Attachment 14

Coastal Effects Assessment
Report prepared by Beca Limited

Sensitivity: General

Coastal Effects Assessment Report

Proposed New Bledisloe North Wharf and Fergusson North Wharf Extension

Prepared for Port of Auckland Ltd
Prepared by Beca Limited

21 November 2024

Contents

Appendices

Revision History

Revision Nº	Prepared By	Description	Date
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Action	Name	Signed	Date
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Approved by	Andy Harvey		22/11/2024
on behalf of	Beca Limited		

Executive Summary

This report assesses the potential environmental impacts of the proposed new Bledisloe North (BN) Wharf and Fergusson North (FN) Wharf extension in Waitematā Harbour, Auckland (referred to as the proposed developments). The primary objective is to determine the degree to which these proposed developments will affect tidal flows, currents, waves, sediment processes, and coastal hazards in the harbour.

These proposed developments are critical to maintaining reliable and sustainable harbour operations. Port of Auckland Limited (POAL) also recognises that the construction and operation of the proposed developments need to comply with relevant environmental standards. The report findings will directly inform decision-making regarding their planning, design, construction and operation.

Key findings suggest the following:

- **Effects on Tidal Flows and Currents:** While localised increases in current velocities may occur near the wharves, these changes are not expected to extend into the wider harbour, and the primary tidal regime will remain unaffected.
- **Effects on Waves and Wakes:** The proposed new BN Wharf, comprising piled structures, may cause localised wave reflection and wake pattern changes. However, these effects will remain confined to the immediate area around the new piles and externally will be similar to the existing situation. Berthed vessels could contribute to localised reflection adjacent to the wharf, though this impact is unavoidable due to the alignment of the vessel and its near vertical face. Similarly, the FN Wharf extension will have minimal impact on waves and wakes due to its alignment with the existing structure. Overall, the proposed developments are expected to have no more than minor impacts on wave and wake conditions, with negligible effects on the broader harbour wave climate.
- **Effects on Sediment Processes and Sedimentation:** The FN Wharf extension aligns with the existing wharf geometry, resulting in minor disruption to sediment dynamics. The proposed new BN Wharf, located over an existing revetment, is expected to have a minimal impact on sediment processes. Some scour of the seabed in the vicinity of the wharves is expected with vessel movements.

The summary of the assessed effects on various coastal conditions is provided in Table 1 below:

Table 1: Summary of Environmental Effects of the new Bledisloe North Wharf and Fergusson North Wharf Extension

Effects on Coastal Condition	Bledisloe North (BN)	Fergusson North (FN)
Tidal Flows and Currents	Negligible	Negligible
Waves and Wakes	No more than minor	No more than minor
Sediment Processes and Sedimentation	Negligible	Negligible
Coastal Hazards	Negligible	Negligible
Cumulative Effects	No more than minor	

A mitigation and monitoring plan has been proposed to comply with the relevant environmental standards. This plan includes ongoing monitoring of bathymetry, currents, and structural adaptations to address potential future climate change impacts.

The overarching conclusion is that the effects are negligible/minor because the scale of the proposed developments is small compared with the immediate coastal area (i.e. the lower harbour area and main channel). That area is where adverse effects are avoided/minimised by the proposed developments. Consequently, the effects tend to be localised and generally do not extend into the immediate coastal area.

1 Introduction

1.1 Report Context

Beca Ltd. (Beca) has been engaged by Port of Auckland Ltd. (POAL) to undertake a coastal effects assessment as part of the proposed developments within Waitematā Harbour. This study is a key component of the broader Assessment of Environmental Effects (AEE) report, which will support an application made under the Fast-track Approvals Act 2024 for resource consents to authorise the construction and operation of the new Bledisloe North Wharf and Fergusson North Wharf extension.

This report, along with the attached Hydrodynamic Modelling Report, provides a detailed assessment of coastal conditions at BN and FN and evaluates the potential impacts associated with the proposed development. The coastal assessment addresses key coastal processes, including tidal currents, sediment transport, wind and swell waves, and vessel wakes, contributing to the overall proposed developments impact analysis.

1.2 Report Structure

The structure of this report is outlined as follows:

- **Section 1: Introduction**
  Provides an overview of the report's context, including the roles of POAL and Beca, the reporting framework, and a summary of the proposed developments.
- **Section 2: Existing Environment**
  Describes the present coastal conditions at the proposed developments, including tidal currents, sediment transport, and wave conditions.
- **Section 3: Modelling and Performance Criteria**
  Details the hydrodynamic modelling study undertaken for the proposed wharf developments. This section also outlines the parameters and performance criteria used for the modelling and qualitative assessments.
- **Section 4: Assessment of Environmental Effects**
  Evaluates the potential effects of the FN Wharf extension and proposed new BN Wharf on the physical coastal processes. This includes an assessment of changes in tidal currents, sediment movement, and wave impacts.
- **Section 5: Mitigation and Monitoring**
  Presents the proposed measures to mitigate any adverse effects on coastal processes and outlines the monitoring strategies to be implemented during and after construction.
- **Section 6: Conclusions**
  Summarises the key findings of the coastal processes assessment, including the anticipated impacts, mitigation measures, and monitoring requirements.
- **Appendices**
  - Appendix A: Hydrodynamic Modelling Report - Contains methodologies and results of the hydrodynamic modelling conducted for the proposed developments.
  - Appendix B: Field Data Collection - Provides a summary of field data collected on tidal currents and bathymetry.

1.3 Proposed Developments

The proposed developments include a 45m extension to the east of FN Wharf, infilling the triangular area (approximately 15x15m) adjacent to this extension (as part of an existing resource consent), and constructing a 330m piled structure to the north of the Bledisloe Wharf. Figure 1 shows the proposed layout of the marine infrastructure, with the yellow areas indicating the proposed piled structures and the grey area representing the infill area at FN.

The objective of the FN Wharf extension is to improve operational efficiencies and enable quay crane accessibility, while the new BN Wharf will provide additional berthing for cruise ships over 300m in length and roll-on/roll-off vessels. The addition of these new structures will alter the existing maritime geometry, potentially affecting tidal circulation patterns and wave dynamics within the surrounding areas.

Figure 1: Site locations (in yellow) within the wider harbour

The occupation areas of the proposed wharf extension work and their spatial relationship within the harbour are presented in Table 2 below. These values, though indicative, are intended to demonstrate the approximate structural footprint and provide estimated occupation areas for both the proposed new BN Wharf and FN Wharf extension. The table lists these areas at key tidal benchmarks, including Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS), and at the seabed.

Table 2: Occupation areas of proposed BN Wharf and FN Wharf extension at MHWS and Seabed

Feature	Occupation Area at MHWS (m^2)	Occupation Area at MLWS (m^2)	Occupation Area at Seabed (m^2)
Proposed new BN Wharf	470	125	0
Proposed new BN Wharf Revetment	0	950	5,400
FN Wharf Extension	75	30	0
FN Wharf Extension Revetment	0	470	6,800

For further detailed descriptions and technical specifications of the proposed new BN wharf and FN Wharf extension, refer to the BN and FN Preliminary Design Reports (Beca, 2024).

2 Existing Environment

2.1 Setting

Waitematā Harbour, also known as Auckland Harbour, is one of New Zealand's most significant natural harbours, extending approximately 20km from the harbour entrance at North Head to the upper reaches near Hobsonville. As a drowned river valley, the harbour features a diverse marine environment shaped by surrounding landforms and human activities.

The harbour includes a variety of environments, from the deep main channel, used for shipping, to shallower tidal flats and estuarine areas. The high tide area covers approximately 180 km^2, and its complex bathymetry consists of deep channels, intertidal flats, and sheltered bays.

Over the past 150 years, extensive reclamation and development have transformed the downtown Auckland waterfront into a hub for maritime activities, including port operations, recreational boating, and urban development.

The proposed development sites are in the southeastern part of Waitematā Harbour, where the hydrodynamic conditions are influenced by tidal movements. Seabed levels around the sites vary from approximately -11m below Chart Datum (CD)[1] in front of the proposed BN wharf to -13.5 m CD at the FN wharf, as shown in Figure 2.

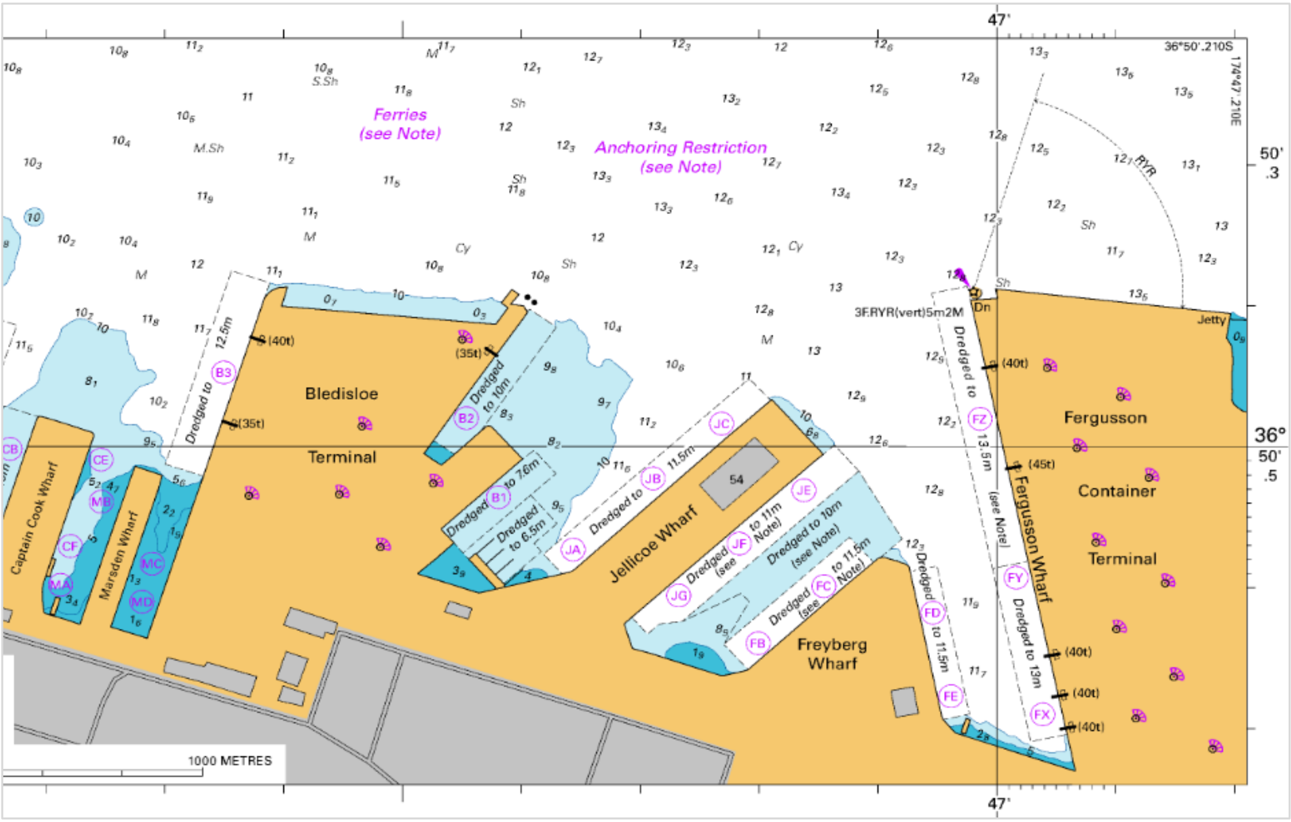


Figure 2: Extract from paper chart NZ 5322 Auckland Harbour East (source: https://charts.linz.govt.nz/charts/paper-chart/nz5322)

[1] Chart Datum is determined as 0.0m CD being approximately the lowest astronomical tide at the time of preparing this report.

It should be noted that the present-day bathymetry and seabed conditions have been considered for this assessment, with future channel approaches and dredge levels excluded. This reflects the upper bounds of potential hydrodynamic effects, as shallower depths result in higher velocities.

2.2 Tides

The tidal regime in Waitematā Harbour is semi-diurnal, with approximately two high and two low tides occurring each day. This regular cycle is a key driver of the harbour's hydrodynamics, influencing currents, sediment transport, and overall coastal processes.

Tidal levels at the proposed developments align with the standard port tidal levels for Auckland Harbour as provided by Land Information New Zealand (LINZ). LINZ provides tide levels in terms of Chart Datum (CD), which is 1.745m below Auckland Vertical Datum 1946 (AVD-46) and 2.077m below New Zealand Vertical Datum 2016 (NZVD-16) for Waitematā Harbour. Table 3 summarises the tidal levels relevant to the proposed developments.

Table 3: Tide levels at Waitematā Harbour (source: https://www.linz.govt.nz/sea/tides/tide-predictions)

Tide Condition	Level in m CD	Level in m NZVD-16
Highest Astronomical Tide (HAT)	3.74	1.66
Mean High Water Springs (MHWS)	3.35	1.27
Mean High Water Neaps (MHWN)	2.80	0.72
Mean Sea Level (MSL)	1.93	-0.15
Mean Low Water Neaps (MLWN)	1.07	-1.01
Mean Low Water Springs (MLWS)	0.52	-1.56
Lowest Astronomical Tide (LAT)	0.08	-2.00

The typical tidal range in Waitematā Harbour varies between 2.83m during spring tides and 1.73m during neap tides, which directly influences the local hydrodynamic conditions and coastal processes at the proposed developments.

2.3 Wind

The wind climate in Waitematā Harbour, particularly around FN and BN, is shaped by the local and regional wind patterns across the lower Hauraki Gulf, Shoal Bay, Motukorea, and Rangitoto channels. The predominant winds generally blow from the north to east directions, as well as from the west to south, exhibiting the typical wind patterns observed in the area.

Wind data for the Waitematā Harbour has been sourced from the Bean Rock weather station, located approximately 4km northeast of FN. The wind rose from Bean Rock, covering the period from 1993 to 2019, shows a bi-modal wind climate with predominant winds from north to east and west to south (see Figure 3). Wind speeds typically average below 10m/s (approximately 20 knots), with occasional gusts exceeding 20m/s (approximately 40 knots).

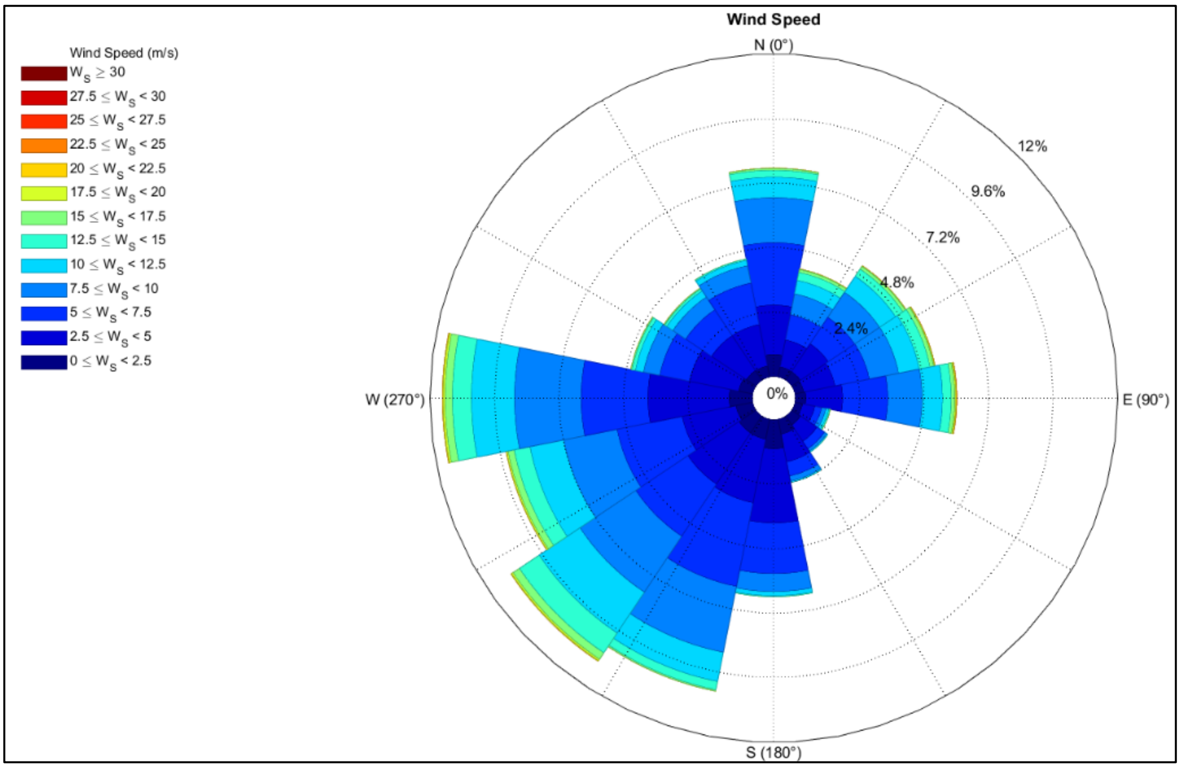


Figure 3: Wind Rose - Bean Rock (1993 to 2019)

2.4 Currents and Tidal Streams

Tidal currents in Waitematā Harbour are primarily shaped by the harbour's entrance configuration, the depth and width of channels, and the presence of structures such as wharves and reclamations. These factors contribute to a dominant flood-ebb current pattern, with variations in speed and direction depending on specific locations within the harbour.

Site-specific hydrodynamic modelling of Waitematā Harbour has been undertaken using the Delft3D model. Details of the modelled currents are provided in Appendix A - Hydrodynamic Modelling Report. Recent boat-mounted Acoustic Doppler Current Profiler (ADCP) measurements from 2013 to 2023, conducted over mean spring tides, were used for the hydrodynamic model validation and provide updated insights into current patterns across Waitematā Harbour. These surveys, covering key areas from Queens Wharf to Devonport, align with the trends identified in earlier studies, such as Vennel (2006).

The hydrodynamic modelling results indicate that tidal currents are strongest in the main harbour channel, with typical velocities reaching up to 1.04m/s (~2 knots) during ebb tides and 0.9m/s (~1.75 knots) during flood tides. In contrast, sheltered areas behind wharves and other structures experience lower velocities and more complex flow patterns. These sheltered areas are influenced by intricate eddy systems driven by the shear stresses from the faster main channel flows, as well as the filling and emptying of the harbour's side arms. Distinctive eddy-driven flows occur in specific areas, forming during both flood and ebb tides. Eddies generally circulate clockwise during ebb tides and anti-clockwise during flood tides, as shown in Figure 4 and Figure 5 for a spring tide.

Wind-generated currents also influence local velocities, with changes of up to 16% observed in relation to measured current data when hourly wind speeds reach around 10m/s and align with the main tidal flow.

Further details on currents and tidal streams within Waitematā Harbour, including relevant datasets, can be found in Appendix A.

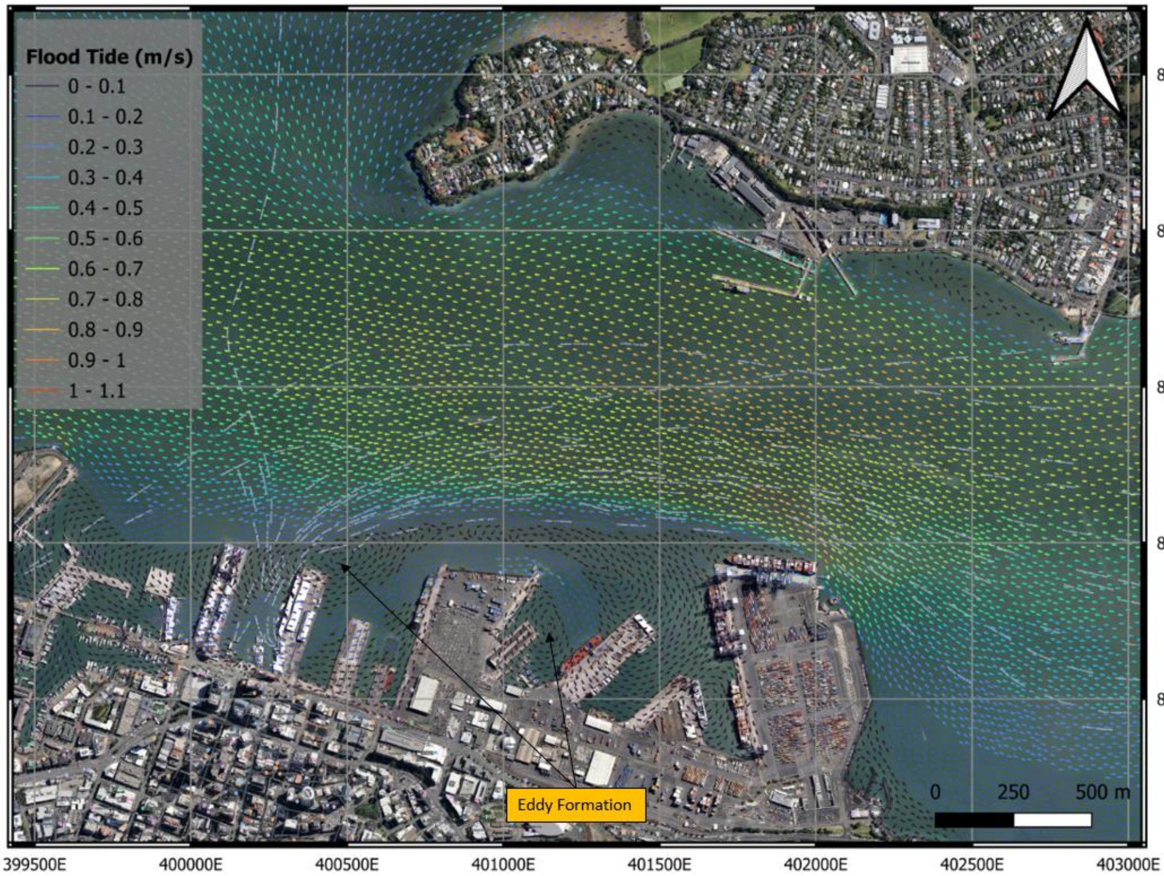


Figure 4: Typical flood tide current patterns and eddy formations

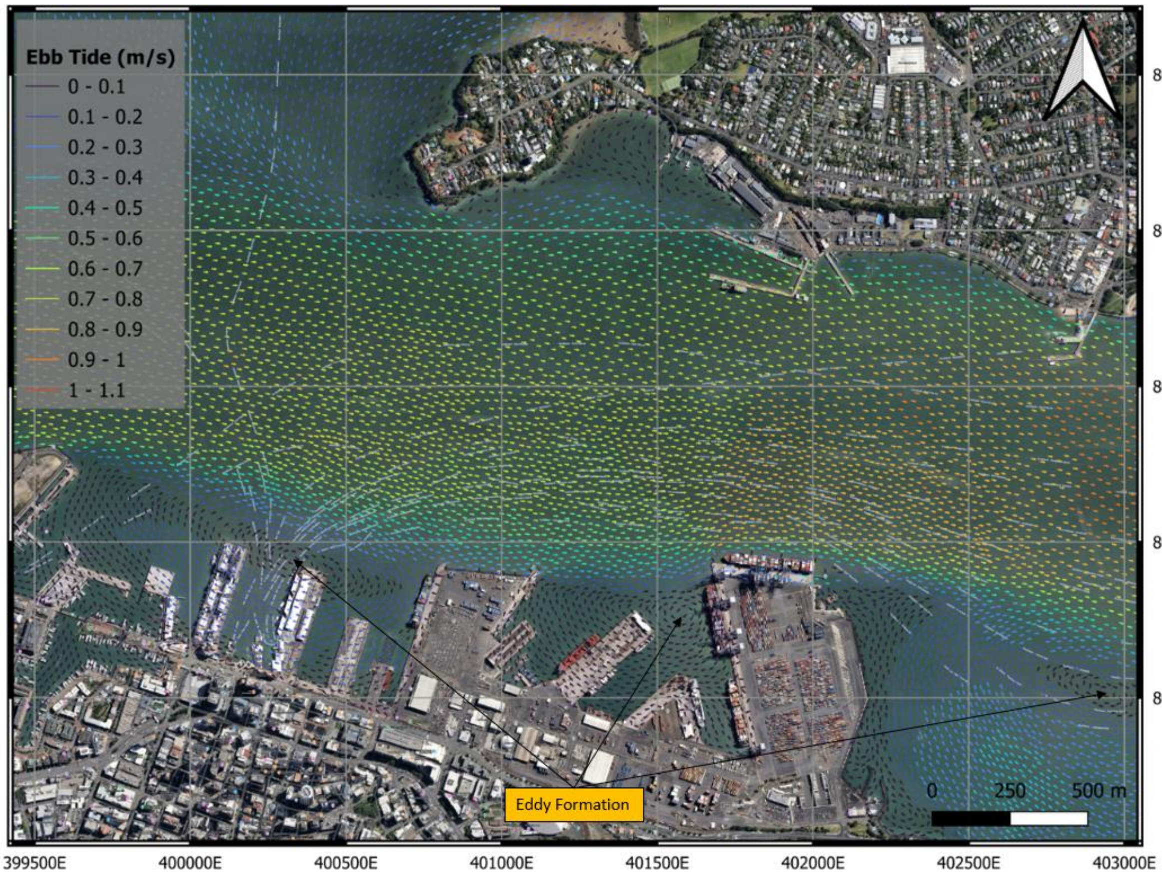


Figure 5: Typical ebb tide current patterns and eddy formations

2.5 Wave Climate

2.5.1 Introduction

The wave climate within the Waitematā Harbour has been determined through a combination of numerical simulations of diffracted waves from outside the harbour and locally generated wind waves within the harbour. These assessments provide an understanding of wave conditions that influence the FN and BN wharves.

In 2019, MetOcean Solutions conducted wave modelling (using SWAN) in the Hauraki Gulf, including 10 monitoring sites located within Waitematā Harbour and Rangitoto Channel. Among these sites, *Site P10* positioned approximately 700m northwest of FN Berth and 500m northeast of the proposed BN wharf, provides wave data relevant to this analysis. For waves diffracted into the harbour from the Hauraki Gulf, the hindcast model for *Site P10* predicts a 50th percentile significant wave height (H_S) of 0.1m under average conditions. For more infrequent events, the model predicts a 99th percentile significant wave height of 0.46m.

Additionally, a site-specific local wind-generated wave assessment is conducted and presented in Section 2.5.2 below.

2.5.2 Wind-generated waves

The proposed new BN wharf is exposed to locally driven wind-generated waves. The enclosed nature of the harbour limits the fetch, resulting in moderate wave heights. However, waves from the WNW to ENE directions can still impact structures and potentially sediment processes along the proposed new BN wharf.

A wind-generated wave assessment was conducted for the proposed new BN wharf area in accordance with the recommendations for fetch-limited conditions outlined in the Coastal Engineering Manual (CEM, 2008). A sensitivity analysis, based on Young (1997) method, was performed to account for the potential influence of shallow water on wave generation and evaluate the impact of water depth on the significant wave height and peak wave period.

The wind-generated waves for the site were considered from the west to east sectors, with the corresponding fetch areas illustrated in Figure 6.

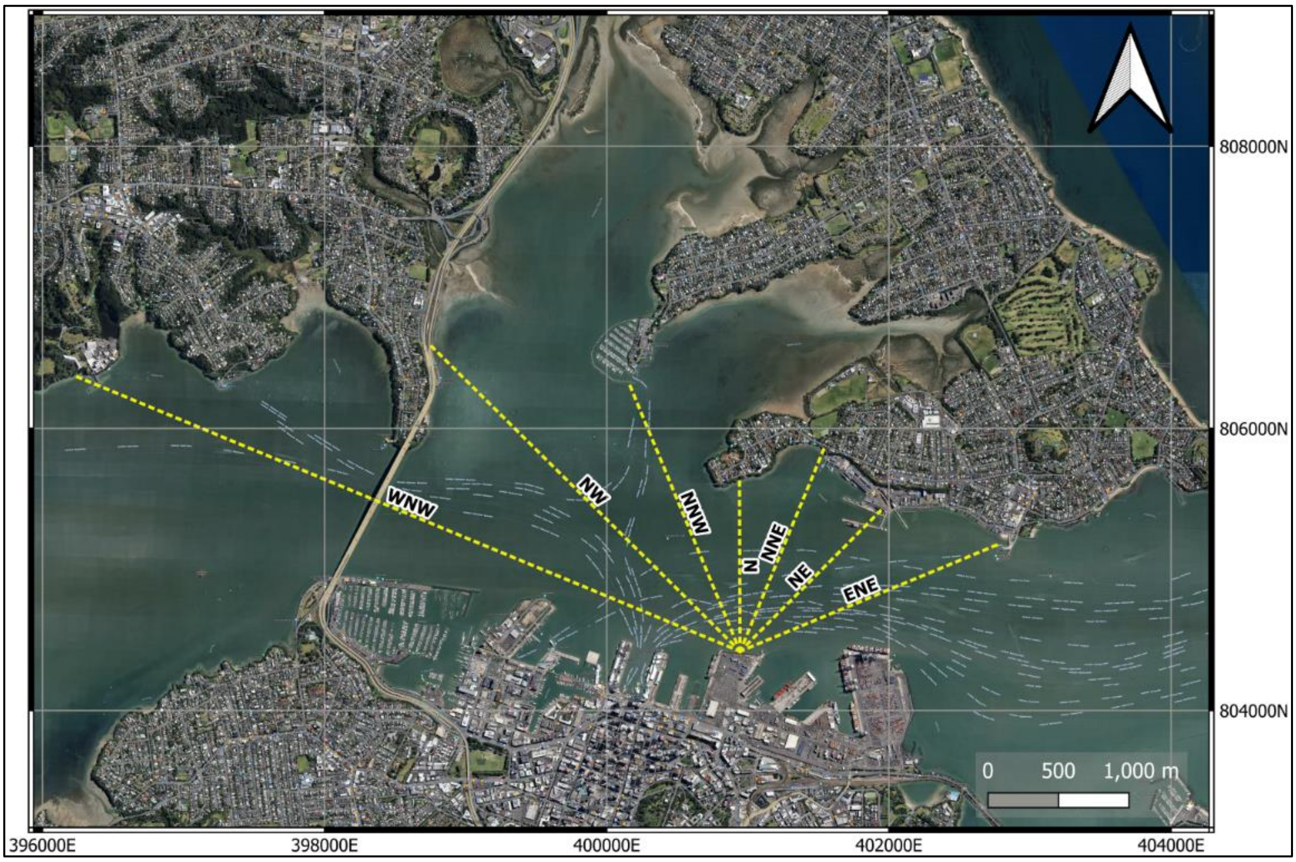


Figure 6: Bledisloe North fetch lengths (Provided in relation to Mount Eden 2000 projection)

The estimated significant wave height (H_s) and peak wave period (T_p) were calculated for various fetch directions, as shown in Figure 6. The results of the assessment, summarised in Table 4 and Table 5 below, represent the worst-case scenario derived from the CEM (2008) and Young (1997) methods.

The 1 in 1-year wind speed event (63% AEP) and 1 in 100-year wind speed event (1% AEP) were extracted from *Table 3* of the AS/NZS 1170.2 design codes (Structural Design Actions Part 2: Wind Actions, 2021) for the Auckland region and converted to hourly wind speeds.

