BEFORE INDEPENDENT HEARING COMMISSIONERS
IN CHRISTCHURCH

TE MAHERE Ā-ROHE I TŪTOHUA MŌ TE TĀONE O ŌTAUTAHI

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of the hearing of submissions on Plan Change 14 (Housing and Business Choice) to the Christchurch District Plan

---

STATEMENT OF PRIMARY EVIDENCE OF DR EMILY MARGARET LANE ON BEHALF OF CHRISTCHURCH CITY COUNCIL

QUALIFYING MATTER: TSUNAMI RISK

Dated: 11 August 2023

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. My full name **is Emily Margaret Lane**. I am employed as Principal Scientist: Natural Hazards and Hydrodynamics at the National Institute of Water and Atmospheric Research (**NIWA**). My expertise is in tsunamis and tsunami modelling.

2. I have prepared this statement of evidence on behalf of the Christchurch City Council (the **Council**) in respect of Plan Change 14 to the Christchurch District Plan (the **District Plan**; **PC14**), and specifically in relation to matters arising from the submissions and further submissions on the proposed Tsunami Risk Management Area Qualifying Matter.

3. I understand that the operative District Plan does not currently include a Tsunami Risk Management Area.

4. PC14 seeks to introduce a Tsunami Risk Management Area Qualifying Matter to manage intensification activities within these risk areas.

5. While impactful tsunamis are rare, when they do happen the results are devastating: damaged and destroyed buildings, infrastructure, lifelines and other assets, wreckage strewn throughout the inundation area and severe life safety risk to anyone in the inundation zone when the tsunami arises.

6. The tsunami scenario used to define the Tsunami Risk Management Area for Christchurch (reported in "Land Drainage Recovery Programme: Tsunami Study" by Bosserelle et al. (2019)[1]) would also impact a large proportion of coastal New Zealand.

7. Sea Level Rise (**SLR**) exacerbates the hazard and risk from any tsunami that does occur. Bosserelle et al., (2019) included a Relative Sea Level Rise (**RSLR**) scenario of 1.06 m in the tsunami hazard modelling which has informed the mapped Tsunami Risk Management Areas used in preparing PC14 as shown in Ms Sarah Oliver's section 42A report.

8. Since the tsunami modelling that informed PC14 was undertaken, new SLR projections and Vertical Land Movement (**VLM**) projections have become available and new sea-level rise guidance has been produced (Ministry for the Environment (**MFE**) 2022). The modelled sea level rise of 1.06 m is 0.45–0.89 m lower than that currently recommended by MFE (2022), depending on VLM, which would imply that the modelled tsunami hazard is underpredicted.

[1] https://ccc.govt.nz/assets/Documents/Environment/Water/Flooding-Land-Drainage/Tsunami-Study-Final-report-June-19.pdf

9. However, the modelled tsunami scenario used to inform the proposed Tsunami Risk Management Areas used a 1:500-year return period tsunami event (0.2% Annual Exceedance Probability, **AEP**) which is 2.5 m higher at the coast than a 1:100-year event (1% AEP) and modelled that tsunami arriving at high tide (Mean High Water Spring; **MHWS**).

10. A 1:500-year event has a 19.3% chance of occurring or being exceeded between now and 2130, whereas a 1:100-year tsunami has a 65.9% chance of occurring in the same timeframe.

11. In my opinion, the current modelling used to inform the proposed Tsunami Risk Management Areas is robust and fit-for-purpose and provides an adequate level of precaution with regards to tsunami inundation and SLR. For this reason, I support adopting as the Tsunami Risk Management Area Qualifying Matter, all areas inundated over 30 cm in the 1:500-year, MHWS, 1.06 m SLR tsunami scenario, as proposed in the amended PC14, and as mapped in the section 42A planning report of Ms Oliver.

12. This evidence addresses submissions raising concerns about Tsunami Risk Management Area Qualifying Matter and requesting that:

    (a) The Tsunami Management Area be reduced to a 1:100-year hazard.

    (b) New rules require minimum building height for houses to be built to two storeys in the zone at risk of tsunami damage. This would give occupants somewhere to go if they cannot evacuate to higher ground in time.

13. Having reviewed these submissions, it is my opinion that the Tsunami Risk Management Area Qualifying Matter in PC14, as notified but now proposed to exclude inundated areas where the depth of inundation is less than 30 cm (and correcting errors in the underlying zoning in the Tsunami Risk Management Area), as explained in Ms Oliver's report (the **Amended Proposal**) is appropriate for mitigating the impacts of tsunamis on Christchurch.

