AWANUI RIVER CATCHMENT FLOOD RISK ASSESSMENT

Habib Ahsan, GHD Limited and Bruce Howse, Northland Regional Council

ABSTRACT

Awanui River Catchment located in Northland covers 45,500 hectares of land with a total stream network of 192 kilometres. To obtain high confidence in modelling results best practice methods were required in this study. The key components of this study are survey of sufficient river cross-sections, use of LiDAR data to generate DTM for 2D model input, sufficient raingauges and flow gauges, model calibration using 1D and 2-D combination and flood hazard mapping. The hydrological component of the model was represented by 195 sub-catchments in MIKE11 while hydraulic component was undertaken using MIKE FLOOD involving MIKE11 and MIKE21.

Extensive model calibration was undertaken using major flood event recorded at five raingauges and five stream gauges. Various ARI rainfalls were derived from HIRDS model based on NIWA rainfall records. HIRDS rainfalls were generated at five locations within the catchment to account for aerial distribution of rainfall.

Flooding of the Kaitaia Township and its suburbs due to spills from Awanui and Tarawhataroa Rivers has been identified as a significant hazard. The current model has identified the problems and possible mitigation options. The model will form a building block and will be used by NRC to undertake remedial options to manage flood risk.

KEYWORDS

MIKE FLOOD, MIKE21, LIDAR, CLIMATE CHANGE, TIME OF CONCENTRATION, AVERAGE RECURRENCE INTERVAL (ARI), 2D AND MIKE11 RR.

PRESENTER PROFILE

Habib has extensive professional experience in the field of water resources engineering. This includes extensive knowledge of river and estuary modelling using MIKE 21; river modelling, MIKE 11; stormwater modelling, MIKE FLOOD; stormwater quality management including the preparation of catchment management plans and design of stormwater quality treatment devices. Habib is Team Leader – Stormwater modeling and leads a group of modelers.

Bruce Howse is a natural resource manager currently employed in the position of Land/Rivers Senior Programme Manager with the Northland Regional Council. Bruce has over 10 years experience in natural resource management, with application to river and coastal geomorphology, natural hazard management and sustainable land management.

1 INTRODUCTION

1.1 BACKGROUND

Flooding has been identified as a significant hazard in the middle and lower reaches of the catchment for many years. Northland Regional Council (NRC) has a requirement to accurately determine these floodplains and determine potential remedial options to mitigate flood risks.

This study aims at developing an integrated model of the entire Awanui River Catchment including the river system in order to allow an accurate assessment of floodplains in the area. This study will enable NRC to manage future development and to manage remedial options to improve flood protection levels of services.

1.2 LOCATION

The Awanui River Catchment has its headwaters located to the south of Veza Road/Warner Road (see Figure 3). The four major upstream rivers namely Takahue River, Victoria River, Karemuhako River and Tarawhataroa River discharge into the Awanui River. The Awanui River along with its large number of tributaries passes through the alluvial foothills and down to the lowlands ultimately discharging into the Awanui Harbour near Ben Gunn. All stormwater discharges to the Awanui Harbour with no flow passing to adjacent catchments.

1.3 PRESENT STUDY

This current study area covers modelling of the entire Awanui Catchment River system, including all tributaries.

For this study, GHD has developed an integrated hydrological and hydraulic model of the entire catchment extending from its headwaters up to the Awanui River outfall in the harbour at Ben Gun. The stream network is based on approximately 110 surveyed cross-sections and about 700 cross-sections generated using LiDAR data. The catchment area has been divided into 195 sub-catchments assigned to the drainage network.

Two models – MIKE11 and MIKE21 have been developed separately using available catchment data. MIKE FLOOD, an interface, was used to combine the two models to facilitate the floodplain modelling and mapping of the catchment.

