REPORT

Nelson Coastal Inundation Mapping Update

Phase A Investigations

Prepared for
Nelson City Council
Prepared by
Tonkin & Taylor Ltd
Date
June 2023
Job Number
1006718.2100 v1

Together we create and sustain a better world
www.tonkintaylor.co.nz

Document control

Title: Nelson Coastal Inundation Mapping Update					
Date	Version	Description	Prepared by:	Reviewed by:	Authorised by:
14/06/2023	1	Phase A Investigations Report	R Haughey	T Shand	D Velluppillai

Distribution:

Nelson City Council 1 PDF copy

Tonkin & Taylor Ltd (FILE) 1 PDF copy

Table of contents

1 Introduction

In 2020 Tonkin & Taylor Ltd (T+T) completed a first-pass coastal inundation assessment for Nelson City Council (NCC) which was intended to identify areas of land which are susceptible to both present-day and future coastal inundation. The inundation extents were assessed using a bathtub approach with the most recently available data at the time, which included 2015 LiDAR and extreme water levels from NIWA (2018).

NCC require updated coastal hazard mapping, which is based on the latest available information, including 2021 LIDAR survey data, and most appropriate methodology. Phase A of the coastal inundation mapping update project has involved several investigations to better understand available information and methodologies.

The following report provides a summary of the investigations that have been undertaken with a recommended approach for undertaking the updated inundation hazard mapping.

2 Review of methods for determining extreme storm tide levels

2.1 Existing hydrodynamic models

As part of the Sustainable Seas National Science Challenge in 2016, MetOcean Solutions developed an operational, hydrodynamic model for Tasman and Golden Bays (as part of a project with NIWA and Cawthron Institute). The main purpose of the model was to model dispersal of E. coli bacteria from rivers and runoff following heavy rainfall events within the bays.

Usage of this model has been considered to include hydrodynamic effects along the open coast boundary. Usage would involve commissioning MetOcean to carry out required modelling which would involve running a 30-year wave and storm surge hindcast with multiple output locations along the coast which would feed into the bathtub modelling. However, it has been noted that NIWA have already undertaken a similar exercise with producing the extreme water levels provided in NIWA (2018). While the MetOcean model may provide higher resolution along the NCC coast, it is unlikely to have a significant impact on the end results and therefore further investigation into the usage of the MetOcean model is not recommended.

2.2 Maitai Wharf tide gauge analysis

NIWA have previously carried out an assessment (NIWA, 2018) of available tide gauge data in order to provide NCC with estimates of extreme water levels based on the probabilities of occurrence. This included the 1% annual exceedance probability (AEP) sea level that has been used by NCC for planning and decision making.

During Ex-Tropical Cyclone (Ex TC) Fehi the Maitai Wharf tide gauge stopped recording over high tide (i.e. the peak water level was not recorded). This was not previously considered by NIWA in their analysis of extremes. Using interpolation, the revised level for Fehi was 2.48 m, compared to the 2.35 m they previously provided (NIWA, 2020). The effect of including Ex TC Fehi was to reduce the estimated AEP for that event from 1% to 0.33%.

NCC note that this is the highest value recorded at the gauge ("1st ranked event"). NIWA's method for assessing the extreme water levels involved separating the skew surge (height above predicted high tide) and performing an extreme analysis. This was then recombined with potential tide heights. Using this analysis, NIWA have stated that Fehi was only the 14th largest skew surge event in the record (a very high tide but paired with a relatively unremarkable surge component). We agree with NIWA's assertion that repeating the analysis with the revised values for Ex TC Fehi would make a negligible difference to the 1% AEP value generated.

In addition to the above, we note that the original analysis by NIWA also incorporated the Fairway tide gauge which did record the peak water level at the gauge location during Ex TC Fehi. This further supports our conclusion that repeating the analysis would produce a negligible difference to the 1% AEP extreme water level. Results from a re-analysis would likely be within the confidence limits of the original assessment and would not produce any practical difference when viewed in context to the SLR scenario applied to future planning. It is recommended that further analysis of the 1% AEP level is deferred until there is a longer tide gauge record that will improve confidence in extrapolating to longer return events. We note that NCC have recently installed a new water level gauge at the Trafalgar Park footbridge within the tidal reach of the Maitai River that will provide an additional data location for future analysis.

Therefore, based on the above, we propose to adopt the 1% AEP storm tide level as previously derived by NIWA (2018) (Table 2.1) for 2022 bathtub coastal inundation modelling.

Table 2.1: Present day storm tide levels sourced from NIWA (2018)

	18% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Storm tide level (m RL, NZVD2016)	2.23	2.27	2.27	2.29	2.34

3 Review of local effects on water level

3.1 Observations during Ex Tropical Cyclone Fehi

It is understood that during Ex TC Fehi there were some locations, particularly around Monaco, where observed inundation levels exceeded the 1% AEP inundation extent previously mapped by T+T (2020). The 1% AEP extents mapped by T+T (2020) were based on a storm tide level of 2.34 m NZVD2016, which was derived from NIWA (2018). The storm tide level during Ex TC Fehi was slightly larger than the 1% AEP event defined by NIWA (2018) and was estimated as 2.48 m NZVD2016 at the Maitai Wharf tide gauge. This difference (0.14 m) provides some explanation as to why the observed inundation levels and extents were larger than the previously mapped 1% AEP extent.

