Vertical land movement and sea level rise

advice for Christchurch City Council staff and local rūnanga

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Date: October 2025

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1. Purpose

This document is intended to support staff in considering the effects of vertical land movement (VLM), as it relates to planning for the effects of sea level rise. Specifically, this document provides direction on how VLM information might be applied at different spatial and temporal scales. This document also identifies key reference materials.

This document does not provide detailed rationale for the advice provided, but does reference the sources of information used to inform this advice. Despite the extensive monitoring and analysis undertaken locally, it is highly likely that advice will change in time, as new information emerges and if/when future large earthquakes occur.

1.1 Intended audience

This document is intended for Christchurch City Council staff, specifically asset managers, planners and similar who might be seeking guidance on sea level rise projections. This document explains how to apply VLM to these projections, so to arrive at more locally appropriate projections of relative sea level rise. This document will also be made available to local rūnanga, to support with their adaptation planning processes.

If all you require is direction, then skip to section 3.

2. Context

2.1 What is VLM

Changes in the vertical position of land as a result of tectonic movements, and shallower processes such as land settlement, are referred to as vertical land movement. New Zealand's landmass is constantly moving, and this can cause uplift and subsidence, as sudden movements during (co-seismic), or following (post-seismic) large earthquakes, and as more gradual changes that occur continuously between large earthquakes (inter-seismic). In particular, VLM impacts areas that are tidally-influenced, by accelerating rates of relative sea level rise in areas experiencing subsidence and slowing rates of relative sea level rise where land is uplifting.

Here in Ōtautahi Christchurch, recent large earthquakes have meant that many parts of the district are now subsiding (see Figure 2), when they were previously relatively stable (see Figure 1). In some locations, rates of post-seismic subsidence are nearly 10mm/year, double the rate of sea level rise over the last ~20 years (measured at Lyttelton Port). This means that rates of relative sea level rise are dramatically accelerated in locations experiencing this rapid land subsidence,

meaning impacts projected for 30 years, could occur within the next 15-20, assuming subsidence continues. The table below provides an example of this, where the pink column shows post-seismic VLM estimates for different locations, the green column shows sea level rise projections without VLM (next 30 years) and the blue column shows the sea level rise projection inclusive of post-seismic VLM.

	Average post-earthquake VLM rate*	Projected sea-level rise for NZ (without VLM) 2020–2050	Projected local sea-level rise (with VLM) 2020–2050
Brooklands to Waimairi Beach	-5.8mm/year	14–23cm	31–40cm
Waimairi Beach to South New Brighton	-4.9mm/year		29–38cm
Southshore Spit	-6.4mm/year		33–42cm
Bromley	-4.2mm/year		27–36cm
Ferrymead	-3.7mm/year		25–34cm
Mt Pleasant to Taylors Mistake	-3.4mm/year		24–33cm
Lyttelton Harbour and Port Levy	-2.9mm/year		23–32cm
Eastern Bays (Banks Peninsula)	-3.5mm/year		24–33cm
Akaroa Harbour	-1.6mm/year		19–28cm

2.2 National and local datasets

To support the consideration of VLM as it relates to sea level rise projections, the NZ SeaRise Programme has released maps that include local estimates of historic VLM (for every 2km stretch of coast). These VLM estimates are applied to IPCC/MfE directed sea level rise projections to produce site-specific relative sea level rise projections. The VLM data shown on the NZ SeaRise webpage is based on how the land moved between 2003-2010, a timeframe that (intentionally) immediately precedes large earthquakes in our region (2010/11 and 2016). What we know locally, is that some parts of our district have moved and continue to move differently than they did before these earthquakes. Therefore, in locations where VLM rates are now much different (post-quake), NZ SeaRise is not representative of our local situation, and so shouldn't be used for relative sea level rise projections, at least not while post-quake subsidence continues. This is made clear in The Ministry for the Environment Coastal Hazards and Climate Change Guidance (2024), where we are directed to use local data in place of NZ SeaRise data, where it is available.

2.3 Local situation

Because of recent large earthquakes in our district (2010/11) and wider region (2016), CCC and Environment Canterbury have commissioned a series of reports/analyses to assess how our district has been moving in more recent years, and what this might mean going forwards ([1, 2] and [3]). What we have found is that:

- land is generally stable or subsiding across the district, very few locations are experiencing uplift
- rates of land subsidence are highly variable across the district, and in some places land subsidence is understood to be driven by shallow processes, such as settlement
- in areas that are experiencing accelerated land subsidence, we are yet to see a slowing down of this effect
- some parts of our district are moving much differently than they were before the earthquakes, and so our local post-seismic datasets should be used for planning purposes
- in other parts of the district, rates of VLM are similar to before the earthquakes, and so NZ SeaRise data is likely to be appropriate for planning purposes

Based on the findings above and the figures below, we recommend that post-seismic VLM data should be used in locations where earthquake influence on VLM is clear and evident, and that NZ SeaRise data should be used where the earthquake influence is limited. In this context, a "limited earthquake-influence" is evidenced by alignment between inter-seismic (NZ SeaRise) and more recent post-seismic data. The following sections of this document describe the proposed approach to considering VLM in these two different situations, noting that for projects that look beyond a 20-30-year timeframe it may be unclear how to apply VLM (temporally), and further advise may be necessary.

