Appendix 10

Coastal Processes Assessment

REPORT

Tonkin+Taylor

Vision for Growth Port Development: Coastal Process Assessment

Prepared for
Northport Ltd

Prepared by
Tonkin & Taylor Ltd

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Executive summary

Northport Ltd (NPL) is a deep-water commercial port strategically situated at Marsden Point near Whangarei in Northland, New Zealand, situated between the Channel Infrastructure (CINZ) jetty to the east and Blacksmiths Creek estuary and Marsden Bay to the west. Northport is planning to expand the port's capacity by reclaiming land and building additional berths to the east of the existing reclamations.

As part of the technical studies being carried, Northport commissioned Tonkin + Taylor (T+T) to assess the potential effects of the proposed activities on coastal processes. This assessment supports the Assessment of Environmental Effects. It is part of a suite of technical reports that assess the actual and potential effects of the applications.

Physical coastal setting

Whangarei Harbour is located at the northern end of Bream Bay on the northeast coast of the North Island and is a meso-tidal drowned river valley. The harbour is relatively shallow due to extensive intertidal flats. The harbour is accessed through a relatively narrow tidal inlet which is around 680 m wide and 32 m at its deepest point. The inlet is bounded by Tertiary volcanic rocks on the northern side and a Holocene prograde sandy barrier spit on the southern side, which forms Marsden Point. Several bays indent the northern shoreline of the lower harbour, the largest of which is Parua Bay. The inlet channel separates a large ebb tide delta that extends seaward to around the 20 m depth contour. Mair Bank is situated on the northern side of the channel, largely within the intertidal and subaerial portion of the southern ebb tide delta. Snake Bank and McDonald Bank are the two main flood-tidal deltas located within the harbour inlet embayment.

The sediments within the tidal inlet largely comprise medium to fine sands with a reasonable proportion of shell and low levels of silt. Most of the sediment within the subtidal areas of Bream Bay including the deeper parts of the ebb tide shoal can be generally characterised as fine to medium sand with some shell fragments. There is an increase of silt content in deeper water. Beaches on the open coast comprise predominately fine to medium sand.

Typically, the suspended sediment concentration values within the tidal channel are low (around 6 mg/L). Concentrations of up to 30 mg/L on the intertidal areas of the harbour occur during moderate to low energy conditions. Significantly higher suspended sediment concentrations within Bream Bay can occur during more energetic wave conditions.

The mean tide range is 2.3 m during spring tide and 1.5 m during neaps. Tidal current velocities gradually decrease up-harbour, from around 1 m/s (≈2 knots) at Marsden Point to 0.8 m/s (≈1.5 knots) at Limestone Island. Tidal streams are strongest in the area adjacent to Home Point southeast of Marsden Point, where rates up to 1.5 m/s (≈ 3 knots) may be experienced. The constricted tidal inlet results in currents reaching peak depth-averaged velocities of 1.1-1.3 m/s (≈2.1 to 2.3 knots) during spring tides.

The Whangarei Harbour inlet entrance emerges in a zone of low energy that provides natural stability to the inlet. Wave activity inside the harbour is mostly locally generated (fetch ~5km near Marsden Point) although some ocean swell refracts and diffracts to reach the port vicinity. Numerical modelling results shows the sheltering effect of Whangarei Heads and the influence of the ebb tide delta in locally reducing wave heights. Even during extreme onshore storms wave heights are generally less than 5 m offshore from the delta and reduce to less than 0.5 m at Marsden Point. Offshore average significant wave heights are typically between 0.7 and 1.0 m.

Coastal processes

Within Bream Bay an annual net northerly littoral drift of 20,000 m^3 per annum has been estimated between Ruakaka River Inlet and Marsden Point. This is the net difference between northerly and southerly directed transport and is a relatively small value for open coast locations but is consistent with a low energy and predominantly shore normal wave direction. These low transport rates suggest that the formation of the ebb tide delta is more controlled by local wave climate effects influenced by the sheltering effect of Whangarei Heads, together with the strong tidal flows from the harbour. The ebb delta and flood tide shoals within the harbour entrance are supplied by small amounts of northerly directed alongshore transport.

Based on an average suspended sediment concentration of 6 mg/L[1] and the tidal prism, the suspended tidal flux entering and departing the harbour is approximately 360 m^3/tide. The tidal flux is an order of magnitude greater than the alongshore transport, confirming the dominance of tidal effects at the entrance to the harbour.

The analysis of historic bathymetric data over the 76-year period for which records are available (1939 to 2015) shows that there has been no significant change to the tidal inlet and its associated flood and ebb tide deltas. More detailed analysis of aerial and satellite imagery shows shoreline accretion has occurred along the shoreline between the CINZ Jetty and Northport. No significant changes were observed within Marsden Bay to the west of Northport. Stability of the harbour entrance has also been attributed to the presence of shell material, which provides an armour layer protecting the underlying soft sands.

Sea level rise may result in increased erosion pressure on the ebb tide shoal with changes in tidal asymmetry increasing sediment transport potential into the harbour.

Proposed development

The proposal is for an eastern extension comprising a reclamation of around 13.7 ha extending an additional 250 m eastward extensions for Berth 5 from the already consented Berth 4 extension and dredging of around 1.72Mm^3 within the berthing and manoeuvring pocket.

There will be a need for maintenance dredging within the dredged area. This dredging will be done by cutter suction, or a barge mounted hydraulic excavator. Dredging will be used for raising land levels within the port, made available for beneficial reuse by others (such as beach nourishment) or disposed of to an approved disposal site.

Assessment of effects on the physical coastal environment

Effects have been considered based on hydrodynamic and morphodynamic modelling carried out by MetOcean Solutions Ltd (MOS, 2022 a and b) without the CINZ channel deepening project being in effect. However, MOS (2018) report on morphological response to capital dredging and land reclamation considered morphological change both with, and without, the CINZ channel deepening. They concluded there was little difference and did not expect either situation to measurably change morphological change in the vicinity of the NPL project. Therefore, the findings and conclusion will apply whether or not the channel deepening project is realised.

Construction effects

Construction effects can be managed by effective controls during construction to reduce the release of fines. With these controls, construction effects on physical coastal processes outside the port area for the reclamation and seawalls are considered negligible.

[1] based on records in the harbour entrance see Section 3.4.2

For the proposed dredging, monitoring should be included in the construction management plan to determine the actual level of plume extent and concentration. Mitigation for the potential risk could include sediment curtains around the dredge vessel or operating during limited periods associated with low tidal flows if required.

Long term effects assessment of the eastern extension

The proposal is an extension of an existing consented port reclamation and the proposed reclamations are aligned with the existing face of the reclamation that minimises potential adverse effects on tidal flows and sediment transport. The proposed developments add to the increased occupation of the CMA in this area and increase the spatial extent of effects on the seabed and shoreline due to the increased occupation. The eastern extension has a more significant effect due to occupation of both the seabed and beach areas, and the effects on tidal currents and sediment transport extend eastward along the existing channel to around the CINZ jetty. The remaining effects on coastal processes are minor.

Recommended measures to remedy or mitigate effects

There is no practicable way of avoiding all effects with the current proposal, however Northport has:

1. carefully selected and refined the dredging, design and construction approach to mitigate effects, including on the SEA to the west of NPL;
2. Undertaken to beneficially re use dredged material in the designation and/or sand bar (see below) where practicable; and
3. proposed a carefully located and designed sand bar for bird roosting to the west of the existing port within Marsden Bay. The size of the roost and location are set out in this report and the adverse effects are also considered and found to be negligible.

Monitoring

The construction management plans should include controls to manage accidental discharge of sediments and other pollutants into the CMA. Apart from the monitoring and management of the dredge plume, no other monitoring is considered necessary for managing effects on coastal processes during construction.

The areas to monitor for long term potential change are within Marsden Bay and along the shoreline from the port to the CINZ jetty and Mair Bank. Surveys should be carried out after completion of each stage of the development and at least annually for a period of not less than five years. Pre and post dredging surveys should be retained by the consent holder in a compatible format to augment this data set and information of the volumes and locations of deposition of both the capital and maintenance dredging recorded.

Sediment sampling and analysis of surficial sediments within the eastern end of Marsden Bank could also be carried out to confirm any change in sediment properties that may potentially affect ecology in this area.

1 Introduction

1.1 Background

Northport is a deep-water commercial port strategically situated at Marsden Point near Whangarei in Northland, New Zealand. Northport Ltd (NPL) is planning to expand the port's capacity by reclaiming land, dredging, and building additional berths.

As part of the technical studies being carried, Northport commissioned Tonkin + Taylor (T+T) to assess the potential effects of the proposed activities on coastal processes. This assessment supports the Assessment of Environmental Effects. It is part of a suite of technical reports that assess the actual and potential effects of the applications.

This report makes use of the following reports to inform the assessment of effects on coastal processes prepared for this study:

- MetOcean Solutions (MOS, 2022a) Hydrodynamic modelling update: Effects of proposed reclamation and dredging layout on hydrodynamics, report prepared for Northport, August 2022.
- MetOcean Solutions (MOS, 2022b) Morphodynamic modelling for the Northport environment: modelling update, predicted morphological response to proposed eastern land reclamation, report prepared for Northport, August 2022.
- MetOcean Solutions (MOS, 2022c) Dredge plume modelling: dredging sediment plume dispersion over existing and proposed port configurations, report prepared for Northport, August 2022.
- WSP (2022) Northport Berth 5 Concept Design], report prepared for Northport, August 2022.

The report also relies on previous studies for NPL for previous port development configurations, and for the channel deepening project for CINZ.

1.2 Report layout

Section 2 sets out the proposed project and the physical setting of the harbour entrance and the northern part of Bream Bay is described in Section 3 followed by a description of the existing coastal processes in this area in Section 4. Section 5 sets out the predicted changes in physical processes based on field investigations and numerical model studies. Section 6 includes the assessment of effects of the changes and Section 7 sets out the proposed methods to avoid, reduce and mitigate effects. Section 8 describes the proposed bird roost mitigation and assesses the effect of the activity. Proposed monitoring conditions are included in Section 8.

Figure 1-1: Location plan

1.3 Datums and coordinates

All levels within this report are presented either in terms of One Tree Point Vertical Datum 1964 (OTP64 or Reduced Level) or Chart Datum. Coordinates are presented in terms of New Zealand Transverse Mercator (NZTM).

2 Description of the proposal

2.1 Capital works for the reclamation and dredging

Northport's current footprint totals 58 hectares, with 570 linear metres of berthage consisting of three berths, 30 hectares paved and being used for cargo operations, and berth with a depth at Chart Datum (CD) of 13 m at Berths 1 and 2, and 14.5 m at Berth 3. Berth 4, a reclamation of around 4.5 ha that provides an additional 270 m of berthing to the east of the existing port is consented but yet to be constructed.

The eastern reclamation for Berth 5 (WSP, 2022) consists of a reclamation of around 11.7 ha within the CMA extending an additional 250 m eastward extensions for Berth 5 from the already consented Berth 4 extension and occupying 20,767 m^2 above MHWS. Dredging is also proposed to deepen the berth and manoeuvring area to depths of 14.5m (16.1 m MSL) and 16 m CD (17.6 m MSL) as shown in Figure 2-1. The dredge volumes to achieve the required navigable depth is around 1,720,000 m^3 with a bulking factor allowance of 1.1. The dredged volumes will be used to form the reclamation.

2.2 Construction methodology

Construction methodology is described in detail in the WSP report (WSP, 2022). In simple terms it comprises constructing the perimeter of the reclamation area using an armoured embankment seawall, combi-piled walls, and temporary sheet piling, then dredging and placing dredged sediment into the reclamation area. The armoured seawalls will be constructed using land-based methods and the combi-piled will be constructed by a mix of floating and land-based equipment.

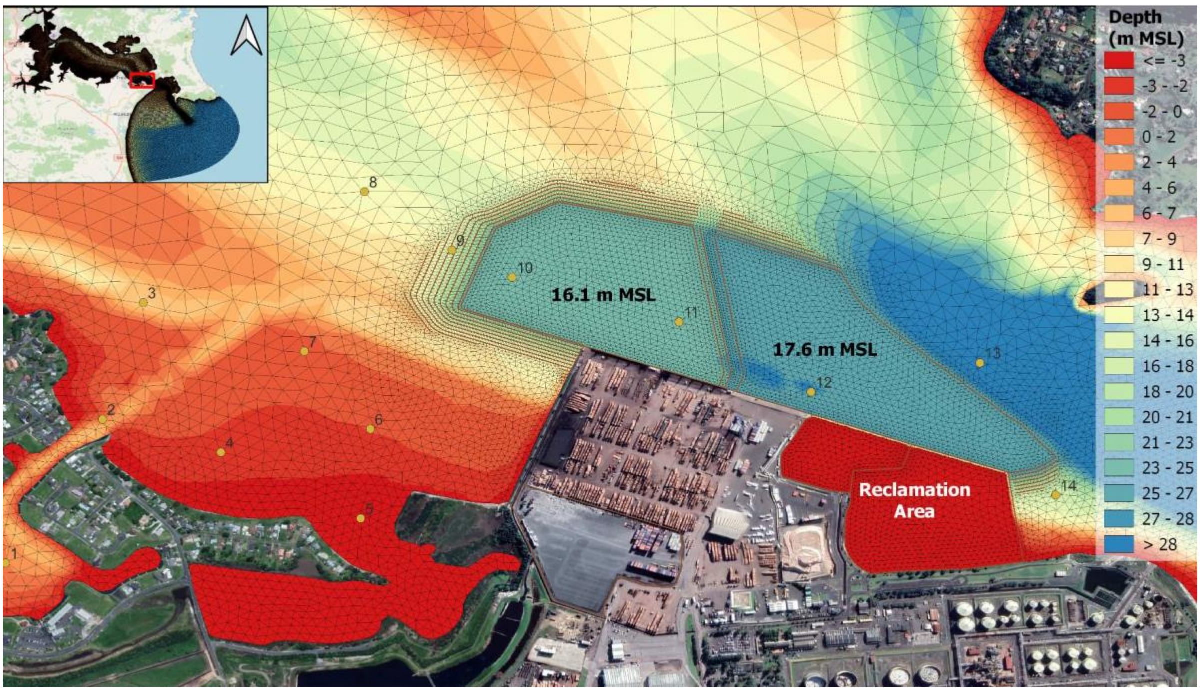

Figure 2-1: Proposed dredging and reclamation extents (Source: MOS, 2022a)

2.2.1 Capital dredging

Three types of dredgers are most likely to be used and most likely in combination, due to the confines of the dredge area for some plant. These dredging methods are:

- Trailer Suction Hopper Dredge (TSHD)
- Cutter Suction Dredge (CSD)
- Backhoe Dredge (BHD).

The majority of the dredged material is expected to be sandy silt or silty sand and will be used for reclamation fill. Any unsuitable dredging will be disposed of to an approved disposal area.

The dredge material used for the reclamation will be discharged within the reclamation bund and any decanting will occur with sediment settling within the reclamation encloser and returning water will be release through a pipe located near the seabed at the corner of the existing quay.

2.2.2 Maintenance dredging

Relatively small volumes (up to 258,000 m^3) of maintenance dredging may need to occur every 5 to 15 years to maintain navigable draft (i.e., sedimentation of around 17,200 m^3/year). It is likely that the sediment will comprise clean coarse sand and shell. This sediment could be used for ongoing development within Northport such as raising land levels, made available for beneficial use, such as beach nourishment or disposed of to an approved disposal area. Dredging plant and methods are similar to that described for capital dredging.

2.3 Bird roost for avifauna mitigation

2.3.1 Purpose

The purpose of the bird roost is to mitigate for the area of around high tide beach of around 20,800 m^2 lost due to the eastern reclamation.

2.3.2 Design constraints

The proposed bird roost needs to:

- Be reasonably close to the area lost
- Be independent from the existing shoreline during high tide to provide a safe area
- Be largely, or completely formed from sand to provide a similar habitat to that lost
- Provide a reasonable area above mean high water springs
- Be situated away from ecologically significant areas
- Be sufficiently far from any identified wetland areas to avoid current Freshwater NPS policies
- Avoiding potential future developments, such as the dry dock area
- From a constructability and practical point of view it was also important to locate the roost in an intertidal area to reduce the volume of fill and the occupation area in the CMA.

2.3.3 Consideration of options

2.3.3.1 Location

There is no suitable area within the Harbour to the east of the reclamation due to the coastal infrastructure of CINZ, the narrow intertidal area and the increasing high currents and wave climate nearer the harbour entrance. Marsden Bay to the west of the existing port provides the closest practical area, being relatively sheltered from currents and waves and having a reasonably wide intertidal shelf. Further to the west between Marsden Bay and One Tree Point the intertidal area is too narrow to site. Based on advice from the marine ecologist, the western most side of Marsden Bay and landward of the area of more significant cockle habitat had the smallest extent of ecological habitat. As shown on Figure 2-2 there is a relatively small area of intertidal area available to consider for a bird roost However, this area is also where there is an existing remnant flood spit feature that was present prior to the existing port development (see Figure 3-13).

Figure 2-2: Constraint lines (red) for wetland, potential reclamation, cockle bed area and western limit showing the existing deflated spit as the preferred location for a bird roost

2.3.3.2 Sand source

Practical sand sources for the roost are either won sand from the dredging process or beach sand from the area to be occupied for the eastern reclamation. The sand source from dredging includes sandy silt and silty sand (MOS, 2022c) and includes up to 30% silts, but typically around 14% with predominantly fine to medium sands. Beach grading samples of the sand that forms the beach and intertidal area east of the port (see Figure 2-3 for location). The sediment grading curves are show in Figure 2-4 and show fine to medium beach sand with a D10 of around 0.1 mm, a D50 of around 0.2 mm and a D90 of around 0.3 mm with no significant proportions of silt. Either sand source location could be used, but the dredged sand would need processing and rework to remove the fines and to only retain clean medium to fine sands.

Figure 2-3: Location of beach sediment samples (Source: Northport, 2022)

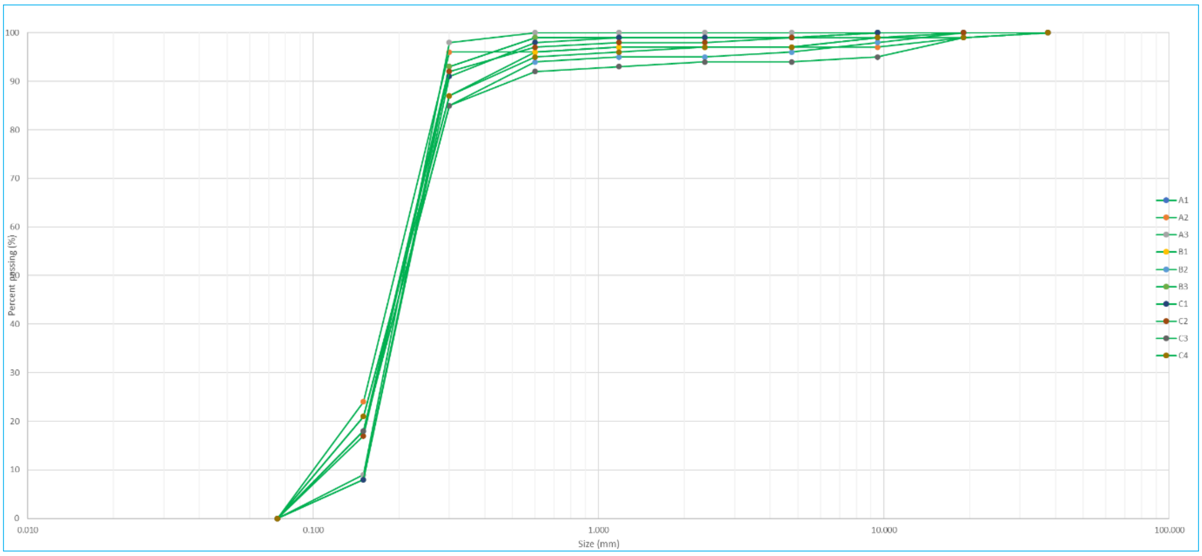

Figure 2-4: Sediment grading from eastern beach area (Source: Northport, 2022)

2.3.4 Form of bird roost

The preferred nature-based approach for forming the roost is to use fine to medium sand to augment the existing sandy flood spit feature extending along its length, recognising that this will adapt and adjust to the coastal processes over time. This approach uses sediments similar to that present on the intertidal area. Alternatives, such as using rock armour or vertical walls to create a stabilised perimeter could result in a slightly smaller footprint and be more stable but would restrict bird movement down the face of the roost as the tide recedes and introduces a different form.

The cross section of the roost was informed by the slopes and elevation of the existing shoreline. The existing beach face on the spit is around 8(H):1(V) with a back slope of around 4(H):1(V) and the crest of the beach is around 3.1m CD. The design has been based on these slopes extending to a crest level of 3.4m or around 0.6m above MHWS. This elevation would be sufficient to retain a dry area apart from significant events and onshore winds, where overtopping could occur resulting in the landward migration of the roost and possibly lowering and deflating of the reef form.

To provide a smaller construction profile the roost would be constructed with steeper slopes (say 4(H):1(V)), with the expectation that the seaward slope would adjust overtime to flatter slope. The location of this bird roost is indicated in Figure 2-5, with larger plans and sections shown in Appendix D. Table 2-1 shows the indicative areas of occupation and above MHWS post construction and after the expected initial adjustment and the volume of sand required, including an allowance for some settlement, but it does not include any allowance for bulking factors or sand loss during construction, which is likely. The above MHWS area is approximately 9% of the eastern beach area occupied by the proposed reclamation.

