CLEVEDON FLOOD HAZARD MAPPING

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ABSTRACT

This paper details the flood hazard mapping study of the Wairoa River and Taitaia Stream that Tonkin & Taylor carried out for Manukau City Council. The purpose of the study was to provide flood extents that can be used in the Clevedon Village Sustainable Development Plan, and be incorporated into a plan change to the Manukau Operative District Plan for Clevedon Village. The plan provides for the expansion of the existing Clevedon settlement onto the rural land outside the existing village core and between the Wairoa River and Taitaia Stream.

The hydrological modeling involved calibration and validation of a number of sub-catchments for the 263 km^2 Wairoa catchment (including Taitaia sub-catchment). Key hydrological features were the application of data from two flow gauges and five rainfall gauges and role of two large water supply dams.

The hydraulic modeling assessment was carried out using a dynamically coupled 1D/2D model of the Wairoa River and Taitaia Stream. We carried out calibration using historical records and carried out a sensitivity assessment of the flood extents to challenge various assumptions that were made in the modelling process.

KEYWORDS

Flood, stormwater, flood hazard mapping, hydrology, hydraulic, modelling

PRESENTER PROFILE

Jon Rix has 9 years experience in New Zealand and the UK carrying out hydraulic assessments in both urban and rural environments. His extensive numerical modelling and analytical skills have been used to design, optimise and assess a diverse range of projects for private sector clients and local and regional authorities.

1 INTRODUCTION

The Clevedon Village Sustainable Development Plan (SDP) sets out a strategy to guide development of Clevedon over the next 50 years. The SDP outlines key principles, concepts and outcomes to be incorporated into a plan change to the Manukau Operative District Plan for Clevedon Village. This will inform growth decisions for Clevedon within the future Auckland Plan and the rules and consent requirements for development in the plan change area.

The SDP provides for expansion of the existing Clevedon settlement onto rural land outside the existing village core and between the Wairoa River and Taitaia Stream. Much of the study area is located in low-lying terrain and flooding is a key issue, as well as a constraint to growth in Clevedon. The requirement of flood hazard mapping for the SDP was to identify the flood extents during a 100 year ARI (Average Recurrence Interval) design flood. The 100 year ARI flood extents will be used to limit development to areas outside the floodplain.

This paper details the flood hazard mapping study that Tonkin & Taylor (T&T) have carried out for Manukau City Council (MCC) (now known as Auckland Council) to provide flood extents that have been used for the SDP and the plan change application.

2 CATCHMENT HYDROLOGY

2.1 MODELS

The US Army Corps of Engineers HEC-HMS model was selected to simulate the hydrological processes. The Soil Conservation Service (SCS) method was used to represent rainfall-runoff processes in accordance with the Auckland Regional Council (ARC) Technical Publication 108 (TP108).

The locations of sub-catchments were defined based on topography and hydrological features such as the location of flow monitoring stations and dams. The sub-catchments were then represented using the hydrological model.

The approach taken was to calibrate and validate the hydrological model based on historical rainfall and flow records, where available. The calibration process involved modifying hydrological parameters so that the flows predicted by the hydrological model reasonably simulate the flows recorded by gauges for a number of storm events.

The validation process involved analysing each calibrated storm event and choosing a single set of design catchment characteristics that best represent the catchment. The hydrological model was then rerun for a historical storm event not used in the calibration process to determine whether the model was predicting flows accurately. The rainfall from a 100 year ARI design storm was then applied to the calibrated and validated hydrological model to determine design 100 year ARI flows.

