DEFINING THE FLOOD HAZARD IN TAKAKA: A TOWN AT RISK

Nick Simpson (Aurecon)

ABSTRACT

The township of Takaka has an extensive history of flooding. Located adjacent to the confluence of the Takaka and Anatoki Rivers, previous events inundated large sections of the lower catchment and have raised issues for both Council and the community to work through relating to emergency management, planning controls, infrastructure and the influence of potential protection works.

A comprehensive 2-dimensional model has been established defining the flood hazard both for the township and the surrounding catchment. Outputs from this modelling process have been linked with the real-time flood forecasting product FLOOD Watch and the presentation and interrogation tool Water RIDE, to establish a cost effective real-time hazard prediction tool for the use of Council.

This paper looks to outline some of the unique features and issues encountered in the development of this project including: An overview on key aspects of the modelling process (including particular comment on the advantages and limitations on some of the tools used), a review on the effectiveness of some historical informal structures used to “contain” the river, a summary of implications and associated decisions for the community, and comment on potential development of real-time and predictive tools into the future.

KEYWORDS

Takaka, Flood Hazard Mapping, Flood Damage Analysis, Hydraulic Modelling, Real-Time Flood Forecasting

PRESENTER PROFILE

Nick Simpson has over 15 years experience in Civil Engineering with a strong focus on flood modelling and stormwater management. He has led numerous large scale modeling projects nationally, including a stormwater team lead on the ICS and the project lead on the QLDC Stormwater Catchment Management Plans. Nick is a water executive with Aurecon and currently manages the Wellington team.

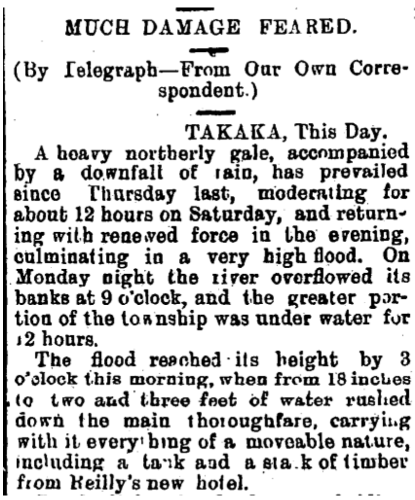
1 INTRODUCTION

The township of Takaka has an extensive history of flooding. Within the past 30 years there have been two significant return period events where the Takaka River has breached its banks and inundated the town centre (Figure 1). The existing flooding risk has posed significant issues relating to: future planning within the township; the protection of existing assets; and establishment of appropriate strategies for emergency response.

Throughout the years there have been numerous formal and informal attempts to train the river in the vicinity of the township. Debate on the relative effectiveness of various options has been a source of contention within the community.

Figure 1: Scenes of recent Flooding in Takaka

(Top Left and Middle) December 2008 event, breached the existing informal stopbank and inundated the town centre and adjacent roads; (Bottom Left) December 2010 floodplain adjacent to the township in the vicinity of the existing Wastewater treatment plant; (Bottom Right) Reports on flooding incidents are numerous - 24 June 1902: Nelson Evening Mail.



MUCH DAMAGE FEARED.

(By Telegraph—From Our Own Correspondent.)

TAKAKA, This Day.

A heavy northerly gale, accompanied by a downfall of rain, has prevailed since Thursday last, moderating for about 12 hours on Saturday, and returning with renewed force in the evening, culminating in a very high flood. On Monday night the river overflowed its banks at 9 o'clock, and the greater portion of the township was under water for 12 hours.

The flood reached its height by 3 o'clock this morning, when from 18 inches to two and three feet of water rushed down the main thoroughfare, carrying with it everything of a moveable nature, including a tank and a stack of timber from Reilly's new hotel.

This paper summarizes works completed to date, looking in detail at the modelling tools and processes utilised, outputs and how outputs both define risk and can be used as a real–time hazard prediction tool.

This paper does not attempt to comment on the appropriate level of service, zoning implications, or best long term solution for the township. These issues are for the community to resolve in consultation with Council.

2 HYDROLOGY

The main flooding risk to the township is from the Takaka River. Situated adjacent to the confluence of the Takaka and Anatoki Rivers the total catchment of approximately 844 km^2 extends from the Cobb Valley, deep within Kahurangi National Park to the South, Aorere Peak in the West, and Takaka Hill to the East (Figure 2).