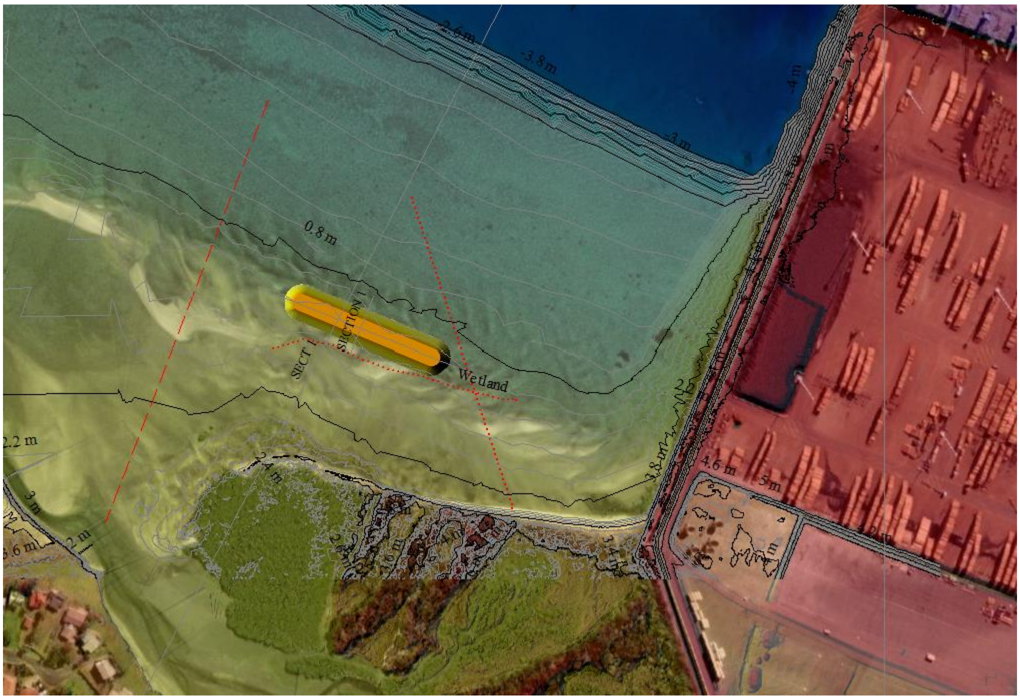

Figure 2-5: Proposed form and location of the sand bird roost

Table 2-1: Indicative areas of seabed occupation and area above mean high water springs and volume of sand required

Timing	Occupation area on CMA (m^2)	Area above MHWS (m^2)	Volume (m^3)
Constructed	4,573	2,703	7,400
After adjustment	5,423	2,381	

2.3.5 Construction approach

The preferred construction approach for the formation of the roost is a marine based approach, with sand bought to the area at high tides with shallow draft barges and unloaded and shaped with hydraulic excavators. Land based approaches were considered but were not practicable.

The marine based approach would require sand to be brought to the roost location in a shallow draft barge at high tides. These barges generally have reasonably limited carrying volume (in the order of several hundred cubic metres). The barge could be retained at this location during falling tides and unloaded to the proposed line and level and this process repeated until the roost was completed. This is likely to require at least 40 barge loads and take one to three months to complete.

2.3.6 Expected performance of the bird roost

The proposed bird roost is situated in a relatively sheltered environments, with low tidal currents (typically less than 0.2 m/s) and generally low wave heights (typically lower than 0.2 m) with higher waves only likely to occur to this level during higher stages of the tide and during periods of strong north-westerly winds.

There is evidence that the existing barrier beach is slowly moving landward. This is likely a result of wave overtopping and over-wash, potentially exacerbated by higher sea levels that would allow slightly higher waves to act on the beach, as well as reduced sediment supply. The roost will create a more sheltered environment between the roost and the existing barrier spit. This sheltering is likely to result in a reduction of the landward retreat of the existing barrier beach at this location and is also likely to enable the existing mangrove to extend further seaward in the lee of the roost.

It can also be expected that the proposed roost will gradually deflate and lower due to wave overtopping moving sediment landward. The deflation and lowering is expected to result in locally raising the seabed level between the roost and the landward spit feature and potentially merging with this spit.

The period that the bird roost will remain with a reasonable area above MHWS is difficult to predict. However, the evidence from aerial imagery suggest that the remnant spit feature has remained at this location since prior to the original port construction. It is anticipated that the proposed roost could remain effective for periods of years to decades, although it is likely that some sediment loss will occur. If overwash occurs, moving sand to the landward side of the spit, this could retain a crest area above MHWS, but with a progressive landward location. However, it also possible that if the roost deflates there could remain a high point, but below MHWS.

This means that top-ups of the roost may be required to maintain a reasonable high tide area. Therefore, there will need to be monitoring and a top-up plan established as part of the management of this roost. We recommend a top up volume of 10% of the capital be allowed for (i.e., 740m^3) every five years, although the actual volume will be dependent on the performance of the roost.

3 Physical setting

3.1 Location

Northport is situated at Marsden Point along the narrow inlet to Whangarei Harbour. Whangarei Harbour, located at the northern end of Bream Bay on the northeast coast of the North Island, is a meso-tidal 98 km^2 drowned river valley with a spring tide prism[2] of around 155 x 10^6 m^3 (Hume and Herdendorf, 1988). The harbour is relatively shallow (mean high-tide depth of 4.4 m) due to extensive intertidal flats, particularly in the lower harbour which accounts for 58% of the high tide area (Swales et al, 2013). The harbour is typically unstratified and has minimal inputs of fresh water (Inglis et al., 2006). The Hātea River is the main source of fresh water to the harbour, with a mean annual flow of 1 m^3 s^{-1}. The Waiarohia and Raumahanga streams have mean annual flows of 0.35 m^3 s^{-1} and 0.34 m^3 s^{-1}, respectively (Reeve et al., 2010). During summer, most of the harbour is well mixed, while in winter the lower harbour remains well mixed.

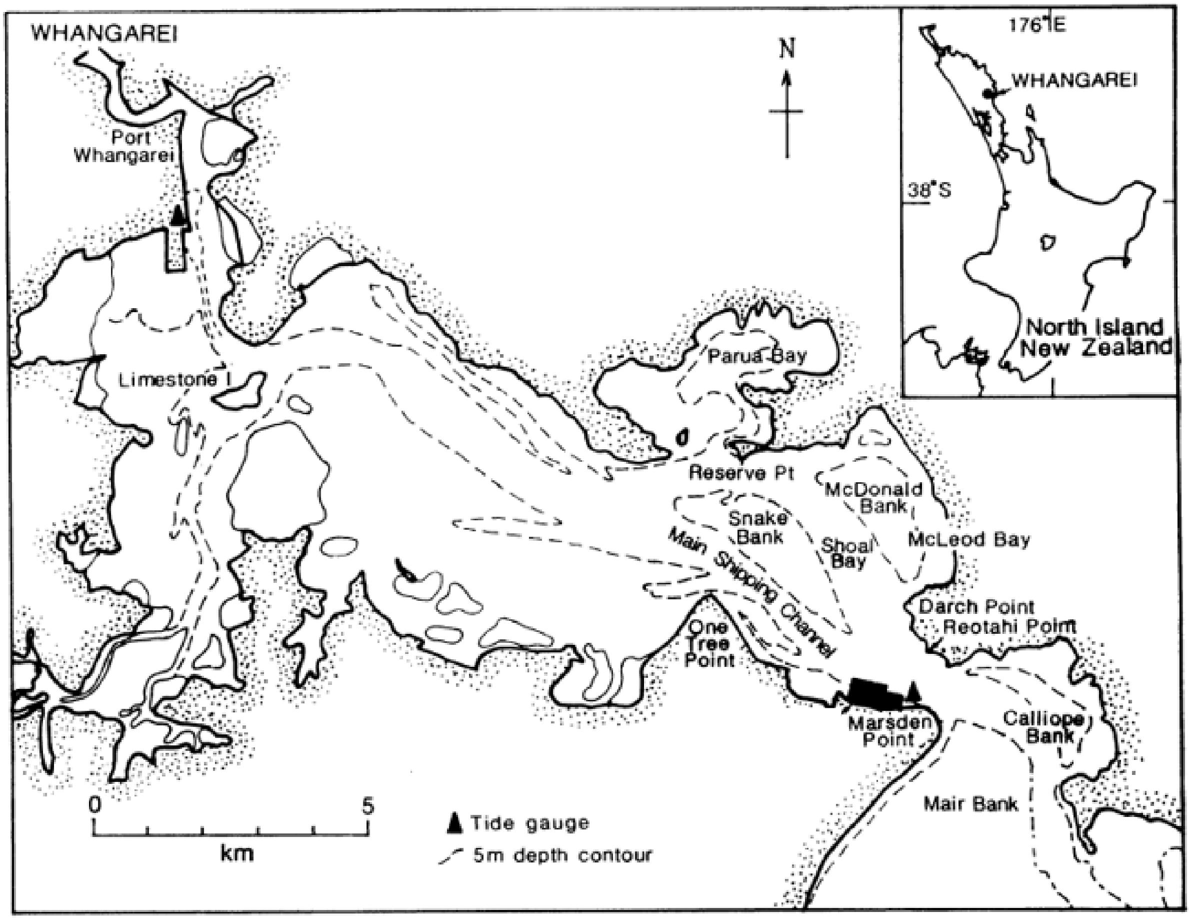

Figure 3-1: Location of shoals and banks adjacent to Marsden Point (Source: Black et al, 1989)

The harbour is accessed through a relatively narrow tidal inlet which is around 790 m wide and 32 m at its deepest point. The inlet is bounded by Tertiary volcanic rocks on the northern side and a Holocene prograde sandy barrier spit on the southern side, which forms Marsden Point (Longdill and Healy, 2007). Several bays indent the northern shoreline of the lower harbour, the largest of which is Parua Bay Figure 3-1. The inlet channel separates a large ebb tide delta that extends seaward to around the 20 m depth contour (refer Figure 1-1). Mair Bank, situated largely within the intertidal and subaerial portion of the southern ebb tide delta, extends to the east of Marsden Point and

[2] Tidal prism is the volume of water between low and high spring tides.

Calliope Bank is situated on the northern side of the channel. Snake Bank and McDonald Bank are the two main flood-tidal deltas located within the harbour inlet embayment (Morgan et al., 2011).

The harbour shoreline to One Tree Point is a sandy beach system backed by weakly consolidated cliffs. The sandy beach comprises fine sand fronted by intertidal flats which range in width between 30 m and 200 m out to the entrance channel.

The open coast section has a sandy beach comprising fine sand. The beach has a narrow dry beach with a width of approximately 5 m above the high tide line. The dune system has a crest elevation of between RL 5 to 13 m, increasing towards the north. The dune face is generally over steep with recent erosion scarps, particularly at the northern end of the shoreline. Dune vegetation exists along the dune crest (spinifex).

Figure 3-2: Beach and dune system at Marsden Point

3.2 Geology

GNS Science geological maps reveal a very variable geological nature (displayed on Figure 3-3). Whangarei Harbour has experienced relatively recent submergence followed by considerable infilling. Other work indicate that the harbour may technically be termed an estuarine lagoon, however a number of tectonic movements may have contributed to the harbour's formation. These include a combination of tectonic activity, ancient block faulting, the formation of a drowned river valley and the existence of a barrier enclosing the mouth of the former valley.

The oldest rocks in the Marsden Point area are Palaeozoic greywackes and argillite of the Waipapa Group. These rocks outcrop north, south, and southwest of the harbour and constitute the basement to Quaternary costal and estuarine sediments at the site. Although Tertiary sandstones, mudstones and limestone overlie basal Waipapa Group rocks and outcrop west of Ruakaka and at Mangawhai Point, these rocks are discontinuous and are not encountered in the Marsden Point Area.

Andesitic agglomerate, lava and dikes and small areas of andesitic tuffs, cones and lava outcrop with Tertiary mudstones and together comprise the Whangarei Heads, directly across the Whangarei Harbour (NE) from the site.

The low-lying Marsden Point area comprises Quaternary aged older foredunes higher terrace deposits and undifferentiated sands with rare peaty areas, collectively described as alluvium.

The site is located between two parallel inferred faults orientated northwest southeast. To the west, a fault in part concealed beneath recent alluvial materials extends along the Ruakaka River Valley and the Otaika Stream. The second fault, immediately north of the site is inferred to have resulted in the present harbour alignment. Neither fault is considered to be active.

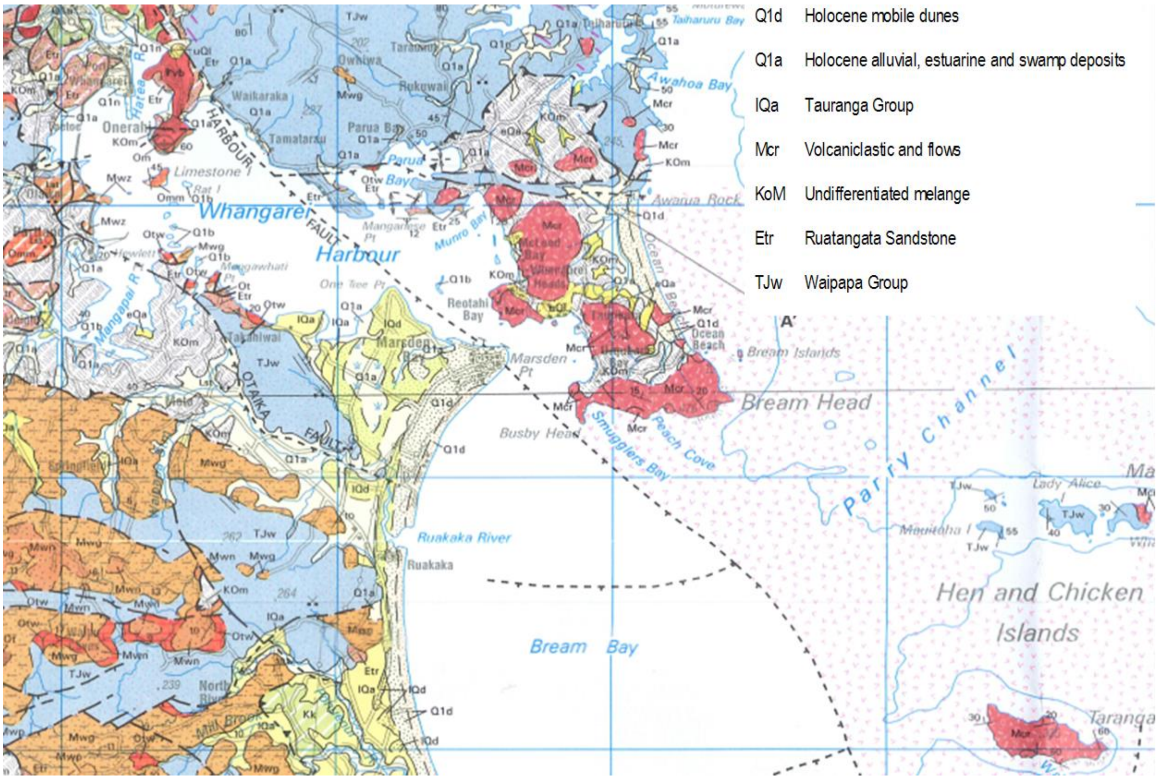

Figure 3-3: Geological Map, known faults are represented by solid and dashed lines (source: GNS 1:1,000,000 Geological Units)

3.3 Vertical land movement

Beavan and Litchfield (2012) assessed vertical land movement around New Zealand's coastline. They found Northland to be tectonically stable utilising both long-term geological markers and shorter-term GPS markers with Kaitaia and Whangarei exhibiting -0.3 mm/year and +0.3 mm/year trends respectively. The recently published vertical land movement information (https://www.searise.nz) show similarly low rates of vertical sea rise in the vicinity of Northport of -0.4mm/year and -0.27 mm/year.

3.4 Sediment data

3.4.1 Seabed characteristics

Marine sediment data for the area in the vicinity of the dredging area is available from previous port development studies (Black et al. 1989, Hawthorn Geddes, 2009), Beca (1992) as well as investigations commissioned by NRC (Swales et al., 2013). Figure 3-4 shows a schematic of the surficial sediment on the harbour bed based on interpretation of the various data sets and inspections. Figure 3-5 shows the grading envelope from sampling that extends from Snake Bank to the CINZ jetty. The sediments in the vicinity to Northport are predominantly fine to medium sands with a reasonably proportion of shell and only a small quantity of silts and clays.

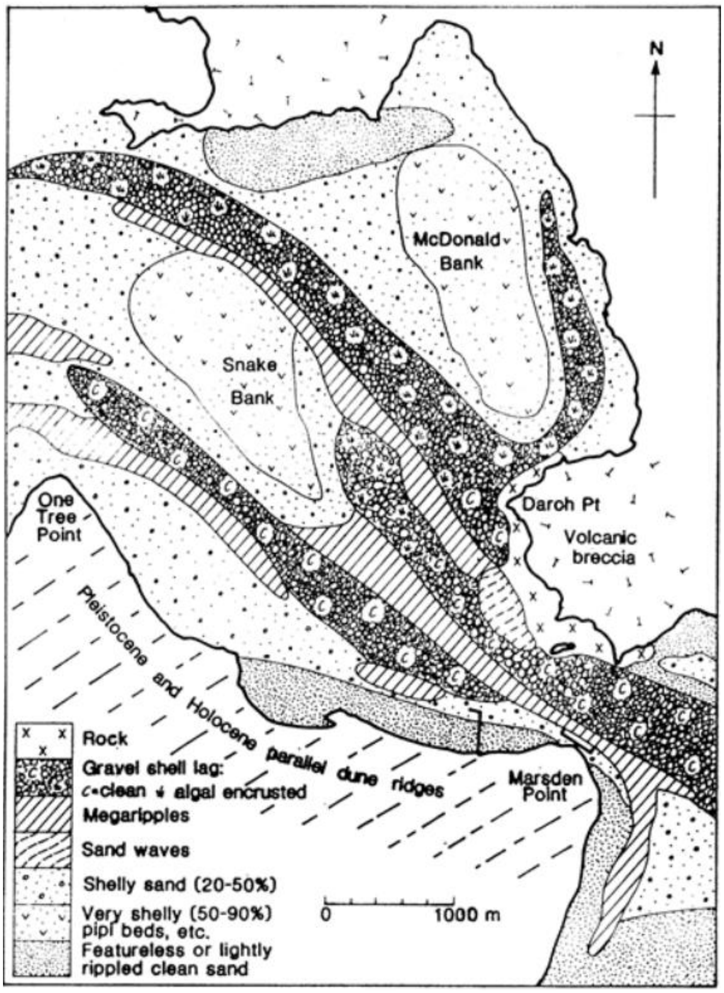

Figure 3-4: Simplified bottom sediment facies for Whangarei Harbour (Source: Black et al., 1989)

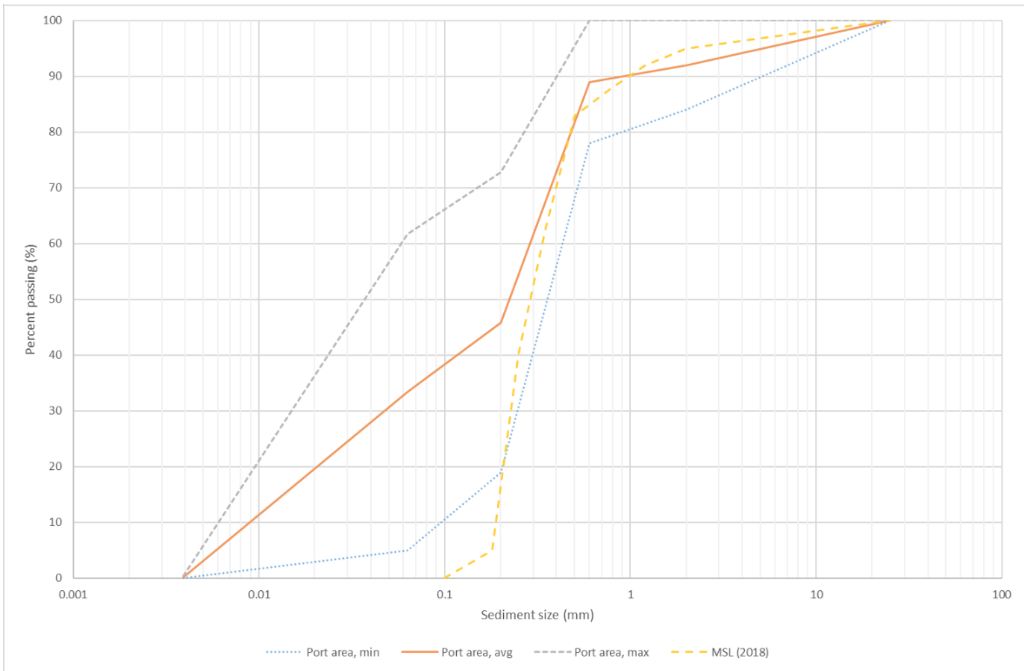

Figure 3-5: Grading envelop of the sediment within the lower harbour area from Snake Bank to CINZ Jetty

3.4.2 Suspended sediment

Suspended sediment sampling was carried out by MWH between June 2008 and May 2009 at four locations in the vicinity of the harbour entrance; at the harbour entrance, in the channel off Busby Head, south of Mair Bank and on the southern Ebb tide shoal (refer Figure 3-6). A table of the resulting suspended sediment concentrations is included in Appendix A. Average values of around 6 mg/L occur on the intertidal areas of the harbour seabed, while within the channel and ebb tide shoal areas, average values are also around 6 mg/L.

Figure 3-6: Water quality location plan (Source: MWH, 2009)

3.5 Bathymetry

Historic and current hydrographic charts of the harbour and approaches to Marsden Point that show the wider coastal context are summarised in Table 3-1. A more detailed assessment of bathymetry is included in MOS (2016). There are frequent surveys of the fairway, approaches terminal and shoal areas that have been carried out to confirm the lowest depths. There have also been regular surveys of Mair Bank, situated on the intertidal and subaerial part of the ebb tide delta, that were commissioned by Northland Regional Council.

Table 3-1: Summary of bathymetric survey information

Information type	Survey date
Bathymetric chart	1848
Bathymetric Chart	1849
Fairsheet	1939
Fairsheet	1959
Chart NZ 5213 (1970)	First published 1964 with updates in 1966 and 1970
Fairsheet	1981
NZ5214 (2004)	Main channel and port area to One Tree Point 2011. Ebb tide area 1981, Nearshore area around Ruakaka 1961, Nearshore area around point 2003.
Channel surveys to confirm least depth in the fairway, approaches, terminal and shoal area	2004 to 2009 at approx. 6 monthly intervals (Feb 04, Aug 05, Apr 06, Dec 06, Aug 07, Nar 08, Sep 08, Mar 09, Oct 09) 2010 to 2014 annual (Mar 10, Mar 11, Mar 12, Apr 13, Mar 14).
Surveys of Mair Bank, the ebb tide delta and edges of channel	Annual surveys from 2000 to 2021

3.6 Water level data

Key components that determine water level are:

- Astronomical tides
- Barometric and wind effects, generally referred to as storm tide
- Long-term changes in sea level due to wave transformation processes through wave setup and run-up.