Given the relatively short fetch lengths in the Waitematā Harbour for most wind directions, the wind-generated waves are likely to develop over shorter time periods than the hourly wind speeds account for. To better represent wave generation under fetch-limited conditions, adjustments were made to account for shorter wind durations where applicable.

Table 4: 1 in 1-year (63% AEP) resultant significant wave height (H_s) and peak wave period (T_p)

u_{dir} (from)	hourly u (m/s)	Fetch (km)	H_s (m)	T_p (s)
N	19.5*	1.2	0.4	1.9
NNE	20.0*	1.6	0.4	2.1
NE	20.6*	1.4	0.4	2.1
ENE	19.4**	8.0***	1.0	3.5
WNW	20.9	5.1	0.8	3.1
NW	20.3	3.1	0.6	2.6
NNW	20.0*	2.1	0.5	2.3

*Note: 30-min wind speed used to generate wave height

**Note: 2-hourly wind speed used to generate wave height

u_{dir} (from)	hourly u (m/s)	Fetch (km)	H_s (m)	T_p (s)
***Note: The effective fetch length from the ENE direction was calculated by averaging the fetch lengths at 5-degree intervals within a 25-degree range around the ENE line in Figure 6.				

Table 5: 1 in 100-year (1% AEP) resultant significant wave height (H_s) and peak wave period (T_p)

u_{dir} (from)	hourly u (m/s)	Fetch (km)	H_s (m)	T_p (s)
N	26.4*	1.2	0.5	2.1
NNE	27.1*	1.6	0.6	2.4
NE	27.9*	1.4	0.6	2.3
ENE	27.9**	8.0***	1.4	4.0
WNW	28.3	5.1	1.2	3.5
NW	27.5	3.1	0.9	3.0
NNW	27.1*	2.1	0.7	2.6

*Note: 30-min wind speed used to generate wave height

**Note: 2-hourly wind speed used to generate wave height

***Note: The effective fetch length from the ENE direction was calculated by averaging the fetch lengths at 5-degree intervals within a 25-degree range around the ENE line in Figure 6

The wind-generated waves from the east-northeast are predicted to generate the largest waves at the proposed BN wharf, with an H_S of 1.4m and an associated peak wave period (T_P) of 4.0s. Such waves, which are more extreme than waves diffracted into the harbour, dominate the local wave climate.

2.6 Wakes

As defined in the previous section, the overall wave climate within the Waitematā Harbour is relatively calm, but vessel wakes, particularly from larger recreational craft, ferries, and commercial vessels, can impact coastal structures and sediment transport. Recreational and commercial vessels, including powerboats and ferries, generate wakes with wave heights measured up to 0.55m (and periods of 4-5s) in the lower Waitematā Harbour (Beca and Tonkin & Taylor, 2018).

Port shipping also contributes to wake activity, with typical 270m container ships travelling at 10 knots around North Head towards Devonport generating wakes of approximately 0.3 to 0.4m (Beca, 2019). However, these vessels slow down to no more than 0.4 knots from Devonport Wharf through to the port approaches.

These vessel wakes differ in height, period, and energy compared to naturally occurring waves, leading to localised areas of increased hydrodynamic activity. The propagation of wakes is further influenced by the reflection and dissipation of wave energy by the harbour's shoreline and structures. Breakwaters, seawalls, and wharves can either reflect or absorb wake energy, altering the wave climate in their vicinity.

2.7 Vessel Activity

POAL is one of the New Zealand's largest trading ports, handling approximately 1,200 vessels annually. This number has decreased in recent years as ships have increased in size, enabling fewer vessels to carry a larger freight load. POAL has provided the following clarifications regarding the current and future (expected) vessel activities.

Vessels using the FN Wharf currently range from 4,100 TEU (twenty-foot equivalent units) up to 10,000 TEU in size, noting that there are some constraints with the quay cranes when unloading / loading these larger vessels given the size of the current FN wharf. The primary purpose of the FN Wharf extension is to improve these operational efficiencies and enable quay crane accessibility to accommodate the larger vessels with fewer constraints. These larger vessels (up to 10,000 TEUs) are approximately 350m long, with a 46m beam and a draft of 14.5m.

The optimum berth occupancy for FN is expected to be around 60%, occasionally reaching 70%. It is anticipated that ships exceeding 4,100 TEU will occupy the berth approximately 40% of the time (67 hours per week), while vessels under 4,100 TEU will occupy the berth around 20% of the time (33 hours per week). Overall, berth occupancy is projected to increase to about 50%, with the largest vessels accounting for approximately 25%.

The proposed new BN Wharf is being developed to handle larger vessels, such as the Ovation of the Seas cruise ship, which is 348m long, with a 41m beam at the waterline (48m with projections), and a draft of 8.5m. Large cruise ships are expected to make around 40 calls annually, with each visit lasting approximately 12 hours.

2.8 Sediment Processes and Sedimentation

In general terms, gravitational circulation and tidal dynamics interact with bed exchange and particle transformations, such as flocculation, to establish transport patterns. These patterns can be modulated by spring–neap variations in tidal range and influenced by the suppression of mixing due to stratification. The sediment budget in Waitematā Harbour is contributed by several creeks and streams that drain into the harbour, such as Henderson Creek, Lucas Creek, Whau River, Onepoto Stream and others.

Waitematā Harbour is a semi-enclosed estuarine environment with complex sediment transport processes driven primarily by tidal currents, which are the dominant force in the system. Wave action is less influential within the inner harbour due to limited fetches, but during storms, wave-driven resuspension can occur, particularly along exposed shorelines and in shallow areas. These events can temporarily redistribute sediments locally. Residual sediments are carried in the main channel adjacent to the port. It is estimated that the mean sediment load in suspension is about 1600 tonnes per tide. (Beca, 2000).

2.8.1 Subsurface Sediments Near the Proposed Developments

Previous studies (Coastal Consultants, 2001) reveal that the subsurface sediments in the areas adjacent to the proposed developments predominantly consist of marine mud. In some locations, thin layers of sandy and shelly material are present over these mud deposits. These subsurface sediments, which can extend several meters below the seabed, are underlain by Waitematā Group sandstone and siltstone.

2.8.2 Surficial Sediments Near the Proposed Developments

Surficial sediment composition near the proposed developments varies, but the dominant material is semi-consolidated marine mud, consisting of a mixture of clay, silt, and some sand. The presence of sand and shell materials is more prominent in areas where sediment winnowing has occurred due to tidal currents (e.g., towards the centre of the Waitematā Harbour as referenced by Kingett Mitchell, 2001).

Investigations have shown that the distribution of surface sediments in the vicinity of the proposed developments is a result of historical sediment deposition patterns influenced by local hydrodynamics. The spatial distribution of surficial deposits within the Waitematā Harbour is shown in Figure 7. (Coastal Consultants, 2001)

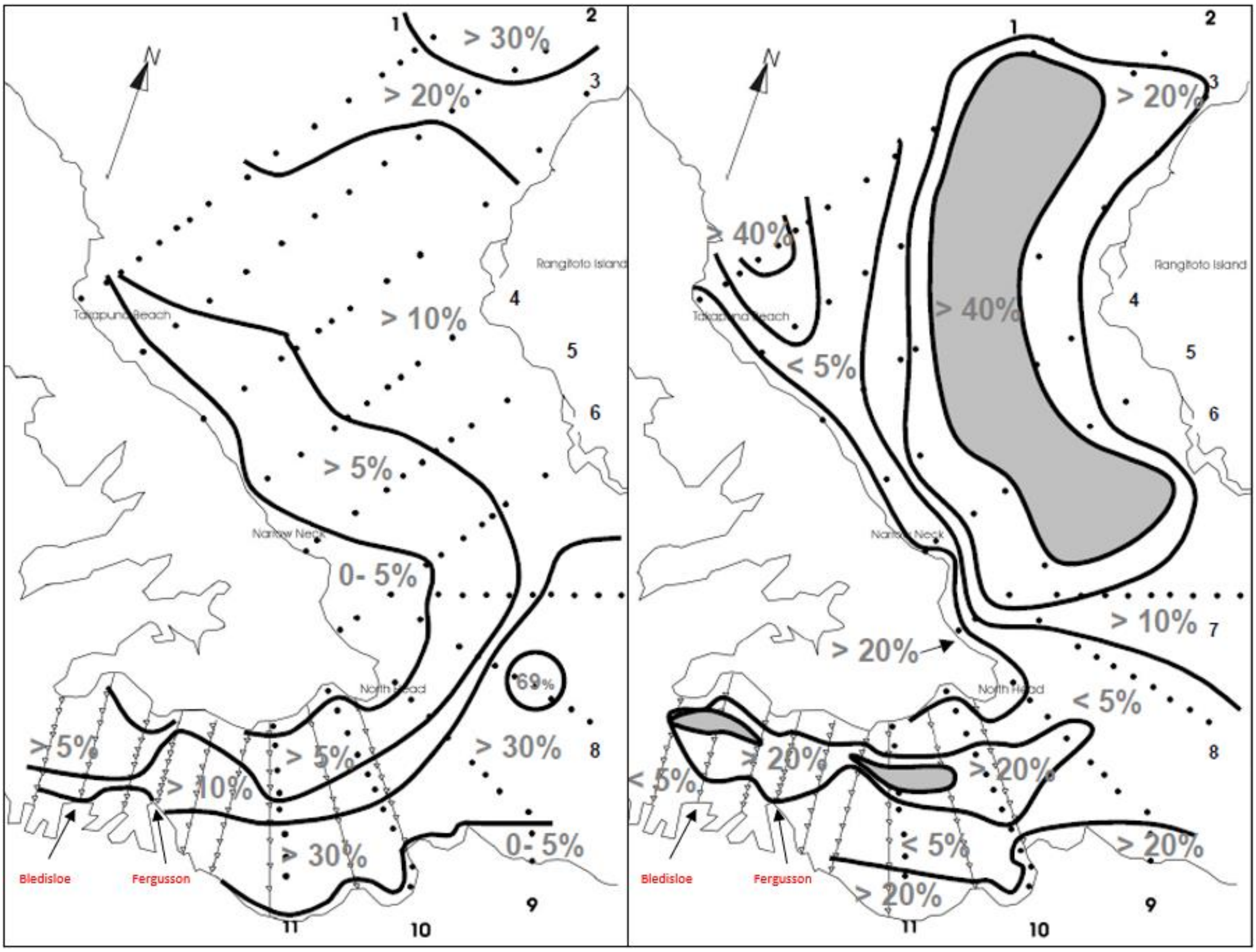


Figure 7: Spatial distribution of silt- and clay-size sediment (left) and gravel-size sediment (right) in surficial deposits of Waitematā Harbour (Coastal Consultants, 2001).

2.8.3 Sediment Distribution and Impacts

The sediment dynamics in this part of the harbour are primarily driven by tidal forces, with marine mud accumulating in lower-energy zones close to the shorelines. Wave action has limited influence within the harbour due to restricted fetches, though storm events can cause localised resuspension of sediments along exposed shorelines. These processes help shape the sediment distribution in the area.

2.8.4 Historical Bathymetry and Sediment Monitoring

Historical bathymetric surveys and sediment sampling, including those conducted during the Fergusson Terminal reclamation, provide a baseline for evaluating current sediment conditions. However, the historical surveys covered varying extents and areas. The 2000 bathymetric data and the 2023–2024 data, which have a similar survey extent, have been used for the sedimentary change assessment within the area bounded by Devonport, Stanley Point, Wynyard Point, and the Fergusson North Wharf. This approach represents conditions before and after the Fergusson Terminal development, offering a broad dataset to assess changes in local seabed morphology and hydrodynamic conditions.

A comparison of the 2000 and 2023–2024 bathymetric data, shown in Figure 8, reveals seabed lowering in the main channel and its margins, along with areas of accretion near Stanley Point, and around the Bledisloe and Fergusson wharves. This seabed lowering is likely a result of ongoing natural sediment processes, the effects of the Fergusson reclamation, and potential scour caused by the passage of deeper-draft vessels.

It should be that the hydrographic survey techniques have evolved, with the 2000 data captured by a single-beam survey and the 2023–2024 data using a more advanced multi-beam survey, which provides significantly higher resolution. This improvement in resolution may account for some localised differences. However, the overall comparative analysis remains robust in identifying key trends in bathymetry changes.

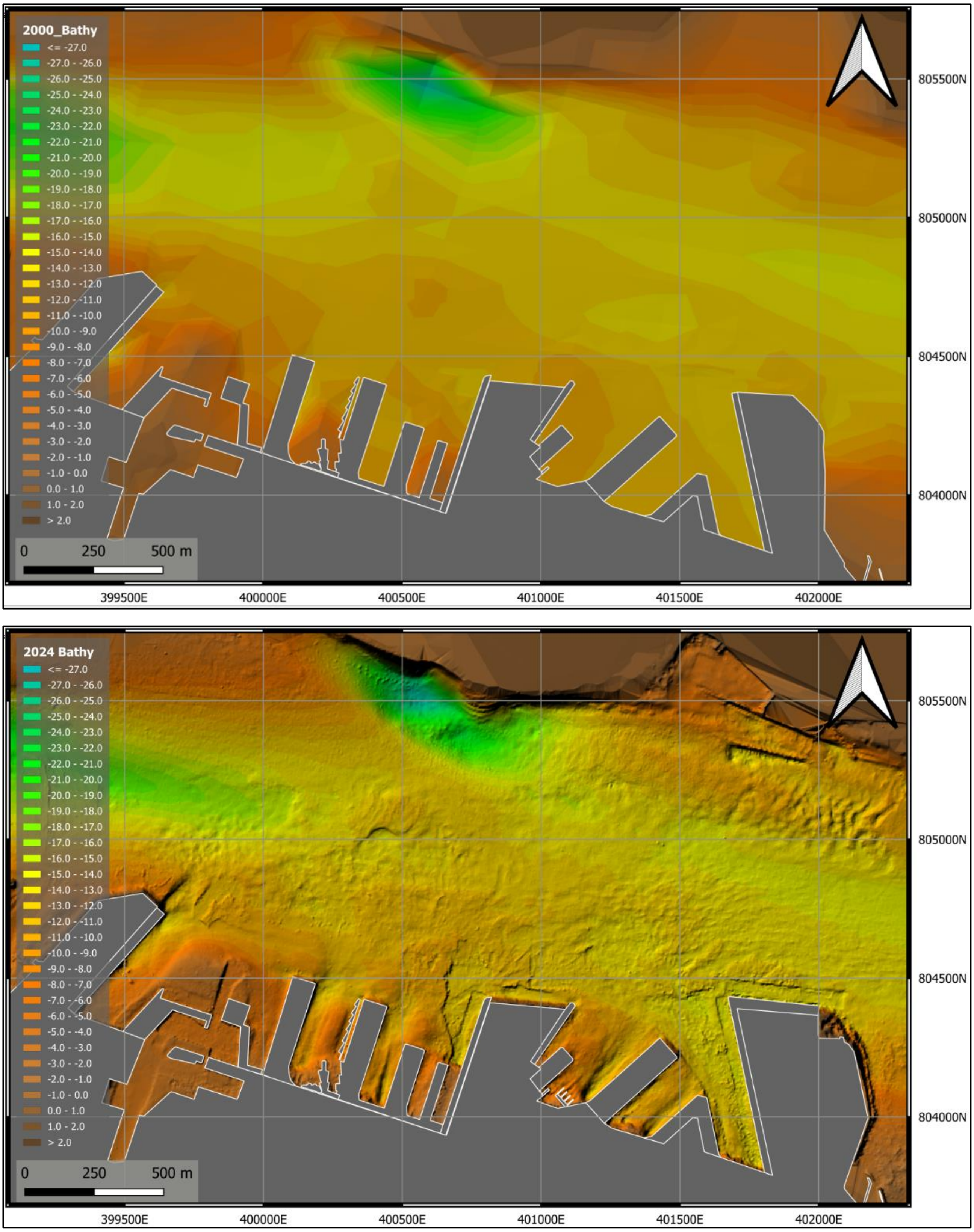


Figure 8: Comparison of the 2000 bathymetry (top) and 2024 bathymetry (bottom)

2.9 Coastal Hazards and Climate Change

2.9.1 Extreme Sea Levels

Extreme sea levels can result from several processes including astronomical tides, monthly mean sea level anomalies, and storm surges. The extreme sea levels for the proposed developments have been considered with reference to Part 1 of "*Auckland's Exposure to Coastal Inundation by Storm-tides and Waves, Technical Report 2020/024*", which assessed the extreme sea level elevations within the Auckland region, Waitematā Harbour. The storm-tide elevations are set out in *Part 1, Table 3-3* of the report. The reference site applicable to the project location is Site 3.

The storm tide elevations were determined for a base date of 2011 (NIWA, 2013). An allowance has been made to adjust the storm tide elevations using the measured historical sea level rise for Auckland of 2.54mm/year between 1961 and 2020 as given in "Update to 2020 of the annual MSL series and trends around New Zealand" (Bell and Hannah, 2022).

This gives an adjustment of approximately 0.04m which has been added to the extreme sea levels listed in Table 6 below.

Table 6: Extreme Sea levels adopted for Waitematā Harbour

Average Recurrence Interval (ARI) (years)	Annual Exceedance Probability (AEP)	Present-day (2025) extreme sea level (m CD)
2	39%	3.77
5	18%	3.85
10	10%	3.91
20	5%	3.96
50	2%	4.03
100	1%	4.08
200	0.5%	4.13

2.9.2 Relative Sea Level Rise

Current Sea Level Rise guidance (MfE, 2024) recommends that Relative Sea Level Rise (RSLR) be considered for project planning and development. Relative Sea Level Rise is the combination of the projected future Sea Level Rise (SLR) due to climate change and Vertical Land Movement (VLM) due to gradual land uplift or subsidence (RSLR = SLR + VLM).

The guidance relates to the national RSLR, SLR and VLM information released in 2022 by the NZ SeaRise Programme (https://searise.takiwa.co, 2023; IPCC, 2021) and the international climate change information provided in the Intergovernmental Panel on Climate Change Sixth Assessment Report. It should be noted that the information from the NZ SeaRise Programme was recently updated in June 2024 and will be referenced in this document.

The RSLR values have been obtained from https://searise.takiwa.co. for the 50-year and 100-year sea rise predictions, which are given relative to the 1995 to 2014 baseline period. FN and the proposed BN wharf are located close to Site 1235. The VLM results show the area is subsiding at a rate of 2.38 mm/year over the VLM monitoring period.

As the proposed BN wharf can be classified as 'Category C: Land-use planning controls for existing coastal uses and assets', the relative sea level rise is assessed using SSP5-8.5 M in accordance with *Table 8* of MfE (2024) guidance.

Table 7 below outlines the RSLR for the Waitematā Harbour project area over 50-to-100-year timeframes (50 years corresponds to the usual design life for marine structures, and 100 years is consistent with the New

Zealand Coastal Policy Statement). Projections have been calculated at 10-year interpolation intervals and have been selected for median uncertainty p50 (50th percentile).

Table 7: Relative Sea Level Rise (50-year and 100-year outlook)

Year	SSP5 – 8.5M (m)
Baseline (2005)	0.00
Present Day (2025)	0.10
50-year Outlook (2075)	0.57
100-year Outlook (2125)	1.29

The predicted extreme water level adopted for the proposed developments for the next 50- and 100-year outlook can be estimated from the extreme sea levels defined in Table 6 (1%AEP) plus the relative sea level rise defined in Table 7 (RSLR under SSP5-8.5M scenario).

The predicted extreme water levels are summarised in Table 8 below.

Table 8: Extreme water level (50-year and 100-year outlook)

Year	Extreme Sea Level (1% AEP) (m CD)	SSP5 – 8.5M (m)	Predicted Extreme Water Level (m CD)
2075	4.08	*0.47	4.55
2125	4.08	*1.19	5.27

*Note: the RSLR for the next 50 - and 100-year timeframes have been subtracted RSLR from the present year (2025) in Table 7 to calculate the predicted extreme water levels.

2.9.3 Wave Overtopping

The proposed developments involve extending the existing structures at their current level of approximately 5.4m CD, without altering the height above the existing levels. Figure 9 illustrates the current level in relation to different sea levels. Based on these levels, direct inundation of the existing structure is not expected under the future 1% AEP extreme sea level scenario.

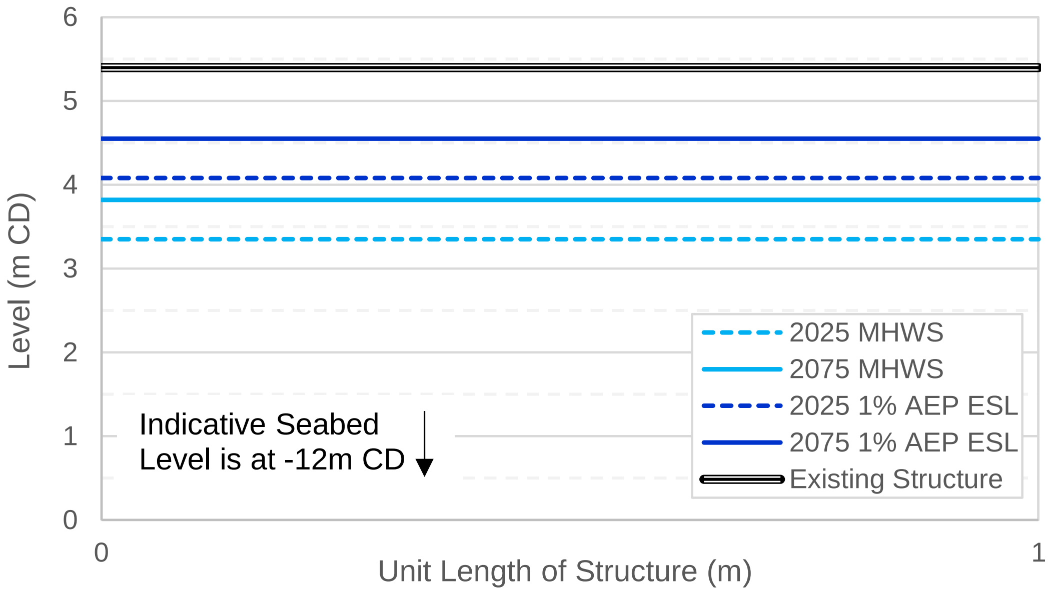


Figure 9: Existing structure level of 5.4m CD versus present-day and future MHWS and 1% AEP Extreme Sea Level (ESL)

Some wave overtopping does occur on the eastern side of Fergusson Terminal and is managed by the internal drainage system.

2.9.4 Tsunami

A 2010 NIWA study for Auckland Council indicates that maximum tsunami velocities associated with a 2500-year Annual Recurrence Interval generally range between 0.5 to 1m/s in the shipping lane (see Figure 10). These speeds are comparable to tidal currents and have the potential to mobilise silty sand seabed sediments but are unlikely to disturb marine muds. However, observations suggest that the main channel sediments have experienced erosion. This erosion is likely due to a combination of factors including tidal currents, vessel movements, and infrequent high-energy events. While tsunami velocities alone may not be sufficient to disturb marine muds, the interaction of vessel-induced currents with tidal and occasional extreme currents can contribute to sediment redistribution and erosion in the channel.

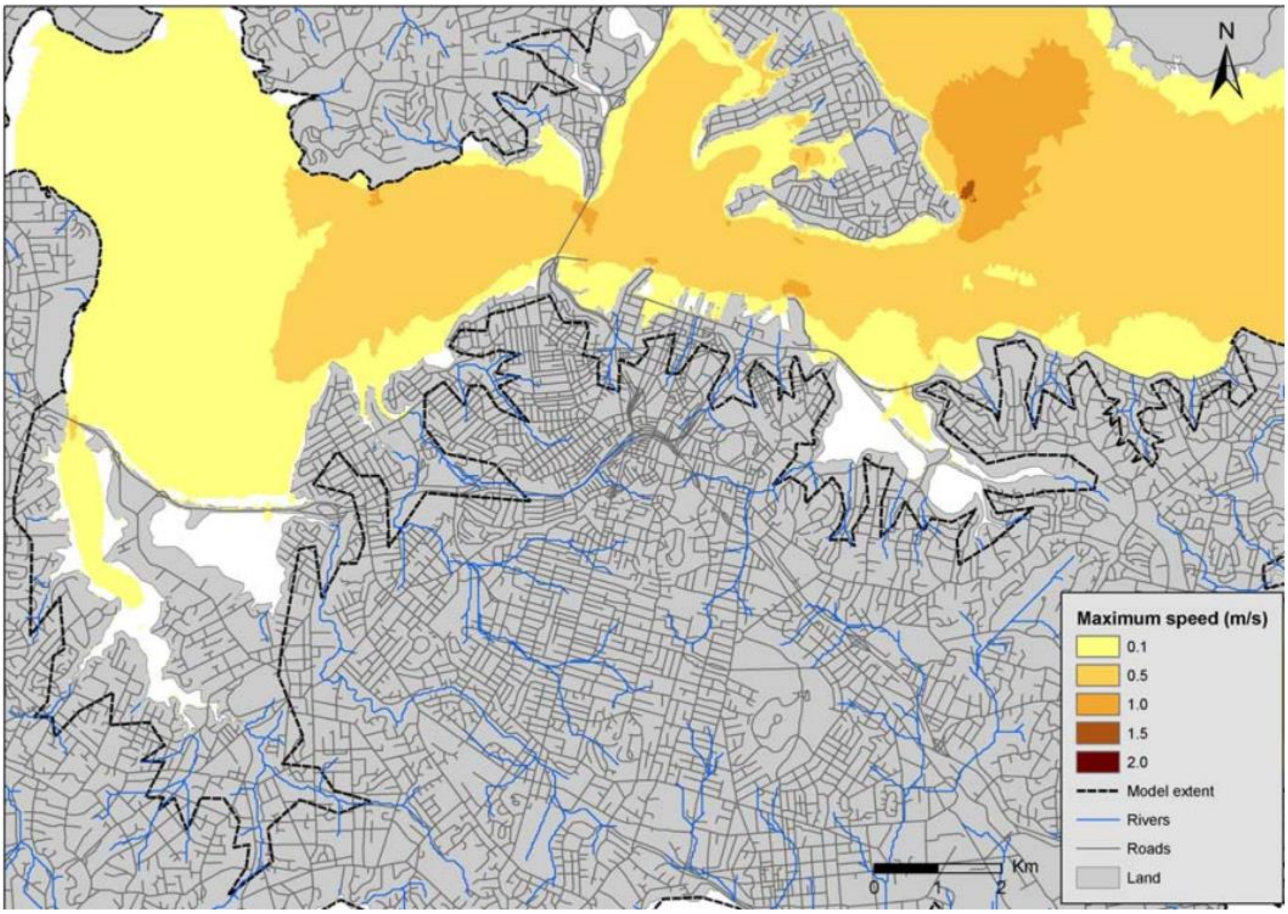


Figure 10: 2500-year Annual Recurrence Interval exceedances for maximum tsunami speed (NIWA, 2010)

The study also includes modelled tsunami heights for the Auckland region. As shown in Figure 11, wave heights exceeding 2 meters can be expected in much of the Rangitoto Channel roughly once every 2500 years. The Waitematā Harbour, however, is largely shielded from significant tsunami impacts due to the protection provided by the Hauraki Gulf islands.

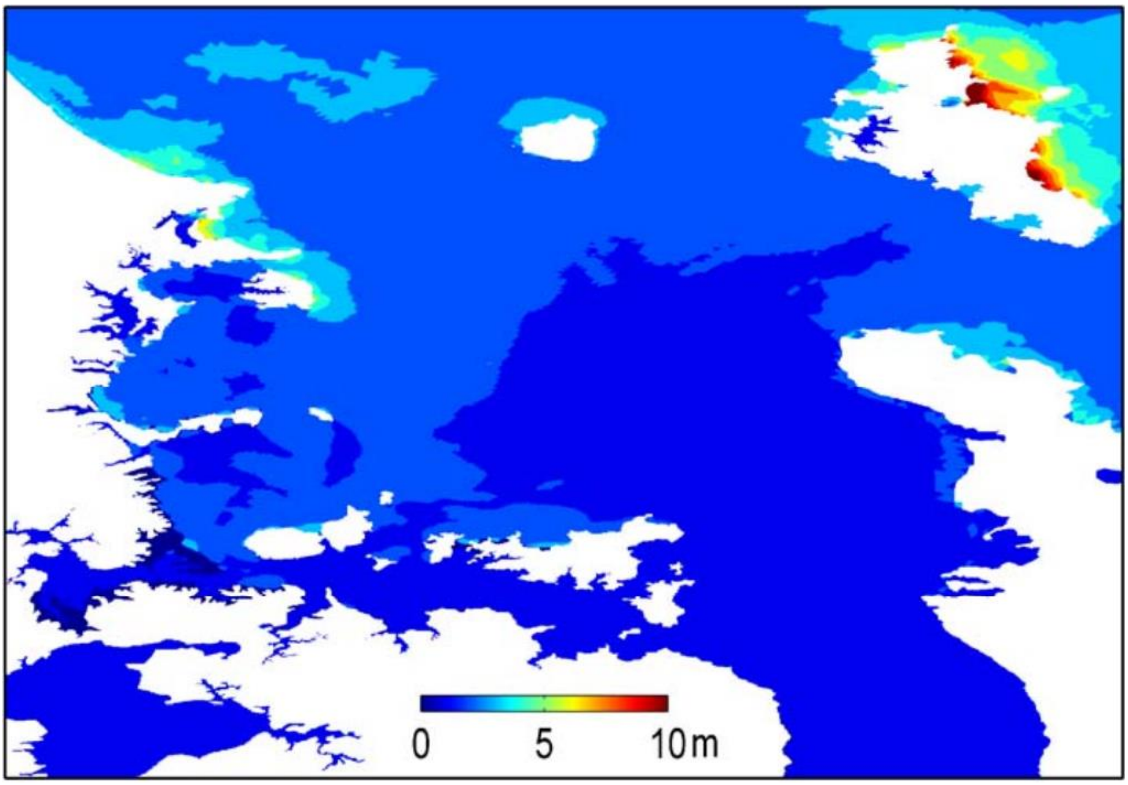


Figure 11: Probabilistic hazard analysis and modelling of tsunami inundation for the Auckland region from Regional Source Tsunami (NIWA, 2010)

In addition to NIWA's 2010 study, Auckland Council's hazard viewer now features updated tsunami evacuation zones, which offer more actionable and localized insights into potential risks. These zones are defined as follows:

- **Red Shore and Marine Threat Zone:** Encompasses the beach and adjacent low-lying areas most vulnerable to tsunami impacts. Avoidance of this zone is recommended following any tsunami alert until it is declared safe.
- **Yellow Land Threat Zone:** Covers areas that would need to be evacuated in the event of a dangerous tsunami. Evacuation is advised if requested by authorities or upon observing natural warning signs of a tsunami.

These updated hazard maps reflect the latest understanding of tsunami risks along Auckland's coastline, providing a practical framework for emergency response. While the 2010 study continues to offer valuable insights into tsunami velocities, these updated evacuation zones (see Figure 12) provide a more detailed, real-time guide for managing risks and ensuring public safety, aligning with present-day evacuation protocols.