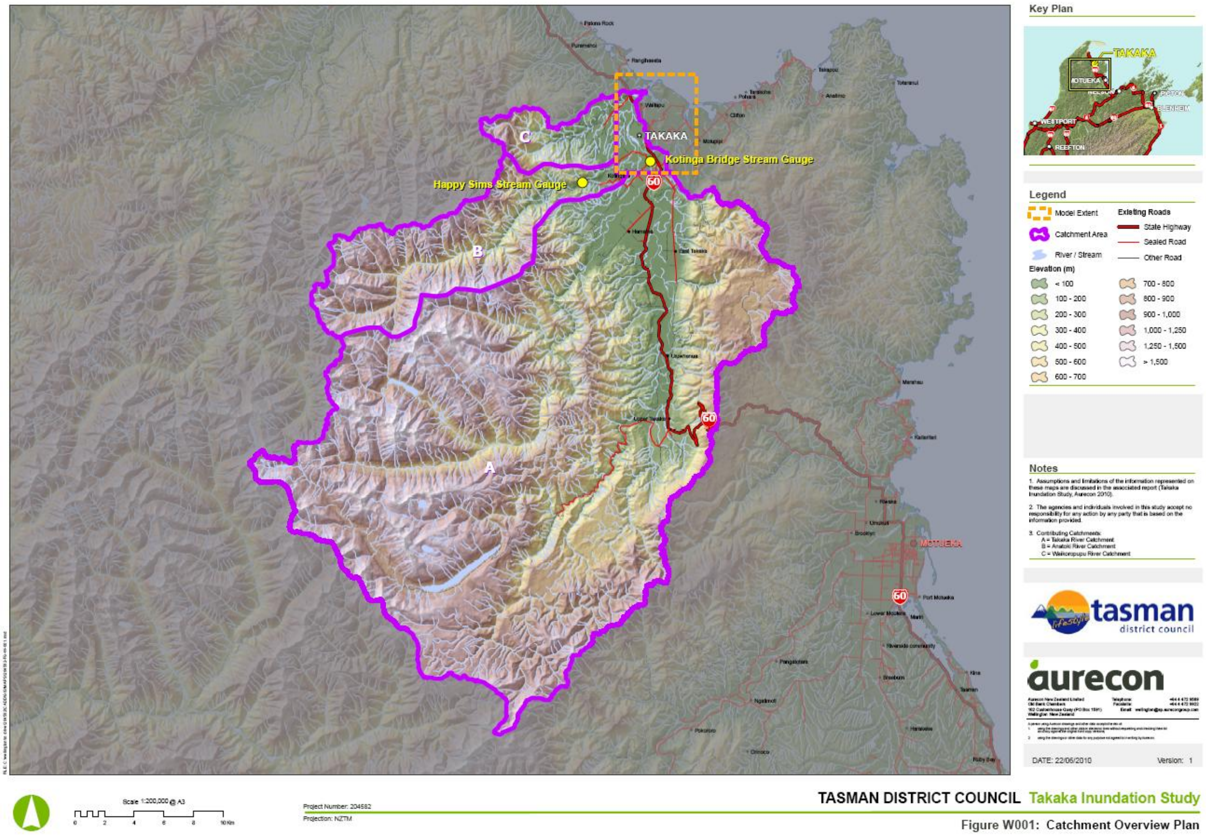


Figure 2: Takaka River Catchment and Modelled Area

Large floods in the Takaka Valley have typically been a product of northerly storms, often trending to the North East. Rainfall characteristics for larger events have been defined by Tasman District Council as follows:

"The rainfall is mainly orographic, resulting from a windflow stretching back up into the tropics bringing warm air laden with moisture. Rain from these events drops over the full catchment for an extended period, albeit at moderate rainfall rates, and this allows all sub catchments to contribute to the flow at Kotinga. When a cold front or some convective activity occurs within the more generalised rainfall system, heavier rain can

result for a period, and often this is at the tail end of the storm when the catchment is saturated."

Hydrological inputs for the modelling have been established by in-house Tasman District Council staff, in consultation with Aurecon New Zealand Ltd.

There are gauging sites at Happy Sams on the Anatoki River and on the Kotinga Bridge, just upstream of the existing confluence on the Takaka River (ref Table 1). These existing flow gauges have been used to establish typical hydrograph shapes, timings and peak inflows relationships. Flood Frequency Analysis (Gumbel distribution) was applied to determine the associated peak flow values for various return period events.

The peak flow rates calculated at Kotinga are as follow:

Table 1: Takaka River Peak ARI Flows (Kotinga Gauge)

Return period	Mean Annual Flood	10 year	20 year	50 year	100 year	200 year
Peak Flow (m^3/s)	1050	1510	1710	1960	2150	2340

3 MODEL STRUCTURE

Detail of the flooding hazard is required in the vicinity of the township. A preferred modelling methodology was established so as to best align with the catchment characteristics:

- Flows in the area are dominated by flows from the two main contributing catchments (Takaka and Anatoki).
- There is gauging on both of these rivers relatively close to the boundary of the unconfined floodplain (refer Figure 2).
- Flows on the main Takaka river are effectively confined until just upstream of the Takaka township.
- The unconfined floodplain area is relatively small in comparison with the main contributing cathments.
- Flowpaths through portions of the township are not clearly defined.
- The hydraulic grade through the area is relatively steep.
- Storage has minimal influence within the floodplain.

Information provided by Tasman District Council for the purposes of modelling included:

- Flow records from the following sites:
    - Takaka at Kotinga
    - Anatoki at Happy Sams
- Design flows/ inflow hydrographs to be modelled (the input)
- LIDAR survey data (+/- 0.14 m)
- Digital aerial photography (0.5m resolution)
- Maps of flooding extent drawn after previous floods (notably the large 1983 event)
- Previously established Rainfall/Runoff model for Takaka ("FLOOD Watch")

Modelling outputs are to assess the inundation extent, flood depth, timing, velocities and duration of inundation for a range of design flood events. Sensitivities were established looking at the impact of possible modifications to an existing informal stopbank, changes to the riverbed over time (believed to have lowered approximately 1m since the early 1980's), raised building platforms and proposed new dwelling footprints to be utilised for the future planning of the Takaka township.