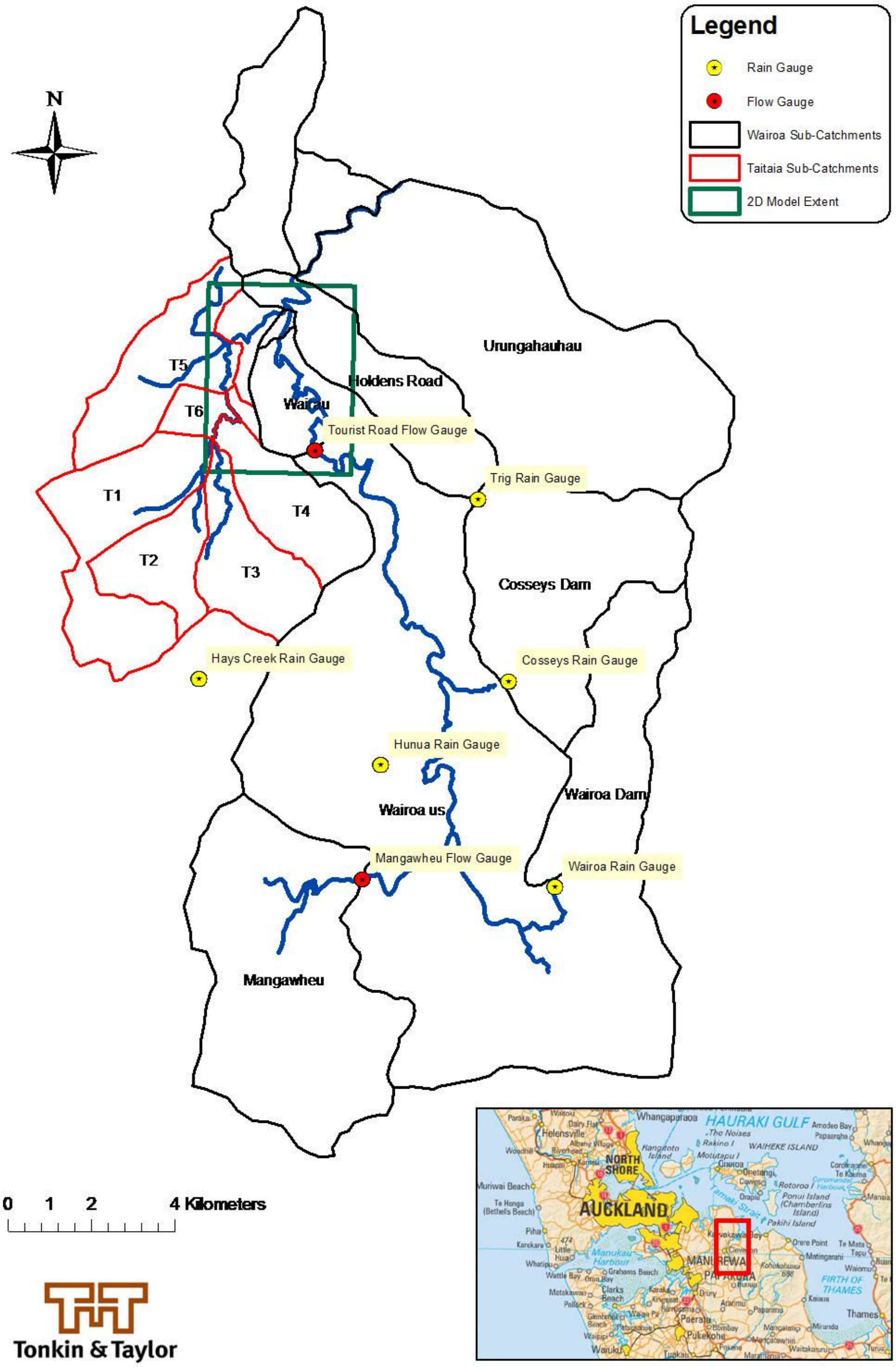
2.2 CATCHMENTS

The hydrological sub-catchments of the Wairoa River and Taitaia Stream are shown in Figure 1. The catchment areas are summarised in Table 1.

Table 1: Hydrological sub-catchments for the Wairoa River and Taitaia Stream

Catchments	Sub-catchments	Area
Wairoa Upstream of Tourist Road	Mangawheu (30.4 km^2)	148.1 km^2
	Cosseys Dam (21.3 km^2)	
	Wairoa Dam (13.2 km^2)	
	Wairoa upstream of Tourist Road (83.2 km^2) (excluding Mangawheu, Cosseys and Wairoa)	
Taitaia		43.6 km^2
Clevedon township		5.5 km^2
Holdens Road catchment		11.0 km^2
Clevedon North		9.3 km^2
Wairoa Mouth		3.7 km^2
Urungahauhau		41.1 km^2

Figure 1: Location plan and catchment extents



2.3 HYDROLOGICAL DATA

The following subsections detail the rainfall and flow gauging records that were used to assist with the hydrological model calibration. Analysis of the records also helped to formulate and support modelling assumptions discussed later in the paper.

