Wellington International Airport Limited Southern Seawall Renewal Project - Surfbreak Impact Assessment

Numerical Modelling of Impact on Wave Climate and Surf Quality
Final Report Rev. 1.0

DHI Ref. No.: 44802028

September 2, 2025

Prepared for: Wellington International Airport Ltd.

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Approval date:	2 September 2025
Revision:	Final 1.0
Classification:	**Open:** This document may be shared inside and outside the DHI Group entities without the client's prior approval.
File Name:	Wellington International Airport Limited Southern Seawall Renewal Project - Surfbreak Impact Assessment FINAL

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Executive Summary

A numerical modelling study was undertaken to assess the potential impact of the proposed Wellington Airport Southern Seawall Renewal Project (**Project**) on the wave climate, recreational user safety and surf quality of the Corner and Airport Rights surf breaks at Lyall Bay.

A MIKE 3 Wave FM model was developed to assess the Project's impact on wave climate and recreational user safety, while DHI's surfing amenity analysis model, OptiSurf, was utilised to determine potential changes to surfing quality.

Generally, for wave climate, the differences in wave heights are localised to in front of the renewed seawall. Sea level rise will increase the area of larger wave heights in front of the seawall. No wave height differences are apparent at the western beach, middle beach, or the Corner.

Impacts on surf quality have been assessed at the Corner for small, good and exceptional conditions. For all scenarios, it has been concluded that the Project will have no net impact on surf quality at the Corner.

Impacts on surf quality have been assessed at Airports Rights for an exceptional condition. This is because the dangerous nature of Airport Rights means there is only a limited number of surfers that surf this break and there is little evidence of it being surfed apart from when conditions are exceptional. The surf quality analysis indicates a potential slight improvement on the surf quality for this scenario. However, it is uncertain whether reflected waves from the renewed seawall would have a slight positive or negative impact on surf at this location. Detailed CFD modelling might be able to confirm this, however, noting that the break works only under a narrow range of conditions and can get heavy close outs which further limit its use, this further level of modelling has not been pursued.

With regards to recreational user safety, the impacts on the mean wave induced currents are either negligible or localised to the east of the renewed seawall, an area where strong currents in order of 1 m/s already exist.

1 Introduction

Wellington International Airport Limited (WIAL) is progressing planning and design for the Southern Seawall Renewal Project (**Project**). The existing sea defence structures are shown in Figure 1.1, and include:

- Southern Seawall, including 10 tonne and 12 tonne Akmon armour units, rock underlayer and rock fill, constructed in 1972.
- Lyall Bay Breakwater, mass concrete blocks with armour units (12 tonne Akmons, tetrapods) on southern and western faces, built in 1954-1955.
- Western Seawall, steel sheet pile and rock armour, built in 1955-1956 and modified between 1983 and 1987.
- “Eastern Area”, fill material with informal rubble protection, constructed in 1972.

The Project involves renewing the southern seawall only and this is the focus of this report. An example cross section of the proposed renewed southern seawall is presented in Figure 1.2.

It is noted that an amendment to the cross section and design of the southern seawall was issued in January 2025 by BECA, after the primary analysis that informs this report was carried out. The January 2025 version of the cross section and design reflects what is being applied for via the FTAA. DHI has briefly assessed the implications of this design amendment on the numerical modelling results and to the overall findings and conclusions of this study and has found that the results and outcomes of this study remain unchanged and valid, despite the structural amendments. For additional details, the reader is referred to Appendix A.

Figure 1.1 Wellington Airport Sea Defences

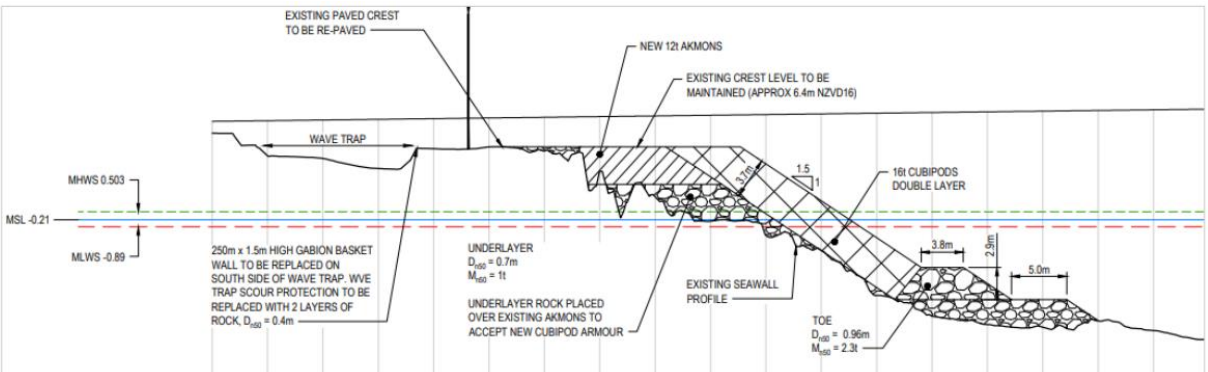


Figure 1.2 Example Cross Sections for Southern Seawall Renewal

WIAL has commissioned DHI to undertake an assessment of the effects of the Project, including in respect to the following:

- Effects on the wave climate;
- Effects on recreational users of the beach (from changes to wave driven currents); and
- Effects on the surf break quality.

This was achieved by developing a detailed wave model of Lyall Bay. For selected wave events the wave climate (phase averaged significant wave height) was compared with and without the proposed renewed seawall

For these wave events, changes to wave induced currents with the proposed renewed seawall have been assessed to determine any implications for recreational user safety.

For selected wave events, the impacts on surfable rides were assessed to determine impacts on surf quality. The main breaks of concern are ‘The Corner’ and ‘Airport Rights’, as shown in Figure 1.3. Middle Beach is not assessed as no impact is to be expected this far away from the proposed renewed seawall.

This report is provided for use to support the application for resource consents and other approvals under the Fast-track Approvals Act 2024 (FTAA) being lodged by WIAL for the Project.

DHI previously undertook a similar impact assessment for a proposed runway extension for WIAL (DHI, 2016 – the extension did not proceed at that time). The 'baseline' environment is largely unchanged since 2016, and the methodology used in this assessment is similar to what was used previously, with some modifications based on new technology available since the original study and/or different requirements to properly simulate the effects of the proposed renewed southern seawall.

Figure 1.3 Lyall Bay surf breaks - The Corner, Airport Rights and Western and Middle beaches

The authors of this report are Danker Kolijn for the wave modelling and Simon Brandi Mortensen for the Optisurf surfing amenity modelling. We have the qualifications and expertise set out in Appendix A and confirm that we have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2023. This report has been prepared in compliance with that code, as if it was expert evidence presented in proceedings before the Environment Court. Unless we state otherwise, this report is within our area of expertise, and we have not omitted to consider material facts known to us that might alter or detract from the opinions expressed in this report.

1.1 Proposed Assessment Scenarios

To assess the relative changes in wave climate and surfing characteristics due to the Project, several wave scenarios have been simulated as part of this study. The proposed modelling scenarios are broken down into two categories:

Wave climate assessment only encompassing the following events:

a) 63% AEP storm (1-year return period event); and

b) 50th percentile wave height.

Wave climate and surf quality assessment encompassing the following events:

a) Small waves for surfing the Corner;

b) Good waves for surfing the Corner;

c) Exceptional waves for surfing the Corner; and

d) Exceptional waves for surfing Airport Rights.

Only exceptional waves have been assessed for surfing Airport Rights. This is because the dangerous nature of Airport Rights means there is only a limited number of surfers that surf this break and there is little evidence of it being surfed apart from when conditions are exceptional.

An assessment for any potential impact on recreational user safety with regards to nearshore wave induced currents has been undertaken. For all simulated scenarios, changes in predicted nearshore wave induced currents, commonly referred to as sweep (longshore) and rip (outgoing cross shore) currents has been calculated.

Further justification for the selection of the wave conditions is presented in Section 4 of this report.

2 Site Data Overview

Multiple datasets have been provided to DHI to support the modelling effort in this study. This section of the report details the specifics of all the data that has been provided.

2.1 Water Levels

Tidal elevations at Lyall Bay are presented in Table 2.1 in both local Chart Datum (CD), and the New Zealand Vertical Datum 2016 (NZVD16). The tidal elevations and conversion from CD to NZVD16 have both been provided to DHI by Beca (2025).

Table 2.1 Tidal elevations at Lyall Bay

Tidal Datum	Tide (m)	
	Chart Datum (CD)	New Zealand Vertical Datum 2016 (NZVD16)
Highest Astronomical Tide (HAT)	1.90	0.64
Mean High Water Springs (MHWS)	1.79	0.53
Mean High Water Neaps (MHWN)	1.48	0.22
Mean Sea Level (MSL)	1.14	-0.12
Mean Low Water Neaps (MLWN)	0.80	-0.46
Mean Low Water Springs (MLWS)	0.53	-0.73
Lowest Astronomical Tide (LAT)	0.43	-0.83

2.2 Sea Level Rise

Two sea level rise (SLR) scenarios have been outlined for this study and provided to DHI by Beca. The two SLR scenarios outlined are for the year 2080 and 2130, which constitute a +1.04 m and +2.19 m increase in water levels respectively.

2.3 Bathymetric Data

A merged bathymetric data set has been provided to DHI by Beca which is derived from the data sources outlined in Figure 2.1. The dataset consists of data at varying resolution with the finest data being a 50 cm DEM in front of both the existing and renewed seawall and the coarsest being approximately 25 m in the offshore area.

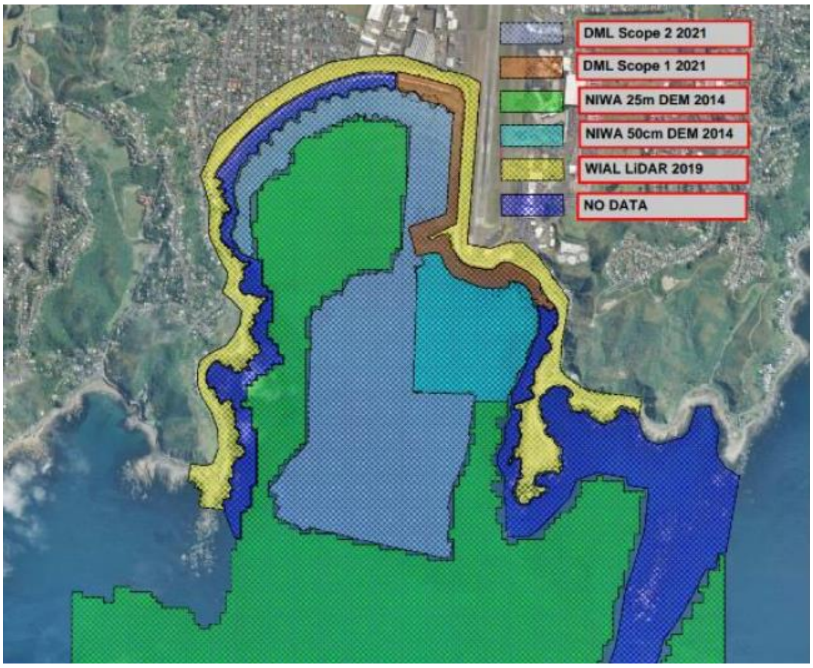


Figure 2.1 Extents of Lyall Bay Surveys

Figure 2.2 outlines the raw scatter dataset that was used to derive the bathymetry for the model. From Figure 2.2 it is apparent that there are several areas that are highly resolved in the bathymetric dataset. The area in front of the Southern Seawall and Western Seawall are highly resolved and the Corner is well resolved. It is noted that there is a limitation of the survey data, which does not cover the wading area between the deeper water and land (green inset in Figure 2.2). The raw survey points were used to derive the model bathymetry further detailed in this report.

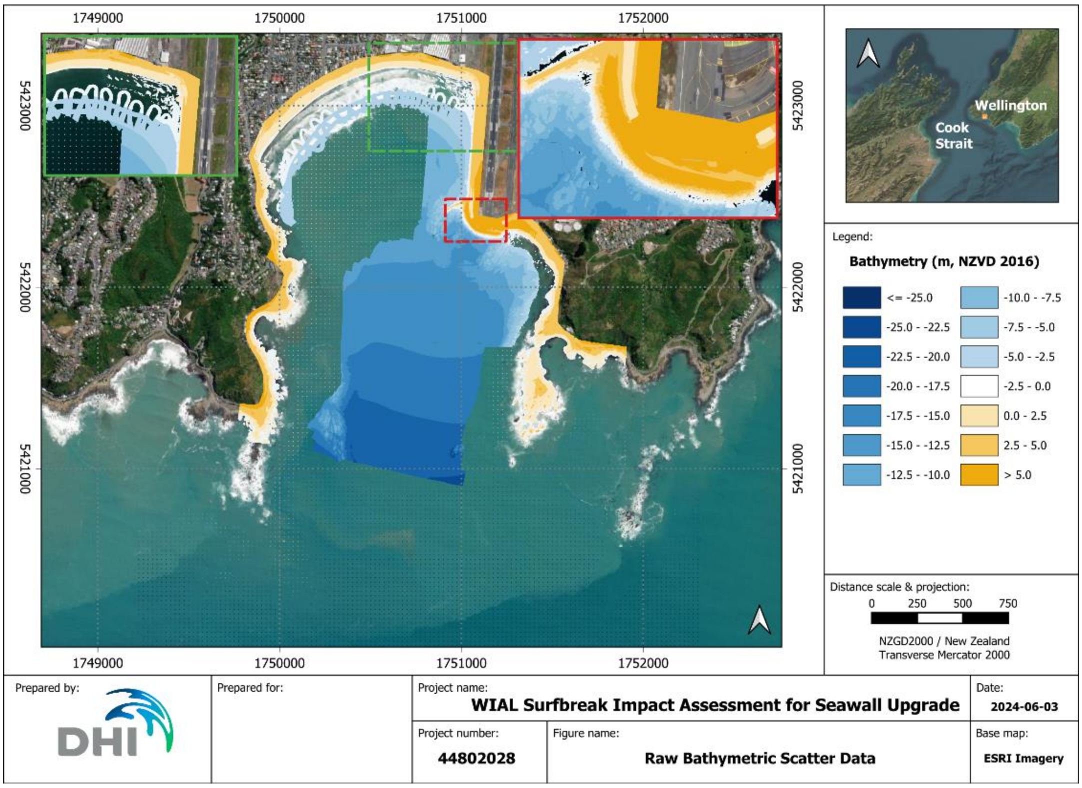


Figure 2.2 Lyall Bay Raw Survey Scatter Data

2.4 Measured Wave Data

Measured wave data was provided to DHI by Beca for calibration and validation of the numerical wave model developed for this study. Figure 2.3 outlines the measured wave data locations, which consists of a Northern and Southern Lander buoy and a Spotter buoy. It is noted that the Spotter buoy changed positions throughout its deployment period and, as such, has two positions dictated on Figure 2.3. The measurement campaign collected wave data for the time period between approximately September 22, 2023, and December 7, 2023.

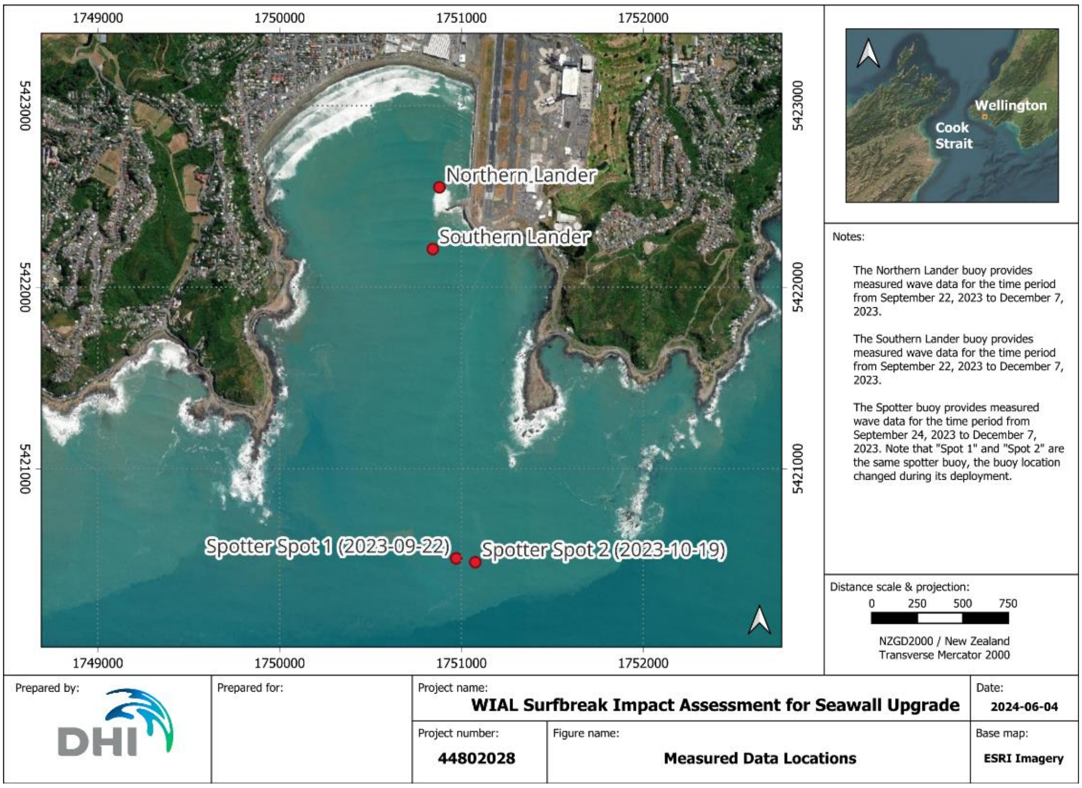


Figure 2.3 Measured Wave Data Locations

Figure 2.4 outlines the timeseries of measured wave conditions at the three buoys. During the measurement campaign the Spotter buoy recorded a maximum wave height of 5.39 m, associated with a wave period of approximately 12.5 s. This event resulted in wave heights of 5.15 m and 3.41 m at the Southern and Northern Lander buoys, respectively. This event suggests that there is not a significant amount of wave energy lost as waves propagate from the Spotter to the Southern Lander buoy; the wave height has decreased by approximately 25 cm (~4.5%) for this peak event. The Northern Lander buoy is slightly more sheltered due to the Lyall Bay Breakwater, which forces waves to diffract around the breakwater before reaching the buoy. The Northern Lander buoy saw a decrease in wave height of approximately 2.0 m (~37%) from the Spotter buoy for this peak event.

Figure 2.5 depicts the wave height roses for the three buoys. All three buoys show that the predominate wave direction aligns with the most exposed fetch, which encompasses the southerly directions. Generally, as waves refract into the bay from the Spotter buoy to the Southern and Northern Lander buoys, the waves tend to align more with the south south-easterly directions.

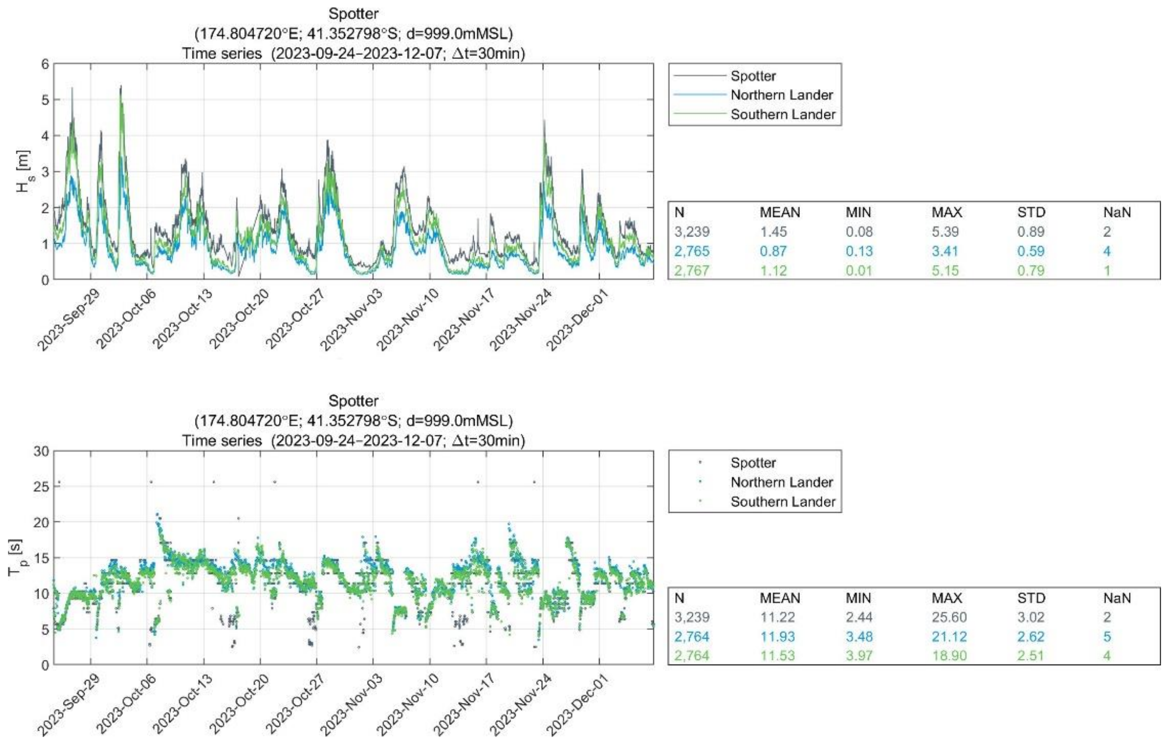


Figure 2.4 Timeseries of measured wave data at Lyall Bay

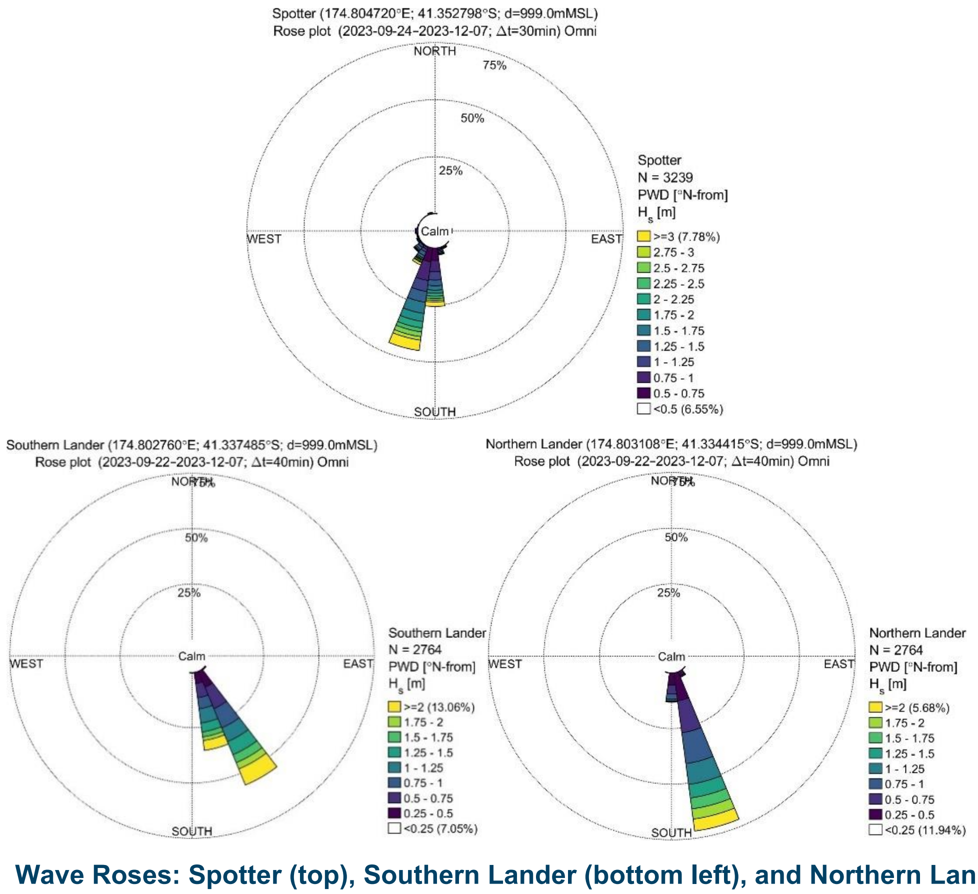


Figure 2.5 Wave Roses: Spotter (top), Southern Lander (bottom left), and Northern Lander (bottom right).

2.5 Offshore Hindcast

An offshore hindcast has been provided by MetOcean Solutions to DHI at the two Spotter buoy locations outlined in Figure 2.3. This offshore hindcast is used to force the numerical wave model developed for this study. The wave hindcast was developed by MetOcean Solutions using a modified version of the Simulating Wave Nearshore (SWAN) spectral wave model. The numerical model was calibrated and validated against measured wave data available at Baring Head near the entrance of Wellington Harbour and the Spotter buoys. Further details about the hindcast and its performance can be found in MetOcean (2024).Figure 2.6 outlines the wave height roses for both Spotter buoy locations. The wave roses demonstrate that both of these locations experience very similar wave climates and that the directions align well with the measured data outlined in Figure 2.5.

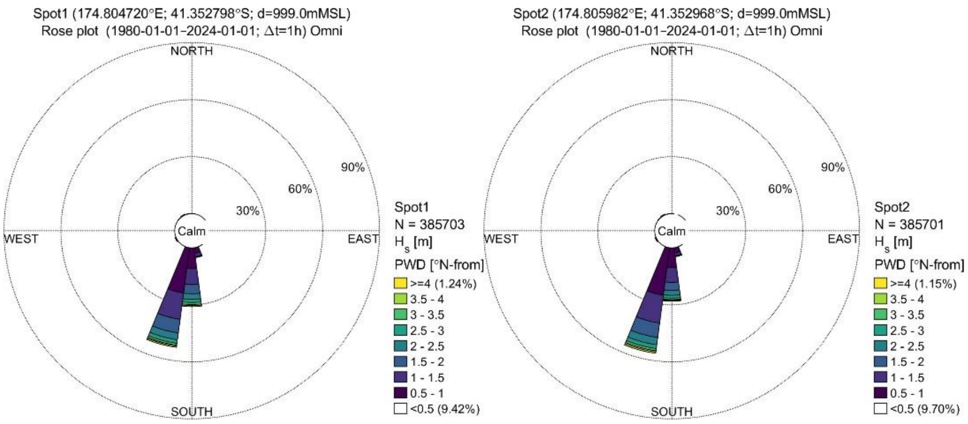


Figure 2.6 Wave Roses: Spotter Location 1 (left) and 2 (right)

3 Modelling Assessment Framework

This section outlines the tools that were used to assess the effects of the proposed renewed southern seawall on wave climate, recreational user safety and surf quality within Lyall Bay.

3.1 MIKE3 Wave FM Model

To investigate the effects on the wave climate, recreational users and surfing quality due to the Project, DHI's MIKE3 Wave FM (M3W) model (DHI, 2024) was used.

A model was required which can represent the proposed renewed southern seawall with a focus on the potential impacts on wave reflection. M3W is most suitable for prediction of this type of detailed wave breaking behaviour. The model can accurately represent porous structures like breakwaters, sea defences and beaches with natural porosity and provides the ability to calculate wave transmission and wave reflection with more confidence than traditional nearshore wave models.

The M3W model is a phase-resolved non-hydrostatic wave model based on the 3D Navier-Stokes equations with a free surface described by a height function. The model is capable of simulating the following processes:

- Shoaling, refraction, and diffraction;
- Partial reflection and transmission;
- Bottom dissipation;
- Wave breaking;
- Wave runup and overtopping;
- Frequency and directional spreading; and
- Wave-wave and wave-current interaction.

In the M3W model, dynamic and phase resolving wave/current interaction is incorporated implicitly into the governing equations and as a result time averaged wave driven currents can be extracted automatically. Comparisons in time averaged wave induced currents can be assessed to predict impacts on recreational user safety.

3.1.1 Model Parameterisation

Mesh Resolution and Bathymetry

Two M3W meshes were developed with high resolution in either the Corner or Airport Rights surfing zone and coarser resolution offshore. One mesh was developed for the Corner surfing waves and the second mesh was developed for the Airport Right waves. The model utilised a resolution of approximately 3 m offshore and 1.5 m within the surfing zones (either the Corner or Airport Rights) as shown in Figure 3.1. The zoomed area of interest in the figure below does not cover the whole surf zone, rather it provides an indication of model resolution for these key locations.

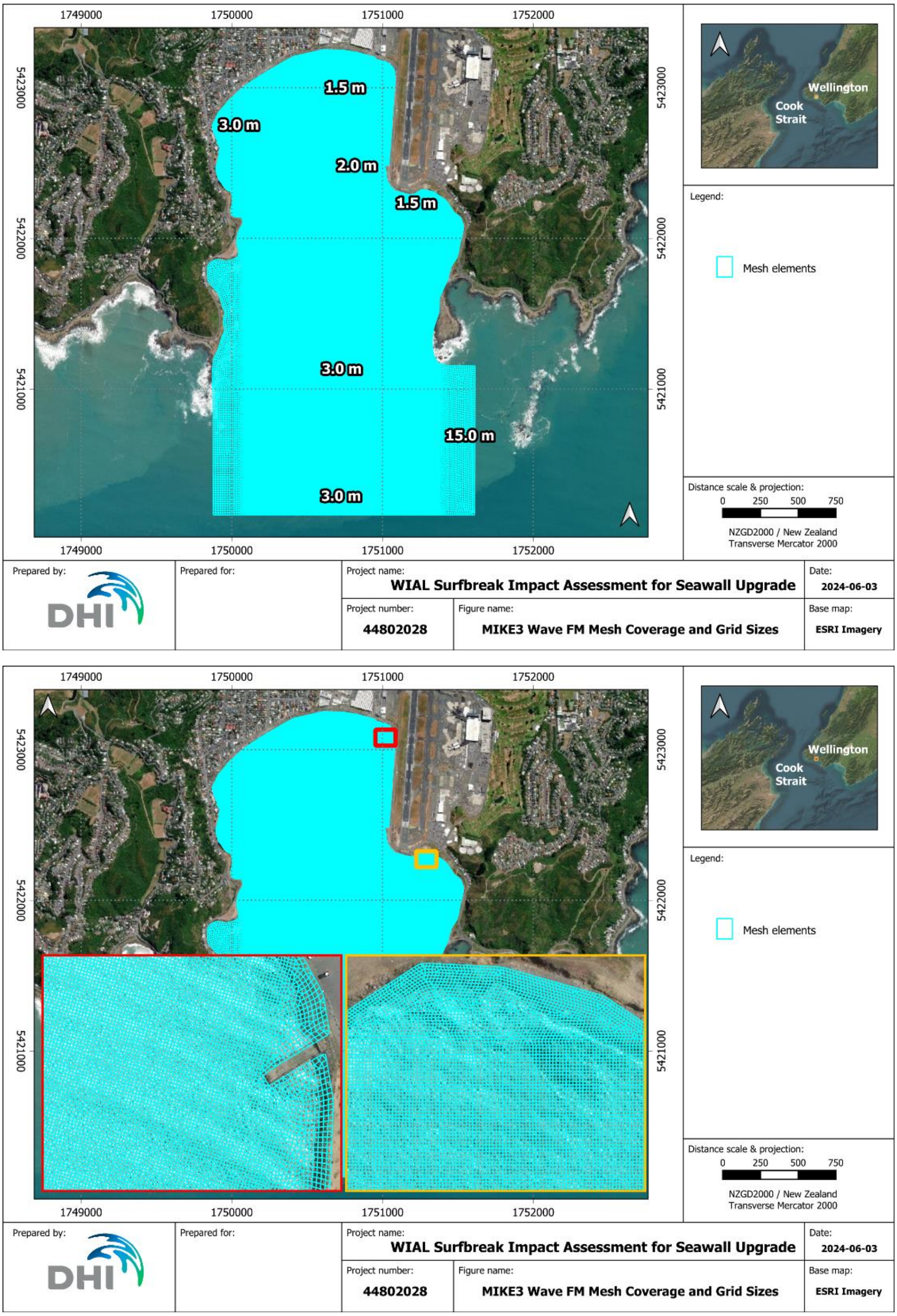


Figure 3.1 M3W Mesh Resolution (top) and Zoomed in Area of Interest (bottom)

The bathymetric data outlined in Section 2.3 was interpolated onto the model mesh shown in Figure 3.1. The interpolated bathymetric data is depicted in Figure 3.2.