The assessment looks to define the hazard and associated timings so as to enable structuring of an appropriate response by Council and the wider community. Several modelling tools have been used to achieve the objectives outlined above and enable a real time assessment of risk.

Response from the upper catchments utilised existing rain gauge data and a model using DHIs "FLOOD Watch" software (works undertaken by DHI in 2009). Flood extents in the main floodplain have been established using DHI's 2D floodplain model MIKE21 for a range of events and associated outputs are represented and interrogated using Worley Parsons "Water RIDE".

Greater detail on the selected software and associated model is provided below:

- **FLOOD Watch (DHI)** – Rainfall Runoff Model established previously by TDC and DHI Ltd. Includes provision for rain gauges in the upper catchment to be integrated into a real-time forecast of runoff and predicted flows at downstream gauging points.

  The model incorporates a hydrological runoff tool with the routing of resulting flow hydrographs via a simplified MIKE 11 model of the upper catchment, data management and forecast modelling.

  The system is used by council engineers to provide real-time forecasts and to issue early warnings to flood response managers and the public. The system is used to forecast model inflows at gauging locations.

- **MIKE 21 (DHI**) – Modelling of the floodplain in the vicinity of the Takaka township has been established using MIKE 21, a 2-dimensional hydraulic model.

  The selection of this package was considered to be the most suitable given the following:

  - The wide unconfined nature of the existing topography adjacent to the township.
  - A two-dimensional hydraulic model is best suited to calculate the inundation extent, maximum flood depth, flood velocity, duration of inundation and establish animations of flooding behaviour (a specific client request for future community liaison).
  - Potential compatibility with the existing "FLOOD Watch" software and outputs.

  The resulting model is fully compatible with existing models, enabling future coupling as required. Additional runs will be used to assess the input of specific upgrade options.

- **Water RIDE (Worley Parsons)** – Modelled water levels from the various 2-dimensional runs have been used to interpolate flood extents for predicted inflows.

  Water RIDE interpolates water levels and flow conditions for specified boundary conditions (between modelled events). While relatively new to New Zealand this package has been used extensively with success throughout Australia and in this application brings the following aspects to the project:

  - A common graphical interface designed to accept input from various calculation techniques (potential both 1D & 2D simulation results)
  - Enables rapid interpolation of events (removing the need for extended run times)
  - Advanced provision for interrogating data.
  - Assistance in establishment of hazard maps and associated Flood Damage Analysis.

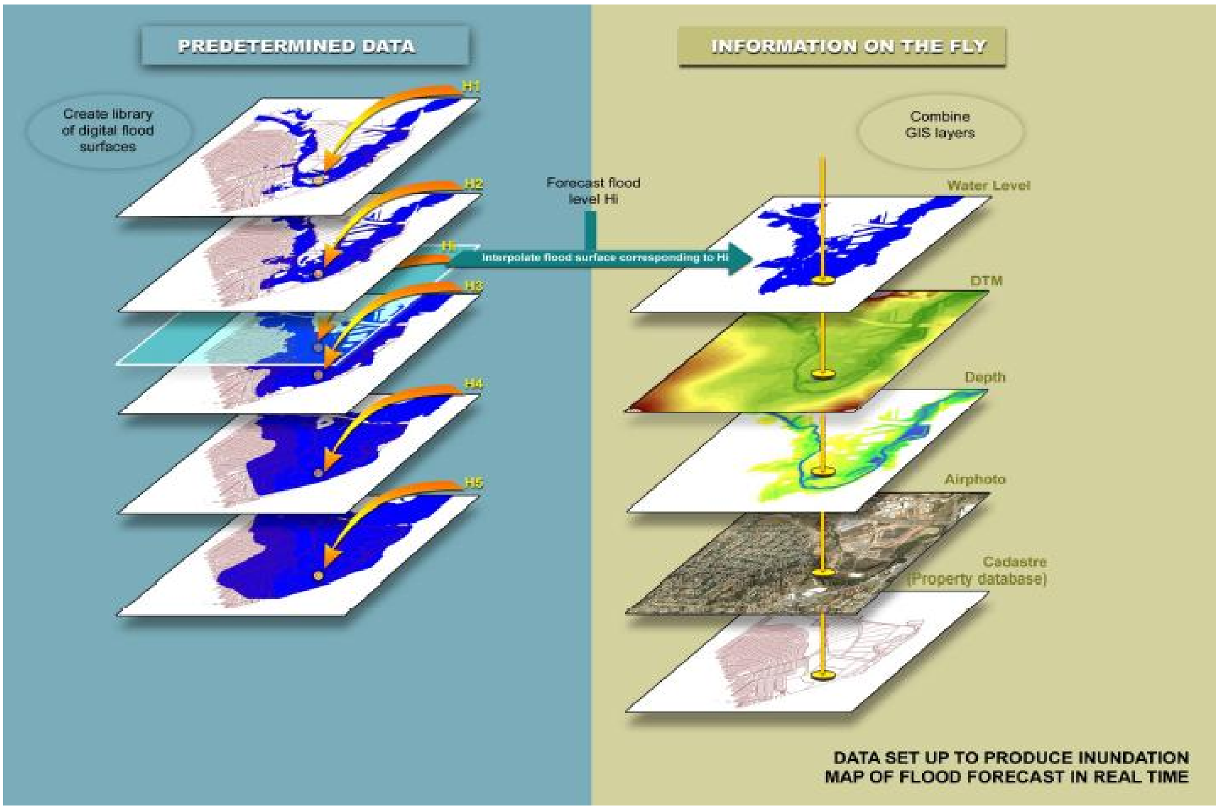


Figure 3: Schematic of how the waterRIDE package predicts flood data from predetermined model output (Worley Parsons)

