Report on submissions and further submissions on the Proposed Waikato District Plan

Hearing 27C:

Natural Hazards: Flood Hazards

Appendix 4: Flood Modelling - Evidence of Greg White

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Concerning – Proposed Waikato District Plan – Flood Modelling

Dear Janice,

Greg Whyte Introduction

My full name is Gregory Mark Whyte. I hold the position of Managing Director at DHI Water & Environment (DHI). I have been in this position since March 2008.

I hold a Bachelor of Civil Engineering from the University of Canterbury, which I gained in 1996. I am also a Chartered Professional Engineer with Engineering New Zealand (ENZ), which I have held since 2003.

I have been engaged by the Waikato District Council (WDC) to give evidence on the flood modelling done for Waikato Regional Council (WRC) that was used as a basis for mapping of the flood risk areas in the Proposed Waikato District Plan (PWDP).

DHI have provided flood hazard and flood forecasting services to WRC since 2004.

The key document I have used, or referred to, in forming my view while preparing this evidence is:

a) WRC Lower Waikato 2D Modelling, Huntly, Ohinewai and Horotiu Model Build, DHI, 2020

Background of Waikato Regional Council Modelling

Flood modelling that the Council conducts uses computational computer models to predict flood extents and depths across a catchment. The models use rainfall and tidal data as inputs to produce flood extent and depth outputs. The hydrological model simulates the rainfall-runoff processes occurring at a catchment scale. It is a lumped, conceptual rainfall-runoff model, simulating the overland, interflow, and baseflow components of catchment runoff as a function of the moisture contents in various conceptual storages. These process's produce what is termed "runoff" which is then further routed through pipes (if they are represented), open channel waterways and rivers. Once these primary systems are at capacity the runoff then enters the floodplain areas or the secondary flowpath areas.

The rainfall the models use is commonly called design rainfall because it has been determined by a statistically related procedure of a certain return period. Design rainfall depths have been obtained from NIWA's High Intensity Rainfall Design System (HIRDS) v4 and use a "Chicago Storm" temporal pattern. Historical event rainfall that has been used to validate the model (1998, 2002, 2004 and 2017) has been distributed across the catchment by a Thiessen polygon approach.

The models use either observed tidal data at Port Waikato for the validation events or a constant water level of RL 1.69 metres for the design simulations.

A model simulation consists of "running" the model for a certain period or window of time which could reflect the critical duration of the model or a part of the model. If you want to understand the entire flood event from the beginning to peak and the recession, then the model may have a long run time, but maybe less if you are only interested in the peak flood levels. The model run time is how long the model takes to complete the model simulation which may be faster or slower than the simulation period depending on the hardware the computer has and the model timestep used for the simulation.

DHI (formally known as the Danish Hydraulic Institute) are the producers of the MIKE software that WRC uses for the majority of its flood modelling and the Lower Waikato Flood model. DHI was formed in 1964 in Denmark and released its first commercial software package "MOUSE" in 1983. DHI produce water modelling software and undertake specialist consulting projects around the world, with over 1200 staff worldwide based in over 30 countries. DHI New Zealand has 19 staff based between Auckland and Christchurch.

The mathematical equations used by the software code for flood modelling is either solving the St Venant 1-Dimensional (1-D) shallow water equations or the depth averaged Navier Stokes 2-Dimensional (2-D) equations. If the software code solves the 1-D equations it is commonly referred to as a 1D model, likewise for a 2D model. The WRC Lower Waikato Flood model is a 1-D/2-D. Flood modelling in the last 15 years has moved from purely 1-D models to 1-D/2-D models that are more reliable than 1-D models in floodplain or secondary flow path environments.

WRC has been carrying out flood modelling studies with DHI software since early 2000's, in-house, using MIKE 11 for open channel analysis. The in-house WRC studies built and used 1-D models or in some cases pseudo 2-D models. A pseudo 2-D model is where a 1-D model has been used to represent a 2-D flow situation. The original 1-D main river model for the Lower Waikato was built by WRC.

In 2017 DHI started discussions with the Council to update the Lower Waikato model.

The Lower Waikato river model consists of a rainfall runoff component and a hydraulic routing component. It makes make use of a DHI rainfall runoff model called "NAM", which is a lumped conceptual model. The rainfall runoff calculations are carried out in MIKE 11. Essentially the hydrological model produces the net runoff for each sub-catchment when a specific rainfall is applied to which some hydrological losses are removed.