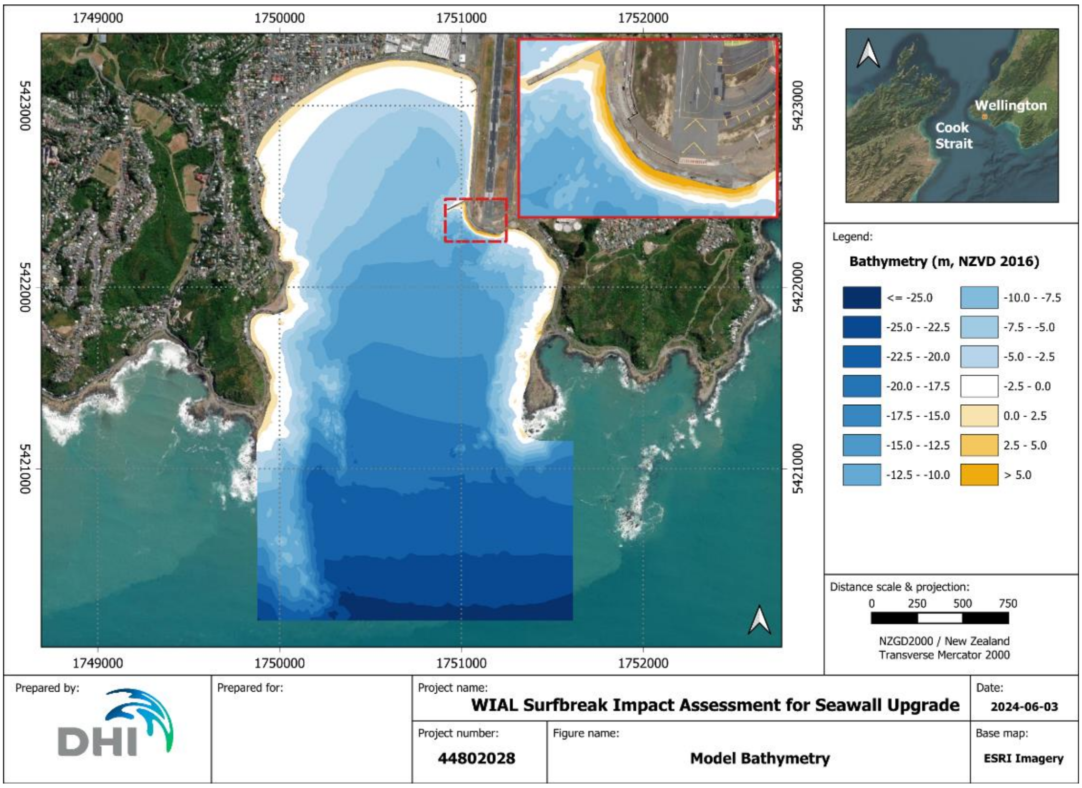


Figure 3.2 Interpolated Bathymetric Data

Wave Generation

An internal wave generation line was placed within the model domain at the boundary with spectral data defined by the offshore wave hindcast (Section 2.5) for the scenarios outlined in Section 4.1. Figure 3.3 depicts the input wave energy density spectra from the offshore hindcast for each wave scenario.

The model resolves a frequency range of 0.03 Hz (33.33 s) at the minimum and 0.3 Hz (3.33 s) at the maximum. It utilizes 946 Fourier components and allows for a maximum deviation of 45° from the main wave direction.

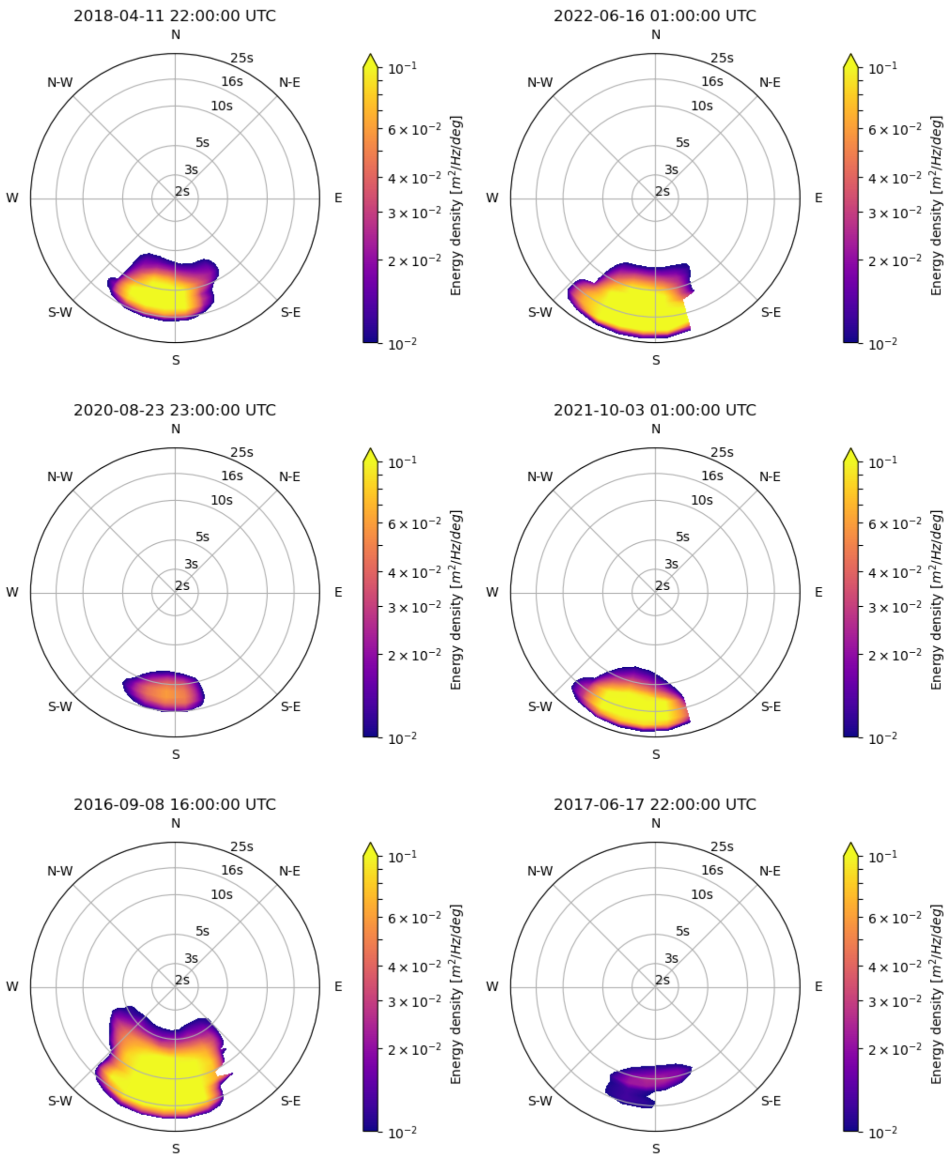


Figure 3.3 Input Wave Energy Density Spectra
Exceptional Airport Rights (top left), Exceptional Corner (top right), Small Corner (middle left), Good Corner (middle right), 63% Annual Storm (bottom left), and 50th Percentile Wave (bottom right).

Porosity

Porosity in M3W is used to model partial reflection, absorption, and transmission of wave energy at porous structures. The M3W model defines porosity as the volumetric porosity of a solid. Figure 3.4 outlines the four areas in the model domain that have been identified as porous structures: (1) Revetment; (2) Outfall; (3) Breakwater; (4) Seawall.

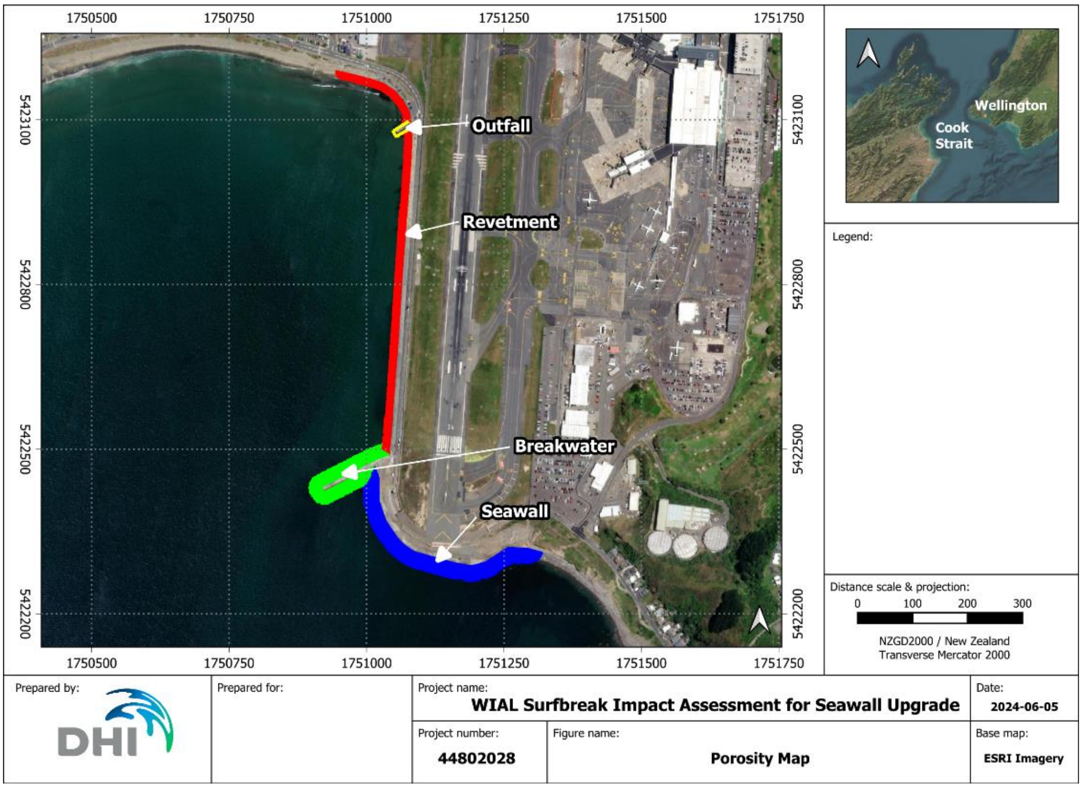


Figure 3.4 Model Porosity Zones

The following assumptions have been made regarding the porosity of the existing structures using DHI's experience on similar projects and applications of M3W:

- The existing revetment has a porosity of 0.75.
- The outfall has a porosity of 0.99.
- The breakwater has a porosity of 0.65.
- For the seawall, two porosity values where used:
  - The existing southern seawall consists of Akmon units which under ideal conditions have a reported porosity of 0.60 (Paape & Walther,1962). Given that the Akmon units along the seawall have shifted over time, resulting in greater void spacing and irregular distribution of units along the face, it is assumed that porosity is slightly higher than those under idealized conditions. Therefore, a porosity of 0.68 was utilized for the existing southern seawall, based on a recommended limit as per Paape & Walther (1962).
  - For the proposed renewed southern seawall a porosity of 0.40 was utilised. This is based on the assumption of double layer of Cubipod armour units. This value was selected as the median between a "closed arrangement" and "open arrangement" which have a porosity of approximately 0.30 and 0.50, respectively (Medina & Gómez-Martín, 2016).

3.1.2 Model Validation

Sensitivity to Simulation Duration

A sensitivity test was conducted to evaluate the impact of model simulation duration on significant wave height. The model was run for a simulation time of 90 minutes, and significant wave height was monitored at the Corner, Northern Lander Buoy, and Southern Lander Buoy. Figure 3.5 illustrates the variation of significant wave height over the model simulation time. Generally, the model spin-up period is present within the first 30 minutes of simulation time, indicated by the variation in wave heights. After

30 minutes the significant wave height fluctuates by approximately +/- 10cm, indicating that the wave height is stable after 30 minutes of simulation time. All models were run for a total of 60 minutes to ensure that the surfing analysis utilised a stable wave climate.

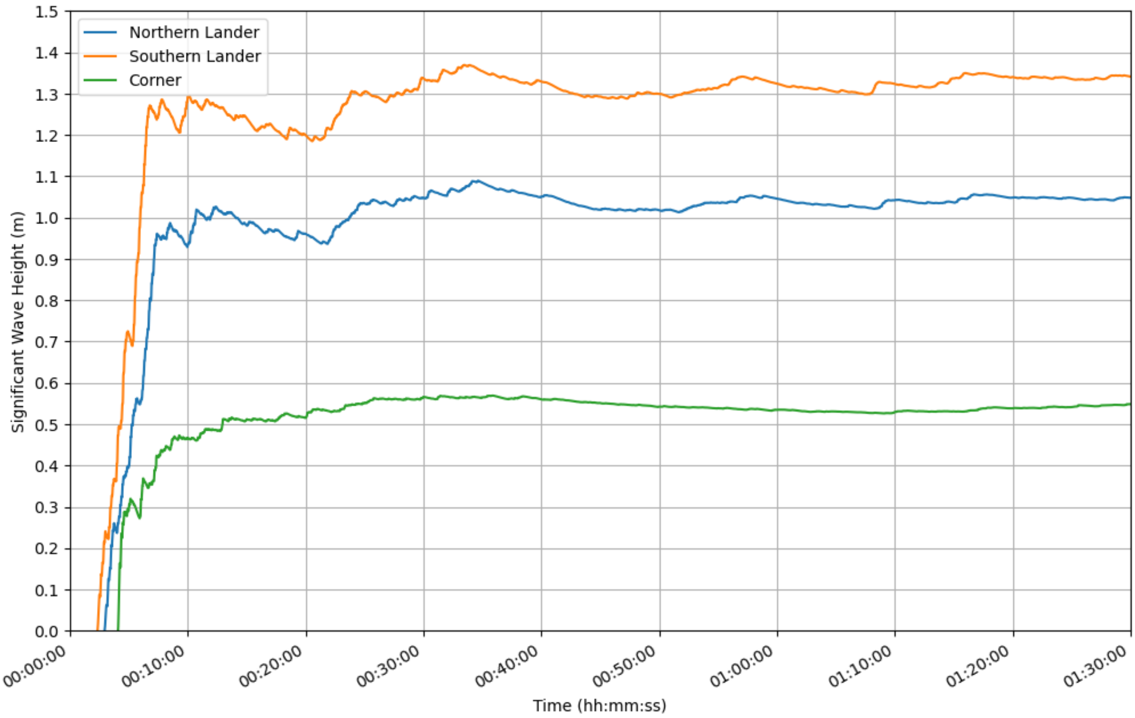


Figure 3.5 Model Sensitivity to Simulation Time

Validation to Specific Wave Events

The M3W model was validated at the Spotter, Southern Lander, and Northern Lander buoys for three observed wave events. The boundary conditions for the model were derived from the hindcast presented in Section 2.5. The model assumes a constant water level of 0 m, MSL and no additional total water level was applied to the domain. Note that the hindcast timeseries reports wave spectra at regular intervals (1 hourly), whereas the buoys do not report data exactly on the hour. Therefore, to evaluate the model's performance against the observed data, three specific measurement periods were compared. For each event the measured timestamp closest to the hindcasted timestamp was compared to the model, with an additional buffer of +/- 1 timestamp in the measurements to bound the model results.

The three validation events and their wave offshore wave characteristics are described in Table 3.1.

Table 3.1 Description of M3W Validation Events

Hindcast Timestamp	Significant Wave Height, Hs (m)	Peak Wave Period, Tp (s)	Mean Wave Direction, MWD (°)
Dec 5th, 2023, 01:00 UTC	1.57	12.5	190
Oct 27th, 2023, 20:00 UTC	2.56	12.5	190
Oct 2nd, 2023, 18:00 UTC	5.25	12.5	187

Table 3.2 outlines the significant wave height comparison between the modelled and measured results for all three events. At the Spotter buoy location, the model accurately captures the wave height measured for all three events. This result implies that M3W is generating the correct input wave spectra, as the wave generation line in the model is located near to the Spotter buoy location.

At the Southern Lander buoy, the model tends to overestimate for the smaller wave height events (Dec 5th and Oct 27th), while underestimating the wave heights for the large event (Oct 2nd). This trend is also apparent at the Northern Lander buoy as well.

For the larger wave event, the model tends to underestimate wave heights. This underestimation may be attributed to the numerical scheme used to represent wave breaking within the model. For breaking waves, the model uses a shock capturing scheme to dissipate the wave energy. This shock capturing scheme could be leading to over-dissipation of energy when compared to the wave heights observed in measurements. Additionally, the model was run at a 0 m, MSL water level and for this large event a high tide or surge could impact how the waves are propagated to the buoy.

For the smaller wave events, the model tends to overestimate the wave heights. This overestimation could be attributed to seabed features or benthic habitat that are not included in the bathymetric dataset provided to DHI. Seabed features and bed roughness can play a role in the waves experienced at the Northern and Southern Lander buoys.

Further details on the water levels at the time of these events, seabed characteristics, and local benthic habitat could provide insights into why the model is overestimating the smaller wave events and underestimating the larger wave events. It is important to note that the primary objective of this study is to evaluate the relative performance of the existing southern seawall compared to the proposed renewed southern seawall. Therefore, while the exact wave height magnitudes relative to measurements are informative and give confidence on the model's performance, they are not the primary focus. Given this context, the model is considered acceptable for the purposes of this study.

Table 3.2 M3W Validation Performance, Significant Wave Height (m)
Measured +/- 1 indicates the closest measured timestep +/- 1 timestep.

Event	Location	M3W	Measured - 1	Measured	Measured + 1
Dec 5th	Spotter	1.56	1.57	1.62	1.49
	Southern Lander	1.40	1.15	1.15	1.27
	Northern Lander	1.14	0.84	0.84	0.95
Oct 27th	Spotter	2.56	2.51	2.61	2.56
	Southern Lander	2.31	1.80	1.78	1.77
	Northern Lander	1.84	1.33	1.30	1.38
Oct 2nd	Spotter	5.15	5.09	5.39	4.68
	Southern Lander	4.37	3.91	5.15	4.69
	Northern Lander	2.20	2.78	3.41	3.25

3.2 OptiSurf Surfing Amenity Modelling

Overall Description and Methodology

OptiSurf developed by DHI utilises the instantaneous M3W model wave output of surface elevation and the turbulent kinetic energy to track the moving transition point between unbroken and broken waves. Each of these points are classified as 'take-off points' if the wave steepness is large enough to complete a take-off or alternatively these would be classified as 'pocket points' if not steep enough to complete take-off but steep enough for the surfer to sustain momentum from the wave.

For each time step, OptiSurf stiches together valid take-off points and pocket point combinations that are below maximum specified thresholds for maximum surfer speed and acceleration. When no valid pocket points can be connected to a surf ride, it is terminated, and the total ride characteristics logged. Through this method multiple surf rides are tracked concurrently, which each represent all the alternative approaches to surf each wave with regards to choice of take-off location and speed profile throughout the ride.

Output from OptiSurf can be used to undertake a comparative assessment between each layout examined. Model output is assessed for surf quality (or surfability) of a given break, which can be quantified by the following key parameters:

- Wave height;
- Length of wave ride; and
- Recurrence or frequency.

Figure 3.6 presents a depiction of surfable wave steepness characteristics and an example of a OptiSurf output from a Computational Fluid Dynamic (CFD) model output.

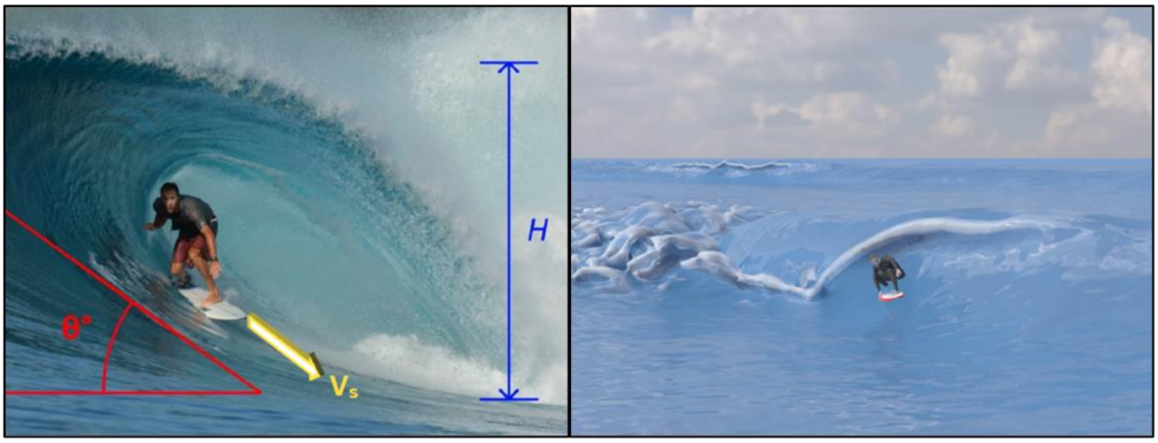


Figure 3.6 Depiction of surfable wave steepness characteristics (left) and example OptiSurf output CFD output (right)

Most recreational surfers surf waves from 1 m to 5 m. Breaker shape can be classified under the four (4) categories: spilling, plunging, collapsing, and surging. Of the four (4) classifications, spilling waves are only desired by early-stage beginners while plunging waves are desirable for all other surfers. Collapse and surging waves are generally deemed not surfable. For a wave to be surfable the wave must break progressively along the wave crest. The speed with which this happens is called the ‘peel rate’ of the wave. Along with the peel rate, the associated peel angle is defined as the angle enclosed by the wave crest and the breaker line, where the value of the peel angle needs to be sufficiently large in order for a wave to be surfable. The level of difficulty is also gauged by peel angle whereby larger peel angles create slower breaking waves suitable for beginners (60-70°) and smaller angles create (<27°) create waves suitable for highly advanced surfers.

As part of this study, OptiSurf was used to assess and compare surfing conditions for the range of wave scenarios listed in Table 4.1, for both existing and proposed conditions (i.e., with the existing seawall and with the proposed renewed seawall) This was done to compare the change in overall surfability after the proposed renewed seawall has been constructed. Both the Corner and Airport Rights areas were considered in the OptiSurf analysis.

Figure 3.7 shows the extents of the model domain areas that were considered for both analysis regions.

Figure 3.7 Extents of the model domain area that were considered for both analysis regions

For both locations, the pertinent wave conditions listed in Table 4.1 of Section 4.1 had both surface elevation and turbulent kinetic energy extracted. The turbulent kinetic energy was used to mark the transition between breaking and unbreaking waves, and the surface elevation was used to drive the physics-based surf ride generation algorithm described above. The assessment was done using outputs from the M3W model extracted at one second regular intervals, and for up to thirty minutes of stabilised wave conditions at each location.

The output of the OptiSurf model is a series of surf rides including a time series of their coordinates, horizontal and vertical speed, wave face height, horizontal and vertical angle, as well as statistics such as overall ride length and maximum wave face height.

4 Wave Climate, Recreational User and Surf Quality Assessment

This section of the report uses the numerical modelling framework established in the previous section to describe any relative changes in wave climate, wave induced currents and surfing characteristics due to the proposed renewed southern seawall.

4.1 Wave Climate and Surfing Scenario Selection

As identified in Section 1.1, several scenarios are proposed to assess the relative changes in wave climate and surfing characteristics due to the Project. The wave parameters identified for each scenario are derived from the hindcast results at the Spotter buoy presented in Section 2.5.

The modelling scenarios are broken down into two categories:

Wave climate assessment only encompassing the following events:

a) 63% AEP storm (1-year return period event); and

b) 50th percentile wave height.

Wave climate and surf quality assessment encompassing the following events:

a) Small waves for surfing the Corner;

b) Good waves for surfing the Corner;

c) Exceptional waves for surfing the Corner; and

d) Exceptional waves for surfing Airport Rights.

For all simulated scenarios, changes in nearshore wave induced currents, commonly referred to as sweep (longshore) and rip (outgoing cross shore) currents, have been predicted to assess any potential impact on recreational user safety.

The wave climate assessment conducted for the 1-year return period event and the 50th percentile wave height are based on the hindcasted waves at the Spotter buoy locations (Figure 2.3). Beca has specified that the 1-year return period storm event has a significant wave height of 5.61 m, no peak wave period or direction were provided. As no peak wave period or direction were specified, an event was found within the hindcasted timeseries at the Spotter location that had a significant wave height of 5.61 m and was associated with a peak wave period in the order of 12.5 s.

The peak wave period was calculated from the 50th percentile best fit line of the significant wave height and peak wave period scatter shown in Figure 4.1. In the hindcast timeseries supplied at the Spotter, an event that represents these wave parameters occurred on September 8th, 2016, at 16:00 UTC and has a significant wave height of 5.63 m, peak wave period of 12.9 s, and peak wave direction of 185°.

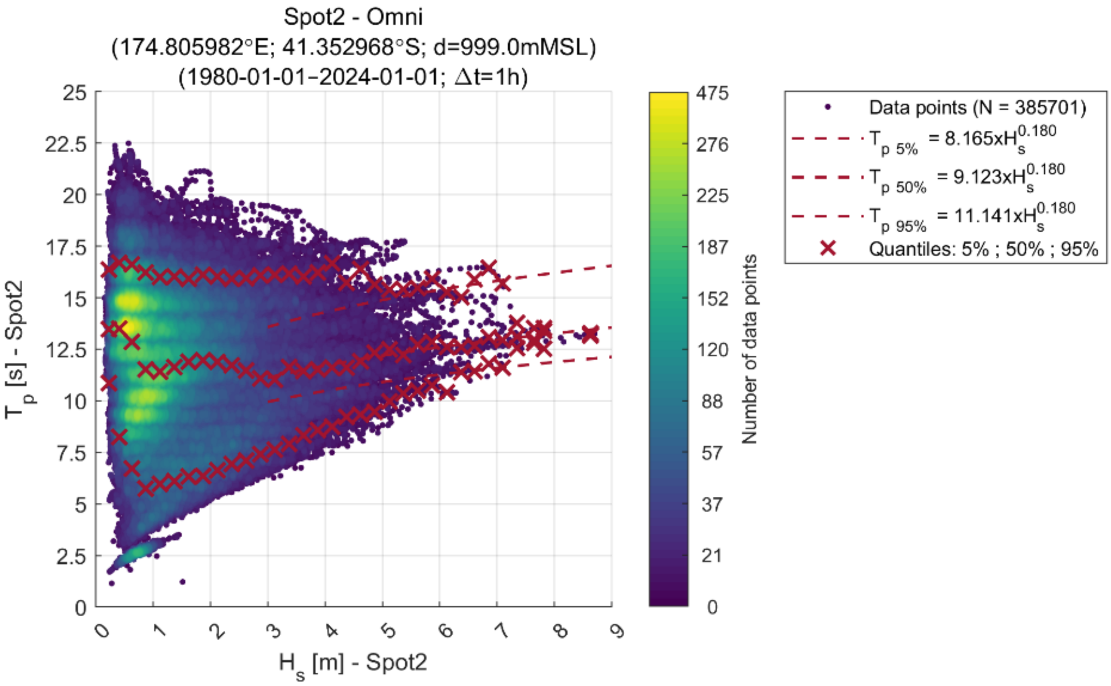


Figure 4.1 Hindcast Significant Wave Height and Peak Wave Period Scatter at the Spotter Spot 2

The 50th percentile wave height event has been specified by Beca as having a significant wave height of 1.01 m and peak wave period of 10.27 s, no direction was provided. In the hindcast timeseries supplied at the Spotter, an event that represents these wave parameters occurred on June 17th, 2017, at 22:00 UTC and has a significant wave height of 1.01 m, peak wave period of 10.3 s, and peak wave direction of 181°.

Through consultation with members of the Wellington Boardriders Club, photos of when surfing was possible at Lyall Bay were provided along with a time stamp. The following wave conditions were requested for investigation by the members of the Wellington Boardriders Club:

- small Corner;
- good Corner; and
- exceptional Airport Rights.

The time and date to simulate was provided by the Wellington Boardriders Club. The timestamp of the events (either provided specifically by Wellington Boardriders Club or from the time stamp from a photo) have been used to extract the wave conditions from the hindcast.

The small wave conditions at the Corner are identified as an event occurring on August 23rd, 2020, at 23:00 UTC with a significant wave height of 1.28 m, peak wave period of 12.5 s, and peak wave direction of 186°.

The good wave conditions at the Corner are identified as an event occurring on October 3rd, 2021, at 01:00 UTC with a significant wave height of 2.12 m, peak wave period of 16.5 s, and peak wave direction of 188°. The Wellington Boardriders Club had indicated that this was an exceptional event, however the hindcast does not match wave conditions of what would be considered exceptional, hence why DHI selected an additional event from the photos, where the hindcast and photos aligned for what would be considered exceptional.

An exceptional Corner wave was identified by DHI from the provided photos of surf events. Figure 4.2 demonstrates the small and exceptional wave conditions at the Corner.

The exceptional wave conditions are identified as an event occurring on June 16th, 2022, at 01:00 UTC with a significant wave height of 3.73 m, peak wave period of 16.6s, and peak wave direction of 187°.

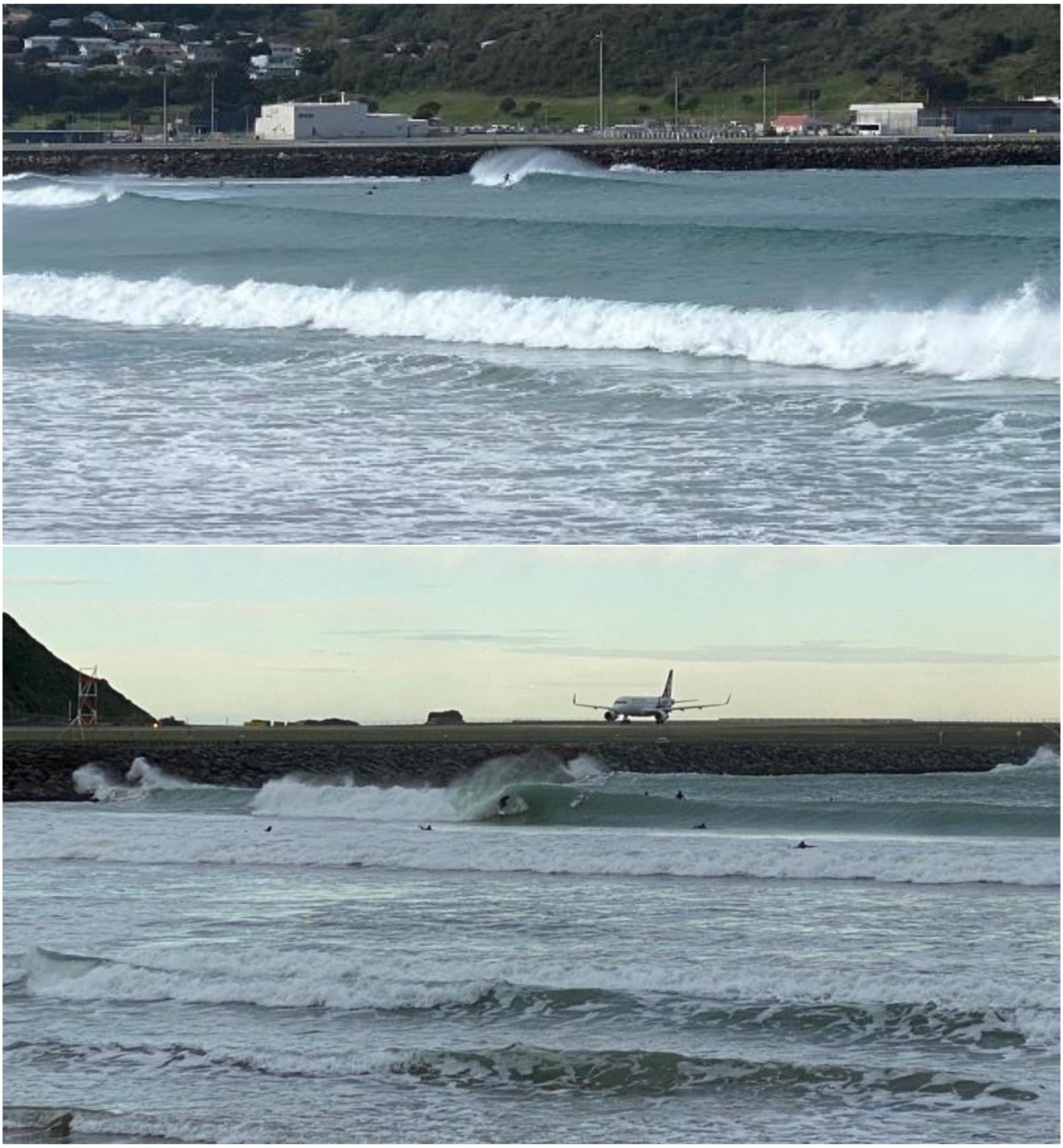


Figure 4.2 Small (top) and Exceptional (bottom) Corner Wave Events

Figure 4.3 demonstrates the exceptional wave conditions at the Airport Rights. The exceptional wave conditions are identified as an event occurring on April 11th, 2018, at 22:00 UTC with a significant wave height of 2.60 m, peak wave period of 12.45s, and peak wave direction of 186°.

Table 4.1 details the full list of simulations that were run for the wave climate and surfing assessment. It is noted that all events were run at different water levels and for different sea level rise conditions as identified in Table 4.1.