We have also completed further investigation into what components contributed to the varied water levels around the coastline during Ex TC Fehi. Based on 2021 LiDAR and photographs taken during Ex TC Fehi, the peak water level observed around Nelson has been estimated at nine different locations. Figure 3.1 shows an example of the LiDAR cross-section and photograph taken near 47 Martin St, Monaco, where the observed peak water level was estimated at 2.8 m NZVD2016. Note, the exact timing that the photographs were taken, compared with the timing of the peak of the storm were not available (i.e. the photo may not have been taken when the water level was at its highest during the event). Figure 3.3 shows the estimated peak water levels for each location where photographs and observations were made. Overall, water levels reached on average 2.8 m NZVD16 at the Waimea Inlet sites, with slightly higher levels along the northern side of Monaco and slightly lower levels in some of the sheltered sites (e.g. near the Tahunanui BMX track and on the southern side of Monaco).

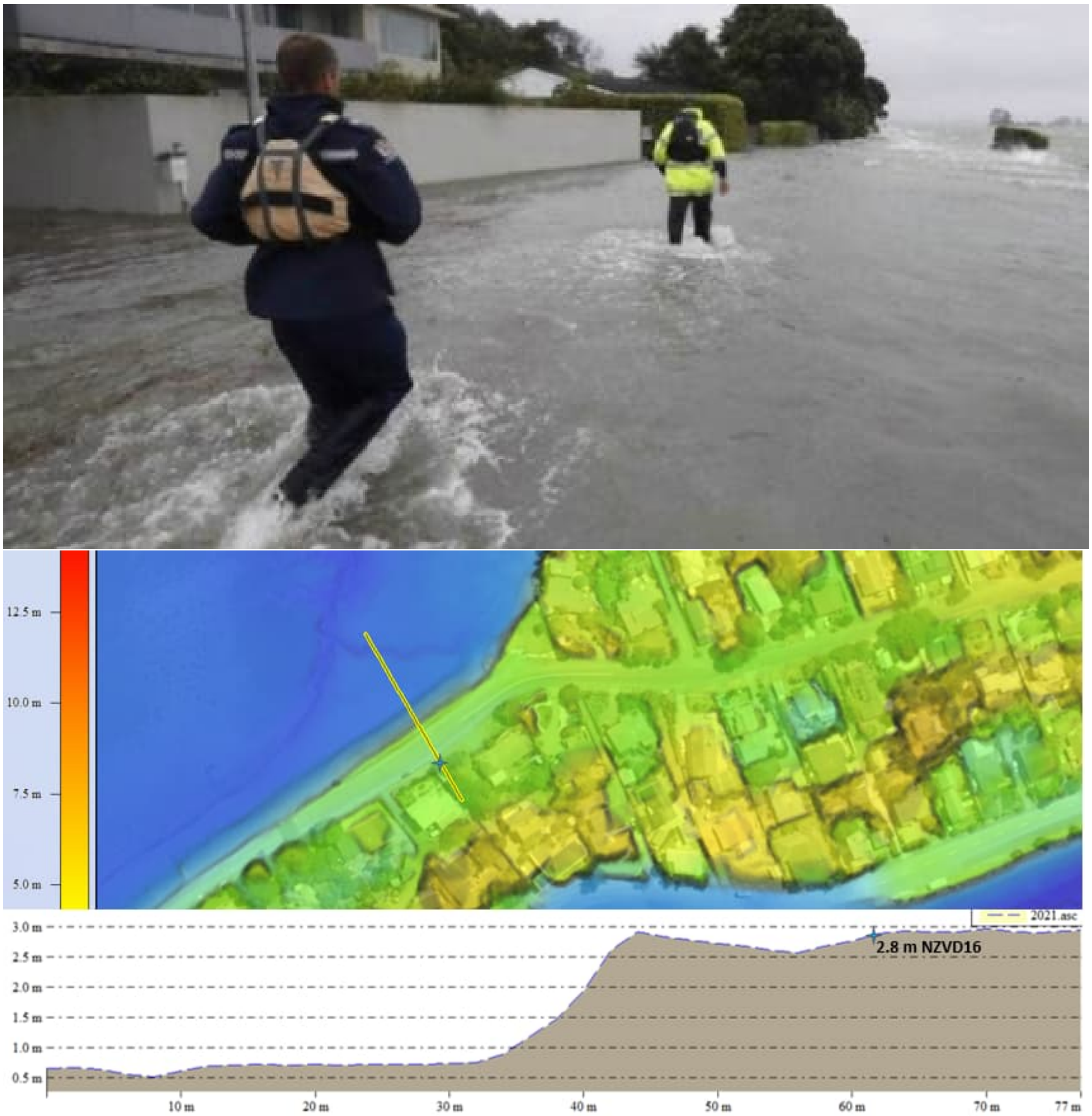


Figure 3.1: (Top) Observed inundation levels near 47 Martin Street, Monaco during Ex TC Fehi (sourced from NZ Flood Pics), (bottom) Cross-section through 2021 LiDAR showing crest levels and approximate inundation extents.

Figure 3.2: Observed inundation levels along Hathaway Terrace in the Nelson CBD. Sourced from Toby Kay, NCC.

Figure 3.3: Estimated peak water levels based on observations and photos taken during Ex TC Fehi

The peak water level interpolated at the Maitai gauge was 2.48 m NZVD2016, which is approximately 0.1 to 0.3 m lower than levels observed within the Waimea Inlet and CBD.

3.2 Review of potential contributors to elevated water level

Some of the potential factors contributing variations in water level include (Figure 3.4):

1. Wind setup

During Ex TC Fehi there was strong northerly wind blowing into the Waimea Inlet. This wind is likely to have caused local setup with water pushed up along the southern end of the Bay. While some of this regional wind setup may have contributed to the water levels at Maitai Wharf gauge, the effect of wind setup is likely to have further attenuated through the Waimea Inlet. Based on 5 km fetch N-S across the Waimea Inlet, the estimated wind setup during Ex TC Fehi is 0.2 m along the southern shorelines. However, Monaco is only 2 km from the inlet entrance and therefore is likely to be subject to less setup.

