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Nicola Etheridge
Planning Policy Manager
Upper Hutt City Council
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Dear Nicola

RE: Mangaroa River Flood and Erosion Hazard Peer Review

This letter provides the final close out of the peer review that has been undertaken on the flooding and erosion hazard assessments which form the basis for Plan Change 43 for the Mangaroa Valley. The initial peer review was completed in January 2014 and a draft peer review report produced on 14 April 2014. The draft peer reviewed concluded that the following items were acceptable and in line with best practice –

- Model schematisation/representation of structures;
- Delineation and linking of 1-D/2-D domains;
- Model stability and computational parameters; and
- The methodology and outputs from the erosion hazard assessment.

Two critical issues which were considered unacceptable in the draft peer review were –

- Unacceptable variance between measured and modelled flows in model calibration (up to 38% compared to the generally accepted +/- 15%); and
- Conservative and inconsistent application of freeboard in some areas of the model.

A meeting was held at the Greater Wellington Regional Council offices on 4 April 2014 to discuss these issues and agree a way forward. In terms of the model calibration it was agreed that the hydraulic model would be recalibrated using an integrated hydrological model to achieve acceptable model performance. The freeboard needed further consideration and it was agreed that a workshop was required to determine the appropriate scenarios to consider when assessing the freeboard requirements.

A workshop on freeboard was held on 20 May 2015 and parameters were agreed to define freeboard for the Mangaroa Valley which built on current NZ best practice as well as international guidelines. The agreed freeboard parameters are provided in the attached memorandum.

An updated modelling report (Revision F dated 6 November 2015) was produced incorporating the agreed changes.

Most importantly the following changes were evident –

- The model calibration/verification was greatly improved and was within the acceptable range (+/- 15%). Specifically the February 2004 event (250 m^3/s) was modelled to within 12%, and May 1981 (250 m^3/s) was modelled to within 14%; and

- Freeboard was appropriately and consistently applied across the catchment in line with NZ and international best practice.

With these changes completed it is now considered that the integrated hydrological and hydraulic model of the Mangaroa Valley is fit for purpose and the flood hazard outputs from the model are appropriate for use in defining flood hazard zones as part of Plan Change 43.

Yours faithfully

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Encl. Copy of Minutes of Freeboard Workshop

JACOBS

Meeting Minutes

Purpose	**FINAL Minutes of Mangaroa Hazard Mapping Workshop held Wed 20th May 2015**		
Project	Mangaroa Flood Hazard Mapping	**Project No.**	AE04609 / IZ016700
Prepared by	Ruth Abbott	**Phone No.**	+64 4 914 8469
Location	Jacobs Wellington office	**Date/Time**	10/06/2015
Participants	Craig Martel (Awa Consultng), Ben Fountain (Jacobs) Sharyn Westlake (GWRC) Mark Hooker (GWRC) Susan Borrer (GWRC) Kyle Christensen (Cardno)		
Distribution	All participants		

Notes	
1	The context of the Mangaroa hazard mapping in relation to Pinehaven was noted i.e. advised that if there are any differences between freeboard approach and mapping between Pinehaven and Mangaroa, these will need to be justified. Noted that there are legitimate differences between the two catchments e.g. rural vs urban.
2	Noted that there is a need to provide clear explanation and transparency when communicating the approach adopted in hazard mapping and determining freeboard. The use of a numerical approach linked back to known values or best engineering judgement should help to ensure that the process adopted is seen to be robust and defensible. *Post-meeting, Ben sent round an email regarding recent experience in Auckland which supports the above position.*
3	A methodology for determining freeboard for the Mangaroa Hazard Mapping was proposed. This is presented below.
Actions	
i	**Craig** provide examples from literature supporting appropriate magnitude of freeboard for the factors of uncertainty that are not represented in the model and cannot be captured through sensitivity modelling (see Section C in 'Proposed methodology for determining freeboard for the Mangaroa Hazard Mapping' below). *Post-Workshop note: Craig has done this. In general there is not a great deal of applicable material in the literature. The WRc Fluvial Freeboard Guidance Note[1] (i.e. UK freeboard best practice guidance) provides some useful suggestions and where possible/appropriate these have been used as explained in relevant sections of the 'Proposed methodology for*