3.6.1 Astronomical tide

Nautical tidal levels for primary and secondary ports of New Zealand are provided by LINZ based on the average predicted values over the 18.6-year tidal cycle. The table also includes MHWS-10 (Mean high water springs levels exceeded by 10% of high tides) from NIWA (2015). Values for Marsden Point in terms of Chart Datum are presented in Table 3-2. The mean tide range is around 2.3 m during spring tide and 1.4 m during neaps.1

Table 3-2: Tidal levels given for Marsden Point

Tide state	Chart Datum (m)	OTP64 (m)	NZVD2016 (m)
Highest Astronomical Tide (HAT)[1]	3.01	1.33	1.26

Tide state	Chart Datum (m)	OTP64 (m)	NZVD2016 (m)
Mean High Water Springs (MHWS-10)[2]	2.77	1.09	1.02
Mean High Water Springs (MHWSn)[1]	2.74	1.06	0.99
Mean High Water Neaps (MHWNn)[1]	2.31	0.63	0.56
Mean Sea Level (MSL)[1]	1.60	-0.08	-0.15
Mean Low Water Neaps (MLWNn)[1]	0.9	-0.78	-0.85
Mean Low Water Springs (MLWSn)[1]	0.46	-1.22	-1.29
Lowest Astronomical Tide (LAT)[1]	0.13	-1.55	-1.62

1. Source: https://www.linz.govt.nz/sea/tides/tide-predictions/standard-port-tidal-levels accessed 12/07/2021
2. NIWA(2015)

3.6.2 Storm tide

The combined elevation of the predicted tide, storm surge and medium-term fluctuations is known as the storm tide. An extreme value analysis of hourly sea level data for Marsden Point was done using a Weibull distribution. Resulting extreme water levels for a range of return periods for Marsden Point are shown in Table 3-3. These results, provided by NIWA with respect to MSL (2010-2019), were corrected to NZVD2016 using offsets included in NIWA (2020) and offset levels provided by NRC (T+T, 2021).

Table 3-3: Extreme water levels (m) for Marsden Point

Datum	5-year ARI	10-year ARI	20-year ARI	50-year ARI	100-year ARI	200-year ARI	500-year ARI
NZVD-16	1.42	1.46	1.52	1.60	1.67	1.71	1.84
Chart Datum	3.17	3.21	3.27	3.35	3.42	3.46	3.59

3.6.3 Medium term fluctuations and cycles

Atmospheric factors such as season, ENSO and IPO can all affect the mean level of the sea at a specific time. Seasonal fluctuations and IPO phase changes can both be in the order of $\pm$4 to 8 cm and ENSO fluctuations can be in the order of ±12 cm. The combined effect of these fluctuations may be up to 0.25 m (Bell, 2012).

3.7 Wind

A wind rose for Whangarei is shown in Figure 3-7. This shows that the predominant wind direction is from the west and southwest sectors, but that strong winds can also occur from the east. Winds are generally light for around 25% of the time and are strong for a similar proportion, although can be more frequently strong in Winter and Spring. Average wind speeds are less than 18 km/hr (5 m/s) although winds can exceed 61 km/hr (17m/s) for around 22 days per year, but only exceed 96 km/hr (26.7m/s) for a few hours per year (Chappell, 2013).

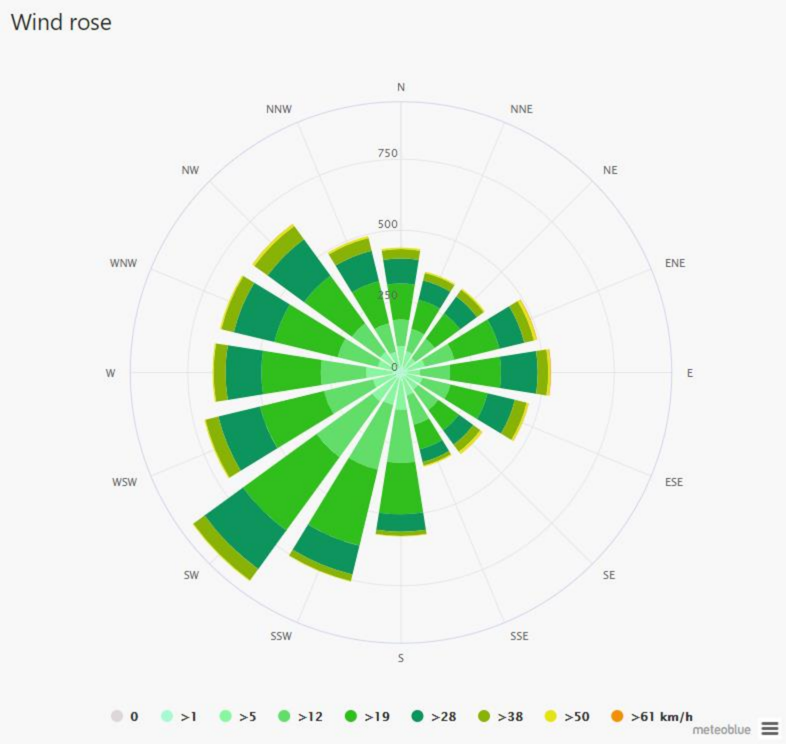

Figure 3-7: Windrose for Whangarei based on global weather models over a 30-year period with 30 km resolution (Source: meteoblue)

3.8 Wave climate

The wave climate in the vicinity to the harbour entrance has been modelled by MOS (2018b). This modelling shows that very little of the wave climate within Bream Bay propagates into the inlet of Whangarei Harbour (see Figure 3-8). This is due both to the sheltering effect of Mair Bank and the ebb tide delta as well as Whangarei Heads. Wave heights at the port from swell entering the harbour are typically less than 0.5 m.

Table 3-4 shows the significant wave height and peak periods of wind generated waves for a range of wind speeds at high tides with a water depth of around 2.3 m and a fetch length of 5 km which is representative of a north-western fetch to Marsden Bay. This table also shows wind generated waves are typically less than 0.5 m, except for the rare situation where winds exceed 61 km/hr.

Table 3-4: Wind generated waves heights within Marsden Bay for a range of wind speeds

Wind speed (km/hr)	Significant wave height (m)	Peak wave period (s)
5	0.04	1.0
12	0.10	1.5
19	0.17	1.8
28	0.25	2.1
38	0.33	2.4
50	0.42	2.7
61	0.50	2.9
96	0.80	3.5

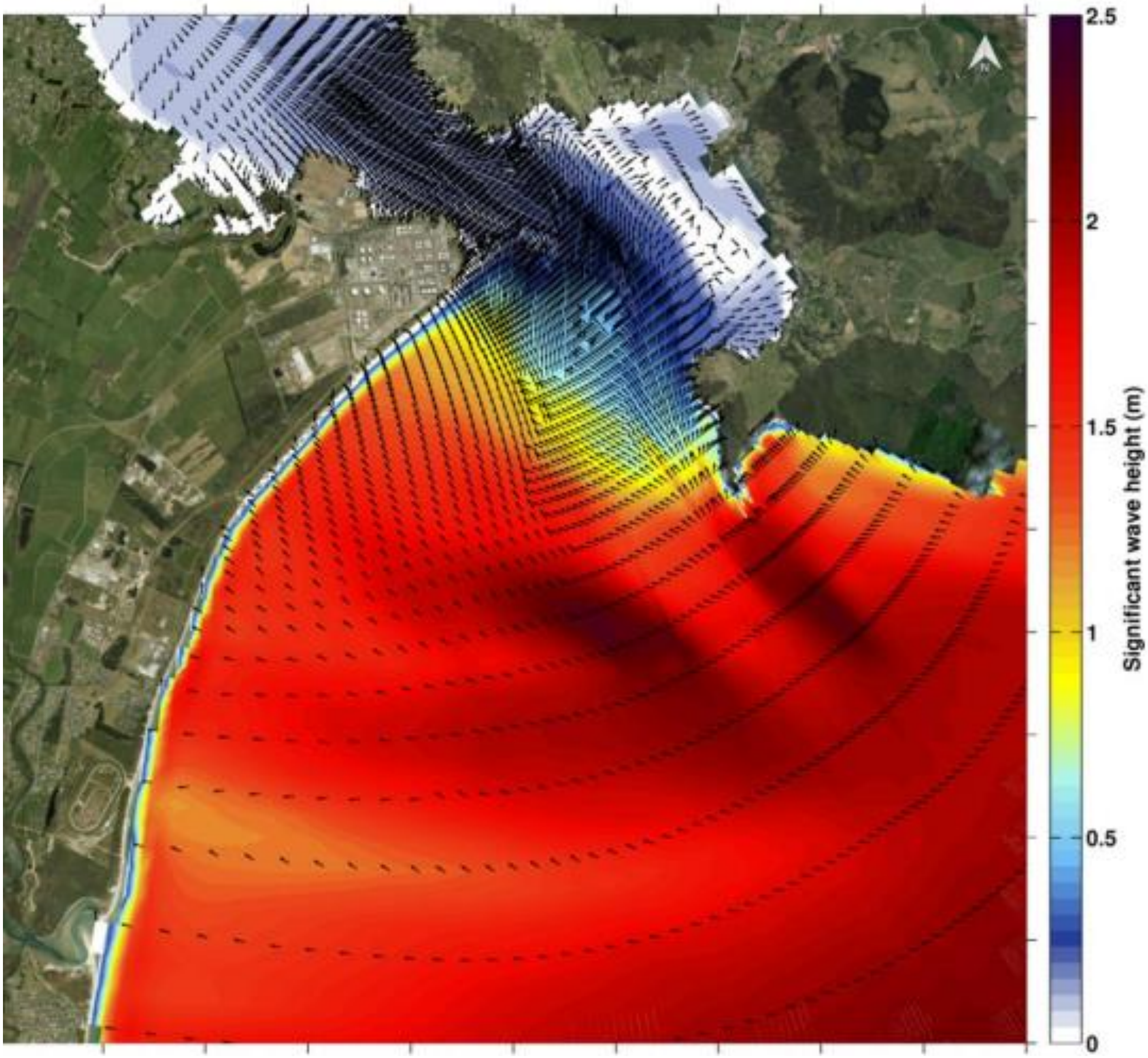

Figure 3-8: Significant wave heights of 2.5 m within Bream Bay shown to be significantly reduced at Northport due to sheltering effects of the delta and headlands (Source: MOS, 2018b)

3.9 Tidal currents

Based on previous studies, it was identified that tidal current velocities gradually decrease up-harbour, from around 1 m/s at Marsden Point to 0.8 m/s at Limestone Island (Inglis et al., 2006). Tidal streams are strongest in the area adjacent to Home Point southeast of Marsden Point, where rates up to 1.5 m/s may be experienced (Inglis et al., 2006). The constricted tidal inlet results in currents reaching peak depth-averaged velocities of 1.1-1.3 m/s during spring tides (Black et al., 1989; Longdill and Healy, 2007).

Tidal currents have been modelled by MOS (2018a) using a calibrated and validated hydrodynamic model for both the existing situation and with the deepened channel that CINZ has consent for. Figure 3-9 shows the present-day maximum ebb and spring tide velocities. During spring tide, the ebb tide creates the highest velocities along the edge of the ebb tide delta and Mair Bank with velocities reaching 1.3 m/s. Figure 3-10 shows the maximum velocities for the neap tide. In this situation the trend is similar to Black et al. (1989).

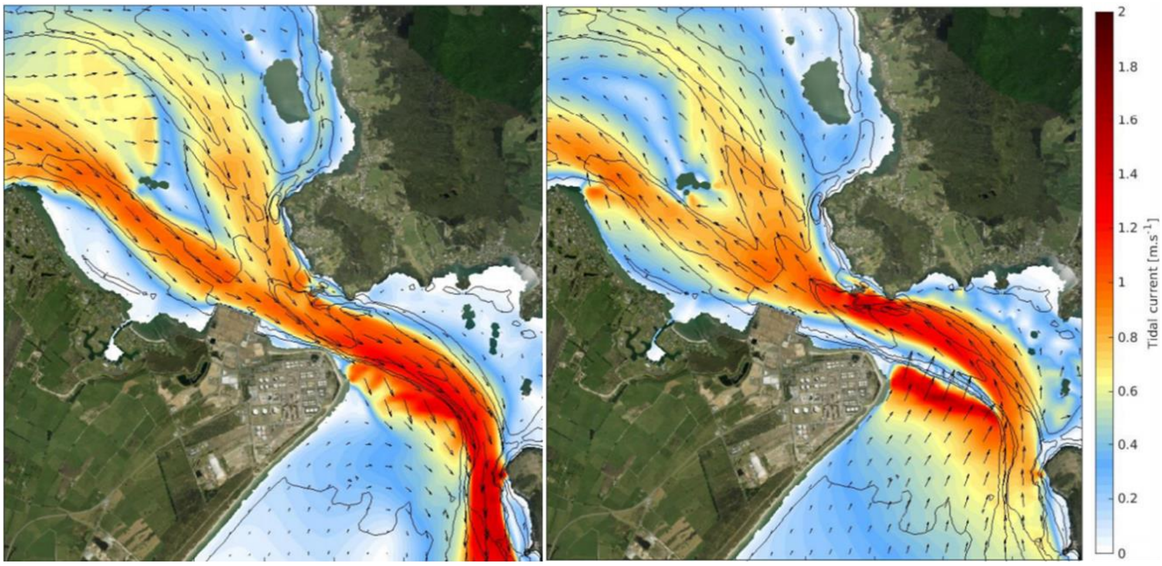

Figure 3-9: Modelled maximum ebb (left) and flood (right) spring tide velocities (Source: MOS, 2018a)

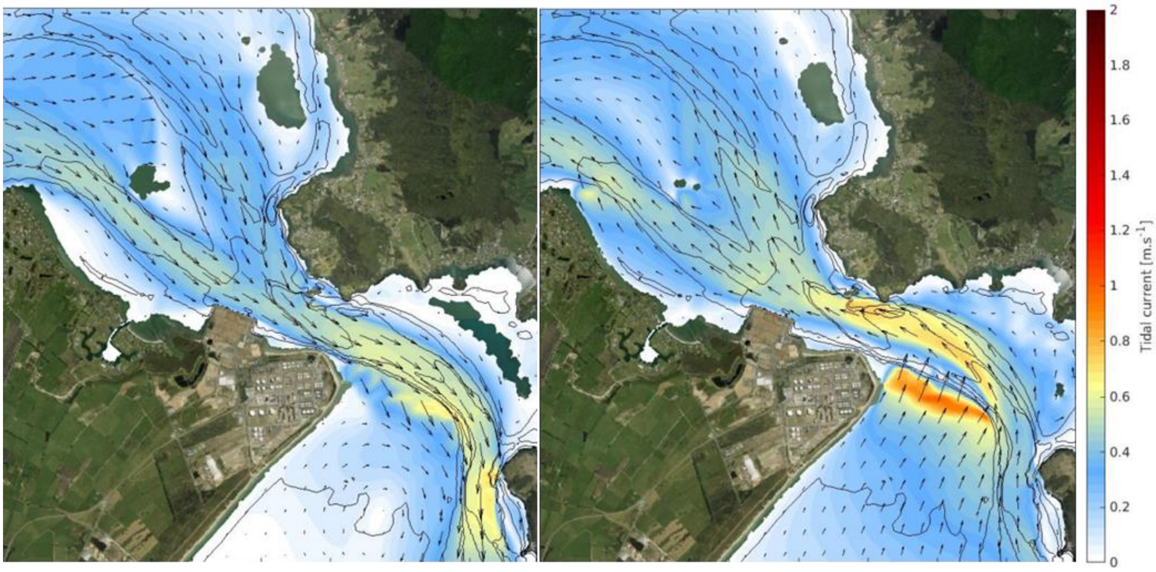

Figure 3-10: Modelled maximum ebb (left) and flood (right) neap tide flows (Source: MOS, 2018a)

Detailed flood and ebb modelling around Northport (Figure 3-11) show the formation of back eddies adjacent to either side of the port. These eddies can affect sediment transport pathways. The velocity residuals (Plot C) show very slight ebb dominance around the port, but with residual velocities less than 0.002 m/s.

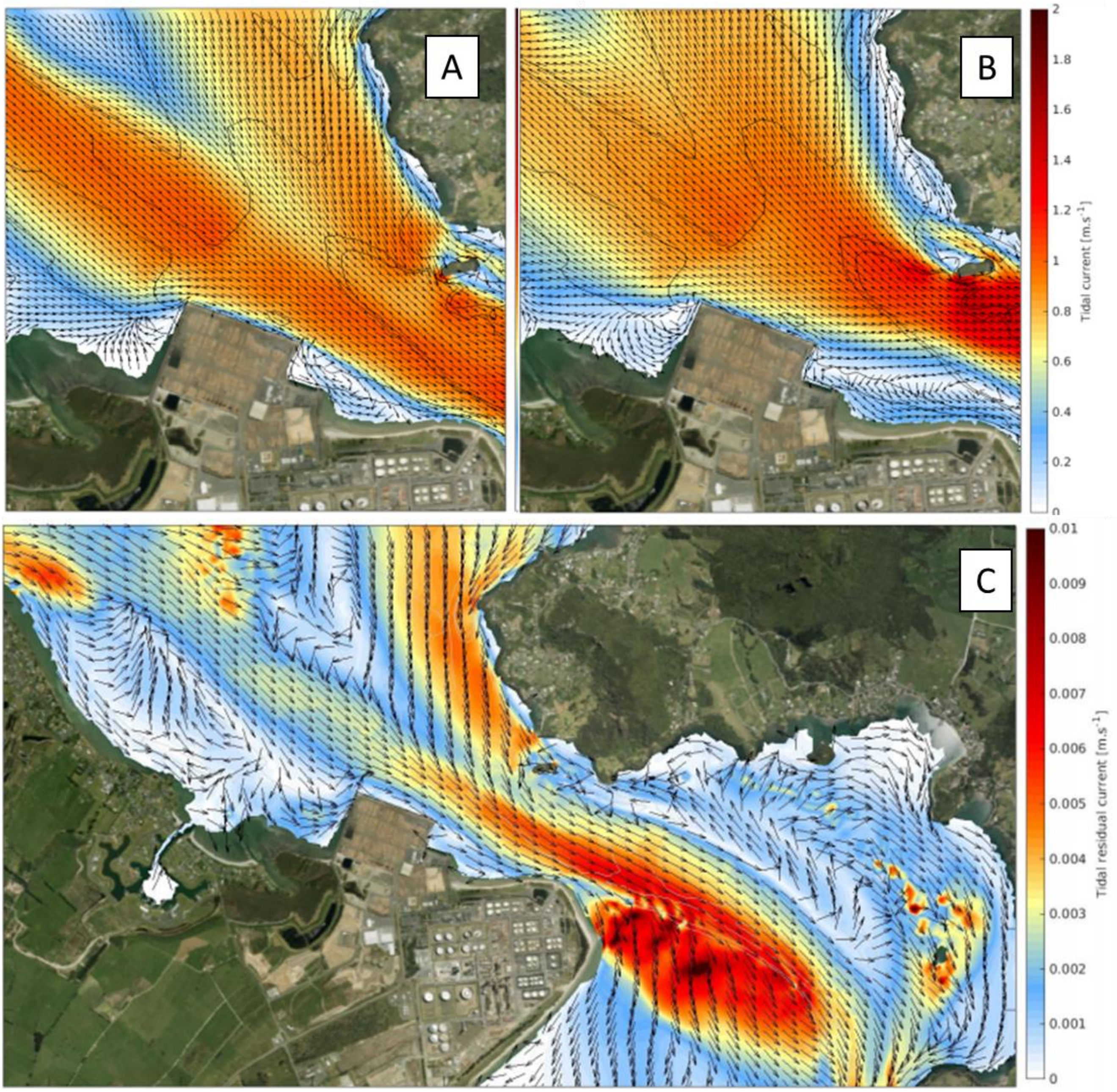

Figure 3-11: Modelled ebb (A) and flood flows (B) during spring tides showing eddies to the east and west of the port reclamation, with the difference between tides shown in (C). A and B have the same velocity scale. C has a different velocity scale (source: MOS, 2018a)

3.10 Tidal flux

Tidal flux is the rate of water flow through a defined area. Tidal flux was obtained from the tidal model at four locations as shown in Figure 3-12 extending from a transect from Marsden Point to Home Point within Bream Bay to a transect from One Tree Point to Reserve Point. Tidal flux was calculated for spring and neap conditions for both flood and ebb tides. The result of this analysis is shown in Table 3-5. The results show tidal flows are predominantly ebb dominated, with higher peak ebb flows than flood flows apart from the more open coast transect from Marsden Point to Home Point, where flux is slightly flood dominated.

Figure 3-12: Location of transects (yellow lines) to calculate tidal flux

Table 3-5: Changes in peak tidal flux

Tide stage	Transect location	Tidal flux (m^3/s)		
		Ebb	Flood	Difference
Springs	One Tree Point	9,778	8,823	955
	Northport	12,773	11,657	1,116
	CINZ Jetty	12,439	12,187	252
	Marsden Point to Home Point	16,378	13,411	2,967
Neap	One Tree Point	4,614	3,601	1,013
	Northport	5,876	4,650	1,226
	CINZ Jetty	6,241	4,555	1,686
	Marsden Point to Home Point	6,369	6,487	-118

3.11 Sediment transport trends

Tidal currents, waves and winds can cause movement of sediment on the seabed. Figure 3-13 shows a series of images from the mid-70s to 2020 of the coastline and intertidal area adjacent to Northport. Prior to the port there was evidence of sandy beaches along the shore and a shallow (expected to be intertidal) flood tide spit feature that extended along the deeper part of the channel. This flood spit feature is evident both to the east and west of the port in subsequent photos (see Figure 3-13). The continued evidence of this feature shows that the port appears to have had relatively minor impact within Marsden Bay and Blacksmith Creek, with the presence of the spit still evident along the edge of the channel. The shell bank at the entrance to Blacksmith Creek may have moved slightly landward and straightened from 2010 to 2020, but still appears to maintain its form. There has been sediment accumulation along the shoreline to the east of the port. This appears to be a combination of the welding to shore of an ebb tide inter-tidal spit that was evident along the edge of the channel as well as sediment transported into the harbour inlet from the edge of the outer channel area.

MOS (2018b, 2022b) carried out a morphological model study for the existing situation using the inputs of the hydrodynamic modelling to develop a typical tide stage and schematised waves conditions that was continuously run to calculate seabed changes that could occur over one year. Figure 3-14 shows the result of their assessment of annual change for the existing situation and Figure 3-15 shows a difference plot of bathymetric surveys taken in 2014 and 2017.

The model study shows similar trends of erosion and sedimentation with the measured changes and information from the aerial imagery. The model results show relatively small changes in depth over a year (i.e., less than ±0.3 m over the year). The most significant changes occur at the distal end of Snake Bank, where sand wave migration can be seen, which is represented by parallel areas of accretion and erosion as the ebb tide flow cause these sand waves to move along the seabed and some slightly higher accretion at the western extent of the Port area. There is also slight accretion along the intertidal channel along Marsden Bay, at a similar location to the subtidal bar evident in the aerial imagery, as well as accumulation between Northport and the CINZ jetty. The numerical modelling appears to be representing the observed physical changes well.

