Before the Hearings Panel
At Porirua City Council

Under	Schedule 1 of the Resource Management Act 1991
In the matter of	the Proposed Porirua District Plan
Between	**Various**
	Submitters
And	**Porirua City Council**
	Respondent

Statement of evidence of Dr William Lawrence Power on behalf of Porirua City Council

Date: 4 November 2021

INTRODUCTION:

1 My full name is Dr William Lawrence Power. I am employed as a Senior Scientist (Geophysicist - Scientific Programmer) at GNS Science, Lower Hutt, New Zealand.

2 I have prepared this statement of evidence on behalf of the Porirua City Council (**Council**) in respect of technical related matters arising from the submissions and further submissions on the Proposed Porirua District Plan (**PDP**).

3 Specifically, this statement of evidence relates to the matters in Chapter NH – Natural Hazards.

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

QUALIFICATIONS AND EXPERIENCE

5 I hold the qualifications of Batchelor of Science in Physics (1st Class) from Imperial College in 1990, Master of Arts in Physics from the University of Rochester in 1992, and Doctor of Philosophy in Physics from Imperial College in 1995.

6 I have worked for GNS Science for 20 Years. Since 2004 tsunami research has been the primary focus of my work, and I have been involved in multiple studies involving tsunami modelling, post-tsunami field investigations, and tsunami hazard assessments. In 2013 I led the development of the National Tsunami Hazard Model, the first such model to assess tsunami hazard to all regions of the New Zealand coast. I have contributed to the systems that are used to provide forecasting and warning of tsunamis affecting New Zealand, including the first iteration of the tsunami forecast database, and the design of the DART tsunami detection network for the Southwest Pacific. I have been

involved in the development of methods for assessing tsunami inundation hazard (the hazard posed by tsunamis onshore), including studies of Gisborne, Porirua, and Wellington.

7 I am a member of the Geoscience Society of New Zealand, and of the International Union of Geodesy and Geophysics Tsunami Commission. I am a member of the New Zealand Tsunami Experts Panel[1].

Code of conduct

8 I have read the Code of Conduct for Expert Witnesses set out in the Environment Court's Practice Note 2014. I have complied with the Code of Conduct in preparing my evidence and will continue to comply with it while giving oral evidence before the Environment Court[2]. My qualifications as an expert are set out above. 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.

SUMMARY

9 My name is Dr William Lawrence Power.

10 I have been asked by the Council to provide tsunami hazard evidence in relation to the appeal on Chapter NH – Natural Hazards, which primarily relates to Porirua Harbour.

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[1] The Tsunami Experts Panel provides advice to the National Emergency Management Agency in the event of a tsunami.

[2] The Hearings Commissioners in this case.

11 My statement of evidence addresses submissions (158.5 and 159.4, submitted by Steve Grant) seeking clarification and/or revision of tsunami hazard mapping in Paremata and Plimmerton.

12 Based on my analysis of the information presented with the submission I summarise my opinion in response to these submission points as follows:

12.1 in response to submission point 158.5 it is my opinion that the 1:100yr tsunami hazard layer could be modified to not extend into 99 - 109 St Andrews Road.

12.2 Regarding submission 159.4, the submitter has asked for an explanation of the 1:1000yr hazard overlay at 112 Mana Esplanade. On examination of the overlay and the flow-depth data it is based upon, it is my opinion that the overlay is physically unrealistic at the edge of inundation due to numerical approximations in its derivation. It is my opinion that if the threshold flow-depth for identifying a tsunami hazard was changed here to 0.1m, it would result in a reduced horizontal extent of inundation at the property of about 10 metres which would be more realistic.

13 I explain my reasoning for these findings in paragraphs 15 to 20 below.

INVOLVEMENT WITH THE PROPOSED PLAN

14 I have been involved in the PDP since 8 September 2021 when engaged to provide this statement of evidence. I have had no prior involvement with the PDP. I am a co-author of the report by Gusman, Power and Mueller (2019) commissioned by the Earthquake Commission with co-funding from PCC that is referenced in the section 32 reports and forms the underlying data for the Tsunami Hazard Zones mapped in the PDP.