INTRODUCTION

14. My full name is **Emily Margaret Lane**. I am employed as Principal Scientist: Natural Hazards and Hydrodynamics at NIWA. My expertise is in tsunamis and tsunami modelling.

15. The operative District Plan does not include a Tsunami Risk Management Area.

16. PC14 as notified proposes to introduce a Tsunami Risk Management Area. This area was developed on the basis of the best available information and modelling available at the time of notification, which was undertaken for the Council and reported in Bosserelle et al., (2019).[2] The proposed Tsunami Risk Management Area based on that modelling is mapped in Ms Oliver's section 42A report.

17. Since the modelling that informed PC14 (Bosserelle et al., 2019) was undertaken, new SLR projections and vertical land motion projections have become available and new SLR guidance has been produced (MFE 2022).

18. I was engaged by the Council to assess whether the Tsunami Risk Management Area as notified in PC14 would appropriately mitigate the impacts of a tsunami in Christchurch. Below I set out my analysis and conclusion that the Tsunami Risk Management Area as mapped in the Amended Proposal for PC14 would appropriately mitigate the impacts of a tsunami on Christchurch.

19. In preparing this evidence I have:

(a) Reviewed Bosserelle et al., (2019), the tsunami hazard assessment work NIWA undertook for the Council;

(b) Reviewed documents pertaining to SLR[3], tsunami vulnerability functions[4] and vertical evacuation[5];

(c) Reviewed the draft section 42A planning report of Ms Oliver insofar as it relates to my evidence; and

(d) Reviewed sub-section 6.16 of the section 32 report.

20. I am authorised to provide this evidence on behalf of the Council.

QUALIFICATIONS AND EXPERIENCE

21. I hold the qualifications of PhD in Applied Mathematics with a Geoscience minor from the University of Arizona, Tucson, Arizona, USA.

22. I have worked at NIWA in coastal hazards and tsunamis since February 2006. During that time, I have undertaken extensive research and consultancy around

---

[2] Bosserelle et al., (2019) https://ccc.govt.nz/assets/Documents/Environment/Water/Flooding-Land-Drainage/Tsunami-Study-Final-report-June-19.pdf.
[3] MfE (2017) https://environment.govt.nz/publications/preparing-for-coastal-change-a-summary-of-coastal-hazards-and-climate-change-guidance-for-local-government/ and MfE (2022)https://environment.govt.nz/publications/interim-guidance-on-the-use-of-new-sea-level-rise-projections/
[4] Tarbotton, C., F. Dall'Osso, D. Dominey-Howes and J. Goff (2015). "The use of empirical vulnerability functions to assess the response of buildings to tsunami impact: Comparative review and summary of best practice." Earth-Science Reviews 142: 120-134. https://doi.org/10.1016/j.earscirev.2015.01.002
[5] MBIE (2017) https://www.building.govt.nz/assets/Uploads/building-code-compliance/geotechnical-education/tsunami-vertical-evacuation-structures.pdf

risks to people and property, arising from tsunami events, including the preparation of tsunami hazard assessments for five regional councils around New Zealand.

23. I have participated in multiple research projects on tsunamis including Natural Hazards Research Platform projects on submarine landslide generated tsunamis, a Marsden project on Volcanic tsunamis (which I was Principal Investigator on), the National Science Challenge – Resilience to Nature's Challenges tsunami subtheme and an Endeavour programme on seismic tsunamis (**RCET**). I was also on the panel who provided input into the 2020 Ministry of Business Innovation and Employment (**MBIE**) report on vertical evacuation structures for tsunamis.

24. I am a member of the NZ Tsunami Expert Panel, a group of New Zealand tsunami researchers who provide advice to the National Emergency Management Agency (**NEMA**) during tsunami responses. I am also a member of the New Zealand Coastal Society and the Tsunami Society International.

CODE OF CONDUCT

25. While this is a Council hearing, I have read the Code of Conduct for Expert Witnesses (contained in the 2023 Practice Note) and agree to comply with it. Except where I state I rely on the evidence of another person, I confirm that the issues addressed in this statement of evidence are within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

SCOPE OF EVIDENCE

26. My statement of evidence addresses the following matters:

    (a) Tsunami modelling for the Council;

    (b) SLR as it pertains to tsunami modelling;

    (c) Tsunami scenarios;

    (d) Tsunami impacts; and

    (e) Vertical evacuation.