Figure 3-13: Satellite and aerial photograph imagery showing morphological change along the coastal edge adjacent to Northport

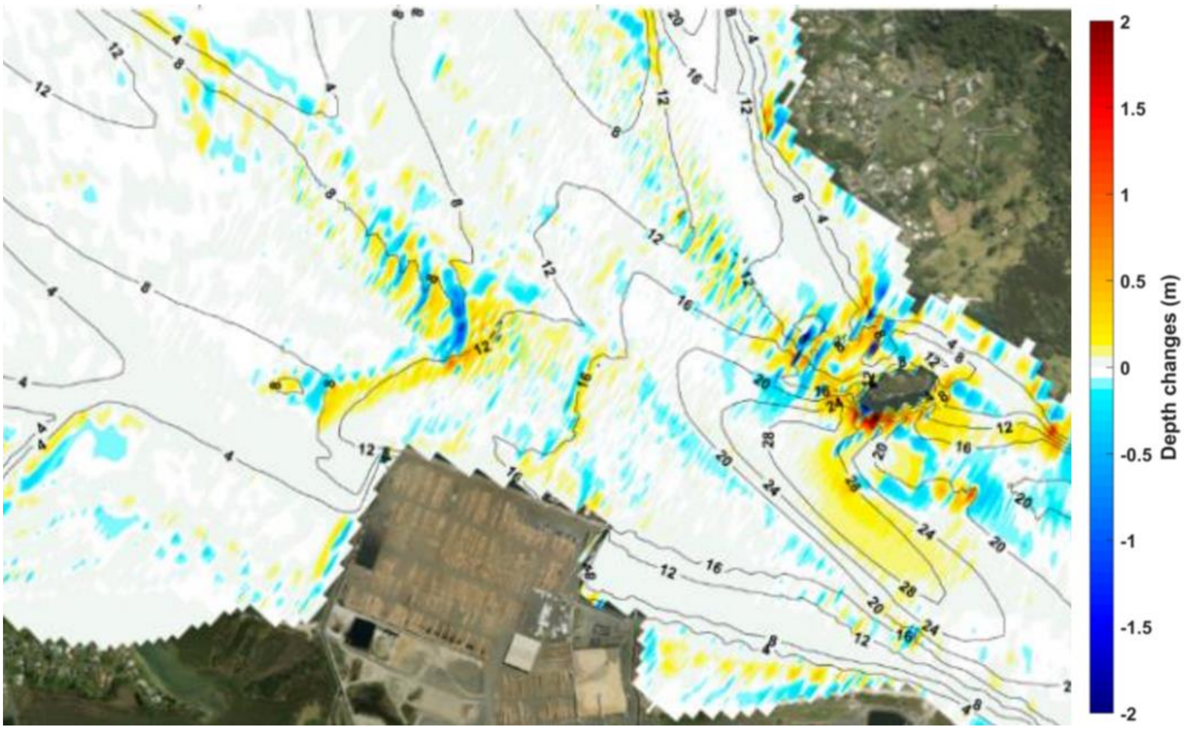

Figure 3-14: Modelled morphological response for the existing situation (Source: MOS, 2022b)

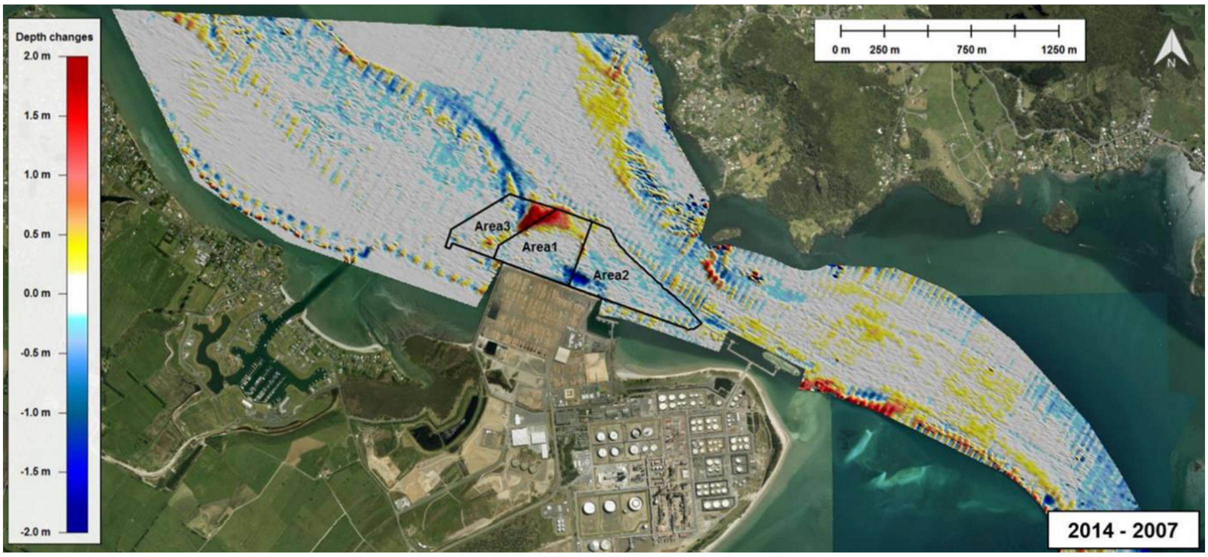

Figure 3-15: Measured seabed changes based on hydrographic surveys from 2014 and 2017 (Source: MOS, 2081b)

3.12 Tsunami

Northland Regional Council contracted NIWA to undertake an initial study on the risk of tsunami inundation facing communities in the Northland Region (Arnold et al., 2011). Two credible sources were modelled: one for a South American origin with a return period 50-100 years, and a less frequent tsunami event with moment magnitude scale (M*) 8.5 and M* 9.0 from the Tonga/Kermadec Trench. The return period of the Tonga/Kermadec Trench events is much longer (500-2000+ years) and represents a worst-case scenario for a tsunami striking the Northland coast.

The study investigated tsunami propagation into the Whangarei Harbour using computer simulation. Inundation modelling was performed assuming that the tsunami arrives at Mean High Water Spring

(MHWS) and for MHWS + 50 cm to assess potential effects of sea level rise. Results of the MHWS inundation depth and velocity plots are included in Appendix B.

These results show relatively low levels of inundation in the vicinity of the harbour entrance and that inundation is greater for the South American tsunami. Similarly, velocities within the tidal inlet are higher, with velocities of up to 3 m/s, approximately double the tidal velocities. The additional 0.5 m of sea level rise from climate change results in small increases in velocities.

The large velocities can cause large scale changes to the physical system. This is likely to manifest in scour along the inlet and along Mair Bank and deposition both within the inner harbour and offshore. Over time a proportion of the transported sand may return to the ebb tide shoal system, but there may also be some volume that is not able to be returned as it may either be too far up on the inner harbour system, or in too deep water within Bream Bay. Even in the present-day situation this is likely to require inspection of the channel and inlet to confirm the safe operability of vessels accessing the port and jetty and it is likely that some maintenance dredging may be required to maintain operability.

3.13 Climate change effects

Climate change effects include changes to sea level and potential effects on storms, wind, storm-tide, and wind.

3.13.1 Sea level rise

Historic sea level rise in New Zealand has averaged 1.81 ± 0.05 mm/year from around 1900 to the present, with the rate doubling to 2.44 mm/year for the period 1961 to 2018 compared to data from 1900 to 1960 (Bell and Hannah, 2019). The more recent rate is like the Marsden Point data that exhibiting a rate of 2.2 ± 0.6 mm/year.

The MfE (2017) guideline recommends four SLR scenarios to cover a range of possible sea-level futures. The scenarios are based on the scenarios included in the AR5 IPCC report (IPCC, 2013) (Figure 3-16).

- Low to eventual net-zero emission scenario (RCP2.6 median projection).
- Intermediate-low scenario (RCP4.5 median projection).
- High-emissions scenario (RCP8.5 median projection).
- Higher extreme H+ scenario, based on the RCP8.5 83rd percentile projection from Kopp et al. (2014).

IPCC has produced the latest climate change projections (IPCC AR6, 2021). This has been downscaled by NIWA (NZ SeaRise Programme). The new assessment includes five emission scenarios with the 2.6, 4.5 and 8.5 scenarios that are similar, but not the same, as the AR5 report. The modelling projects slightly more warming for a given pathway than AR5 scenarios. This means that there may be slight increases in sea level rise of in the order of 10 to 20cm at 2150 for the extreme (8.5) scenarios.

The modelling also includes the potential for a low likelihood, high consequence event of marine ice cliff instability (MICI), although this scenario is characterised by deep uncertainty due to limited process understanding and limited availability of evaluation data. If this event does occur, sea level changes could be in the order of 2 to 5m at 2150.

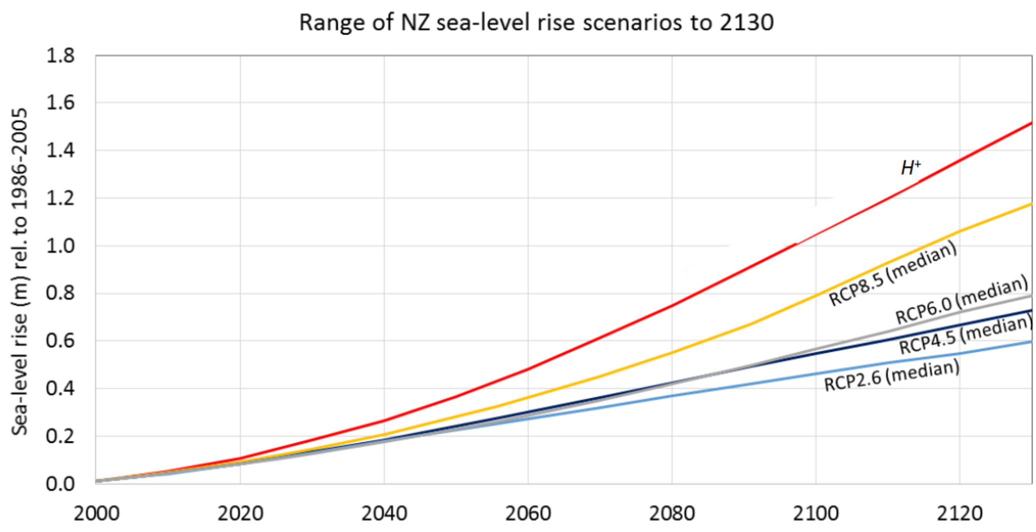

Figure 3-16: Range of SLR scenarios to 2130 (Stephens, 2017)

3.13.2 Climate change effects on storms, winds, storm tide and waves

NIWA has investigated possible future changes to storm surge and wave climate around New Zealand for present day conditions and then with future scenarios of climate change based on the IPCC emission projections. The results of this assessment suggest the southern New Zealand region would expect only small increases in mean annual wave height (generally less than 2 to 3%) with slight increases on the western and southern coasts, but small decreases in mean wave height elsewhere. For the extreme wave height increases of between 0 to 5% could be expected with a lower likelihood of increases up to 15%.

3.13.3 Proposed design levels

The stated design life of the wharf structures is 50 years with the ability to do upgrades to extend the structures for another 50 years. The proposed wharf and reclamation crest level is 5 m CD which is around 2 m above present day Highest Astronomic Tide and around 1.6m above the 1%AEP storm surge level of 3.42 m CD (1.67m NZVD2016 as shown in Table 3-3).

Based on the RCP8.5(M) projection, sea levels will increase by 0.55 m in 2080 and 1.18 m at 2130 (MfE, 2017) with up to 1.52 m increase for the RCP8.5+ trajectory. The wharf and reclamation crest levels will be above these water levels, although the soffit of the wharf deck could be regularly inundated during tidal conditions from 2080. Therefore, raising of the wharf level and reclamation levels between 50 and 100 years is likely to be required for operability reasons if these predicted levels occur.

4 Coastal processes

4.1 Definitions and key processes

A tidal inlet includes the narrow entrance channel together with the intertidal and submarine deltas that can form at one or both ends of the entrance channel (Hume and Herdendorf, 1987). The major morphological units are (refer Figure 4-1):

- Ebb tidal delta – this covers the seaward part of the inlet and includes the main ebb channel, swash bars and marginal flood channels. It represents a volume of sediment stored on the seaward side of the inlet entrance. It is formed mainly by tidal currents and waves.
- The narrow deep channel at the inlet entrance (throat/gorge).
- Flood tide delta, typically comprising a shield of sand that develops in the tidal basin landward of the throat, including flood channels, tidal flats, and ebb spits.

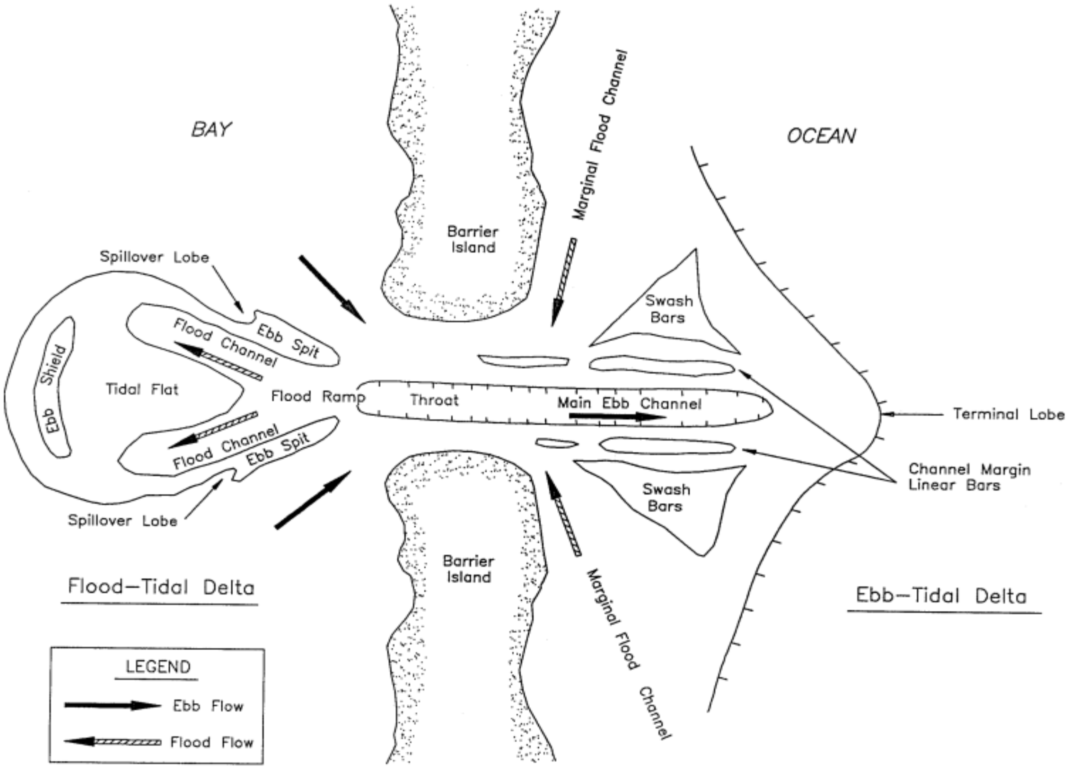

Figure 4-1: Definition of a conventional tidal inlet (USACE, 2008)

Based on the classification of Hume and Herdendorf (1985), Whangarei Harbour inlet can be classified as a single spit enclosed estuary of fluvial origins. The Mair Bank and Calliope Bank are swash bars that are formed largely within the intertidal and subaerial parts of the ebb tide delta.

4.1.1 Locational stability

Morphological stability of tidal inlets has two main components: location stability and cross-sectional stability. Locational stability describes the lateral migration of the channel, and cross-sectional stability relates to the variability of the cross-sectional area and its relation to tidal flow characteristics. The inlet to Whangarei Harbour is situated in the lee of the Tertiary volcanic rock Whangarei Heads and, as such, is reasonably stable in terms of position, with the main controls on the ebb tide delta size and shape being a function of the tidal flows into the harbour, the incident wave direction, sediment grain size and the alongshore drift rate (Figure 4-2).

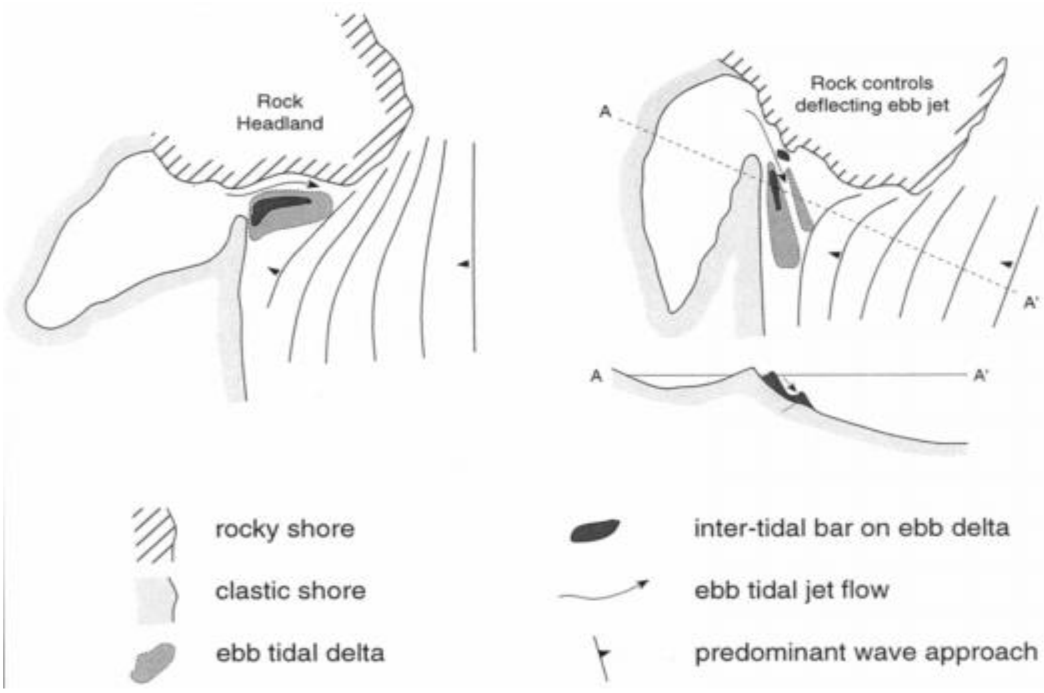

Figure 4-2: Schematic diagrams depicting controls on ebb delta size and shape for half delta inlets (Hicks and Hume, 1996)

The key characteristics of the tidal inlet and ebb delta at the entrance to Whangarei Harbour are summarised in Table 4-1.

Table 4-1: Characterisation of the Whangarei Harbour tidal inlet and the ebb delta (Hume and Herdendorf, 1988)

Ebb delta sand volume (10^6 m^3)	168
Ebb delta shape	High-angle half delta
Mean spring tidal range (m)	2.1
Mean Spring tidal prism, Ω ($10^6 m^3$)	155
Throat width at mean tide (m)	790
Throat area at mean tide (m^3)	14,600
Mean throat depth (m)	18.5
Ebb jet angle (Deg)	55
Beach slope to 10 m depth contour	0.0111
Annual net littoral drift, M_{total} (m^3/year)	20,000
Ebb delta length/breadth ratio	1.6
Average sand size, d_{50} (mm)	0.17
Wave energy factor ($m^2 sec^2$)	22
Daily mean runoff (m^3/sec)	1
Ω/M_{total} ratio	7,750 (> 150, good flushing and little bar formation)

A study of wave refraction patterns in Bream Bay showed the Whangarei Harbour inlet entrance emerges in a zone of low energy that provides natural stability to the inlet (Duder & Christian, 1983) due to the sheltering effect of Whangarei Heads from northern and eastern wave energy.

There is a large volume of sand storage, and this directs tidal flows against the volcanic rocks of Whangarei Heads. Annual net littoral drift of 20,000 m^3 per annum is a relatively small value for an open coast location. However, based on observations of movement of the Ruakaka River entrance to the south, there is little evidence of pronounced trends of movement, either to the south or north, also suggesting a small net littoral transport rate. These low transport rates indicate the local wave climate effects and the influence of the sheltering effect of Whangarei Heads play a significant part in the formation of the ebb tide delta.

The ebb delta and flood tide shoals are supplied by small amounts of northerly directed alongshore transport. A key observation from Table 4-1 is that the tidal prism, is large ($155 \times 10^6 m^3$) in relation to the net littoral drift (20,000 m^3/year). The ratio of tidal prism to net littoral drift, introduced by Bruun and Gerritsen (Bruun, 1978) relates these two important parameters that control inlet stability. The resulting ratio of 7,570 is significantly greater than the threshold of 150 that was determined by Bruun and Gerritsen to characterise good flushing and little bar formation on the ebb delta. This suggests the delta should be very stable with good flushing and little bar formation. This is confirmed by the bathymetric survey data that shows very little change in bathymetry in the outer parts of the ebb tide delta.

Based on an average suspended sediment concentration of 6 mg/L within the harbour entrance and the tidal prism of $155 \times 10^6 m^3$, the suspended tidal flux entering and departing the harbour is approximately 360 m^3/tide. There are around 715 tides per year, so the annual tidal flux of 257,600 m^3/yr. is an order of magnitude greater than the net littoral drift, confirming the dominance of tidal effects over wave driven sediment transport at Marsden Point.

4.1.2 Inlet cross sectional stability

4.1.2.1 Empirical relationship assessment

The inlet cross-sectional stability is often evaluated based on the relationship between the tidal prism and cross-sectional area of the inlet. Figure 4-3 shows the results of the relationship for Whangarei Harbour in relationship with other New Zealand inlets. This figure indicates that the inlet is stable with no significant trend to erosion or deposition in the inlet.

