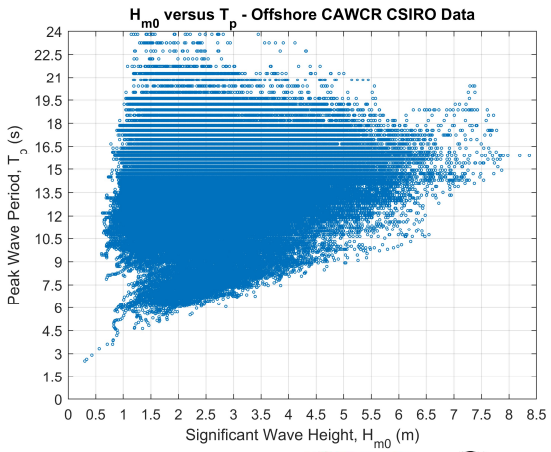
02 Offshore Wave Data

> **Offshore Wave Data**

- 42 years (1979 through 2020) of hindcast model wave and wind data was obtained from the CSIRO CAWR WaveWatch III™ Australian wind and wave model system at an offshore location.





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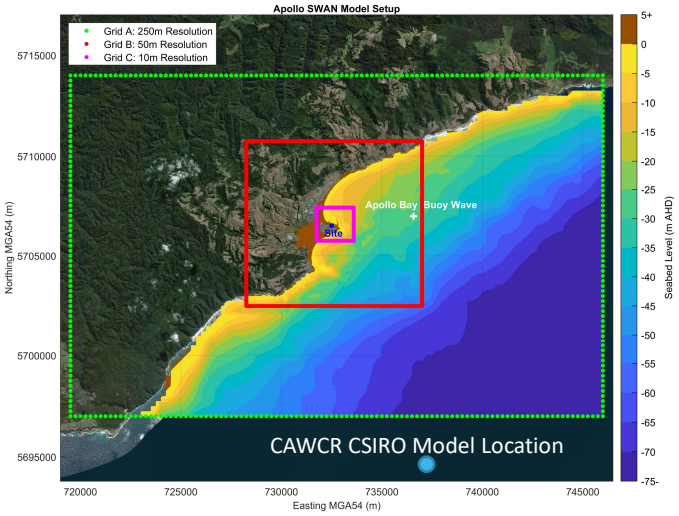
03 Nearshore Wave Modelling

> **Modelling Software**

The wave model applied for wave transformation modelling was based on SWAN.

The SWAN model was used to prepare the time-series of wave parameters at two particular locations:

1. Apollo Bay Buoy Wave Location – within intermediate grid used for SWAN model validation
2. Phase-resolving Model Boundary Location – within fine grid used for defining the SWASH model boundary conditions



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03 Nearshore Wave Modelling

> **Offshore to Nearshore (Harbour Entrance) Wave Transformation**

The propagation of Southern Ocean/Bass Strait swell waves into Apollo Bay was undertaken by implementing the SWAN wave model to prepare wave transfer coefficients for a full suite of offshore wave heights, periods and directions, namely:

- Significant wave heights (H_{m0}) of 1 to 9 m - at 1m intervals;
- Peak wave periods (T_p) ranging from 4s to 24s - at 2s intervals;
- Wave directions from east (90 °TN), clockwise through to west (270 °TN) - at 11.25-degrees intervals

✓ A constant water level corresponding to MSL was adopted for the simulations.

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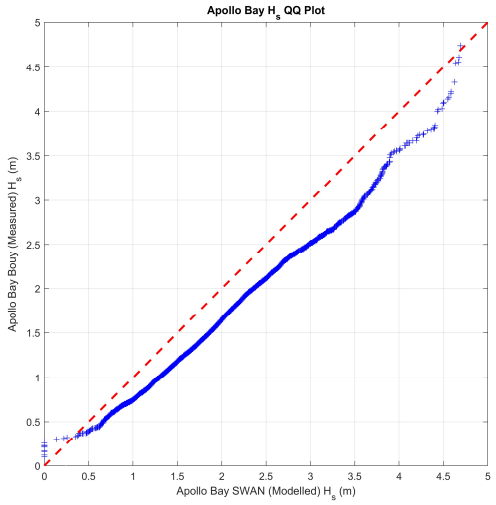
03 Nearshore Wave Modelling Calibration

