Tonkin+Taylor

Job No: 1005528
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Waikato Regional Council
Regional Hazards and Environmental Compliance
Private Bag 3038
Hamilton 3240

Attention: Rick Liefting

Dear Rick

Lower Waikato River Model Review

On 20 April 2018, Waikato Regional Council ("WRC") and Tonkin & Taylor Ltd ("T+T") entered into a Contract for Service, WRC2014-2017-447.61, Council document number #12378033. On 28 June 2018 and 30 June 2019, the Contract was varied by way of a Contract Addendum(s) WRC2014-2017-447.61.01 and WRC2014-2017-447.61.02 with Council document numbers #12703517 and #15003033. Purchase order number 119868 was provided for the current phase reported on in this document.

While T+T has been involved since 2018 in the review of and discussion on elements of the modelling process, the final review reported on in this document is focussed on the end product as described in the report by DHI (2019).

1 Project outcomes

T+T was engaged to undertake independent review of and technical comment on the modelling process that was being done, covering the lower Waikato River (from the downstream side of Karapiro Dam to the open coast at Port Waikato). T+T was not engaged to undertake a review of the actual model, with the review being focussed at a higher level and on principles and approaches applied.

The key outcome from this process was delivery of a model that was capable of results of a suitable degree of confidence for the purposes intended.

2 Services provided

The agreed review process encompassed the following elements:

1. Develop an understanding of model purpose and intended uses and outcomes.
2. Review model architecture in context of item 1 above. Will the proposed model structure be able to meet the requirements/intended purposes?
3. Modelling philosophy review. Review what is proposed in terms of calibration, validation and design event simulation.
4. Reporting, by email, telephone in person and by written document(s).

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3 Model purpose

In 2017 WRC had a suitably calibrated 1D hydrodynamic model of the lower Waikato River that had been used for a range of purposes, including flood forecasting, prediction of extreme levels and assessments of flood scheme performance. An update to this model was seen to be required, largely to build in 2D representation of the river floodplain and adjacent areas in and around Huntly. This was largely driven by the need, from Waikato District Council, for this information to meet the requirements of the Regional Policy Statement.

The 2D parts of the model were expanded to include areas around Ohinewai and Horotiu.

The stated purpose of the model development was to enable suitably accurate estimation of peak flood levels in these 2D areas, to enable flood mapping (showing depths, extents and levels) for a range of different flood event scenarios. These scenarios include events of different likelihood and also different future climate horizon.

4 Modelling philosophy

The overall philosophy applied covers a standard approach consisting of model development, model testing and confirmation of accuracy and then model simulations for design event conditions. Specific comment on these stages is provided in the following sections of this report.

The development of the model has been done on the basis that it is an extension to an existing model. The existing model has previously been considered to have been adequately calibrated. The proposed extension was to include a 2D domain in certain specific areas of interest. In addition, the report (DHI, 2019) provides reference to several other improvements to the existing model, as well as updates to input parameters where current recommendations differ from previous (such as rainfall and the effects of climate change on rainfall).

5 Model architecture

We understand that the model is comprised of a hydrological model (rainfall-runoff) and a hydraulic model (1D and 2D elements). In simple terms, the following are key elements applied:

- Main river channel, represented by cross sections. This extends from the Karapiro spillway to the coast at Port Waikato, and includes tributaries. Also included are certain structures (bridges).
- Floodplain area adjacent to the main channel, extending from the Hamilton City boundary in the south (upstream end) to a location adjacent to Lake Waikare in the north (downstream end). This area has been included in the model as a digital elevation model ("DEM"), with elevations based on those obtained via two separate LiDAR surveys. The DEM is contained within the bounds shown in Figure 5.1.
- Boundaries, which include discharge at the Karapiro spillway, rainfall-runoff boundaries applied as inflows to the model, plus sea level boundary applied at the open coast.
- Hydrodynamic model parameters, which are used in the numeric solution scheme in the model computation engines.

We note that the model contains no piped stormwater network, with the following statement being made in the report (DHI, 2019):

"As agreed with WRC, based on the time-constraints and quality of the GIS drainage information, it was decided to exclude the pipe networks, open channels and pumps from the model and simply simulate flooding from the river over the design-level stopbanks, as the number of questions it would raise will outweigh any benefit of high-resolution flood mapping."

This statement represents a change from the initially stated model purpose, as no floodplain mapping will be available within the Huntly area where flooding is caused by a mechanism other than stopbank overtopping. It is often the case that flooding in urban areas adjacent to stopbanks is caused by impedance of flows against high river levels, and not by river flooding itself. If such flood mechanisms exist at Huntly, these have not been captured in the floodplain mapping undertaken to date. It is understood that this approach was established by agreement between WRC and DHI.

