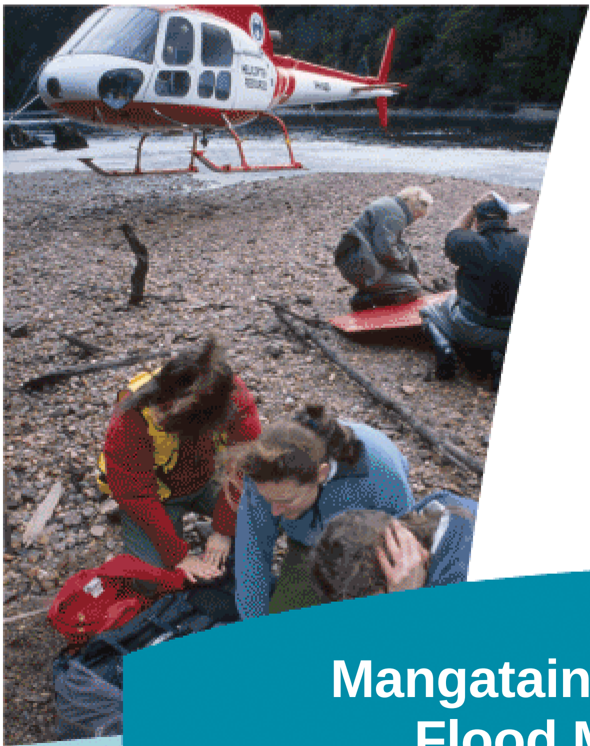
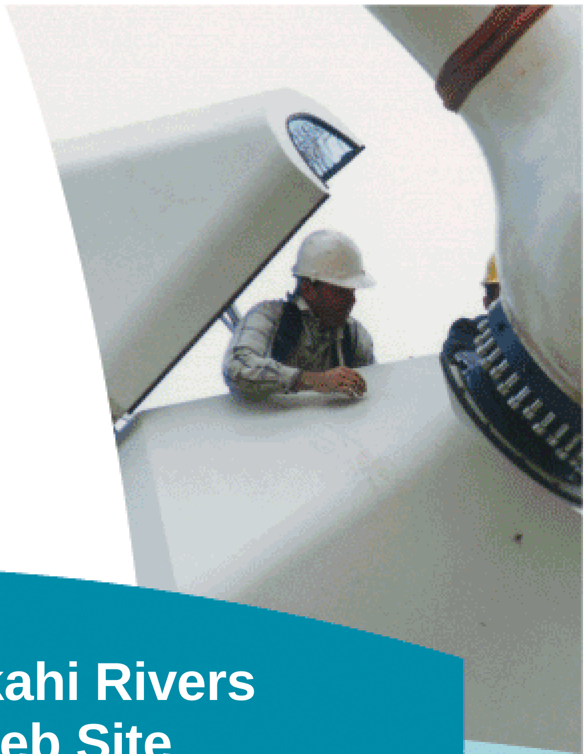
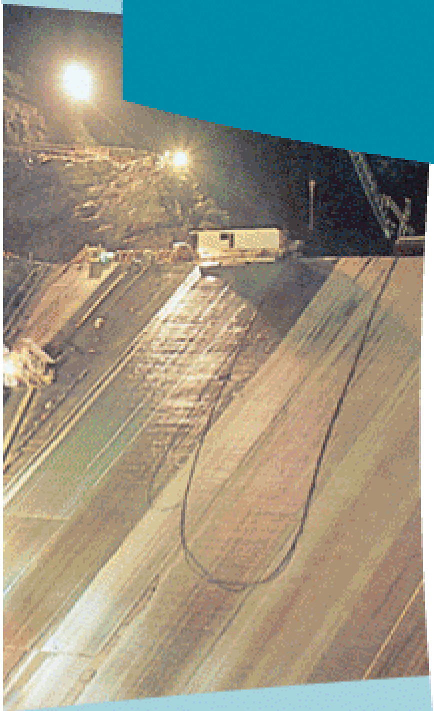
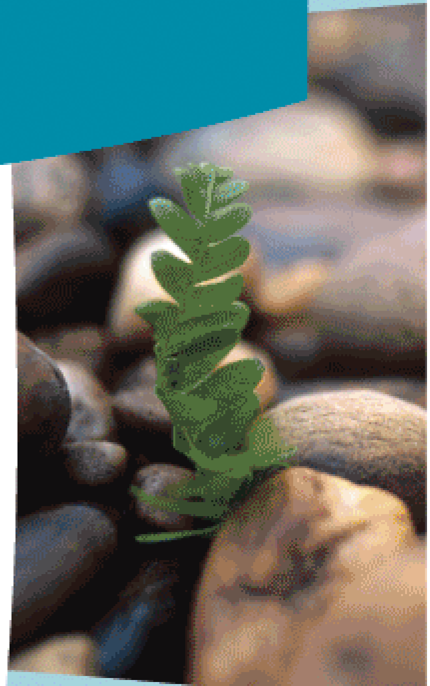


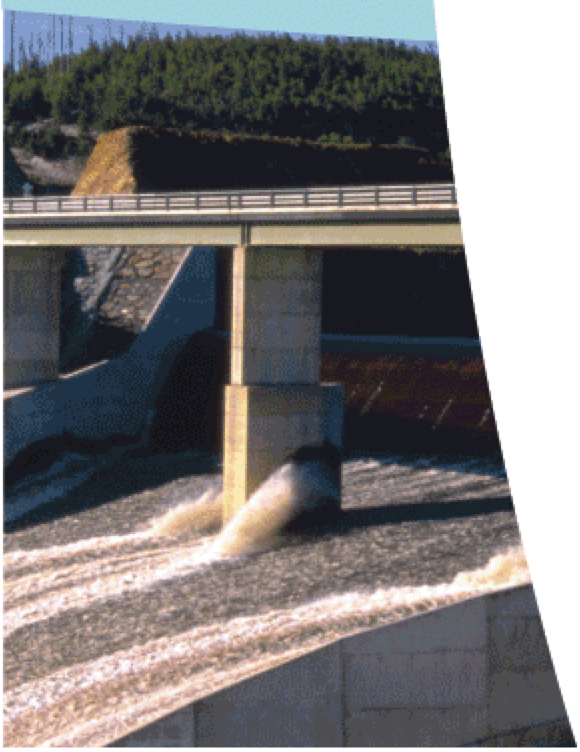


Hydro Tasmania Consulting

Mangatainoka and Makakahi Rivers Flood Mapping and Web Site Development







Prepared by
Hydro-Electric Corporation
ARBN: 072 377 158
ABN 48 072 377 158
4 Elizabeth Street, Hobart
Tasmania, Australia

Document information

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Contents

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List of Tables

1. Introduction

Hydro Tasmania Consulting (HTC) was commissioned by Horizons Regional Council (HRC) to develop a two-dimensional hydraulic model of the Mangatainoka and Makakahi Rivers between Hamua and Mangatianoka.

The scope of the project involved the development of a library of high resolution flood inundation extent for the Mangatainoka and Makakahi Rivers based on 2D hydraulic modelling. These extents were integrated with the flood forecasting system developed by HTC and are referenced to 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 AEP and 1 in 200 AEP design flood events.

- Provides a description for the 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 produced for input to the hydraulic model using the measured flow records at Mangatainoka River at Larsons and Makakahi River at Hamua. Six locations have been designated for hydrograph input to the hydraulic model upstream of Pahiatua. These inflow locations are shown in the table below and in Figure 3-1 in the following section.

Table 2-1: Catchment details at the input locations of the hydraulic model

Location	Site Used for Scaling	Catchment Area (km2)	Mean Annual Rainfall (mm)
Top of Mike11	Mangatainoka at Larsons	124.76	2500
Pukohai Str	Makakahi at Hamua	27.42	1650
Mangamaire Str	Makakahi at Hamua	27.35	1300
Top of Mike Flood	Makakahi at Hamua	161.31	1900
Manganui Str	Makakahi at Hamua	15.61	1200
Owhaia Str	Makakahi at Hamua	23.32	1200

To determine the appropriate site to transpose and weighting factors for each inflow location, a hydrological routing model was developed to accumulate all inflows and compare with the total flow at the Mangatainoka at Pahiatua site. The October 2000 event was used to verify the flows and the results are shown in Figure 2-1. Originally the flows for each input location were proportioned based on catchment area and mean annual rainfall, but to achieve a comparable event peak and volume at Pahiatua all inflow hydrographs had to be scaled up (by as high as 10% in the Makakahi River catchment).

Based on advice from HRC, the October 2000 event was used as the hydrograph shape of all flood mapping run hydrographs and the 1 in 100 AEP and 1 in 200 AEP design flood hydrographs produced for input to the hydraulic model. For each hydrograph the October 2000 hydrograph was scaled to match the required peak discharge for the mapping and design flood events.