[1] WRc (Environment Agency), 2000, "Fluvial Freeboard Guidance Note. R&D Technical Report W187"

	determining freeboard for the Mangaroa Hazard Mapping' presented below.
ii	**GWRC** advise whether they are able to provide a 100 year flood hydrograph on the Hutt River at the Mangaroa confluence for use in the 'downstream boundary' sensitivity run.
iii	**GWRC** advise on future proposed urban development (as per Craig's emails at the end of last week). Seeing as Mangaroa was incorporated into the District Plan as a growth area, should/how this be incorporated into the Hazard Mapping/Modelling being undertaken? *GWRC have now confirmed that future proposed urban development scenarios do not need to be incorporated into the modelling as there are no firm plans for development.*
iv	**All workshop participants** read through and confirm agreement with the 'Proposed methodology for determining freeboard for the Mangaroa Hazard Mapping' presented below. Any suggestions for alternative approach/values should be emailed to all participants to aid further discussion and final agreement.
v	**Ruth** to provide Sharyn with revised proposal. The existing proposal will need revising in light of the number of proposed sensitivity runs and confirmation of the use of the 'modelling technique' (as opposed to more traditional 'mapping technique') for adding on freeboard.

Proposed methodology for determining freeboard for the Mangaroa Hazard Mapping

A. Identify and quantify hazards that can be represented in the model and can be captured through undertaking Sensitivity Runs.

In the Workshop (and in some instances during post-Workshop supplementary investigation) the following factors and their associated appropriate representation in a Sensitivity Run were agreed. In accordance with the Actions listed above, it is hoped that all participants in the Workshop will review and confirm (or suggest alternative) values proposed herein.

Factor	Magnitude of allowance for incorporation in Sensitivity Run	Reasoning behind choice of magnitude value in previous column
Blockage	As per *Appendix A*. Culverts and bridges blocked between 20% and 90% Plus blockage in Black Creek downstream of Wallaceville Road.	The proportion of blockage allocated for each of the structures represents an engineering judgement on the likely behaviour of the system in a large flood event. This judgement has been informed by the type and size (shape/height/length) of structure. A greater proportion of blockage expected at culverts compared to large bridges. The Mangaroa catchment is rural and the channel is heavily vegetated along many of the reaches, The potential for mobilisation of this vegetation (and subsequent structure blockage) in a large flood event is therefore a significant hazard in this catchment. A comparison of the downstream hydrograph for blockage vs no blockage situation will be undertaken.
Manning's	Increase	Due to lack of good calibration of the model against

'n'	floodplain and in-channel Manning's n value by 25%	flows/levels throughout the catchment, +25% is appropriate for capturing the level of uncertainty associated with the choice of Manning's 'n' value in this particular model. 25% is slightly more conservative than the often-used 20%.
Hydrology	21%	As stated in the Mangaroa Hydraulic Modelling Report, the Flood Frequency Analysis undertaken in on the Te Marua gauge data (using full gauge record and EV1 Gumbels distribution) suggests 1% AEP flood event discharge (and associated uncertainty) of 355 ± 73 m^3/s. The proposed increase of 21% is of a similar magnitude to the IPPC High scenario allowance (an additional 24%)
Downstream boundary	100 year flow on the Hutt River coinciding with 100 year flow in Mangaroa.	This is a conservative approach which reflects the current uncertainty in understanding the probability/timing of a large flood on both rivers and associated tailwater effect on the lower reaches of the Mangaroa.
Combination run	Blockage as above PLUS +10% hydrology PLUS +10% Manning's	In reality, these factors may coincide and have inter-related effects.
Landslide/ Aggradation	No Sensitivity Run required,	Whilst landslide/aggradation are known potential hazards that could be subject to inclusion in a Sensitivity Run, it has been determined that such runs will not be undertaken as part of the Mangaroa Hazard Mapping as their effect will be accounted for in the blockage Sensitivity Run.

