Kerikeri Flood Model Upgrade 2016

Model Built, Calibration and Option Simulations

Report

March 2017

The expert in **WATER ENVIRONMENTS**

Kerikeri Flood Model Upgrade 2016

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Project number	44800972
Approval date	20 March 2017
Revision	Draft: 0.1
Classification	Restricted

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1 Introduction

1.1 Background

A numerical hydraulic model of the Kerikeri catchment was first developed by GHD in 2011. Subsequent revisions of the model have continued, with DHI carrying out the work, with version 4 being used to model the proposed Kerikeri Spillway and provide information for the resource consent application for the spillway.

Meanwhile, hydrological and hydraulic data collection has continued within the catchment, with rated flow sites being added. Further flow events occurred in 2014 and 2016, large enough to contribute useful data for a flooding model.

The model includes catchments north and south of the Kerikeri catchment: Pungaere and Wairoa Streams respectively. Both these streams receive overflows from the Kerikeri River during the largest flood events.

1.2 Brief for Version 5

This study has followed a proposal from DHI dated 29th July 2016, in response to a Scope of Works provided by Northland Regional Council on 24th June 2016. The Scope set out four stages of work:

- Model Updates and Recalibration: upgrading to MIKE 2014 software with Flexible Mesh 2D (FM) model, calibration against four significant events, and various minor modifications.
- Baseline simulations of Design Storms with the catchments substantially as now existing. The Design Storms are the 10yr ARI, 50yr ARI, 100yr ARI events including allowance for climate change.
- Scheme Simulations with Design Storms, including the proposed Kerikeri Spillway.
- Processed flood extents: For both baseline and scheme scenarios, flood extents fitted to a 1m DEM, for application in planning maps.

As well as the flooding maps ready for use in planning documents, the deliverables include the MIKE output files as well as raster files of maximum depth, water level and velocity.

This report is intended to follow DHI's proposal by describing the modelling steps that have been taken and any strengths and limitations of model output.

2 The updated MIKE FLOOD model

2.1 Software

The model upgrade has been carried out within the 2014 version of MIKE software (with Service Pack 3), which is the version that NRC now holds.

The MIKE 21 overland flow part of the model has been converted to FM, but (for most of the domain) retaining the square cells of the former mesh.

Post-processing to produce refined maps of the flooding extent is being carried out using WaterRide.

2.2 Model Upgrade

2.2.1 Changes to the MIKE 21 overland flow model, including conversion to Flexible Mesh

The Flexible Mesh version of MIKE 21 was developed more recently than the classic rectangular-grid version, and generally runs more efficiently. It therefore seemed wise to convert the Kerikeri MIKE 21 model to flexible mesh. As noted above, the square cells were retained over most of the model, in order to minimise the changes from the previous model. The change to flexible mesh has thus been made largely to take advantage of newer and more efficient code and simulation times rather than a more efficient grid.

Three areas have been represented by triangular mesh elements of varying size. This is the more conventional form of flexible meshes, and provides more detail in critical areas with larger elements used in non-critical areas of reasonable even bathymetry. The three areas are:

- Floodplain areas at Kerikeri Basin which were part of the MIKE 11 component of previous model versions;
- The recently constructed Cobham spillway; and
- The area designated for the proposed Kerikeri Spillway, along with related excavation areas. The Spillway itself was modelled as part of the MIKE 11 network in earlier model versions, and is thus an addition to the MIKE 21 domain.

The hydraulic resistance of the Kerikeri Spillway area was revised, to provide an accurate point of comparison when the spillway is modelled. Manning's n values of 0.03 (pasture) and 0.1 (scrub and trees) were adopted following our site inspection, and the overall effect will have been a reduction in flow resistance.

2.2.2 Removal of MIKE URBAN component

The MIKE URBAN part of the previous model was removed. This comprised a small number of drains, considered unnecessary for the model's present purpose, and runoff from the sub-catchments contributing to those drains had to be re-directed.

In the previous model, hydrological calculations of runoff were carried out within MIKE URBAN. The sub-catchments were transferred to the MIKE 11 component of the model. This required re-specification of those sub-catchments discharging to the MIKE URBAN components, including amalgamation of some sub-catchments. All modelled sub-catchments now discharge to the MIKE 11 network. The new set of sub-catchments are shown in Figure 1.