27. I address each of these points in my evidence below.

TSUNAMI MODELLING FOR THE COUNCIL

28. In 2018, I contributed to the development of a tsunami hazard model for the Council reported in Bosserelle et al, (2019). The modelling was undertaken using Basilisk

software, an internationally recognised software package that has been shown to accurately replicate tsunami benchmark cases. This software has been used to model tsunamis in New Zealand and around the world.

29. The tsunamis scenarios modelled were based on the GNS Science Consultancy Reports "Review of Tsunami Hazard in New Zealand (2013 Update)" and "Tsunami hazard curves and deaggregation plots for 20 km coastal sections, derived from the 2013 National Tsunami Hazard Model (2014)" undertaken by Dr W. L. Power of GNS Science (Power et al., 2014). These reports identify that large subduction earthquakes occurring in the South Peru/North Chile region are likely to cause tsunamis most hazardous to Christchurch. These events (scenarios) are similar to the 1868 tsunami which inundated significant areas in the Chatham Islands and resulted in multiple loss of life.

30. Two return period scenarios were taken from Power et al. (2014): A 2,500-year return period (84th percentile) tsunami generated by a Mw 9.485 subduction earthquake and a 500-year return period (84th percentile) tsunami generated by a Mw 9.24 subduction earthquake. These represent the largest tsunami expected to impact Christchurch in 2,500 years and 500 years respectively. These represent tsunami events having a 0.04% and 0.2% likelihood of occurring in any given year respectively.

31. The 1:500-year 50th percentile tsunami hazard in Christchurch is around 6.5 m wave-height-at-coast compared to a 4 m wave height at coast for a 1:100-year event and 5 m wave-height-at-coast for a 1:200-year event as calculated in Power et al. (2014).

32. There is a 65.9% probability that the 1:100-year tsunami inundation is reached or exceeded between now and 2130, a 41.5% chance that the 1:200-year tsunami inundation is reached or exceeded between now and 2130 and a 19.3% chance that the 1:500-year tsunami inundation is reached or exceeded between now and 2130.

33. Both tsunami scenarios were modelled assuming that the maximum wave arrived at MHWS (high tide) for current sea level and three SLR scenarios, 0.19 m, 0.41 m, and 1.06 m. For higher sea level, these tsunamis are even more damaging as they can inundate areas deeper and reach further inland. Even recent smaller tsunamis would have caused far more damage with 1 m of SLR and a large event like the 1868 tsunami would have had far greater impacts with an additional 1 m of SLR.

34. Results of this study are available in the NIWA consultancy report: "Land Drainage Recovery Programme: Tsunami Study (2019)" by Bosserelle, Arnold and Lane.[6] The results from that report were used to define the maps of Tsunami Risk Management Area shown in the section 42A planning report of Ms Oliver.

35. I understand PC14 as notified adopted as Tsunami Risk Management Area the entire area inundated by Bosserelle et al., (2019), however the Amended Proposal excludes inundated areas where the depth of inundation is less than 30 cm. This is because inundation below that level is less likely to be damaging to property or harmful to life safety.

SEA LEVEL RISE

36. The SLR of 1.06 m was the projected SLR by 2120 based on the 2017 Tonkin & Taylor report: Coastal Hazard Assessment – Stage Two, Report for the Council.[7] This represents the expected SLR by 2120 under the RCP8.5 scenario based on Kopp et al (2014) and as stated in Ministry for the Environment report "Preparing for coastal change" (2017).

37. The following policies from the New Zealand Coastal Policy Statement[8] (**NZCPS**) are relevant:

> *Policy 24 Identification of coastal hazards*
>
> *(1) Identify areas in the coastal environment that are potentially affected by coastal hazards (including tsunami), giving priority to the identification of areas at high risk of being affected. Hazard risks, over at least 100 years, are to be assessed having regard to:*
>
> > *(a) physical drivers and processes that cause coastal change including sea level rise;*
> >
> > *(b) short-term and long-term natural dynamic fluctuations of erosion and accretion;*
> >
> > *(c) geomorphological character;*
> >
> > *(d) the potential for inundation of the coastal environment, taking into account potential sources, inundation pathways and overland extent;*

[6] https://ccc.govt.nz/assets/Documents/Environment/Water/Flooding-Land-Drainage/Tsunami-Study-Final-report-June-19.pdf
[7] https://www.ccc.govt.nz/assets/Documents/Environment/Land/Costal-Hazards/Summary-of-Coastal-Hazards-Report-2017.pdf
[8] https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement-2010.pdf

(e) cumulative effects of sea level rise, storm surge and wave height under storm conditions;

(f) influences that humans have had or are having on the coast;

(g) the extent and permanence of built development; and

(h) the effects of climate change on:

(i) matters (a) to (g) above;

(ii) storm frequency, intensity and surges; and

(iii) coastal sediment dynamics;

taking into account national guidance and the best available information on the likely effects of climate change on the region or district.