2 PROJECT METHODOLOGY

2.1 SUBCATCHMENT DELINEATION

The hydrology of the catchment has been modelled using the MIKE11 Urban Runoff Module. The hydrological component of the MIKE11 Runoff Model is represented as 195 sub-catchments connected to nodes within the river network of the MIKE11 model. Sub-catchments were delineated with consideration of the stormwater network configuration in the urban areas of Awanui and Kaitaia, LiDAR contours and available 5m contours in the area beyond LiDAR extent, catchment characteristics, Property and road boundaries, road crossing structures such as bridges and culverts, the soil types and Landuse.

2.2 IMPERVIOUSNESS

The existing development imperviousness was estimated using the aerial photographs of the catchment. For each sub-catchment used in this study, the land use and impervious area were analysed for input into the hydrological model under two categories of pervious and impervious area. Each category was then assigned different hydrological parameters as required to describe actual processes.

The assessment of sub-catchment road surfaces imperviousness was undertaken as a GIS integration of the sub-catchment boundary and the road surface. The resultant impervious area was assigned as flat impervious area within the model. This was carried out by GIS integration of various GIS layers. The existing imperviousness data was used to calibrate the model using the measured data at various gauge locations in the catchment.

Future imperviousness assessment was based on the Far North District Council (FNDC) District Plan allowances, the Maximum Probable Development (MPD) impervious area percentages for various landuse categories were used. The MPD imperviousness was used for the flood hazard mapping for various ARI storm events.

2.3 HYDROLOGICAL MODEL

The catchment runoff was modelled using the MIKE11 Urban Runoff Module. The key features are:

- Runoff rate and volume calculated with the MIKE11 Urban Model B Module
- A separate catchment analysis of pervious and impervious components
- Estimate of areas of different landuse categories
- Subcatchment slope calculated using the Equal Area Method

2.4 HYDRAULIC MODEL

1-D Model: The hydraulic model used was the MIKE11 Hydrodynamic (HD) Module. The key features of the model are:

- Approximately a total of 110 cross-sections were surveyed for model input
- Approximately 700 cross-sections were generated from LiDAR data
- 8 bridges and 3 culverts
- 67 river branches

2-D Model: LiDAR data was utilized to generate grid for the MIKE21 model. To facilitate accurate flood prediction with a reasonable model simulation time considering the desktop computer capacity, grid sizes of 8 m x 8 m were generated for input into MIKE21 model.

2.5 MODEL CALIBRATION

2.5.1 1-D VS 2-D MODEL

As part of initial commission, 1-D MIKE11 model was developed and calibrated using the observed data in the catchment with near perfect matching between model results and the recorded data at the gauges. Later on, NRC engaged GHD to undertake Flood Hazard Mapping (FHM) of the catchment. As apart of FHM, MIKE FLOOD model was developed. The 1-D calibrated model was combined with 2-D MIKE21 model using MIKE FLOOD interface.

2.5.2 1-D VS 2-D MODEL RESULTS

The MIKE FLOOD model produces significantly lower flows at the gauges located at the lower catchment compare to the records with the calibrated 1-D MIKE11 model. The flowing Tables 1 and 2 indicate the results from I-D calibrated model and un-calibrated MIKE FLOOD models:

Table 1 Comparison of Flows from 1-D and MIKE FLOOD Models for July 2007 Event

Gauge Location	Calibrated 1-D Model (m^3/s)	Un-calibrated MIKE FLOOD (m^3/s)	Gauge Record (m^3/s)
Awanui School Cut	250	75	225-250
Whangatane Spillway	143	50	143

Table 2 of Level from 1-D and 2-D MIKE FLOOD Models for July 2007 Event

Gauge Location	Calibrated 1-D Model (mRL)	Un-calibrated MIKE FLOOD (mRL)	Gauge Record (mRL)
Awanui School Cut	15.83	13.10	15.81
Whangatane Spillway	12.51	11.20	12.84

It can be seen from the above tables that both flows and flood levels have been reduced when the calibrated 1-D MIKE11 model was combined with MIKE FLOOD (MIKE21 and MIKE11). This is due to large floodplain storages in the upper catchment, which are difficult to model in 1-D model. Therefore, the model was re-calibrated using both 1-D and 2-D combinations using MIKE FLOOD interface.

