Mapping for priority coastal hazard areas in the West Coast Region

Coastal inundation hazard update using 2022 LiDAR

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Executive summary

This report describes the methodology used to update the coastal inundation hazard maps from the 2022 NIWA study using the newly released 2022 LiDAR data. The design extreme storm-tide elevations are identical to the previous work, but water depth and extent are different because of the updated topography data.

The LiDAR topography data overcomes the flaws of the Shuttle Radar Topography Mission (SRTM) data and hence produces a more accurate inundation extent.

The analysis supersedes coastal inundation hazard information where:

- No inundation analysis was done before (most non-priority coastal hazard areas).
- Only SRTM was available (e.g., Haast, Neils Beach, Jackson Bay, Punakaiki).
- LiDAR was previously available but dynamical modelling was not carried out (e.g., Hector, Granity, Ngakawau, Rapahoe, West of Westport).

However, the results presented here use a relatively simplistic "bathtub" inundation mapping that tend to overestimate flood extent when compared with a dynamical model. Therefore, these results do not replace the coastal inundation hazard layers for Westport/Orowaiti (north of Buller River only).

1 Introduction

In 2022, a report was completed by NIWA to assess coastal inundation and erosion hazard for priority area of the West Coast Region (Bosserelle and Allis 2022). This previous work was completed before the result of the latest LiDAR (Light Detection and Ranging) topographic survey (WCRC-LINZ 2022) was made available, but a contingency was put in place to update the result of the analysis once the LiDAR data were available. This report describes the methodology used to produce coastal inundation hazards maps based on the storm-tide and wave inundation levels calculated by Bosserelle and Allis (2022) and the latest LiDAR dataset.

This analysis intends to replace coastal inundation hazard information where:

- No inundation analysis was done before (most non-priority coastal hazard area).
- Only Shuttle Radar Topography Mission (SRTM) data were available (e.g., Haast, Neils Beach, Jackson Bay, Punakaiki).
- LiDAR was previously available but dynamical modelling was not carried out (e.g., Hector, Granity, Ngakawau, Rapahoe, West of Westport).

The analysis does not intend to replace the hazard layers previously created with a dynamical inundation model in Westport/Orowaiti (north of Buller River only).

2 Methods

The analysis presented here is an update of the NIWA work initially described by Bosserelle and Allis (2022). The analysis is repeated here using a new topography dataset. The design extreme storm-tide elevations are identical to the NIWA report, but water depth and extent are different because of the updated topography data. Some table and figures are repeated from the 2022 NIWA report for consistency.

Bosserelle and Allis (2022) highlighted that the bias-corrected SRTM topography had significant flaws and may lead to a poor assessment of inundation depth and extent. The primary issues with these data were the coarse resolution of the topography (30 m) and the lack of distinction between ground and vegetation. The LiDAR topography data does not have such flaws and hence produces a more accurate inundation extent.

The analysis used to assess the inundation hazard in priority coastal hazard areas is a static “bathtub” inundation assessment where flow pathways and inundation momentum are ignored. This is not as accurate as dynamical numerical model that solves hydrodynamic equations to predict inundation area.

Therefore, the update static inundation hazard assessment with the LiDAR topography presented here supersedes the analysis previously undertaken with SRTM topography but does not supersede existing dynamic inundation hazard assessment that uses hydrodynamics modelling (i.e., Westport and Orowaiti).

2.1 Storm-tide + wave design values

The design event calculated by Bosserelle and Allis (2022) for the 1% AEP storm-tide (the storm tide water elevation with a 1% chance of exceedance in any given year), $Z_{1\%AEP}$, is based on the original work of Stephens et al. (2020) with an added allowance for wave setup (0.8 m for the region). The elevation calculated for priority sites across the region is repeated in Table 2-1. The inundation elevation is thus calculated as:

$$Z_{1\%AEP} = MHWS_7 * 1.32 + 0.28 + Z_{DATUM} + W_{setup} + SLR$$

where $MHWS_7$ is the Mean High Water Spring relative to mean sea level defined as the 7th percentile of all predicted tides; Z_{DATUM} is the adjustment of Mean Sea Level (MSL) to the vertical datum (NZVD16); $W_{setup}$is the wave setup allowance; and SLR is the Sea-Level Rise allowance. The linear relationship between $MHWS_7$ and the 1% AEP storm-tide (i.e., the 1.32 and 0.28 values) was originally calculated by Stephens et al. (2020).

