BEFORE THE TAUPŌ DISTRICT COUNCIL

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER Proposed Plan Change 34 (Flood Hazard) to the Taupō District Plan

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STATEMENT OF EVIDENCE OF Dr JOHN (JACK) ALLEN McCONCHIE FOR TAUPŌ DISTRICT COUNCIL

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INTRODUCTION

1. My full name is Dr John (Jack) Allen McConchie.

2. My evidence is given on behalf of the Taupō District Council (**TDC**) in relation to an application for a change to the District Plan – Plan Change 34 – Flood Hazard (**PC34**). The plan change seeks to identify flood hazard areas adjacent to Lake Taupō and its major tributaries, and manage use and development within them.

3. I hold a Bachelor of Science degree with First Class Honours, and a PhD. I am a member of several professional and relevant associations including the:

(a) New Zealand Hydrological Society;
(b) American Geophysical Union;
(c) New Zealand Geographical Society;
(d) Australia-New Zealand Geomorphology Group; and
(e) Environment Institute of Australia and New Zealand.

4. I am an accredited MfE “Making Good Decisions” RMA decision-maker (2011-present) and an Independent Professional Adviser to the New Zealand Transport Agency (**NZTA**) (2011-present).

5. I was the New Zealand Geographical Society representative on the Joint New Zealand Earth Science Societies’ Working Group on Geopreservation. This group produced a discussion paper *'Landforms and geological features: a case for preservation*' published by the Nature Conservation Council in 1988. It also developed the first geopreservation inventory for the country, published in 1990 as the ‘*New Zealand Landform Inventory’*.

6. I am employed by WSP Opus, previously Opus International Consultants Ltd, as the Technical Principal (Hydrology & Geomorphology).

7. Prior to the start of 2008, I was an Associate Professor with the School of Earth Sciences at Victoria University of Wellington. I taught undergraduate courses in hydrology and geomorphology, and a postgraduate course in hydrology and water resources.

8. For more than 40 years my research and professional experience has focused on various aspects of hydrology and geomorphology, including hydrometric analysis, flood hazard assessments and hydraulic modelling, landscape evolution, slope stability and erosion, and natural hazards.

9. Within these fields I have edited one book. I have written or co-authored 10 book chapters and over 50 internationally-refereed scientific publications, including several papers focused specifically on flood hydrology and natural hazards.

10. I have been involved in numerous projects focusing on flood hazard assessments, flood mitigation and modelling, and fluvial geomorphology since completing my PhD.

11. I have been working with TDC on identifying and assessing the flood hazard to land adjacent to Lake Taupō and its major tributaries since 2009.

12. Of particular relevance to this hearing, I:

(a) Undertook the *Taupō District Flood Hazard Study* which was the basis for TDC's Flood and Erosion Strategy;

(b) Completed flood hazard assessments of the Tongariro, Tauranga Taupō, Hinemaiaia, Whareroa, Kuratau and Tokaanu catchments on behalf of Environment Waikato (now Waikato Regional Council) and TDC;

(c) Presented technical evidence on behalf of TDC to the Environment Court (ENV-2010-AKL-000140) for Plan Change 20, which related to land use zoning at Kuratau;

(d) Am responsible for maintaining Mercury's (previously Mighty River Power Ltd's) hydrometric database for the Waikato Hydro Scheme, including Lake Taupō; and

(e) Undertook the assessment of the impact of Mighty River Power Ltd's (now Mercury) hydro operations on the erosion and geomorphic processes along the Waikato River from Lake Taupō to Waikato Heads. I presented the findings of that investigation as technical evidence to the resource consent hearings in 2000.

13. Because of this experience, I have extensive and detailed knowledge of:

(a) The flood hazard affecting land adjacent to Lake Taupō and its major tributaries; and

(b) The physical environmental processes operating within Lake Taupō, its various tributaries, and the wider Waikato catchment including rainfall, flood hydrology, and erosion.

My Role

14. I was engaged by TDC to assist with assessing the potential flood hazard posed by Lake Taupō and its tributaries. This included assisting Councillors to understand the nature of the hazard, and the means by which it was assessed. I also advised on various communications to ensure that they were consistent with the findings of the flood hazard assessment.

15. I have undertaken numerous site visits to Lake Taupō, and met with members of the community both during the project, and in discussing the results of the flood hazard assessments. A number of these persons provided valuable qualitative calibration data for large flood events in some of the catchments.

16. As a consequence of the public consultation process and feedback from residents, in September 2016 I undertook a re-assessment of the flood hazard affecting six properties. In most of these instances, there was evidence that the topography and relative relief of the properties had changed significantly since the capture of the LiDAR[1] information used in the various flood models. My recommendations are outlined in the *Site-specific flood hazard re-assessments* report.[2]

17. I have reviewed the 25 submissions received in response to the public notification of PC34. My responses to the technical matters raised in these submissions are included in this brief of evidence.

18. In preparing my evidence, I have used my detailed and comprehensive local knowledge and experience of the Lake Taupō basin gained over the past 10-

[1] LiDAR stands for Light Detection and Ranging, and is a remote sensing surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. LiDAR is now the preferred standard when developing digital terrain models.

[2] McConchie, J.A. 2016: Site-specific flood hazard re-assessments – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, September 2016. 14p.

years of working for various clients, including: TDC, Environment Waikato (Waikato Regional Council), Mighty River Power Ltd (now Mercury), Cheal Consultants, King Country Energy, Trustpower and Genesis Energy.

SUPPORTING DOCUMENTATION

19. TDC engaged Opus International Consultants Ltd to assess and delineate the flood hazard posed by Lake Taupō and its six major tributaries. While there are a number of editions of some of the resulting flood studies, the latest iterations are presented in the following reports:

(a) Knight, J. & McConchie, J. 2010: Taupō District Flood Hazard Study: Tauranga Taupō River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. July 2010. 48p.

(b) Maas, F. & McConchie, J. 2011: Taupō District Flood Hazard Study: Tongariro River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. July 2011. 59p.

(c) Smith, H. Paine S. & Ward, H. 2011: Taupō District Flood Hazard Study: Kuratau River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. July 2011. 52p.

(d) Paine, S. & Smith, H. 2012: Taupō District Flood Hazard Study: Hinemaiaia River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. June 2012. 46p.

(e) Paine, S. & Smith, H. 2012: Taupō District Flood Hazard Study: Whareroa Stream. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. June 2012. 48p.

(f) Paine, S. & Smith, H. 2012: Taupō District Flood Hazard Study: Tokaanu Stream. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. June 2012. 50p.

(g) Ward, H., Morrow, F. & Ferguson, R. 2014: Taupō District Flood Hazard Study: Lake Taupō. Report prepared by Opus International Consultants. Draft for internal review. June 2014. 108p.

20. These reports are integral to, and should be read in conjunction with, this brief of evidence.

21. These reports were written largely for a 'lay' audience. Therefore, the amount of technical detail provided relating to the hydrological analysis and computational hydraulic modelling was deliberately kept to a minimum. The only exception to this approach was the detailed technical report prepared for Waikato Regional Council relating to the Tongariro River 2-D hydraulic modelling (Maas & McConchie, 2011). That report was prepared for a very different audience. The detail in that report was required because the modelling and results were a significant departure from the hydraulic modelling which had been done previously on the Tongariro River. The report used a 2-D (MIKE21) as opposed to a 1-D (MIKE11) hydrodynamic model.

22. It was subsequently suggested during the external peer-review process[3] that some additional technical information might be useful to facilitate discussion and inform hearings relating to any proposed District Plan changes aimed at recognising the flood hazard.

23. Rather than modifying each individual report, a 'Technical Compendium'[4] was developed. This provides the background, technical detail, and analyses which underpin the individual reports.

24. This approach provides the level of technical detail and robust analysis necessary for having confidence in the findings, while also ensuring the reports can be read easily and understood by a 'lay' audience, without repetitive and potentially confusing scientific and statistical detail.

25. The Technical Compendium addresses issues of background, approach, philosophy, assumptions and limitations, hydrology and data reliability, principles and constraints of hydraulic modelling, wave run-up analysis,

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[3] McConchie, J. A. 2015: Peer Review Discussion – Taupō District Flood Hazard Studies. Document produced by J.A. McConchie of Opus International Consultants Ltd, and approved by R. Henderson NIWA, for Taupō District Council, May 2015. 15p.

[4] McConchie, J. A. 2015: Technical compendium – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, October 2015. 55p.

combined probabilities and the residual uncertainty of the results and conclusions inherent in the studies.

26. Most of this material is already available in different formats, or it is implicit in the various flood studies. However, its incorporation into the Technical Compendium results in a more robust explanation and justification for any proposed changes to the District Plan regarding recognition of the potential flood hazard within the Lake Taupō catchment.

27. In February 2015, the Council employed NIWA to peer review the seven flood reports outlined in paragraph 19 of this evidence. This involved evaluating the assumptions and methodology used to determine the level of potential flood hazard in a 1% Annual Exceedance Probability (**AEP**) event, assessing whether the methodology has been consistently applied across the suite of reports, highlighting weaknesses (if any) in the preparation of the reports or with the data that has been used, and highlighting any other issues that became apparent over the course of the review. They produced the following peer review document: NIWA 2015: *Peer review of Taupō District flood hazard reports.*[5]

28. This peer review report raised some issues which resulted in discussions between myself and NIWA staff to address these issues. These agreements were then documented in the following report: McConchie, J. A. 2015: *Peer Review Discussion – Taupō District Flood Hazard Studies*.[6]

CODE OF CONDUCT

29. I confirm I have read the Expert Witness Code of Conduct set out in the Environment Court's Practice Note 2014. I have complied with the Code of Conduct in preparing this evidence, and I agree to comply with it while giving oral evidence before the hearing commissioner. Except where I state that I am relying on the evidence of another person, this written evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence.

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5 Report prepared R. Henderson, M. Duncan & M Hicks from NIWA Christchurch for Taupō District Council. March 2015. 32p

6 Document produced by J.A. McConchie of Opus International Consultants Ltd, and approved by R. Henderson NIWA, for Taupō District Council, May 2015. 15p

SCOPE AND STRUCTURE OF EVIDENCE

30. The purpose of this evidence is to provide clarification relating to:

(a) Key information relating to the comprehensive flood hazard assessments which underpin PC34;

(b) Misunderstandings or uncertainties regarding the rationale and methodology behind the flood hazard assessments; and

(c) Consideration of the technical issues raised in submissions seeking specific relief relating to PC34.

CONSTRAINTS

31. It is necessary that natural hazards and associated information are mapped at a scale appropriate for the end-use; in this case, allowing planners to provide guidance regarding land use on or close to potentially hazardous areas. Generally the larger the scale the better the resolution and detail available, however, cost acts as a major constraint. Decisions need to be made regarding the cost of any hazard investigation and where these costs should lie. For example, which costs should be borne by the Council on behalf of ratepayers in general, and which should be borne by a developer and individual landowner?

32. Waikato Regional Council holds broad scale (i.e. 1:50,000) flood hazard maps for the Waikato Region. These maps provide an overview of the flood hazards associated with many water bodies. This information, however, is not suitable for land-use planning processes, other than identifying potential flooding issues that may require further discussion and investigation.

33. It has been suggested that local authorities should map hazard information to an appropriate planning-level scale of approximately 1:10,000 to 1:20,000; with a larger scale being appropriate for ‘urban’ areas. Such an approach has been adopted in the Taupō District Flood Studies.

34. While the highest resolution data has been used in all the modelling, including LiDAR topographic information for defining the terrain, there remains some inherent uncertainty which is difficult to define without robust calibration. Robust flood calibration data exists only for the Tongariro and Tauranga Taupō Rivers; with some qualitative data also available for the Kuratau River. Even in those cases where calibration data are available, this tends to be for relatively small events when compared to the design events used in the various flood studies (i.e. the 1% AEP event, plus an allowance for the potential effects of climate change). Since the scenarios modelled in the Taupō District Flood Study are relatively ‘extreme’, more precise calibration is not possible currently.

35. The purpose of the various flood studies was to provide a district-scale assessment of the potential flood hazard over the longer term. However, constraints meant that the studies could not provide definitive flood hazard assessments at the scale of individual sites or building platforms. Consequently, the studies were developed as a screening tool to identify those areas where the flood hazard is not a consideration, and those where some further investigation may be warranted. The uncertainty inherent in both flood modelling of extreme design events, and a district-scale assessment, mean that the resulting flood maps should not be regarded as ‘definitive’. While the maps are robust, given the various assumptions and the contemporary situation, should either of these change, then so too might the scale and extent of the flood hazard.