Figure 4.3 Exceptional Airport Rights Wave Event

Table 4.1 Full Simulation Matrix Details

<table>
<tr><th>Scenario</th><th>Existing or Proposed Southern Seawall</th><th>Tide (m, NVZD16)</th><th>Sea Level Rise (m)</th><th>Assessment Type</th></tr>
<tr><td rowspan="4">63% Annual Storm</td><td rowspan="2">Existing</td><td rowspan="4">-0.12</td><td>-</td><td rowspan="4">Wave climate</td></tr>
<tr><td>+2.19</td></tr>
<tr><td rowspan="2">Proposed</td><td>-</td></tr>
<tr><td>+2.19</td></tr>
<tr><td rowspan="4">50th Percentile Wave Height</td><td rowspan="2">Existing</td><td rowspan="4">-0.12</td><td>-</td><td rowspan="4">Wave climate</td></tr>
<tr><td>+2.19</td></tr>
<tr><td rowspan="2">Proposed</td><td>-</td></tr>
<tr><td>+2.19</td></tr>
<tr><td rowspan="2">Exceptional Corner Waves</td><td>Existing</td><td rowspan="2">-0.12</td><td rowspan="2">-</td><td rowspan="2">Wave climate, surfing quality</td></tr>
<tr><td>Proposed</td></tr>
<tr><td rowspan="8">Good Corner Waves</td><td rowspan="4">Existing</td><td rowspan="3">+0.53</td><td>-</td><td rowspan="8">Wave climate, surfing quality</td></tr>
<tr><td>+1.04</td></tr>
<tr><td>+2.19</td></tr>
<tr><td>-0.73</td><td>-</td></tr>
<tr><td rowspan="4">Proposed</td><td rowspan="3">+0.53</td><td>-</td></tr>
<tr><td>+1.04</td></tr>
<tr><td>+2.19</td></tr>
<tr><td>-0.73</td><td>-</td></tr>
</table>

Scenario	Existing or Proposed Southern Seawall	Tide (m, NVZD16)	Sea Level Rise (m)	Assessment Type
Small Corner Waves	Existing	+0.53	-	Wave climate, surfing quality
		-0.73		
	Proposed	+0.53		
		-0.73		
Exceptional Airport Rights	Existing	+0.53	-	Wave climate, surfing quality
		-0.73		
	Proposed	+0.53		
		-0.73		

4.2 Assessment of Effects on the Wave Climate and Recreational User Safety

The following section assesses changes to the nearshore wave climate attributed to the proposed renewed southern seawall, relative to existing conditions. The impact to surfing amenity is not addressed in this section but is assessed in Section 4.3. The impact of renewing the seawall on the wave climate is assessed for the 63% AEP storm and the 50^{th} percentile wave height events as described in Section 4.1. Difference plots for significant wave height and mean wave induced current speed are presented in this section, while the underlying significant wave height and mean current speed results for each individual scenario are presented in Appendix C.

Figure 4.4 and Figure 4.5 outline the differences in the height of significant waves and current speeds between existing and proposed conditions (i.e. with the existing seawall and with the renewed seawall) for the 63% AEP storm. Figure 4.4 presents the no SLR condition, while Figure 4.5 outlines the 100-year SLR condition. The wave height differences demonstrate that directly in front of the seawall, the wave heights can vary in the order of +/- 0.4 m. At the Airport Rights, the wave heights are approximately 0.1 – 0.2 m higher with the proposed renewed seawall compared to the existing seawall.

These results are expected, as the proposed structure is less porous, leading to a larger reflected wave when compared to a more porous structure. The 100-year SLR condition results in a larger area of increased wave heights when compared to the no SLR condition.

The current speed differences between existing and proposed conditions are minimal for the 100-year SLR condition (Figure 4.5), with variations in the order of +/- 0.2 m/s to the area to the east of the proposed renewed southern seawall (along Moa Point Road). This is an area of strong wave induced currents (in order of 1 m/s) in the existing situation and is thus already a concern for recreational user safety, regardless of the noted current speed variations attributed to the proposed renewed southern seawall.

For the no SLR condition, there is almost no current speed differences between proposed and existing conditions (see Figure 4.4). No differences in wave height or current speed are noted at the western beach, middle beach, or the Corner.

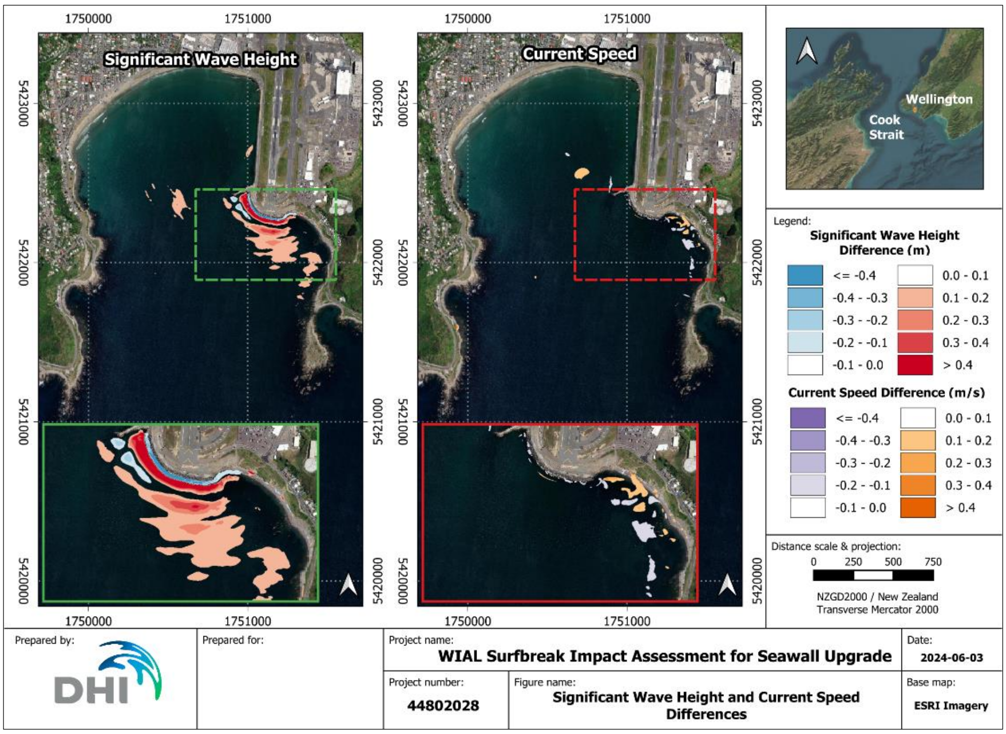


Figure 4.4 63% AEP Storm Wave Height and Current Speed Differences – No SLR
Significant wave height and current speed difference maps represent the existing seawall results subtracted from the proposed renewed seawall results. A positive value indicates that the proposed renewed seawall results have larger values than the existing seawall results.

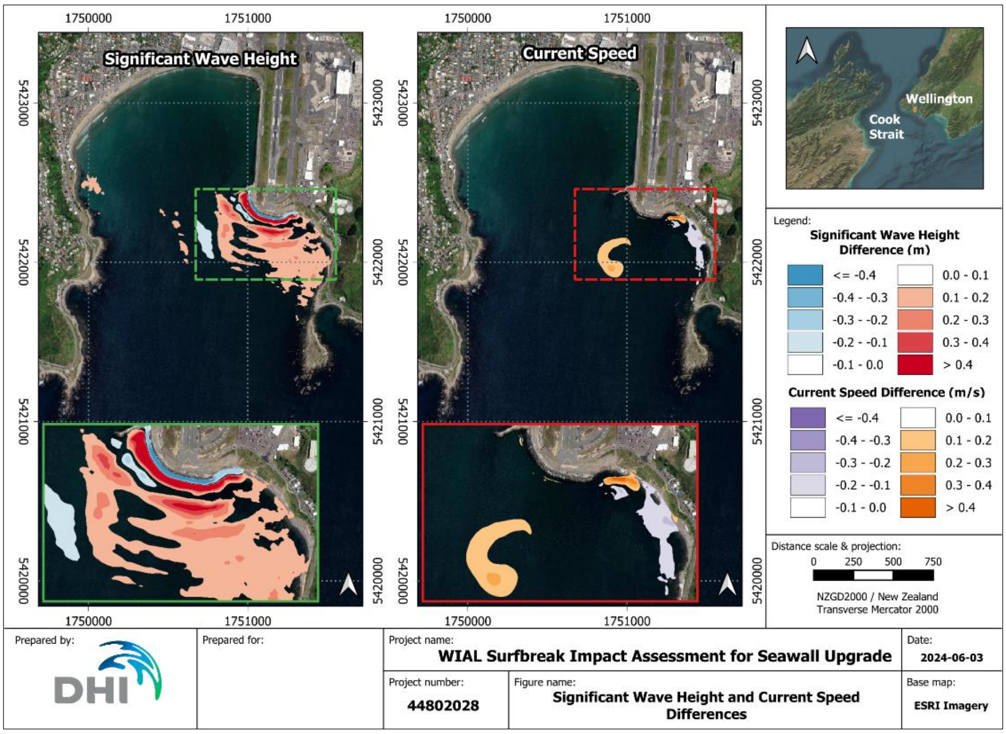


Figure 4.5 63% AEP Storm Wave Height and Current Speed Differences – 100-SLR
Significant wave height and current speed difference maps represent the existing seawall results subtracted from the proposed renewed seawall results. A positive value indicates that the proposed renewed seawall results have larger values than the existing seawall results.

Figure 4.6 and Figure 4.7, outline the significant wave height and current speed differences between the existing and proposed conditions for the 50th percentile wave condition. Figure 4.6 presents the no SLR condition, while Figure 4.7 outlines the 100-year SLR condition.

Observing both figures, it is apparent that for the 50th percentile wave height, there are almost no differences in current speeds. Wave height differences are localised to directly in front of the seawall, no differences are apparent at the western beach, middle beach, or the Corner.

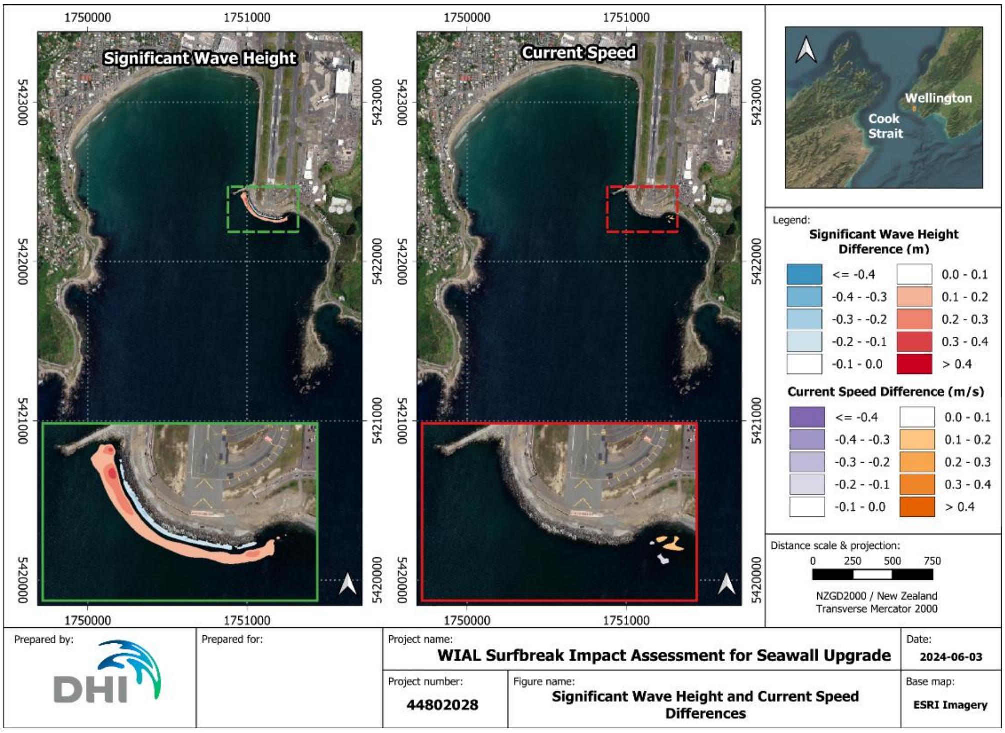


Figure 4.6 50th Percentile Wave Height and Current Speed Differences – No SLR
Significant wave height and current speed difference maps represent the existing seawall results subtracted from the proposed renewed seawall results. A positive value indicates that the proposed renewed seawall results have larger values than the existing seawall results.

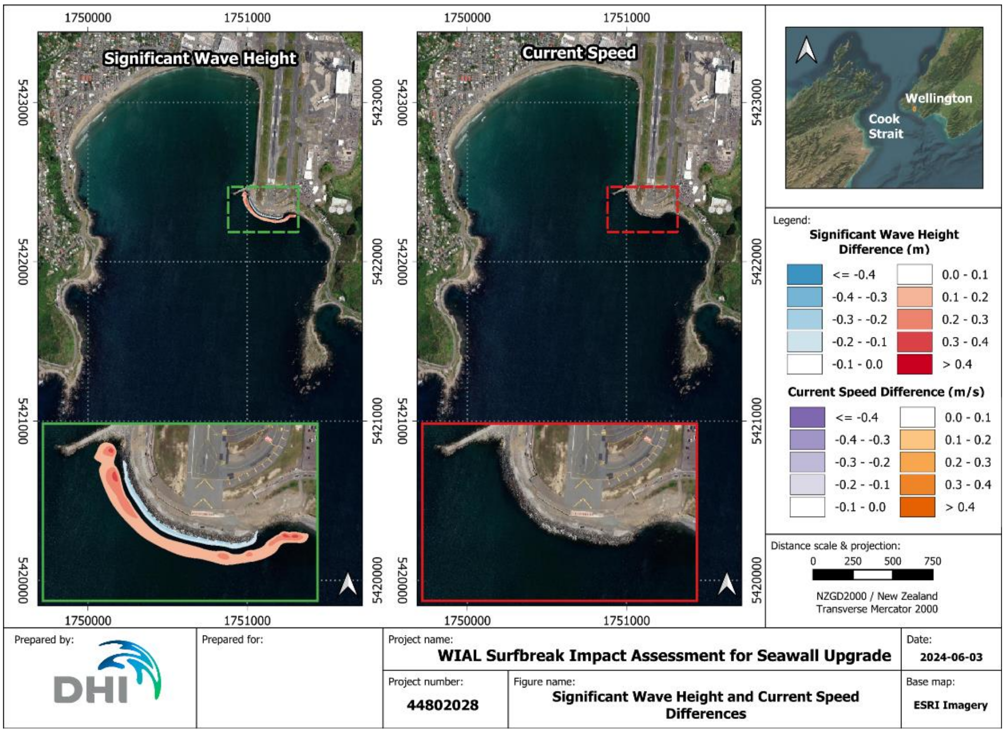


Figure 4.7 50th Percentile Wave Height and Current Speed Differences – 100-SLR
Significant wave height and current speed difference maps represent the existing seawall results subtracted from the proposed renewed seawall results. A positive value indicates that the proposed renewed seawall results have larger values than the existing seawall results.

Generally, for both wave events the differences in wave heights are localised to in front of the seawall and for current speeds for the area to the east of the seawall (along Moa Point Road). The proposed renewed southern seawall results in slightly larger waves due to the structure being less porous than the existing structure. SLR increases the area of larger wave heights in front of the seawall.

4.3 Assessment of Effects on Surf Quality

Difference plots for significant wave height and mean current speed are presented in the main body of report in the following sub-sections, while the underlying significant wave height and current speed results for each individual scenario are presented in Appendix C.

4.3.1 Wave Conditions (M3W Model)

Small Corner Wave Event

Figure 4.8 and Figure 4.9, outline the significant wave height and mean current speed differences between the existing and proposed conditions for the small Corner surfing wave condition. Figure 4.8 presents the MLWS tidal condition, while Figure 4.9 outlines the MHWS tidal condition. Observing both figures, it is apparent that for the small Corner surfing wave event, there are almost no differences in current speeds. Wave height differences are localised to directly in front of the seawall, no differences are apparent at the western beach, middle beach, or the Corner.

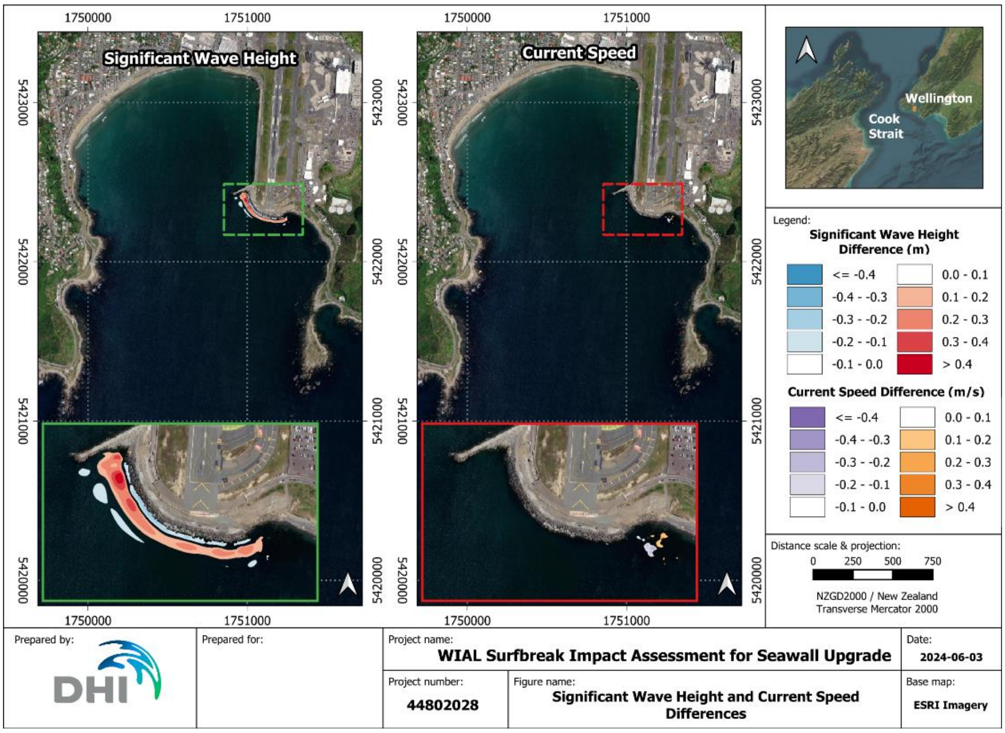


Figure 4.8 Small Corner Wave Height and Current Speed Differences – MLWS

Significant wave height and current speed difference maps represent the existing seawall results subtracted from the proposed renewed seawall results. A positive value indicates that the proposed renewed seawall results have larger values than the existing seawall results.

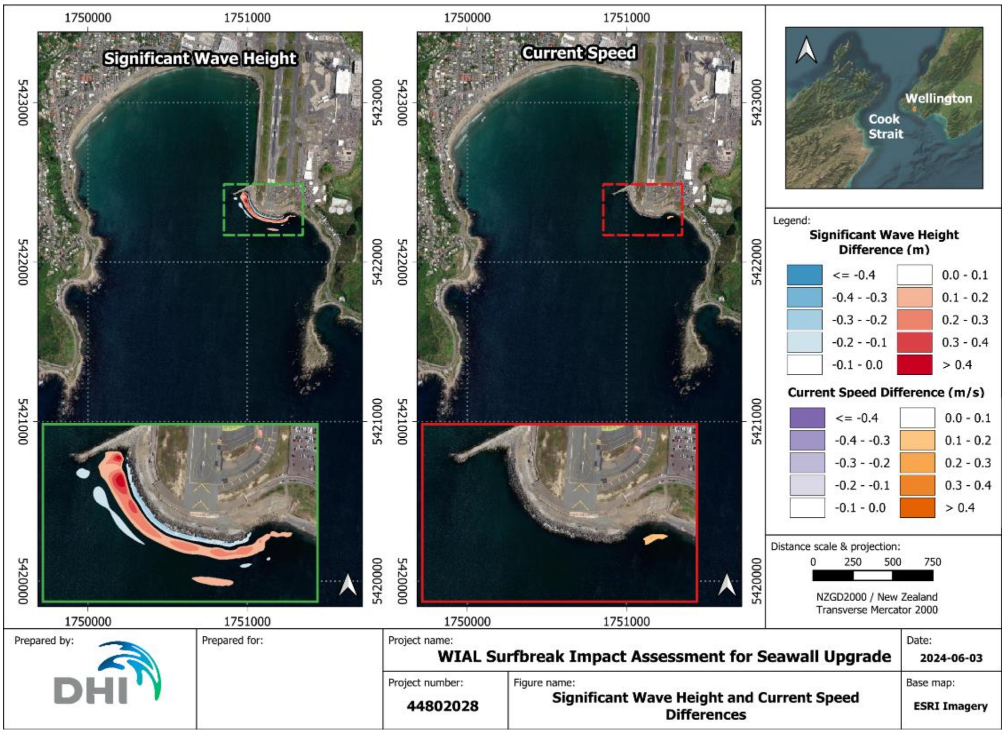


Figure 4.9 Small Corner Wave Height and Current Speed Differences – MHWS

Significant wave height and current speed difference maps represent the existing seawall results subtracted from the proposed renewed seawall results. A positive value indicates that the proposed renewed seawall results have larger values than the existing seawall results.

Good Corner Wave Event

Figure 4.10, Figure 4.11, Figure 4.12, Figure 4.13, outline the significant wave height and mean current speed differences between existing and proposed conditions for the good Corner surfing wave condition. Figure 4.10 presents the MLWS tidal condition, Figure 4.11, Figure 4.12, and Figure 4.13 outline the MHWS tidal condition for no SLR, 50-year SLR, and 100-year SLR, respectively.

Observing all figures, the mean current speed differences between existing and proposed conditions are localised to the east of the seawall along Moa Point Road. No current speed differences are apparent at the western beach, middle beach, or the Corner.

Similarly, wave height differences are localised to directly in front of the seawall and along Moa Point Road. The proposed renewed southern seawall results in slightly larger waves due to the proposed structure having a less porous design (i.e. greater reflection and less absorption of wave energy) than the existing structure. It is important to note that, as the water depth increases with SLR the area of larger wave heights in front of the seawall also increases, due to a higher threshold of wave breaking and transformation in deeper water. No wave height differences are apparent at the western beach, middle beach, or the Corner.

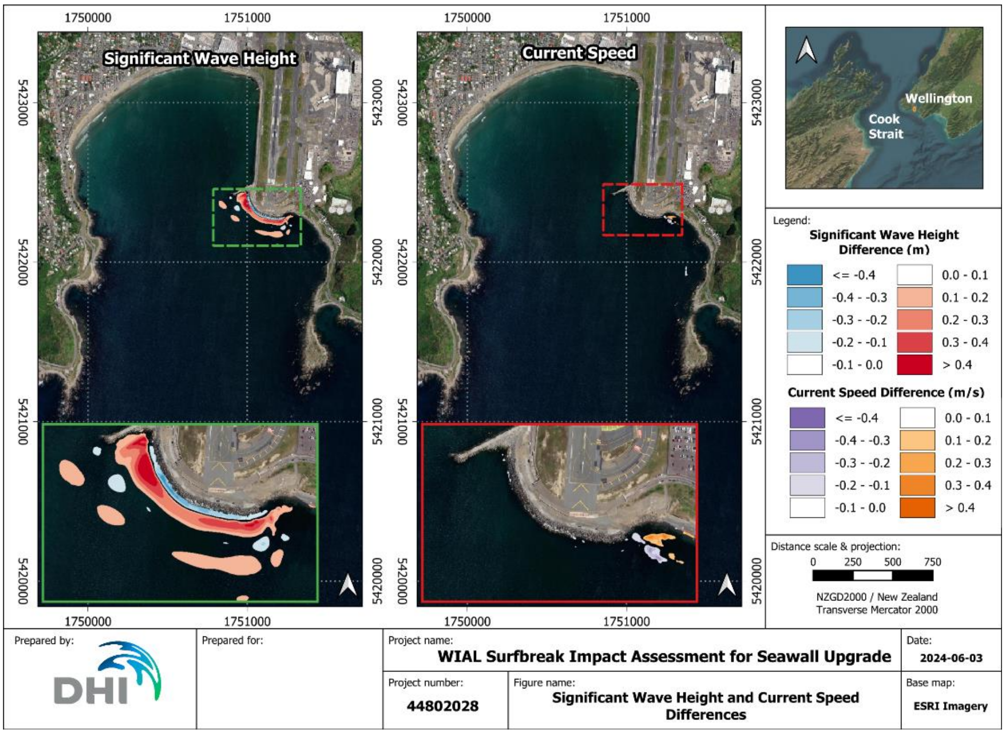


Figure 4.10 Good Corner Wave Height and Current Speed Differences – MLWS, no SLR
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

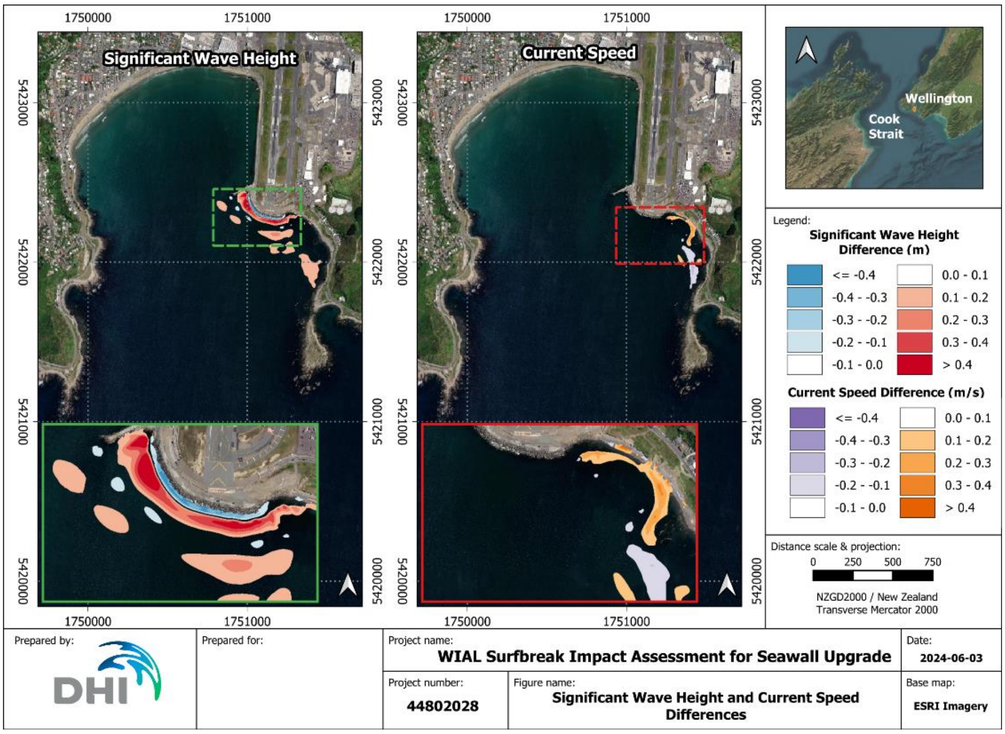


Figure 4.11 Good Corner Wave Height and Current Speed Differences – MHWS, no SLR
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

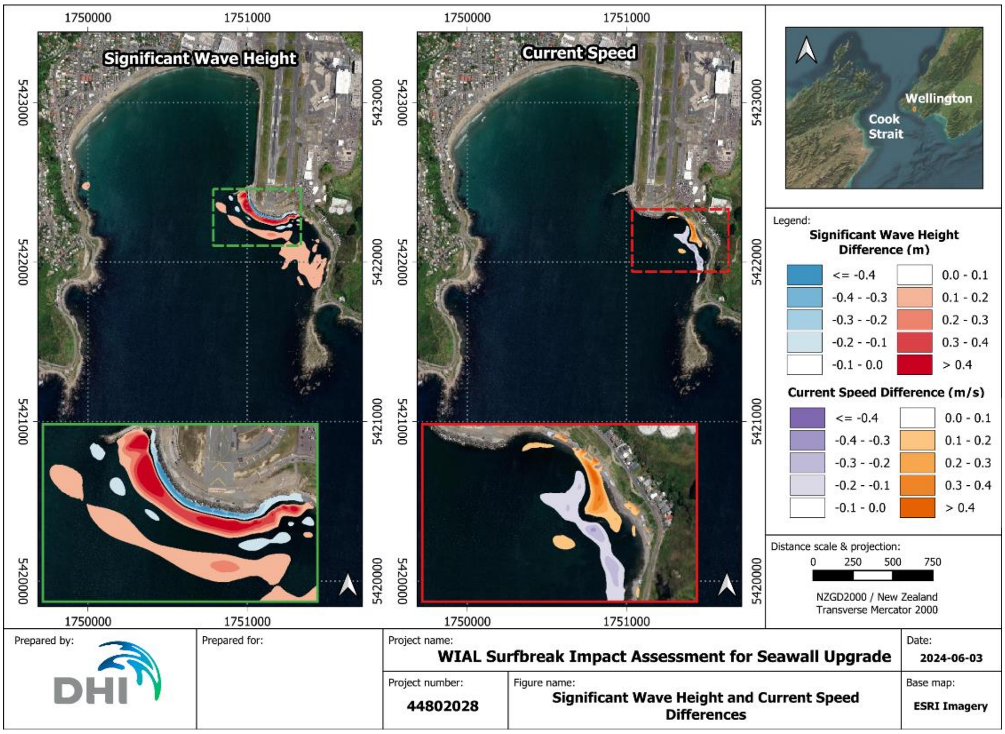


Figure 4.12 Good Corner Wave Height and Current Speed Differences – MHWS, 50-Year SLR
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

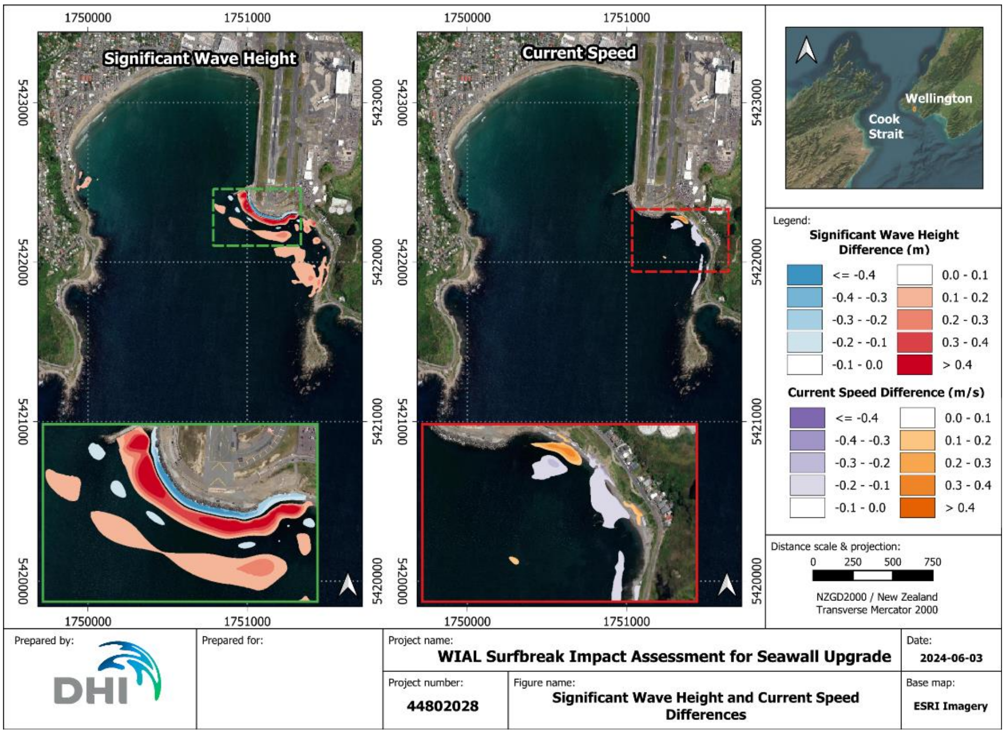


Figure 4.13 Good Corner Wave Height and Current Speed Differences – MHWS, 100-Year SLR
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

Exceptional Corner Wave Event

Figure 4.14 outlines the significant wave height and mean current speed differences between existing and proposed conditions for the exceptional Corner surfing wave condition at MSL. It is apparent that for the exceptional Corner surfing wave event, there are almost no differences in current speeds between existing and proposed conditions. Wave height differences are mostly localised to directly in front of the seawall, with minimal differences (+/- 20cm) at the offshore of the western and middle beaches.

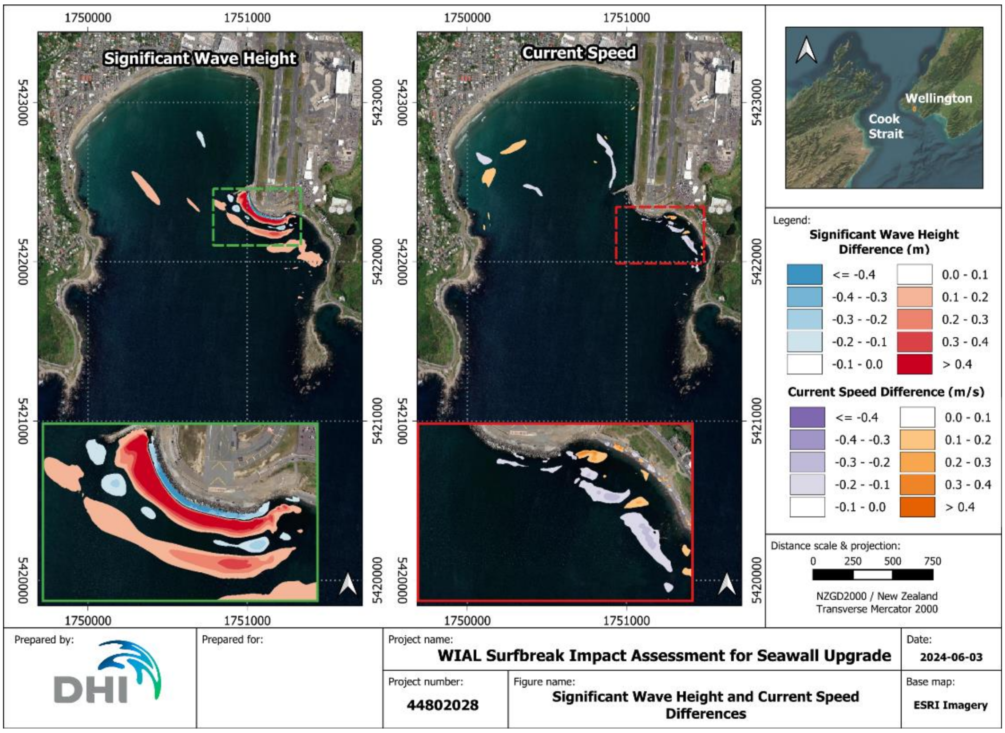


Figure 4.14 Exceptional Corner Wave Height and Current Speed Differences – MSL
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

Exceptional Airport Rights Wave Event

Figure 4.15 and Figure 4.16 outline the significant wave height and mean current speed differences between existing and proposed conditions for the exceptional Airport Rights surfing wave condition. Figure 4.15 presents the MLWS tidal condition and Figure 4.16 outlines the MHWS tidal condition, no SLR was considered in this analysis.

