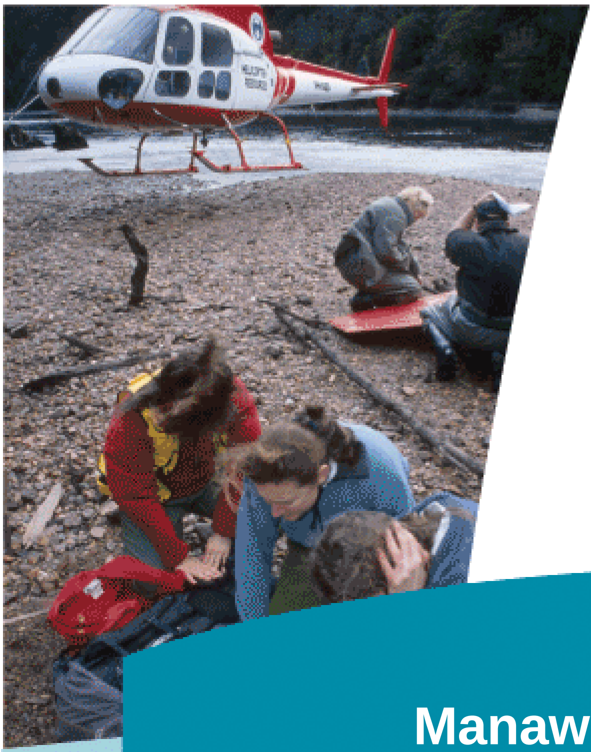
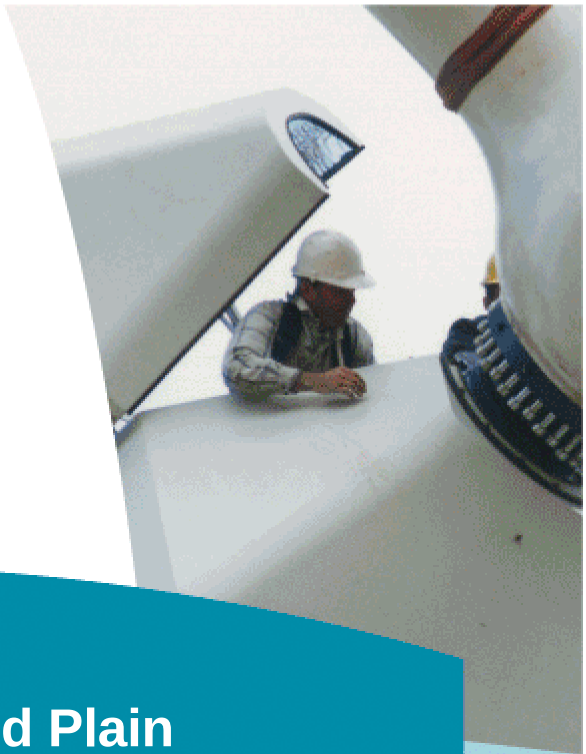
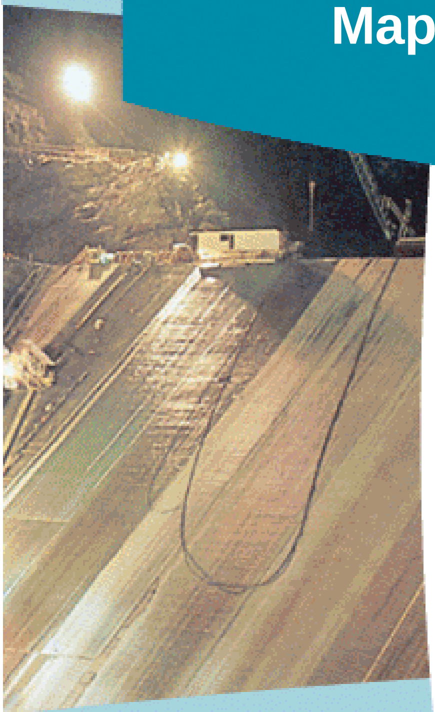
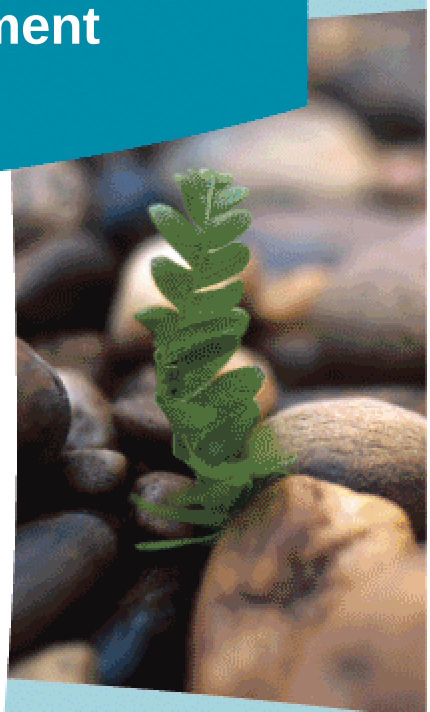
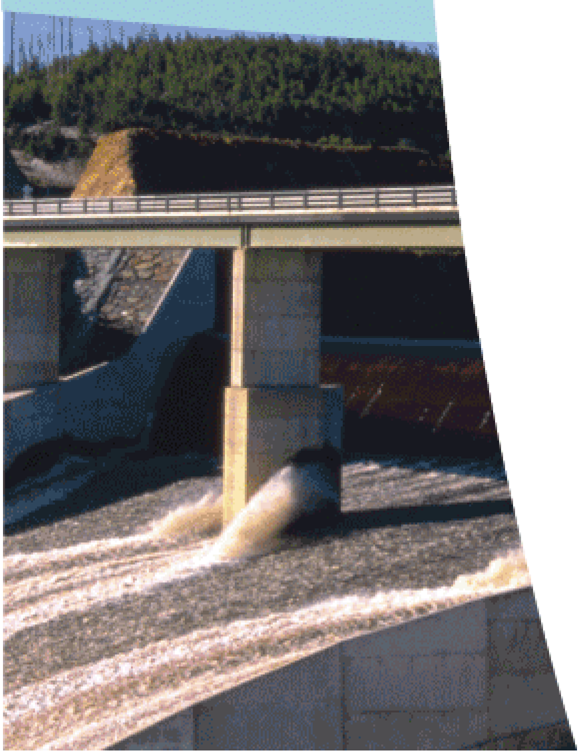



