Report

NRC Priority Rivers Modelling Report

10 MARCH 2011

Prepared for

Northland Regional Council

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Background

This report is intended to explain various technical aspects relating to the development of the Priority Rivers Flood Risk Reduction Project (Priority Rivers) models as built in Infoworks RS (river systems) modelling software. It is expected that this report address the status of critical information and methodology adopted in the modelling. The report is also intended to assist future modelling improvements to these river models.

The Modelling Policy Statement (MPS) developed by Dr Steve Joynes for NRC was particularly adapted to using DHI Mike11 and Mikeflood software. The MPS was discussed with both Dr Steve Joynes and NRC staff. The MPS was used as a guidance tool for common modelling methodology to begin the project. As allowed for in the MPS certain aspects of the modelling have deviated from the MPS. This was due to the level of detail and information gathered during the project stages. The critical areas in which we have adopted particular techniques to deal with in depth issues include:

- Application of automated model build routines to complete a large number of project focused models built within a short time period;
- Sub-catchment rainfall runoff modelling and automated connection with river hydraulic models
- Critical data gaps in various areas and proper application of survey and LiDAR data
- GIS integration
- Mass result processing for flood, flood hazard and risk mapping

We believe we have adopted the best practicable modelling technologies and methods applied to each modelled catchment by the team. Each main step has been discussed with NRC staff and we are pleased that the modelling technologies have been accepted by Northland Regional Council.

The following aspects are addressed in this document.

- General Modelling Approach
- GIS data Processing
- Rainfall Processing
- Hydrological Modelling
- River Network Model
- Data Gap Analysis
- Model Calibration Methodology
- Data Management
- GIS and Model Integration

Modelling Objectives

It is stated in the Priority Rivers RFP, issued by NRC, Section 3.2 Part 4. Development of detailed hydraulic flood models addressed that detailed hydraulic flood models are required to be developed (model build and calibration) for the Group 1 river systems.

It was anticipated that these models were to be developed for the use of:

- Flood hazard map production, maps to contain flood extent, depth, velocity and flood hazards (based on velocity and depth), for a range of specified AEP's.
- Scenario modelling for analysis of flood risk reduction management options.

Other than Priority 1 Catchments, the Manaaki Awa team considered development of models for Priority 2, 3 and 4 catchments to a reasonable level based on the available information. The priorities, details, level of complexity of these catchments vary. However, the similar modelling results will be generated to:

- provide reasonable level of flood maps for the flood risk assessment
- evaluate options where needed
- potentially be further developed for Early Warning System(s)

3 General Modelling Approach

We accepted the Modelling Policy Statement prepared by Dr Steven Joynes for the Priority Rivers Project.

It is our view that modelling is about generating knowledge and understanding from the data used. The project team have reviewed all pertinent available data, identified data quality and data gaps. Data quality control and strict model processing procedures were adopted when developing the models.

The models were developed in rough and detailed model build stages, as stated in our original Proposal. However, the procedure was modified and improved with the consideration of the following aspects:

- The 2009 LiDAR and available GIS data have made it possible to build detailed models for all catchments;
- The modelling software applied enables the project team to develop a consistent modelling framework, which will provide a good basis for future model updates when needed;
- An early warning system may be considered a cost effective option for river management. 2D hydrodynamic model is normally quite time consuming to run and not practical for these types of emergency situations.
- The accuracy of 2D hydrodynamic model results is heavily subject to the 2D model grid size and treatment of break lines and structures.

The following sections explain the rough model and detailed model build approaches. The improved approach will increase model build time, but will:

- Reduce model running time significantly
- Deliver better, more consistent formatted flood maps for the current and future risk assessment and GIS flood mapping
- Deliver higher quality models to NRC
- Deliver a sound foundation for future model updates, management of the river systems and the opportunity for the application of future early warning systems.

3.1 Rough Model

A rough model is an early version of the detailed model. It was expected to be developed based on the pertinent available GIS information and the 2009 LiDAR data. There was no model calibration required at this stage.

This was anticipated to provide a good review of the available data and help identify critical data gaps for modelling.

The rough models produced flood maps. These maps were used as media for NRC staff to check issues from staff and local community knowledge. Comments were offered on identified areas for further model improvement during the detailed model stage.

The rough flood extent information identified hotspots, verified the preliminary model outputs, identified if and where survey and site visits were required. The level of the model details in each individual catchment depended upon the goals defined for each catchment. Each catchment model was schematised to have sufficient details to enable the model to simulate focused areas for each river as identified in the Goals refinement stage.

3 General Modelling Approach

Full LiDAR data then was not available until September 2009. The review of the first batch of LiDAR data indicated that the LiDAR data was of good quality with 1 m grid and standard vertical error of less than 15cm. With the consideration of possible future use for early warning system, the rough model build was modified and improved as follows:

Modelling Build Tasks	Rough Model	Detailed Model
Define model extent	Y	Y
Define sub-catchment boundaries	Y	Y
Connect all sub-catchments with river network, either point entry, or lateral entry	Y	Y
Conceptual x-sections using 20m contour map	Y	Y
X-sections using 2009 LiDAR	Y	Y
2009 Survey X-sections		Y
Critical hydraulic structures		Y
2D flood mapping	N	Y
2D hydrodynamic floodplain (Priority one catchments only)	N	Y
lower tidal boundary conditions defined	assumed	Y
Hydrological Parameter calibration		Y
Hydraulic Calibration		Y

3.2 Detailed Model

The level of details were dependent upon the priority level of the catchment. The level of detail available for each catchment varied, therefore, the general rules are as follow.

	Hydrological modelling	Hydraulic modelling	Calibration	Memo
Group 1	Calibration required	Detailed 1D +2D hydrodynamic model for areas of flood interest where LiDAR is available. Critical hydraulic structures to be included.	Detailed calibration+ verification with a flood event	extra survey carried out covering critical missing information

3 General Modelling Approach

	Hydrological modelling	Hydraulic modelling	Calibration	Memo
Group 2	Hydrological parameter refer to calibrated catchment Group 1 with consideration of differences in elevation, soil cover and gradients	Detailed 1D model +2D flood mapping. Other than surveyed bridges, no hydraulic structures will be included.	Verified with historical flood information if available	Critical bridge x-sections with a 4-8 x-sections per catchment surveyed to improve the model. Detailed 1D model based on 2009 LiDAR.
Group 3&4	Hydrological parameter refer to calibrated catchment Group 1 with consideration of differences in elevation, soil cover and gradients	Detailed 1D model +2D flood mapping. Other than surveyed bridges, no hydraulic structures will be included.	Verification with staff and local community knowledge	No extra survey. Models are be built based on available information with available LiDAR Data. Detailed 1D model based on 2009 LiDAR.

Modelling Gap Analysis

The gap analysis is intended to provide a summary of data collection, and review and identify the gaps within the data set particularly pertaining to modelling issues. Appropriate measures for dealing with insufficient critical data were identified. Appropriate assumptions were made where practical. Critical data gaps are explained in greater detail in the Calibration and Verification Report, refer to Appendix A

Gap analysis was not a separate stage in the project, but instead was carried out through all the stages of the project. As particular needs and issues were encountered the project team referred to the goals for each catchment and a collective decision was made in regards with the gaps. NRC staff was extensively involved in helping the project team to analyse data and source important information within the available databases. This proved to be an efficient way to minimise major data gaps whilst realising the project goals within the project budget.

The analysis was intended to evaluate the critical data received such as:

- GIS Catchment boundaries
- Streams
- Existing models
- Existing flood information
- X-sections
- LiDAR data
- Hydrological data
- Historical flood information

4.1 Data Received

The project team continued to receive series of data and information throughout the project. GIS data received from NRC included:

- Streams and river catchments boundaries based on 30m grids (NIWA)
- Drinking water Supply sources
- Geology
- Soils
- Landcare septic model
- Hydrogeology
- 20m contours
- Infrastructure
- Roads
- Hydraulic Structure locations, but no attributes
- Bridge locations, but no attributes
- Dam locations, but no attributes
- Sites of Importance
- Power Supply
- Many other ground layers

Other than the NRC GIS data base, other data received are summarised in the Table 4-1 below:

4 Modelling Gap Analysis

Table 4-1 Document Summary

Catchment No.	Catchment Name	NRC records	Previous Catchment Management Plans	Flood Survey Report	Previous flood flow/levels	Previous Models
01	Waiarohia-Raumanga Rivers	Y	Y		Y	Y
02	Ruakaka River	Y	Y		Y	
03	Otaika River	Y			Y	Y
04	Waitangi River	Y				
05	Hatea River	Y	Y		Y	Y
06	Kawakawa River	Y		Y	Y	
07	Waihou River	Y		Y	Y	
08	Wairau River	Y				
09	Pupuke River	Y				
10	Rotokakahi River	Y				
11	Whangaroa Streams	Y		Y		
12	Panguru Rivers	Y				
13	Awapokonui River	Y				
14	Whangarei Heads Streams	Y				
15	Taupo Bay River	Y				
16	Helena Bay River	Y		Y		
17	Ngunguru River	Y	Y		Y	
18	Whirinaki River	Y				
19	Tauranga River	Y				
20	Matangirau River	Y			Y	Y
21	Waima and Punakitere Rivers	Y		Y	Y	Y
22	Waimamaku River	Y			Y	

A document register was prepared for each of the catchments, refer to Appendix D of the individual River Management Plans.

Of those documents received from NRC, the following reports provided the most useful information summarising the main issues, previous studies, available data and knowledge for each catchment and the region overall:

- RFP Appendix 8 – Priority Rivers Flood Risk Reduction Project - Data Summary Report, 11 November 2008, prepared by Bob Cathcart.
- Priority rivers flood risk reduction project - An Overview of Priority Rivers, prepared by Bob Cathcart, 5 August 2008.

- Prioritising the Preparation of the River Management Plans, File: 815.2, reported by Bob Cathcart, 4 March 2008.
- Flood Survey Report and Data - Otaika, Waipu, Ngunguru, Ruakaka, prepared by Beasley & Burgess Surveyors Limited, January 2008.

4.2 Overall Quality and Data Criticality

In general, data received is sufficient to build catchment hydrological and hydraulic model. The data is of reasonably good quality for general use in GIS. However, further processing was needed for proper catchment modelling.

- The 20 m contours were sufficient to refine catchment boundaries(Manaaki Awa used 15 m grid Vs NIWA 30m), generate whole catchment ground model, and re-define sub-catchments boundaries;
- GIS stream lines provided a basis to define sub-catchments. Stream centre lines were improved based on the 15m grid ground model and the 2009 LiDAR. Stream centre lines may not be important hydraulically, but are important when using GIS ground model, LiDAR data for model processing and result presentation;
- 2009 NRC LiDAR is 1m grid and has a vertical accuracy of 15 cm. This provides a good basis to capture x-sections shapes.
- 2009 x-section survey matched the LiDAR data fairly well above the water level. Differences were shown below the water describing the channel, as was expected. Although the surveyed cross sections were of greater spacing than typically required in most river modelling projects. The surveyed channel below the water provided good information that was used to interpolate a below water level channel for the LiDAR generated cross sections. This process was performed for the priority one main rivers between surveyed x-sections.
- GIS Land cover and Soil group. These provided ground information for estimating rainfall loss parameters for each sub-catchment;
- Rain gauge and flow gauge data is available. The availability varies between catchments.
- Various reports describing historical flood events with photos. Flood level surveys were also available for some of the catchments.

4.3 Critical Aspects

4.3.1 Geographic Information System (GIS) Data

NRC provided a GIS database for the project, including hundreds of layers with region-wide coverage. This provided a solid foundation of information from which the project could be launched.

Manaaki Awa has reviewed the GIS data provided by NRC for modelling purposes, and has made the following observations:

- Catchment boundaries were defined with a 20 m contour and 30 m grid, while sub-catchment boundaries were defined on major tributaries. The latter has to be broken down to meet the requirements of Priority river model schematic. As such, the sub-catchment boundaries provided at the beginning of the project needed to be completely re-defined.
- Stream centre lines, which are important when laying and processing model cross-sections, need to be corrected with up-to-date (2009) LiDAR data.
- Most streams and sub-catchments provided in the NRC GIS data required names.

- Most of the layers for assets have only type and location information.

4.3.2 Hydrology

Please see the separate Hydrological Rainfall Processing Report for the Priority River Project prepared by Tom Kerr in 2010.

4.3.3 Flood information

Flood information for some of the catchments is available through various, previous catchment management plans or flood investigation reports. The majority of this information includes a description and some photos, but is lacking in terms of spatial location information of flooding and correct datum.

In order to improve model accuracy and demonstrate model credibility, a lot of time and effort has been taken during the model calibration and verification stages using this information with extensive assistance and support from NRC staff.

4.3.4 Previous Models

There are a number of previous river network models available, all of which were developed with DHI Mike 11 or MikeFlood modelling software. The latter is a combination of 1D and 2D models, using Mike11 and Mike 21.

The models received from NRC were mainly focused on particular river reaches, or areas with some surveyed cross-sections. There was no catchment or sub-catchment information included in these models. The coverage of modelled catchments was quite limited.

The following two models provided by NRC serve as examples of this limitation:

1. Priority 1 Catchment No 3-Otaika Catchment model: Covered only the lower section of Otaika Catchment. The model used inflows as a boundary input, and didn't include any structures such as bridges or culverts. The model had two branches: Otaika River and Otakaranga, each with 36 and 4 cross-sections respectively.
2. Priority 1 Catchment No 1&5- Waiarohia and Hatea Catchments: The model covered the Waiarohia catchment and a small portion of the Hatea River. It also used inflows as boundary inputs; however it did include some bridge structures within the modelled area. The model consisted of four branches, with three branches in the Waiarohia catchment. Waiarohia River model had 68 cross-sections, Raumaunga River had 12 cross sections, and the Kirikiri Stream had 6 cross-sections. The fourth branch of the model was located in the Hatea catchment and corresponded to the river section downstream of the confluence.

Figures 4-1 and 4-2 below provide a comparison of model coverage, between the previous Mike11 model and the InfoWorks model which was later expended extensively to cover the whole catchment.

4 Modelling Gap Analysis

Figure 4-1 Existing Waiarohia Mike 11 Model Extent

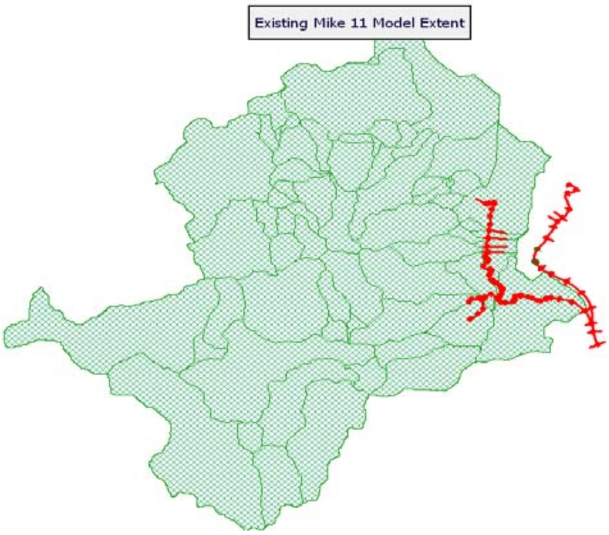
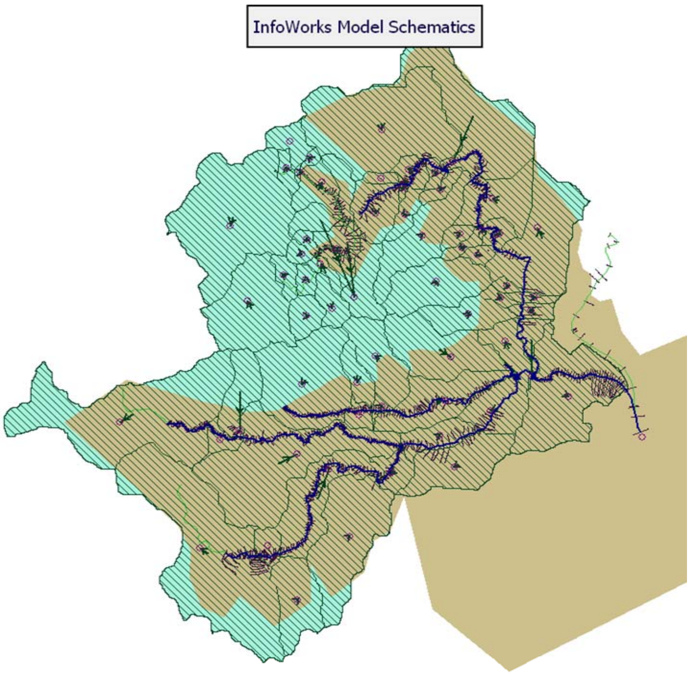


Figure 4-2 Waiarohia InfoWorks RS Model Extent



4.3.5 Surveyed cross-sections

A total of 180 previously surveyed cross-sections were provided by NRC; however, they only covered four catchments within the region.

4 Modelling Gap Analysis

Detailed modelling required sufficient numbers of surveyed cross-sections and structures. Manaaki Awa identified which surveys would be required in September 2009, based on judgements by modellers and the requirements of the MPS. Survey works were carried out by the client, with separate funding. Due to limited funds for surveying, the number of cross-sections to survey was minimised for those of higher priority. Table 4-2 below provides a summary of previous cross-sections, and those completed during the 2009 survey initiated by NRC.

Table 4-2 Summary of Cross Sections

Catchment No	Catchment Name	No of X-sections		2009 Survey (without bridges)
		Previous survey	2009 survey	
1	Waiarohia	86	55	19
2	Ruakaka		18	10
3	Otaika	39	42	18
4	Waitangi		37	5
5	Hatea	29	50	13
6	Kawakawa		30	20
7	Waihou		8	8
8	Wairua		4	8
9	Pupuke		5	6
10	Rotokakahi		5	6
21	Waima/Punakitere	25(estimate)		13

4.3.6 LiDAR data boundaries

A LiDAR survey conducted in 2009 covered most of the key areas of concern for each catchment. However, there are a number of critical areas missing. These include:

- Coastal areas of most of the catchments, particularly the extension of the major river mouth. It is difficult to extend the main river boundaries sufficiently far enough to reach the true tidal boundary. Figures 4-3 and 4-4 illustrate how this issue, which is common in the following catchments:

06_KAWAKAWA_RIVER
07_WAIHOU_RIVER
08_WAIRAU_RIVER
09_PUPUKE_RIVER
10_ROTOKAKAHI_RIVER
12_PANGURU_RIVERS
13_AWAPOKONUI_RIVER
17_NGUNGURU_RIVER
18_WHIRINAKI_RIVER
20_MATANGIRAU_RIVER
21_WAIMA_AND_PUNAKITERE_RIVERS

4 Modelling Gap Analysis

Figure 4-3 Catchment No 7 LiDAR Area Vs Expected Model Tidal Boundary

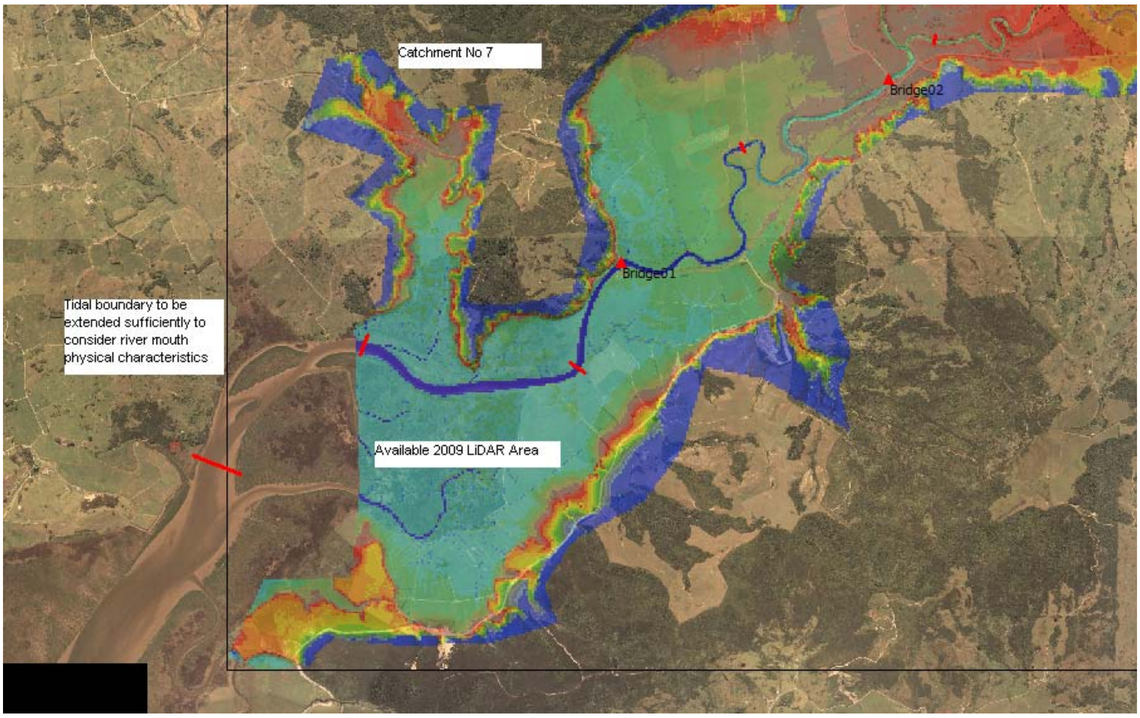
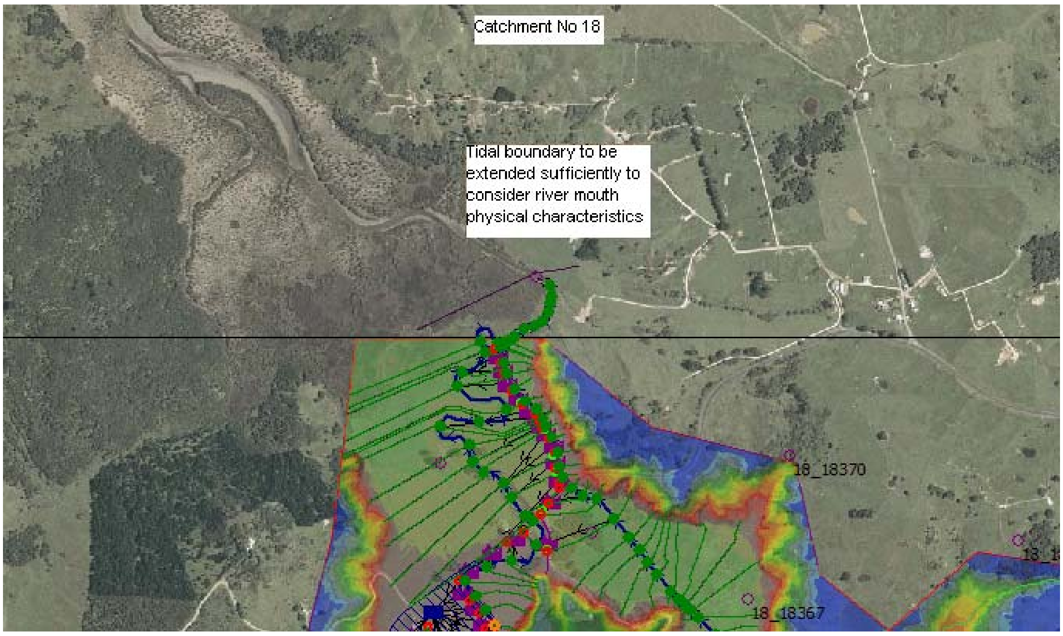


Figure 4-4 Catchment No 18 LiDAR Boundary Vs Expected Model Tidal Boundary



4.3.7 Data for Model Calibration

Manaaki Awa has identified the following issues with respect to flow and rainfall data:

- There is a significant lack of rain gauge and flow gauge data for model calibration in the six Priority 1 river catchments. For example, there are only:
  - Seven flow gauges;
  - Seven rain gauges;
  - One tidal level gauge located in catchment 1 (Waiarohia-Raumanga Rivers).
- The rainfall data was difficult to process due to the format and irregular time steps provided.
- There is a huge difference in data availability for both flow and rainfall data;
- There is no flow data available for Catchment No 3 (Otaika River).
- There is no rain gauge in Catchment No 1 Waiarohia Catchment

It was difficult to identify the corresponding rainfall gauge, since a couple of catchments do not have any rain gauges. Manaaki Awa's approach to this issue was to analyse all appropriate rain gauges with recorded rainfall events that could have contribution to catchment runoff. The analysis had to be prudent. Data availability for each catchment is detailed in Table 4-3

Table 4-3 Calibration Gauges Available Data

Catchment Number	Catchment Name	Flow Gauges			Rainfall Gauges			Water Level Gauges		
		No.	Location	Record duration	No.	Location	Record duration	No.	Location	Record duration
1	Waiarohia-Raumanga	5527	West (downstream)	1979-2009	No gauges in catchment – used closest gauges in Hatea catchment			5539	Close to existing flow gauges	1986-2009
		5528	West (downstream)	1979-2009	546301	North-west of catchment, in Hatea	1988-2009			
					545201	20km north of catchment	1988-2009			
					640436	35km south of catchment	1981-2009			
2	Ruakaka	5901	Central-west	1986-1994	No gauges in catchment – used closest gauges outside catchment for analysis			-		
					640436	25km south of catchment, in Hatea	1981-2009			
3	Otaika	No gauges – model cannot be calibrated			No gauges – model cannot be calibrated			-		
4	Waitangi	3707	Central-west	1984-2000	533817	South-east (upstream)	1998-2009	-		
					543010	South-west	1986-2008			
					532821	Outside catchment – analysed to determine influence on results	1984-2008			
5	Hatea	5538	South (downstream)	1986-2009	5	Hatea	5538	-		
					545201	25km north of catchment	1988-2009			
6	Kawakawa	3819	Central-north	1967-2009	No gauges in catchment – used closest gauges outside catchment for analysis			-		
		3829	North-west (downstream)	1989-1996	545201	20km south-west of catchment	1988-2009			
					543010	10km north, in south-west of Waitangi catchment	1986-2008			

Manaaki Awa identified two events per catchment to determine the most appropriate event for calibration. Plots of rainfall and flow data for these events are presented in Figures 5 and 6 below.