Schematics detailing the structure of the resulting models and associated WaterRIDE tools are outlined in Figure 3 & 4:

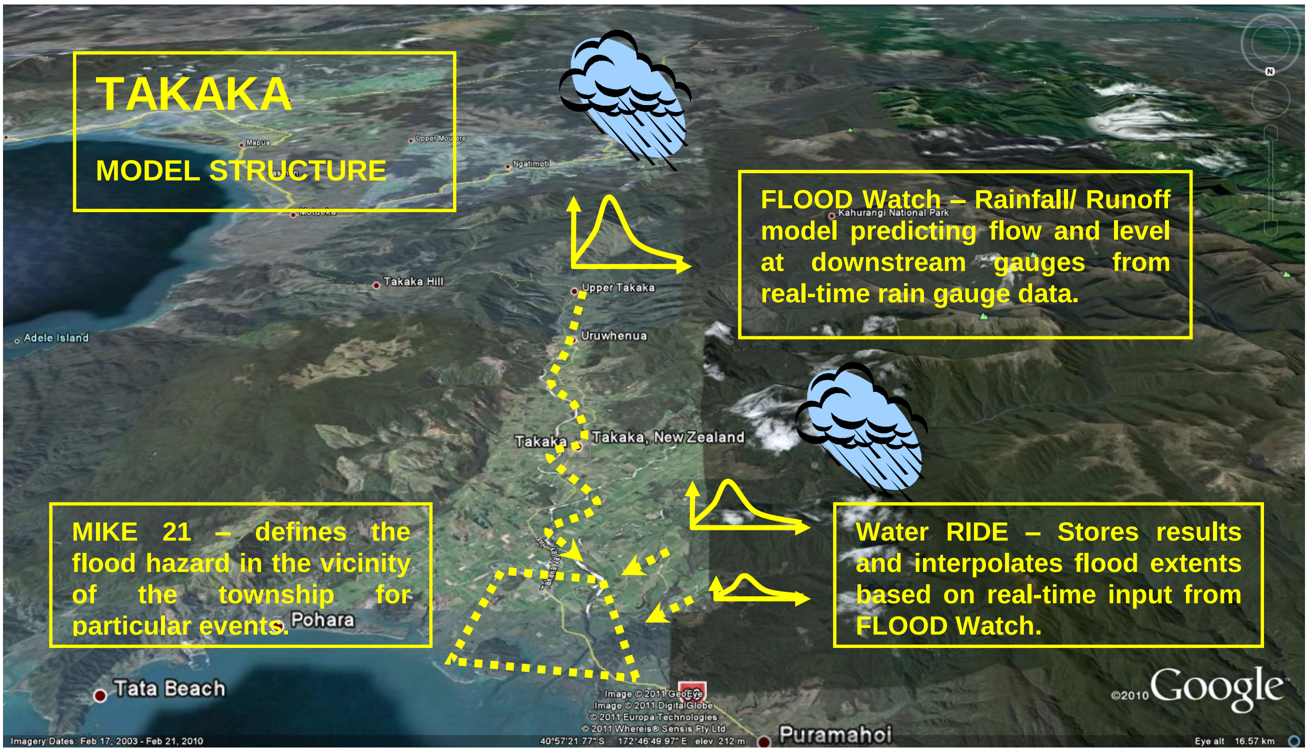


Figure 4: Schematic of existing model components and structure

The modelling process for Takaka included the following steps:

- Preliminary FLOOD Watch Model Build – Incorporates 9 raingauages, NAM hydrological model, and routing via a skeletonised network. Includes 4 component sub-models of associated subcatchments, including Anatoki and Upper Takaka.
- 2-D Model Build - Develop a two-dimensional (2D) hydraulic model of the lower Takaka River floodplain using DHI's MIKE 21 modelling software.
- Validation - Run validation scenarios (July 1983 and November 2008 flood events).
- Flooding Assessment - Run design event scenarios to be used as predetermined input to the WaterRIDE flood forecasting model (10, 20, 50, 100 and 200 year ARI design flood events).
- Sensitivity Runs – Undertake design sensitivity runs developed in consultation with TDC (includes: tidal boundary review, review of modified Takaka River bed levels and associated river geometries, and future urban development scenarios).
- Scenario Runs - Selected additional runs looking at prescribed development and flood protection scenarios.
- Flood Forecast Model - Develop a flood forecast model using the WaterRIDE package. The WaterRIDE model will use predicted flood level at the gauge in Kotinga from the "FLOODWatch" programme for real time floods to predict the maximum flood inundation, depth and velocity that will be reached in the Takaka Township and lower Takaka River floodplain.
- Hazard Maps – Again WaterRIDE was used to represent associated Flood Hazards.
- Flood Damage Assessment – Utilising the various model runs, WaterRIDE was used to establish Annual Average Damage Curves for various scenarios.