2. Wave setup

As the Maitai Wharf gauge is in a relatively sheltered, deep water environment, wave setup is unlikely to contribute to the water levels. However, wave setup may have contributed to the higher water levels around Monaco in two ways:

- Local wind causing waves to break near the shore.
- Swell waves breaking on the bars at the inlet entrance.

For the 1% AEP water level, T+T (2020) estimated 0.2 m of wave setup along the Waimea Inlet and Nelson Haven shorelines, which accounts for local wind waves breaking near the shore.

During Ex TC Fehi the observed water levels appear to be slightly higher on the northern side of Monaco compared with the southern side and other sheltered areas within the inlet. This difference is likely due to greater wave set up on the northern side which would have been exposed to greater wave breaking, compared with the southern side (which would have had negligible waves).

Figure 3.4: Schematic showing the potential setup components contributing to different levels in the Waimea Inlet.

3. Tidal amplification

As the tide propagates from the ocean into an estuary or river, its amplitude can be decreased (attenuation) or increased (amplification). The change in amplitude is associated with physical characteristics such as morphology and hydraulic drag. Observations suggest that there may be some tidal amplification up the Maitai River which contributes to the higher water levels observed in the CBD.

During Ex TC Fehi the water levels observed within the CBD were approximately 0.1 to 0.2 m higher than the peak water level interpolated at the Maitai gauge (Figure 3.2 and Figure 3.3). This difference is likely to be due to a combination of factors, including wind and wave setup effects generated within the Nelson Haven, river flows and tidal amplification.

To investigate the potential tidal amplification, we have compared water level records from the Maitai tide gauge and the Maitai Footbridge near Trafalgar Park for the period January 2018 to February 2022 (Figure 3.5 and Figure 3.6). The data shows that peak water levels measured at the Maitai Footbridge are generally higher than the peak levels measured at the Maitai tide gauge (Figure 3.6). The difference in peak water levels tends to be slightly larger during spring tides compared with neap tides. The average difference in peak water levels during spring tides ranges from 0.05 to 0.1 m, whereas the average difference during neap tides ranges from 0 to 0.05 m. These observations imply that there may be the influence of tidal amplification within the downstream extent of the Maitai River.

