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Floodplain Mapping

Feilding Township and Adjacent Rural and Semi-Rural Areas

ENTURA-5457F

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1. Introduction

Entura was commissioned by Horizons Regional Council (HRC) to carry out a flood study for Feilding and the surrounding rural and semi-rural areas that are potentially affected by flooding from urban stormwater runoff and the coincident flooding from the Makino and Kiwitea Stream/Oroua River.

The scope of this study included the following:

- Develop MIKE 21 DEM and roughness grid from LiDAR data provided by HRC.
- Set up integrated 1D/2D MIKE FLOOD hydraulic model for the township of Feilding based on cross sections of Makino Stream, details of bridges along Makino Stream and MIKE 21 DEM and roughness grid.
- Convert the existing Infoworks model of Feilding Stormwater Network to MIKE URBAN model and then couple the MIKE URBAN model to 2 dimensional MIKE FLOOD hydraulic model.
- Set up hydrological rainfall-runoff model and then produce design rainfall hyetograph and flood hydrograph to include in the model.
- Include new and raised existing stopbanks and levees along the Oroua River in DEM of model.
- Run the hydraulic model for the 1 in 100 AEP and 1 in 200 AEP design events for the existing condition of Reid Line Stopbank and the 1 in 100 AEP and 1 in 200 AEP design events with the Reid Line Stopbank lowered by 500 mm (freeboard).
- Include suction of water from Makino Stream at diversion structure to incorporate bed scouring during larger flood events.
- Convert MIKE 21 result files to WaterRide files (.wrr files).

This report summarises the hydrologic and hydraulic modelling that was carried out. Raw result files (MIKE URBAN, MIKE 11 and MIKE 21) were provided to HRC. MIKE 21 result files were converted to WaterRide files (.wrr files), and provided to HRC to be viewed using the WaterRIDE software package to assess flood levels, depth, inundation and hazard for the modelled events. MIKE URBAN result files for the pipe stormwater drainage system and MIKE 11 result files for the open channel streams and drainage system can be viewed using the MIKE VIEW software package.

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2. Hydrology

2.1 Overview

Design hydrographs and rainfall inputs have been produced for input into the MIKE FLOOD Urban hydraulic/hydrologic model developed for the Fielding area. The following inputs have been produced:

- For the Makino River to Boness Rd catchment – rainfall runoff model with design rainfall inputs.
- For the stormwater drain catchments in the urban areas – direct rainfall was prepared for input to the MIKE FLOOD Urban hydrologic model.

The following steps were taken to prepare the inflow hydrographs for the rivers and streams:

- Design Rainfalls and temporal patterns were derived for the Makino River catchment.
- A rainfall runoff routing model was developed and calibrated to historical flood events at Makino River at Rata St and Makino River at Reids Line. Rainfall losses were accounted for using an initial loss proportional runoff (IL PR) model.
- Design rainfall losses were adopted by calibrating the model with design rainfall inputs to the flood frequency curve at Rata St.
- Design flow hydrographs were produced for a range of rainfall durations from 30 minutes up to 24 hours for annual exceedance probabilities of 1:100 and 1:200.

The direct rainfall was used as an input to the MIKE FLOOD Urban model whose hydrologic engine was used to estimate urban runoff following the procedure recommended by the Auckland Regional Council (1999).

2.2 Input Data

Figure 2-1 and Table 2.1 show the location and relative details of the available streamflow and rainfall gauging site information. The way each site has been utilised in the study is outlined in the table and in the following sections.

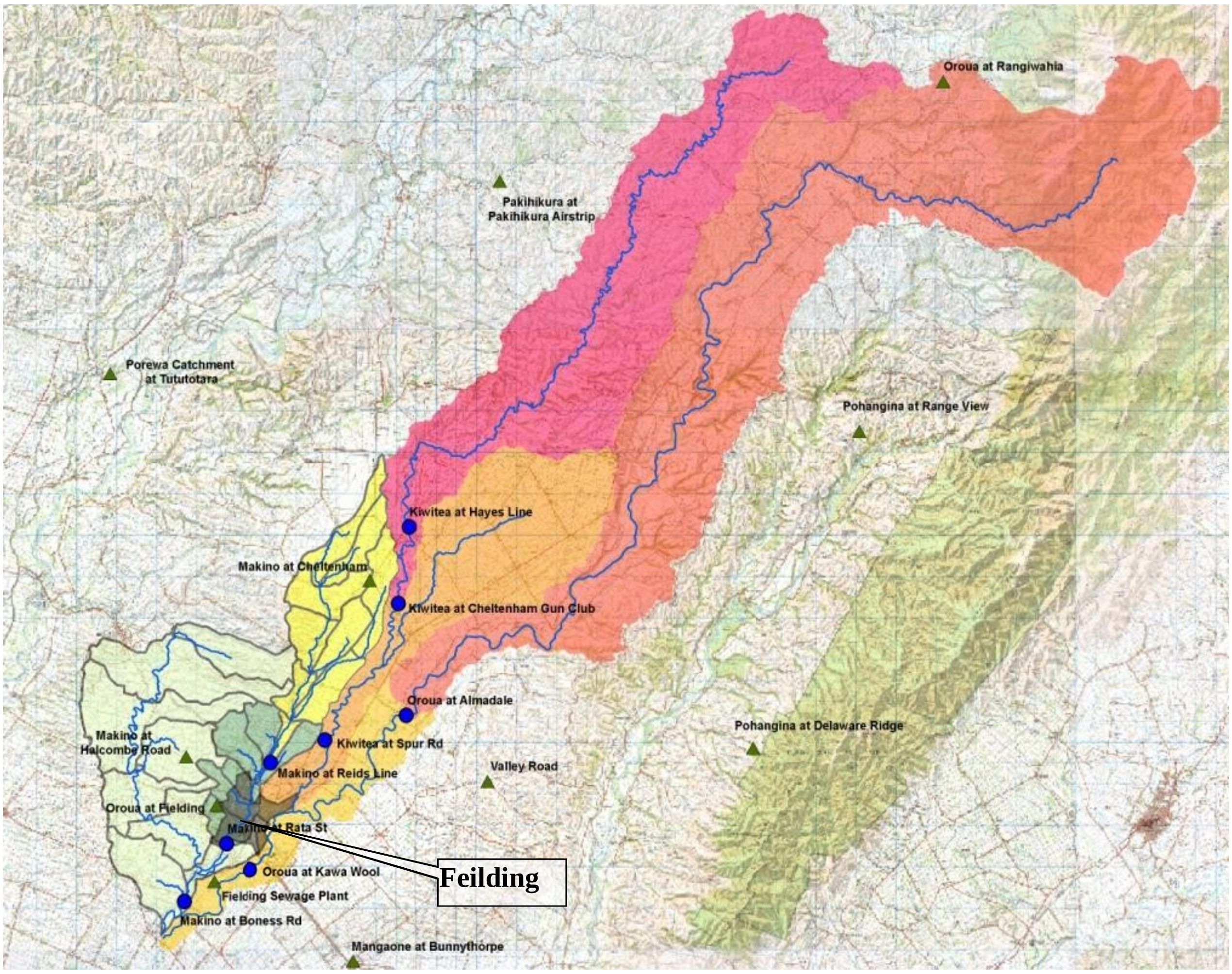

Figure 2-1
Location of Streamflow (Blue circle) and Rainfall (Green Triangle) time series data

Table 2.1
Flow and rainfall station details

Site	Measurement	Start	Finish	Used For
Makino at Boness Rd	Flow	1992	2011	Record not used. Affected by outbreak flows in floods
Makino at Rata St	Flow	1987	2011	Primary site used for event and loss calibration of the model
Makino at Reids Line	Flow	1987	2011	Used for event calibration
Kiwitea at Cheltenham Gun Club	Flow	1999	2004	Used to check against flows at other locations
Kiwitea at Haynes Line	Flow	2005	2011	Used to check against flows at other locations
Kiwitea at Spur Rd Extension	Flow	1976	1998	Used for deriving inflow flood hydrographs

Site	Measurement	Start	Finish	Used For
Mangaone at Milson Line	Flow	1978	2009	Used to check against flows at other locations
Oroua at Almadale	Flow	1948	2011	Used for deriving inflow flood hydrographs
Oroua at Kawa Wool	Flow	1967	1992	Used to check against flows at other locations
Feilding Sewage Plant	Rainfall	1967	2000	Note long period of missing record. Used for mean annual rainfall calculations over catchment
Makino at Cheltenham	Rainfall	1990	2011	Primary rainfall site used in model calibration due to time step and record quality
Makino at Halcombe Rd	Rainfall	1999	2011	Primary rainfall site used in model calibration due to time step and record quality
Mangaone at Bunnythorpe	Rainfall	1967	1998	Used for mean annual rainfall calculations over catchment
Mangaone at Milson Line	Rainfall	2001	2011	Used for mean annual rainfall calculations over catchment
Mangaone at Valley Rd	Rainfall	1973	2011	Used as replacement for Halcome Rd site in model calibration where Halcome Rd record not available
Oroua at Fielding	Rainfall	1960	2003	Used for mean annual rainfall calculations over catchment
Oroua at Rangiwahia	Rainfall	1974	2011	Used for mean annual rainfall calculations over catchment

2.2.1 Design Rainfalls

Design rainfall depths were supplied by HRC and derived using HIRDS software at the following locations:

- Feilding Sewage Plant
- Makino at Cheltenham
- Makino at Halcome Road
- Mangaone at Bunnythorpe
- Mangaone at Milson Line
- Mangaone at Valley Road
- Ngahere Park Climate Station
- Oroua at Feilding

- Oroua at Rangiwahia

Design rainfalls were derived for three catchments: Makino at Rata St, Makino at Reids Line and Feilding Urban Area. These are plotted in Appendix A for a range of flood AEPs and durations. For each duration the 1:200 AEP rainfalls have been extrapolated to best fit the log curve of the rainfall depths of all other AEPs up to 1:100.

Rainfall aerial reduction factors were used to adjust the rainfall depths according to methodology that applies to South East Australia (Siriwardena & Weinmann, 1996). Aerial reduction factors at two locations in Europe (Witter J.V, 1983) are found to compare well with those in SE Australia for two sample events as shown in Table 2.2 below. The tables of modified rainfall depths for each catchment are also located in Appendix A. For the Makino at Rata St catchment, the catchment rainfall is the average of the Makino at Cheltenham and Feilding point rainfalls, multiplied by the areal reduction factor.

	24hr, 1000km2	1hr, 5 km2
Netherlands	0.878	0.904
UK	0.866	0.912
SE Aust	0.837 - 0.88	0.91

Table 2.2
Aerial Reduction Factors in various locations around the world

Design temporal patterns have been derived for the catchment using the average of rainfall records at Makino at Cheltenham and Makino at Halcombe Rd for each event analysed. Thirty patterns have been derived for each duration based on the largest rainfall bursts in the historical record. The temporal patterns from the ten largest storms were used in the design model runs. The temporal patterns are filtered to ensure that there are no embedded bursts of more extreme rainfalls than the AEP range of interest (RORBWin 2007). The resultant design temporal patterns for each duration between 30 minutes and 48 hours are shown in Appendix A.

A uniform spatial pattern was adopted for design rainfalls over the catchment.

2.3 Hydrologic Model Development

A rainfall runoff routing model was built using Hydstra Modelling software. Rainfall losses were accounted for using an initial loss proportional runoff (IL PR) model.

The rainfall runoff routing model is linked to an interface developed in Microsoft Excel that can prepare the input data, perform multiple model runs and summarize all the outputs. The interface was used to perform 150 multiple model replicates for each AEP and duration, each run randomly selecting from the range of 10 temporal patterns. This produces a distribution of results from which the median magnitude flood peak is adopted. It also provides an indication of the possible range of results depending on which temporal pattern is used.

The model catchment break-up for calibration is shown in Figure 2-2. Two models were prepared: one to calibrate to flow events and flood frequency at Makino at Rata St, and the other to produce the design hydrographs for input to the hydraulic model.

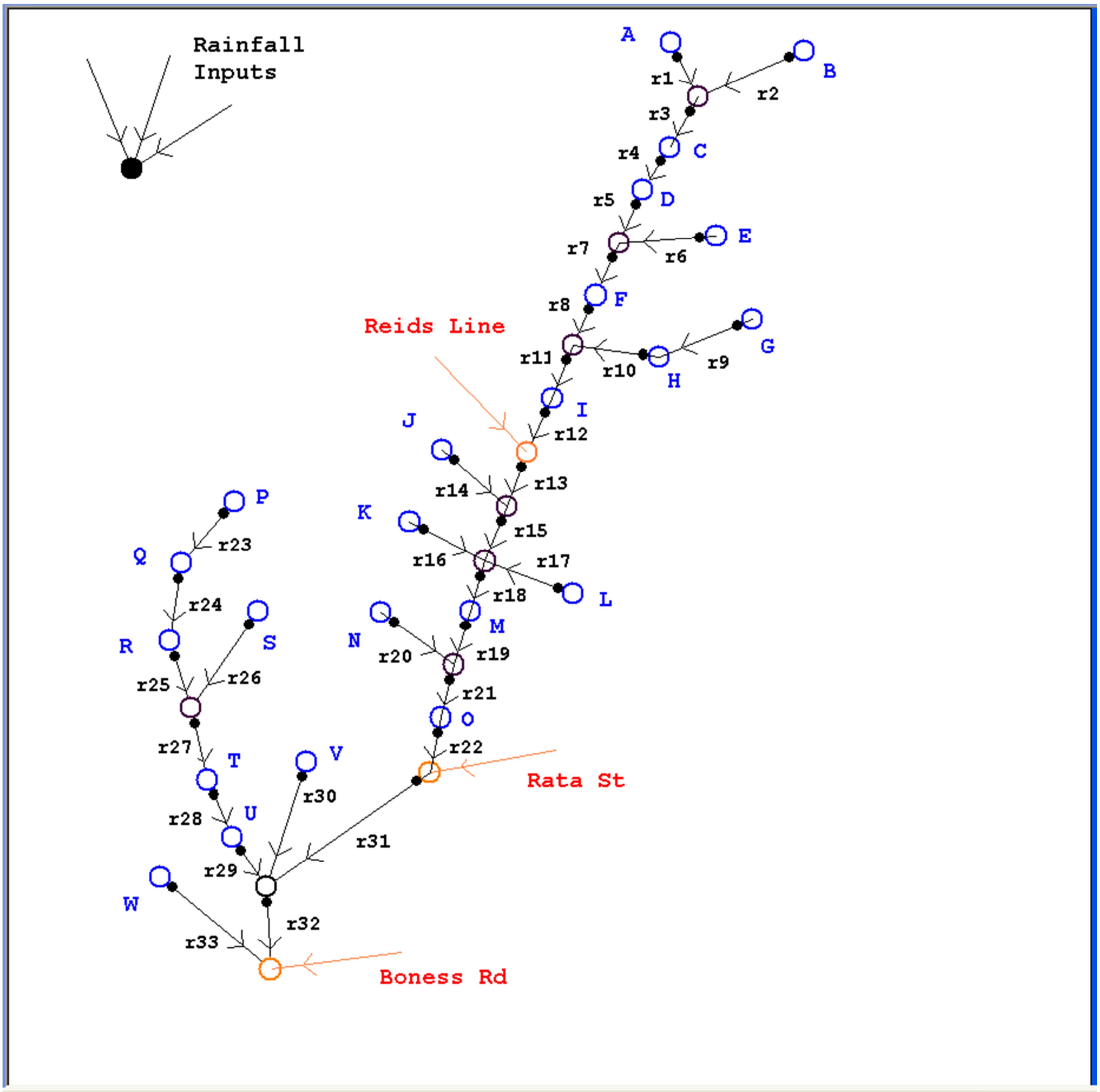

Figure 2-2
Model catchment sub areas for event calibration

2.4 Model Calibration

The hydrologic model was calibrated in two stages:

- Firstly the channel lag parameters (Alpha, n and Time Delay) were calibrated by best fitting the modelled flows to measured flood events at Makino at Rata St and Makino at Reids Line. Measured rainfalls were input into the model.
- Secondly the rainfall loss parameters (IL and PR) were calibrated by best fitting the modelled flood peaks to the measured flood frequency curve at Makino at Rata St, particularly for the rarer AEPs (1:50 and 1:100). Design rainfall depths and temporal patterns were used as inputs.

The results of each approach are discussed further below.

2.4.1 Event Calibration

Seven events were selected for event calibration including at each site.

Measured rainfall inputs were distributed through the model. Rainfalls from Makino at Cheltenham were used for the upper catchments, and Makino at Halcombe Rd rainfalls were used for the lower catchment. Rainfalls in the middle catchment were weighted based on distance from each of these sites.

A baseflow separation model was used to derive the baseflow component of each flood hydrograph. These flows have been added to the modelled surface runoff during the calibration of each event. The event plots are shown in Appendix B and a results summary for each site is shown in Table 2.3. A constant Alpha of 1.15 was also trialled for calibration of events at Rata St and was found to give good results.

The adopted parameters for design runs are:

- Alpha = 1.15
- n = 0.8

The estimated baseflows at the time of the peak of each event have also been provided in the table below. The average baseflow at the peak of each event was found to be 1.2 m^3/s.

Table 2.3
Results of hydrologic model event calibration

Reids Line						
Event	**Peak Flow (m^3/s)**	**Alpha**	**IL (mm)**	**PR**	**Delay (hrs)**	**Base Flow (m^3/s)**
Feb-04	91	1.5	2	0.90	2.33	0
Aug-01	62	0.90	3	0.89	1.83	2
Nov-94	48	1.12	0	0.85	2.50	1
Sep-10	46	0.85	15	0.87	1.00	0
Nov-99	43	1.50	15	0.70	0.83	0
Oct-98	34	1.12	13	0.98	1.33	0
Jul-98	31	1.12	2	0.68	1.83	0
AVERAGE	50.71	1.16	7.14	0.84	1.66	0.4
MEDIAN	46.00	1.12	3.00	0.87	1.83	0.0
MIN	31.00	0.85	0.00	0.68	0.83	0.0
MAX	91.00	1.50	15.00	0.98	2.50	2.0
St DEV	20.44	0.26	6.82	0.11	0.64	0.8

Rata St						
Event	**Peak Flow (m^3/s)**	**Alpha**	**IL (mm)**	**PR**	**Delay (hrs)**	**Base Flow (m^3/s)**
Feb-04	100	1.35	1	0.73	0.50	2.0
Aug-01	68	0.85	2	0.85	1.67	4.0
Nov-94	56	1.15	2	0.80	1.17	2.5
Sep-10	53	1.30	8	0.80	0.50	0
Nov-99	54	1.35	2	0.53	1.83	0
Oct-98	56	0.90	15	1.00	1.83	0
Jul-98	51	1.00	10	1.00	1.17	0
AVERAGE	62.57	1.13	5.71	0.82	1.24	1.2
MEDIAN	56.00	1.15	2.00	0.80	1.17	0.0
MIN	51.00	0.85	1.00	0.53	0.50	0.0
MAX	100.00	1.35	15.00	1.00	1.83	4.0
St DEV	17.40	0.21	5.38	0.16	0.58	1.6

2.4.2 Losses Calibration

Using the adopted parameters from the event calibration, the model was run using design rainfall inputs to confirm the rainfall loss parameters. The results are plotted against the measured flood frequency curve at Rata St in Figure 2-3.

The adopted loss parameters are:

- IL = 2 mm
- PR = 0.62 (PR is the proportion of continuous runoff from the rainfall)

It was noted that the PR parameter of 0.62 is lower than the average of the event calibration. The design rainfalls were checked against the input rainfalls and were found to be approximately 15 percent larger than the equivalent design rainfalls derived from a frequency curve at the Cheltenham gauge. The design rainfalls from HDIRS were retained and the calibrated PR of 0.62 was used for design.

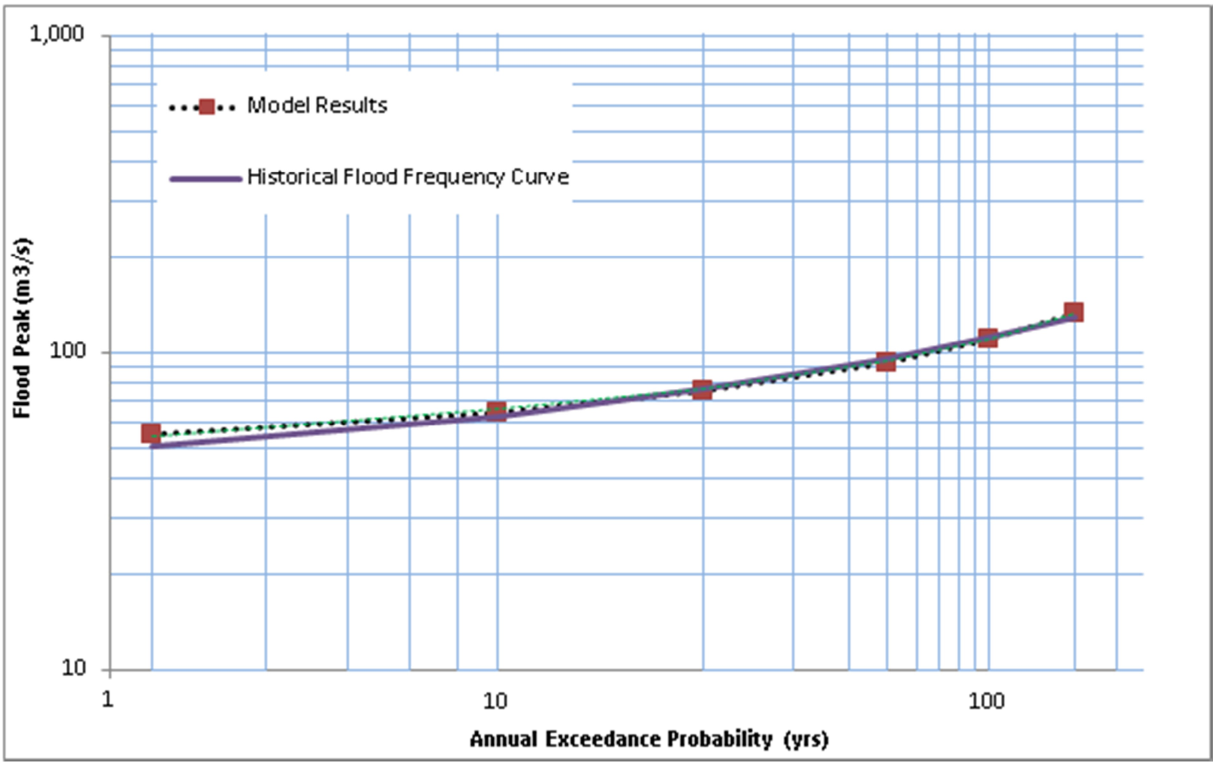

Figure 2-3
Measured flood frequency at Rata St showing results of hydrologic model loss calibration

2.5 Derivation of Design Inflow Hydrographs

Design flood inputs have been produced for Annual Exceedance Probabilities (AEP) of 1:100 and 1:200 for the following range of storm durations: 20min, 30 min, 1 hr, 2hr, 6hr, 12hr and 24 hr. Hydrologic inputs to the hydraulic models comprise of both:

- Design hydrographs inputs at the boundary of the coarse scale MIKE 21 model extent and within the MIKE FLOOD Urban extent for all catchments that drain directly into the river system.
- Direct design rainfall inputs (no losses applied) for all the catchments that drain into the stormwater network. The MIKE FLOOD Urban model was used to model runoff in these catchments and is discussed in more detail in Section 2.6.

The likelihood of concurrent flooding was investigated (i.e. the likelihood of inflows at Oroua and Kiwitea occurring at the same time as a flood peak in the Makino at Rata St catchment). This was done by plotting the largest historical events with measured flows at Makino, Oroua and Kiwtea and rainfall histograms. The approximate AEP of the event at each site was determined, along with the timing difference between flood peaks. Using the results of this analysis and discussions with HRC, it was decided to use the same AEP for the concurrent flood for Kiwitea as for Makino. At Oroua a concurrent flood of 1:50 AEP was used for the 1:100 AEP flood in Makino River, and 1:75 AEP flood for the 1:200 AEP flood in Makino River.

Figure 2-4 shows the locations of the inflow points for the hydraulic model. For the inflows at Kiwitea and Oroua, the inflow hydrographs have been derived by scaling of the hydrograph for the July 1998 event at each flow gauge. These hydrographs are shown in Appendix C for the 1:100 and 1:200 AEP events in Makino River at Rata St, along with the design flood hydrographs for all other input locations. The 6hr duration was found to be critical for these floods.