4 Modelling Gap Analysis

Figure 4-5 Calibration Gauge Locations

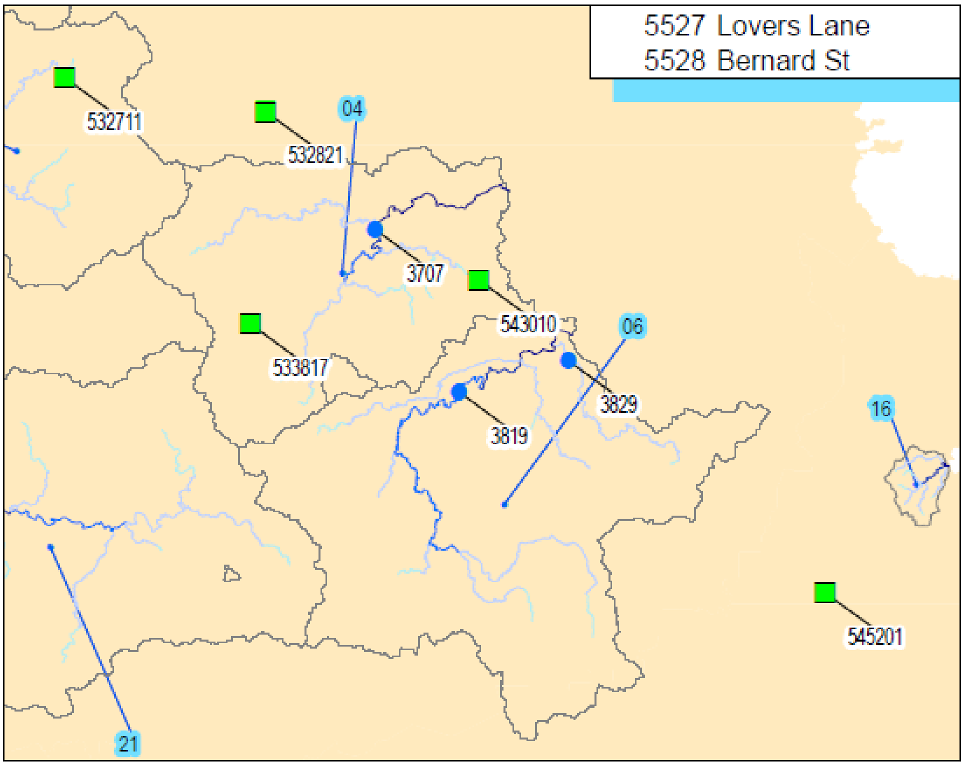
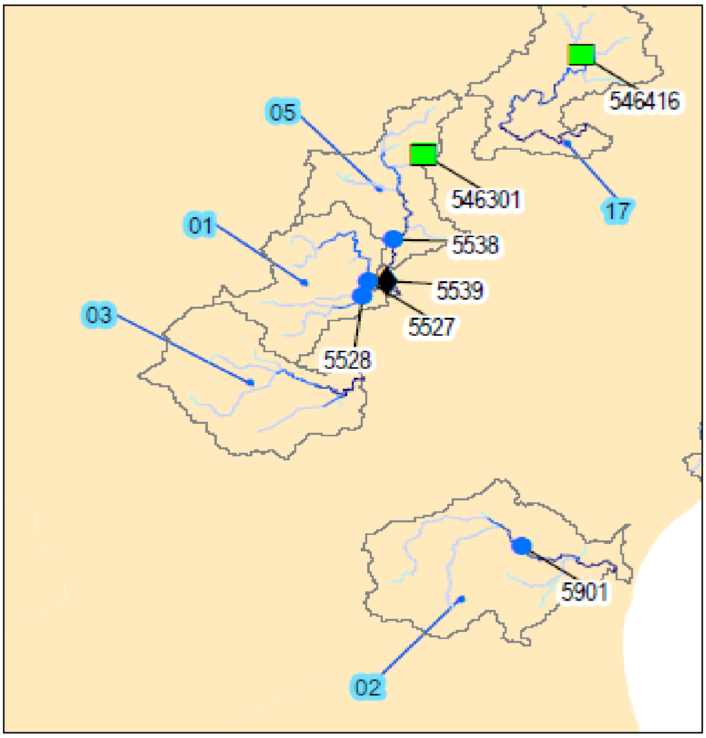


Figure 4-6 Calibration Gauge Locations



GIS Data Processing

The following shape files were processed in GIS in preparation for the model build:

- Subcatchment boundaries, including main channel length, slope, Tc & Tp (TP108 formulation), and other GIS tools.
- Stream centre lines (using existing NRC GIS data)
- Stream left and right bank lines (if available from NRC GIS)
- Land use/cover map
- Soil map
- Asset layers; such as properties, roads, farms, etc.
- River structures, bridges locations, etc.
- Image layers (for example, aerial photographs)
- Initial data validation
- Process of 2009 surveyed x-sections

Data processed in GIS was seamlessly used in the InfoWorks models.

5.1 Catchment Delineation

A 15 x 15 m^2 DEM was developed to delineate the catchments and sub-catchments. Table 5-1 compares the size of DEMs for derived catchments with those provided by NRC (from NIWA).

Table 5-1 Comparison of DEM areas

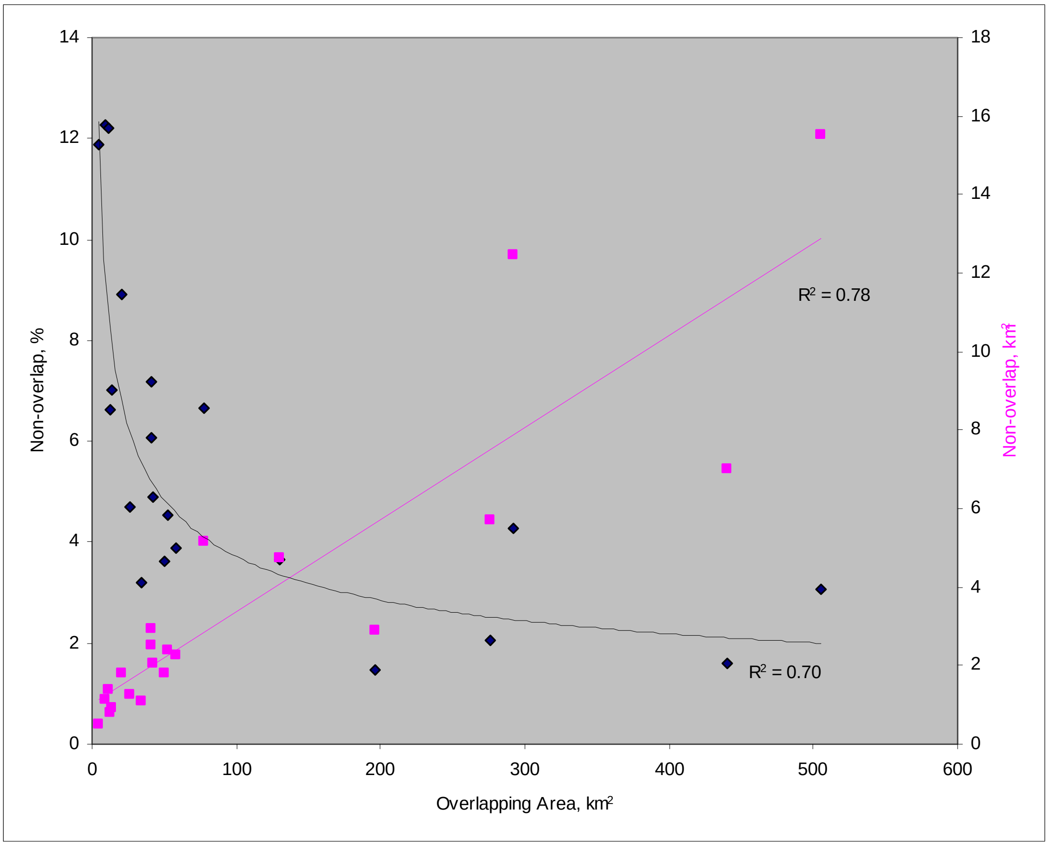
Catchment	Overlapping Area (km^2)	Non-Overlapping Area (km^2)	% Difference
01	41.1	3.0	7.2
02	77.4	5.1	6.7
03	58.0	2.3	3.9
04	292.5	12.5	4.3
05	41.6	2.5	6.1
06	439.7	7.0	1.6
07	275.8	5.7	2.1
08	26.5	1.3	4.7
09	50.0	1.8	3.6
10	196.7	2.9	1.5
11	20.3	1.8	8.9
12	34.5	1.1	3.2
13	9.2	1.1	12.3
14	N/A	N/A	N/A
15	4.3	0.5	11.9
16	12.3	0.8	6.6
17	52.2	2.4	4.6
18	41.9	2.0	4.9

5 GIS Data Processing

Catchment	Overlapping Area (km2)	Non-Overlapping Area (km2)	% Difference
19	13.2	0.9	7.0
20	11.4	1.4	12.2
21	505.7	15.5	3.1
22	130.1	4.8	3.7

The difference between overlapping and non-overlapping areas can be attributed to different cell sizes within the DEMs used by NIWA (30 x 30 m^2) and URS (15 x 15 m^2). As expected, the difference expressed in area units is more significant for larger catchments, while the relative difference shows a negative correlation with catchment size.

Figure 5-1 Comparison of overlapping and non-overlapping catchment areas



Truly significant changes have been made only to 04_WAITANGI_RIVER (Figure 5-2) and 21_WAIMA_AND_PUNAKITERE_RIVERS (Figure 5-3) catchments.

5 GIS Data Processing

Figure 5-2 04_WAITANGI RIVER Catchment areas

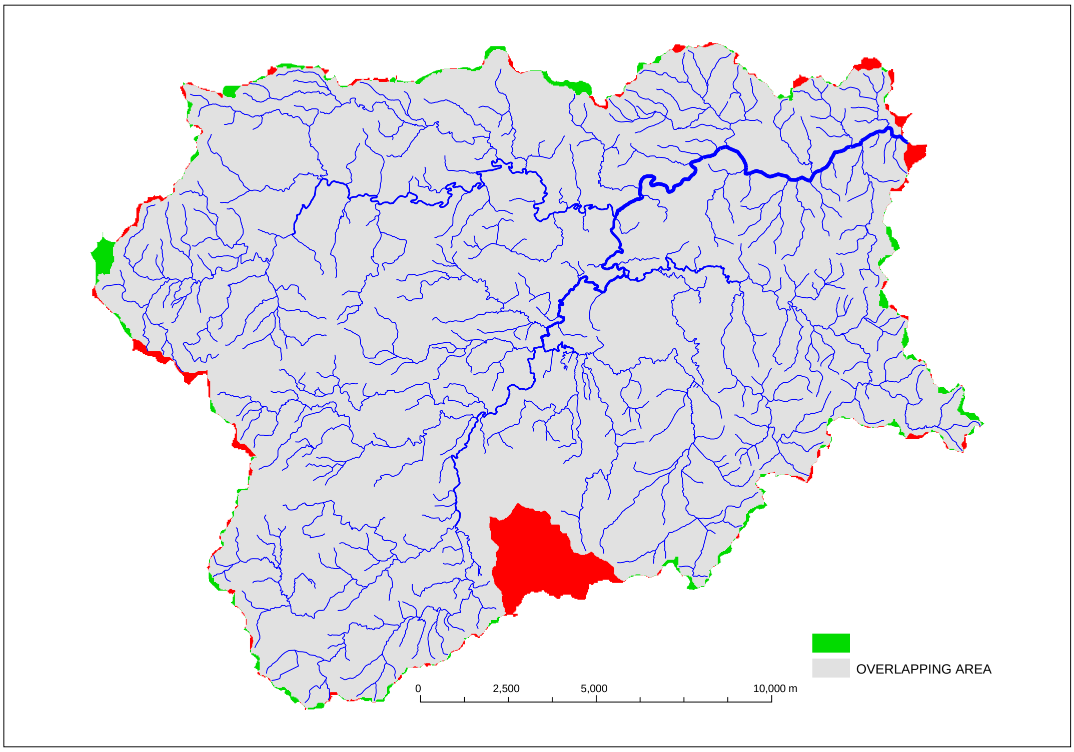
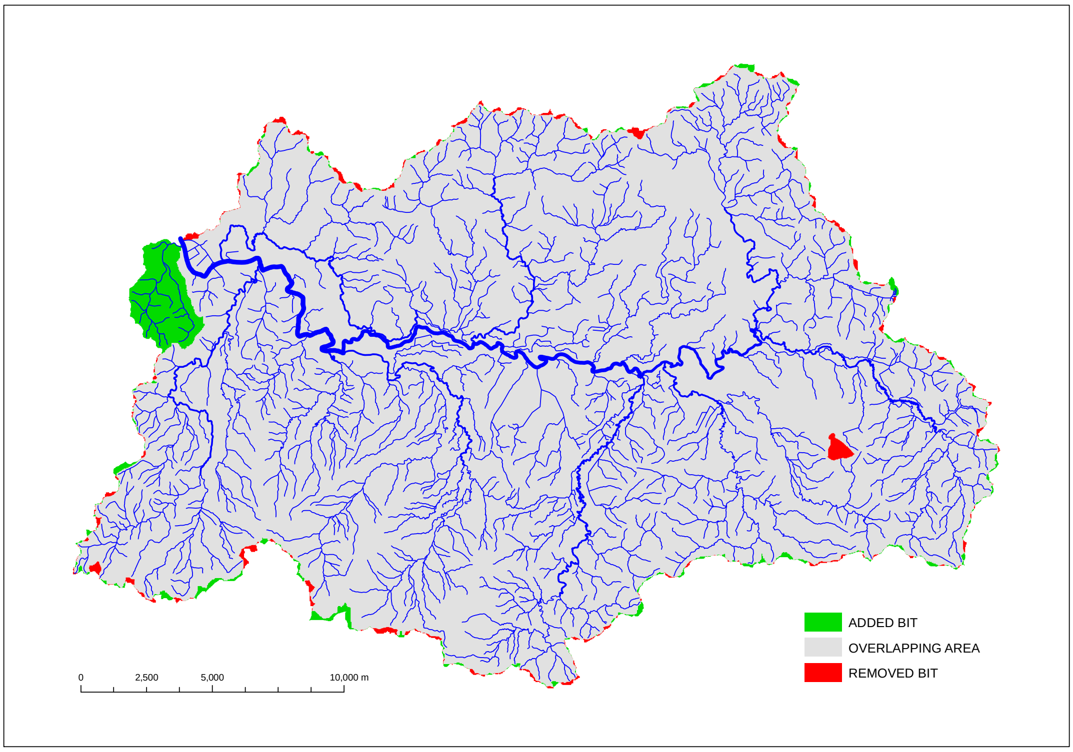


Figure 5-3 21_WAIMA_AND_PUNAKITERE_RIVERS Catchment areas



5.2 Stream Network

The stream network was built using the streams layer from NRC's geo-database. This network served as a basis for the hydrologic model. New features were added to the existing network to provide connectivity. The Figures 5-4 and 5-5 shows the original networks and modifications for the 22_WAIMAMAKU_RIVER catchment.

Figure 5-4 22_WAIMAMAKU_RIVER Original network

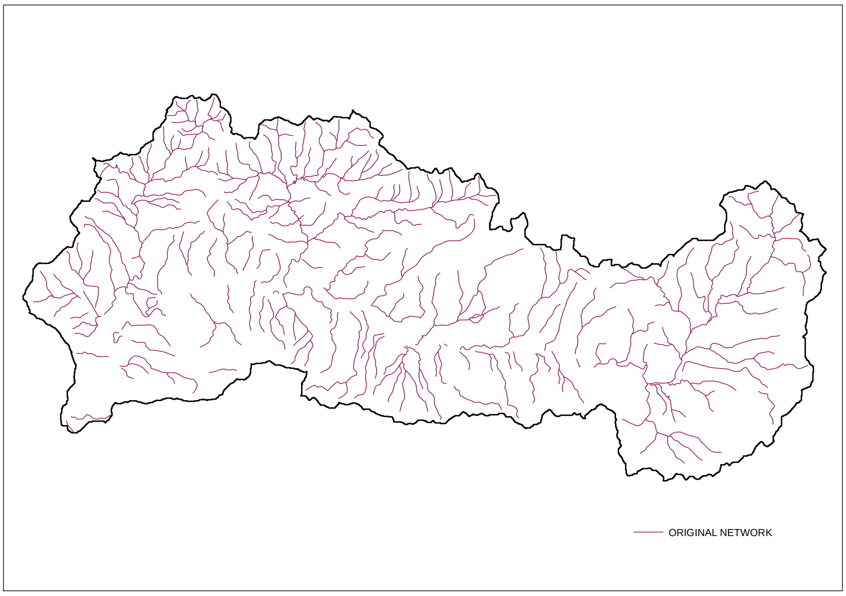
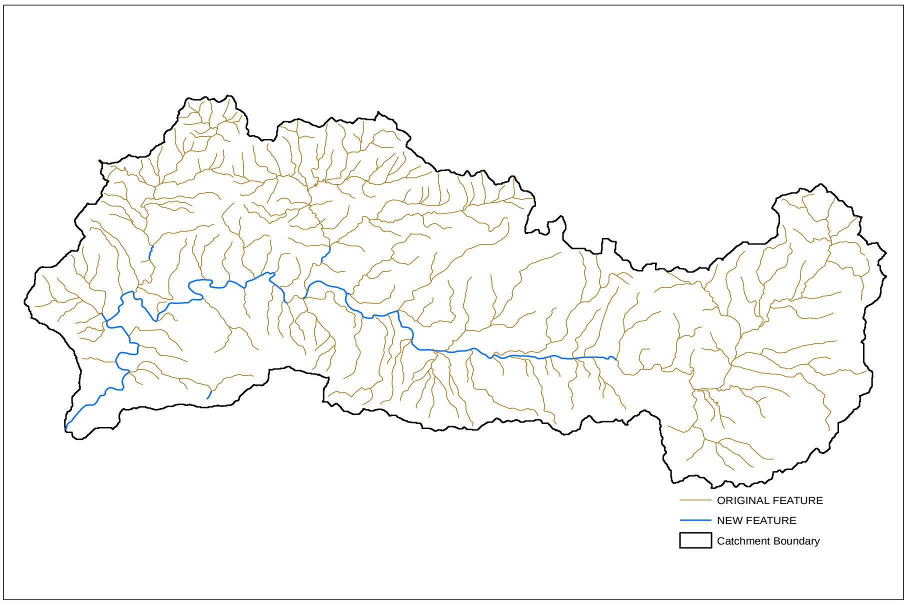


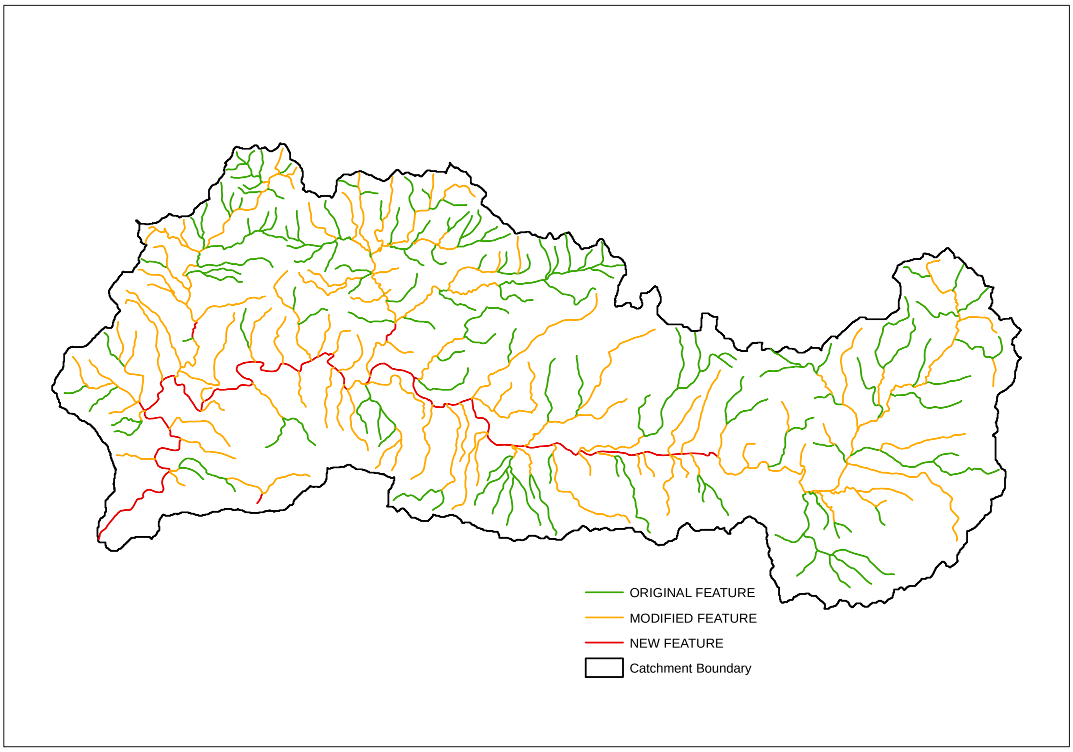
Figure 5-5 22_WAIMAMAKU_RIVER Modified network



5 GIS Data Processing

Some of the existing features were modified for the sake of connectivity. Figure 5-6 highlights the modified features within the 22_WAIMAMAKU_RIVER catchment.

Figure 5-6 Modified features within the 22_WAIMAMAKU_RIVER catchment



The features were modified by the processes of extension, trimming, splitting and flipping. Figures 5-7 and 5-8 illustrate the use of flipping to determine flow direction in the original and modified networks.

5 GIS Data Processing

Figure 5-7 Flipping: Original network

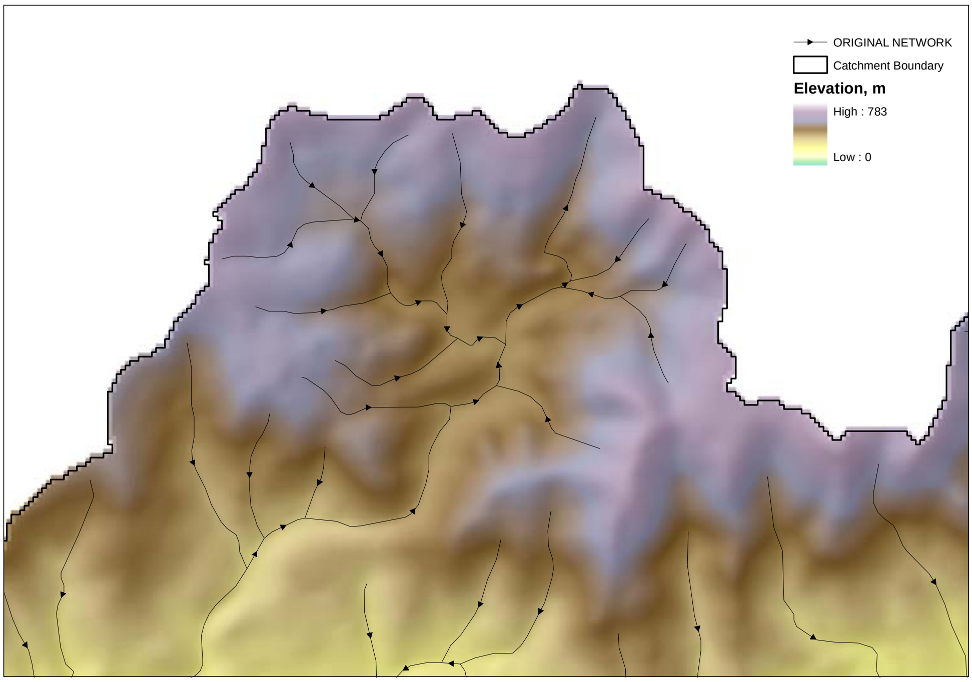
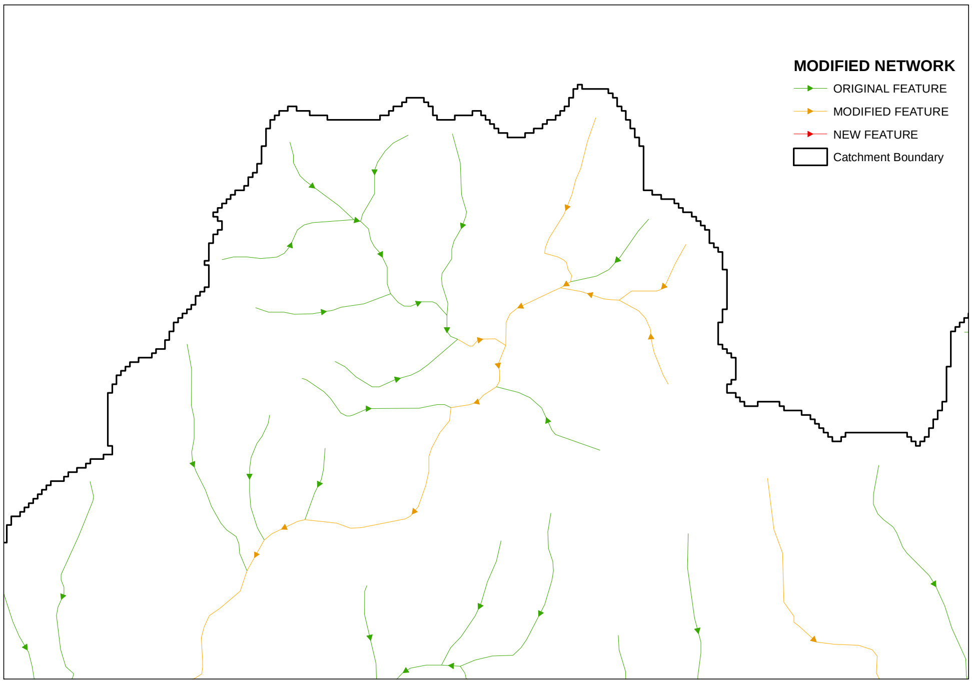


Figure 5-8 Flipping: Modified network



The stream network is a very important component in a hydrological correct DEM computation, in addition to 20 metre contours. However, the network and contours need to be consistent. Hence, the vertices for 1240 streams were moved to what was determined to be correct locations, as evident when comparing stream locations illustrated in Figures 5-9 and 5-10 below.