Because $MHWS_7$, and Z_{DATUM} vary across the region, the $Z_{1\%AEP}$ values are different between different priority coastal areas.

Table 2-1: Extreme storm-tide + wave setup elevations on the open coast as mapped for priority coastal hazard area assessment. Elevations in NZVD2016 including uniform 0.14 m MSL offset. Coordinates in NZ Transverse Mercator (NZTM).

Site name	Priority coastal hazard area index	Easting	Northing	1% AEP Storm-tide + wave setup elevation (m NZVD2016)
Westport	3, 4	1499608	5390870	3.085
Punakaiki	12, 13	1464850	5336372	2.9578
Rapahoe	16	1455269	5307735	2.887
Greymouth	17, 18	1446107	5293434	2.8232
Hokitika	21	1432634	5268459	2.770
Okuru	25	1270468	5130759	2.4872
Jackson Bay	26	1255444	5123506	2.5872

Because the new LiDAR dataset covers a significant part of the West Coast region (Figure 2-1) the inundation mapping was extended outside of priority areas to the full LiDAR extent. In order to extend the analysis beyond the priority area, values of $MHWS_7$ and Z_{DATUM} were linearly interpolated to create a smooth surface of $Z_{1\%AEP}$ from Hector to Jackson Bay.

2.2 Sea-level rise

Maps of the coastal inundation hazard correspond to the 1% AEP storm-tide and waves and varying amounts of relative sea-level rise. As in Bosserelle and Allis (2022), 0.2 m increments of sea-level rise were applied from present to 2.0 m above present day mean sea level. Refer to Bosserelle and Allis (2022) for project timing for each increment under different greenhouse gas representative concentration pathways.

2.3 2022 LiDAR

A 5 m resolution DEM grid for the coastal area of the West Coast was constructed. The extent of the DEM covers all the priority coastal hazard area between Jackson Bay and Granity (i.e., as far north as LiDAR data coverage) and from the shoreline to the 10.0 m elevation contour (NZVD16). The DEM was constructed using the classified LiDAR point-cloud by averaging all the points classified as ‘ground’ within a radius of 7.5 m from each grid cell centre. This is sufficient to fill small gaps in the LiDAR coverage (Figure 2-1). LiDAR points classified as water surfaces, buildings or vegetation were ignored, leaving “no-data holes” in the DEM. The inundation analysis is not significantly affected by the “no-data holes” since most of the larger “holes” (larger than 1–2 pixels) corresponds to water bodies.