SCOPE OF EVIDENCE

15 My statement of evidence addresses the following matters:

- Submission point 158.5, which requests that the Tsunami Hazard - 1:100yr Inundation Extent overlay be removed from 99 - 109 St Andrews Road (SH 1), Plimmerton, Porirua City 5026; and

- Submission point 159.4, which requests clarification and explanation of the Tsunami Hazard - 1:1000yr Inundation Extent overlay at 112 Mana Esplanade (SH 1), Paremata, Porirua City 5026. Clarification and explanation sought extends to site specific features at the address and a comparison of overlay coverage with adjacent properties.

OVERARCHING COMMENTS

16 The basis for the Tsunami Hazard layers in the proposed district plan is described in the report by Gusman, Power and Mueller (2019). The main steps can be summarised as:

16.1 A process of 'deaggregation' was used to select a set of tsunami-causing earthquake scenarios for each of three return periods 1:100yr, 1:500yr and 1:1000yr.

16.2 For each of the scenarios a numerical tsunami model was run representing the physics of the generation and propagation of a tsunami, through to inundation on the coasts around Porirua.

16.3 The results from each set of inundation scenarios were then combined to form the onshore tsunami hazard layers.

16.4 The hazard layers were converted to a standard Geographical Information System (GIS) format.

17 The inundation modelling on shore was conducted using a Digital Elevation Model (DEM) to represent the topography of Porirua. This inundation modelling DEM was represented in the numerical model using a rectangular grid with a spacing of approximately 11m. At this grid spacing fine details of the topography that occur over smaller distances are smoothed over. This smoothing over of topographic details is a significant factor in the raised submission points.

18 The scenarios used in Gusman, Power and Mueller (2019) were derived from the 2013 National Tsunami Hazard Model (Power 2013), with some minor updates. A substantially revised version of the National Tsunami Hazard model is due to be released before the end of 2021. The 2021 National Tsunami Hazard Model is not going to produce maps ready to insert into district plans. The national model only calculates hazard at the shoreline (not inundation), but it does provide a list of scenarios that can be used to perform the inundation modelling. So, there is an extra piece of work required to go from the new national model to the maps needed for district plans. Both 2013 and 2021 tsunami hazard models acknowledge that there is significant uncertainty regarding assessment of tsunami hazard.

SUBMISSION POINT 158.5

19 Submission point 158.5 requests the removal of the Tsunami Hazard - 1:100yr Inundation Extent from 99 - 109 St Andrews Road (SH 1), Plimmerton, Porirua City 5026. The reason given is: “The Tsunami hazard indicated on the Coastal Hazard Plan for 99-109 Saint Andrews Road, Plimmerton does not make clear sense. It appears to be a standalone area not connected to the sea (the source of any Tsunami)”. Background information relevant to my consideration of this

submission point is covered in Paragraphs 16-18. My response to this submission point is as follows:

19.1 The Tsunami Hazard – 1:100yr Inundation Extent map in the Proposed District Plan shows two isolated patches of inundation along the Taupo Stream, one of which overlaps with the property at 99-109 Saint Andrews Road; the other is slightly to the north by Ulric Street (Figure 1 in Appendix). These patches of inundation arise from the 1:100yr modelling in the EQC report by Gusman, Power and Mueller (2019).

19.2 The Digital Elevation Model (DEM) used in Gusman, Power and Mueller (2019) uses a modelling grid of approximately 11m resolution. At this resolution the Taupo Stream is not well represented in the DEM, and only isolated points on the grid will capture the elevation of the stream itself (Figure 2 in Appendix).

19.3 The modelling in Gusman, Power and Mueller (2019) assumes a background water level at high tide, specifically Mean High Water Springs, with an additional 1.0m of Sea Level Rise. Such a background water level (in total 1.6m above current mean sea level) is most likely above the elevation of the Taupo Stream bed for some distance inland, and at least as far as the patches mentioned in Paragraph 19.1 of this statement. However, as the width of the stream is small compared to the modelling grid it is not represented in the model as a continuous feature and only isolated points along it appear as 'wet' by virtue of being below 1.6m above mean sea level.