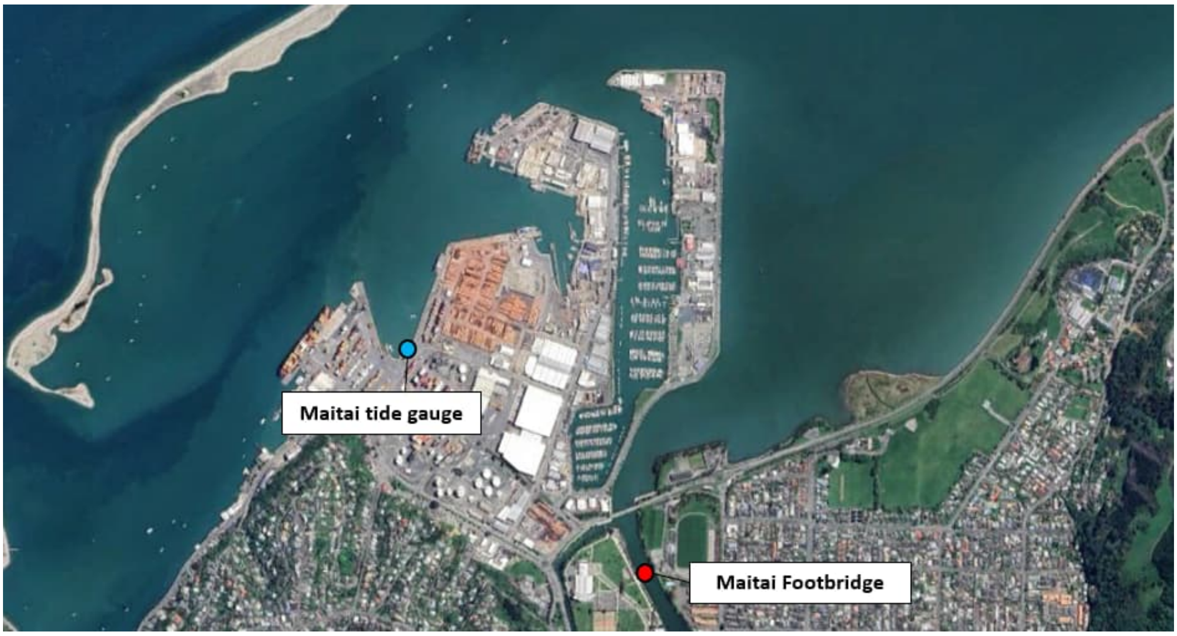


Figure 3.5: Location of water level gauges

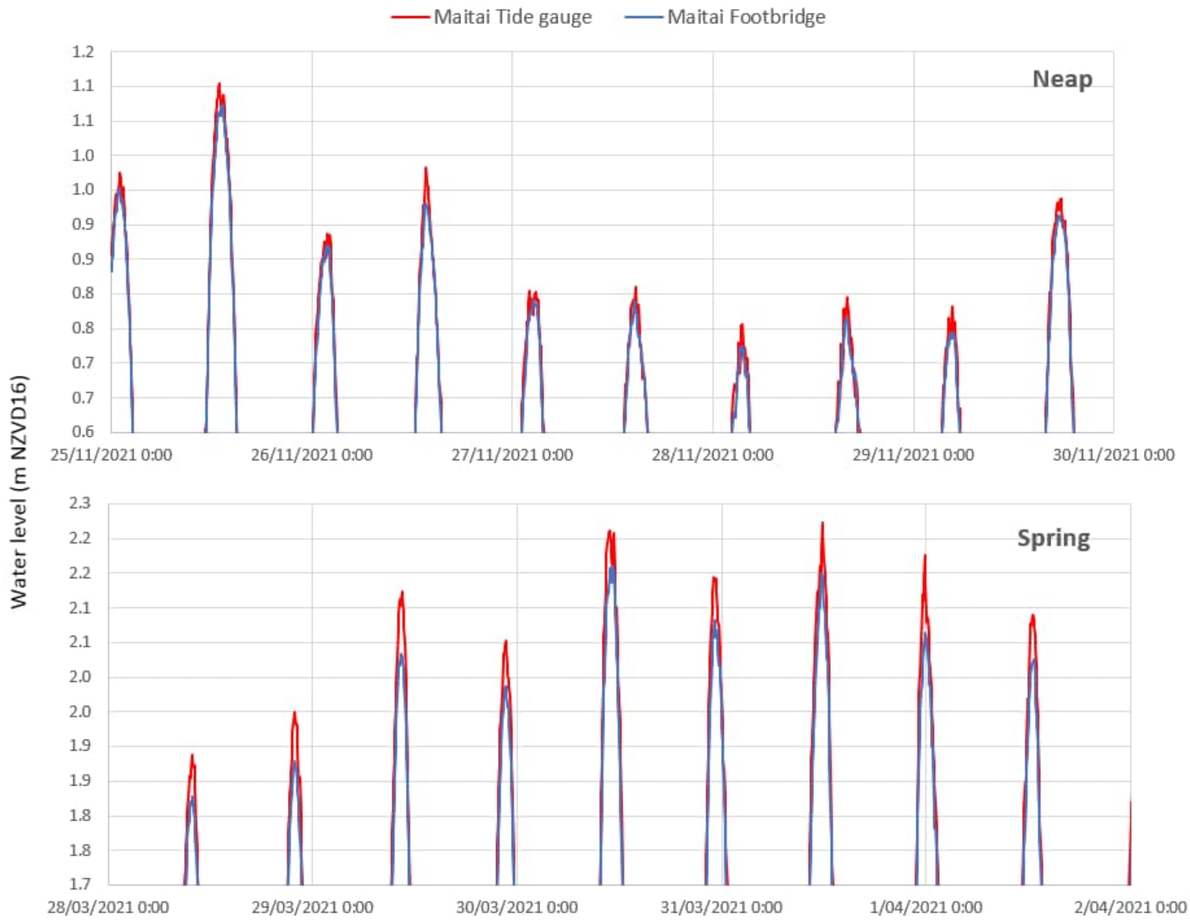


Figure 3.6: Example of peak water levels measured at the Maitai tide gauge and the Maitai Footbridge for spring (top) and neap (bottom) tides during 2021

3.3 Recommendations

Overall, during Ex TC Fehi, there appeared to be 0.1 to 0.3 m difference between the interpolated peak water level at the Maitai tide gauge and the water levels observed within the CBD and Waimea Inlet. Factors potentially contributing to this difference include:

- Wind setup (attenuated through the narrow inlet from northerly winds)
- Local wind wave setup
- Swell wave setup (breaking at the inlet entrance)
- Tidal wave amplification (through the Maitai River channel).

The previous T+T (2020) assessment accounted for some of this difference through the contribution of wind wave setup (i.e. 0.2 m within Waimea Inlet and the Nelson Haven). For this updated assessment we recommend including 0.3 m setup within Waimea Inlet when assessing the 1% AEP inundation extents. For the CBD, we recommend increasing the tidal component by 0.1 m to account for potential tidal amplification within the Maitai River. However, we recommend reducing the wave setup component to 0.1 m within the CBD. Due to the location of the CBD shoreline, it is likely to have less setup compared to the rest of Nelson Haven, where the 1% AEP static water level accounts for 0.2 m wave setup.