5 GIS Data Processing

Figure 5-9 Original stream locations

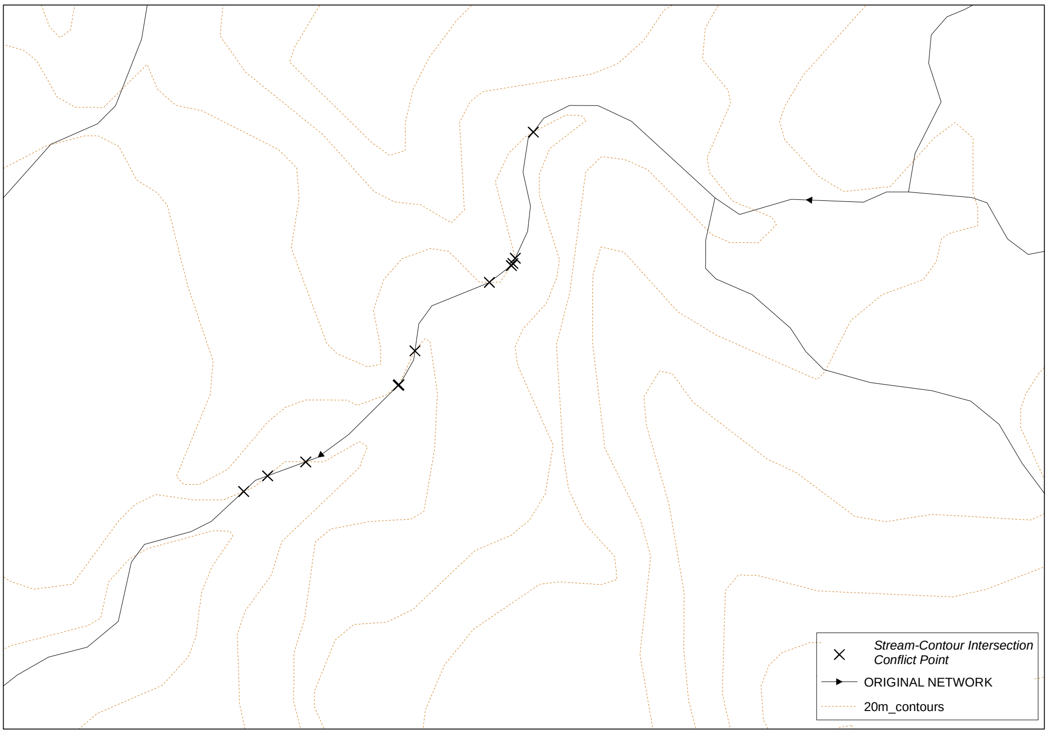
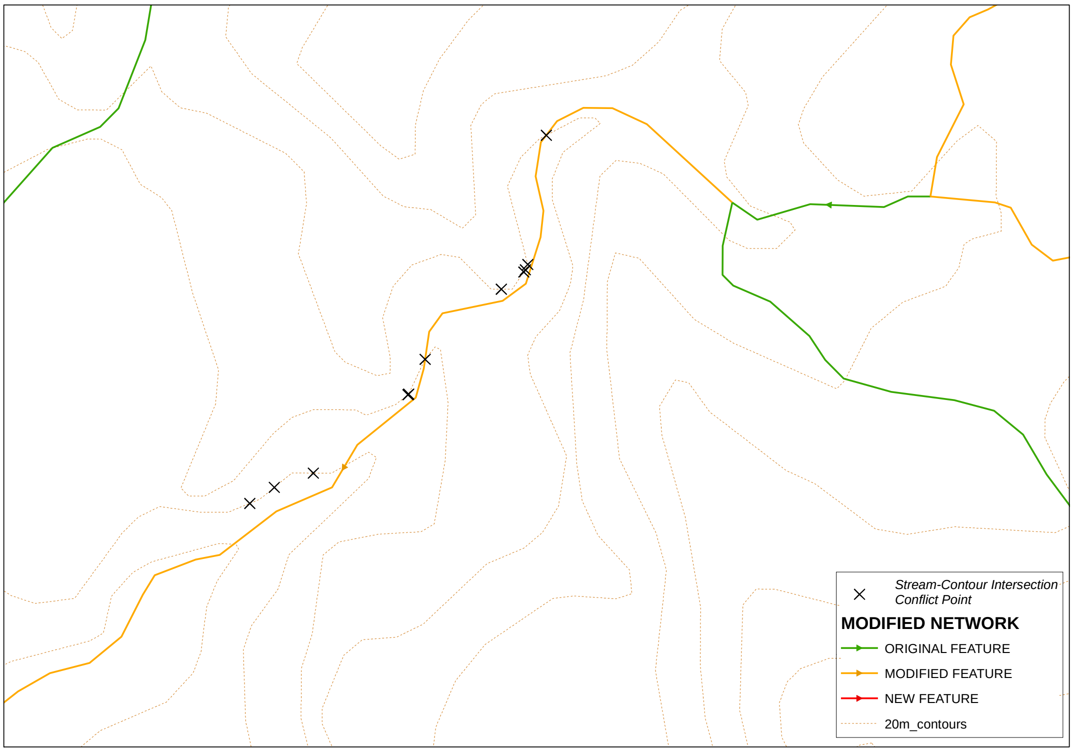


Figure 5-10 Modified stream locations



5 GIS Data Processing

This type of editing task is often tedious and time-consuming; however in this scenario it has saved a significant amount of time in catchment and sub-catchment delineation, and calculations (e.g. longest flow paths and the computation of long sections).

Table 5-2 summarises the modifications performed for each catchment in preparation for modelling.

Table 5-2 Modifications performed, per catchment

Catchment	Streams Count			
	Original	Modified	New	Grand Total
01_WAIAROHIA_RAUMAUNGA_RIVERS	75	82		157
02_RUAKAKA_RIVER	301	138	43	482
03_OTAIKA_RIVER	166	152		318
04_WAITANGI_RIVER	439	274	35	748
05_HATEA_RIVER	109	138		247
06_KAWAKAWA_RIVER	977	524	119	1620
07_WAIHOU_RIVER	733	455	47	1235
08_WAIRAU_RIVER	27	45		72
09_PUPUKE_RIVER	104	102	2	208
10_ROTOKAKAHI_RIVER	282	135	17	434
11_WHANGAROA_STREAMS	53	19		72
12_PANGURU_RIVERS	24	34		58
13_AWAPOKONUI_RIVER	29	13		42
14_WHANGAREI_HEADS_STREAMS	23	22	4	49
15_TAUPO_BAY_RIVER	15	6		21
16_HELENA_BAY_RIVER	55	38	6	99
17_NGUNGURU_RIVER	208	298	24	530
18_WHIRINAKI_RIVER	213	77	2	292
19_TAURANGA_RIVER	22	19		41
20_MATANGIRAU_RIVER	20	23		43
21_WAIMA_AND_PUNAKITERE_RIVERS	1120	600	59	1779
22_WAIMAMAKU_RIVER	195	182	43	420
Grand Total	**5190**	**3376**	**401**	**8967**

Hydrology

6.1 Rainfall Data Analysis

Refer to the Rainfall Assessment Report section of the Hydrological Report, Appendix G of the River Management Plans. The statements listed below in Sections 6.1.1 through 6.3 are quoted from the Hydrological Report conclusions.

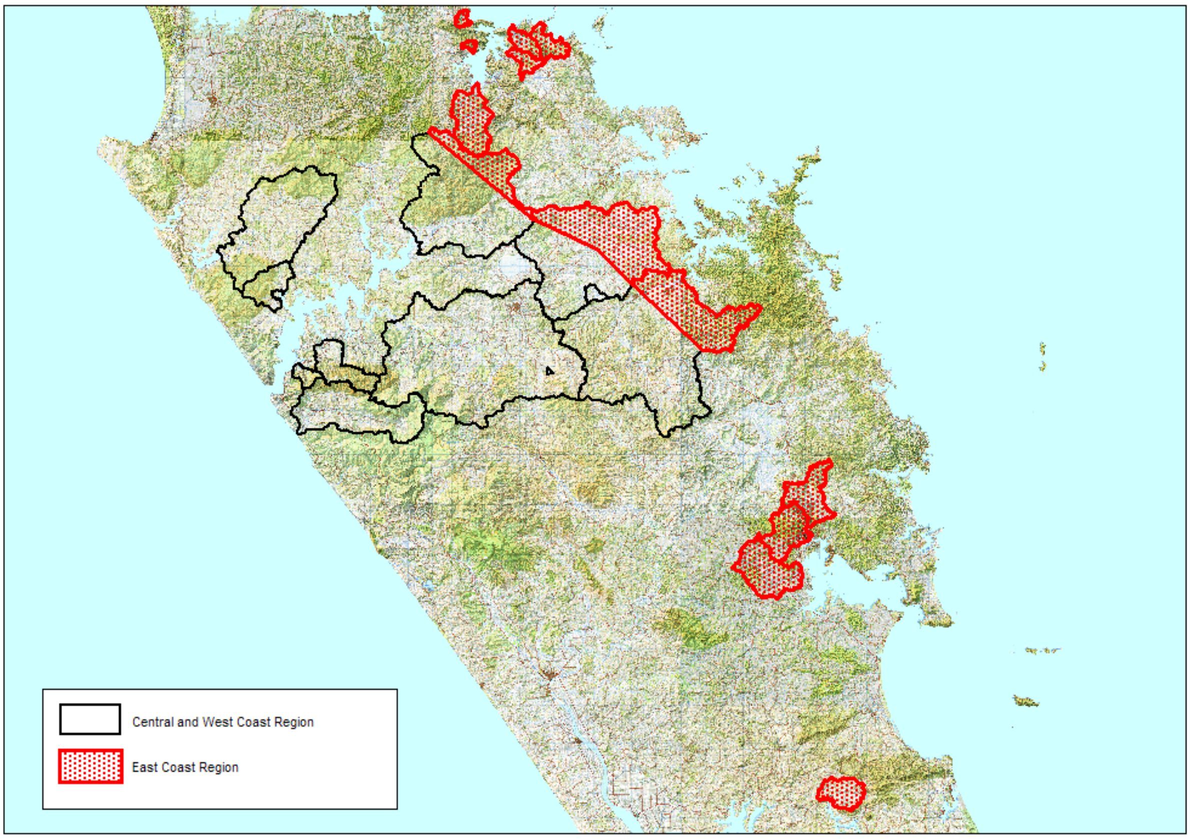
6.1.1 Design Rainfall

In summary, the current version of HIRDS provides a good representation of the spatial distribution of storm rainfall across the region. It does however, appear to produce rainfall depths approximately 15% lower than the results of frequency analysis on data recorded at long term intensity raingauges on the east coast (12% lower for the 100 year 6 hour event). There is also approximately a 10% increase in 24 hour 100 year ARI rainfall depths between 2001 and 2009 for both daily and intensity data. Although information is limited mainly to the east coast the results are considered sufficient evidence to apply a +10% correction factor to HIRDS design rainfall estimates on the east coast and a 5% correction factor on the west coast and central regions.

The boundary for these two areas is shown in **Error! Reference source not found.**.

HIRDS V3 is likely to be released very shortly. A quick comparison between the above rainfall analysis result and the draft HIRDS V3 data was carried out. The suggestion was to use HIRDS V3. This decision now is waiting for the NRC's final confirmation.

Figure 6-1 East Coast Boundary



6.1.2 Rainfall Temporal Pattern

A standard temporal rainfall pattern was developed for the region based on the largest storms recorded at four intensity raingauges. The storms were extracted from the record at each gauge and normalised so that the peak rainfall depth and time to peak both equal 1.0 as shown in Figure 6-2 The normalised storms were then converted to cumulative curves and the average of the curves determined. (Figure 6-3). Compared to published standard temporal patterns eg Huff 1967.

The storms investigated peak relatively late.

Figure 6-2 Development of Temporal Pattern

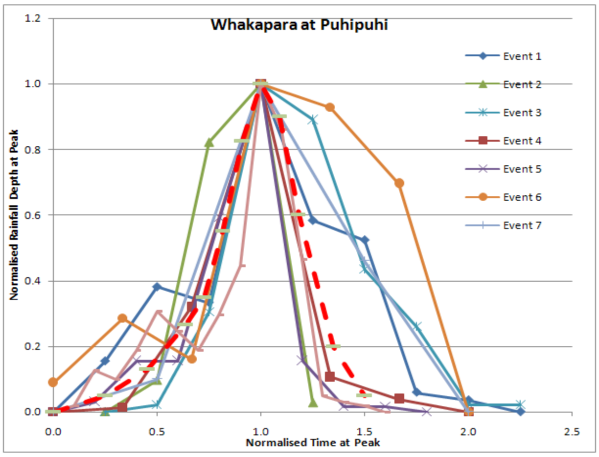
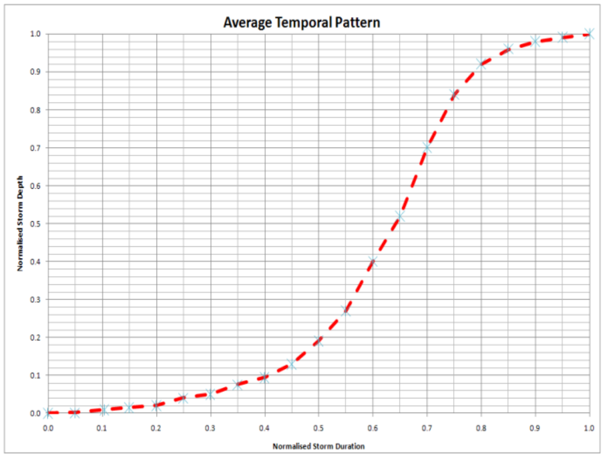


Figure 6-3 Average Temporal Pattern

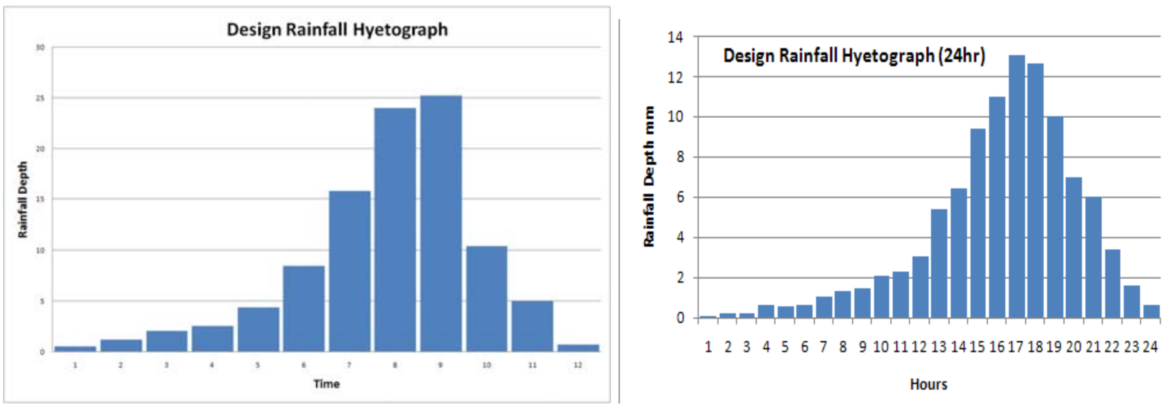


6.2 Catchment Hyetographs

Catchment hyetographs were produced by extracting HIRDS data for each required location, applying the correction factor and then applying the derived temporal pattern. See section on Hydraulic Modelling for a description of the locations where hyetographs were produced.

An example of the hyetograph produced in shown in Figure 6-1.

Figure 6-1: Design Hyetographs - 12 and 24 hour



6.3 Climate Change

1The project brief specified that in addition to the 0.01 AEP flood, the 0.0005 AEP flood event should be modelled to account for climate change. The difference between 100 year and 200 year rainfall for the Glenbervie and Puhipuhi raingauges is 10%.

An alternative approach would be to adopt the predicted increases to storm rainfall described in "Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand 2nd Edition" May 2008.

The results of climate change modelling presented in the 2008 guidance manual predict that between 1990 and 2040 there is likely to be an increase in temperature of around 0.9 degrees (range is 0.2 to 2.6). By 2090 temperature is predicted to rise by 2.1 degrees (range is 0.6 to 5.9). As a warmer atmosphere can hold more moisture (about 8% for every 1 degree increase in air temperature) there is a corresponding potential for more extreme high rainfalls.

The tables below show the percent increase in rainfall predicted for 2040 and 2090 for Northland.

Table 6-1 Projected % Increase in Extreme Rainfalls 2040, Middle Scenario, Northland

	ARI (years)			
Rainfall Duration (hours)	10	20	50	100
1	6.7	6.9	7.2	7.2
2	6.5	6.8	7.2	7.2
3	6.3	6.8	7.2	7.2
6	6.1	6.7	7.2	7.2
12	5.9	6.6	7.2	7.2
24	5.7	6.5	7.2	7.2

6.4 ARF

Rainfall always varies across a catchment; therefore the rainfall measured at a rain gauge in the catchment is not the same as the average falling across the whole catchment. The Areal Reduction Factor (ARF) is used as a multiplying factor on the rainfall profile, reducing point rainfall to obtain areal average values.

Areal reduction factors are used to apply point estimates of rainfall for large catchments. Areal reduction factors (ARF) should be used with the SCS method if it is applied to catchments larger than 10 km2 in size. The use of the SCS method on large catchments has not been validated in this study and validation of model performance against field data will be necessary. In the first instance, it is recommended that the ARF presented in TP19 (ARC, 1992) be used. These were based largely on a study by Tomlinson (1980) and are shown in Table 6-2. For convenience, it is suggested that an ARF value is selected from Table 6-2 according to the catchment area and time of concentration and this factor is applied to the 24 hour rainfall depth input to the model.

[1] Quoted from NRC Priority Rivers Rainfall Assessment Report

Table 6-2 Areal Reduction Factors for the Auckland Region (Table 2-2, from ARC, 1992)

Table 2.2 - Areal Reduction Factors for the Auckland Region (from ARC, 1992)							
Area	Time of Concentration (hrs)						
(km^2)	0.5	1	2	3	6	12	24
≤10	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20	0.90	0.91	0.93	0.94	0.95	0.96	0.97
50	0.72	0.75	0.82	0.86	0.92	0.94	0.96
100	0.71	0.74	0.79	0.83	0.86	0.89	0.90
200	0.70	0.72	0.75	0.79	0.82	0.85	0.86
500	0.68	0.70	0.72	0.74	0.76	0.79	0.81

6.5 Design Rainfall

6.5.1 Duration

The most critical design storm is normally the storm with the duration approximately equal to the time of concentration of the catchment.

As a starting point, Time of Concentration (Tc) of each catchment is estimated from the aggregated theoretical Tc of the sub-catchments in the longest flow path. This is to be used as a rough guide to determine the critical storm duration. It should be noted that the aggregated catchment Tc of each catchment is not used in the modelling. Only Tcs of each sub-catchment are used for hydrological modelling to define Unit Hydrograph of the corresponding subcatchment.

Time of Concentration of the sub-catchment was calculated with the ARC TP 108 method, which uses catchment slope, CN number, channelisation factor:

$$\boxed{Tc = 0.14 \cdot C \cdot L^{0.66} \cdot \left(\frac{CN}{200 - CN}\right)^{-0.55} \cdot Sc^{-0.30}}$$

Tc of each catchment was rounded to 3 hours, namely 3, 6 ,9,12 and 24. the results are as below:

Table 6-3 Catchment Time of Concentration Calculations

Catchmen	Priority	LENGTH	SLOPE	CN	TC (min)	Tpeak=2/3* Tc (min)	Tc (hours)	Design Strom Duration (hours)	Run Duration (hours)
01	1	14614	0.02890	77.5	184	123	3.07	6	12
02	1	21777	0.01420	73.4	310	207	5.17	6	12
03	1	17812	0.01152	74.0	287	191	4.78	6	12
04	1	42026	0.01040	74.0	522	348	8.70	9	18
05	1	17076	0.01976	76.6	231	154	3.85	6	12

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Catchmen	Priority	LENGTH	SLOPE	CN	TC (min)	Tpeak=$^2/_3$* Tc (min)	Tc (hours)	Design Strom Duration (hours)	Run Duration (hours)
06	1	69213	0.00649	73.6	840	560	14.00	24	48
07	2	41843	0.01445	71.8	484	323	8.07	9	18
08	2	11331	0.03138	74.0	158	105	2.63	3	6
09	2	23392	0.02752	72.9	268	179	4.47	6	12
10	2	53819	0.01335	72.8	579	386	9.65	12	24
11L	3	2764	0.14189	74.2	39	26	0.65	3	6
11R	3	6033	0.06661	74.2	83	55	1.38	3	6
12	3	7726	0.10182	72.2	88	59	1.47	3	6
13	3	6058	0.12061	72.1	71	47	1.18	3	6
14	3	1486	0.32564	74.9	20	13	0.33	3	6
15	3	3714	0.05197	74.2	65	43	1.08	3	6
16	3	6828	0.05481	72.6	97	65	1.62	3	6
17	3	25038	0.01317	73.5	348	232	5.80	6	12
18	3	22170	0.04539	71.5	227	151	3.78	6	12
19	3	8746	0.04908	72.6	118	79	1.97	3	6
20	4	8229	0.04533	73.4	115	77	1.92	3	6
21	4	58812	0.01566	73.6	579	386	9.65	12	24
22	4	35798	0.02902	72.1	353	235	5.88	6	12

However, the definition and estimate of critical storm duration are normally applied to small catchments (a few km^2) and urban catchments. There are limitations when applying these concepts to big rural catchments due to the impact of soil storage and upper catchment detention. Relying on Tc of the whole catchment to determine storm duration may under estimate rainfall losses on rural areas, because losses will build up over time.

In summary, for design storm duration and profile, relying on historical records is probably more practical then desk top Tc estimate and universal rainfall profile for all durations. Model calibration will be based on historical events. A calibrated model will probably offset various uncertainties themselves. Storm duration and profile derived from historical records with the calibrated model, we believe, will better reflect the actual catchment performance under design scenarios.

Design storm duration and rainfall profile can be derived from historical records, which might have caused the severe flooding in the history.

As an example from historical records, the figure below demonstrates the storm and flood event in March 1988 in Hatea Catchment. This event was probably about 50 Yr ARI. The rainfall lasted for over 2 days with almost averaging intensity. Flow did not respond clearly until about 12 hours after the storm started. It is clear that the flood peak was caused by prolong rainfall.

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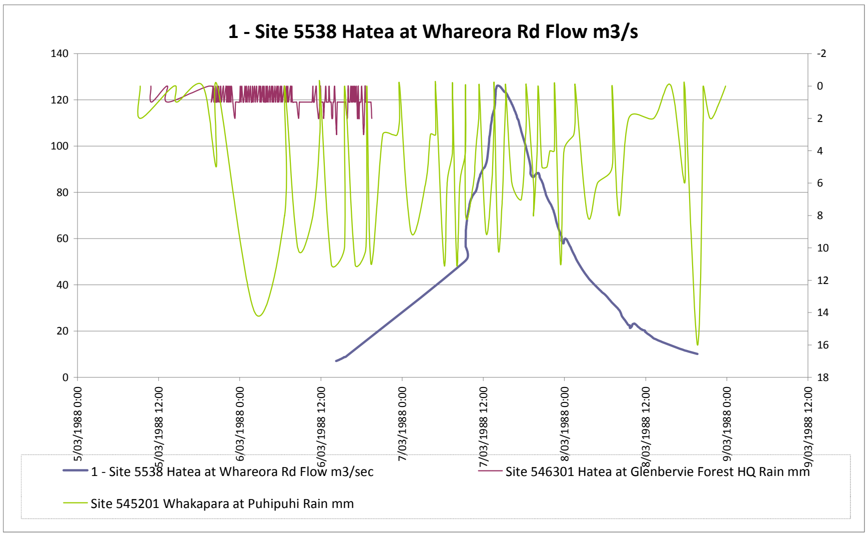
Figure 6-4 Storm and Flood event in March 1988 in Hatea Catchment



Therefore, due to the significant impact of soil storage during storm events, it is considered necessary to choose storm duration longer than hydrologic estimated Tc, such as the rounded figures in the table above, or simply gather from experiences based on historical data. In summary, the options are:

Option 1- use Tc from the above Table in this section

Option2- Use the recommended Tc in the table below.