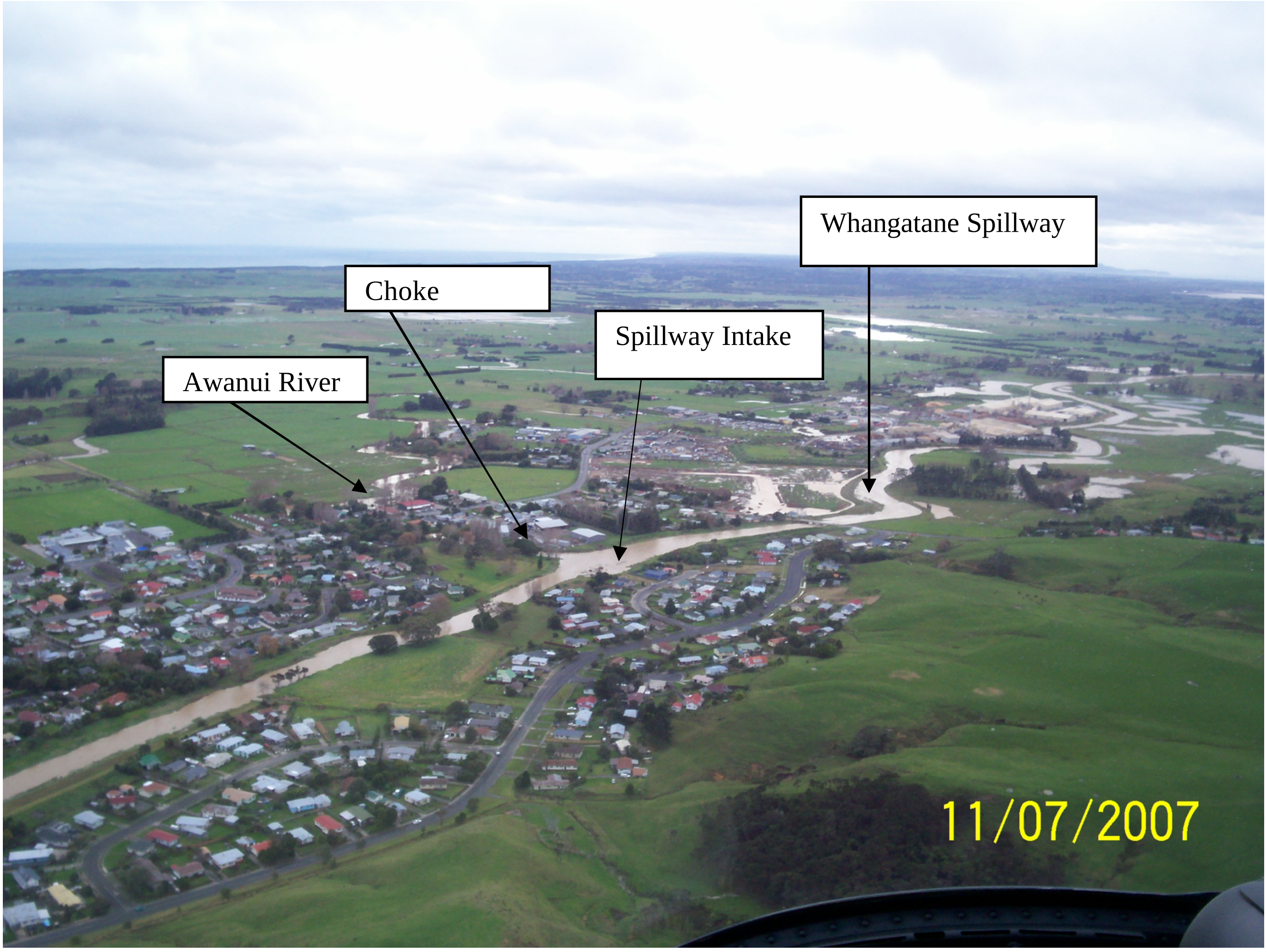
2.5.3 THE “CHOKE” A SIGNIFICANT ISSUE

A feature of the scheme design is a “Choke” on the Awanui River downstream of the Whangatane Spillway intake. The "Choke" is a narrow section of the Awanui River that serves to apportion flow to the Whangatane Spillway during flood, reducing the extent of overtopping in the downstream Awanui River and reducing flood risk to the Awanui Township. A downside of this design feature is the accumulation of debris, such as fallen trees, in the "Choke". As the “Choke” is not a fixed structure, its size has been configured in the model through trial and error during the calibration process to replicate the flows recorded at Awanui School Cut and Whangatane Spillway. A Photograph showing the “Choke” created by fallen trees is shown in Figure 1 below:

Figure 1: The "Choke" on the Awanui River Created by Fallen Trees.

The effect of the "Choke" on flooding in the area during July 2007 storm event is shown in Figure 2 below:

Figure 2: The Effects of the “Choke” on flooding in the area



It can be seen from Figure 2 above that the Awanui River is flowing bank full before the spillway intake and the flow has been reduced significantly downstream of the “Choke”. The Whangatane Spillway appeared to be the main flowing channel with widespread flooding along its way.