Policy 25 Subdivision, use, and development in areas of coastal hazard risk

In areas potentially affected by coastal hazards over at least the next 100 years:

(a) avoid increasing the risk of social, environmental and economic harm from coastal hazards;

(b) avoid redevelopment, or change in land use, that would increase the risk of adverse effects from coastal hazards;

(c) encourage redevelopment, or change in land use, where that would reduce the risk of adverse effects from coastal hazards, including managed retreat by relocation or removal of existing structures or their abandonment in extreme circumstances, and designing for relocatability or recoverability from hazard events;

(d) encourage the location of infrastructure away from areas of hazard risk where practicable;

(e) discourage hard protection structures and promote the use of alternatives to them, including natural defences; and

(f) consider the potential effects of tsunami and how to avoid or mitigate them.

38. Since the tsunami modelling was undertaken, future sea level projections have been revised, which include a transition to Shared Socioeconomic Pathways (**SSPs**) an extension to the prior Representative Concentration Pathways (**RCPs**) and revisions

to the contributions to SLR. The new approach is summarised in MFE (2022) interim guidance on the use of new SLR projections. Furthermore, MFE (2022) has revised the MFE (2017) transitional guidance for future SLR planning.

39. The MFE (2022) guidance recommends the use of the SSP scenarios, a timeframe out to 2130 (previously 2120) and the use of SSP5-8.5H+ plus VLM (previously RCP8.5H+) for changes in land use and development (intensification), where prior a dynamic pathways approach based on a range of sea level rise scenarios was recommended. The SLR projections as per the MFE (2022) guidelines are presented in **Table 1**. According to NZ SeaRise (https://www.searise.nz/maps-2), VLM in the Christchurch Region ranges from -2.91 mm/yr (subsidence) near Kaiapoi to +1.458 mm/yr (uplift) further south in a location in Ihutai Avon/Heathcote Estuary. This suggests that the VLM in 100 years could alter the sea level rise projections between −0.1458 m and + 0.291 m. Thus, the maximum relative sea-level rise is 1.95 m, which is 0.89 m above the 1.06 m scenario being applied.

Table 1. Sea level rise projections relative to 1986-2006 MSL baseline.

Year	SLR Scenario	M (50%ile, m)	H+ (83%ile, m)
2120	SSP5-8.5	1.09	1.47
2130	SSP5-8.5	1.22	1.66[a]

A New Zealand average sea level rise projection recommended in MFE (2022).

40. The earliest 1.06 m RSLR (i.e., SLR + VLM) is projected to occur assuming the greatest subsidence and the fastest SLR scenario is around 2085. So at least up until 2085, the current tsunami modelling provides for a 1:500-year tsunami event.

41. Although the 1.06 m RSLR scenario by 2120 is less than the currently recommended RSLR scenario (possibly by up to 0.89 m), the 1 in 500-year tsunami scenario is around 2.5 m higher at coast than a 1:100-year event and 1.5 m higher than a 1:200-year event. We also model the conservative approach of the maximum wave height arriving at MHWS.

42. The difference in RSLR scenario is a lot lower than the difference between a 1:500-year scenario and either a 1:100-year or 1:200-year scenario. Considering the uncertainty in potential large tsunami arrivals over the next 100 years this seems a reasonable level of precaution.

43. Therefore, it is my opinion that this modelling still contains a reasonable level of precaution appropriate for defining the Tsunami Risk Management Area.

TSUNAMI SCENARIOS

44. Several scenarios were modelled to understand what a worst-case scenario might look like for each return period. While these scenarios are unlikely to exactly match a future event, the combined results provide a reasonable overview of the likely extent and severity of a tsunami with that level of probability impacting Christchurch.

45. The largest tsunamis likely to affect Christchurch are generated by subduction zone earthquakes (megathrust events) on the South American Subduction Zone. Depending on where along the subduction zone the tsunami generated by these events occurs, a tsunami is likely to take between 11-15 hours to reach the New Zealand shores, after the fault rupture.