GNS 2023 report.

GNS 2024 report.

GNS 2025 report.

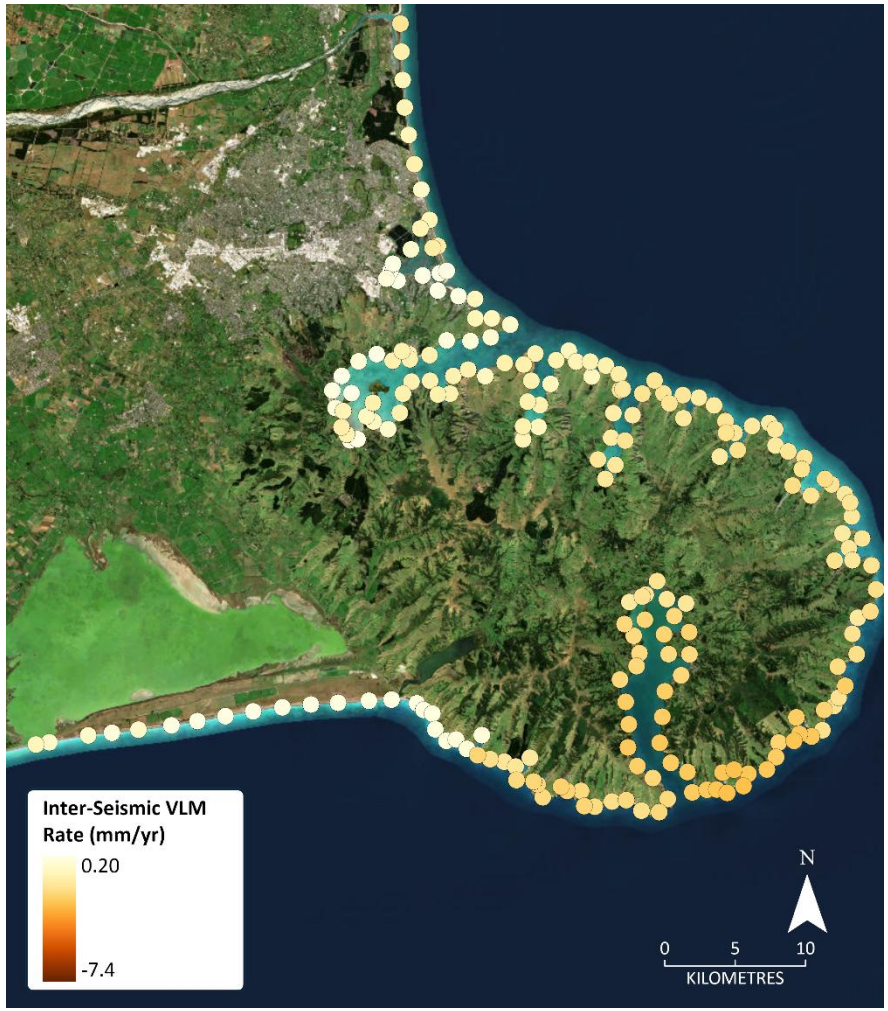


*Figure 1: **inter-seismic** vertical land movement estimates for the Christchurch District. This data has been taken directly from NZ SeaRise. Generally, this shows stability or low amounts of subsidence. The most significant subsidence rates are evident around the southern part of Banks Peninsula and are ~2.5mm/year.*