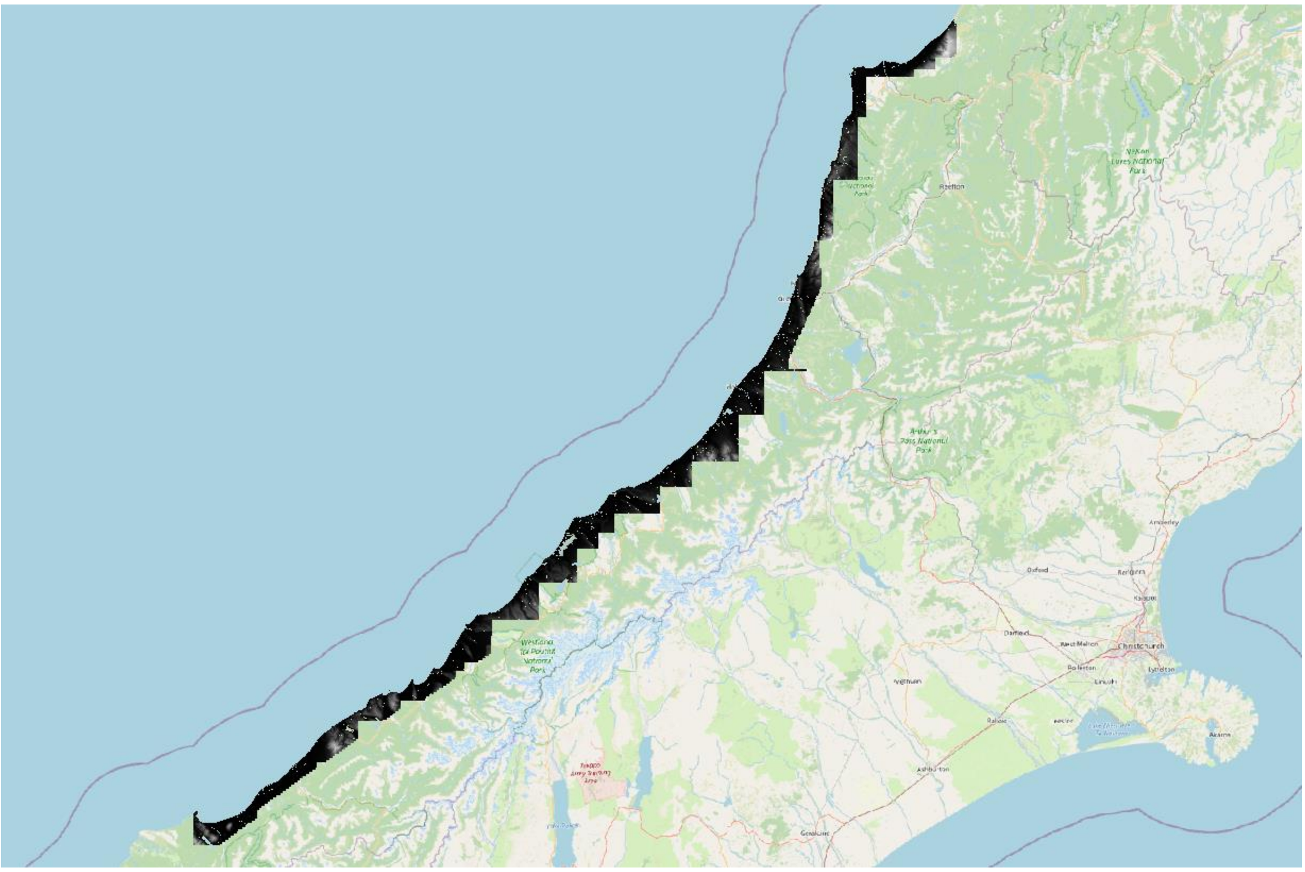

Figure 2-1: The extent of the LiDAR DEM created using the latest LiDAR dataset for the coastal area (dark-grey shading). Note that the actual LiDAR coverage extend further inland, but that part of the DEM was not required for the analysis.

2.6 Mapping of inundation

Inundation extent and depth are calculated for the entire region based on a static level or “bathtub” flood mapping approach. Bathtub mapping is a simple approach that is normally conservative.

For each SLR increment, $Z_{1\%AEP}$ (spatially varying) is calculated over the whole DEM. All the DEM values below $Z_{1\%AEP}$ are then considered inundated. The inundation outputs are:

- GIS raster of the $Z_{1\%AEP}$ for inundated pixels.
- GIS raster of the inundation depth for inundated pixels ($Z_{1\%AEP} - Z_{DEM}$).
- GIS shapefile of the inundation extent.

The inundation extent polygons presented in the GIS shapefile have not been smoothed or simplified. This is to remain consistent with results of dynamical models such as presented for Westport/Orowaiti in Bosserelle and Allis (2022). The GIS outputs were clipped over Westport/Orowaiti so they do not include any of the domain covered by the dynamical model.

3 Discussion

Many of the limitations to static "bathtub" analysis presented in Bosserelle and Allis (2022) are also valid for this report, but the quality of the inundation assessment is greatly improved by using the high-resolution LiDAR.

It should be noted that the LiDAR dataset only represents the topography of the coast at a 'point-in-time' and cannot account for gradual and seasonal changes caused by wave action or sudden changes in the topography caused by natural disaster (storms, floods, earthquakes and landslides). This is particularly relevant because the LiDAR was surveyed mostly during summer months, where beaches are at their widest. Hence, the coastal inundation hazard zone may appear further offshore than the beach in winter (e.g., Figure 3-1). Similarly, some beaches that cyclically fill with sediment may appear seaward the coastal inundation hazard zone but would be inundated when that sediment is eroded away.