The hydraulic routing component of the models consist of open channels that are represented in MIKE 11. Some of the floodplains of the waterways and rivers are represented in the 2-D software MIKE 21.

Technical Integrity

The MIKE software tools have been used for thousands of projects around the world over the last 50+ years. They are widely accepted across the industry as tools suitable for assessing flood risk.

DHI New Zealand works in accordance with the quality management system standard: ISO 9001 as certified by Det Norske Veritas (DNV). The ISO 9001 certificate covers the following products or services within the area of water, environment, and health:

- Consulting;
- Software;
- Research & Development; and
- Laboratory Testing, Analysis and products.

DHI's quality management system requires all deliverables to be reviewed and approved by appropriately qualified staff.

A number of DHI New Zealand staff and other DHI staff from around the world have been involved in flood modelling work for the Council over the last 17 years with experience ranging from two years to 20+ years. Junior staff are supervised more closely than senior staff with all deliverables subject to the firm's quality management system.

The Lower Waikato model has been continuously developed since the early 2000’s and encapsulates WRC knowledge of the land drainage system and the operation of that system during a flood event.

An important change in the way the Lower Waikato River system is modelled occurred when changing from a 1-D to a 1-D/2-D model in 2020. The 1-D model relies on user defined floodplain or secondary flow path definition, whereas the 1-D/2-D model directly uses detailed topographical data to determine the floodplain flow paths.

A measure of a model's ability to represent reality is how well calibrated or validated the model is. A textbook calibration/validation would consist of three or four calibration events and a validation event. The calibration events would consist of historic flood events representative of the purpose of the model. For example, if the purpose of the model was to predict large or infrequent flood events then the ideal calibration events would consist of large or infrequent flood events. Likewise for medium sized events and small or frequent flood events. A validation event could consist of a separate historical event to the calibration event that might test the overall integrity of the model using the calibrated model parameters.

The calibration/validation of a flood model provides a degree of confidence that the model represents reality but also that it is technically robust. In order for a model to represent reality it needs to be schematised correctly and to represent the flooding processes occurring in the catchment.

The Lower Waikato Flood Forecasting model has been validated to four historical flood events, July 1998, July 2002, March 2004 and April 2017. These were the four largest recorded events in the last two decades.

Model Assumptions

A flood model is a simplified representation of reality and hence there are many assumptions and approximations made when building and using a flood model. The 2020 DHI "Lower Waikato 2-D Modelling" report endeavours to limit and document the assumptions required in building and running the flood model.

Key assumptions include, allowing for a climate change induced increase in design rainfall depths as per the Intergovernmental Panel on Climate Change (IPCC), Representative Concentration Pathway (RCP) scenario RCP 6.0 (an increase in temperature of 2.3^{o}C) and no allowance for sea level rise as the sea level is unlikely to significantly affect flood levels in the WDC area of interest. Pipe networks, open channels and pumps have been excluded from the modelled floodplain areas due to the poor quality of the data. Because of this the model is limited to simulating flooding from the river to the floodplain and not to the river from the floodplain. Culverts, pumps, bridges, weirs and control structure are included in main channel branches of the model.

Peer Review of Modelling

DHI routinely peer review other consultants' models and have our models reviewed by other consultants. Peer review at the end of a project can be of limited use, especially if some fundamental aspect of the model is wrong. We find a better approach is to be involved at key stages of a modelling project to minimise any reworking or time taken to correct the model for any errors/omissions or modifications required.

The Lower Waikato model had a staged review undertaken by Mark Pennington of Tonkin & Taylor Limited. The concluding comment from the review was:

"It appears that the original purpose of the model has evolved during the modelling process, to the point that there is reported acceptance that the model will not produce flood extents and depths from all flood mechanisms in the areas of interest. Rather, the model only produces estimates of flooding outside of the river channel under stopbank overtopping conditions. In this case, the model has been adequately set up and run for this intended purpose. Furthermore, the model results may be used by subsequent local drainage analysis for which tailwater levels are required."

Concluding Remarks

The concluding comment from the peer reviewer highlights a limitation of the model but this should not be viewed as the modelling is not fit for purpose. Localised drainage outside of the main river or tributaries is not represented, where instead it is assumed for a large event, such as the 1% AEP design storm event, this infrastructure is overwhelmed, flood water can get to the main river or tributaries.

If a property is shown as flooded it is for one of two reasons; it is either not protected by stopbanks or the stopbanks in that area are overtopped by the 1% AEP design storm event.

Best regards

DHI

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