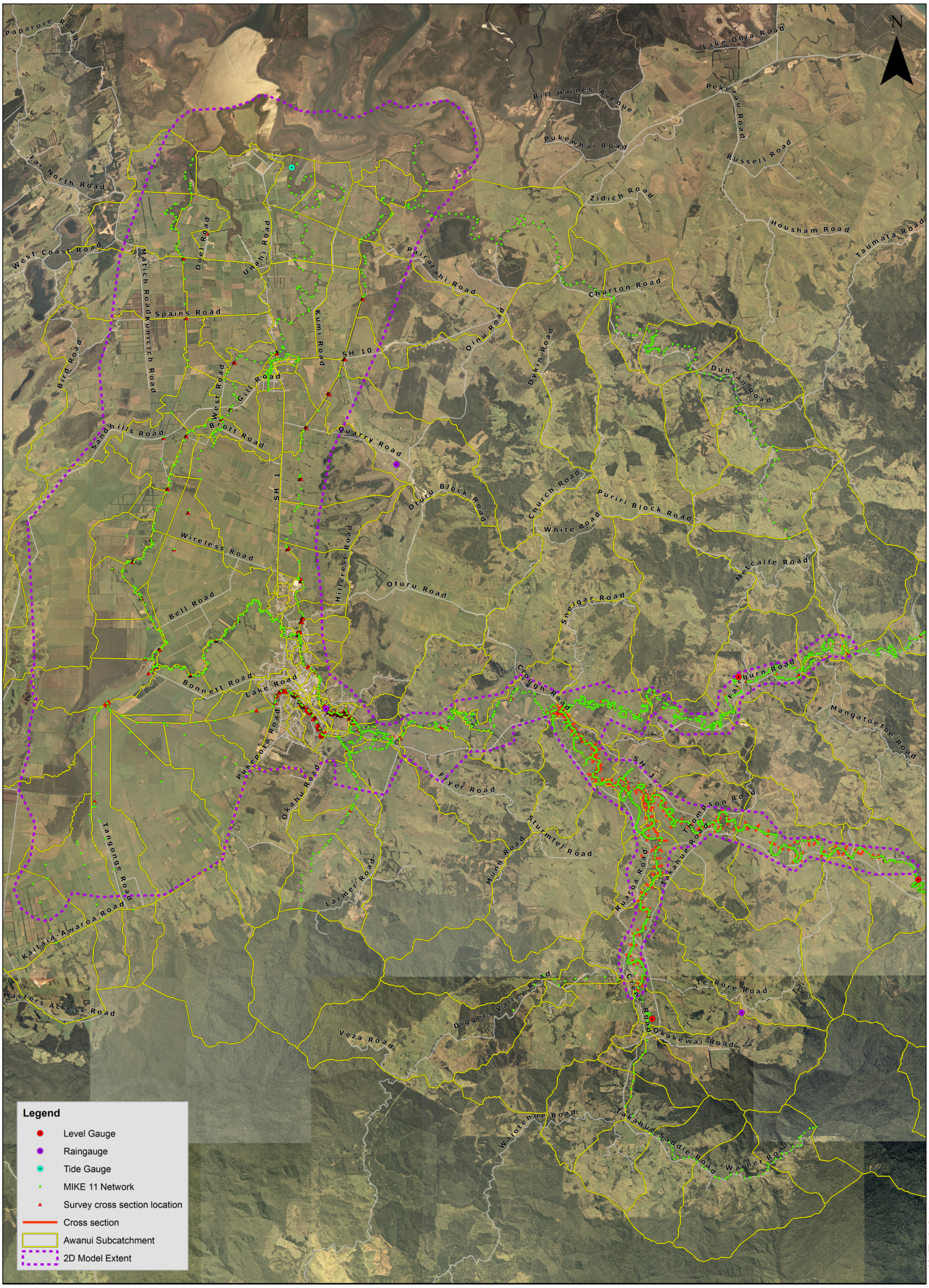
2.6 MIKEFLOOD CALIBRATION

2.6.1 RAINFALL AND LEVELS/FLOW DATA

Rainfall records are available at five locations in the catchment. Long-term timeseries rainfall data was available from all the raingauge locations. There are six water level gauges namely Victoria, Takahue, Tarawhataroa, Awanui School Cut, Whangatane Spillway and Ben Gunn (Tides) having records of varying periods. Flow records (based on rating curves) at Awanui School Cut and Whangatane Spillway (at Donald Road) are also available for the calibration event.

Timeseries records at the gauges are available and were utilised for the calibration of the model. The Awanui River catchment along with the location of gauges are shown in Figure 3 below:

Figure 3: Awanui River Catchment and the gauge Locations



2.6.2 CALIBRATION / VALIDATION EVENTS

Since NRC commenced extensive scheme restoration works in October 2006, the largest storm event causing widespread flooding in the catchment, occurred in July 2007. There are less severe events occurred in the catchment- one in February 2007 and another in late July 2007. Larger storm events before the stream works were not considered, as it will not replicate the existing conditions, as over $2 millions in restoration works have been undertaken over 18 km of river, including 210,000 m^3 of earthworks and the removal of over 2,000 trees which blocked the efficiency of channels to carry flood waters.. Photographs of the Flooding of the State Highway 1 (SH1) (see Figures 4 and 5 below) and the area around