> Validation of SWAN Wave Modelling

- A wave buoy was deployed by Deakin University off the coast of Apollo Bay located in an approximate depth of 30 m.
- The SWAN modelled data was compared against the available measured offshore Apollo Bay wave buoy data.
- Validation has been undertaken over a 1.2-year period (Oct 2019 to Dec 2020), when the measured data was available.
- Results show the model over estimates measured data, and can therefore be considered conservative



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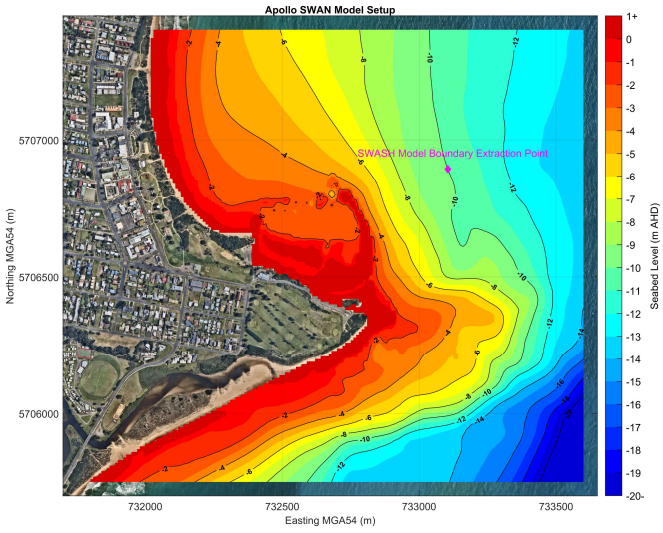
03 Harbour Wave Modelling

> Wave Climate at SWASH Model Boundary Location

- To estimate wave conditions in and around the harbour, the detailed phase resolving SWASH model was applied
- The SWASH model set up consisted of a 2m resolution rectilinear grid extending 850m offshore (in the E-W direction) and alongshore (in the N-S direction).
- The results of the SWAN wave modelling are extracted at a location in 10m AHD water depth.



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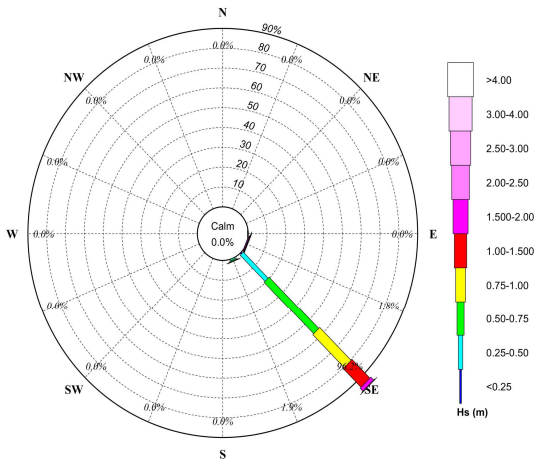
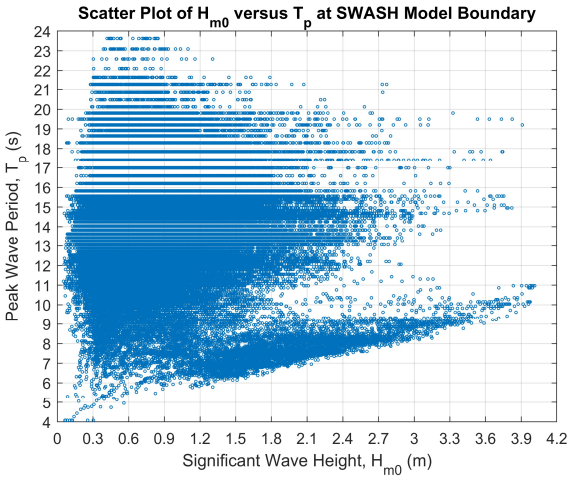
03 Harbour Wave Modelling