B. Produce an output which captures the effect of these hazard factors on the flood risk.

As detailed above, there will be a total of 5 sensitivity runs. The results will be *combined* to produce a Peak Hazard Sensitivity Output representing the worst case from each of the Sensitivity Runs over the catchment. Note this output is not produced by adding all the individual maximum depth result grids; rather, the worst result at each cell in the model will be taken. This reflects the fact that the most influential hazard factor from the list above will vary spatially throughout the catchment.

C. Identify a freeboard which captures factors that are not represented in the model and cannot be accounted for through hazard sensitivity modelling.

This freeboard should be included in the map-producing process. Based on discussion in the Workshop and subsequent research, the following factors have been considered and an appropriate magnitude of freeboard presented.

Factor	Reasoning
LiDAR	LiDAR is generally accepted to have an accuracy of approximately ±100 mm in open, un-vegetated areas. However, the potential for inaccuracy is higher in areas of dense vegetation and at thin linear features e.g. narrow channels. The apparent inaccuracy of the LiDAR data in a key vegetated floodplain flow path location within the Mangaroa catchment has been highlighted in the Mangaroa Hydraulic Modelling Report; the current version of the model has an area in which raw LiDAR data has been smoothed to remove inaccuracies in the LiDAR.
Cross section survey	The survey used to construct the Mangaroa model includes all structures and the open channel sections are typically approximately 300 m apart. This is a typical resolution of survey for a model of this nature and should be sufficient to capture the key geometric variables influencing hydraulic behaviour under flooding conditions. There may, however, be some reaches of the channel between cross section locations whose geometry has a local influence that will not be captured in the model.
Wave effects arising from uneven floodplain surface or from cars driving through floodwater	This is a known phenomenon which has been reported in the Wellington region during recent flood events. Magnitude is hard to measure and effects are localised. Over a wide area +100 mm is considered appropriate.
Hydrodynamic Action	The localised increase in flooding depth on the upstream side of building on a floodplain, as has been observed in numerous steep catchments across the Wellington region (e.g. Waikanae). Magnitude is velocity dependant, however, values of 100-300 mm are typical.
Superelevation	A method of estimating the rise in water surface elevation relative to normal water level due to superelevation at bends is presented in the WRc Fluvial Freeboard Guidance Note (i.e. UK freeboard best practice guidance). This has been applied on bends on the Mangaroa and super elevations of between 100-200 mm were calculated.

Consideration of each of these factors as presented above indicates that **a freeboard of 300 mm** is appropriate. This value represents a best engineering judgement in the absence of a formal prescriptive methodology for calculating a single freeboard magnitude from a range of factors of this nature. The engineering judgement was informed with consideration to the purpose of the maps for which freeboard is being derived; that is, as maps to inform the planning process and allow the hazard associated with fluvial flooding to be accounted for in planning decision making.

A potential approach would be to add all of the uncertainty magnitudes for each of the factors identified (e.g. 200mm for superelevation + 200 mm for hydrodynamic action + 100 mm for LiDAR etc) however this is considered to be an overly conservative approach which effectively represents a situation whereby the uncertainty associated with all of the factors uniformly affects the catchment across its whole area. This is not reflective of reality, as it is known for example that Superelevation effects are generally restricted to river bends, and Hydrodynamic Action primarily affects the area immediately surrounding building walls.

A more realistic scenario is that at any one point in the catchment, the uncertainty associated with 3 or 4 of the above 5 factors is having a potential impact on the modelling results. As such, 300 mm is an appropriate freeboard magnitude to use.

D. Incorporate the freeboard magnitude above into the mapping process.

The 300 mm freeboard from Section C will be added to the Peak Hazard Sensitivity Output from Section B to produce a hazard map.