Donald Road (in Whangatane Spillway) were available and were utilized for the validation of the model. The recorded flood levels at the gauges covered most major streams in the middle (Awanui School Cut, Tarawhataroa and Whangatane Spillway gauges) catchment and some in the upper catchment (Takahue and Victoria gauges) and provide useful data for calibration of the model. However, there was no record in the lower catchment except the tide records at Ben Gunn. The catchment parameters for the lower catchment were assessed based on the catchment characteristics similar to those in the middle and upper catchments.

Figure 4: Photographs Indicating Flooding of SH1 during July 2007 Storm Event

Figure 5: Photographs Indicating Flooding of SH1 during July 2007 Storm Event

2.6.3 CALIBRATION METHODOLOGY

An integrated Awanui River Catchment hydrological and hydraulic model was developed incorporating all the major rivers and their tributaries.

The model was calibrated using the largest rainfall event. Calibration involved running MIKE FLOOD model comprising MIKE11 Runoff and Hydrodynamic modules and MIKE21 simultaneously using the recorded rainfall and flow/level gauging data for the event.

The stream base flow condition for the rainfall event was derived through the calibration process as there is no flow gauge in the upper catchment. Constant lateral flows at several locations in the model were assigned and iterative processes were adopted until a satisfactory correlation between the modelled peak flow/level and the recorded flow/level was achieved.