> **Wave Climate at SWASH Model Boundary Location**





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04 Wave Penetration Modelling

> **Harbour Wave Agitation Modelling Methodology**

The propagation of waves into the harbour was undertaken to prepare wave transfer coefficients adopting unity significant wave height at the boundary for an appropriate suite of wave periods and directions:

- Peak wave periods (T_p) ranging from 4s to 24s - at 2s intervals; and
- Wave directions from ≈east (100 °TN), clockwise through to south (180 °TN) - at 10-degrees intervals.

✓ A total of 99 SWASH simulations were undertaken to prepare wave coefficients within the harbour.

✓ A constant water level corresponding to MSL was adopted for the simulations.

✓ Each SWASH simulation was run for 30 minutes, including an initial warmup period of 10 minutes.

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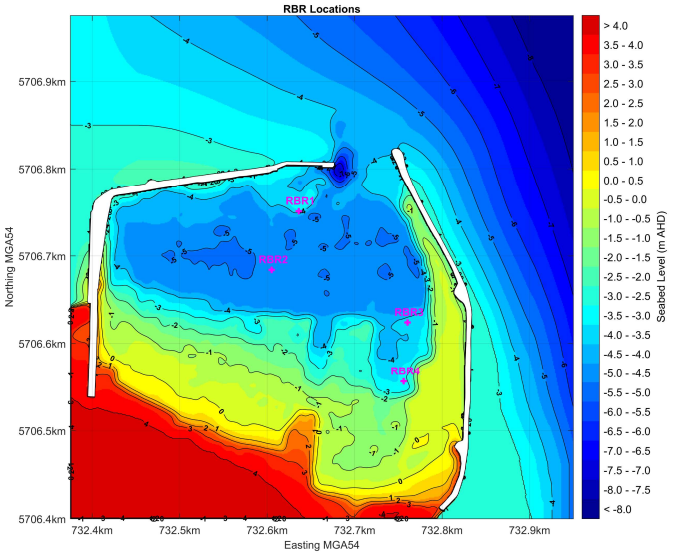
04 Wave Penetration Modelling

> Validation of SWASH Wave Modelling

- Colac Otway Shire Council provided some in-harbour wave data, recorded by RBR instruments, and was used for SWASH model calibration.
- The SWASH modelled data was compared with the measured wave data recorded by RBR instruments at four locations within the harbour.
- Validation of the model system was undertaken over a 4-months period (mid-July 2020 to mid-Dec 2020), when the measured data were available.



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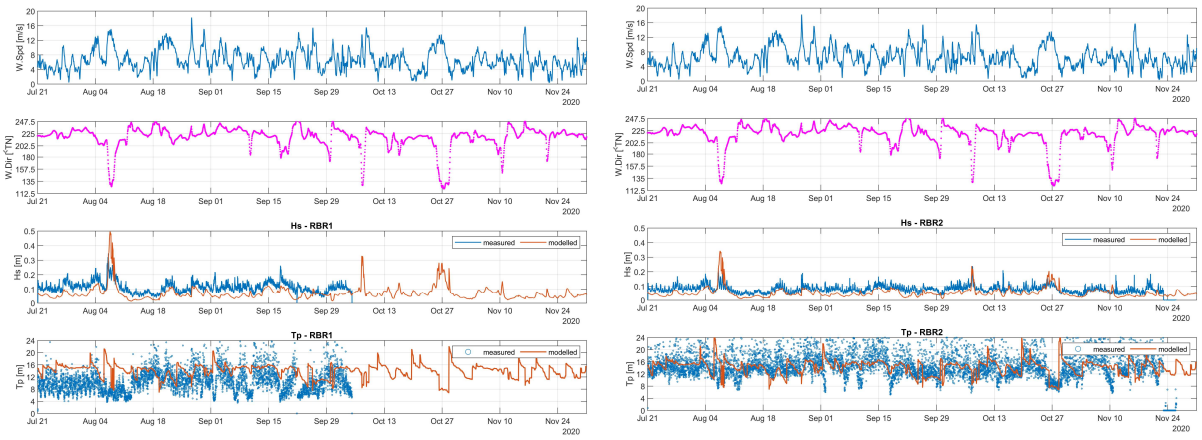
04 Wave Penetration Modelling