A summary of the revised 1% AEP levels for each coastal cell are shown in Table 3.1.

Table 3.1: Revised present day 1% AEP levels for the NCC coastal cells

Coastal cell	MHWS-6	Storm tide (m NZVD16) 1% AEP	Wave height (m)	Wave set-up (m)	Extreme static water level (m NZVD16)
Waimea Inlet	1.72	2.34	1.1	0.3	2.64
Tahunanui	1.72	2.16[1]	3.0	0.5	2.66
Rocks Road	1.72	2.16[1]	3.0	0.36	2.52
Nelson CBD	1.82[2]	2.44[2]	1.0	0.1	2.54
Nelson Haven	1.72	2.34	1.0	0.2	2.54
Boulder Bank to Pepin Island	1.72	2.13[1]	3.7	0.92	3.05
Delaware Bay Estuary	1.72	2.34	1.0	0.2	2.54
Delaware Open Coast	1.72	2.12[1]	3.8	0.74	2.86
Oananga Bay	1.72	2.12[1]	3.8	0.5	2.62

1 Joint-probability storm tide

2 Increased by 0.1 m to account for tidal amplification within the Maitai River

Table 3.2 presents the assessed 1% AEP present day static coastal water levels for each coastal cell rounded up to the nearest 0.1 m. As was done previously, this rounding up to the nearest 0.1 m is to align with the 0.1 m mapping increments. It is more appropriate to round up with slight conservatism in places, instead of rounding down and potentially missing areas of land that may be susceptible to coastal inundation.