2.3.1 RAINFALL

There are four rain gauges located in the Wairoa catchment and no rain gauges in the Taitaia catchment. There is an additional rain gauge (Hays Creek) that is located outside of both the Taitaia and Wairoa catchments, but located nearby to both catchments. The rain gauges are described in Table 2 and their locations can be seen in Figure 1.

Table 2 Rain gauge details

	Site start date	Elevation	Location (NZTM)
Trig Rain Gauge	August 1997	RL 339m	1786551, 5900514
Cosseys Dam	November 1996	RL 175m	1787291, 5896146
Wairoa Dam	July 1992	RL 144m	1788403, 5891214
Hunua Rain Gauge*	September 1997	RL 75m	1784237, 5894142
Hays Creek Dam	August 1997	RL 159m	1779867, 5896200
* Prior to September 1997, a rain gauge called Hunua at Nursery was located approx 50m away from the Hunua Rain Gauge site.			

The rainfall hyetograph used in the hydrological model calibration was based on recorded rainfall from the gauges identified in Table 2.

The 100 year ARI design rainfall depth and temporal distribution was determined using the methodology detailed in Auckland Regional Council Technical Publication 108 (TP108).

In accordance with Ministry for Environment (2008)) guidance, an allowance for climate change was included in the design rainfall storm. MCC requested adoption of medium projections for climate change for planning purposes. The MfE guidance for the medium projection of climate change indicated a 2.1°C projected increase in annual temperature for the Auckland Region. This corresponds to a 16.8% increase in the 24 hour, 100 year ARI rainfall depth for the year 2090. The effect of climate change on rainfall can be seen in Table 3.

An areal reduction factor of 0.83 (reference ARC TP108) was used across the catchment based on the time of concentration and catchment area.

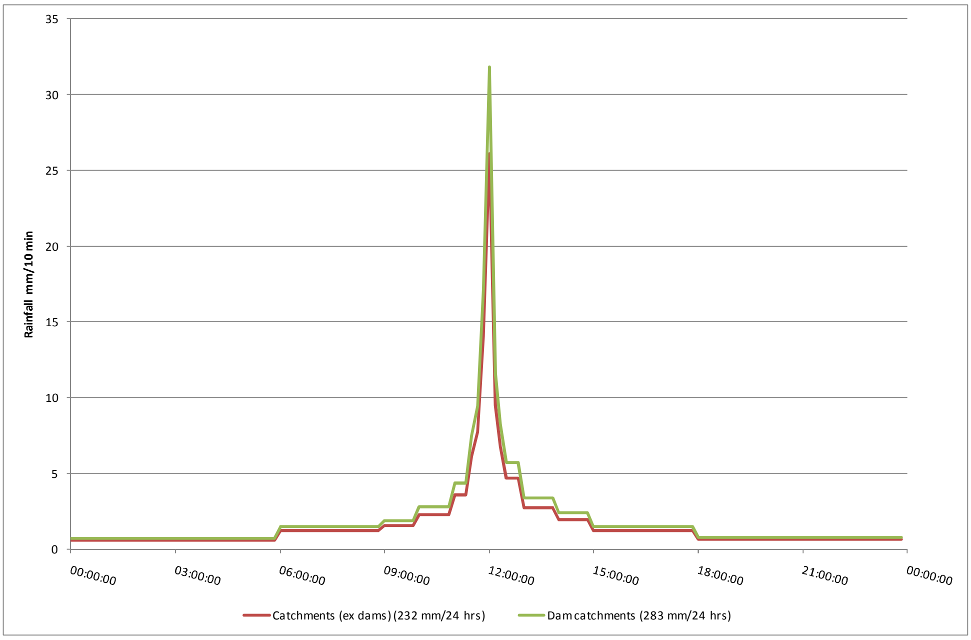
In order to reflect differences in rainfall from the east side of the catchment to the west side of the catchment, and in accordance with TP108 isohyets, the catchments that are dammed (Cosseys and Wairoa) used an increased rainfall depth. The rainfall depths can be seen in Table 3.