Further comment on the hydrological and hydraulic model components is provided in Sections 5.1 and 5.2 of this report respectively.

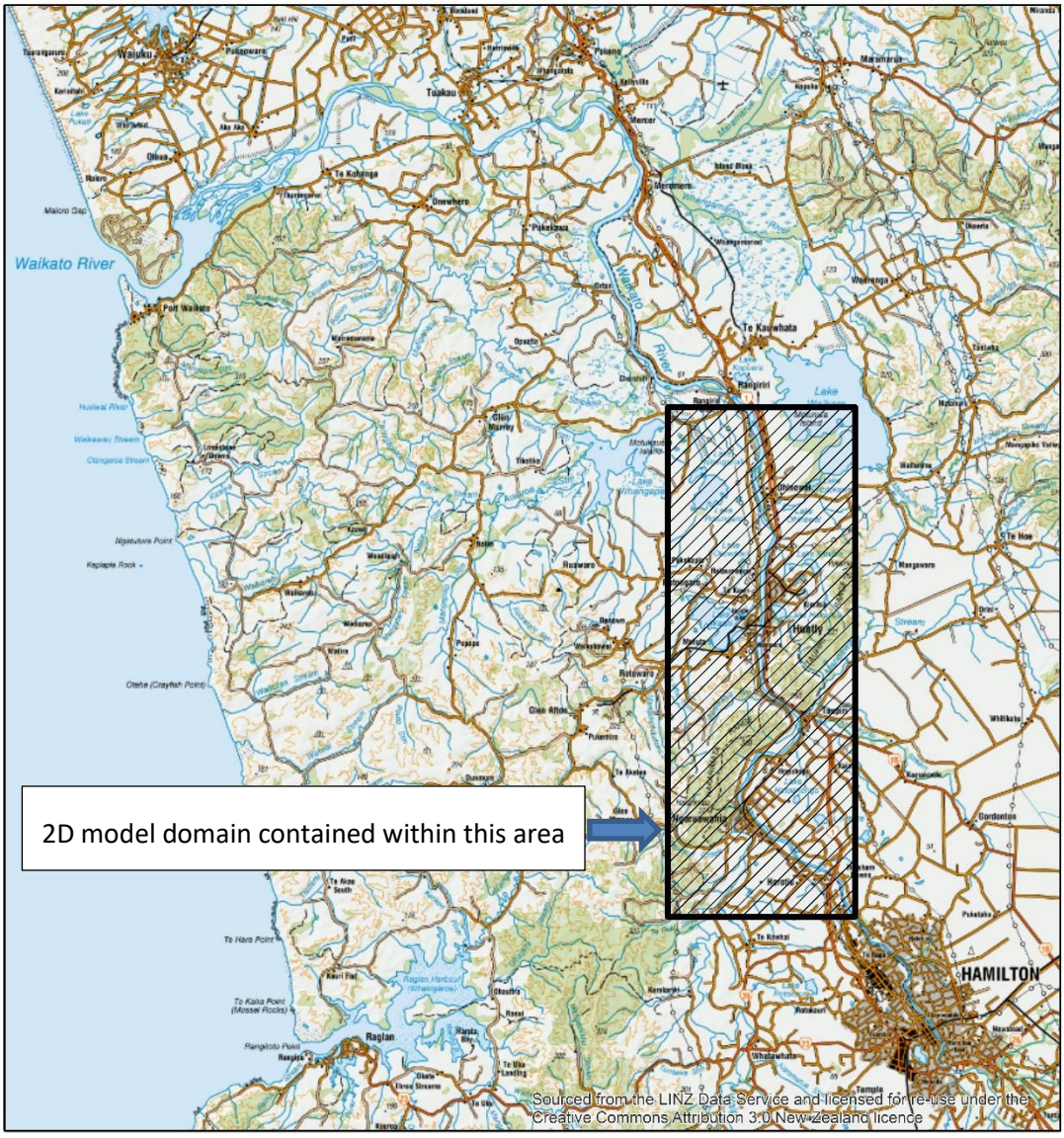

Figure 5.1: Bounds within which 2D model domain is located

5.1 Hydrological model

The hydrological model comprises a series of sub-catchments, with responses to rainfall simulated using Mike NAM software. The NAM model has been calibrated using long term time series (rainfall and resulting discharge) from a number of gauging locations. Calibrated parameters were then applied to the design rainfall event simulations. Model validation was also undertaken.

For design event simulation, the NAM models were pre-run to establish sensible start conditions – a standard and recognised approach.

Rainfall depths, temporal pattern and areal reduction applied to the model were taken from applicable sources.