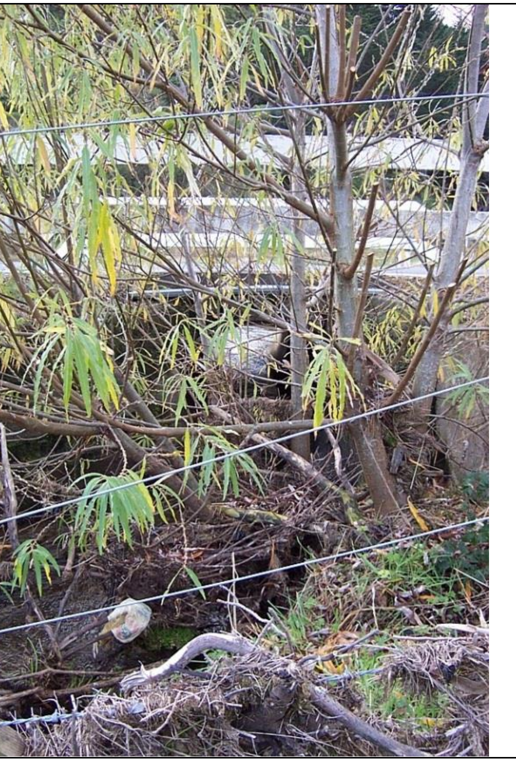
It was agreed in the Workshop that a modelling approach will be used to achieve this through using initial conditions representing the freeboard in the model. Note that there is a need to take care to ensure an appropriate run time is used when ‘modelling’ the freeboard. Run time should be sufficient to let the water spread out and capture the impact of hazard in one cell on those elsewhere, however, too long a run time can result in ‘over’ routing and artificial build up behind structures. A sensibility check on the results will be undertaken.

It was discussed in the Workshop that whilst there are some disadvantages to this approach (e.g. associated with applying a total volume of water into the model and routing this through the system), this approach does have advantages over the more traditional mapping approach in which freeboard is added through contouring. These advantages include the usefulness of an output raster grid with values at all locations throughout the modelled catchment; and the ability to capture the decreasing hazard at the floodplain fringes compared to the floodplain immediately adjacent to the channel.

Appendix A

ID	Structure name	Proportion blocked in Blockage Sensitivity Run	Photo
1	Bridge 913 Whitemans Valley Road	20%	