> Validation of SWASH Wave Modelling



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04 Wave Penetration Modelling

> **Validation of SWASH Wave Modelling**

Overall, the modelled wave data agree comparatively well with the measured data at the four harbour RBR locations – both in terms of wave height and temporal variation.

Generally, significant wave heights recorded at the measurement sites are marginally higher than the modelled data, except during the storm events.

Nonetheless, significant wave heights are generally in good agreement, with differences typically within a few centimetres.

04 Design Wave Conditions

> **Design Wave Conditions at Harbour Nominated Output Locations**

The SWASH modelling results, in terms of wave transfer coefficients, were extracted at selected points inside the harbour.

Inshore wave time-series at the nominated output locations were produced by transfer of the time-series of wave parameters at the SWASH model boundary, and using the wave transfer coefficients.

Extreme Value Analyses (EVA) were undertaken on independent peak event significant wave heights at each nominated output location.

A correlation was also fitted to the wave height and period data to determine the Tp associated with a particular design wave height.

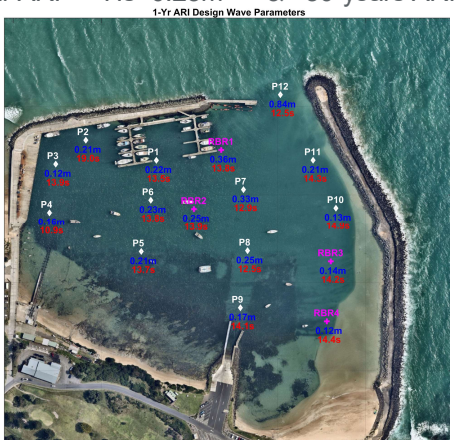
Apollo SWASH Model Output Points

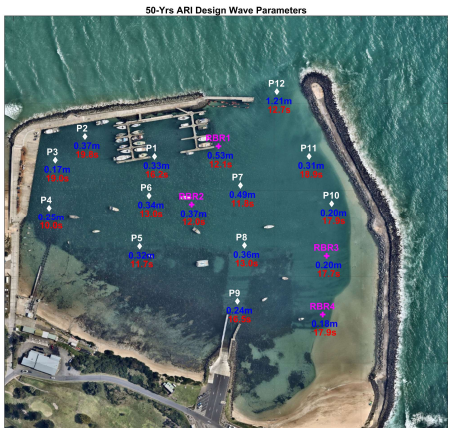
04 Design Wave Conditions

> **Design Wave Conditions at Harbour Nominated Output Locations**

AS3962 specifies that, for Tp>2s, the following are to be fulfilled for oblique waves:

> 1-year ARI Hs<0.25m & 50-years ARI Hs<0.40m





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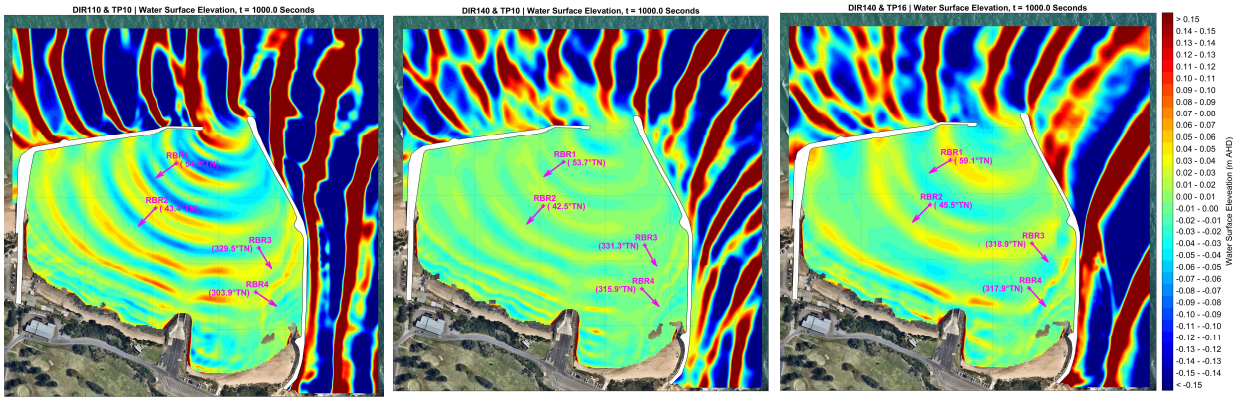
04 Wave Penetration Modelling