The sub-catchment split applied to the model is reasonably coarse but is in proportion to the overall model coverage. If more detailed assessment is required at a localised scale, then the sub-catchment domain could be refined.

We note the comment in the report that *"The choice of hyetograph shape and timing of the peak has a significant influence on the results."* (DHI, 2019). No sensitivity assessment was reported on for this, in spite of this being a potential source of uncertainty. This applies only to design event simulation, as for simulation of calibration events the applied rainfall is as recorded.

5.2 Hydraulic model

The hydraulic model, comprised of both 1D and 2D computational elements, was built using data from several different sources. As land use change and catchment works occur, ground elevations do change with time. From examination of the ground elevation data used for the model build, it is clear that the sources relate to capture that occurred at different points in time. Below are quotes from the report (DHI, 2019) that demonstrate this:

"It was agreed with WRC to use existing Flood Forecast model cross-section data and re-assess with the expansion of the model beyond the Huntly area. The cross-section data for the Waikato upstream of Ngaruawahia is from 1987-1994 survey and downstream of Ngaruawahia and at the Waipa River is from 1998. The processed data levels and position of markers were adjusted where the channel conveyance was incorrectly calculated. The cross-section radius type was also adjusted to ensure consistency across the river reach."

"The MIKE 21 topography was derived from the 2010/2011 LiDAR survey for the Ohinewai area and the 2007/2008 LiDAR survey for the rest of the model."

The different capture dates of the various components opens up the possibility of incompatibilities at the interface between different sources. In spite of this, the model has been shown to be able to run and produce results without obvious error.

Hydraulic parameters used in the model are provided in the report (DHI, 2019), but no justification for the selection of values was given. While standard values appear to have been applied, it would be useful to understand the appropriateness in this specific context.

5.3 Model boundaries

The downstream boundary condition applied at Port Waikato was stated to be "a fixed tidal level of 1.69 m…". While hydrodynamic simulations lend themselves to dynamic tidal boundaries being applied, care needs to be exercised in the timing of high/low tides relative to flood peaks. Given that the points of interest (Huntly, Ohinewai, Horotiu) are located at least 70 km upstream of the open coast, application of a time-varying tidal boundary is unlikely to significantly affect model results, especially as the modelling has been focussed around the peaks of flood events. Should there be a focus on low flow conditions and levels, then tidal fluctuation may become more significant in terms of peak levels attained and general hydraulic performance in the areas of interest.

The boundary inflow time series applied at Lake Karapiro was developed (and approved) separately, and has not been reviewed.

Other inflow boundaries to the model were developed via rainfall-runoff simulation in the NAM model. These have been based on rainfall and on hydrological parameters obtained through calibration.

6 Flood event simulation

The report (DHI, 2019) states that a calibration and sensitivity analysis for the 1998 flood event should have been carried out but was not, with the reason given being that aerial photography was provided only "*after the modelling exercise was complete*". The report goes on to state that such calibration was "*particularly important*" at the Waipa River. This represents a weakness in the modelling undertaken.

Flood event simulation was undertaken by application of design rainfall and inflow to the model against a sea level at the coast. Given that the catchment area of the lower Waikato River is large, areal reduction was applied to point rainfall estimates. However, the timing of rainfall applied was uniform across the entire catchment. This is a common approach to design event simulation in smaller catchments, where the size of the weather system causing the event is large compared with the catchment area. In a catchment as large as that of the lower Waikato River, weather systems that show rainfall differential across the area the size of this catchment are difficult to adequately represent. Without a comprehensive and detailed investigation into this potential effect, and in recognition of the intended purpose of the model, the approach adopted is reasonable.

7 Discussion

As described in Section 5 above, the model does not include any of the stormwater and local drainage network in and adjacent to the Huntly township. The report (DHI, 2019) states that this was agreed with WRC. In so doing, the results from the modelling undertaken are applicable only to estimation of flooding when derived by stopbank overtopping. However, the model results will be able to be used in any subsequent drainage analysis of localised areas in that these results provide for tailwater levels. Should further flood mapping be undertaken at a localised scale, then there should be no need to include the lower Waikato River in any modelling, as boundary tailwater level time series can be extracted from the work reported on in this document.

8 Suitability of the model for the intended purpose

It appears that the original purpose of the model has evolved during the modelling process, to the point that there is reported acceptance (DHI, 2019) 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.

9 References

DHI (2019), *WRC Lower Waikato 2D Modelling*, report prepared for WRC under project number 44801126, final draft 3 October 2019. An updated version was subsequently provided that was dated February 2020.

10 Applicability

This report has been prepared for the exclusive use of our client Waikato Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

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