4 MODEL DEVELOPMENT

Inflows from the three main contributing catchments were used as boundary conditions to the model. Peak flows of 2150, 677 and 155 m^3/s were established for the 100 year ARI events for the Takaka, Anatoki, and Waikoropupu catchments respectively.

Flood frequency relationships at existing gauges were used to establish design peaks. Inflow hydrograph shapes, timings and relationships were established for the Takaka and Anatoki Rivers based on gauging records. A synthetic hydrograph was established for the smaller Waikoropupu catchment.

Given the hydraulic grade of the catchment, and the relative contributing areas, no inflows were established on the adjacent, relatively small Motupipi catchment at this stage. Similarly, localised runoff contributions and reticulated drainage effects are ignored.

A two dimensional Mike 21 model was established of the wider Takaka floodplain, utilising a 6m grid. Grid size and shape for the model was established to minimise runs times, meet required level of detail, and maintain integrity of calculations. The associated model area was 1155 cells (6.7km) x 910 cells (5.5km). Roughness and associated losses at key hydraulic structures were established in the model.

The selection of the 6m cell grid size is considered the smallest acceptable size providing hydrostatic flow distribution and maintaining manageable simulation times. Key hydraulic structures were incorporated into the model by locally modifying roughness. This justified the use of 2D modelling software without the need for modelling the river in a 1D environment.

Static tidal boundaries were established in the model for design events (with associated sensitivity runs). With a large portion of the upper catchment being either national park (Kahurangi) or rural land, the future development in this area is assumed negligible.

A simplified scaled rainfall and fixed tidal increase has been used to establish the impact of Climate Change in associated scenario runs (in line with current Ministry for the Environment Guidelines guidelines – MfE, 2008).

Depth and velocity surfaces were established for numerous sensitivity and design scenarios. These included a review of tidal influence, modifications to the existing river bed, flood protection options and various future development scenarios. Outcomes from this process are still being worked through with the community.

4.1 MODEL VALIDATION

The MIKE 21 hydraulic model was validated against the historic flooding events (July 1983 and November 2008) through comparison of recorded flood levels and extents with the numeric modelling outputs.

Boundary conditions were established with event gauging data at Kotinga and Happy Sams and tidal information. For the 1983 event the Digital terrain Model (DTM) was modified to account for changes in the Takaka river bed (due to local erosion) and recent informal flood protection measures (base and revised model – Table 2).

Event hydrographs from the Kotinga Bridge, Happy Sams gauges along with recorded tidal levels were established as boundary conditions for the model, similarly topographical features modified to best replicate conditions for the events.

The model results have been validated through comparison with recorded levels during the July 1983 event. There is generally good correspondence between recorded and predicted levels, with the modelled peak flood levels being on average -0.07m below actual, with approximately 86% of the spot heights being within +/-0.3m of the recorded value (reference table 2 below).

Table 2: Summary table observed and modelled levels for July 1983 flood event

Scenario	Average Difference	Root Mean Square	Variance (Number and % of observations within the range)			
			x<-0.3	-0.3<x<0	0<x<0.3	0.3<x
Base Model (Existing topography)	-0.14m	0.28m	14 (27%)	25 (49%)	12 (24%)	0 (0%)
Revised Model (Raised bed level and stopbank removed)	-0.07m	0.23m	5 (10%)	29 (57%)	15 (29%)	2 (4%)

Note: x = Modelled Level – Observed Level

Predicted flood extents, associated debris lines and recorded level locations are outlined in Figure 5 below.