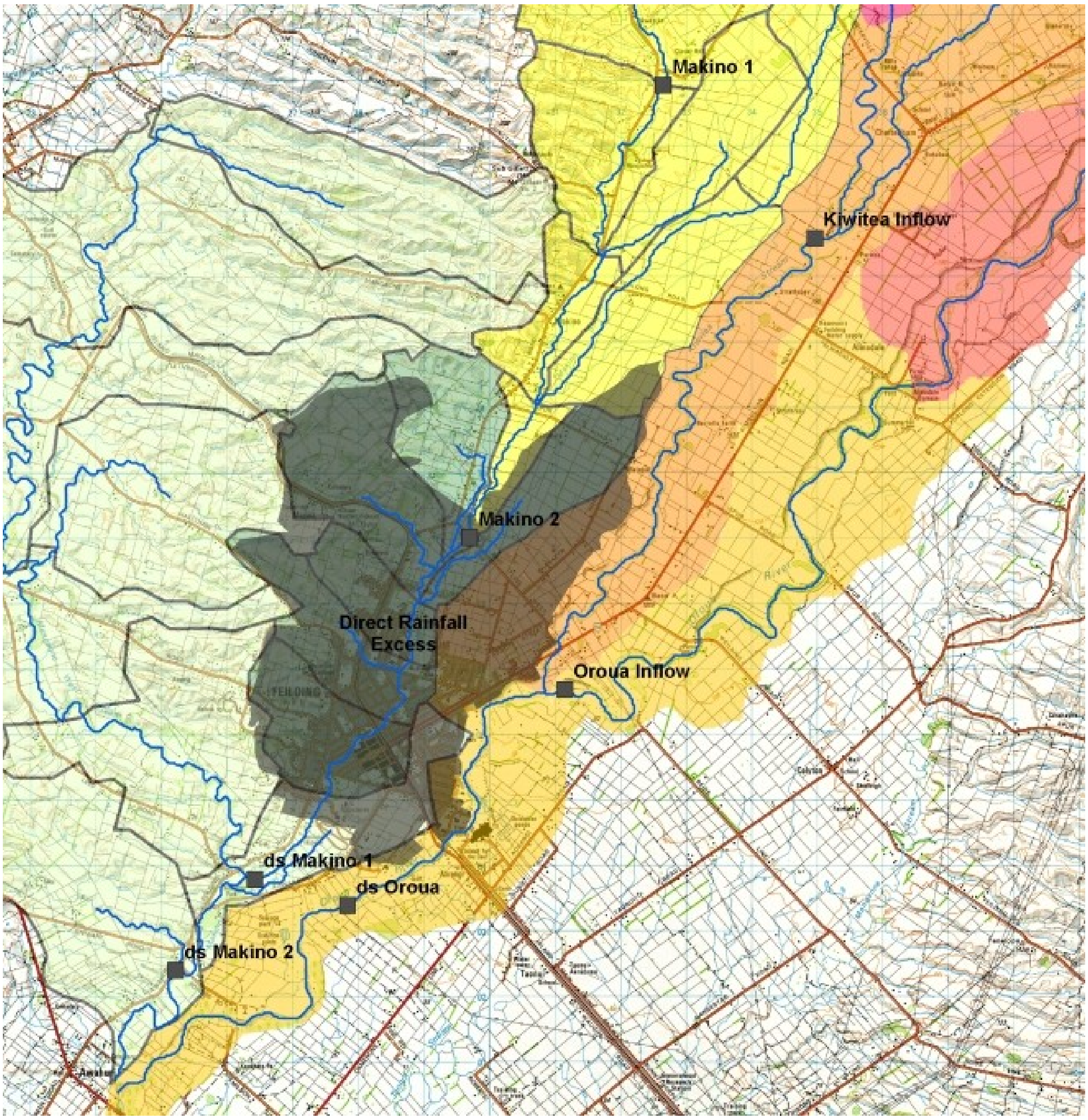

Figure 2-4 Location of inflow hydrographs

2.6 Urban Hydrology

Runoff from the urban catchments, as defined by the catchment boundaries shown in Figure 2-4 shaded in grey, was estimated using the Unit Hydrograph Method (UHM) based on the direct design rainfall inputs discussed in Section 2.5.

The UHM is recommended by Auckland Regional Council for modelling stormwater runoff from urban catchments based on evaluation of the method against gauged catchments. Details of the method are provided in Technical Publication 108.

The UMH is supported by the MIKE URBAN software package and the following inputs are required:

- Rainfall patterns and depths.
- Rainfall losses.
- Catchment area.
- Catchment slope and lag time for runoff calculations.

2.6.1 Rainfall Patterns and Depths

The rainfall patterns and depths outlined in the previous sections of the report were adopted.

2.6.2 Rainfall Lossess

Rainfall lossess were estimated using the set of curves developed by the US Soil Conservation Service (SCS, 1972). The curves represent the differing typical land types within urban and cultivated catchments for a range of four different soil types.

The SCS generalized method was adopted to take into account initial losses consisting of interception, infiltration and storage as well as continuing losses.

Antecedent storage depths are used to represent initial rainfall losses based on the curve numbers adopted for the catchments. The adopted antecedent storage depths are shown in Table 2.4 and are based on Table 10.1 (SCS, 1972) using antecedent moisture content Type III (AMC-III). AMC-III was adopted as it provided a maximum initial loss of 9mm for rural soils.

Based on advice from HRC, soil type similar to Pahiatua ie, soil type C was adopted and the infiltration for this soil of 1-4mm/hr best matches the rate of infiltration expected for the Feilding soils.

For each catchment within the urban area a curve best representing the land type was chosen. The typically adopted curves and antecedent storage depths for Feilding are provided below. The adopted curve number for each catchment is provided in Appendix D.

Table 2.4:
SCS curve numbers and antecedent storage depths

Curve Number	Description	Antecedent Storage Depth (mm)
98	Roads and large parking lots.	0.51
94	Commercial and industrial areas.	0.7
90	1/8 acre residential lots, approx 65% impervious area.	2.08
83	1/4 acre residential lots, approx 38% impervious area.	3.8
81	1/3 acre residential lots, approx 30% impervious area.	4.4
80	1/2 acre residential lots, approx 25% impervious area.	5.01
70	Rural and grasses areas.	8.9

2.6.3 Catchment Area

The catchment areas within the urban area were based on the Infoworks model provided by HRC. The adopted catchment areas are provided in Appendix D.

2.6.4 Catchment Slope and Length

For each urban catchment, the catchment length and equal area slope were taken from the Infoworks model provided by HRC for use in calculation of the catchment lag time by the MOUSE (DHI 2011) calculation engine in the MIKE URBAN model. The catchment lengths and equal areas slope are based on the InfoWorks model provided by HRC and are provided in Appendix D.

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3. Hydraulics

3.1 Introduction

The hydraulic modelling for this project was carried out using the MIKE FLOOD Urban (version 2011) software package. This software package combines the MIKE 11 1D, MIKE URBAN 1D and MIKE 21 2D software packages into a single model, where the significant river channels/open channels were modelled using MIKE 11 cross sections, stormwater drainage was modelled using MIKE URBAN (MOUSE computational engine) and overland flow is modelled using MIKE 21. The model was developed by coupling river channels to overland flow and stormwater drainage to both river channels and overland flow.

3.2 General Setup

A MIKE FLOOD Urban model was developed for the township of Feilding and the surrounding rural and semi-rural areas that are potentially affected by stormwater flooding, the coincident flooding from the Makino and Kiwitea Stream and the Oroua River and the water spilled from Reids Line Stopbanks.

The study area was divided into three areas (model area A, model area B and model area C) to cover the entire study area. The model area A extends from Cheltenham (downstream of Cheltenham Hunterville Road) to Reid Line Road. The west boundary of the model area A includes Makino Stream and rural catchment on the west side of Makino Stream. The east boundary of the model area A includes Kiwitea Stream. The model area B extends from upstream of Reids Line Stopbanks to the south boundary of Manfeild Autocourse. The east and west boundaries of model area B encompass the entire township of Feilding and Kiwitea Stream and the Oroua River. The model area C includes rural areas along Makino Stream and the Oroua River on the east and west side of the river channel.

Coarser 10m grid MIKE FLOOD models were set up to represent the rural and semi-rural areas in model A and C. These two models were run separately from the MIKE URBAN model.

For the model area B, a more detailed MIKE FLOOD model was set-up linking the MIKE URBAN underground stormwater drainage, MIKE 11 channels and a finer scale 5m MIKE 21 grid representing the floodplain.

Makino Stream, major streams passing through the township of Feilding and the open channel drains crossing the Reids Line Spillway where they pass through the two dimensional model domains are modelled using MIKE 11. In each of the models the streams in the MIKE 11 extend downstream of the two dimensional model boundary to the Makino Stream and the Oroua River at their corresponding location of confluence.

The extent of the MIKE FLOOD model of model area A and model area C including the two dimensional model boundary and river channels as modelled in MIKE 11 are shown in Appendix E. The extent of the MIKE FLOOD URBAN model of model area B including the two dimensional model boundary, river channels as modelled in MIKE 11 and stormwater drainage network are also shown in Appendix E.

3.3 MIKE 21 Floodplain Grids

Two separate MIKE 21 models were set-up for the model area A and model area C representing the floodplain to model flow that breaks out from the river/creek channels. A separate MIKE 21 model was set up for the model area B representing the floodplain to model flow that breaks out from the river/creek channels as well as the interaction between the floodplain and the underground stormwater drainage system.

3.3.1 Floodplain Surface

The model area A shown in Appendix E was set-up using a 10m grid based on the LiDAR provided to Entura. This model is linked to the MIKE 11 river channel of Makino Stream using MIKE FLOOD. Kiwitea stream was modelled in the MIKE 21 grid. The Reids Line Stopbank was included in this model to incorporate the storage upstream of the Stopbank after limiting the flow through the diversion structure of the Makino Stream and to transfer the flood to the Kiwitea Stream through the drop structure of the Reid Line Stopbank. The model provides the flood extent upstream of Reids Line Stopbank.

The second MIKE 21 grid covers the urban part of Feilding (Area B in Appendix F) and was set-up using a 5m grid based on the LiDAR provided to Entura. The MIKE 21 grid of This model is linked to both the MIKE 11 river channels and MIKE URBAN piped stormwater drainage system using MIKE FLOOD. The outflow from the diversion structure in the Makino Stream at Reids Line Stopbank and Kiwitea Stream at the downstream boundary of Model Area A provides the inflows to this model.

The third model also used a 10m grid encompasses Area C in Appendix E and provides the flood extents in this area. The outflow at the downstream boundary of the finer scale MIKE URBAN model area B provides the inflows to this model.

The raised existing and new stopbank along the Oroua River were included in DEM of model area B and C. The stopbank levels at the location of surveyed cross sections and the drawings showing the position of stopbank provided by HRC were used to determine the profile of those stopbanks.

The study area was split into two levels of resolution to reduce the number of grid cells within one single model to limit the required computation time.

For all MIKE 21 models, high resolution LiDAR data was resampled to create digital elevation models (DEM) using ARC GIS software. Relevant features such as levees, roads and creek inverts were identified and given priority to ensure they were included in the re-sampled DEMs. The re-sampled grids then formed the ground surface for the MIKE 21 models.

3.3.2 Roughness

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 Manning's values

Land Type	Roughness, Manning's M	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

Lateral links were set-up for transfer of flow between the MIKE 11 cross sections and the MIKE 21 models. The parameters and values used for lateral links used are summarized in Table 3.2 below.

Table 3.2
Lateral Link Structure Details (Common for all 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	HGH adopted for model stability.
Depth Tolerance	0.1m	For model stability.
Weir C	1.838	Default discharge coefficient.
Manning's n	0.05	Adopted value.

Urban links were set up for the transfer of flow between the MIKE URBAN stormwater pipe and the area B MIKE 21 model. The parameters and values used for urban links used are summarized in Table 3-3 below.

Table 3.3
Urban Link Structure Details (Common for all links)

Parameter	Value	Comment
Type	MIKE 21 to inlet	
Maximum Flow	0.1 m^3/s	Computed for the existing stormwater inlet
Inlet Area	0.055 m^2	Computed for the existing stormwater inlet
Inlet Method	Orifice equation	

The type of link used for the river urban link was MIKE URBAN outlet to MIKE 11 as all the stormwater drainage pipes are discharging to Makino Stream.

3.5 MIKE 11 Model

A single MIKE 11 model was set up for the main streams and drainage channels passing through the township of Feilding. The model includes Makino Stream and other drainage channels named for this study as Channel A, Chanel B, Channel C, Channel D, Channel E, Channel F, Channel G, Channel H, Channel I, Channel J, Chanel K, Channel L and Channel M. The Makino Stream and the Channel L were extended to the confluence with the Oroua River. This model was used to couple with the MIKE 21 grid in the model area A, B and C.

3.5.1 River Cross Sections

Surveyed cross sections of Makino Stream were provided by HRC, who also provided cross sections at each bridge structure within the river. The cross sections for other drainage channels (viz. Channel A to Channel M) through the township of Feilding were extracted from the recent LiDAR survey provided by HRC.

Makino Stream and other drainage channels included in the model and the locations of cross sections used in the MIKE 11 model are shown in Appendix E.

3.5.2 Hydraulic Structures

The bridges and major culverts and weirs located on Makino Stream and the streams and tributaries through the township of Feilding were incorporated in the model. The locations and sizes of the bridges and culverts were based on:

- Site visit information gathered by Entura.
- Design drawings provided by HRC.
- Infoworks model of Feilding stormwater network.

The opening geometry of bridges over Makino Stream within the study area was based on cross sections at the bridges provided by HRC. The soffit levels of the bridges over the Makino Stream were not included in the survey data at the bridge cross sections. From the site visit photos, it was estimated that the soffit level of the bridges were approximately 0.5 m below the top of the bank. For this study the soffit level of the bridges were assumed 0.5 m below the surveyed top of the banks. This approach was agreed by HRC. The geometry of the remaining bridges and culverts on other streams and tributaries through the township of Feilding were based on Infoworks model and site visit measurements.

The invert levels of the bridges along Makino Stream were based on survey data provided by HRC. The invert levels of culverts over other streams and tributaries and the road levels over the culverts and bridges were based on the LiDAR survey. Table 3.4 shows the bridges and culverts while Table 3.5 shows the weir structures included in the MIKE 11 model.

All irregular shaped structures were modelled as irregular culverts in MIKE 11.

Table 3.4
Bridge and culvert hydraulic structures included in MIKE 11 model

MIKE 11 Branch	Chainage (m)	Structure Name	Type	Dimensions
Makino River	2115	Reid Line Bridge	Bridge	Irregular
Makino River	5005	North St Bridge	Bridge	Irregular
Makino River	5275	Duke St Bridge	Bridge	Irregular
Makino River	5580	Derby St Bridge	Bridge	Irregular
Makino River	5810	Denbigh St Bridge	Bridge	Irregular
Makino River	6160	Beattie St Bridge	Bridge	Irregular
Makino River	6220	Church St Bridge	Bridge	Irregular
Makino River	6515	Manchester St Bridge	Bridge	Irregular
Makino River	6780	Warwick St Bridge	Bridge	Irregular
Makino River	7360	South St Bridge	Bridge	Irregular
Makino River	7885	Rata St Bridge	Bridge	Irregular
Makino River	10640	Kawakawa Rd Bridge	Bridge	Irregular
Makino River	11540	Private Bridge 1	Bridge	Irregular
Makino River	11815	Private Bridge 2	Bridge	Irregular
Makino River	12170	Boness Rd Bridge	Bridge	Irregular
Makino River	13500	Private Bridge 3	Bridge	Irregular
Makino River	14470	Private Bridge 4	Bridge	Irregular
Channel A	330	Cnl A Culvert	Circular	1.17 m diameter concrete
Channel B	335	Cnl B Culvert	Circular	0.76 m diameter concrete
Channel E	10	Cnl E Culvert	Circular	0.6 m diameter concrete
Channel F	490	Cnl F Culvert	Circular	0.45 m diameter concrete

MIKE 11 Branch	Chainage (m)	Structure Name	Type	Dimensions
Channel G	230	Cnl G Culvert	Circular	0.72 m diameter concrete
Channel H	200	Cnl H Culvert	Circular	0.53 m diameter concrete
Channel E	850	Cnl E Culvert 2	Circular	0.7 m diameter concrete
Channel F	1180	Cnl F Culvert 2	Circular	0.3 m diameter concrete
Channel A	10	Cnl A Culvert 1	Circular	0.3 m diameter concrete
Channel B	10	Cnl B Culvert 1	Circular	0.45 m diameter concrete
Channel C	10	Cnl C Culvert 1	Circular	0.75 m diameter concrete
Channel D	10	Cnl D Culvert 1	Circular	0.75 m diameter concrete
Channel F	10	Cnl F Culvert 1	Circular	0.45 m diameter concrete
Channel G	10	Cnl G Culvert 1	Circular	0.45 m diameter concrete
Channel H	10	Cnl H Culvert 1	Circular	0.375 m diameter concrete
Channel I	140	Cnl I Culvert 1	Circular	2.8 m diameter concrete
Channel I	335	Cnl I Culvert 2	Circular	1.05 m diameter concrete
Channel I	1370	Cnl I Culvert 3	Circular	2.0 m diameter concrete
Channel J	185	Cnl J Culvert 1	Circular	1.6 m diameter concrete
Channel J	280	Cnl J Culvert 2	Circular	1.8 m diameter concrete
Channel J	370	Cnl J Culvert 3	Circular	1.95 m diameter concrete
Channel J	525	Cnl J Culvert 4	Circular	2.1 m diameter concrete
Channel J	580	Cnl J Culvert 5	Circular	2.15 m diameter concrete
Channel L	165	Cnl L Culvert 1	Circular	1.35 m diameter concrete
Channel L	270	Cnl L Culvert 2	Circular	0.625 m diameter concrete
Channel L	415	Cnl L Culvert 3	Circular	1.5 m diameter concrete
Channel L	1045	Cnl L Culvert 4	Circular	1.2 m diameter concrete
Channel M	475	Cnl M Culvert 1	Circular	0.6 m diameter concrete
Culvert	1440	Pharazyn Road Bridge	Rectangular	2.4 (W) x 0.9 (H) Concrete

Table 3.5
Weir structures included in MIKE 11 model

MIKE 11 Branch	Chainage (m)	Structure Name
Makino River	1675	Weir at Diversion
Makino River	2115	Reid Line Bdg Weir
Makino River	5005	North St Weir

MIKE 11 Branch	Chainage (m)	Structure Name
Makino River	5275	Duke St Weir
Makino River	5580	Derby St Weir
Makino River	5810	Denbigh St Weir
Makino River	6160	Beattie St Weir
Makino River	6220	Church St Weir
Makino River	6515	Manchester St Weir
Makino River	6780	Warwick St Weir
Makino River	7360	South St Weir
Makino River	7885	Rata St Weir
Makino River	10640	Kawakawa Rd Weir
Makino River	11540	Private Bdg Weir1
Makino River	11815	Private Bdg Weir 2
Makino River	12170	Boness Rd Weir
Makino River	13500	Private Bdg Weir 3
Makino River	14470	Private Bdg Weir 4
Channel A	330	Cnl A Weir
Channel B	335	Cnl B Weir
Channel E	10	Cnl E Weir
Channel F	490	Cnl F Weir
Channel G	230	Cnl G Weir
Channel H	200	Cnl H Weir
Channel E	850	Cnl E Weir 2
Channel F	1180	Cnl F Weir 2
Channel A	10	Cnl A Weir 1
Channel B	10	Cnl B Weir 1
Channel C	10	Cnl C Weir 1
Channel D	10	Cnl D Weir 1
Channel F	10	Cnl F Weir 1
Channel G	10	Cnl G Weir 1
Channel H	10	Cnl H Weir 1
Channel I	140	Cnl I Weir 1
Channel I	335	Cnl I Weir 2

MIKE 11 Branch	Chainage (m)	Structure Name
Channel I	1370	Cnl I Weir 2
Channel J	185	Cnl J Weir 1
Channel J	280	Cnl J Weir 2
Channel J	370	Cnl J Weir 3
Channel J	525	Cnl J Weir 4
Channel J	580	Cnl J Weir 5
Channel L	165	Cnl L Weir 1
Channel L	270	Cnl L Weir 2
Channel L	415	Cnl L Weir 3
Channel L	1045	Cnl L Weir 4
Channel M	475	Cnl M Weir 1
culvert	1440	Pharazyn Road
Drop Structure	2020	Drop Structure

According to the Makino Flood Action Plan (Manawatu District Council, 2011) the water level upstream of Duke Street Bridge should be below 76.971 m Wellington Datum (76.85m Moturiki Datum) to contain the water within the channel and avoid flooding at the downstream side of the bridge during large flood events. A diversion structure in Makino Stream at Reids Line Stopbank is used to divert some or all the flow from Makino Stream to Kiwitea Stream during large flood events to prevent flooding in the township.

Bed scouring during larger flood events was not modelled in this study but a consideration to bed scouring in Makino Stream has been incorporated in this study as discussed below.

Based on information provided by HRC, water level at upstream of Duke Street Bridge will be approximately 76.971 m Wellington Datum during 1 in 200 AEP design flood event if the flow through the diversion structure at Reids Line Stopbank is limited to 40 m^3/s. Similarly, in case of 1 in 100 AEP design flood event, the water level at the upstream of the bridge will be approximately 76.971 m Wellington Datum if the flow through the structure is limited to 50 m^3/s. From a series of iterative model runs carried out by Entura, it was found that the water level at the upstream of Duke Street Bridge reached approximately 76.971 m Wellington Datum when 7 m^3/s is released through the diversion structure during the 1 in 200 AEP design flood event. Similarly, in case of the 1 in 100 AEP design flood event, the water level at upstream of the bridge reached that level when 21 m^3/s is released through the structure. Thus, it has been assumed that the difference between the flow provided by HRC and the modelled flow for each design flood event is the increase in channel capacity due to bed scour. Thus, the flow equivalent to increase in channel capacity due to bed scouring (ie, 29 m^3/s for the 100 AEP design event and 33 m^3/s for the 200 AEP design event) is taken out from the model at Reids Line Spillway gate to compensate for bed scouring. This assumption was agreed by HRC.

Diversion structure at Reids Line Spillway was modelled using two separate special weirs; one for flow down to Makino Stream and the other to take out the flow from upstream of the structure to compensate for the increase in channel capacity due to bed scouring.

For the 1 in 100 AEP design flood event, diversion structure for flow down to Makino Stream was modelled as a special weir where for flows below 21 m^3/s the flow through the structure is equivalent to the two diversion culverts. The structure to take out the flow from the model was also modelled as special weir where for flows in between 21 m^3/s and 50 m^3/s the flow through the structure is equivalent to the two diversion culverts.

For the 1 in 200 AEP design flood event, diversion structure for flow down to Makino Stream was modelled as a special weir where for flows below 7 m^3/s the flow through the structure is equivalent to the two diversion culverts. The structure to take out the flow from the model was also modelled as special weir where for flows in between 7 m^3/s and 40 m^3/s the flow through the structure is equivalent to the two diversion culverts.

3.5.3 Manning's Roughness Value

A Manning's n roughness value of 0.045 was adopted for the Makino Stream as this value had been used to calibrate the Fielding reach flow of the Makino Stream to various known floods by HRC. The same Manning's value was used for other streams and tributaries through the township of Feilding.

3.5.4 Downstream Model Boundary

The downstream model boundary of the Makino Stream (modelled in MIKE 11) is at the confluence of the Oroua River. The Oroua River is modelled in MIKE 21. MIKE 21 water level of the Oroua River at the confluence has been used as the downstream boundary of the Makino Stream. Similarly, the MIKE 21 water level of the Oroua River at the confluence with Channel L has been used as the downstream boundary of Channel L.

3.6 MIKE URBAN Model

A MIKE URBAN model was developed for the model area B representing the underground stormwater drainage system in the township of Feilding based on the Infoworks model, developed by MWH for Manawatu District Council, provided by HRC. The underground drainage network includes stormwater sumps, manholes, pipes and outlets.

3.6.1 Network Set-up

The network representing the underground drainage system was provided to Entura in InfoWorks format. To import the data into MIKE URBAN the InfoWorks data was exported to .csv files which were then imported to Microsoft Access. A MIKE URBAN stormwater drainage network was then set-up using the Microsoft Access files thus generated.

3.6.2 Manholes

Manholes were modelled as having a sealed lid which means that water can not leave or enter the manhole via the lid.

3.6.3 Sumps

Ground levels and invert levels of all the sumps in the study area were available from the Infoworks model. The ground levels of some of the sumps were modified to match with the ground level of the DEM generated from the LiDAR survey data. All sumps were coupled with the MIKE 21 grid to transfer stormwater runoff from the catchment to the underground stormwater drains.

All sumps were assumed to have the same inlet capacity based on flow entering through the lintel at the rear of the sump (ie zero capacity due to full blockage assumed for flow through sump grill due to flat terrain in the township of Feilding).

The inlet capacity of the sumps used for Pahiatua Township Flood Study (Entura, 2010) has been used for this study. The inlet capacity was estimated by assuming weir flow (weir coefficient of 1.6) through the lintel with 100% blockage of the grill. Zero blockage of the lintel was assumed. Figure 3-1 shows the assumed inlet capacity for the Feilding sumps.

For catchments not directly connected to the river channel or stormwater sumps, dummy sumps and pipes were used to connect the catchment runoff to the MIKE 21 grid. The inlet capacity was set to be high to ensure the flow into the sumps would not be restricted.

For catchments that flow directly to open water courses, dummy sumps and pipes were used to connect the catchment runoff to the MIKE 11 model. These dummy sumps were not connected to the MIKE 21 grid and their size and that of the dummy pipes were made artificially large so to not affect the shape of the hydrograph. The inlet capacity was set to be high to ensure the flow into the sumps would not be restricted.

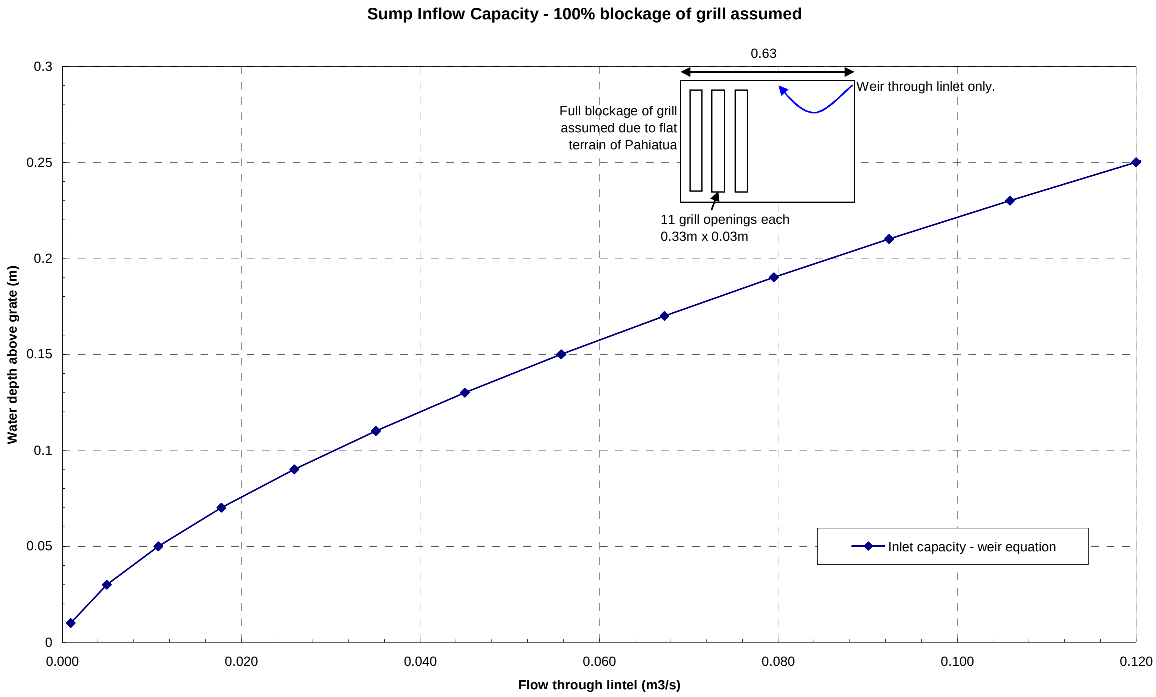

Figure 3.1: Sump Inflow Capacity

3.6.4 Pipes

The diameter and invert levels at the upstream and downstream ends of all pipes used in the model were available from the InfoWorks model. All pipes were assumed to be reinforced concrete.