Hydro Tasmania
Consulting

Manawatu Gorge Flood Plain Mapping and Website Development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1. Introduction

Hydro Tasmania Consulting (HTC) was commissioned by Horizons Regional Council (HRC) to develop a two-dimensional hydraulic model of the Manawatu and Mangahao Rivers upstream of the Manawatu Gorge.

The scope of the project involved the development of a library of high resolution flood inundation maps based on 2D hydraulic modelling. These maps were integrated with the flood forecasting system developed by HTC and are referenced real time during a flood event with a web-based display to provide an indication of the current and estimated peak flood extents.

This report:

- Briefly summarises the hydrologic and hydraulic modelling that was carried out for the development of the library of flood inundation maps and the assessment of the 1 in 100 and 1 in 200 AEP design flood event.
- Provides a description for web-based display. An outline of the makeup of the forecast file and the web-site functionality is given along with user specifications for the website.

2. Inflow Derivation

Inflow hydrographs have been derived for input to the hydraulic model for the purposes of model calibration and design flood inundation runs. The hydrographs are based on the measured flow records supplied by HRC at the following sites:

- Manawatu River at Hopelands
- Tiraumea River at Alfredton
- Mangatainoka River at Pahiatua
- Mangahao River at Ballance

Inflow hydrographs have been produced for three input locations in the hydraulic model. The locations of these inputs are displayed in the following chapter (Figure 3-1) and the methodology for deriving inflows at each location is outlined below:

- **Lumped into top of MIKE FLOOD, upstream of Ngawapurua Bridge**. Flows were derived that represent the catchment upstream of the Manawatu River and Tiraumea River confluence. The three measured flow sites were factored up to allow for the unaccounted catchment area downstream of each site as follows: Hopelands x 1.03, Mangatainoka x 1.03, Tiraumea x 1.24. Some channel routing was applied to the flows at these three sites to represent the travel time and flow attenuation to the Manawatu/Tiraumea River confluence. This routing used parameters and methodology as applied in the Upper Gorge flood forecasting model.
- **Top of MIKE FLOOD, Mangahao**. Mangahao River at Ballance flows are left unaltered for this input.
- **MIKE11 at Ruawata**. Runoff from the remaining ungauged catchment to the Manawatu at Upper Gorge gauge site was included by using the measured flow at Hopelands. This was factored down to achieve a best match of event volume when combined with the other two flow inputs and compared to the measured discharge at Manawatu River at Upper Gorge.

The five largest events since the beginning of 1990 were selected for calibration, earlier events were not considered due to the Hopelands record being unavailable.

The estimated inflow hydrographs are provided in Appendix A.

3. Hydraulic Model Setup

3.1 Introduction

The hydraulic modelling for this project was carried out using the MIKE FLOOD (version 2008) software package. This software package combines both the MIKE 11 1D and MIKE 21 2D software packages into a single model, where the significant river channels are modelled using MIKE 11 cross-sections and out of channel flooding is modelled using the MIKE 21 grid.

3.2 General Setup

A MIKE FLOOD model was developed for upstream of the Manawatu Gorge incorporating:

- The Upper Manawatu River from the Gorge gauge site upstream to the Ngawapurua Bridge.
- The Mangahao River from its confluence with the Upper Manawatu River upstream to the Mangahao at Balance gauge site.

MIKE 11 cross-sections for the Upper Manawatu River and the Mangahao River were provided by HRC. A cross-section of the Upper Manawatu River, representing the narrowest part of the gorge just upstream of Old Balance Bridge was obtained from LiDAR survey. The profile of the cross section below water surface was based on the surveyed upstream and downstream cross-sections provided by HRC.

A 20 m grid size was used for the MIKE 21 model, using the LiDAR data provided by HRC. A 20 m grid size was chosen for the MIKE 21 model for the purpose of reducing the run-time of the MIKE FLOOD model. As a reference, the design flood events described below, had a run-time of approximately 24 hours.