Table 3 Design rainfall depths

Description	**Rainfall depth (mm/24 hrs)**	
	Wairoa, Taitatia, Mangawheu catchments	**Cosseys and Wairoa Dam sub-catchments**
100 year rainfall depth and areal reduction factor	199	242
100 year rainfall depth incorporating 16.8% allowance for climate change	232	283

The design rainfall hyetograph (including climate change) can be seen in Figure 2.

Figure 2 100 year ARI Design rainfall hyetograph



2.3.2 RIVER FLOWS

There are two flow gauges that monitor river flows in the Wairoa catchment. These are the Tourist Road and Mangawheu flow stations, are described in Table 4 and the locations shown in Figure 1. In addition there are a further two gauges that record flows released from Cosseys and Wairoa dams. There are no flow gauges in the Taitaia catchment.

Table 4 Flow gauge details

	Site start date	Elevation	Upstream catchment area	Location
Tourist Road	June 1979	RL 20m	148.1 km^2	1782664, 5901676
Mangawheu	June 1988	RL 100m	30.4km^2	1783781, 5891411

The Mangawheu flow station is situated on the Mangawheu River in a steep gorge 3.25 km upstream from its confluence with the Wairoa River in the Hunua foothills. The upstream catchment is primarily pasture with some native and exotic plantation forest.

Flows in the Wairoa River are recorded by a flow gauge at Tourist Road. The flow gauge has been recording flows and levels since 1979. The gauge is located in a shifting gravel bed site. Performance of the gauge is understood to be affected by some bypassing with floodwaters overtopping the road shortly after water level rises above the underside of the road bridge. T&T (1996) noted that recorded flows above 125 m^3/s are likely to have been underestimated because of significant overbank flows above this stage.

2.4 HYDROLOGICAL MODEL CALIBRATION

Calibration of the Wairoa and Mangawheu sub-catchments was carried out using the Tourist Rd and Mangawheu flow gauges respectively. Calibration of the Tourist Rd catchment included recorded flows from Mangawheu, and consideration of the Wairoa and Cosseys dams.

It was not possible to calibrate the Wairoa and Cosseys dam catchments because flows from the dams are significantly affected by operational decisions (e.g. diversion for water consumption, water level at the start of a flood event).

The Taitaia catchment and the Wairoa catchment downstream from Tourist Road are not gauged for river flows, therefore it was not possible to calibrate these areas.

Four storm events over a five year period were identified as suitable for model calibration purposes. In order to be a suitable storm event for model calibration, the peak flows recorded at Tourist Road needed to be less than 125m^3/s, to avoid the uncertainty in the flow gauge at higher flows. Calibration events over the last five years were chosen so that calibration reflects the current catchment land use and development including dam operations and dam improvements. The events were chosen as they were the largest storm event of each year (defined by peak flow). The events are detailed in Table 5.

Table 5 Calibration storm events

Event start date	**Peak flow (m^3/s)**	
	Mangawheu Flow Gauge	**Tourist Road Flow Gauge**
17/7/2005	14.1	50.4
7/8/2006	22.3	80.0
29/7/2007	19.5	52.3
29/6/2009	24.9	55.6

The hydrological parameters used by the model to define the catchments include the rainfall, loss method, transformation method, hydraulic routing and sub-catchment area. These parameters were adjusted individually or in combination to obtain a good comparison between model predictions and recorded flows.

2.4.1 CALIBRATION RESULTS - MANGAWHEU CATCHMENT

Calibration of the Mangawheu sub-catchment was attempted using rainfall from the Hays Creek and Hunua rainfall gauges for the four calibration storm events. In three of four events, better calibration was achieved using the rain gauge from Hunua. For each three events, the rainfall at Hays Creek was more variable than at Hunua and consequentially produced a more variable flow than the historical flow records indicated. For the fourth event (2009) there was very little difference between the records from the two gauges.