19.4 While it is plausible that tsunami waves could propagate along a section of the Taupo Stream that has become tidal after 1.0m of Sea Level Rise has taken place, it also appears plausible to me that such waves would be confined to within the dimensions of the stream channel when alongside 99-109 Saint Andrews Road, and that the current modelling is inadequate to demonstrate that a 1:100yr hazard that extends into the property at 99-109 Saint Andrews Road.

19.5 I consider that since a 1:100yr tsunami hazard cannot be clearly demonstrated to 99-109 Saint Andrews Road, in my opinion it would be appropriate to amend the Tsunami Hazard - 1:100yr Inundation Extent overlay to remove coverage at this address.

19.6 I note that there appear to be other similar isolated inundation patches mapped in the overlay included in the Proposed District Plan. I have not undertaken a review (beyond the two sites identified in the submission points addressed in my evidence) of the layer and its application to along narrow streams and other waterways for which similar considerations might apply.

SUBMISSION POINT 159.4

20 Submission point 159.4 requests clarification and explanation of the Tsunami Hazard - 1:1000yr Inundation Extent overlay at 112 Mana Esplanade (SH 1), Paremata, Porirua City 5026. The reason given is “The Tsunami Hazard applicable to 112 Mana Esplanade, Paremata does not differentiate between adjacent properties that have street level parking and those with original contour from the street. 112 Mana Esplanade has a raised front garden. The 1:1000 year Tsunami event needs its criteria more specifically and detail applied, than the present

broad brush approach. This impacts on more than 25% of the site, greater than the adjacent properties that have level front yard access”. Background information relevant to my consideration of this submission point is covered in Paragraphs 16-18. My response to this submission point is as follows:

20.1 The Tsunami Hazard – 1:1000yr Inundation Extent map in the Proposed District Plan shows the tsunami hazard extending onto approximately 25% of the site at 112 Mana Esplanade on the western part of the site at the road frontage (Figure 3 in Appendix). This inundation extent comes from the 1:1000yr modelling in the EQC report by Gusman, Power and Mueller (2019).

20.2 The Digital Elevation Model (DEM) used in Gusman, Power and Mueller (2019) uses a modelling grid of approximately 11m resolution. At this level of resolution site specific details with dimensions smaller than the grid spacing are not captured, and features such as retaining walls for raised garden beds are effectively ‘smoothed over’.

20.3 The extent of the Tsunami Hazard – 1:1000yr Inundation Extent overlay at 112 Mana Esplanade is similar in distance from the road frontage to that of the neighbouring properties (110 and 114 Mana Esplanade), except for the northern boundary of 114 Mana Esplanade with 116 Mana Esplanade where the inundation extent is slightly reduced.

20.4 Comparison of Google Streetview images on 19 October 2021, indicates that the property to the south (110 Mana Esplanade) appears to have a smoother (less stepped) elevation gradient from the road compared to 112 Mana Esplanade, and the property to the north (114 Mana

Esplanade) appears to have a flat parking area and a single larger elevation rise just before the house.

20.5 I do not consider the extent of the Tsunami Hazard – 1:1000yr Inundation Extent overlay at 112 Mana Esplanade to be significantly inconsistent with that shown for neighbouring properties. However, analysis of the 1:1000yr tsunami flow-depth GIS layer suggests that the horizontal extent of inundation may have been overestimated with the GIS data showing a thin-layer of tsunami-flow (a few cm depth) extending further from the road frontage than appears physically realistic, most likely a result of reprojection of the numerical modelling grid into GIS format (Paragraph 16.4). The way in which GIS software interpolates flow-depths between wet and dry points at the edge of the modelled inundation may also be a factor.