For MLWS, the current speed differences between existing and proposed conditions are minimal. For MHWS, there is a larger current speed difference when compared to the MHWS, however, it is localised to along Moa Point Road. No current speed differences are apparent at the western beach, middle beach, or the Corner.

Wave height differences are localised to directly in front of the seawall and along Moa Point Road for both MLWS and MHWS. For MHWS, the area of large wave heights in front of the seawall is larger than when compared to the MLWS. This trend is similar to all other simulations, as the water depth increases, the area of larger wave heights in front of the seawall also increases. No wave height differences are apparent at the western beach, middle beach, or the Corner.

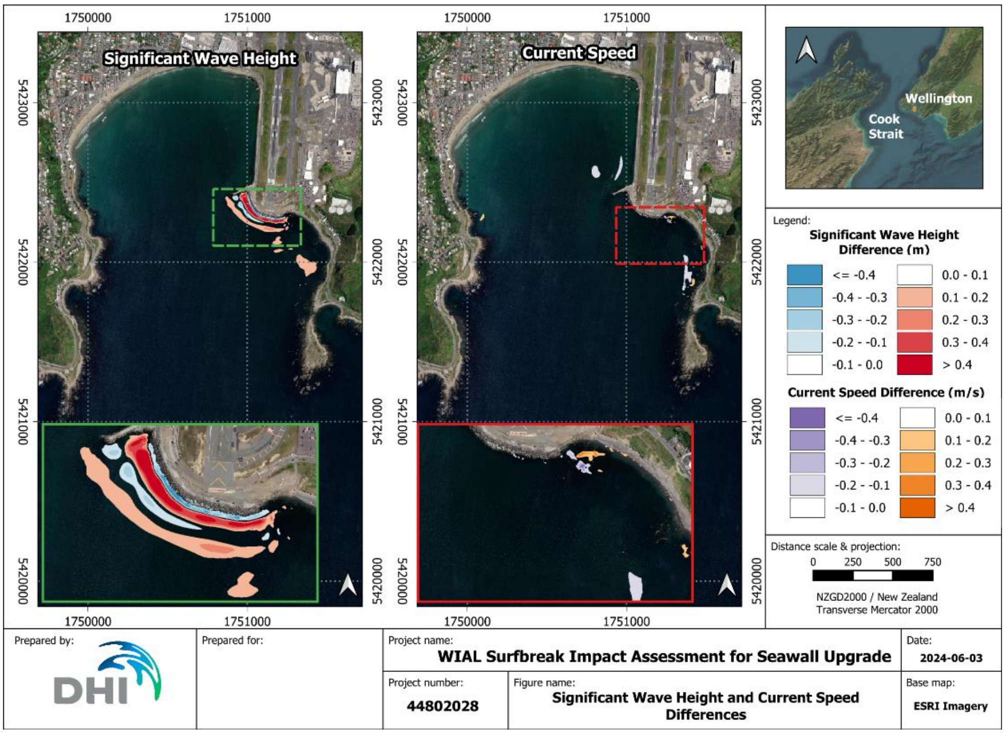


Figure 4.15 Exceptional Airport Rights Wave Height and Current Speed Differences – MLWS
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

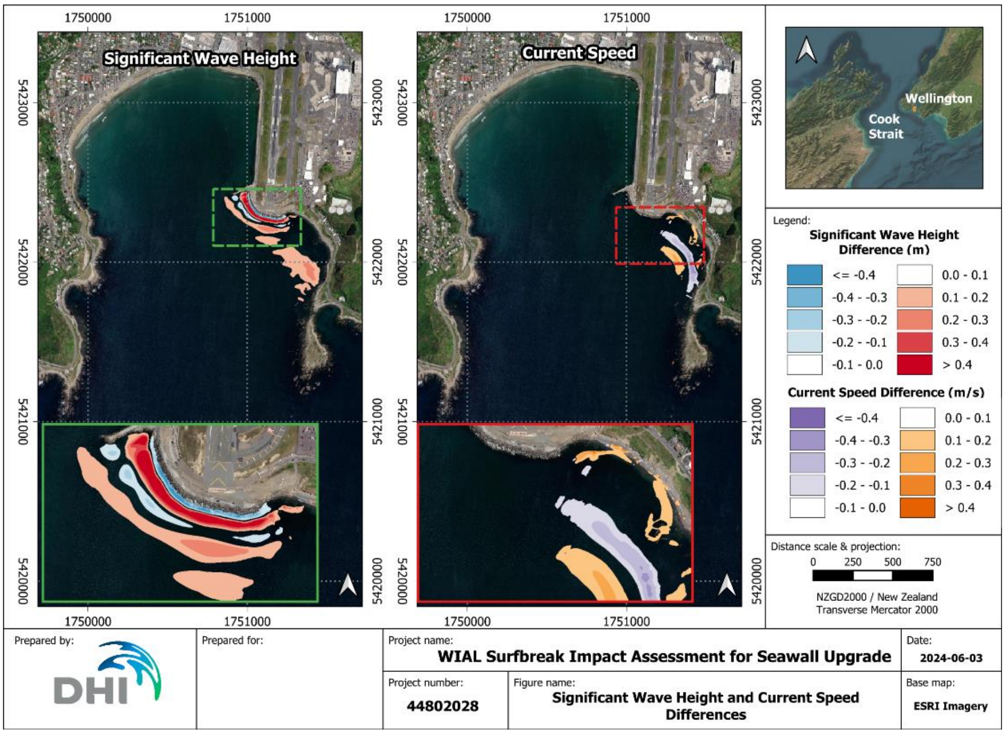


Figure 4.16 Exceptional Airport Rights Wave Height and Current Speed Differences – MHWS
Significant wave height and current speed difference maps represent the existing southern seawall results subtracted from the proposed renewed southern seawall results. A positive value indicates that the proposed renewed southern seawall results have larger values than the existing southern seawall results.

4.3.2 OptiSurf Analysis

In this section the comparison between potential surf rides is presented for a range of representative wave conditions to screen for any quality differences introduced by the proposed renewed southern seawall.

To obtain a robust statistical resolution of variations in surf characteristics of the individual propagating waves, detailed OptiSurf Simulations were carried out using a 30-minute wave field input (after 30-minute warm up period). In order to sustain acceptable simulation times, the time step in OptiSurf was coarsened to 1 second. Due to subtle numerical differences in M3W model propagation this affected, to a minor degree, how OptiSurf distinguishes between potential rides. The subtle differences presented for the Corner are predominantly due to these numerical resolution limitations.

Results at The Corner

The results presented below correspond to the Corner location for exceptional wave conditions at mean sea level with no SLR.

Figure 4.17 shows surf rides under existing and proposed conditions calculated in OptiSurf in the Corner for the exceptional MSL wave condition. The Wellington Boardriders Club provided an overview of where the take-off zone for surf would typically be located for exceptional surf at the Corner. This location is between yellow lines in Figure 4.17. OptiSurf predicted a take-off within 10 to 15 m of this location which was deemed reasonable.

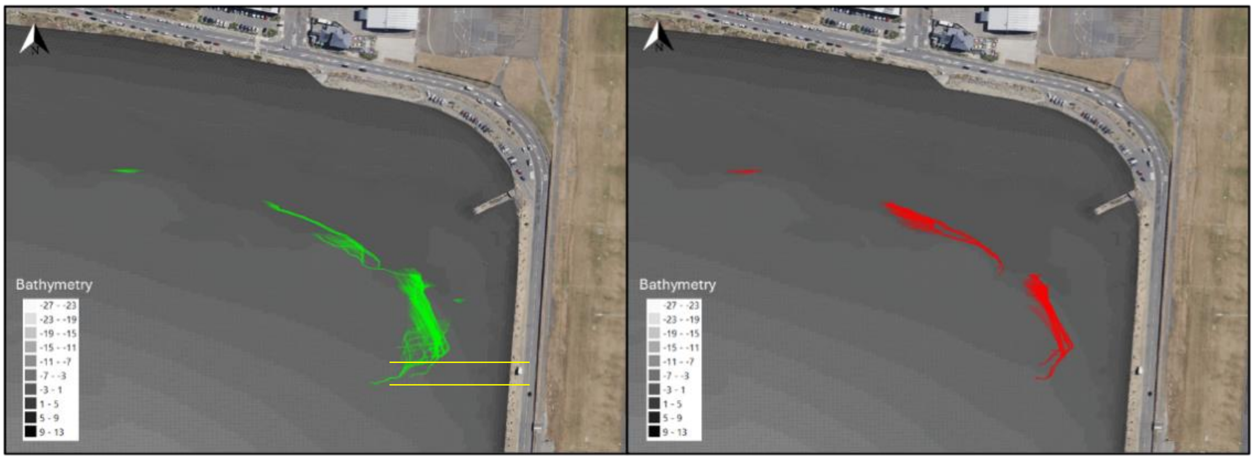


Figure 4.17 Corner OptiSurf surf rides (with the existing southern seawall left and proposed renewed southern seawall right) for exceptional wave conditions at MSL
Yellow lines indicate take off zone described by Wellington Boardriders Club.

Largely, the rides appear very similar in length, shape, and in the take-off/ending locations. It should be noted that, while the significant wave height statistics are generally unchanged (reference Figure 4.14), there are some small perturbations and differences between the existing and proposed conditions. These perturbations/differences are considered within the range of the numerical accuracy of the M3W model itself.

A comparison of surface elevation time series and peak wave crests and troughs at key locations (denoted in Figure 4.18) along OptiSurf surf rides is presented in Figure 4.19.

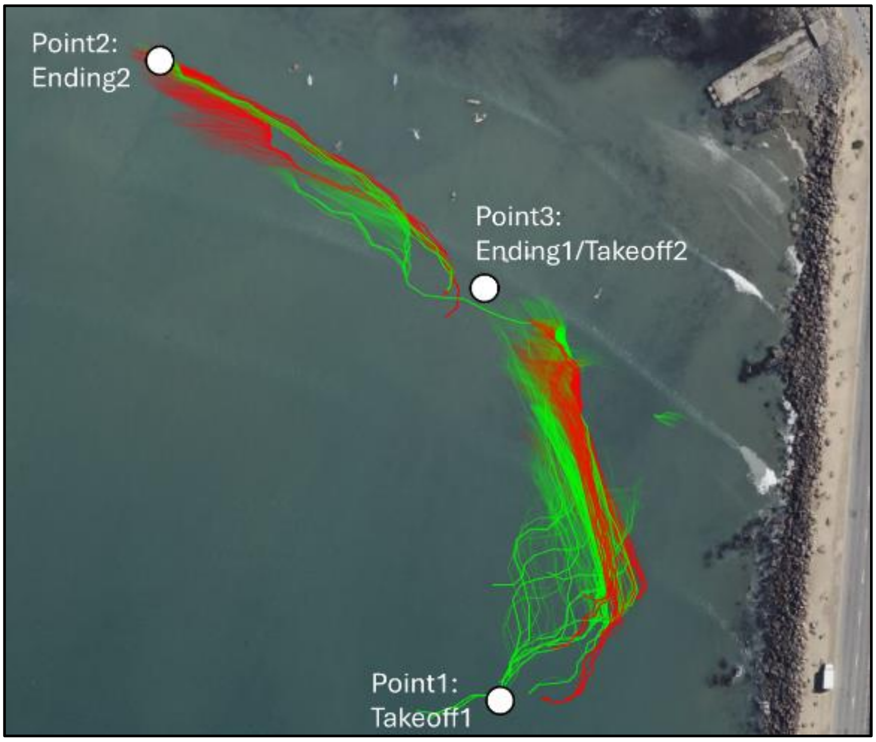


Figure 4.18 Location of three key points along generated OptiSurf surf rides with existing southern seawall (in green) and proposed renewed southern seawall (in red)

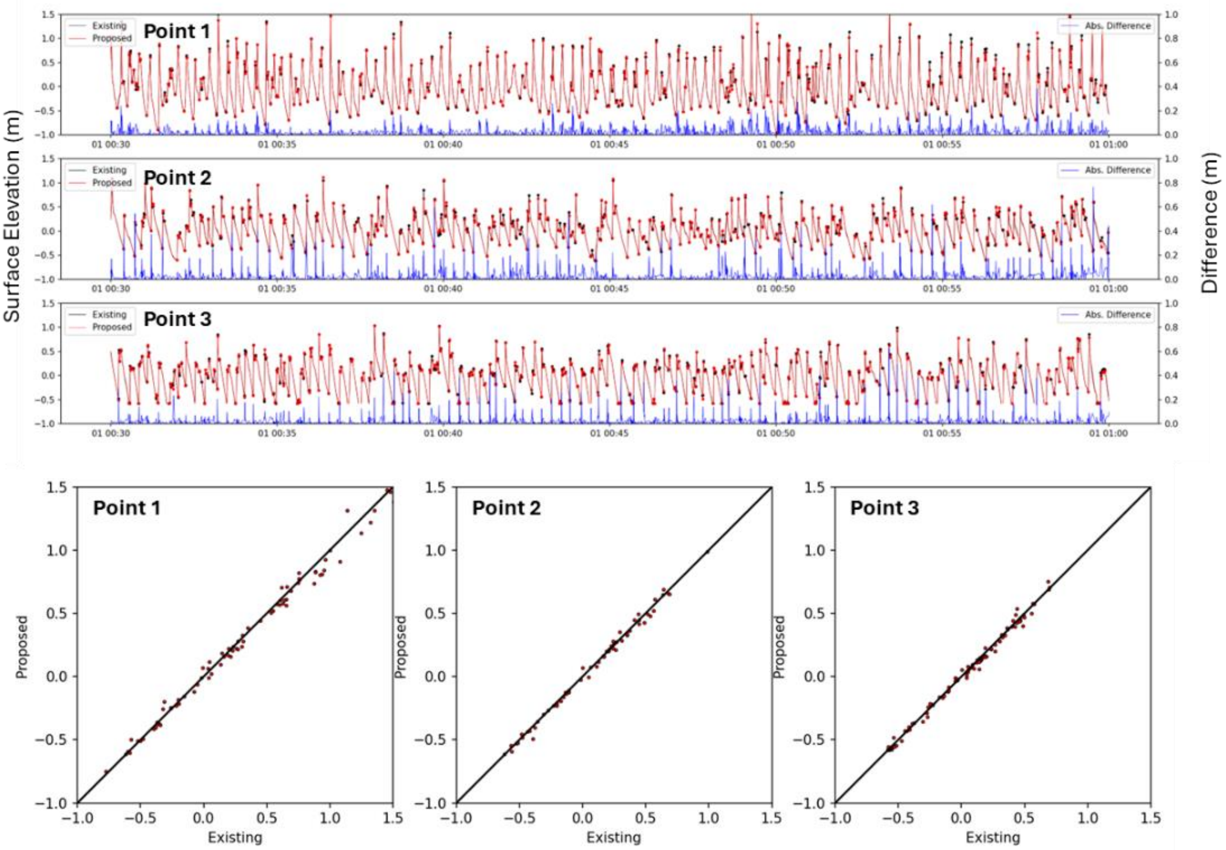


Figure 4.19 Comparison of surface elevation time series and peak wave crests and troughs at key locations along OptiSurf surf rides

While the general pattern and magnitude of surface elevation is nearly identical between existing and proposed conditions, there are slight phasing/timing difference that can cause different branching of predicted rides in the OptiSurf algorithm. From the lower subplots, it is also apparent that peak crests and troughs (illustrative of wave height patterns at each location) are generally similar to within approximately +/- 0.10 m, which is well within the range of numerical accuracy of the M3W model.

The below stacked bar chart (see Figure 4.20) shows the composition of these predicted OptiSurf rides for both existing (bars on the left or each pair) and proposed conditions (bars on the right of each pair), binned by maximum wave face height (maximum wave face height that was experienced over the course of an entire ride) and coloured by ride length.

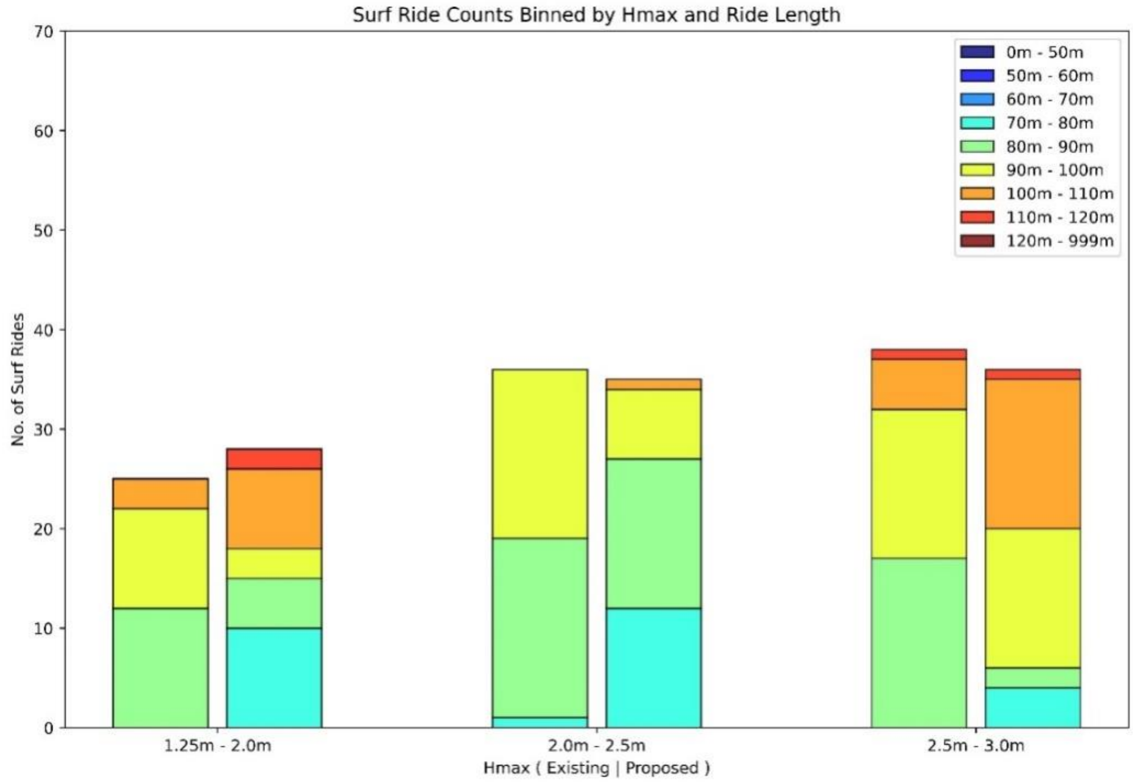


Figure 4.20 Binned maximum wave face height and ride length statistics for exceptional Corner waves at MSL with existing southern seawall (bars-L) and proposed renewed southern seawall(bars-R).

This shows that the composition of rides is very similar between existing and proposed conditions both in terms of wave conditions and ride length. Given the probabilistic nature of OptiSurf when applied to M3W model results, and the numerical accuracy of the model itself, it can be concluded that there are no appreciable changes in surfability shown here.

Figure 4.21 presents a 3D visualisation of two surf rides (one with the existing southern seawall and one with the proposed renewed southern seawall) that started at Point 1 in Figure 4.18, and ended at Point 3. This was done to showcase the similarity of both wave and surfing conditions between existing and proposed conditions when comparing rides initiated at the exact same wave fronts.

Figure 4.21 Example surf ride with the existing southern seawall (left) and Proposed renewed southern seawall (right) for exceptional Corner waves at MSL

Both good and small wave conditions were analysed in OptiSurf at MHWS, as well as good wave conditions at MLWS as a sensitivity test to show the change in surfability at different tide levels.

The good wave conditions analysis for MHWS is presented in Figure 4.22 and Figure 4.23, while the analysis for MLWS is presented in Figure 4.24 and Figure 4.25.

Similar to results for exceptional conditions, the composition of rides under good conditions is very similar between existing and proposed conditions (i.e. with the existing southern seawall and proposed renewed southern seawall) both in terms of wave conditions and ride length. There is a negligible difference in comparison between MHWS and MLWS.

The small wave conditions analysis for MHWS is presented in Figure 4.26 and Figure 4.27. The composition of rides is very similar in existing and proposed conditions both in terms of wave conditions and ride length.

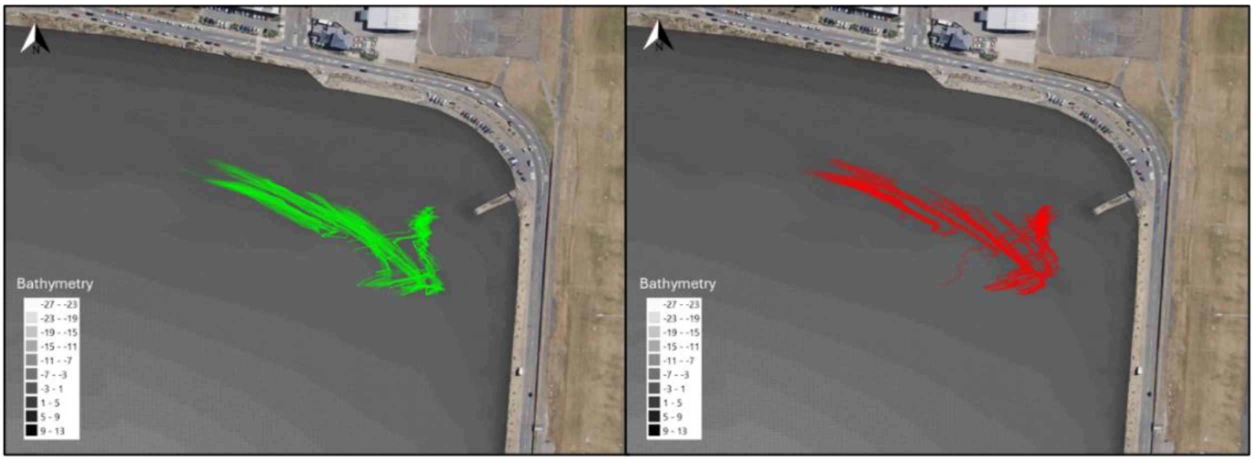


Figure 4.22 Corner OptiSurf surf rides (with existing southern seawall left and proposed renewed southern seawall renewal right) for good wave conditions at MHWS.

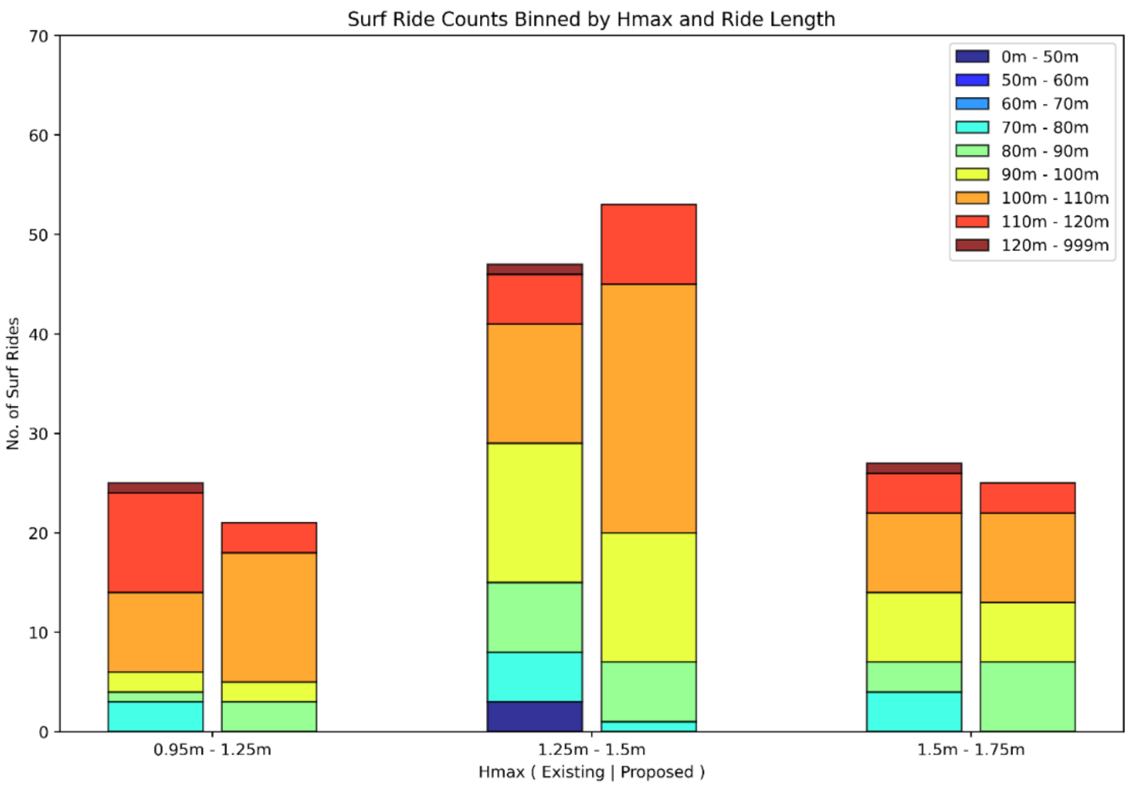


Figure 4.23 Binned maximum wave face height and ride length statistics for good Corner wave conditions at MHWS for existing southern seawall (bars-L) and proposed renewed southern seawall renewal (bars-R).

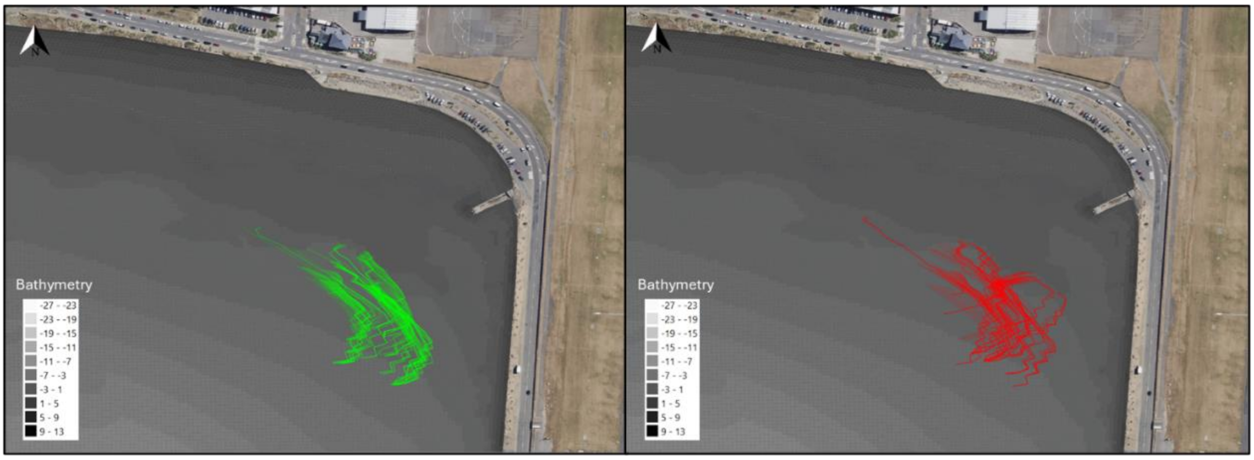


Figure 4.24 **Corner OptiSurf surf rides (with existing southern seawall left and proposed renewed southern seawall renewal right) for good wave conditions at MLWS**

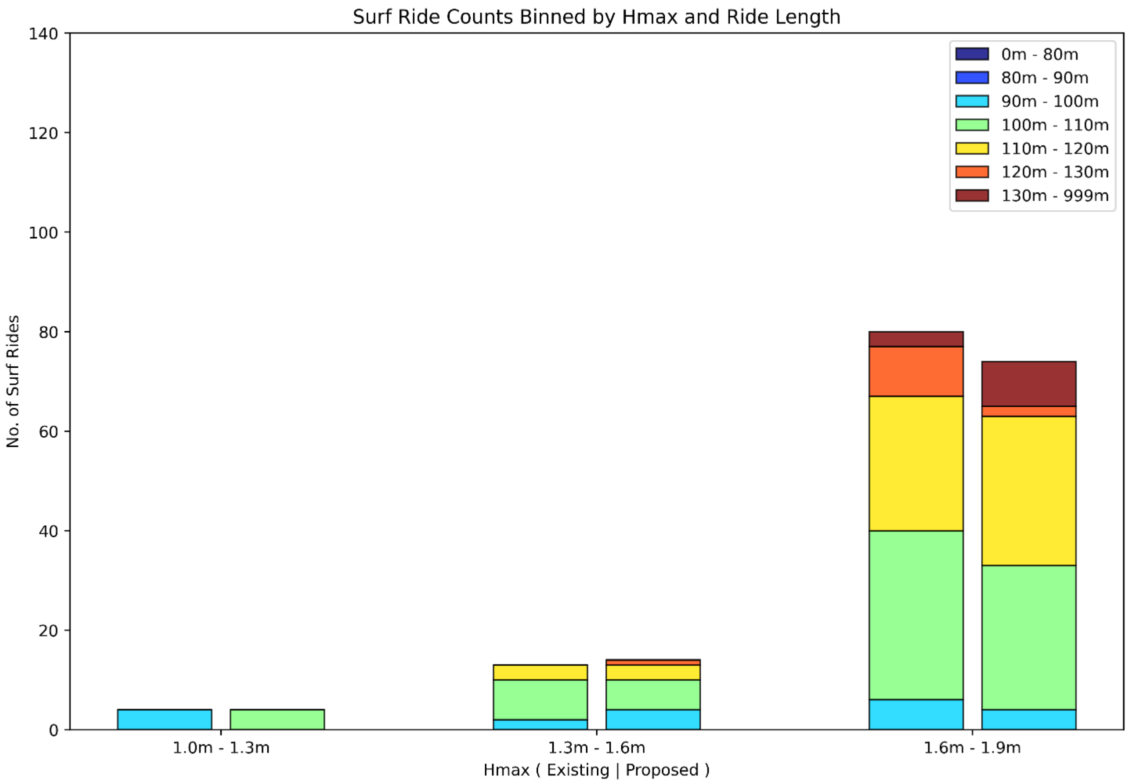


Figure 4.25 **Binned maximum wave face height and ride length statistics for good Corner wave conditions at MLWS with existing southern seawall (bars-L) and proposed renewed southern seawall (bars-R).**

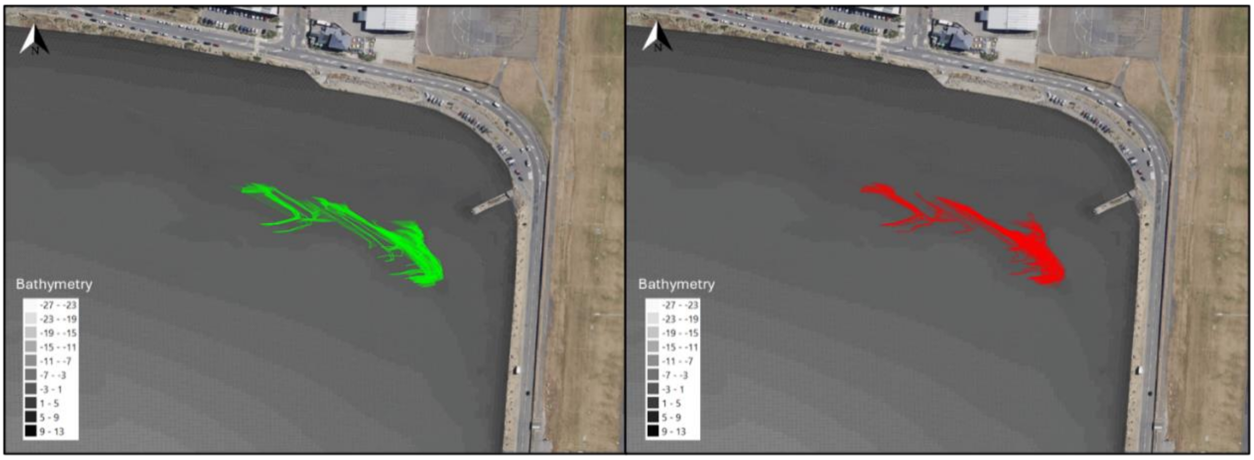


Figure 4.26 Corner OptiSurf surf rides (with existing southern seawall left and proposed renewed southern seawall right) for small wave conditions at MHWS

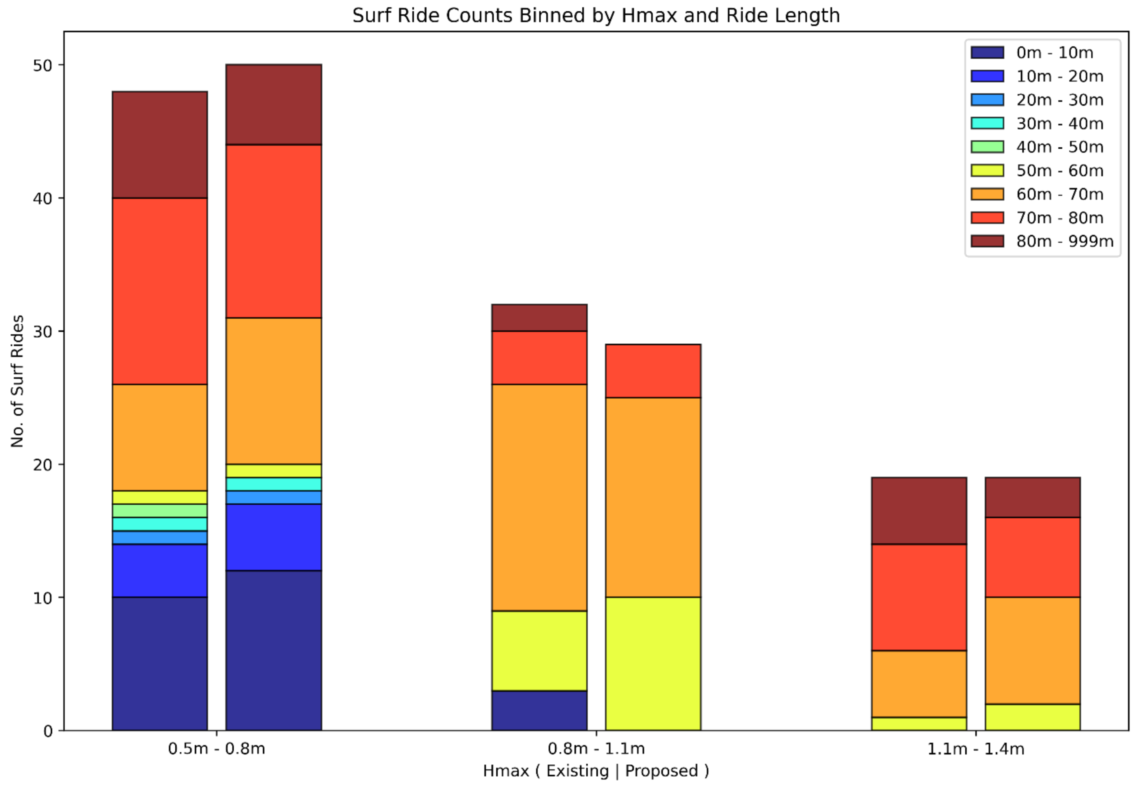


Figure 4.27 Binned maximum wave face height and ride length statistics for small Corner wave conditions at MHWS with existing southern seawall (bars-L) and proposed renewed southern seawall (bars-R).