3.6.5 Outfalls

Outlets discharging to the river channel were coupled with the MIKE 11 model (river channels) at their corresponding locations defined in the InfoWork model. The outlets discharging to the Oroua River were coupled with the MIKE 21 grid at their corresponding locations defined in the InfoWorks model.

3.7 Model Inflow Locations

Three types of inflows were applied to the MIKE FLOOD Urban model:

- Direct catchment runoff applied as a source to the MIKE 21 grid (using dummy sumps outlined in Section 3.6.3).
- Direct catchment runoff applied to a MIKE 11 channel.
- Direct catchment runoff applied to sumps in the MIKE URBAN model.

The catchment break-up is shown in Figure 2.4 with catchments:

- Applied directly to the MIKE 21 grid shaded in other than grey, green and off white.
- Applied directly to MIKE 11 channels shaded in green and off white.
- Applied to stormwater sumps shaded in grey.

3.8 Other Parameters

Other critical parameters for the MIKE 21 models are provided below:

- Calculation time-step: 0.5 seconds.
- Flooding and drying enabled:
  - Drying depth: 0.02m.
  - Flooding depth: 0.03m.
  - Eddy viscosity: 0.125m^2/s.

3.9 Model Datum

The modelling was carried out in Wellington Vertical Datum.

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4. Hydraulic Model Calibration

The MIKE FLOOD Urban hydraulic model was not calibrated as flood data such as recorded flood levels or photographs showing flood extents were not available.

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5. Hydraulic Modelling of Design Flood Events

5.1 Model Scenarios

The MIKE FLOOD models for model area A and C and the MIKE FLOOD URBAN model for model area B were used for the following scenarios:

- 1 in 100 AEP design event for the existing condition of Reids Line Stopbank
- 1 in 200 AEP design event for the existing condition of Reids Line Stopbank
- 1 in 100 AEP design event for the crest level of Reids Line Stopbank lowered by 500 mm
- 1 in 200 AEP design event for the crest level of Reids Line Stopbank lowered by 500 mm.

5.2 Model Result

5.2.1 Model area A Result

The model area A model was run for the above mentioned scenarios with flows at Makino Stream and Kiwitea Stream.

For the of 1 in 100 AEP design flood event, the modelled maximum flow through the diversion structure was 21 m^3/s. Also, the modelled maximum flow out of the model from the diversion structure to compensate the increase in channel capacity due to bed scouring during this flood event was 29 m^3/s. The flow in excess of 50 m^3/s was diverted to Kiwitea Stream through the drop structure in the Reids Line Stopbank. The stopbanks didn't overtop for both the existing condition of the stopbank and the stopbank lowered by 500 mm. For both scenarios, the peak of the flow transferred to the Kiwitea Stream is 50 m^3/s.

For the of 1 in 200 AEP design flood event, the modelled maximum flow through the diversion structure was 7 m^3/s. Also, the modelled maximum flow out of the model from the diversion structure to compensate the increase in channel capacity due to bed scouring during this flood event was 33 m^3/s. The flow in excess of 40 m^3/s was diverted to Kiwitea Stream through the drop structure in the Reids Line Stopbank. In the case of the existing condition of Reids Line Stopbank, the stopbank didn't overtop and the peak of the flow transferred to Kiwitea Stream through the drop structure is 83 m^3/s. In case of the stopbank lowered by 500 mm, the stopbank was overtopped near Pharazyn Road for approximately 1:25 hrs. The peak of the spilled flow at that location is 0.25 m^3/s. In this case, the flow transferred to Kiwitea Stream through the drop structure is 81 m^3/s.

Figure 5.1 below presents the hydrograph of the flow transferred to Kiwitea Stream through the drop structure of the Reids Line Stopbank.

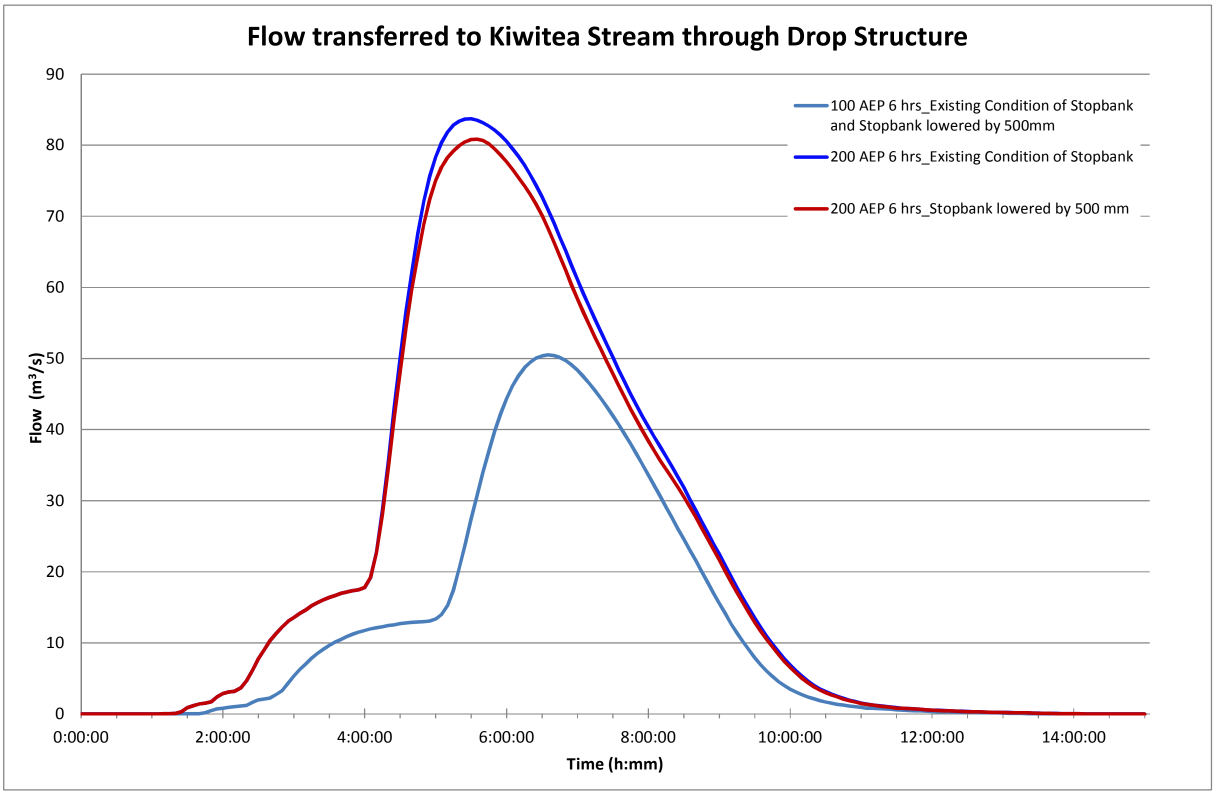

Figure 5.1: Flow transferred to Kiwitea Stream through Drop Structure of Reids Line Stopbank

5.2.2 Model area B Result

MIKE FLOOD URBAN model for the model area B was run for the 1 in 100 AEP design event for the for the crest level of Reids Line Stopbank lowered by 500 mm, 1 in 200 AEP design event for the existing condition of Reids Line Stopbank and 1 in 200 AEP design event for the crest level of Reids Line Stopbank lowered by 500 mm. For each of the scenarios, the outflows from the corresponding model area A were assigned as inflows at their corresponding location in model area B. In addition to this, direct catchment runoff from the sub catchments within the model area B were assigned to the sumps of the stormwater drain in the MIKE URBAN model. Also the flow from the Oroua River was included in the model at its corresponding location.

For the 1 in 100 AEP design flood event with existing condition of stopbank and the stopbank lowered by 500mm, the flow through the diversion structure in Makino Stream at Reids Line Stopbank plus local pick-up downstream of the stopbank to Duke Street Bridge resulted in a peak water level at the upstream of Duke Street bridge of 76.94 m which matched well with the desired maximum water level (76.971m) at this location. The corresponding peak flow at Duke Street bridge is 40.8 m^3/s.

In case of the 1 in 200 AEP design flood event with stopbank lowered by 500 mm, the stopbank was slightly overtopped at one location but it does not contribute to rise the peak flood level at upstream of Duke Street bridge. The peak flood level at upstream of the bridge for both the existing condition of stopbank and the stopbank lowered by 500 mm was found to be 76.83 m which is 0.14 m lower than the desired maximum water level (76.971 m) at this location. The corresponding peak flow at Duke Street bridge is 37 m^3/s.

5.2.3 Model area C Result

MIKE FLOOD model for the model area C was run for the above mentioned scenarios. For each modelled scenarios, the outflows from the corresponding model area B were assigned at the corresponding location at model area C. Tributary flows of the Makino Stream and the Oroua River were also included in the model.

From the model result it was found that the in case of both the 1 in 100 AEP and 1 in 200 AEP design flood events, the stopbank along the Oroua River was overtopped at some locations and the overtopped flow were transferred to Makino Stream causing flooding the area in between the Oroua River and Makino Stream as well as the area along the Oroua River and Makino Stream.

5.3 Provision of Results to HRC

Preliminary model run results

MIKE 21 result files for all preliminary modelled scenarios were converted to WaterRide format. All MIKE 11 result files were converted to WaterRide wr1d, wrcan and wrb format. Mike 21 wrr files were then trimmed to have the same number of time steps. All trimmed wrr files were combined in wrc file format that can be played with time lapse animation. Trimmed WaterRide wrr files for all modelled scenarios and WaterRide wrc files were provided to HRC.

The maximum depths of flooding for each of the modelled scenarios were extracted from the MIKE 21 result files and provided to HRC in ASCII format.

Final model run results

As agreed by HRC all the raw MIKE URBAN, MIKE 21 and MIKE 11 results files were provided to HRC along with the MIKE 21 grid. The MIKE URBAN files can be viewed using the MIKE VIEW/ZERO software packages to assess water levels and discharges within the piped stormwater drainage system. The MIKE 11 and MIKE 21 files can be viewed using the MIKE VIEW/ZERO and waterRIDE software.

5.4 Flood Inundation Map

Hardcopy flood inundation maps were not prepared for the study.

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6. References

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Appendices

A. Design rainfalls
B. Hydrologic model event calibration
C. Inflow hydrographs
D. Catchment characteristics
E. MIKE URBAN model layout

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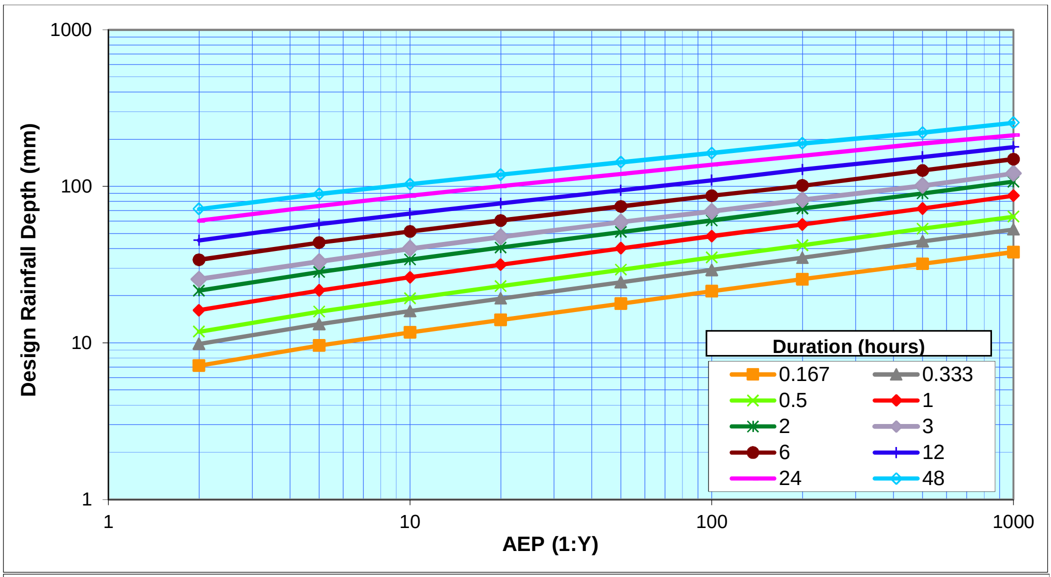
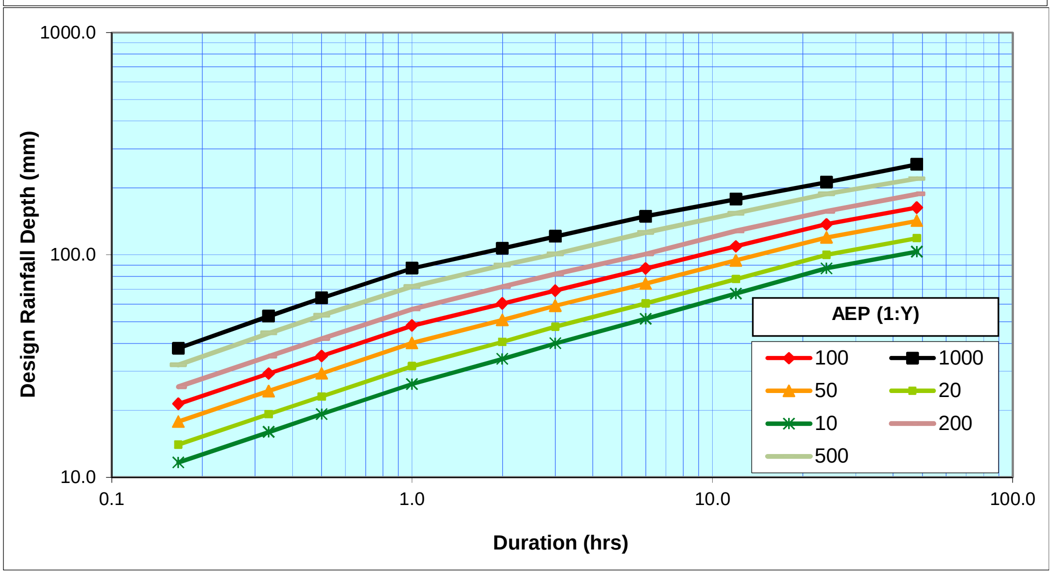
A Design rainfalls

A.1 Makino at Rata St – point design rainfall depths

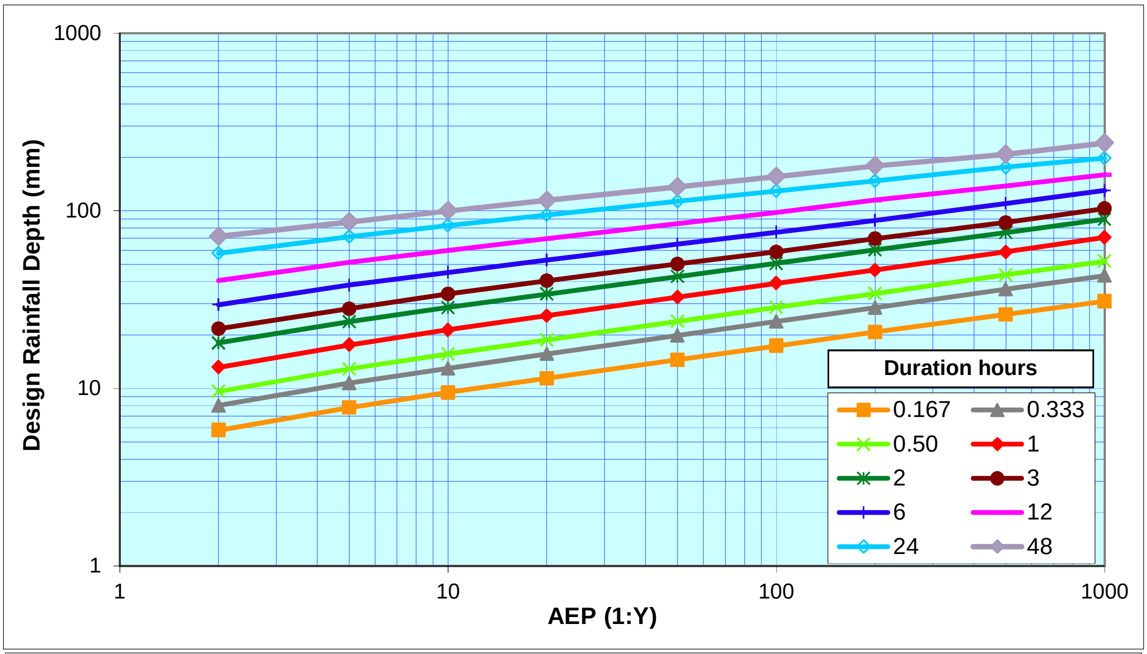
Design rainfall depths for Makino Catchment											
	Duration (hrs)										
ARI	AEP	0.167	0.333	0.5	1	2	3	6	12	24	48
2	0.5	7.2	9.9	11.8	16.2	21.6	25.5	33.9	45.2	60.3	71.6
5	0.2	9.6	13.2	15.8	21.6	28.4	33.0	43.7	57.3	75.1	89.3
10	0.1	11.7	16.0	19.2	26.2	34.1	40.0	51.6	67.0	86.9	103.3
20	0.05	14.0	19.2	23.1	31.6	40.6	47.5	60.5	77.8	100.0	118.8
50	0.02	17.8	24.4	29.3	40.2	51.0	59.0	74.4	94.4	119.8	142.4
100	0.01	21.4	29.3	35.1	48.1	60.4	69.0	86.9	109.2	137.3	163.1
200	0.005	25.5	35.0	42.0	57.0	72.0	82.0	101.0	128.0	157.0	188.0
500	0.002	32.0	44.5	53.5	72.0	90.0	101.0	126.0	154.0	188.0	220.0
1000	0.001	38.0	53.0	64.0	87.0	107.0	121.0	149.0	178.0	212.0	255.0

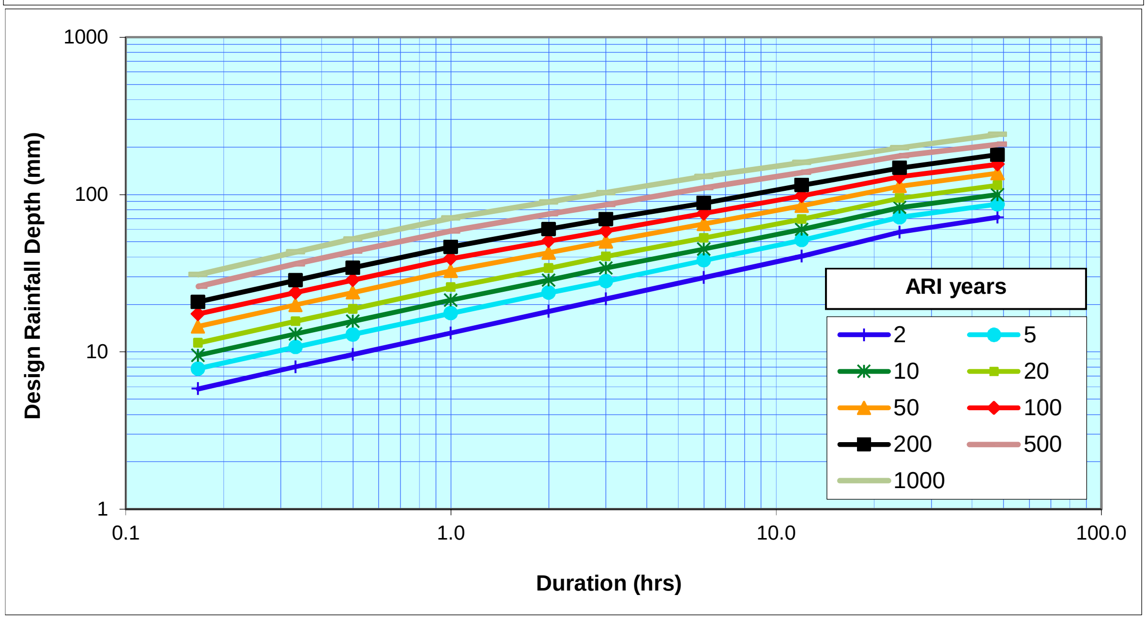




A.2 Makino at Rata St – catchment design rainfall depths

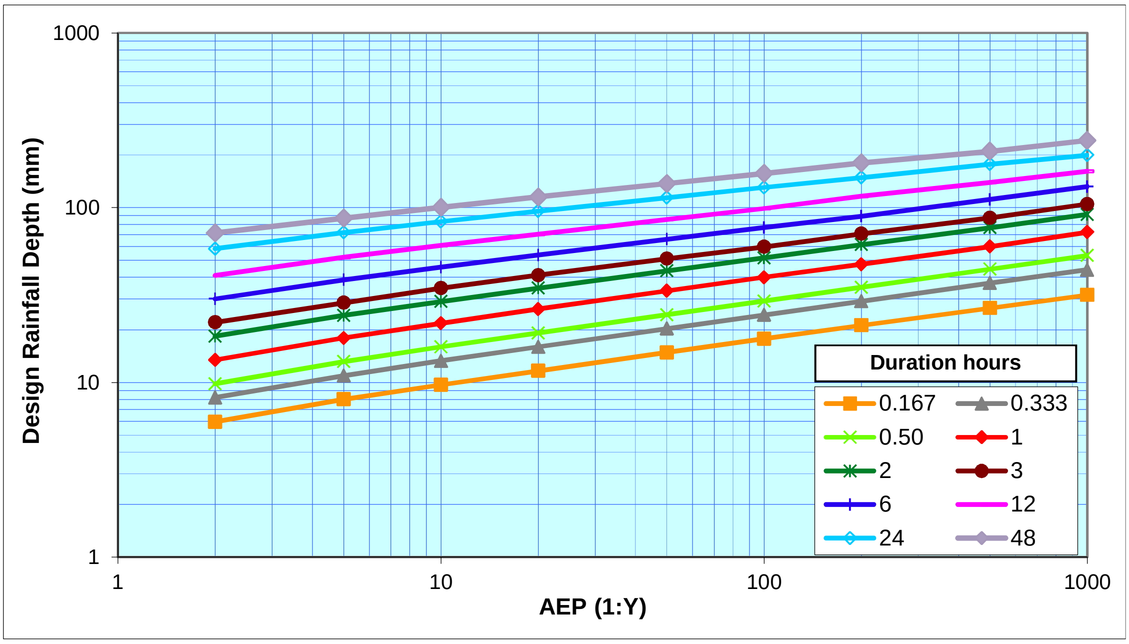
Design rainfall depths for the Makino at Rata St Catchment (62.3 km2)											
ARI	AEP	Duration (hrs)									
		0.167	0.333	0.50	1	2	3	6	12	24	48
2	0.5	5.8	8.0	9.6	13.2	18.0	21.7	29.6	40.5	57.6	71.6
5	0.2	7.8	10.7	12.9	17.6	23.7	28.1	38.1	51.3	71.6	86.5
10	0.1	9.5	13.0	15.6	21.3	28.5	34.0	45.0	60.0	82.6	99.7
20	0.05	11.4	15.6	18.8	25.7	34.0	40.4	52.8	69.7	94.8	114.3
50	0.02	14.5	19.9	23.9	32.7	42.7	50.2	64.9	84.6	113.2	136.4
100	0.01	17.4	23.8	28.6	39.1	50.6	58.7	75.9	97.9	129.3	155.6
200	0.005	20.8	28.5	34.2	46.4	60.3	69.7	88.2	114.7	147.5	178.8
500	0.002	26.1	36.2	43.6	58.6	75.3	85.9	110.0	138.0	175.9	208.3
1000	0.001	30.9	43.2	52.1	70.8	89.6	102.9	130.1	159.5	197.8	240.6

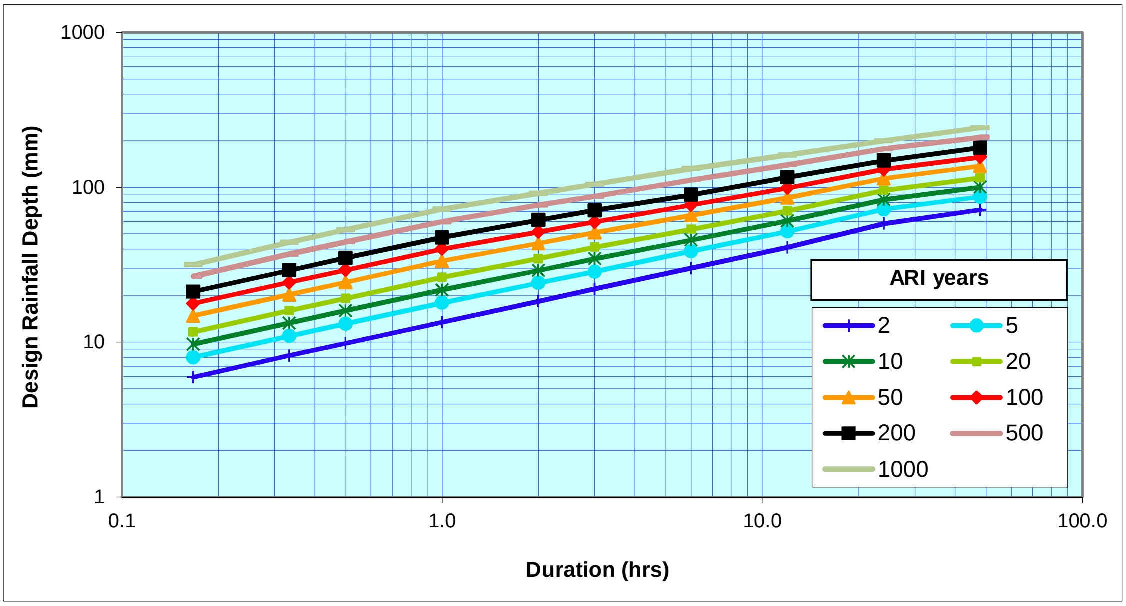




A.3 Makino at Reids Line – catchment design rainfall depths

Design rainfall depths for the Makino at Reids Line Catchment (41.3 km2)											
ARI	AEP	Duration (hrs)									
		0.167	0.333	0.50	1	2	3	6	12	24	48
2	0.5	6.0	8.2	9.8	13.4	18.4	22.1	30.1	41.0	58.2	71.6
5	0.2	8.0	10.9	13.2	18.0	24.2	28.6	38.7	51.9	72.2	87.0
10	0.1	9.7	13.3	16.0	21.8	29.1	34.6	45.7	60.7	83.3	100.4
20	0.05	11.7	16.0	19.2	26.3	34.6	41.1	53.6	70.5	95.5	115.1
50	0.02	14.8	20.3	24.4	33.4	43.5	51.1	65.9	85.6	114.1	137.4
100	0.01	17.8	24.3	29.2	40.0	51.5	59.7	77.0	99.1	130.4	156.8
200	0.005	21.2	29.1	35.0	47.4	61.4	71.0	89.5	116.1	148.8	180.2
500	0.002	26.6	37.0	44.5	59.9	76.8	87.4	111.7	139.7	177.6	210.0
1000	0.001	31.6	44.1	53.3	72.4	91.3	104.7	132.1	161.5	199.8	242.7