2.2.3 Changes to MIKE 11 components

There were some changes made to the MIKE 11 network, most of which were specified in NRC's scope:

- The addition of newly surveyed channel sections in the Kerikeri River channel;
- A new branch representing the drain at Waitotara Drive, from polyline shapefile and 8 surveyed cross sections and 1 culvert survey for this network, with consequent re-assignment of a runoff sub-catchment;
- Removal of PUNGAERESTREAM_BRANCH2, which represented a particularly minor drain, and re-assignment of runoff routed to this branch;
- Insertion of a weir at Puketotara gauging site (near the Kerikeri River confluence);
- Insertion of cross-sections derived from the LiDAR data at a number of locations where waterfalls or rapids were identified, with the upstream cross-sections defined as weirs;
- Adjustment of cross-sections at Kerikeri Basin to accommodate inclusion of the floodplain there in the MIKE 21 model; and
- A culvert on State Highway 10 was corrected to include weir flow over the deck, which had been omitted in error from previous model versions.

2.2.4 Revision of linking between MIKE 11 and MIKE 21 components

The linking between the updated MIKE 11 model and the new MIKE 21 FM model was revised to address model stability and accuracy problems that resulted from irregularities in the original linking. Without this revision, the increased modelling speed provided by the flexible mesh would have been compromised.

3 Model Calibration

The model has been calibrated afresh, by modifying parameters to match observations from four flood events specified by NRC as suitable for the calibration, from 2007, 2011, 2014 and 2016.

There are now five water level recorders in all, with rated flow available from four of these sites. However, all but the Tyrees Ford site were established at various times after the 2007 event. Calibration therefore relied more on peak flood levels (from the first three events) as determined at the time by surveying debris lines.

3.1 Hydrological calibration

At NRC's suggestion, the 2014 and 2016 events were used to calibrate the existing runoff models and the resulting flow hydrographs. This hydrological calibration aimed for reasonable agreement between modelled and gauged flood volumes and between modelled and gauged peak flows.

Thiessen polygons (Figure 1) were used to assign areas to the recording rain gauges available for each event.

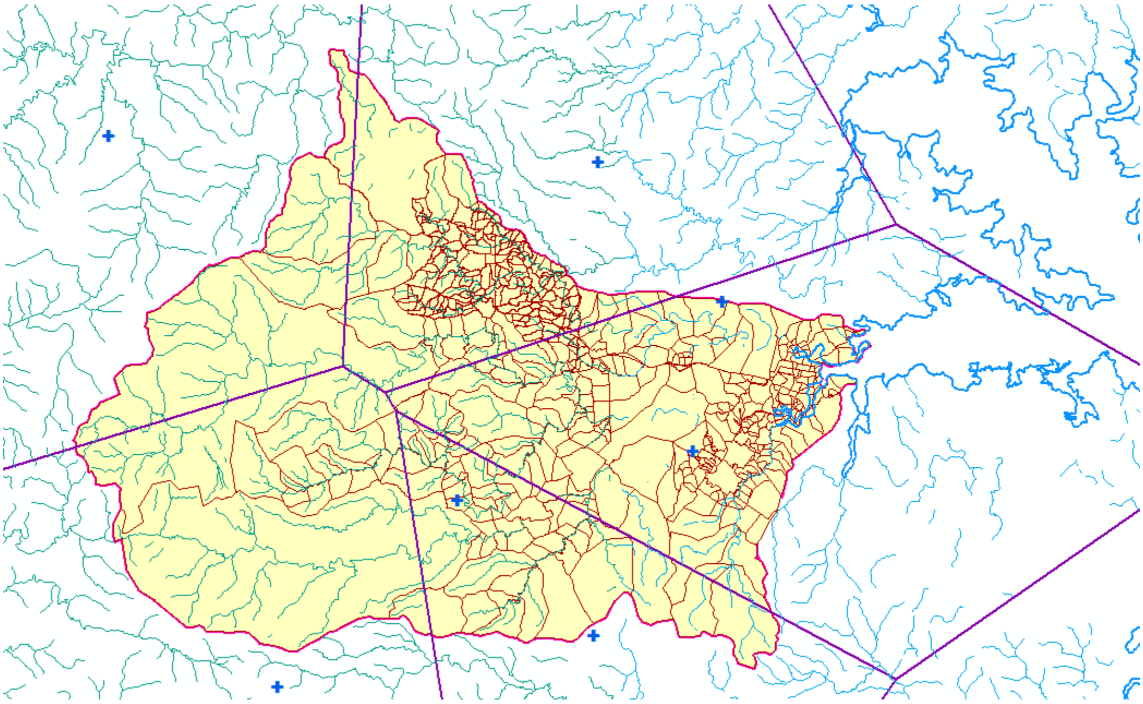

Figure 1 Sub-catchments of the Kerikeri model, showing Thiessen polygons for 2014 event. Raingauges (including two storage gauges) are marked by blue crosses.