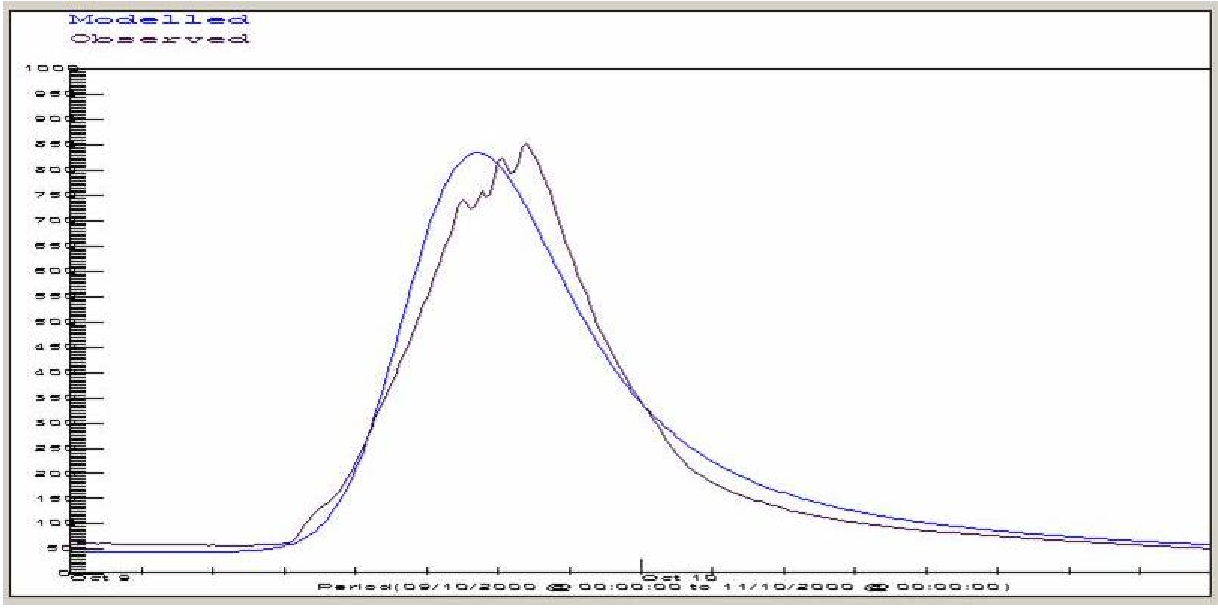


Figure 2-1 Hydrologic Model Comparison at Mangatainoka at Pahiatua, Oct 2000 Event.

3. Hydraulic Model Setup

3.1 Introduction

The hydraulic modelling for this project was carried out using the MIKEFLOOD (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 MIKE11 model of the Mangatainoka and Makakahi Streams was developed, which extended from the vicinity of Hamua Rd to the Suspension Bridge gauging site near Mangatainoka. The model incorporated eight bridge structures, which were modelled using a culvert and weir arrangement in MIKE11, and fifteen groynes, modelled as 1 m high weirs, which have been built on the Mangatainoka River for environmental purposes.

MIKE 11 cross sections for the Mangatainoka River were provided by HRC, who also provided cross sections at each bridge structure. Cross sections for the Makakahi River, as well as some intermediate locations on the Mangatainoka River were obtained from LiDAR survey. Where there was no instream LiDAR data due to the presence of water (on the stream inverts) at the time of survey, a triangular channel shape was assumed below water surface with an invert 0.3 m lower than the lowest nearby LiDAR level (based on agreement with HRC).

The MIKE 11 model was linked to a 10 m grid size MIKE 21 model, which was developed using the LiDAR data provided by HRC. A 10 m grid size was chosen for the MIKE 21 model for the purpose of reducing the run-time of the MIKEFLOOD model. As a reference, the design flood events described below, had a run-time of approximately 48 hours. The LiDAR data, which had a very high resolution, was re-sampled to create a digital elevation model (DEM) with a 10 m grid size using ARC GIS software. Relevant features such as levees, roads and creek inverts were picked up 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 MIKEFLOOD model is shown in Figure 3-1**.**

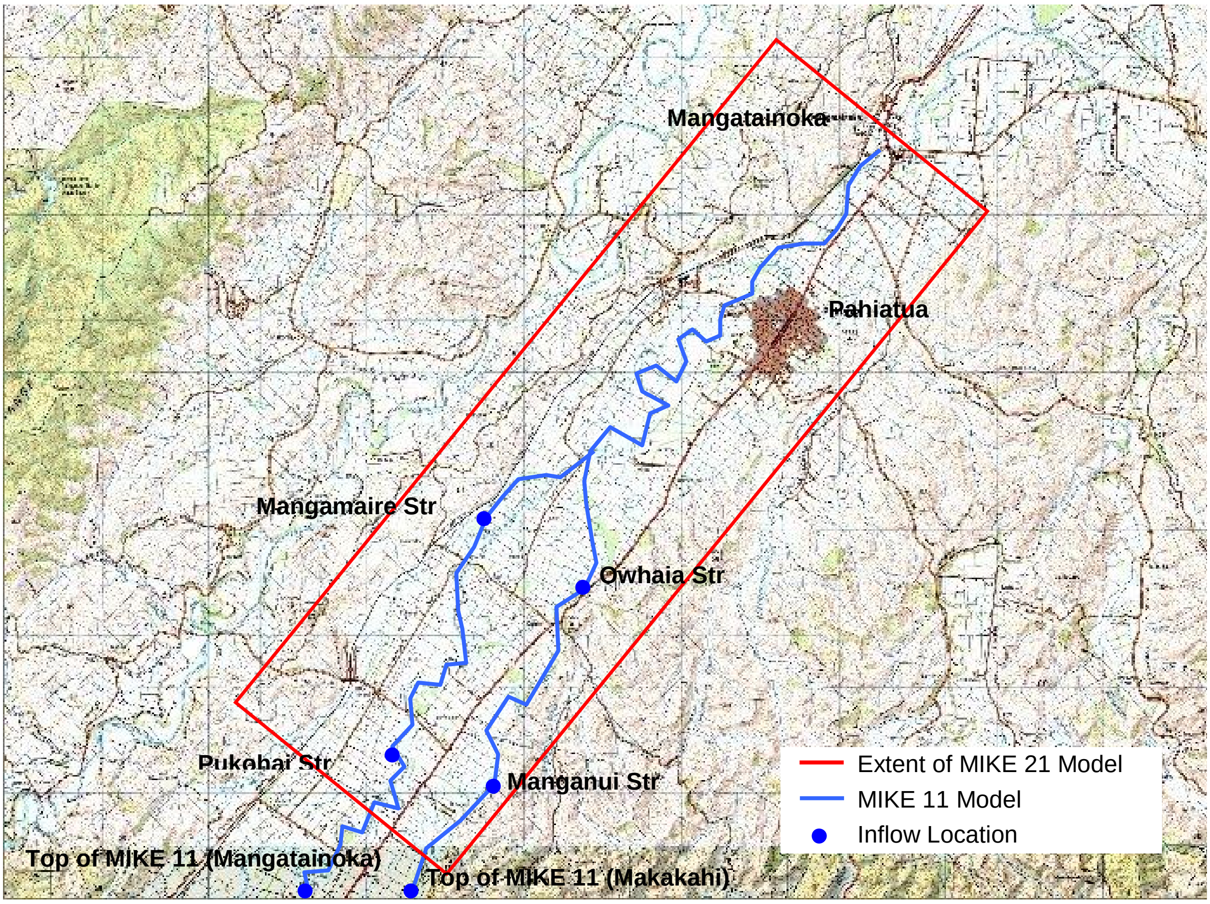


Figure 3-1 Extent of MIKEFLOOD model

3.3 Roughness and Manning's Values

A Manning's 'n' value of 0.033 was adopted for the Mangatainoka and Makakahi River channels. This value is typical for streams with gravel invert as found in the model area.

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 and Whanganui Rivers.

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

Land Type	Roughness Mannings 'M'	Equivalent Manning's 'n' (1/Roughness)
Built up Areas	6	0.167
Dense Vegetation	15	0.067
Open Space	27	0.037
Waterways	30	0.033
Roads	56	0.018

3.4 Link Structures

89 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 89 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	HGH	Maximum of MIKE 11 cross-section level and MIKE 21 grid cell level used as invert level for the link.
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 MIKEFLOOD model are provided below:

- Calculation time-step: 2 seconds.
- Flooding and drying enabled:
  - Drying depth: 0.05 m.
  - Flooding depth: 0.08 m.
- Eddy viscosity: 0.02m^2/s.

3.6 Downstream Model Boundary

For each of the flood events modelled, a discharge vs. depth (Q/H) relationship was used as the downstream boundary, which was located at the suspension bridge gauging site on the Mangatainoka River. This rating was provided by HRC. The Q/H relationship boundary used in the modelling is provided in Table 3-3 below.

Table 3-3 Q/H Discharge Relationship at Mangatainoka Suspension Bridge

Source is
H:\data\Resource\Hydrometric_archive.hts
Mangatainoka at Suspension Bridge
Rating at 09-Nov-2004 09:00:00

Stage (mm)	Discharge (l/s)
1392	1983
1583	4706
1734	8140
1882	12994
2063	21045
2279	34643
2642	72668
3171	157783
4193	370338
5161	623623
6084	908727

The gauge zero is 93.61m (Wellington Datum)

3.7 Model Datum

The modelling was carried out in Wellington Vertical Datum.