The hydrological and hydraulic parameters for the selected calibration event were determined through iterative processes by undertaking a series of simulations until satisfactory agreements between the modelled and observed peak flow, peak water level, and total volume parameters were achieved. The calibrated model parameters were used to validate the flooding indicated by photographs at SH1 and in the area near Donald Road provided by NRC. The processes of calibration and validation were repeated until the model predicted results provide fairly good correlation with the measured data.

2.6.4 MODEL SIMULATION

MIKE FLOOD model was simulated for the duration of 9 hour to 24 hour with a maximum time step of 1.20 seconds for the flood hazard mapping simulations. The peak rainfall for the design rainfall occurs at about 12 hours and therefore, the simulation starting time of 9 hours allows all the losses and filling of depression storages to occur well ahead of peak rainfall. The peak flow at various locations in the catchment occurs between 12 hours to 22 hours depending on the location. Therefore, the simulation until 24 hours is well past the time of peak flow. The maximum flood levels, depths and speed at all grid points from the result file were used using MIKE21 post processing facilities for plotting in GIS environment. The calibration event was simulated for an approximately duration of 50 hours.

The model run times varied depending on the number of computational grid points of the model. The run time for the simulations was about 5 days (120 hours) for the calibration event and approximately 2 days (48 hours) for the flood hazard mapping simulations.

2.6.5 MODEL CALIBRATION/VALIDATION RESULTS

The model results were viewed using the DHI MikeView Module to assess the goodness of fit between the MIKE11 modelled results and the observed values. The result verification tool of MikeView provides a range of parameter values to quantify the differences between the modelled and measured timeseries. The observed and model predicted data for the largest calibration event of July 2007 at the gauge locations are shown in Table 3 below:

Table 3 Comparison of model predicted and Gauge data during July 2007 Event

Gauge	Flow (m3/s)		Flood Level (mRL)	
	Model	Gauge	Model	Gauge
Takahue	194	N/A	46.4	46.3
Victoria	93	N/A	63.9	63.8
Tarawhataroa	59	N/A	16.2	16.2
Awanui School Cut	250	225-250	15.8	15.8
Whangatane Spillway	143	143	12.5	12.5

It can be noted that the gauge at Awanui School Cut was flooded during the July 2007 storm event. The flood level at this location as shown in Table 3 was determined based on survey of post flood water mark and the flow was estimated based on rating curve.

2.7 FLOOD HAZARD MAPPING

The following Table 4 summarises the flood hazard mapping simulations that were undertaken:

Table 4 Flood Hazard Mapping Simulations

Simulation	Landuse	Rainfall	Return Period
1	MPD	HIRDS	20 Year ARI
2	MPD with Climate Change	HIRDS	20 Year ARI
3	MPD	HIRDS	100 Year ARI
4	MPD with Climate Change	HIRDS	100 Year ARI

2.7.1 IMPACTS OF CLIMATE CHANGE

Predictions of future climate depend on projections of future concentrations of greenhouse gases and aerosols, as well as model assessments of how the global climate system will respond to these changing concentrations of emissions, which depend in turn on national and international policies, and changes in population, economic growth, technology and energy availability.

Based on the full range of Intergovernmental Panel on Climate Change (IPCC) emission scenarios and using a range of global climate models the Ministry for the Environment (MfE) has prepared guidelines (2007) to help councils across New Zealand assess the likely effects of projected climate change during the 21st century and plan appropriate responses where necessary. According to this guideline, a rise in temperature in the range of 0.6 to 3.8^{o}C is likely during 2080. The guidelines also state that for the 24hour 100 year ARI rainfall intensity, per degree Celsius of warming, the increase could be 6.7 percent. The sea levels have risen by an average of 16 cm during the period 1900 to 2000. Sea levels rise of 30 to 50 cm (New Zealand average) are expected between 1990 and 2100.