The LiDAR data, which had a very high resolution, was resampled to create a digital elevation model (DEM) with a 20 m grid size using ARC GIS software. Relevant features such as levees, roads and creek invert were identified and given priority to ensure they were included in the re-sampled DEM. This re-sampled grid then formed the bathymetry for the MIKE 21 model. The extent of the MIKE FLOOD model is shown in Figure 3-1.

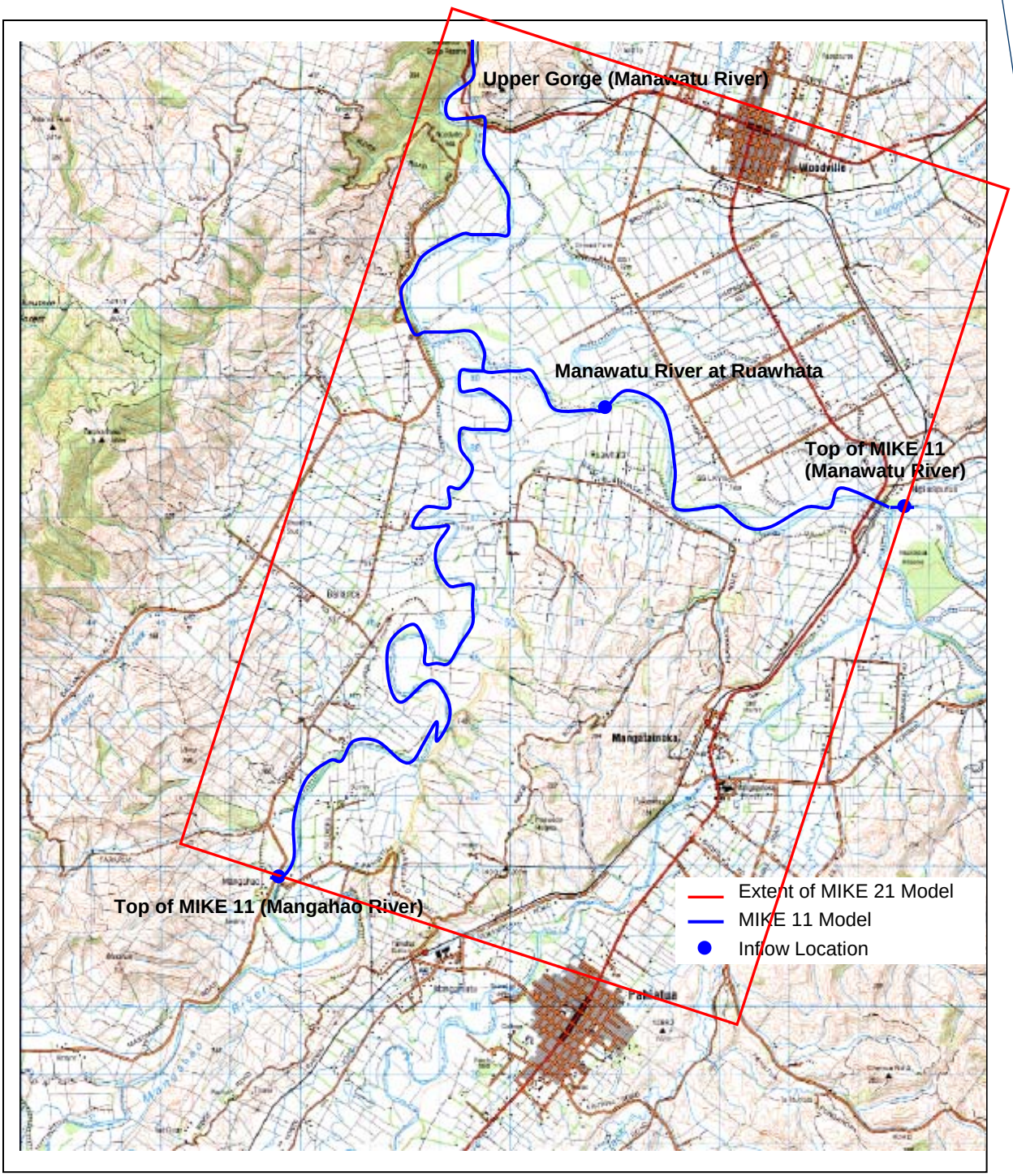

Figure 3-1 Extent of MIKEFLOOD model

3.3 Roughness and Manning's Values

The Manning's n value for the Upper Manawatu and Mangahao Rivers was taken as 0.035 with Manning's n = 0.044 near the Manawatu Gorge. These values were adopted during the model calibration process. The higher roughness value for the gorge, in addition to friction

loss, was used to represent contraction and expansion losses through the narrowest part of the gorge.

The roughness and equivalent Manning's n values for the MIKE 21 grid were based on land use information provided by HRC. The adopted values are shown in Table 3-1. These values have been successfully used for similar flood mapping projects on the Manawatu, Rangitikei, Mangatainoka and Whanganui Rivers.

Table 3-1 MIKE 21 Roughness and Manning's Values

Land Type	Roughness	Equivalent Manning's 'n' (1/Roughness)
Built up Areas	6	0.167
Dense Vegetation	15	0.067
Open Space	27	0.037
Waterways	35	0.029
Roads	56	0.018

3.4 Link Structures

41 lateral links were set-up for transfer of flow between the MIKE 11 cross-sections and the MIKE 21 grid. The link structure type used for all the links is summarised in Table 3-2 below.