20.6 Site-specific effects (including both the depth and velocity of inundation) may be modified by structures and land modifications in a specific area. I consider it plausible that topographical features such as; a raised garden bed, retaining structures or land modification could impact the site-specific extent of the inundation hazard. In this case I have not undertaken a site-specific modelling analysis of the propagation of a 1:1000yr tsunami extent at 112 Mana Esplanade. The specificity of the modelling at this location is consistent with the model's application to other areas of the city/coast.

20.7 If the flow-depth threshold used to make the tsunami hazard overlay were to be raised to 0.1m in my opinion it would produce a more robust overlay with less sensitivity to reprojection errors and site-specific effects. Further discussion of this point is provided in Appendix 2. This would reduce the extent of the 1000yr hazard layer onto the property at 112 Mana Esplanade by about 10 meters.

20.8 I note that the problems identified with defining the boundary of the tsunami hazard layer at 112 Mana Esplanade are not specific to that property but can be expected to occur elsewhere along the tsunami hazard overlay boundary.

CONCLUDING COMMENTS

21 The tsunami inundation model that informs the tsunami overlays in the PDP is not sufficiently detailed to respond to small features that are too small to be accurately represented in the DEM. However, in my opinion the overlay serves as a general indication of the presence of a tsunami hazard to a site. To my knowledge Gusman, Power and Mueller (2019) represents the most up-to-date inundation modelling currently available for Porirua. I note that the underpinning National Tsunami Hazard Model is being revised in 2021. This will revise the set of scenarios that would have to be modelled to define the inundation extents (Paragraphs 16.1 and 16.2). Following the release and review of the new National Model regional and district models may suitably be revised.

22 I consider it import to identify the limitations of the tsunami modelling used to inform the hazard overlays, particularly as the extent of this overlay affects properties along the edges of the hazard zones. Specifically, there are uncertainties due to the limited resolution of the tsunami numerical model which cannot fully resolve small topographic features, and further uncertainties that are introduced by the conversion of data to and from the numerical modelling format. Raising the tsunami flow-depth threshold for inclusion in the hazard layer would help to improve the robustness of the results.

Date: 4/11/2021

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APPENDICES

1. FIGURES

Figure 1. Annotated GIS Layer from the Proposed District Plan showing the 1:100yr Tsunami Hazard in purple for the Taupo Stream. Note the two isolated areas of tsunami hazard marked A and B, the southern one (A) extends into 99-109 Saint Andrews Road (marked C). The approximate position of the Taupo Stream has been indicated with a blue line.