36. The flood hazard maps therefore provide guidance as to what level of planning control might be appropriate, rather than determining the appropriateness of specific activities. The maps also indicate where detailed, site-specific, studies might be required before any major capital works are undertaken.

37. That is, the various flood hazard maps should be regarded as a planning tool and a guide for further investigation, rather than necessarily providing the ‘exact answer’ to the nature and magnitude of the flood hazard at specific locations e.g. the depth of inundation and the velocity of any flood waters.

38. While every endeavour was made to use the highest resolution data during the Taupō District Flood Studies, there remains some residual uncertainty at the specific site or property level. This uncertainty is likely to be greatest at the boundaries of any mapped inundation zone.

39. It is important to note, however, that the scale of the mapping and the resolution of the various flood hazard zones tend to ‘moderate’ and ‘smooth’ the inherent uncertainties in some of the input data. For example, at the scale of the analysis and mapping, the effect of a 10-20% change in the peak discharge of a design flood event, or consideration of the potential effect of climate change, has been shown to have a relatively minor effect on the extent and depth of inundation. While the absolute numbers may be different, the pattern of flooding is the same.

40. The potential effects of uncertainty of the input data are also moderated by the major influence of topography on the extent and depth of inundation. Rather than topography increasing gradually and evenly away from the lake or rivers, the landscape is often comprised of a series of 'steps' and terraces, or distinct 'breaks in slope'. These 'steps' in the landscape tend to constrain the extent of any potential inundation until the threshold of the 'step's' elevation is exceeded by the water surface, and water can start to flood over the next level.

PREVIOUS SITE RE-ASSESSMENTS

41. The hydraulic modelling undertaken as part of the Taupō District Flood Hazard Study covered the entire lakeshore, and six major watercourses. The results from these studies were presented to the community via a web-based mapping tool. Consultation with iwi, stakeholders and potentially affected landowners occurred during November and December 2015, and again during March and April 2016.

42. In response to the flood hazard information, several residents raised potential issues regarding the assessed flood hazard to their property; in particular, that the LiDAR information underpinning the topography used in the modelling did not reflect the current situation. Specifically, that they had undertaken earthworks or other landscaping which had affected the topography, and therefore the potential flood hazard.

43. While several specific properties were reviewed,[7] no attempt was made to consider the likely effect of any changes in topography on adjacent properties i.e. if flood waters no longer inundate a particular property it is likely that there may be a slightly greater impact on adjacent properties, particularly if they are low-lying.

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[7] McConchie, J. A. 2016: Site-specific flood hazard reassessments. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, September 2016. 20p.

44. A key input to the flood hazard assessment, for both lake and river-induced flooding, is a description of the underlying terrain. The terrain was defined using Digital Terrain Models (**DTMs**) with a maximum spatial resolution of 5m.

45. All the terrain models were based on a LiDAR survey during June-July 2006. This was supplemented with later data, flown in 2009, for two locations: in the vicinity of Waihi, towards the southern end of Lake Taupō; and the lake foreshore adjacent to the Taupō township. All the LiDAR data has a spatial resolution of 1m, and a quoted vertical accuracy of ±0.1m. The LiDAR information was used to provide a three-dimensional model of the shoreline of Lake Taupō, and the floodplain topography adjacent to the various rivers and streams.

46. It should be noted that the flood hazard is modelled using the 'relative elevations' of the lake, river, and adjacent floodplains; not the absolute heights. Therefore, as long as all the LiDAR information is in the same datum, and has been processed in the same manner, the relative height differences within the topography will be 'captured' and modelled accurately; even if the absolute height relative to some datum is less certain. Elevations and water depths obtained from the various flood models should therefore not be compared to the height of the ground surface obtained from terrestrial or GPS surveys at a site scale, irrespective of the datum used.

47. The majority of the issues raised in submissions regarding the potential flood hazard at particular properties relate to either, the accuracy with which the topography was represented in a particular flood model, or changes to the topography subsequent to the LiDAR surveys.

48. The original flood hazard maps, and the associated water depth and velocity layers attached to each report, showed all the results from the modelling. However, prior to going out for public consultation, the TDC removed all flood hazard areas where the depth of inundation was less than 10cm. This was because flooding of such a shallow depth is unlikely to represent a significant hazard, and because floor levels need to be higher than this threshold (under the Building Act 2004).

49. No individual property inspections were undertaken by myself. The re-assessments relied solely on the information provided by the property owner, and consideration of how this might affect the assessment of the potential flood hazard.

50. The two principal considerations were:

(a) Has the relative topography across the property been altered to such an extent that it affects the previously assessed flood hazard significantly?

(b) Are the changes permanent, to the degree that they will persist until the next review of the flood hazard in 10 years' time?

51. The construction of fences and buildings is not considered sufficient to mitigate the flood hazard. Earth bunds, stop-banks and retaining walls, however, assuming they prevent the entry of flood water onto a site, can reduce, and potentially remove, the flood hazard.

52. While the principal focus of the review was to consider the potential effect of changes in topography, and consequently the depth of inundation, some consideration was also given to potential changes in flow velocity. Consequently, all three layers relating to the flood hazard were reviewed, and adjusted if this was considered necessary i.e. the flood hazard, water depth and water velocity layers were all adjusted.

53. These site-specific flood hazard re-assessments involved making relatively small changes to the depth of inundation that might occur as a result of changes to the terrain subsequent to the LiDAR surveys. However, modifying the results of a larger flood model on a case by case basis is never ideal. This is because changes in only one parameter are assessed, generally on limited information, and the flood hazard is actually multi-dimensional. While the change in water depth, caused by 'infilling' of the terrain, can be approximated, no information is available regarding any consequential effects on the velocity of flow. However, these are likely to be small because the scale of changes on individual properties is unlikely to have any material influence on the accuracy of the model for a larger area.

54. For grids where the depth of inundation was adjusted, because of an increase in the relative ground elevation, an adjusted velocity was interpolated from the velocities of the surrounding cells. If the surrounding cells are of lower velocity, then the ‘adjusted velocity’ will also be lower. If the surrounding cells have a higher velocity, then that of the modified cell may actually increase. In general, the inferred changes in velocity are very small, and probably within the margin of error of the original flood modelling. The changes in assumed velocity have no effect on the actual hazard classification. In effect, the ‘filling of cells’ i.e. reducing the water depth, is likely to change the velocity of a number of surrounding cells but this cannot be ‘re-assessed’ until the flood models are re-run using new LiDAR information at some stage in the future. For these reasons, I am entirely comfortable that the model and its outputs remain accurate and fit for purpose when identifying the extent of flood hazard.

METHODOLOGY

55. There are a number of issues raised by submitters with regard to the methodology used to identify the flood hazard in PC34. Responses to the specific questions, or the required clarifications, are provided below.

Annual Exceedance Probability

56. Design events can be described either in terms of their AEP or Average Recurrence Interval (**ARI**). Both approaches attempt to describe the frequency or likelihood of the design event occurring. It is then possible to balance the cost of any intervention, protection or mitigation against the likelihood of the event.

57. The AEP quantifies the probability of a design event being equalled or exceeded in any year. For simplicity, and possibly clarity, AEPs are generally described as a percentage i.e. the probability x 100. For example, a design flood with the probability of being equalled or exceeded each year of 0.01 is described as the 1% AEP design event.

58. While AEPs are generally the preferred way to describe design events, occasionally ARIs are used. An ARI is the AEP in terms of the likely average number of years between such events. For example, the 1% AEP design event is considered to have an ARI of 100 years. A 2% AEP design event is considered to have an ARI of 50-years and so on.

59. Therefore, AEPs focus on the randomness of extreme events, which can occur at any time, and the occurrence of one such event provides no 'guidance' as to the occurrence of the next.

60. ARIs, however, tend to focus on the average time between events. This leads to the perception that once a design event has occurred, another is unlikely to occur within the next X-years. In fact, the likelihood of a flood of the magnitude of the design event occurring subsequent to such an event is the same as prior to the event.

61. The use of AEPs has therefore been preferred in the Taupō District Flood Hazard Study.

The design flood

62. The Taupō District Flood Hazard Study has adopted the 1% AEP flood as the basic design event. The 1% AEP event, the so called '100 year flood', is generally accepted as the design criterion for flood hazard studies in New Zealand, even though there appears to be no statutory requirement for such a design standard.

63. Waikato Regional Council has also adopted the 1% AEP event as its design standard for flood hazard assessments. The adoption of the 1% AEP by TDC ensures consistency, from the planning and risk management perspectives, and also the communication and public education perspectives.

64. Also, the test for 'determinations' by Ministry of Business Innovation and Employment relating to s73 of the Building Act (2004) has been established as whether the property would be subject to inundation in a 1% AEP event. The 2% AEP event is tied only to Clause E1.3.2 re 'housing'.

65. In addition, NZTA's Bridge Manual,[8] in reference to the 'Basis of design', states that bridges shall remain operationally functional for all highway traffic, without interruption or disruption of traffic, during and following flood events up to a Serviceability Limit State (SLS) 2 event - an event with an annual probability of exceedance of 1/100 (i.e. the 1% AEP event).

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8 The NZ Transport Agency's Bridge Manual SP/M/022 Third edition, Amendment 2 Effective from May 2016.

66. For the purpose of assessing probabilistic effects of loading, such as floods, the design working life of a bridge is assumed to be 100 years in normal circumstances.

67. I consider therefore that using a 1% AEP flood event is appropriate for TDC's modelling and assessment.

68. The Resource Management Act 1991 (**RMA**) requires consideration of the potential effects of climate change. This has generally been interpreted to mean 'including' the potential effects of climate change.

69. Consequently, the design flood for assessing the flood hazard posed by the major tributaries flowing into Lake Taupō includes:

(a) The 1% AEP flood assessed using a frequency analysis of the annual flood maxima series available for the particular river (or alternative methodology); and

(b) An allowance for the potential effects of climate change over approximately the next 100 years.

70. The design flood for assessing the flood hazard posed by high water levels within Lake Taupō includes:

(a) The 1% AEP water level assessed using a frequency analysis of the annual lake level maxima series since 1980;

(b) An allowance for the potential effects of climate change over approximately the next 100 years;

(c) An allowance for the increase in water level caused by seiche (that is, pressure-induced differences in water level 'slopping around' in the lake); and

(d) An allowance for ongoing deformation of the shoreline over the next 100 years.

Nature of flooding

71. The risk from flooding in the Lake Taupō catchment comes from three potential sources:

(a) High water levels within Lake Taupō;

(b) Flood flows in the various tributaries flowing into Lake Taupō; and

(c) Intense, localised rainstorms either over flat, low-lying land, or over slopes draining to flat, low-lying land which is generally located adjacent to Lake Taupō and its tributaries.

72. It is considered that any flood risk from intense, localised rainstorms can be mitigated adequately through appropriate stormwater management plans.

73. The Taupō District Flood Hazard Study therefore focused on the flood hazard from high lake levels, and extreme flood events within the major tributaries. Detailed discussion of how the flood hazard was assessed with respect to Lake Taupō and its six major tributaries is contained in the various reports.

74. The flood hazard to land adjacent to Lake Taupō takes into account a range of factors including lake level, seiche, land use and climate change, and tectonic deformation. The risk from a combination of high lake levels and large waves was excluded from consideration because of the lack of empirical data to calibrate the results of the wave modelling; beyond a qualitative level.

75. The flood hazard posed by the major tributaries was assessed by combining hydrometric analyses with catchment parameters and computational hydraulic models of the floodplains.

76. Essentially, both approaches determine the maximum water level during specific design flood events. These water levels were then used, in combination with high resolution terrain models, to determine the extent and depth of inundation. In the case of riverine flooding, consideration is also given to the velocity of any flood waters; with higher velocity causing a greater hazard.

FLOOD RISK FROM LAKE TAUPŌ

77. In 2008, I commenced a detailed analysis on behalf of Environment Waikato and TDC into the flood hazard associated with land adjacent to Lake Taupō.[9]

78. That research was subsequently externally-peer-reviewed,[10] subject to public scrutiny, and presented at hearings related to the Taupō District Flood Hazard Study.

79. The risk of high water levels in Lake Taupō comes from four sources:

(a) High static water levels (that is, the water level in Lake Taupō relative to the surrounding landscape);

(b) Tectonic deformation of the land adjacent to the lake;

(c) Waves acting on top of high water levels, effectively increasing the 'reach' of the water; and

(d) The backwater effect of the lake level on flooding in rivers and streams draining to Lake Taupō.