Table 3-2 Link Structure Details (Common for all 41 links)

Parameter	Value	Comment
Method	Cell to cell	
Type	Weir 1	$Q = W \cdot C \cdot (H_{us} - H_w)^k \cdot \left[1 - \left(\frac{H_{ds} - H_w}{H_{us} - H_w}\right)^k\right]^{0.385}$ Refer to MIKE 11 reference manual for details.
Source	M21	MIKE 21 grid cell level at lateral links are used as invert level for the link. HGH was initially trialled but unrealistically restricted breakout flow.
Depth Tolerance	0.1m	For model stability.
Weir C	1.838	Default discharge coefficient.
Manning's n	0.05	Adopted value.

3.5 Other Parameters

Other critical parameters for the MIKE FLOOD model are provided below:

- Calculation time-step: 2 seconds.
- Flooding and drying enabled:

- Drying depth: 0.02 m.
- Flooding depth: 0.03 m.

- Eddy viscosity: 0.10m^2/s.

3.6 Downstream Model Boundary

The downstream model boundary is located at the Manawatu at Upper Gorge gauge site. The discharge vs depth (Q/H) rating for this site was provided by HRC and used as the model boundary condition. The Q/H relationship used is provided in Table 3-3 below.

Table 3-3 Q/H Relationship at Manawatu at Upper Gorge

Stage (mm)	Discharge (l/s)
65	0
409	5716
487	7658
593	11079
752	18291
936	29448
1285	57393
1968	123059
2919	228890
4135	373856
6539	731863
7912	968447
10438	1476057
14292	2382851
19966	3957309
25966	5817309

3.7 Model Datum

The modelling was carried out in Wallington Vertical Datum.

4. Model Calibration

Since no hydraulic model existed for the model area, a model calibration was required to provide confidence that the outputs of the hydraulic model were reasonable. The hydraulic model was calibrated by comparing:

- Modelled and measured discharges at the Manawatu at Upper Gorge gauge.
- Modelled flood extents against observed flood extents using surveyed flood levels and available flood photographs provided by HRC.

The July 1992, October 2000 and February 2004 flood events were used for model calibration.

The MIKE FLOOD model was set up to read inflows at three locations as shown in Figure 3-1. These inflows are located at:

- Manawatu River upstream of Ngawapurua Bridge (at confluence of Manawatu and Mangatainoka River) at the upper extent of the MIKE 11 model.
- Mnagahao River upstream of Mangahao Bridge at the upper extent of the MIKE 11 model.
- Manawatu River at Ruawhata.

July 1992 Flood

The resulting modelled hydrograph at Upper Gorge of the Manawatu River and the observed hydrograph at that location are shown in Figure 4-1 below. This shows that the modelled flood duration along with the timing of peak discharge compares well with the observed hydrograph, although the peak of the modelled hydrograph is slightly higher than the peak of the observed hydrograph.

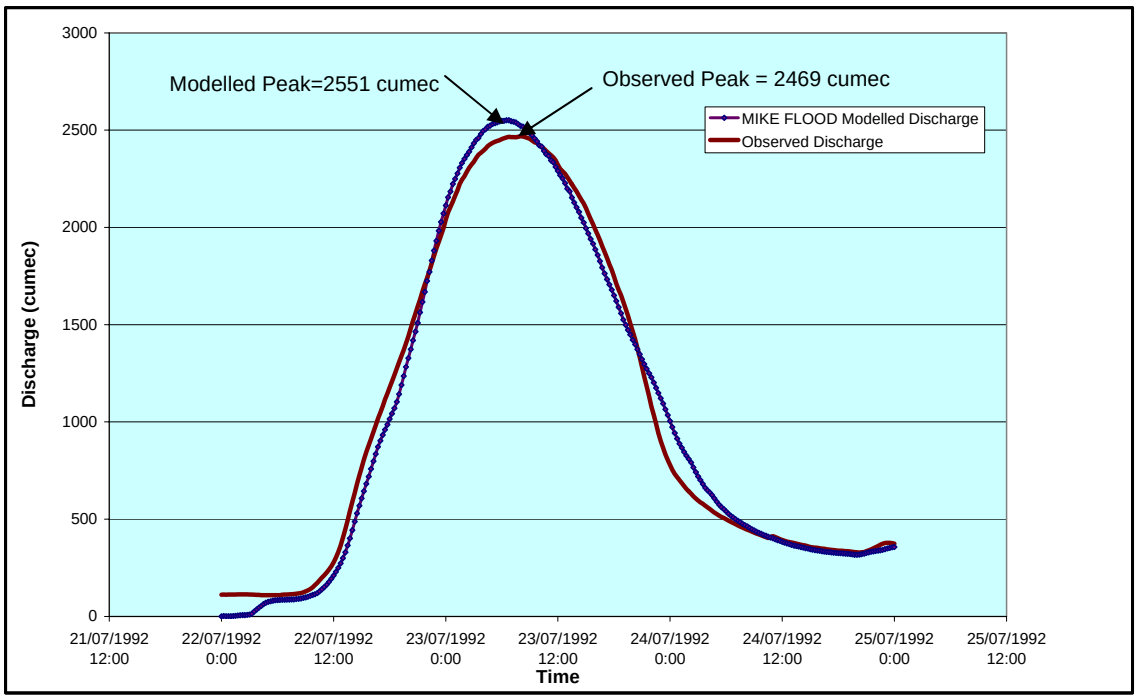

Figure 4-1 Observed vs Modelled Discharge at Upper Gorge for July 1992 Flood

The modelled flood levels at different locations were also compared with the available observed flood levels provided by HRC. The measured and modelled flood levels at those particular locations are shown in Table 4-1.