> **Spatial Variation in Harbour Wave Direction**

The mean wave direction vectors show that ‘at-berth’ wave directions vary with offshore wave direction and wave period, as well as spatially.



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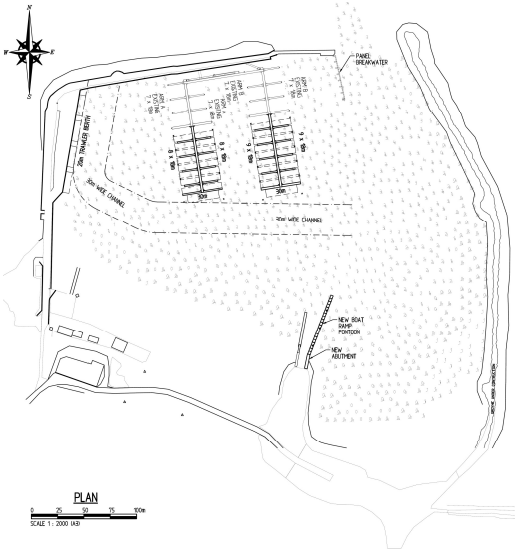
05 Proposed Modification Investigation

Following a review of the wave modelling results for existing condition, additional investigations was requested to be undertaken for a proposed panel breakwater extension from the lee breakwater into Apollo Bay harbour.

Two proposed marina layouts were proposed by IMC and the requirement was that 'an improved wave climate near the entrance (to these marina extensions), was required to satisfy the good oblique wave conditions for the 1 and 50-years ARI scenarios.'

Cardno undertook initial modelling to assess the panel breakwater length required to ensure the requested compliance with AS3962. These preliminary investigations were termed Case 01, with the final results been categorised as Case 02.



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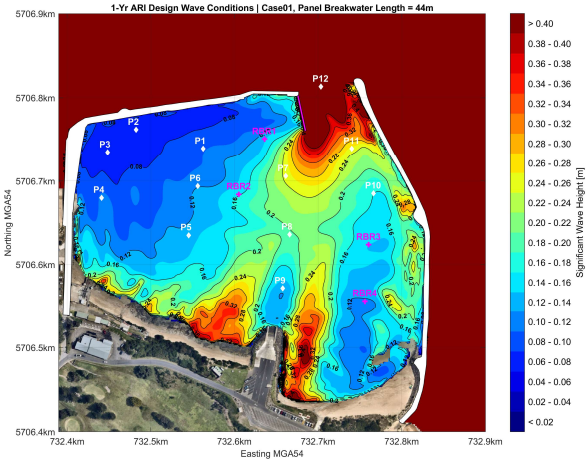
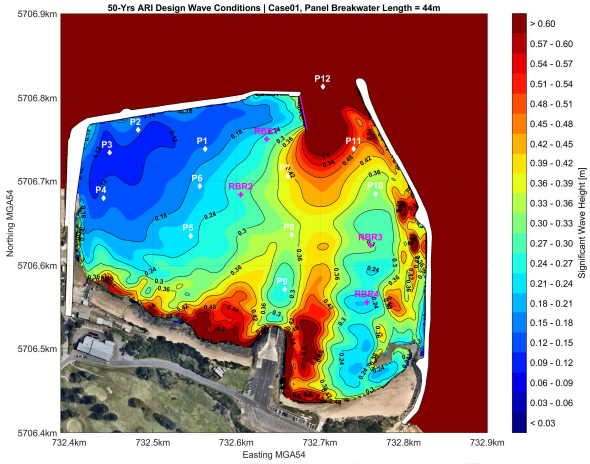
05 Wave Agitation Modelling for Proposed Modification

The modelling results revealed that extending wave screen from the lee breakwater into the harbour would make an area in the harbour entrance experience higher waves – due to reflection from that new wall.