4. Model Calibration

Calibration of the MIKEFLOOD model was required to provide confidence that the outputs of the model were reasonable. The hydraulic model was calibrated in two ways. Firstly, the inflows were run through the model and the combined discharge compared against measured discharge at Pahiatua Town Bridge for a known flood event (October 2000). The second calibration method was to compare the modelled flood extents against observed flood extents provided by HRC.

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

- Mangatainoka River at the upper extent of the MIKE 11 model,
- Makakahi River at the upper extent of the MIKE 11 model,
- Pukohai Stream,
- Mangamaire Stream,
- Manganui Stream, and
- Owhaia Stream.

The resulting flood hydrograph at Pahiatua Town Bridge is shown in Figure 4-1 below. This shows that the modelled hydrograph compares well with the measured hydrograph, although the timing of the modelled hydrograph is slightly early.

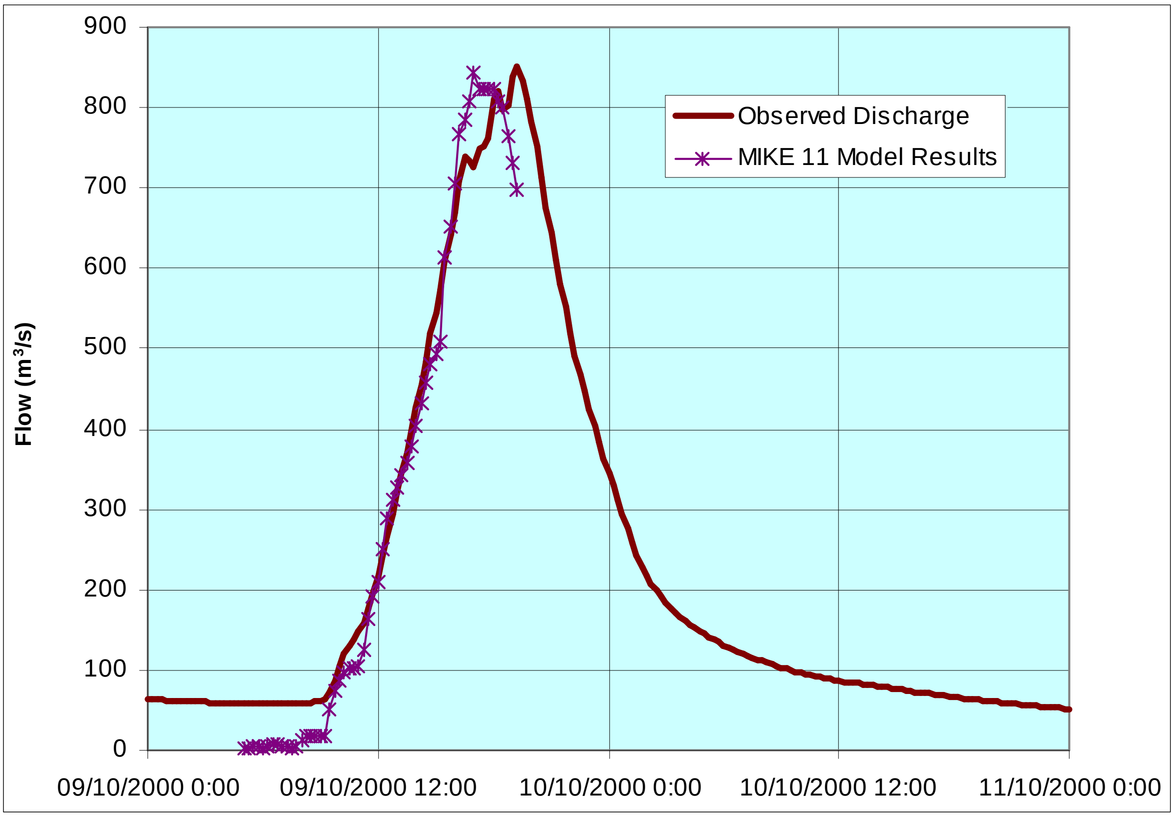


Figure 4-1 Observed vs Modelled Discharge at Pahiatua Town Bridge

5. Design Flood Runs

The calibrated MIKEFLOOD model was used to develop electronic flood extent inundation and flood depth maps (for MIKE 21 grid only, flood depths not provided for MIKE 11 cross-sections) for the 1 in 100 AEP and 1 in 200 AEP flood hydrographs. These maps were provided to HRC electronically in ARC GIS format.

Standard design flood hydrographs, routed through the hydrologic model, were used as the basis for the design hydrographs. These hydrographs were scaled based on the peak discharges (provided by HRC) and the shape of the October 2000 historical flood event to develop a hydrograph for each of the design floods. The flood hydrographs used for the design flood events are provided in Appendix A. The peak discharges used to scale the October 2000 flood are shown in Table 5-1.

Table 5-1 Design Flood Peak Discharges

Return Period AEP	Makakahi at Hamua (m^3/s)	Managatainoka at Larsons Road (m^3/s)	Managatainoka at Pahiatua Town Bridge (m^3/s)
1 in 100	452	280	797
1 in 200	487	283	834

6. Library Flood Map Runs

A series of hydrographs were run through the MIKEFLOOD model for various combinations of flows in the Mangatainoka and Makakahi Rivers, with the purpose of developing a series of inundation maps, which were then integrated with the flood forecasting system. These maps are referenced to real time, and posted to the web site for viewing or animation, during a flood event based on the forecast discharge at Mangatainoka River at Larsons Rd and Makakahi River Hamua. Table 6-1 shows the matrix of flood map reference runs generated for the web site library.

Table 6-1 Matrix of Library Flood Map References

	Makakahi at Hamua Discharge		
Mangatainoka at Larsons Rd Discharge	**150 m^3/s**	**220 m^3/s**	**300 m^3/s**
130 m^3/s	Mak150 Mang130	Mak220 Mang130	Mak300 Mang130
180 m^3/s	Mak150 Mang180	Mak220 Mang180	Mak300 Mang180
220 m^3/s	Mak150 Mang220	Mak220 Mang220	Mak300 Mang220
265 m^3/s	Mak150 Mang265	Mak220 Mang265	Mak300 Mang265

7. Web Site Interface

7.1 Introduction

The web site was developed in order to provide a visual estimate of expected inundation extents along the Mangatainoka River and Makakahi River based on the forecast estimates of discharge at Mangatainoka at Larsons and Mahakahi at Hamua from the real time flood forecasting model which was developed by HTC.

Visual estimates of flooding for the previous web site developed by HTC (Whanganui River) were based on a library of flood inundation maps developed from approximately 40 separate MIKEFLOOD model runs. This methodology was not possible with the Mangatainoka and Makakahi Rivers due to the nature of the breakout and overland flow where inundation follows various flow paths between the Mangatainoka and Makakahi Rivers. To take account of this, the visual estimates of flooding (for a particular forecast flood event) for the web site are based on the results from a single 24 hour model run (based on October 2000 flood) whose peak discharge best matches the peak discharge forecast by the real-time flood forecasting model. With this method the animation (see below) will display the progression of the flow through the overland flow paths as the flood event evolves.

Based on the outputs from the latest flood forecasting model run, the most appropriate set of model run results (a series of 96 inundation maps from a single model run of a 24 hour flood event) is chosen from the library (refer to Table 6-1) for display (either as a step through animation or individual maps) along with relevant data for the particular flood event.

Flood maps are shown on the web site for:

- The current situation.
- The peak forecast over the 48 hour forecast period.
- A fade through animation at a 15 minute time step for the entire 24 hours of the model run results selected from the library.

Based on advice from HRC, a flood discharge at Pahiatua of approximately 375m^3/s represents when flow is likely to breakout of the Mangatainoka and Makakahi Rivers. For all forecast flows below 375m^3/s at Pahiatua, a standard base map showing no flooding, is displayed on the website.

7.2 Linkage to Real Time Flood Forecasting Model

The web site is supplied with information in an xml file which is output from the most recent flood forecast run and updated every 30 minutes. The code that produces the xml file is in the Upper Manawatu hydrologic model named "Upper_Gorge.tso" which will be located with the other Manawatu flood forecasting models (as part of the HRC Flood Forecasting System). This model continuously updates every 30 minutes and produces output over a period from -12 hours to +48 hours.