In consultation with NRC, a 3^{o}C rise in temperature with a 20.1 percent increase in 100 year ARI HIRDS 24-hour rainfall was used to assess the impacts of climate change on flood levels on the Awanui Catchment River System. The downstream tidal boundary used was the MHWS (1.10 m RL) plus 0.20 m to account for the rise in sea level due to global weather warming.

2.7.2 SIGNIFICANT FLOODPLAIN AREAS

The areas around Kaitaia and its suburbs were identified as the significant areas of flooding. The flooding in middle and lower catchment such as Kaitaia is due to the spilling of river banks due to flow from upper catchment. Large numbers of properties were predicted to be affected during various ARI storm event considered for simulation. The following Table 5 indicates the number of properties predicted to be affected during various ARI storm events:

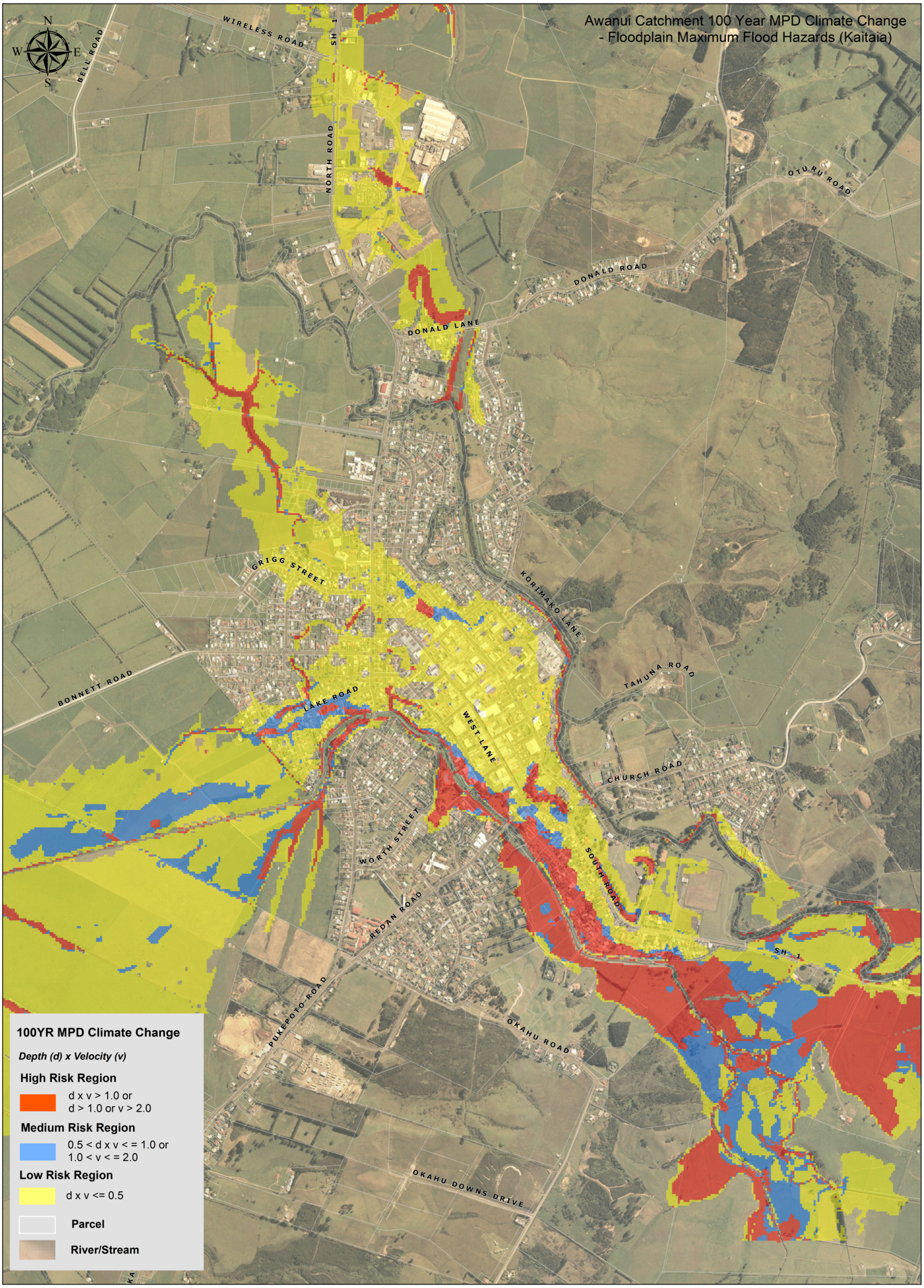
Table 5 Properties Predicted to be affected from different Source of Flooding