Results at Airport Rights

The results presented in detail below correspond to the Airport Rights location for exceptional wave conditions at MHWS level. This can be contrasted with exceptional wave conditions at MLWS level (refer Appendix D to see the change in surfability impact at different tide levels). Figure 4.28 shows the surf rides generated by OptiSurf for this wave scenario and location, just offshore of the proposed shoreline structure, with both existing and proposed conditions.

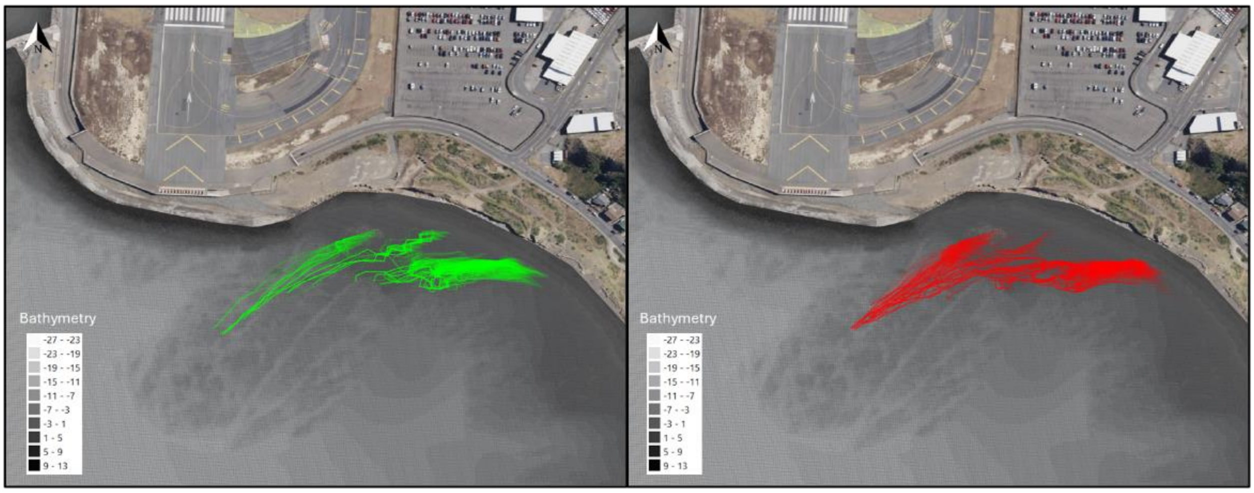


Figure 4.28 Airport Rights OptiSurf surf rides for exceptional wave conditions at MHWS (with existing southern seawall left and proposed renewed southern seawall right)

Largely speaking, the maps of surf rides show that the overall trend is quite similar in existing and proposed conditions. The impact of the proposed renewed southern seawall is accounted for in the wave model as a different (and higher) reflection coefficient, in addition to the altered bathymetry in the structure footprint.

This results in a slight change in the wave climate just in front of the proposed renewed southern seawall, which is illustrated in Figure 4.16. Because of this, there are some slight differences in terms of where rides start and end, their route, and the maximum wave face height encountered over the rides. These categorical changes are best reflected in Figure 4.29.

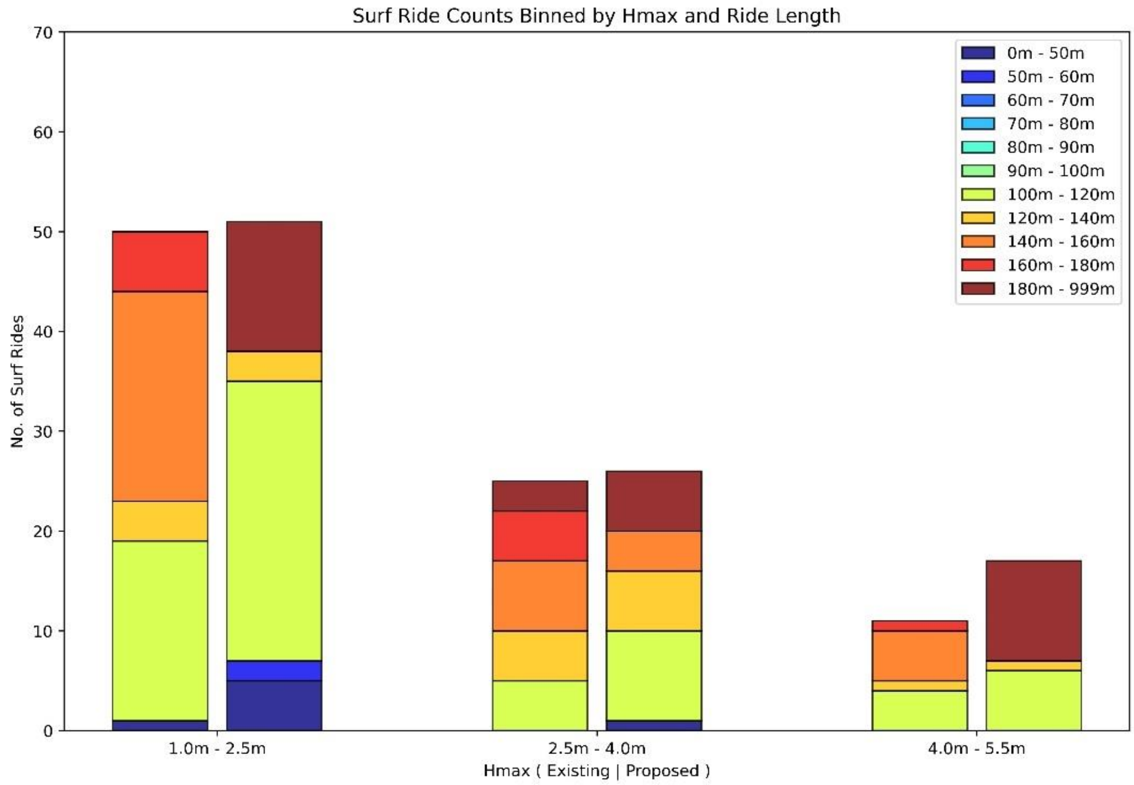


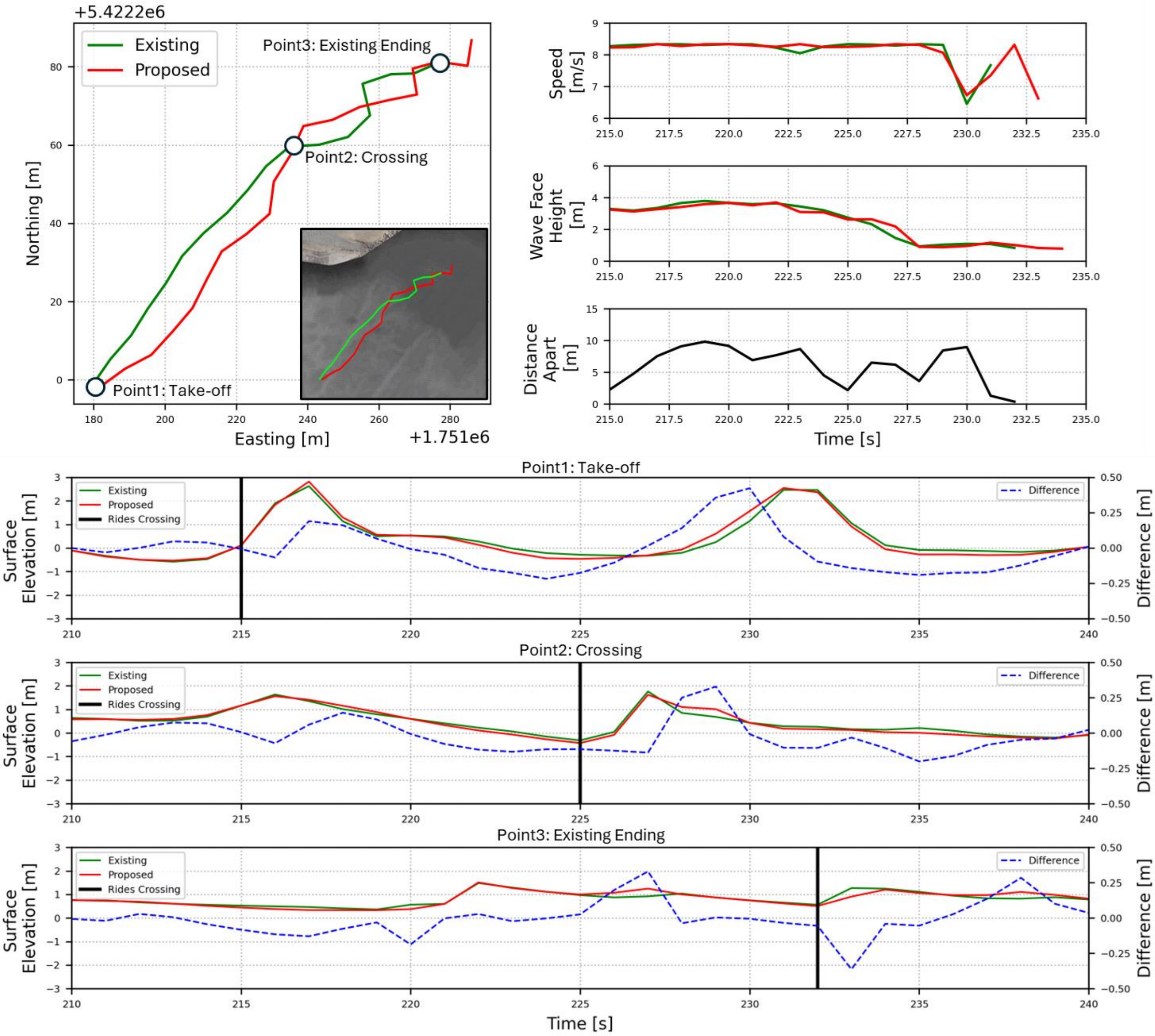
Figure 4.29 Binned maximum wave face height and ride length statistics for exceptional Airport rights waves at MHWS with existing southern seawall (bars-L) and proposed renewed southern seawall (bars-R).

This indicates that the proposed condition has a slightly different distribution. There are more of the longest rides (i.e. 180 m or longer) with proposed renewed southern seawall when compared to existing conditions. In addition, there are more of the extreme rides (i.e., rides with the highest maximum wave face heights of over 4m) when compared to existing conditions.

Effect of Reflection at Airport Rights

The porosity of the existing southern seawall and proposed renewed southern seawall was approximated as 0.68 and 0.40 in the wave model, corresponding to reflection coefficients of approximately 40% and 65% in a numerical flume test. As Figure 4.16 suggests, this leads to some differences in terms of peaks and troughs directly in front of the seawall, in turn affecting the ability for surfers to take-off on individual waves and slightly different conditions over the length of a given ride.

Figure 4.30 shows one surf ride under both existing and proposed conditions, that took off around the same location and at the same time in the wave simulation. In addition, the surface elevation is shown at key locations along the surf rides, to showcase the difference caused by the proposed renewed southern seawall and its reflection characteristics.



	Existing	Proposed
Take-off Time (s)	215	215
Duration (s)	18	20
Length (m)	138.4	153.1
Max. Wave Face Height (m)	3.69	3.79
Mean Speed (m/s)	7.69	7.65

Figure 4.30 Comparison of surf rides and impact of surfing conditions posed by reflection characteristics of both existing southern seawall and proposed renewed southern seawall

Rides under both existing and proposed conditions took off at the exact same wave (time in wave simulation), however the ride with the proposed renewed southern seawall lasted 2 seconds longer in duration, and approximately 15 m longer in length. Although this is a small temporal sample of the wave conditions in front of the seawall, it is clear that there are small phasing differences, and differences between peak crests and troughs over each wave cycle. This small sample shows the effect of these differences resulting in slightly longer rides with higher maximum wave face heights, as is reflected in Figure 4.29.

It is likely the reflected wave field creates perturbations that create localised crest elevations that could make the take off earlier and even prevent a wave from closing out.

To illustrate this, Figure 4.31 presents a comparison of the wave fields under both existing and proposed conditions at one time step from the exceptional condition for Airport Rights at MHWS. This indicates an increase in the reflected wave energy that comes from the north-west (indicated with yellow circle).

Generally, reflected waves directly opposite the direction of incoming waves is bad for surfing. The moment the two opposing wave crests meet creates a problem in the take-off as it reduces the steepness of the wave crest a surfer is trying to take off on, but then a moment later it rapidly causes this bounce effect, which can make a surfer lose their balance.

However, in this case, the reflection is coming from almost a 90-degree angle. This may create a different effect that is less transient and there is the potential it might not be negative for surfing.

There is even the potential that surfing at Airport Rights might improve with the seawall renewal. Detailed CFD modelling might be able to confirm this, however, noting that the break works only under a narrow range of conditions and can get heavy close outs which further limit its use (*http://www.nzsurfguide.co.nz/surf_breaks/wellington/airport-reef, https://www.surf-forecast.com/breaks/Airport-Rights_1#:~:text=Airport%20Rights%20in%20Wellington%20is,direction%20is%20from%20the%20south.*), this further level of modelling has not been pursued.

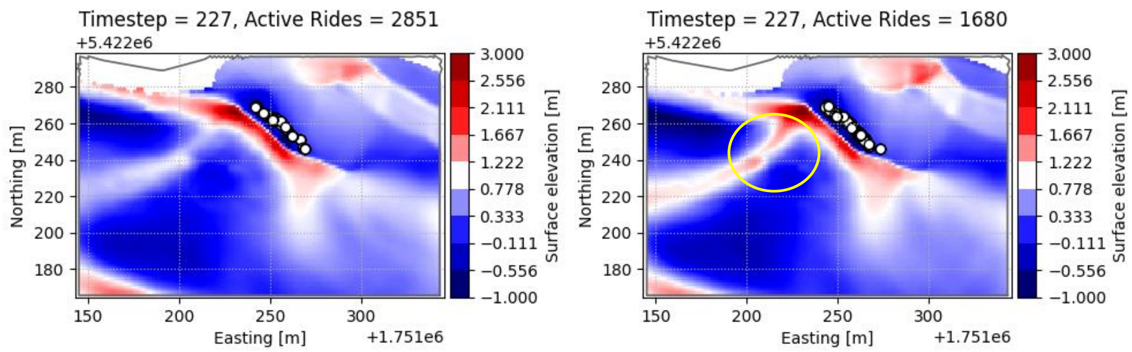


Figure 4.31 Comparison of wave field in exceptional condition for Airport Rights at one time step with the existing southern seawall (left) and proposed renewed southern seawall (right). Increase in reflected wave energy that comes from the northwest with the renewed seawall is circled in yellow.

5 Conclusions

A numerical modelling study was undertaken to assess the potential impact of the Project on the wave climate, recreational user safety and surf quality of the surf breaks at Lyall Bay.

A M3W model was developed to assess the impact on wave climate and recreational user safety, while DHI's surfing amenity analysis model, OptiSurf, was utilised to determine potential changes to surfing quality. Boundary conditions for the M3W model were obtained from an offshore wave hindcast provided by MetOcean Solutions. The model was validated against wave data collected offshore of Lyall Bay and to the north and south of the Lyall Bay breakwater. Impacts on wave climate have only been assessed for a 63% AEP storm (1-year return period event) and 50th percentile wave height for existing sea level and with 100-year SLR.

Generally, for both wave events the differences in wave heights are localised to in front of the seawall. The proposed renewed southern seawall results in slightly larger waves due to the structure being less porous than the existing structure. SLR increases the area of larger wave heights in front of the seawall. Impacts on wave climate and surf quality for four scenarios have been assessed at the Corner (three events – small, good and exceptional) and Airport Rights (one event - exceptional). The wave climate has been assessed for MLWS and MHWS for existing sea level; 50-year SLR and 100-year SLR. The exception is the exceptional event at the Corner, which was only simulated for existing sea level at mid tide.

For wave climate, wave height differences are typically localised to directly in front of the seawall (and for some scenarios along Moa Point Road) for both MLWS and MHWS. For MHWS, the area of large wave heights in front of the seawall is larger than when compared to the MLWS. As the water depth increases with SLR the area of larger wave heights in front of the seawall also increases. No wave height differences are apparent at the western beach, middle beach, or the Corner.

Surf quality has been assessed at the Corner for small, good and exceptional conditions. The take-off zone for the exceptional condition was shown to be within 10 to 15 m of what is expected by the local surf community, while for small and good conditions, the take-off zone is much further inshore but aligns with what is expected by the local surf community.

For all scenarios, surf quality for the Corner has been assessed and shows that the composition of rides was very similar in existing and proposed conditions both in terms of wave conditions and ride length. Given the probabilistic nature of OptiSurf when applied to M3W model results, and the numerical accuracy of the model itself, it has been concluded that the proposed renewed southern seawall will have no net impact on surf at the Corner.

Surf quality has been assessed at Airports Rights for an exceptional condition. Although the surf quality analysis indicates a slight improvement on the surf quality for this scenario, it is still uncertain whether reflected waves from the proposed renewed southern seawall would have a slight positive or negative impact on surf at this location. Generally, reflected waves directly opposite the direction of incoming waves are bad for surfing. However, in this case, a reflected wave at almost a 90-degree angle could make the take off earlier and even prevent a wave from closing out, which could improve surfing for this location.

Detailed CFD modelling might be able to confirm this, however, noting that the break works only under a narrow range of conditions and can get heavy close outs which further limit its use, this further level of modelling has not been pursued.

With regards to recreational user safety, the impacts on the mean wave induced currents are either negligible or localised to the east of the proposed renewed southern seawall (along Moa Point Road). This area already experiences strong currents in order of 1 m/s and would not currently be considered safe for most recreational users.

6 References

Beca (2025) WIAL Southern Seawall Renewal. Assessment of Effects on Coastal Processes. Report prepared for Wellington International Airport Ltd.

DHI (2016) Wellington Airport Runway Extension Surf Break Impact Assessment. Report prepared for Wellington International Airport Ltd.

DHI (2024) MIKE 3 Wave Model FM. User Guide.

Median J.R. and M.E. Gomez-Martin (2016) Cubipod Manual.

MetOcean (2024) Provision of hindcast wave data offshore Lyall Bay Wellington, New Zealand. Report prepared for Beca.

Paape, A., Walther, A.W.: Akmon armour unit for cover layers of rubble mound breakwaters. Hydraulics Laboratory Delft, Publication No. 27, 1962.

Appendix A Post Numerical Modelling Adjustment of Seawall Configuration

DHI completed the numerical modelling of the seawall upgrades using the seawall configuration depicted in Figure 1.1 and Figure 1.2, as presented in Chapter 1. Since the completion of this report and issuing the findings from the numerical modelling study, there have been adjustments to the Southern Seawall design, which are reflected in the following issued drawings (higher resolution imagery and original drawings in PDF or DWG format are available upon request from BECA):

- **Figure A-1**: Plan view of revised seawall configuration, received December 2024
- **Figure A-2**: Plan view of revised seawall configuration, received January 2025
- **Figure A-3**: Plan view of revised seawall configuration at airport rights, received December 2024
- **Figure A-4**: Cross sections for chainages 160m and 170m showing rock toe with rock blanket.
- **Figure A-5**: Cross sections for chainages 240m and 250m showing rock toe, no rock blanket and minor clearance of rock "pinnacles" on seabed.
- **Figure A-6**: Cross sections for chainages 280m and 290m showing toe excavated into rock seabed. This configuration is similar to the original toe arrangement depicted in Figure 1.2.

DHI understands that the rock toe (i.e., Figure C-4 and Figure C-5) extends from chainage 65m to 265 m (approximate extents denoted in red in Figure C-1). The excavated toe (Figure C-6) extends from chainage 0 m to 65m and chainage 265 m to 400 m (approximate extents denoted in blue in Figure C-1). It is observed that the excavated toe detail is similar to the cross sections initially provided to DHI at the onset of this investigation (Figure 1.2) and are thus representative of the cross section that DHI integrated into its numerical models for this study. More recent drawings also indicate a slight realignment of the crest from chainage 0m to approximately 50m, as indicated in Figure C-2.

The following Addendum is intended to address whether the changes noted above and depicted in Figures C-1 through C-6, will have a consequential impact on the findings and outcome of this study, and whether the modelling results presented within this report remain valid and accurate. To address this, the two areas of interest are addressed separately:

- **The Corner:** DHI is of the opinion that the revised seawall configuration, as described within this addendum, will not impact or change both the numerical modelling results and the findings presented in this study, for the area of interest referred to as "The Corner". The findings presented herein, and the modelling work used to support these findings are thus valid and remain unchanged. The basis for DHI's opinion that the revised seawall configuration will not impact the numerical modeling results or findings at *The Corner* rests on the following key factors:

  - **Location Relative to the Seawall**: *The Corner* surf break is situated at a significant distance from the modified portion of the southern seawall. The hydrodynamic influence of localized structural changes (e.g., rock toe revisions or realignments) dissipates with distance, and *The Corner* lies outside the zone where wave reflection, transmission, or diffraction patterns are meaningfully affected by the design amendments.
  - **No Wave Height or Current Speed Changes at The Corner**: The modeling results throughout the report, including Figures 4.4–4.14, show that wave height and current speed differences between the existing and proposed seawall are effectively zero at *The Corner*. This suggests the structure's revised geometry has negligible hydrodynamic influence at this location.
  - **OptiSurf Output Consistency**: The OptiSurf analysis for *The Corner* (e.g., Figures 4.17–4.27) demonstrated that surf ride length, take-off points, and wave face height statistics

remained nearly identical under both existing and proposed conditions. These results were already based on the structural configuration similar to what was ultimately finalized.

- **Numerical Model Resolution and Stability**: The M3W model mesh and bathymetry were calibrated for high accuracy around *The Corner*, and results indicate the model had reached stable wave conditions, with no sensitivity to minor phasing or structural changes upstream. The confidence in model accuracy at this location supports the assertion that downstream design adjustments do not compromise the validity of the analysis.

In summary, DHI's opinion is founded on spatial separation, unchanged wave/current conditions, and corroborated surf quality metrics—all of which indicate that *The Corner* is hydrodynamically insulated from the revised seawall design.

- **Airport Rights:** DHI is of the opinion that the revised seawall configuration, as described within this addendum will not impact the findings presented in this study, for the area of interest referred to as "Airport Rights". The surfing area of interest directly in-front of the seawall known as Airport Rights, consists of an excavated toe detail (demarked in blue in Figure C-1, to the eastern extent of the seawall), which is similar to the excavated toe detail which DHI initially integrated into the numerical models for its analysis and assessment. Therefore, it is anticipated that no material change in the results will be experienced as a result of the design amendments of the seawall adjacent to the Airport Rights footprint. It is acknowledged that the numerical modelling results are likely to differ somewhat from chainage 65m to 265m (denoted by the red line in Figure C-1), given that the toe of the structure is not keyed into the seabed but instead sits on the seabed (Figure C-4 and Figure C-5). It is anticipated that the node and antinode of the incoming / reflected wave train may shift slightly, although be of similar magnitude, as depicted by the modelling results in the body of this report. In summary, the findings and results for the Airport Rights depicted in this report remain unchanged and valid, despite the design amendments to the Southern Seawall presented within this addendum.

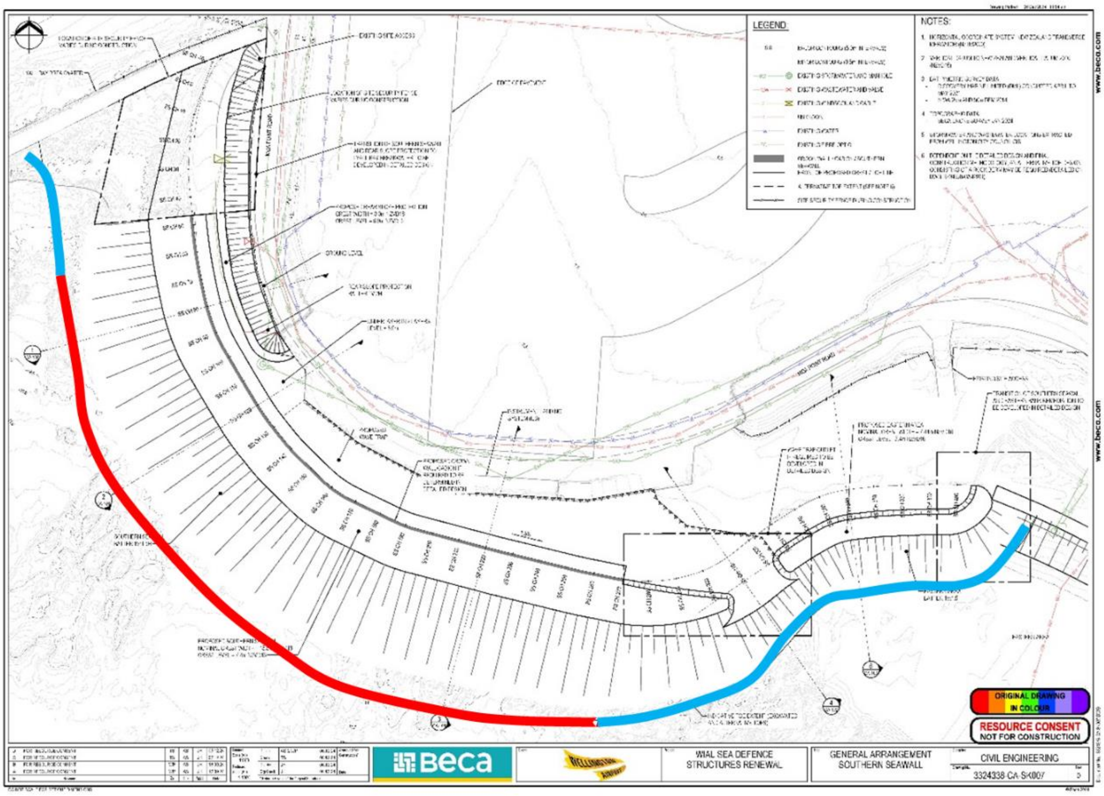


Figure A-1 Plan View of Revised Seawall Configuration, received December 2024

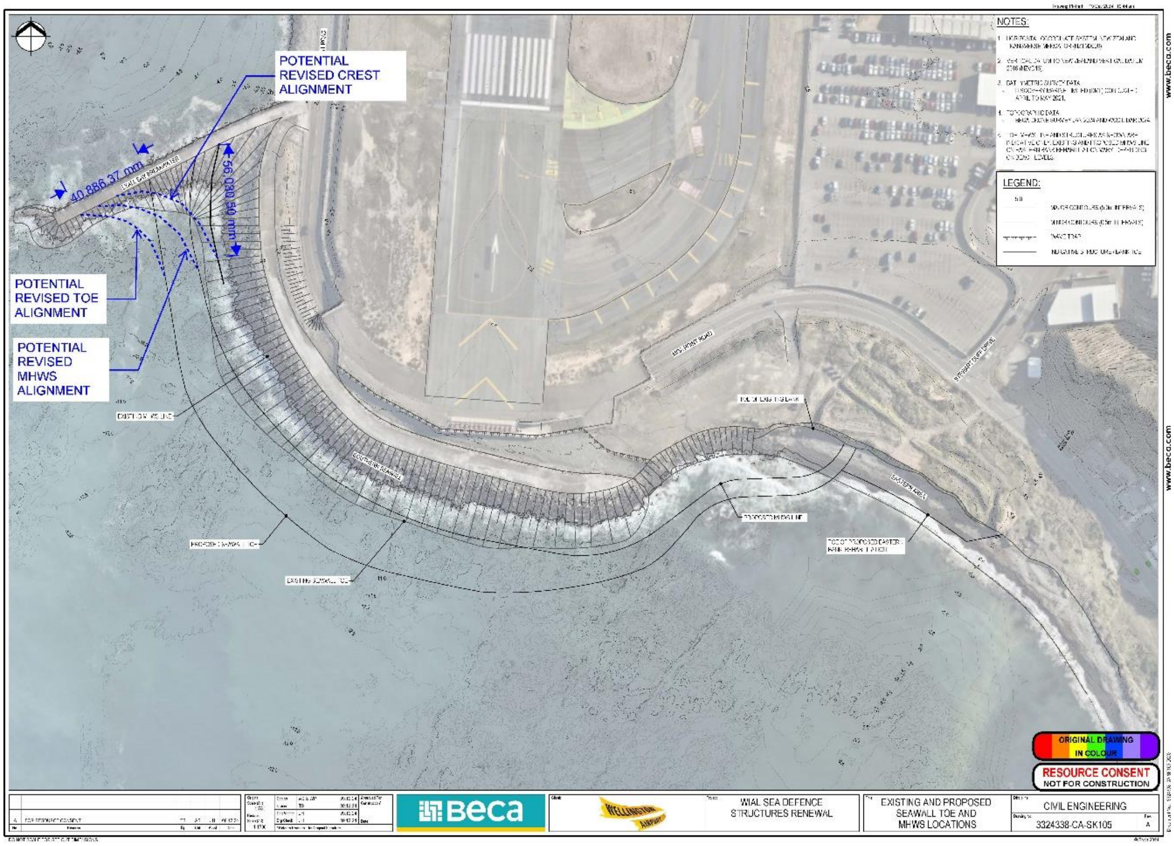


Figure A-2 Plan View of Revised Seawall Configuration, received January 2025

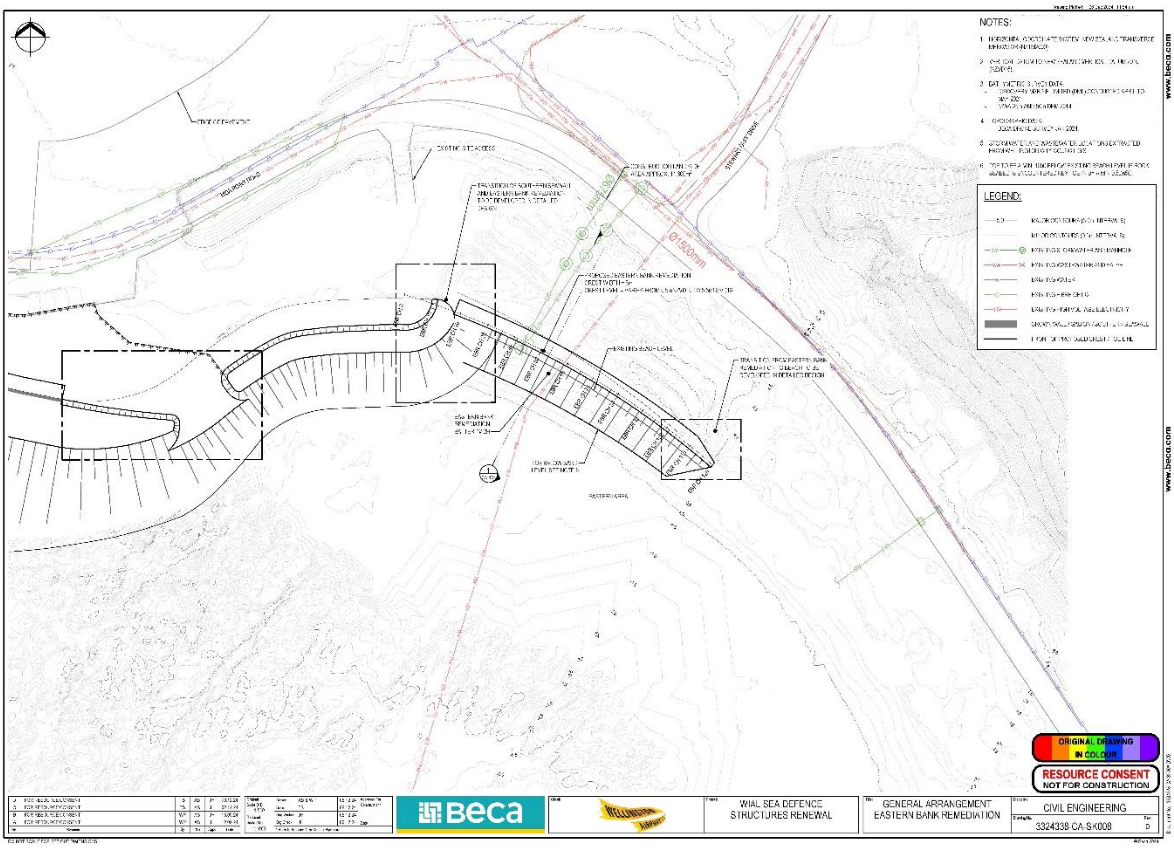


Figure A-3 Plan View of Revised Seawall Configuration at Airport Rights, received December 2024