Table 6-4 Storm Duration

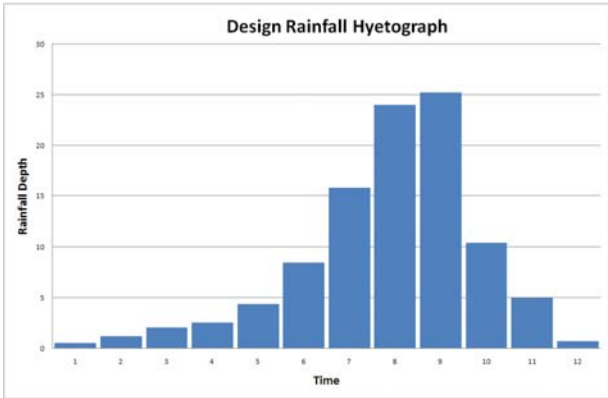
Catchment ID	Priority	Catchment Area (ha)	LENGTH	Recommended Strom Duration (hours)
01	1	4337	14614	12
02	1	7817	21777	12
03	1	6215	17812	12
04	1	28750	42026	**24**
05	1	4296	17076	12
06	1	44365	69213	**48**
07	2	27899	41843	**48**
08	2	2700	11331	24
09	2	5094	23392	24
10	2	19825	53819	**48**
11L	3	1835	2764	24
11R	3	263	6033	24
12	3	3495	7726	24
13	3	1000	6058	24
14	3	962	1486	24
15	3	450	3714	24

Catchment ID	Priority	Catchment Area (ha)	LENGTH	Recommended Strom Duration (hours)
16	3	1272	6828	24
17	3	5384	25038	12
18	3	4290	22170	24
19	3	1371	8746	24
20	4	1198	8229	24
21	4	51691	58812	**48**
22	4		35798	**48**

6.5.2 Patterns

Use the universal design rainfall pattern as shown below from Hydrological Analysis in Section 6.1.2.

Figure 6-5 Design Rainfall Hyetograph



For catchments calibrated with historical events, the historical rainfall profile used in the calibration might be used for design events.

6.6 Flow Assessment

Data from these flow stations were used to carry out flood frequency analysis to estimate flood peaks for the required design floods. Regional flood frequency methods were also used to determine design flood peaks.

6.7 Review and Assessment of Available Data.

Flow data was provided by NRC. Table 6-5 lists the data received. Figure 6-6 shows the locations of the flow stations.

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Table 6-5 Priority 1 Catchment Flow Gauges

Site no.	River name	Site name	Easting	Northing	Catchment Area km^2	Recording Authority	Record Begins	Record Ends
3707	Waiaruhe	Puketona	2598104	6654930	175	NRC	1-Feb-84	10-May-00
3819	Waiharakeke	Willowbank	2603396	6644629	229	NRC	2-Feb-67	
4901	Ngunguru	Dugmores Rock	2637800	6616400	13	NRC	22-Aug-69	
5527	Waiarohia	Lovers Lane	2629802	6607579	19	NRC	17-Oct-79	
5528	Raumanga	Bernard St	2629502	6606673	16	NRC	30-Oct-79	
5901	Ruakaka	Flyger Rd	2637403	6591542	45	NRC	19-Mar-84	
3722	Waitangi	Wakelins	2606139	6657724	302	NIWA	8-May-16	
47804	Waipapa	Forest Ranger	2573046	6658281	122	NIWA	3-Aug-05	
3806	Kawakaw	SHB	2607202	6646627	315	NIWA	4-May-67	
3710	Whanga	Wiroa R	2588686	6658302	2	NIWA	25-Jul-16	6-Jun-84
5538	Hatea	Whareora Rd	2631062	6610105	39	NRC	30-Jun-86	24-Mar-95
5539	Hatea	Town Basin	2630700	6607600		NRC	7-Jan-86	10-May-94
3829	Tirohanga	D/S County Intake	2610300	6646600	56	NRC	21-Mar-89	23-Dec-96

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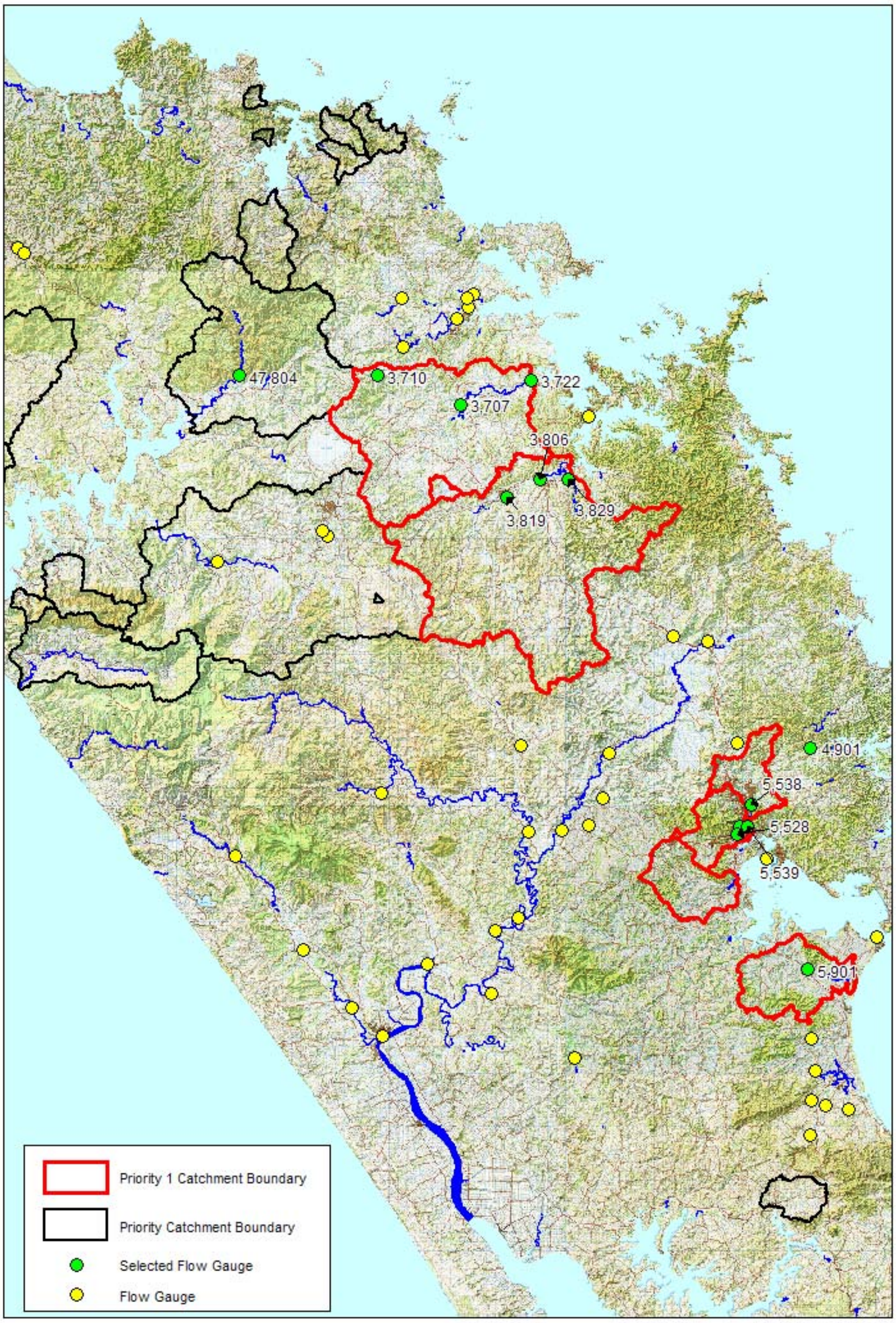
Figure 6-6 Flow Gauge Locations



Results of the frequency analysis and regional flood frequency analysis are listed in Table 6-6. It is recommended that results from the regional method be adopted for comparison with modelled flows.

Table 6-6 Frequency Analysis Results

Gauge Name	Site Number	Area (km^2)	Easting	Northing	100 ARI Flow (m^3/s)	
					Frequency Analysis (Gumbel)	Regional Method
Waiaruhe at Puketona	3707	175	2598104	6654930	331	404
Waiharakeke at Willowbank	3819	229	2603396	6644629	212	295
Ruakaka at Flyger Rd	5901	45.3	2637403	6591542	90	271
Waiarohia at Lovers Lane	5527	18.6	2629802	6607579	97	126
Raumanga at Bernards St	5528	16.3	2629502	6606673	72	113
Hatea at Whareora Rd	5538	38.55	2631062	6610105	183	228

6.8 Sea Level Rise

Based on the IPCC Fourth Assessment Report presented in Coastal Hazards and Climate Change: Guidance Manual (2008), sea-level rise estimates for 2090 should use a base value sea-level rise of 0.5m relative to the 1980–1999 average. Where impacts are likely to have high consequence or where additional future adaptation options are limited, all assessments should (at the very least) consider the consequences of a mean sea-level rise of at least 0.8m relative to the 1980–1999 average.

For this project the 0.5m sea level rise scenario was adopted.

6.9 Storm Surge

Storm surge is defined as a temporary rise of mean sea level along a coast lasting for a few hours or days due to the effects of low atmospheric pressure and sea level gradients set-up by strong winds. There is relatively little known in New Zealand about the recurrence intervals of storm surges, waves or Tsunami because of the lack of good quality sea level data of any length, (Bell et el, 2000)2.

To allow for storm surge as a boundary condition in the hydraulic flood models for the priority catchments a frequency analysis of Marsden Point sea level data for the period 1989 to 2009 was carried out. The record does not include Cyclone Bola which occurred in March 1988. The results of the analysis are shown in Figure 6-7 below.

[2] "Sea-level change and storm surges in the context of climate change"; Bell, R G; Goring, D G; de Lange, W P. IPENZE Transactions, 2000, Vol. 27, No.1.

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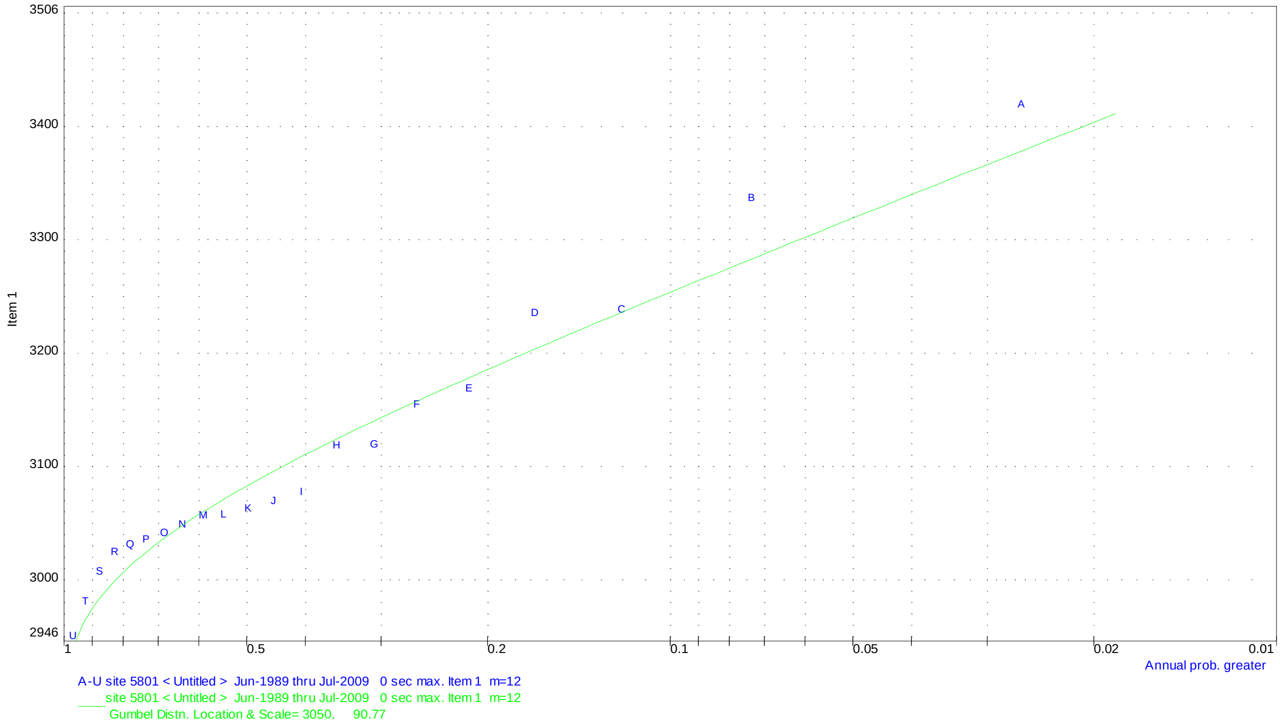
Figure 6-7 Marsden Point Sea Level Frequency Analysis



Peak annual flows and sea levels were compared for the Ruakaka at Flygers Road, Waiarohia at Lovers Lane and Ruamanga at Bernard Street records. Of the three flow records Bernard Street provided the best match with three annual flow events occurring near the time of peak annual sea level over a 21 year period. In crude terms, the annual peak flood coincided with peak sea level 14% of the time over the period of coincident record.

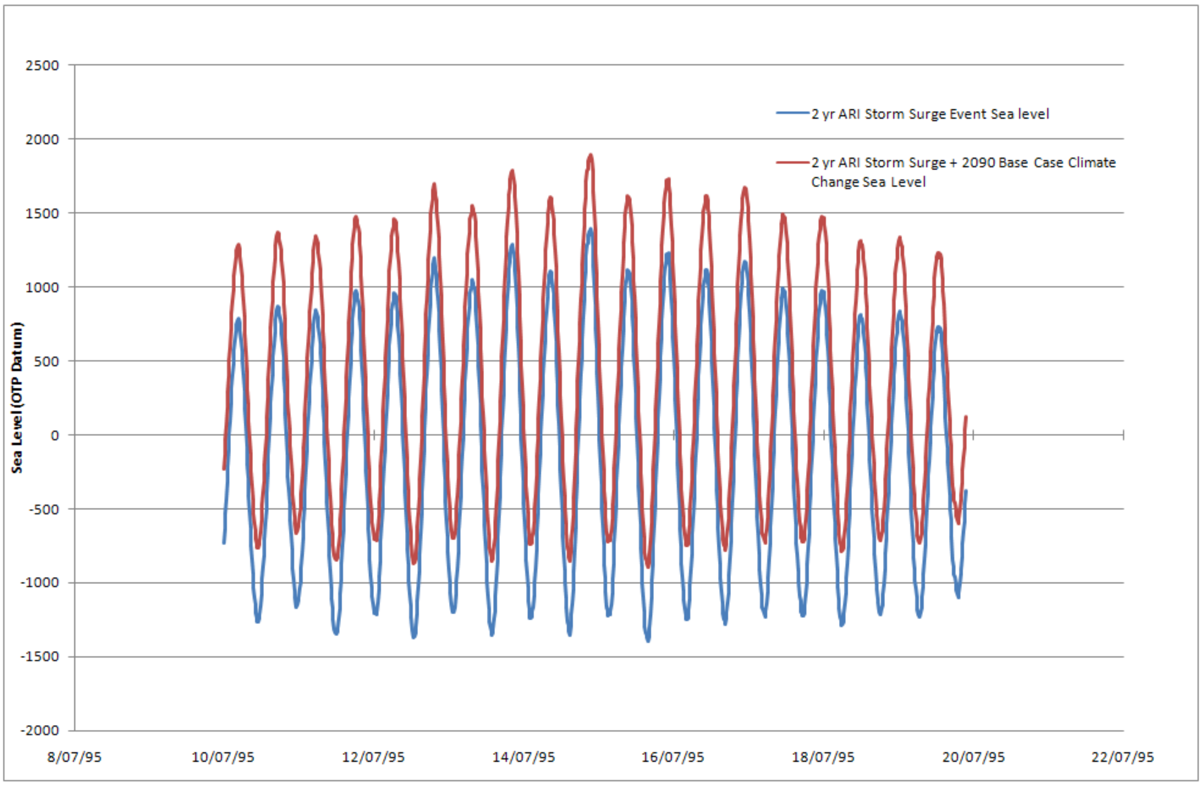
In taking into account the impact of storm surge it is recommended that the combined probability of flood peak and storm surge should not exceed 200 yr ARI. As the ARI of the design event is 100 years, storm surge should therefore have an ARI of 2 years. (0.01 x 0.5 = 0.005 AEP)

From the frequency analysis plotted in Figure 1 above, the 2 year ARI sea level at Marsden Point is 3073mm which is 363mm higher than the Mean High Water Spring level (MHWS) and 1502mm higher than Mean Sea Level (MSL).

These levels are in terms of Marsden Point Chart Datum. Levels used in The Priority Rivers Project are in terms of LINZ datum – One Tree Point 1964. The difference between the two is 1.64m. (Dale Hansen personal comment).

The analysis was then used to prepare a time series of sea level and storm surge for input to the hydraulic models. The 2 year ARI storm surge event of 3073 mm was extracted from the Marsden Point record as shown in Figure 6-7. An allowance for the estimated impact of climate change on sea level was made by adding 500 mm (base case scenario) to the 2 year ARI surge level. In the absence of any published data on the impact of climate change on the magnitude of storm surge the existing 2 year ARI storm surge level was left unchanged for the 2090 scenario.

Figure 6-8 2 Year ARI storm Surge Event + Allowance for Sea Level Rise



6.10 Variation in Sea Level around the Northland Coast

To take into account differences in sea level at locations away from Marsden Point, information published by LINZ in the New Zealand Nautical Almanac 2009-10 was used. The document provides a methodology for obtaining the difference in tide height between Secondary and Standard ports.

For Ruakaka and Whangarei no adjustments to Marsden Point levels were applied. For coastal catchments adjacent to the Bay of Islands the Secondary port of Waitangi was used. For West Coast coastal catchments the Secondary port of Rawene in The Hokianga Harbour was used. The Standard port for this area is Taranaki. Factors applied to to account for differences in sea level between Marsden Point and other locations were 0.82 for Waitangi and 1.26 for the West Coast of Northland.

Modelling

7.1 Model Extent

Model extent was determined in conjunction with GIS processing.

Models are expected to cover the catchment sufficiently to capture the major hydrological characteristics in the upper catchment with reasonably divided sub-catchments and conceptual x-sections derived from 20 m contours. Where 2009 LiDAR is available, x-sections were derived from a 1 m grid size ground model produced from 2009 LiDAR.

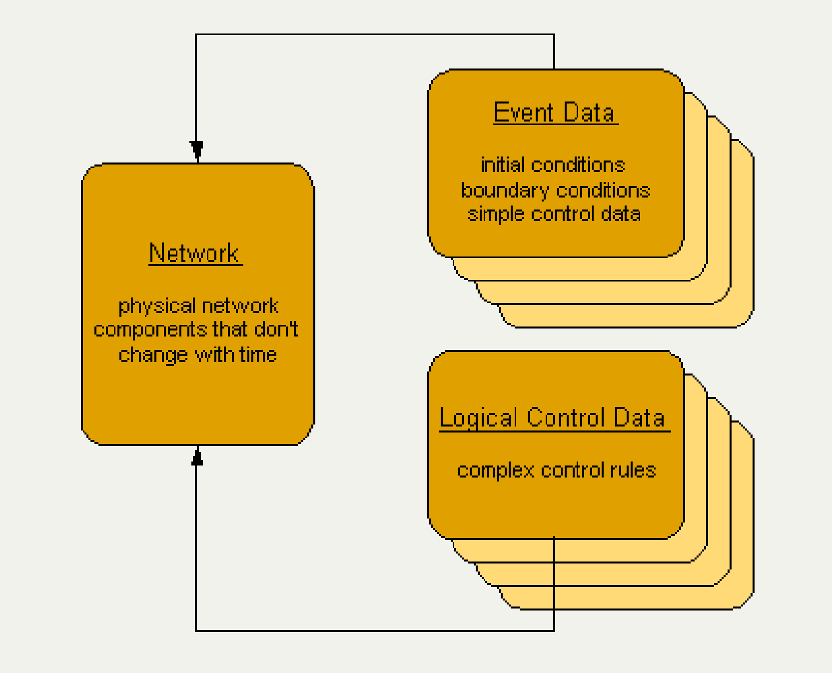
Sub-catchments with geographical features captured from GIS, are linked to the river network with either point inflow or lateral inflow.

Every catchment drains to the coast. A tidal or water level boundary is connected at the catchment outlet. Some assumptions will have to be made to appropriately treat these tidal boundaries.

7.2 River Network Schematic

In InfoWorks, the components that make up a model of a river network are divided into three separate but closely related database items.

Figure 7-1 Basic InfoWork Model Structure



The items are:

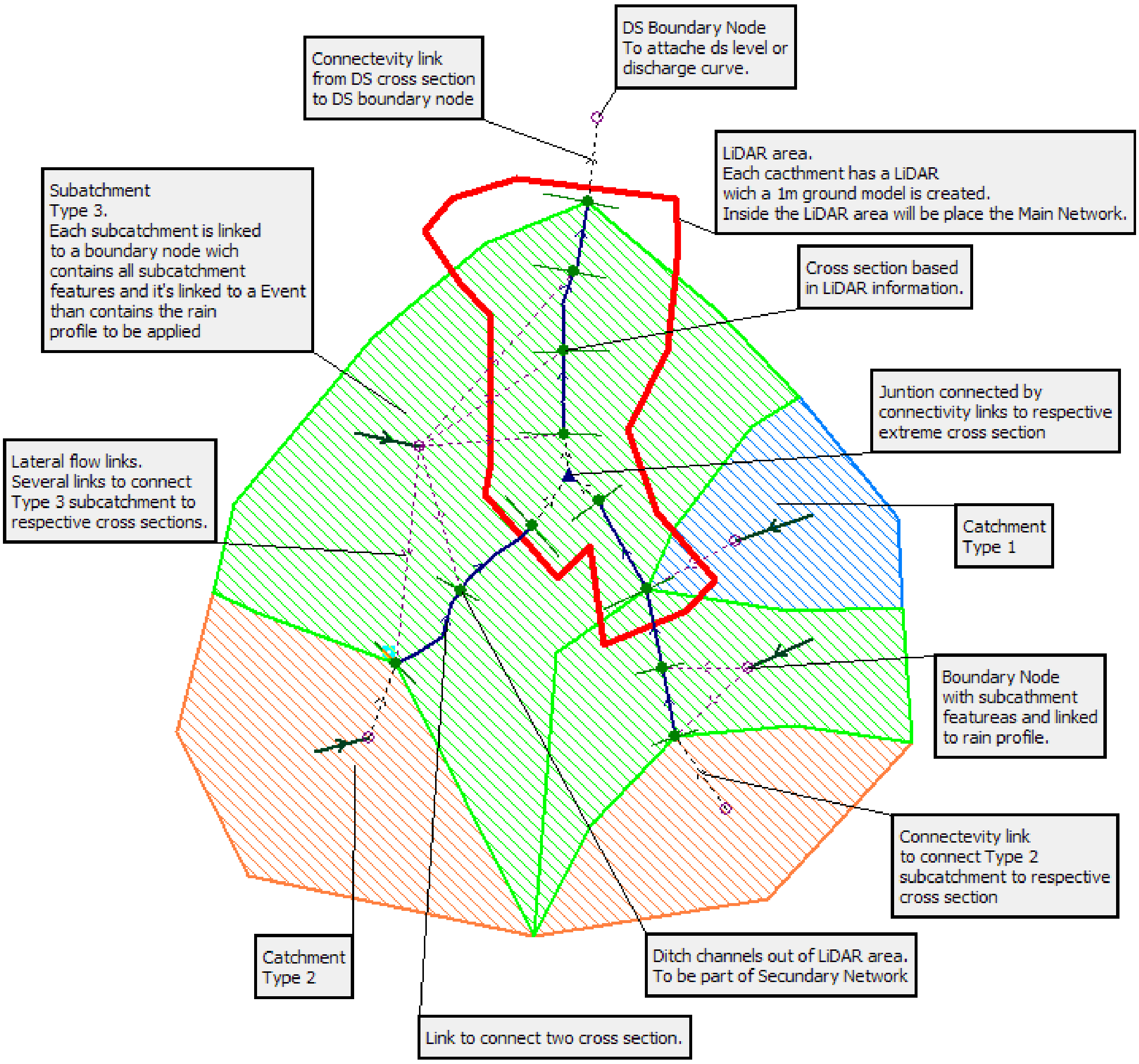
- The Network Database: defines all the physical aspects of the network that do not change over the time frame of a simulation, such as the parameters of a bridge or a channel cross section. You make changes to the network by creating different versions of the network.
- The Event Data: defines aspects of the network that vary with time during the simulation (rain profile, tide levels, discharge curves, inflows, etc), and information about the initial state of the network at the start of the simulation.

- The Logical Control Data: contains rules used to control the more complex operations of some network structures. The Logical Control Data will only be required if there are structures in the model that use complex control rules (pumps, valves, etc.). The Priority Rivers Project currently do not require this type of control.