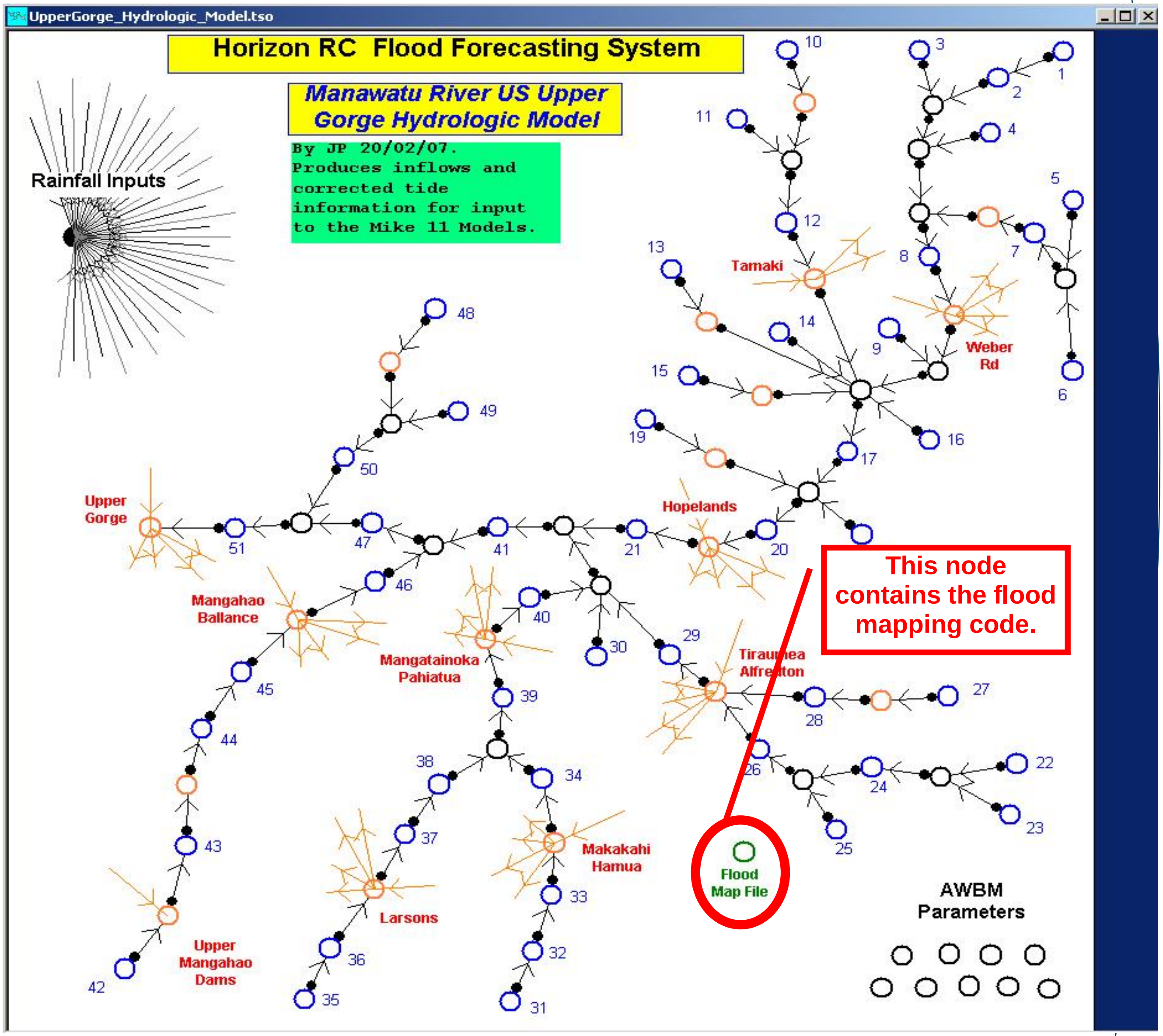


Figure 7-1 Location of xml file code in Upper Gorge hydrological model

The code in the flood forecasting model selects the appropriate map series to display over the 48 hour look-ahead period. A map is selected for every 15 minute time step in the future and for the current time. The map for the flood peak may be selected from the recent past (up to 12 hours before now) if no other significant events are forecast.

Note that the map selection process identifies one representative map series for the entire forecast period. This means that only one design hydrograph (and one design peak) is fit to the forecast, even if there are multiple floods forecast to occur in the 48 hour forecast window. This limitation is discussed further in Section 7.3 below.

To select a map the following process is executed:

- The peak modelled flow at Pahiatua is selected out of three time periods depending on the following criteria in order of decreasing priority (this has been done to ensure that the most appropriate flood is selected if there is more than one flood event during the time period considered by the model):

    1. The forecast maximum over the first 24 hours if it is greater than 375 m^3/s (nominally representing a flood close to breaching the river) even if it is not the maximum peak that has occurred over the entire forecast window. This has been adopted as the highest priority because it poses the most imminent flood threat in the region.

    2. If no case exists for Priority 1, the forecast maximum over the whole 48 hour period if it is greater than 375 m^3/s is selected even if it is not as big as a peak that has just occurred (i.e. within the last 12 hours, -12 hours to 0 hours in the flood-forecasting model run).

    3. If no case exists for Priority 1 or 2, the maximum over the whole time period is considered (i.e. from -12 hours to + 48 hours) is selected.

- As described in Section 6, the mapping run displayed on the web site is based on flows predicted at gauge sites Mangatainoka at Larsons and Makakahi at Hamua. These flows are selected by taking the maximum flow that is predicted to occur (or has occurred) at these sites over the 12 hours preceding the forecast flood peak at Mangatainoka at Pahiatua.

- The peak flows at Mangatainoka at Larsons and Makakahi at Hamua are rounded to the nearest flow value that has a corresponding mapping run in the library to select the appropriate map series (refer to Table 6-1 for the matrix of flood maps produced in this project). If the peak flow at both sites drops below approximately 130 m^3/s then the base map representing no breakout flow is selected.

- The flood maps for animation are then selected by matching the time of the predicted peak at Pahiatua to the time of the map that contains the design flood peak at Pahiatua. There are 96 maps in each map series covering a 24 hour time period (due to the design maps being based on a 24 hr flood event). To fill all other timesteps of the animation period (48 hours forecast) the base map is selected.

The web site automatically reads the map references and loads the correct maps from the library for display or animation.

The flood forecasting model also provides the date, time and flow value for the current time and the forecast peak at the three river gauges within the catchment (Mangatainoka at Larsons, Mangatainoka at Pahiatua and Makakahi at Hamua).

7.3 Web site Limitations

To correctly interpret the flood inundations displayed by the website it is important that the websites limitations are understood.

The website provides a 48 hour forecast period, however the 12 sets of flood model run results that the website displays are generated from model runs using a 24 hour duration flood event. This means that the total event hydrograph rises and falls within 24 hours, and correspondingly the animation displayed on the web site will show flooding spreading and then receding over 24 hours. This should be kept in mind when interpreting the web site animations for actual flood events whose during is significantly shorter or longer than 24 hours.

The real-time flood forecasting model does not pick a set of model run results for each peak flow in the 48 hour forecast period. Instead the maps shown on the website are from the most appropriate model run results, whose peak discharge is in time centred on the peak discharge forecast by the flood-forecasting model. This is shown graphically in Figure 7-2.

Note that the forecast period for flood peak selection varies depending on three priorities as discussed in Section 7.2. The intention of this is to ensure that if a potential river breach is forecast to occur within the next 24 hours, it is selected in preference to a flood of greater magnitude that may have just peaked or is forecast to occur further than 24 hours into the future.