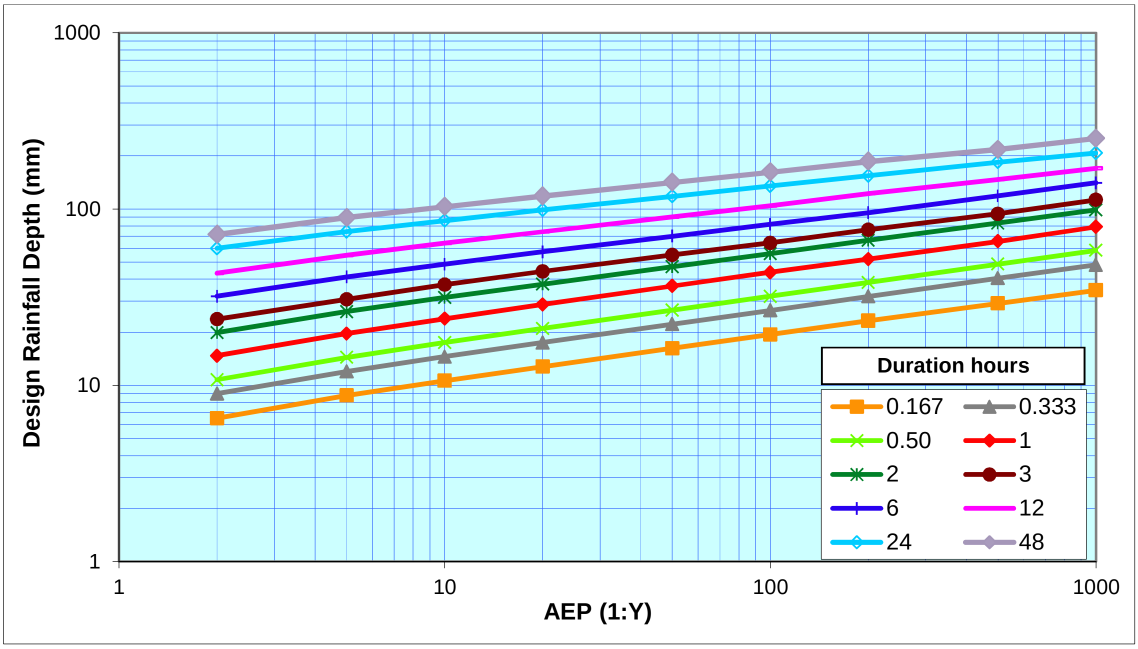


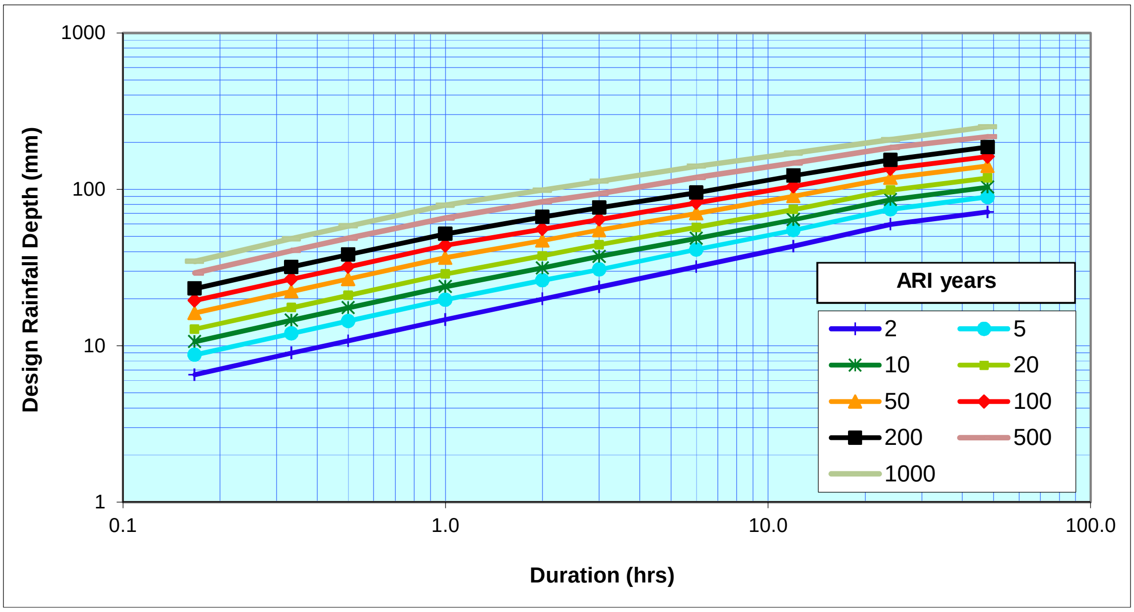


A.4 Fielding Urban Area – catchment design rainfall depths

Design rainfall depths for the urban area of Feilding (4.8 km2)

ARI	AEP	Duration (hrs)									
		0.167	0.333	0.50	1	2	3	6	12	24	48
2	0.5	6.5	9.0	10.7	14.7	19.9	23.7	32.0	43.2	59.9	71.6
5	0.2	8.7	12.0	14.4	19.7	26.2	30.7	41.2	54.7	74.5	89.2
10	0.1	10.6	14.5	17.5	23.9	31.4	37.2	48.6	64.0	86.0	103.1
20	0.05	12.8	17.5	21.0	28.7	37.5	44.2	57.1	74.3	98.8	118.3
50	0.02	16.2	22.2	26.7	36.6	47.1	54.9	70.1	90.2	118.2	141.5
100	0.01	19.4	26.6	32.0	43.8	55.8	64.2	81.9	104.4	135.2	161.7
200	0.005	23.2	31.9	38.3	51.9	66.5	76.3	95.3	122.4	154.4	186.1
500	0.002	29.1	40.5	48.7	65.6	83.1	94.0	118.9	147.2	184.5	217.2
1000	0.001	34.6	48.3	58.3	79.2	98.8	112.6	140.6	170.2	207.8	251.3





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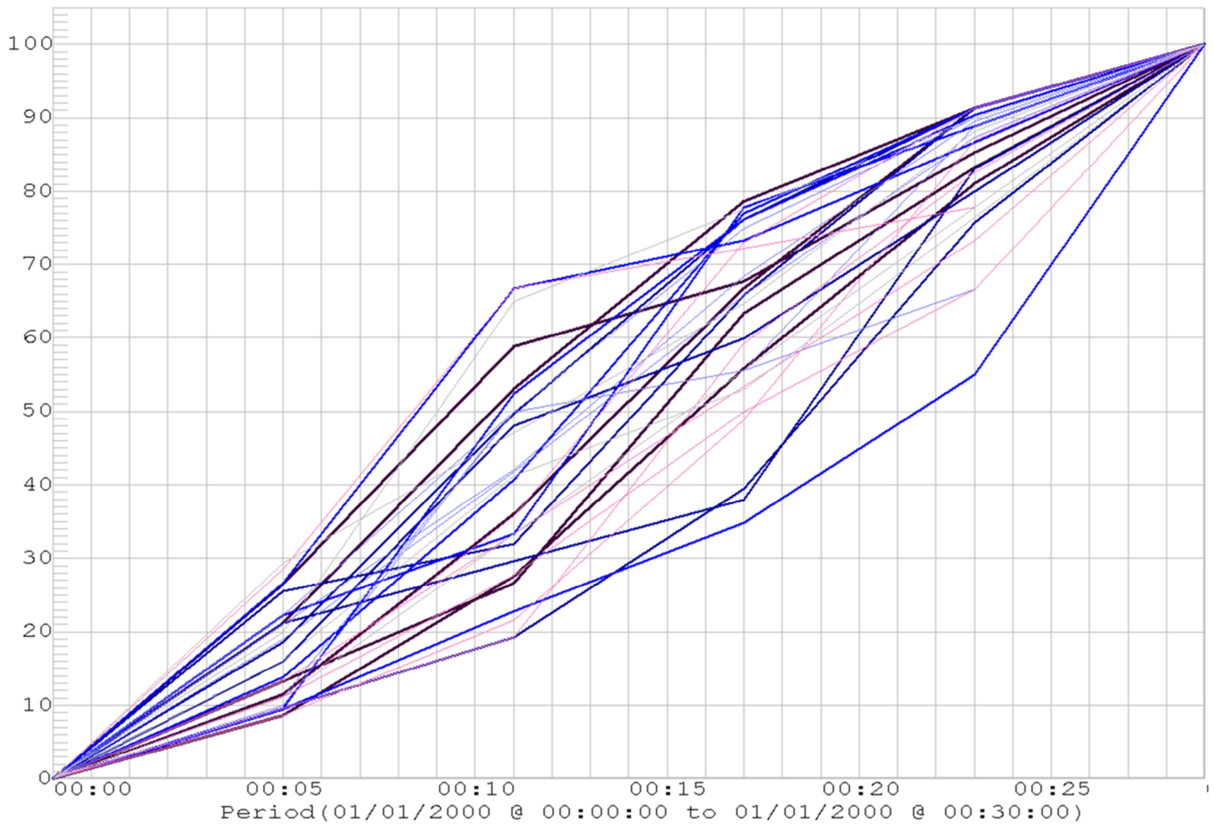
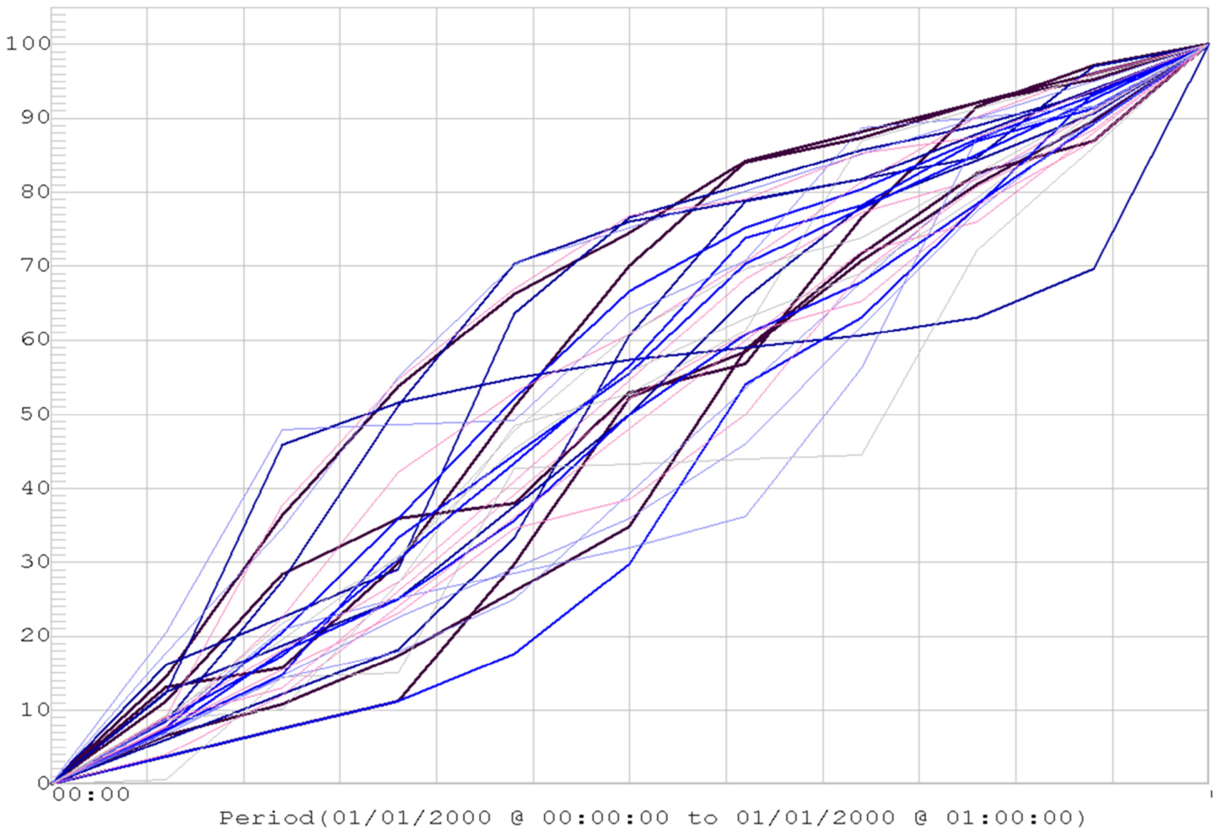
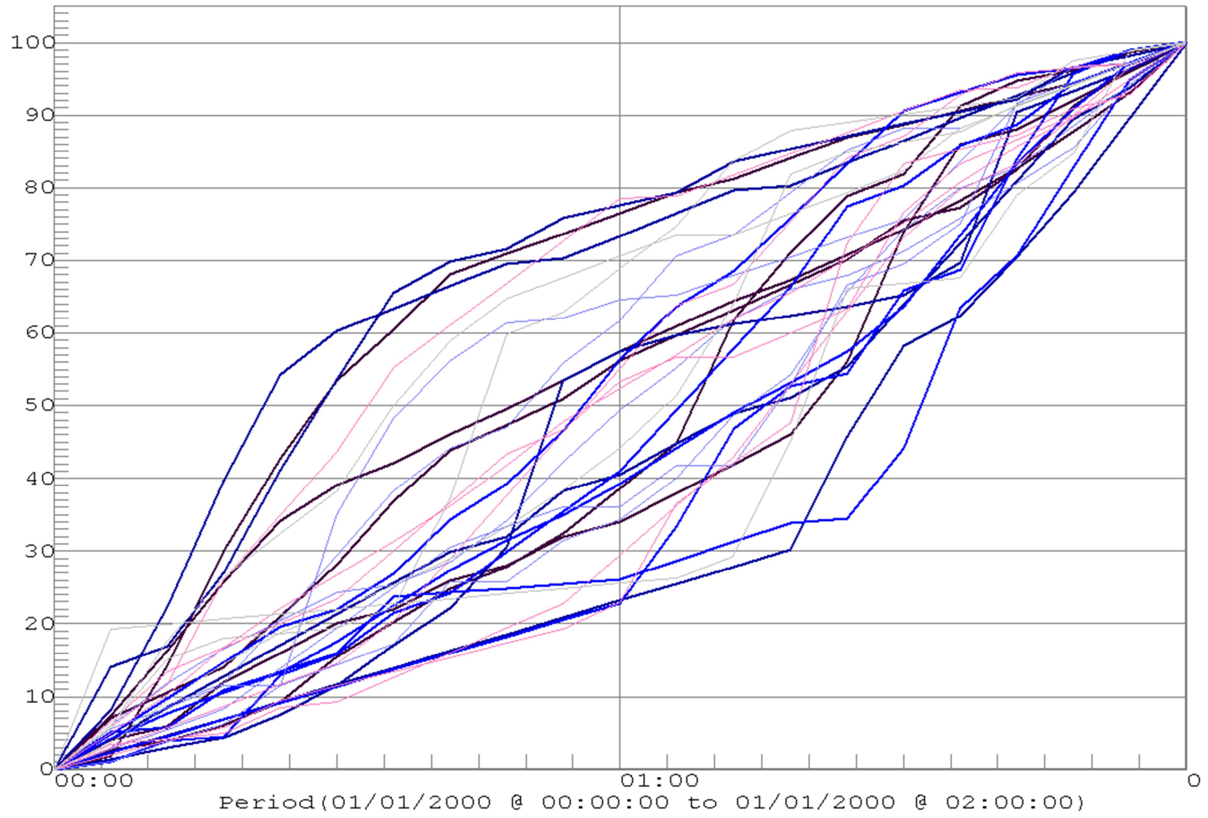
A.5 Design temporal patterns






100
90
80
70
60
50
40
30
20
10
0
00:00
01:00
0
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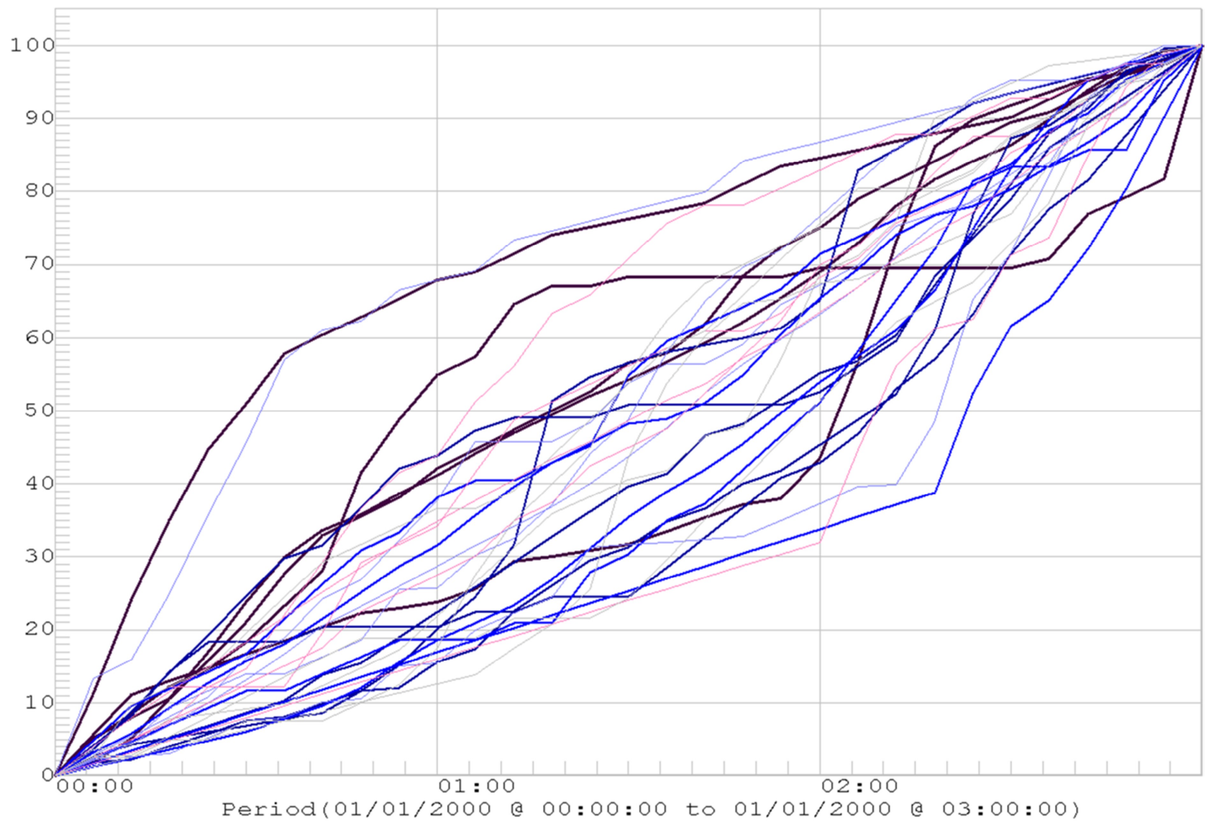
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70
60
50
40
30
20
10
0
00:00
01:00
02:00
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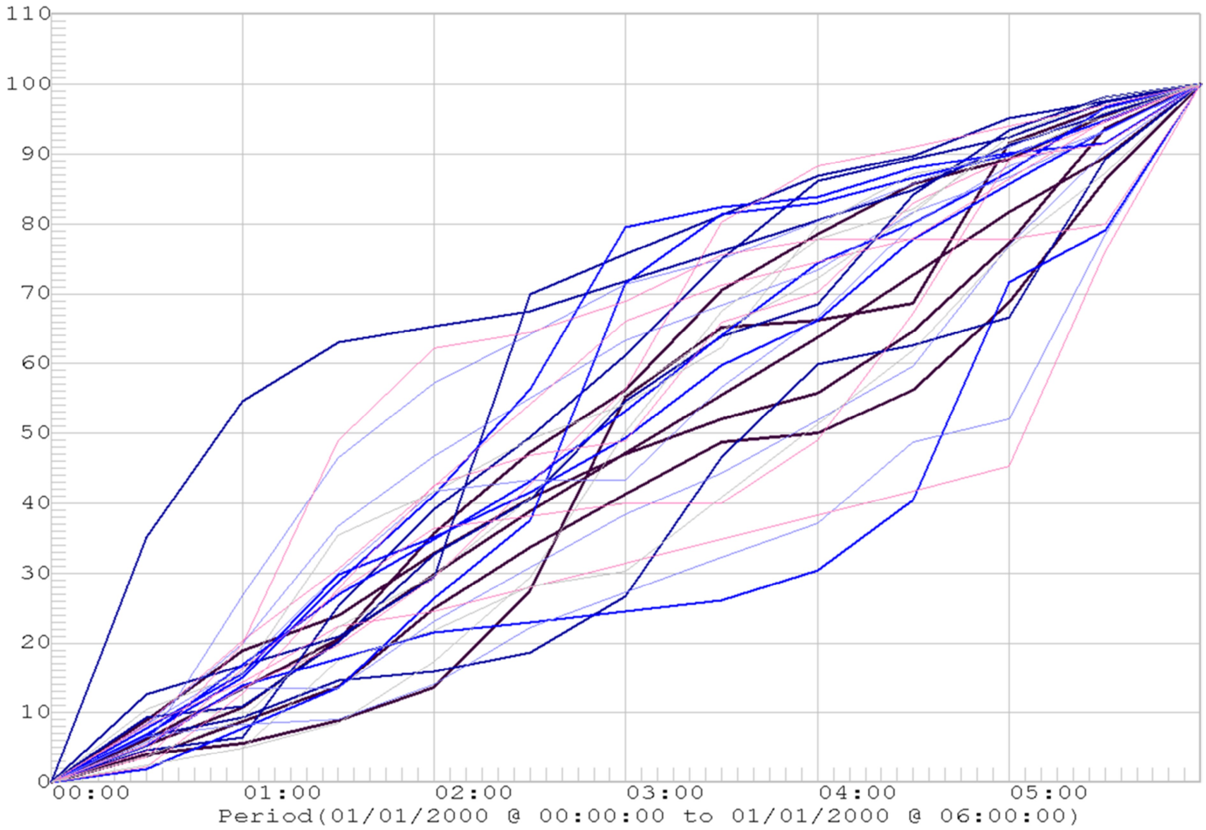
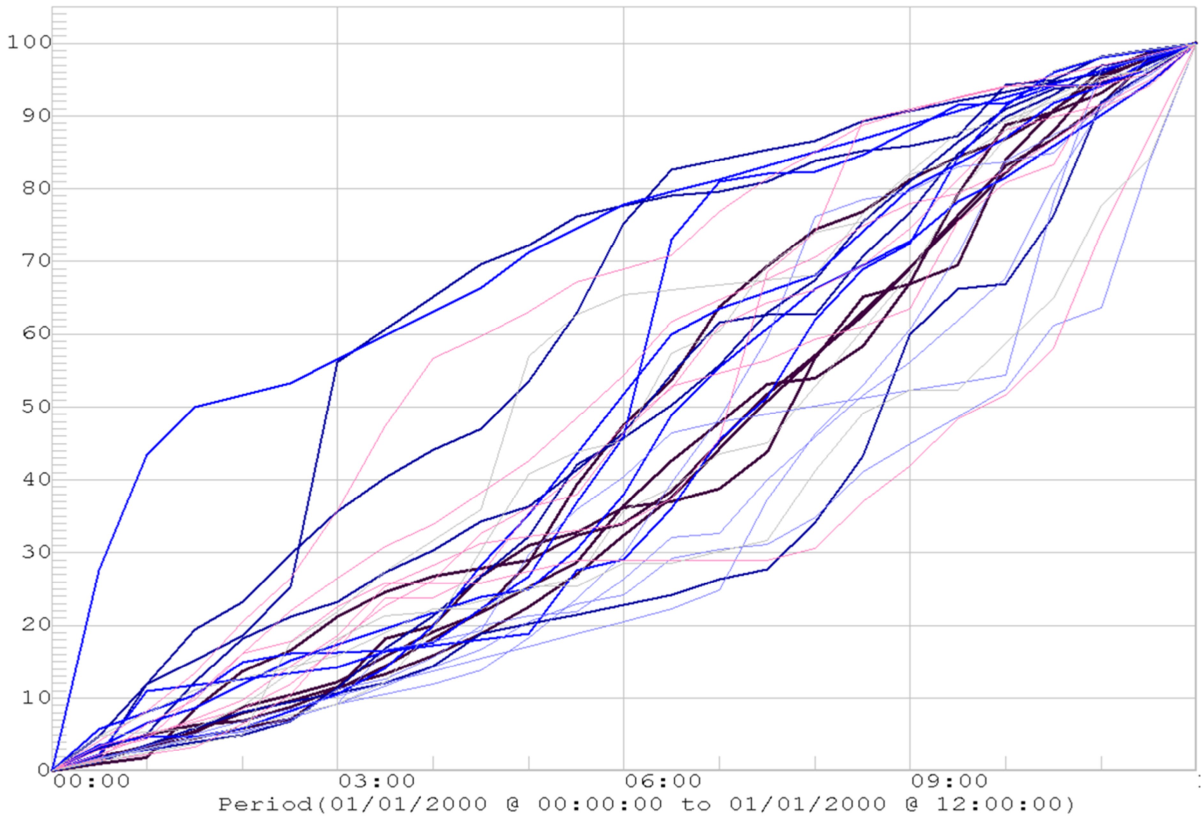
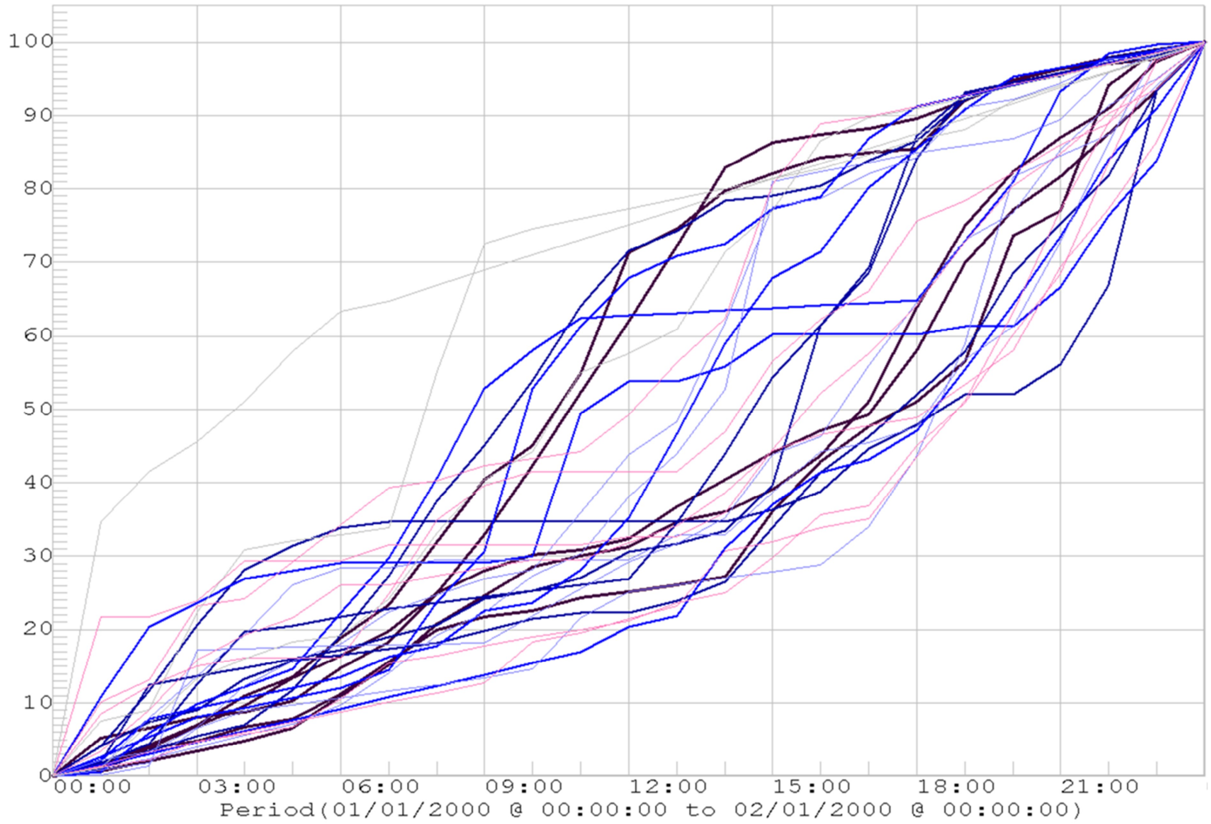
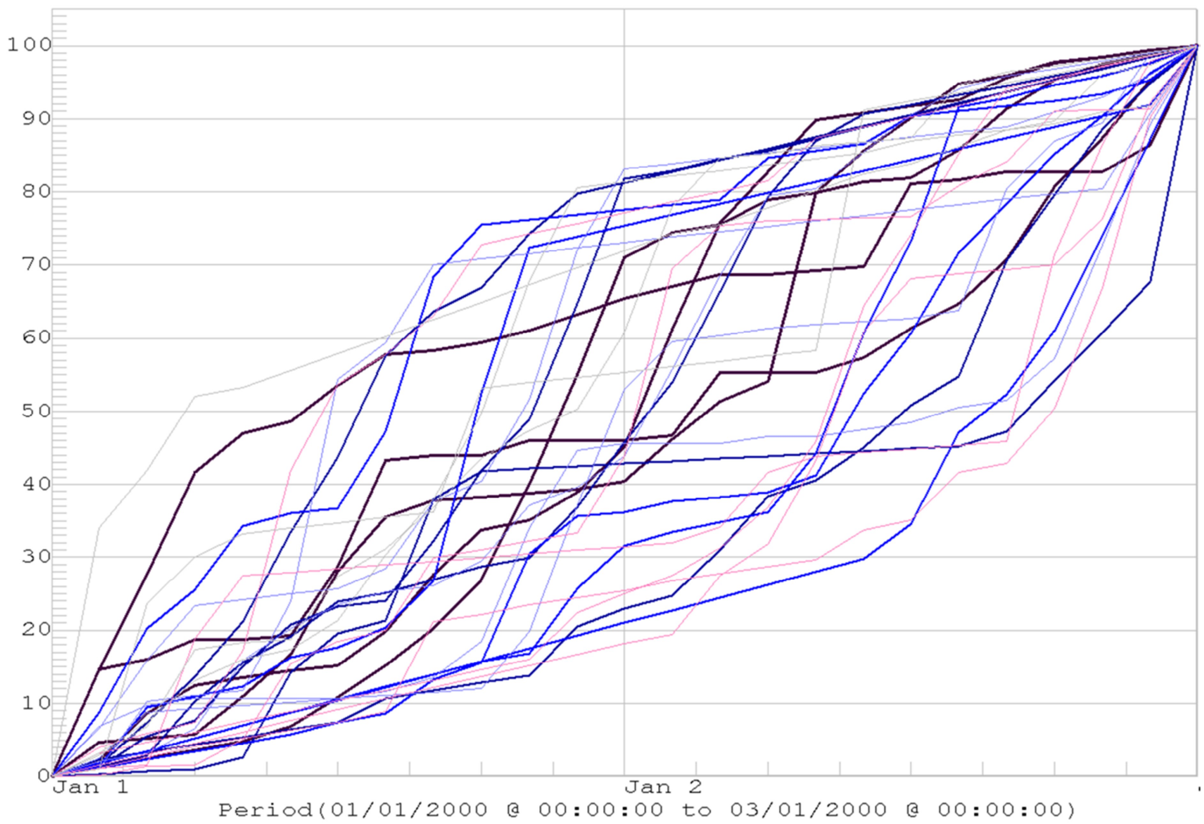