In practice, the 2016 event was of limited use in this calibration, as it improved impossible to replicate the timing of runoff peaks. However, reasonable agreement between modelled and measured runoff volumes for this event was obtained.

Reasonable agreement of flow volume, flow peak and the timing of the peak was obtained for the 2014 event (e.g. Figure 2). To obtain this agreement required infiltration to be reduced to very small rates: some typical catchments were assigned an initial infiltration rate of 11.5 mm/hour, reducing over time to 0.5mm/hour.

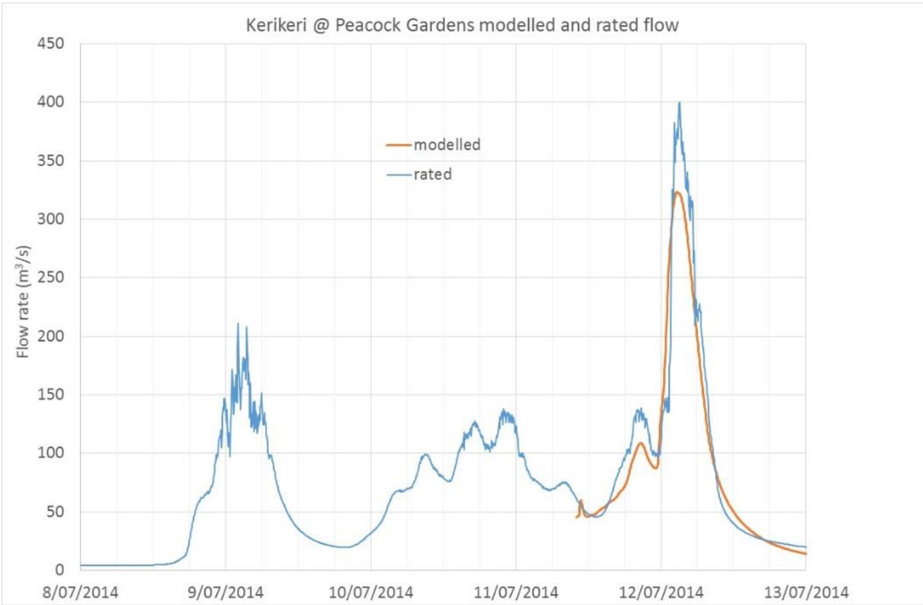

Figure 2 Rated and modelled flow rates, 2014 event, at Peacock Gardens (lower Kerikeri River)

3.1.1 Remarks on the calibrated hydrological model

Calibration against measured runoff for the 2014 and 2016 events has resulted in a hydrological model that allows most rainfall to go to runoff as quick-flow, i.e. losses are low.

Without a considerable amount of field data, aimed at determining the fate of rainfall, it is not possible to say whether this representation is accurate. The catchment's particular geology might allow some infiltrating runoff to reappear quickly as stream flow. However, the calculated runoff does match the available rainfall and stream flow measurements, and peak flows and their timing are also reasonably well-modelled.

There is always some uncertainty about the true rainfall distribution during a calibration effect. The Kerikeri area has a good density of recording rain gauges. However, the nature of the major rainfall events, and the approximation inherent in adopting Thiessen polygons, make it impossible to be sure that the true rainfall volume has been measured.

The hydrological model is therefore likely to be as accurate as is practicable with present data. However, improvements should be possible if catchment hydrology is reviewed as further data become available.

3.2 Hydraulic calibration

The earlier and larger 2011 and 2007 events were then used for calibrating flow resistance, with the 2014 event also included in the last iteration of the calibration process.

Surveyed debris lines and measured water levels at the gauging stations, were compared with modelled peak water levels. Flow resistance was then adjusted iteratively to obtain reasonable agreement.

This required some compromise between model results for the different events, indicating some uncertainty in the data and hence in the calibrated model. However, we believe that the calibrated model provides a robust representation of the hydraulic processes, quite accurate enough for the purposes of the model.

Output from calibration model runs is shown in Figure 3 and Figure 4. The computed 2007 peak water levels are a little below the debris line, but those in 20011 are a little above the debris line.