80. High static water levels in Lake Taupō come about as a result of inflows from the tributaries exceeding the outflow capacity into the Waikato River. It should be recognised that this risk has been mitigated by the construction of the Taupō Gates in 1941. The outflow capacity of the Gates and artificial channel is now significantly greater than the capacity of the natural channel. Despite this, the enhanced flow capacity of the modified outlet is still much less than inflows to the lake during flood events. This causes largely uncontrollable rises in lake level.

81. In assessing the risk of high lake levels to adjacent land, all those factors that potentially affect the water level were quantified. This included: lake inflows, lake level variation, seiche, climate change to the 2090s (based on Ministry for the Environment guidelines from 2010), land use change with conversion from forestry to pasture, and site-specific tectonic deformation of the shoreline.

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9 Ward, H., Morrow, F. & Ferguson, R. 2014: Taupō District Flood Hazard Study: Lake Taupō. Report prepared by Opus International Consultants. Draft for internal review. June 2014. 108p.

10 NIWA 2015: Peer review of Taupō District flood hazard reports. Report prepared R. Henderson, M. Duncan & M Hicks from NIWA Christchurch for Taupō District Council. March 2015. 32p.

82. Since the effects of lake level, seiche, and climate change are consistent around the lake, the use of a single value (for a particular design event) is appropriate (Table 9.1 from Ward *et al.*, 2014).[11]

Table 9.1 Expected static water level for different design events.

Return Period	Lake Level (m)	Climate Change 2080s (m)	Seiche Effect (m)	TOTAL STATIC WATER LEVEL (m)
2.33	357.17	0.07	0.08	357.32
5	357.29	0.10	0.09	357.48
10	357.35	0.12	0.10	357.57
20	357.41	0.14	0.11	357.66
50	357.47	0.16	0.11	357.74
100	***357.50***	***0.18***	***0.11***	***357.79***
200	357.53	0.19	0.11	357.83
500	357.57	0.21	0.11	357.89

83. The total static water level for the 1% AEP design event (100 year ARI) in Lake Taupō is 357.79m.

84. It should be noted that the difference in the lake level during a mean annual event i.e. 2.33 AEP (357.32) and 1% AEP (357.79) design event is only 0.47m. Of this 47cm, 33cm is from the difference in lake level, 11cm from the potential impact of climate change, and 3cm from seiche.

85. Tectonic deformation varies significantly around the lake. Where an area is subsiding, the effect of the lowering of the ground on the effective water level must be considered. The amount of subsidence over the planning period must therefore be added to the total static water level discussed above.

86. For example, the average subsidence between 2002-2013 at Kinloch and Waihi were 5.7mm and 6.4mm respectively. If this rate was to persist over a 100 year planning time-frame, these areas would subside by a greater amount than the variation in lake level over design events ranging from the mean annual to the 0.5% AEP (i.e. 200-year ARI) event.[11]

[11] Ward, H., Morrow, F. & Ferguson, R. 2014: Taupō District Flood Hazard Study: Lake Taupō. Report prepared by Opus International Consultants. Draft for internal review. June 2014. 108p.

FLOOD RISK FROM TRIBUTARIES

87. The flood hazard posed by the major tributaries was assessed by:

(a) Determining the magnitude of the design event under current climate conditions from a frequency analysis of the empirical annual flood maxima series; or surrogate maxima series scaled appropriately where no long-term instrumental record exists (e.g. Tokaanu and Whareroa);

(b) Increasing the magnitude of the design flood to allow for the potential effects of climate change;

(c) Determining the characteristics of the 'type-hydrograph', which was then scaled to the magnitude of the design flood;

(d) Setting the downstream boundary condition at Lake Taupō at 357.5mRL, likely to be about a 20% AEP event over the longer term; and

(e) Applying the design flood hydrograph at the upstream limit of a computational hydraulic model of the floodplain. The upstream limit of the model was chosen so that the entire design flow would be confined to the channel.

Combining the components of the flood hazard

88. The various studies provided a holistic assessment of the potential flood hazard posed by each of the tributaries, and Lake Taupō. Since the flood hazard is generally a function of a number of variables, there is the potential for the different elements to cumulate, resulting in the potential over-estimation of the actual flood hazard.

89. With regard to the hazard posed by high water levels in Lake Taupō, there are a number of factors which affect water level. These include the variability in lake level, seiche, the potential effect of climate change on periods when inflows exceed the discharge capacity of the Taupō Gates, and any longer term deformation of the shore. The linear addition of all these variables results in a 1% AEP water level only 30cm higher than that estimated from the lake level record alone.

90. The inclusion of the effect of seiche is essential to restore the 3-hourly water level data to that likely to be experienced at a shorter time period. About 8cm of the 11cm effect of seiche is the result of frequent oscillations in water level, and therefore must be included to provide a robust estimate of lake level variation.

91. About two-thirds of the additional water level is caused by increased inflows caused by climate change. While this effect is likely to increase only in the longer-term, it must be added to the contemporary situation to provide a 'realistic expectation' of the flood risk towards the end of the longer term planning time-frame i.e. 100 years hence.

92. In the case of river flooding there are three main controls: the peak discharge of the design event; the potential effect of climate change; and any tectonic deformation over the longer term. The lake level used as the downstream boundary condition, i.e. 357.5m, has relatively little effect on the extent and depth of flooding because of the relatively steep gradient of the various tributaries.[12] The peak discharge of the design event is the major control on the extent and depth of any flooding.

93. Furthermore, while a lake level of 357.5m is a 1% AEP event under current conditions, it may become a 20% AEP event (i.e. 5-year ARI) when seiche and the potential effects of climate change are added.

94. While climate change might increase the peak discharge by ~20%, the effect of this on the extent and depth of flooding is generally small. In almost every tributary, the increase in flow resulting from climate change tends to 'fill in' those areas within the flood extent which remained 'dry' during the currrent 1% AEP event. The change in the flood extent was generally within the grid resolution of the floodplain component of the hydraulic model (i.e. 5m).

95. Because the floodplains of the various tributaries are 'large' relative to the flood discharge, the change in flood depth is also small. For example, a 1km^2 floodplain such as that of the Tongariro River requires 10,000m^3 of flood water to raise the level by only 1cm. It would require 100,000m^3 to raise the level by 10cm, which is still less than the likely resolution of the various hydraulic

[12] Smith, H. Paine S. & Ward, H. 2011: Taupō District Flood Hazard Study: Kuratau River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. July 2011. 52p.

models. Consequently, with respect to the flood hazard posed by the rivers, the potential effect of taking a cumulative and conservative approach is relatively small, and likely within the resolution of the models.

96. Obviously there is considerable uncertainty as to the potential effects of climate change over the longer term. However, by adopting a slightly conservative approach, it is possible for the various flood hazard zones to 'contract' over time as more robust information becomes available. It would be significantly more difficult to 'expand' the flood hazard zones in the future, once development had occurred, if this was to become necessary.

97. The inclusion of a tectonic component to the flood hazard is also considered reasonable and realistic. The available information shows that while tectonic deformation around the lake shore is variable, it tends to be relatively consistent at specific locations i.e. either uplift or subsidence. Consequently, it is highly likely that the relative elevation of the ground will change over the longer term planning time-frame. It is considered appropriate therefore that this element of the flood hazard is added to those other elements affecting the overall flood hazard.

Seiche

98. Large lakes such as Taupō exhibit seiching. Seiching is the free oscillation of a body of water as it 'slops' back and forth in an enclosed or partially enclosed basin. This produces standing waves that can either increase or decrease the effective height of the water surface. The frequency of the wave oscillation depends on the size and shape of the basin, its depth and bathymetry, and the temperature of the water. Deep lakes such as Taupō are particularly prone to seiching as the effect of bottom friction is relatively small.[13]

99. The water level of Lake Taupō is measured at both Acacia Bay and Tokaanu; with the data being recorded every 5 minutes. Since the seiche period in Lake Taupō is approximately 30 minutes, all the effects described above are present in these lake level records. The effects of wind-waves are minimised because the recorders are in stilling wells.

[13] Ward, H., Morrow, F. & Ferguson, R. 2014: Taupō District Flood Hazard Study: Lake Taupō. Report prepared by Opus International Consultants. Draft for internal review. June 2014. 108p.

100. The lake level record for Lake Taupō, however, is stored 3-hourly averages and therefore the effects of seiche and other measurement uncertainties have been largely smoothed from those data. The effect of seiche must therefore be added back to the lake level record to determine the actual short-term water level.

101. The variability of the 5-minute data about the 3-hourly average ranges up to approximately ±100mm. From the perspective of the flood hazard, the effect of the seiche on the height of the effective water surface above the 3-hourly average is critical. Since the magnitude of the seiche varies over time, as a result of all the factors which affect seiche, a frequency analysis was used to determine the magnitude of the increase in water level during design events of different frequencies (Table 9.1 from Ward *et al.*, 2014).[14]

102. While the median increase in effective water level is only 3mm, 10% of the variability is greater than 10mm. The combined seiche effect ranges from 8-11cm. To adopt a slightly conservative approach, an increase in water level of 11cm was added to the the design lake level. This value includes all those factors which affect the magnitude of the seiche, but also any uncertainty associated with the measurement of the level of Lake Taupō.

Climate change

103. The RMA requires consideration of the potential effects of climate change. This has generally been interpreted to mean 'including' the potential effects of climate change.

104. With respect to the potential effects of climate change, most attention has been given to increasing temperatures and rising sea level. There has also been a focus on the frequency and intensity of rainfall. However, climate change also has the potential to affect runoff and peak runoff, snowfall and therefore snowmelt, evapotranspiration, soil moisture, antecedent conditions, vegetation patterns, coverage and density etc. Consequently, it is very difficult to model all the potential effects of climate climate, how these may interact, and how the cumulative effect may affect the flood hazard.

[14] Ward, H., Morrow, F. & Ferguson, R. 2014: Taupō District Flood Hazard Study: Lake Taupō. Report prepared by Opus International Consultants. Draft for internal review. June 2014. 108p

105. Incorporating the potential effects of predicted climate change into flood frequency analyses is problematic for a number of reasons. These include uncertainty over:

(a) The magnitude of predictions of increases in temperature. This uncertainty increases with the length of the period under consideration;

(b) The magnitude and significance of climate variability inherent in the annual flood maxima series;

(c) The relationship between increases in average temperature and increases in specific storm rainfall;

(d) The relationship between storm rainfall and event runoff and flood magnitude;

(e) The stability of the rainfall-runoff relationship with increasing flood magnitude and reducing flood frequency; and

(f) The stability of any existing rainfall-runoff relationship in response to climate change.

106. Consequently, there is no single definitive way to include the potential effects of climate change into any flood frequency analysis. Any methodology adopted must involve a significant level of professional judgement, and will result in considerable residual uncertainty. This uncertainty must be accommodated through the use of conservative, but still realistic and reasonable, design flood estimates.

107. The results of a detailed review of the available flood maxima series and temperature data for the Tongariro River and Turangi has a number of implications for flood hazard assessments in the Taupō basin:[15]

(a) While average daily temperatures recorded at Turangi over the past 46-years exhibit some cyclic behaviour there has been no consistent trend of increasing temperature;

[15] Ward, H., Morrow, F. & Ferguson, R. 2014: Taupō District Flood Hazard Study: Lake Taupō. Report prepared by Opus International Consultants. Draft for internal review. June 2014. 108p.

(b) Whether any trend in temperature has occurred in the headwaters of the Tongariro catchment cannot be confirmed since there are no long term temperature data from higher elevations;

(c) The 57-year flow record from the Tongariro River shows no increase in the magnitude or frequency of flooding over time. There has been no increase in flood activity, and no increase in the magnitude and frequency of 'large' flood events;

(d) Flood activity in the Tongariro River, and by inference the other rivers and streams draining to Lake Taupō, tends to be seasonal. The passage of weather systems, antecedent conditions, and topography are also significant controls on flood activity;

(e) Despite there currently being no quantifiable relationship between flood magnitude and temperature (other than at a seasonal level), certainly for larger flood events, and no consistent rise in temperatures within the Tongariro catchment, the magnitudes of various design flood events for the rivers and streams draining to Lake Taupō have been increased to allow for the predicted effects of increased temperatures; and

(f) Using a predicted increase in average temperature and increase in storm rainfall will likely be conservative for flood hazard assessment; yielding higher potential runoff rates, with larger flood peaks and volumes, and consequently higher lake levels.