110
100
90
80
70
60
50
40
30
20
10
0
00:00
01:00
02:00
03:00
04:00
05:00
Period(01/01/2000 @ 00:00:00 to 01/01/2000 @ 06:00:00)

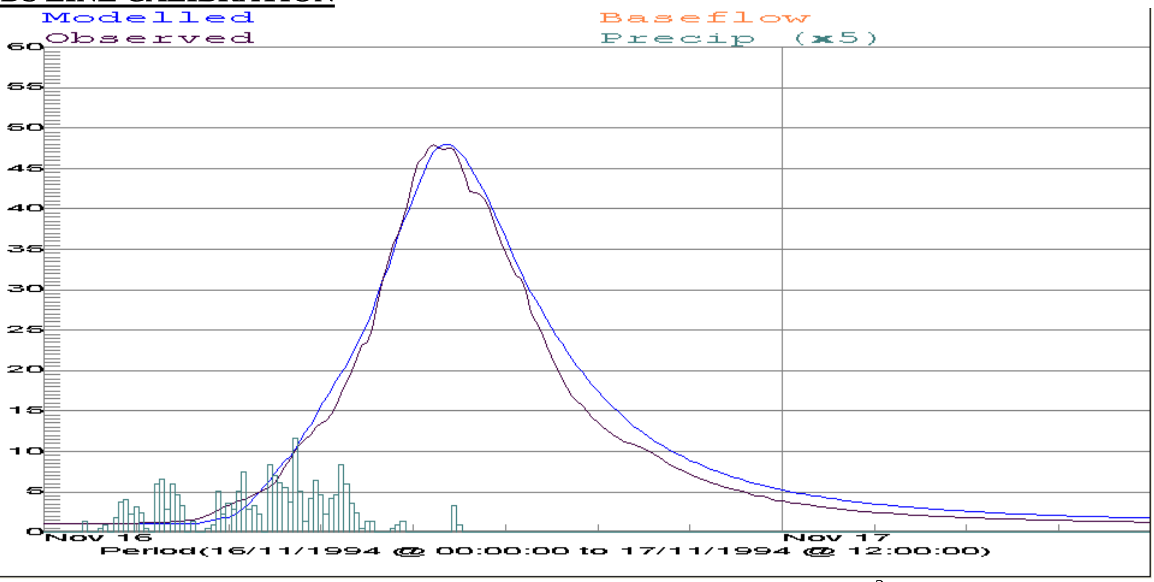

100
90
80
70
60
50
40
30
20
10
0
00:00
03:00
06:00
09:00
Period(01/01/2000 @ 00:00:00 to 01/01/2000 @ 12:00:00)


100
90
80
70
60
50
40
30
20
10
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Period(01/01/2000 @ 00:00:00 to 02/01/2000 @ 00:00:00)

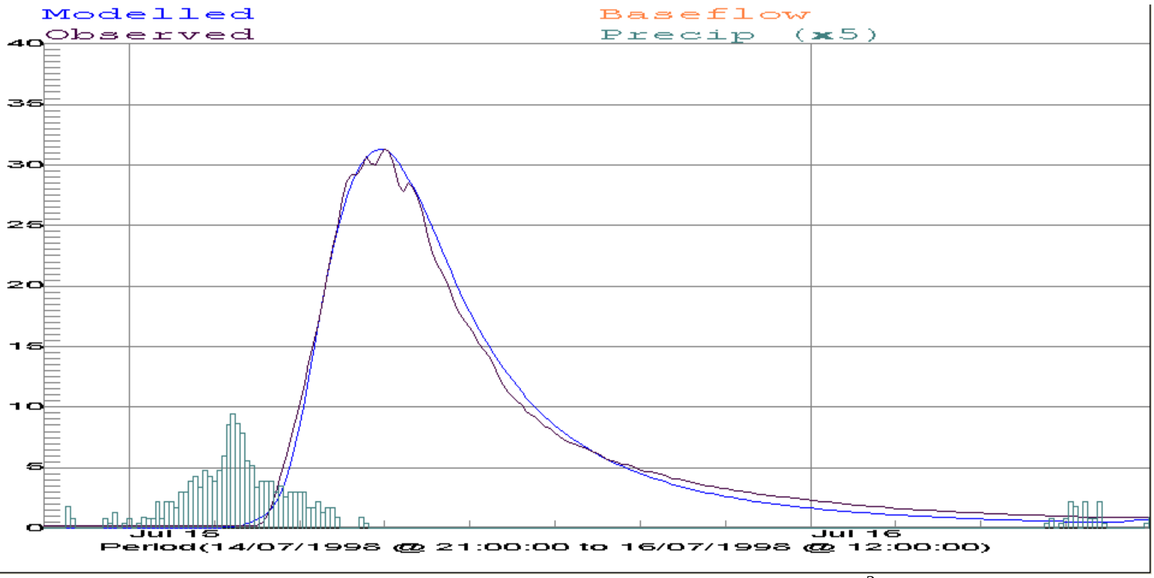

100
90
80
70
60
50
40
30
20
10
0
Jan 1
Jan 2
Period(01/01/2000 @ 00:00:00 to 03/01/2000 @ 00:00:00)

B Hydrologic model event calibration

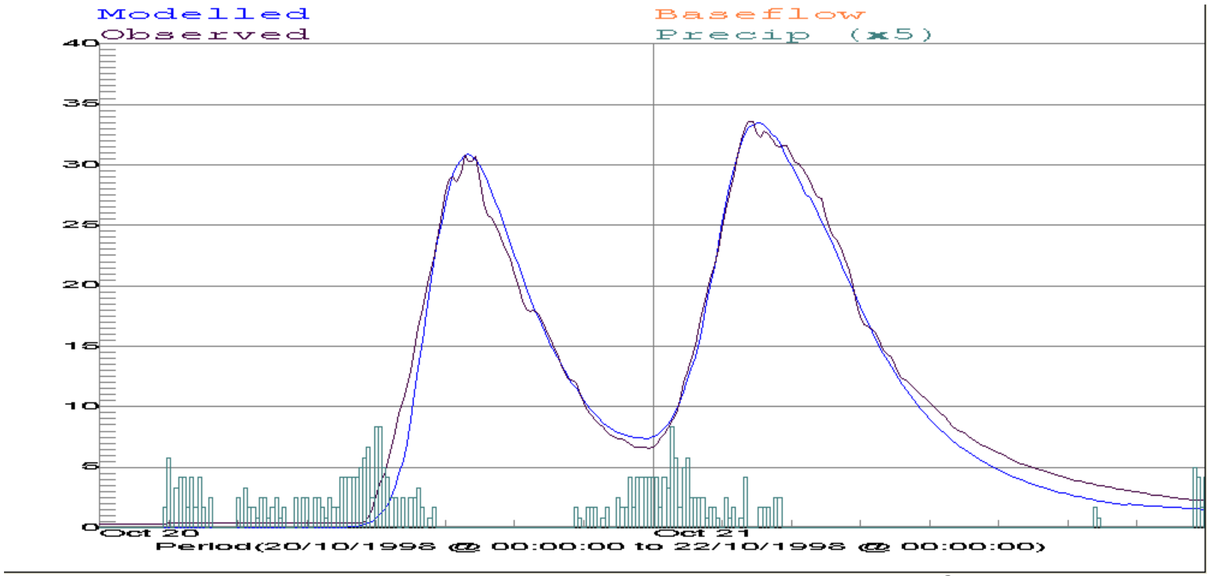
REIDS LINE CALIBRATION



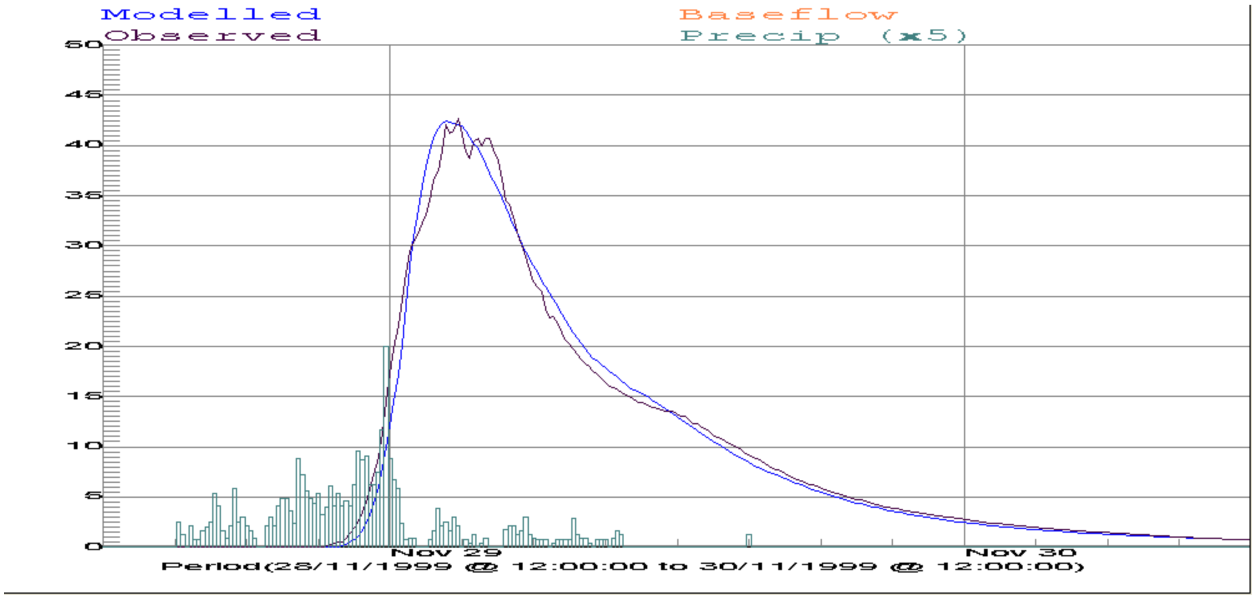
Nov 1994: Alpha – 1.12, IL – 0mm, PR – 0.85, Delay – 2.5hrs, Baseflow – 1m^3/s



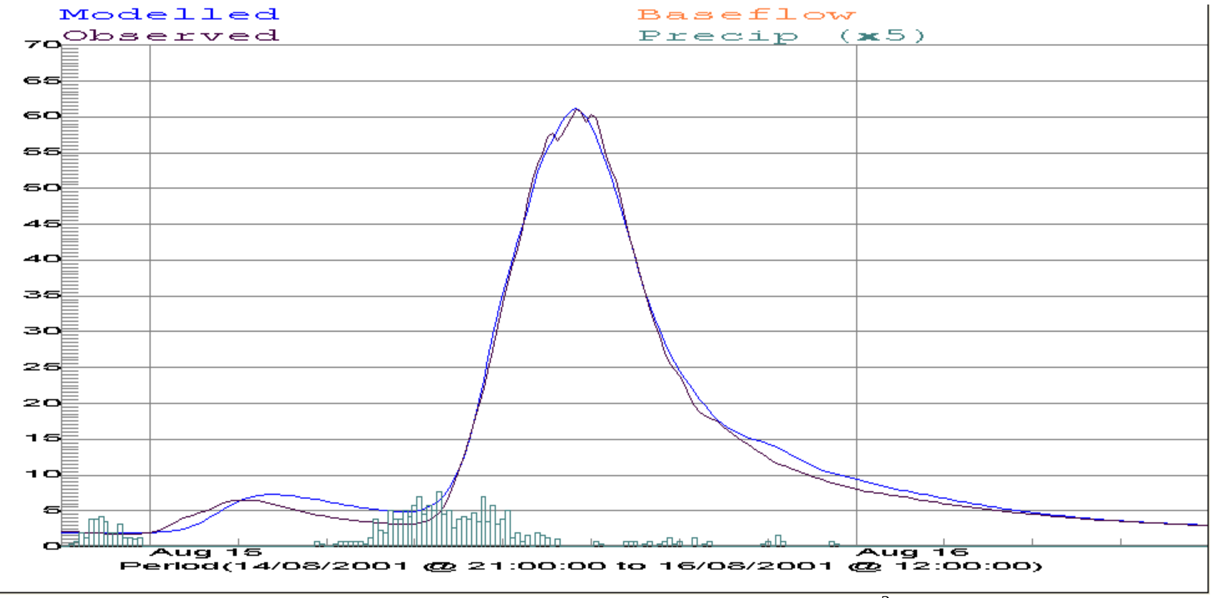
Jul 1998: Alpha – 1.12, IL – 2mm, PR – 0.68, Delay –1.83hrs, Baseflow – 0m^3/s



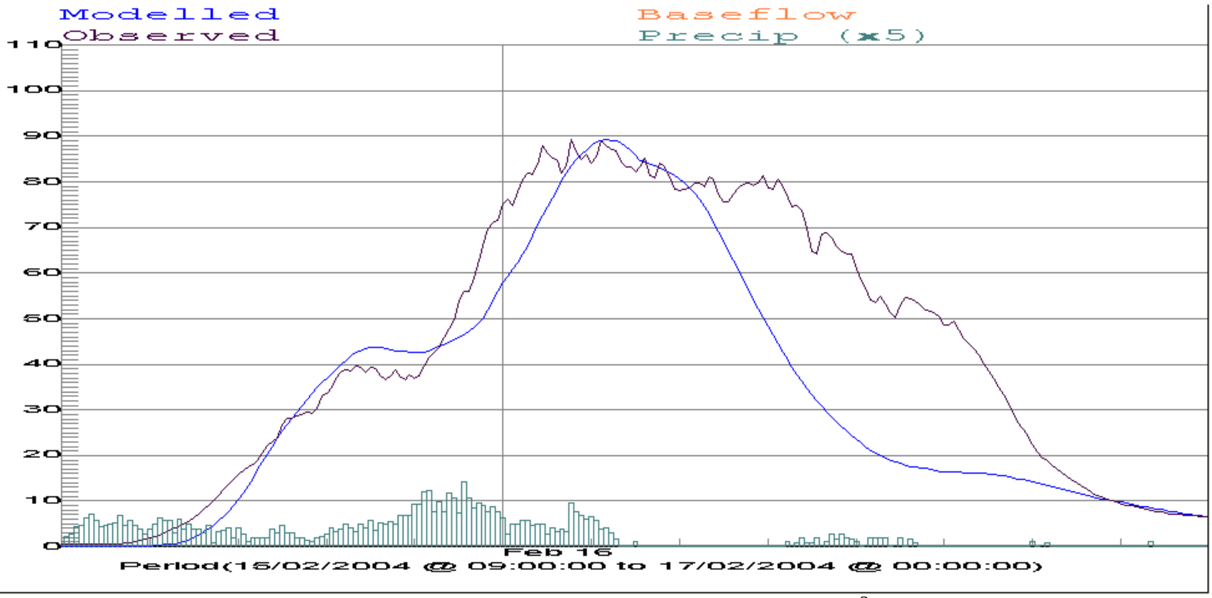
Oct 1998: Alpha – 1.12, IL – 13mm, PR – 0.98, Delay –1.33hrs, Baseflow – 0m^3/s
** Cheltenham rainfall deemed unreliable – only Valley Rd used.



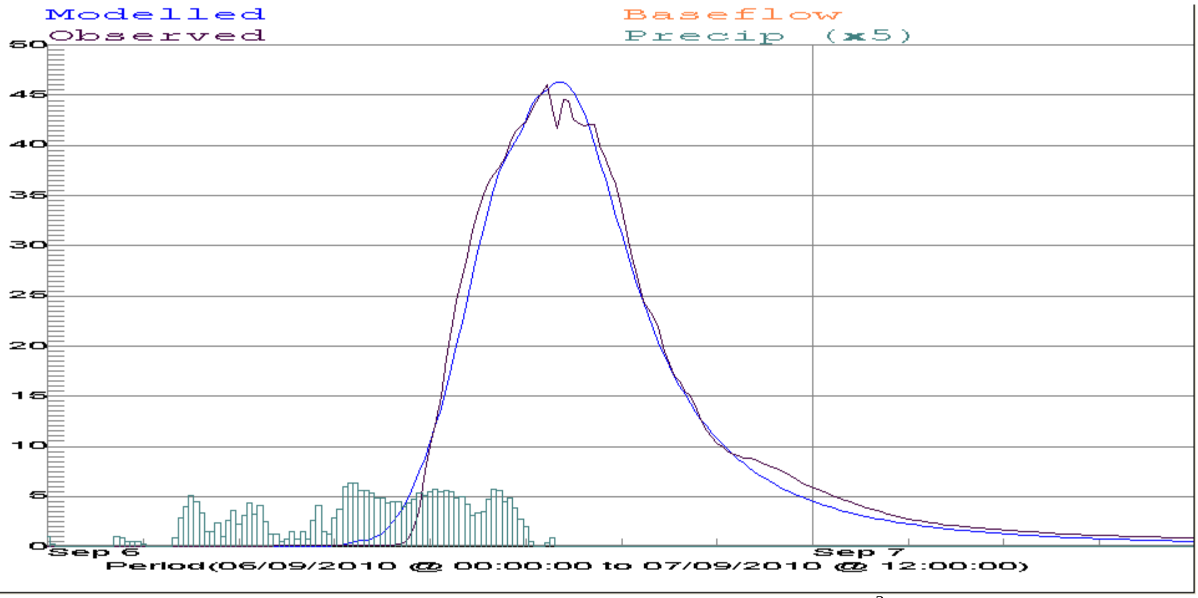
Nov 1999: Alpha – 1.5, IL – 15mm, PR – 0.7, Delay –0.83hrs, Baseflow – 0m^3/s