2	Whitemans Valley Road Bridge	50%	
3	#13 Russel Road	90%	

4	Whitemans Valley Trib Stream Bridge	90%	

5	Bridge 750 Whitemans Valley Road	20%	
6	Bridge 408 Whitemans Valley Road	20%	

7	Bridge Whitemans Valley Road	20%	
8	Bridge Mangaroa Valey Road	20%	

9	Bridge 1	50%	
10	Bridge #280 (Gun Club)	50%	

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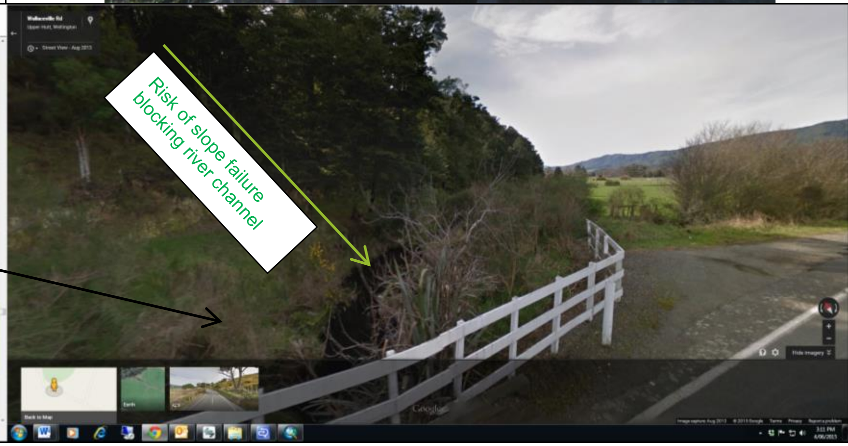
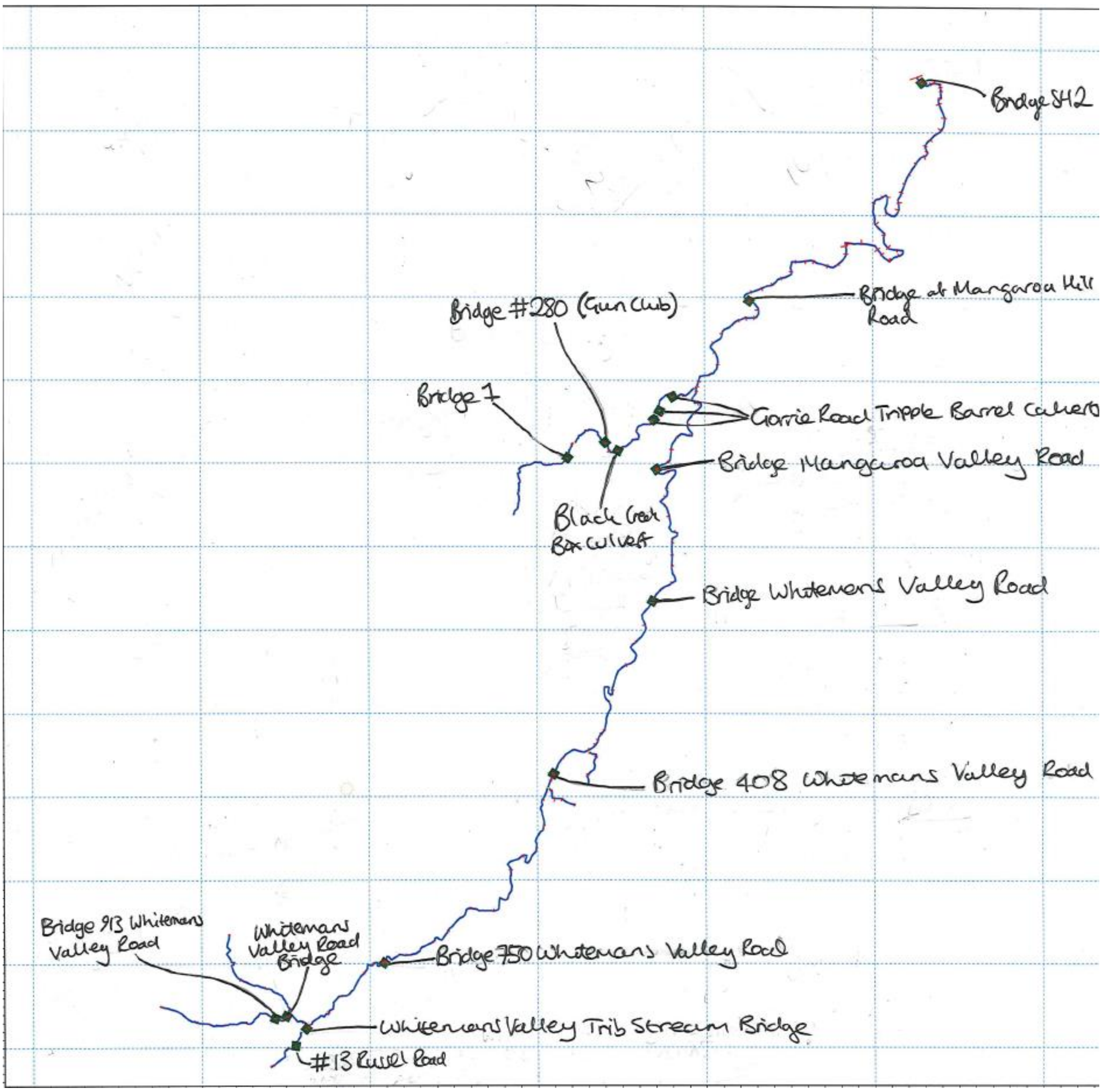
11	Black Creek Box culvert	50%	
	Blockage in Black Creek downstream of Wallaceville Road.		

12	Gorrie Road triple barrel culvert 1	90%		
13	Gorrie Road triple barrel culvert 2	90%		

14	Gorrie Road triple barrel culvert 2 (# 85)	90%	
15	Bridge at Mangaroa Hill Road	20%	

16	Bridge SH2	20%		


Bridge 842
Bridge at Mangaroa Hill Road
Bridge #280 (Gun Club)
Bridge 7
Gorrie Road Tripple Barrel Culverts
Bridge Mangaroa Valley Road
Black Creek Box Culvert
Bridge Whitemans Valley Road
Bridge 408 Whitemans Valley Road
Bridge 913 Whitemans Valley Road
Whitemans Valley Road Bridge
Bridge 750 Whitemans Valley Road
Whitemans Valley Trib Stream Bridge
#13 Russel Road