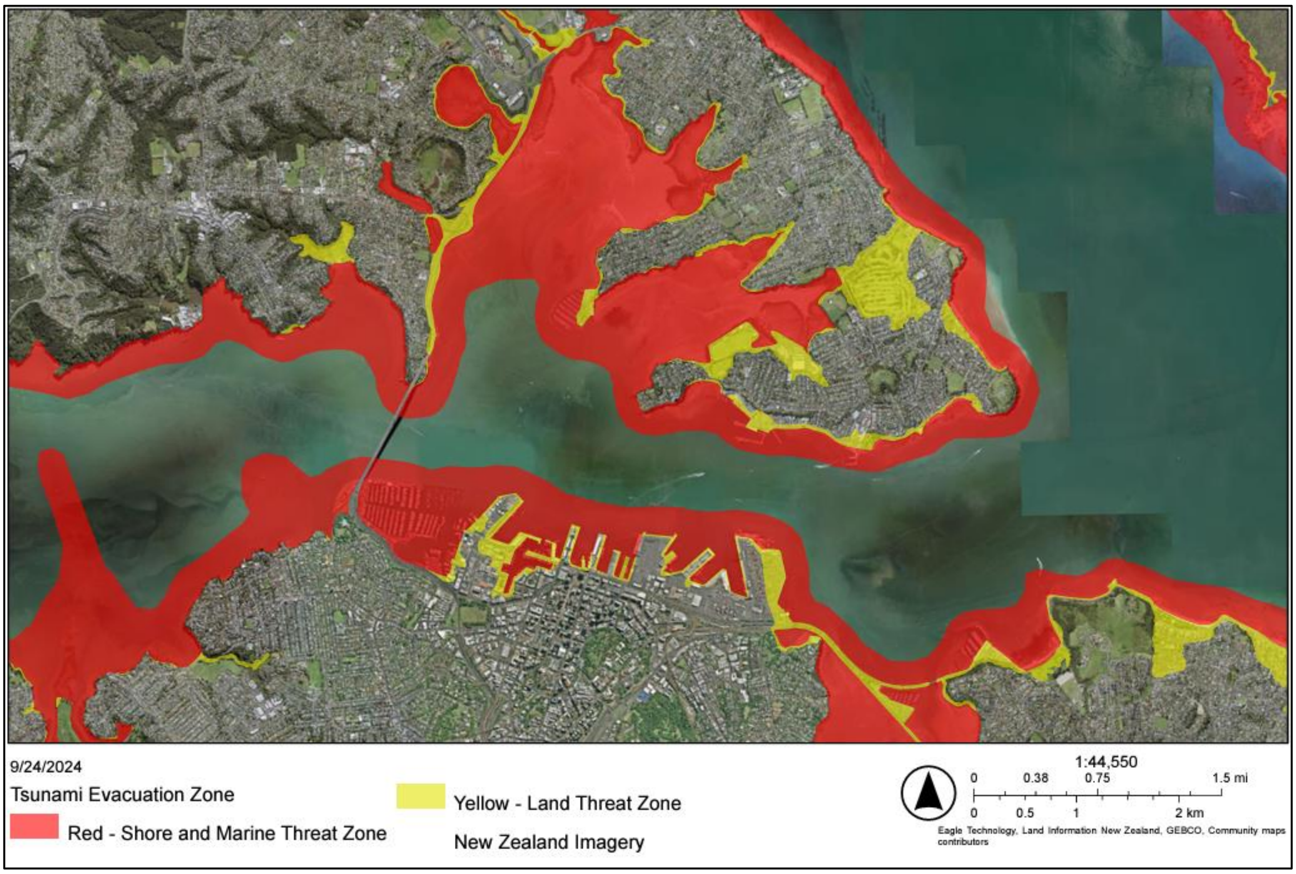


Figure 12: Updated Tsunami Evacuation Zones (Auckland Council Hazard Viewer, 2024 – accessed at https://services1.arcgis.com/n4yPwebTjJCmXB6W/arcgis/rest/services/Tsunami_Evacuation_Zone/FeatureServer/0).

3 Approach for Assessing Environmental Effects

3.1 Previous studies, monitoring and assessments

To establish a baseline for this assessment, a review of previous studies, monitoring data, and relevant guidelines was conducted. This section summarises the key findings and highlights how historical data and guidance documents have informed the approach to assessing environmental effects.

- Historical Data Analysis
  - RMA Assessments: Previous Resource Management Act (RMA) assessments have provided key data on tidal currents, wave action, and sediment transport within the Waitematā Harbour. These assessments establish the baseline conditions against which the impacts of the proposed new BN Wharf and FN Wharf extension are evaluated.
  - Bathymetry and Current Data: Historical and recent bathymetric surveys and current measurements offer insights into changes in bathymetry and flow conditions. This data helps to better understand the long-term changes within the harbour.
- Monitoring Data
  - Recent Fieldwork: Updated measurements from ADCPs were utilised to refine the numerical model. The recent survey data supplements the contemporary understanding of the harbour's current distribution and improves the hydrodynamic model's accuracy.
- Guidance Documents
  - PIANC Guidelines: The assessment follows the Permanent International Association of Navigation Congresses (PIANC) guidelines for modelling or assessing currents, waves, and sediment transport, aligning with international best practices.
  - Coastal Engineering Manual (CEM, 2008): The recommendations for fetch-limited wave conditions from the Coastal Engineering Manual were utilised.
  - Rock Manual (CIRIA, 2007): Guidelines from the Rock Manual were used to inform design considerations and empirical calculations related to waves, rock armour and coastal defence structures.
- Influence on Assessment Approach
  - Baseline Conditions: Historical and recent data provide a thorough understanding of baseline conditions, which is essential for evaluating the potential impacts of both developments.
  - Modelling Approach: A calibrated numerical model, informed by recent current and bathymetry data, was used to predict hydrodynamic changes.

The available field data and numerical modelling forms the basis for assessing the tidal currents and likely changes in the harbour area.

3.2 Hydrodynamic Tidal Modelling

Numerical modelling is considered a standard tool used to assess projects within the coastal environment, particularly those with the potential to impact coastal processes over a large area. For the proposed new BN Wharf and FN Wharf extension, the Delft3D Flow module was utilised to develop and calibrate a numerical model of the harbour's tidal system. This modelling serves several key purposes:

- Effect Identification and Quantification: The primary aim is to identify and quantify the effects of the proposed wharf developments on tidal currents, and other hydrodynamic conditions. By simulating these factors, the models help in understanding potential changes to existing coastal conditions.
- Scenario Analysis: Various berthing configurations, including the proposed developments, are analysed to evaluate their impact on the harbour's current distribution. This analysis helps in predicting and managing potential changes in current distributions and tidal flows resulting from the new developments.

POAL indicated that there are no future plans to deepen the berth pocket in the new BN Wharf area, as it already has more than adequate depth. However, there may be potential deepening of the FN berth and the Fergusson approaches. It should be noted that the model does not account for any future changes to the existing berth pocket depths at the FN Wharf, nor for any potential changes to approach channels. Instead, vessels were modelled as extended land using existing bathymetry, which represents a conservative estimate. This approach is expected to have more pronounced effects on tidal velocities compared to a scenario with deepened berths and channels.

Calibration of the models involved recent tidal data and current measurements to represent the present hydrodynamic conditions within the harbour. Validation with measured data supports the reliability of the models in predicting changes to the harbour geometry. Detailed information on the hydrodynamic modelling can be found in Appendix A.

3.3 Wave/Wake Assessment

The approach to assessing wave and wake impacts involves using empirical calculations based on guidelines from the Coastal Engineering Manual (CEM, 2008) and the Rock Manual (CIRIA, 2007). The assessment considers fetch-limited conditions and evaluates potential wave impacts and wake effects from the proposed new BN Wharf and FN Wharf extension.

Reflection coefficients are also considered to account for the potential changes in wave behaviour resulting from the presence of structures and/or vessels. By applying these guidelines and incorporating reflection effects, the approach aims to provide an appropriate estimate of how the proposed developments might alter local wave dynamics and wake generation within the harbour.

3.4 Sedimentation Assessment

The sedimentation assessment involved a comprehensive review of historical and present sedimentation patterns to evaluate the potential impacts of the proposed new BN Wharf and FN Wharf extension. This analysis examined how sedimentation patterns have evolved over time due to previous port developments and other activities within the harbour. Historical bathymetry data and development records were compared with present-day bathymetry to identify trends in sediment distribution and deposition.

This approach supported the development of a predictive model for sedimentation trends, considering factors such as sediment composition and changes in seabed bathymetry. The findings were then used to assess the potential sedimentation impacts of the proposed wharf developments.

3.5 Cumulative Effects Assessment

The cumulative effects of the proposed upgrades to both the new BN Wharf and FN Wharf have been assessed. The assessment of combined effects has been approached as follows:

- Integrated Modelling: Separate modelling for each upgrade and the combined upgrades has been conducted. This includes scenarios with and without berthed vessels to fully capture the potential impacts. The combined modelling helps to understand how the proposed developments interact and their overall influence on coastal processes.
- Consideration of Other Activities: The assessment includes cumulative effects from existing and planned activities in the region. This broader perspective considers how the upgrades interact with ongoing coastal processes and other infrastructure developments.
- Qualitative Assessment: In areas where detailed modelling was not available or feasible, a qualitative assessment was carried out. This approach uses professional judgment and available data to evaluate the potential interactions and combined effects.

- An effects assessment requires the proposed development to be compared to a baseline. For this study, the baseline is the existing environment as outlined in Section 2. This approach recognises historic developments such as harbour reclamation and structures, catchment development, and maritime activities as being legitimate features that are encapsulated in the existing environment.

4 Assessment of Effects on the Environment

4.1 Change Assessment Criteria

The long-term effects of the proposed changes to the harbour are assessed across various categories. The assessment focuses on the anticipated impacts over a period longer than one year, with particular attention given to whether the changes are expected to result in negligible effects, no more than minor effects, or significant effects on the harbour environment.

The criteria for assessing these effects are based on a combination of hydrodynamic modelling, empirical data, and expert judgement. Each category of analysis includes an examination of the potential changes in physical processes due to the proposed developments. The assessments consider the following key factors:

- **Magnitude of Change**: The extent to which the proposed developments will change existing conditions.
- **Spatial Extent:** The area over which the changes are expected to occur, from highly localised effects near structures to broader impacts on the wider harbour environment.
- **Duration and Frequency:** The persistence of the effects over time, particularly whether they are short-term (e.g., during construction) or long-term (greater than one year) and the frequency of occurrence (e.g., during specific wind or tidal conditions).

Based on the criteria described above the significance of the changes are rated as follows.

- **Negligible:** Changes are minimal and unlikely to result in any noticeable impact (mainly on vessel operation and sediment transport).
- **No More Than Minor:** Changes are measurable but are not expected to have a significant effect on the overall harbour coastal environment.
- **Significant:** Changes are considerable and may lead to substantial impacts on the overall harbour coastal environment.

For each category assessed in this report, a concluding summary paragraph provides a final evaluation of the likely relative effects, maintaining a consistent approach across all areas of analysis.

4.2 Layouts/Cases for the Assessment

The potential effects of the proposed new BN Wharf and FN Wharf extension on tidal velocities, flow patterns, and eddy formation within the harbour were analysed through numerical modelling across various scenarios. These scenarios included different configurations for the wharf developments and ship berthing arrangements.

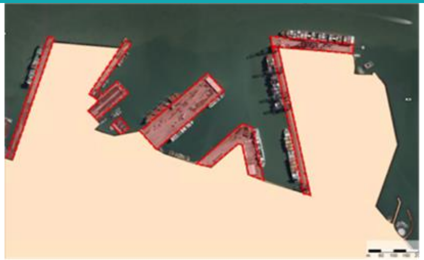
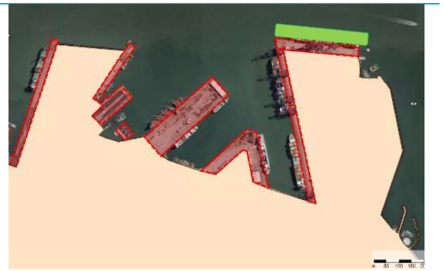
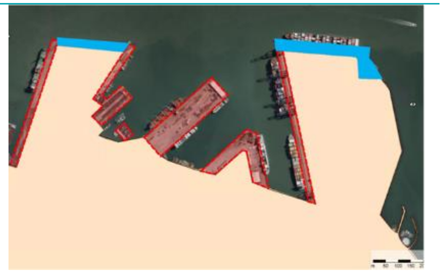
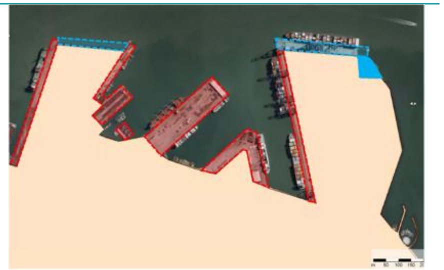
The proposed developments were modelled as two different configurations:

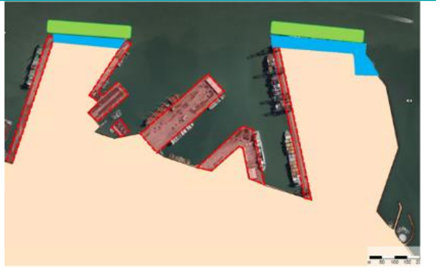
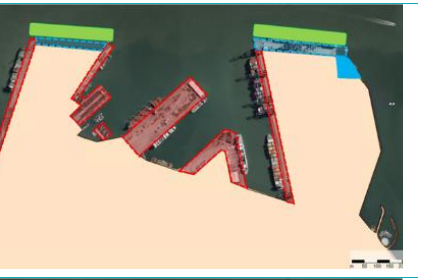
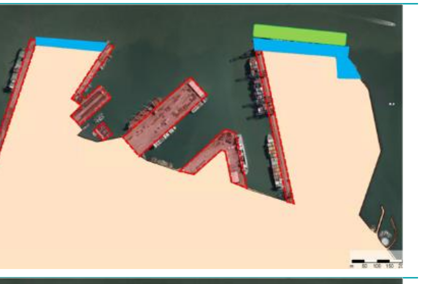
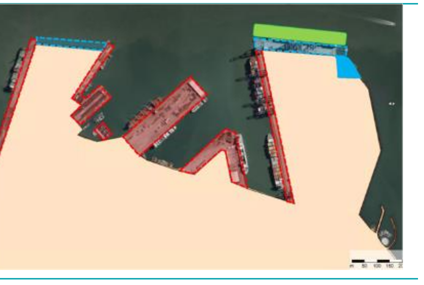
- Piled Structures: Simulating the wharves as piled structures, incorporating roughness factors similar to other existing piled wharves within the harbour.
- Land Extensions: Treating the proposed developments as solid land areas, effectively blocking the flow in the areas where the wharf piles and front skirts would occupy space in the water.

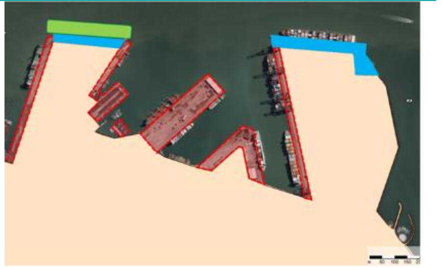
In addition to these wharf development configurations, the influence of berthed vessels alongside the proposed structures was included in the simulations to evaluate their impact on tidal velocities and eddy formations.

These scenarios were compared with existing baseline conditions to quantify changes in tidal velocities and current distributions, offering insights into potential long-term effects. The respective scenarios and proposed layouts are provided in Table 9.

Table 9: Model run cases and proposed layouts

Scenario	Tidal Condition	Model Geometry	Model Layout
Existing	• Neap (1.5 m range) Tide • Spring (3.0 m range) Tide	• All surrounding piled structures modelled as roughness • No ship berthing	
Existing (Base Case)	• Neap Tide • Spring Tide	• All surrounding piled structures modelled as roughness • With ship berthing at FN	
Proposed 1	• Neap Tide • Spring Tide	• No ship berthing • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 2	• Neap Tide • Spring Tide	• No ship berthing • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	

Scenario	Tidal Condition	Model Geometry	Model Layout
Proposed 3	• Neap Tide • Spring Tide	• With ship berthing • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 4	• Neap Tide • Spring Tide	• With ship berthing • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	
Proposed 5	• Neap Tide • Spring Tide	• With ship berthing at FN • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 6	• Neap Tide • Spring Tide	• With ship berthing at FN • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	

Scenario	Tidal Condition	Model Geometry	Model Layout
Proposed 7	• Neap Tide • Spring Tide	• With ship berthing at BN • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 8	• Neap Tide • Spring Tide	• With ship berthing at BN • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	

4.3 Assessment of Effects on Tidal Flows and Currents

The proposed changes to the harbour layout, including proposed wharf developments and additional berthing, are expected to alter tidal flows and currents. The hydrodynamic modelling suggests that tidal currents within both the main harbour channel and at the wharves will experience slight changes. Further details of the hydrodynamic modelling results are provided in Appendix A.

4.3.1 Effect of wharf extension (no ships berthed alongside)

The most notable changes are expected near the wharves, where current velocities could increase by up to 5% due to the additional structures at the new BN Wharf and FN Wharf. Similar increases of up to 5% are anticipated in the main channel, likely resulting from a slight reduction in tidal prism. These variations are considered minor and are not expected to affect the overall hydrodynamic regime of the harbour.

Additionally, a sensitivity analysis was conducted to evaluate the impact of projected sea-level rise (SLR) on the current velocities. Hydrodynamic modelling scenarios, based on a 0.5m relative sea-level rise (RSLR) as per Ministry for the Environment guidelines (MfE, 2024), show that this increase leads to a slight rise in local current velocities around the proposed developments, with a maximum increase of approximately 6%. This is an increase of 1% compared to the current velocities without sea-level rise.

Overall, the influence of the proposed wharf developments on current velocity is considered to be **negligible**.

4.3.2 Effect of wharf extension (ships berthed alongside)

The influence of ships berthed alongside the proposed developments was assessed by comparing the base case scenario (ship berthed at FN) to a scenario where ships are berthed at both the new BN Wharf and FN Wharf. This comparison revealed minimal changes in overall harbour velocities. However, a localised velocity reduction of around 15% is observed west of the new BN berth due to the blockage effect of the ship.

These changes are confined to the vicinity of the wharves and do not extend further into the harbour. The duration of these effects is expected to persist as long as the structures remain in place and ships continue to berth at the new locations. However, the frequency of occurrence is likely to be tied to specific tidal and operational conditions as well as berth occupancy. Thus, the influence of the proposed wharf developments with ships berthed alongside is considered to have a **negligible** effect on the overall harbour hydraulics.

4.3.3 Comparison of Historical and Recent Tidal Current Measurements

In addition to the hydrodynamic modelling results, historical ADCP tidal current measurements, taken before the 2005 construction of the Fergusson Terminal extension (from Vennel, 2006), were exported and compared against the most recent measurements collected during spring tides from 2013 to 2023. To maintain comparability, the maximum peak velocity of the measurements (2013 to 2023) was adjusted to a 3.0m tidal range and compared with the pre-2005 average maximum, as shown in Figure 13.

From these comparisons, it is evident that peak velocities have remained of the same magnitude, however, there has been some reduction in the general trend of peak velocities over the area. This velocity reduction could be attributed to the deeper bathymetry compared to pre-2005 conditions. Further details of the field measurements are provided in Appendix B.

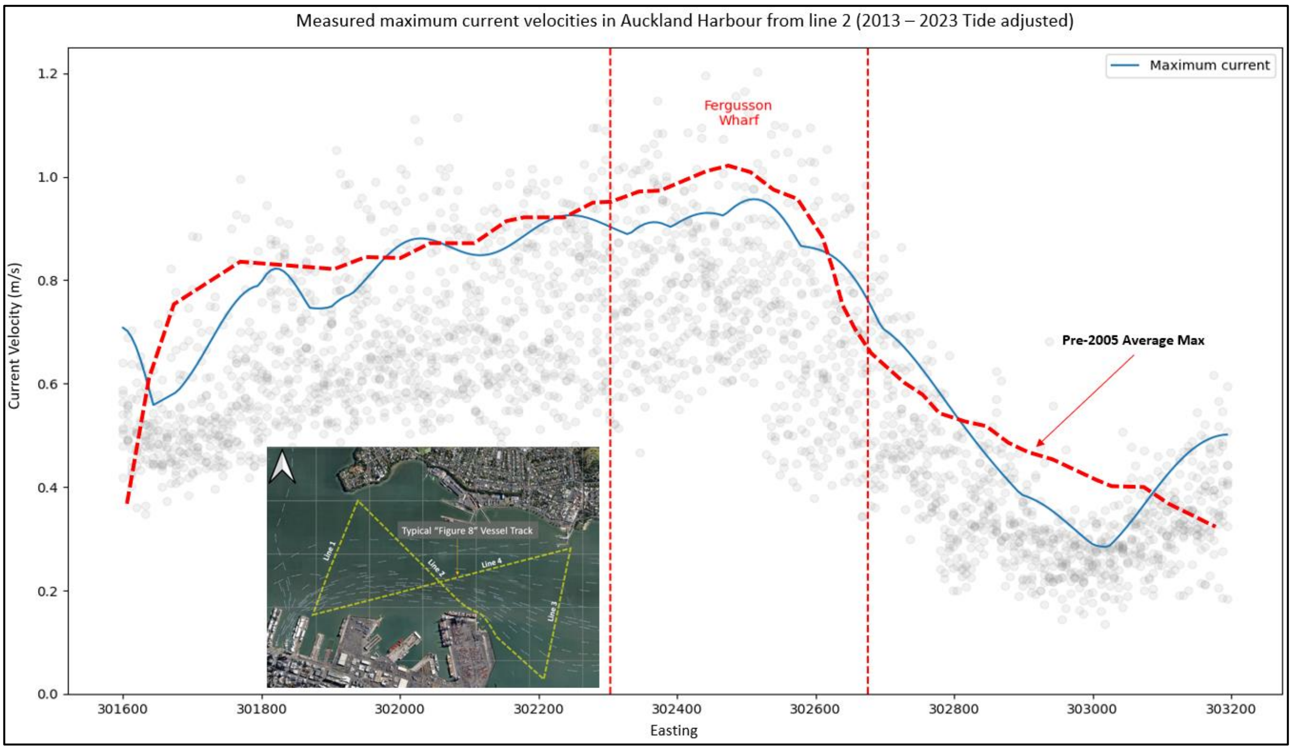


Figure 13: Comparison of measured maximum current velocities

Overall, the long-term effects of the proposed changes on tidal flows and currents are assessed as **negligible**. The primary tidal regime remains largely unaffected, with only minor changes near the new structures, which are not expected to impact the wider harbour environment.

4.4 Assessment of Effects on Waves and Wakes

Waves approaching the FN Wharf extension and the proposed new BN Wharf from the north-northwest to north-northeast directions are expected to induce wave reflections. The type of structure and wave period influences the magnitude of the reflected wave. Permeable structures, such as rock revetments, are less susceptible to large reflections compared to impermeable structures like vertical walls and vessels.

Observations at FN during a 25-30 knot northeasterly storm indicated that the reflective wave field was not sufficiently pronounced to be recorded. The only noticeable effect was a slightly confused sea state rather than a distinct reflected wave pattern (Beca, 1996).

The influence of the reflected waves can be demonstrated by comparing the incident wave conditions from the NNW with a significant wave height (H_S) of 0.5m, which represents a typical 1 in 1-year wind conditions (63% AEP), and is within the same order of magnitude to the vessel wakes expected within the harbour (refer to Section 2.6). The reflective structures and their associated coefficients, inferred from Goda (2010), are shown in Table 10.

Table 10: Wave Reflections for typical 1 in 1-year wind conditions (63% AEP) from NNW to NNE

Reflective Structure	Incident wave height	Coefficient	Reflected wave height
Rock-armoured embankment	0.5m	0.5	0.25m
Berthed Vessel	0.5m	0.9	0.45m
Wharf structure with a partial front skirt above MLWS and rock armour on the leeward side	0.5m	0.5	0.25m

4.4.1 Effect of waves on revetment and wharf extension (no ships berthed alongside)

The proposed new BN Wharf is a piled structure built over an existing revetment, with a partial front skirt (4m wide at approximately 20m centres) extending down to 2.3m CD to accommodate the wharf fenders and a seaward-facing beam extending down to 3.95 m CD. This structure will not increase the reflective wave characteristics for waves up to MHWS.

The existing revetment is a rock-armoured structure, which due to its permeability, is expected to reflect approximately 50% of the incident wave height. This results in a superimposed reflected and incident wave height of approximately 0.75m for both the existing conditions and is similar to the wharf-only condition. The proposed piles are expected to have only a localised influence on reflected waves.

For the new BN Wharf, these effects are typically localised and may include increased wave turbulence and altered wake patterns under the wharf. Due to the transient nature of wind-induced waves and wakes, the long-term impact on the overall wave climate is expected to be **negligible**.

For the 45m FN Wharf extension, which aligns with the existing structure, the impact on waves and wakes is expected to be **negligible**, as it is similar to the existing adjacent condition.

4.4.2 Effect of waves with ships berthed alongside

Reflected waves from the vessel hull are expected to reflect approximately 90% of the incident wave, resulting in a superimposed wave height of approximately 0.95m, an increase of 0.20m compared to the existing situation.

For the wind-induced waves, this difference will be imperceptible due to the concurrent sea state, where the wave field will be very choppy and confused. This confused wave state is due to scattered waves reflecting off various harbour infrastructure, as well as turbulence resulting from interactions between incident and reflected waves.

For vessel wakes the reflected wave pattern will be more noticeable as the concurrent sea state could be quite calm. These effects are typically localised and may include increased wave turbulence and altered wake patterns in the vicinity of the wharf. The overall wave pattern will be like a berthed vessel at the existing FN wharf, or a vessel berthed in the main harbour channel.

Due to the temporary nature of berthed vessels and the transient nature of wind-induced waves and wakes, the long-term impact on the overall wave climate is expected to be **no more than minor**. Given that the purpose of the proposed developments is to berth vessels in line with the main harbour channel, reflected wave patterns will occur for which there is no ready mitigation.

For the 45m FN Wharf extension, since it is being extended in alignment with the existing structure and no change in vessel size is planned, the impact on waves and wakes is expected to be **negligible** like the existing adjacent condition.

4.5 Assessment of Effects on Sediment Processes and Sedimentation

The proposed new BN Wharf and FN Wharf extension will have varying impacts on sediment processes and sedimentation patterns within the Waitematā Harbour. The expected effects are based on the specific characteristics of each extension and their location relative to current sediment dynamics.

The FN Wharf extension of approximately 45m, located to the east of the existing structure, is situated in an area already influenced by the existing wharf geometry. Since this extension aligns with the existing structure and does not significantly alter the surrounding environment, its impact on sedimentation is expected to be minimal. However, due to the minor increase in current velocity associated with the extension, some additional localised erosion is anticipated near the extension.

This localised erosion is not expected to increase the overall erosion rate in other areas of the harbour or introduce new sedimentation patterns. Therefore, the long-term effect of the FN Wharf extension on sedimentation is anticipated to be **no more than minor**, with impacts expected to occur soon after construction and then remain unchanged.

The proposed new BN Wharf, which involves a piled structure, is positioned in a less active part of the harbour and does not extend into the main flow areas of the harbour (i.e., it is south of a direct line between Fergusson Terminal and Wynyard Point). As the extension is built over an existing revetment, its influence on sediment transport is expected to be limited. The primary effect may be localised changes in sediment accretion and erosion around the immediate vicinity of the extension. These effects are likely to persist over the long term, occurring during specific hydrodynamic conditions. The overall impact on broader sedimentation patterns and transport is anticipated to be **negligible**.

Historical and recent sedimentation data reveal a general trend of seabed lowering in high-traffic areas (such as the main harbour channel and turning areas of vessels) and accretion in less active zones. To provide a clearer understanding of the observed morphological changes, a difference map was generated using 2m x 2m gridded data, as illustrated in Figure 14. This difference map compares the 2024 data with the 2000 bathymetric data (see Figure 8). The 2024 data, obtained using high-resolution multibeam technology, offers greater detail compared to the coarser 2000 data.

In Figure 14, blue bands represent varying rates of erosion, while red bands indicate areas of accretion. The map reveals a general trend of erosion, with depths reaching up to 0.6m primarily along the main channel. Notably, localised erosion of up to 1m is observed north of Fergusson Wharf, probably attributable to the consented channel and approach dredging in 2001-2010 (consented dredge areas shown in black outline) and ship movements. In addition, the map shows a general accretion of up to 0.6m near Stanley Point, as well as to the east of Fergusson and Bledisloe Wharves.

These sedimentation patterns are likely due to the ongoing natural sediment processes, the Fergusson reclamation, and the activity of deeper vessels. As discussed in Section 4.3, the recent tidal currents are similar to, if not slightly lower than, the pre-Fergusson terminal tidal currents. The historical bathymetry and tidal current data indicate that, although excursions into the harbour have the potential to increase tidal currents, the coastal processes (through dynamic equilibrium) tend to lower the seabed levels (which creates a larger wetted cross-sectional area) and subsequently lowers the tidal currents close to the pre-development levels.

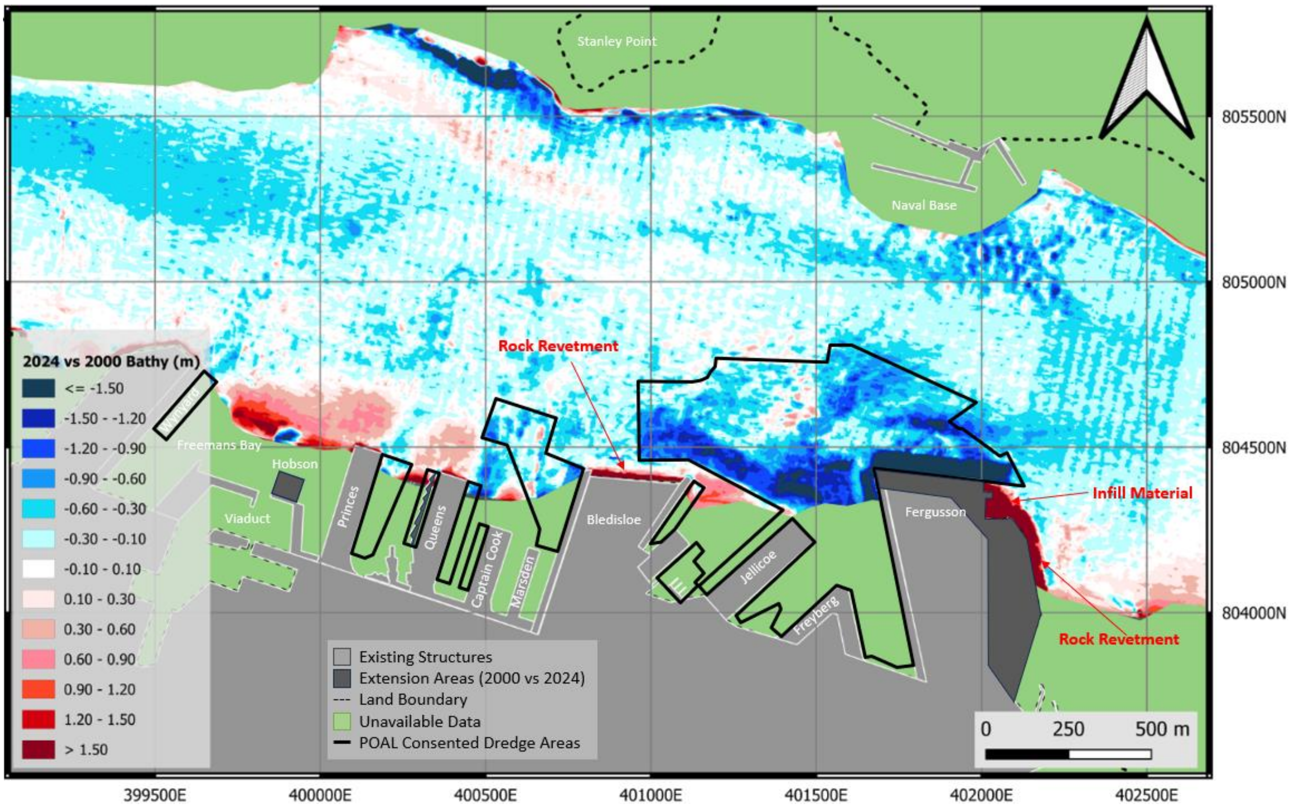


Figure 14: Difference map showing erosion areas in blue and accretion areas in red.