Aug 2001: Alpha – 0.9, IL – 3mm, PR – 0.89, Delay –1.83hrs, Baseflow – 2m^3/s

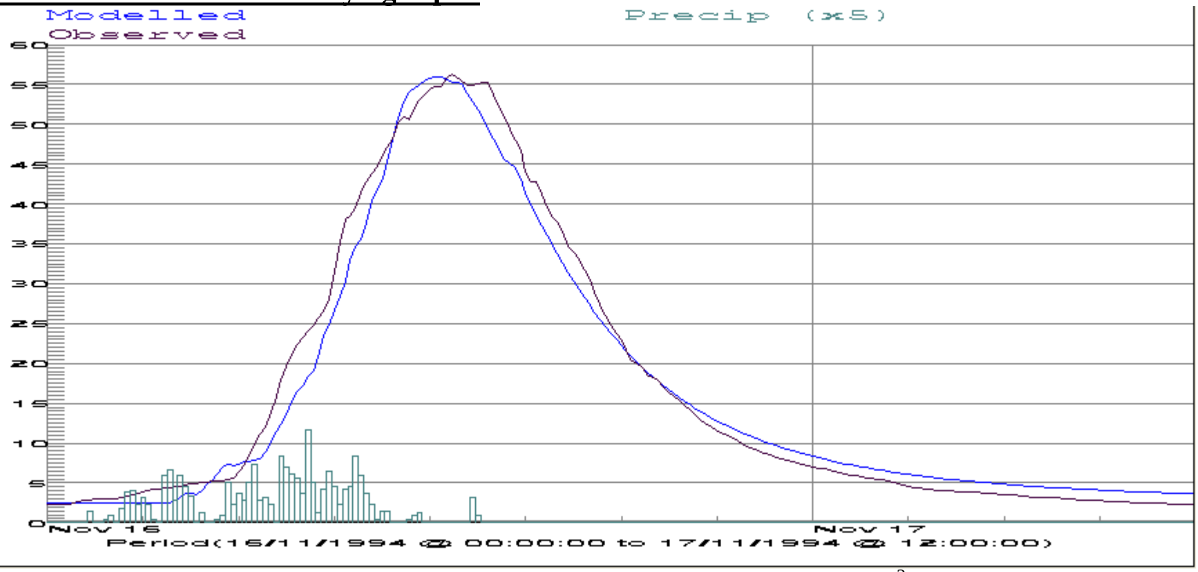


Feb 2004: Alpha – 1.5, IL – 2mm, PR – 0.9, Delay –2.33hrs, Baseflow – 0m^3/s

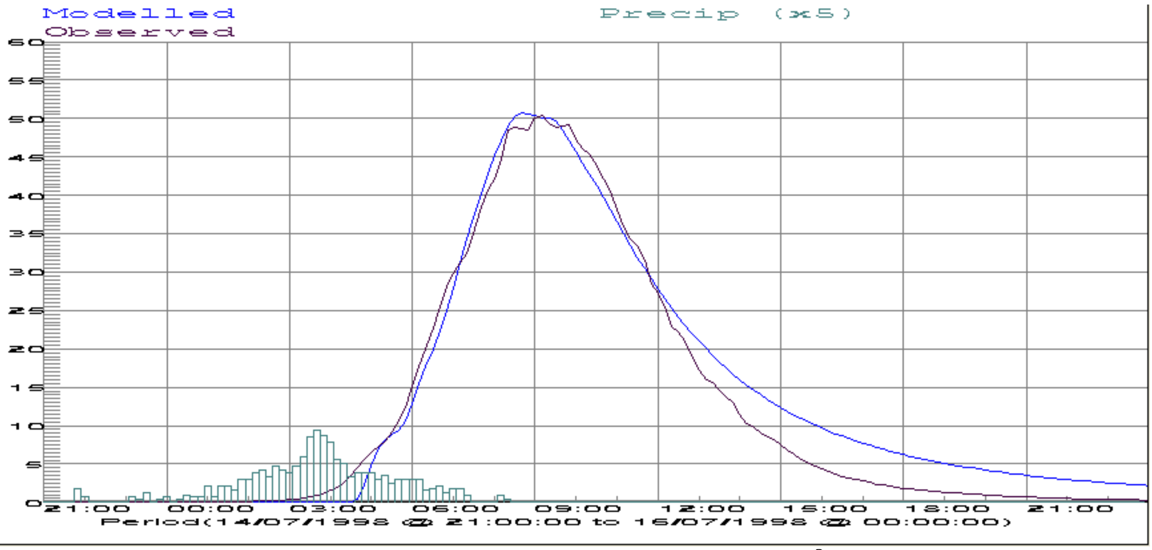


Sep 2010: Alpha – 0.85, IL – 15mm, PR – 0.87, Delay –1.0hrs, Baseflow – 0m^3/s

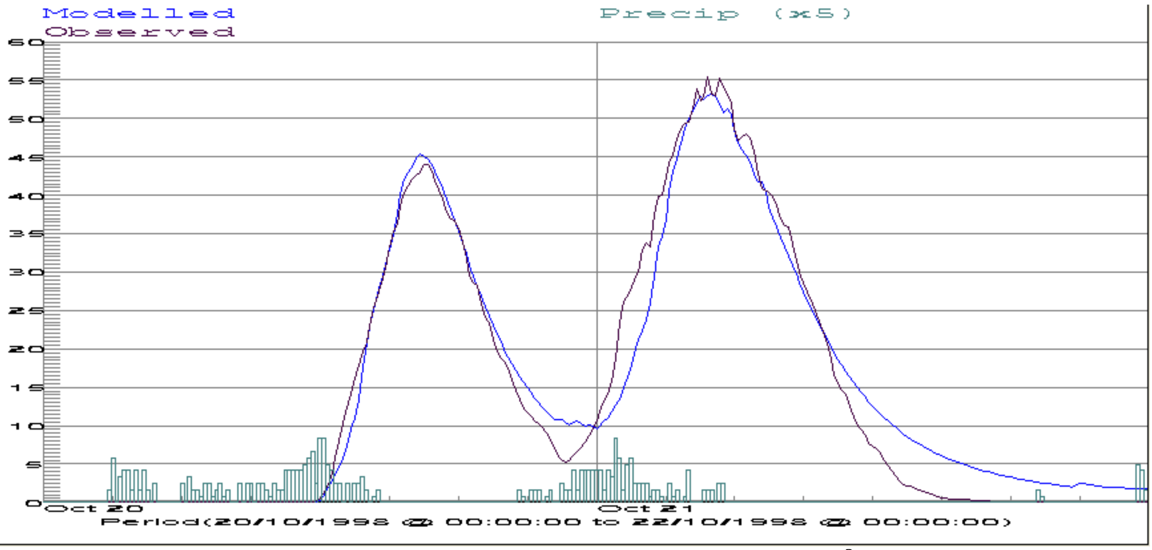
<u>RATA ST CALIBRATION varying Alpha</u>



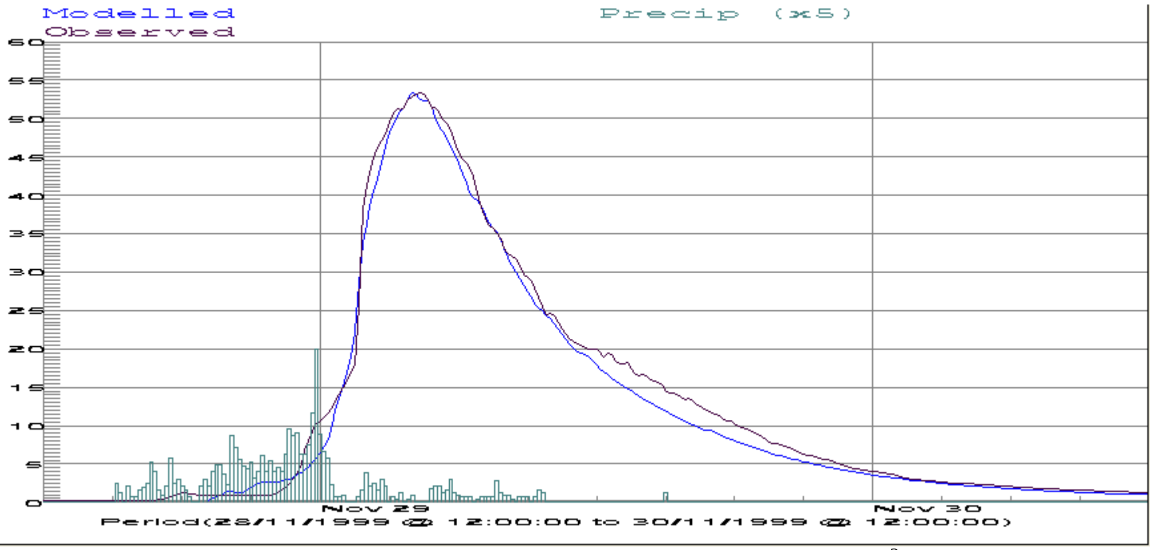
Nov 1994: Alpha – 1.15, IL – 2mm, PR – 0.8, Delay – 1.17hrs, Baseflow – 2.5m^3/s



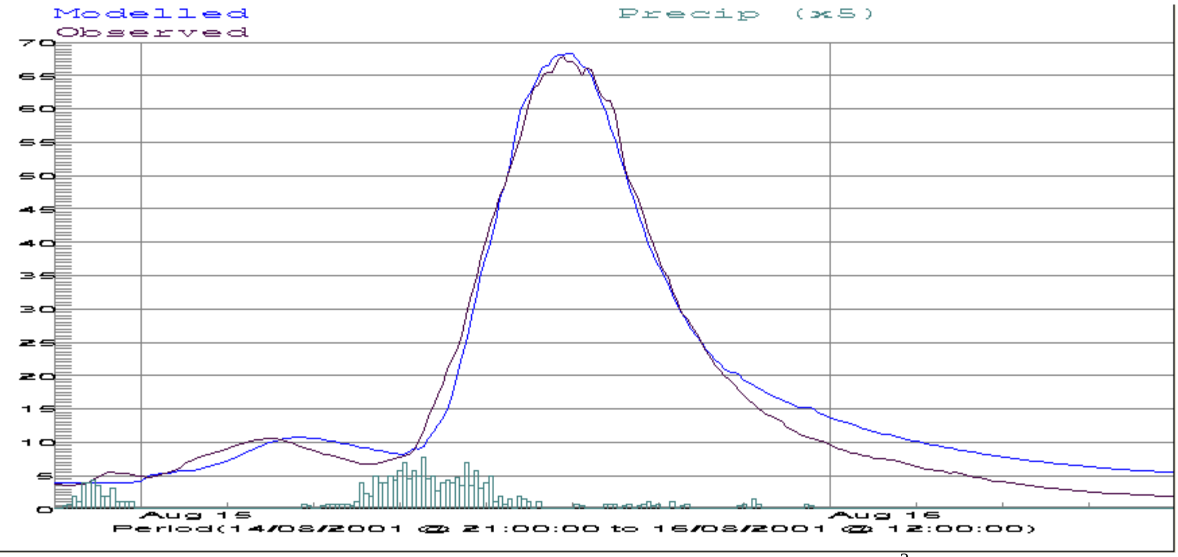
Jul 1998: Alpha – 1, IL – 10mm, PR – 1, Delay – 1.17hrs, Baseflow – 0m^3/s



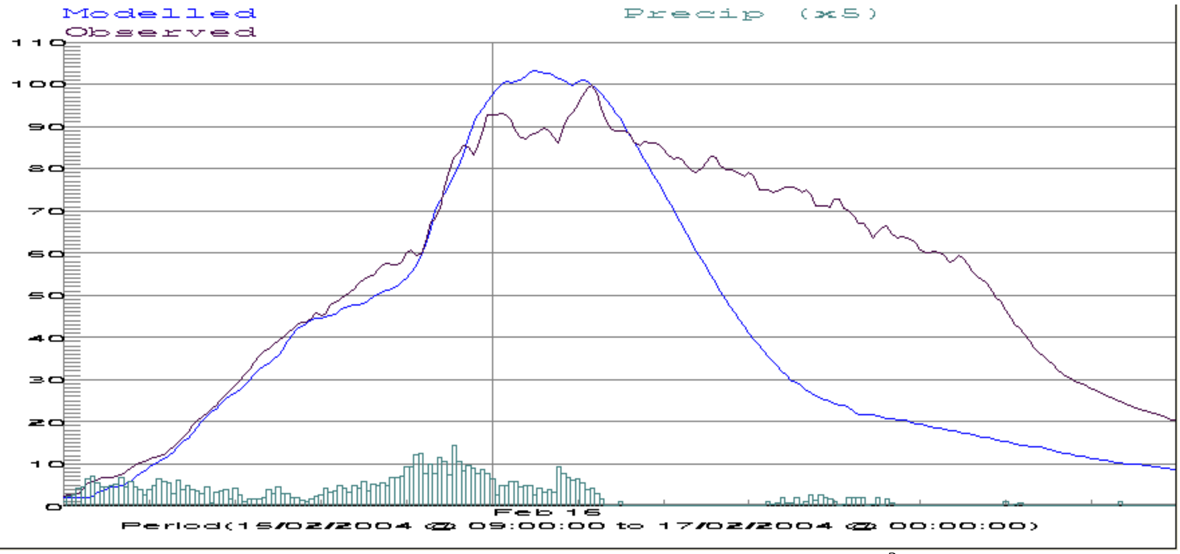
Oct 1998: Alpha – 0.9, IL – 15mm, PR – 1, Delay – 1.83hrs, Baseflow – 0m^3/s



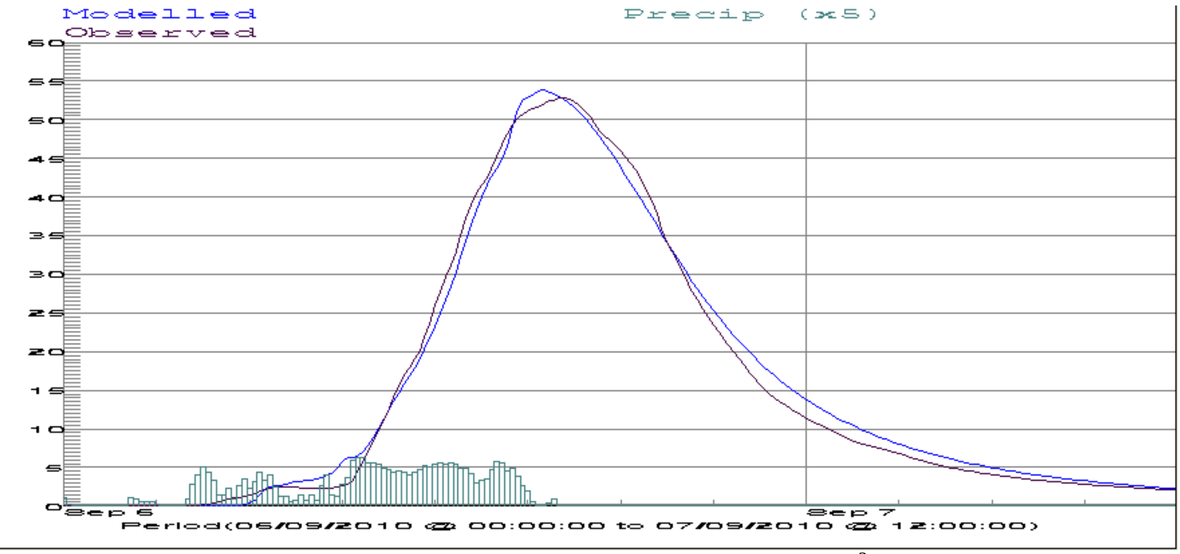
Nov 1999: Alpha – 1.35, IL – 2mm, PR – 0.53, Delay – 1.83hrs, Baseflow – 0m^3/s



Aug 2001: Alpha – 0.85, IL – 2mm, PR – 0.85, Delay – 1.67hrs, Baseflow – 4m^3/s

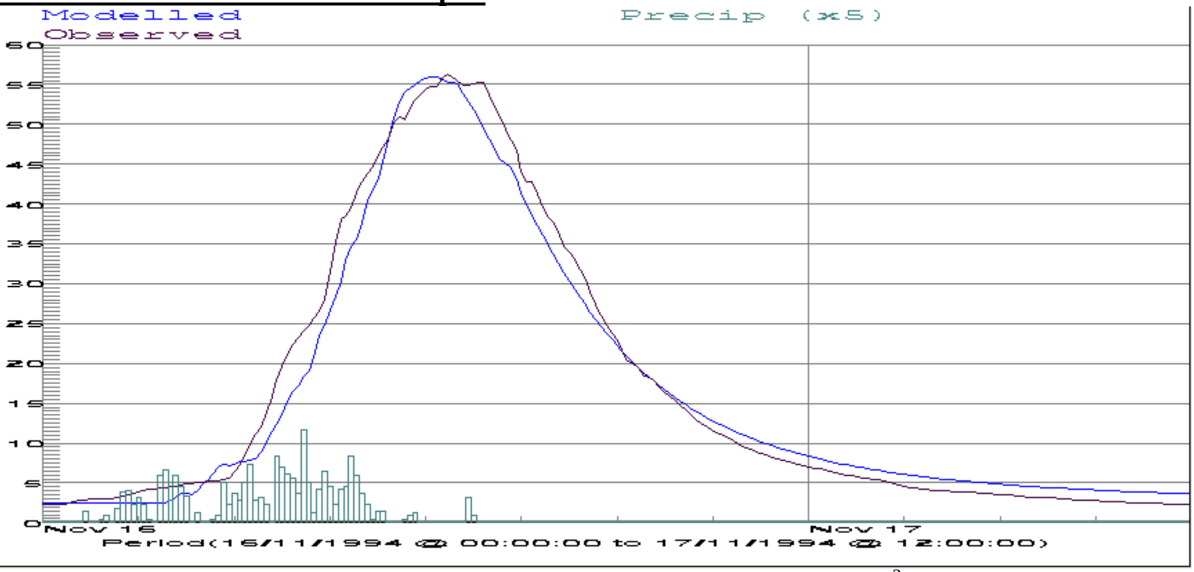


Feb 2004: Alpha – 1.35, IL – 1mm, PR – 0.73, Delay – 0.5hrs, Baseflow – 2m^3/s

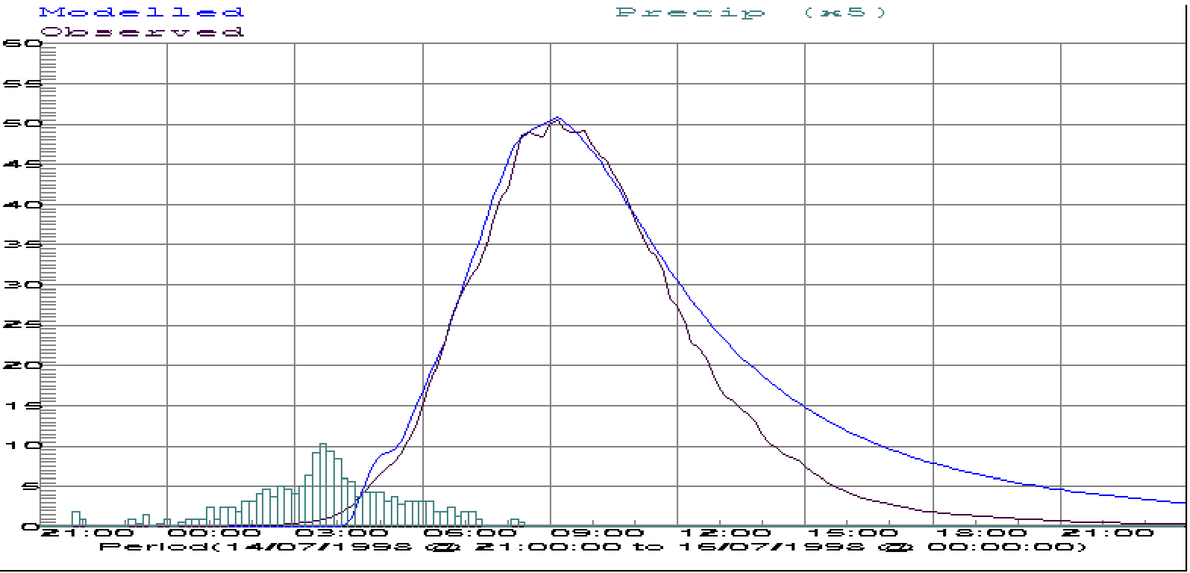


Sep 2010: Alpha – 1.3, IL – 8mm, PR – 0.8, Delay – 0.5hrs, Baseflow – 0m^3/s

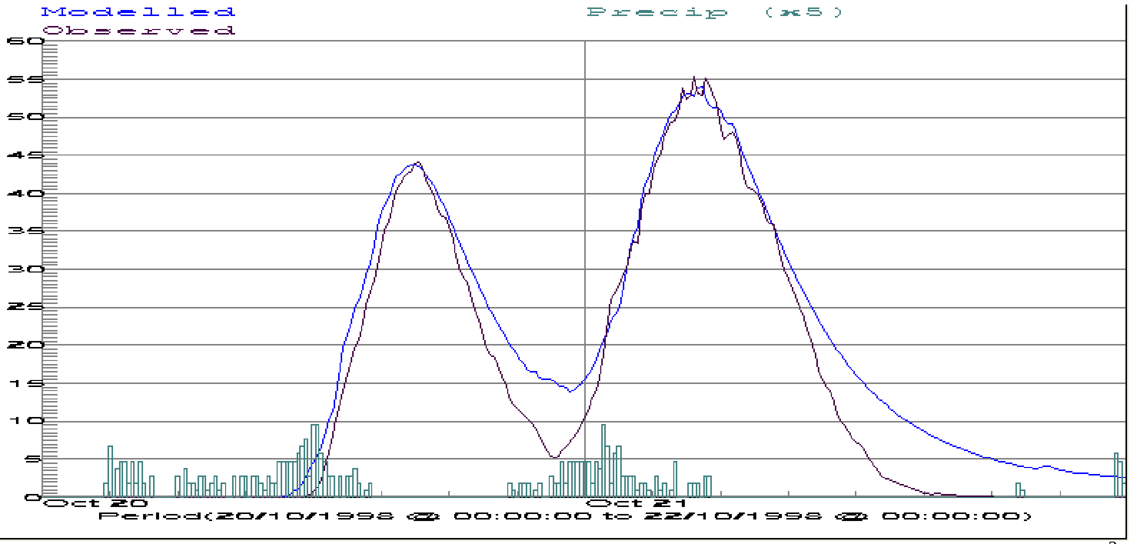
RATA ST CALIBRATION constant Alpha



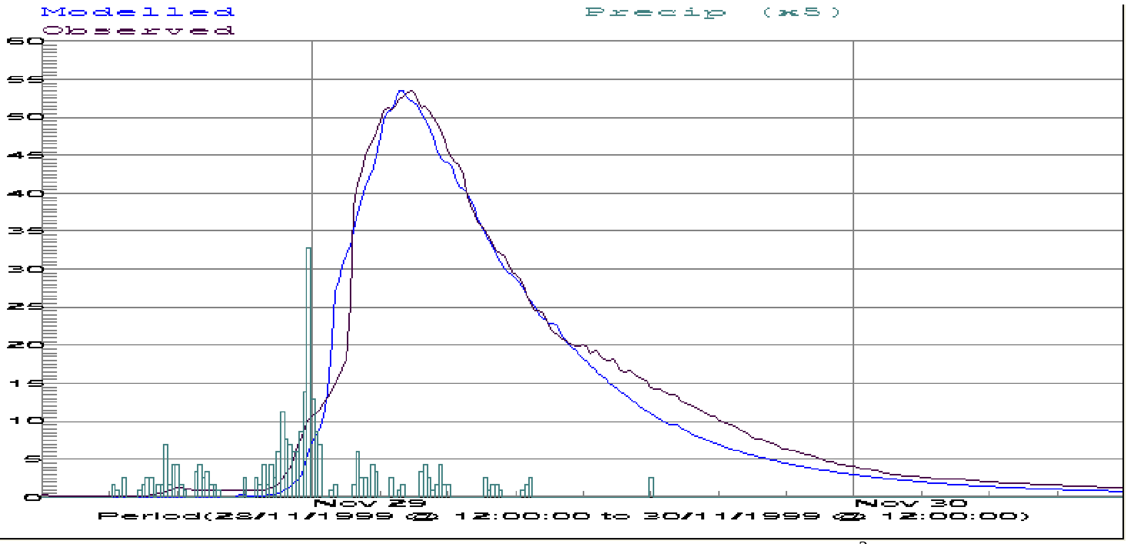
Nov 1994: Alpha – 1.15, IL – 2mm, PR – 0.8, Delay – 1.17hrs, Baseflow – 2.5m^3/s



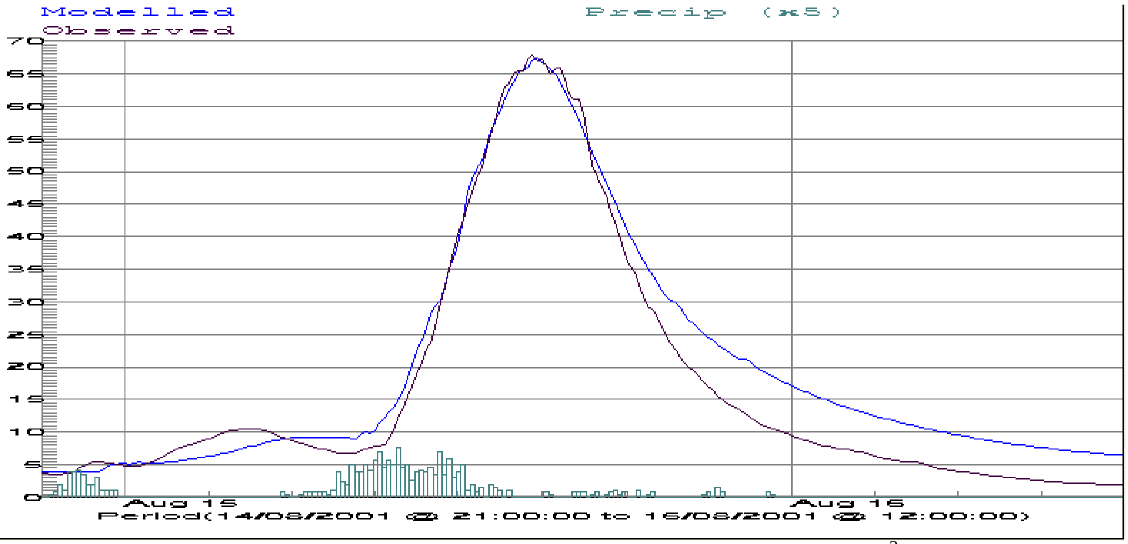
Jul 1998: Alpha – 1.15, IL – 10mm, PR – 1, Rainfall scaled by 1.08, Delay – 0.83hrs, Baseflow – 0m^3/s



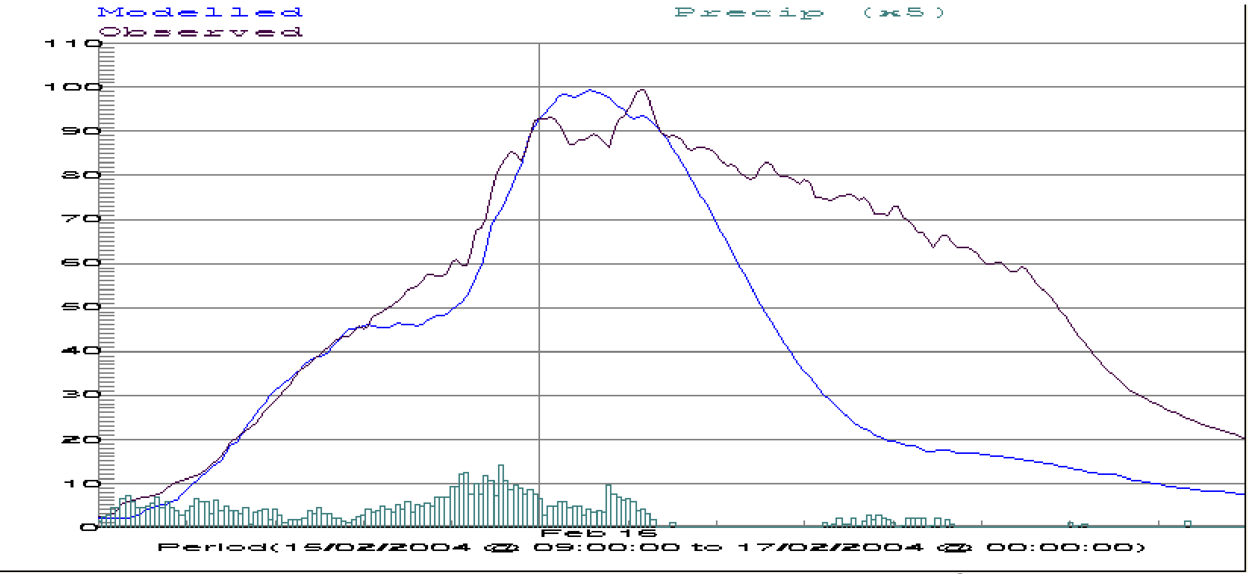
Oct 1998: Alpha – 1.15, IL – 16mm, PR – 1, Rainfall scaled by 1.15, Delay – 1hrs, Baseflow – 0m^3/s, Only Valley Rd rainfall used