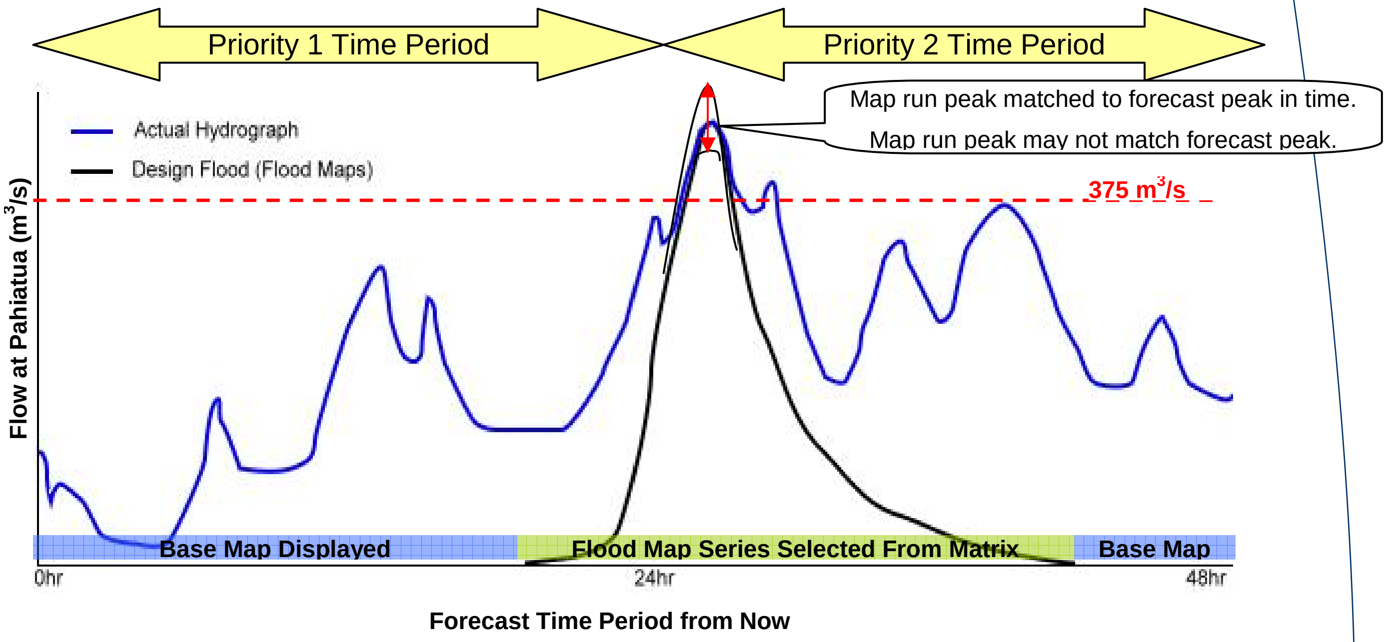


Figure 7-2 Location of the Modelled Hydrograph within the Forecast Period

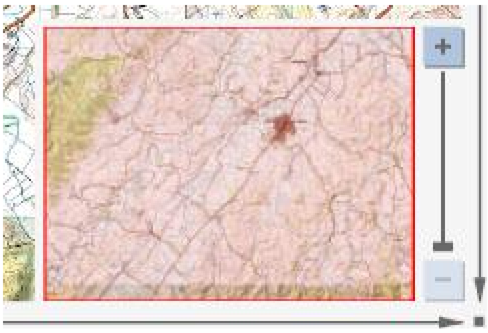
7.4 Web site Description

The web site has been developed utilising HTML, Javascript and SVG technologies. HTML and Javascript are handled as default by web browser's, most web browser's require a plugin to be installed to handle SVG. If your browser does not have the plugin installed the web site will notify you and give you the option to download it before continuing.

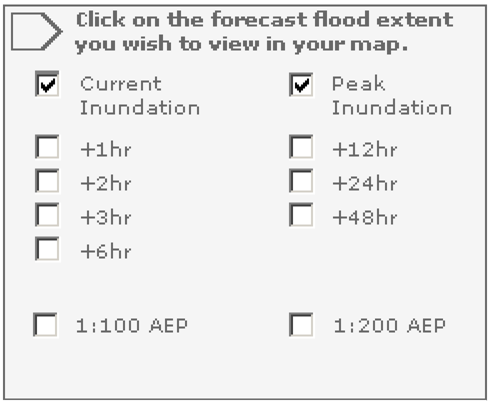
The web site has been optimised for Internet Explorer. The layout has been developed for a screen resolution of 1024*768, it should however operate satisfactorily at a variety of screen resolutions.

The following functionality has been presented in the web site:

Basic GIS Navigation Tools



Pan, Zoom, Zoom Full Extent, Mouse Pointer Coordinate Readout, Locality Window, Slider Bar Zoom In\Out.



Layer manipulation

Flood Forecast

The web site reads flood forecast information dynamically from a file summarising forecast results which is produced by the real time flood forecast model. See Section 7.2 for more information on the flood forecast. If administrators wish to look at the raw forecast file it can be found in the web site root directory, forecastData.xml.

Relevant components of the forecast information from this file are displayed to the user in the web sites "General Information" section.

Fade Through and Animations

The fade through represents an animated picture of the forecast floodlines for the period from time of forecast to 48hrs into the future at 15minute time steps. See Section 7.3 for an explanation of how this series is generated.

Technical

Installation of the web site was coordinated by Chris Veale of Horizons Regional Council.

The web site interface has been built upon open source SVG solution provided by carto.net, for more information see the following web site: http://www.carto.net/papers/svg/navigationTools/.

The following notes are relevant to the setup of the web site,

- All web site files are stored within in the MR_FDSS directory on the web server.
- The web site must be hosted on a machine accessible by the machine on which the Real Time Flood Forecast Model (RTFFM) is hosted. The RTFFM needs to be configured to upload its forecast files to the MR_FDSS root directory.

- User's machine clock must be on the same time zone as the server's clock.

Map Development

Two types of map data are displayed in the web interface – Background image and Floodlines.

Background Image: Sourced from 1:50k topographic maps supplied by Horizons. This image is a jpeg file and has been optimised for size whilst still retaining satisfactory image quality.

Floodlines: These are the lines\polygons displayed by the web site when the user turns on the Current\Peak\1hr\2hr\etc floodlines in the web site legend. These are also the floodlines used in the fade through. These lines are SVG vectors derived from ESRI Shapes files of the MIKEFLOOD model run outputs. They are accurate to 10m, the same resolution as the input grids used by MIKE FLOOD.

8. References

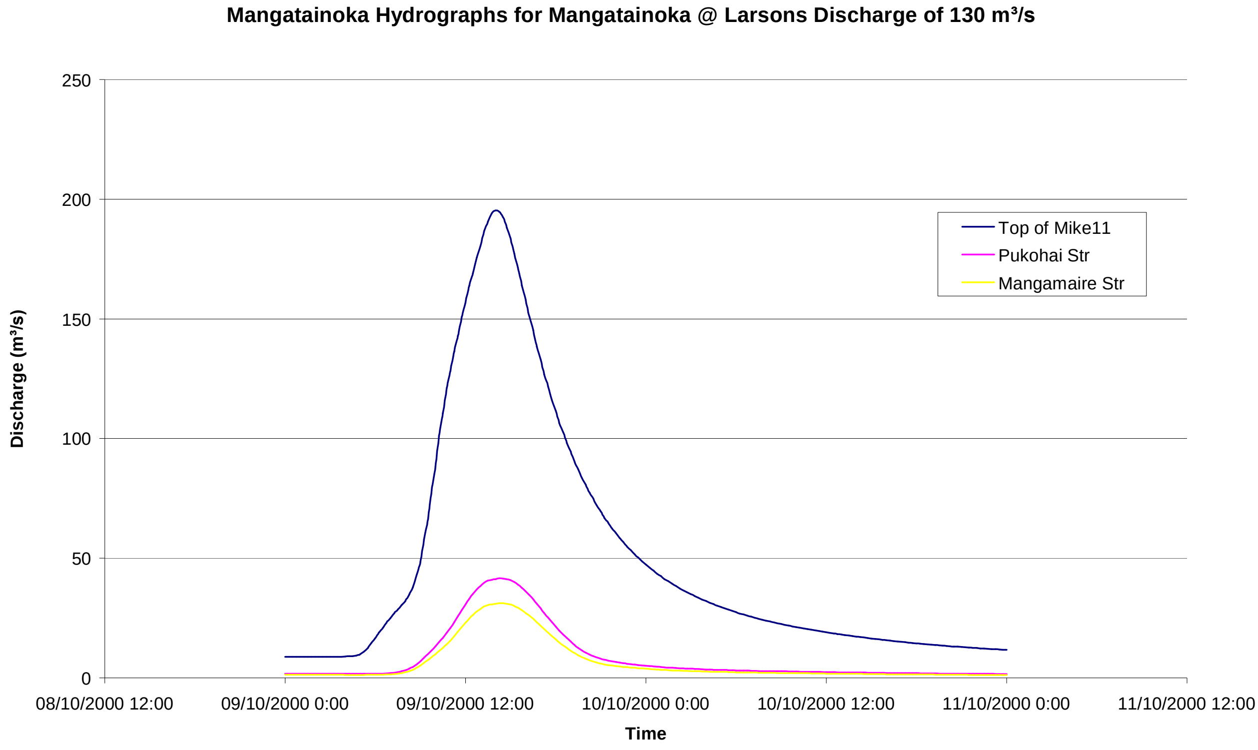
Hydro Tasmania Consulting, *Whanganui River Flood Forecasting System, Flood Map Preparation and On-Line Real Time Map Presentation*, E201911-Report-01, October 2007.