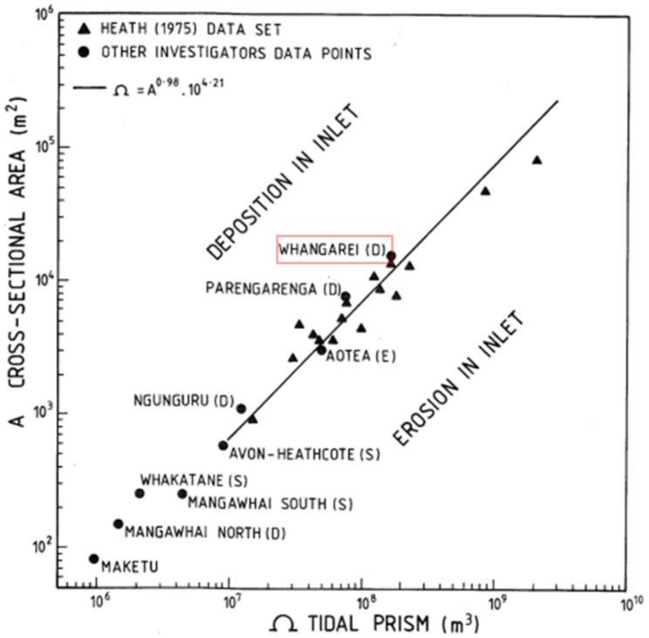

Figure 4-3: Stability of New Zealand tidal inlets using Heath (1975) relationship (Source: Hume and Herdendorf, 1985)

4.1.2.2 Previous assessments and modelling studies

Stability of the harbour entrance has also been attributed to the presence of shell material, which provides an armour layer protecting the underlying soft sands. This was confirmed by Healy and Black (1982) who investigated sediment transport in Marsden Point and concluded the shell lag present on much of the inlet rarely moves, even in spring tide conditions, and that much of the bed have an aged appearance with the shells being covered by algae, a testimony to the stability of the sediment and the low rates of sand supply by alongshore drift. Morgan, et al. (2011) and Kerr and Associates (2016) also identify the role of shells in the long-term stability of the ebb tide delta and Mair Bank.

4.1.2.3 Bathymetric survey assessments

The comparisons of bathymetric surveys carried out by Healy and Longdill (2007) revealed that the lower harbour is very stable with essentially no change to bathymetry in many areas over a 20-year interval. Recorded tidal flows were found to be faster than the threshold speed for typical sandy sediments, but insufficient to disturb lagged shell beds (Black et al., 1989). Previous studies suggest that suspended sediment transport in the lower harbour is low and that most of sediment transport in the channels and channel margins occurs as bed load (Longdill and Healy 2007).

Analysis of bathymetric surveys was carried out by MetOcean Solutions (2018b) from 2007 to 2017 (Figure 4-4). This figure shows a difference plot of the surveyed seabed between 2007 and 2014 and then more recent changes between 2015 and 2016 and 2016 and 2017. Generally, there is relatively small changes in seabed levels, with many of the inferred changes over the longer period (2007 to 2014) a result of known survey inaccuracies. However, there is also some evidence of sand wave migration from Snake Bank into the port area and some local scour and deposition around the faces and corners of the port reclamation. The more detailed annual comparisons of 2015-2016 and 206 and 2017 more clearly show the sand ripple migration that is occurring as tidal flows move the bed forms present on the seabed. Since there have not been significant changes to the bathymetry since that time, the findings from the earlier studies and empirical assessment findings support the findings of a stable inlet.

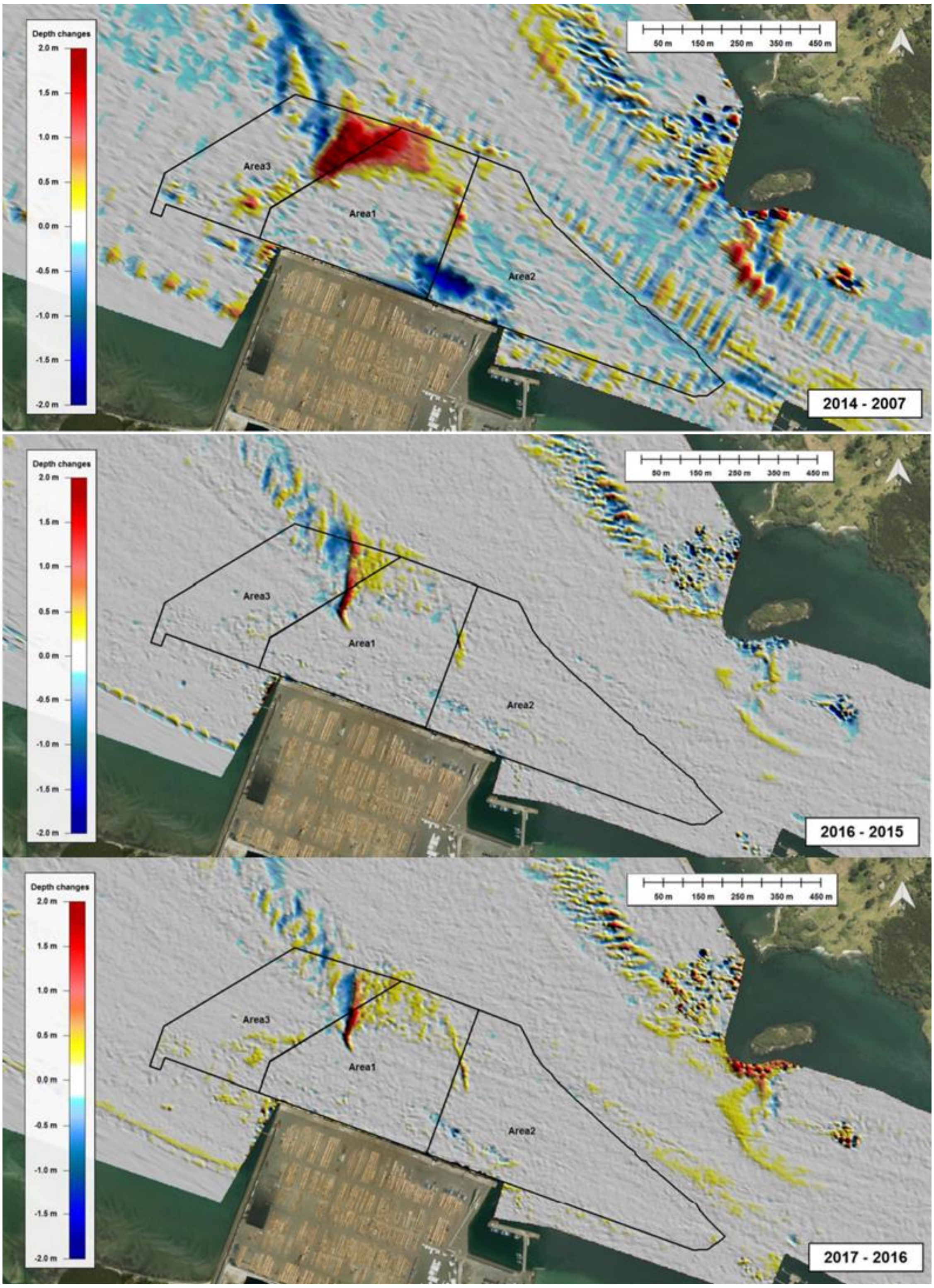

Figure 4-4: Difference plots from bathymetric surveys taken in 2007, 2014, 2015, 2016 and 2017 showing relatively minor changes to seabed in the port area (Source: MetOcean, 2018b)

4.1.3 Mair Bank stability

Due to a Pipi population decline on Mair Bank over recent decades, there has been a number of studies specifically looking at the stability of Mair Bank. Morgan et al. (2011) analysed digitised aerial photography of Mair Bank over 56 years to determine multi-decadal changes in the position and planform configuration of major morphological units (refer Figure 4-5). It was identified that the footprint of Mair Bank has remained constant over this time period, but significant changes in surface morphology have occurred with dynamic sediment reworking. These changes were largely above chart datum, while contours below 5 m Chart Datum were largely unchanged.

The dynamics of the surficial sediment are illustrated by western end of the seaward shell swash bar migrating landward at an average rate of 10m/yr. between 1950 and 2006. Morgan et al. (2011) also calculated the largest subaerial change in sand storage volume occurred between 2003 and 2006, when volume increased from 1.107 x 10^5 m^3 to 1.690 x 10^5 m^3. The change in volume is around 60,000 m^3, or 20,000 m^3/yr. and equivalent to the full amount of net littoral transport estimated by Hume and Herdendorf (1985). In terms of material accumulation over the extent of the ebb delta, this equates to a uniform bed level rise of 10 cm across Mair Bank, or a 1.3% increase in total volume of the bank.

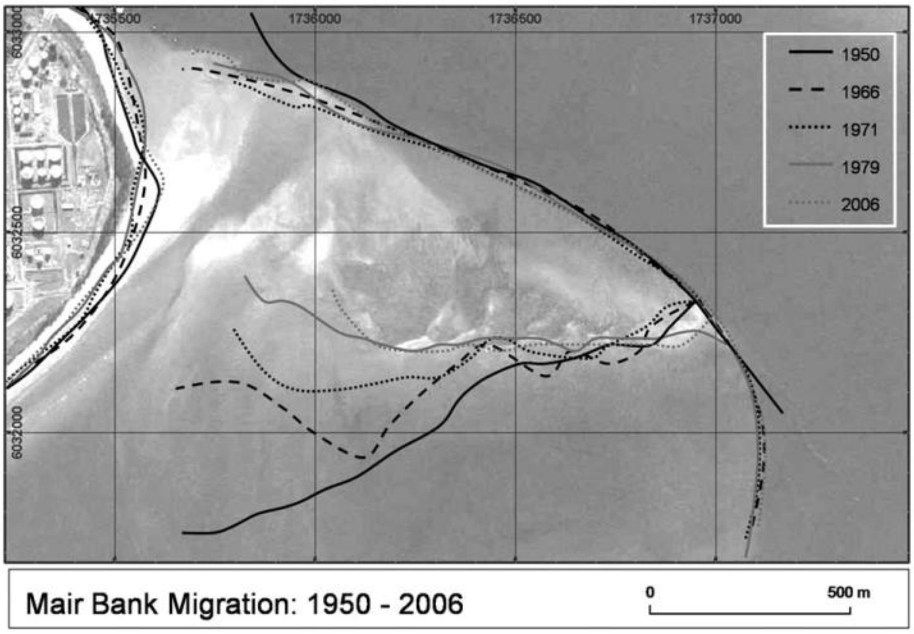

Figure 4-5: Mair Bank morphological changes from 1950 to 2006 based on interpretation of aerial photographs using the wet beach line along the coast, the northern boundary of Mair Bank and the crest of the southern seaward shell swash-bar as proxies to estimate changes over time (source: Morgan et al. 2011)

The Morgan et al. (2011) study also confirms that minor changes in delta configuration have been shown to have pronounced effects on the erosion and accretion of adjacent shorelines (Oertel, 1977), particularly if the changes result in consequential impacts to wave energy and direction arriving at the coast. Consequently, the geomorphic stability of these sand bodies is important to adjacent shoreline morpho dynamics, as reduction in size, a change in position or loss of sediment volume have the potential to alter physical processes acting on the coast and promote coastal change.

4.1.4 Ebb tide delta stability

An assessment of the stability of the ebb tide delta has been made by comparing the 5 m, 10 m and 15 m depth contours from 1939 to 2015 (refer Figure 4-6 and Figure 4-7).

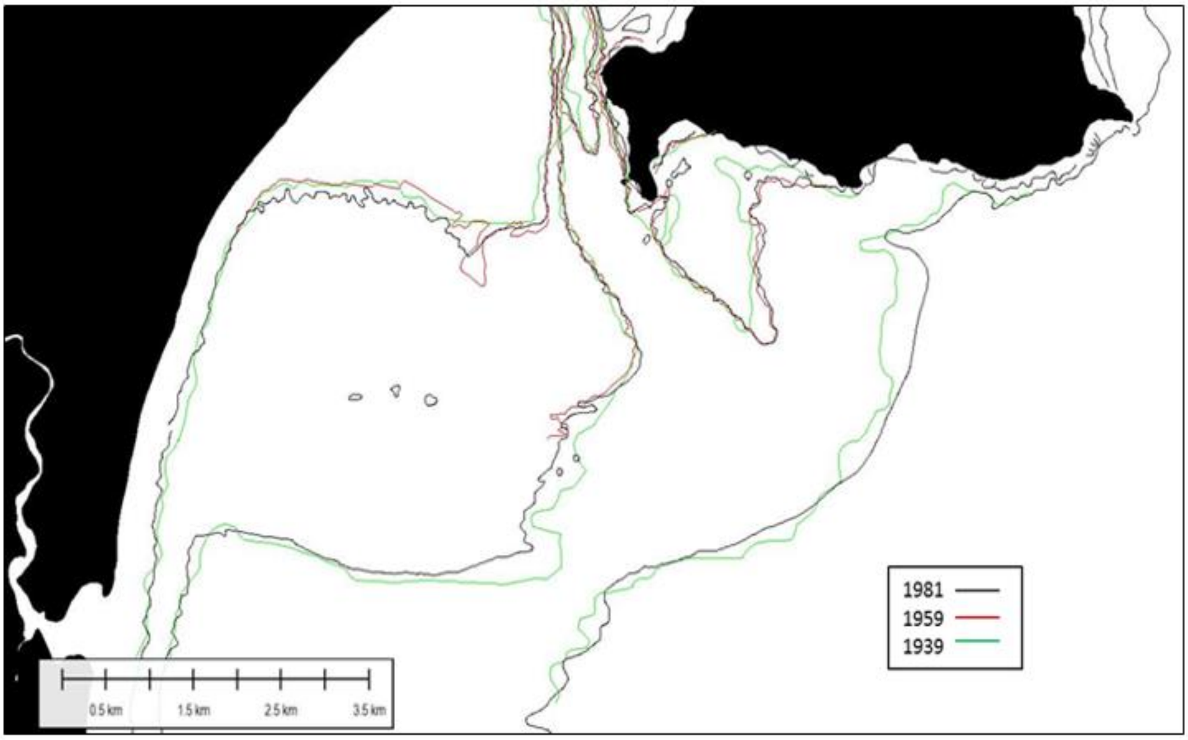

Figure 4-6: Historic changes at the 5 m,10 m and 15 m depth contours from 1939 to 1981

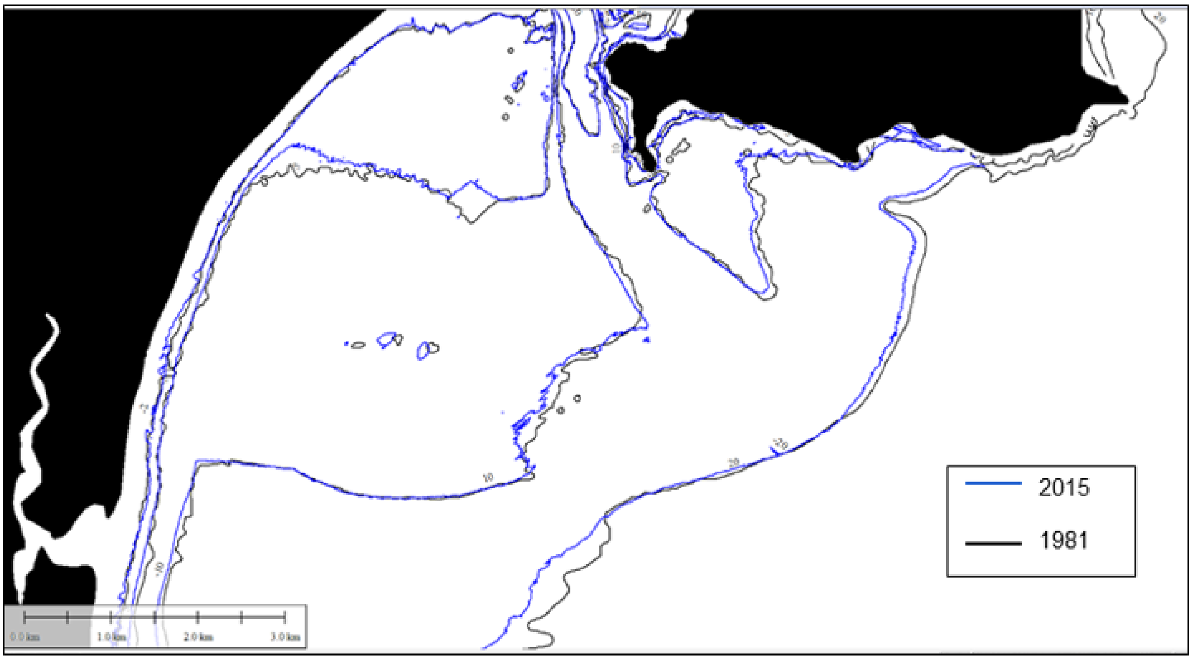

Figure 4-7: Historic changes at the 5 m,10 m and 15 m depth contours from 1981 to 2015

The resulting analysis shows that over the 76-year period there has been no significant change to the ebb tide delta or the approaches below the 5 m depth contour. This stability has remained despite both anthropogenic (human induced) and natural changes within the harbour. There appears to be more change occurring above the 5 m depth contour and this is considered in the following section.

4.1.5 Stability of the inner harbour

The lower harbour sediment dynamics are consistent with established patterns for tide-dominated inlets, with separation of the channel into areas of ebb and flood dominance, and typical transport patterns over the flood tidal delta. Broad-scale inlet geomorphology has been maintained, which is consistent with other dredged tide dominated inlets (Longdill and Healy, 2007). Concentrations of shell gravel lag were found to play an important stabilising role in determining the overall characteristics of the inlet stability and sediment dynamics (Longdill and Healy, 2007).

The comparisons of bathymetric surveys carried out by Longdill and Heally (2007) revealed that the lower harbour is very stable with essentially no change to bathymetry in many areas over a 20-year interval. Recorded tidal flows were found to be faster than the threshold speed for typical sandy sediments, but insufficient to disturb lagged shell beds (Black et al., 1989). Previous studies suggest that suspended sediment transport in the lower harbour is low and that most of the sediment transport in the channels and channel margins occurs as bed load (Longdill and Healy 2007).

Residual distance vectors computed by Longdill and Healy (2007) in the lower harbour indicate that between 2002 and 2007 (i.e., post NorthPort developments), the large-scale pattern of sediment transport dynamics remained consistent. Minor and localised modification of transport potentials were observed immediately adjacent to the NorthPort developments. These modifications included a slight realignment of current flows near the reclamation wall and some leakage from a previously identified transport loop near the dredged basin. The potential for scour was identified by Longdill and Healy (2007) along the eastern margin of the dredged basin, and they suggested this could remove material moving downslope into the basin from its western edge. The observations were consistent with the earlier numerical model results that predicted minimal consequences resulting from the developments (Black and Healy, 1982). Since there have not been significant changes to the bathymetry since that time, the findings from the earlier studies are still valid.

Sediment transport pathways were inferred by Black et al. (1989) from observations and numerical modelling (refer *Figure 4-8*). According to their results, there is a net ebb imbalance in the lower harbour southern end, and they suggested that deposition as a result of the NorthPort developments should be minimal, which is in general agreement with the modelling carried out by MOS (2016b).

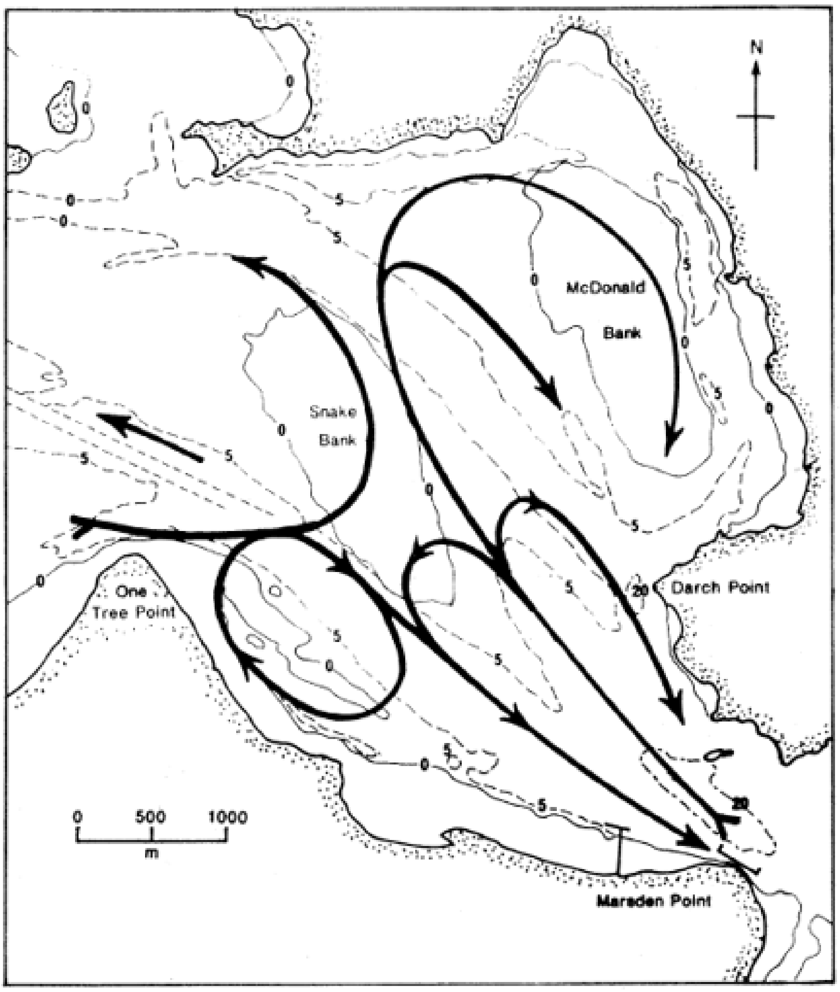

Figure 4-8: Schematic diagram showing sediment transport pathways within Whangarei Harbour based on residual velocities (Source: Black et al., 1989)

4.1.6 Changes to the open coast beaches from Mair Bank to Ruakaka River mouth

The open coast beaches along the shoreline of the ebb tide shoal to the Ruakaka River mouth have been experiencing low rates of erosion over the last few decades. Erosion in this location is likely to be a result of insufficient sand transported alongshore or increases in sand transport from this area to the tidal inlet and inner harbour areas.

The assessment of existing survey data has shown that while the ebb tide delta is dynamically stable below 5 m CD, there has been a recent northward shift in sand volumes and a loss of sand from the southern part of the ebb tide shoal with an associated lowering of levels. This lowering of the seabed close to the open coast beaches results in greater wave energy (higher waves) arriving at the coast. The lowering of the seabed may change refraction processes which may result in changes to alongshore drift as well as increase storm erosion of the beaches and dunes. This process may be contributing to the observed erosion on the open coast at Marsden Point.

4.1.7 Summary of sediment budget for the present day

Figure 4-9 shows a summary of the existing sediment budget of the ebb tide shoal system, with variability of volume due to annual fluctuations in the order of 100,000 m^3/year, sources (alongshore drift and biological shell production) and known losses (shell removal through harvesting and over wash). The resulting budget appears largely in equilibrium which supports the observations of the overall stability of the ebb tide shoal based on long term historic survey analysis.