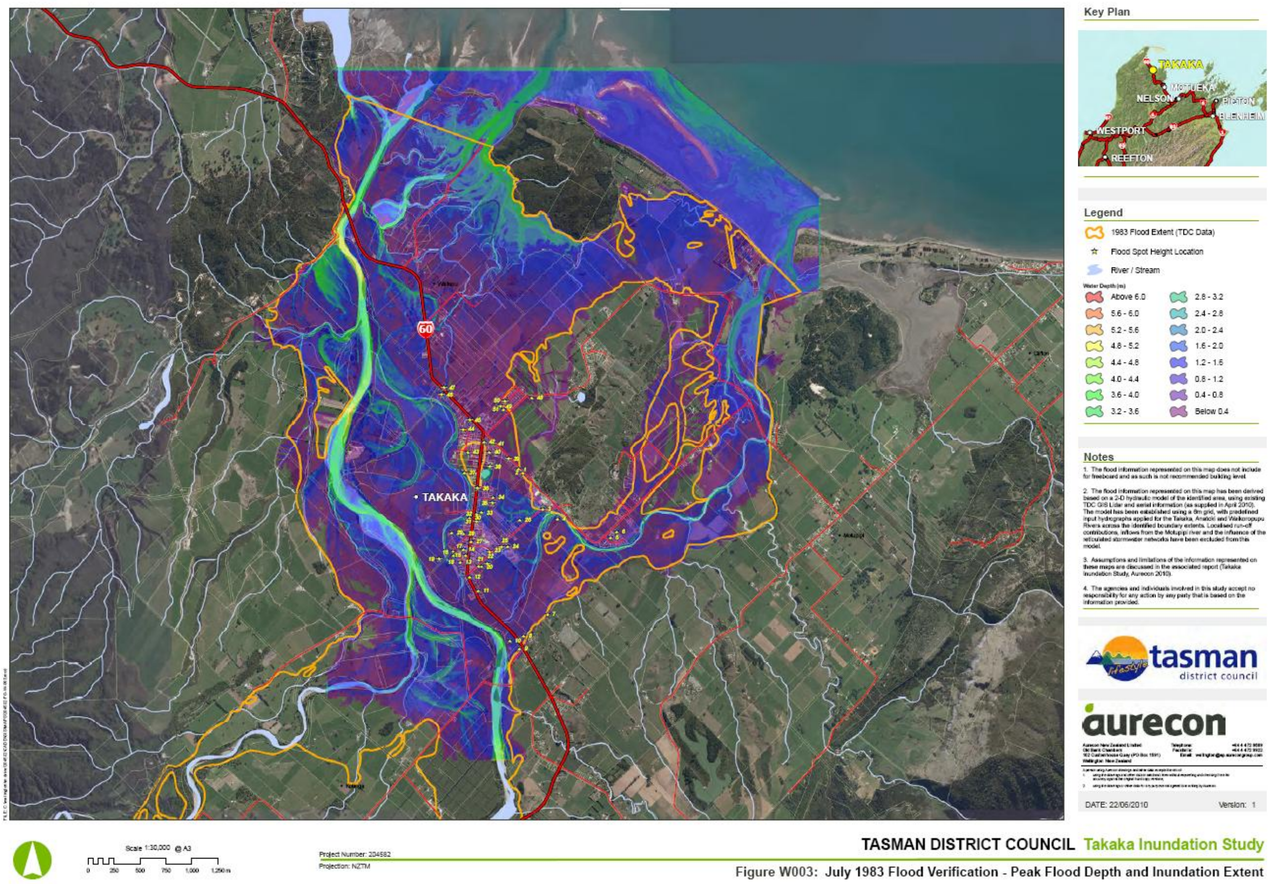


Figure 5: Mapping of flood validation results for the 1983 event outlined below

4.2 REAL TIME FORECASTING

The output from the MIKE 21 modelling was used to create the WaterRIDE flood forecasting model for the Takaka Township. The WaterRIDE model uses the predetermined MIKE 21 results for various return period events to create a library of digital flood surfaces. Flood extents for each of these events are equated to a peak flood depth at the Kotinga Gauge.

Rain gauges in the upper catchment feed in real time into the FLOODWatch rainfall runoff model which routes inflows so as to predict flow and level at downstream gauges.

The WaterRIDE model uses a predicted peak flood level at the Kotinga Bridge gauge from the FLOODWatch programme and defines a predicted flood surface by interpolating between two known surfaces predetermined from the hydraulic modelling.

To date this process has not been automated and requires manual input into the WaterRIDE model. However, where time is a critical factor predictions can be made on the extent, nature and timing of inundation without lengthy model run times.

Review of the associated flood levels, velocities and timing on the interpolated results can be undertaken in WaterRIDE, including the extraction of associated time series, profile plots and hydrographs.

4.3 FLOOD HAZARD ASSESSMENT

The flood forecasting model can be used as an emergency response tool to predict the extent and severity of flood events, timing of when evacuation routes are rendered impassable, and prediction on peak flood depths and velocities. This information will assist emergency services make early decisions regarding the need to evacuate, school closures, placement of emergency response vehicles, and safe evacuation points that residents can get to during a flood event.