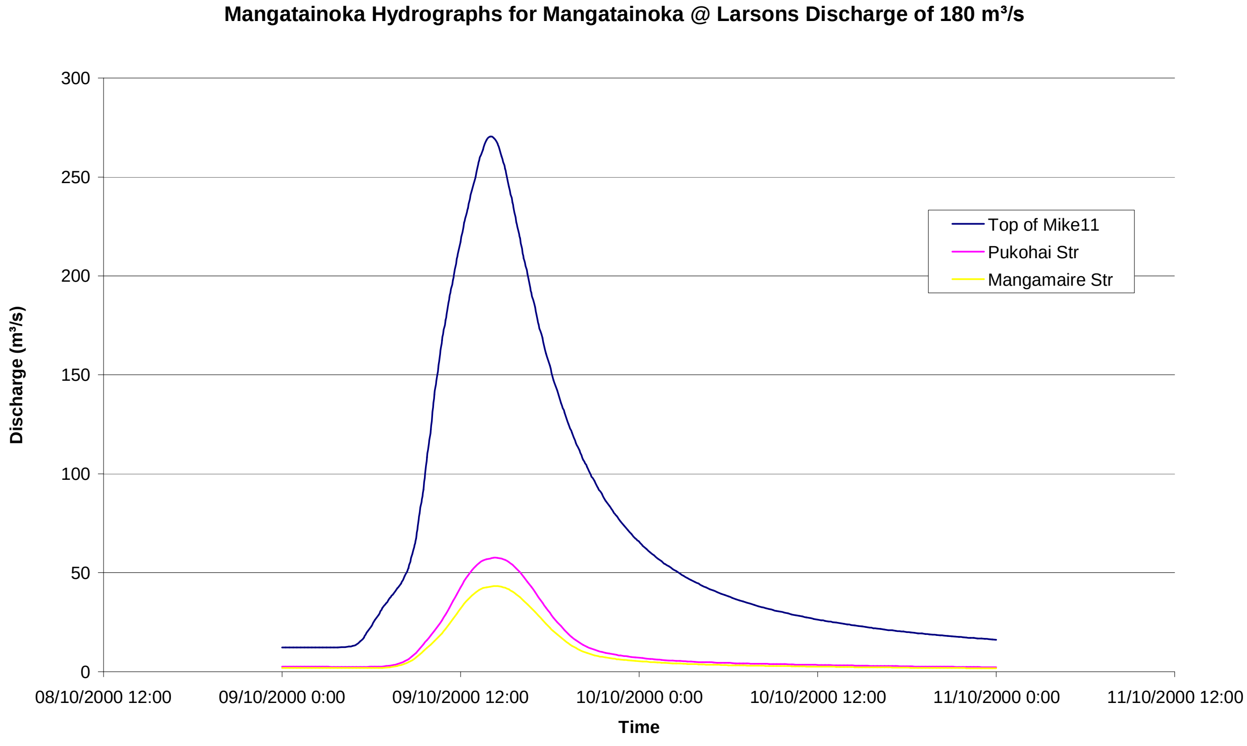
Hydro Tasmania Consulting, *Horizons Regional Council Flood Forecasting System - Whanganui Catchment Operating Manual*, 121040-Report-02, October 2007.

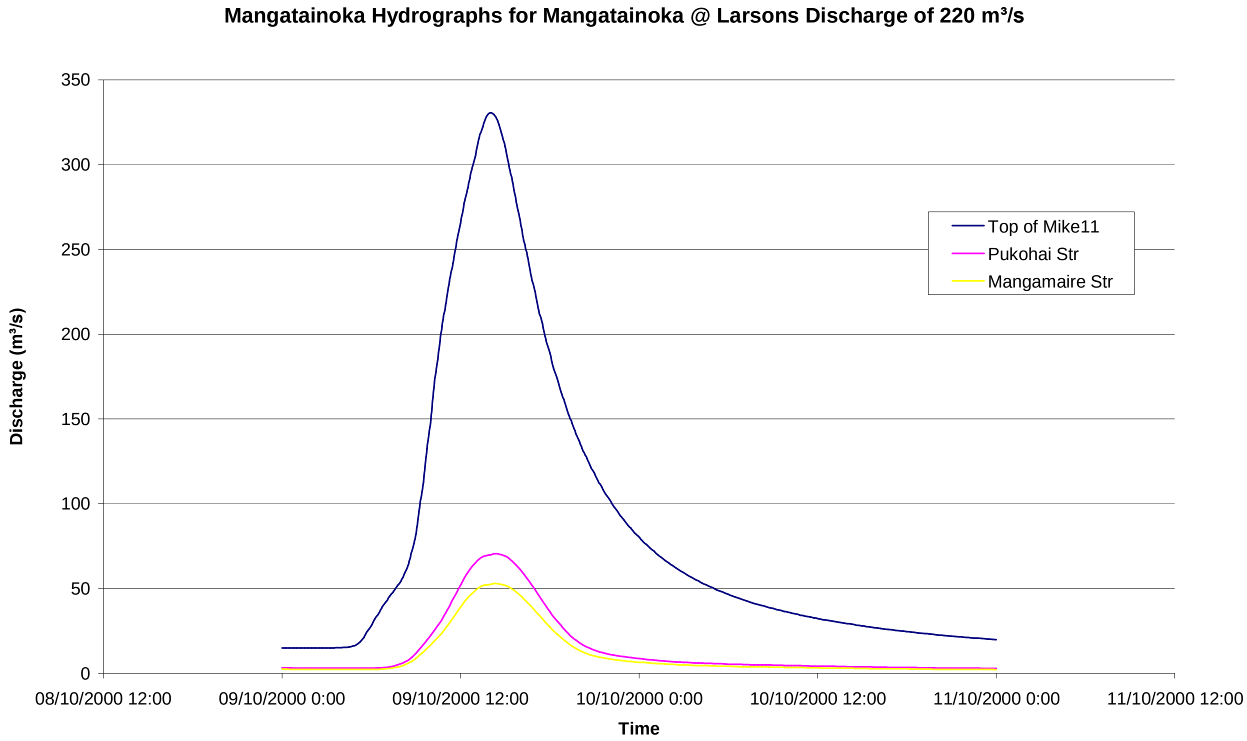
A. Flood Hydrographs

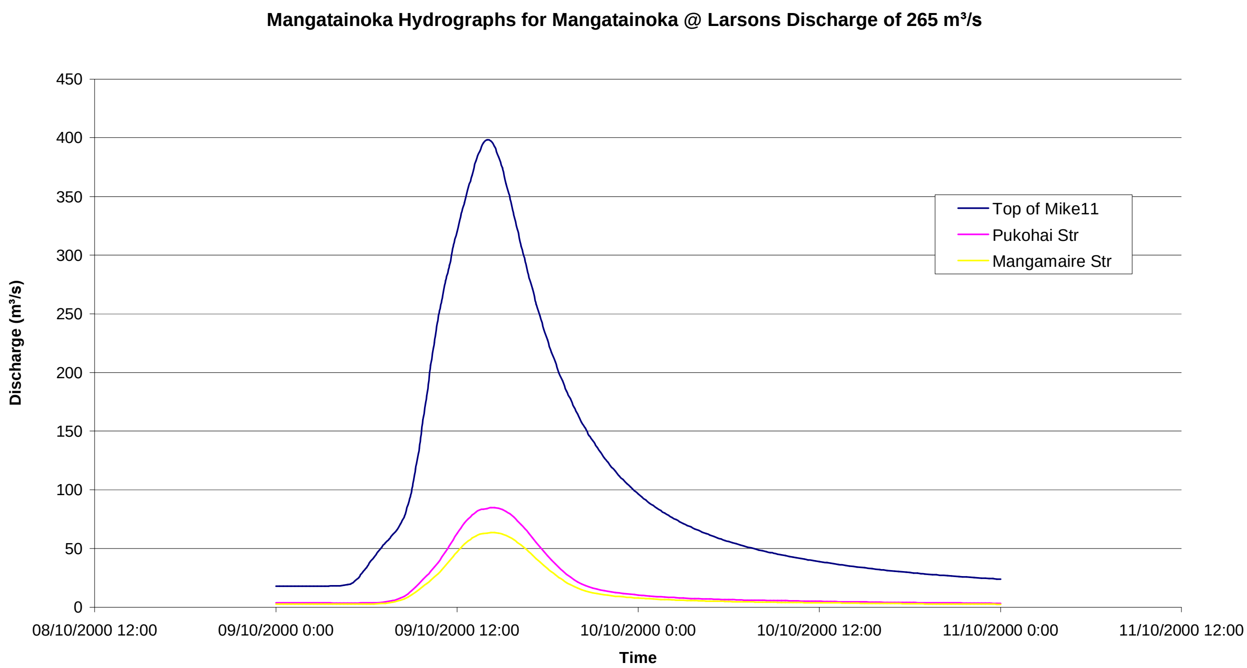
Flood hydrographs are provided for each of the flood events modelled.