The proposed developments are expected to align with these existing trends rather than significantly change them. Due to the intermittent nature of berthed vessels and their low level of excursion into the harbour, their impact on sedimentation processes will be limited. The FN Wharf extension's impact will be consistent with current conditions due to its alignment with existing structures (**no more than minor**), while the proposed new BN Wharf's effects are expected to be minimal given its location and design (**negligible**).

4.6 Assessment of Effects on Coastal Hazards

The new BN Wharf will feature a deck-on-piles structure with a revetment underneath for infill protection extending up to the underside of the wharf deck. Given this design configuration and the relative elevation of the deck level above the storm tide level (see Figure 9), wave overtopping is expected to be similar to the existing condition and will not increase overtopping risks. The facing wharf beams, however, will become more influential in creating wave reflection patterns with future sea level rise.

Similarly, the 45m eastern extension of FN Wharf, which is designed to match the existing structure, is not expected to increase overtopping risks.

However, while the design minimises overtopping risks, wave loading on both the proposed new BN Wharf and FN Wharf extension remains a critical consideration. The structural design must account for the dynamic forces from wave action on the deck, piles, and interfaces with the existing structures to maintain stability during extreme conditions.

The proposed new BN Wharf and FN Wharf extension are planned to align in elevation with the existing facilities, resulting in similar exposure to coastal hazards. These proposed developments will occupy a negligible additional percentage of land within Waitematā Harbour. Consequently, it is expected the effects of proposed developments on the tide levels, extreme sea levels and tsunami within the harbour be **negligible**.

However, it should be noted that future sea level rise could potentially lead to more severe coastal hazards compared to current conditions, impacting on the proposed developments. These changes may affect the functionality of structures and drainage systems, which could be exposed to higher water levels and waves, and increased risk of overtopping.

While there is some uncertainty regarding the long-term future of the port, the new BN Wharf and FN Wharf are expected to remain valuable assets, serving the city in roles such as cruise terminals, lifeline structures, and public access points. In the event of port relocation, alternate uses for the land may involve raising the site by 1m to account for sea level rise.

If the sea level rises significantly over the next century, the wharves may require additional adaptations, such as topping to raise deck levels, though this would reduce their loading capacity from heavy port operations to light vehicle or pedestrian use.

In this context, it is recommended that the proposed developments consider future coastal hazard conditions, where feasible. Any long-term mitigation efforts would likely be coordinated with broader citywide strategies to manage sea level rise, impacting not only the port but also nearby areas like the Central Business District, Viaduct, Wynyard Quarter, and Westhaven.

4.7 Cumulative Effects

The assessment process compared the effects of the proposed development with the existing environment which encapsulates all past anthropogenic developments within the harbour. The assessment also recognised other proposed developments that have resource consents. For example, deepening the FN berth and the navigable harbour approaches (for which there are resource consents to do so) were not included because more conservative results (i.e. higher current velocities) are associated with the existing bathymetric conditions.

Overall, the cumulative adverse effects of the proposed new BN Wharf and FN Wharf extension are expected to be **no more than minor,** as the combined impacts remain within acceptable limits for coastal processes and the surrounding environment due to the small scale of the proposed developments. These potential adverse effects need to be weighed up with the beneficial effects of the proposed development.

5 Mitigation and Monitoring

While the proposed new BN Wharf and FN Wharf extension are expected to have minimal impact on the overall harbour hydraulics, it is recommended that a mitigation and monitoring plan be implemented to address any potential effects arising from the proposed developments, to maintain compliance with environmental standards. The plan includes the following components:

- Monitoring Plan:
  - ADCP Measurements: Continuation of the ADCP measurements (refer to Appendix A) to provide continuous data on current conditions, detecting any changes in the harbour environment. Measurements to be conducted before construction and then every 2 years for a period of 6 years.
  - Bathymetric surveys: Surveys to be conducted before construction and then every 2 years for a period of 6 years.
  - Results of the above surveys to be reported to Auckland Council.
- Mitigation Measures: Implementation of strategies to mitigate any potential impacts, including:
  - Structural Adaptations: Design of wharf piles and other structures with consideration for future climate change impacts. Although immediate increases in wharf levels are not planned, reviews should be conducted in 2040 to consider potential adjustments based on updated climate predictions.
- Emergency Preparedness: As a lifeline operator, POAL has procedures in place to manage emergency situations, including:
  - POAL receives tsunami alerts and has an established system to assess the likely impacts on port operations based on the magnitude and location of seismic events.
  - POAL has emergency procedures in place to manage a range of scenarios, covering both coastal and land-based risks. These procedures are in place to maintain the safety and continuity of port operations, including the release of vessels during emergency situations.

These measures are intended to effectively manage potential impacts and provide compliance with the consent conditions.

6 Conclusions

The assessment of the effects of the proposed new Bledisloe North (BN) and Fergusson North (FN) Wharf extension on coastal processes within Waitematā Harbour was carried out using a combination of empirical calculations, historical data analysis, and hydrodynamic modelling. The assessment focused on changes in current distribution, current velocity, wave reflection and potential impacts on sediment transport dynamics.

- **Effects on Tidal Flows and Currents:** While localised increases in current velocities may occur near the wharves, these changes are not expected to extend into the wider harbour, and the primary tidal regime will remain unaffected.
- **Effects on Waves and Wakes:** The proposed new BN Wharf, comprising piled structures, may cause localised wave reflection and wake pattern changes. However, these effects will remain confined to the immediate area around the new piles and externally will be similar to the existing situation. Berthed vessels could contribute to localised reflection adjacent to the wharf, though this impact is unavoidable due to the alignment of the vessel and its near vertical face. Similarly, the FN Wharf extension will have minimal impact on waves and wakes due to its alignment with the existing structure. Overall, the proposed wharf developments are expected to have no more than minor impacts on wave and wake conditions, with negligible effects on the broader harbour wave climate.
- **Effects on Sediment Processes and Sedimentation:** The FN Wharf extension aligns with the existing wharf geometry, resulting in minor disruption to sediment dynamics. The proposed new BN Wharf, located over an existing revetment, is expected to have a minimal impact on sediment processes. Some scour of the seabed in the vicinity of the wharves is expected with vessel movements.

The assessment indicates that the overall environmental effects are expected to be minor and localised. Table 11 below provides a summary of the evaluated impacts on various coastal conditions.

Table 11: Summary of Environmental Effects of new Bledisloe North Wharf and Fergusson North Wharf Extension

Effects on Coastal Condition	Bledisloe North (BN)	Fergusson North (FN)
Tidal Flows and Currents	Negligible	Negligible
Waves and Wakes	No more than minor	No more than minor
Sediment Processes and Sedimentation	Negligible	Negligible
Coastal Hazards	Negligible	Negligible
Cumulative Effects	No more than minor	

A mitigation and monitoring plan has been proposed to comply with relevant environmental standards. This plan includes ongoing monitoring of bathymetry, currents, and structural adaptations to address potential future climate change impacts.

The overarching conclusion is that the effects are negligible/minor because the scale of the proposed developments is small compared with the immediate coastal area (i.e. the lower harbour area and main channel). That area is where adverse effects are avoided/minimised by the proposed developments. Consequently, the effects tend to be localised and generally do not extend into the immediate coastal area.

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A

Appendix A – Hydrodynamic Modelling Report

Sensitivity: General

Beca

Hydrodynamic Assessment of Waitematā Harbour

Delft3D Modelling Report

Prepared for Port of Auckland Ltd
Prepared by Beca Limited

21 November 2024

Contents

Appendices

Revision History

Revision N°	Prepared By	Description	Date
1	Victor Muller	Draft For Internal Review	26/08/2024
2	Victor Muller	Draft For Client Review	30/08/2024
3	Victor Muller	Final For Client Approval	14/10/2024
4	Victor Muller	Final For Client Approval	21/11/2024

Document Acceptance

Action	Name	Signed	Date
Prepared by	Victor Muller		21/11/2024
Reviewed by	Reza Shafiei Stephen Priestley		22/11/2024
Approved by	Andy Harvey		22/11/2024
on behalf of	Beca Limited		

Executive Summary

Beca Ltd. (Beca) has been commissioned by Port of Auckland Ltd. (POAL) to carry out a hydrodynamic modelling study as part of the Assessment of Environmental Effects (AEE) for proposed developments within Waitematā Harbour. This study supports an application made under the Fast-track Approvals Act 2024 for resource consents to authorise the construction and operation of the new Bledisloe North Wharf and Fergusson North Wharf extension.

The new Bledisloe North (BN) Wharf, approximately 330m in length, will accommodate a new berth for cruise ships over 300m in length and roll-on/roll-off vessels, while the Fergusson North (FN) Wharf extension involves a 45m addition to the existing wharf to improve operational efficiencies and enable quay crane accessibility.

The study assesses the potential impacts of these developments on tidal currents and water movement within the Waitematā Harbour. Key findings indicate that peak velocities are notably higher during spring tides compared to neap tides, with velocities during spring tides typically being twice those during neap tides.

The analysis reveals that the proposed wharf developments have minimal impact on overall tidal velocities. Additionally, wind effects were assessed, showing that while wind influences localised current patterns, it does not significantly alter overall harbour hydraulics. In addition, the relative effect of sea level rise between the existing and proposed development is negligible.

The presence of a ship berthed at one wharf while another is occupied causes only minor changes in the overall harbour dynamics, with some localised decreases in velocity observed near the berthed ships. Overall changes in current velocities within the wider harbour are less than 10%.

In conclusion, the proposed wharf developments, and local wind conditions will slightly alter the existing hydrodynamic conditions within Waitematā Harbour, with tidal forces continuing to dominate the overall flow patterns. It is therefore concluded that the effect of the proposed development on the tidal currents is less than minor.

1 Introduction

1.1 Background

Beca Ltd. (Beca) has been commissioned by Port of Auckland Ltd. (POAL) to conduct a hydrodynamic modelling study. This study is a key component of the Assessment of Environmental Effects (AEE) report, which will support an application made under the Fast-track Approvals Act 2024 for resource consents to authorise the construction and operation of the new Bledisloe North Wharf and Fergusson North Wharf extension.

The new Bledisloe North (BN) Wharf, approximately 330m in length, will accommodate a new berth for cruise ships over 300m in length and roll-on/roll-off vessels. The Fergusson North (FN) Wharf extension involves a 45m addition to the existing wharf to improve operational efficiencies and enable quay crane accessibility. The locations of the existing facilities and adjacent wharves are shown in Figure 1.

This hydrodynamic modelling study aims to assess the potential impacts of these proposed infrastructure developments on tidal currents and water movement in the surrounding marine environment. The findings of this study will inform the design process and support the coastal effects assessment presented in the Coastal Processes Report (Beca, 2024).

Figure 1: Site locations (in yellow) within the wider harbour

1.2 Scope of Work

The scope of this hydrodynamic modelling study includes the following key tasks:

- Development of a hydrodynamic model covering the Waitematā Harbour and adjacent water areas. The model accounts for both existing conditions and proposed infrastructure changes.
- Calibration and validation of the model using observed tidal data, including current velocity measurements from the POAL measuring campaign.

- Simulation of hydrodynamic conditions under different geometric scenarios, including variations in tidal phases (spring and neap tides).
- Assessment of potential impacts on coastal processes, including changes in tidal velocities and water circulation patterns.
- Sensitivity analysis to evaluate the influence of roughness and wind speeds on model outcomes, providing a robust basis for understanding the potential range of impacts under varying environmental conditions.

1.3 Limitations

The hydrodynamic model's accuracy and reliability are influenced by several factors, including:

- Data Constraints: The model relies on the best available data for bathymetry and tidal currents. In some areas, data may be sparse or outdated, potentially affecting model precision.
- Model Assumptions: To balance computational efficiency and detail, certain simplifications were made, such as uniform sediment characteristics and steady-state boundary conditions, which may not capture all dynamic environmental factors.
- Hydrodynamic Focus: DELFT3D FLOW-FM primarily simulates tidal currents and flow circulation in 2D or 3D, as well as morphological changes. It does not directly model wave-driven processes. Wave reflection coefficients are generally not required for simulating tidal current hydrodynamics in a harbour area with coastal structures or berthed vessels. Instead, the focus is on tidal-driven currents, circulation patterns, and overall flow behaviour, which are largely independent of wave interactions unless there is significant wave activity.
- Wave Effects: If wave effects (e.g., wind waves, swell, or vessel-induced waves) are significant, wave reflection can be assessed by coupling wave models, such as SWAN, with DELFT3D FLOW-FM. However, given the moderate wave energy in the Waitematā Harbour, wave reflection effects are accounted for manually using empirical coefficients. These coefficients are applied during post-processing to estimate the influence of reflected waves on surrounding areas.

Confidence in the model is gained by verifying the output with comparative measured field data.

These limitations suggest that while the model provides valuable insights into relative changes between current and proposed conditions, care should be taken when interpreting absolute values. The relative changes remain a reliable indicator of the expected hydrodynamic effects of the proposed developments.

2 Existing Environment

2.1 Marina Geometry

2.1.1 Existing Configuration

The Waitematā Harbour extends approximately 20km from the harbour entrance at North Head to the upper reaches near Hobsonville. Formed as a drowned river valley, the harbour features a diverse marine environment shaped by surrounding landforms and human activities.

The harbour's marine infrastructure includes key wharves and deep-water channels supporting various maritime activities. The FN Wharf serves as an important terminal for container shipping, while the proposed new BN Wharf will accommodate cruise ships, multi-cargo vessels and roll-on/roll-off vessel operations.

The layout of these wharves, along with adjacent land reclamation areas, shapes the harbour's overall configuration and influences tidal flows, current patterns, and sediment transport within the area.

The eastern part of the harbour, where the project sites are located, experiences hydrodynamic conditions primarily driven by semi-diurnal tides. Figure 2 shows the layout of the existing marine infrastructure, with the inner harbour areas predominantly lined with vertical seawalls (shown in red), while the wharves are mainly piled structures (shown in orange).

Figure 2: Existing harbour configuration

2.1.2 Proposed Developments

The proposed developments include a 45m extension to the east of FN Wharf, infilling the triangular area (approximately 15x15m) adjacent to this extension (as part of an existing resource consent), and constructing a 330m piled structure to the north of the Bledisloe Wharf. Figure 3 shows the proposed layout of the marine infrastructure, with the yellow areas indicating the proposed piled structures and the grey area representing the previously consented infill area at FN.

The objective of the FN Wharf extension is to improve operational efficiencies and enable quay crane accessibility, while the new BN Wharf will provide additional berthing for cruise ships over 300m in length and roll-on/roll-off vessels.

The addition of these new structures will alter the existing marina geometry, potentially affecting tidal circulation patterns and wave dynamics within the surrounding areas. The proposed layouts have been incorporated into the hydrodynamic model to simulate and investigate these potential changes.

Figure 3: Proposed harbour developments

2.2 Bathymetry

Detailed bathymetric data for the Waitematā Harbour has been obtained from POAL to support the hydrodynamic modelling study. The seabed levels within the harbour vary, with depths ranging from approximately -6m Chart Datum (CD)[1] within Freemans Bay and near the shorelines to around -14m CD in the deeper channel areas. Notable features shown in Figure 4 include the berthing pockets dredged adjacent to the FN and new BN Wharves and natural seabed contours within the main harbour channel that influence

[1] Chart Datum is determined as 0.0m CD being approximately the lowest astronomical tide at the time of preparing this report.

tidal flows and sediment transport. This bathymetric information has been integrated into the hydrodynamic model representative of the seabed.

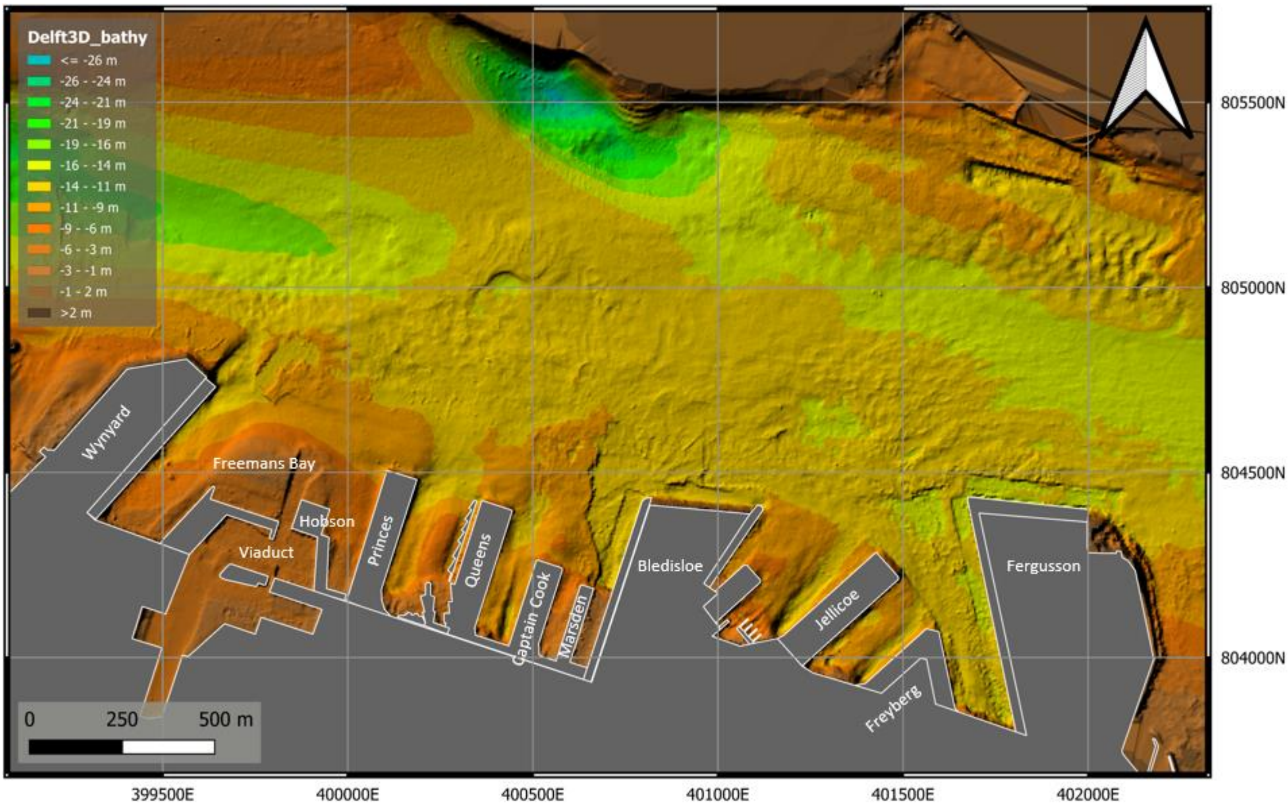


Figure 4: Latest bathymetry data (Source: POAL)

2.3 Tide Levels

The tidal regime in Waitematā Harbour is semi-diurnal, with approximately two high and two low tides occurring each day. This regular cycle is a key driver of the harbour's hydrodynamics, influencing currents, sediment transport, and overall coastal processes.

Tidal levels at the project sites align with the standard port tidal levels for Auckland Harbour as provided by Land Information New Zealand (LINZ). LINZ provides tide levels in terms of Chart Datum (CD), which is 1.745m below Auckland Vertical Datum 1946 (AVD-46) and 2.077m below New Zealand Vertical Datum 2016 (NZVD-16) for Waitematā Harbour. Table 1 summarises the tidal levels relevant to the project.

Table 1: Tide levels at Waitematā Harbour (source: https://www.linz.govt.nz/sea/tides/tide-predictions)

Tide Condition	Level in m CD	Level in m NZVD-16
Highest Astronomical Tide (HAT)	3.74	1.66
Mean High Water Springs (MHWS)	3.35	1.27
Mean High Water Neaps (MHWN)	2.80	0.72
Mean Sea Level (MSL)	1.93	-0.15
Mean Low Water Neaps (MLWN)	1.07	-1.01
Mean Low Water Springs (MLWS)	0.52	-1.56
Lowest Astronomical Tide (LAT)	0.08	-2.00

2.4 Wind

Wind data for the Waitematā Harbour has been sourced from the Bean Rock weather station, located approximately 4km northeast of FN. The wind rose from Bean Rock, covering the period from 1993 to 2019, shows a bi-modal wind climate with predominant winds from north to east and west to south (refer to Figure 5). Wind speeds typically average below 10 m/s (approx. 20 knots), with occasional gusts exceeding 20 m/s (approx.40 knots). This data has been integrated into the hydrodynamic model to assess the wind effect on the water movement within the harbour (refer to Section 3.4).

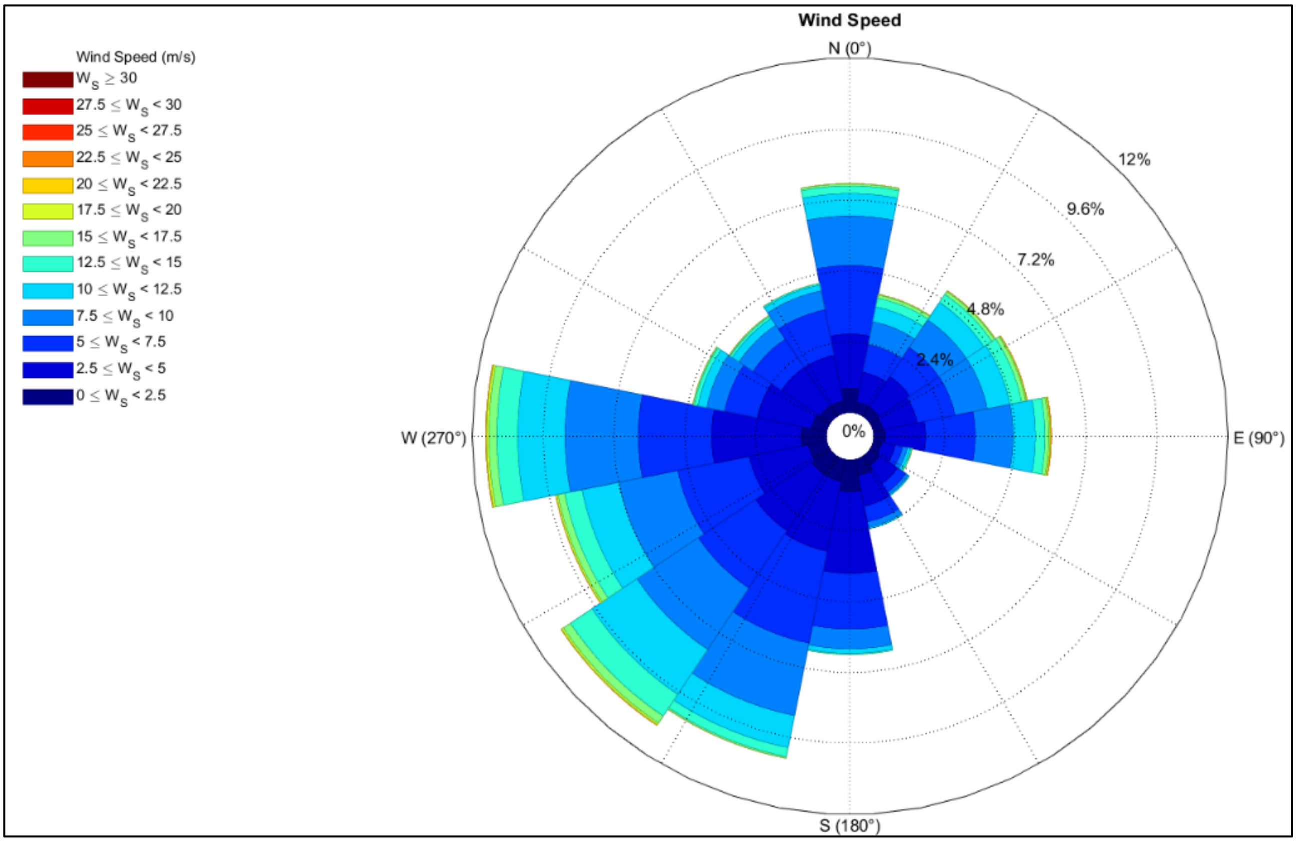


Figure 5: Annual wind rose - Bean rock (1993 to 2019)

2.5 Currents

Tidal currents within Waitematā Harbour are primarily driven by the configuration of the harbour entrance, the depth and width of channels, and the presence of existing structures such as wharves and reclamations. The currents in the harbour exhibit a flood-ebb pattern, with variations in speed and direction based on location within the harbour. Detailed analyses of current patterns and tidal streams are provided in Section 3. The currents are strongest during mid-flood and ebb tides, with a decrease in velocity observed during slack water periods.

For this hydrodynamic modelling study, the following datasets were utilised:

- Historic Acoustic Doppler Current Profiler (ADCP) tidal current measurement surveys collected from 1995 to 2005. These measurements were taken during spring tides and covered areas from Queens Wharf to Devonport, prior to the 2005 construction of the Fergusson Terminal extension (Vennel, 2006).
- Boat-mounted ADCP measurements collected during spring tides from 2013 to 2023, covering areas from Queens Wharf to Devonport. Approximately 13 runs were completed during each measurement session, which lasted around 12 hours. These measurements were conducted as part of POAL's ongoing monitoring campaign (refer to Figure 6).

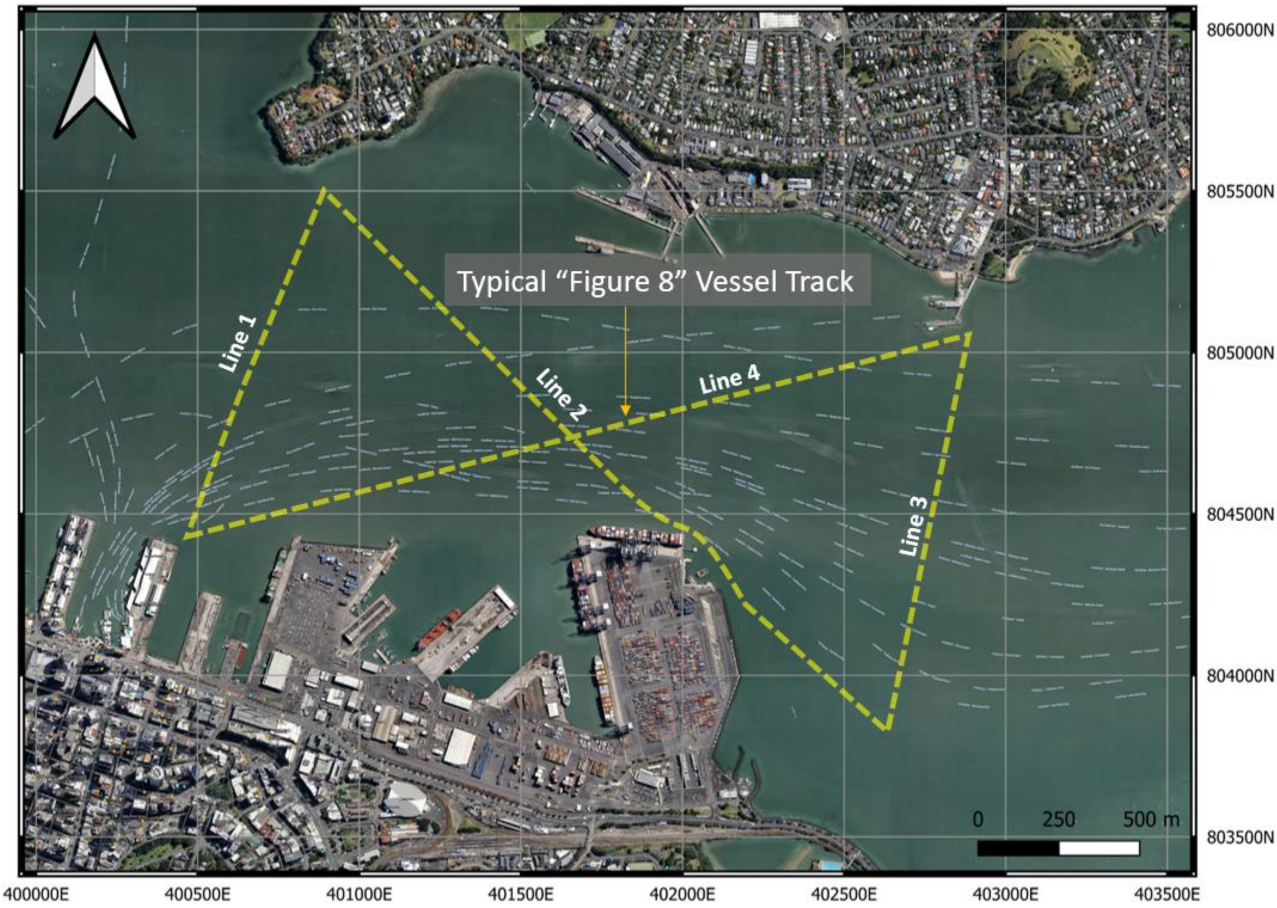


Figure 6: Typical vessel track during the measurement campaign

Of particular relevance to the project, measurements along Line 2 offer insights into current velocities near the FN Wharf extension, while Line 4 provides insights near the new BN Wharf. Detailed current velocity data along these lines can be found in Appendix A1.

3 Hydrodynamic Modelling

3.1 Model Description

The hydrodynamic modelling was conducted using the Delft3D Flexible Mesh Suite 2020.02 HMWQ (D-Flow FM). D-Flow FM, developed by Deltares, is a hydrodynamic modelling tool that supports the simulation of complex water movement using unstructured grids. This model is particularly well-suited for modelling in environments with intricate bathymetry and varying boundary conditions. D-Flow FM includes several equations and physical processes to simulate complex hydrodynamic phenomena. For this project, the 2D shallow water equations were employed, enabling accurate simulation of tidal currents and water levels across the study area.