46. The Hikurangi Subduction Zone is directly offshore Wellington and the southeast coast of the North Island (Tairāwhiti to Wellington), while there has not been a large megathrust earthquake on this subduction zone in recent times, there is paleoseismic evidence that they have occurred in the past. There is uncertainty in how far south the subduction zone extends as the tectonic plate boundary type transitions from subduction to strike-slip along the Alpine Fault. The impact of an event on Christchurch will depend on how far south the subduction zone extends. If it extends further south and an earthquake occurs that ruptures this southern portion, then it could cause significant hazard to Christchurch. Some scenarios could pose similar hazard to an extreme South American tsunami scenario, such as was modelled.

47. A megathrust event on the Hikurangi Subduction zone would be felt moderately to strongly in Christchurch and would last for over a minute. The tsunami would take around 80 minutes to reach Christchurch after fault rupture.

48. A tsunami event of this size (either South American Subduction Zone or Hikurangi Subduction Zone) would not be localised to Christchurch but would affect the whole of New Zealand. Severe inundation would occur for all low-lying regions on the east coast of New Zealand and even some west coast locations. Christchurch most likely could not rely on external help from other parts of the country during the immediate response and longer-term recovery phases as they would be dealing with the event in their own regions.

TSUNAMI IMPACTS

49. Impacts from tsunamis are not just caused by the water but also the debris picked up by the water. In built-up areas tsunami velocities can be increased by water being channelled between buildings. Higher velocities increase the likelihood of damage to buildings and property and life safety risk. Thirty centimetres of fast-moving water is enough to float a small car or other debris which then become projectiles. It can also sweep a person away. After the tsunami retreats it may leave behind wreckage from buildings, cars, boats, and anything else it has picked up, which subsequently become injury-causing hazards during response and recovery phases.

50. There is variation in the studies on the expected damage to residential properties as a function of tsunami depth. Tarbotton et al. (2015) "*The use of empirical vulnerability functions to assess the response of buildings to tsunami impact: Comparative review and summary of best practice*" reviews the research. Some studies show a chance of minor to moderate damage for depths greater than around 30 cm. A study of a dataset from the 2011 Japan tsunami showed around 75% of buildings that were inundated up to 50 cm deep by the tsunami suffered damage of some kind with around 3% being destroyed. Damage increases for higher inundation depth, by 2 m depth more than half the buildings were destroyed. Extreme damage is more likely to occur when there is debris in the water. During the 2016 Kaikōura tsunami a log picked up by the tsunami broke down the door of an outbuilding even though it was only inundated to around 30 cm depth.

51. In a large tsunami, the entire inundation zone (the Tsunami Risk Management Areas in the maps that form part of section 42A planning report of Ms Oliver) will not only have damaged and destroyed buildings and other infrastructure but will be strewn with wreckage from collapsed buildings, cars, and any other debris the tsunami has picked up.

52. Very few people who are swept away by tsunamis survive. They may be drowned, battered by debris in the water. Even if they survive the tsunami, a lot of people die several days later from pneumonia-like symptoms called tsunami lung. Longer-term effects of survivors also include psychological trauma and mental illness, as well as loss of livelihood.

53. A tsunami of this size will not just impact Christchurch but will cause severe damage to all the coastal towns and cities on the east coast of New Zealand. We most likely will not be able to rely on help from other regions during the response and recovery phases as they will be dealing with the impacts in their regions.

54. In summary, Christchurch (as well as the rest of New Zealand) will be impacted by a devastating tsunami at some point in the future. SLR will exacerbate the impacts of any tsunami that occurs. If the tsunami originates in South America, the risk to life safety can be mostly mitigated because we will have 11-15 hours warning time between the earthquake occurring and the tsunami arriving. This will be much harder if the tsunami is generated by a megathrust earthquake on the southern Hikurangi subduction zone because there will only be around 80 minutes between the earthquake and the tsunami arrival. Furthermore, the earthquake itself might cause damage to Christchurch that would impede evacuation. As we have seen from major past events in Indonesia (2005) and Japan (2011) the damage to buildings and infrastructure within the inundation zone will be significant.

55. While we cannot say for certain that a tsunami of this size will happen in our lifetime, it will happen at some point in the future, and it is only prudent to ensure that we are not putting more people, property, or infrastructure in harm's way by intensifying population in these higher risk locations.

56. While I consider the tsunami hazard modelling to be sound and fit for purpose, should a more comprehensive risk assessment be required to assess the impacts and cost of this tsunami event and how these would be increased by intensification within the Tsunami Management Area, I would recommend using RiskScape[9] or similar to undertake that assessment.