108. To allow for the potential effects of climate change, the predicted rise in average temperature by the 2090s was adopted. Rainfall was then increased by 8% per degree of warming as is standard practice in New Zealand for longer duration, extreme events (MfE, 2008[16] & MfE, 2010[17]). There is, however, no standard method for translating the predicted rise in rainfall to an increase in runoff, much less an increase in peak runoff during the design event.

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[16] Ministry for the Environment. 2008. *Climate Change effects and Impacts Assessment: A guidance manual for local government in New Zealand.* 2nd edition, Mullan, B., Wratt, D., Dean S., Hollis, M., Allan, S., Williams, T., Kenny, G. and MfE. Ministry for the Environment, Wellington.

[17] Ministry for the Environment. 2010. *Tools for estimating the effects of climate change on flood flow: A guidance manual for local government in New Zealand*. Woods, R., Mullan, A.B., Smart, G., Rouse, H., Hollis, M., McKerchar, A., Ibbitt, R., Dean, S., and Collins, D. (NIWA). Prepared for Ministry for the Environment.

109. As mentioned, there has been little work in New Zealand that quantifies the effect of global warming on runoff and lake levels. Therefore, for the Taupō District Flood Hazard Study it was assumed that there would be the same percentage increase in peak runoff as there is in peak rainfall. This assumption is untested, but appears to be a reasonable first approximation. During extreme design events, any storage within the catchment is likely to be full, and the regolith (the unconsolidated material overlying the bedrock) saturated. Therefore, any additional rainfall is likely to lead to additional runoff. The effect of wet antecedent conditions is also likely to be inherent in the larger floods within the instrumental record.

110. In the various tributaries, the peak discharges of the design flood hydrographs were increased by ~17% to allow for an average temperature increase by the 2090s of 2.1°C (i.e. 2.1°C x 8%/degree).

111. It should be noted, however, that the predicted flood peaks by 2040, using the highest temperature forecasts, are similar to those by 2090 using the 'average' values (i.e. 19% vs 17%). This is therefore considered to be a conservative approach. It allows predicted increases in flood peaks to be managed efficiently now, given the current level of uncertainty. There is sufficient lead time by 2090 that, should the maximum predicted increase appear likely, further mitigation of the flood risk will be possible.

TRIBUTARY DESIGN HYDROGRAPHS

112. In each of the tributaries, the design hydrographs developed for the 1% AEP event under the current climate conditions were increased by 17% to allow for the potential effects of climate change out to the 2090s. All other characteristics of the type-hydrograph were kept constant. Therefore, the climate change hydrograph has the same shape as characteristic large floods experienced within the catchment under current conditions.

113. This approach was applied to the preliminary design of the Peka Peka to Otaki Expressway, which was then considered by the Board of Inquiry. Since the approach was 'new', it was peer reviewed by NIWA, who believed that the approach adopted *"seems reasonable and does make a genuine effort to account for projected climate change effects".* [18]

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[18] *NZ Transport Agency Peka Peka to North Otaki Expressway Effects of Major Watercourse Crossings on Floods Adjusted for Possible Climate Change to 2130.*

LAKE TAUPŌ

114. The size of Lake Taupō, and discharge via the Taupō Gates, means that a different approach to the potential impact of climate change is required regarding lakeshore flooding.

115. Any potential effect of climate change will be moderated and attenuated within Lake Taupō, except when inflows exceed the capacity of the Taupō Gates. At these times the lake level will rise in a largely unmanaged manner.

116. Therefore, the daily average inflows between 1980 and 2013 were increased by 17% to allow for the predicted effects of climate change and all occasions when inflows exceeded the maximum possible lake outflow ($310m^3/s$) identified. These are periods when lake levels would rise even if there was no control of the Taupō Gates. By cumulating the excesses of inflow, and assuming a constant lake surface area of $615km^2$, the potential 'natural' rise in lake level was calculated.

117. The greatest effect of climate change is on events that produce a relatively small increase in lake level (i.e. less than 100mm total change), and on events with durations less than about 3 days. The 2090 climate change scenario did result in an event when theoretical inflows would exceed outflows continuously for 17 days. However, each of these events would potentially cause a total increase in lake level of approximately 400mm. In comparison, the climate change adjusted 1998 flood event would cause a lake level change of 483mm over 10 days. Again, this assumes that the Taupō Gates are fully open. If the gates were used to restrict flow to $30m^3/s$ (increased now to $50m^3/s$), as can be required by Mercury's Flood Rules within the High Flow Management Plan under Condition 5.2 of their resource consent, then Lake Taupō would rise an additional 39mm/day.

118. Using the method outlined in paragraph 116, the projected increase in lake level caused by the effect of global warming on a 1% AEP extreme inflow event by the 2090s would be 185mm. The increase in lake level from projected climate change can then be added to the lake level under the current climate regime to indicate the potential static water level, including the effect of climate change.

119. The potential for an increase in lake level to cause flooding is related to the lake level at the start of an inflow event. The higher the lake level, the less it can rise before it is likely to have a significant effect. High inflows at high lake levels therefore represent the greatest hazard. However, lake level change caused by high inflows is unrelated to the lake level at the start of any event. This means that the change in lake level caused by inflows is independent of the initial lake level, and therefore the two variables must be considered separately.

120. It has been suggested that the impact of climate change on the flood hazard should be evaluated using rainfall-runoff models. However, to calibrate such models for the extreme magnitude of the various design flood events is not feasible. A range of assumptions would be necessary to extrapolate the rainfall-runoff behaviour during relatively small flood events to that under extreme scenarios.

121. The only parameter in any rainfall-runoff model which has been investigated in any detail with regard to the potential effects of climate change is rainfall. It is suggested, however, that if there is a significant change in rainfall, one would also expect changes in evapotranspiration, soil storage, vegetation cover, runoff coefficient, and a range of other factors. All these factors affect the rainfall-runoff relationship. Unless the effect of changing climate on each of these parameters can be quantified, any rainfall-runoff model would be simplistic, and unlikely to reflect the catchment response under an extreme flood scenario. Such a model therefore, while creating the 'illusion' of accuracy and sophistication, could actually be quite misleading.

122. The general approach adopted for this study is considered reasonable, and makes a genuine attempt to incorporate the predicted effects of projected climate change. To purport a more detailed and sophisticated analysis would imply a greater level of understanding of the role of temperature on the rainfall-runoff process than exists currently.

Protection works

123. The flood hazard assessment assumed the current environment, including the present effect of any flood protection or mitigation measures. However, no assumptions were made regarding any future flood protection measures. The assessment was to quantify the nature of the existing flood hazard, not how it could or should potentially be managed.

124. To mitigate the flood risk on the lower floodplains, often extensive programmes of work have been undertaken. This has included the construction of stopbanks, the provision of bank protection, the removal of riparian willow, and channel modifications. This protection is designed to protect those areas at greatest risk, often with high capital investment.

125. The deposition or erosion of material within the channel, and changes in channel geometry, can affect the capacity of the channel to contain flood flows, and therefore the potential for overbank (flood) flows. While these effects can either exacerbate or limit the flood extent, duration, and inundation depth, they are difficult to build into any flood hazard model. This is because they are essentially random occurrences in both time and place. Assuming that the river channel capacity is maintained to the current standard, any adverse effects of sedimentation within the channel should be minimised.

126. The effect of existing flood protection measures on the flood hazard was well-illustrated with respect to the Tongariro River.[19] The modelled flood extent during the February 2004 flood, which was used as the calibration event, was in good agreement with that recorded. The only major difference is that the model results suggested that Awamate Rd, north of Turangi, would have been high enough to prevent the flood waters from reaching the Turangi Sewerage Treatment Plant. This is contrary to experience.

127. However, Environment Waikato subsequently provided confirmation that Awamate Rd was raised after the February 2004 event, and prior to the LiDAR survey. The MIKE21 model is therefore accurate, and reflects the flood hazard remaining, taking into account the presence of the existing flood protection measures.

Management of Lake Taupō

128. In the Taupō District Flood Hazard Study, the lake level record from 1980 to the end of 2013 was used. Although this is a shorter length of record than

[19] Maas, F. 2009: *Taupō District Flood Hazard Study: Tongariro River and Delta Flood Model.* Opus International Consultants, Wellington, New Zealand.

available, it includes only data from when the lake and its inflows have been managed in a more consistent manner. For example, this is the period since the commissioning of the Tongariro Power Development, since Mighty River Power Ltd and then Mercury have been operating the Waikato Hydro System, and following the granting of the current consents to manage the level of Lake Taupō in 2006. It therefore limits the potential impact of non-stationarity of data that may be an issue if the longer data record was analysed.

129. This approach precludes the inclusion of the highest recorded lake level (i.e., 1909). However, discussions with Mercury's operators, and reference to the High Flow Management Plan (developed under Condition 5.2 of their resource consent) suggests that under current management, the lake levels for a similar event would not be so high. Its inclusion in any analysis would therefore have the potential to distort unrealistically any estimates of extreme lake levels.

130. This analysis has also assumed that the future operation of the Taupō Gates will result in substantially the same pattern of lake level variation as discussed above.

131. The pattern of lake level variation was very similar over the 10-years prior to and after the granting of these resource consents. The dominant control on lake level variation is the inflow regime; not management decisions relating to flood mitigation or hydro power generation.

Additional factors affecting Tokaanu

132. The flood hazard posed by Tokaanu Stream focused specifically on the Tokaanu catchment west of the Tokaanu tailrace, and its various sub-catchments. The study did not consider the flood hazard posed by Omoho, Waimatai and Waihi Streams to the east. To the east, the flood hazard of Tokaanu Stream 'merges' with that posed by the Tongariro River which was assessed separately.

133. The Tokaanu floodplain has over time been modified by a range of human activities, interventions, and development. The floodplain has been 'separated' from the Tongariro Delta by the construction of the Tokaanu Power Station tailrace. An aqueduct at the State Highway 41 Bridge over the tailrace now conveys a maximum of $2m^3/s$ from the upper catchment to the lower Tokaanu Stream.

134. State Highway 41 (SH41) forms a slightly raised profile above the swampy land that covers the lower part of the floodplain. The highway crosses the stream approximately 500m upstream of Lake Taupō. The bridge over the stream acts as a constriction on flood flows, while the raised profile of the road acts as a barrier to the overland flow of flood water directly to the lake.

135. The lack of reliable, locally-derived, flow information for Tokaanu Stream means that an alternative approach for determining the magnitude of various design floods was required. Two different approaches were adopted; the Rational Method, and flow scaling from adjacent catchments.

136. There are four main sub-catchments below the Tokaanu tailrace aqueduct. These four sub-catchments contribute the majority of the 'uncontrolled' flow upstream of Tokaanu. This is because the tailrace aqueduct allows only a maximum flow of approximately $2m^3/s$ to enter Tokaanu Stream. Any flow from the upstream catchment, which is in excess of $2m^3/s$, is discharged directly into the Tokaanu Power Station tailrace. These high flows therefore bypass the lower reaches of Tokaanu Stream. Since the flood hazard assessment is focussed largely on Tokaanu Stream downstream of the tailrace, a flow of $2m^3/s$ was assumed immediately below the tailrace, and downstream to the first tributary.

137. It was also assumed that the flows from each of the four sub-catchments enter the main stem of Tokaanu Stream at the same time. Such an approach is likely to be slightly conservative for two reasons. First, it is unlikely that a rainstorm event would remain static over all the sub-catchments for the duration of the flood. Second, the different sizes of the various sub-catchments mean that the time of concentration of each catchment is different (i.e. the time it takes water to move from the furthest part of the sub-catchment to the confluence). Consequently, it is unlikely that the peak flows from each of the sub-catchments would occur concurrently. Therefore, the magnitude of the combined flow during an actual flood would likely be less than assumed in this analysis. The results from the hydraulic modelling are therefore likely to be conservative, predicting slightly higher water levels.

138. Ground deformation measurements in the vicinity of the lower reaches of Tokaanu Stream show that the area is subsiding at approximately 6.4mm/year. Because of its magnitude, and potential impact on water levels, this tectonic deformation needs to be built into projections of future lake and river levels, and consequently the flood hazard model. Over a 100 year period the lower Tokaanu Stream is likely to subside approximately 300mm. The effect of this on the flood hazard is that lake levels will be relatively higher, and this, in combination with reduced channel slopes, may increase the extent, duration, and depth of flooding caused by large storm events.

139. Flood modelling identified that, while much of the low-lying area adjacent to the river is potentially at risk from flooding, the flood hazard is relatively low because of shallow water depths and low flow velocities.