Table 4-1: Measured vs Modelled Flood Level at different locations for July 1992 Flood

Location	Measured Flood Level (m)	Modelled Flood Level (m)
Ngawapurua Bridge	82.40	82.52
Mangamania Bridge	73.61	73.74
Old Balance Bridge	73.29	73.78

Note: Measured flood levels from Tables 30, 31, 32, 33, 34. Ponding levels and water surface slopes at Manawatu Gorge. Referance Unknown.

Table 4-1 shows that a good match between modelled and measured flood levels has been achieved at those flood measured locations. Figure 4-2 shows the flood extent map and observed flood levels at different locations.

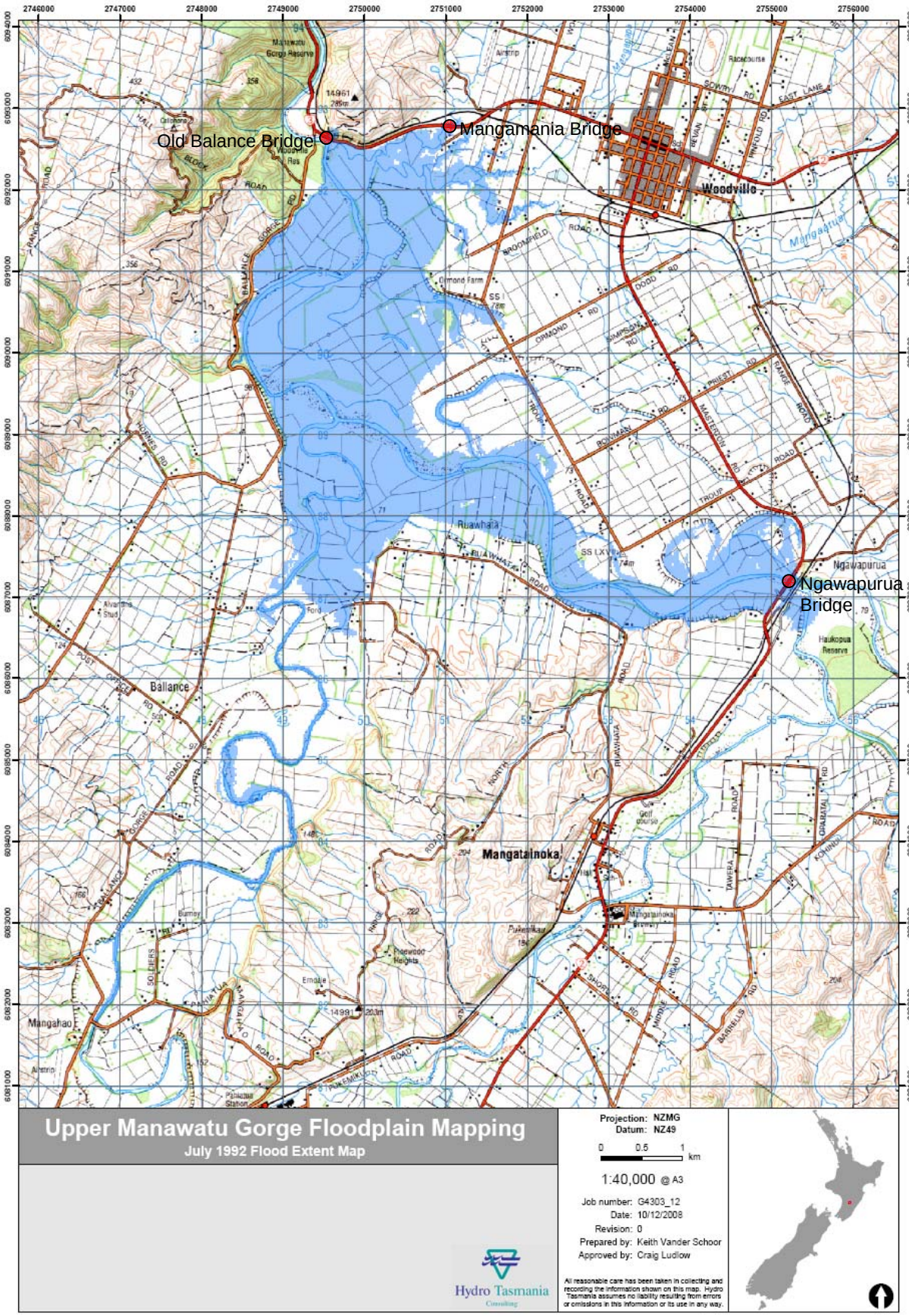

Figure 4-2 Flood Extent Map of July 1992 Flood

October 2000 Flood

The modelled flood hydrograph at Upper Gorge of the Manawatu River and the measured hydrograph at that location are shown in Figure 4-2 below. This shows that the modelled hydrograph compares well with the measured hydrograph, although the peak of the modelled hydrograph for the second peak is slightly higher than the observed hydrograph.