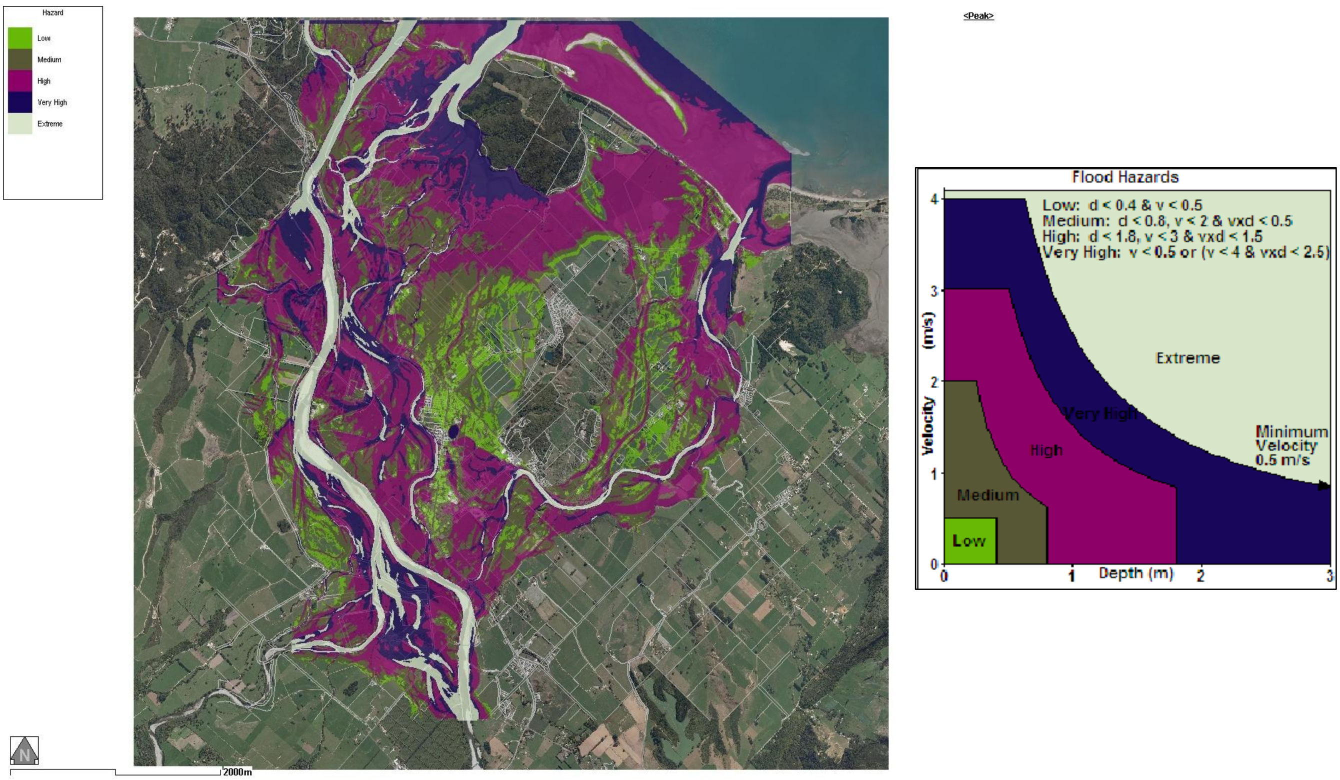


Figure 6: 200 year ARI Takaka Flood Hazard Map

The WaterRIDE model was used to create flood hazard maps for the township. In Figure 6 above a related hazard map has been defined for the 200 year ARI event in the Takaka Township. Hazard classifications are in line with the New South Wales Floodplain Management Manual (NSW Government, 2005).

4.4 FLOOD DAMAGE ANALYSIS

There are many potential consequences associated with flooding. Costs are typically broken into tangible and intangible aspects, which in-turn can be broken into direct and in-direct components.

Tangible aspects can be valued via a market price, while intangible elements are not easily quantified in monetary terms. Direct costs are those resulting from damage caused by physical contact from the flood water, where as indirect aspects reflect the follow-on impacts of damage through the community.

Examples of the four resulting categories are as follows:

- Tangible, direct: damage to buildings, goods and infrastructure
- Tangible, indirect: business disruption, lifelines breakage, lost wages
- Intangible, direct: loss of life, sentimental possessions/ memorabilia
- Intangible, indirect: impact of stress, disruption to education

Given the difficulties associated with quantifying intangible losses, flood damage assessments tend to focus more on tangible elements. This does not diminish the significance of intangible elements, and the focus of hazard assessments look where possible to mitigate associated risks.

The main focus of work to date in Takaka has been on quantifying tangible impacts of freshwater floods. Internationally there are a number of methods available for the assessment of tangible losses. In New Zealand the most common means of assessment is via application of appropriate depth damage curves to modelled flood surfaces (NZIER, 2004).

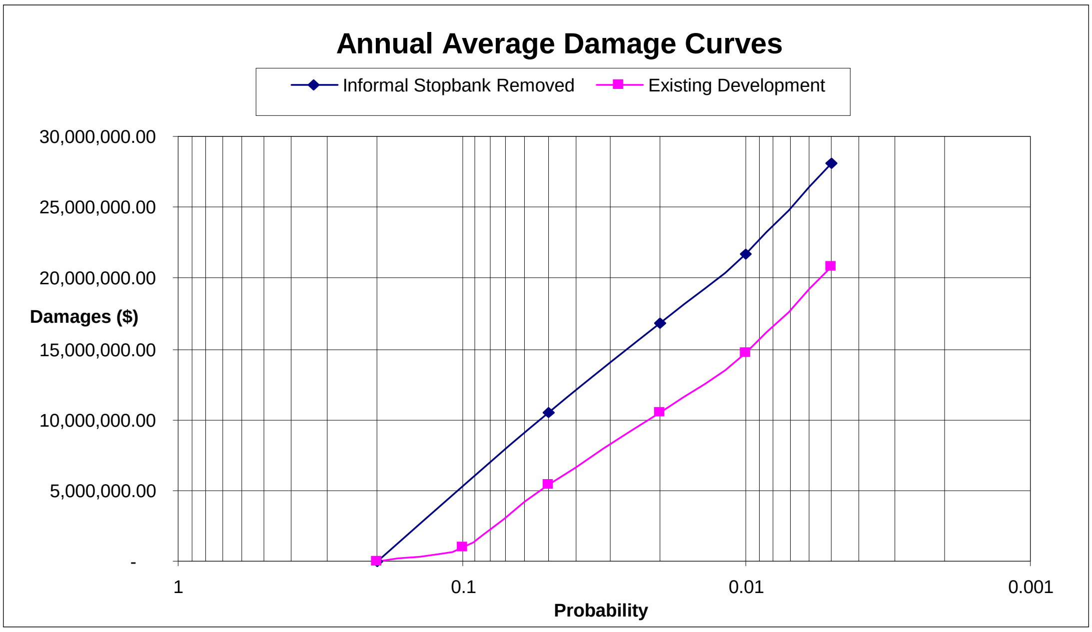


Figure 7: Comparison of various topographical runs for Takaka

Damage curves for various property types were applied provisional on landuse (ACC, 2008).