We were able to calibrate peak flows using the Standard SCS transformation method. However, for three of the four storm events we were unable to satisfactorily calibrate the hydrograph shape using the Standard SCS transformation (peak rate factor = 484). Therefore, we applied the "Delmarva" SCS transformation (peak rate factor = 284) to the model, which places more of the runoff volume in the time after the peak discharge than the Standard SCS method. Peak rate factors have been shown to vary from 600 in steep terrain to 100 or less in flat, swampy country (USDA, 2007).

The results of the Mangawheu hydrological model calibration can be seen in Figure 3 and summarised in Table 6.

Figure 3 Mangawheu catchment hydrological model calibration

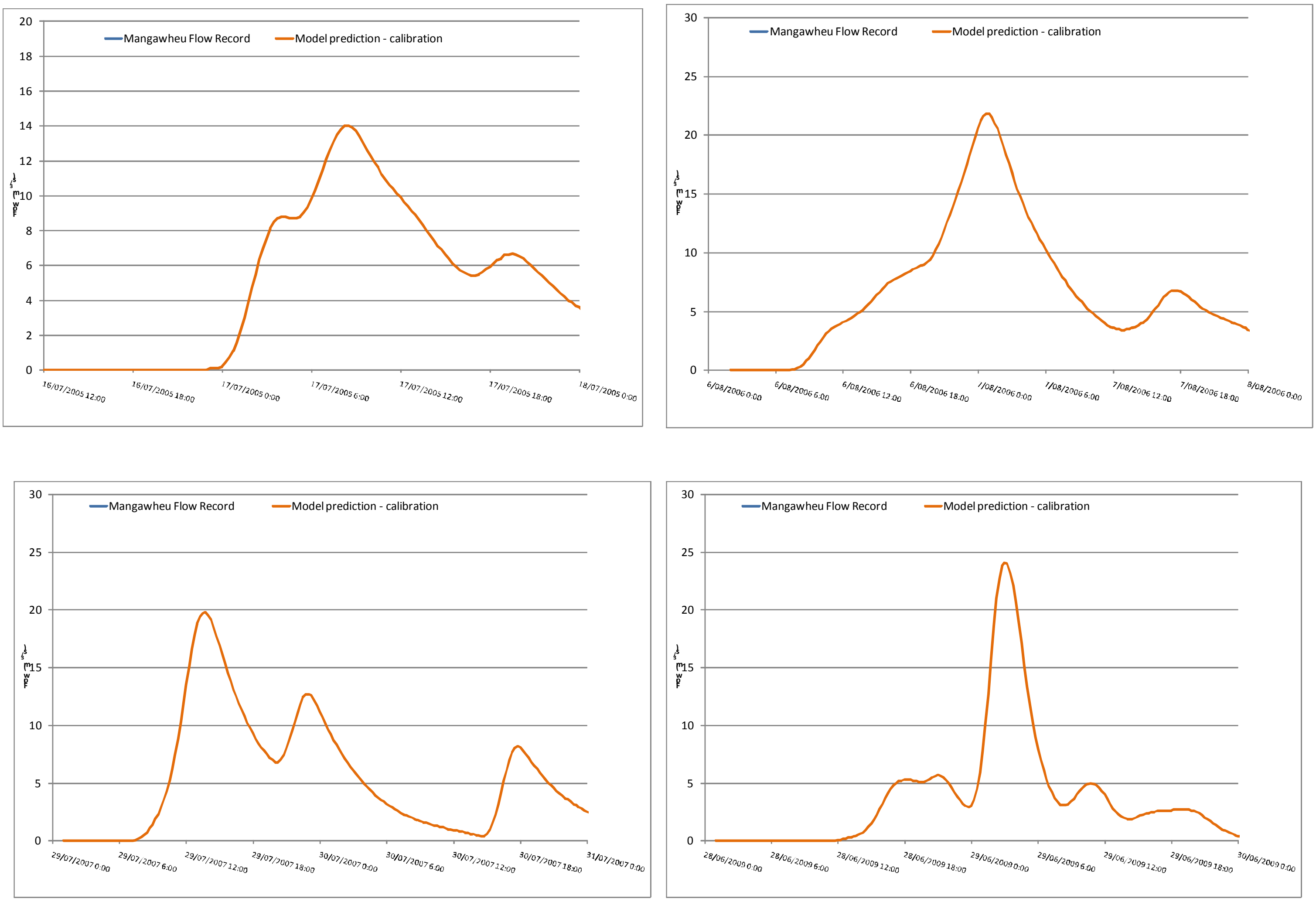


Table 6 Mangawheu catchment calibration parameters

	Calibration event			
	17/7/05	**7/8/06**	**29/7/07**	**29/6/09**
Rainfall	Hunua Rainfall +15%	Hunua Rainfall +10%	Hunua Rainfall +10%	Hunua Rainfall + 15%
Transformation	Delmarva SCS	Delmarva SCS	Delmarva SCS	Standard SCS
SCS Curve Number	84	81	82	82
Lag time	210 mins	180 mins	165 mins	165 mins
Open channel	N/A	N/A	N/A	N/A