VERTICAL EVACUATION

57. Vertical evacuation is considered in some places around the world as an option of last resort, especially in locations where there is not enough time to evacuate out of the inundation zone before the tsunami is expected to arrive.

58. Vertical evacuation buildings have additional requirement in terms of understanding the maximum inundation depths and flows expected at that sites and ensuring the building can withstand the expected hydrostatic and hydrodynamic loads. MBIE has produced a report on considerations for vertical evacuation structures: Tsunami Loads and Effects on Vertical Evacuation, Technical Information, May 2020.

59. While buildings can be designed to withstand tsunamis, it is a risky proposition. The requirements for building a structure that can withstand a tsunami are far higher than standard building requirements. People died in the 2011 Japan tsunami in vertical evacuation structures because the tsunami exceeded what the structure

[9] https://riskscape.org.nz/

was designed for. It is far safer to be out of the inundation zone, which is why, in my opinion, it is better to avoid intensification in the tsunami hazard zone.

RESPONSE TO SUBMISSIONS

60. The following submissions were made concerning the proposed Tsunami Risk Management Area relevant to my evidence and area of expertise:

(a) That the Tsunami Management Area be reduced to a 1:100-year hazard (Submissions #834 and #877).

(b) That new rules require minimum building height for houses to be built to two storeys in the zone at risk of tsunami damage. This would give occupants somewhere to go if they cannot evacuate to higher ground in time (Submission #114).

61. My responses to these submissions are as follows:

(a) With respect to Submissions #834 and #877), it is highly likely (65.9%) that an event up to or greater than a 1:100-year tsunami will occur between now and 2130, i.e., we are only 34.1% certain that the 1:100-year tsunami inundation area will include all the tsunamis that occur until 2130. However, there is only a 19.3% likelihood that a 1:500-year tsunami will occur, i.e., we are 80.7% certain that the 1:500-year tsunami inundation area will include all the tsunamis that occur until 2130. This is why I recommend using the Tsunami Risk Management Area as proposed in the Amended Proposal for PC14.

(b) With respect to Submission #114, while I defer to the planning expertise of Ms Oliver on this matter, in my opinion, if multi-storey buildings were being proposed within the Tsunami Risk Management Area with the understanding that they could be used as shelter in the event of a tsunami, it would be necessary to ensure that they were sufficiently high and built to appropriate standards to withstand a tsunami, otherwise these would just be providing a false sense of security.

62. For the above reasons, in my opinion, the Tsunami Risk Management Area proposed under PC14 is provides the best means of protecting Christchurch against the impacts of a tsunami.

CONCLUSION

63. In conclusion, while impactful tsunamis are rare, when they do happen the results are devastating: damaged and destroyed buildings, infrastructure, lifelines and other assets, wreckage strewn throughout the inundation area and severe life safety risk to anyone in the inundation zone when the tsunami arises.

64. The tsunami scenario used to define the Tsunami Risk Management Area in Christchurch (Bosserelle et al., 2019) would also impact a large proportion of coastal New Zealand.

65. SLR exacerbates the hazard and risk from any tsunami that does occur. Bosserelle et al., (2019) included a RSLR scenario of 1.06 m in the tsunami hazard modelling which has informed the mapped Tsunami Risk Management Areas used in preparing PC14.

66. Since the tsunami modelling that informed PC14 was undertaken, new SLR projections and VLM projections have become available and new sea-level rise guidance has been produced MFE (2022). The modelled sea level rise of 1.06 m is 0.45–0.89 m lower than that currently recommended by MFE (2022), depending on VLM, which would imply that the modelled tsunami hazard is underpredicted.

67. However, the tsunami scenario used a 1:500-year return period tsunami event (0.2% AEP) which is 2.5 m higher at coast than a 1:100-year event (1% AEP) and models that tsunami arriving at MHWS (high tide).

68. A 1:500-year event has a 19.3% chance of occurring or being exceeded between now and 2130, whereas a 1:100-year tsunami has a 65.9% chance of occurring in the same timeframe.

69. In my opinion, the current modelling used to inform the proposed Tsunami Risk Management Areas is robust and fit-for-purpose and provides an adequate level of precaution with regards to tsunami inundation and SLR. For this reason, I support adopting as the Tsunami Risk Management Area Qualifying Matter, all areas inundated over 30 cm in the 1:500-year, MHWS, 1.06 m sea level rise tsunami scenario, as proposed in the amended PC14, and as mapped in the section 42A planning report of Ms Oliver.

Dated: 11 August 2023

Dr Emily Margaret Lane