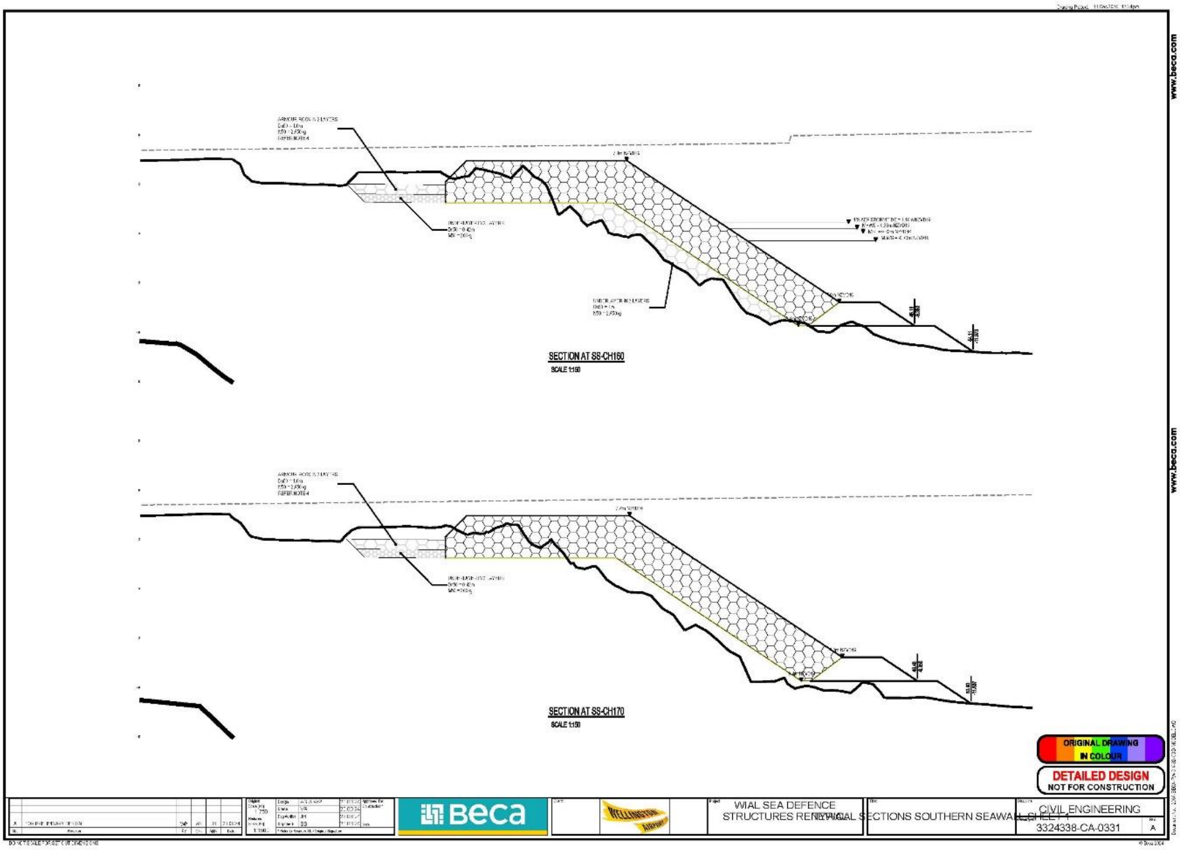


Figure A-4 **Cross sections for chainages 160m and 170m showing rock toe with rock blanket**

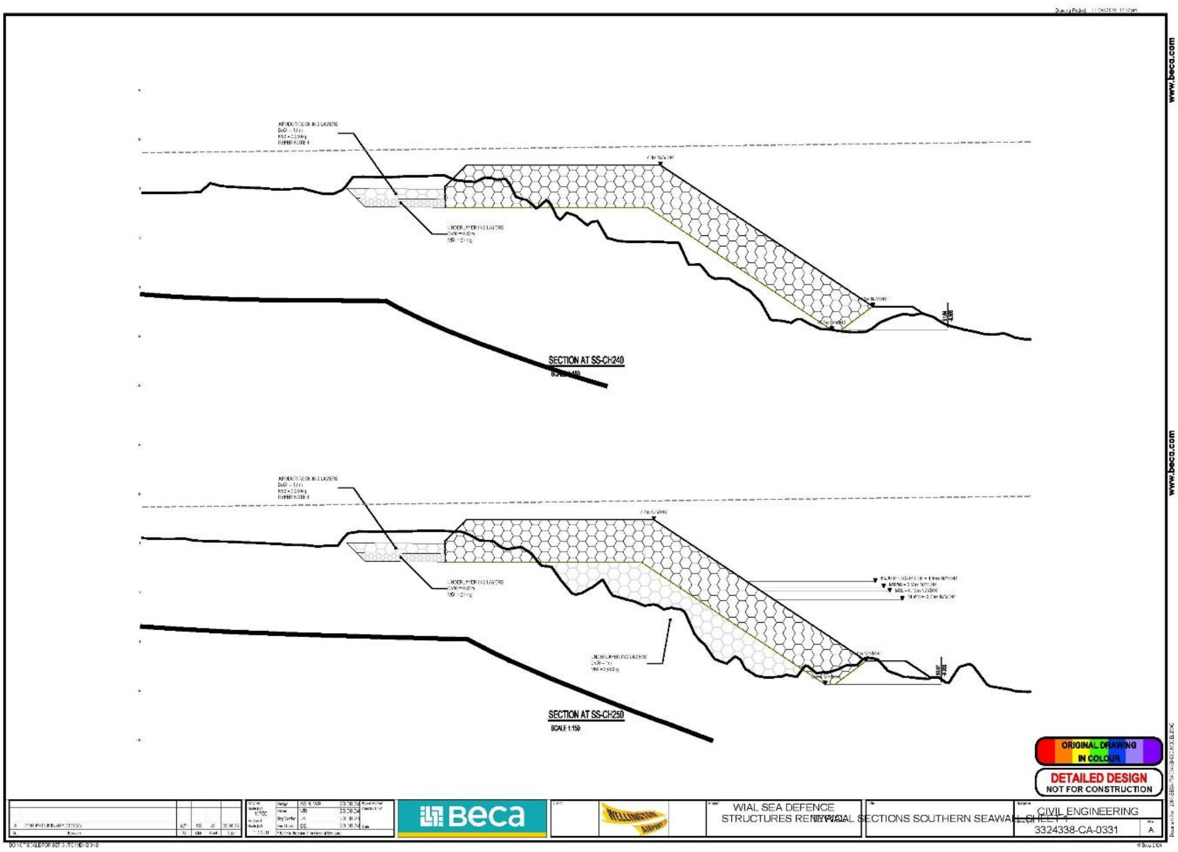


Figure A-5 **Cross sections for chainages 240m and 250m showing rock toe, no rock blanket and minor clearance of rock "pinnacles" on seabed.**

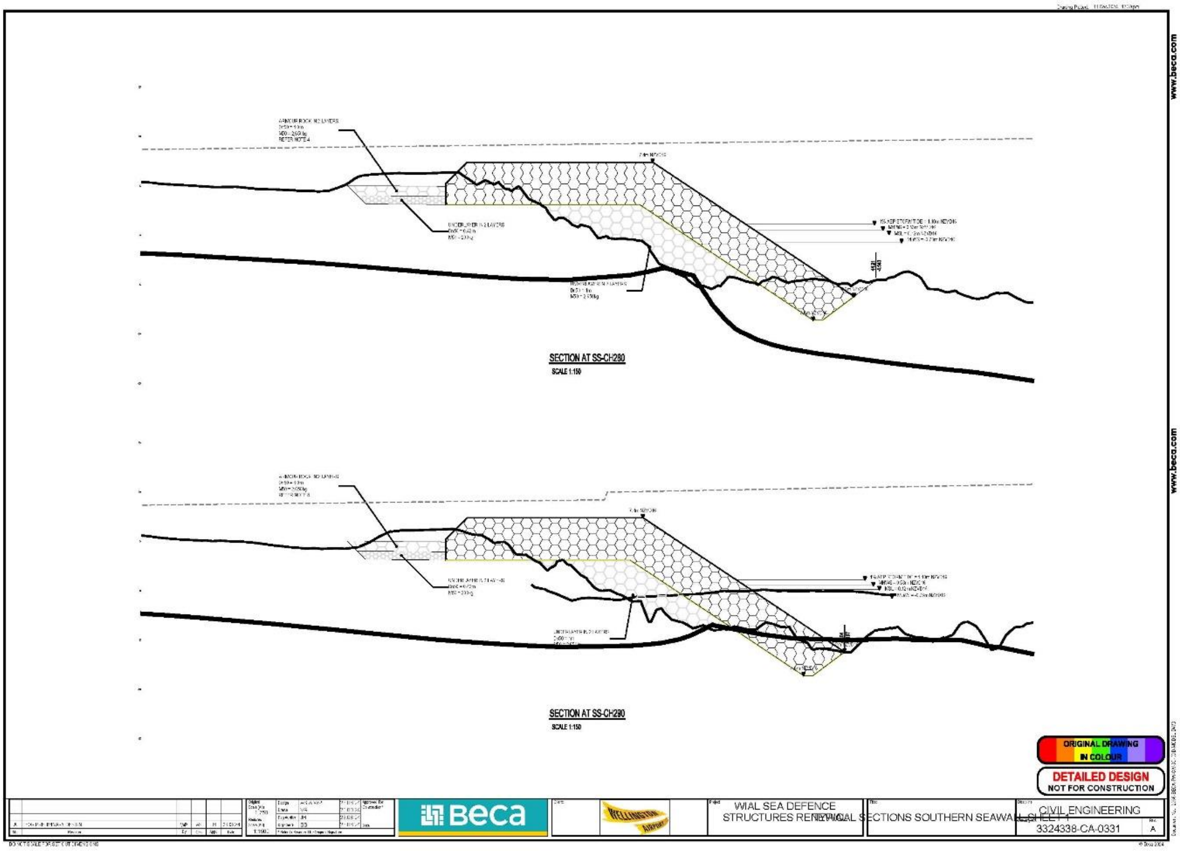


Figure A-6 Cross sections for chainages 280m and 290m showing toe excavated into rock seabed

Appendix B Qualifications and Expertise of Authors

Simon Mortensen

Position	Head of Digital Marine based in Gold Coast, Australia.
Education	M.Sc., Civil Engineering, Technical University of Denmark, 2006 B.Sc., Engineering, Technical University of Denmark, 2004
Five Selected Projects to Illustrate Relevant Experience	Technical Specialist. Multipurpose Artificial Surf Reef Design, Jalisco, Xala Mar, Mexico. 2021 – Present. *Assessments to support development of an artificial reef structure intended to enhance coastal stability, ecosystem value, climate resiliency and surfing/recreational amenities at the Xala Mar development site in Jalisco, Mexico.*
	Technical Specialist. Surf Lakes Beach Break Design Optimisation, Surf Lakes Holdings Ltd, Australia. 2017 – Present. *Supporting Surf Lakes in the design and optimization of their inland surf pool since 2017. This support has been primarily through providing CFD simulations of various aspects of the design.*
	Technical Specialist, Wellington Airport Extension - Surfbreak Impact Assessment, Wellington International Airport Ltd, New Zealand. 2015 to 2020. *Impact assessment for proposed extension of Wellington Airport runway on the wave climate, swimmer safety and surf quality of the surf breaks at Lyall Bay.*
	Technical Specialist. GCCC Design Reference Report for the Palm Beach Shoreline Project, Gold Coast City Council, Australia. 2015 – 2018. *Detailed numerical performance assessment and sensitivity study of a coastal protection initiative using a submerged control structure (SCS) with potential for a new surf break included. The study included validation against physical model experiments leading to further refinements of the numerical model framework.*
	Quality Supervisor. Quality Supervisor, Eastbourne Surf Amenity Assessment, CentrePort Wellington, New Zealand. 2016 – 2017. *Surf quality impact assessment for Eastbourne surfbreaks for proposed dredged channel through Wellington Harbour entrance.*

Danker Kolijn

Position	Head of Coastal & Marine Solutions, Americas based in Vancouver, Canada.
Education	M.Sc., Coastal Engineering, Technical University of Delft, 2014 M.Eng., Civil Engineering, University of British Columbia, 2012
Five Selected Projects to Illustrate Relevant Experience	Project Manager and Technical Specialist. Multipurpose Artificial Surf Reef Design, Jalisco, Xala Mar, Mexico. 2021 – Present. *Assessments to support development of an artificial reef structure intended to enhance coastal stability, ecosystem value, climate resiliency and surfing/recreational amenities at the Xala Mar development site in Jalisco, Mexico.*
	Project Manager & Senior Coastal Engineer, Prince Edward Island - DFO-Small Craft Harbor - McAuleys Shore Reconstruction, Harbourside Engineering, Canada. 2022. *SCH upgrade and redevelopment project which required the design of new wharf infrastructure. The project included numerical modelling in the MIKE 21 suite of hydrodynamic (HD), spectral wave (SW), and Boussinesq (BW) wave processes, overtopping analysis, and the preliminary design of several proposed concepts.*
	Project Manager & Senior Coastal Engineer, Storm Surge & Wave Modelling for Climate Change Flood Risk Mapping, Government of Newfoundland, KGS Group, Canada. 2021 – 2022. *Model development of a 40-year wave and storm surge hindcast. The hindcast data was used to derive extreme water levels using joint probabilistic methods to establish flood elevations for coastal infrastructure. Wave overtopping and run-up analysis using MIKE21 SW model out for extreme scenarios is used to define coastal risk & required flood defense elevations.*
	Coastal Hazard Adaptation Assessment and Feasibility Study Along Dallas Road, City of Victoria, British Columbia 2024-2025 *Mr. Kolijn is the senior technical resources to complete a comprehensive coastal hazard adaptation assessment and feasibility study Along Dallas Road in the City of Victoria. Danker led the modelling in MIKE21 SW, HD and MIKE3 WaveFM models to investigate coastal hazards associated with sea level rise, map flood construction levels, conduct a coastal hazard assessment and generate a feasibility study to inform coastal infrastructure investment, planning, and policy. The hazard assessment was completed using the PIEVC protocol, and design typologies developed at a high-level for costing purposes.*
	Project Manager and Senior Coastal Engineer, Coupled Hydrodynamic and Wave Modelling of Hurricane Impacts in Jamaica and the Dominican Republic 2024 *Mr. Kolijn was the DHI project manager and Senior Coastal Engineer to develop MIKE21 hydrodynamic (HD) and wave (SW) models for Miches, Dominican Republic and Old Harbour Bay, Jamaica to simulate conditions during Hurricane Irma and Maria, both occurring in September 2017. The intent of the models was to demonstrate the importance of natural assets such as mangroves and/or coral reefs, in a changing climate, to offer protection to coastal communities and ecosystems from large storm events. Mr. Kolijn also offered training to TNC staff for the use of numerical modelling tools to investigate and demonstrate the value of natural assets for coastal protection.*

Appendix C M3W Modelling Results

Appendix C.1 63% AEP Storm

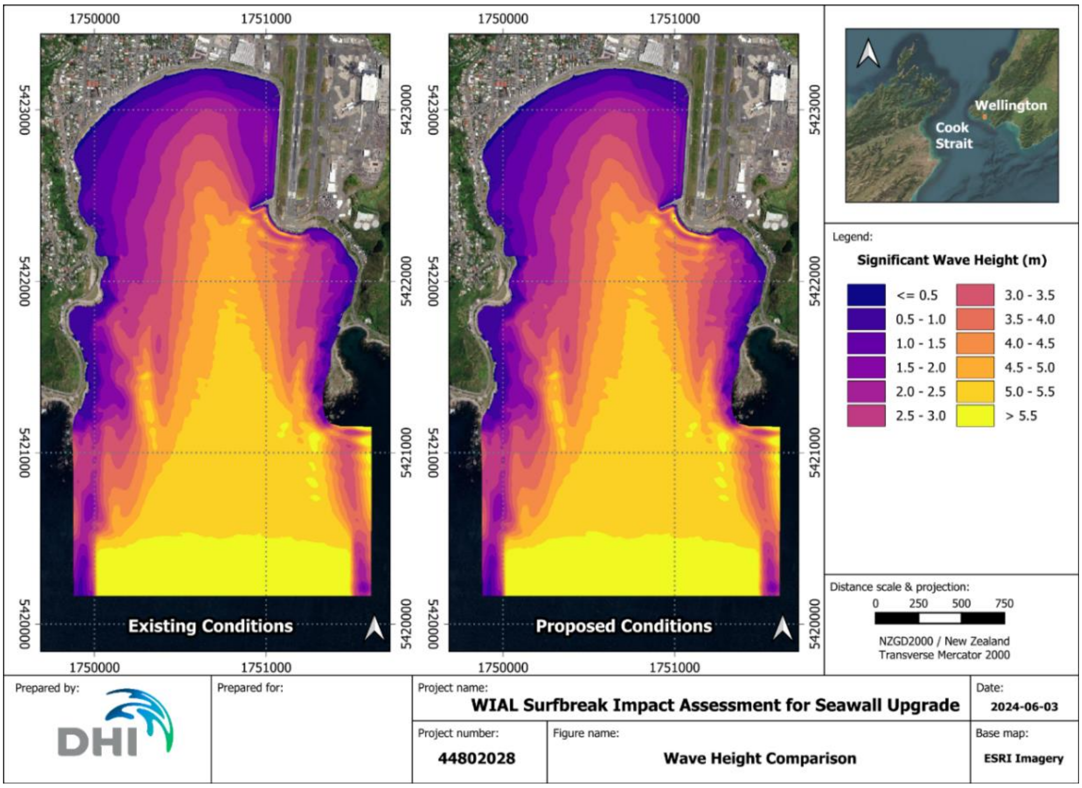


Figure C-1 63% AEP Storm – Significant Wave Height Comparison, no SLR

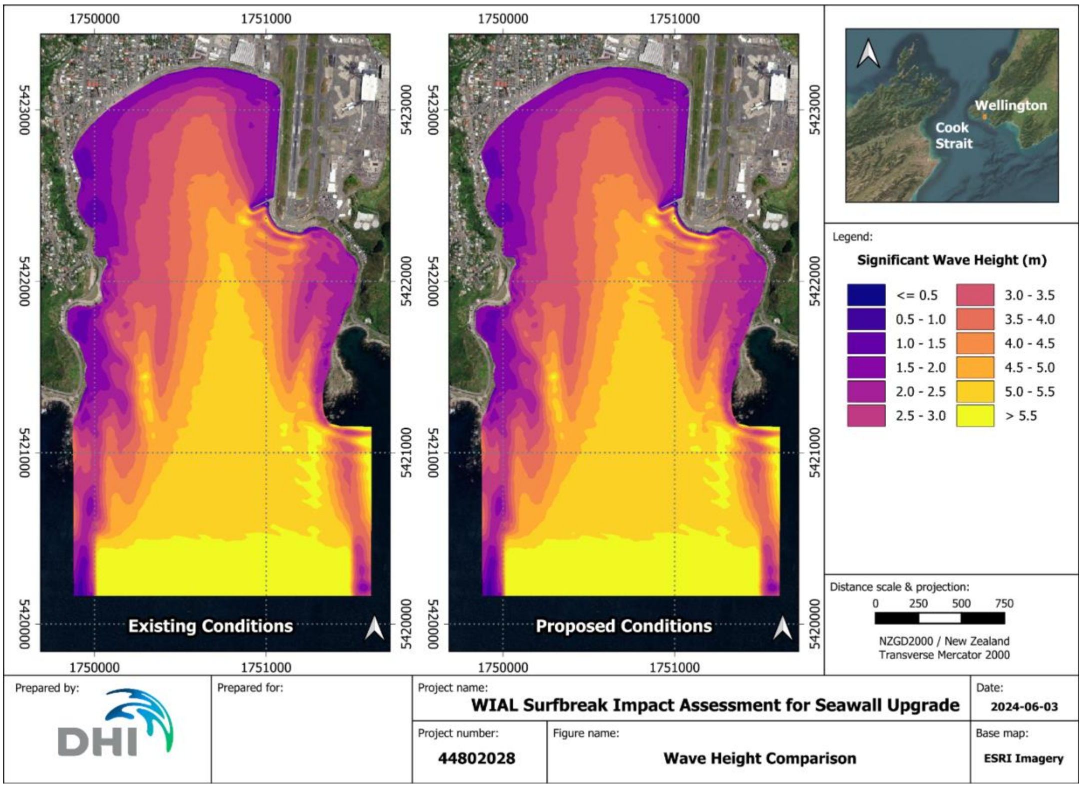


Figure C-2 63% AEP Storm – Significant Wave Height Comparison, 100 Year SLR.

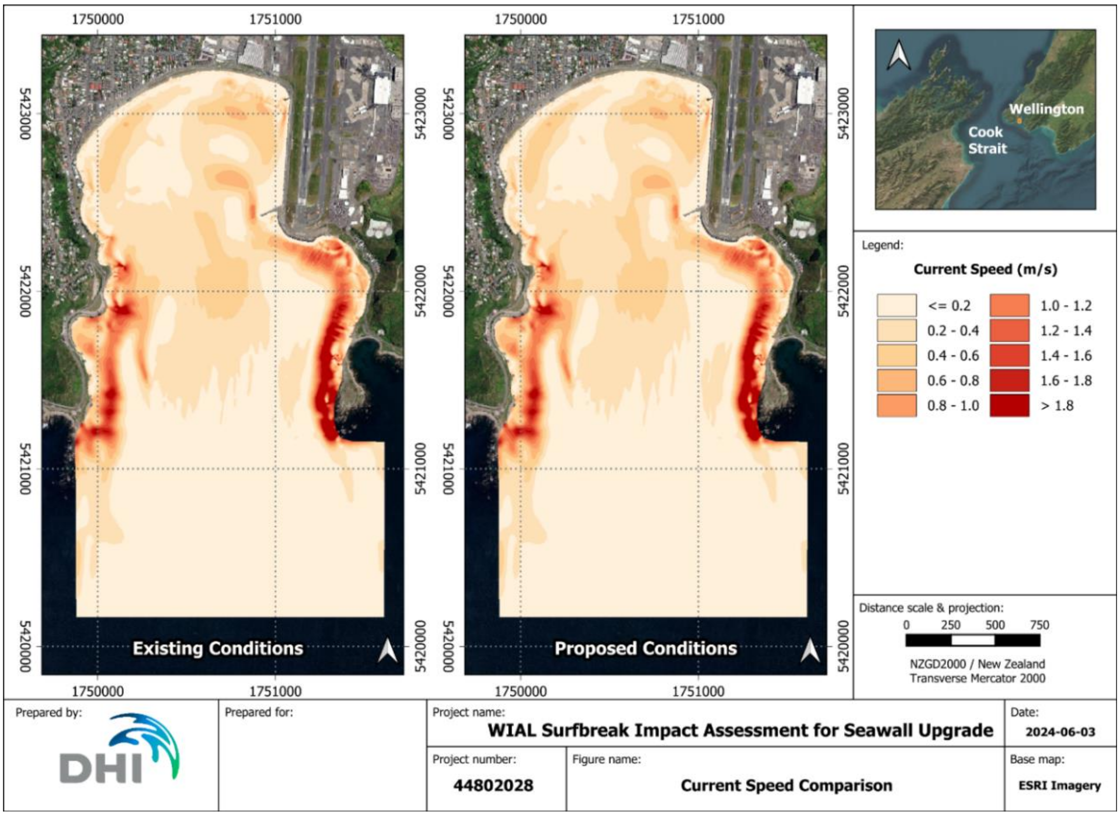


Figure C-3 63% AEP Storm – Current Speed Comparison, no SLR.

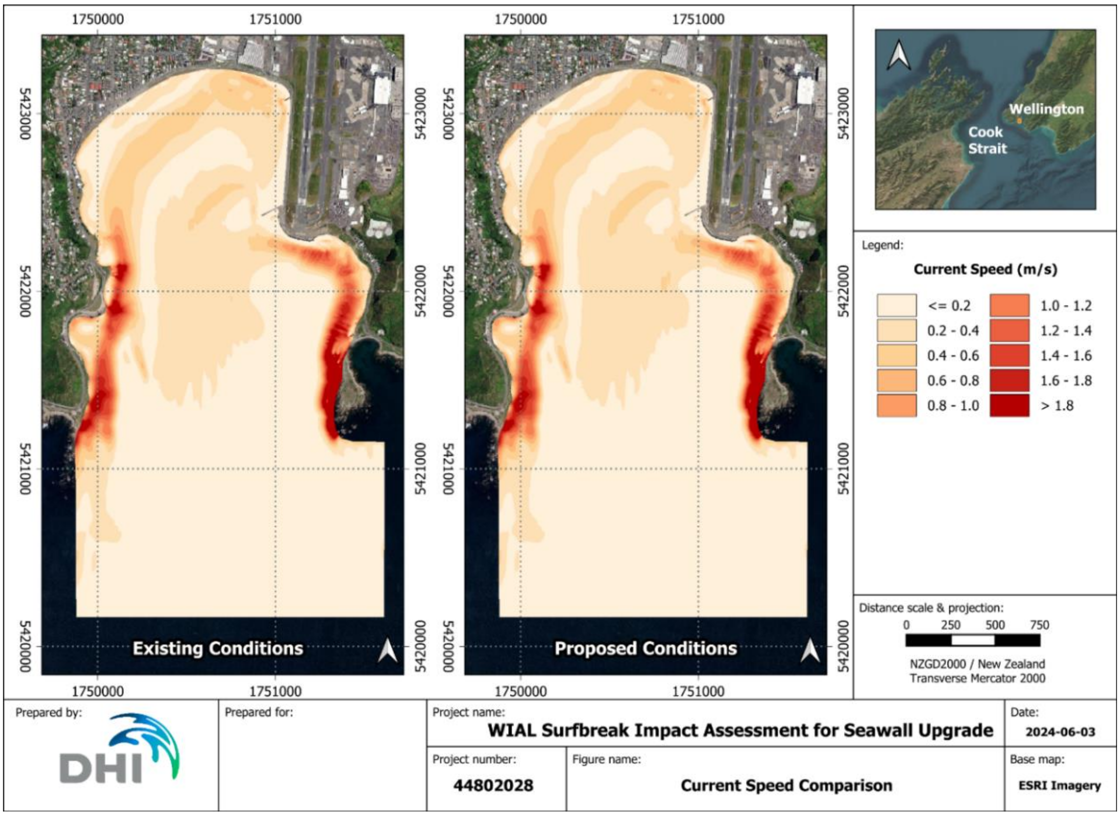


Figure C-4 63% AEP Storm – Current Speed Comparison, 100 Year SLR

Appendix C.2 50th Percentile Wave Event

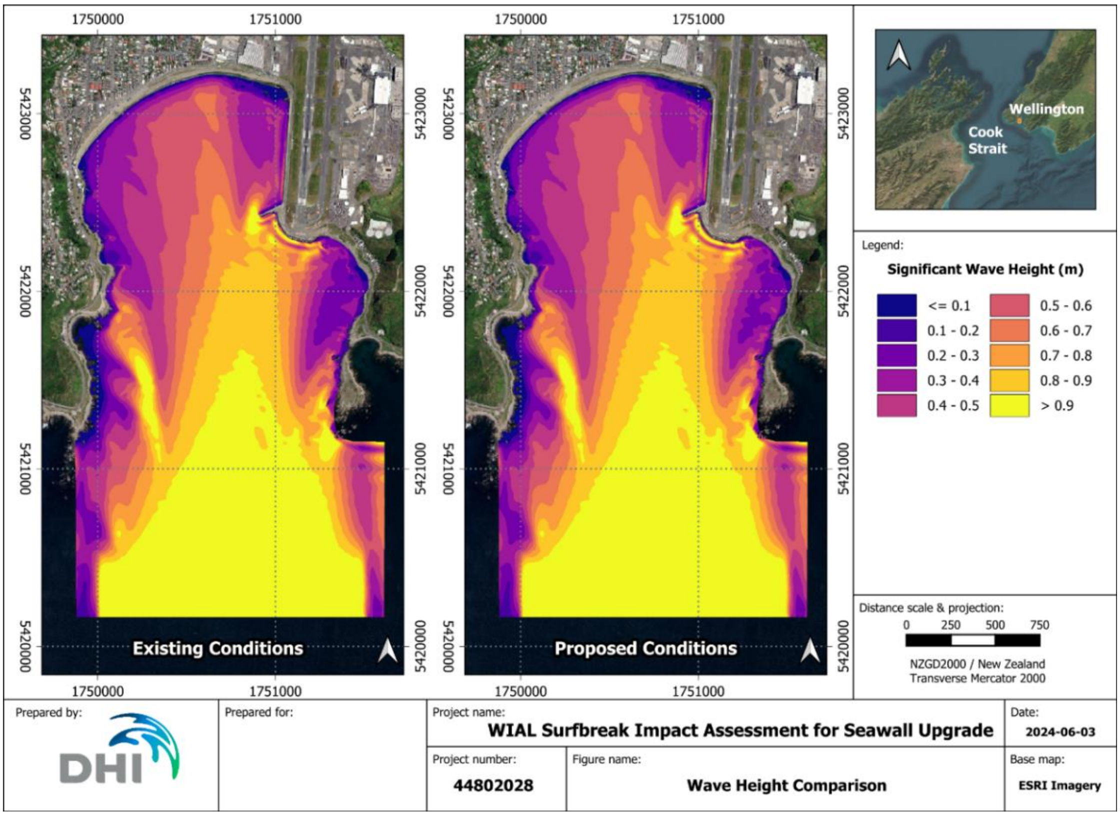


Figure C-5 50th Percentile Wave Event – Significant Wave Height Comparison, no SLR

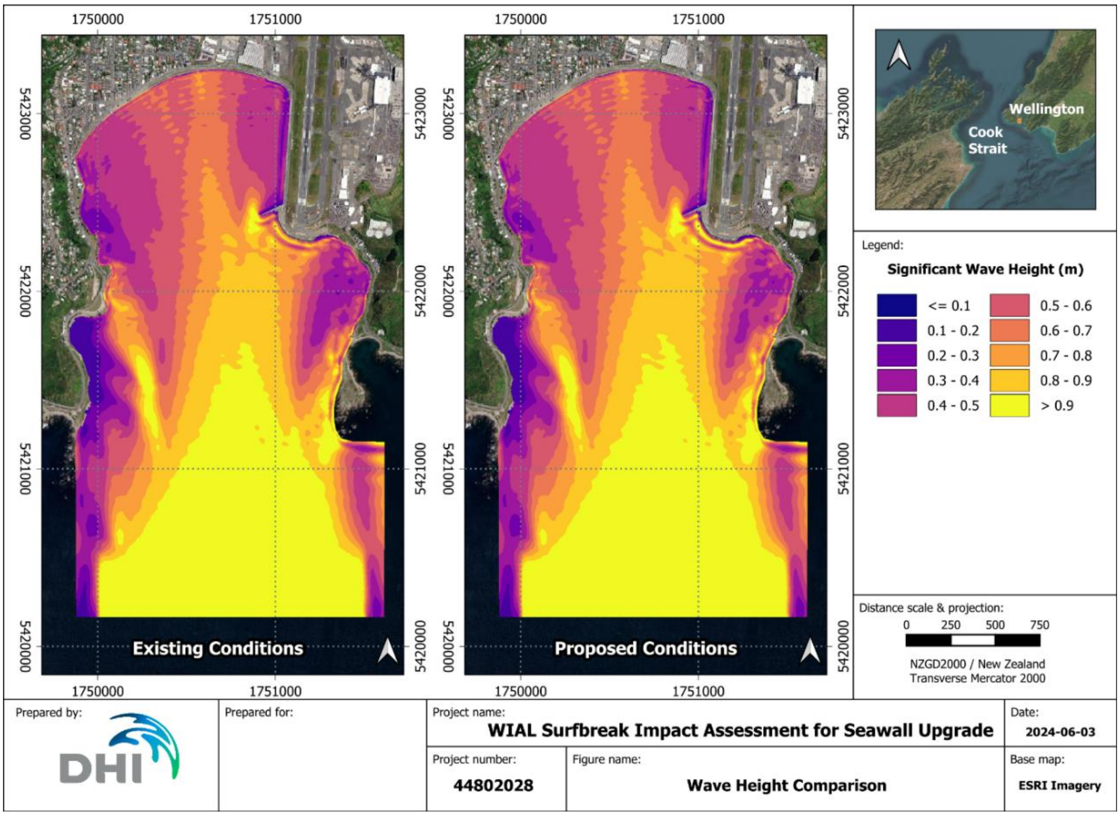


Figure C-6 50th Percentile Wave Event – Significant Wave Height Comparison, 100 Year SLR