Two-dimensional (2D) modelling is appropriate for this study. It enabled easy comparison with the historical measured currents which were depth averaged. As an example, during a specific measurement in the main channel, recorded velocities ranged from approximately 0.1m/s near the seabed to 1.3m/s near the surface. The depth-averaged velocity for this particular sample was calculated to be around 0.8m/s. The depth-averaged velocity has been calculated at 0.4D (where D is the water depth) from the seabed and 0.6D from the water surface. This depth-averaged velocity represents the flow across the entire water column, providing the smoothed profile of the vertical velocity and offering a general indication of the current strength in the channel.

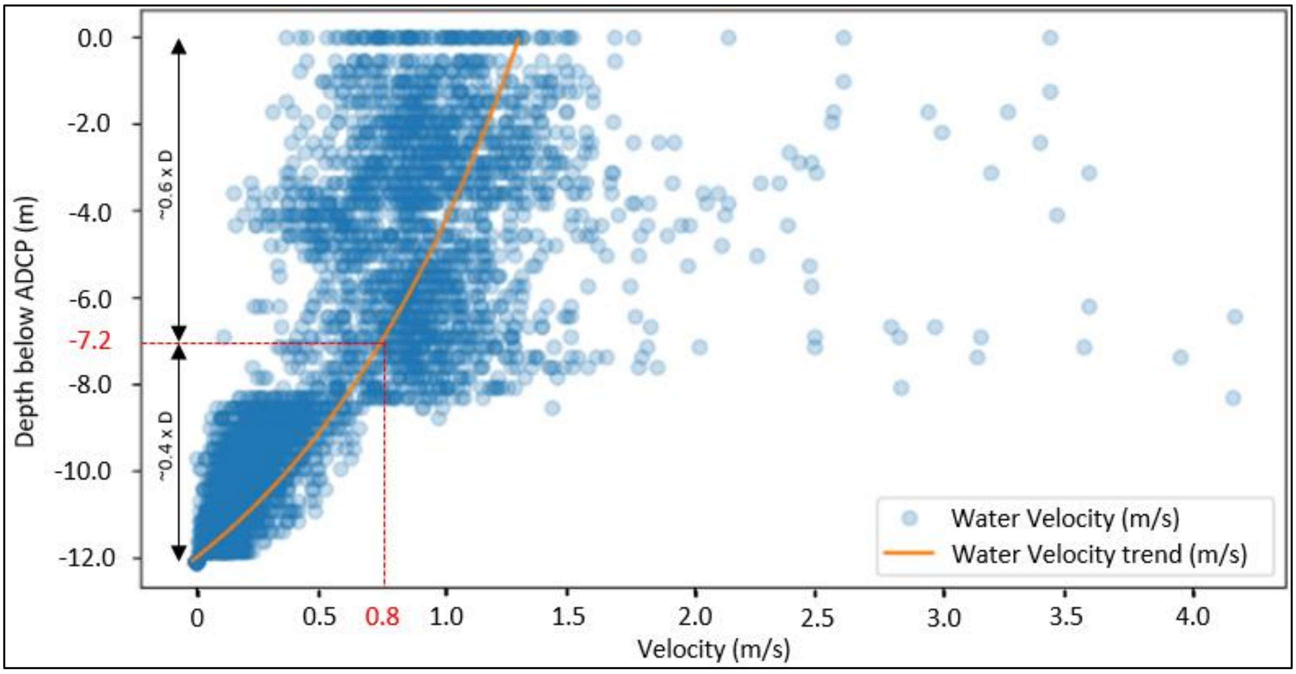


Figure 7: Example of the depth-averaged current velocity taken from 100 consecutive ADCP samples

3.2 Model Computational Domain

The model incorporates bathymetric survey data provided by POAL, which covers the harbour and marina areas (refer to Section 2.2). For the intertidal zones, where additional information was necessary, existing data was extracted from previous studies by Beca, particularly the *America's Cup Hydrodynamic Modelling Report* (Beca, 2018).

The model computational domain, encompassing the wider Waitematā Harbour in addition to the respective project sites, was created using a variable unstructured mesh. A snapshot of the model's computational domain is shown in Figure 8.

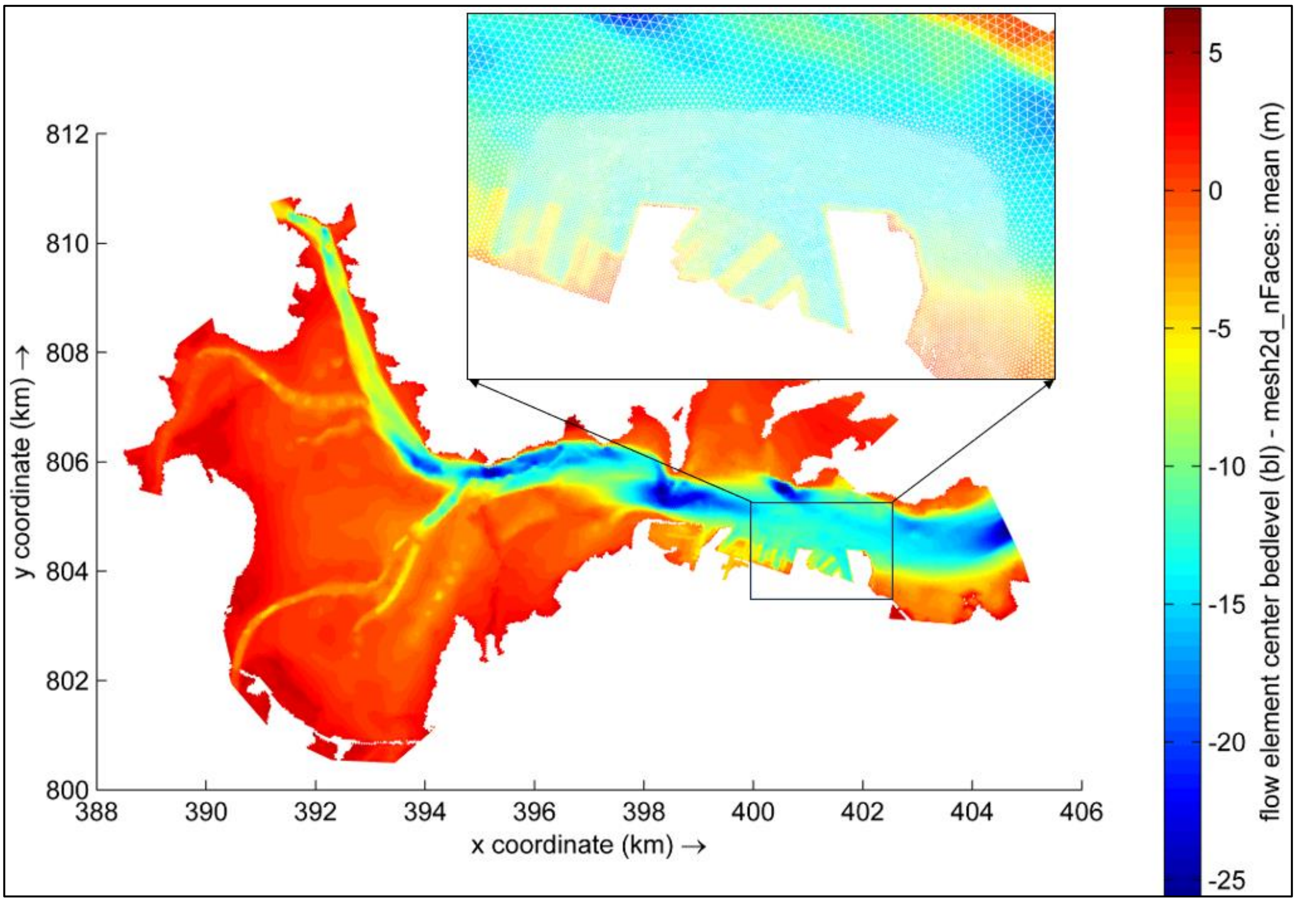


Figure 8: Hydrodynamic model domain

The grid comprises 59,214 nodes and 117,186 grid cells, with typical grid cell sizes ranging from approximately 15m in areas of high interest (such as around the proposed wharf developments) to 25m in the inner harbour to 50m in outer less critical areas. This resolution was selected to strike a balance between computational efficiency, the scale of processes, and the level of detail required.

3.3 Model Validation

3.3.1 Processing Measured Current Velocities

The approach used to filter the ADCP measurements collected from spring tides between 2013 and 2023, spanning from Queens Wharf to Devonport (refer to Figure 8), was based on methodologies used in the historic ADCP (Acoustic Doppler Current Profiler) tidal current measurement surveys conducted by Vennel (2006). These earlier measurements, taken between 1995 and 2005, provided a foundation for data refinement.

The raw measurements (spanning between 2013 and 2023) were cleaned to correct inaccuracies and reduce noise from sources such as measurement technology, vessel roll, passing ship interference, and small-scale eddies. Subsequently, depth-averaged velocities were calculated by integrating the velocity measurements vertically from the water surface to the depth recorded by the ADCP, and then dividing this integral by the ADCP-measured depth.

Profiles were discarded if they:

1) Were recorded during rapid vessel manoeuvres (heading changes exceeding 20 degrees per ensemble), such as during sharp or fast turns of the survey vessel. The rationale for discarding these profiles is that rapid changes in the vessel's heading can introduce errors in the data due to the

instrument's inability to accurately measure water velocities when the vessel is moving erratically. By excluding such profiles, the data quality is improved, leading to more reliable results.

2) Displayed current velocities above 1.7 m/s, as recorded historical data had a maximum of 1.0m/s.
3) Showed vessel speeds greater than 5 m/s (approximately 10 knots).
4) Contained unreliable bottom track data.

The processed data, after removing these profiles, were used for further analysis and model calibration. An example of the aggregated depth-averaged measured tidal currents is illustrated in Figure 9. The figure provides an example of a single circuit, approximately 50 minutes in duration, completed during the October 2023 survey. It shows a snapshot of depth-averaged tidal currents observed during this particular run. The maximum raw tide height recorded during this circuit was 3.16m CD, while the lowest raw tide level reached 2.32m CD. The red arrows in the figure represent the depth-averaged velocity vectors during the survey run. The magnitude of the velocity is indicated by the scale in the legend: the smaller arrows represent velocities closer to 0.5m/s while larger arrows indicate velocities approaching 1m/s.

The blue colour in the legend corresponds to the background scale used to differentiate the magnitudes of current velocities, while the red arrows depict the actual measured data for the selected example circuit. Additionally, the maximum tidal range specified refers to the unfiltered tidal range, which is further illustrated in Figure 10.

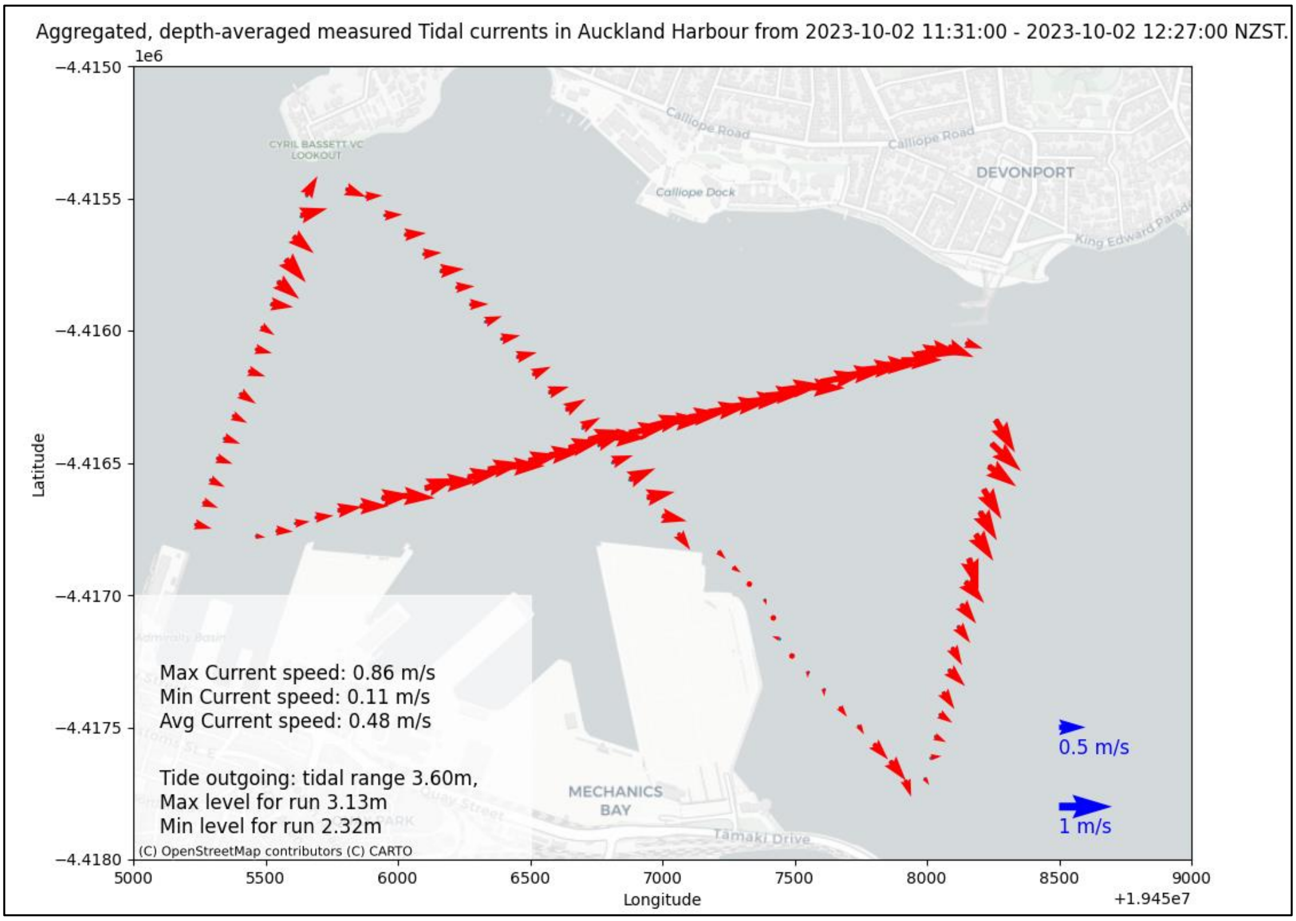


Figure 9: Example measured depth-averaged spring tidal currents during ebb flow

Further details of the tidal analysis based on this processed data for the complete dataset are provided in Appendix A1.

3.3.2 Model Validation

For model validation, spring tide measurements from the POAL measurement campaign on October 2, 2023, were used as the base case. The measured tide levels, as shown in Figure 10, were applied as input boundary conditions. Tidal conditions for the specific date, along with the day before and after to account for model ramp-up and ramp-down, were obtained from NIWA's tidal hindcast database. This tidal data was compared with on-site measurements and incorporated into the model to simulate these conditions with the current model geometry (as outlined in Section 2.1.1).

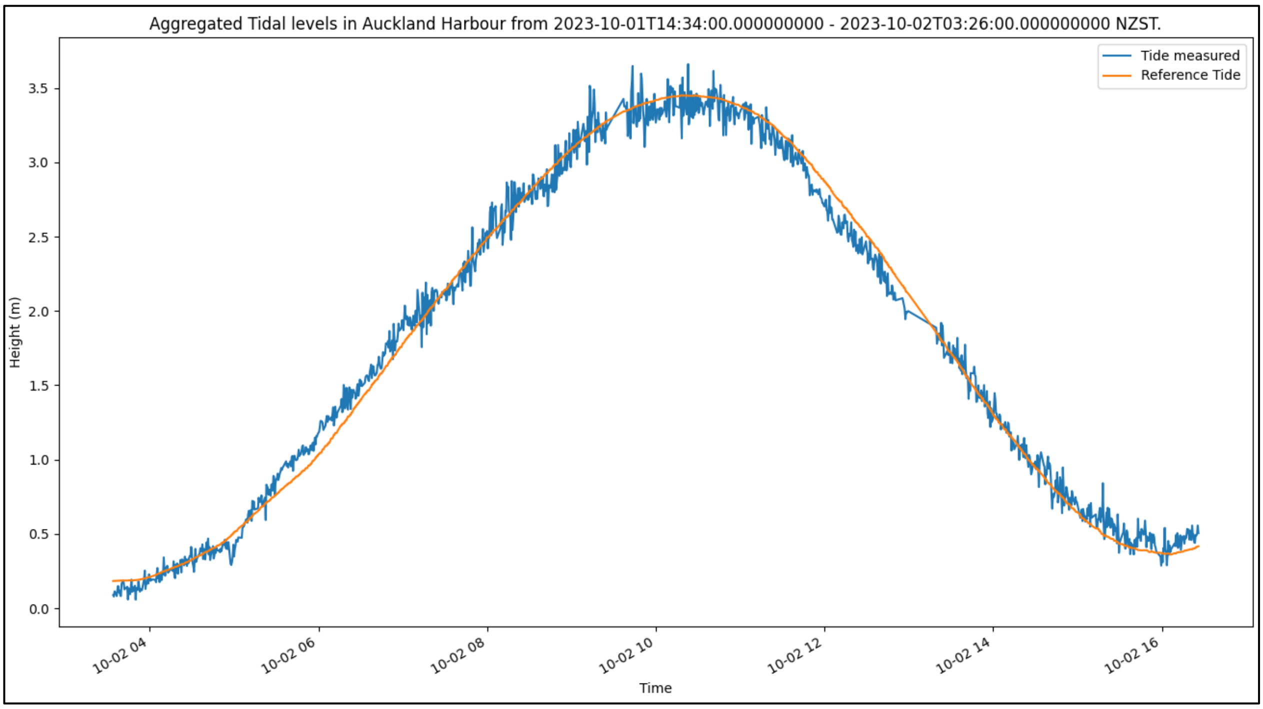


Figure 10: Measured ADCP tide data during the October 2023 measurement campaign and assumed harmonic profile.

The modelled velocities were validated against the measured data at ten observation points along the vessel's track, covering key areas of the "Figure 8" track. These observation locations are shown in Figure 12. The following model parameters were adjusted to calibrate the hydrodynamic model.

Bed friction was varied across the domain, with a base roughness value of 0.02 applied to most areas. To accurately represent the complex flow dynamics around the wharves and their substructures, a higher roughness value of 0.05 was used. This adjustment was based on an assessment of the proportional reduction in flow area caused by these substructures. The typical plan layout of these roughness factors is illustrated in Figure 11, for the scenario where the piled structures within the harbour are modelled as roughness.

Figure 11: Typical roughness values applied to the Delft3D model

Turbulence effects in the model were captured using the k-epsilon turbulence closure model within the D-Flow FM module. This approach involves solving transport equations for the turbulent kinetic energy (k) and its dissipation rate (epsilon), from which the eddy viscosity is derived.

This eddy viscosity was specified using grid and flow-dependent coefficients. The model's horizontal background eddy viscosity and diffusivity were set to 0.4m²/s, a value determined through model calibration and sensitivity analysis and in line with standard recommendations for hydrodynamic studies.

The vertical background eddy viscosity and diffusivity were set to $5x10^{-5}$m²/s, again, in line with standard recommendations for hydrodynamic studies. These values reflect the different scales of mixing and turbulence in horizontal and vertical directions, with horizontal coefficients typically being an order of magnitude larger than their vertical counterparts due to the larger scales of horizontal mixing in coastal and estuarine environments.

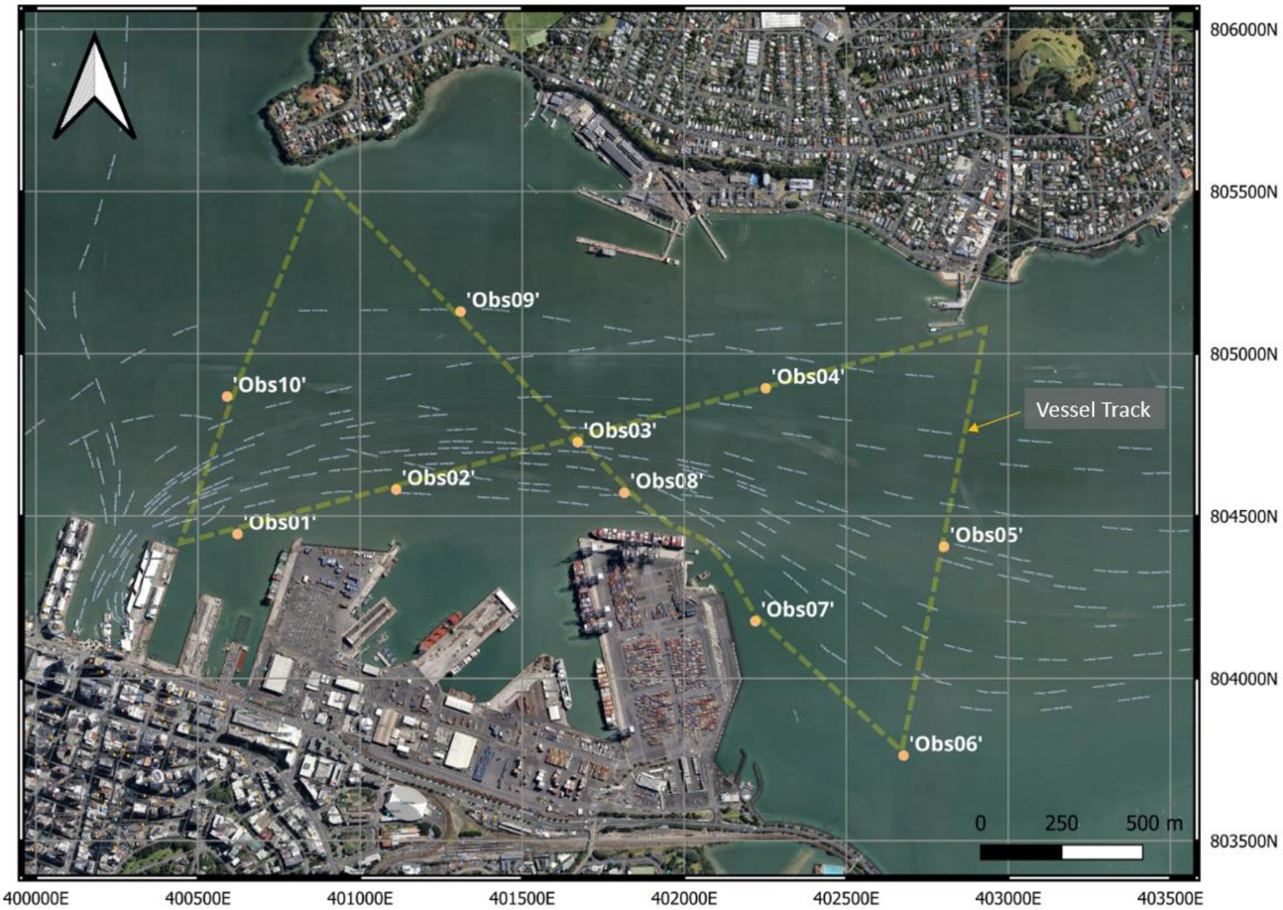


Figure 12: Observation locations within the D-Flow FM model

The model's peak velocity predictions at the observation points were compared with the measured data for a spring tide with a range of 3.27 m. The results are provided in Table 2, indicating a good agreement between the model and observed velocities, validating the model's accuracy in simulating tidal conditions.

Table 2: Measured and modelled peak spring tidal velocity comparisons

Observation Location	Measured (m/s)	Modelled (m/s)	Difference (m/s)
Obs1	0.36	0.31	0.05
Obs2	0.65	0.62	0.04
Obs3	0.82	0.76	0.06
Obs4	0.89	0.85	0.03
Obs5	0.73	0.78	-0.05
Obs6	0.34	0.32	0.02
Obs7	0.40	0.37	0.03
Obs8	0.79	0.78	0.00
Obs9	0.74	0.77	-0.03
Obs10	0.73	0.71	0.02

The typical current velocities and eddy formations during spring tides for ebb (Figure 13) and flood (Figure 14) tidal conditions are shown below.

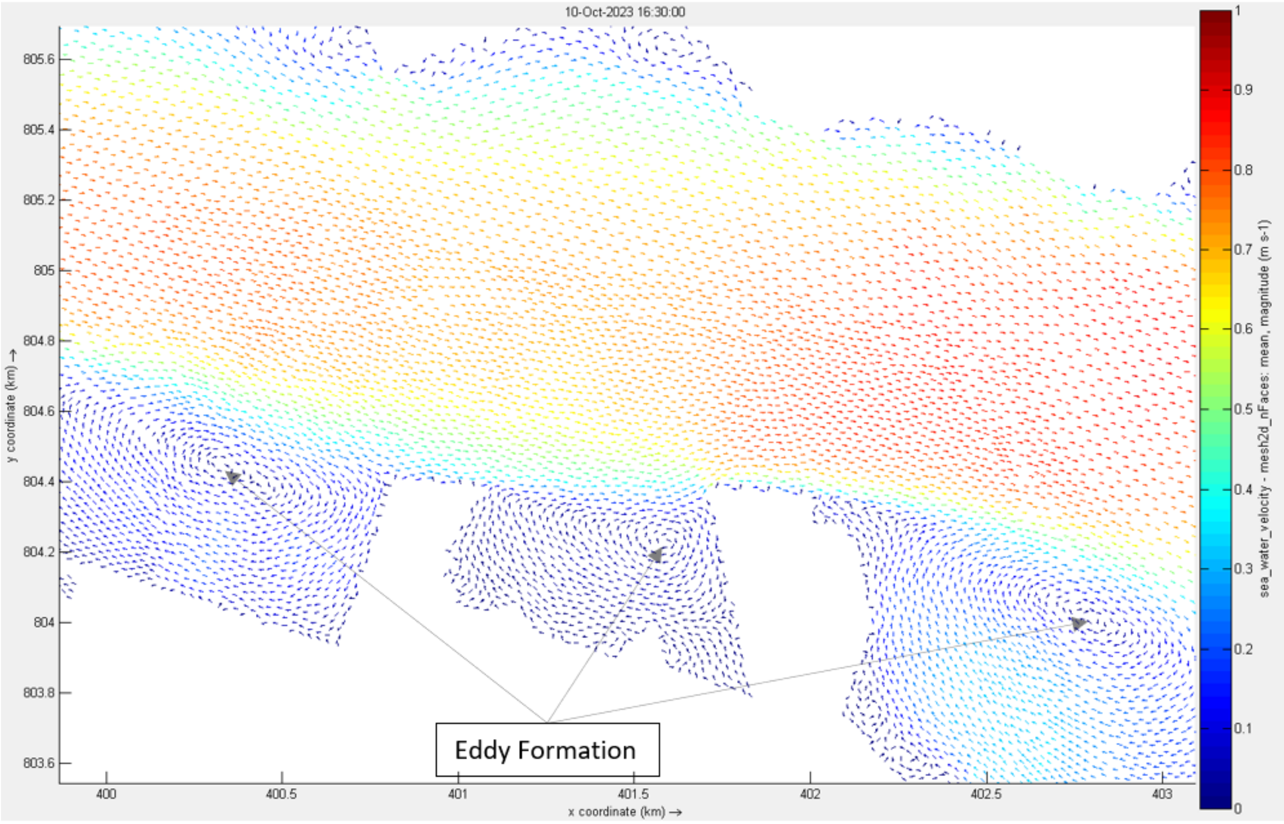


Figure 13: Typical ebb velocity vectors during 3m spring tide

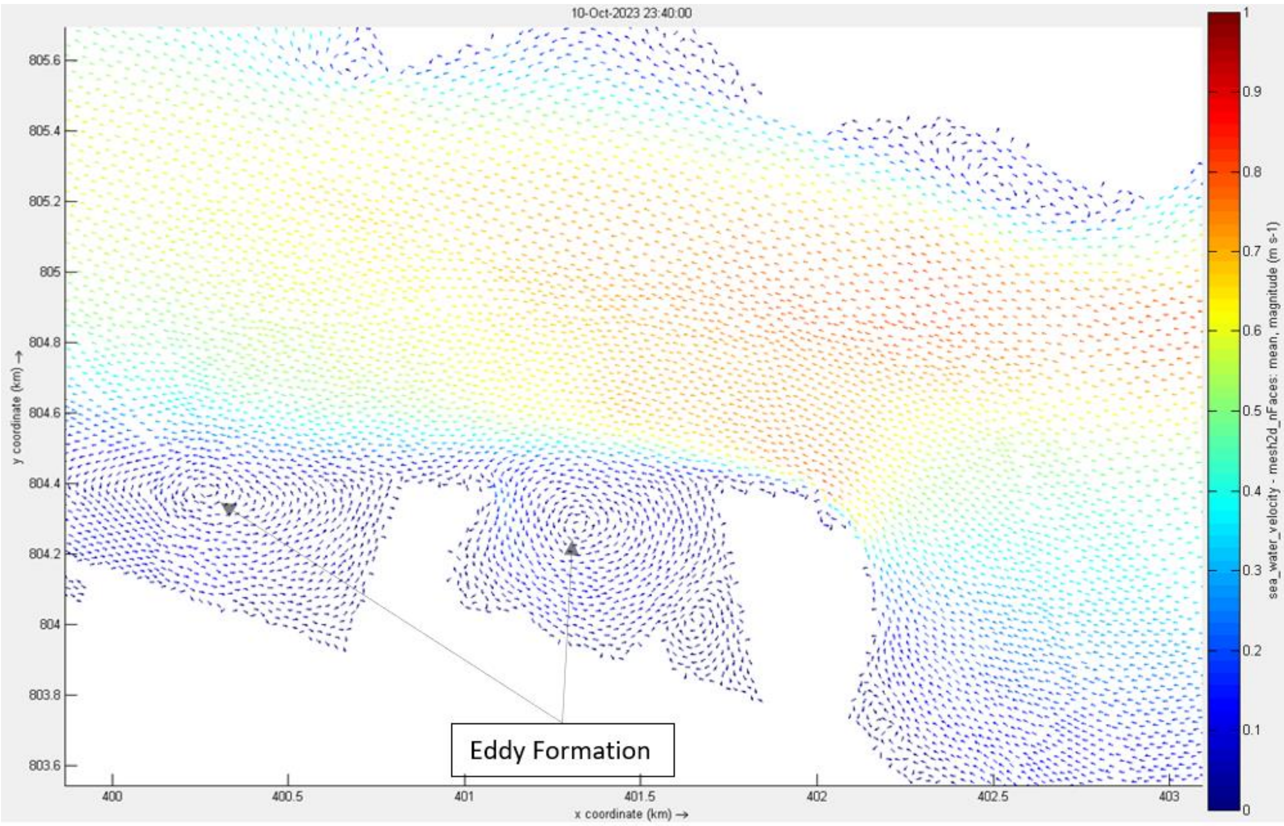


Figure 14: Typical flood velocity vectors during 3m spring tide

3.4 Model Run Scenarios

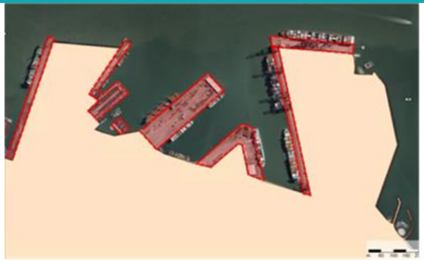
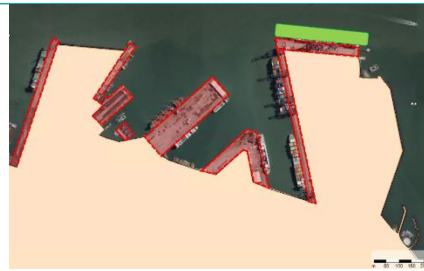
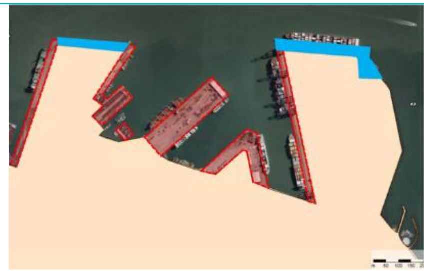
The validated hydrodynamic model was utilised to assess changes in tidal velocities across the various configurations described below.