Table 3.2: 1% AEP coastal water levels for present day and future sea levels (m NZVD16)

Site	Present Day 1% AEP water level	Future 1% AEP water level			
		With 0.5 m SLR	With 1 m SLR	With 1.5 m SLR	With 2 m SLR
Waimea Inlet	2.7	3.2	3.7	4.2	4.7
Tahunanui Beach	2.7	3.2	3.7	4.2	4.7
Rocks Road	2.6	3.1	3.6	4.1	4.6
Nelson CBD	2.6	3.1	3.6	4.1	4.6
Nelson Haven	2.6	3.1	3.6	4.1	4.6
Boulder Bank to Pepin Island	3.1	3.6	4.1	4.6	5.1
Delaware Bay Estuary	2.6	3.1	3.6	4.1	4.6
Delaware Open Coast	2.9	3.4	3.9	4.4	4.9
Oananga Bay	2.7	3.2	3.7	4.2	4.7

4 Review of coastal cell extents

The cells adopted in T+T (2020) were split up where the exposure to wave action or the nearshore beach slope significantly varies, or where a different NIWA (2018) output location is applicable. The landward extent of the coastal cells was based on an estimation of what area is inundated that is connected to the coastline of each coastal cell. Figure 4.1 shows the extents of coastal cells in T+T (2020).

Through discussions with NCC, it has been agreed that the updated inundation modelling will include revised cell splits between Waimea Inlet and Tahunanui, and between Nelson Haven and Boulder Bank Glenduan. The revised cell splits are outlined below.

Figure 4.1: Overview of cell splits adopted in T+T (2020)

With the revised extreme static water levels, there is only 0.02 m difference between the Waimea Inlet and Tahunanui cells. Subsequently the two cells could be merged and treated as one cell. However, the coastal processes influencing the water levels do differ slightly between the sites and the wave run-up level is expected to be higher for the Tahunanui cell. As the static water level increases there is a point where the inundation from the open coast at Tahunanui joins with inundation from the Waimea Inlet side. This location is approximately at Rotherham St. We propose to adjust the coastal cell boundary further north to run across the golf course opposite from Rotherham Street (Figure 4.2).

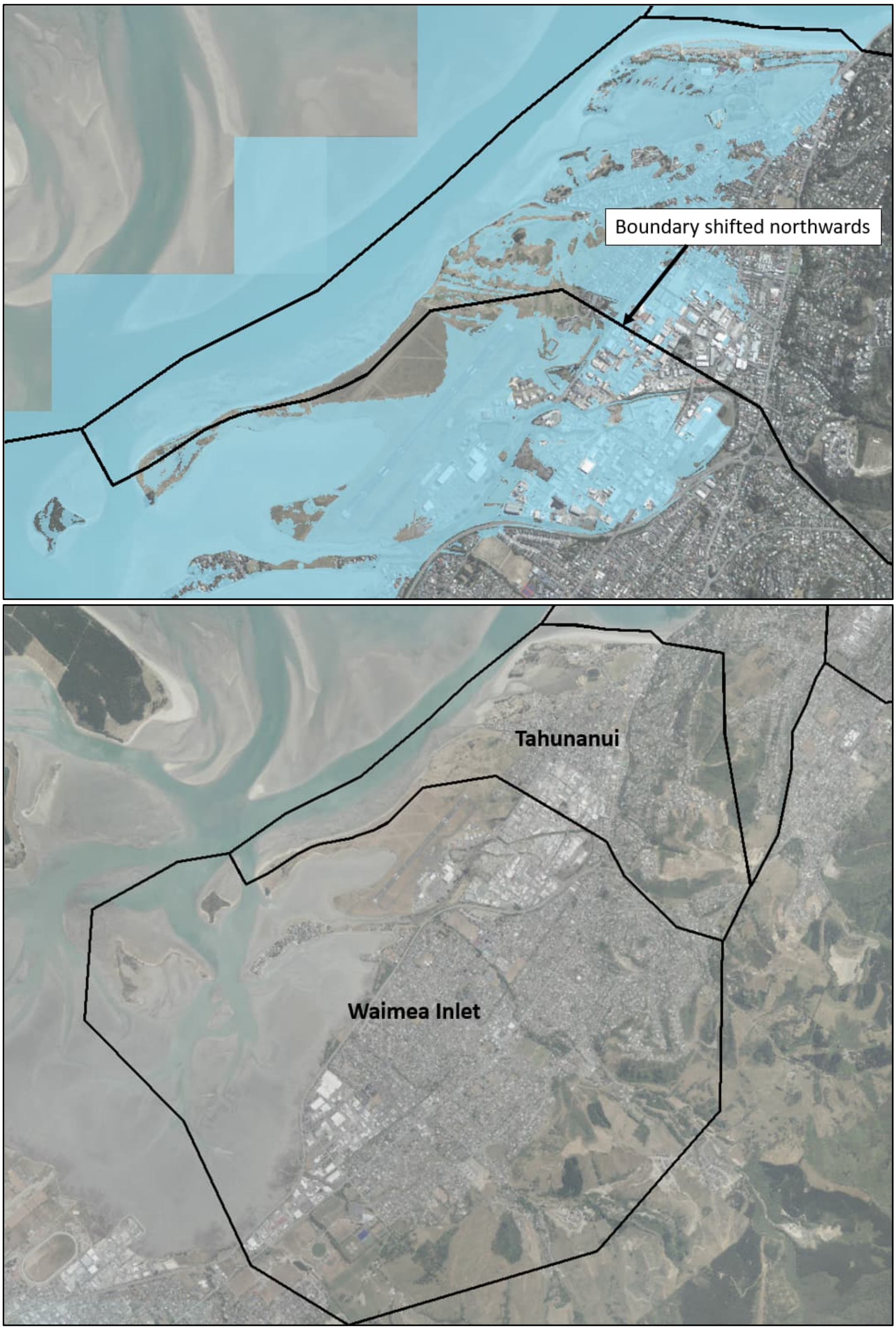
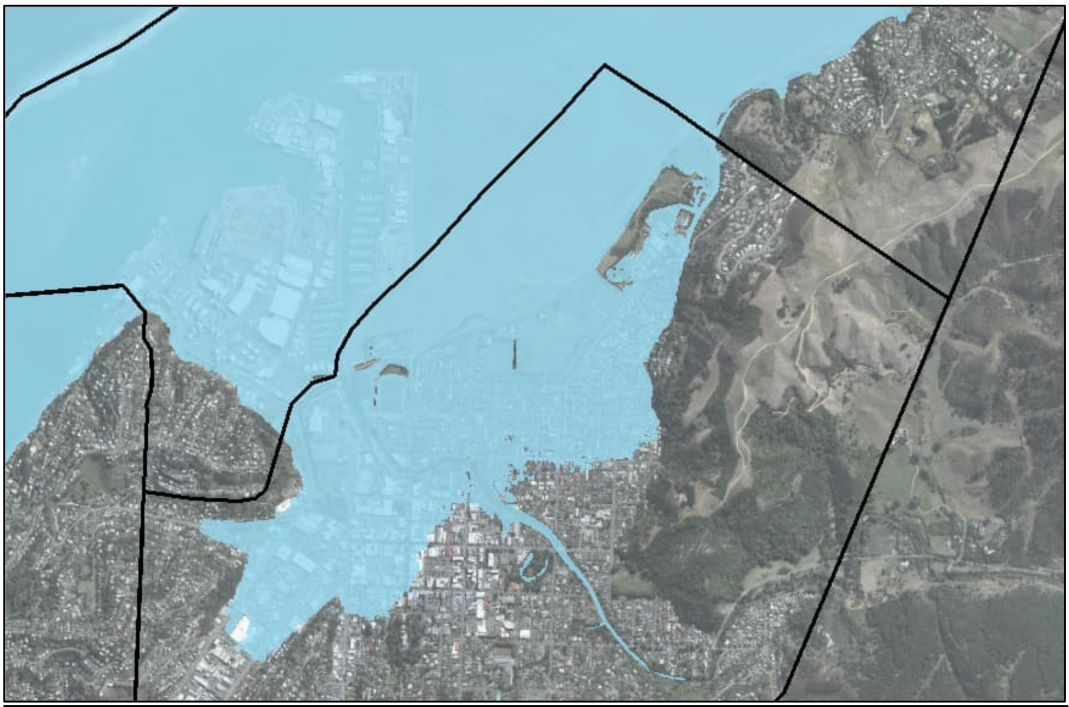