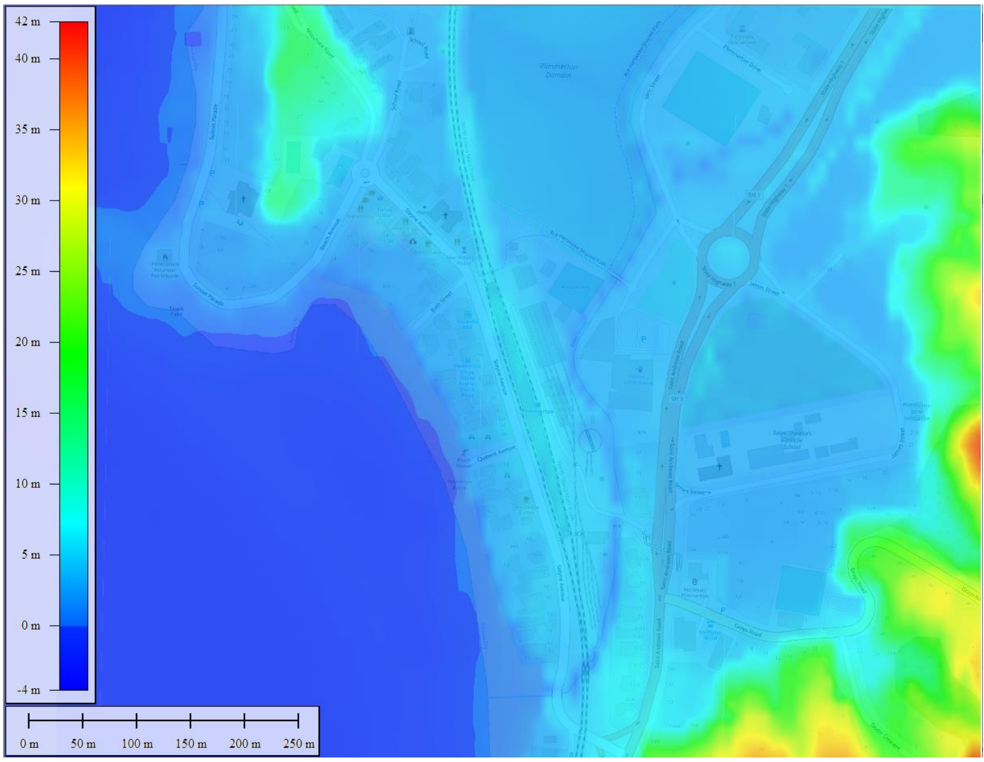

Figure 2. View of a portion of the Digital Elevation Model used as input to the numerical tsunami model covering the Taupo Stream area. As the stream is narrower than the grid spacing it appears as a series of lower elevation points rather than as a well-defined continuous feature.

Figure 3. Annotated GIS Layer from the Proposed District Plan showing the 1:1000yr Tsunami Hazard in purple centred on 112 Mana Esplanade (outlined in

red). The approximate position of the retaining wall in front of the raised garden bed is shown with a red dashed line.

2. JUSTIFICATION FOR CHANGE TO THE TSUNAMI FLOW-DEPTH THRESHOLD

Currently locations appear in the tsunami hazard layers if the estimated tsunami flow-depth is greater than zero[3]. For the property at 112 Mana Esplanade I propose changing this threshold to a flow-depth of greater than 0.1m with the following reasons[4]:

- Structural damage to buildings is very unlikely to occur at flow-depths of less than 0.1m.
- The tsunami numerical model used to define the hazard overlays becomes increasingly less-reliable at low flow-depths, and in particular the conversion between numerical modelling grids and GIS layers introduces errors in the form of thin layers of inundation around the edge.
- At shallow flow-depths the tsunami inundation can easily be influenced by small-scale topographic features (raised beds, gutters and so forth) which are not captured by the numerical model. Setting a higher threshold improves the robustness of the hazard layers.
- The typical accuracy of Lidar-derived DEM data is of the order of 0.1m.

As the reasons for changing the flow-depth threshold are not specific to 112 Mana Esplanade, the council should consider applying a raised threshold generally.

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[3] This is my inference from the appearance of the tsunami hazard layer overlay created by PCC from the tsunami flow-depth GIS layer provided by GNS Science.

[4] In theory land-use planners in Porirua could have reasons for using a threshold depth larger than 0.1m, and strictly speaking my recommendation is that the threshold is not set any lower than 0.1m.

Figure 4 illustrates the effect on the 1000yr tsunami hazard of changing the flow depth threshold to 0.1m in the vicinity of 112 Mana Esplanade.

Figure 4. Comparison of the 0.01m (Purple) and 0.1m (Green) tsunami flow-depth contours in the 1000yr Tsunami Hazard layer in the vicinity of 112 Mana Esplanade. The purple 0.01m contour approximates the boundary of the hazard layer as currently in the PDP, and the green 0.1m contour approximates the boundary with a change to a 0.1m flow-depth threshold. These contours were created using Global Mapper and may vary slightly if created in other software.

3. REFERENCES

AR Gusman, WL Power, C Mueller 2019. Tsunami modelling for Porirua City : the methodology to inform land use planning response. Lower Hutt, N.Z.: GNS Science. GNS Science report 2019/80. 51 p.; doi: 10.21420/SEG2-Q850

WL Power (compiler) 2013. Review of tsunami hazard in New Zealand (2013 update). GNS Science consultancy report 2013/131. 222 p. (prepared for, and published by the Ministry of Civil Defence and Emergency Management –

subsequently renamed the National Emergency Management Agency) https://www.civildefence.govt.nz/cdem-sector/cdem-research-/mcdem-research-projects-and-resources/review-of-tsunami-hazard-in-new-zealand/