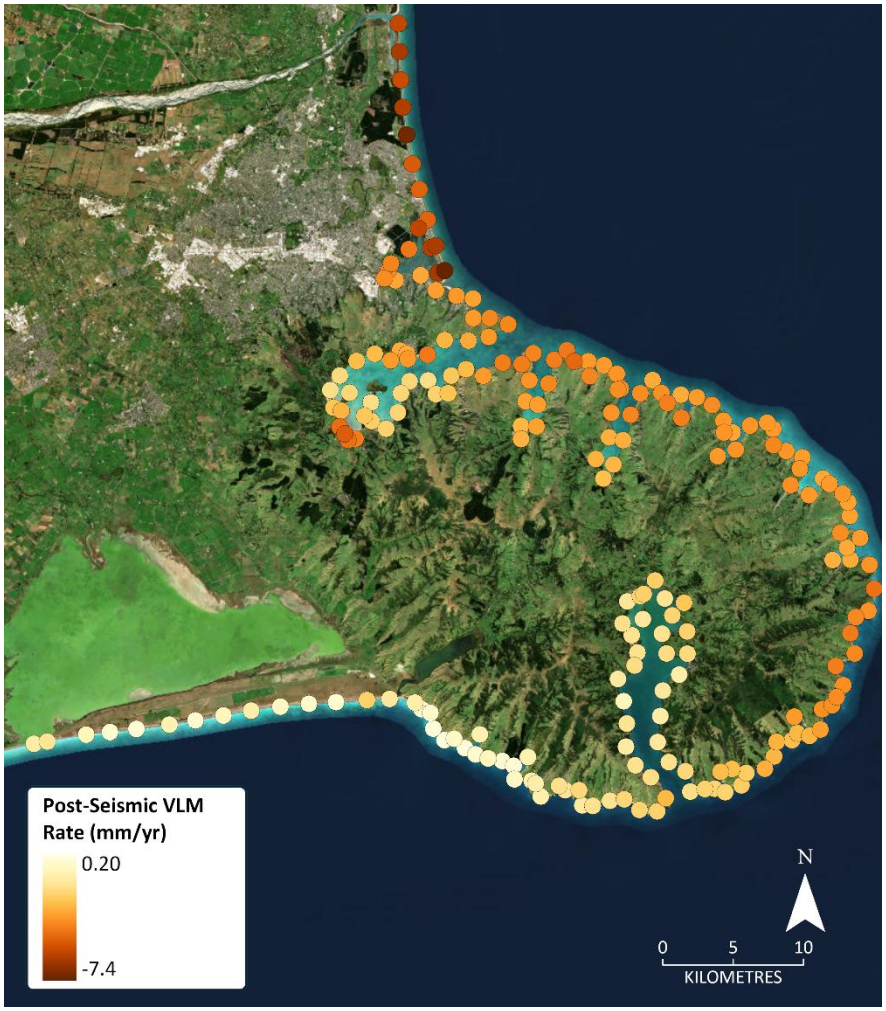


*Figure 2: **post-seismic** vertical land movement estimates for the Christchurch District – GNS, 2025. It is evident that VLM rates are largely unchanged (from Figure 1) around Southern Bank Peninsula and Birdlings Flat. In contrast, far higher rates of land subsidence are shown to the north, particularly at Southshore, where subsidence rates are ~7mm/year.*

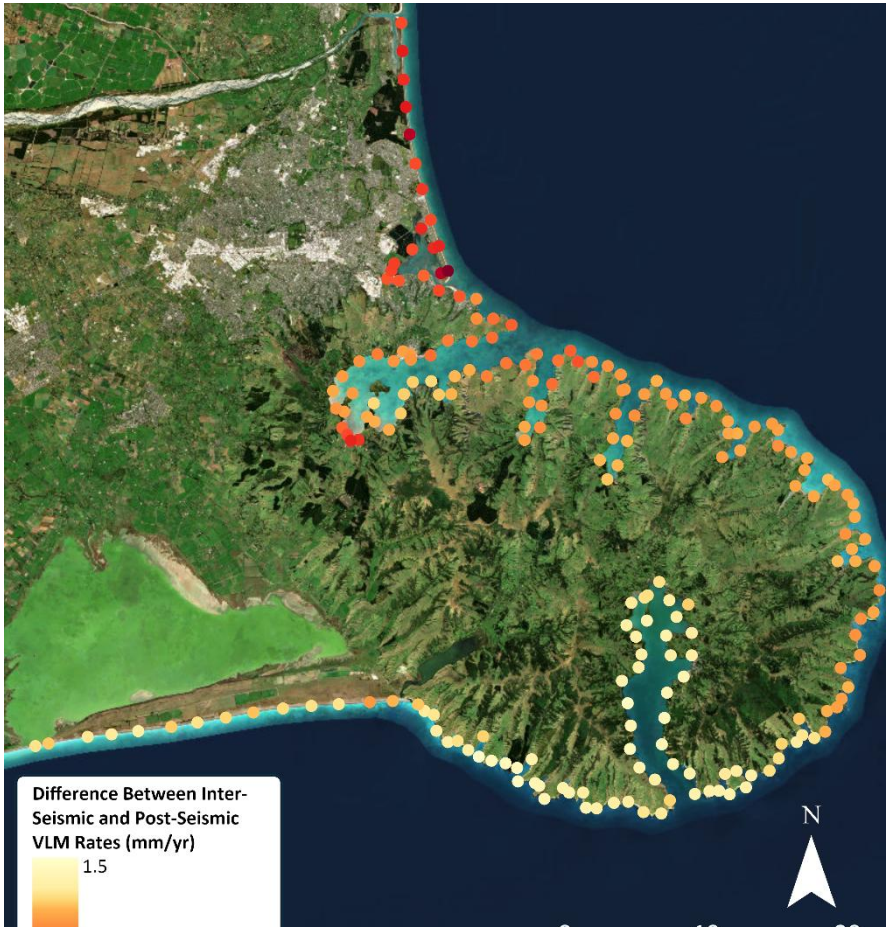


Figure 3: VLM difference between inter-seismic (before Canterbury earthquakes) and post-seismic datasets (Figures 1 and 2). This figure shows that the recent earthquakes have had little to no influence on rates of VLM in the southern part of Banks Peninsula and along Kaitorete Spit. The difference is most pronounced in the city, namely around Southshore.