140. The SH41 Bridge over the Tokaanu Stream constricts flows, raising flood levels in that portion of Tokaanu Village upstream of the bridge. Furthermore, the raised foundation of SH41 acts as a barrier to overland flood flow from the stream. This causes further backing up of flood water within Tokaanu Village.

141. Given the 'screening' nature of these flood studies, and the fact that the Tokaanu flood model could not be calibrated, it is considered that conservative flood estimates, and consequently flood extents, velocities and depths, are appropriate. For example, it will be easier to 'retract' or 'reduce' flood hazard areas as more information becomes available than to 'expand' them once development has taken place.

Non-contiguous areas

142. The flood hazard mapping resulted in some areas of non-contiguous flooding i.e. small isolated areas of flooding which appear to have no hydraulic-connection to adjacent areas of flooding.

143. In the case of the riverine flooding, these non-contiguous zones of flooding are likely to be 'real'. This is because 2-D hydraulic modelling within MIKE21 and MIKEFLOOD assesses the movement of water across a network of cells. Flooding, however, is only shown when the depth of water flowing over the ground surface represented by a cell is greater than 3cm. Consequently, it is possible to have water flowing over the surface, but the area not appearing at risk of flooding, as long as any water is less than 3cm deep.

144. It is therefore possible to have what appear to be non-contiguous areas of flooding i.e. areas where water depths exceed 3cm, but which are separated from other areas of flooding by zones of very shallow surface flow i.e. <3cm. Although these areas appear to be non-contiguous on the flood hazard map, they are actually connected by zones of shallow surface runoff and flooding.

145. Therefore, on the flood hazard maps associated with the various tributaries to Lake Taupo, the non-contiguous areas were left.[20]

146. Flooding of the shoreline of Lake Taupō as a result of high lake levels was assessed in a different manner to the river-based flooding. Critical water levels were overlaid on the LiDAR-derived DTM, and adjusted for any effects of tectonic subsidence. Any areas where the elevation of the ground was less than the water level were initially indicated as 'flooded'; and the depth of flooding derived by subtracting the ground elevation from the water level.

147. This approach to modelling the flood hazard, however, assumes that the high water levels can actually 'connect' to any low-lying areas inland from the shore. In some cases this 'hydraulic-connection' exists i.e. where there are rivers, streams, drains or culverts. However, in other cases the low-lying areas inland from the shoreline are separated by relatively impermeable beach ridges, berms, and road embankments etc. In these situations, water in the lake cannot move inland to these low-lying areas despite the water being at a higher elevation.

148. Consequently all the areas of flooding adjacent to the lake shore were reviewed. Where a hydraulic connection could be identified between the lake and areas of flooding, these were mapped as having a flood hazard. However, non-contiguous areas of flooding, where no apparent hydraulic connection could be identified, were removed from the flood hazard map.

149. As a result, there are some areas of low-lying topography inland from the shoreline of Lake Taupō which are not shown as having a flood hazard resulting from high water levels within the lake. It should be recognised that these areas are, however, likely to be susceptible to flooding and impeded drainage during localised rainstorm events.

[20] McConchie, J. A. 2015: Technical compendium – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, October 2015. 55p.

Consideration of the wave hazard

150. As part of the Taupō District Flood Hazard Study the lakeshore was divided into 10 wave environments, and the potential wave run-up modelled. Within each environment, the potential for wave run-up was relatively consistent; however, significant differences occurred between each environment.

151. The wave run-up modelling, while using an internationally accepted approach, could only ever be calibrated at a qualitative level. The calibration and available empirical data indicated reasonable agreement at the scale of a district-wide hazard assessment. However, at the individual site scale, specific factors such as geology, shoreline protection, vegetation or slope, could mitigate and moderate any hazard.

152. Since the shoreline of Lake Taupō is over 200km long, and the majority of it is unpopulated, it is not cost-effective to review all those factors with a potential to affect wave run-up at the site-specific scale.

153. Current information relating to wave run-up is based on what was termed the effective water level (**EWL**). The EWL was derived from an analysis of the combined effect of the measured lake level record, and a synthetic wave run-up series obtained using the LAKEWAVE model for the shoreline of Lake Taupō. No water depths were computed, although when the EWL is overlaid on a DTM, the depth of water between the EWL and the ground surface can be estimated.

154. NIWA's peer review of the methodologies used for both the flood and wave run-up data suggested that SWAN would be a better model for determining the wave run-up for the lake than LAKEWAVE. *"Further refinement and calibration of the wave environment of Lake Taupō should be based on a more modern wave hindcast model, such as SWAN 2D."* [21]

155. Given the lack of calibration and site specific data, and therefore the uncertainty inherent in the wave run-up and EWL, it was decided not to pursue identification of this potential hazard within PC34. TDC is developing a work programme to address the wave run-up hazard in more detail in the future.

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[21] NIWA 2015: Peer review of Taupō District flood hazard reports. Report prepared R. Henderson, M. Duncan & M Hicks from NIWA Christchurch for Taupō District Council. March 2015. 32p.

ASSESSMENT OF SUBMISSIONS

156. No individual property inspections had been undertaken by myself in respect of the submissions at the time of preparing this brief of evidence. The re-assessments have relied solely on the information provided in the submissions, and consideration of how this might affect the previous assessment of the potential flood hazard.

157. Prior to the hearing, it is my intention to visit both 139 Taupahi Road, Turangi and those properties on Kinloch Esplanade which back onto the Kinloch Marina. I will provide an addendum, summarising my recommendations, to the hearing following these site visits.

158. The two principal considerations are:

(a) Has the relative topography across the property been altered to such an extent that it affects the flood hazard assessed previously significantly?

(b) Are the changes permanent, to the degree that they will likely persist until the next review of the flood hazard in 10 years' time?

Fraser, 3 Kinloch Esplanade, Kinloch (OS1.1)

159. The Fraser submission (OS1.1) argues that the construction of a 1m high retaining wall, and the configuration of the property, are not recognised by the 5m grid used in the flood hazard modelling. They therefore suggest that the flood hazard within the boundary of 3 Kinloch Esplanade should be removed (Figure 1).

160. The potential flood hazard to those properties between Kinloch Esplanade and the Kinloch Marina was discussed in detail in the site-specific flood hazard re-assessments following public consultation.[22] That re-assessment saw the removal of the area of 'Low Hazard' from encroaching onto No. 7 & 8 Kinloch Esplanade. It appears reasonable that, assuming the 1m retaining wall has been constructed along the rear (i.e. north-eastern) boundaries of all these

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[22] McConchie, J.A. 2016: Site-specific flood hazard re-assessments – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, September 2016. 14p.

properties, the area of 'Low Hazard' should also be removed from encroaching on all properties.

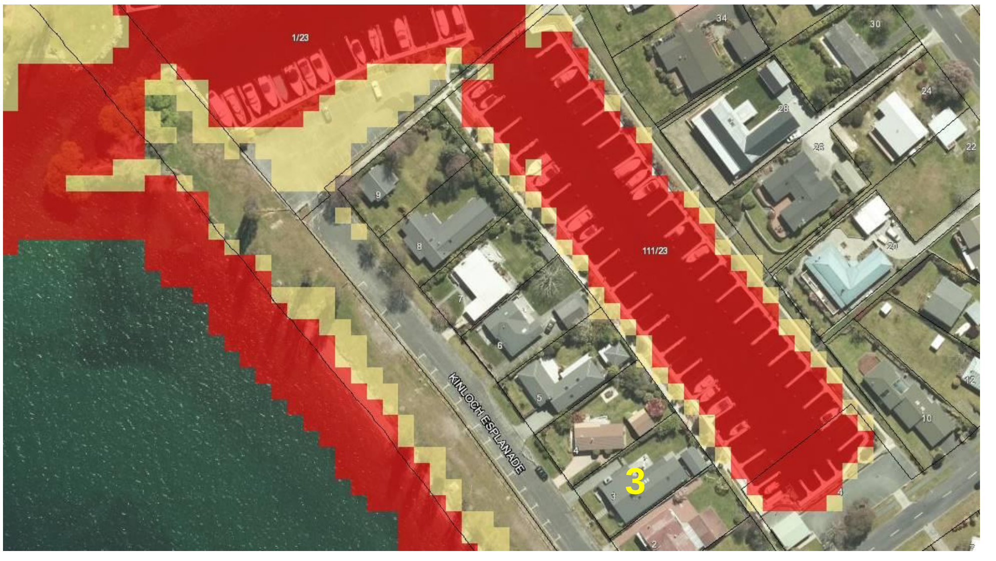

Figure 1: Flood hazard mapping between Kinloch Esplanade and the Kinloch Marina.

161. It is therefore suggested that, following a site visit to confirm the configuration of the retaining wall and landscape, and assuming that the conditions are as argued by the submitter, the area of 'Low Hazard' should be removed from all the affected properties on Kinloch Esplanade which bound the marina. In most instances, the properties are only 'clipped' by 'Low Hazard' cells, and these cells show only a shallow depth of flooding i.e. <0.2m.

Kemp Family Trust, 139 Taupahi Road, Turangi (OS3.1)

162. The Kemp submission (OS3.1) argues that the resolution of the LiDAR, in combination with the grid size used for mapping, obscured the topographic distinction between an upper and lower terrace. They suggest that the area of 'Low Hazard' on the upper terrace should be removed, and that a flood hazard should only be recognised on the lower terrace (Figure 2).

163. Discerning the difference in elevation between the two terraces (suggested to be 1.5-2m) in this particular area is problematic because of the heavy vegetation cover. Although a range of algorithms are used to remove the effect of vegetation from the LiDAR signal, there remains greater uncertainty in the ground level under heavy vegetation.

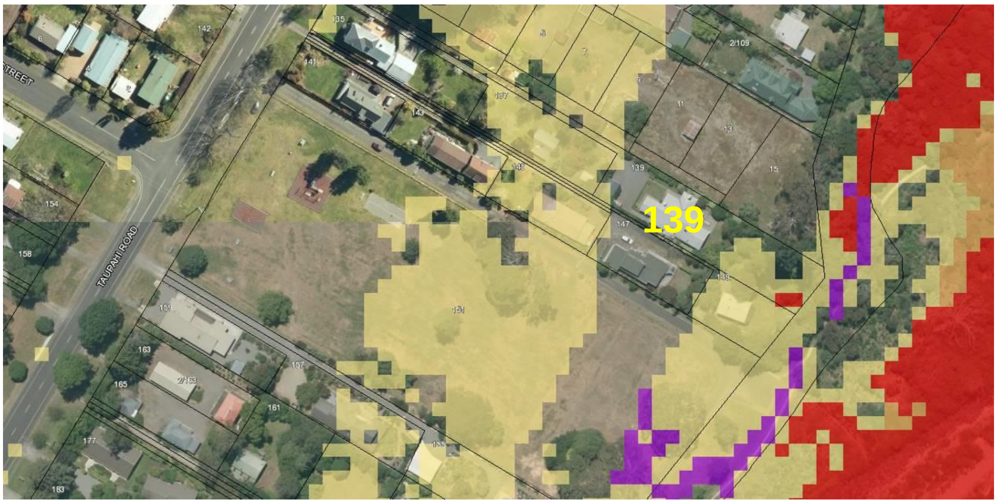

Figure 2: Flood hazard mapping near 139 Taupahi Road, Turangi.

164. A review of the water depths across this area indicates that the presence of two terraces at different elevations is not reflected in the model topography. Assuming that there are two terraces, with distinctly different elevations, then the flood hazard mapping should be adjusted. The area of ‘Low Hazard’ should be removed from the upper terrace, but remain on the lower terrace.

Baker, 2 Piri Road, Turangi (OS4.1)

165. The Baker submission (OS4.1) argues that the flood mapping is incorrect based on their personal experience, and because the area has not flooded over the past 50-years. They also argue that the lack of accuracy was ‘exposed’ when a swimming pool was included even though it had been filled in 10-years previously. They therefore request an independent assessment to remove the area of Low Hazard from their property (Figure 3).

Figure 3: Flood hazard mapping near 2 Piri Street, Turangi.

166. The potential flood hazard to this property was reconsidered and discussed in detail in the site-specific flood hazard re-assessments following public consultation.[23] The area of 'High Hazard', originally associated with a swimming pool which had been filled in, was reduced to 'Low Hazard' following that investigation.

167. As discussed in all the flood hazard reports, the modelling was undertaken relative to a digital terrain model based on LiDAR information captured in 2006. Consequently, the base terrain data are now over 10-years old, and some changes to the topography may have occurred during the intervening period. These changes will be identified, and quantified, in future LiDAR surveys. They will then be incorporated within any future flood hazard assessments.