An informal stopbank was established on the banks of the Takaka River immediately upstream of the township. There has been much debate within the community on the effectiveness of this structure. Integrity issues aside, Annual Average Damage (AAD) curves were derived with and without the proposed stopbank. Results are outlined in Figure 7.

5 MODEL OUTCOMES

Modelling outputs enabled Tasman District Council to assess the impacts and timings of flooding and quantify the associated risks. Specifically, clarity was provided on the following issues:

- Existing Break-out: The flood level which just enters town has a recurrence interval of 10 years on average (as demonstrated in 2008 event).
- Sensitivity to Topography: At this 'breakout' level, modelling is extremely sensitive to small changes in topography, vegetation and structures. The 2008 flood should be used as the best indicator of what happens for this flow.
- Informal stopbank: The existing informal stopbank impacts on the distribution of flows through the catchment. Peak depths are worsened to the north and discharge towards the Motupipi River is significantly reduced. Direct Tangible flood damages are significantly increased for the township if the stopbank were to be removed
- Tidal Influence: The Highest Astronomical Tide (HAT) with an additional 0.8m sea level rise does not extend into the built up area of town either during low flow or flood flow conditions. Similarly, the HAT with 0.8m rise does not affect the waste water ponds during low flow or flood flow conditions.
- Bypass of Limited Benefit: The existing bypass up stream of the township at Paynes Ford is of limited effect during significant return period events.
- Development Impact: Localised effects from development of building platforms do not tend to propagate far upstream due to the hydraulic grade of the floodplain. In general the terrain drops around 3m per km.
- Influence of River Bed Levels: Records indicate bed levels have eroding steadily for the past 30 years or so. Modelling indictaes the increased conveyance in the main river channel today will reduce flood levels through the township. A general reduction in inundation depth of between 100 and 200 mm is expected for the 100year ARI event (when compared to 1983 topography).
- Stopbanking: Stop banking the township appears to be a potentially effective solution, provisional on approvals and cost.

6 CONCLUSIONS

In undertaking any flood management project a key aspect is to utilise appropriate tools and develop a methodology that will best achieve results within prescribed budgets.

Given the characteristics of the existing catchment it was impractical and unnecessary to develop a full 2-dimensional model of the entire Takaka catchment. A three tiered modelling approach was established, utilising three discrete modelling packages and tailoring outputs to meet TDC requirements.

Outputs from this process enabled cost effective establishment of:

- A validated, detailed, 2-dimensional model of the associated floodplain
- Real-Time flood forecasting
- A tool enabling a rapid predictive assessment of associated hazards
- Annual Average Damage curves for various mitigation options

The following considerations were critical in the successful execution of this project.

- **Selection of the appropriate modelling tool**

  Significant flooding of the Takaka township is dominated by flows from the upper catchment and associated Takaka river. The elements used in the modelling exercise were selected to best align with the charateristics of this catchment. Gauging and the associated rainfall/ runoff model develops provision to assess the real-time response of the catchment. MIKE 21 is used to define the flood risk in the unconfined floodplain (adjacent to township) for specified events. In Water RIDE a GIS based tools looks to utilise the outputs from both processes to best effect.

  The level of detail in each of these components was targeted to best meet client needs within associated budgets.

- **Understand sensitivities**

  WaterRIDE in particular is not a hydraulic modelling tool. Interpolating results from existing modelling surfaces has its limitations. Understanding where the sensitivities in area this process is key to assessing the appropriateness of the result.

- **Understand uncertainties**

  A number of scenario runs were undertaken looking at the impact on modification to topography and associated parameters. While outcomes are indicative, caution is urged in the interpretation of results, where greater uncertainties may sit elsewhere in the modelling assumptions/ inputs (eg rainfall/ runoff model, gauging).

- **Appropriate gauging/ model**

  Gauging levels at Kotinga were used to drive the interpolation tool within WaterRIDE. The existing model indicates the limited flows from the main river break-out prior to the gauge at Kotinga. This led to issues at high flows and impacted on the appropriateness of using level as a parameter to control the Flood Forecast model at this location.

At the time of model development WaterRIDE applications in New Zealand were limited. For the purposes of this project this software performed well. However it is emphasised that this application is a GIS and not a hydraulic modelling tool. While the level of presentation is high the following aspects need to considered when interpreting results.

- The accuracy of the flood surface is limited by the base assumptions in the original modelling
- Interpolated surfaces are just that, and interpolations will be limited by the similarity of model results and proximity to nearest design run.

- The shape of the input hydrograph will impact the inundation extent and associated interpolation (not just peak levels at flow gauges). This will be of particular importance where storage is a critical element (not so in the case of Takaka).
- The effectiveness of the predictive tool will be conditional on operating range (this was not great for the Kotinga Gauge).

It is emphasised that WaterRIDE outputs are not a substitute for modelling, more an effective tool for collating and interrogating outputs.

While there are numerous areas for future development, the outputs from the existing project meets the interim objectives of Council. Specifically, the models serve to define the flood risks in Takaka, provide a basis for engagement with the community on appropriate mitigation options, while predicting potential associated hazards in a cost effective tool so as to guide emergency response.

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