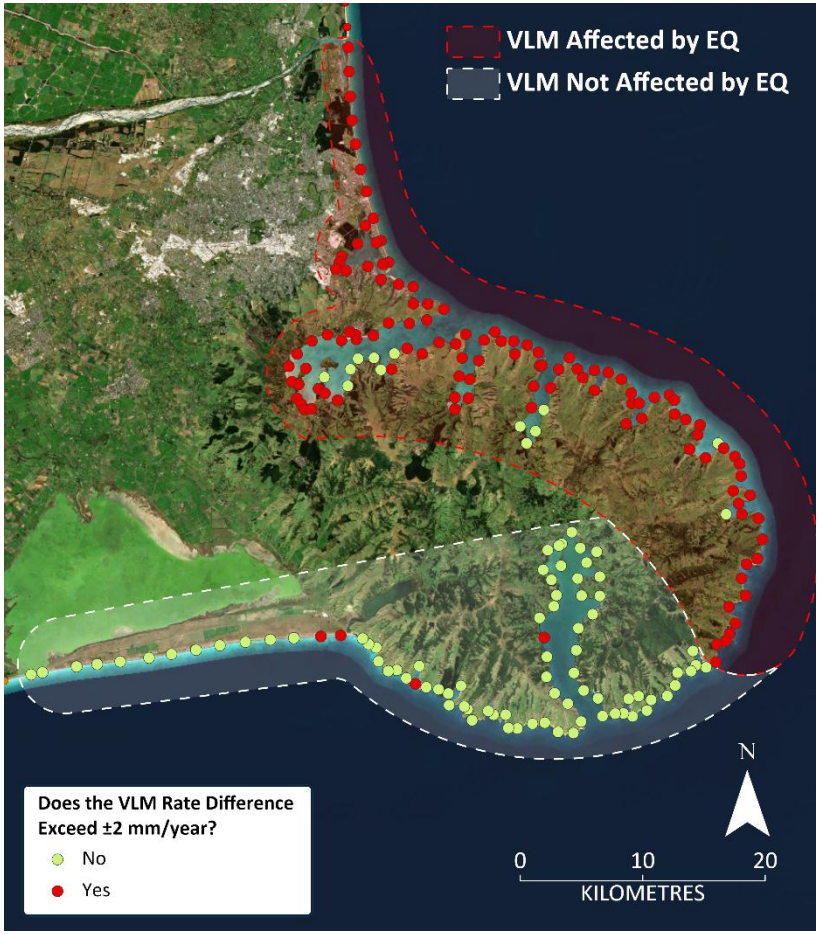


Figure 4: classification of local VLM estimates based on their degree of earthquake influence. Red dots being where there is a "significant" difference (+/-2mm year) between inter-seismic and post-seismic estimates. This 2mm/year difference has been chosen as it exceeds the error associated with the data sets. The red and white dashed polygons represent the areas where we propose staff use post-seismic and inter-seismic data respectively.