168. Rather than the 'swimming pool' highlighting the inaccuracy of the flood hazard mapping, I believe that it actually reinforces the accuracy of the mapping. First, the presence of the pool and its location were accurately identified. Also, while LiDAR does not generally penetrate more than a few 10s of centimetres below the water surface, the difference in elevation over the pool was sufficient to move that area from 'Low' to 'High Hazard'. The issue relating to the swimming pool, however, has been 'corrected' following its identification by the submitter.

169. It must be remembered that the design event used in the Flood Hazard Study is the 1% AEP flood in the Tongariro River, increased by ~17% to allow for the potential effect of an average increase in temperature of 2.1°C. It is therefore perhaps not surprising that the submitter has yet to experience a flood event of this magnitude.

170. It should also be noted that the depth of flooding indicated on the flood hazard maps is only between 10-20cm. This is considered realistic in this area during such an extreme design event.

171. After reviewing the available flood hazard information, the LiDAR, and the information provided by the submitter, further changes to the flood hazard as they are shown to affect 2 Piri Road are not recommended at this time.

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[23] McConchie, J.A. 2016: Site-specific flood hazard re-assessments – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, September 2016. 14p.

Brown, 203 Puanga Street, Tokaanu Turangi (OS5.1)

172. The Brown submission (OS5.1) argues that the property at 203 Puanga Street should not be considered within a flood hazard zone as it was not flooded in 2004, the most significant flooding event experienced in the past 25-years. They also suggest that the analysis does not consider the effects of hydro development and 'man-made' structures on the flood hazard. As a result, they request that the Low Hazard zoning be removed from their property (Figure 4).

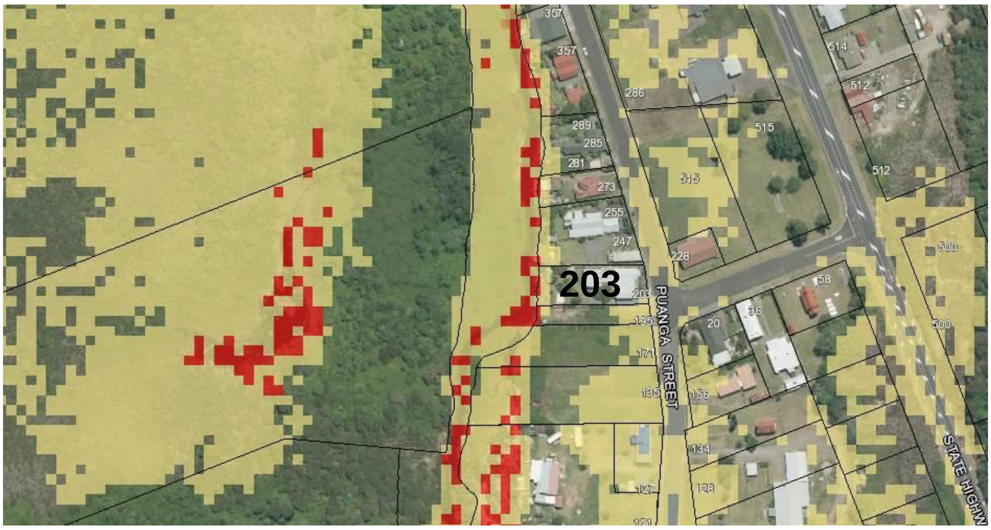

Figure 4: Flood hazard mapping near 203 Puanga Street, Tokaanu.

173. The flood hazard shown with respect to 203 Puanga Street is largely towards the 'bottom' of the property, adjacent to Tokaanu Stream. This is not considered unrealistic. There is also a small area of flooding during the design event shown on the SE corner of the property. The water in this area is only 0.1m deep.

174. The flood risk posed by Tokaanu Stream and high lake levels to the Tokaanu community has been assessed in the same manner, and with the same inherent assumptions, as the other major tributaries to Lake Taupō.

175. The design event used in the Flood Hazard Study is the 1% AEP flood in Tokaanu Stream, increased by ~17% to allow for the potential effect of an average increase in temperature of 2.1°C. It is therefore perhaps not surprising that the submitter has yet to experience a flood event of this magnitude.

176. The effects of both Genesis's and Mercury's operations relating to various hydro developments are fully considered in respect of the flood hazard assessment relating to Tokaanu Stream, as are the effects of SH41 and various bridges over Tokaanu Stream. These are discussed in detail in the Tokaanu Flood Hazard report.[24]

177. As discussed in detail in the flood report relating to Tokaanu Stream,[24] there is greater uncertainty regarding the flood hazard assessment in this catchment than in some of the other catchments. This is the result of limited empirical flow data to define the design flood, and to calibrate the numerical hydraulic model. However, the flood hazard assessment has used the best available information and a consistent, industry-standard, approach. It is possible that the flood hazard assessment has produced slightly conservative results i.e. higher water levels. However, it is considered expedient to have conservative flood hazard zones, the extent and risk of which can be contracted and reduced over time. It would be more problematic to increase the flood hazard at some stage in the future.

178. The mapped flood hazard is consistent with both the landscape and the presence of extensive swamps throughout the lower valley. Further, the flood hazard is compounded by the continual subsidence of the area which is likely to result in flood levels up to 640mm higher than at present over the next 100 years.

179. PC34 adopts a risk-based approach to recognising and mitigating the potential effects of the flood hazard. I believe that the flood hazard assessment for Tokaanu Stream and the surrounding land is consistent with this approach. I believe that no change should be made to the flood hazard maps with respect to 203 Puanga Street at this time.

180. It is also noted that Mercury opposes this submission. Mercury considers that PC34 adopts a risk-based approach that aims to provide new and strengthened provisions within the District Plan to manage the effects from flood hazards on people, property and infrastructure. It must also give effect to the Waikato Regional Policy Statement. I agree with Mercury's submission.[25]

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[24] Paine, S. & Smith, H. 2012: Taupō District Flood Hazard Study: Tokaanu Stream. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. June 2012. 50p.

[25] Mercury, 2018: Further submissions on proposed Plan Change 34 – Flood hazard plan change to the Taupō District Plan. 18 May 2018.

Houpt, 6 Kinloch Esplanade, Kinloch (OS6.1)

181. The Houpt submission (OS6.1) argues that the construction of a retaining wall, and the configuration of the property, are not recognised by the 5m grid used in the flood hazard modelling. They therefore suggest that the flood hazard within the boundary of 6 Kinloch Esplanade should be removed (Figure 5).

Figure 5: Flood hazard mapping near 6 Kinloch Esplanade, Kinloch.

182. The potential flood hazard to those properties between Kinloch Esplanade and the Kinloch Marina was discussed in detail in the site-specific flood hazard re-assessments following public consultation.[26] That re-assessment saw the removal of the area of 'Low Hazard' from encroaching onto No. 7 & 8 Kinloch Esplanade. It appears reasonable that, assuming the 1m retaining wall has been constructed along the rear (i.e. north-eastern) boundaries of all these properties, the area of 'Low Hazard' should also be removed from encroaching on all properties.

183. It is therefore suggested that, following a site visit to confirm the configuration of the retaining well and landscape, and assuming that the conditions are as argued by the submitter, the area of 'Low Hazard' should be removed be all the affected properties on Kinloch Esplanade which bound the marina. In most instances, the properties are only 'clipped' by 'Low Hazard' cells, and these cells show only a shallow depth of flooding i.e. <0.2m.

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[26] McConchie, J.A. 2016: Site-specific flood hazard re-assessments – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, September 2016. 14p.

Abercrombie, 9 Kokopu Street, Turangi (OS8.1)

184. The Abercrombie submission (OS8.1) does not accept the methodology adopted by the Taupō District Flood Hazard Study. They also argue that they are paying rates to Waikato Regional Council for protection from a 1-in-100 year flood, and that this is inconsistent with the results of TDC's mapping (Figure 6). As a result, they request PC34 not be implemented.

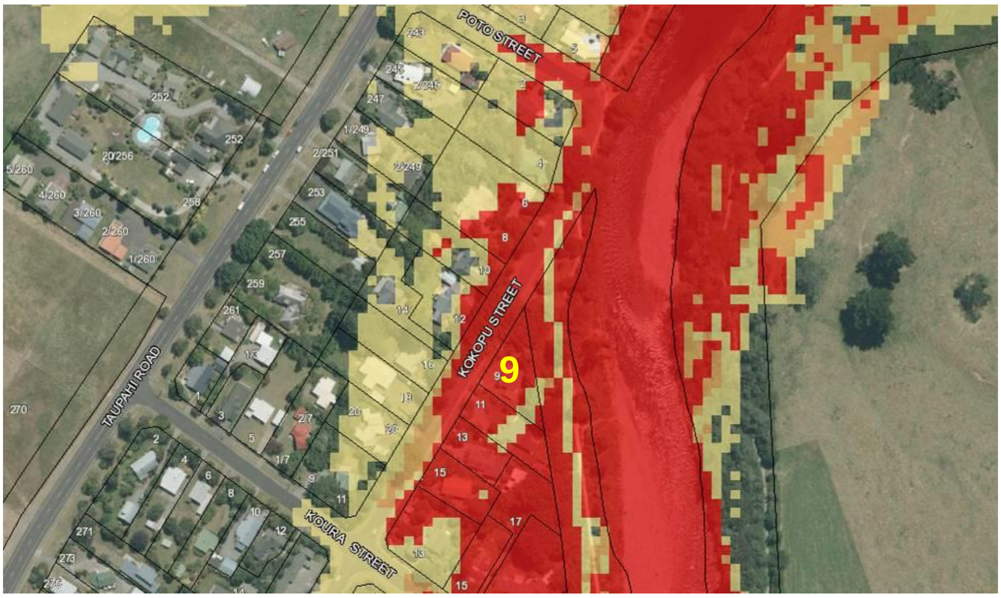

Figure 6: Flood hazard mapping near 9 Kokopu Street, Turangi.

185. There are a number of reasons for the differences between the Waikato Regional Council and TDC flood hazard assessments. The principal differences are:

(a) The magnitude of the design event. WRC use the 1% AEP event under current climate conditions, while TDC use the 1% AEP event increased by 17% to allow for the potential effects of climate change;

(b) WRC used a simple 1D MIKE 11 computational hydraulic model of the Tongariro River, with 'glass walls' at the edge of the channel, and stopbank heights derived from plans. TDC used a 2-D model of the channel and floodplain, and the stopbanks defined using the latest LiDAR information.

186. The effect of the higher design flow, and the use of a 2-D hydraulic model (which allows super-elevation of the water surface around bends in the river) account largely for why the TDC model shows flooding while the WRC model does not.

187. It should be noted that the flood hazard was assessed assuming only the existing flood defences and channel alignment. Obviously the risk that has been identified can be mitigated using a range of interventions. These are beyond the scope of this investigation, and PC34. However, should any changes be made e.g. higher or different stopbanks, then these would be included in any future modelling, and likely see a reduction in the hazard.

188. As already mentioned, the modelled flood extent during the February 2004 flood, using the TDC 2-D model, was in good agreement with that observed. The only significant difference is that the MIKE21 model results suggested that Awamate Rd, north of Turangi, would have been high enough to prevent the flood waters from reaching the Turangi Sewerage Treatment Plant. This is contrary to experience.

189. However, Waikato Regional Council subsequently provided confirmation that Awamate Rd was raised after the February 2004 event, and prior to the LiDAR survey. The MIKE21 model is therefore accurate, and reflects the flood hazard remaining after the existing flood protection measures.

190. As part of a 'Service Level Review' Waikato Regional Council used the MIKE21 model with the same parameters and boundary conditions as used in the Tongariro Flood Study (Grant, 2014).[24] Two changes, however, were made. These were:

(a) Using a flood hydrograph rather than a constant flood discharge; and

(b) Updating the representation of the stopbanks within the model using their actual surveyed heights.

191. These changes, particularly the inclusion of what are slightly higher stopbanks, resulted in some changes to the pattern of flooding previously presented in Maas (2009) and Maas & McConchie (2011).

192. To ensure that the latest information is used to inform the district planning process, the results from this latest modelling have been adopted (i.e. those from Grant, 2014).[27] These results are considered to best represent current conditions likely to affect the flood risk to land adjacent to the Tongariro River.

193. As a result of the above discussion, I believe that no change should be made to the flood hazard maps with respect to 9 Kokopu Street, Turangi at this time.