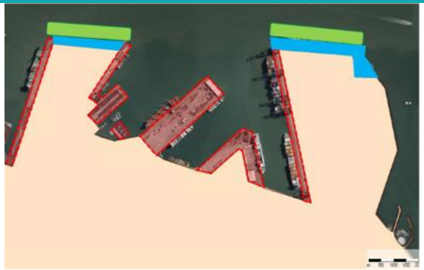
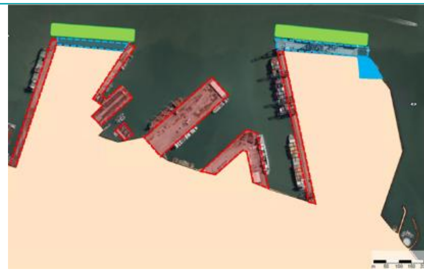
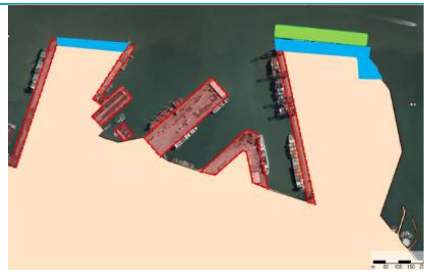
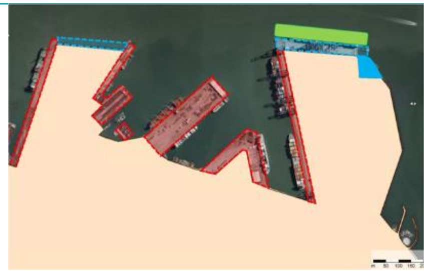
The effect of newly introduced structures within the harbour on tidal velocities and eddy formation was evaluated across various scenarios to quantify the impact of different potential configurations on local tidal conditions.

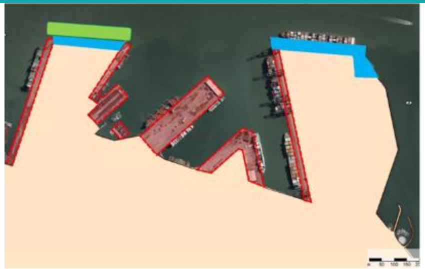
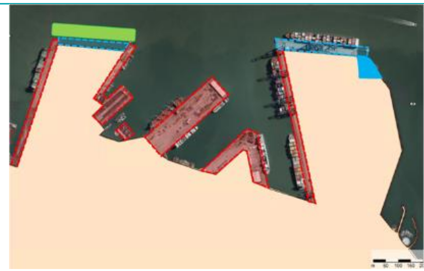
The proposed new BN wharf and FN Wharf extension were modelled in two ways: as piled structures (with roughness factors consistent with other piled structures within the harbour) and as land extensions (effectively treated as infilled areas in the model for the area occupied by the piled structure). In addition, the influence of vessels berthed alongside these proposed developments was included to evaluate the impact on tidal velocities.

It should be noted that future dredging depths for the FN berth pocket and any potential modifications to approach channels were not incorporated into this model. The vessels were modelled as extended land, which provides a conservative estimate of the impacts. This approach is expected to result in more pronounced effects on tidal velocities compared to scenarios where berths and channels are deepened.

Table 3: Model run cases and proposed layouts

Scenario	Tidal Condition	Model Geometry	Model Layout
Existing	• Neap (1.5 m range) Tide (Run 1) • Spring (3.0 m range) Tide (Run 2)	• All surrounding piled structures modelled as roughness • No ship berthing	
Existing (Base Case)	• Neap Tide (Run 3) • Spring Tide (Run 4)	• All surrounding piled structures modelled as roughness • With ship berthing at FN	
Proposed 1	• Neap Tide (Run 5) • Spring Tide (Run 6)	• No ship berthing • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 2	• Neap Tide (Run 7) • Spring Tide (Run 8)	• No ship berthing • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	

Scenario	Tidal Condition	Model Geometry	Model Layout
Proposed 3	• Neap Tide (Run 9) • Spring Tide (Run 10)	• With ship berthing • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 4	• Neap Tide (Run 11) • Spring Tide (Run 12)	• With ship berthing • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	
Proposed 5	• Neap Tide (Run 13) • Spring Tide (Run 14)	• With ship berthing at FN • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 6	• Neap Tide (Run 15) • Spring Tide (Run 16)	• With ship berthing at FN • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	

Scenario	Tidal Condition	Model Geometry	Model Layout
Proposed 7	• Neap Tide (Run 17) • Spring Tide (Run 18)	• With ship berthing at BN • Proposed new BN Wharf modelled as land • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as land	
Proposed 8	• Neap Tide (Run 19) • Spring Tide (Run 20)	• With ship berthing at BN • Proposed new BN Wharf modelled as roughness • Proposed corner extension at FN modelled as land (infill) • The existing piled structure at FN modelled as roughness	

3.5 Proposed Model Boundary Conditions

The modelling process utilises these tidal levels to predict changes in water movement within the harbour under various development scenarios. For the purposes of numerical modelling, a constant recurrence of a 1.5m mean neap tide and a 3.0m mean spring tide has been adopted to represent average tidal conditions. Tide levels at 5-minute intervals, referenced to CD, are presented in Figure 15 and Figure 16. It should be noted that these tidal variances are slightly different than the mean values presented in Table 1. The decision to use a larger tidal variance for spring tides was made to align with the tide measurement campaigns conducted by POAL as part of their monitoring efforts within the Waitematā Harbour.

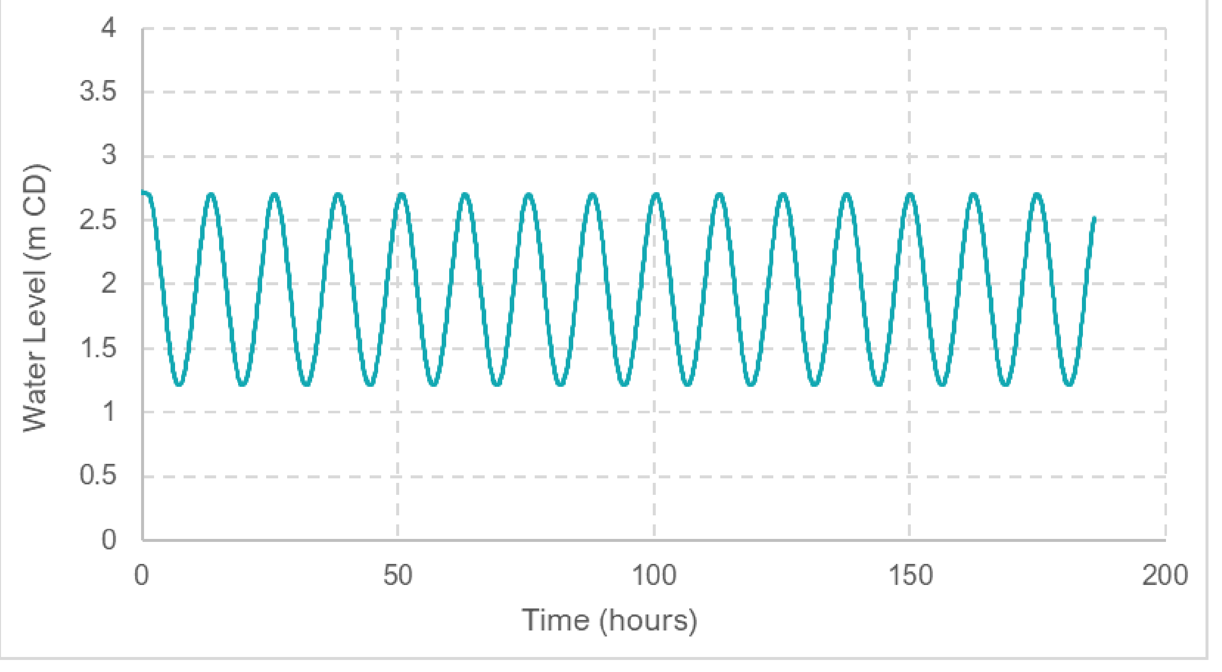


Figure 15: Time series of neap tides

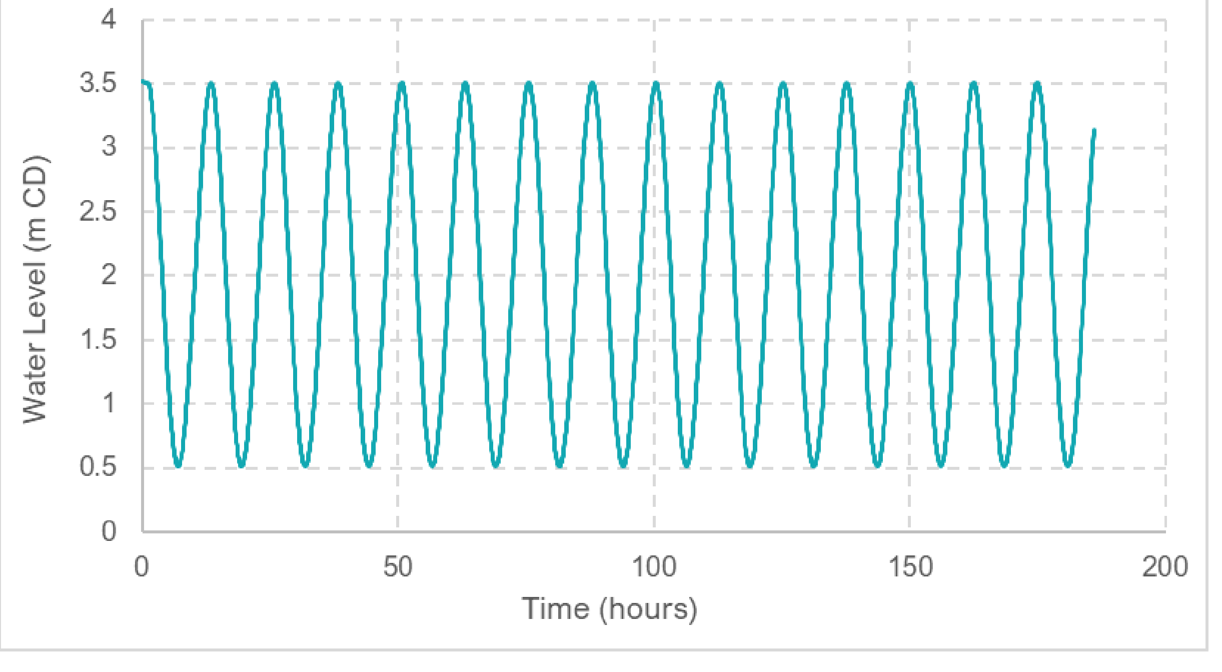


Figure 16: Time series of spring tides

3.6 Proposed Model Runs

A total of 20 different model runs were conducted, combining various proposed model configurations with neap and spring tide boundary conditions, as listed in Table 3. In addition, typical wind speeds of 10m/s (refer to Section 2.4) from various directions were incorporated in Runs 21 to 23 to assess their impact on current velocities. These specific runs were chosen to be representative of typical operational conditions in the harbour during moderate wind events. The effect of 0.5m relative sea-level rise over the next 50 years was also assessed in Runs 24 and 25. This relative sea-level rise accounts for both rising sea levels and vertical land movement, based on the Ministry for the Environment's (MfE) guidance for 50-year SSP5-8.5M projections (refer to the Design Criteria report (Beca, 2024)).

3.7 Changes in Tidal Velocities

3.7.1 Effect of Harbour Geometry

Table 4 summarises the observed changes in peak velocities from Run 1 to Run 20 at the designated observation locations illustrated in Figure 12. Note that the grey-shaded cells refer to the neap tide runs.

The results suggest the following:

- **Spring vs. Neap Tides:** As expected, the peak velocities within the harbour are generally larger during spring tides compared to neap tides. This is evident across all observation points and model scenarios, with velocities during spring tide conditions typically being almost twice as high as those during neap tides (e.g., comparing Run 1 with Run 2).
- **Effect of Modelling Developments as Extended Land:** Modelling the proposed wharf extensions as extended land results in slightly more conservative peak velocities compared to modelling them as roughness (e.g., comparing Run 6 to Run 8 shows a maximum increase of approximately 4%). This suggests that the "extended land" approach introduces a slight loss of tidal prism, causing a slight increase in localised current velocities.
- **Influence of Wharf Developments on Local Currents:** Comparing Run 2 (existing model, no ships) with Run 6 (proposed model, no ships) shows that the proposed developments to the new BN wharf and FN wharf cause a slight increase in localised currents within the vicinity of the wharves, with a maximum increase of approximately 5%. This indicates that the presence of the proposed developments has a minimal effect on the tidal velocities.
- **Effect of proposed end state against the original baseline:** Comparing Run 4 (base case: existing model, ship at FN) with Run 10 and Run 12 (ships berthed at both BN and FN) shows minimal changes in overall velocities. However, a localised decrease in velocity is observed west of the new BN berth (Observation 1), with a reduction of approximately 15% in Run 10 and 13% in Run 12. This is likely due to the blockage effect of the berthed ship at BN. These results suggest that while the addition of a ship at BN does not significantly impact the overall harbour hydraulics, localised effects, such as reduced flow near the BN berth, are expected due to the physical presence of a vessel.
- **Effect of Multiple Ships on Harbour Hydraulics:** Comparing Run 14 (ship berthed at FN) with Run 10 (ships berthed at both BN and FN) shows that having a ship berthed at BN while another ship is already berthed at FN has minimal influence on the overall current distribution across the harbour, with a maximum change of approximately 2%. However, localised effects, such as a reduction of approximately 14% in velocity at Observation Point 1 (Obs1), are likely due to the blockage effect of the berthed ship at BN.
- **Comparison of Ships at FN or BN:** When comparing Run 14 (ship berthed at FN) with Run 18 (ship berthed at BN), it is apparent that the velocities for the new BN wharf (with ship) are up to 9% lower in the channel compared to those for FN wharf (with ship), except at Observation point 2. This difference can be attributed to the geometry of the wharves, as the new BN wharf does not extend as far into the main harbour channel as the FN wharf, resulting in minimal influence on the overall current distribution.

3.7.2 Influence of Wind on Current Velocities

In addition to the 20 run cases, the effect of local winds on current velocities and patterns within Waitematā Harbour was analysed, as provided in Figure 5. A typical average wind speed of 10m/s (refer to Section 2.4) was applied from the West (Run 21), North (Run 22), and East (Run 23). Wind-induced effects were modelled to assess how different wind directions could impact the flow dynamics within the harbour.

For reference, these scenarios were modelled using the 'Proposed 1' geometry and compared to the spring tide scenario (Run 6).The results from the wind assessment suggest the following:

- **Effect of Westerly Winds (Run 21):** Comparing Run 21 (which includes westerly winds) to Run 6 (the spring tide scenario without wind) shows the impact of westerly winds on current velocities is minimal. Most observation points exhibit only minor variations in velocity, typically around ±0.02m/s. For example, Observation Points 2 and 8 display marginal increases in velocity, indicating that westerly winds may introduce minor localised effects, but do not significantly alter the overall flow patterns in the harbour.
- **Effect of Northerly Winds (Run 22):** Northerly winds show negligible changes, with current velocities remaining consistent across all observation points. The variations in velocity stay within ±0.01m/s, suggesting that typical northerly winds have minimal effect on the main harbour channel hydrodynamics, and tidal conditions continue to dominate.
- **Effect of Easterly Winds (Run 23):** Winds from the east have a similar, but opposite, effect compared to westerly winds. In particular, Observation Points 6 and 7 exhibit noticeable increases in velocity, with the current at Observation Point 7 rising from 0.34m/s in the base case (Run 6) to 0.40m/s in Run 23. These localised increases suggest that easterly winds align more directly with the tidal currents during flood tides in this area, leading to stronger wind-induced currents. However, the overall impact remains localised, and the general flow patterns are still consistent with those observed under spring tide conditions.
- **Comparison of Wind Effects:** Overall, the influence of local winds on current velocities within Waitematā Harbour is relatively minor. Northerly winds have minimal effects on the main channel hydraulics, while western and eastern winds result in some localised changes in velocity. The dominant tidal forces remain the primary driver of flow hydrodynamics, with wind effects only causing small adjustments to the baseline current patterns observed during spring tide conditions.

3.7.3 Influence of Sea Level Rise on Current Velocities

To assess the potential impacts of sea-level rise on current velocities, additional model scenarios were created for Runs 24 and 25. These scenarios simulate a 0.5m relative sea-level rise over the next 50 years under the SSP5-8.5M climate change scenario. Runs 24 and 25 correspond to Run 2 (existing conditions, no ships) and Run 6 (proposed wharf developments, no ships), respectively, but with the inclusion of the projected 0.5m sea-level rise.

A comparison between Run 24 (existing model with SLR, no ships) and Run 25 (proposed model with SLR, no ships) indicates that with future sea level rise the proposed developments to the new BN and FN wharves cause a slight increase in localised currents near the wharves, with a maximum increase of approximately 6%. This represents a 1% greater increase compared to the difference observed between Run 2 and Run 6.

Overall, the changes in current velocities due to a 0.5m relative sea-level rise are minimal, with localised effects similarly minor and no notable change in velocities near the proposed wharf developments.

3.7.4 Summary of Results

The relative changes in current velocities for all the above scenarios are generally less than the differences in measured velocities for similar tidal ranges, measured at different times (see the last figure in Appendix A1). This suggests that the proposed harbour developments and environmental factors such as sea-level rise are unlikely to introduce significant changes to the current flow distributions in the harbour.

Table 4: Model results

m/s	Obs_1	Obs_2	Obs_3	Obs_4	Obs_5	Obs_6	Obs_7	Obs_8	Obs_9	Obs_10	Comments
Run_1	0.17	0.34	0.37	0.39	0.33	0.20	0.26	0.40	0.35	0.30	Existing Model - No Ship- Neap
Run_2	0.29	0.63	0.74	0.85	0.82	0.34	0.35	0.79	0.72	0.75	Existing Model - No Ship- Spring
Run_3	0.17	0.33	0.42	0.42	0.38	0.22	0.26	0.43	0.39	0.33	Existing Model - With Ship at FN - Neap
Run_4	0.38	0.63	0.80	0.90	0.84	0.34	0.37	0.89	0.82	0.75	Existing Model - With Ship at FN - Spring
Run_5	0.17	0.34	0.39	0.40	0.36	0.21	0.26	0.41	0.37	0.31	Proposed Model - No Ship - Extended Land - Neap
Run_6	0.29	0.63	0.77	0.87	0.83	0.34	0.34	0.83	0.76	0.75	Proposed Model - No ship - Extended Land - Spring
Run_7	0.17	0.34	0.37	0.39	0.34	0.20	0.26	0.40	0.36	0.30	Proposed Model - No Ship - Roughness - Neap
Run_8	0.29	0.63	0.75	0.84	0.81	0.33	0.35	0.80	0.73	0.75	Proposed Model - No Ship - Roughness - Spring
Run_9	0.17	0.35	0.43	0.42	0.38	0.22	0.26	0.42	0.40	0.34	Proposed Model - With ship - Extended Land - Neap
Run_10	0.32	0.64	0.81	0.91	0.85	0.35	0.35	0.87	0.82	0.75	Proposed Model - With ship - Extended Land - Spring
Run_11	0.17	0.35	0.43	0.42	0.38	0.22	0.26	0.42	0.39	0.34	Proposed Model - With Ship - Roughness - Neap
Run_12	0.33	0.64	0.80	0.90	0.85	0.34	0.35	0.86	0.82	0.75	Proposed Model - With Ship - Roughness - Spring
Run_13	0.17	0.34	0.43	0.42	0.38	0.22	0.26	0.43	0.39	0.33	Proposed Model - With ship at FN - Extended Land - Neap
Run_14	0.37	0.63	0.81	0.91	0.85	0.36	0.35	0.88	0.83	0.75	Proposed Model - With ship at FN - Extended Land - Spring
Run_15	0.17	0.33	0.42	0.42	0.38	0.22	0.26	0.43	0.39	0.33	Proposed Model - With Ship at FN- Roughness - Neap
Run_16	0.38	0.64	0.80	0.90	0.84	0.34	0.35	0.88	0.82	0.75	Proposed Model - With Ship at FN- Roughness - Spring
Run_17	0.17	0.35	0.39	0.40	0.35	0.21	0.26	0.41	0.37	0.32	Proposed Model - With ship at BN - Extended Land - Neap
Run_18	0.27	0.65	0.78	0.87	0.83	0.34	0.34	0.83	0.75	0.75	Proposed Model - With ship at BN - Extended Land - Spring
Run_19	0.17	0.36	0.37	0.39	0.33	0.20	0.26	0.39	0.36	0.31	Proposed Model - With Ship at BN - Roughness - Neap
Run_20	0.27	0.65	0.76	0.84	0.81	0.33	0.35	0.79	0.73	0.75	Proposed Model - With Ship at BN - Roughness - Spring

Table 5: Influence of wind on modelled results

m/s	Obs_1	Obs_2	Obs_3	Obs_4	Obs_5	Obs_6	Obs_7	Obs_8	Obs_9	Obs_10	Comments
Run_6	0.29	0.63	0.77	0.87	0.83	0.34	0.34	0.83	0.76	0.75	Proposed Model - No ship - Extended Land - Spring
Run_21	0.30	0.65	0.77	0.85	0.83	0.32	0.30	0.85	0.76	0.75	Proposed Model - Wind W - No ship - Extended Land - Spring
Run_22	0.29	0.63	0.77	0.86	0.83	0.33	0.34	0.83	0.77	0.75	Proposed Model - Wind N - No ship - Extended Land - Spring
Run_23	0.31	0.61	0.77	0.88	0.84	0.36	0.40	0.82	0.76	0.77	Proposed Model - Wind E - No ship - Extended Land - Spring

Table 6: Influence of sea level rise on modelled results

m/s	Obs_1	Obs_2	Obs_3	Obs_4	Obs_5	Obs_6	Obs_7	Obs_8	Obs_9	Obs_10	Comments
Run_24	0.30	0.63	0.75	0.85	0.84	0.33	0.39	0.80	0.75	0.77	Existing Model - SLR - No Ship- Spring
Run_25	0.31	0.63	0.78	0.87	0.84	0.33	0.39	0.84	0.79	0.77	Proposed Model - SLR - No ship - Extended Land - Spring

It is important to note that while the general trend of velocity changes across different observation points remains consistent for various runs, some positive and negative differences in velocity changes can be observed when comparing different tidal ranges. For example, certain runs indicate slightly higher velocities during lower tidal ranges. These fluctuations can be attributed to several factors, primarily variations in tidal range and the precise location of eddy formation. The current data extraction is based on the observation points, where values are assigned to each point. A minor shift in the eddy location can lead to slight discrepancies in the velocity readings. However, as previously mentioned, these discrepancies are very minor and are typically observed only in the second decimal place.

3.8 Changes in Water Level

The effect of the proposed developments on water levels within the harbour was assessed by comparing the modelled maximum and minimum water levels at various observation points. Table 7 summarises the modelled water levels observed for Run 2 and Run 6 (refer to Table 3). These runs were selected to compare the existing conditions with the worst-case scenario proposed conditions, where the extensions are conservatively modelled as a solid land boundary occupying the coastal area, rather than as a piled structure. The spring tide was chosen due to its representation of the highest and lowest water levels, providing a more comprehensive comparison than neap tide conditions.

Table 7: Influence of proposed developments on water level

Description	Obs_1	Obs_2	Obs_3	Obs_4	Obs_5	Obs_6	Obs_7	Obs_8	Obs_9	Obs_10
Run 2: Max	3.56	3.55	3.54	3.53	3.53	3.53	3.53	3.54	3.55	3.56
Run 2: Min	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.50	0.50	0.49
Run 6: Max	3.56	3.55	3.54	3.53	3.53	3.53	3.53	3.54	3.55	3.56
Run 6: Min	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.50	0.50	0.49

The results show that the proposed developments have a negligible effect on water levels within the harbour. The maximum and minimum water levels remain unchanged across all observation points. This is likely due to the relatively small area occupied by the proposed structures within the larger context of the Waitematā Harbour, which is an open water body. The open nature of the harbour allows for effective tidal exchange, meaning that the minor reduction in water area caused by the new developments does not impact overall water levels.

4 Conclusion

The hydrodynamic assessment of Waitematā Harbour was conducted using D-Flow FM numerical simulations. Current velocities at various observation points around BN and FN Wharves were analysed for existing conditions and proposed scenarios, including multiple potential extension designs and ship berthing configurations. It is noted that this assessment is based on comparing current velocities with no subsequent change in the existing bathymetry, which is conservative.

The hydrodynamic modelling of Waitematā Harbour highlights the following key findings:

- Tidal Influence
  - Spring tides produce significantly higher peak velocities compared to neap tides.
  - Tidal forces remain the dominant driver of hydrodynamic conditions in the harbour.
- Wharf Developments:
  - The proposed wharf (piled structures) developments modelled as land extensions result in slightly higher peak velocities compared to the wharf (piled structures) modelled as an additional increase in the roughness.
  - Localised current velocities near the wharves increase slightly by up to 5%, but overall harbour hydrodynamics remain largely unchanged.
- Impact of Different Ship Berthing Configurations:
  - The presence of multiple berthed ships at both BN and FN wharves causes minimal changes to the overall current distribution when compared to having a ship berthed at only FN.
  - The FN wharf has a more noticeable impact on current patterns due to its location in the main harbour channel.
- Wind Effects:
  - Northerly winds have minimal influence on current velocities.
  - Westerly and easterly winds cause slight increases in localised velocities, though wind effects are generally minor compared to tidal forces.
- Sea Level Rise Effect:
  - The impact of a 0.5m relative sea-level rise on the proposed developments is minimal compared to the existing harbour geometry.

In conclusion, the proposed wharf developments and local wind conditions will slightly alter the existing hydrodynamic conditions within Waitematā Harbour, with tidal forces continuing to dominate the overall flow patterns. It is therefore concluded that the effect of the proposed development on the tidal currents is less than minor.

5 References

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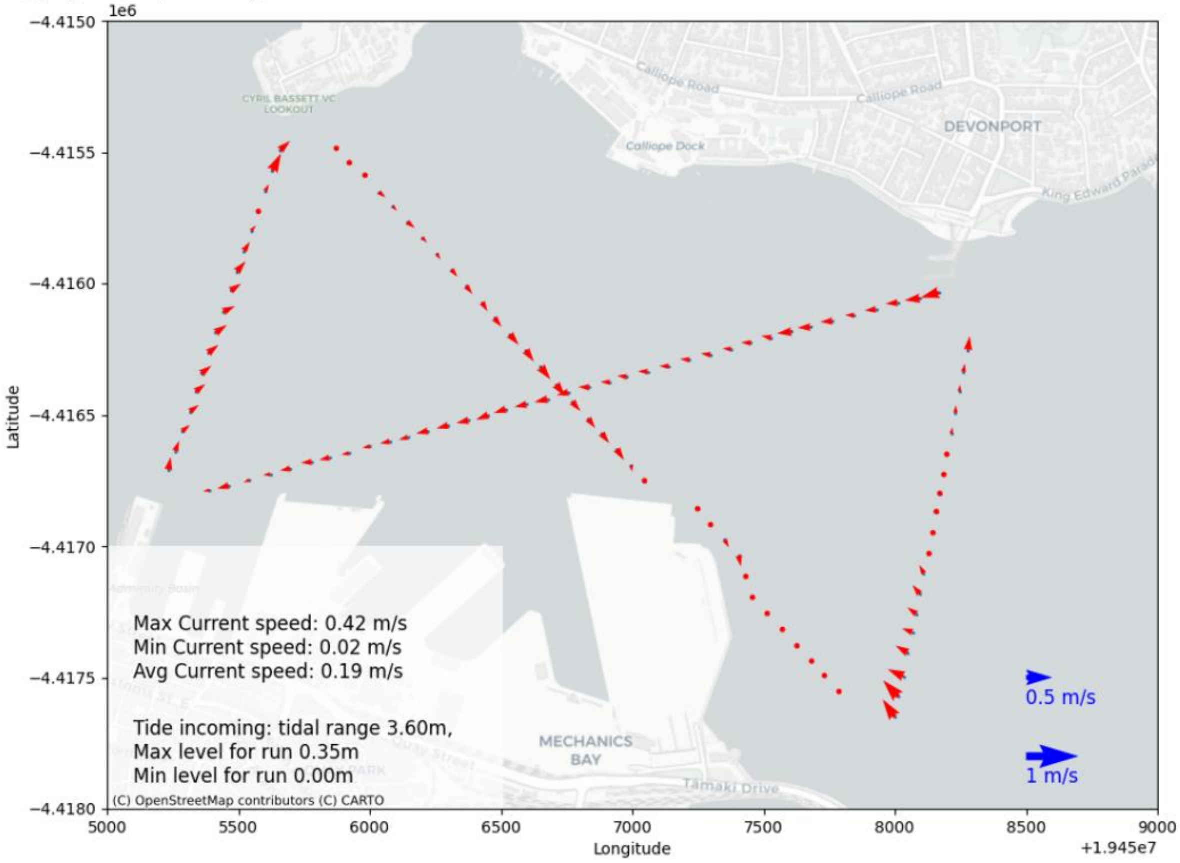
- Delft3D FM Flow (2024). Delft3D FM Flow user manual. Deltares. Available at: https://content.oss.deltares.nl/delft3dfm2d3d/D-Flow_FM_User_Manual.pdf.
- Vennel, R., 2006. Fergusson Terminal Extension Acoustic Doppler Current Profiler Tidal Current Measurement Surveys 1995 to November 2005. Prepared for Port of Auckland Ltd. Auckland: Ocean Currents Ltd.