Figure 4.2: Revised coastal cell split for Waimea Inlet and Tahunanui. (Top) Revised boundary overlaying the 3.8m NZVD inundation extent. (Bottom) Cell overview

The Boulder Bank cell will be split along the crest of Boulder Bank, instead of through the centre of the estuary (Figure 4.3). As a result, the shoreline at the northern end of the Nelson Haven (Wakapuaka Flats) will be mapped using the same inundation levels as adopted for the rest of

Nelson Haven, which is dominated by estuary hydrodynamics instead of the open coast dynamics along Boulder Bank.

Due to the additional tidal amplification effects within the Maitai River, an additional cell will be included for the Nelson CBD area (Figure 4.3). The CBD cell split is at Atawhai Drive at the northern end and is along SH6 on the western side. The adopted levels for the CBD and Nelson Haven are the same, however the coastal processes contributing to the levels differ slightly (i.e. tidal amplification and wave setup contributions).



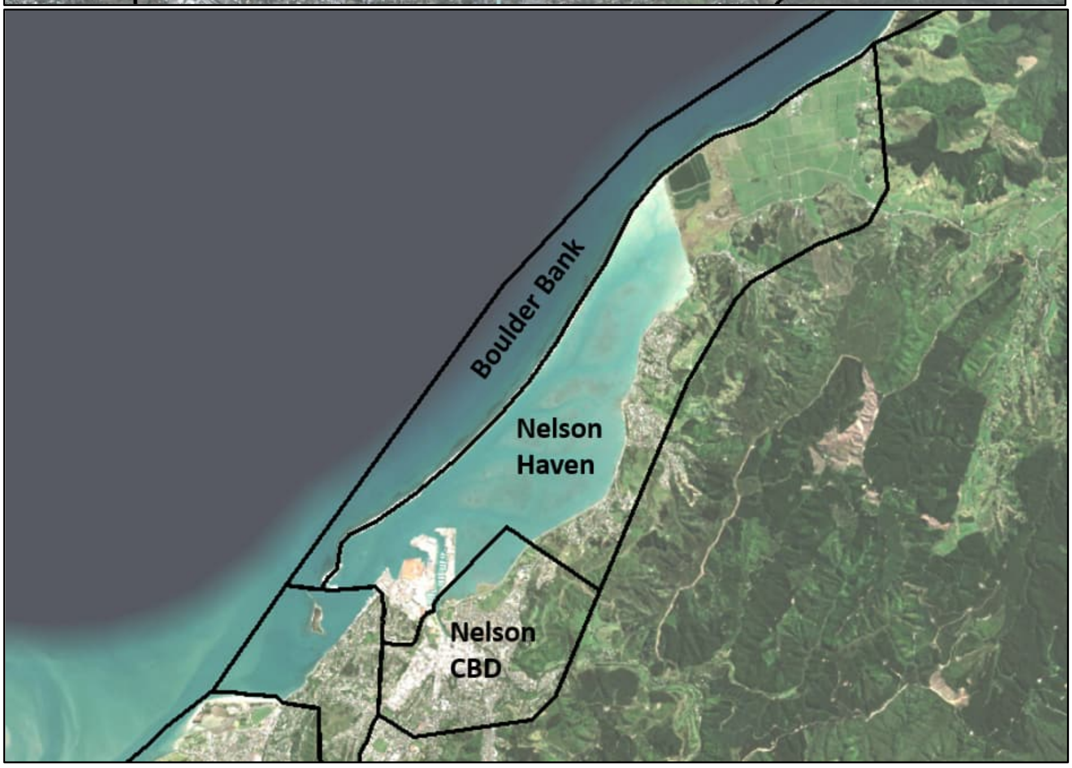


Figure 4.3: Revised coastal cell split for Boulder Bank, Nelson Haven and Nelson CBD. (Top) Cell split for CBD and Nelson Haven overlaying the 4.7 m NZVD16 inundation extent. (Bottom) Cell split overview

5 Review hydrodynamic model feasibility

The previous T+T (2020) assessment included a bathtub modelling approach across the entire district. A refined hydrodynamic model for the Wood and CBD was investigated (making use of NCC's existing fluvial flood model). NCC adopted the bathtub inundation mapping for use in their Nelson Plan mapping and for community consultation, as this provided a consistent approach across the city, and was slightly more conservative than the hydrodynamic modelling in this area. A recommendation from the previous assessment was to complete hydrodynamic modelling for other largely inundated areas such as Wakapuaka flats and Tahunanui.

We have reviewed the feasibility of developing a district-wide hydrodynamic model with consideration of the advantages and disadvantages associated with both hydrodynamic and bathtub modelling approaches.

With the LiDAR and bathymetric data available and software capabilities, a district-wide hydrodynamic model is likely to be feasible. However, there are a several practical limitations that arise with a hydrodynamic model that can be avoided with the bathtub approach:

- A district-wide hydrodynamic model will practically be limited to approximately 4-10 m resolution whereas the bathtub approach allows a higher resolution at 1 m. Hydrodynamic models can be highly sensitive to the small-scale features such as bunds, which may not be resolved by the resolution of the model.
- A hydrodynamic model is reliant on accurate definition of the boundary and forcing conditions such as the tidal boundary, freshwater inflows and wind. The model requires values for all freshwater inflows whether static or time-varying, and there are numerous combinations that might be considered for joint probability between extreme sea level and stream/river flow.
- Due to the scale and complexity of the Nelson coast (i.e. combination of estuaries and open coast), it is likely several different models would need to be developed and it can be difficult to established varied boundary conditions across the region. The bathtub approach avoids the complexity and assumptions of defining boundary conditions as it utilises the specific extreme levels derived from the gauge (so is directly linked to actual physical observations).
- Unlike the bathtub model, the hydrodynamic model does not necessarily identify areas of "non-connected" inundation which could be affected by raised groundwater levels or flow paths/drainage network not resolved by the model. We note that use of NCC's stormwater network models (currently in development) in future years could be a step to understanding the role of the piped system in coastal inundation.

These disadvantages can make hydrodynamic analysis less useful than bathtub modelling for assessing scenarios where these future conditions and calibration parameters are unknown or highly uncertain.

Hydrodynamic modelling does have the technical advantage compared with the simpler bathtub approach, in that is takes full account of hydraulic characteristics that can limit the inundation extents based on tidal duration (i.e. there is a limit to how far inundation can extend before the tide turns). As a result, the hydrodynamic inundation extents tend to be less compared with the bathtub inundation extents.

We have done a comparison of the inundation extents from the two different modelling approaches for The Wood/CBD which are presented in Figure 5.1. The difference between hydrodynamic modelling and bathtub modelling tends to be greatest for the lower water levels (Figure 5.1). For example, the T+T (2020) hydrodynamic model found for peak water levels below 3.4 m NZVD2016, the flooding over stopbanks occurred only briefly, resulting is less inundation than suggested by the bathtub model. However, at more extreme future sea level rise scenarios, the inundation extents predicted by the hydrodynamic modelling were more similar to the bathtub extents.

Overall, there is substantially more time and cost involved to develop and calibrate a hydrodynamic model which would still leave uncertainty regarding the absolute accuracy of model results because of the uncertainty in the input parameters. Given the assumptions required, and the high time and cost involved with developing a suitable hydrodynamic model for comparatively small refinement in results (particularly for high future SLR scenarios), we recommend adopting the bathtub approach to assess future inundation extents across the NCC district.