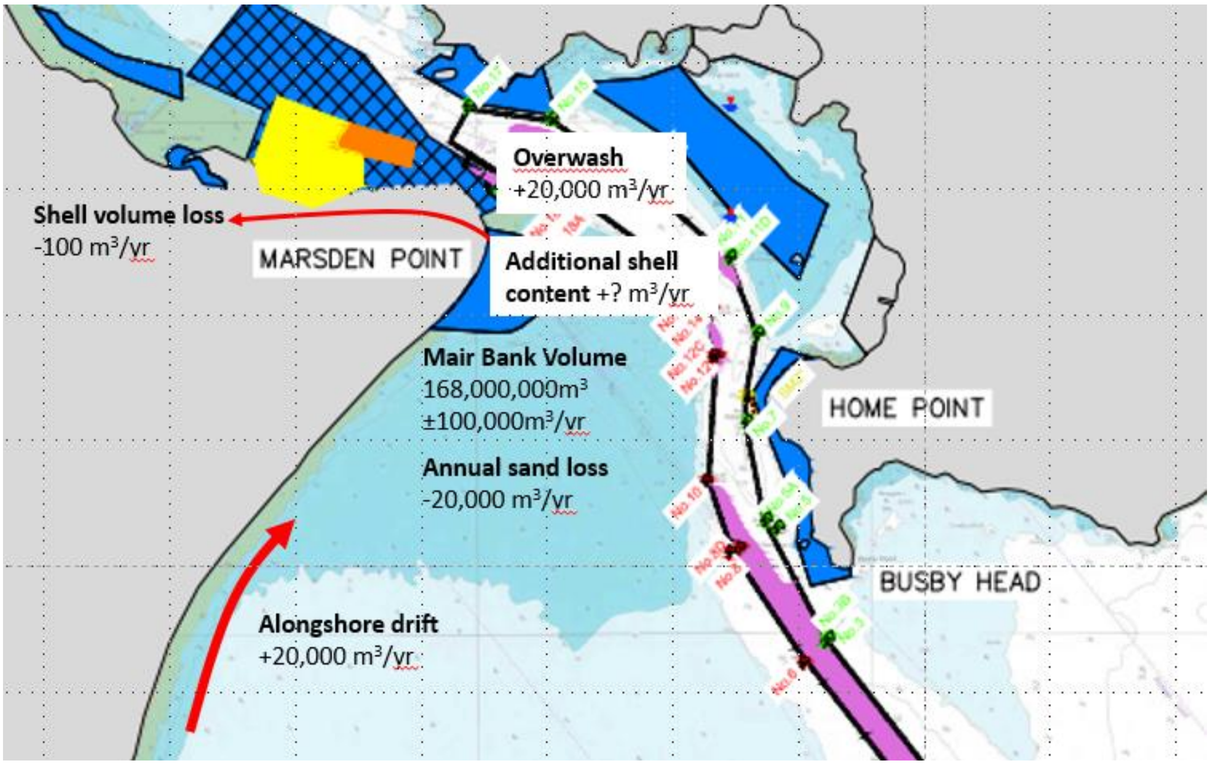

Figure 4-9: Sediment budget summary for existing situation

4.1.8 Effects of sea level rise

The results of modelling carried out by Van der Wegen (2013) suggests sea level rise can change the trend of sediment transport from equilibrium/export (little or net seaward movement of sediment) to import (sand moving into the estuary) because of sea level rise over long time periods due to changes in tidal asymmetry. The process of changing tidal asymmetry could result in removal of sediment from the ebb tide shoal into the harbour area over a period of decades to centuries of higher water levels. Unless replenished by alongshore transport, the loss of sediment from the ebb tide shoal could result in changes to the nearshore wave environment which could then lead to changes in the areas of accretion or erosion along the open coast shoreline adjacent to the ebb tide shoal.

Due to the existing climate variability that includes varying tide levels due to decadal and longer time cycles, as well as variations in annual wave climate, this process is unlikely to be noticeable over the next few decades when the projected increase in sea level rise is still within the range of annual fluctuations but may become more noticeable over a longer time frame (many decades to centuries). This change may be identified by ongoing monitoring of the coastal edge and the seabed level changes surveyed annually by the port.

4.2 Summary of coastal processes

The Whangarei Harbour entrance is stable, controlled by Whangarei Heads to the north and the large ebb delta to the south. The northward directed net longshore sediment transport on the open coast of Bream Bay is very small in comparison with the sediment flux that enters and exits the harbour because of tidal exchange. Therefore, the inlet is tide dominated, with tidal flows significantly greater than the net littoral transport which results in a stable inlet.

The seabed within the tidal inlet in the vicinity of the Port appears relatively stable, with localised areas of erosion and accretion. The main movement being relatively slow migration of sand bars from Snake Bank into the current port dredged area. The historic flood bar has progressively welded to the coast to the east of the port, and this, combined with relatively small sediment transport from the open coast, has resulted in accretion of the beach areas between the port and the CINZ jetty.

The analysis of historic bathymetric data shows that over the 76-year period there has been no significant change to the ebb tide delta with the feature dynamically stable, with natural fluctuations in the surface topography in the order of ± 1 m (vertical) and ± 2 m (horizontally) as banks and channels shift in response to storm events and tidal currents.

Ongoing and accelerated sea level rise may result in increased erosion pressure on the ebb tide shoal with changes in tidal asymmetry increasing sediment transport potential into the harbour that could increase erosion pressure along the open coast shoreline over a period of decades to centuries.

5 Assessment of effects of changes on physical coastal processes

MOS modelling and the evaluation of the change in currents and sediment transport has been done comparing the most recent bathymetric survey with the proposed development, including areas where there are already consents to modify the environment, such as the Berth 4 reclamation and some areas of dredging. This means that the changes in hydrodynamics and associated sediment transport presented in the MOS reports include for changes already allowed for. However, this approach does provide the maximum extent of likely change from the present day.

5.1 Construction effects of the reclamation and dredging

Construction elements within and adjacent to the CMA are the forming of the reclamations and the seawalls that protect them as well as the dredging to locally deepen part of the port area.

5.1.1 Reclamation and seawalls

These components will be built using a combination of land-based equipment and barge mounted equipment. The potential effects of construction of these components are diversion of tidal currents and waves due to the location of the completed structures and the occupation of the seabed and the increase in suspended sediment plumes during the construction of the seawalls. Provided the rocks used are relatively free from dirt and contaminants the likelihood of any significant sediment plume extending beyond the port development boundary is low. **Construction effects on physical coastal processes outside the port area for the reclamation and seawalls is considered negligible**.

5.1.2 Dredging

Dredging of the channel is within the predominantly fine to medium sand layers that overlies predominantly clay and silts and bedrock situated well below the base of the basin.

The sediment to be dredged is fine silty sand and is similar to the general seabed morphology in the inlet and lower harbour areas. Based on an analysis of sediment chemistry from previous investigations the dredged sediment is clean with most potential contaminant levels either below detection or within the lower range of acceptable guidance criteria (Coffey, 2016).

Modelling by MOS (2022c) shows that mean total sediment concentrations follows the main channel (see Figure 5-1). There is more sediment concentration evident with the TSHD than either the cutter suction dredge or backhoe dredge. From a coastal process perspective, the main impact of these sediment concentrations is the accretion that may occur in these areas.

The overwash and release of fines are largely limited to the dredge footprint and along the main channel immediately to the west of the dredging areas. This is illustrated in Figure 5-2 for a range of dredging methods and locations. Deposition within the dredging footprint will be addressed by the dredging plant in achieving the required dredge levels. Any sedimentation to the west is likely to return to the dredged area over time, to be recovered during maintenance dredging campaigns

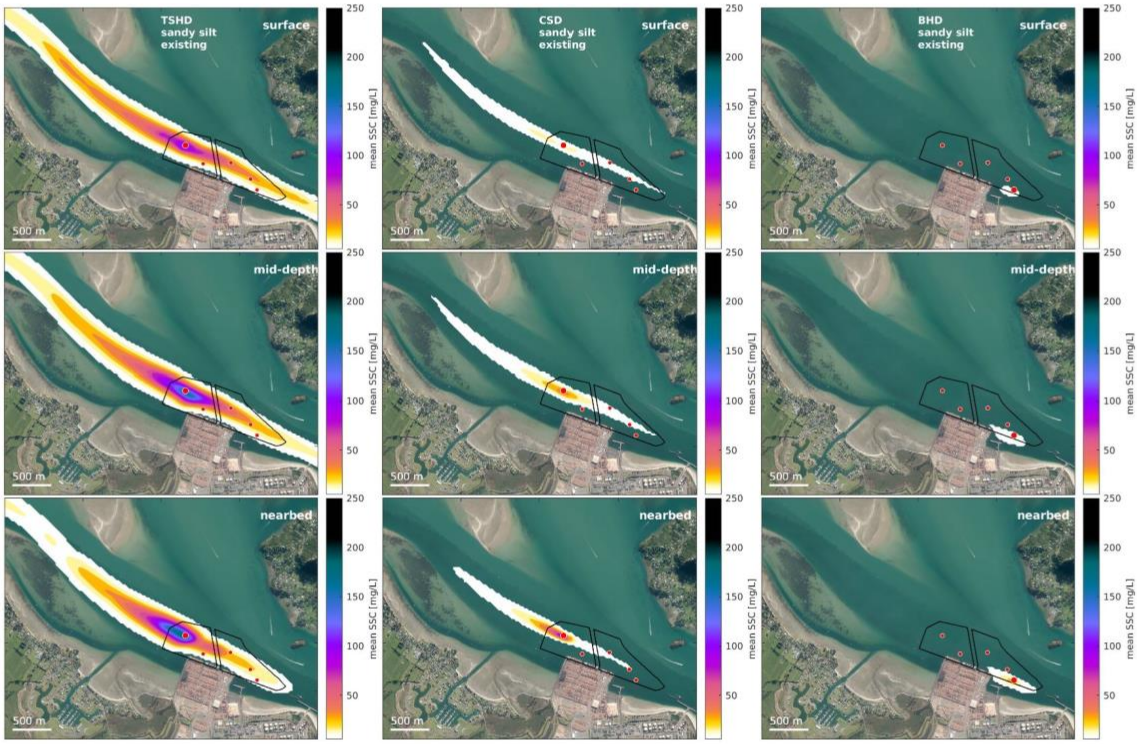

Figure 5-1: Comparison of mean total suspended sediment concentration at the surface, mid-water and near-bed levels (top to bottom) for TSHD (left), CSD (middle) dredging at the western end of the site and BHD dredging at the Berth Pocket site for the existing bathymetry assuming sandy silt (Source: MOS, 2022c)

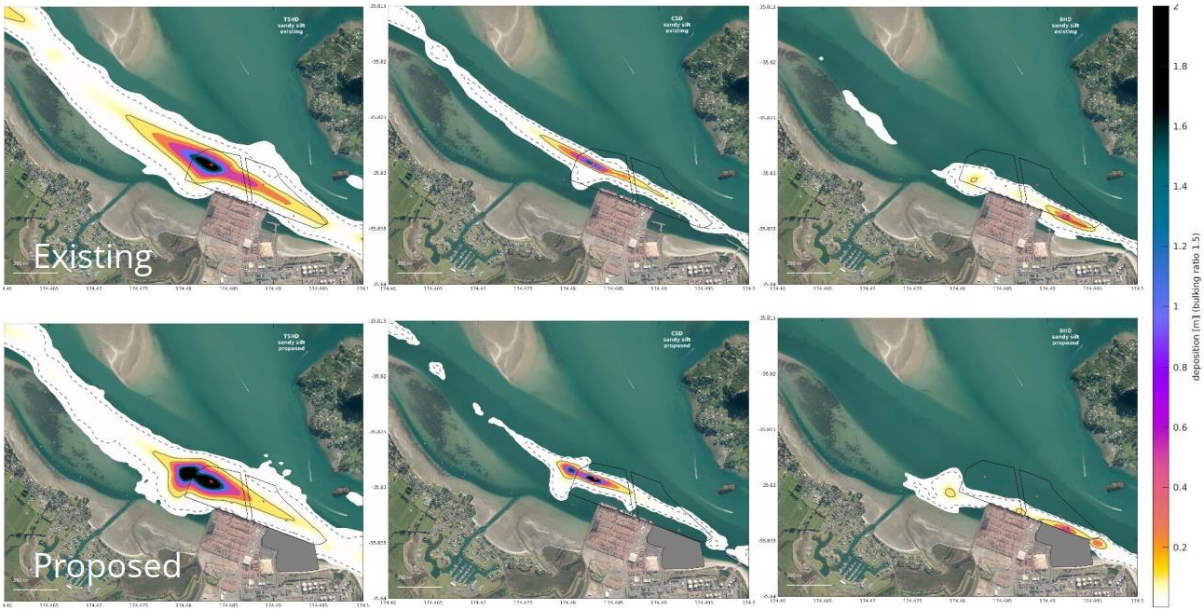

Figure 5-2: Comparison of final cumulative sediment deposition thickness for TSHD (left), CSD (middle) dredging at the western end of the site and BHD dredging at the Berth Pocket site for the existing and proposed bathymetries assuming sandy silt (Source: MOS, 2022c)

Relating the modelling with observations from previous dredging campaigns suggest the modelling may result in a conservative (upper bound) of potential effects. 4Sight Consulting who made observations from previous dredging campaigns, including the original port construction and maintenance dredging carried out in 2018 reported significantly lower values of suspended solids than predicted by the numerical modelling (4Sight, 2021). Monitoring should be included in the construction management plan to determine the actual level of plume extent and concentration. Mitigation for the potential risk could include sediment curtains around the dredge vessel, or timing limited to periods of low tidal flows, if required. **Construction effects on physical coastal processes outside the port area for dredging is considered minor**.

5.2 Long term effects of the eastern reclamation

This section summarises the changes to waves and currents in the nearshore environment resulting from the eastern reclamation and is based on our assessment of the hydrodynamic and morphological modelling carried out by MOS (2022a and 2022 b). Effects have been assessed based against the criteria set out in Appendix C that describes the definition of effects and the associated criteria.

Effects have been considered based on modelling that did not include the CINZ channel deepening project being in effect. However, MOS (2018) report on morphological response to capital dredging and land reclamation considered morphological change both with, and without, the CINZ channel deepening. They concluded there was little difference and did not expect either situation to measurably change morphological change in the vicinity of the NorthPort project. Therefore, the findings and conclusion will apply whether or not the channel deepening project is realised.

5.2.1 Occupation

The proposed reclamation will permanently occupy about 2.1 ha of beach above MHWS and around 11.7 ha of coastal marine area below MHWS. It will change these areas from sea to land and therefore coastal process within this occupation footprint will not occur. The reclamation will also extend over some 380 m of sandy beach foreshore between the port and the Refining NZ jetty permanently occupying the CMA and beach area affecting coastal process within this occupied area.

5.2.2 Waves

Northport is sheltered from the larger waves in Bream Bay (see Figure 3-8). However, the proposed reclamation extends seaward to be closer to the inlet entrance and is likely to increase wave turbulence during extreme events due to the more reflective surface of the port reclamation.

These changes in wave heights during high energy events has the potential to locally increase erosion and scour of the beach and inter tidal area between the port and the CINZ jetty. **The effect of the proposed development on waves is minor.**

5.2.3 Currents and sediment transport

Changes to currents and morphology as a result of the eastern reclamation has been modelled by MOS (2022a and 2022b) with the existing channel configuration. Modelling of currents and morpho dynamics carried out with an earlier design configuration (MOS, 2018b) both with and without the CINZ channel deepening identified that the channel deepening will not change the results of the assessment.

The comparison of tidal velocities with and without the proposed development during flood and ebb tides is shown on Figure 5-3. This figure removes small scale velocities (i.e., between -0.05 m/s and +0.05 m/s) to allow focus on the larger velocities that may have more significant consequences.

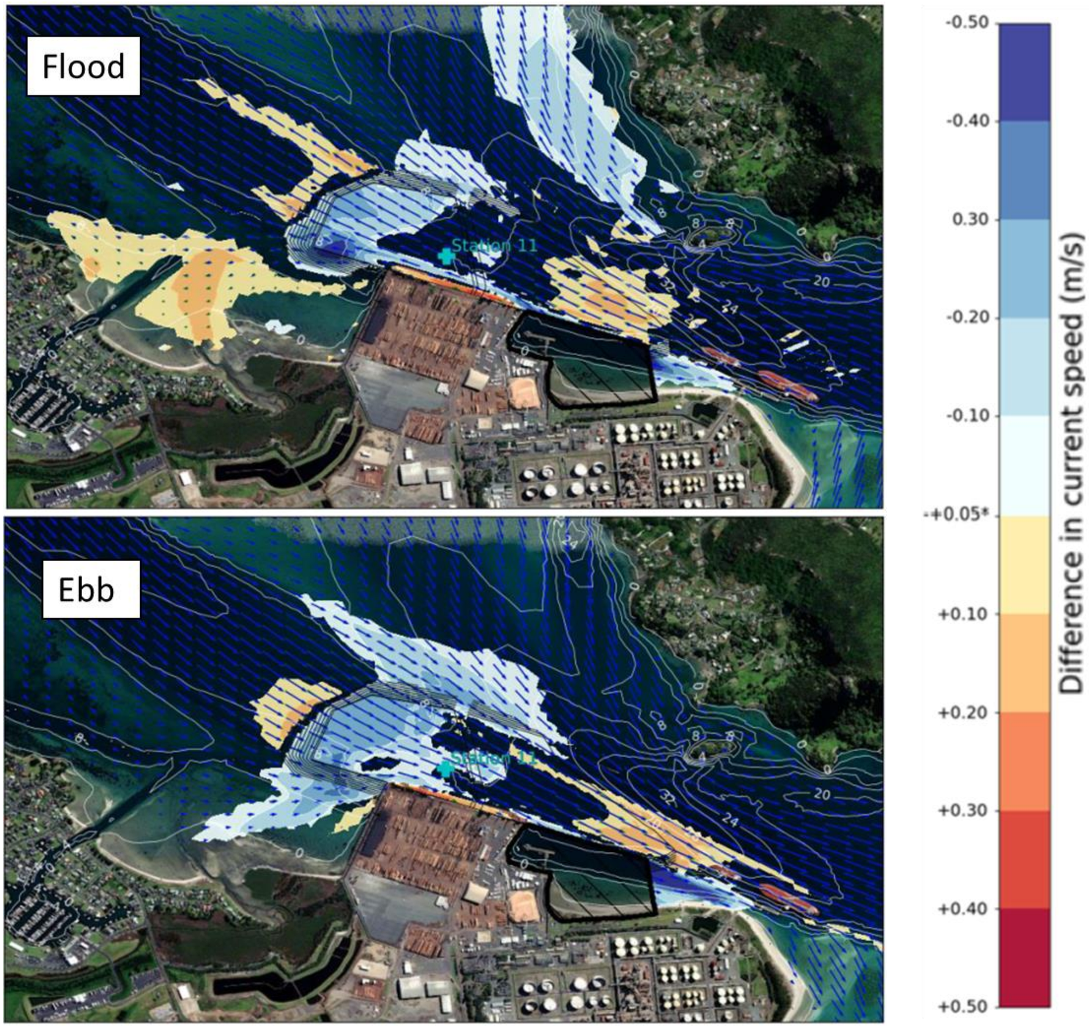

Figure 5-3: Difference in peak tidal currents during Springs with the proposed eastern reclamation over a tide cycle (Source: MOS, 2022a)

The results show reductions in tidal currents along the intertidal and side channel extents between the port and the CINZ jetty of down to 0.6 m/s immediately to the east of the reclamation, reducing in change towards the east and some slight increases or around 0.2 m/s within the base of the channel adjacent to the seaward edge of the reclamation. There is a very small increase in currents towards Marsden Bay during flood tides and a similarly small reduction during ebb tides. The modelling indicates no significant change in tidal currents east of the CINZ jetty. Within the port basin area changes in peak currents are less than 0.5 m/s.

Changes in tidal current speed at specific locations within and adjacent to the proposed development are shown in Figure 5-3 for spring tide conditions. Neap tide, with lower tidal currents exhibit similar trends, but have lower velocities. The results show that there are relatively minor changes at most locations, with the exception of points 10 and 14. Point 10 is in an area that is proposed to be deepened through dredging, and the associated reduction in velocity is to be expected due to the effective change in cross-sectional area of the channel at this location. However, the velocities are of a similar magnitude to Points 11 and 12, also situated within the dredged area. This means that seabed characteristics and morphology are likely to be similar at these locations. Point 14 is to the east of the proposed reclamation and also shows that there will be a reduction in both flood and ebb tide peak velocities due to the sheltering effect of the reclamation.

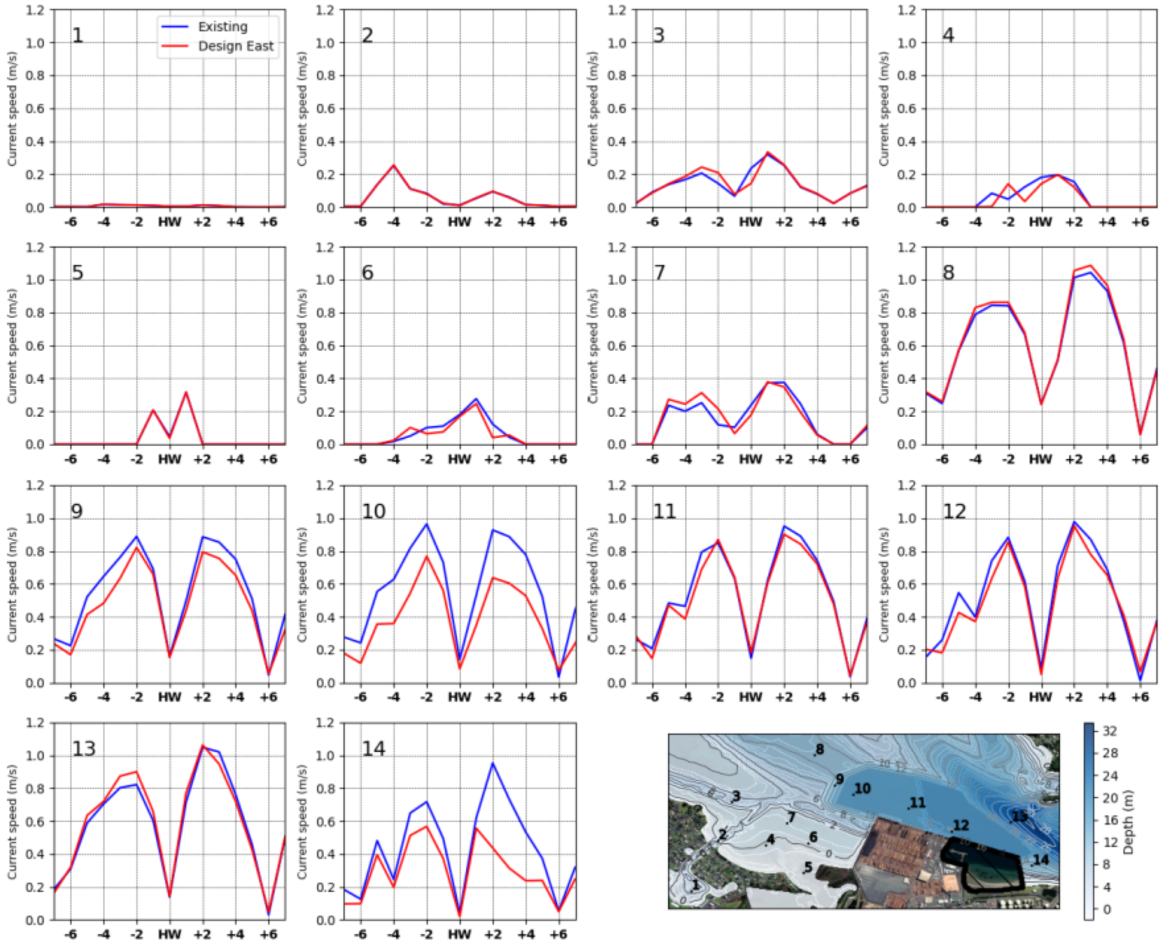

Figure 5-4: Comparison between modelled current speeds for the existing and proposed layout for spring tides (Source: MOS, 2022a)

The reduction in currents to the immediate east of the reclamation is likely to affect sediment transport patterns in this area as the reduced currents are likely to support sedimentation. An indication of the potential changes in depth changes resulting from changes in sediment transport is shown in Figure 5-5 that shows predicted depth changes over a one- and five-year period. This figure shows that most changes occur in the dredge basin. There is an indication of some erosion immediately to the west of the dredge footprint, although this is the area identified as being potentially subject to additional sedimentation from the dredge process, which may negate the likely changes in depth. The difference plots also show some general very slight changes, both indicative of erosion and deposition more broadly around the harbour. These changes are likely to be similar to depth changes evident with the migration of existing bedforms shown in Figure 4-4..