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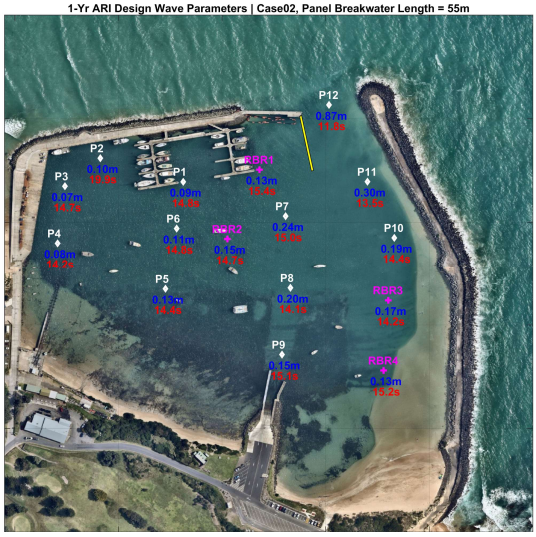
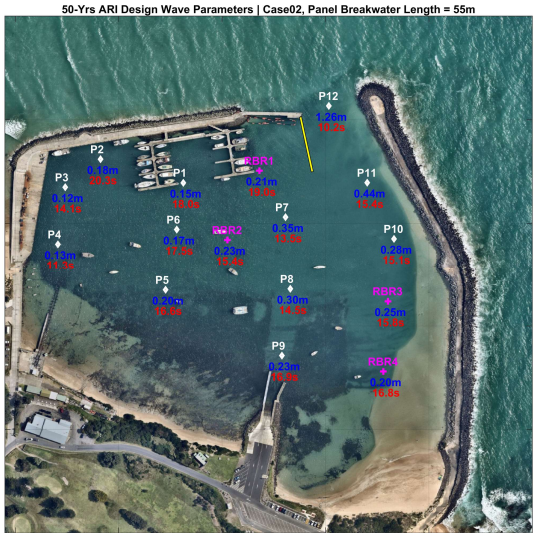
05 Wave Agitation Modelling for Proposed Modification





1-Yr and 50-Yrs ARI design wave conditions (Hs and Tp) at output locations with a full-depth panel breakwater extension of 55m

06 Conclusion

Cardno applied available data and numerical wave modelling to the development of operational and design wave parameters required for the design of marina extension facilities within the Apollo Bay Harbour in south western Victoria.

The modelling included SWAN spectral wave transformation modelling to transform offshore waves to the harbour entrance, as well as applying a detailed phase resolving SWASH model to simulate wave penetration into the harbour.

Design wave heights (H_{m0}) have been determined for a range of ARI, together with associated peak wave periods at nominated output locations.

06 Conclusion

Following the initial investigations for the existing condition, similar investigations were undertaken, but with the inclusion of a panel breakwater arm extending into the harbour from the seaward end of the existing northern panel breakwater and deck.

Initial modelling was undertaken to assess the panel breakwater length required to ensure the requested compliance with AS3962. These preliminary investigations were termed Case 01 with a full-depth panel breakwater extension of ≈44m. The modelling results for Case01 showed that the draft extension of 44m 'just' fulfils AS3962.

Given some uncertainties in wave data and model results, it was decided to adopt a 55m long full-depth panel breakwater 'extension'. The final results were categorised as Case 02 with a full-depth panel breakwater extension of ≈55m.

Note that such a wave screen made an area in the harbour entrance experience higher waves – due to reflection from that new wall.