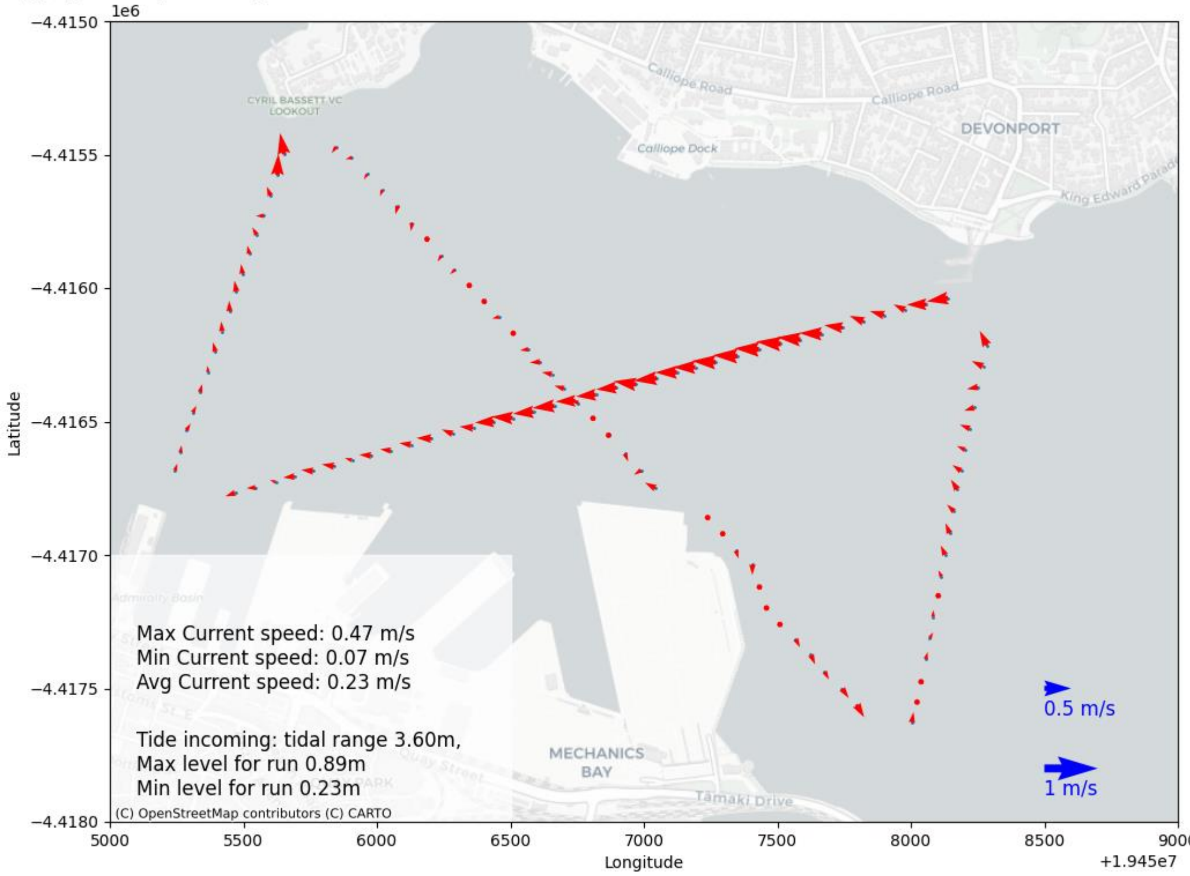
A1

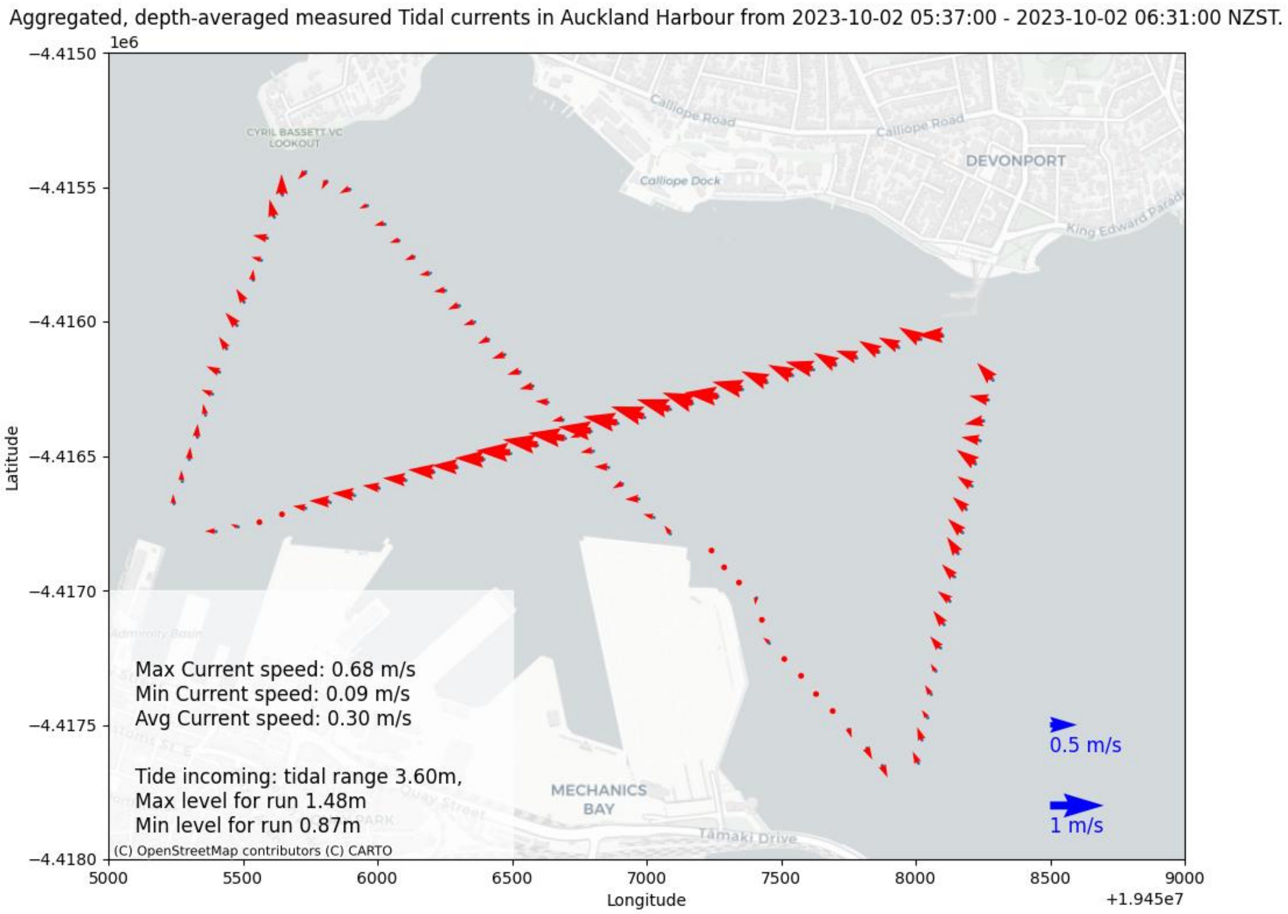
Appendix A1 – Measured Current Velocities

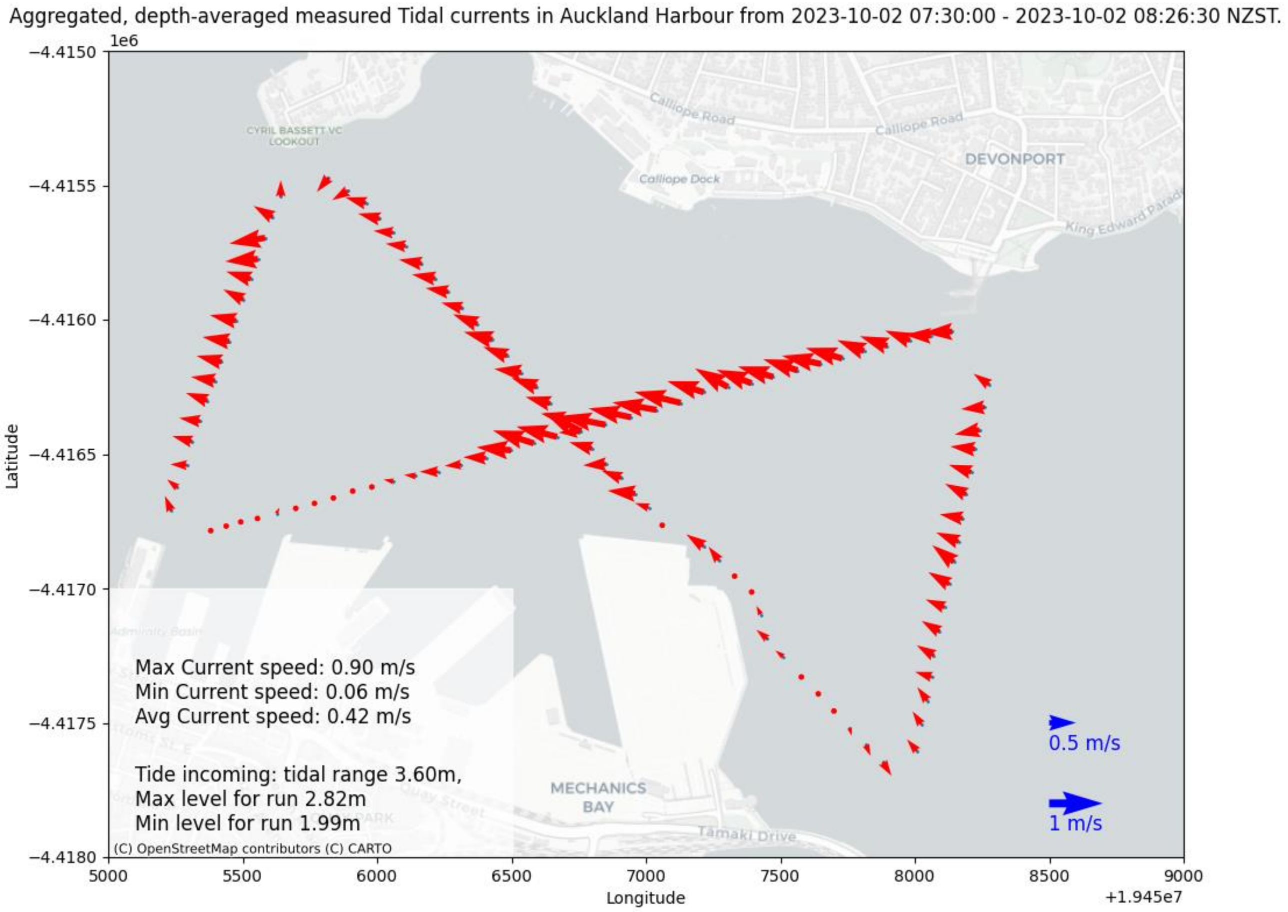
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 03:34:00 - 2023-10-02 04:33:30 NZST.



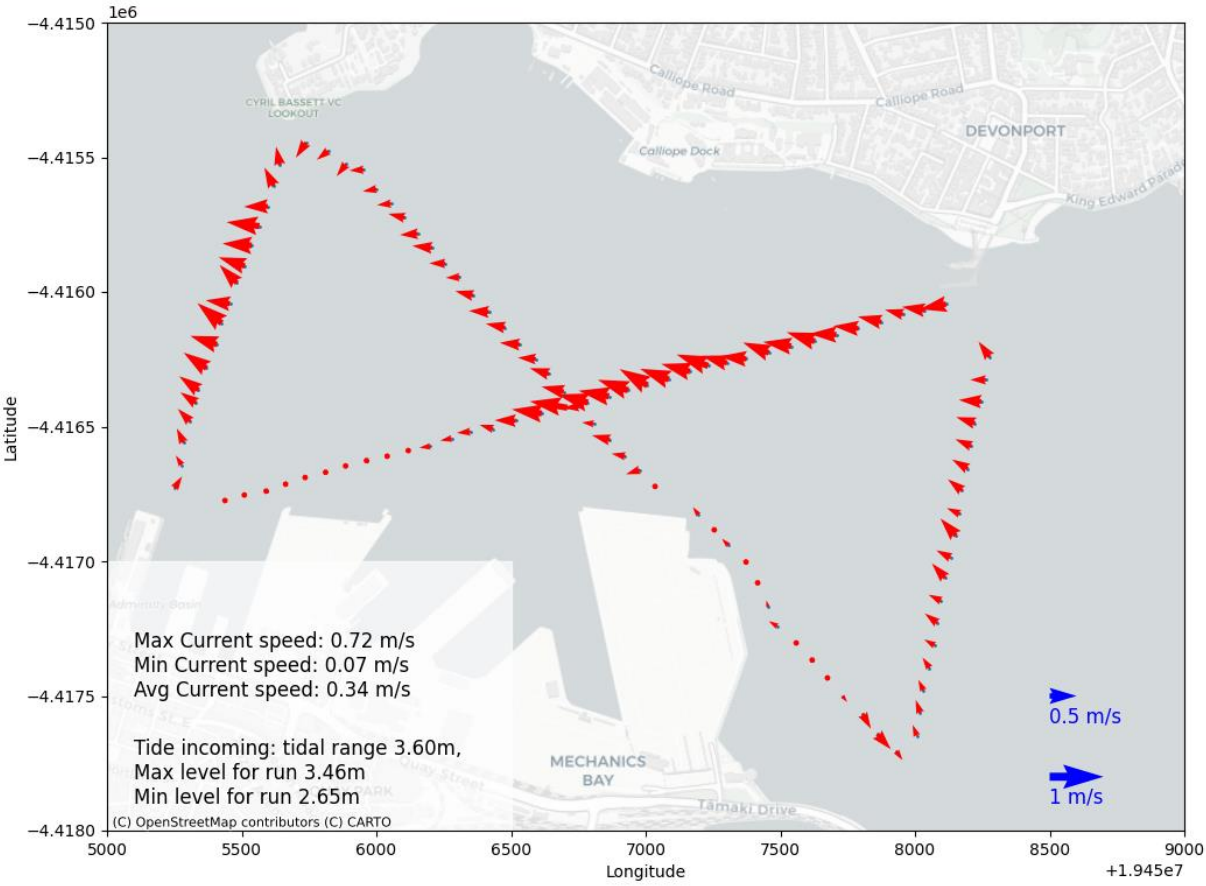
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 04:35:30 - 2023-10-02 05:34:30 NZST.



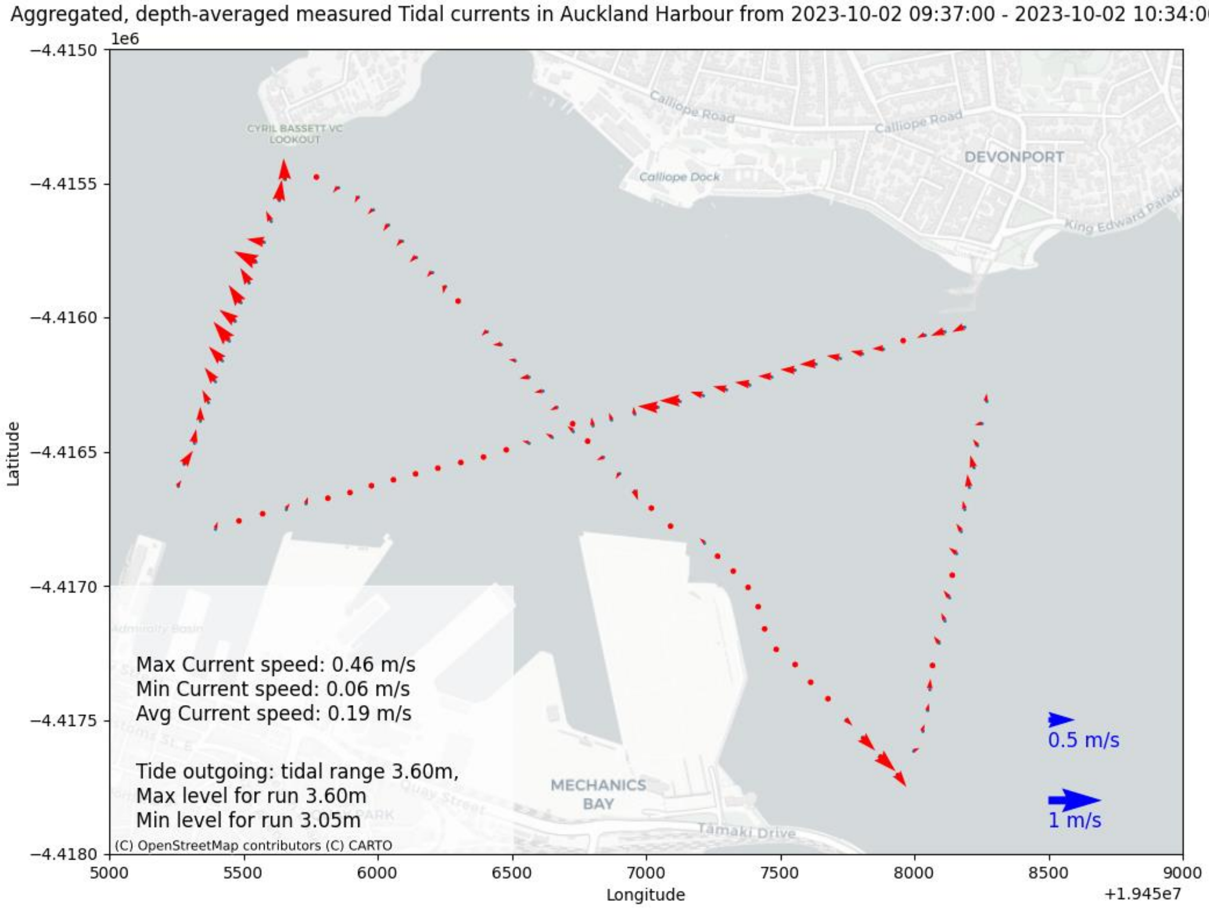

Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 05:37:00 - 2023-10-02 06:31:00 NZST.
Max Current speed: 0.68 m/s
Min Current speed: 0.09 m/s
Avg Current speed: 0.30 m/s
Tide incoming: tidal range 3.60m,
Max level for run 1.48m
Min level for run 0.87m
0.5 m/s
1 m/s
Latitude
Longitude
(C) OpenStreetMap contributors (C) CARTO


Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 07:30:00 - 2023-10-02 08:26:30 NZST.
Max Current speed: 0.90 m/s
Min Current speed: 0.06 m/s
Avg Current speed: 0.42 m/s
Tide incoming: tidal range 3.60m,
Max level for run 2.82m
Min level for run 1.99m
0.5 m/s
1 m/s
Latitude
Longitude
(C) OpenStreetMap contributors (C) CARTO

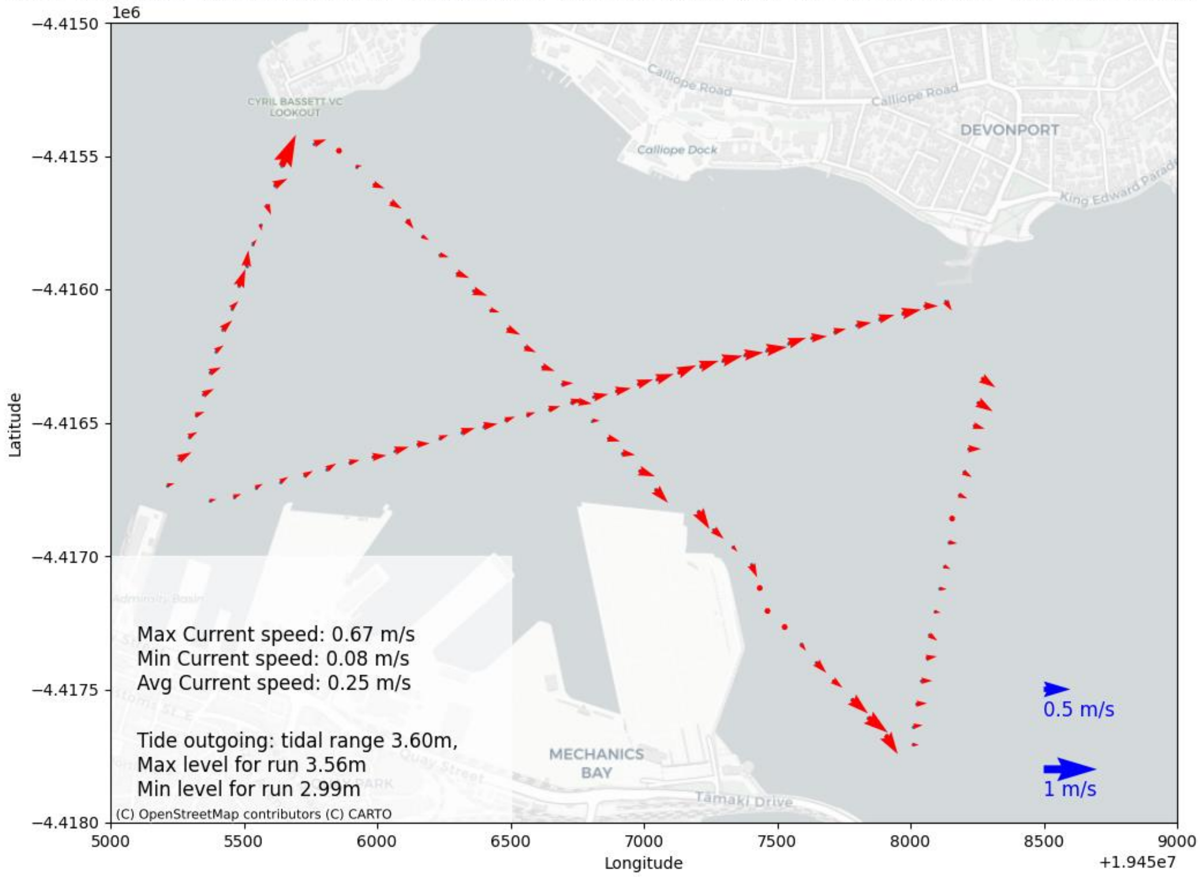
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 08:28:30 - 2023-10-02 09:25:30 NZST.



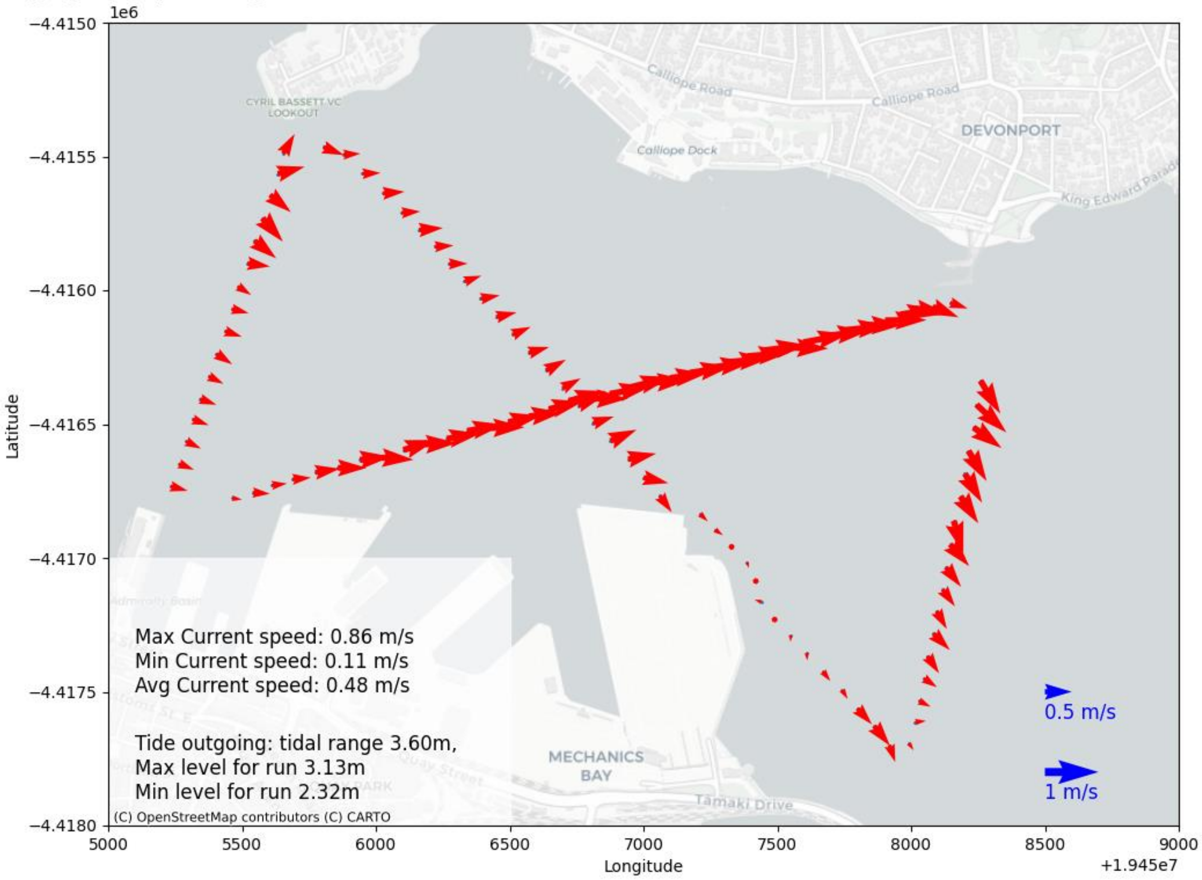
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 09:37:00 - 2023-10-02 10:34:00 NZST.



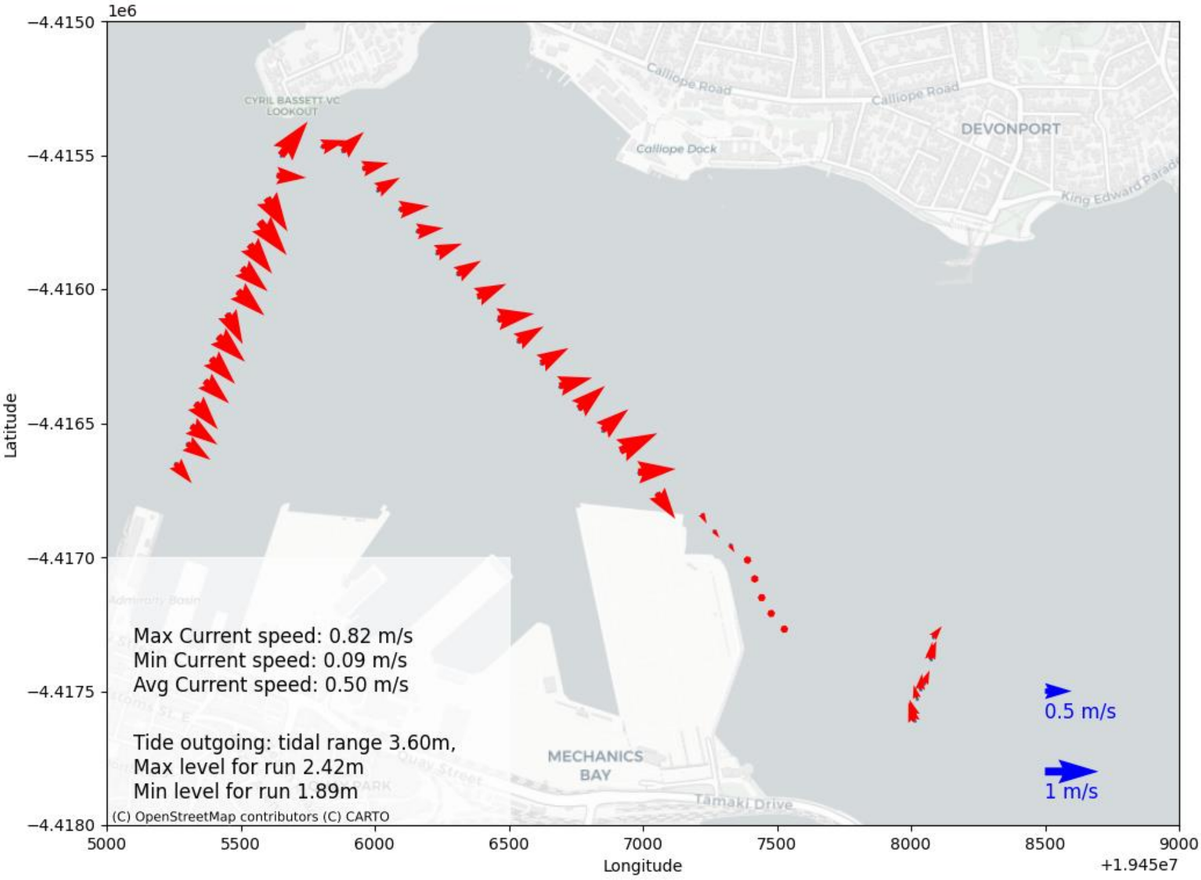
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 10:35:30 - 2023-10-02 11:29:30 NZST.



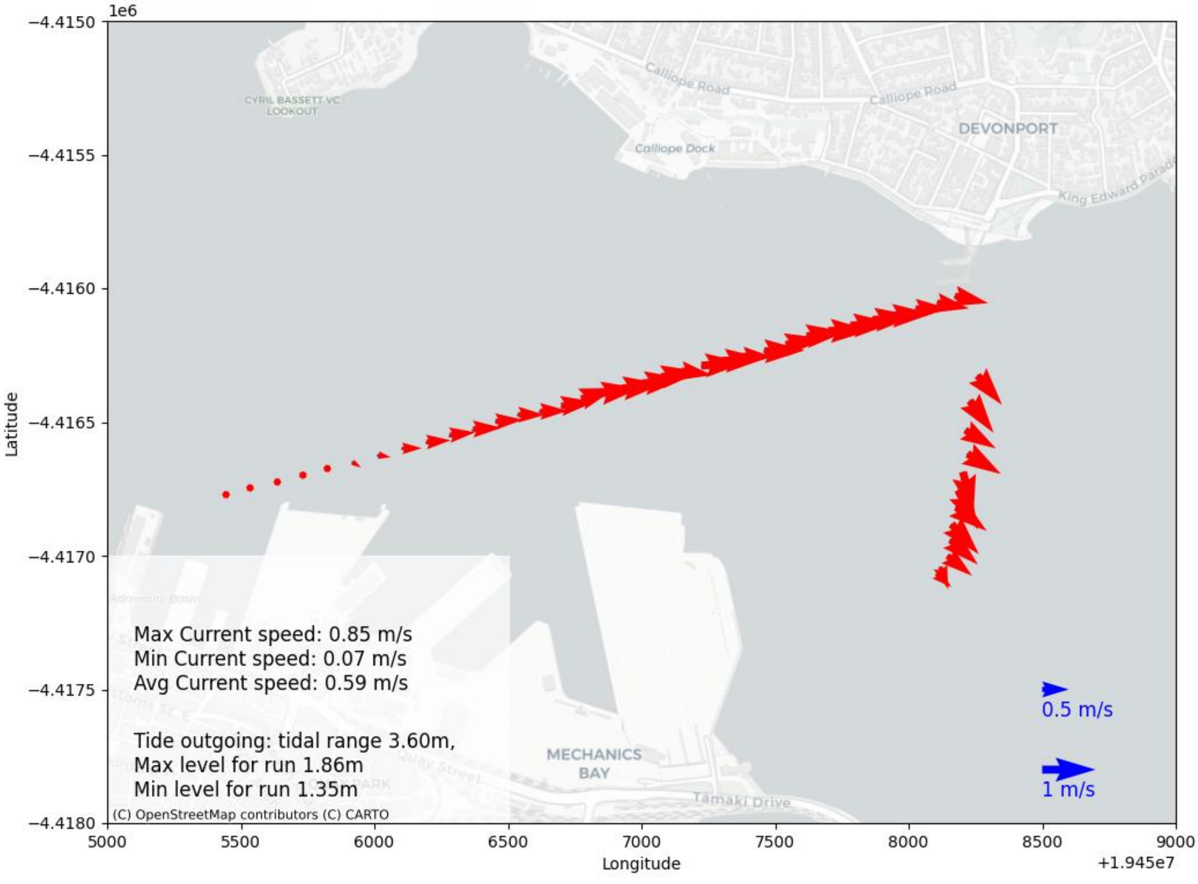
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 11:31:00 - 2023-10-02 12:27:00 NZST.