The calibration process indicated good comparison between model predictions, and peak recorded flows was obtained with a unique calibration for each event, but there is some variability in calibration parameters for the four calibration events. The Delmarva transformation method in 3 of the 4 storm events is the most appropriate method to use, rainfall from the Hunua Rainfall gauge should be increased between 10% and 15%. The SCS curve number in all events was similar, varying by only 3 points. The lag time varies by up to 45 min. However, for 3 of the 4 storm events there was only a 15 min variation.

2.4.2 CALIBRATION RESULTS - TOURIST ROAD CATCHMENT

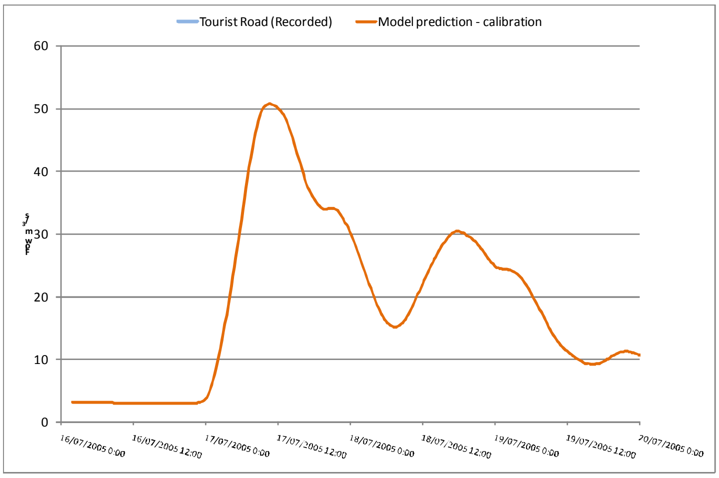
Initial calibration of the Tourist Road sub-catchment was attempted using rainfall from individual rain gauges. However, we were unable to identify the most representative rain gauge for the catchment since there were differences for each event. We therefore investigated the use of between 2 and 4 gauges to represent rainfall across the catchment. We determined that an average rainfall from all the rain gauges was the most appropriate rainfall source for the Tourist Rd catchment. Better calibration was achieved for all calibration storm events using the Standard SCS transformation than the Delmarva SCS transformation.

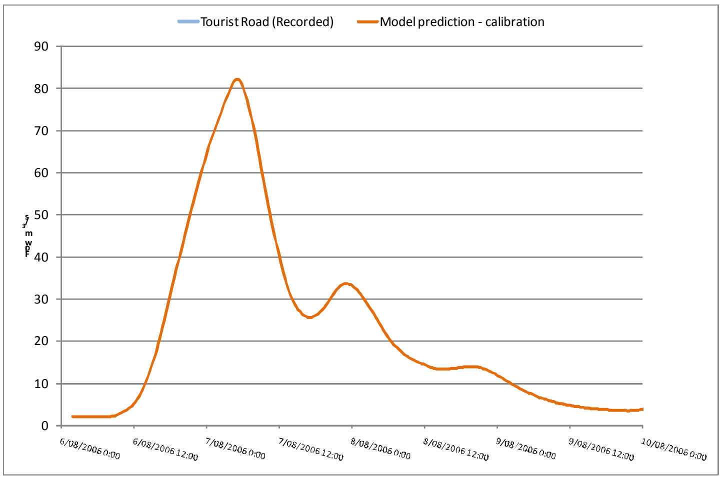
The SCS curve number used to calibrate the model varied in a narrow range from 80 to 82. Increases in catchment wide rainfall were required for two of the four storm events to achieve good calibration.