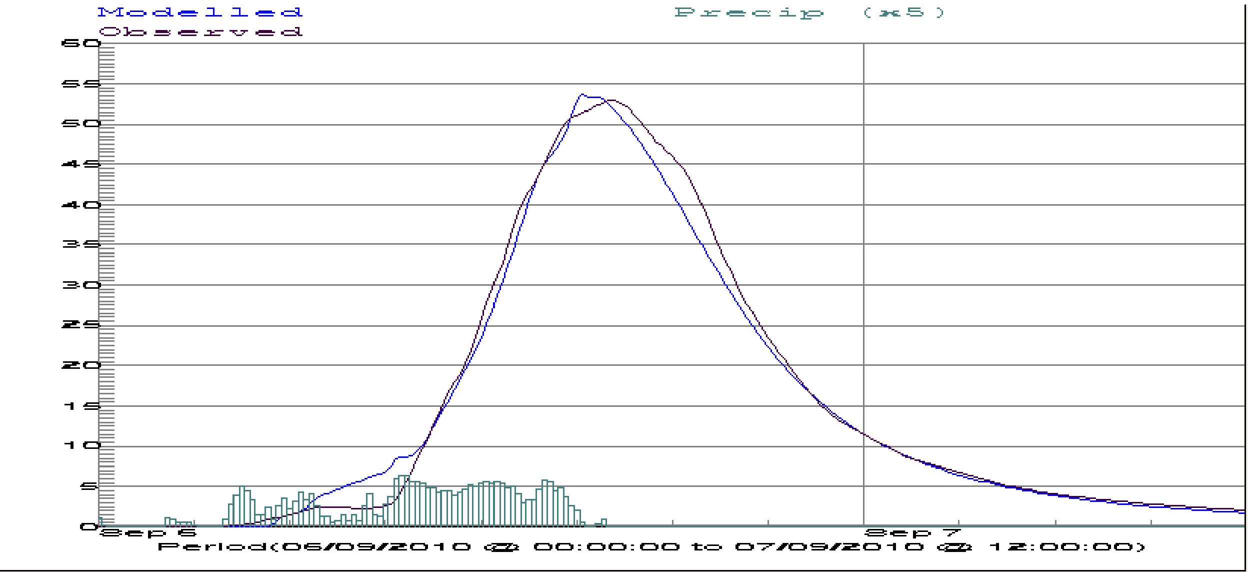
Oct 1999: Alpha – 1.15, IL – 10mm, PR – 0.73, Delay – 1hrs, Baseflow – 0m^3/s



Aug 2001: Alpha – 1.15, IL – 2mm, PR – 0.97, Delay – 0.83hrs, Baseflow – 4m^3/s



Feb 2004: Alpha – 1.15, IL – 0.5mm, PR – 0.67, Delay – 0.83hrs, Baseflow – 2m^3/s



Sep 2010: Alpha – 1.15, IL – 5mm, PR – 0.7, Delay – 0.83hrs, Baseflow – 0m^3/s

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C Inflow Hydrographs

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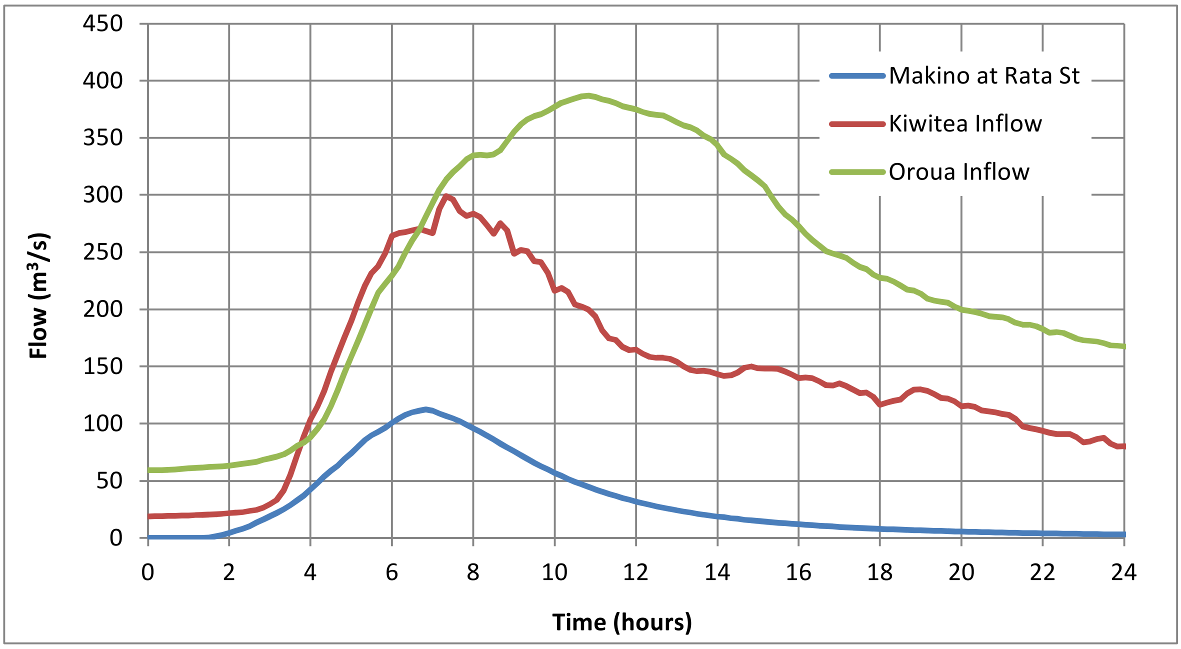
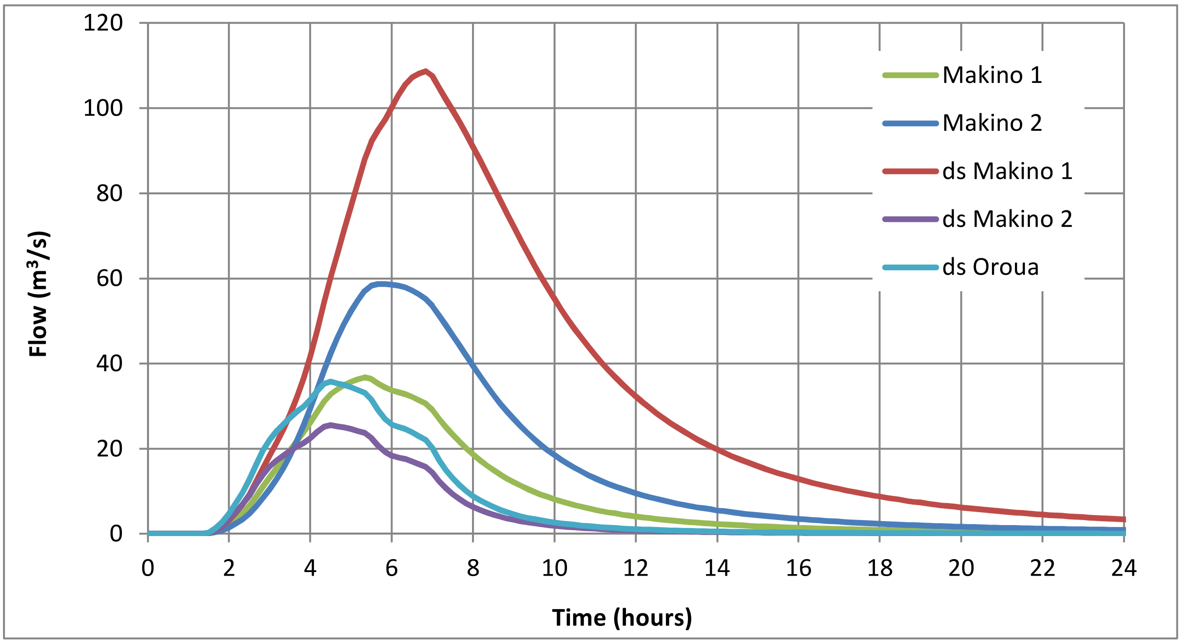
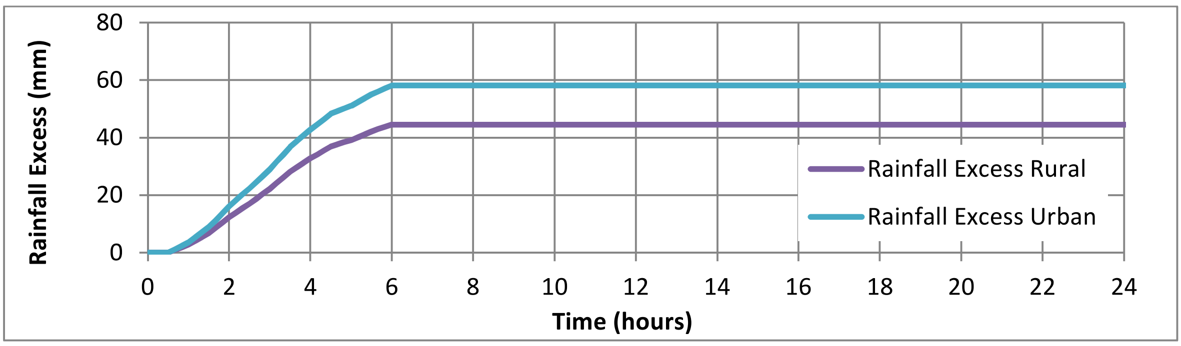
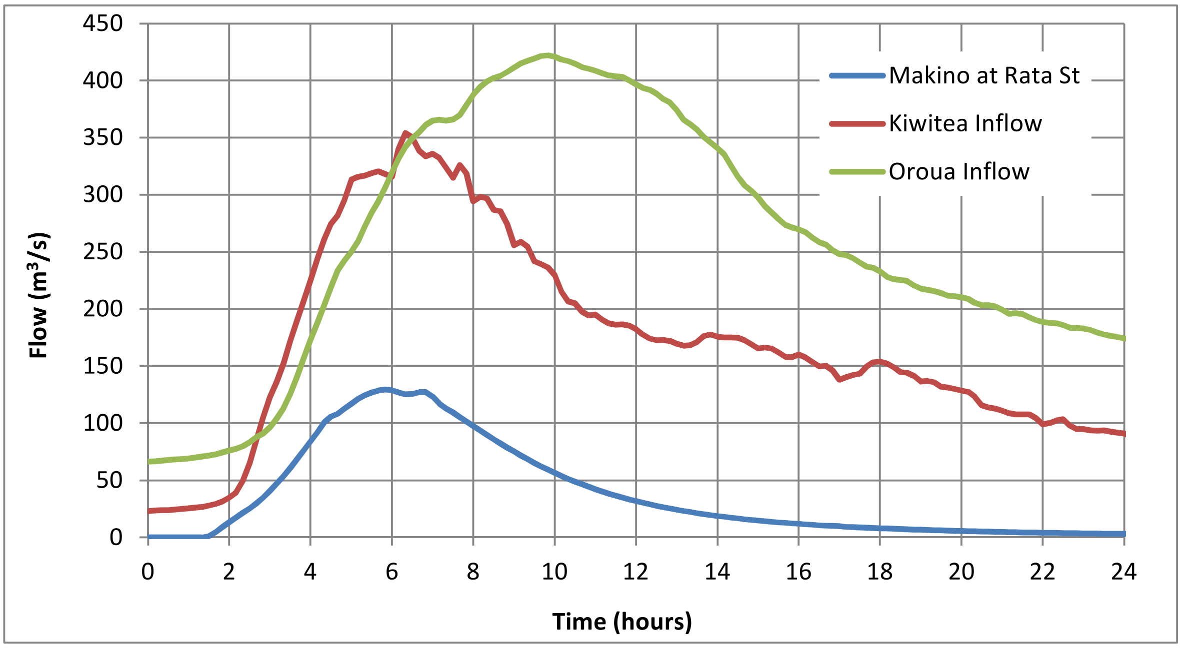
C.1 1:100 AEP

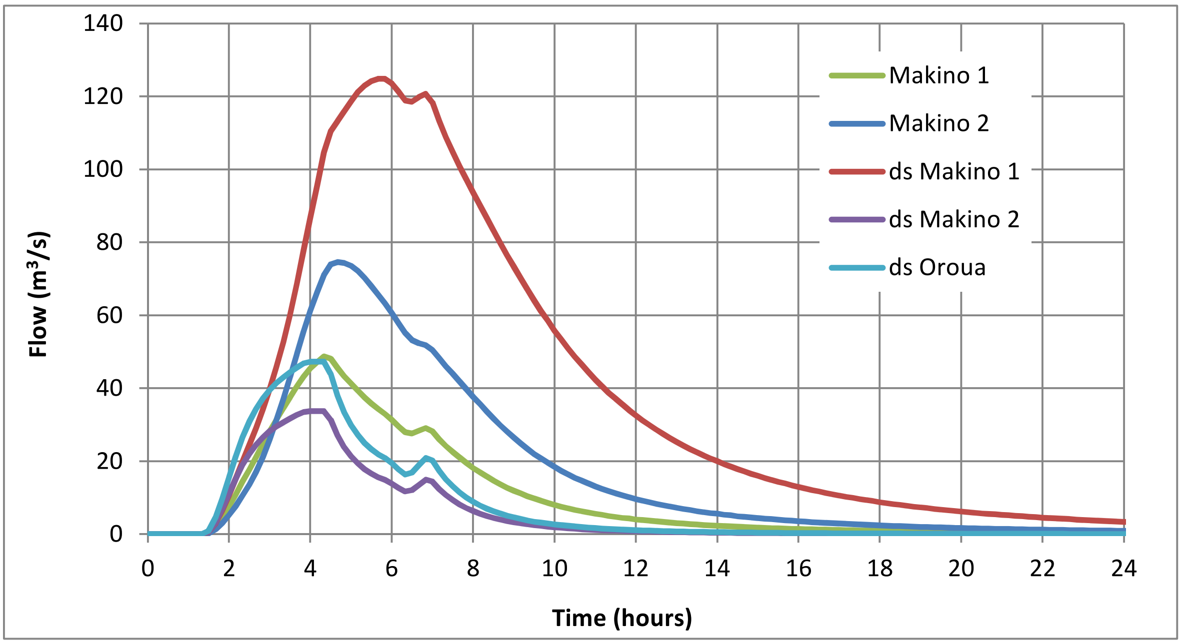

Makino at Rata St
Kiwitea Inflow
Oroua Inflow
Flow (m³/s)
Time (hours)
0
50
100
150
200
250
300
350
400
450
0
2
4
6
8
10
12
14
16
18
20
22
24

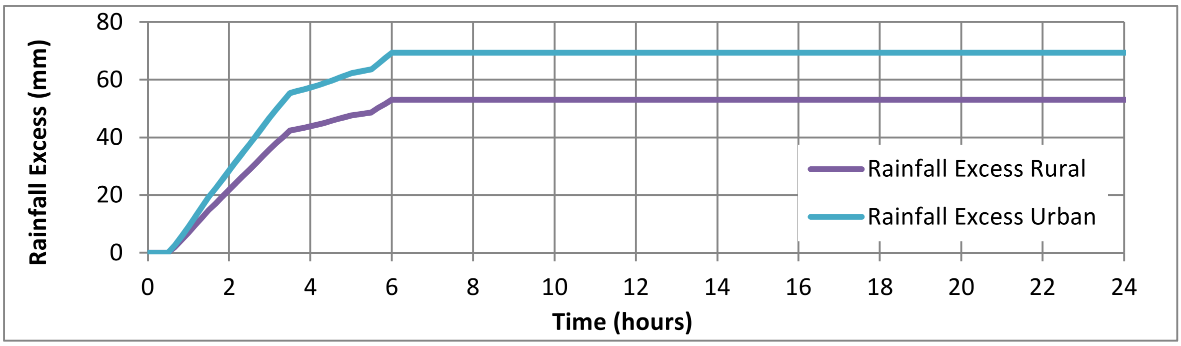

Makino 1
Makino 2
ds Makino 1
ds Makino 2
ds Oroua
Flow (m³/s)
Time (hours)
0
20
40
60
80
100
120
0
2
4
6
8
10
12
14
16
18
20
22
24


Rainfall Excess Rural
Rainfall Excess Urban
Rainfall Excess (mm)
Time (hours)
0
20
40
60
80
0
2
4
6
8
10
12
14
16
18
20
22
24

C.2 1:200 AEP


450
400
350
300
250
200
150
100
50
0
Flow (m³/s)
0 2 4 6 8 10 12 14 16 18 20 22 24
Time (hours)
Makino at Rata St
Kiwitea Inflow
Oroua Inflow


140
120
100
80
60
40
20
0
Flow (m³/s)
0 2 4 6 8 10 12 14 16 18 20 22 24
Time (hours)
Makino 1
Makino 2
ds Makino 1
ds Makino 2
ds Oroua


80
60
40
20
0
Rainfall Excess (mm)
0 2 4 6 8 10 12 14 16 18 20 22 24
Time (hours)
Rainfall Excess Rural
Rainfall Excess Urban

D Catchment Characteristics

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_434	4.803	123.7	0.05	70
Catchment_435	2.483	88.9	0.4	80
Catchment_436	1.396	66.7	0.8	81
Catchment_437	2.480	1000	0.5	83
Catchment_438	5.122	1000	0.5	83
Catchment_439	1.108	59.4	2.7	83
Catchment_440	3.198	100.9	0.5	83
Catchment_441	1.283	63.9	0.4	90
Catchment_442	2.550	90.1	0.7	90
Catchment_443	3.089	99.2	0.5	83
Catchment_444	1.974	79.3	0.5	80
Catchment_445	1.764	74.9	0.7	81
Catchment_446	1.455	68.1	0.5	83
Catchment_448	3.670	108.1	0.5	81
Catchment_449	0.867	52.5	0.2	83
Catchment_450	1.419	67.2	4	83
Catchment_451	2.746	93.5	0.8	83
Catchment_452	2.836	95	0.4	80
Catchment_453	2.727	93.2	1	83
Catchment_454	4.586	120.8	0.4	90
Catchment_455	3.391	103.9	0.1	83
Catchment_456	5.407	131.2	0.6	83
Catchment_457	0.902	53.6	0.2	83
Catchment_458	21.987	264.6	1	98
Catchment_459	1.177	61.2	0.4	80
Catchment_460	1.243	62.9	0.5	90
Catchment_461	4.044	113.5	0.3	83
Catchment_462	3.830	110.4	1	83
Catchment_463	7.323	152.7	1	83
Catchment_464	2.976	97.3	0.8	83
Catchment_465	5.535	132.7	1	90
Catchment_466	1.420	67.2	1	90
Catchment_467	0.970	55.6	0.7	94
Catchment_468	5.805	135.9	1.2	83
Catchment_469	6.470	143.5	1	83
Catchment_470	3.651	107.8	0.5	83
Catchment_471	2.455	88.4	0.3	83
Catchment_472	1.331	65.1	0.7	90
Catchment_473	3.309	102.6	0.5	83
Catchment_474	3.010	97.9	0.8	83
Catchment_475	1.391	66.5	0.5	83

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_476	2.779	90	0.5	90
Catchment_477	1.853	76.8	0.5	83
Catchment_478	1.966	79.1	0.4	83
Catchment_479	2.467	88.6	1	83
Catchment_480	0.916	54	0.3	83
Catchment_481	1.391	66.5	1	83
Catchment_482	0.698	47.1	1	83
Catchment_483	1.173	61.1	0.3	90
Catchment_484	2.710	92.9	1	81
Catchment_485	1.141	60.3	0.8	83
Catchment_486	1.606	71.5	1	83
Catchment_487	2.242	84.5	0.4	83
Catchment_488	6.748	146.6	0.4	80
Catchment_489	1.823	76.2	0.3	83
Catchment_490	1.863	77	0.4	83
Catchment_491	3.593	106.9	0.5	90
Catchment_492	1.010	56.7	0.6	90
Catchment_493	2.656	91.9	0.3	90
Catchment_494	1.233	62.6	0.3	81
Catchment_495	0.237	27.4	0.2	94
Catchment_496	1.322	64.9	0.7	81
Catchment_497	2.330	86.1	0.1	83
Catchment_498	1.182	61.3	0.2	83
Catchment_499	3.552	106.3	0.3	83
Catchment_500	1.135	60.1	0.6	90
Catchment_501	2.307	85.7	0.3	90
Catchment_502	4.069	113.8	0.5	81
Catchment_503	2.724	93.1	0.5	83
Catchment_504	2.039	80.6	0.5	83
Catchment_505	4.213	115.8	0.5	80
Catchment_506	3.548	106.3	0.4	83
Catchment_507	2.653	91.9	0.5	83
Catchment_508	2.224	84.1	0.2	81
Catchment_509	3.792	109.9	0.5	70
Catchment_510	0.639	45.1	0.1	83
Catchment_511	1.752	74.7	0.3	83
Catchment_512	2.336	86.2	0.7	83
Catchment_513	4.604	121.1	0.3	90
Catchment_514	7.255	152	0.5	83
Catchment_515	1.068	58.3	0.3	90
Catchment_516	3.147	100.1	0.7	90
Catchment_517	2.357	86.6	0.8	70
Catchment_518	4.828	124	0.7	70
Catchment_519	2.842	95.1	0.9	94

Catchment Name in MIKE URBAN	**Catchment Area (ha)**	**Catchment Length (m)**	**Equal Area Slope**	**UHM Curve Number**
Catchment_520	3.115	99.6	0.7	90
Catchment_521	1.932	78.4	0.4	80
Catchment_522	3.233	101.5	0.3	90
Catchment_523	1.329	65	0.4	90
Catchment_524	2.324	86	0.4	90
Catchment_525	1.334	65.2	0.9	90
Catchment_526	4.218	115.9	0.5	90
Catchment_527	1.549	70.2	0.8	94
Catchment_528	2.676	92.3	0.3	94
Catchment_529	0.970	55.6	0.2	98
Catchment_530	0.527	41	0.5	94
Catchment_531	1.315	64.7	0.3	94
Catchment_532	1.369	66	2.4	98
Catchment_533	1.652	72.5	0.7	90
Catchment_534	4.232	116.1	0.4	98
Catchment_535	0.732	48.3	0.7	98
Catchment_536	0.981	55.9	0.5	90
Catchment_537	1.297	64.2	0.7	98
Catchment_538	0.925	54.2	0.7	98
Catchment_539	0.793	50.2	0.8	98
Catchment_540	5.594	133.4	1	98
Catchment_541	1.189	61.5	0.5	90
Catchment_542	2.075	81.3	1	81
Catchment_543	1.677	73.1	0.4	83
Catchment_544	1.753	74.7	0.3	90
Catchment_545	1.321	64.8	0.3	83
Catchment_546	0.458	38.2	0.6	83
Catchment_547	1.723	74.1	0.5	83
Catchment_548	1.608	71.5	0.5	90
Catchment_549	0.849	52	0.7	90
Catchment_550	2.862	95.4	0.1	70
Catchment_551	0.771	49.5	0.7	98
Catchment_553	2.356	86.6	0.1	90
Catchment_554	0.119	19.5	0.5	83
Catchment_555	2.616	91.2	0.3	90
Catchment_556	0.554	42	0.5	90
Catchment_557	3.287	102.3	1.2	80
Catchment_558	0.563	42.3	0.8	83
Catchment_559	1.102	59.2	4	83
Catchment_560	1.555	70.3	0.5	83
Catchment_561	5.289	129.8	1	80
Catchment_562	1.268	63.5	0.4	90
Catchment_563	4.278	116.7	0.6	98
Catchment_564	0.812	50.8	0.5	90

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_565	1.425	67.3	0.3	90
Catchment_566	2.059	81	0.1	83
Catchment_567	2.473	88.7	0.1	83
Catchment_568	0.919	54.1	0.9	83
Catchment_569	1.080	58.6	0.3	90
Catchment_570	1.590	71.1	0.3	83
Catchment_571	6.997	149.2	2	80
Catchment_572	1.353	65.6	0.5	83
Catchment_573	0.885	53.1	0.5	83
Catchment_574	0.553	49.1	0.5	83
Catchment_575	0.645	45.3	2	83
Catchment_576	0.252	28.3	0.5	80
Catchment_577	3.557	106.4	1.3	81
Catchment_578	2.350	86.5	2.3	81
Catchment_579	0.724	48	0.3	81
Catchment_580	0.299	30.9	0.5	81
Catchment_581	2.461	88.5	0.3	81
Catchment_582	0.907	53.7	0.9	83
Catchment_585	5.834	136.3	0.5	83
Catchment_586	3.697	101.8	0.1	83
Catchment_587	1.931	78.4	2	83
Catchment_588	3.921	111.7	1	81
Catchment_595	3.243	101.6	1	83
Catchment_596	15.032	218.7	1.8	70
Catchment_597	2.553	90.2	0.2	83
Catchment_598	1.728	74.2	0.1	83
Catchment_599	2.008	79.9	1	83
Catchment_600	1.409	67	1	83
Catchment_601	4.723	122.6	0.5	94
Catchment_602	3.530	106	2.4	83
Catchment_603	3.871	111	1.2	80
Catchment_604	2.685	92.4	0.7	94
Catchment_605	1.947	78.7	0.5	81
Catchment_606	4.989	126	0.5	81
Catchment_607	3.537	106.1	0.7	94
Catchment_608	2.006	79.9	0.4	81
Catchment_609	1.284	63.9	0.5	81
Catchment_610	1.968	79.2	1	81
Catchment_611	1.491	68.9	0.5	83
Catchment_612	3.189	100.8	0.4	83
Catchment_613	1.389	66.5	0.9	81
Catchment_614	1.846	76.7	0.4	83
Catchment_615	13.908	210.4	0.3	80
Catchment_616	1.310	64.6	1	83