7.3 River Network framework

The following diagram shows the basic structure of a river network InfoWorks model.

Figure 7-2 Basic Structure of a River Network



Others objects such as orifices, weirs, bridges, culverts, spill ways, pond, and storage areas can also be added to the model and connected by links, connectivity links, junctions and spill links, depending on each case.

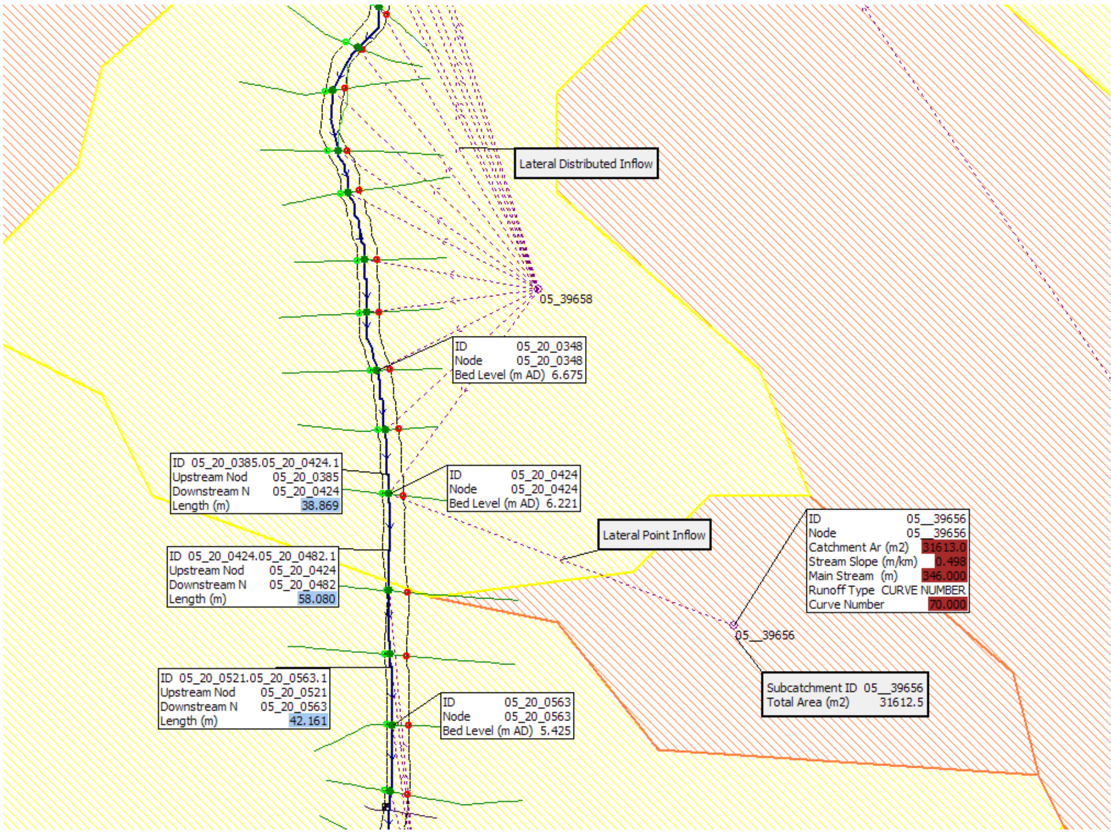
7.4 Naming convention

The names of particular model components in InfoWorks are irrelevant to model numerical calculation. They are expressed with understandable labels with reference to the priority catchment number for automatic processing in both GIS and InfoWorks.

See the figure below:

- Sub-catchment: using 2 digits of Catchment ID, with 4 digits of sub-catchment unique number. These were generated in GIS
- X-sections: 2 digits of Catchment ID, 2 digits of river centre line ID, and x-section chainage. These were generated in GIS
- Links: ID is automatically generated by InfoWorks, which is upstream x-section ID and downstream x-section ID
- Boundary Nodes: a hydrological boundary node has the same ID as the connecting sub-catchment ID.

Figure 7-3 Naming Convention



7.5 Catchment Hydrological Modelling

7.5.1 SCS Method - Runoff Hydrograph

The US SCS Method Hydrological Boundary is a hydrological model for determining runoff from rainfall for a sub-catchment using the United States Soil Conservation Service (US SCS) unit hydrograph method. It is used as an upstream boundary condition producing output equivalent to a Flow Time Boundary.

The US SCS unit hydrograph method is a well established method for determining a flow hydrograph based on a unit hydrograph approach which changes rainfall to runoff through the convolution procedure.

The hydrograph produced by the US SCS Boundary can be viewed prior to use as a table of values or a graph on the Calculated Hydrograph Page or the Calculated Hydrograph Plot Page of the Boundary Node Property Sheet. InfoWorks carries out a limited Boundary Mode simulation to generate the hydrograph.

7.5.2 SCS Curve Number

The main requirements for input data are rainfall, calculated time to peak for the selected unit hydrograph and a Runoff Curve Number, CN, which is determined from a set of tables which are reproduced below. The choice of Curve Number depends on an assessment of the dominant hydrological soil group, the type of land use and antecedent soil moisture conditions.

Runoff Curve Numbers for two different land uses can be specified, in which case InfoWorks calculates an area weighted average composite CN.

The two GIS files should contain polygon data and an additional field defining the Land Use or Soil Type.

Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups (HSG) based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D. Where A generally has the smallest runoff potential and D has the greatest.

Details of this classification can be found in ‘Urban Hydrology for Small Watersheds’ published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release–55.

- Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
- Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
- Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
- Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of

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clay soils with high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

Both Soil map and Land cover are available in GIS. The CN number, which represent to rainfall loss, for each land cover will be calibrated in the modelling stage. As an example, the initial parameters for the rough model build are shown in the table below.

Table 7-1 Initial parameters for the rough model build

LCDB2NAME	COUNT	ID	CN Number				Channelisation	Description
			GROUP A	GROUP B	GROUP C	GROUP D	facto (C)	
Afforestation (imaged, post LCDB 1)	137	11	43	65	76	82	1.0	Woods (Thin Cover)
Afforestation (not imaged)	3	11	43	65	76	82	1.0	Woods (Thin Cover)
Broadleaved Indigenous Hardwoods	313	10	30	55	70	77	1.0	Woods (Thick Cover)
Built-up Area	65	1	77	85	90	92	1.0	Residential (High Density)
Coastal Sand and Gravel	4	6	76	85	89	91	1.0	Disturbed/Transitional
Deciduous Hardwoods	81	11	43	65	76	82	1.0	Woods (Thin Cover)
Dump	1	12	98	98	98	98	1.0	Impervious
Estuarine Open Water	6	13	100	100	100	100	1.0	Water
Flaxland	1	9	30	58	71	78	1.0	Meadow
Forest Harvested	80	6	76	85	89	91	1.0	Disturbed/Transitional
Gorse and Broom	122	9	30	58	71	78	1.0	Meadow
Herbaceous Freshwater Vegetation	53	11	43	65	76	82	1.0	Woods (Thin Cover)
Herbaceous Saline Vegetation	6	11	43	65	76	82	1.0	Woods (Thin Cover)
High Producing Exotic Grassland	255	8	39	61	74	80	1.0	Open Land – Good
Indigenous Forest	2676	10	30	55	70	77	1.0	Woods (Thick Cover)
Lake and Pond	53	13	100	100	100	100	1.0	Water
Landslide	1	6	76	85	89	91	1.0	Disturbed/Transitional
Low Producing Grassland	140	8	39	61	74	80	1.0	Open Land – Good
Major Shelterbelts	59	10	30	55	70	77	1.0	Woods (Thick Cover)
Mangrove	6	10	30	55	70	77	1.0	Woods (Thick Cover)
Manuka and or Kanuka	711	11	43	65	76	82	1.0	Woods (Thin Cover)
Mixed Exotic Shrubland	26	10	30	55	70	77	1.0	Woods (Thick Cover)
Orchard and Other Perennial Crops	43	7	67	77	83	87	1.0	Agricultural
Other Exotic Forest	439	10	30	55	70	77	1.0	Woods (Thick Cover)
Pine Forest - Closed Canopy	262	11	43	65	76	82	1.0	Woods (Thin Cover)
Pine Forest - Open Canopy	427	11	43	65	76	82	1.0	Woods (Thin Cover)
River	8	13	100	100	100	100	1.0	Water
River and Lakeshore Gravel and Rock	1	6	76	85	89	91	1.0	Disturbed/Transitional
Short-rotation Cropland	27	7	67	77	83	87	1.0	Agricultural
Surface Mine	32	6	76	85	89	91	1.0	Disturbed/Transitional
Transport Infrastructure	4	12	98	98	98	98	1.0	Impervious
Urban Parkland/ Open Space	75	12	98	98	98	98	1.0	Impervious
Vineyard	5	7	67	77	83	87	1.0	Agricultural

To accommodate antecedent soil moisture there are three conditions to consider:

Condition I	Soils are dry but not to wilting point; satisfactory cultivation has taken place.
Condition II	Average conditions.
Condition III	Heavy rainfall, or light rainfall and low temperatures have occurred within the last 5 days; saturated soil.

The following table gives seasonal rainfall limits for the three antecedent moisture conditions (AMC):

Table 7-2 Seasonal rainfall limits for the antecedent moisture conditions

AMC	Total 5-day antecedent rainfall (mm)	
	Dormant Season	Dormant Season
I	<13	<35
II	13 – 28	35 - 53
III	>28	>53

The following table can be used to adjust the CN from the average conditions referenced in the above CN tables to Antecedent Moisture Conditions I and III.

Table 7-3 Corresponding CN

CN for AMC II	Corresponding CN for	
	AMC I	AMC III
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
10	4	22
5	2	13
0	0	0

7.6 Model Build procedure

In general, all models were built following a series of model build procedures. Each step is outlined in detail below.

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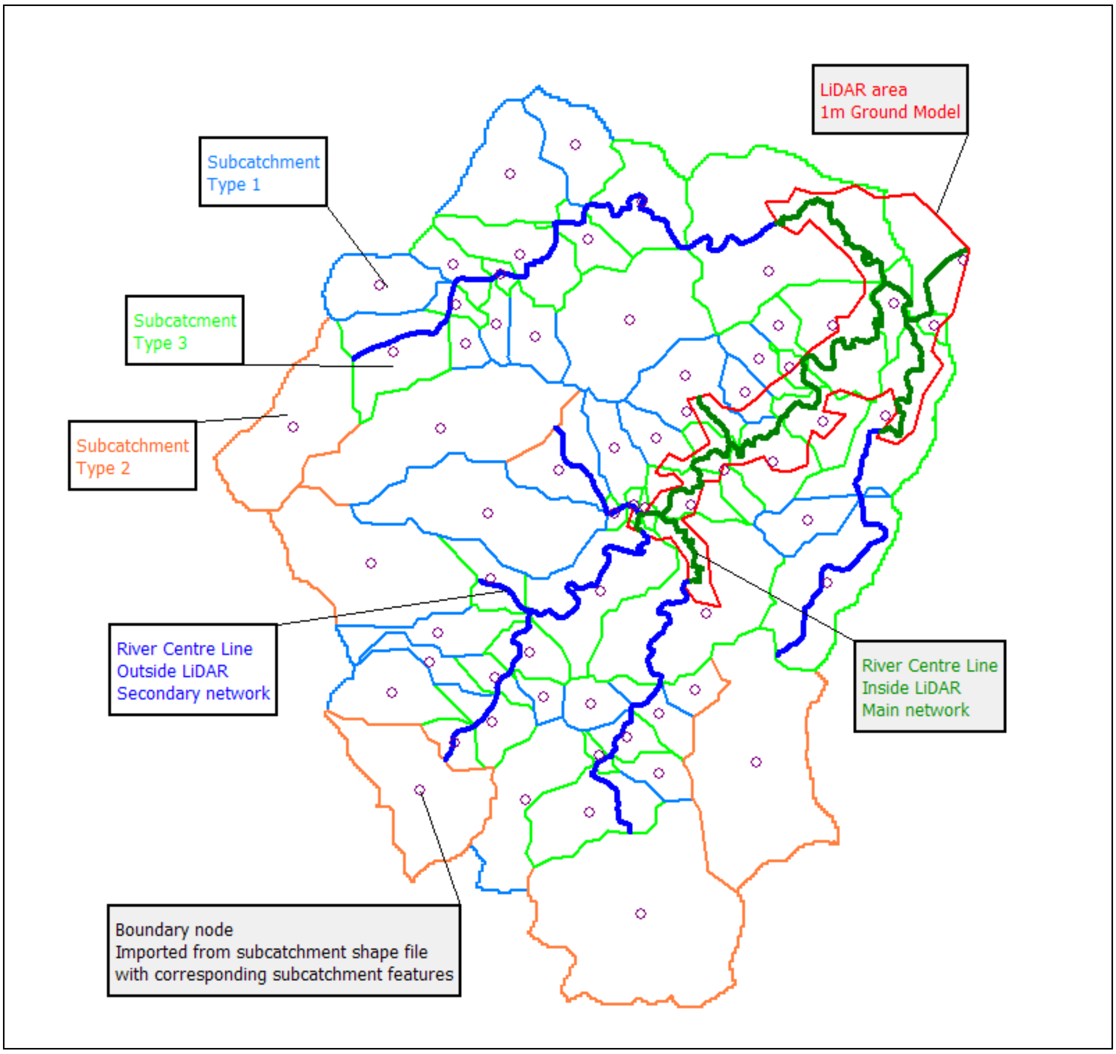
Step 1: Check available GIS information

The following GIS shapefiles are required before building the model:

- Subcatchments
- Nodes
- Links
- 1 metre digital elevation model (1m DEM or ground model) created from LiDAR data
- 15 metre ground model created from 20 metre contours.
- Aerial image of the area of interest
- Longest flow path
- River centre line, based on 1 metre ground model (RCL)

For each catchment, the respective sub-catchment shape file was imported to create sub-catchment and boundary nodes. Links were imported to create River Centre Lines, see Figure 7-4.

Figure 7-4 GIS Components of the Model



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Step 2: Using of Ground model and LiDAR

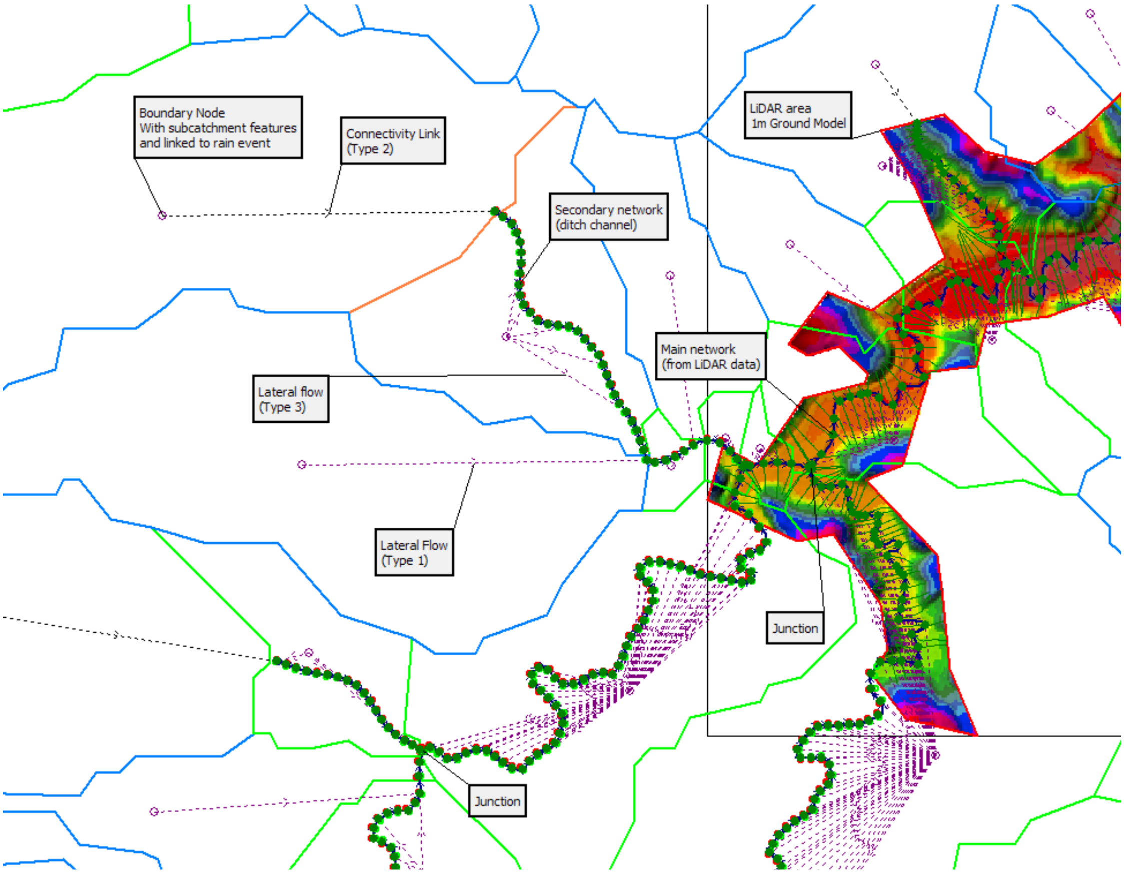
GIS information was loaded into InfoWorks RS and analysed to develop the catchment network system.

Model component names and level information were obtained from GIS. A new shape file with 3D lines (X, Y, and Z) for XS's, RCL's and/or BL's is created, depending on each case. Those lines can then be imported back into InfoWorks RS.

The processed Cross Section Lines are converted into River Sections, then they are automatically linked using the corresponding RCL.

Sub-catchments were created during this step. Network extension was required to connect the main river to the sea effectively.

Figure 7-5 Example of InfoWork RS Component



Step 4: Boundary Nodes, Lateral Flows and Connectivity Links

Sub-catchments are linked to the respective boundary node that will hold all information related to the runoff method, and also linked to the modelled rainfall. There are three types of boundary nodes to be connected:

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- **Type 1:** Sub-catchment inflow as a lateral one point entry; using a single lateral flow link as connection.
- **Type 2:** Sub-catchment discharges to one point, as an upstream inflow of a river branch. Using a connectivity link.
- **Type 3:** Lateral sub-catchment discharging to a stretch of river branch. Using several lateral flow links from the boundary node to the target cross-sections.

The linking process used automatic tools and GIS features to link cross-sections with their respective boundary nodes. Downstream boundary node needs to be added for the downstream boundary condition. This is usually a level (tide level, critical flow, normal flow or discharge curve).

Step 5: Event features and Boundary Nodes

This step involves creating an event, including a rain profile and downstream level conditions. Each series needs to be linked to respective boundary nodes. The flow boundary nodes will be set as *US SCS Boundary*. This method requires the following variables:

- *Rain Event ID*: Event ID of the rain profile is created in an EVENT object and linked to the boundary node. Figure 3-3 provides an example of hydrographs produced at a boundary node
- *Time to peak:* Two-thirds of the time of concentration, expressed in minutes. The time of concentration is calculated in GIS using an estimated CN number.
- *Hydrograph Interval*: To be set the same as the Hydrograph Interval used for the corresponding rain event in the EVENT object. Expressed in hours.
- *CN Number*. Estimated value from GIS. Table 3-1 shows estimated values of CN number for initial calculation based in GIS list of land cover. A Solid Group C was assumed for all catchments at this stage. These values may change, subject to initial soil wetness before model runs.

Figure 7-6 Example: Hydrograph produced at boundary node given a Hydrograph

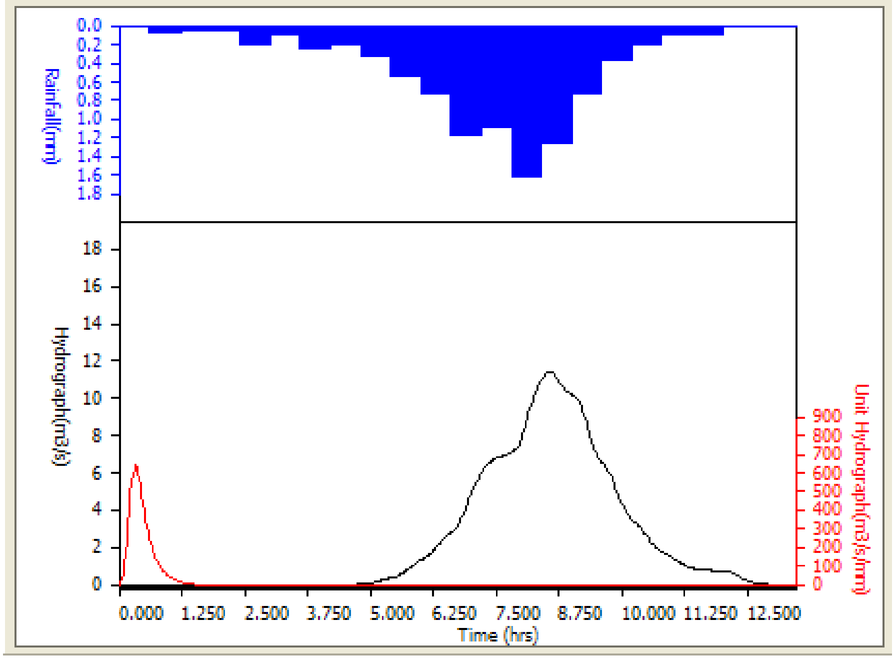

Table 7-4 Estimated CN Number values

ID	Description	Average % Impervious	Curve Number by Hydrologic Soil Group				Typical Land Uses
			A	B	C	D	
1	Residential (High Density)	65.00	77	85	90	92	Multi-family, Apartments, Condos, Trailer Parks
2	Residential (Med. Density)	30.00	57	72	81	86	Single-Family, Lot Size ¼ to 1 acre
3	Residential (Low Density)	15.00	48	66	78	83	Single-Family, Lot Size 1 acre and Greater
4	Commercial	85.00	89	92	94	95	Strip Commercial, Shopping Ctrs, Convenience Stores
5	Industrial	72.00	81	88	91	93	Light Industrial, Schools, Prisons, Treatment Plants
6	Disturbed/Transitional	5.00	76	85	89	91	Gravel Parking, Quarries, Land Under Development
7	Agricultural	5.00	67	77	83	87	Cultivated Land, Row crops, Broadcast Legumes
8	Open Land – Good	5.00	39	61	74	80	Parks, Golf Courses, Greenways, Grazed Pasture
9	Meadow	5.00	30	58	71	78	Hay Fields, Tall Grass, Ungrazed Pasture
10	Woods (Thick Cover)	5.00	30	55	70	77	Forest Litter and Brush adequately cover soil
11	Woods (Thin Cover)	5.00	43	65	76	82	Light Woods, Woods-Grass combination, Tree Farms
12	Impervious	95.00	98	98	98	98	Paved Parking, Shopping Malls, Major Roadways
13	Water	100.00	100	100	100	100	Water Bodies, Lakes, Ponds, Wetlands

Step 6: Flood mapping model

Flood maps were initially produced in InfoWorks for further processing in GIS system.

There are two ways to produce flood maps from the model. One way is to use 1D +quasi 2D model, and the other way is to use 1D flood compartments with dynamic 2D.

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The proceeding is a brief description of the InfoWorks flood mapping module and more information on this is available in InfoWorks RS Help.

The flood maps are produced from a series of flood compartments. A flood compartment is an area in which flood depths are calculated based on levels derived from each cross-section and the ground model. This displays flooding areas with a good approximation. It is noted that flood extension is only based on cross-section levels intersecting the ground model, and volume calculations are not included in this process. Volume is calculated in the hydraulic routine, and based on the volume held between two consecutive cross-sections.

Once the model is running well, a flood compartment can be created to represent the flood extents. The following figure shows an example of a model with a flood compartment.

Figure 7-7 Example: Flood Compartment

7.7 MikeFlood Model Conversion

There are a limited number of Mike 11 models available for the Otaika and Waiarohia catchments. The Waiarohia catchment includes a short stretch of the downstream part of Hatea River, which is part of Hatea catchment. The Mike 11 (1D model) was converted for use in InfoWorks RS.

The InfoWork RS river centre lines were exported from the Mike 11 model.

7.7.1 Otaika River Conversion

The Mike 11 Model for Otaika River, named 1a2.sim11, was imported to InfoWorks RS (refer to the model book of the respective Mike 11 model report). There were two branches in this Otaika Mike 11 Model; Otaika River, and Otakaranga River. The boundary conditions included a static downstream tide level and two upstream inflow discharges and three lateral in-stream discharges. The boundary conditions are represented in Figures 7-8 and 7-9.