Focussing on the eastern side of the figure, the modelling shows an area of slight accretion at the eastern edge of the reclamation and along the edge of the main channel, but no significant morphological change.

Based on the morphological response taking into account the changes in velocity the results of the modelling carried out by MOS (2022b) show that the reduction in velocity that extends towards the CINZ jetty which may enable accumulation on the upper banks of the channel. Sedimentation may occur which has the potential to block stormwater outlets, access to CINZ jetty and locally increase sedimentation within the port mooring area. No significant sediment transport change is observed further to the east of the CINZ jetty. Within Marsden Bay to the west of the Port there are no significant effects. **These effects of the proposal on currents and sediment transport are assessed to be moderate within the area bounded by the eastern extent of the port and the CINZ jetty.**

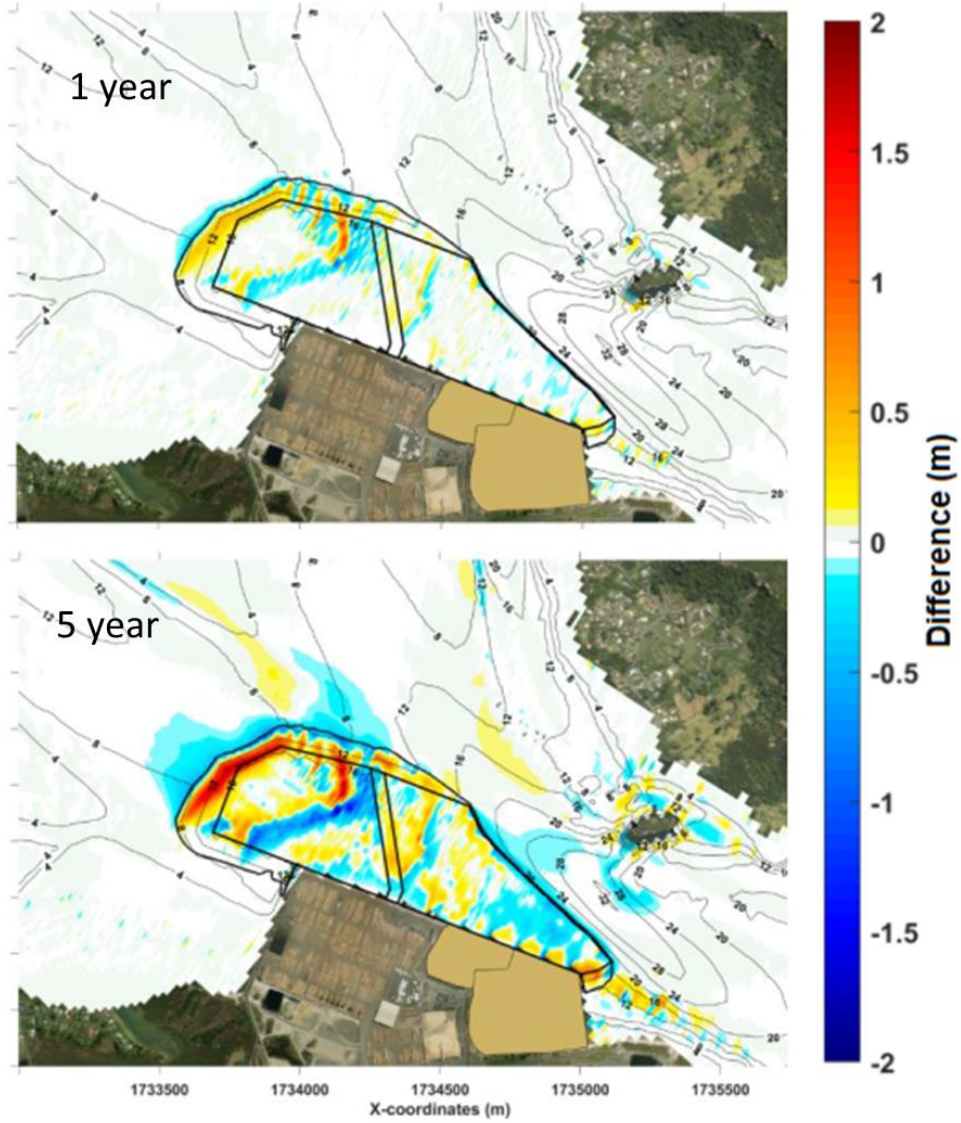

Figure 5-5: Predicted depth changes due to sedimentation at Northport with the eastern reclamation for a 1 year and 5-year period (Source: MOS, 2022b)

5.2.4 Water level

Based on previous studies by MOS (2016b) the relatively small area of reclamation relative to the harbour area, suggests that there will be no measurable change to the water levels within the harbour. **The effect of changes to water level are considered to be nil.**

5.2.5 Expected changes to the inner harbour

The inner harbour area extends into Whangarei Harbour westward of Northport. Tidal flows are low and confined to the channels and waves tend to be locally generated within the harbour. The modelling shows no changes from the present west of Marsden Bay. **The effects of the proposed development for the inner harbour are assessed to be nil.**

5.2.6 Expected changes along the entrance channel

The entrance channel is a tidal inlet to Whangarei Harbour. This area includes the small bays along the rocky coast from Mount Aubrey to Home Point including Calliope Bank, Urquarts Bay and Taurikura. This area is dominated by tidal flows following the alignment of the main channel with smaller flows along the side channels around Calliope Bank. The entrance channel area is relatively sheltered from waves generated in Bream Bay and, due to the small fetches in this area, locally wind generated waves are low. The numerical modelling shows some changes to the tidal currents, with reduced tidal currents along the southern edge of the channel which could result in accretion of this area due to sediments over washing the ebb tide delta during strong onshore wave events. **The expected effect of the proposed development along the entrance channel is expected to be minor.**

5.2.7 Expected changes to the ebb tide shoal and Mair Bank

The ebb tide shoal is a large stable medium to fine sandy feature formed by tidal currents and waves. Mair Bank is a coarse sand and shelly/gravel feature within the intertidal and sub-aerial part of the shoal that has a large biological component (pipi and mussels). The upper parts of the shoal and Mair Bank are more dynamic features that can vary in horizontal elevation by ± 0.5 m and vertical position by ± 2.0 m from year to year responding to higher energy wave events. The numerical modelling shows some small changes to the tidal currents (Figure 5-3), with reduced tidal currents along the southern edge of the channel which could result in accretion of this area due to sediments over washing the ebb tide delta during strong onshore wave events. Based on the analysis of previous survey information, this may occur as a small one-off adjustment, with a new equilibrium restored after conditions stabilise. **The expected effect of the proposed development on the ebb tide shoal and Mair Bank is expected to be minor.**

5.2.8 Expected changes to the open coast shoreline

No changes are expected along the open coast.

5.2.9 Expected effects on existing and future coastal hazards

The sandy shoreline along the northern part of Bream Bay and within Whangarei Harbour are currently susceptible to coastal erosion and are likely to experience greater erosion pressure as a result of sea level rise and climate change effects. The main driver for change will be increased sea levels that allow higher waves to reach the nearshore environment for all wave conditions. As identified in Section 3.13.1 the increase in average conditions is negligible while there is some increase in the less frequent storm events.

The increased sea level will reduce the effect of the proposed dredging on wave processes (i.e., reduced effects from the present-day situation) as the greater water depth will reduce nearshore processes. The potential for increased tidal flow from the harbour will not be affected by the proposal as the throat of the inlet will not be modified and it is this area that controls the tidal flows.

Apart from the occupation of the CMA and impact on the beach area, the proposal has a minor effect on tidal flows, wave energy and sediment transport in the present day. With increased sea level rise the effects of the proposed development is unlikely to significantly change. **The expected effects on existing and future coastal hazards are minor.**

5.2.10 Tsunami

The existing harbour area is vulnerable both to distant and local tsunami sources. The high velocities resulting from the tsunami are likely to result in large scale movements within the sandy systems of the nearshore, ebbtide delta, coastline and inner harbour. Specifically scouring of the narrower parts of the inlet throat with deposition both in deeper water seaward and landward of the inlet in the present-day situation. Even in the present-day situation this is likely to require inspection of the channel and inlet to confirm the safe operability of vessels accessing the port and jetty and it is likely that some maintenance dredging may be required to maintain operability.

Tsunami wave modelling has not been carried out for this assessment, as the narrowest part of the inlet throat has not been modified and, the channel deepening is unlikely to change the large-scale effects of the tsunami on the wider environment.

5.2.11 Overall long-term effects for the eastern reclamation

The proposal is a reclamation of an existing consented port reclamation, and the proposed reclamations are aligned with the existing face of the reclamation that minimises potential adverse effects on tidal flows and sediment transport to the adjacent within the tidal inlet. The proposed developments add to the increased occupation of the CMA in this area and increase the spatial extent of effects on the seabed and shoreline due to the increased occupation. The effects on tidal currents and sediment transport adjacent to the area of occupation extend eastward along the existing channel to the CINZ jetty. **Due to the changes to the currents and wave climate as a result of the eastern reclamation the overall cumulative effect on coastal processes access is moderate.**

5.3 Bird roost avifauna mitigation

5.3.1 Short term

Construction effects will vary depending on the detailed construction methodology but will include the perioding occupation of the CMA by barge. This will have negligible effects to coastal processes.

Risks of accidental spills and discharge can be managed with the appropriate controls, and the compaction of the seabed will be a short-term feature, with the seabed recovering quickly after construction of the roost is complete. **With the appropriate controls,** c**onstruction effects on physical coastal processes the bird roost formation and top-ups are considered negligible**.

5.3.2 Long term

Over the long term the inclusion of sand and the ongoing top-ups will have a beneficial effect on coastal processes by increase the sediment budget within Marsden Bay, offsetting to some degree sea level rise effects and potentially reduce the overwash and landward retreat of the existing barrier beach. The sheltering provided by the roost is also likely to enable the renewal of the mangrove stand that has currently eroded due to the landward migration of the barrier beach.

The sheltering effect may also result in some shoreline adjustment of the existing barrier beach, but these changes are likely to be negligible. **Overall, the effects of the proposed bird roost on coastal processes are considered beneficial due to the re-introduction of sediment to the western end of Marsden Bay and the sheltering of the existing barrier beach, reducing the observed landward migration of this feature**.

6 Proposed avoidance, reduction and mitigation measures

Effects on coastal processes for the eastern reclamation were identified as being moderate, largely due to the occupation of the seabed within the reclamation footprint affecting coastal processes within this footprint as well as changes to currents, waves, and sediment transport patterns along the eastern side of the inlet channel. Excluding the effect of the occupation of the eastern reclamation, the remaining effects on coastal processes are minor.

There is no practicable way of avoiding effects with the current proposal. Reducing effects would require reducing the size of the reclamation and there would still be occupation and local effects that would not significantly reduce the scale of effect, just the extent.

However, due to the occupation of the bird roosting habitat, a bird roost has been proposed by the avifauna expert (Boffa, 2022) and this is proposed to be located in the CMA within Marsden Bay. The concept design and consideration of effects are discussed in the following section.

7 Proposed monitoring conditions

7.1 Capital dredging related monitoring

Apart from the monitoring and management of the dredge plume as recommended by 4Sight (2020), no other monitoring is considered necessary for coastal processes.

7.2 Long term monitoring requirements

The areas to monitor for long term potential change are within Marsden Bay and along the shoreline from the port to the CINZ jetty and Mair Bank. Much of these areas are already subject to hydrographic survey, but intertidal and subaerial survey should be carried out at the same time to provide a comprehensive topographic and bathymetric data set. Surveys should be carried out after completion of each stage of the development and at least annually for a period of not less than five years. The bird roost will need more detailed assessment to confirm performance and the requirements for top-ups.

Monitoring elevation changes (if any) in seabed and shoreline in these areas is the most useful form of long-term monitoring combined with ongoing measurement of waves and water level at the Wave Rider Buoy so that changes in shoreline and seabed elevations can be assessed together with changes in wave energy and water level fluctuations. Sediment sampling and analysis of surficial sediments within the eastern end of Marsden Bank could also be carried out to confirm any change in sediment properties that may potentially affect ecology in this area.

It is anticipated that the turning area will need to be infrequently dredged as part of the port operations, but this area is already subject to annual survey.

Pre and post dredging surveys should be retained by the consent holder in a compatible format to augment this data set and information of the volumes and locations of deposition of both the capital and maintenance dredging recorded.

8 Applicability

We understand and agree that this report will be used by Northland Regional Council and Whangarei District Council in undertaking its regulatory functions in connection with the proposed consent application for reclamation and dredging.

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Appendix A Suspended sediment data

Suspended sediment sampling was carried out by MWH between June 2008 and May 2009 at four locations in the vicinity of the harbour entrance (see figure below).

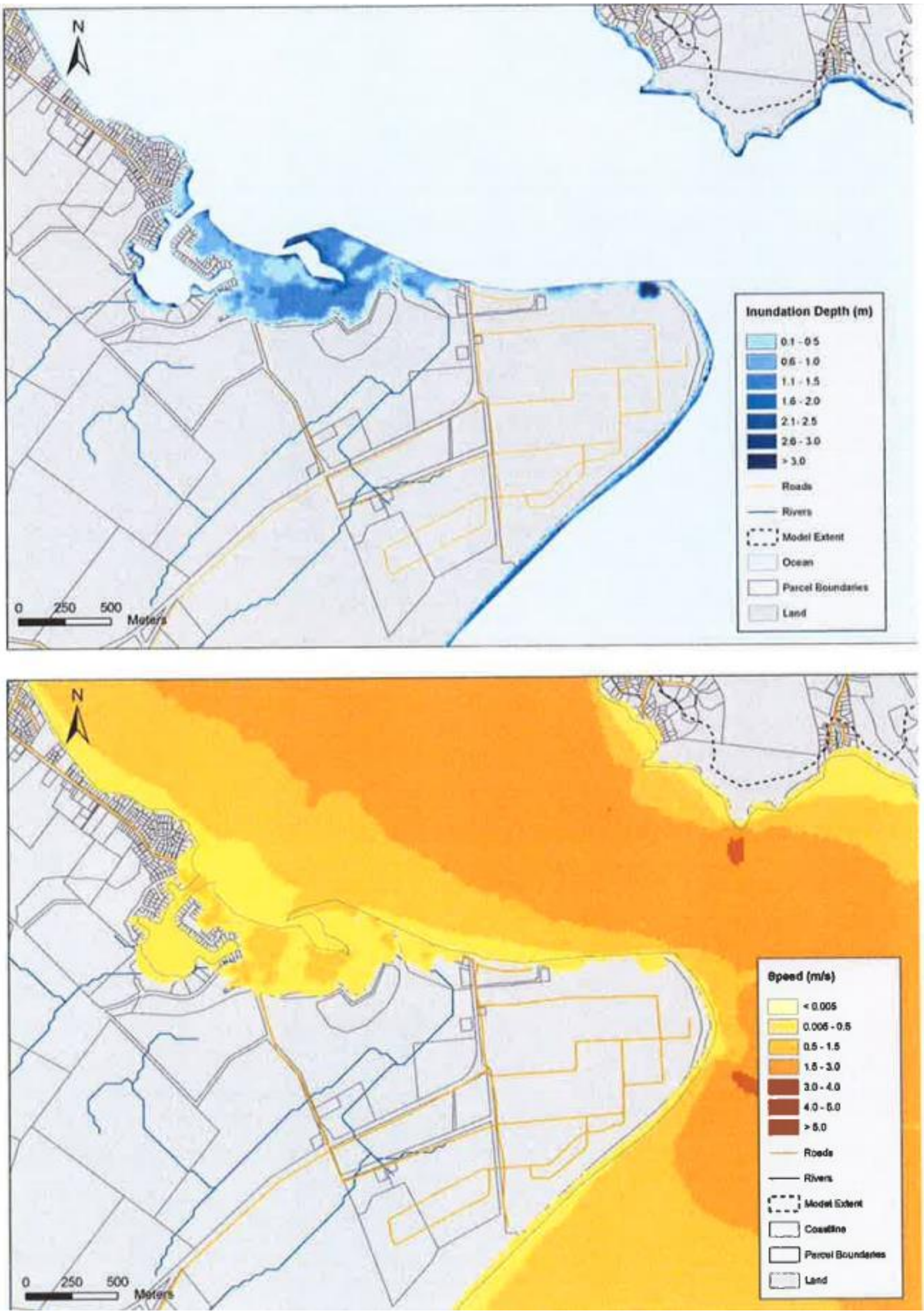
Water quality location plan (Source: MWH, 2009)

Results of surficial water quality survey at four locations in the vicinity of the harbour entrance (Source: MWH, 2009)

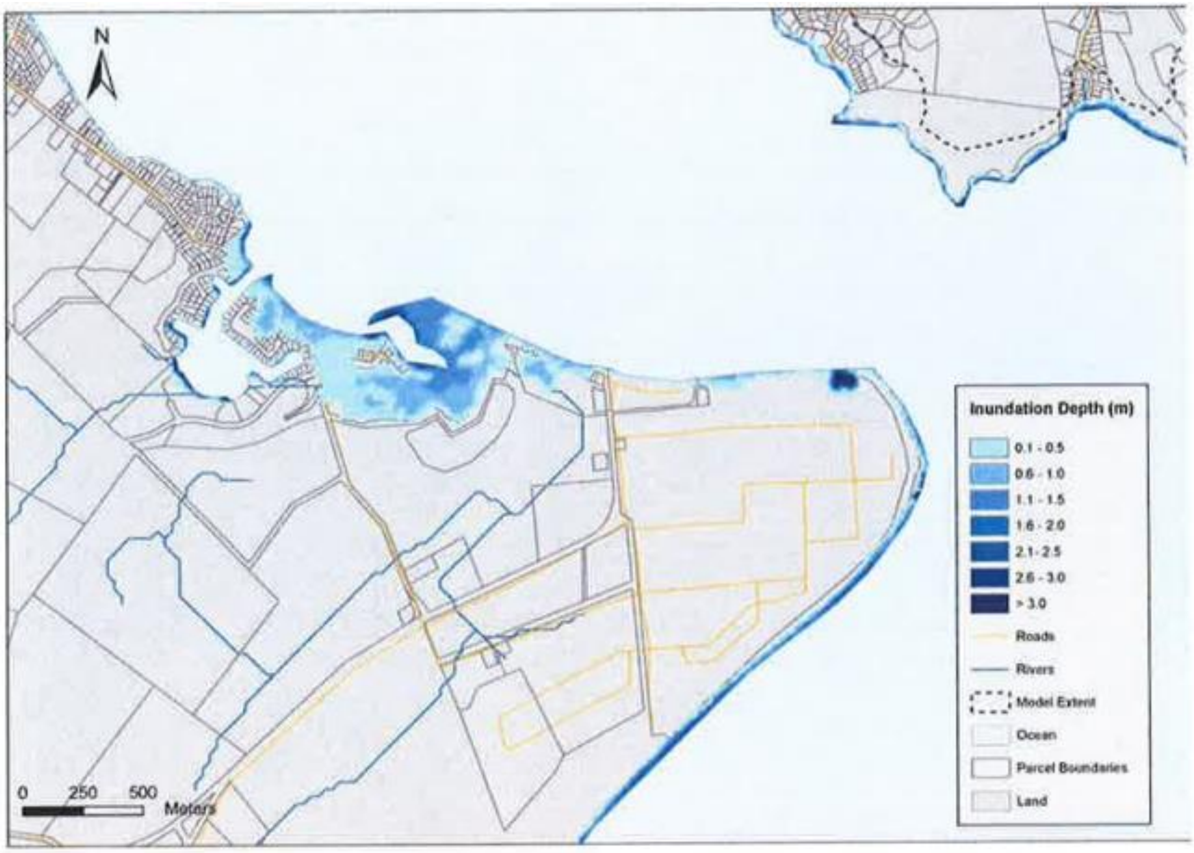
Site	Name	Date	time	tide	weather	TSS (mg/L)
1	Harbour Entrance	16-Jun-08	9:50	ebb	wet	9
1	Harbour Entrance	1-Jul-08	9:15	ebb	dry	5
1	Harbour Entrance	1-Jul-08	12:45	flood	dry	8
1	Harbour Entrance	26-Aug-08		flood	dry	6
1	Harbour Entrance	3-Dec-08	14:11	ebb	dry	3
1	Harbour Entrance	3-Dec-08	8:48	flood	dry	5
1	Harbour Entrance	7-May-09	8:53	ebb	dry	5
2	Mair Bank	16-Jun-08	9:57	ebb	wet	6
2	Mair Bank	1-Jul-08	9:30	ebb	dry	8
2	Mair Bank	1-Jul-08	12:36	flood	dry	5
2	Mair Bank	26-Aug-08		flood	dry	2
2	Mair Bank	3-Dec-08	14:00	ebb	dry	3
2	Mair Bank	3-Dec-08	9:09	flood	dry	4
2	Mair Bank	7-May-09	9:05	ebb	dry	4
3	Ebb Tide Shoal	16-Jun-08	10:02	ebb	wet	7
3	Ebb Tide Shoal	1-Jul-08	9:35	ebb	dry	6
3	Ebb Tide Shoal	1-Jul-08	12:32	flood	dry	21
3	Ebb Tide Shoal	26-Aug-08	N.D.	flood	dry	4
3	Ebb Tide Shoal	3-Dec-08	13:49	ebb	dry	2
3	Ebb Tide Shoal	3-Dec-08	9:24	flood	dry	6