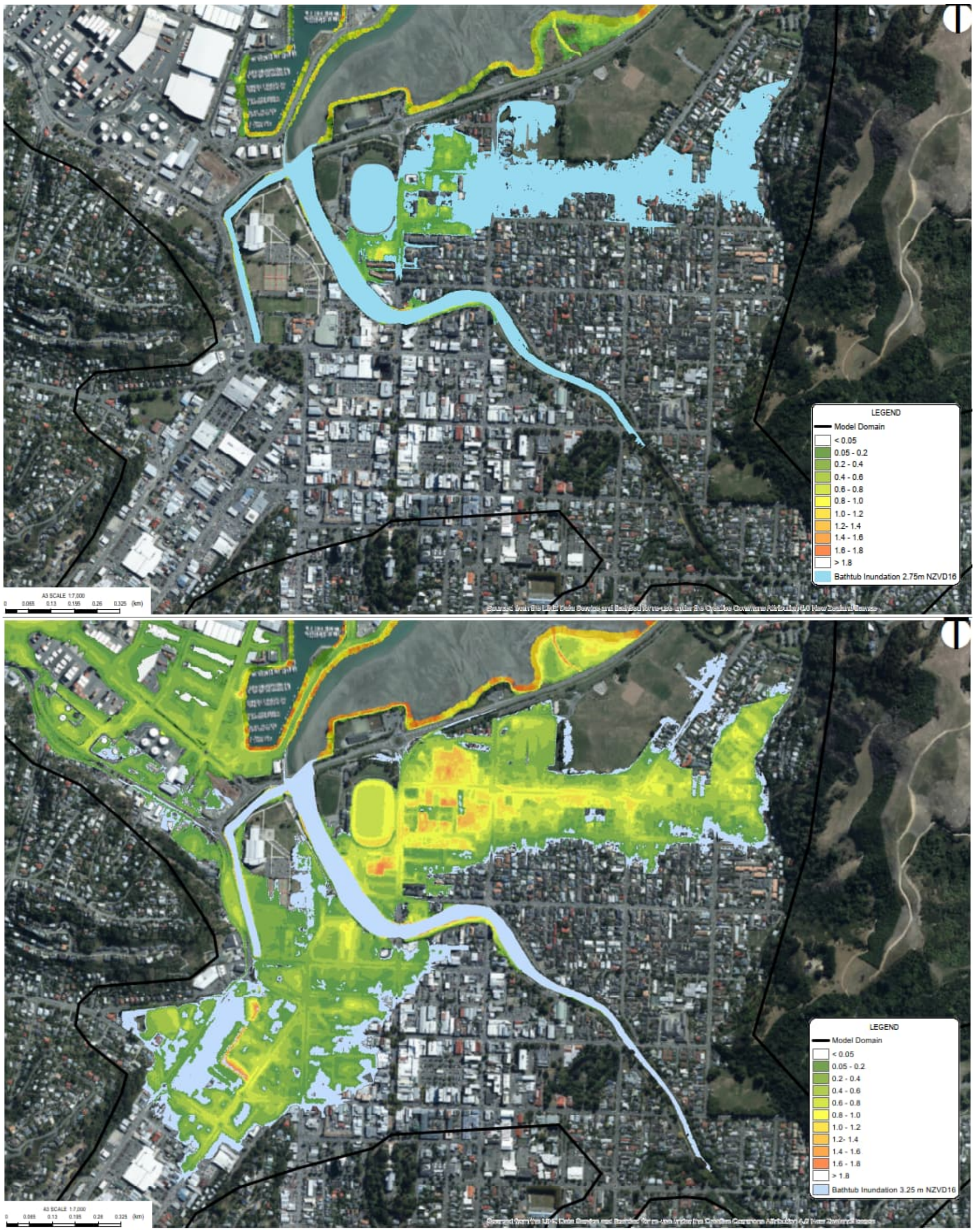


Figure 5.1: Hydrodynamic model outputs compared with bathtub inundation extents (blue). (Top) 2070 RCP2.6 1% AEP extent, (bottom) 2130 RCP 4.5 1% AEP extent.

6 Impacts of wave run-up

The bathtub modelling approach does not include inundation extents from wave runup and overtopping. Wave run-up extents were not previously mapped as the attenuation of wave run-up with distance inland is highly site-specific and is dependent on the run-up elevation, backshore height and slope. For some areas the impact of wave run-up is likely to be more significant than in other areas. For example, photos taken during Ex TC Fehi indicate wave runup contributed to inundation at The Glen, Tahunanui and along Rocks Road (Figure 6.1).

As the bathtub approach does not include impacts of wave runup we recommend completing wave run-up and overtopping modelling and determining likely resulting inundation for the following sites where it appears to have a significant impact:

- Tahunanui Beach
- Rocks Road/Wakefield Quay
- The Glen/Seafield Terrace

Although not as significant as at the sites listed above, wave runup appears to also impact the northern side of Monaco and some of the shoreline around Nelson Haven (i.e. Atawhai, Bay View Road, Figure 6.1).

Figure 6.1: Wave runup and overtopping observed during Ex TC Fehi. (Top left) Wakefield Quay, (top right) Tahunanui Beach, (middle left) Rocks Road, (middle right) Seafield Terrace, The Glen, (bottom) Bay View Road, Atawhai.

7 Summary and recommendations

Following our investigations, we recommend the following:

- Continue to adopt bathtub mapping approach with additional wave run-up assessments in areas prone to wave runup impacts.
- Continue to adopt the extreme water levels assessed by NIWA (2018). Repeating the analysis with the revised values for Ex TC Fehi would make a negligible difference to the 1% AEP value generated.
- Include a revised setup component (0.3 m) for the Waimea Inlet cell.
- Increase the tidal component by 0.1 m for the Nelson CBD cell.
- Revise the coastal cell extents with a split down the crest of Boulder Bank, a split between the CBD and Nelson Haven and a shift in the Waimea Inlet/Tahunanui boundary slightly further north.

8 References

NIWA (2018). Storm-tide and wave hazards in Tasman and Golden Bays. Prepared for Tasman District Council and Nelson City Council.

NIWA (2020). Maitai Joint-Probability River and Sea. Letter provided to Nelson City Council, 4 May 2020

T+T (2020). Coastal Inundation in Nelson City. Report prepared by Tonkin & Taylor Ltd for Nelson City Council.

9 Applicability

This report has been prepared for the exclusive use of our client Nelson City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by:

....

Rebekah Haughey
Coastal Scientist

Authorised for Tonkin & Taylor Ltd by:

....

Damian Velluppillai
Project Director

Reviewed by:

....

Dr Tom Shand

Technical Director – Coastal Engineering

RHAU
t:\auckland\projects\1006718\1006718.2100\issueddocuments\2023.06.16 - phase a summary report v5\phase a investigations. summary report.v5_reportformat.docx

www.tonkintaylor.co.nz