194. It is also noted that Mercury opposes this submission. Mercury considers that PC34 adopts a risk-based approach that aims to provide new and strengthened provisions within the District Plan to manage the effects from flood hazards on people, property and infrastructure. It must also give effect to the Waikato Regional Policy Statement. I agree with Mercury's submission. [28]

Hapeta, 37A Parehopu Street, Kuratau (OS9.2)

195. The Hapeta submission (OS9.1) has correctly identified a 'Low Hazard' affecting the lakeward portion of their property (Figure 7). Although it is not clear what relief they would like, since they do not want to limit their development options one assumes that it is the removal of the flood hazard from their property.

Figure 7: Flood hazard mapping near 37A Parehopu Street, Kuratau.

[27] Grant, D. 2014: Tongariro flood protection scheme – level of service review. Waikato Regional Council Internal Series 2014/28, October 2014. Document #3054315.

[28] Mercury, 2018: Further submissions on proposed Plan Change 34 – Flood hazard plan change to the Taupō District Plan. 18 May 2018.

196. The flood hazard in this location is a function of high lake levels, which it must be remembered would be exacerbated by wave action during strong easterly conditions. Flooding inland of the shore is a function of hydraulic connections through or over the berm at the back of the beach.

197. The modelling indicates flooding to a depth of between 10-20cm i.e. relatively shallow. Since the flooding is caused by high lake levels it will have no velocity component.

198. After reviewing the available flood hazard information, the LiDAR, and the information provided by the submitter, no change to the hazard zoning is recommended at this time.

Marbeck, 229 Taupahi Road, Turangi (OS11.1)

199. The Marbeck submission (OS11.1) has identified a single 'cell' of High Hazard affecting their property (Figure 8). It is suggested that this is caused by a fish pond, and the surrounding ground sloping towards the pond. The submitter has suggested filling in this area so that the depth of inundation remains below the 'High Hazard' threshold. It is noted that the depth of inundation in this area is only 1cm above the 'High Hazard' threshold.

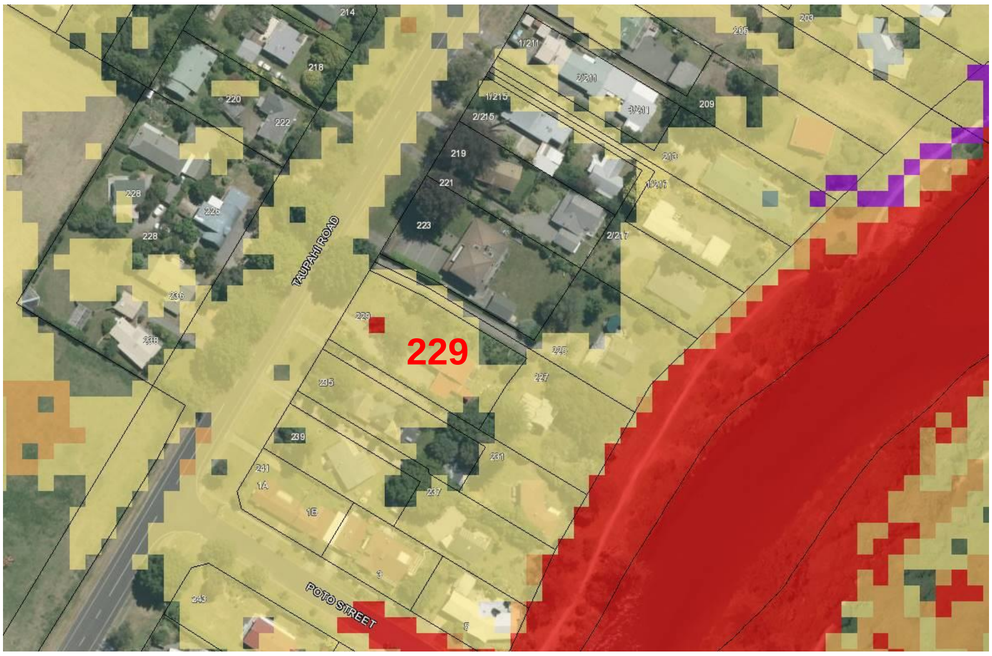

Figure 8: Flood hazard mapping near 229 Taupahi Road, Turangi.

200. This situation again highlights the accuracy and resolution of the flood modelling. There would appear to be two options for 'resolving' the current situation:

(a) The submitter could raise the ground level in this area by a few centimetres so that the depth of inundation during the design event is less than 1m i.e. the area would be re-zoned ‘Low Hazard’, as is the surrounding area; or

(b) Rely on commonsense prevailing, with the explanation for the ‘High Hazard’ zoning being the presence of the pond i.e. the area is not subject to a more general ‘High Hazard’.

201. At this stage, I would not propose changing the ‘High Hazard’ classification of this single 5m cell. If the submitter was to fill this area, then I would certainly recommend that the hazard classification be revised downwards to reflect the shallower depth of inundation during the design event.

Clark, 105 Humu Street, Tokaanu (OS12.1)

202. The Clark submission (OS12.1) has identified the primary factors exacerbating flooding in Tokaanu during the design event. They have also confirmed the existing flood hazard in this area, although they argue that since this is largely anthropogenic in origin, the hazard should not exist (Figure 9).

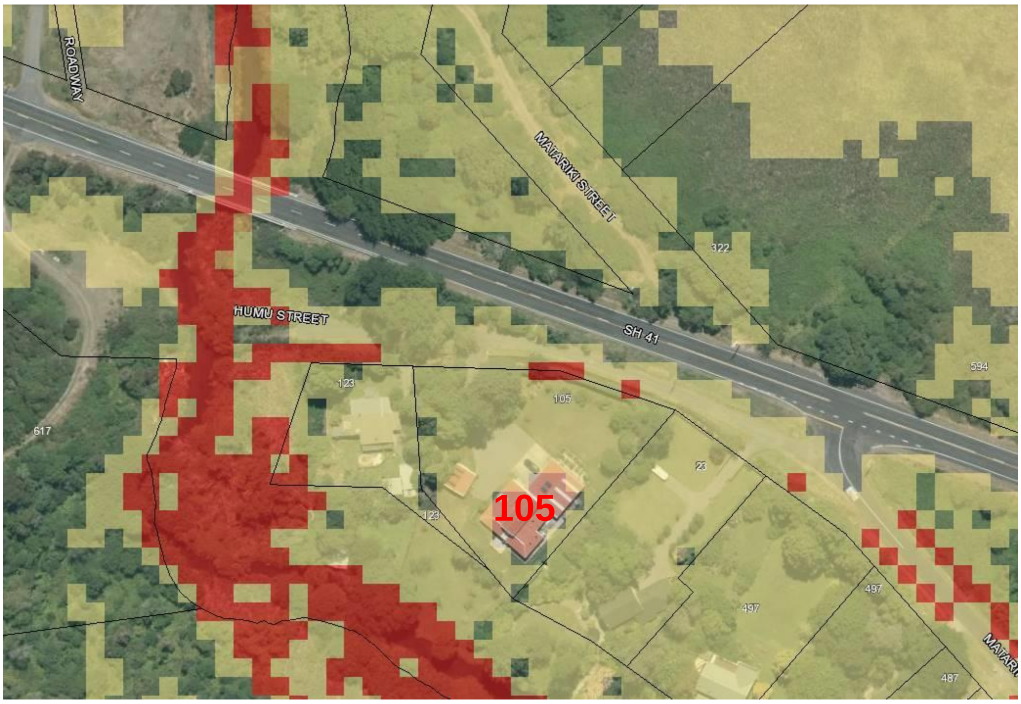

Figure 9: **Flood hazard mapping near 105 Humu Street, Tokaanu.**

203. The flood hazard assessment was primarily aimed at identifying, and quantifying, the existing flood hazard during a design event.

204. In the vicinity of Humu Street, the depth and extent of flooding is exacerbated by the capacity of the culvert/bridge under SH41. This acts as a throttle on the flow, while the embankment formed by SH41 has cut-off various flow paths from Tokaanu directly to Lake Taupō.[29]

205. Obviously, there are a range of interventions which could either remove, or mitigate, the flood hazard in particular locations. Exploring and recommending these interventions was beyond the scope of this investigation.

206. However, I would expect that the results of this study could be used when undertaking 'optioneering' exercises regarding how best to mitigate the existing hazard. In many cases, the responsibility for flood mitigation and flood protection lies not with the TDC but with other agencies.

207. Following the adoption and implementation of any mitigation options, the flood hazard could be reassessed, and the maps in the District Plan associated with PC34 updated.

208. At this stage I would not propose changing the hazard classification in the vicinity of 105 Humu Street, Tokaanu. There is an acknowledged flood hazard in this area. Mitigating this hazard will hopefully be considered at some stage in the future now that it has been quantified.

Grants Motels Ltd – 24 Te Arahori Street, Turangi (OS13.1)

209. The Grants Motels submission (OS13.1) does not appear to dispute the flood hazard to its property. However, they argue that since the hazard can be mitigated through engineering means e.g. engineered fill and stopbanks, the current risk should not be identified within the District Plan.

210. The flood hazard assessment considered only the existing environment, and how it might respond to the design event. Those stopbanks, and any other flood protection or mitigation measures which were present when the LiDAR topographic data were collected, are included. Calibration of the Tongariro hydraulic model using the 2004 flood showed that it provides a robust flood hazard mapping tool.

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[29] Paine, S. & Smith, H. 2012: Taupō District Flood Hazard Study: Tokaanu Stream. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. June 2012. 50p

211. While flooding of up to 0.5m is predicted along Te Arahori Street, water levels across the submitter's property range from 10-20cm (Figure 10).

Figure 10: Flood hazard mapping near 24 Te Arahori Street, Turangi.

212. It is anticipated that one of the possible outcomes from the Taupō District Flood Hazard Study will be an investigation as to how the flood hazard in various areas might be mitigated. Should flood protection and mitigation measures be implemented, and the potential flood hazard reduce, then it is anticipated that this would be reflected in revised Flood Hazard Maps in the District Plan.

213. Therefore, at this time, and considering those flood protection and mitigation measures which have been adopted currently for the Tongariro River, the flood hazard maps proposed to be included in PC 34 are robust. The current map provides a realistic representation of the current flood hazard under the design event modelled.

214. No changes are therefore recommended at this time. Changes may be appropriate following any review of the current flood protection measures, the construction of future measures, or following the capture of more recent LiDAR information.

215. It is noted that Mercury also opposes the submission *"on the basis that the use of engineered works (including but not limited to stop banks and diversion channels) as the only or primary risk treatment measure for flood hazard* *management. Such a focus does not accord with the directives of the Waikato Regional Policy Statement, or the Ministry for the Environment's guidance for local government in New Zealand. Modern best practice is to treat risk with a suite of measures, and that engineering works should be used where other measures are impractical or ineffective on their own. In any event, PC34 does not prevent engineered works being undertaken where deemed appropriate, or necessary, to supplement or replace other risk treatment measures."* [30]

Campbell, 168 Te Rangitautahanga Road, Turangi (OS16.13)

216. The Campbell submission (OS16.13) provides considerable information on the nature of flooding within Turangi, the potential causes of this flooding, and how it might be mitigated by the construction of stopbanks in the future (Figure 11). The submission also suggests that the 1958 and 2004 floods were in excess of the 1% AEP.

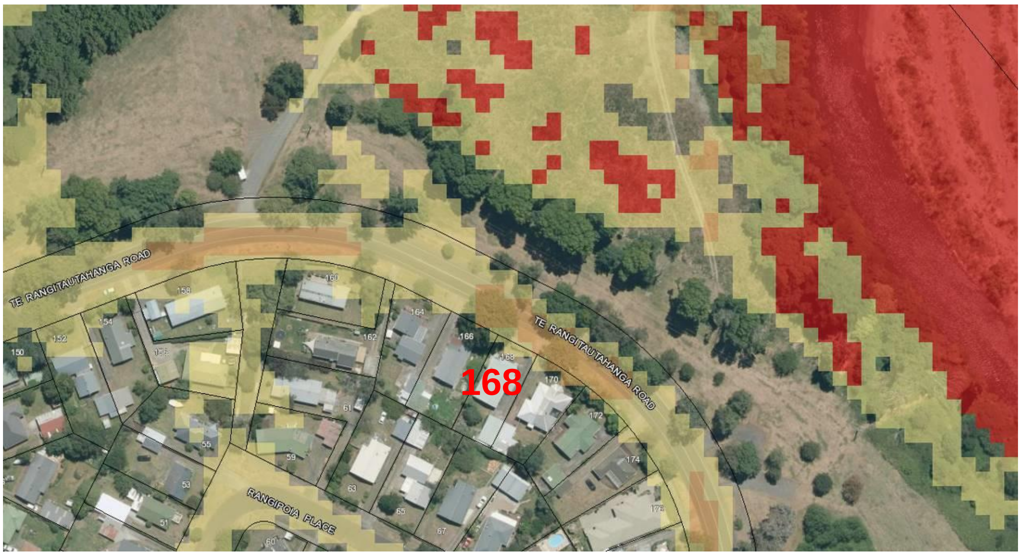

Figure 11: Flood hazard mapping near 168 Te Rangitautahanga Road, Turangi.