Figure 7-8 Inflow Boundary Conditions

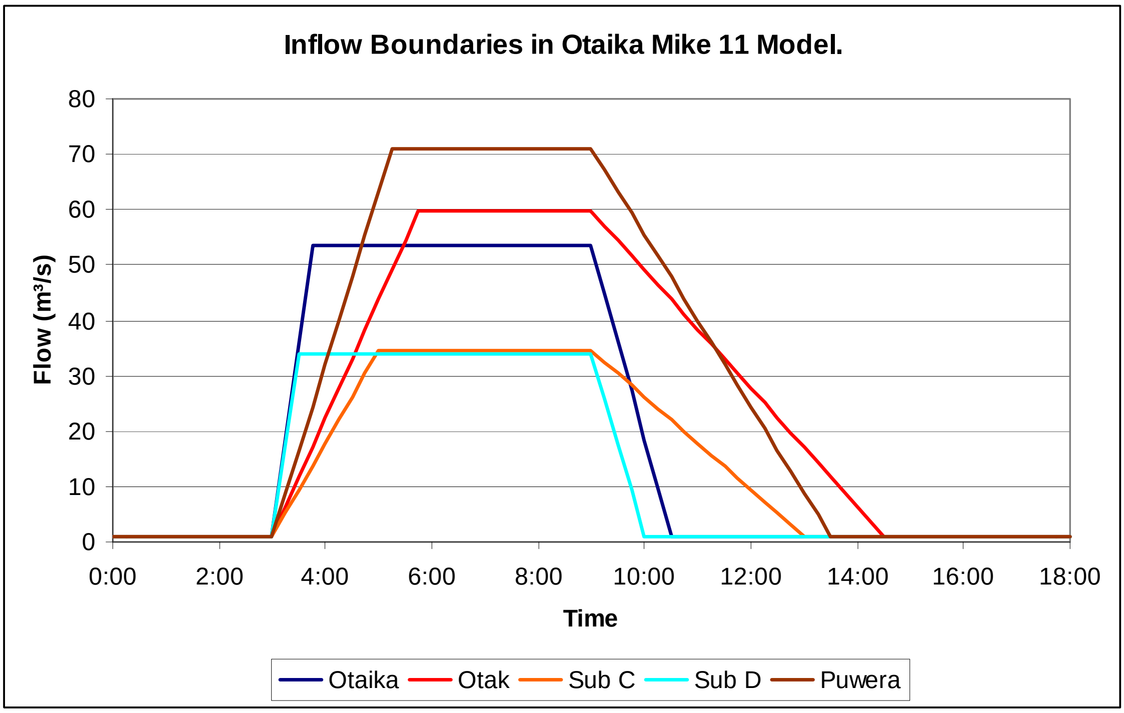
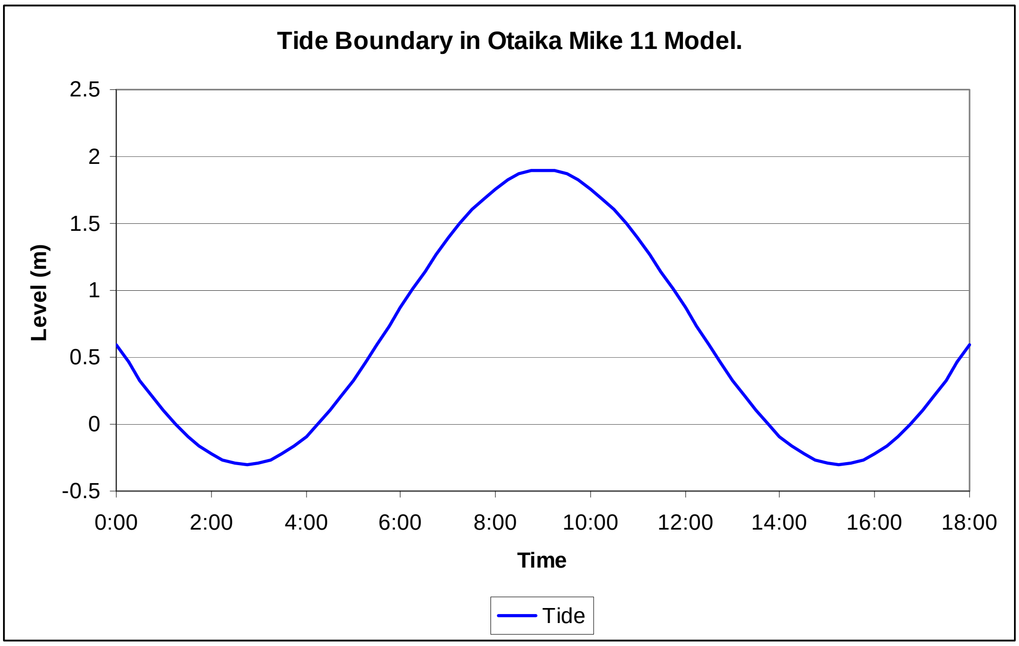


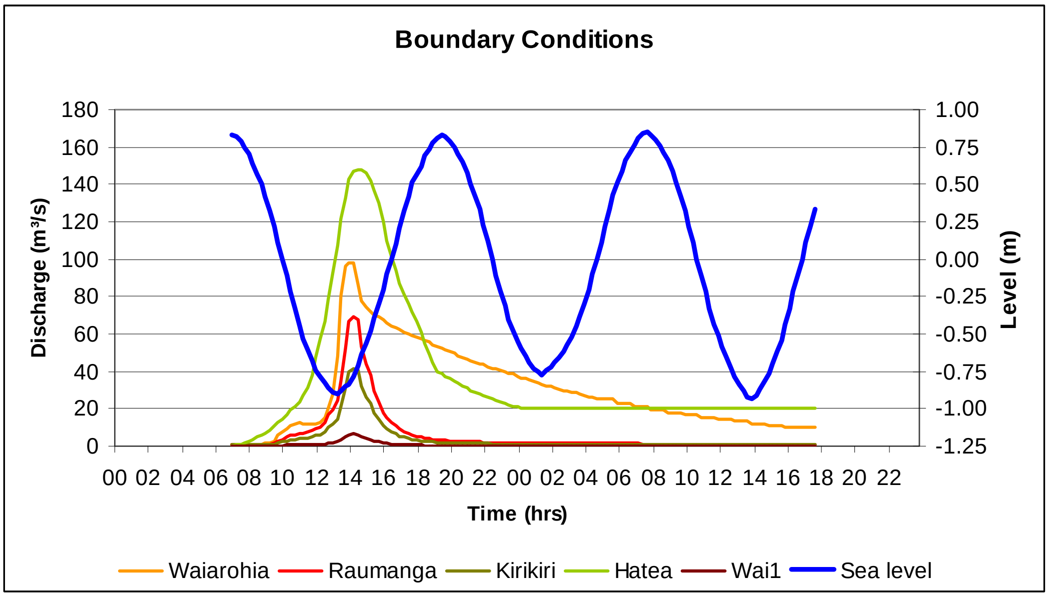
Figure 7-9 Tidal Boundary Conditions



7.7.2 Waiarohia River Conversion

The Mike 11 Model for Waiarohia River, named WDC1999.sim11, was imported to InfoWorks RS (refer to the model book of the respective Mike 11 model report). There were four branches in the Waiarohia Mike 11 Model; Waiarohia River, Hatea River, Raumanga Stream, and Kirikiri Stream. The boundary conditions included a static downstream tide level and four upstream inflow discharges and one lateral in-stream discharges. The boundary conditions are represented in Figure 7-10.

Figure 7-10 Waiarohia Mike 11 Boundary Conditions



7.8 Tide Levels

Tide levels for each catchment will be based on the results of the Hydrologic Assessment report (refer to Section 6 Hydrology). This includes tidal levels, sea level rise factors and storm surge. This report also included an analysis of the relationship between weather, storm and tidal events.

7.9 Dealing with Data Gaps

Data gaps were dealt with through all stages. The following addresses the methodology in dealing with insufficient x-sections with particular technologies.

7.9.1 Cross Sections

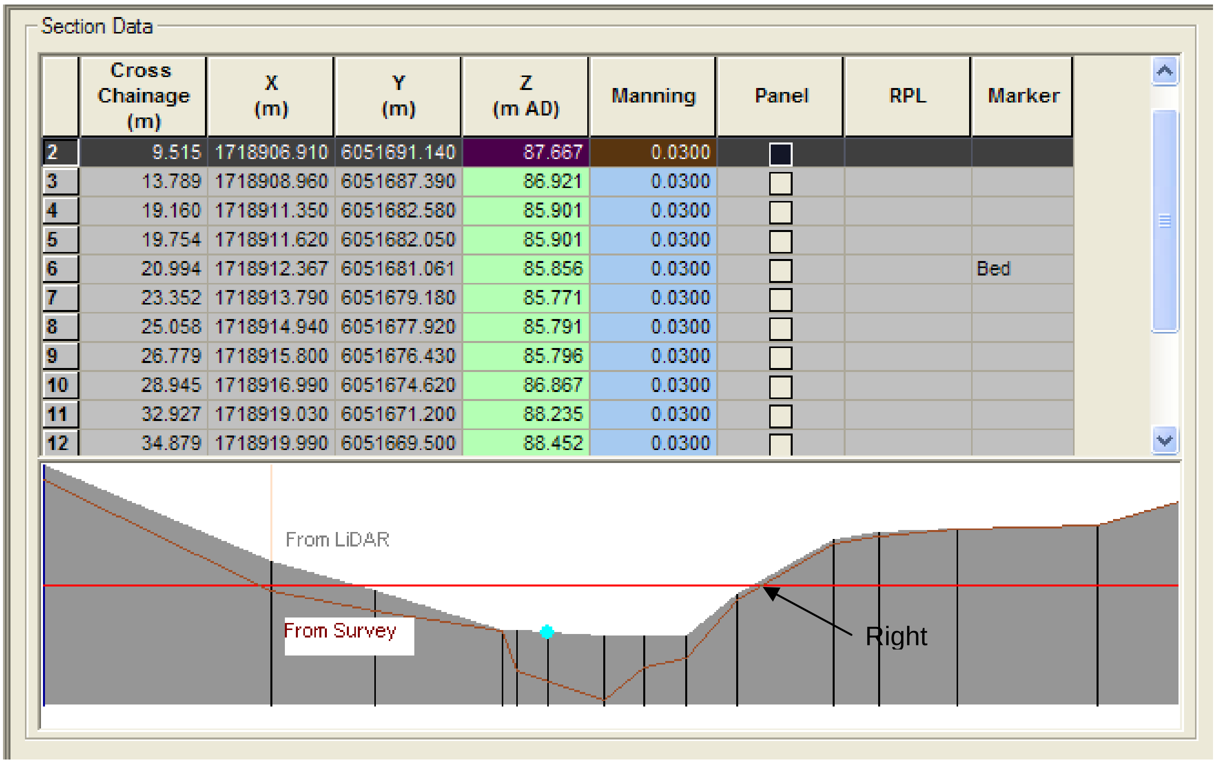
There are a limited number of surveyed cross-sections. The distance between surveyed x-sections varies from a few hundreds metres to over 1.2 km.

It is also noted that the LiDAR data provides good information for the majority of unsurveyed river reaches.

Under this situation, it is inappropriate to directly use survey to interpolate x-sections between surveyed ones, as the interpolation will introduce error in the LiDAR area and in the future cause inaccurate calculation and flood depth errors.

A comprehensive approach was adopted to reflect the under water part of the x-sections in those x-sections generated from LiDAR. The following images demonstrate this concept.

Figure 7-11 Surveyed Cross Sections



Section Data

	Cross Chainage (m)	X (m)	Y (m)	Z (m AD)	Manning	Panel	RPL	Marker
2	9.515	1718906.910	6051691.140	87.667	0.0300			
3	13.789	1718908.960	6051687.390	86.921	0.0300			
4	19.160	1718911.350	6051682.580	85.901	0.0300			
5	19.754	1718911.620	6051682.050	85.901	0.0300			
6	20.994	1718912.367	6051681.061	85.856	0.0300			Bed
7	23.352	1718913.790	6051679.180	85.771	0.0300			
8	25.058	1718914.940	6051677.920	85.791	0.0300			
9	26.779	1718915.800	6051676.430	85.796	0.0300			
10	28.945	1718916.990	6051674.620	86.867	0.0300			
11	32.927	1718919.030	6051671.200	88.235	0.0300			
12	34.879	1718919.990	6051669.500	88.452	0.0300			

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Figure 7-12 Plan View of Surveyed and Interpolated Cross Sections

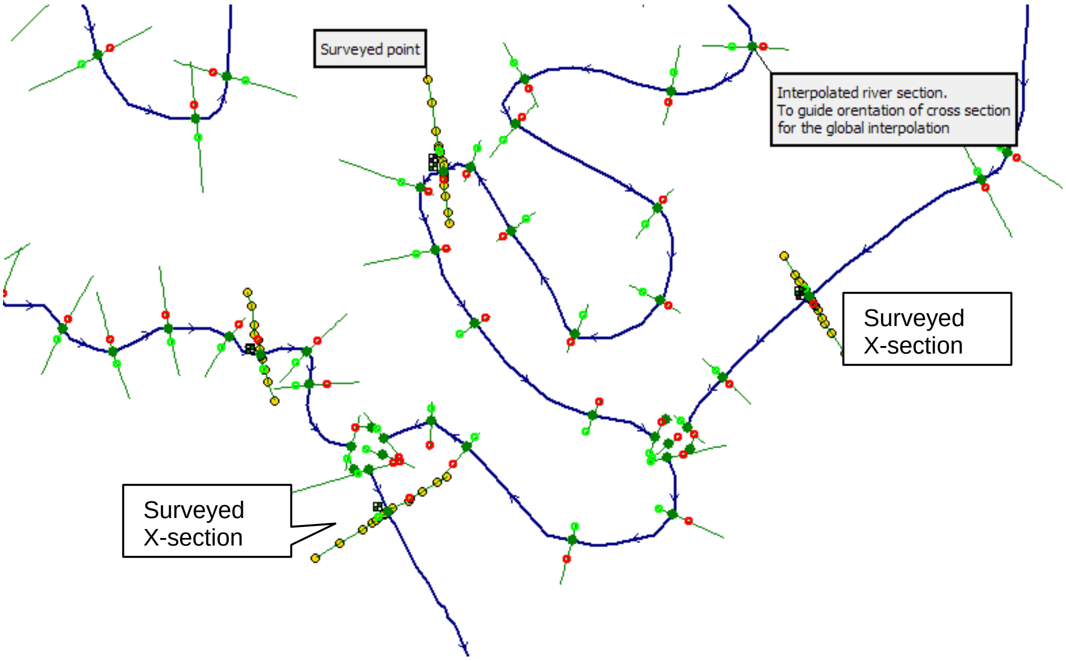
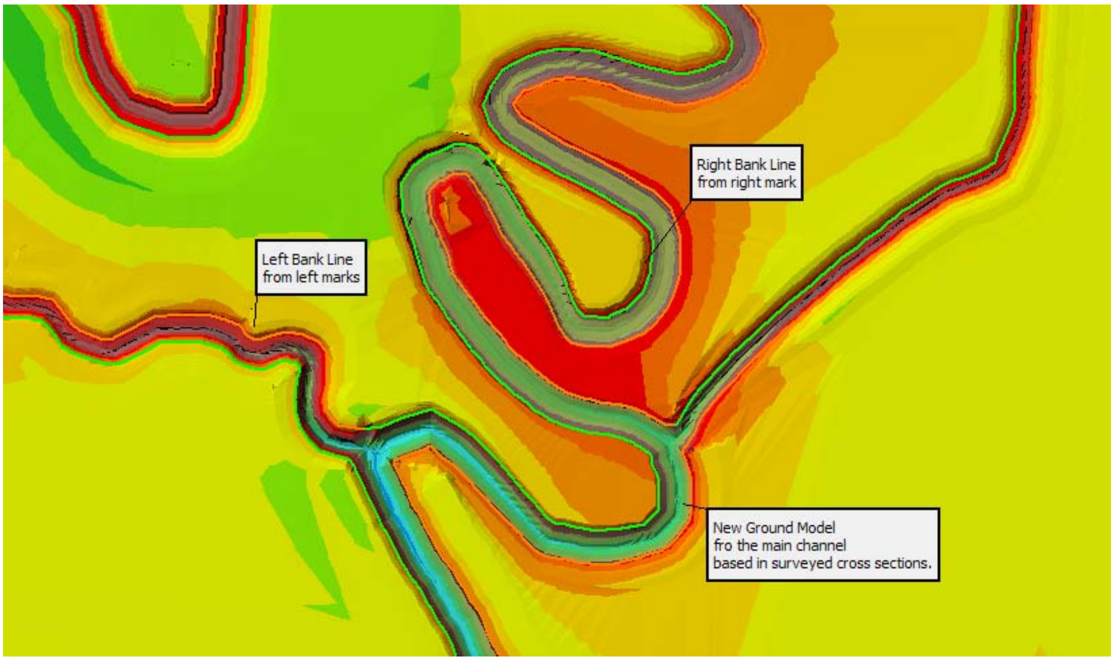


Figure 7-13 Finished ground model with surveyed and interpolated cross sections

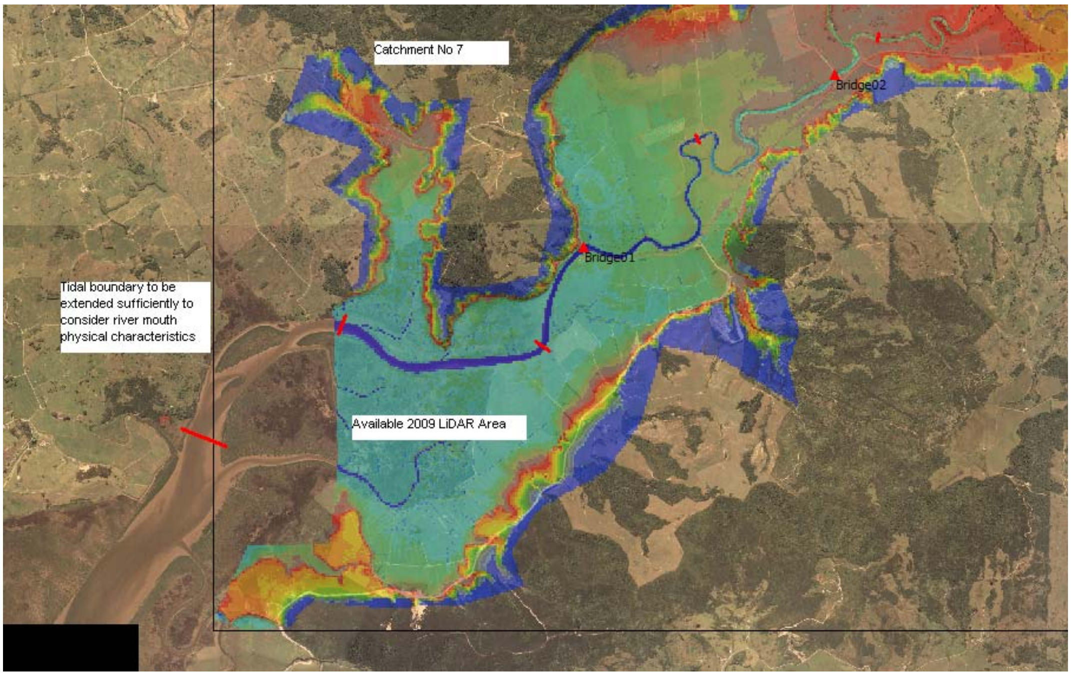


As shown in the figures above, the under water part of the x-sections generated from LiDAR was interpolated from survey data. The modified x-sections are relatively close to the actual cross sections. This technology will extend the value of survey data to un-surveyed cross sections and minimise the survey cost whilst still achieving good results

7.9.2 LiDAR boundary in Coastal area

Many catchments did not have sufficient LiDAR coverage of the coastal area. In these cases assumptions had to be made to extend these main rivers sufficiently to represent the physical constraints beyond the LiDAR. This assumption may have been made using X-sections.

Figure 7-14 Catchment No 7 LiDAR Area Vs Expected Model Tidal Boundary



Rough model results show that the assumption of these x-sections may be sensitive to the model results. LiDAR data reached the bed level of about 0-0.9m.

NRC has identified critical bridges in Priority River 2 and Waima Catchment of Priority River 4. this assessment resulted in an additional 4-10 surveyed cross sections for each of these catchments. These surveyed results were used to improve the rest of the cross-sections from LiDAR and the river extension below the LiDAR boundary.

7.10 Data Management

7.10.1 Data Flag

Data Flags are a powerful tool for recording the source and integrity of data in a model. Presently, six Data Flags are defined as part of the six default flags of InfoWorks RS. The types of Data Flags are summarised in Table 7-6.

Table 7-5 Types of Data Flag

Name	Colour	Description	Memo
#D		System Default	Default Flag
#G		Data from GeoPlan	Default Flag
#I		Model Import	Default Flag
#S		Data from Survey	Default Flag
#T		Data from Ground Model	Default Flag
#V		CSV Import	Default Flag
BM		Infered Data or Calculated from available information.	URS Flag
BX		Missed Data Infered or Guessed	URS Flag
GC		GIS Calculation	URS Flag
GM		Based in Ground Model Information	URS Flag
UR		URS Engineering Judgement	URS Flag
CA		Calibration	URS Flag

7.11 Model Calibration and Verification

Model calibration and verification report is included in this report as Appendix A. The sections below address the methodology and the result comparison regarding the Mike11 converted models.

7.11.1 Calibration and Verification Methodology

Events selected for calibration or verification will be based on the available gauge data. Flood level survey data will be used for the calibration if it is from the same event or used as verification.

At this stage, it seems that there are limited gauge data for model calibration. The number of gauges particularly rain gauges are critical. We have discussed this gap with NRC and have included recommendations for additional raingauges in the individual RMPs. We also asked NRC to seek more rainfall data for the calibration events. The information that resulted from this search is likely from non automatic rain gauge records.

Calibration was processed in the following stages:

- Flow balance analysis was performed to understand rainfall and flow data status within the calibration event and the rainfall distribution over the catchment is critical and has been considered carefully.
- Calibrate rainfall loss parameters and volume at the flow gauges. This will estimate rainfall loss parameter (SCS CN number) for each individual land cover with a particular soil type.
- Compare the loss parameters with other catchments in Priority 1 and derive a common set of parameters if possible. The common set loss parameter may not the best one for one catchment, but is considered fit for purpose in general. This parameter can be improved with a future more in depth study.
- The common set parameter will be used for other catchments. Soil antecedent conditions have been considered when being applied to each design event.
- Hydraulic calibration was analysed against the observed flow. This is to verify x-section manning values, structures and configurations.

7.11.2 Calibration and Verification Results

To be updated when available.

Otaika River Conversion

The Mike 11 Model for Otaika River, named *1a2.sim11*, was imported to InfoWorks RS (refer to the model book of the respective Mike 11 model report). There were two branches in this Otaika Mike 11 Model; *Otaika River*, and *Otakaranga River*. The boundary conditions included a static downstream tide level and two upstream inflow discharges and three lateral in-stream discharges. The boundary conditions are represented in Figures 7-15 and 7-16.

Figure 7-15 Inflow Boundary Conditions

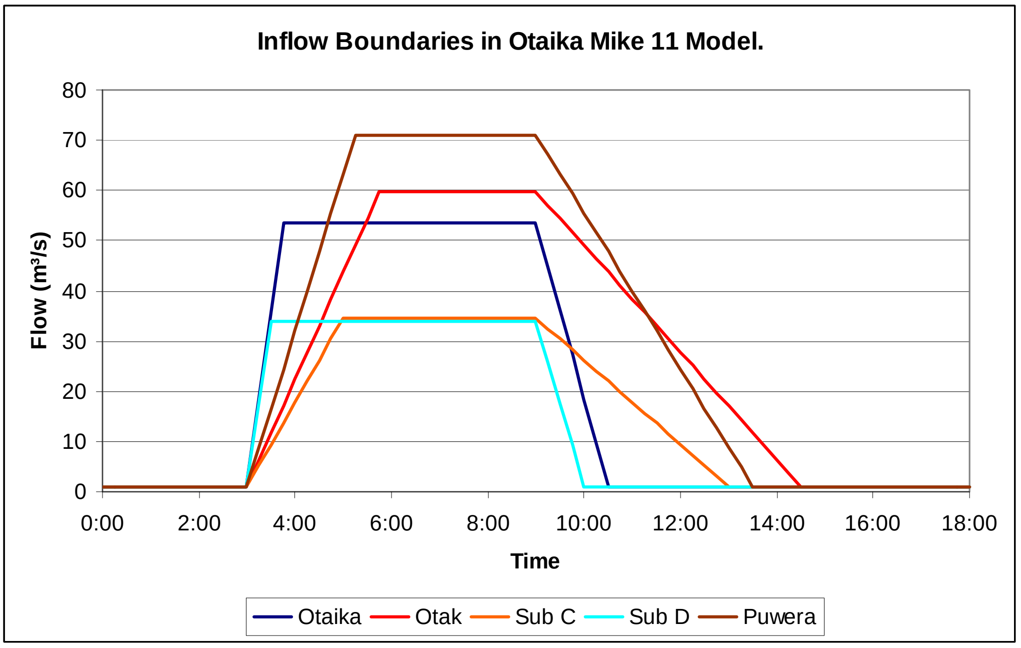


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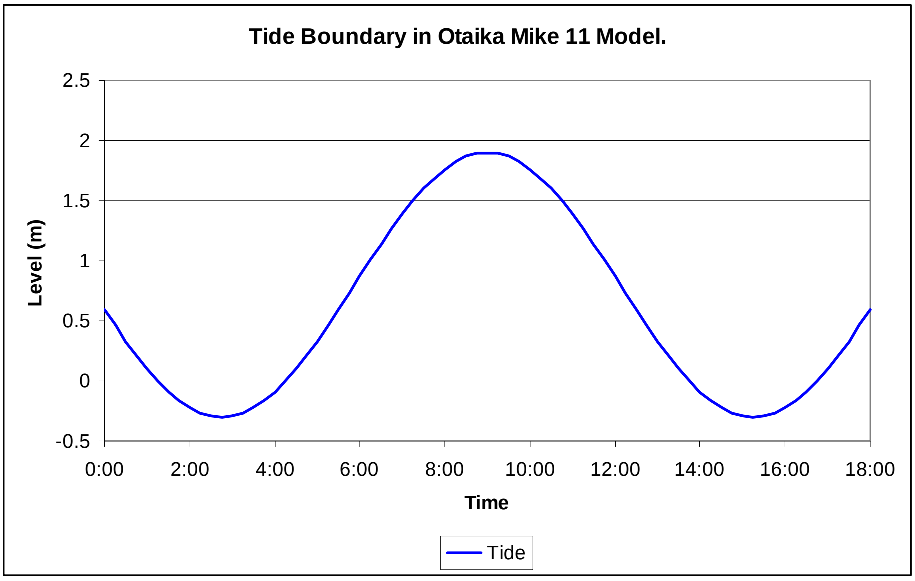
Figure 7-16 Tidal Boundary Conditions



Every effort was made to retain the same features as the Mike11 Model for Otaika, in the first version of the InfoWorks RS model, for as long as possible. The results of the model are summarised in Figures 7-17 to 7-24.