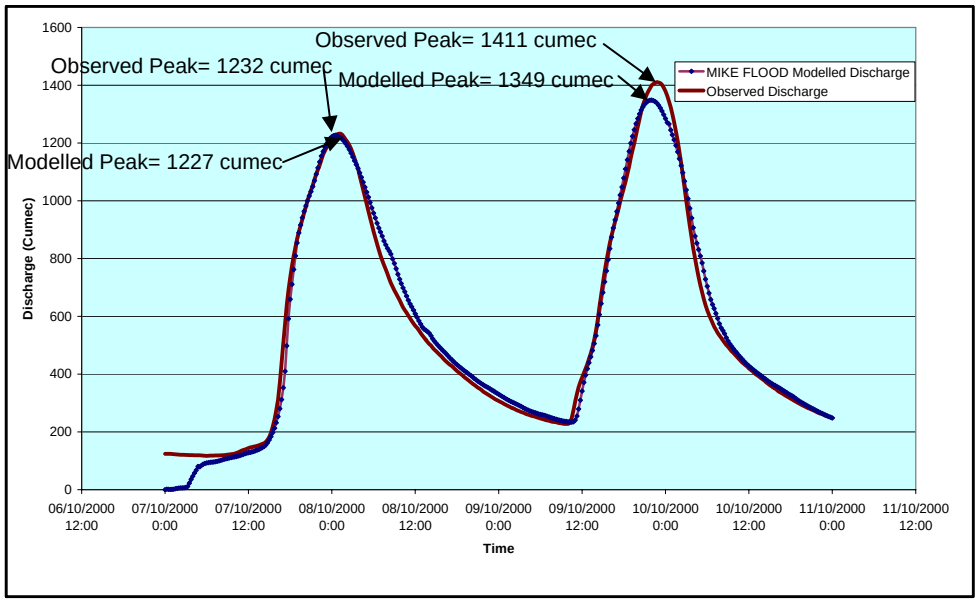

Figure 4-3 Observed vs Modelled Discharge at Upper Gorge for October 2000 Flood

Photographs of flooding that occurred during the October 2000 flood were provided by HRC for use in calibrating the model. The locations of photos were plotted and it was found that they were beyond the extent of the model and could not be used to calibrate the model. The flood extent estimated by the model is shown in Figure 4-4.