Catchment Name in MIKE URBAN	**Catchment Area (ha)**	**Catchment Length (m)**	**Equal Area Slope**	**UHM Curve Number**
Catchment_617	1.064	58.2	0.4	83
Catchment_618	3.437	104.6	1	83
Catchment_619	1.583	71	2.2	83
Catchment_620	2.181	83.3	1.6	90
Catchment_621	2.538	89.9	0.9	83
Catchment_622	0.673	46.3	4.2	81
Catchment_623	3.258	101.8	2	83
Catchment_624	1.618	71.8	0.7	83
Catchment_625	7.203	151.4	1.18	98
Catchment_626	3.649	107.8	0.5	98
Catchment_627	17.644	237	7	98
Catchment_628	2.578	90.6	0.5	98
Catchment_629	3.278	102.1	0.7	81
Catchment_630	1.979	79.4	3	81
Catchment_631	7.467	154.2	0.8	80
Catchment_632	48.872	394.4	7	98
Catchment_633	89.738	534.5	1	70
Catchment_634	141.202	670.4	7	98
Catchment_635	4.606	121.1	1	83
Catchment_636	1.338	65.3	0.7	90
Catchment_637	1.815	76	1.6	80
Catchment_638	0.798	50.4	0.3	83
Catchment_639	2.746	93.5	0.8	83
Catchment_640	2.158	82.9	2	83
Catchment_642	1.037	57.5	1	90
Catchment_643	1.714	73.9	1	80
Catchment_644	0.184	24.2	1.4	90
Catchment_645	0.235	27.3	0.5	83
Catchment_646	0.279	29.8	0.2	83
Catchment_647	1.100	59.2	0.3	83
Catchment_648	1.141	60.3	0.7	80
Catchment_649	18.429	242.2	1	98
Catchment_650	1.377	66.2	0.5	90
Catchment_651	3.013	97.9	0.5	83
Catchment_652	2.787	94.2	3	80
Catchment_653	43.918	373.9	0.5	98
Catchment_654	2.482	88.9	0.1	83
Catchment_655	2.161	82.9	1	81
Catchment_656	50.381	400.5	7	98
Catchment_657	3.708	108.6	4.8	83
Catchment_658	2.020	80.2	4	81
Catchment_659	1.067	58.3	3.8	80
Catchment_660	1.698	73.5	9.2	81
Catchment_661	1.084	58.7	0.4	90

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_662	0.860	52.3	0.5	80
Catchment_663	1.480	68.6	0.2	83
Catchment_664	8.572	165	0.2	98
Catchment_665	3.615	107.3	0.1	80
Catchment_666	67.789	464.5	2	98
Catchment_667	1.561	70.5	0.5	83
Catchment_668	1.459	68.2	0.5	81
Catchment_669	1.041	57.6	0.3	83
Catchment_670	1.840	76.5	0.5	80
Catchment_671	0.420	36.6	0.5	90
Catchment_672	0.122	19.7	0.3	94
Catchment_673	0.678	46.4	0.4	90
Catchment_552_1	0.910	50	2.4	98
Catchment_674_1	7.480	50	2.4	98
Catchment_674_2	2.446	55	2.4	98
Catchment_675	1.168	53.8	0.3	80
Catchment_676	0.598	154.3	1	98
Catchment_677	1.201	88.2	4.8	83
Catchment_678	1.292	61	3	83
Catchment_679	2.148	43.6	0.2	90
Catchment_680	1.088	61.8	6.3	81
Catchment_681	1.307	64.1	6	81
Catchment_682	2.253	82.7	3.1	83
Catchment_683	0.824	58.8	0.4	83
Catchment_684	2.518	64.5	3	83
Catchment_685	1.710	84.7	9.6	81
Catchment_686	1.184	51.2	0.4	83
Catchment_687	2.618	89.5	3	83
Catchment_688	2.044	73.8	1	83
Catchment_689	1.590	61.4	3	83
Catchment_690	2.120	91.3	3	81
Catchment_691	3.023	80.7	0.4	83
Catchment_692	2.296	71.1	1.8	81
Catchment_693	1.522	82.1	0.5	83
Catchment_694	1.396	98.1	2.9	81
Catchment_695	3.412	85.5	0.4	80
Catchment_696	1.693	69.6	4.2	80
Catchment_697	1.125	66.7	3.3	81
Catchment_698	0.918	104.2	4.2	98
Catchment_699	7.713	73.4	3.5	81
Catchment_700	1.605	59.8	4.6	83
Catchment_701	471.638	54.1	0.4	83
Catchment_702	0.755	156.7	4.2	98
Catchment_703	1.011	71.5	0.4	81

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_704	3.682	1265	7	98
Catchment_705	0.831	49	0.6	83
Catchment_706	1.473	56.7	0.4	83
Catchment_707	1.098	108.3	0.1	83
Catchment_708	2.388	51.4	0.4	98
Catchment_710	2.437	59.1	0.2	83
Catchment_709	1.084	68.5	0.6	98
Catchment_711	0.788	87.2	0.5	98
Catchment_712	2.041	88.1	3.4	80
Catchment_713	20.057	58.7	0.4	81
Catchment_714	0.696	50.1	0.4	81
Catchment_715	30.722	80.6	2.1	81
Catchment_716	52.621	252.7	1	70
Catchment_717	3.777	47.1	0.4	81
Catchment_718	0.056	312.7	1	98
Catchment_719	3.061	409.3	1	98
Catchment_720	1.891	109.6	0.5	80
Catchment_721	25.379	13.4	0.3	94
Catchment_722	8.097	98.7	0.5	80
Catchment_723	2.952	77.6	0.6	83
Catchment_724	31.201	284.2	1	98
Catchment_725	17.316	160.5	0.1	98
Catchment_584_1	3.527	94.6	1	70
Catchment_727	0.872	96.9	1	70
Catchment_728	1.794	315.1	1	98
Catchment_729	23.638	234.8	1	98
Catchment_730	1.921	106	2.3	81
Catchment_731	4.698	52.7	0.8	80
Catchment_732	2.464	75.6	1.9	80
Catchment_733	16.399	274.3	1	98
Catchment_734	2.361	78.2	1.7	81
Catchment_735	0.198	122.3	0.3	81
Catchment_736	1.056	88.6	1.2	83
Catchment_737	0.880	228.5	1	98
Catchment_738	0.525	86.7	0.8	83
Catchment_739	2.259	25.1	0.8	83
Catchment_740	2.106	58	0.9	81
Catchment_741	7.534	52.9	0.6	90
Catchment_869_1	2.564	45	0.8	98
Catchment_869_2	1.313	45	0.8	98
Catchment_743	0.890	40.9	0.1	81
Catchment_744	7.250	84.8	0.1	83
Catchment_745	1.493	81.9	0.4	70
Catchment_746	5.049	154.9	1.2	98

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_747	6.616	90.3	0.6	81
Catchment_742_1	7.341	40	0.7	98
Catchment_742_2	1.240	40	0.7	98
Catchment_749	0.671	64.6	0.1	83
Catchment_750	2.074	53.2	1.1	83
Catchment_751	1.029	151.9	0.4	98
Catchment_752	0.692	68.9	3.3	83
Catchment_753	1.318	126.8	0.4	83
Catchment_754	3.882	145.1	0.8	98
Catchment_755	3.909	152.9	0.5	98
Catchment_756	3.134	62.8	3	83
Catchment_757	1.604	46.2	0.4	83
Catchment_758	1.132	81.2	0.5	80
Catchment_759	1.784	57.2	0.4	81
Catchment_761	0.967	46.9	0.1	70
Catchment_762	1.050	64.8	1.8	81
Catchment_763	0.747	111.2	1	80
Catchment_764	1.096	111.5	4	81
Catchment_765	3.316	99.9	0.1	98
Catchment_766	1.452	71.5	1	81
Catchment_767	2.525	60	4.3	83
Catchment_768	1.215	75.4	1	80
Catchment_811_1	1.130	53	3.4	83
Catchment_769	1.097	55.5	4	83
Catchment_770	1.559	57.8	4	83
Catchment_771	1.039	48.7	1.4	81
Catchment_748_1	2.446	45	4	83
Catchment_748_2	1.586	45	4	83
Catchment_773	0.875	59.1	0.5	83
Catchment_774	1.134	102.7	0.7	80
Catchment_775	0.822	68	0.2	83
Catchment_776	2.213	89.6	0.3	83
Catchment_777	1.780	62.2	1.3	83
Catchment_772_1	1.340	60	0.7	90
Catchment_772_2	1.358	60	0.7	90
Catchment_779	1.420	60	0.5	83
Catchment_780	1.076	59.1	0.5	81
Catchment_781	1.807	70.4	0.4	81
Catchment_782	1.984	57.5	0.6	80
Catchment_783	3.548	88.2	0.7	83
Catchment_784	0.918	71.1	0.5	81
Catchment_785	1.394	52.8	0.8	83
Catchment_786	3.020	60.1	1	83
Catchment_787	2.489	51.1	1	80

Catchment Name in MIKE URBAN	**Catchment Area (ha)**	**Catchment Length (m)**	**Equal Area Slope**	**UHM Curve Number**
Catchment_788	3.301	83.9	1	83
Catchment_789	0.539	75.3	0.6	83
Catchment_790	1.465	65.3	1.4	81
Catchment_791	1.220	65.7	0.5	81
Catchment_792	2.288	67.2	1	83
Catchment_793	2.598	58.5	1	83
Catchment_778_1	1.716	50	0.5	83
Catchment_778_2	1.919	40	0.5	83
Catchment_795	2.750	75.8	0.7	81
Catchment_796	2.038	79.5	0.5	81
Catchment_797	1.597	106.3	0.4	80
Catchment_798	2.437	54.1	0.1	83
Catchment_799	0.614	66.6	1	80
Catchment_800	0.397	98	1	83
Catchment_801	1.517	89	0.6	83
Catchment_802	1.641	102.5	0.3	81
Catchment_803	2.372	41.4	1	80
Catchment_804	2.678	68.3	1.5	83
Catchment_805	5.627	62.3	1.6	83
Catchment_806	2.545	85.3	2	83
Catchment_807	19.768	90.9	0.6	81
Catchment_808	1.503	73.9	2.1	81
Catchment_809	1.476	78.2	0.05	83
Catchment_794_1	1.381	90	0.1	83
Catchment_794_2	2.717	70	0.1	83
Catchment_812	1.655	93.6	7.3	80
Catchment_813	1.214	80.6	1.2	83
Catchment_814	1.649	71.3	1.3	83
Catchment_815	2.558	88.1	1.3	83
Catchment_816	1.693	44.2	0.8	81
Catchment_817	1.259	35.5	0.5	90
Catchment_818	0.924	69.5	0.5	81
Catchment_819	1.079	72.3	1.3	83
Catchment_820	21.939	86.9	1.7	81
Catchment_821	2.931	92.3	4.8	83
Catchment_822	0.828	133.8	4.8	80
Catchment_811_2	1.820	70	1	83
Catchment_823	1.101	90	1.6	81
Catchment_824	1.139	250.8	1.2	98
Catchment_825	1.596	69.2	3	81
Catchment_826	1.026	68.5	0.8	83
Catchment_827	1.035	66.3	1.3	81
Catchment_828	1.082	93	5	83
Catchment_829	0.422	72.6	6.6	81

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_830	1.510	62.2	4	81
Catchment_810_1	1.439	65	1.5	83
Catchment_810_2	4.247	70	1.5	83
Catchment_832	3.101	72.5	1.5	83
Catchment_833	2.039	90.2	5.4	81
Catchment_834	1.108	73.4	3.9	81
Catchment_835	0.792	63.3	1.4	81
Catchment_836	0.962	54.2	2.5	81
Catchment_837	1.710	58.6	1.1	81
Catchment_838	1.886	264.3	7	98
Catchment_839	1.172	96.6	0.3	83
Catchment_831_1	0.999	60	0.6	83
Catchment_831_2	2.263	80	0.6	83
Catchment_841	1.397	51.4	2.7	83
Catchment_842	14.746	76.1	0.1	83
Catchment_843	0.635	59.2	1.5	81
Catchment_844	0.725	60.2	1.5	81
Catchment_845	0.534	71.3	0.3	83
Catchment_846	0.950	57.2	0.3	90
Catchment_847	1.254	57.4	0.7	98
Catchment_840_1	1.457	60	0.7	98
Catchment_840_2	0.574	60	0.7	98
Catchment_849	1.041	58.7	0.2	98
Catchment_850	1.272	36.7	4.5	83
Catchment_851	1.817	69.3	0.7	90
Catchment_852	1.827	67.7	1.4	81
Catchment_853	0.705	116.3	4.2	81
Catchment_854	0.707	99.4	0.2	81
Catchment_855	0.631	80.6	1.5	83
Catchment_856	0.972	59.4	0.9	83
Catchment_857	1.154	50.2	0.9	70
Catchment_858	0.904	55.3	0.3	80
Catchment_859	0.969	73.8	1	70
Catchment_860	0.585	77.5	1.4	90
Catchment_848_1	1.006	85	0.6	83
Catchment_848_2	1.082	80	0.6	83
Catchment_862	1.231	61.1	1.4	83
Catchment_863	1.346	56.4	2.5	81
Catchment_864	1.395	84.9	1.1	81
Catchment_865	0.597	66.7	0.5	83
Catchment_866	0.935	216.7	0.5	98
Catchment_867_1	2.231	62.1	1	80
Catchment_867_2	2.775	50	1	80
Catchment_760_2	1.389	55	0.5	80

Catchment Name in MIKE URBAN	Catchment Area (ha)	Catchment Length (m)	Equal Area Slope	UHM Curve Number
Catchment_760_1	1.529	92	0.5	81
Catchment_590_2	1.214	55	1	81
Catchment_641_1	2.192	70	1	83
Catchment_641_2	1.324	75	1	81
Catchment_868_2	1.333	100	0.05	83
Catchment_868_1	2.206	150	0.05	83
Catchment_447_2	2.221	70	0.5	94
Catchment_447_1	7.858	80	0.5	94
Catchment_583_1	1.225	461	0.9	98
Catchment_589_1	2.812	1786	0.9	98
Catchment_584_2	63.858	94.6	1	70
Catchment_593_1	162.347	713	0.9	98
Catchment_591_2	133.376	3592	0.9	98
Catchment_592_2	26.695	2992	0.9	98
Catchment_594_1	38.764	1500	0.9	98
Catchment_594_2	66.013	2100	0.9	98

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E MIKE URBAN Model Layout

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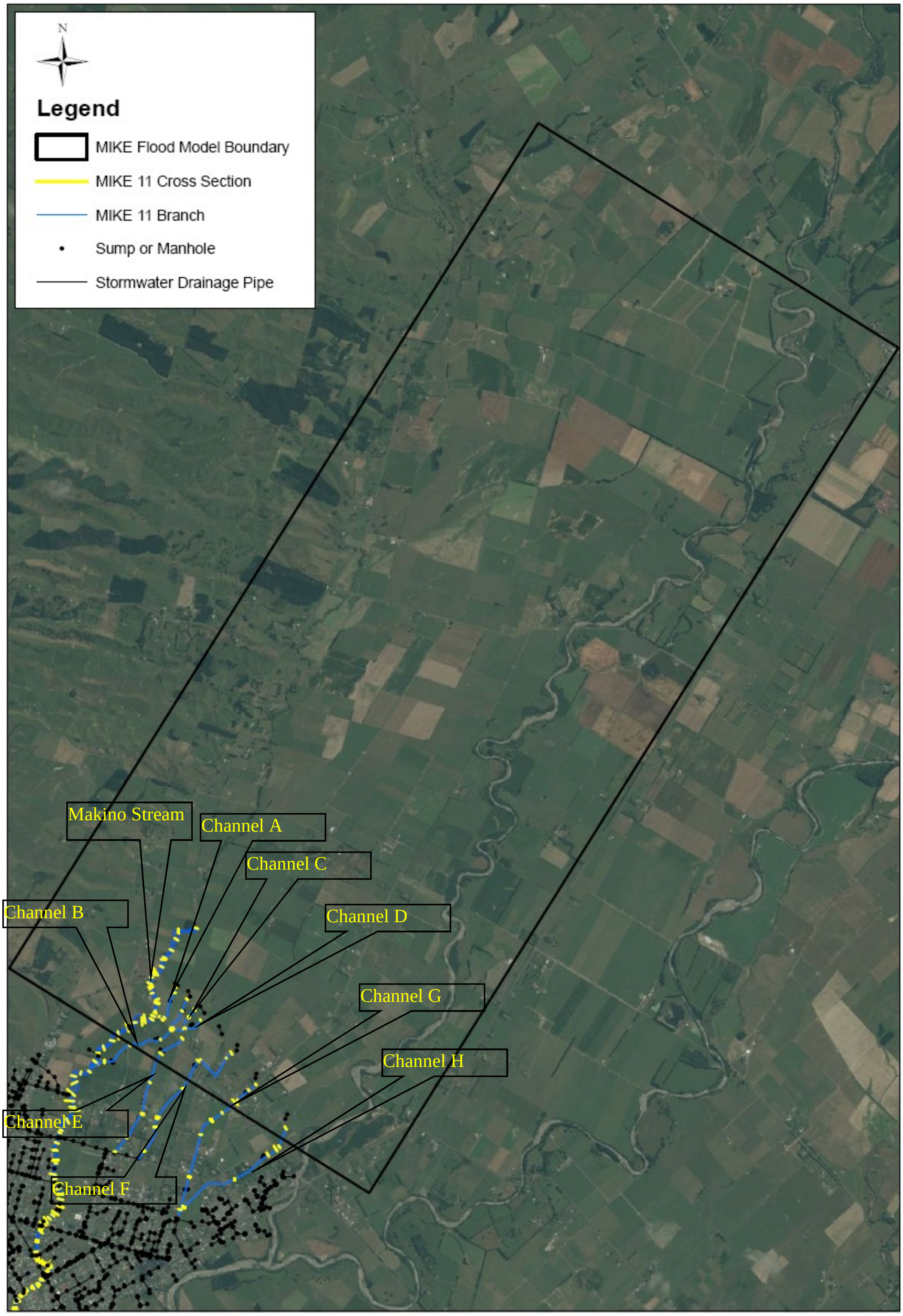
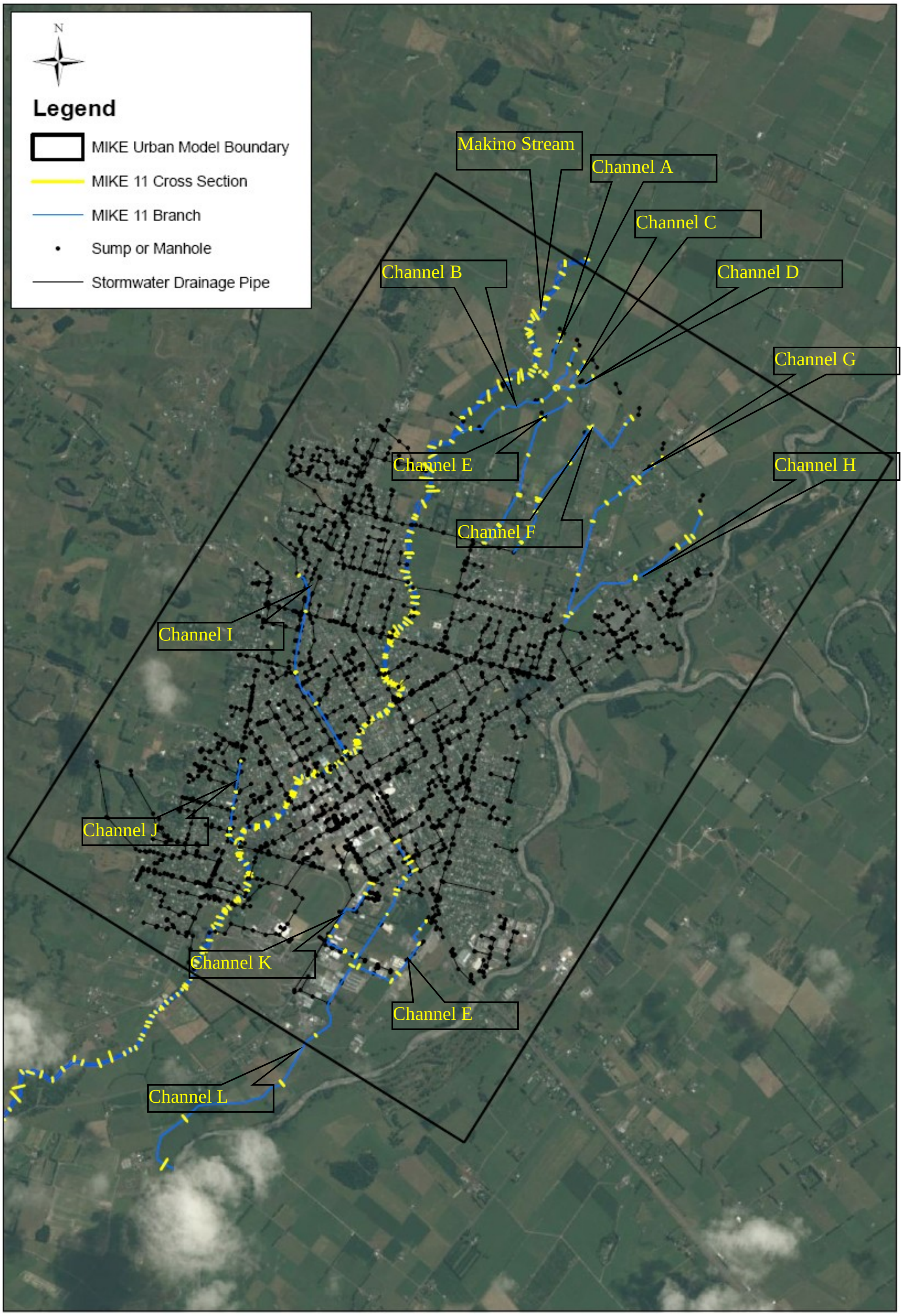
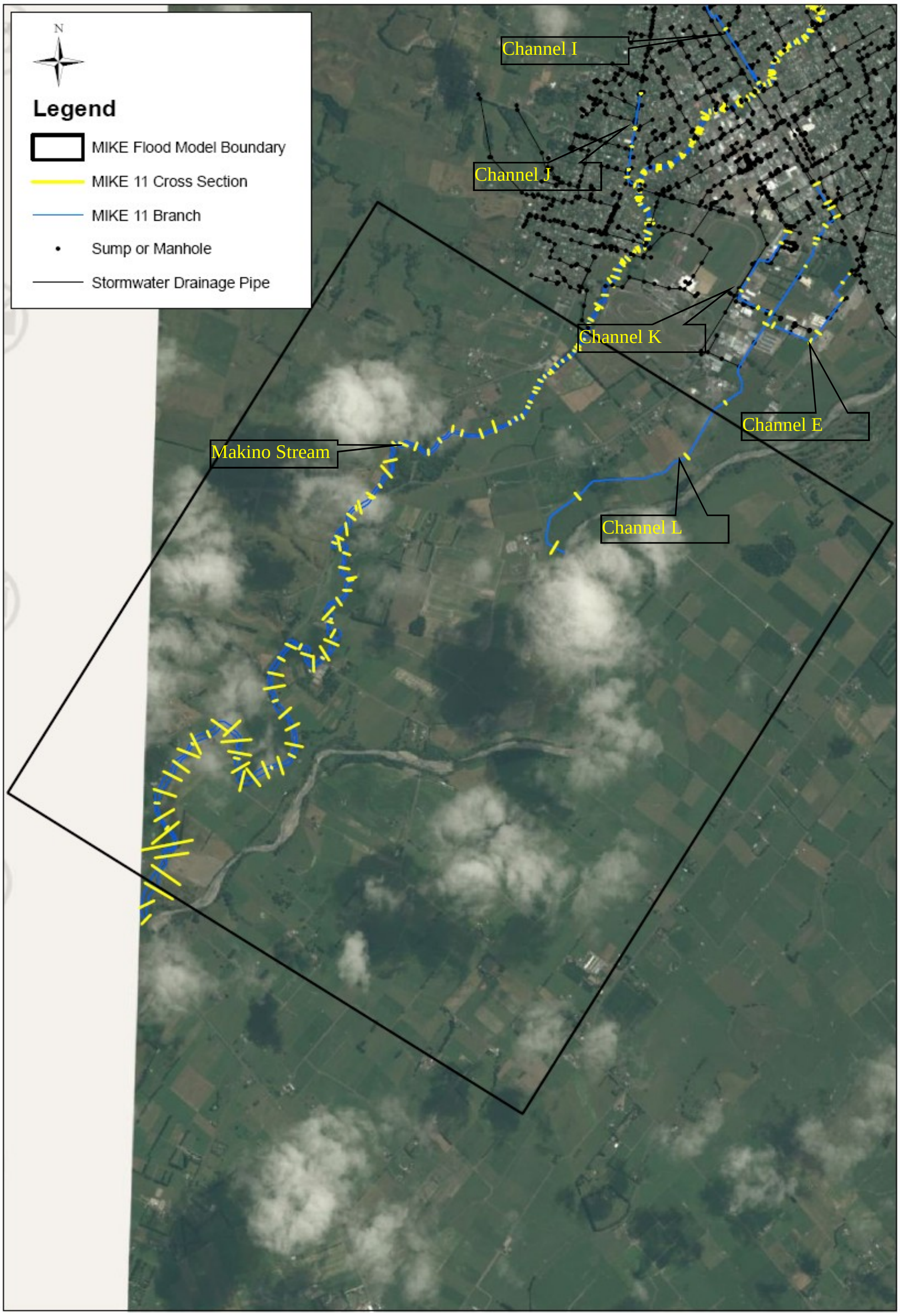
E.1 MIKE FLOOD Model A Layout



E.2 MIKE FLOOD URBAN Model B Layout



E.3 MIKE FLOOD Model C Layout



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