Figure 7-17 Otakaranga Water Level

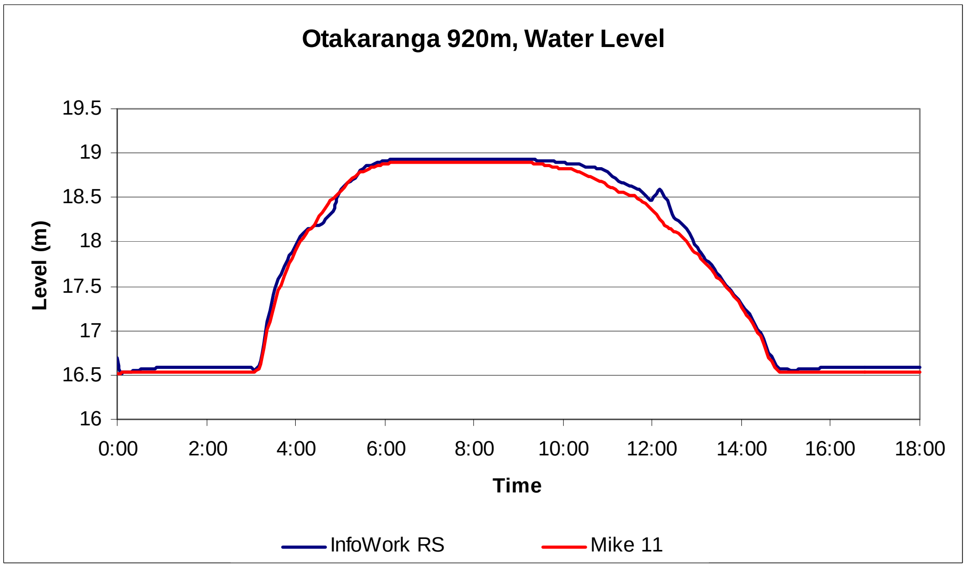


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Figure 7-18 Otaika Water Level Sub-catchment 1

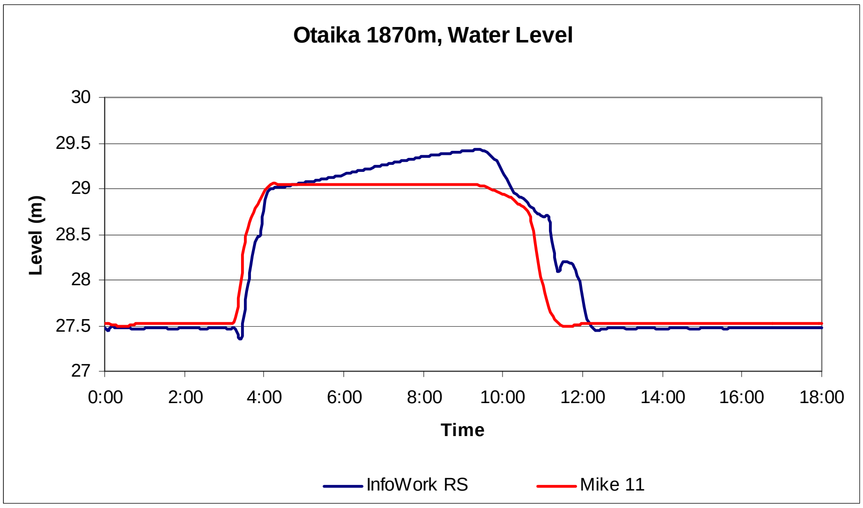

Figure 7-19 Otaika Water Level Sub-catchment 2

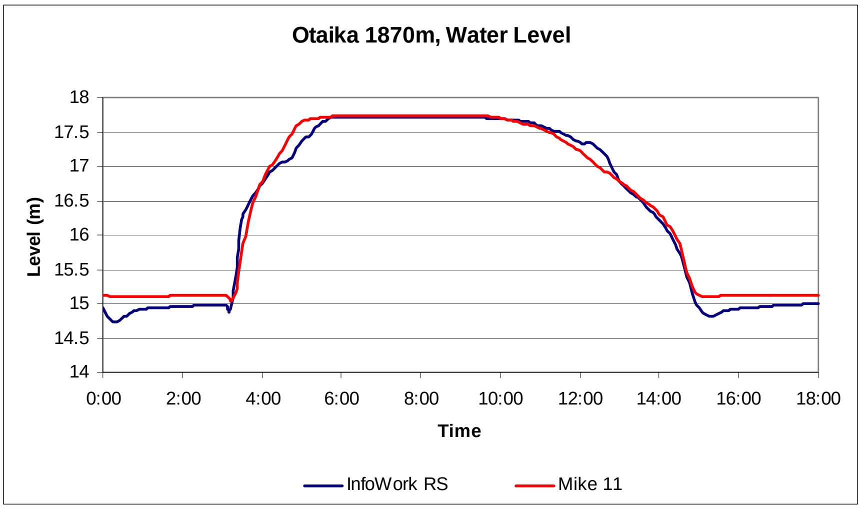

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Figure 7-20 Otaika Water Level Sub-catchment Puwera

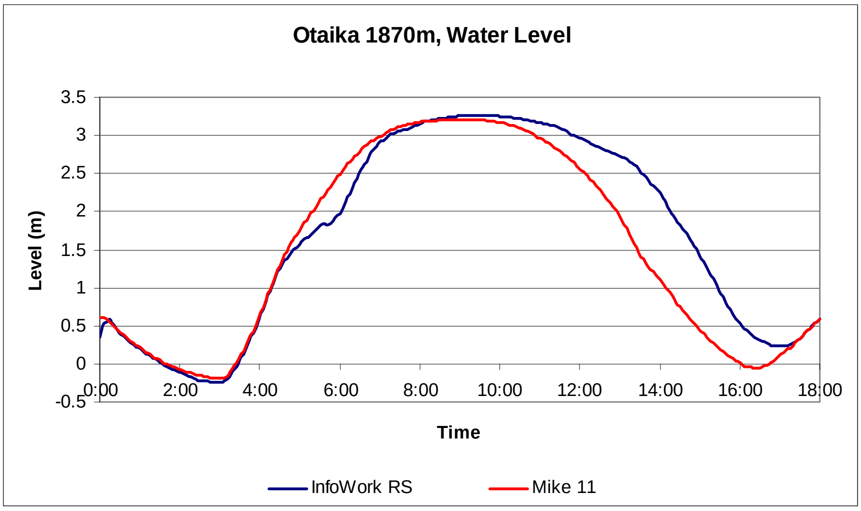

Figure 7-21 Otaika Discharge 1

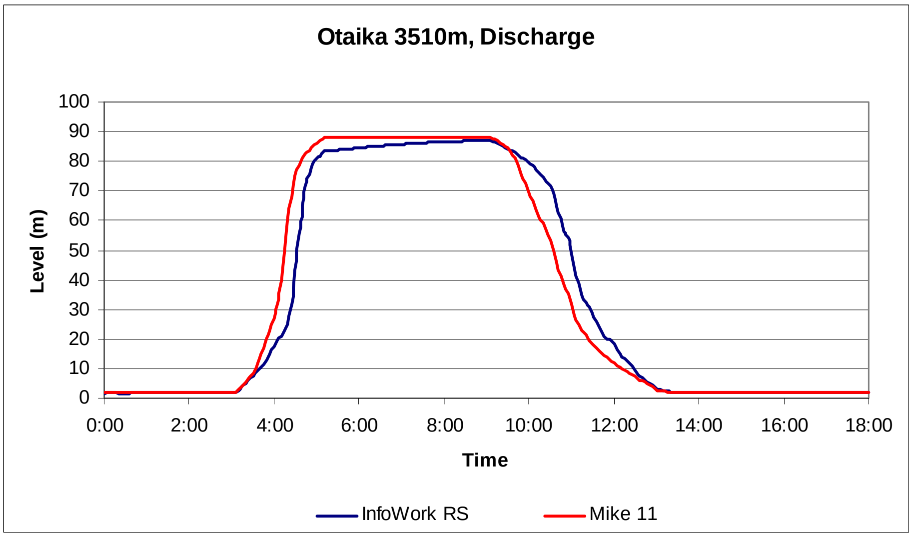

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Figure 7-22 Otaika Discharge 2

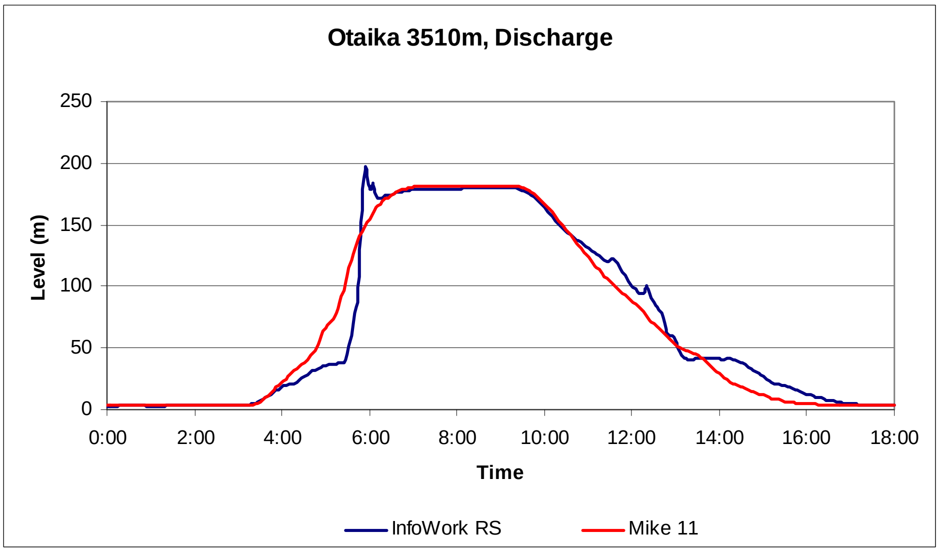


Figure 7-23 Mike 11 v/s InfoWork RS Otaika River

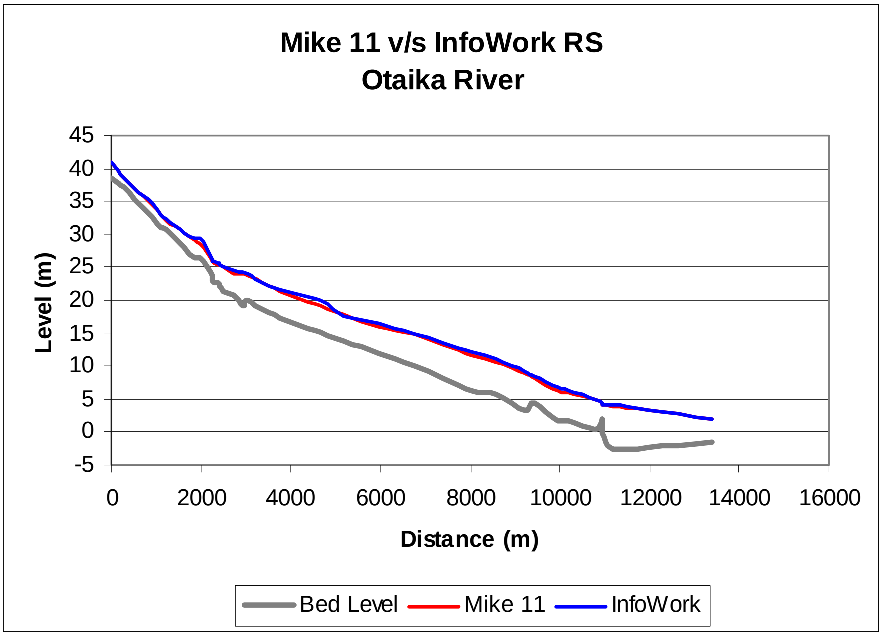
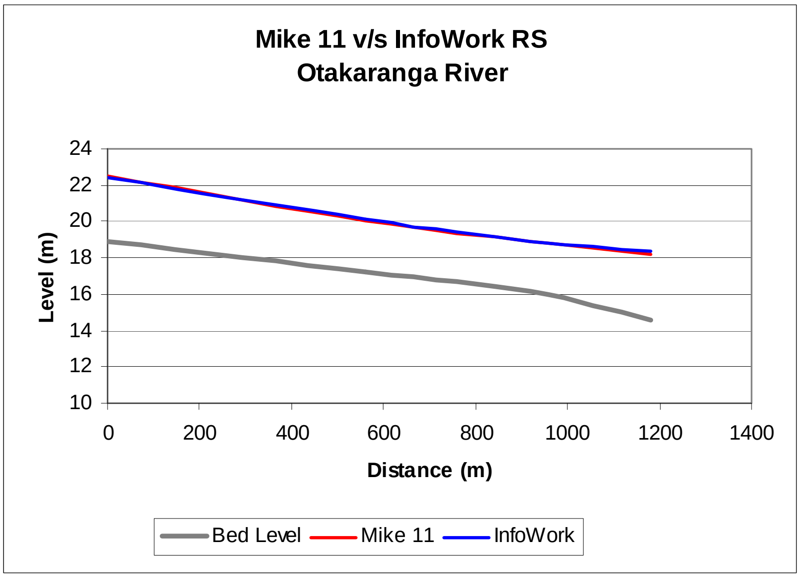


Figure 7-24 Mike 11 v/s InfoWork RS Otakaranga River

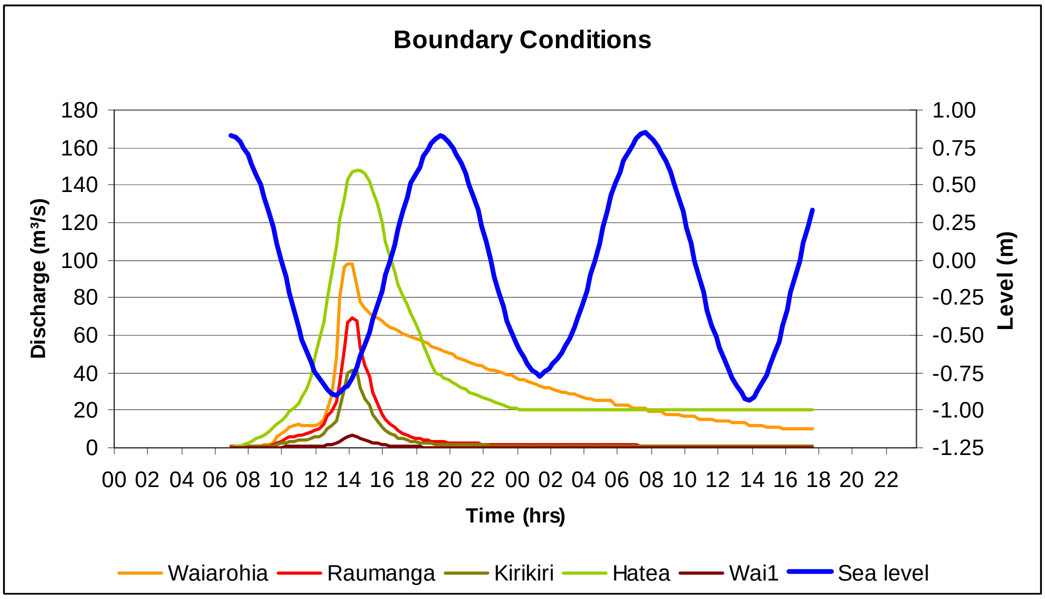


The results presented in the above figures indicate that the conversion between Mike 11 and Infoworks RS was acceptable. This initial version of the InfoWorks RS Otaika Model was extended to include all pertinent LiDAR areas, including survey information.

Waiarohia River Conversion

The Mike 11 Model for Waiarohia River, named *WDC1999.sim11*, was imported to InfoWorks RS (refer to the model book of the respective Mike 11 model report). There were four branches in the Waiarohia Mike 11 Model; *Waiarohia River*, *Hatea River*, *Raumanga Stream*, and *Kirikiri Stream*. The boundary conditions included a static downstream tide level and four upstream inflow discharges and one lateral in-stream discharges. The boundary conditions are represented in Figure 7-25.

Figure 7-25 Boundary Conditions - Waiarohia River



7 Modelling

The results of the model are summarized in Figures 7-26 to 7-33. RS model results shown are very close to the original Mike11 results and therefore the conversion was considered acceptable.

Figure 7-26 Hatea River Water Level

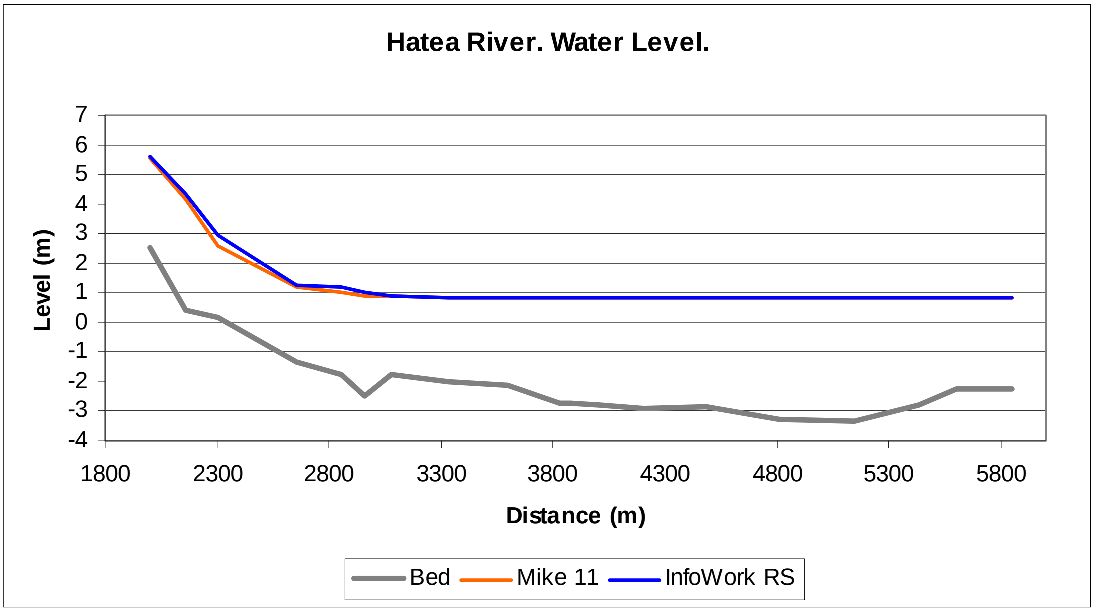
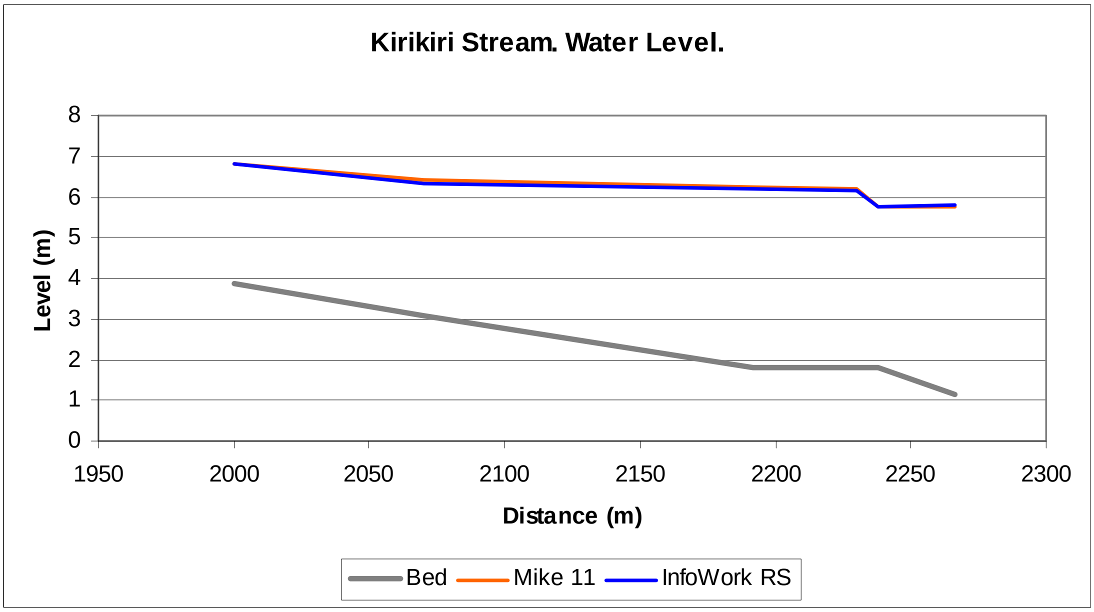


Figure 7-27 Kirikiri Steam Water Level



7 Modelling

Figure 7-28 Raumanga Stream Water Level

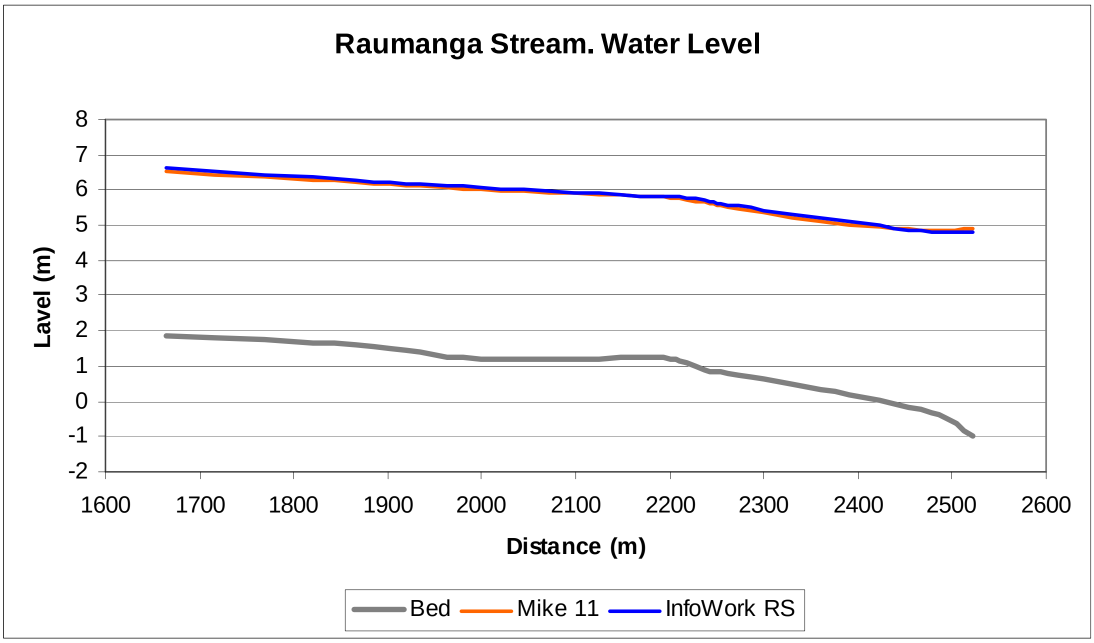
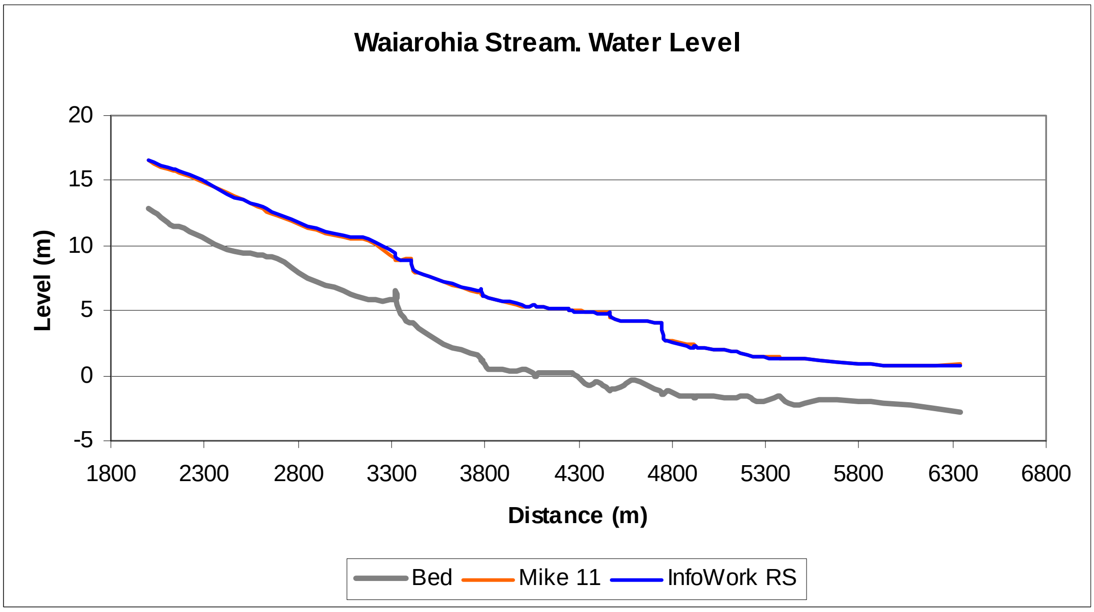