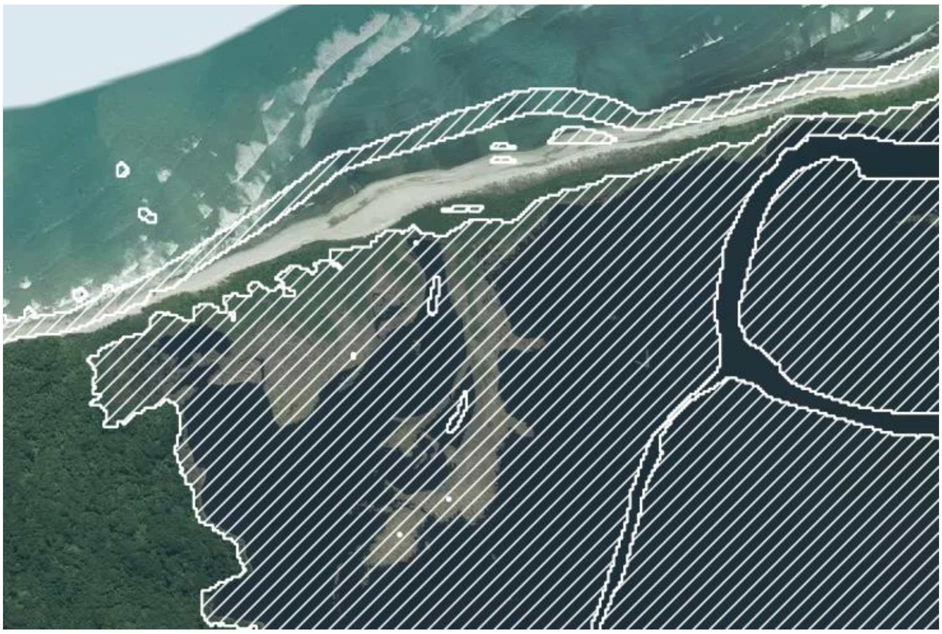

Figure 3-1: Coastal inundation hazard zone (hashed) can appear inconsistent with aerial photography (background) in areas where sediment has recently accreted/eroded. Note: in the situation presented above. for an area north of Whataroa River, the sediment accretion is likely the result of a multi-year process. In contrast, other locations may show a more seasonal cycle of accretion and erosion that may affect the quality of the hazard assessment.

The static "bathtub" analysis also highlights low-lying land that may initially appear far from the coast. However, large storm surge and waves can cause groundwater to rise and either directly flood low-lying backshore area or prevent the infiltration of rainwater thus causing flooding.

3.1 Comparison with previous results

Overall, the recent LiDAR dataset is expected to greatly improves the coastal hazards maps in the coastal hazard priority area where only a SRTM-derived DEM was previously available. Most of the improvement is because the LiDAR better capture the ground elevation and is relatively unaffected by vegetation canopy. For example, the inundation extent in Neils Beach for the 0.0 m SLR increment with LiDAR topography is more realistic than with SRTM topography. This is because, inundation with

LiDAR topography shows the beach and backshore wetlands clearly inundated whereas most of these features are not well captured in the SRTM-derived inundation map (Figure 3-2).

Figure 3-2: Inundation extent in Neils Beach based on SRTM and LiDAR DEM. The inundation extent based on SRTM (pink) does not see the smaller ponds or even the beach itself. The LiDAR-derived inundation extent (hashed) accurately sees ground level below the tree canopy and small inundation pathways.

Static “bathtub” coastal inundation mapping is conservative. Bosserelle and Allis (2022) presented an example using the coastline around Napier. For a local example, the difference between static and dynamic inundation mapping can be highlighted by comparing the result of the “bathtub” methodology with the results of the dynamical model for Westport. Figure 3-3 shows the difference in inundation extent between the dynamical and static models. In area with strong topographical control (i.e., steep topography), both analyses are very consistent. However, in flood plains and flat urban landscapes where the flood water loses momentum because of ground roughness, vegetation and buildings, the static inundation overestimates the inundation extent (e.g., Figure 3-3).