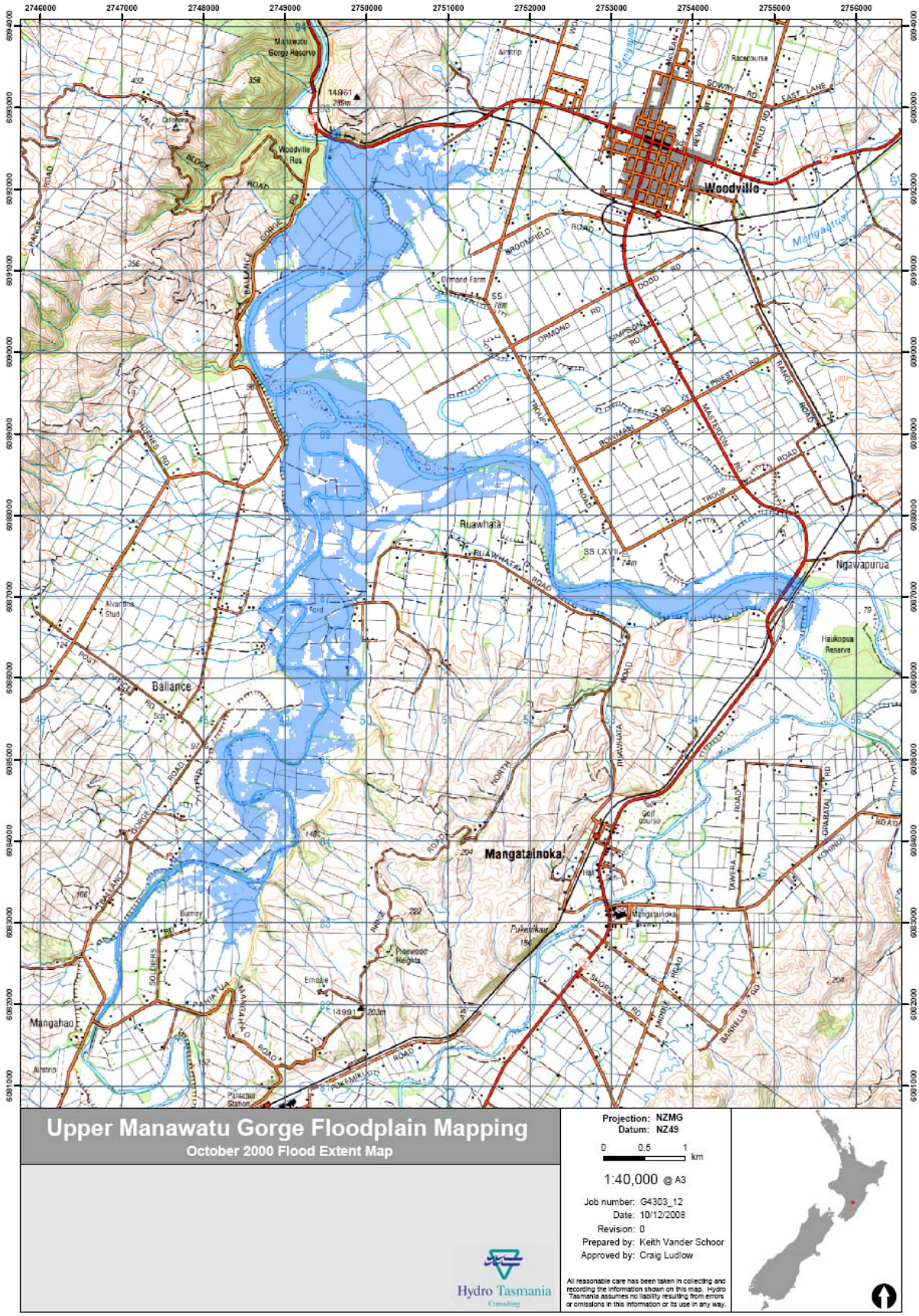

Figure 4-4 Flood Extent Map of October 2000 Flood

February 2004 Flood

The modelled flood hydrograph at Upper Gorge of the Manawatu River and the measured hydrograph at that location are shown in Figure 4-3 below. This shows that the peak of modelled hydrograph at the gorge is slightly higher than the peak of the measured hydrograph, however, the peak timing of modelled and measured hydrograph is same.

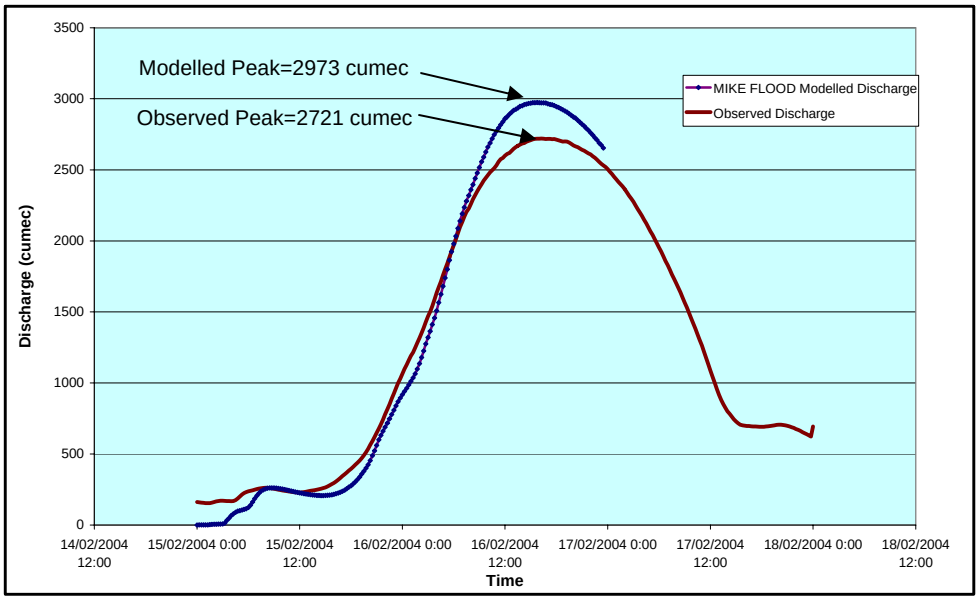

Figure 4-5 Observed vs Modelled Discharge at Upper Gorge for February 2004 Flood

The modelled flood levels of February 2004 flood event were plotted and the inundation map is shown in Figure 4-6. HRC provided photographs of flooding that occurred during the February 2004 event. It is assumed that these photos show the peak of the flood. The locations of these photos are also shown on Figure 4-6. A selection of the photographs are shown in Figure 4-7 to Figure 4-11. The extent of inundation from the MIKE FLOOD modelling shown in Figure 4-6 compares well with the flooding at SH2 and either side of Old Gorge Road as shown in the photos.