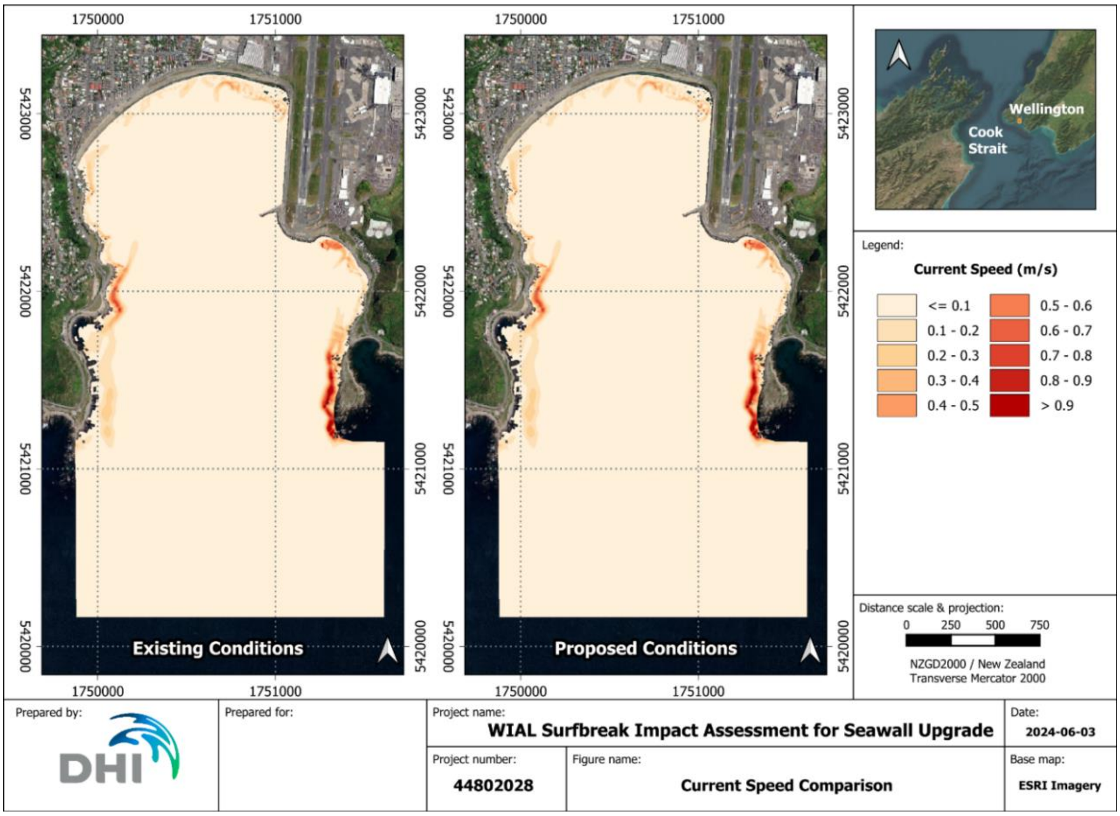


Figure C-7 50th Percentile Wave Event – Current Speed Comparison, no SLR

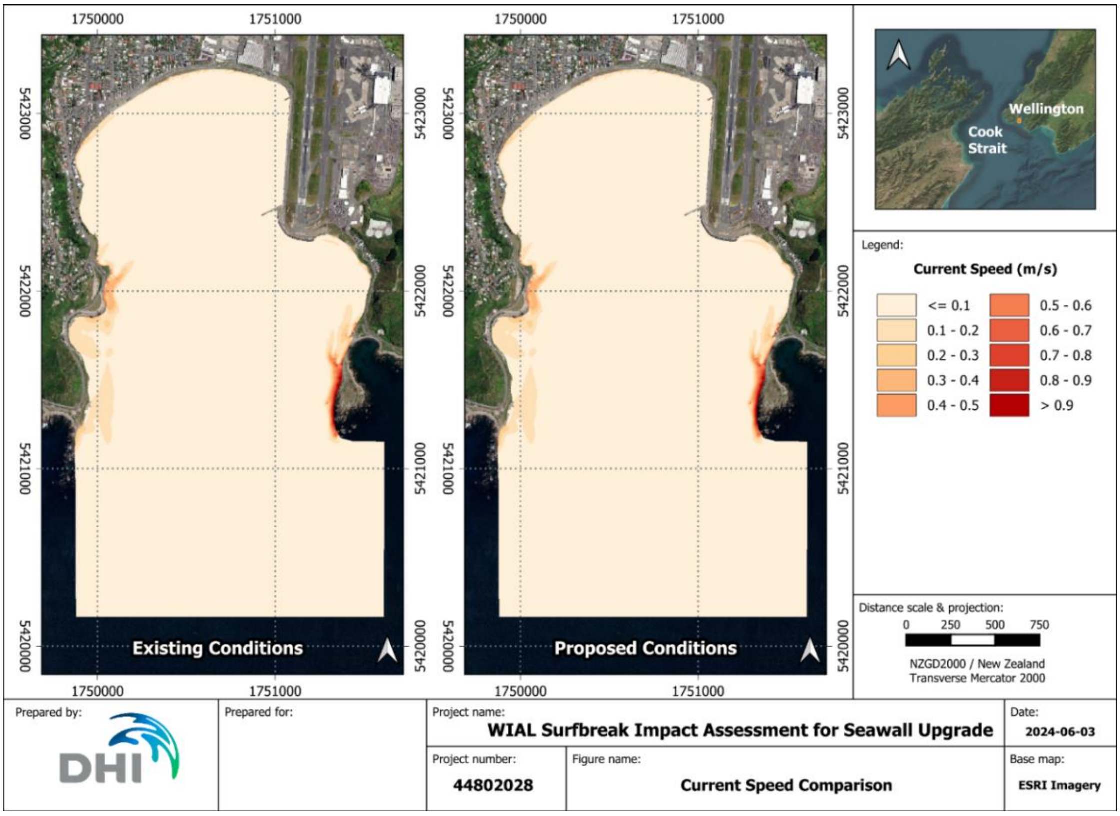


Figure C-8 50th Percentile Wave Event – Current Speed Comparison, 100 Year SLR

Appendix C.3 Small Corner Wave Event

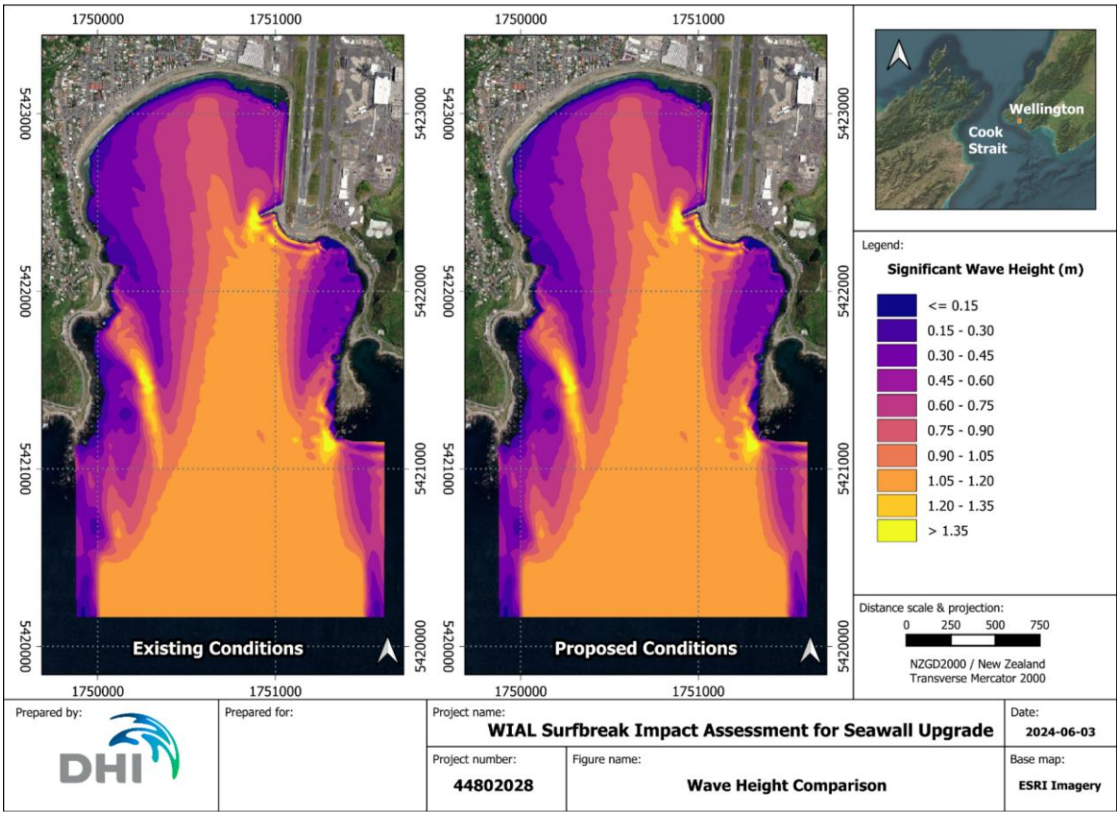


Figure C-9 Small Corner Wave Event – Significant Wave Height Comparison, MLWS

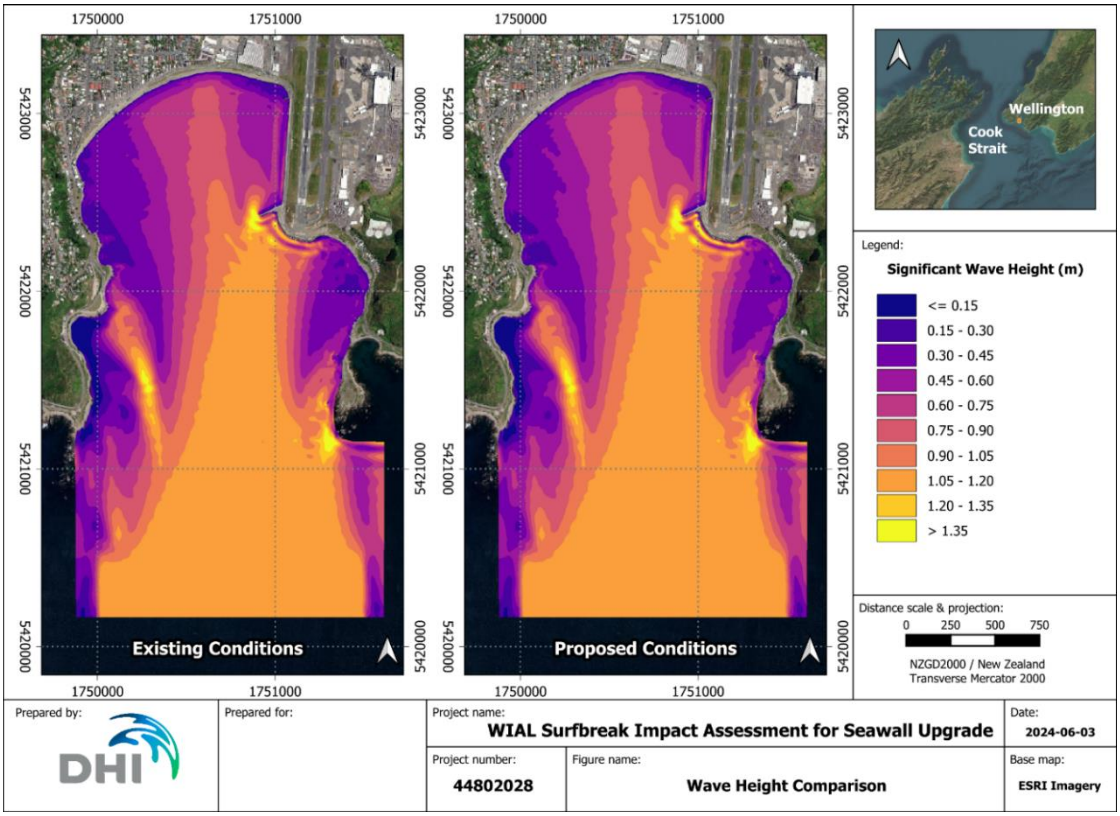


Figure C-10 Small Corner Wave Event – Significant Wave Height Comparison, MHWS

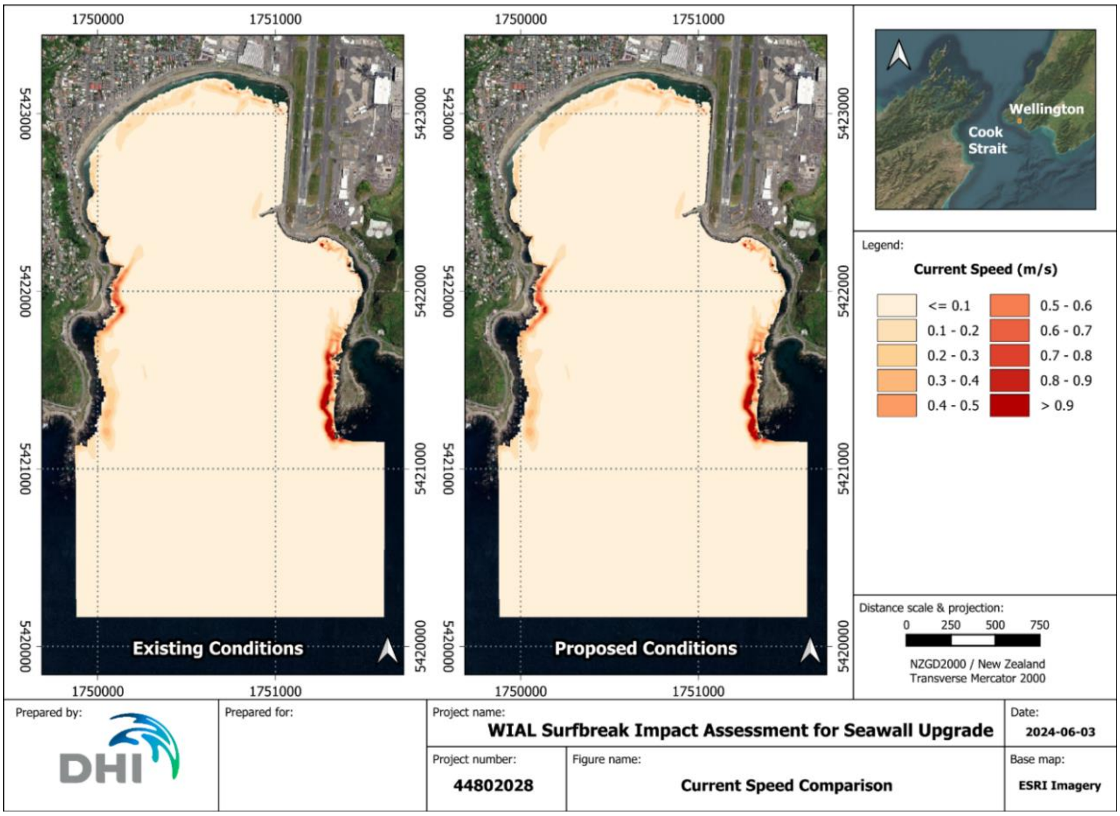


Figure C-11 Small Corner Wave Event – Current Speed Comparison, MLWS

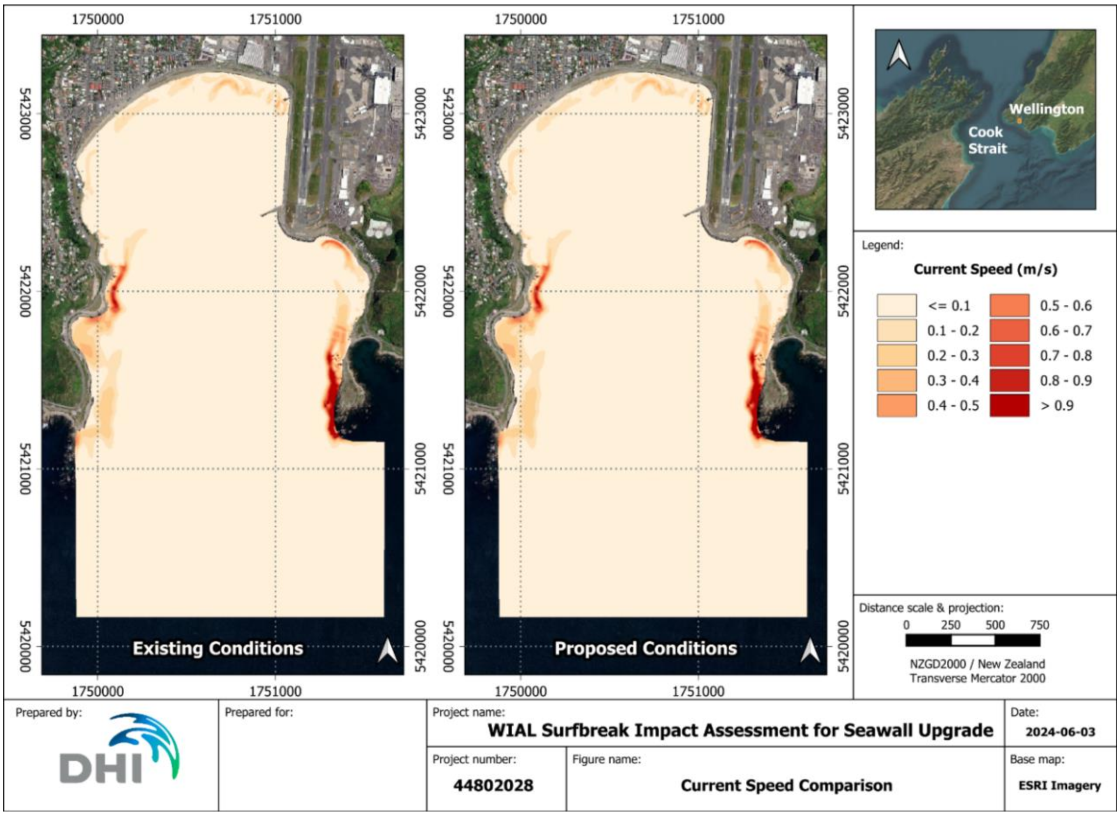


Figure C-12 Small Corner Wave Event – Current Speed Comparison, MHWS

Appendix C.4 Good Corner Wave Event

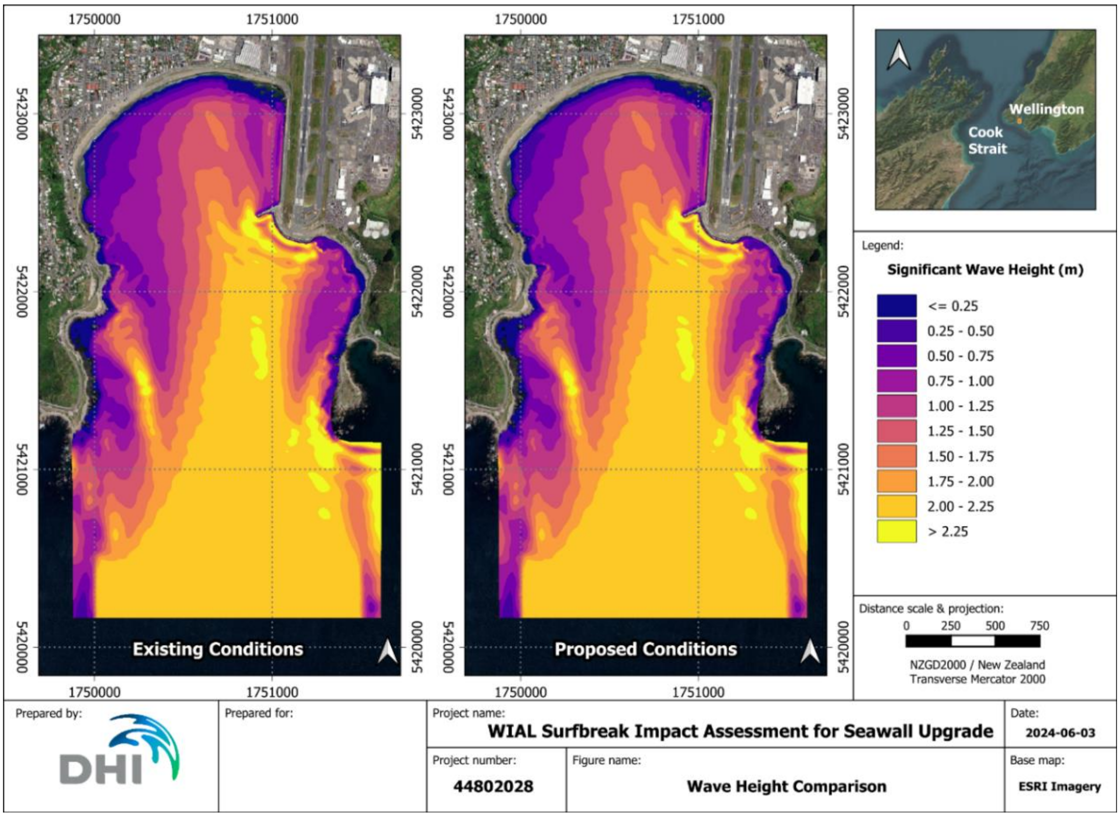


Figure C-13 Good Corner Wave Event – Significant Wave Height Comparison, MLWS

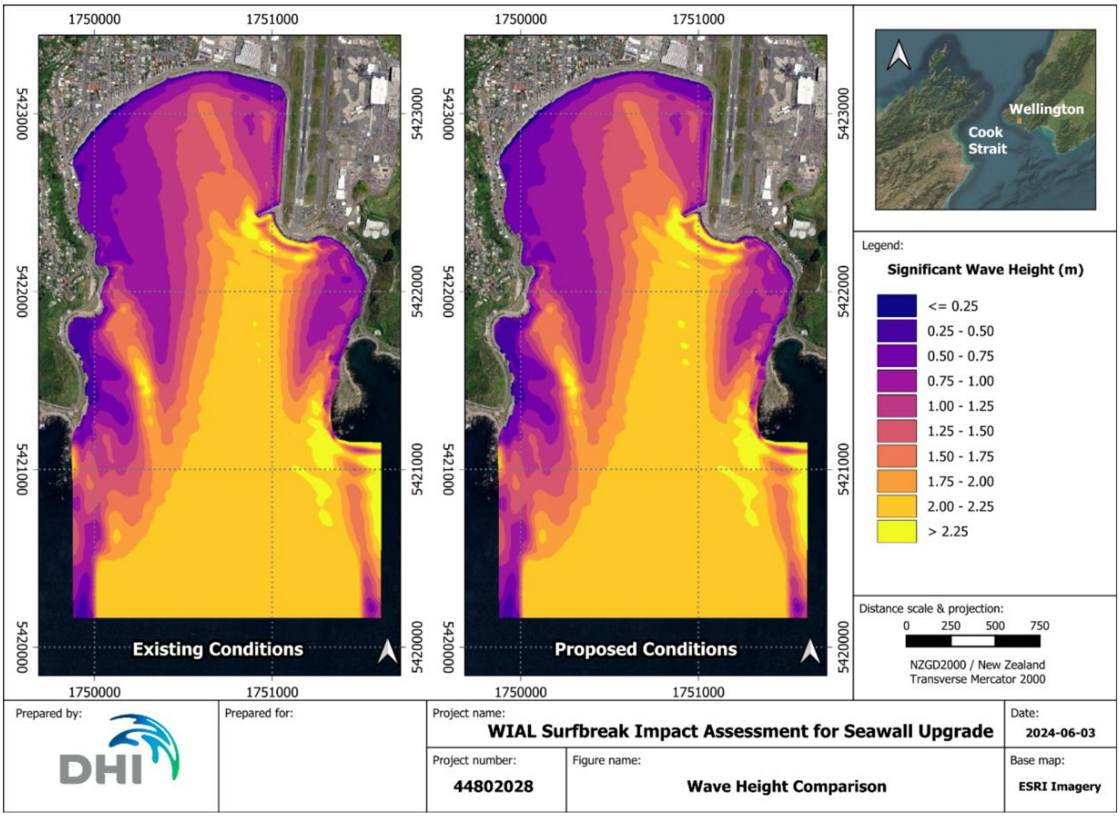


Figure C-14 Good Corner Wave Event – Significant Wave Height Comparison, MHWS no SLR

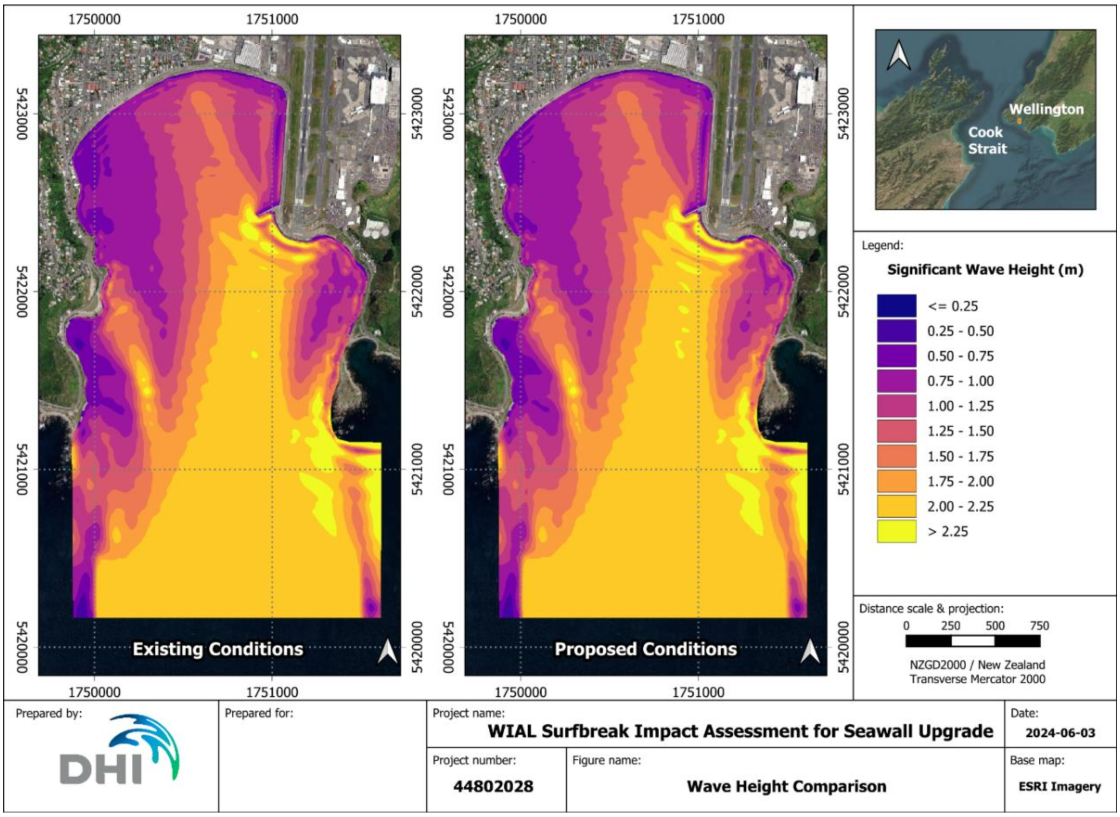


Figure C-15 Good Corner Wave Event – Significant Wave Height Comparison, MHWS 50 Year SLR

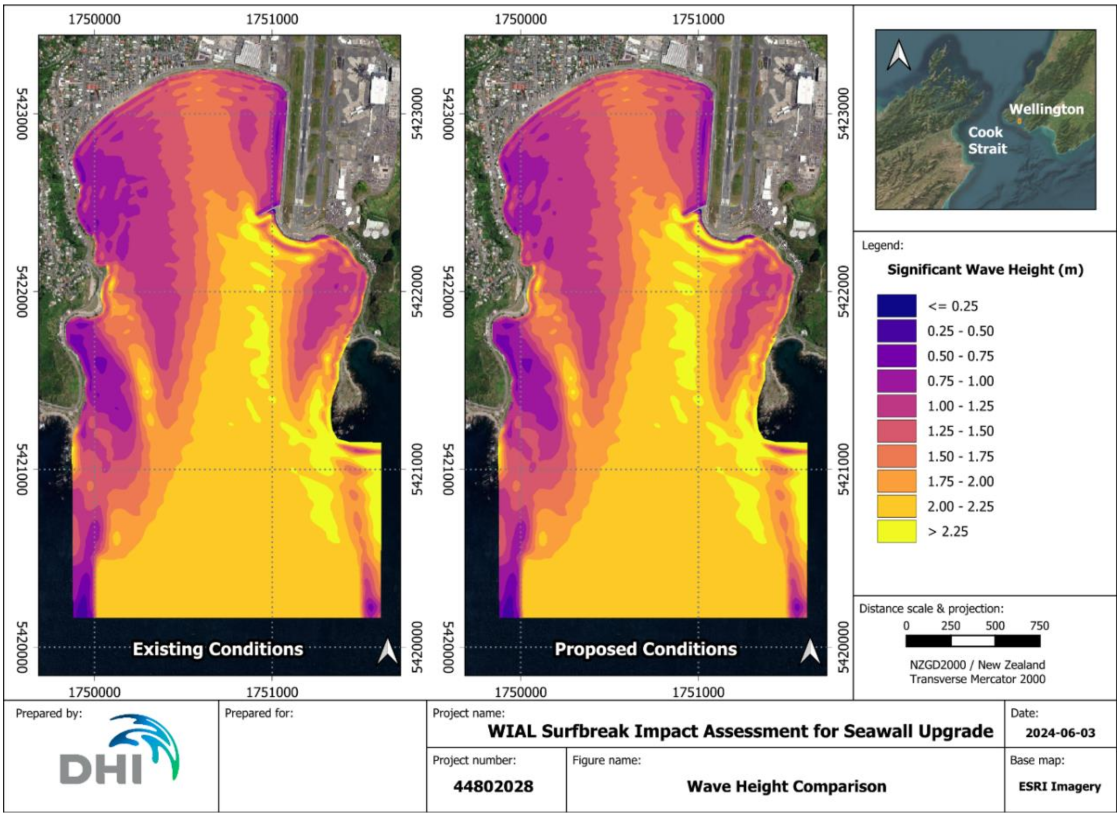


Figure C-16 Good Corner Wave Event – Significant Wave Height Comparison, MHWS 100 Year SLR