Mangatainoka Flood Mapping Run Hydrographs (No Specific AEP)






Mangatainoka Hydrographs for Mangatainoka @ Larsons Discharge of 220 m³/s
Discharge (m³/s)
350
300
250
200
150
100
50
0
08/10/2000 12:00
09/10/2000 0:00
09/10/2000 12:00
10/10/2000 0:00
10/10/2000 12:00
11/10/2000 0:00
11/10/2000 12:00
Time
Top of Mike11
Pukohai Str
Mangamaire Str


Mangatainoka Hydrographs for Mangatainoka @ Larsons Discharge of 265 m³/s
Discharge (m³/s)
450
400
350
300
250
200
150
100
50
0
08/10/2000 12:00
09/10/2000 0:00
09/10/2000 12:00
10/10/2000 0:00
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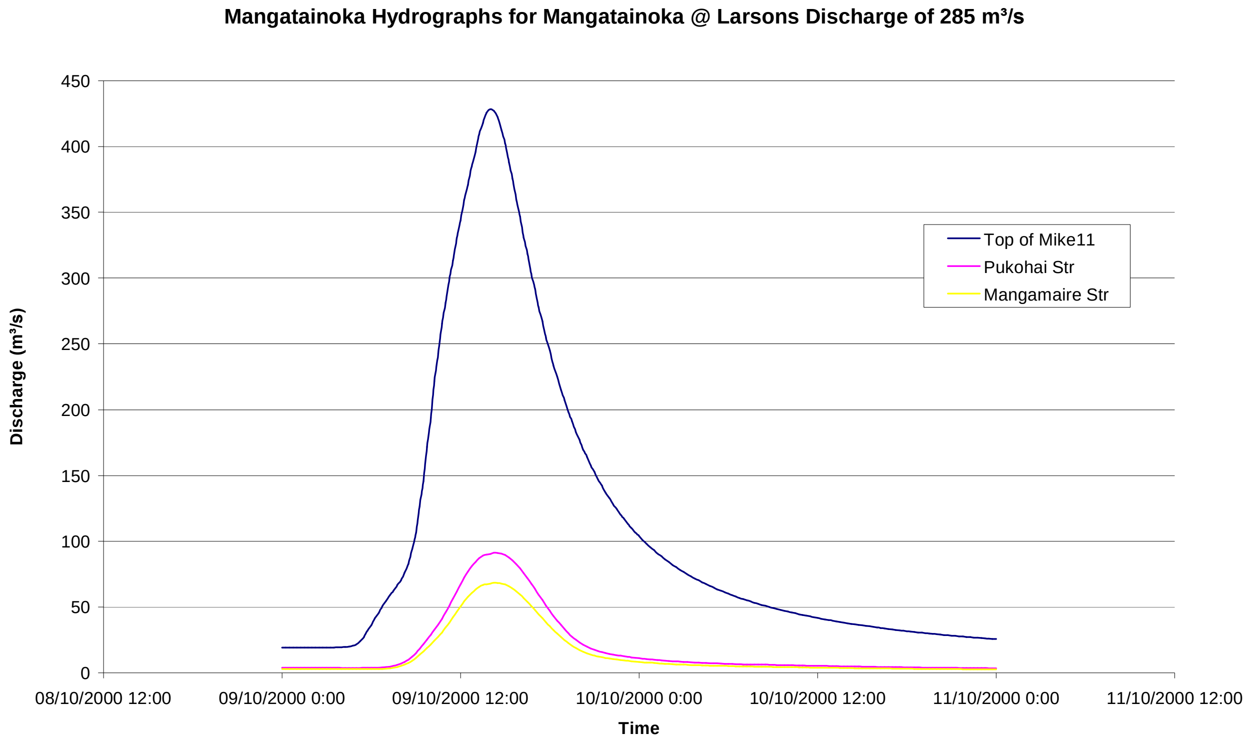
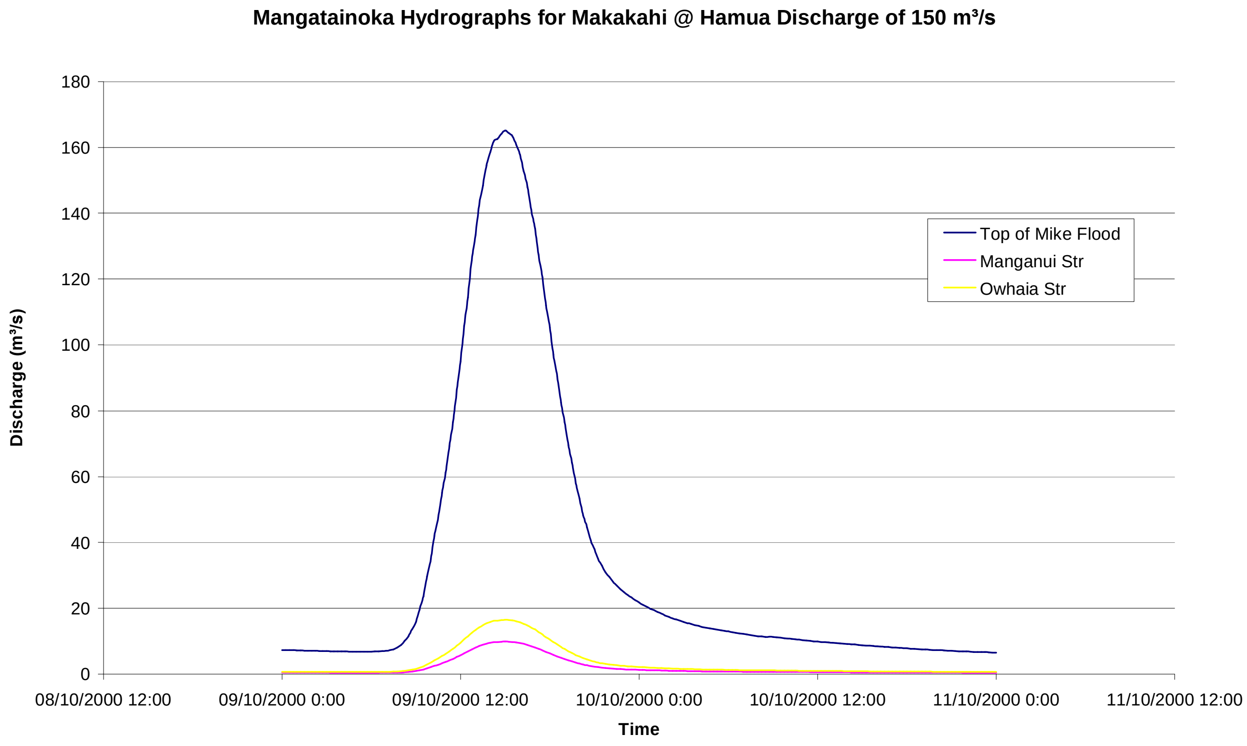
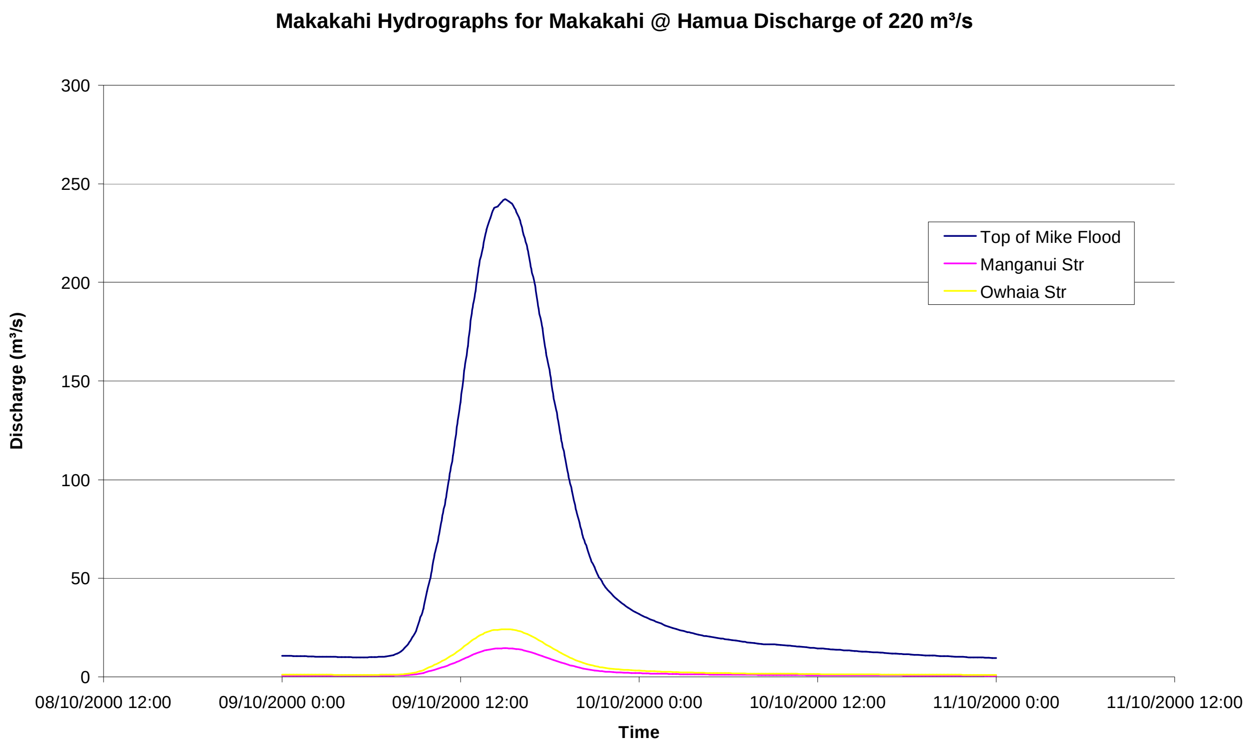
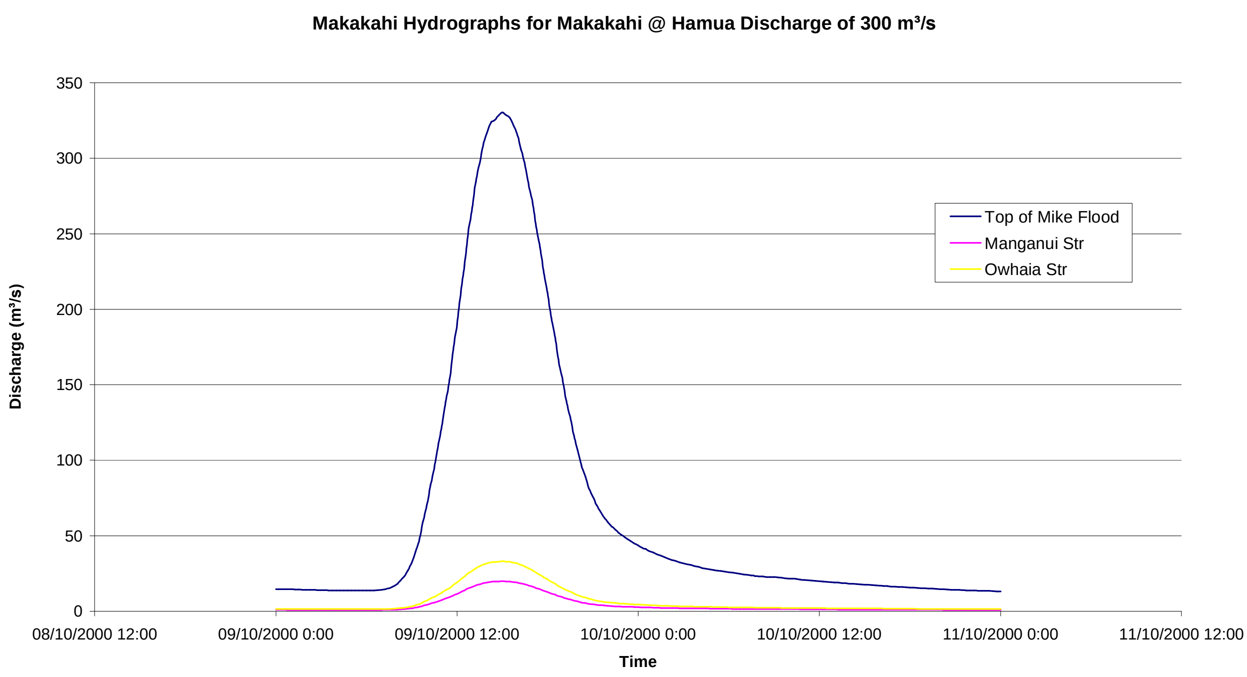
11/10/2000 0:00
11/10/2000 12:00
Time
Top of Mike11
Pukohai Str
Mangamaire Str