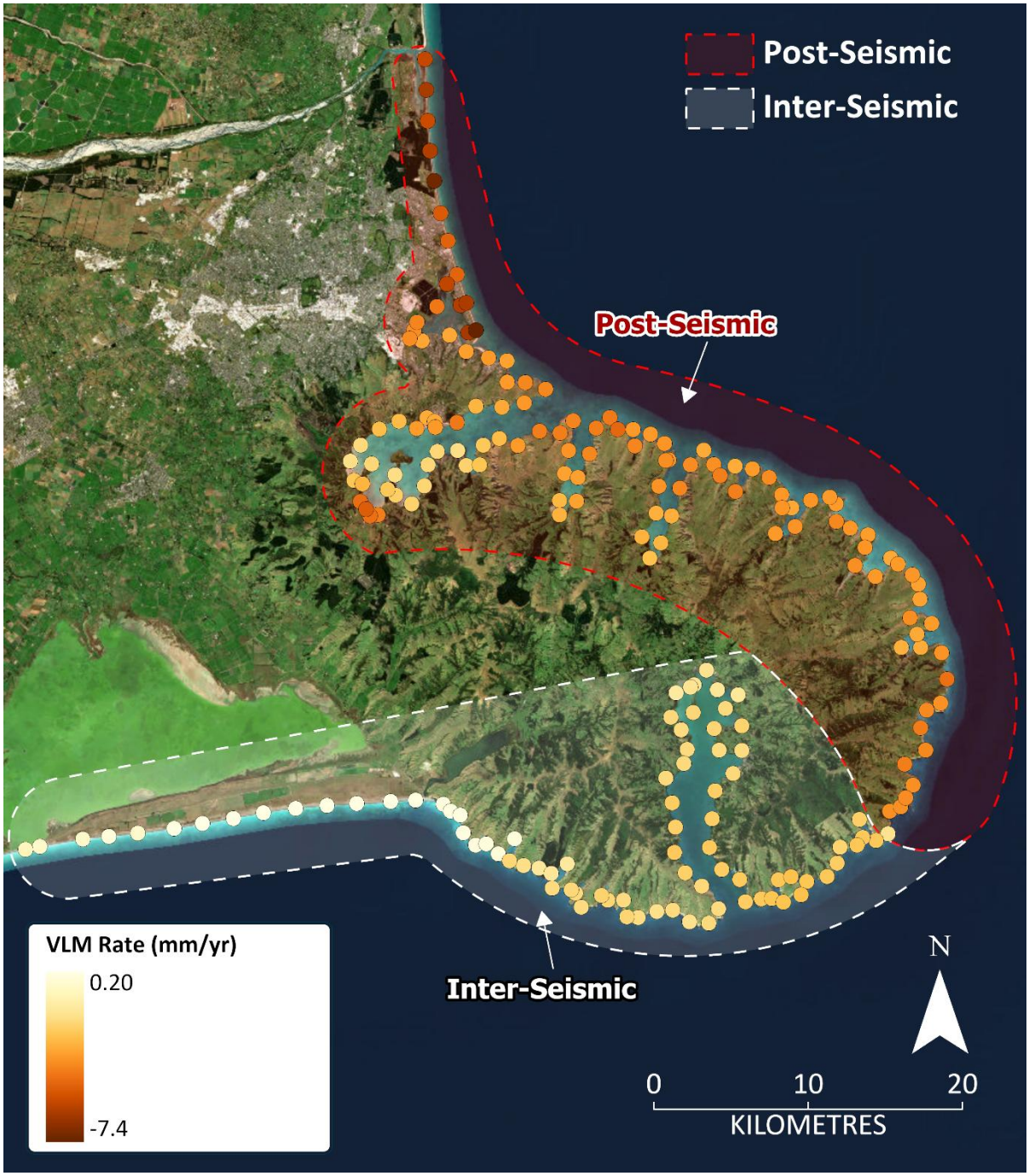


Figure 5: proposed local VLM estimates for different parts of the district, split into red (earthquake-influenced) and white (limited influence) areas. For locations in the white polygon, there is alignment between inter-seismic and post-seismic data and so NZ SeaRise can be used for relative sea level rise projections. For locations in the red polygon, we propose that post-seismic data is used, in line with advice in section 3 below.

3. Advice for "earthquake-affected areas"

The most significant uncertainty when applying post-seismic rates of VLM to projections of local relative sea level rise is that we don't know for how long the land might continue to move in the way that it has over the last 10-15 years. The figure below shows cases from around the world, where post-seismic rates of VLM are immediately accelerated (post-earthquake) before gradually decelerating back to their pre-quake conditions, with the rate of decay being a product of the magnitude/intensity of the earthquake. Locally, we are yet to see evidence of this decay, 15 years on from the 2010/11 earthquakes and 9 years on from the Kaikoura (2016) earthquake. Therefore, we advise towards a precautionary approach (below).

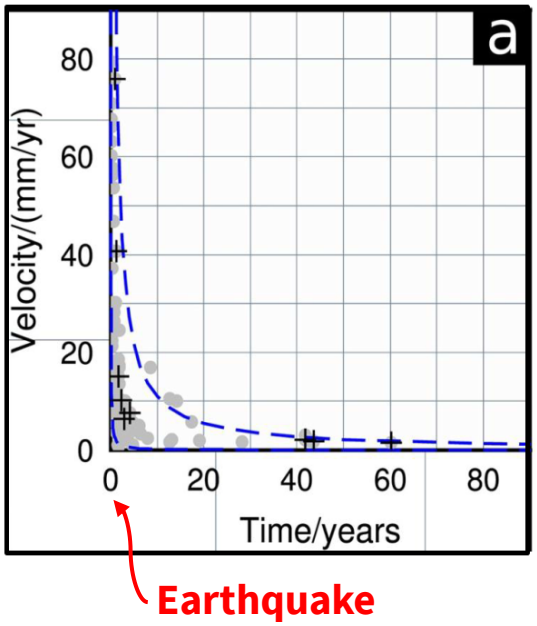


Figure from Ingleby et al., 2017, showing land velocity decay following large earthquakes.