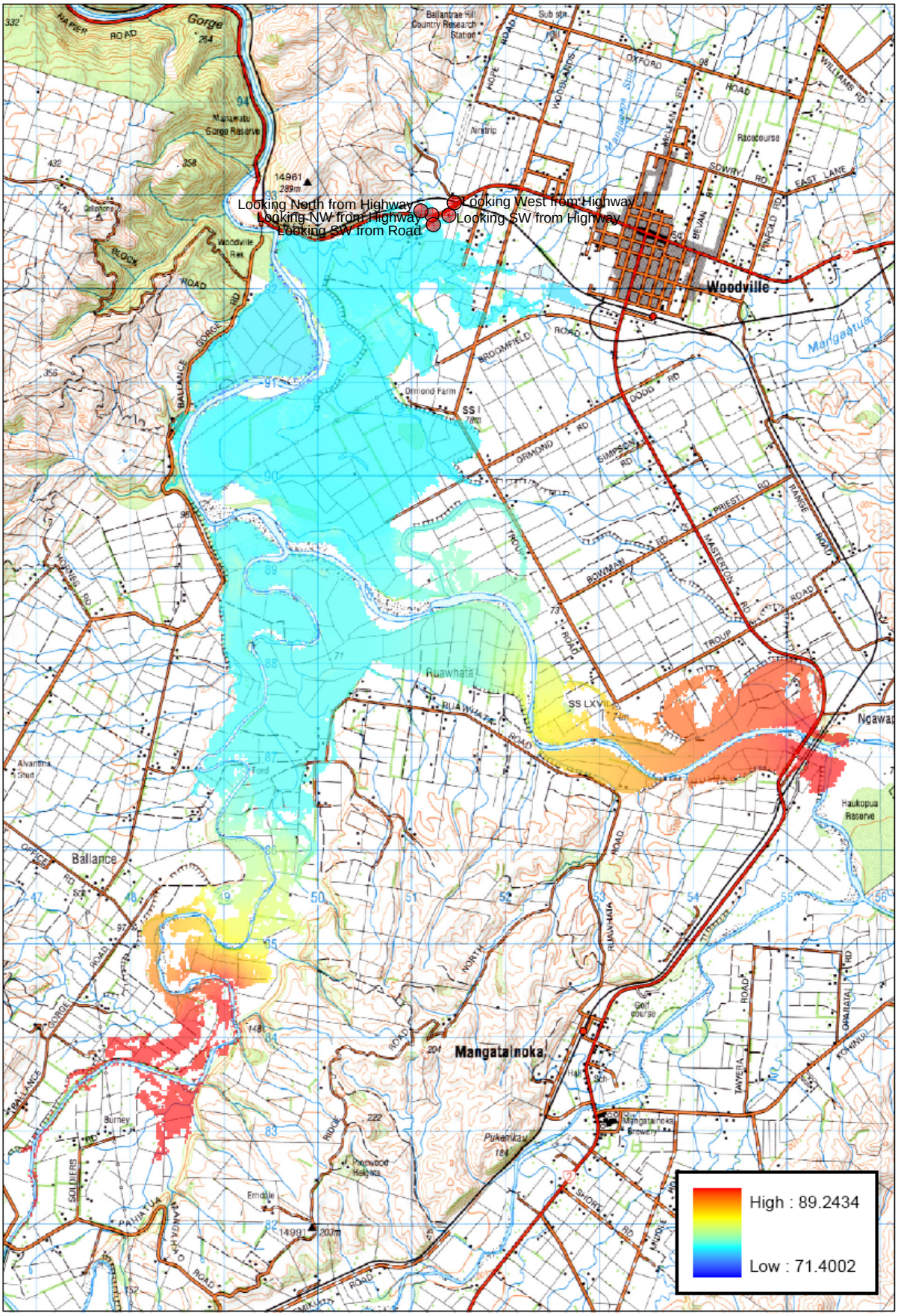

Figure 4-6 Flood Inundation Map for February 2004 Flood Event

Figure 4-7: Looking West from Highway (SH2)

Figure 4-8: Looking South-West from Highway (SH2)

Figure 4-9: Looking North-West from Highway (SH2)

Figure 4-10: Looking North from Highway (SH2)

Figure 4-9: Looking South-West from Old Gorge Road

5. Design Flood Runs

The MIKE FLOOD model was used to develop a set of electronic flood extent inundation and flood depth maps for the 1 in 100 AEP and 1 in 200 AEP flood discharges as measured at the Manawatu at Upper Gorge gauge site. Flood frequency results at this location were provided by HRC and are shown in Table 5-1.

Table 5-1 Flood Frequency Result

Flood AEP	Discharge (m^3/s)
1:50	2720
1:100	3070
1:200	3430

The February 2004 flood event hydrograph was used as the basis of the design runs and the inflow hydrographs to the MIKE FLOOD model for this event were scaled so that the peak discharge at the Manawatu at Upper Gorge gauge site matched the required peak flow for the 1 in 100 and 1 in 200 AEP design events. The 1 in 50 AEP design event was not modelled.

The hydrographs used for design runs are provided in Appendix A.

The maps were provided to HRC electronically in ARC GIS format. Plots of the flood 1 in 100 AEP and 1 in 200 AEP extents are shown in Figure 5-1 and Figure 5-2.

It should be noted that the flood extents shown for the Mangahoa River upstream of approximately Balance do not represent the 1 in 100 AEP and 1 in 200 AEP extents for this section of the river. Downstream of approximately Balance, the estimated flood levels are controlled by the restriction of the gorge. Upstream of Balance, peak flood levels are less influenced by the ponding of flood water upstream of the gorge and are predominantly based on the amount of flow that breaks out of the river. The scaled Feb 2004 flood hydrographs, although contributing to the 1 in 100 and 1 in 200 AEP discharges at the Manawatu at Upper Gorge gauge site do not represent the 1 in 100 and 1 in 200 AEP hydrographs for a local flood on the Mangahao River.

Further modelling is recommended if 1 in 100 and 1 in 200 AEP flood extents are required for the Mangahao River upstream of Balance.