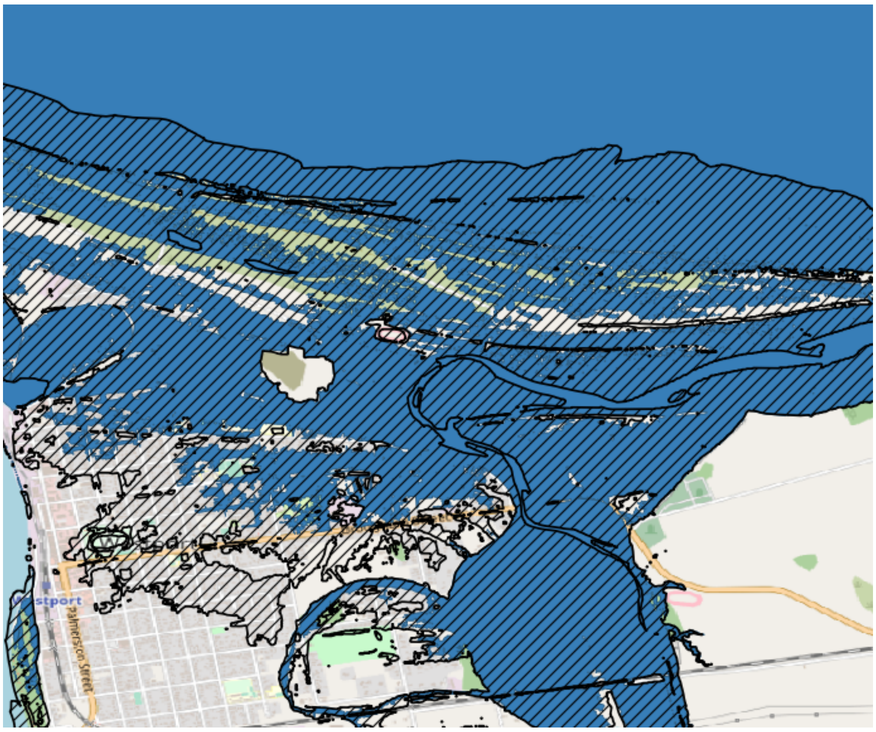

Figure 3-3: Comparison of Westport inundation from the same design event based on a dynamical model (blue) compared to a static "bathtub" model (hashed). Note that in the provided GIS layer, the area covered by the Westport dynamical model is clipped from the static "bathtub" results to avoid confusion between the two methods.

4 Conclusion

The analysis presented here is an update of the NIWA work initially described by Bosserelle and Allis (2022) by replacing the bias-corrected SRTM topographic data with the recently captured LiDAR topography. The LiDAR topography data overcomes the flaws of the SRTM data and hence produces more accurate inundation extent. Therefore, this update supersedes the coastal inundation hazard layers previously produced where:

- No inundation analysis was done before (most non-priority coastal hazard area).
- Only SRTM was available (e.g., Haast, Neils Beach, Jackson Bay, Punakaiki).
- LiDAR was previously available but dynamical modelling was not carried out (e.g., Hector, Granity, Ngakawau, Rapahoe, West of Westport).

However, the results presented here use a relatively simplistic “bathtub” inundation mapping that tend to overestimate flood extent when compared with a dynamical model. Therefore, these results do not replace the hazard layers for Westport/Orowaiti (north of Buller River only). In other locations the results may be superseded by dynamical modelling of the coastal inundation hazard in the future.

5 References

Bosserelle, C., Allis, M. (2022) Mapping for priority coastal hazard areas in the West Coast Region, Supporting Te Tai o Poutini. Prepared for West Coast Regional Council. NIWA client report no: 2022036HN.

Stephens, S.A., Bell, R.G., Haigh, I.D. (2020) Spatial and temporal analysis of extreme storm-tide and skew-surge events around the coastline of New Zealand. Nat. Hazards Earth Syst. Sci., 20(3): 783-796. 10.5194/nhess-20-783-2020 https://www.nat-hazards-earth-syst-sci.net/20/783/2020/

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