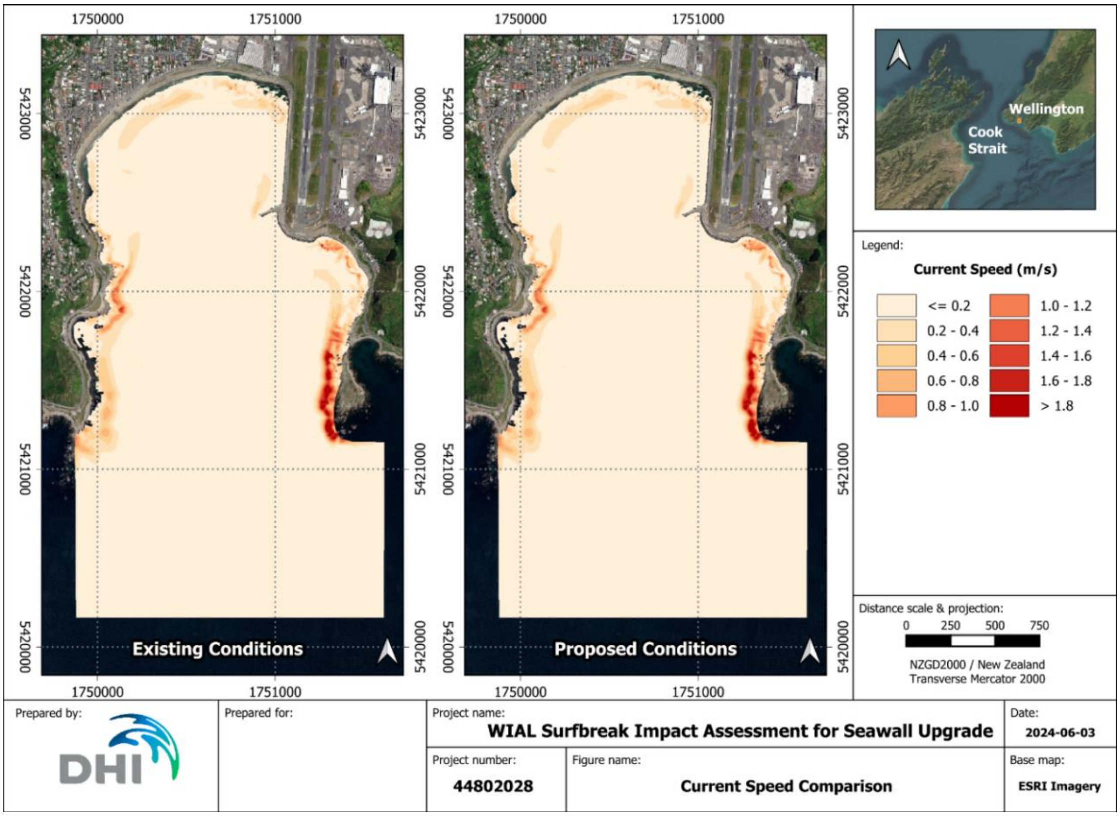


Figure C-17 Good Corner Wave Event – Current Speed Comparison, MLWS

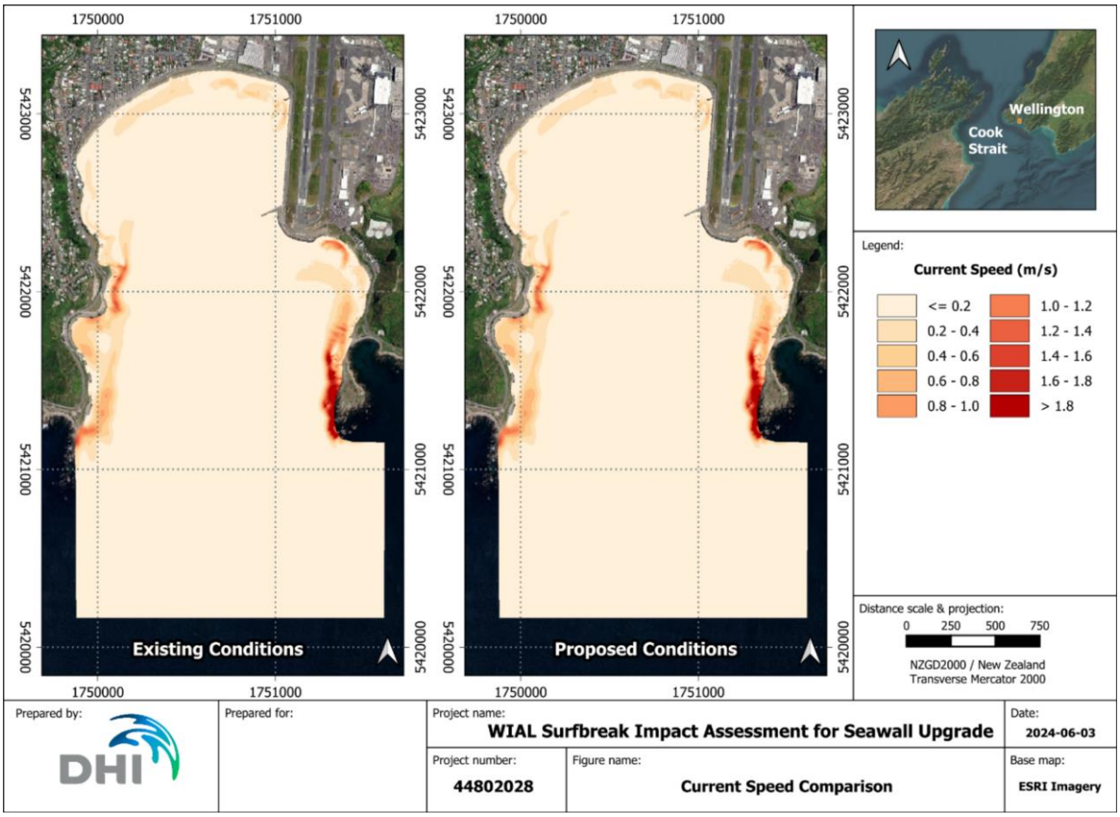


Figure C-18 Good Corner Wave Event – Current Speed Comparison, MHWS no SLR

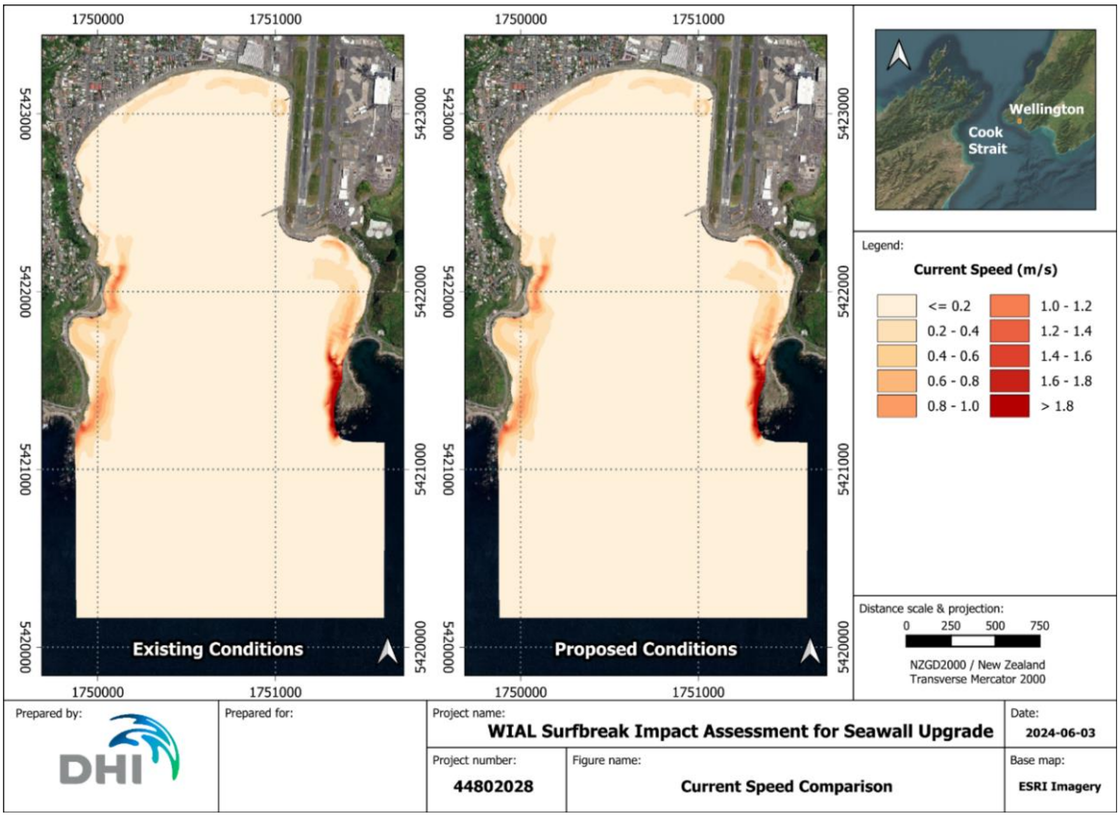


Figure C-19 Good Corner Wave Event – Current Speed Comparison, MHWS 50 Year SLR

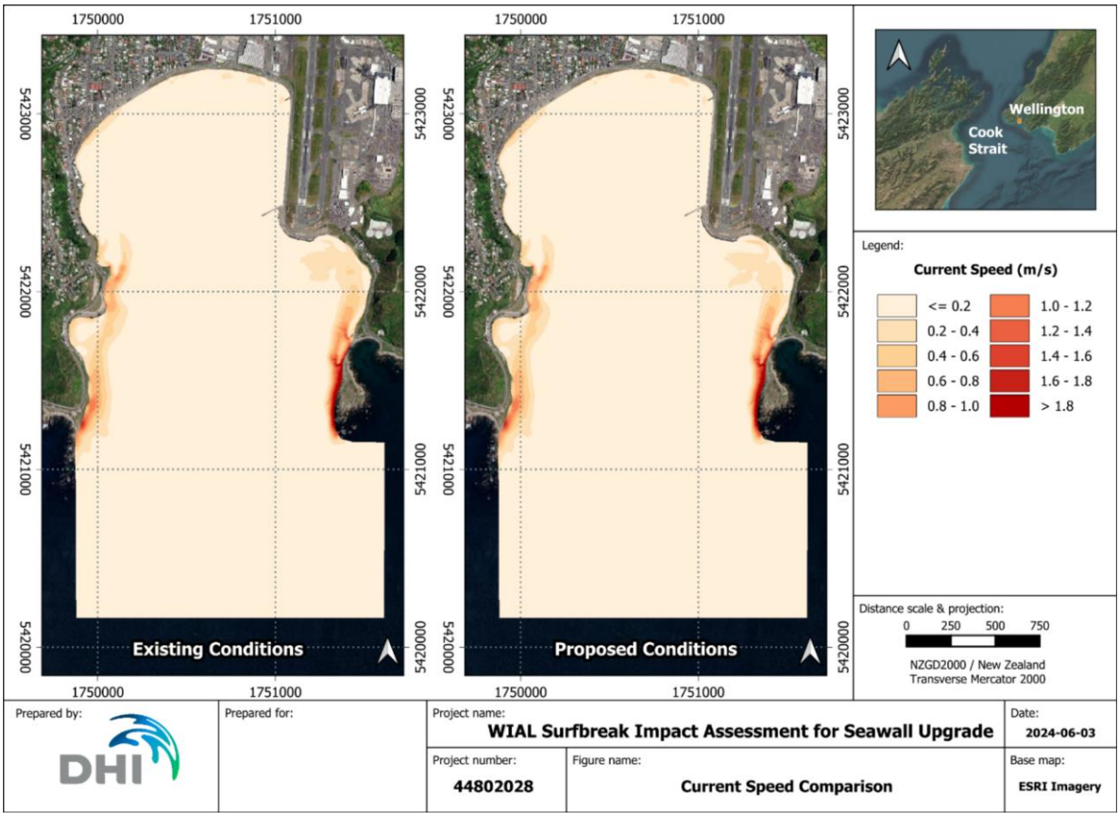


Figure C-20 Good Corner Wave Event – Current Speed Comparison, MHWS 100 Year SLR

Appendix C.5 Exceptional Corner Wave Event

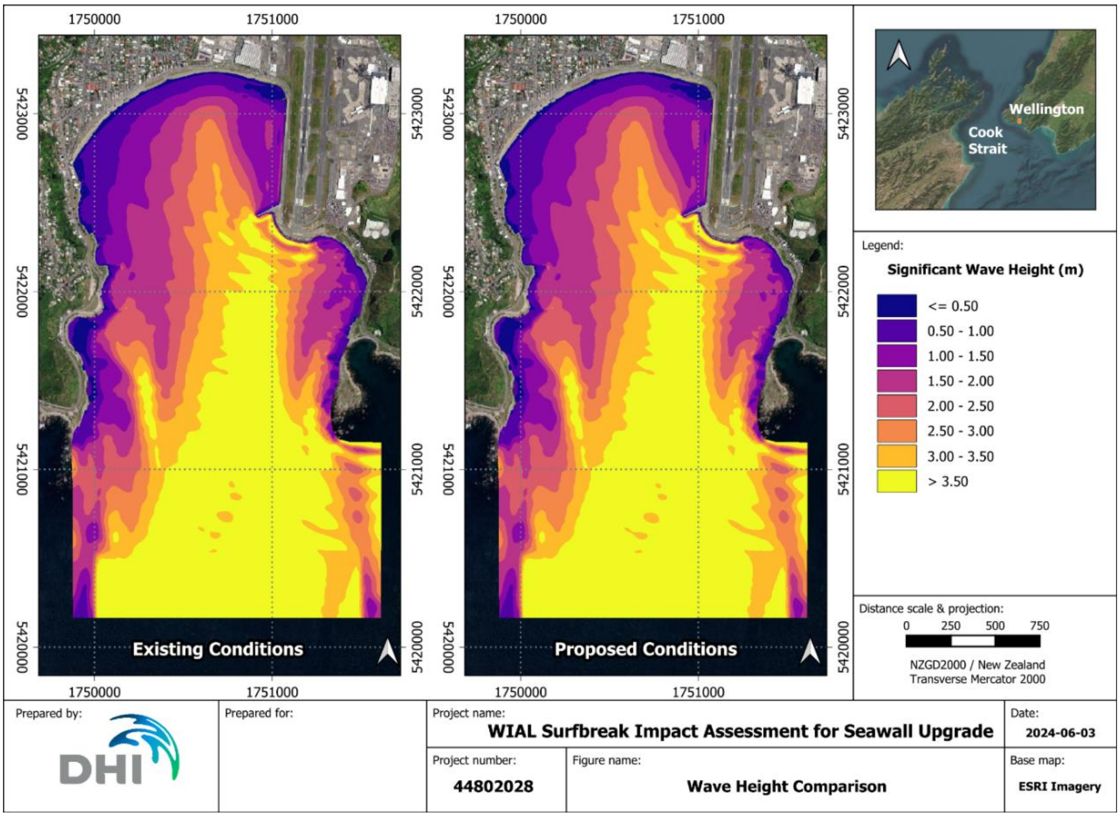


Figure C-21 Exceptional Corner Wave Event – Significant Wave Height Comparison, MSL

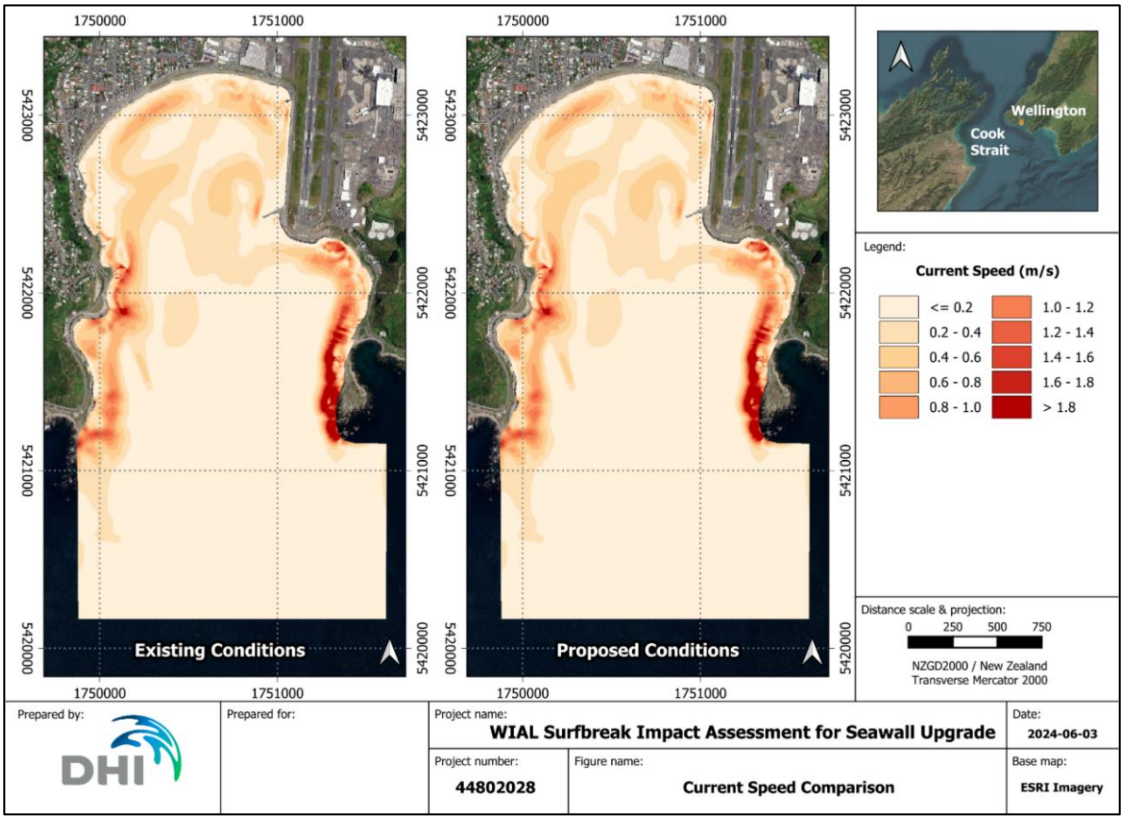


Figure C-22 Exceptional Corner Wave Event – Current Speed Comparison, MSL

Appendix C.6 Exceptional Airport Rights Wave Event

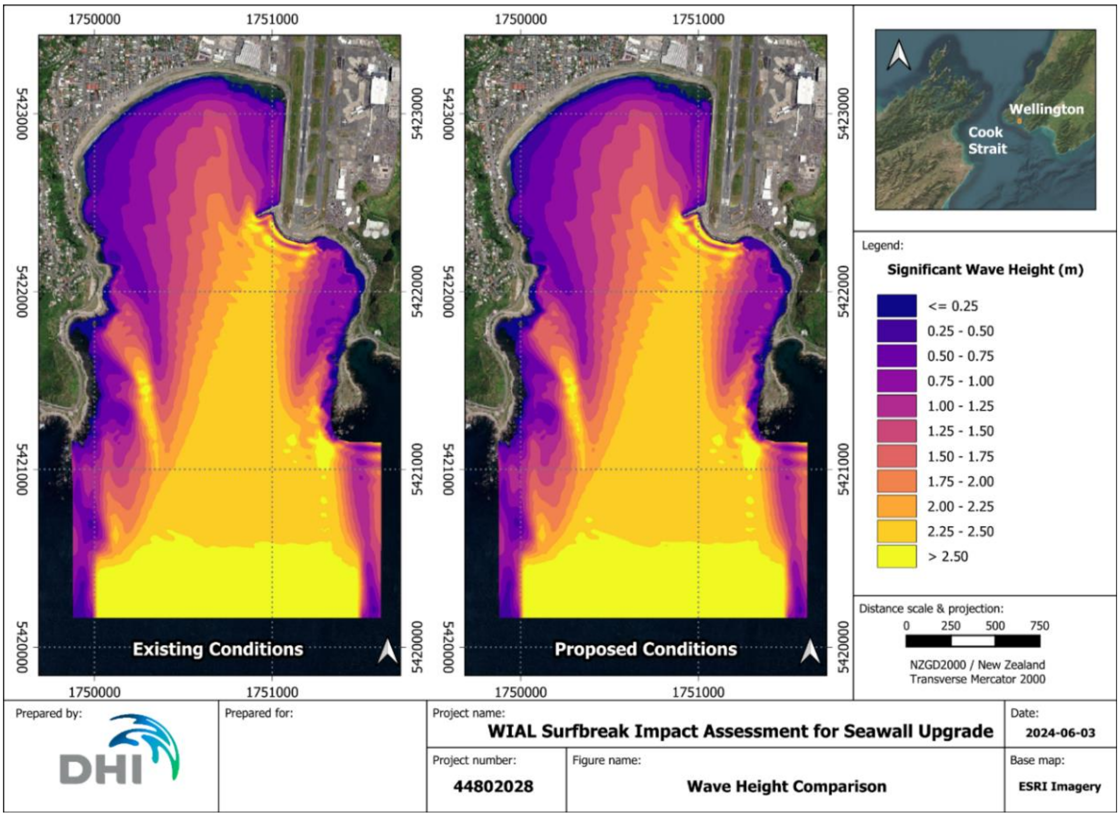


Figure C-23 Exceptional Airport Rights Wave Event – Significant Wave Height Comparison, MLWS

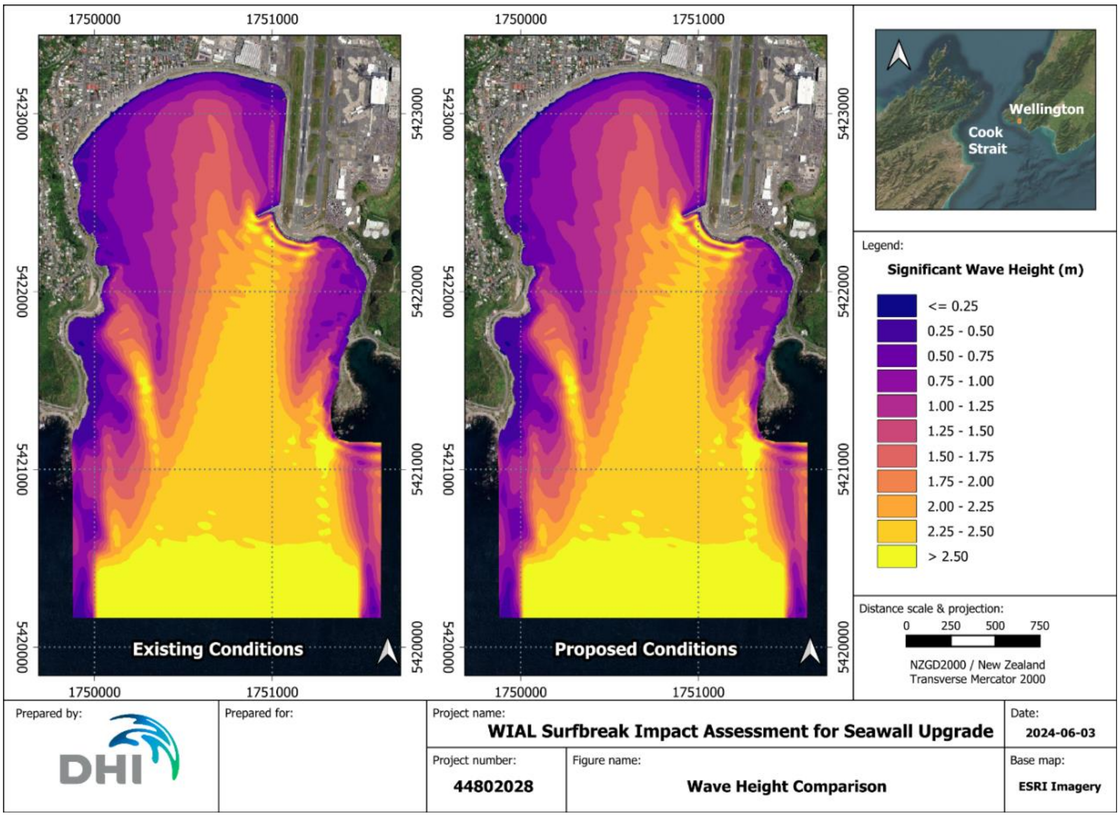


Figure C-24 Exceptional Airport Rights Wave Event – Significant Wave Height Comparison, MHWS

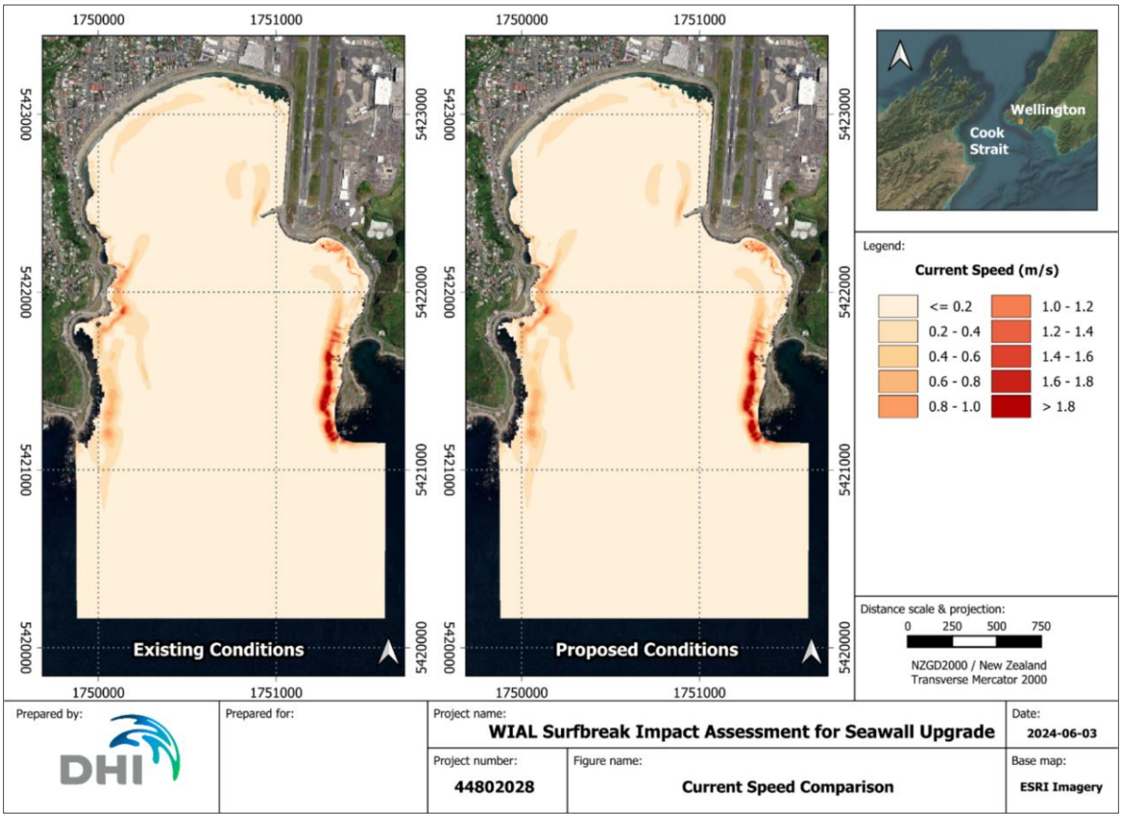


Figure C-25 Exceptional Airport Rights Wave Event – Current Speed Comparison, MLWS.

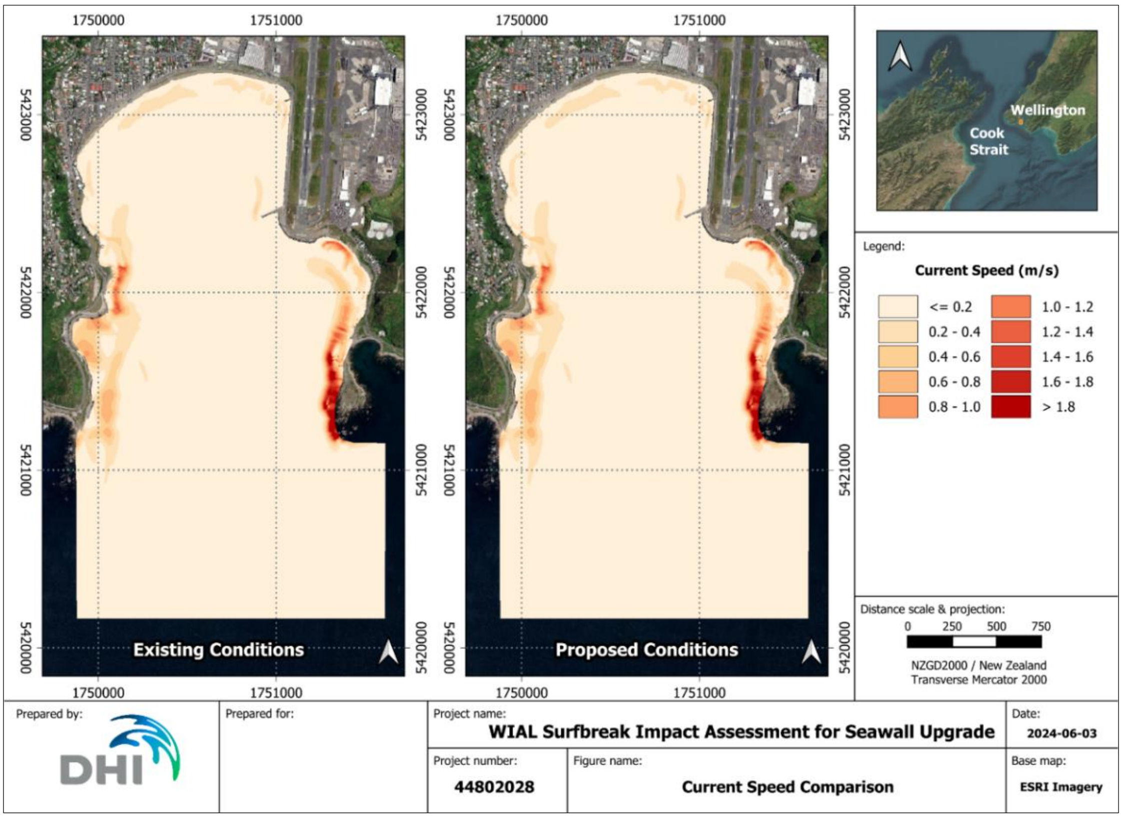


Figure C-26 Exceptional Airport Rights Wave Event – Current Speed Comparison, MHWS.

Appendix D OptiSurf Results – Airport Rights Location

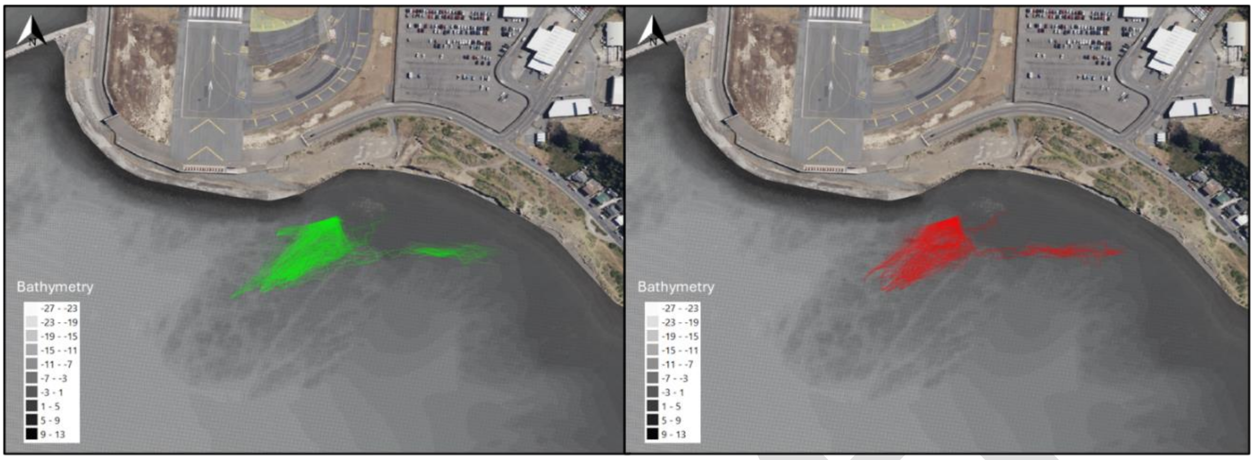


Figure D-1 Airport rights OptiSurf surf rides for exceptional wave conditions at MLWS with both existing southern seawall (left) and proposed renewed southern seawall (right).

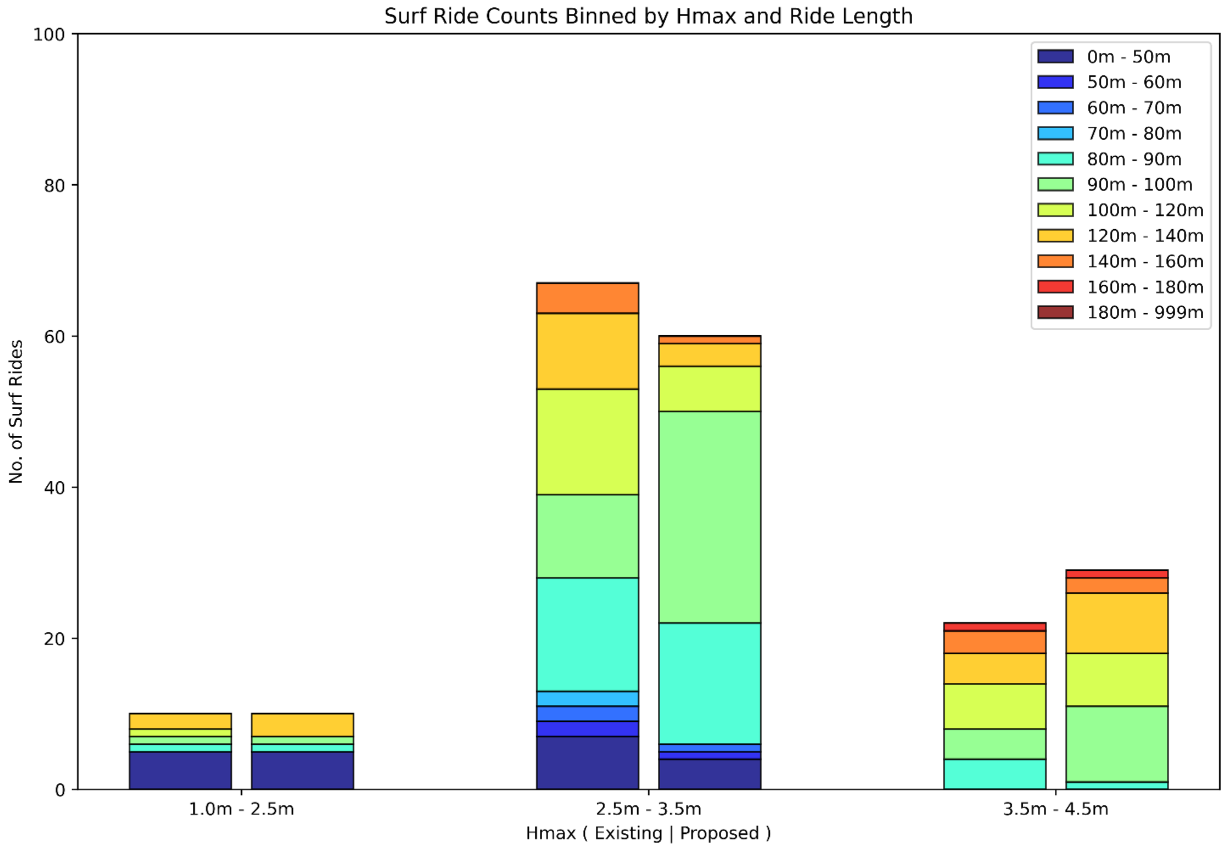


Figure D-2 Binned maximum wave face height and ride length statistics for exceptional Airport rights wave conditions at MLWS with both existing southern seawall (bars-L) and proposed renewed southern seawall (bars-R).