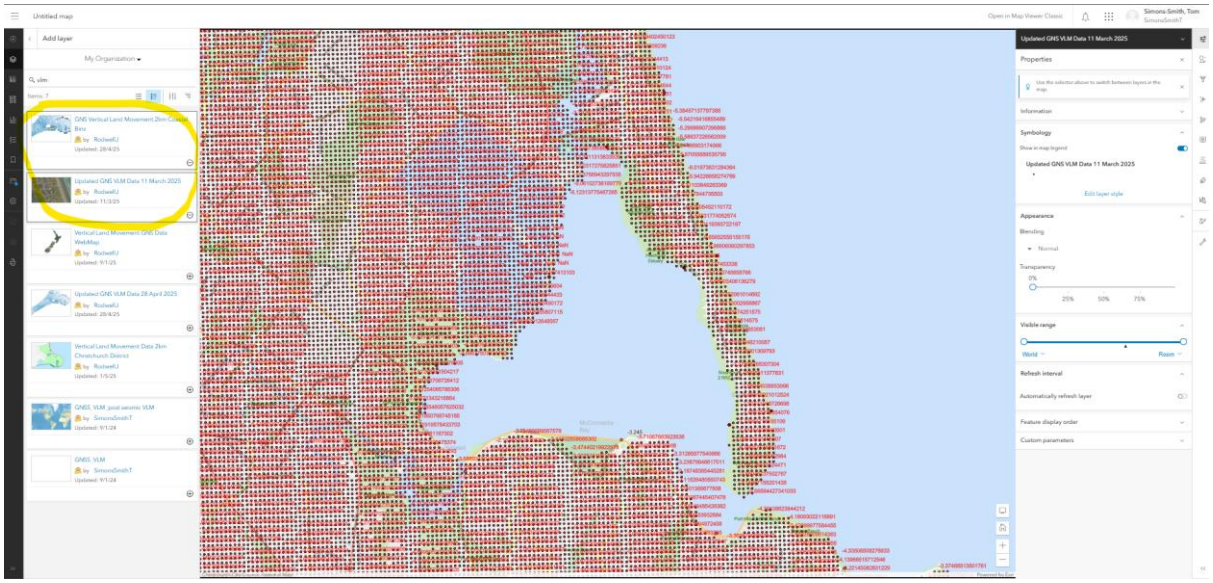
We propose the following, for those locations where earthquake influence is high, and post-seismic rates of VLM significantly differ from the information on NZ SeaRise (red polygon in Figure 5):

- Use the VLM estimate (coloured dot) that is nearest to your area of interest.
- Apply this annual VLM rate to your sea level rise projections (SSP scenarios taken from MfE's Coastal Hazards and Climate Change Guidance 2024, included in Appendix A of this document).
- Apply the post-seismic VLM rate for a period of 30 years (2020-2050). Beyond 2050, apply the inter-seismic VLM rate, from NZ SeaRise, unless there is a clear and obvious reason for applying a more or less precautionary approach, such as a longer or shorter timeframe of post-seismic VLM.
- In cases where sensitivity/stress testing is considered feasible and necessary (significant investment decisions), then apply a range of different future VLM scenarios to test whether extended (or reduced) post-seismic subsidence might impact the investment decision, or require compensating for through design. Please seek advice from the Coastal Hazards Adaptation Planning team on this.

We recognise that the proposed approach has clear limitations and comes with significant uncertainty. This should be flagged clearly when applying the approaches set out in this document. Equally, the magnitude of post-seismic VLM in some parts of the district is such that it stands to have a significant influence on future projections of relative sea level rise, and the timing of related hazard impacts – it should not be ignored.

Note that this document is not intended to inform the selection of sea level rise scenarios (SSPs), but solely the VLM allowances within those sea level rise scenarios. Guidance on sea level rise scenarios should be taken from MfE Coastal Hazards and Climate Change Guidance, 2024, or from CCC's Hazards Network who are currently preparing internal guidance to inform practice.

For CCC staff, the post-quake VLM data can be found on our internal webportal - https://gis.ccc.govt.nz/portal/apps/mapviewer/index.html (screenshot below). Binned data can be found here - Record 25/1208995: Vertical Land Movement GNS Data 2025 2km Bins.