Figure 7-29 Waiarohia Stream Water Level



7 Modelling

Figure 7-30 Waiarohia River Water Level 5.2 km

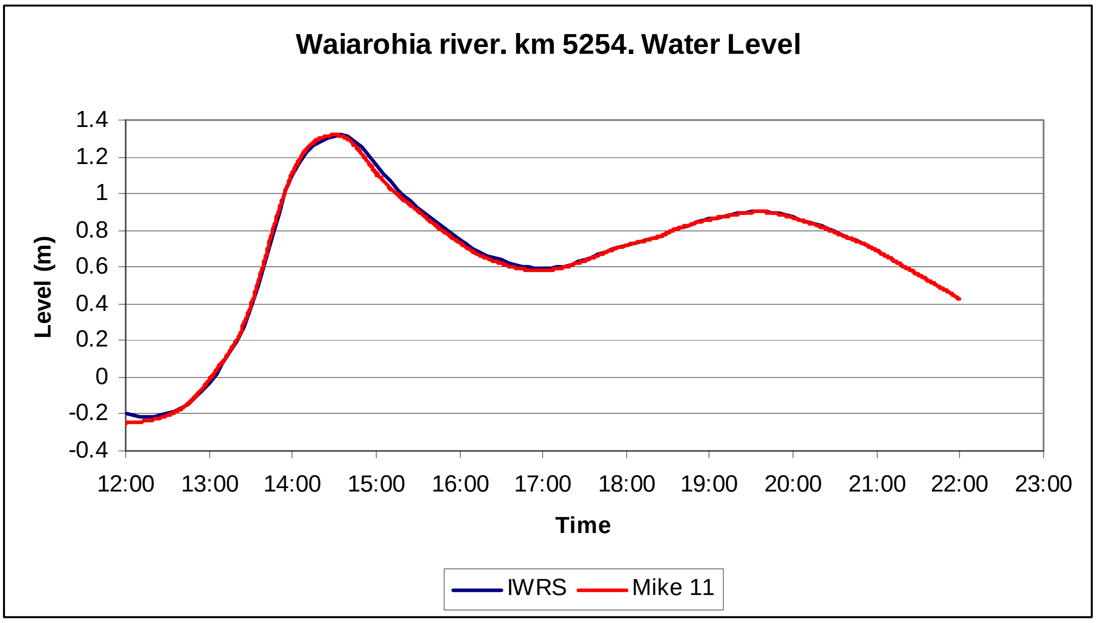
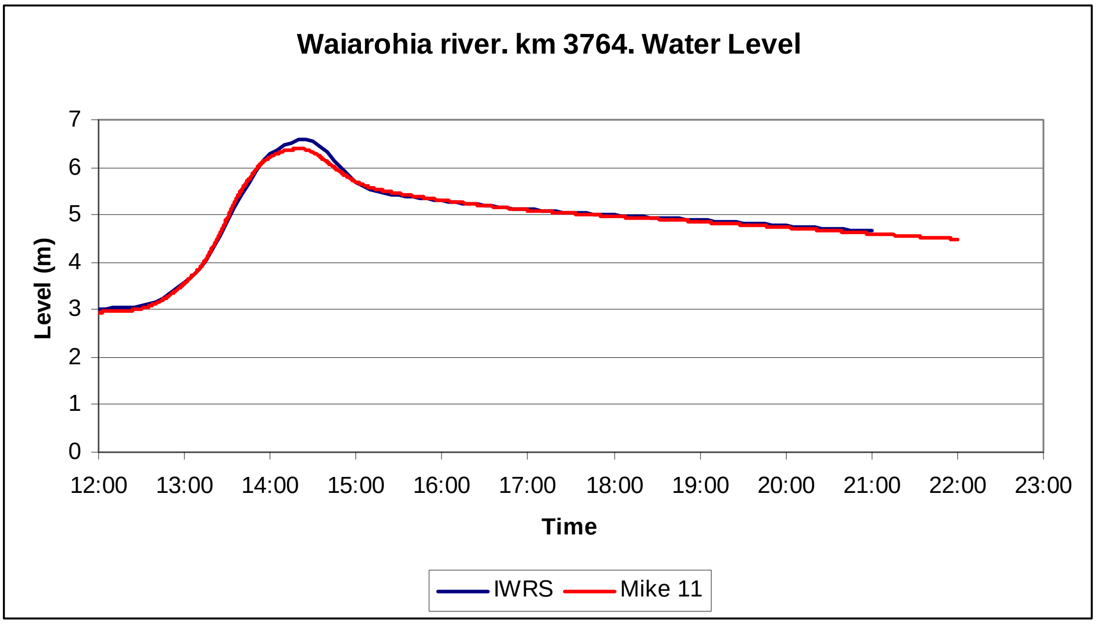


Figure 7-31 Waiarohia River Water Level 3.8 km



7 Modelling

Figure 7-32 Waiarohia River Water Level 4.5 km

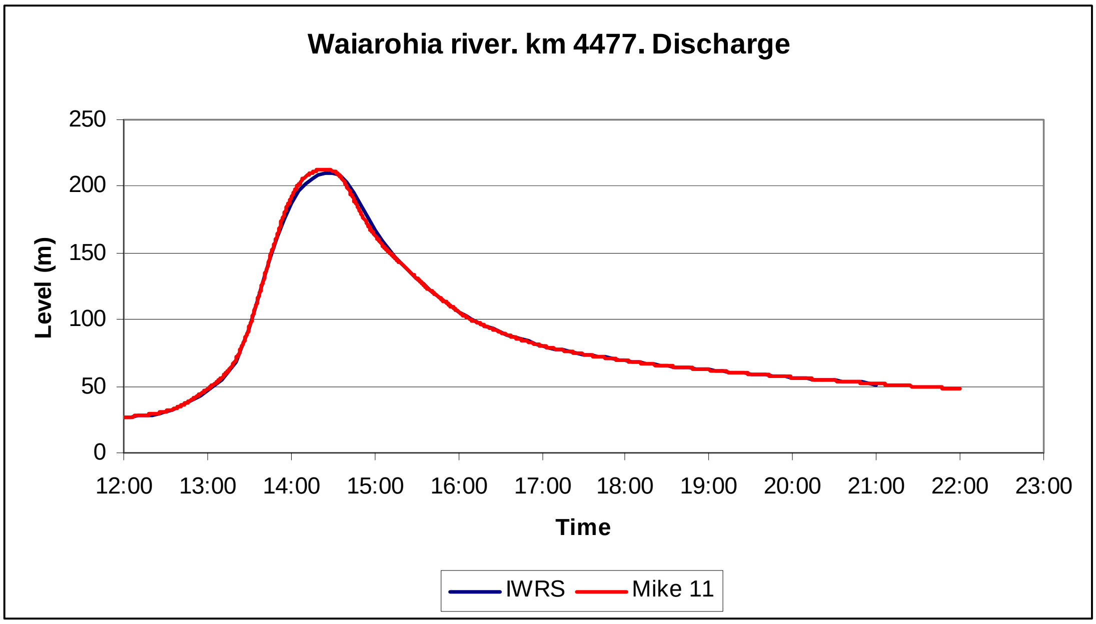
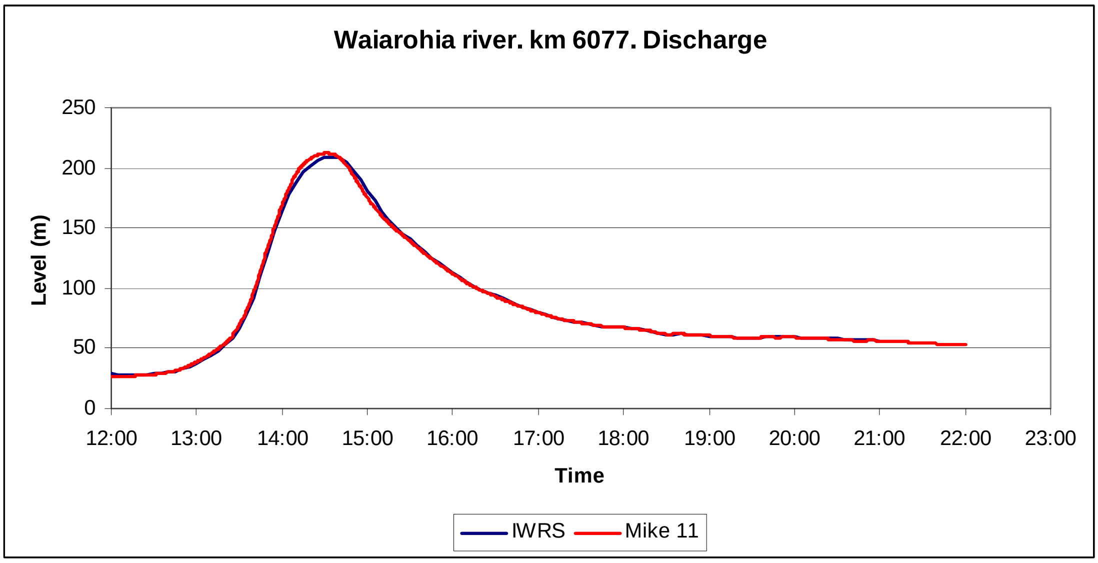


Figure 7-33 Waiarohia River Water Level 6.1 km



7 Modelling

Table 7-6 Summary of the Priority River Models

Catchment		Catchment Area (ha)	No of Sub-catchments	Max Sub-Catchment Area (ha)	No of X-sections	Surveyed X-sections	Memo
01_WAIAROHIA_RAUMAUNGA_RIVERS		4337	63	369	792	160	
02_RUAKAKA_RIVER		7817	165	297	212	28	
03_OTAIKA_RIVER		6215	150	484	947	99	
04_WAITANGI_RIVER		28750	237	1200	473	42	
05_HATEA_RIVER		4296	117	403	1486	92	
06_KAWAKAWA_RIVER		44365	372	1381	1068	50	
07_WAIHOU_RIVER		27899	314	2225	3512	16	
08_WAIRAU_RIVER		2700	56	185	984	12	
09_PUPUKE_RIVER		5094	92	520	260	11	
10_ROTOKAKAHI_RIVER		19825	176	1522	801	11	
11_WHANGAROA_STREAMS	Wahinepua (URS)	560	13	107	293	0	
11_WHANGAROA_STREAMS	Wainui (URS)	688	23	136	308	0	
11_WHANGAROA_STREAMS	Te Ngaire (URS)	587	21	79	246	0	
11_WHANGAROA_STREAMS		263	15	36	32	0	
12_PANGURU_RIVERS		3495	50	285	204	6	
13_AWAPOKONUI_RIVER		1000	42	132	257	0	
14_WHANGAREI_HEADS_STREAMS		962				0	full 2D model
15_TAUPO_BAY_RIVER		450	21	67	118	0	
16_HELENA_BAY_RIVER		1272	62	95	850	0	
17_NGUNGURU_RIVER		5384	174	286	1526	6	
18_WHIRINAKI_RIVER		4290	155	209	1594	6	

Catchment	Catchment Area (ha)	No of Sub-catchments	Max Sub-Catchment Area (ha)	No of X-sections	Surveyed X-sections	Memo
19_TAURANGA_RIVER	1371	41	151	666	0	
20_MATANGIRAU_RIVER	1198	43	140	74	0	
21_WAIMA_AND_PUNAKITERE_RIVERS	51691	235	2784	2000	13	Full 2D model
22_WAIMAMAKU_RIVER	13261	150	1029	897	0	

Infoworks RS Model and GIS Data Integration

8.1 File Structure

The entire model is contained in one InfoWorks RS Master Database and stored in *"…\InfoWork RS Model\NRC_Model.iwm"*. The structure of the Master Database is explained later in this section.

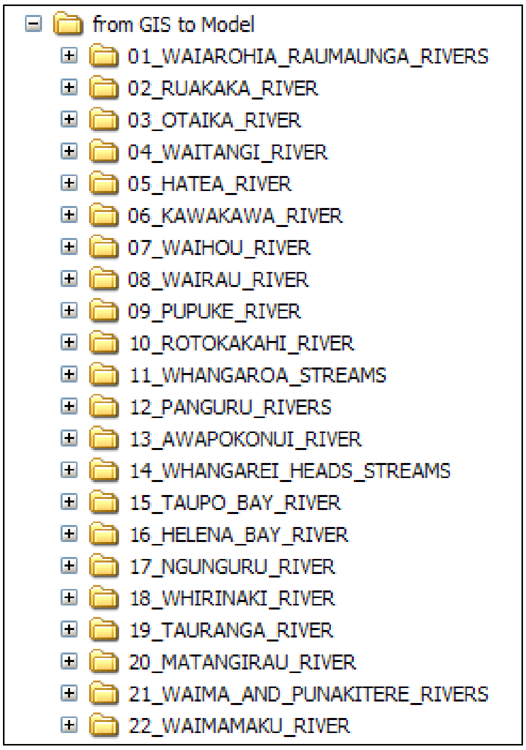
The folder "*\InfoWork RS Model*" contains all shape files, images, hyperlinks, and background information related to the model. This information is organized by sub-folder and linked to the model. The folder structure needs to be consistent to assure hyperlinks are not lost, even if the main folder and Master Database are moved or copied to another file destination. Folders cannot be renamed for similar reasons.

There are two sub-folders of particular interest:

1…\InfoWork RS Model\from GIS to Model

This sub-folder contains all shape files, images, the ground model, and information available from GIS. All of this information can be linked to the model, and plays a significant part in the model itself. The types of files used, and file structure, are explained later in this section. Figure 8-1 lists the names of the subfolders for each catchment.

Figure 8-1 Catchment Sub-folders



2…\InfoWork RS Model\Configuration

This sub-folder contains configuration files to import the necessary information from GIS to InfoWorks RS. There are three files of interest; they serve to import Subcatchments, Boundary Nodes and River Centre Lines using the Data Import Centre in InfoWork RS. The files of interest are as follows:

8 Infoworks RS Model and GIS Data Integration

- Importing Boundary Nodes from subcatchments.cfg
- Importing River Centre Line from links.cfg
- Importing Sub-catchments.cfg

This folder also contains a copy of the current Data Flags of the model; these are explained in Section 7.10.

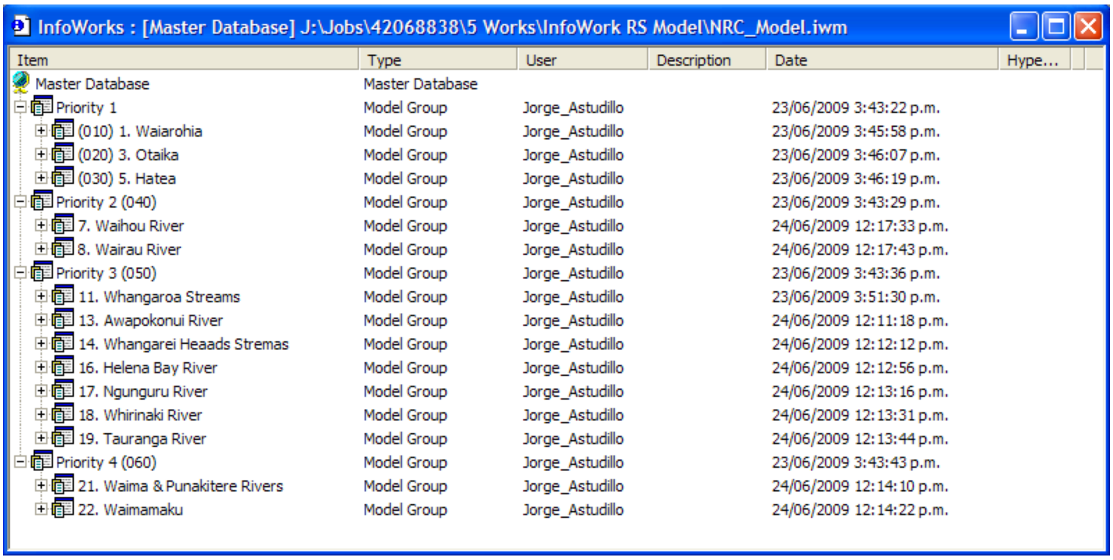
Master Database

All catchment models are contained in one InfoWorks RS Master Database named "*…\InfoWork RS Model\NRC_Model.iwm*".

Each catchment is managed in a Model Group separated by the river priorities defined by NRC.

Figure 8-2 shows the structure used to organize all of the catchment models. It is noted that Priority 4 Rivers will not be modelled, but their data can still be managed through the InfoWorks RS database.

Figure 8-2 Infoworks RS Master Database File Structure


InfoWorks : [Master Database] J:\Jobs\42068838\5 Works\InfoWork RS Model\NRC_Model.iwm

Item	Type	User	Description	Date	Hype…
Master Database	Master Database				
Priority 1	Model Group	Jorge_Astudillo		23/06/2009 3:43:22 p.m.	
(010) 1. Waiarohia	Model Group	Jorge_Astudillo		23/06/2009 3:45:58 p.m.	
(020) 3. Otaika	Model Group	Jorge_Astudillo		23/06/2009 3:46:07 p.m.	
(030) 5. Hatea	Model Group	Jorge_Astudillo		23/06/2009 3:46:19 p.m.	
Priority 2 (040)	Model Group	Jorge_Astudillo		23/06/2009 3:43:29 p.m.	
7. Waihou River	Model Group	Jorge_Astudillo		24/06/2009 12:17:33 p.m.	
8. Wairau River	Model Group	Jorge_Astudillo		24/06/2009 12:17:43 p.m.	
Priority 3 (050)	Model Group	Jorge_Astudillo		23/06/2009 3:43:36 p.m.	
11. Whangaroa Streams	Model Group	Jorge_Astudillo		23/06/2009 3:51:30 p.m.	
13. Awapokonui River	Model Group	Jorge_Astudillo		24/06/2009 12:11:18 p.m.	
14. Whangarei Heaads Stremas	Model Group	Jorge_Astudillo		24/06/2009 12:12:12 p.m.	
16. Helena Bay River	Model Group	Jorge_Astudillo		24/06/2009 12:12:56 p.m.	
17. Ngunguru River	Model Group	Jorge_Astudillo		24/06/2009 12:13:16 p.m.	
18. Whirinaki River	Model Group	Jorge_Astudillo		24/06/2009 12:13:31 p.m.	
19. Tauranga River	Model Group	Jorge_Astudillo		24/06/2009 12:13:44 p.m.	
Priority 4 (060)	Model Group	Jorge_Astudillo		23/06/2009 3:43:43 p.m.	
21. Waima & Punakitere Rivers	Model Group	Jorge_Astudillo		24/06/2009 12:14:10 p.m.	
22. Waimamaku	Model Group	Jorge_Astudillo		24/06/2009 12:14:22 p.m.	

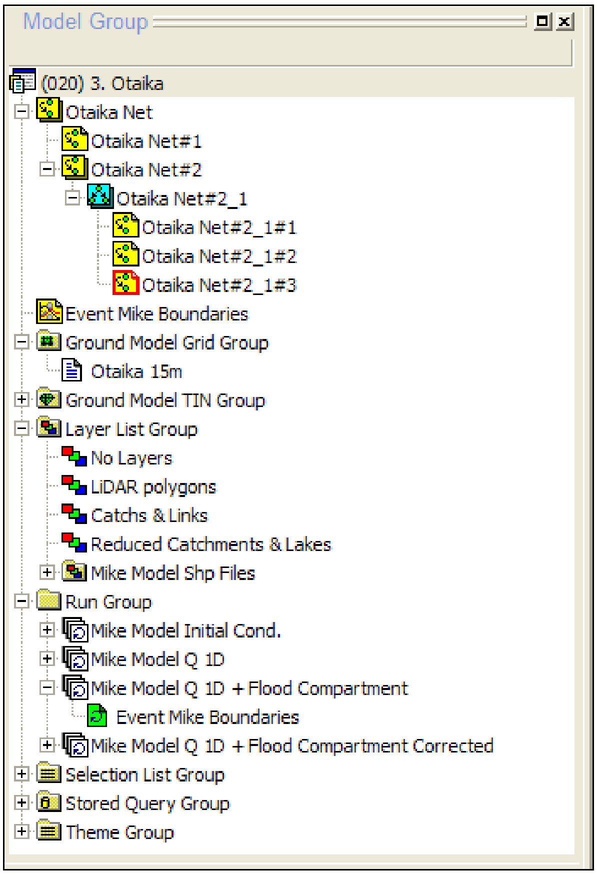
Each Model Group has at least the following elements:

- **Network:** The model itself. The network contains all objects necessary to define the river system (sub-catchments, cross sections, roughness, nodes, links, etc).
- **Event:** Contains all boundary conditions and initial conditions (rain profile, storm rain depth, tide levels, etc). These objects can be linked to their respective objects within the network.
- **Ground Model:** Contains topographic information, or the area of interest, in a grid of points with level information.
- **Layer Group:** Contains the setting to display external files as a background layer. Aerial images, shape files, CAD files, and others are stored in a sub-folder of *\InfoWork RS Model* and linked to InfoWork RS through layer objects.

- **Run Group:** Contains the simulations for modelling, including the network, event, run setting, and results.

Figure 8-3 shows an example of a Model Group with all its components.

Figure 8-3 Structure of a Model Group



GIS File Structure for Infoworks RS Modelling

The folder *…\InfoWork RS Model\from GIS to Model* contains a folder for each catchment, including all the information required to build the model. Each catchment will contain at least the following files:

- **Ground Model:** An ASCII file with all the information required to generate the Ground Model in InfoWork RS. This file can be imported directly into Infoworks RS. There is also a file containing a 15 metre grid for the whole catchment, and a second file with LiDAR data of good resolution for the area of interest (name.asc).
- **Aerial Image:** A geographically referenced JPEG aerial image file (name.jpg).
- **Shape files:** A battery of shape files that can be loaded as background information for the catchment. The number of files will depend on the information available for each catchment, but all folders have at least four shape files, including the following:
- Subcatchments.shp;

8 Infoworks RS Model and GIS Data Integration

- Nodes.shp;
- Links.shp; and
- Flow_path.shp.

These files are described in Table 8-1.

Table 8-1 GIS File Definitions

File Name/Field	Description
Subcatchments.shp	Sub-catchments to be used in runoff calculations. Import as '*Subcatchment*' and also as '*Boundary Node*' where all relevant fields will be placed.
OBJECTID	GIS internal
AREA	Area of catchment
NAME	Name (unique)
LENGTH	Length of sub-catchment.
SLOPE	Slope of sub-catchment.
LOCATION	Discharging node (node.shp)
XCOORD	Center point X coordinates.
YCOORD	Center point Y coordinates.
LEFT	Catchment number
CN	CN number for SCS method based on preliminary table relating to land cover, with a CN of Group C.
TC	Time of Concentration (minutes) based on TP108 formulation and the preliminary CN number.
TL	Time of peak (minutes) based on TP108 method.
Subcatchments_mod.shp	Some sub-catchments may have this file, particularly where the number of sub-catchments has reduced.
OBJECTID	GIS internal
AREA	Area of catchment (to be imported)
NAME	Name (to be imported as Sub-catchment ID)
LENGTH	Length of sub-catchment.
SLOPE	Slope of sub-catchment.
LOCATION	Discharging node (node.shp)
XCOORD	Center point X coordinates.
YCOORD	Center point Y coordinates.
LEFT	Catchment number

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File Name/Field	Description
CN	CN number for SCS method based on preliminary table relating to land cover, with a CN of Group C.
TC	Time of Concentration (minutes) based on TP108 formulation and the preliminary CN number.
TL	Time of peak (minutes) based on TP108 method.
TYPE	Type of inflow: Lateral stream inflow (1), upstream inflow (2) or distributed lateral inflow (3)
Nodes.shp	Discharge points for sub-catchments. Use to develop filters or routines, to link Boundary Nodes to Cross Sections.
ID	GIS internal
NAME	Name (unique)
NODEREC	GIS internal
ONE	GIS internal
ACCUM	GIS internal
FROM	GIS internal
XCOORD	X coordinates
YCOORD	Y coordinates
LEFT	Catchment number
Links.shp	Import as '*River Centre Line*' in InfoWork RS. Corresponds to river alignment.
OBJECTID	GIS internal
FROM	Upstream discharge node (Node.shp)
TO	Downstream discharge node (Node.shp)
LINKREC	GIS internal
TO_INDEX	GIS internal
S_ORDER	GIS internal
GROUP	GIS internal
LENGTH	Length of link
LEFT	Catchment number

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File Name/Field	Description
LN	GIS internal
NEWFIELD1	GIS internal
Flow_paths.shp	Longest flow paths within catchments. For information only. Relevant information has been transferred to the respective sub-catchment shape file.
LENGTH	Flow path length
SLOPE	Slope of flow path
NAME	Name (unique)
LEFT	Catchment number
X	GIS internal
Y	GIS internal
OBJECT	GIS internal
REC	GIS internal

Limitations

URS New Zealand Limited (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Northland regional Council and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 23rd January 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between January 2009 and February 2011 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Calibration and Verification Report

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