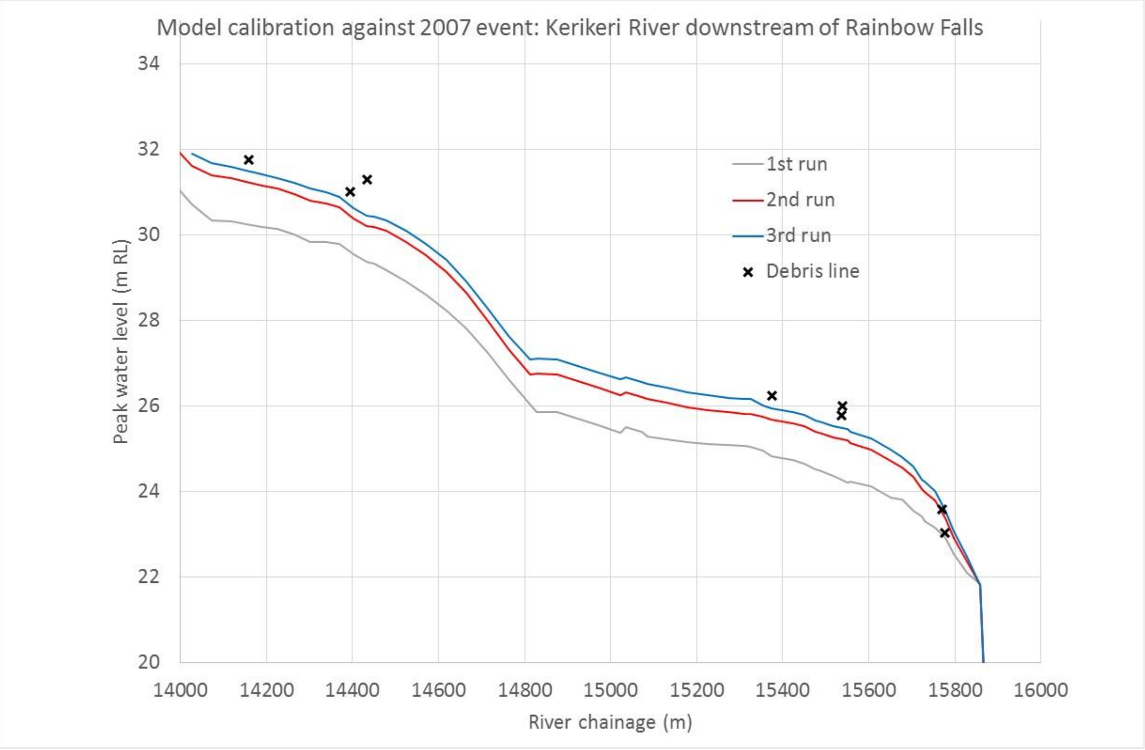

Figure 3 Peak water levels, 2007 event, calibration runs compared with debris levels