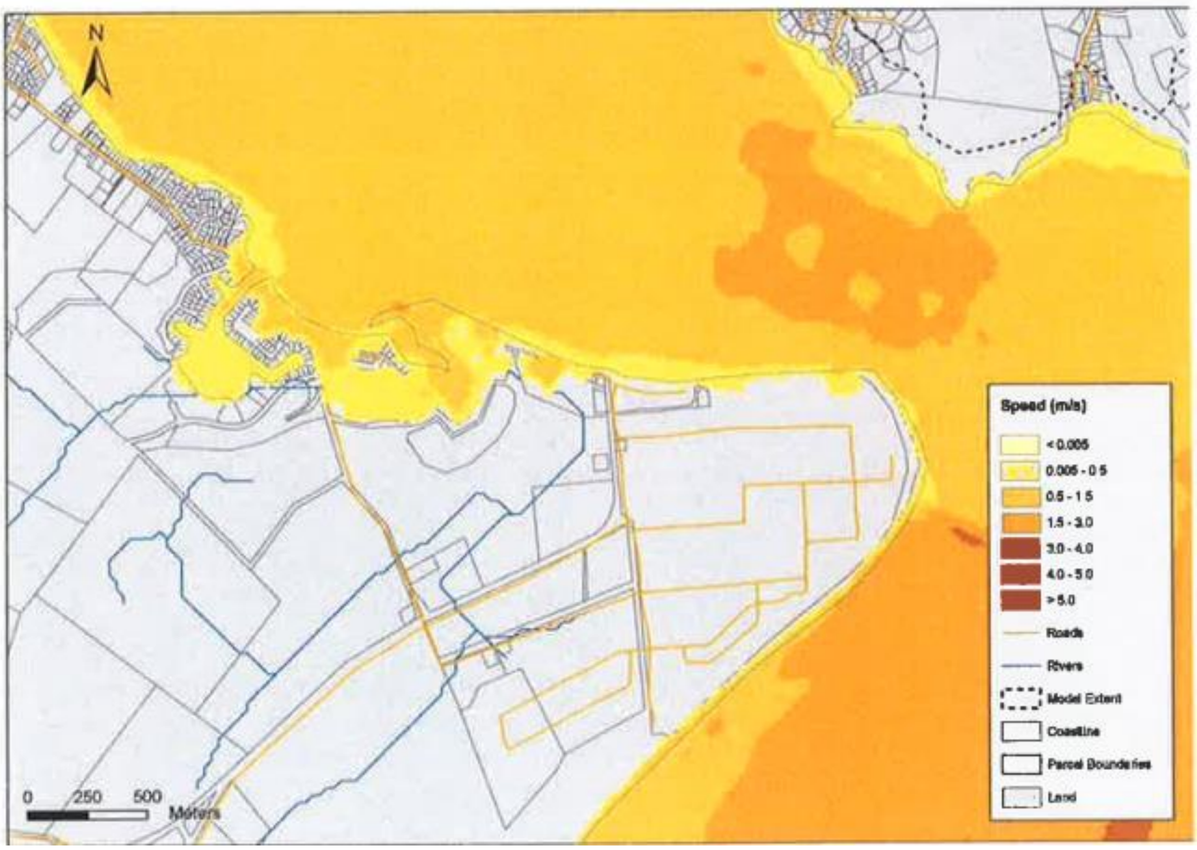
Site	Name	Date	time	tide	weather	TSS (mg/L)
3	Ebb Tide Shoal	7-May-09	9:12	ebb	dry	2
4	Channel off Busby Head	16-Jun-08	10:02	ebb	wet	7
4	Channel off Busby Head	1-Jul-08	9:35	ebb	dry	18
4	Channel off Busby Head	1-Jul-08	12:32	flood	dry	9
4	Channel off Busby Head	26-Aug-08	N.D.	flood	dry	6
4	Channel off Busby Head	3-Dec-08	13:49	ebb	dry	1
4	Channel off Busby Head	3-Dec-08	9:24	flood	dry	7
4	Channel off Busby Head	7-May-09	9:12	ebb	dry	3

Appendix B Tsunami plots from previous studies

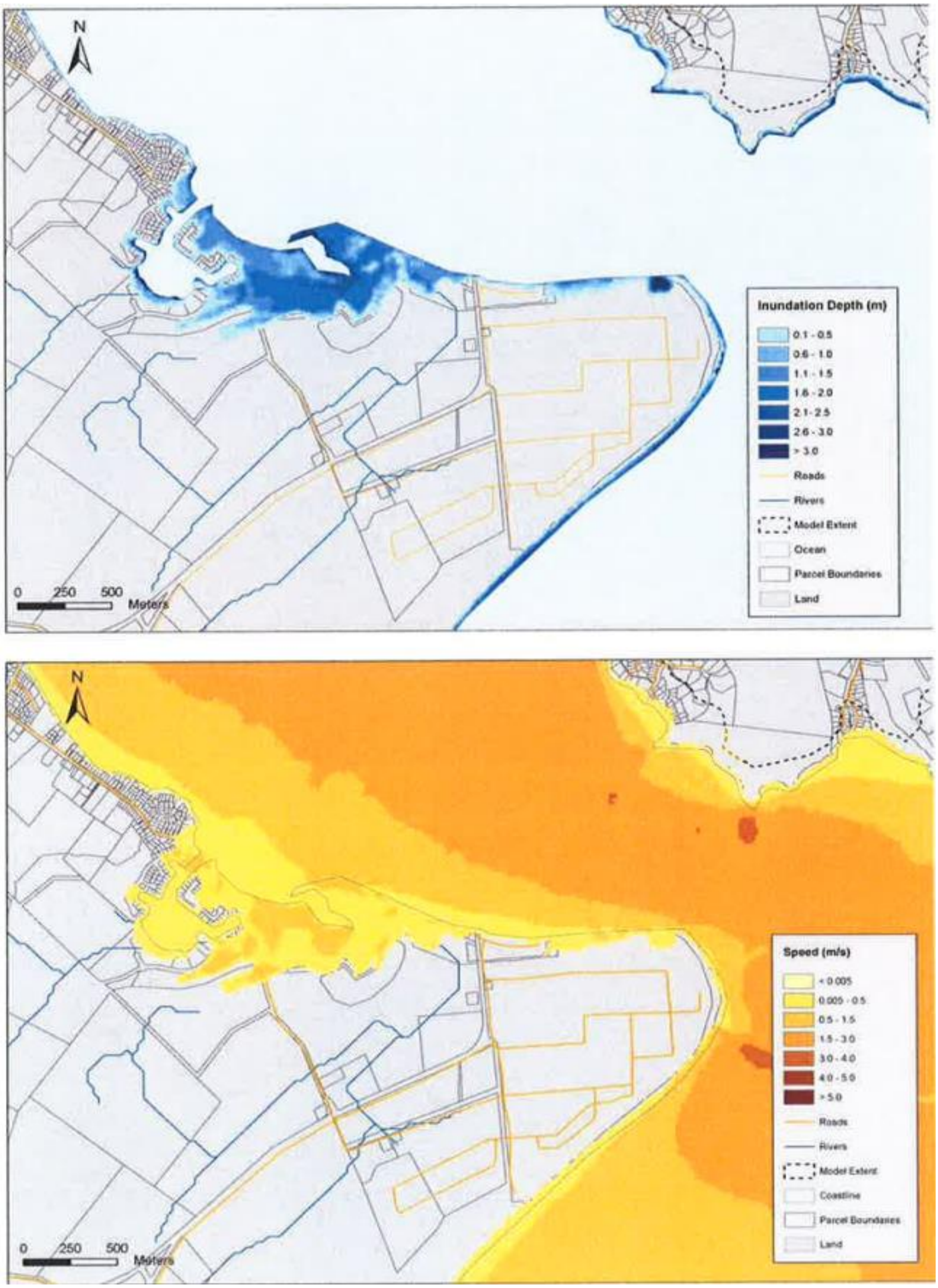


Appendix B Figure 1: Maximum inundation depth (upper) and speed (lower) for the South American tsunami scenario at MHWS (Source: Arnold et al. 2011)





Appendix B Figure 2: Maximum inundation depth (upper) and speed (lower) for the M_w 9.0 Tonga/Kermadec Trench tsunami scenario at MHWS (Source: Arnold et al., 2011)



Appendix B Figure 3: Maximum inundation depth (upper) and speed (lower) for the South American tsunami scenario at MHWS + 0.5 m Sea Level Rise (Source: Arnold et al., 2011)

Appendix C Criteria for describing the magnitude of effects on coastal processes

Significance	Criteria: Coastal Processes
Very High /severe	Total loss of, or very major alteration to, key elements/features of the existing baseline condition such that the post-development character, composition and/or attributes will be fundamentally lost. This includes irreversible changes to tides, currents, waves and/or sand transport causing adverse impacts on significant parts of the shorelines of Bream Bay or Whangarei Harbour, causing increased erosion and/or significant environmental habitat values. Substantial changes to the seabed morphology such that: • the majority of the regional distribution of a habitat type for nationally protected ecological communities is lost or substantially depleted; or such that • the sediment pathway for sand flow to other areas is permanently intercepted.
High (Significant)	Major loss or alteration to key elements/features of the existing baseline condition such that the post-development character, composition and/or attributes will be fundamentally changed. In particular, extensive or acute disturbance (major impact) occurring to the shorelines bordering Marsden Point and Mair Bank, causing increased erosion and/or significant environmental habitat values. Also, substantial changes to the seabed morphology such that: • the majority of the regional distribution of a habitat type for regionally protected ecological communities is lost or substantially depleted; or such that • the sediment pathway for sand flow to other areas is temporarily intercepted.
Moderate /medium (More than minor)	Loss or alternation to one or more key features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed. Changes to tides, currents, waves and/or sand transport affecting parts of the shorelines bordering Bream Bay or Whangarei Harbour, causing short term increased erosion that would affect communities or habitat values, such that natural recovery or mitigation measures would alleviate adverse impacts. Also, substantial changes to the seabed morphology such that the local distribution of a locally valued seabed habitat type is permanently lost or substantially depleted.
Low/minor	Minor shift away from existing baseline conditions. Changes arising will be discernible, but attributes of the existing baseline condition will be similar to pre-development circumstances or patterns. Changes to tide levels, currents, waves and/or sand transport processes causing changes in shoreline stability of limited or temporary nature. Changes to the seabed morphology would be of local spatial extent with no impacts elsewhere.
Negligible (Less than minor)	Very slight changes from the existing baseline conditions. No perceptible impacts on regional hydrodynamics beyond the immediate works area. Local hydrodynamic changes that have no consequent adverse impacts elsewhere. Little or no changes to water level, current, wave or sand transport processes at shorelines such that any impacts to shoreline stability would be imperceptible. Changes to the seabed morphology would be temporary with only local spatial extents and no impact elsewhere.
No effect (Nil)	No detectable change in physical parameters.
Beneficial	Any effects or measures that are expected to result in reduced shoreline erosion where that is presently a problem, or design features or management activities that would make a positive contribution to shoreline amenity or coastal environmental values.

Appendix D Proposed bird roost drawings

- **1017349-02: Bird Roost Concept: Layout Plan**
- **1017349-03: Bird Roost Concept: Layout Details**
- **1017349-04 Bird Roost Concept: Typical Sections**

C:\12dSynergy\data\ALBTCAD\Northport_BirdRoost_1187\CAD\DWG\1017349-02.dwg 2022-Aug-26 12:50:15 pm Plotted By: BRIAN DAVIS

NOTES:
1. VERTICAL DATUM: LOCAL CHART DATUM (4.816m BELOW LINZ BENCHMARK DJM9)
2. AERIAL PHOTO SOURCED FROM LINZ DATA SERVICE (Image Date 2015)
3. EXISTING GROUND CONTOURS CREATED FROM A COMBINED DEM COMPRISING :
   3.1. NORTHLAND REGIONAL COUNCIL 2016 LIDAR (NZVD2016 +1.75m)
   3.2. DML SURVEY 2015 (CD)

LEGEND
- EXISTING GROUND CONTOUR (0.2m INTERVAL)
- 2 — EXISTING GROUND CONTOUR (1.0m INTERVAL)
- MHWS (2.74m CD)
- DESIGN GROUND CONTOUR (0.2m INTERVAL)
- 2.6 — DESIGN GROUND CONTOUR (1.0m INTERVAL)

A3 SCALE 1:2000
0 20 40 60 80 100 (m)

ORIGINAL IN COLOUR

CHECK PRINT	INITIAL	DATE
BACKDRAFTING REQUIRED		
READY TO ISSUE		
CAD SELF CHECK		
DESIGN CHECK		
DRAFTING CHECK		
BACKDRAFTER - EDITS MADE		
BACKCHECKER - EDITS CONFIRMED		

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REV	DESCRIPTION	CAD	CHK	DATE
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1	100m Offset Added	BKD		

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DRAWN	BKD	Aug.22
DESIGN CHECKED		
DRAWING CHECKED		

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APPROVED DATE

DRAWING STATUS
PRELIMINARY DRAFT
PROJECT PHASE
CONCEPT DESIGN

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CLIENT NORTHPORT LTD
PROJECT VISION FOR GROWTH PORT DEVELOPMENT
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UNDER REVISION
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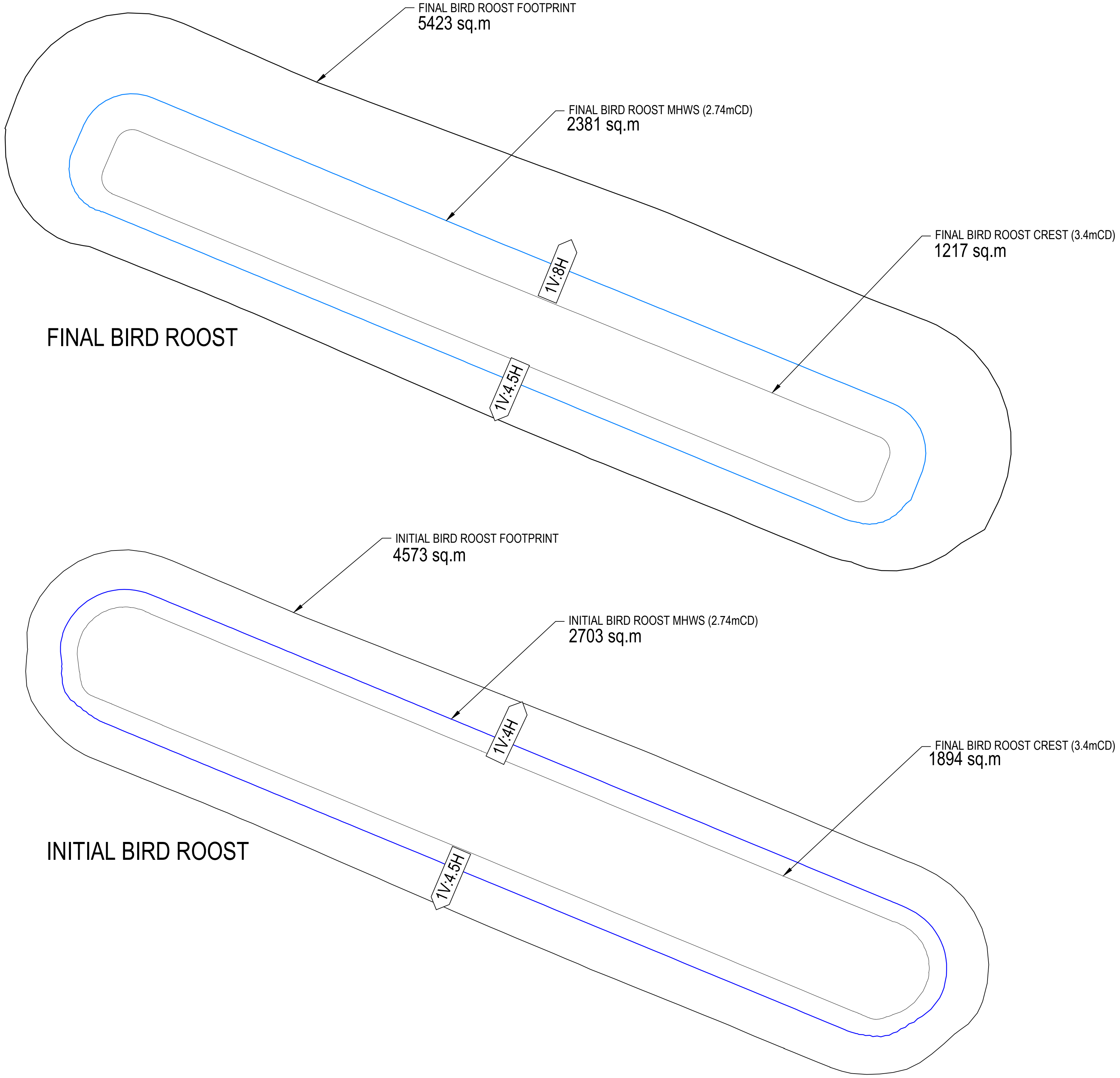

A3 SCALE 1:750

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PROJECT PHASE: CONCEPT DESIGN

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CLIENT: NORTHPORT LTD

PROJECT: VISION FOR GROWTH PORT DEVELOPMENT

TITLE: BIRD ROOST CONCEPT LAYOUT DETAILS

UNDER REVISION

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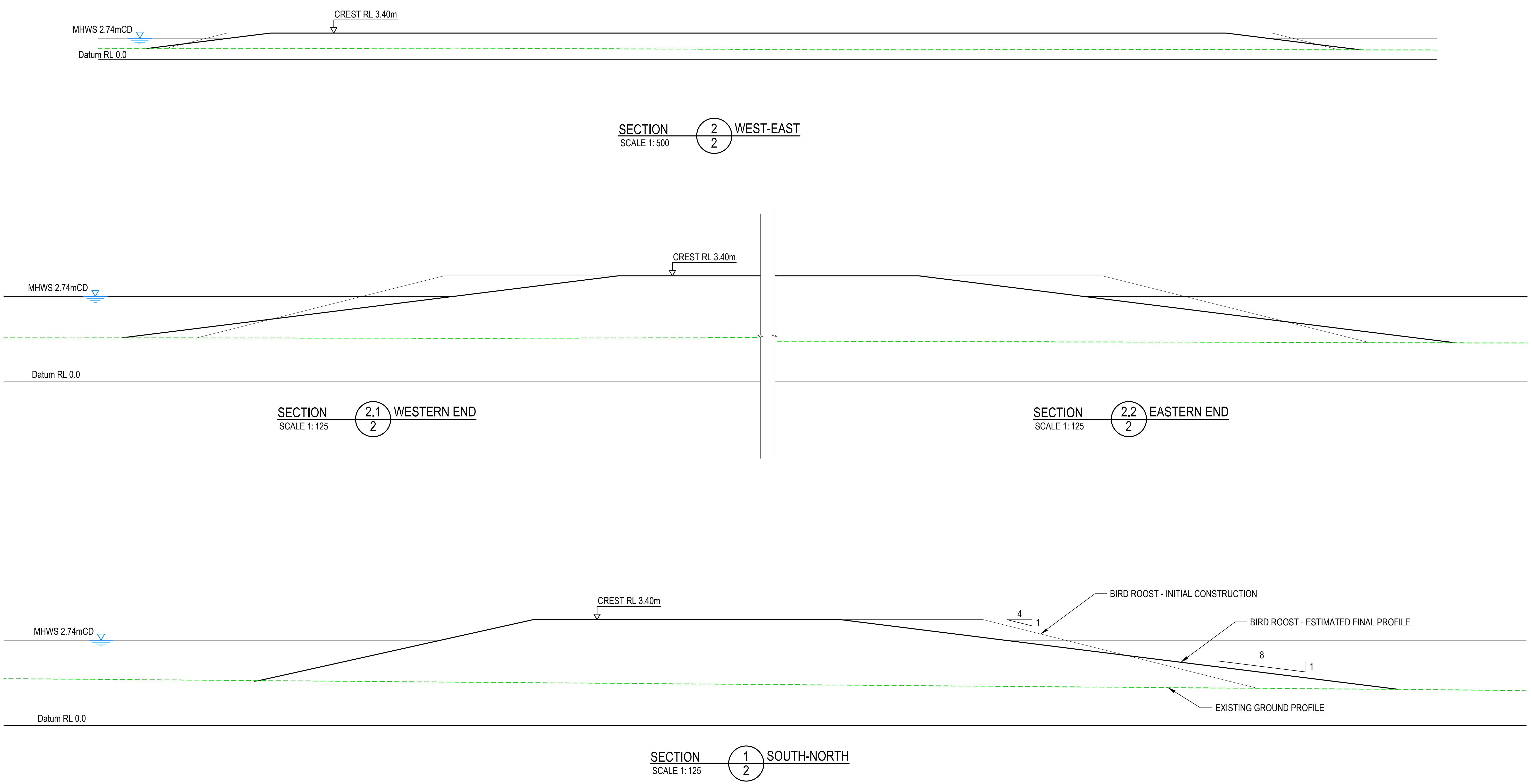

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DESIGN CHECK		
DRAFTING CHECK		
BACKDRAFTER - EDITS MADE		
BACKCHECKER - EDITS CONFIRMED		

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DRAWN	BKD	Aug.22
DESIGN CHECKED		
DRAWING CHECKED		
APPROVED		DATE

DRAWING STATUS
PRELIMINARY DRAFT

PROJECT PHASE
CONCEPT DESIGN

NOT FOR CONSTRUCTION

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CLIENT **NORTHPORT LTD**

PROJECT **VISION FOR GROWTH PORT DEVELOPMENT**

TITLE BIRD ROOST CONCEPT
TYPICAL SECTIONS

UNDER REVISION

SCALE (A3) AS SHOWN DWG No. 1017349-04 REV 0 www.tonkintaylor.co.nz