ARI	Sources of Flooding and Number affected Properties			
	Tarawhataroa	**Whangatane**	**Awanui**	**Total**
20 Year MPD	60	2	0	62
20 Year MPD +CC	122	8	0	130
100 year MPD	244	32	0	276
100 year MPD +CC	Approx. 778 properties as risk with a Capital value of $222M			

The following Figures 6 and 7 indicate typical predicted floodplain and hazard maps of the Kaitaia area during various ARI storm events.

Figure 6: Flood Levels during 20 year ARI MPD with Climate Change (Kaitaia Area)

Figure 7: Flood Hazard during 100 year ARI MPD with Climate Change (Kaitaia Area)



2.8 FLOOD MITIGATION OPTIONS

Based on the assessment of flooding in the catchment and study of the catchment the following options were formulated for consideration by NRC:

- Permanent spill structure at the location of existing “Choke”
- Lowering the spillway (Presently lowest levels are 10.5 m RL at spillway and 6 m RL on Awanui River)
- Dredging of lower reach of Whangatane Spillway
- Possible storage in the upper catchment
- Flow diversion from Lake Tangonge (Waihoe)
- Stop banks along Awanui River, Tarawhataroa River and Whangatane Spillway

2.8.1 PERMANENT STRUCTURE AT “CHOKE” AND DREDGING OF WHANGATANE SPILLWAY

Lowering of the sill level of the spillway from the existing level of 10.5 m RL close to lowest level of 6 mRL of the Awanui River at the vicinity of the spillway intake. More flow will be diverted to the spillway reducing spills from Awanui River at the Upstream of Awanui School Cut. A permanent structure at the existing “Choke” will help control maximum flow through spillway. This higher flow diversion may require stop banking along the Whangatane spillway to contain flow within the channel, as well as consideration of stock access bridges and pumping or provision for on-site retention of impounded incident stormwater from developed areas adjoining the spillway.

Dredging of the lower reach of the Whangatane Spillway is of limited benefit in reducing flooding in the area because of tidal influences.

2.8.2 POSSIBLE STORAGE IN THE UPPER CATCHMENT

Based on available LiDAR contours storage dams can be constructed at the following locations in the upper catchment to help reduce flooding in the lower catchment.

- Three locations along Karemuhuko River.
- One location on the Victoria River at the upstream of the junction with the Karemuhuko River

2.8.3 FLOW DIVERSION FLOW LAKE TANGONGE (WAIHOE)

Flow diversion from Lake Tangonge will help reduce flooding due to spilling of the Tarawhataroa River banks. This diversion can be implemented by diverting flow from Lake Tangonge into Waipapakauri Cut by constructing a diversion channel from Lake Tangonge into Waipapakauri Cut.

2.9 FUTURE FLOOD MANAGEMENT INITIATIVES

The NRC is currently working with the Awanui Flood Management Scheme Liaison Committee to prioritise scheme upgrade options and design standards. Given the potential investment required to achieve a significant increase in protection over the existing scheme design standard, the Council has undertaken a peer review of the model and from this will be developing a model improvement plan which will have a priority focus on calibration against future flood events and improving the quality of hydrometric data applied to the model (i.e. more high level ratings) as to ensure greater confidence in application of the model for determining effectiveness of scheme upgrade options and design standards.

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