217. Prior to the 2004 flood, the AEP of an event of this magnitude was estimated at approximately 1%. Given that there were then two events of this magnitude in the previous 50 years, the return periods were revised after the 2004 event. The 2004 flood was subsequently thought to be a 1 in 55-year event (1.8% AEP), and the 1958 flood a 1 in 60-year event (1.7% AEP). These flood estimates were revised again in 2010 using an additional six years of flow data. The relative lack of flood activity over that 6-year period led to a

[30] Mercury, 2018: Further submissions on proposed Plan Change 34 – Flood hazard plan change to the Taupō District Plan. 18 May 2018.

reduction in the magnitude of specific design floods. For example, the 1% AEP event estimated in 2010 is 1451m³/s; the 1958 flood becoming a 0.93% AEP event, and the 2004 flood becoming a 1.03% AEP event.[31] A subsequent frequency analysis in 2015[32] provided an estimated magnitude of the 1% AEP event of 1413m³/s i.e. about 3% lower than used in the Flood Hazard Study. This change in the estimate of the magnitude of the 1% AEP event is the result of a relatively long period of quiescence (or relative inactivity in terms of large flood events) since 2004.

218. Despite the sensitivity of the estimate of the 1% AEP event to the annual flood maxima series used, it is considered that the estimate under the current climate used in the Tongariro Flood Hazard Study[18] (1451m³/s) is appropriate. Any error in the magnitude of the design flood estimate is likely to be within the resolution of the hydraulic model and LiDAR topography.

219. The flooding in this area is the result of spill over the stopbanks further upstream flowing through the low points (paleo-channels) and then ponding against the inside of the stopbank. The flooding that would potentially affect the submitter's property is generally from 10-20cm deep. Deeper flooding occurs at various low points within the topography.

220. It must be remembered that the design event used to assess the flood hazard was the 1% AEP event under the current climate (1451m³/s), increased by 17% to allow for the potential effects of predicted climate change (1695m³/s). The design event is therefore about 200m³/s larger than the 1958 flood.

221. The flood hazard assessment considered only the existing environment, and how it might respond to the design event. Those stopbanks and any other flood protection or mitigation measures which were present when the LiDAR topographic data were collected are included. Calibration of the Tongariro hydraulic model using the 2004 flood showed that it provided a robust flood hazard mapping tool.

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31 Maas, F. & McConchie, J.A. 2011. Taupō District Flood Hazard Study: Tongariro River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. July 2011. 59p.

32 McConchie, J. A. 2015: Technical compendium – Taupō District Flood Hazard Studies. Report produced by J.A. McConchie of Opus International Consultants Ltd for Taupō District Council, October 2015. 55p.

222. It is anticipated that one of the possible outcomes from the Taupō District Flood Hazard study will be an investigation as to how the flood hazard in various areas might be mitigated. Should flood protection and mitigation measures be implemented, and the potential flood hazard reduce, then it would be anticipated that this would be reflected in revised Flood Hazard Maps in the District Plan.

223. However, at this time, and considering those flood protection and mitigation measures which have been adopted currently for the Tongariro River, the flood hazard maps to be included in PC34 are robust. The current map provides a realistic representation of the current flood hazard under the design event modelled.

224. No changes are therefore recommended at this time.

Trustpower Ltd. Hinemaiaia B Power Station (OS17.3)

225. Trustpower Ltd has requested that the tailrace of the Hinemaiaia B Power Station be removed from the flood hazard map because the infrastructure associated with the Kuratau Hydro-Electric Power Scheme (**HEPS**) has not been included. The reason that Kuratau HEPS infrastructure is not included in the flood hazard assessment is that it is located upstream of the extent of the hydraulic model, and well above any potential effect on the Kuratau community.

226. Since the Taupō District Flood Hazard study was primarily to assess the flood hazard to the community, the primary focus was on the 'floodplains' adjacent to Lake Taupō and the major tributaries.

227. The computational hydraulic model of the Hinemaiaia Stream was extended upstream to the tailrace of Hinemaiaia B Power Station (Figure 12) so that the model could be calibrated against the water level record from the monitoring site 'Below HB Dam'.[33]

228. The aim was also to introduce the design flood to a reach of the river where the entire flow would be contained within the channel i.e. there would be no

[33] Paine, S. & Smith, H. 2012: Taupō District Flood Hazard Study: Hinemaiaia River. Report prepared by Opus International Consultants for Environment Waikato and Taupō District Council. June 2012. 46p.

'out of bank' flow. This is to allow the design flood hydrograph to reach equilibrium, within both the model and channel, upstream of the area of interest.

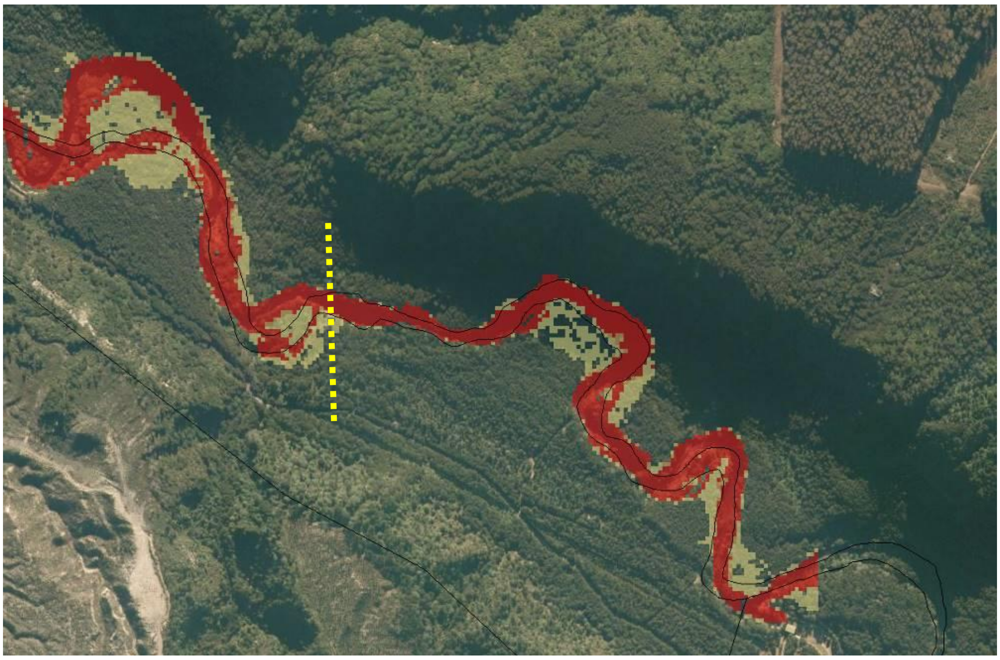

Figure 12: Hinemaiaia River downstream of the tailrace of the Hinemaiaia B Power Station. The proposed limit for the results maps is indicated.

229. The hydraulic model of the Hinemaiaia River, since the upstream boundary is near the tailrace, will be unstable within this reach. The results are not likely to be indicative of the river behaviour during the design flood.

230. It is therefore suggested that the boundary for the results of the hydraulic model of the Hinemaiaia River be shifted downstream to the location indicated on Figure 12. Within this reach, the entire design flow is within the stream channel, and still a significant distance upstream of SH1 and the Hatepe community.

231. It is also recognised that Trustpower Ltd are responsible for dam safety relating to the Hinemaiaia HEPS, and that their responsibilities are independent of, and in addition to, any provisions in the District Plan.

Mercury (OS18.3)

232. Mercury has requested a revised definition of AEP, and that the definition provided in the Waikato RPS should be adopted. It would appear, however, that Mercury may have confused the AEP of an event, with the nature of the design event.

233. A full explanation of the use of AEP, and its technical definition, is provided in paragraphs 56-61 of this brief of evidence. To summarise, the AEP quantifies the probability of a design event being equalled *or exceeded* in any year. Therefore, the definition suggested by Mercury, and by implication used in the Waikato RPS, is technically incorrect. It does not consider the probability of events greater than the design event also occurring.[34]

234. Since PC34 relates to the flood hazard, the design events for both lake and river flooding have been defined in paragraphs 62-70, with specific reference to water level and its various controls.

235. I therefore recommend that the definition sought by Mercury be rejected.

236. However, while the existing definitions are technically correct, I would suggest the following two definitions be added to Section 10 of the District Plan:

(a) Annual Exceedance Probability (AEP): The AEP quantifies the probability of a design event being equalled or exceeded in any year. AEPs are generally described as a percentage i.e. the probability x 100. For example, a design flood with the probability of being equalled or exceeded each year of 0.01 is described as the 1% AEP design flood; and

(b) Design flood: The design flood when assessing the flood hazard posed by the major tributaries flowing into Lake Taupō includes the 1% AEP flood assessed using a frequency analysis of the annual flood maxima series (or alternative methodology), and an allowance for the potential effects of climate change over approximately the next 100 years. The design flood when assessing the flood hazard posed by high water levels within Lake Taupō includes the 1% AEP water level assessed using a frequency analysis of the annual lake level maxima series since 1980, an allowance for the potential effects of climate change over approximately the next 100 years, an allowance

[34] Pearson, C & Davies, T.1997: Stochastic methods. In Floods and Droughts: the New Zealand experience. Edited for the New Zealand Hydrological Society by M.P. Mosley & C.P. Pearson. New Zealand Hydrological Society p65-88.

for the increase in water level caused by seiche; and an allowance for ongoing deformation of the shoreline over the next 100 years.

CONCLUSIONS

237. TDC has made a significant investment in identifying and quantifying the flood hazard within the Lake Taupō basin. This has included quantifying the flood hazard to land adjacent to the lake as well as across the floodplains of the six major tributaries. This is the first time that the flood hazard has been assessed throughout the basin in a consistent and comprehensive manner.

238. Nationally and internationally-recognised techniques have been used to quantify the flood hazard. These techniques have been externally peer-reviewed, and found to be 'fit for purpose'.

239. While the highest resolution data has been used in all the modelling, including LiDAR topographic information for defining the terrain, there remains some inherent uncertainty which is difficult to quantify without robust calibration. Robust flood calibration data exists only for the Tongariro and Tauranga Taupō Rivers; with some qualitative data also available for the Kuratau River. Even in these cases where calibration data are available, this tends to be for relatively small events compared to the design events used in the various flood studies (i.e. the 1% AEP event, plus an allowance for the potential effects of climate change). Since the scenarios modelled in the Taupō District Flood Hazard Study are relatively 'extreme', precise calibration is not possible currently.

240. While every endeavour was made to use the highest resolution data during the Taupō District flood studies, there remains some residual uncertainty at the specific site or property level. This uncertainty is likely to be greatest at the boundaries of any mapped inundation zone.

241. It is important to note, however, that the scale of the mapping, and resolution of the various flood hazard zones, tend to 'moderate' and 'smooth' the inherent uncertainties in some of the input data. For example, at the scale of the analysis and mapping, the effect of a 10-20% change in the peak discharge of a design flood event, or consideration of the potential effect of climate change, has been shown to have a relatively minor effect on the extent and depth of inundation. While the absolute numbers may be different, the pattern of flooding is the same.

242. The potential effects of uncertainty of the input data are also moderated by the major influence of topography on the extent and depth of inundation. Rather than topography increasing gradually and evenly away from the lake or rivers, the landscape is often comprised of a series of ‘steps’ and terraces, or distinct ‘breaks in slope’. These ‘steps’ in the landscape tend to constrain the extent of any inundation until the threshold of the ‘step’s’ elevation is exceeded by the water surface and water can start to flood over the next level.

243. As a result of the public consultation process, the flood hazard at six locations was reassessed. Because of changes to the landscape since the LiDAR used in the modelling was captured in 2006, the flood hazard had reduced in these areas. The flood hazard data were therefore changed to reflect the reduced hazard.

244. A small number of further modifications have been suggested in this brief of evidence in response to the submissions received.

245. Despite some uncertainty regarding the various information used to model the potential flood hazard of Lake Taupō and its tributaries, the mapped hazard zones are considered robust and ‘fit for purpose’.

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