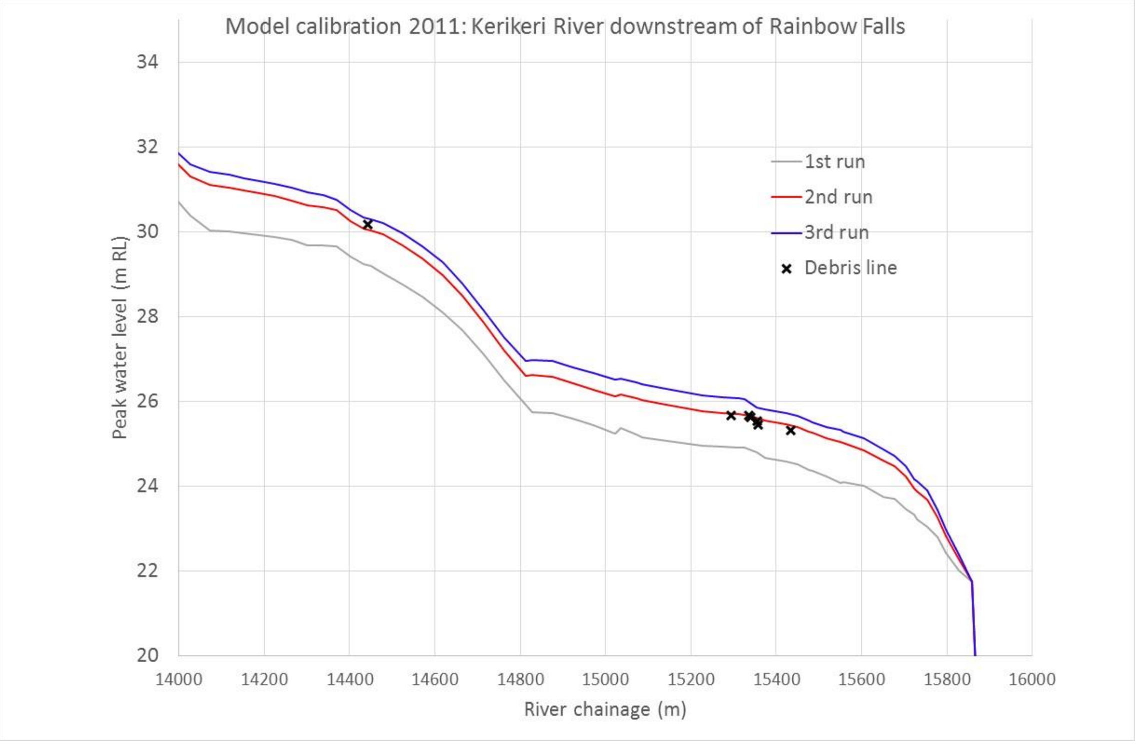

Figure 4 Peak water levels, 2011 event, calibration runs compared with debris levels

3.2.1 Remarks on the calibrated flow resistance

Earlier versions of the model used flow resistance values as calibrated for version 1. These values included some Manning's n values approaching 0.1 in the Kerikeri River upstream of Rainbow Falls; these values are particularly high, higher than might be expected from the appearance of the channel.

The revised hydrological calibration has resulted in higher computed flow rates, so that calibration to the same water level data results in lower flow resistance values being adopted. Nevertheless, the highest Manning's n values, of about 0.07, might be regarded as at the high end of values compatible with the appearance of the channel.

In practice, the hydraulic calibration process accommodates other factors besides the "skin friction" that Manning's n is intended to represent. These include: uncertainties in cross-section area, head losses at flow between floodplain and channel, and various at-a-point head losses. A pragmatic approach is therefore needed, at we consider that the new calibration has provided a workable numerical model that represents the channel hydraulic processes well overall.

One possible source of significant head loss is natural weirs within the stream channel. The significant falls were modelled in version 1, and the present model (version 5) includes a number of other weirs identified primarily from the LiDAR data. It is possible that further natural weirs have still gone unnoticed. Were any of these to be included later, recalibration would lower Manning's n values further.

4 Simulation of design events

4.1.1 Baseline Simulations of design events

The same design storms have been simulated as in previous modelling: the 10yr ARI, 50yr ARI and 100yr ARI events, and applying the same rainfall and the same sea level boundary condition.

4.1.2 Scheme Simulations of design events

The same three design storms were simulated in a version of the model incorporating the proposed Kerikeri Spillway and other proposed works:

- Lengths of proposed stopbank at and near Waitotara Drive;
- The proposed topography of the Spillway and spillway excavation areas, provided by NRC; and
- A revised floodplain roughness map within the spillway area, to reflect removal of several wind breaks as part of the scheme implementation.

As for the baseline case, the simulations included the 10-year, 50-year and 100-year ARI event with allowance for climate change.

4.1.3 Results

Model output files have been collated for NRC, to accompany this report. These include the MIKE 11 files containing flows and water levels within the river channel system, and MIKE 21 files containing output data for overland flow: water levels, depths and velocities.

Files of peak values have been calculated from the MIKE 21 files, and have been converted into rasters for NRC. These include rasters of the difference between output from baseline and spillway simulations.

4.1.4 Mapping refined flood extents

Further processing of peak water level data is in progress, both for baseline and scheme scenarios, to obtain refined flood extents married with a 1m DEM and suitable for planning maps. This work is being carried out using WaterRide.

5 Conclusions

The Kerikeri catchment model has been updated to incorporate new field data and changes to its drainage system. Recalibration has resulted in a more realistic representation of flow resistance in the river channels.

In addition, the model has been transferred to the newer flexible mesh version of MIKE FLOOD, to take advantage of faster running speed and various software enhancements, and despite leaving the square computational cells largely intact.

The three design events previously modelled, of ARIs 10 years, 50 years and 100 years (with climate change) have again been applied to the model.

There remain approximations and uncertainties in modelling Kerikeri floods. In particular, the true hydrological response of the catchment has not been measured in detail, and its representation in the model must therefore be a little uncertain.

Nevertheless, we consider that the present model is robust and fit for its principal purpose of defining flood levels for the purposes of resource management and civil defence. In particular, flooding maps produced from the calculated peak water levels for design events will be suitable for defining their flood hazard zone. We consider that the new calibration, made possible by further field data from additional flood events and additional flow gauging sites, has provided a considerable improvement on previous versions of the model.

The proposed Kerikeri spillway has again been incorporated in a version of the present model. We are confident that the model has provided the data for a good comparison of baseline flood levels with those that would occur with the spillway. Nevertheless, given the inherent inaccuracies in the modelling process, some care needs to be taken when interpreting the effects further downstream.