Makakahi Flood Mapping Run Hydrographs (No Specific AEP)

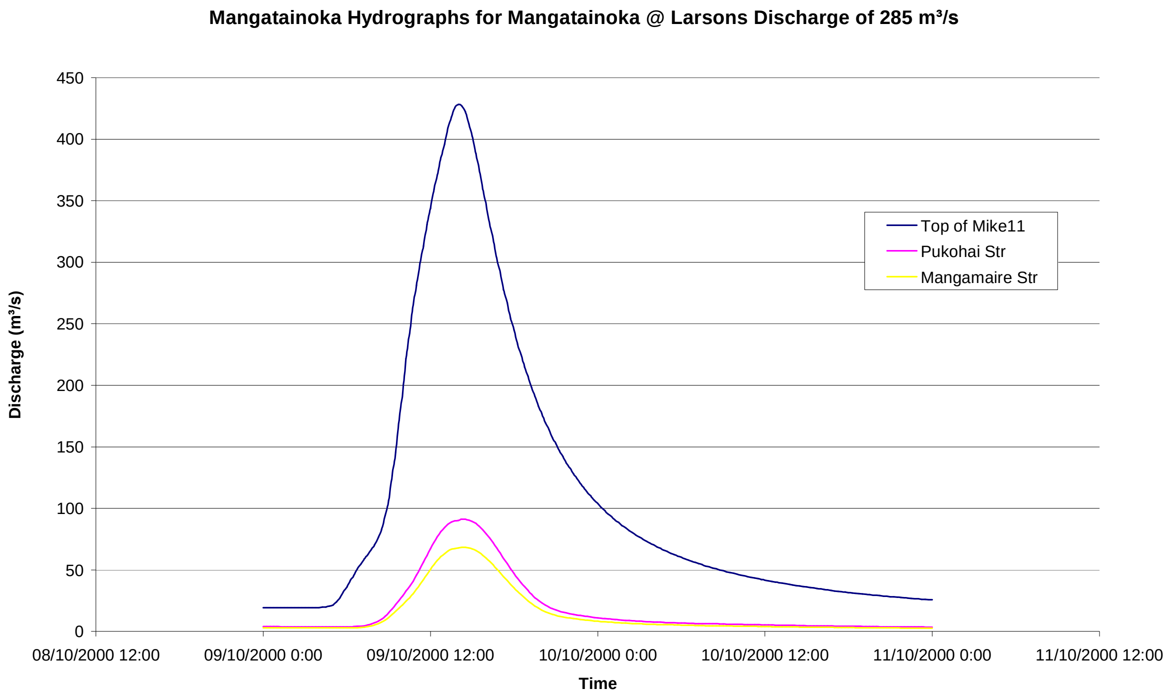



Makakahi Hydrographs for Makakahi @ Hamua Discharge of 220 m³/s
Discharge (m³/s)
300
250
200
150
100
50
0
08/10/2000 12:00
09/10/2000 0:00
09/10/2000 12:00
10/10/2000 0:00
10/10/2000 12:00
11/10/2000 0:00
11/10/2000 12:00
Time
Top of Mike Flood
Manganui Str
Owhaia Str


Makakahi Hydrographs for Makakahi @ Hamua Discharge of 300 m³/s
Discharge (m³/s)
350
300
250
200
150
100
50
0
08/10/2000 12:00
09/10/2000 0:00
09/10/2000 12:00
10/10/2000 0:00
10/10/2000 12:00
11/10/2000 0:00
11/10/2000 12:00
Time
Top of Mike Flood
Manganui Str
Owhaia Str

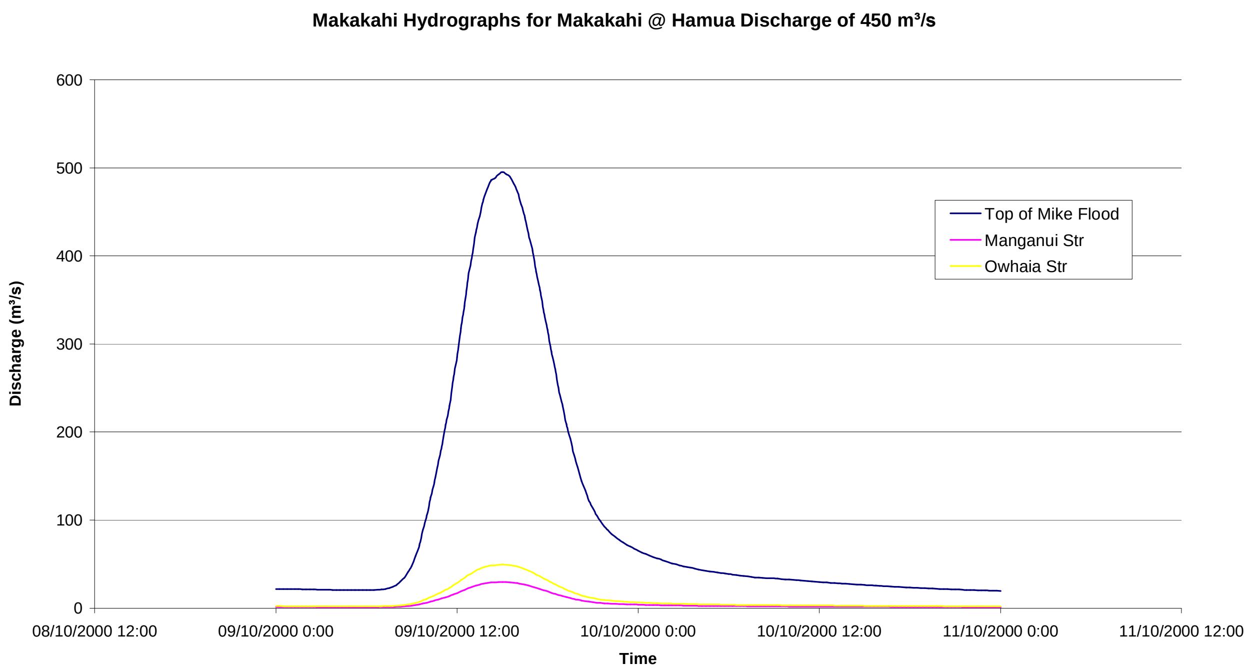
Mangatainoka Design Hydrographs

1:100 AEP Hydrographs and 1:200 AEP Hydrographs Similar



Makakahi Design Hydrographs

1:100 AEP Hydrographs



1:200 AEP Hydrographs