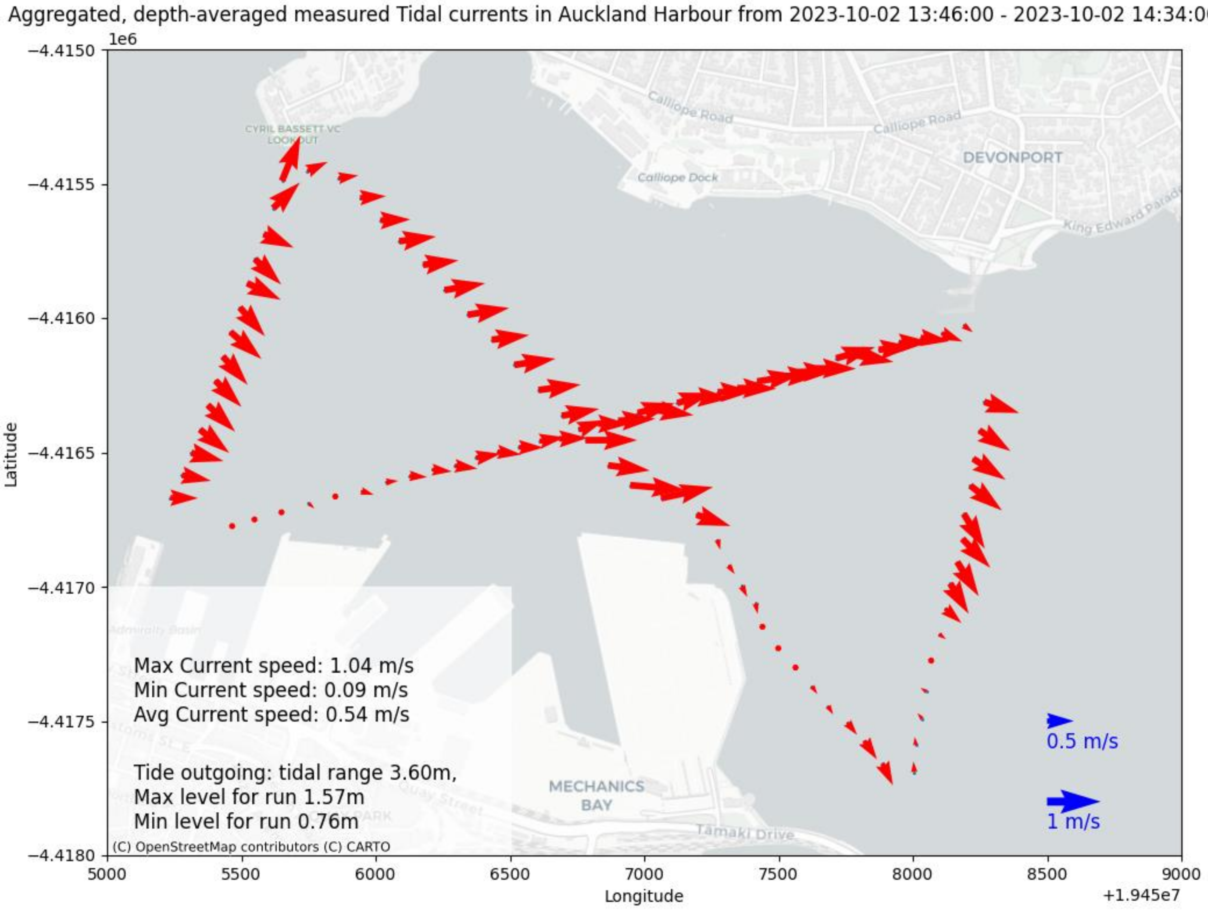
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 12:29:30 - 2023-10-02 12:59:30 NZST.



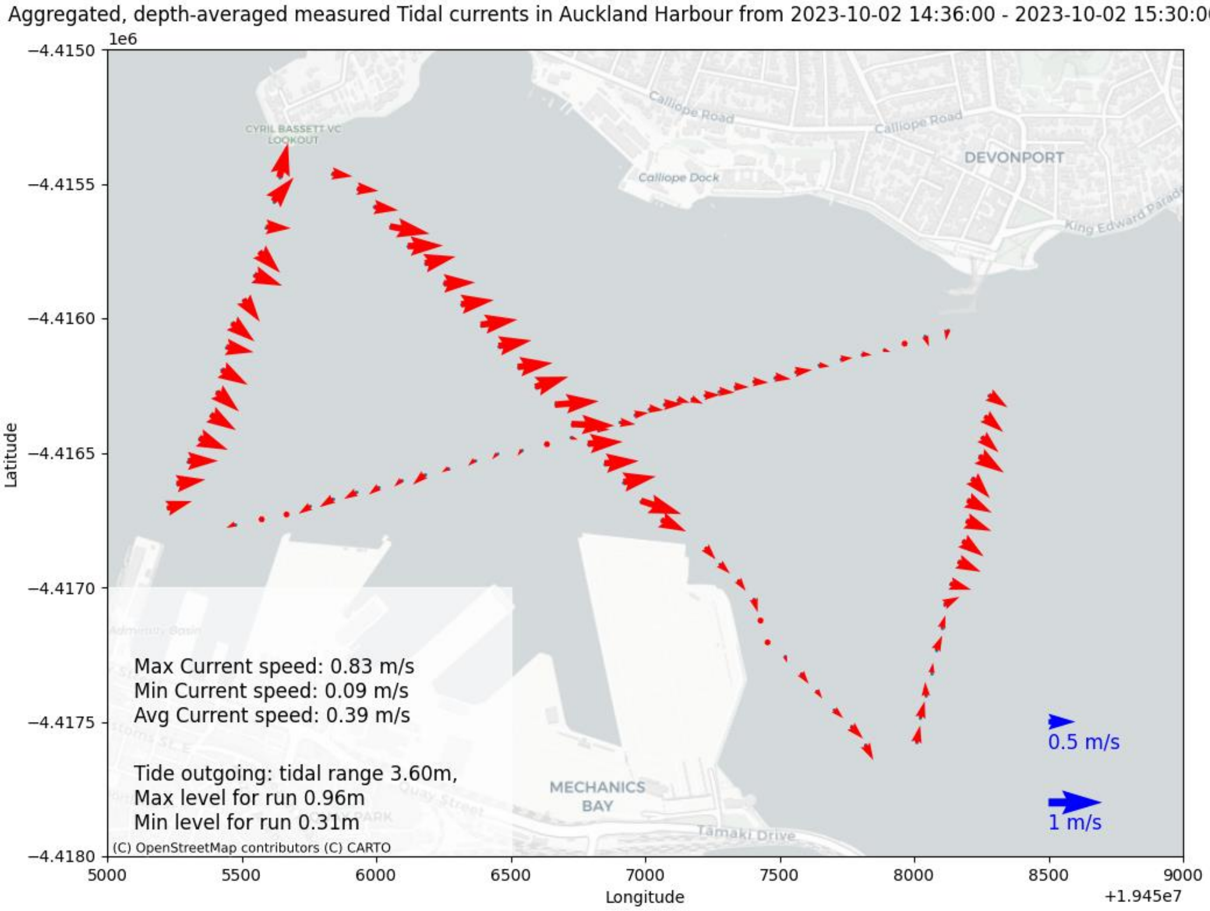
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 13:19:30 - 2023-10-02 13:44:00 NZST.

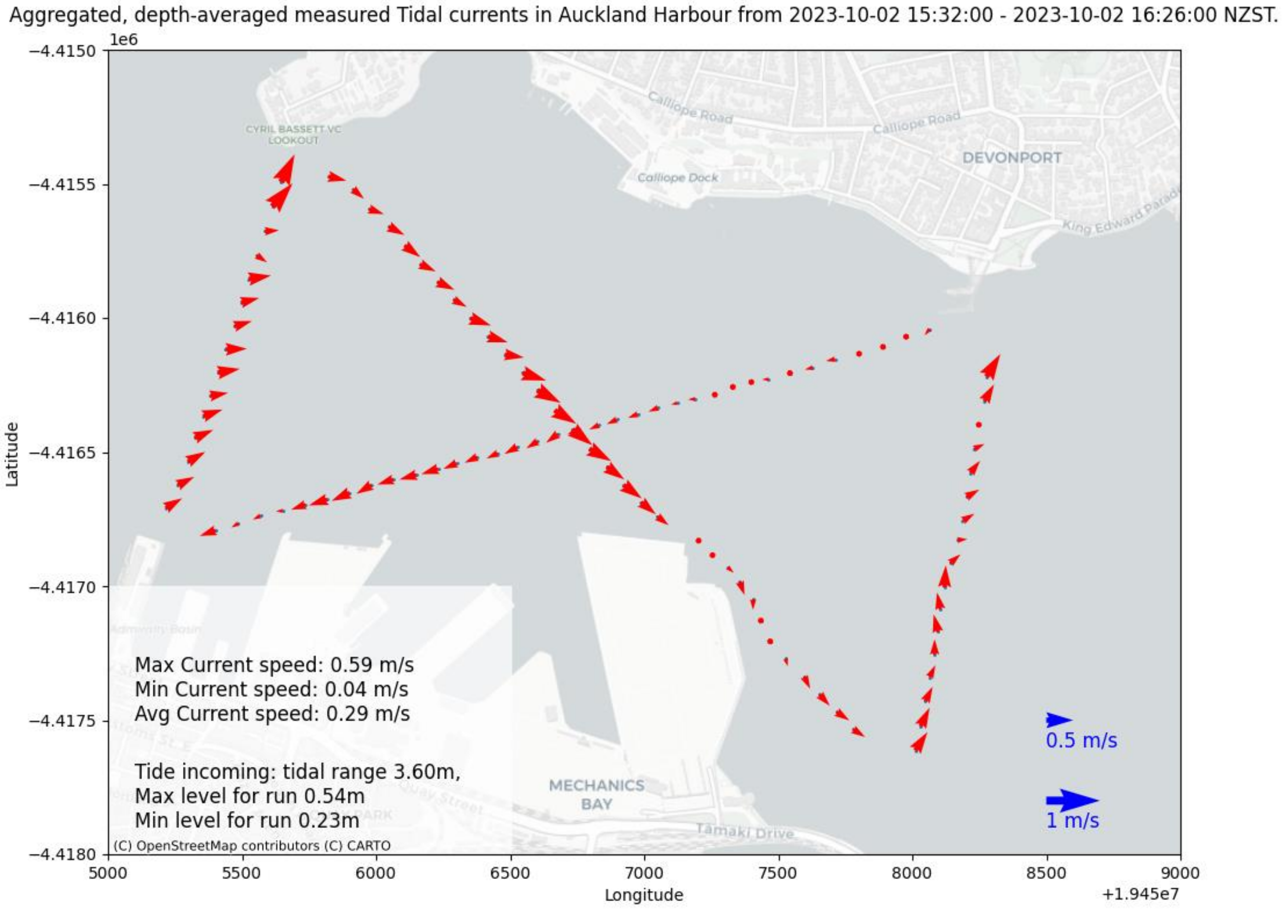


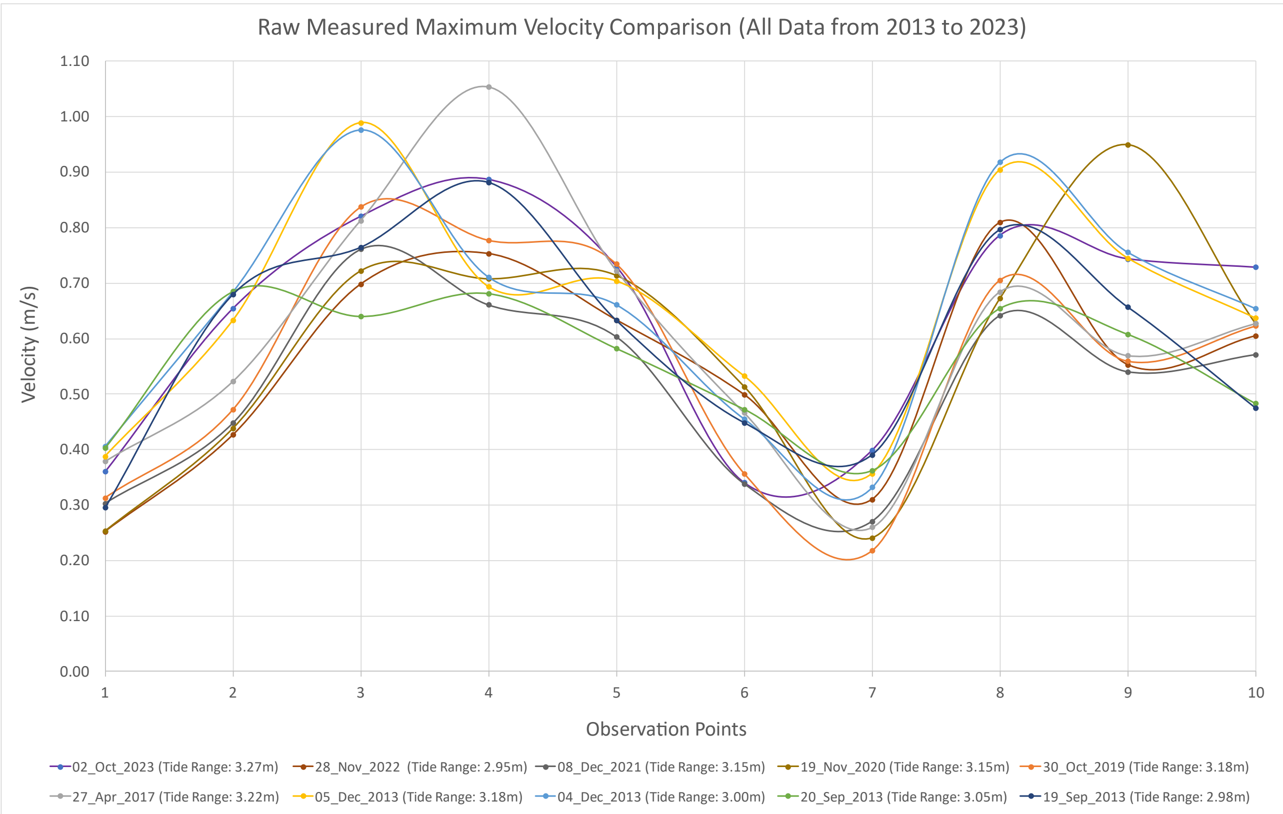
Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 13:46:00 - 2023-10-02 14:34:00 NZST.



Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 14:36:00 - 2023-10-02 15:30:00 NZST.

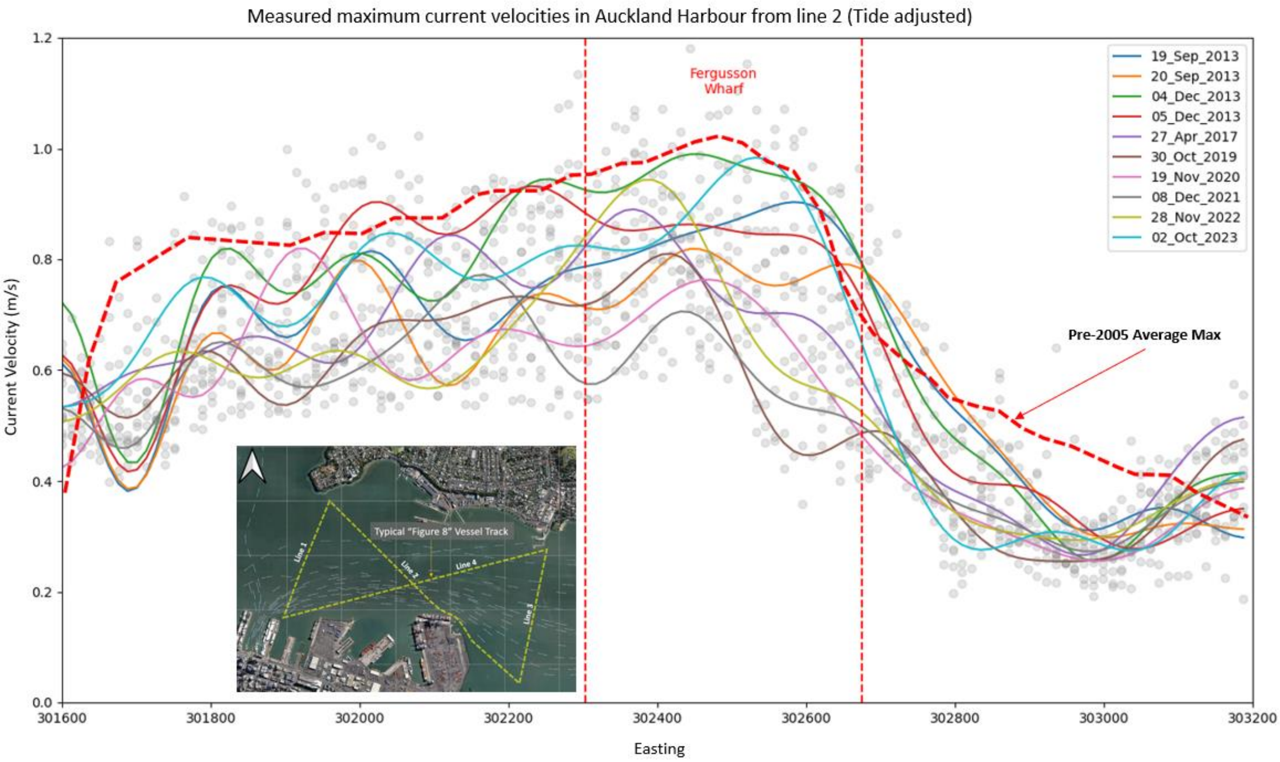



Aggregated, depth-averaged measured Tidal currents in Auckland Harbour from 2023-10-02 15:32:00 - 2023-10-02 16:26:00 NZST.
Latitude
Longitude
1e6
+1.945e7
DEVONPORT
MECHANICS BAY
Max Current speed: 0.59 m/s
Min Current speed: 0.04 m/s
Avg Current speed: 0.29 m/s
Tide incoming: tidal range 3.60m,
Max level for run 0.54m
Min level for run 0.23m
0.5 m/s
1 m/s
(C) OpenStreetMap contributors (C) CARTO

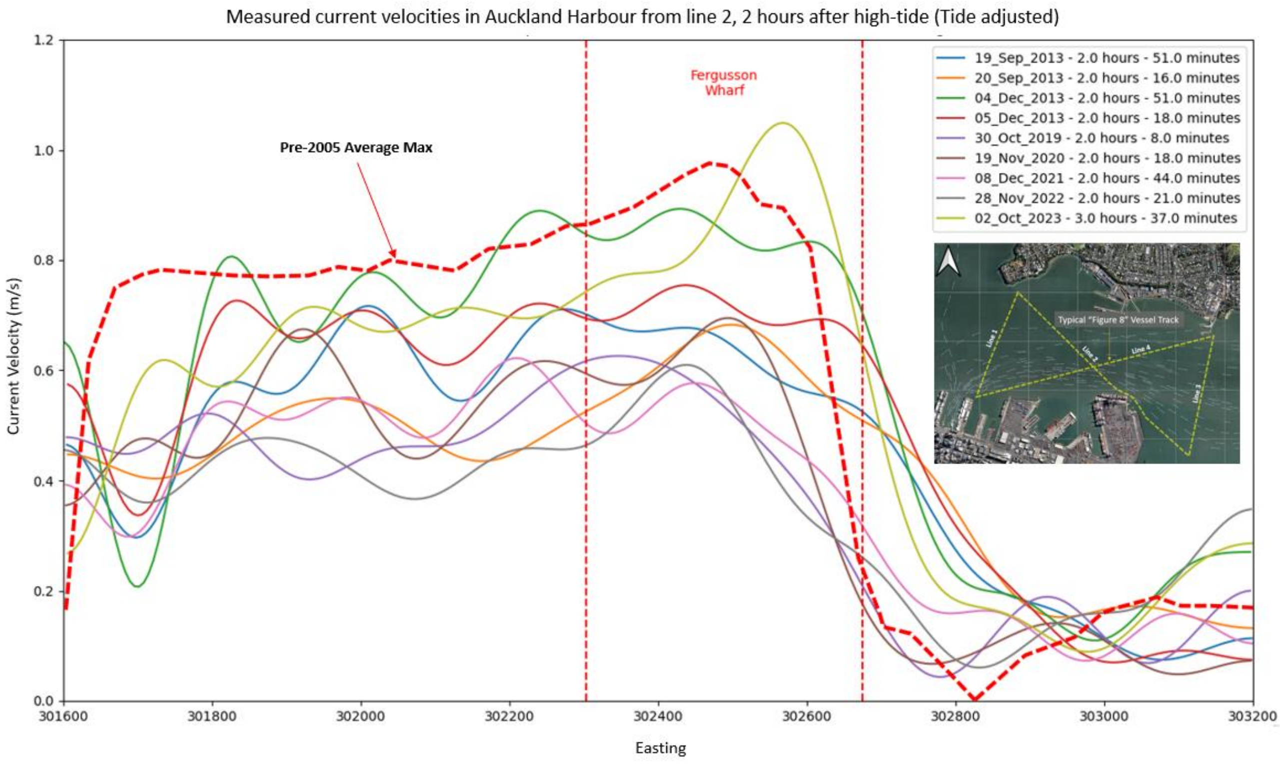

Raw Measured Maximum Velocity Comparison (All Data from 2013 to 2023)
Velocity (m/s)
Observation Points
02_Oct_2023 (Tide Range: 3.27m)
28_Nov_2022 (Tide Range: 2.95m)
08_Dec_2021 (Tide Range: 3.15m)
19_Nov_2020 (Tide Range: 3.15m)
30_Oct_2019 (Tide Range: 3.18m)
27_Apr_2017 (Tide Range: 3.22m)
05_Dec_2013 (Tide Range: 3.18m)
04_Dec_2013 (Tide Range: 3.00m)
20_Sep_2013 (Tide Range: 3.05m)
19_Sep_2013 (Tide Range: 2.98m)

B

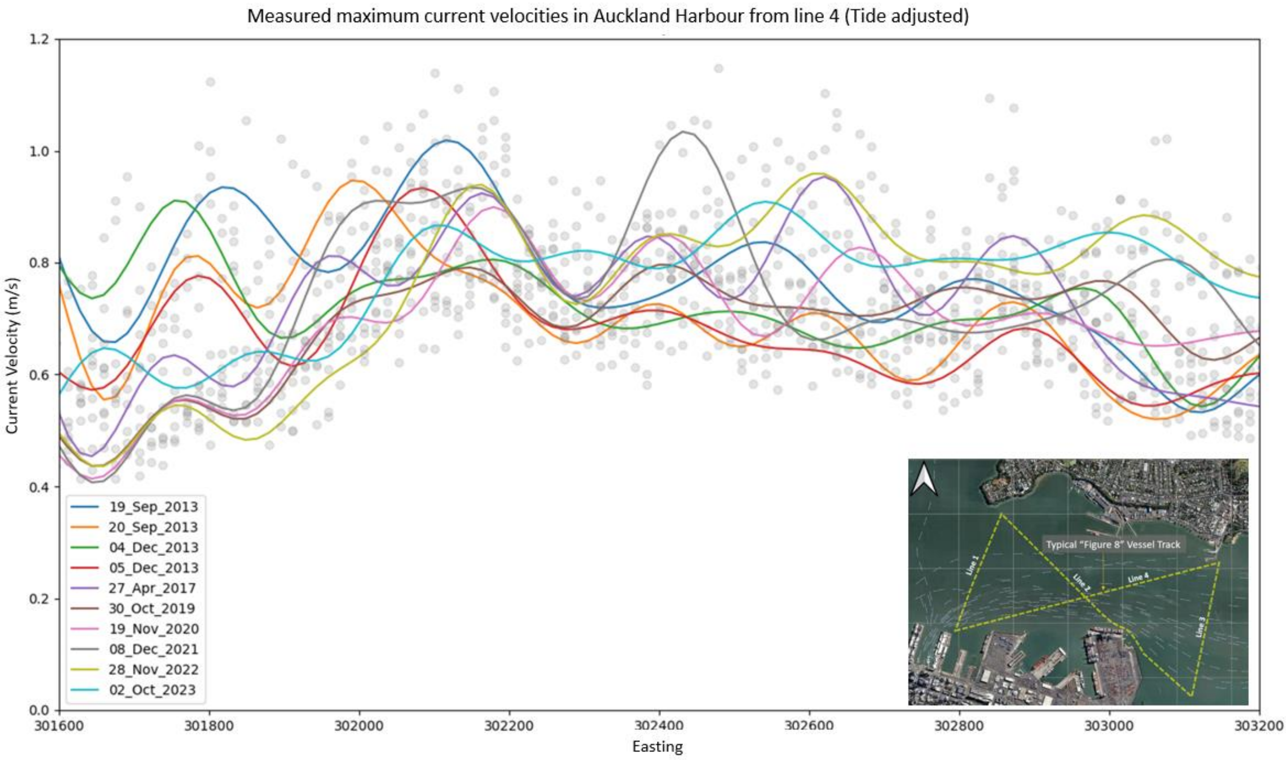
Appendix B – Field Measurements

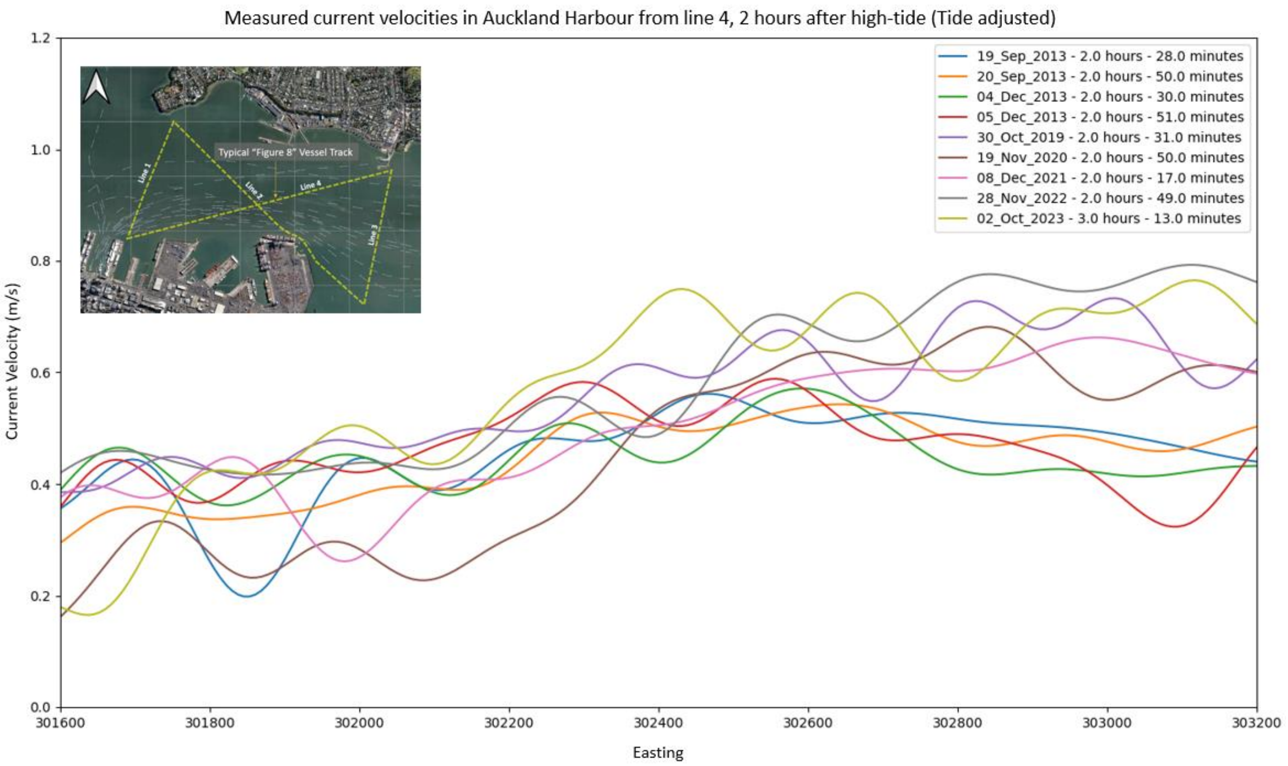


Measured maximum current velocities in Auckland Harbour from line 2 (Tide adjusted)
Fergusson Wharf
Pre-2005 Average Max
19_Sep_2013
20_Sep_2013
04_Dec_2013
05_Dec_2013
27_Apr_2017
30_Oct_2019
19_Nov_2020
08_Dec_2021
28_Nov_2022
02_Oct_2023
Typical "Figure 8" Vessel Track
Current Velocity (m/s)
Easting



Measured current velocities in Auckland Harbour from line 2, 2 hours after high-tide (Tide adjusted)
Fergusson Wharf
Pre-2005 Average Max
19_Sep_2013 - 2.0 hours - 51.0 minutes
20_Sep_2013 - 2.0 hours - 16.0 minutes
04_Dec_2013 - 2.0 hours - 51.0 minutes
05_Dec_2013 - 2.0 hours - 18.0 minutes
30_Oct_2019 - 2.0 hours - 8.0 minutes
19_Nov_2020 - 2.0 hours - 18.0 minutes
08_Dec_2021 - 2.0 hours - 44.0 minutes
28_Nov_2022 - 2.0 hours - 21.0 minutes
02_Oct_2023 - 3.0 hours - 37.0 minutes
Typical "Figure 8" Vessel Track
Current Velocity (m/s)
Easting


Measured maximum current velocities in Auckland Harbour from line 4 (Tide adjusted)
Current Velocity (m/s)
Easting
19_Sep_2013
20_Sep_2013
04_Dec_2013
05_Dec_2013
27_Apr_2017
30_Oct_2019
19_Nov_2020
08_Dec_2021
28_Nov_2022
02_Oct_2023
Typical "Figure 8" Vessel Track
Line 1
Line 2
Line 3
Line 4


Measured current velocities in Auckland Harbour from line 4, 2 hours after high-tide (Tide adjusted)
Current Velocity (m/s)
Easting
19_Sep_2013 - 2.0 hours - 28.0 minutes
20_Sep_2013 - 2.0 hours - 50.0 minutes
04_Dec_2013 - 2.0 hours - 30.0 minutes
05_Dec_2013 - 2.0 hours - 51.0 minutes
30_Oct_2019 - 2.0 hours - 31.0 minutes
19_Nov_2020 - 2.0 hours - 50.0 minutes
08_Dec_2021 - 2.0 hours - 17.0 minutes
28_Nov_2022 - 2.0 hours - 49.0 minutes
02_Oct_2023 - 3.0 hours - 13.0 minutes
Typical "Figure 8" Vessel Track
Line 1
Line 2
Line 3
Line 4