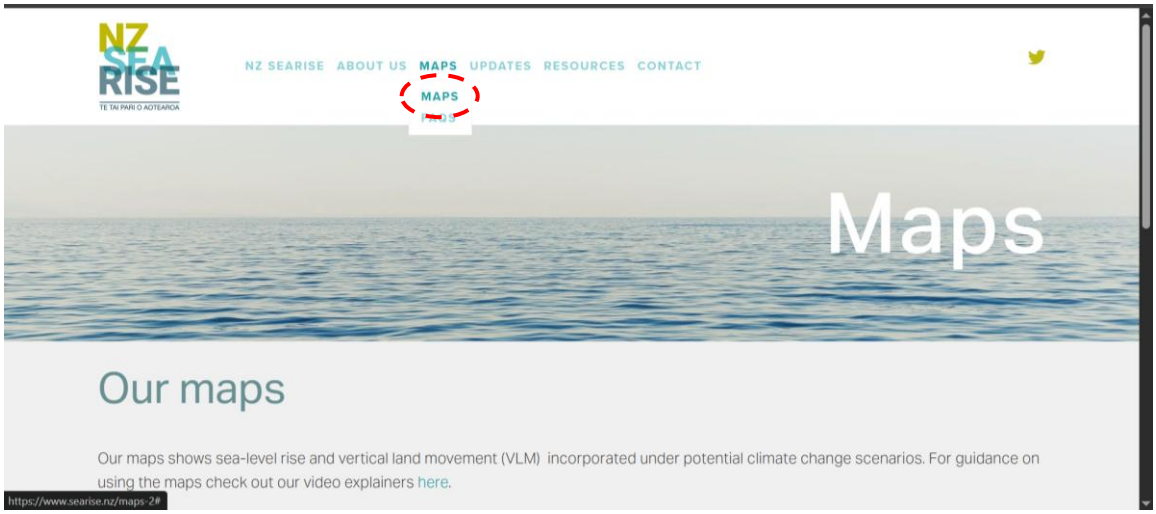


4. Advice for area where earthquake influence on VLM is limited

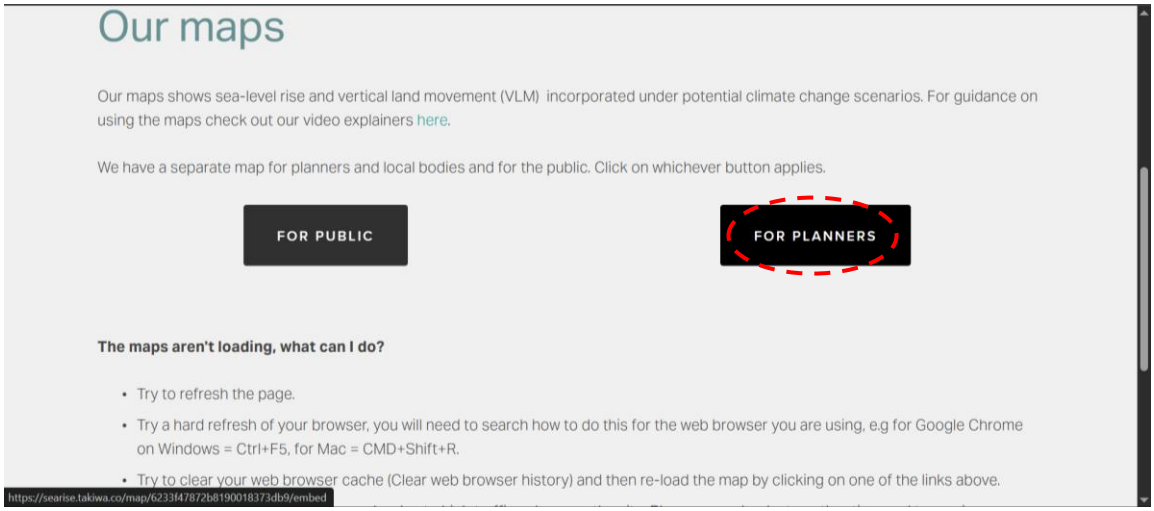
For those areas where post-seismic and inter-seismic VLM data is aligned, and the difference in VLM rates pre and post-quake is minimal, we propose the following:

1. Go to the NZ SeaRise webpage, and navigate to "Maps"

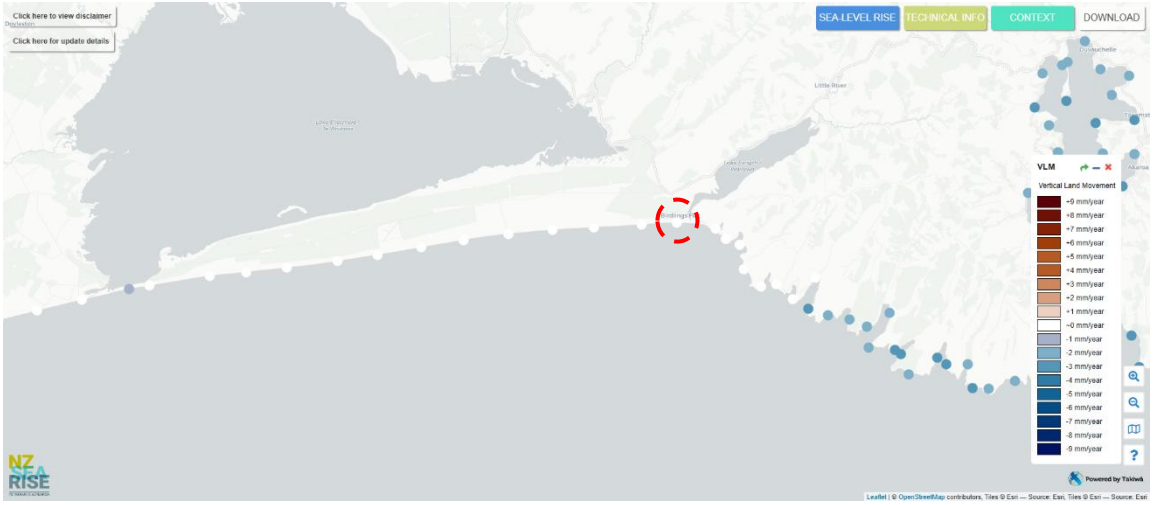
We note that the NZ SeaRise webpage is in the process of being updated to include post-quake VLM data (estimated Q2 2026). CCC staff are working with the NZ SeaRise team as testers on this update.



2. Select “for planners”



3. Navigate to your area of interest and select the associated dot. In this case, Birdlings Flat.



Select the scenarios that you are wanting to consider, ensuring that they are inclusive of VLM.



Note that on the NZ SeaRise webpage "SSP5-8.5" refers to the "SSP5-8.5M" scenario. "SSP5-8.5H+" is represented by the upper band (83rd%tile) of the "SSP5-8.5" projection. Also note the 2005 baseline used for NZ SeaRise relative sea level projections.

Appendix A – national sea level rise projections (MfE, 2024)

	SSP1 - 2.6M		SSP2 - 4.5M		SSP3 - 7.0M		SSP5 - 8.5M		SSP5 - 8.5H+	
	Incremental (m)	Cumulative (m)	Incremental (m)	Cumulative (m)	Incremental (m)	Cumulative (m)	Incremental (m)	Cumulative (m)	Incremental (m)	Cumulative (m)
2020	0	0	0	0	0	0	0	0	0	0
2030	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
2040	0.04	0.09	0.05	0.1	0.05	0.1	0.07	0.12	0.08	0.14
2050	0.05	0.14	0.06	0.16	0.08	0.18	0.08	0.2	0.09	0.23
2060	0.04	0.18	0.06	0.22	0.07	0.25	0.08	0.28	0.11	0.34
2070	0.05	0.23	0.07	0.29	0.09	0.34	0.1	0.38	0.14	0.48
2080	0.05	0.28	0.07	0.36	0.1	0.44	0.12	0.5	0.15	0.63
2090	0.04	0.32	0.07	0.43	0.11	0.55	0.13	0.63	0.18	0.81
2100	0.06	0.38	0.08	0.51	0.12	0.67	0.14	0.77	0.19	1
2110	0.06	0.44	0.09	0.6	0.1	0.77	0.12	0.89	0.19	1.19
2120	0.05	0.49	0.08	0.68	0.12	0.89	0.13	1.02	0.19	1.38
2130	0.05	0.54	0.07	0.75	0.12	1.01	0.13	1.15	0.19	1.57
2140	0.04	0.58	0.08	0.83	0.12	1.13	0.13	1.28	0.18	1.75
2150	0.04	0.62	0.07	0.9	0.11	1.24	0.12	1.4	0.17	1.92

Appendix B – example of how to apply VLM data to sea level rise projections (for an "earthquake affected area")

Step 1: Determine the sea level rise scenarios to be considered (from Appendix A) and the timeframe that you are planning for. CCC Hazards Network to deliver advice on scenario selection in early 2026. In the interim, seek advice from Tom Simons-Smith.

Step 2: determine whether your location of interest is in the red or white area (Figure 5 – to the right).

Step 3: For your area of interest (Southshore in this case) select the nearest VLM estimate (coloured dot). In this case being 6.4mm/year of subsidence.

If your area of interest is larger and extends across multiple VLM estimates, then take a precautionary approach and use the higher subsidence value.

Step 4: Add the annual VLM estimate (-6.4mm/year in this case) to your sea level rise projections (from Step 1 – noting the difference in units - mm/year for VLM and m/decade for sea level rise) for a period of 30 years, or a different timeframe if deemed appropriate.

Step 5: If looking beyond a 30-year timeframe, add the inter-seismic VLM estimate for Southshore (Figure 1 or from NZ SeaRise) to the remainder of your sea level rise projection.