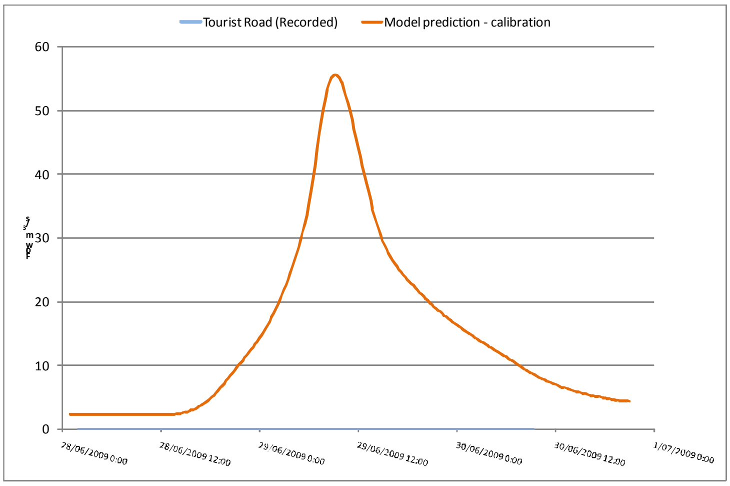
The combination of lag time for the Tourist Road catchment and the hydraulic routing parameters affects the timing of peak flows from each of the catchments, which consequentially affects peak flows considerably at Tourist Road. An iterative process where timings were altered for each of the sub-catchments along with adjustments to the lag time in the Tourist Road sub-catchment was carried out and the calibrated parameters for the four storm events can be seen in Table 7.

The results of the Tourist Road hydrological model calibration can be seen in Figure 4. The results are shown in comparison with recorded flows at the Tourist Road flow gauge to compare predicted and recorded flows.

Figure 4 Tourist Road catchment hydrological model calibration







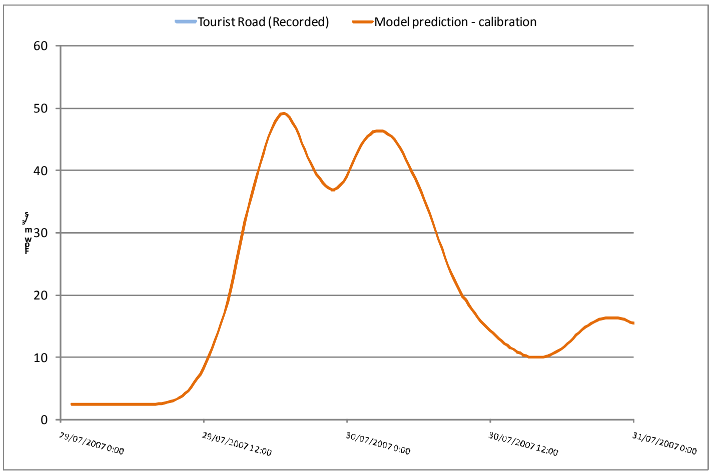


Table 7 Tourist Road catchment calibration parameters

		Calibration event			
		17/7/05	**7/8/06**	**29/7/07**	**29/6/09**
Rainfall		Average gauge	Average gauge + 10%	Average gauge	Average gauge + 10%
CN		82	80	81	82
Lag time		450 mins	520 mins	450 mins	520 mins
Hydraulic Routing (travel time/weighed difference)	**Mangawheu flow gauge to Tourist Road**	5.5 hrs	6 hrs	5.5 hrs	6 hrs
	Confluence of Mangawheu Stream and Wairoa River to Tourist Road	3.5 hrs	4 hrs	3.5 hrs	5 hrs
	Cosseys dam to confluence with Wairoa River	0.25 hrs	0.5 hrs	0.25 hrs	0.25 hrs
	Wairoa dam to confluence of Wairoa River with Mangawheu Stream	0.5 hrs	0.5 hrs	0.5 hrs	0.5 hrs

The calibration process has indicated that a good comparison between model predictions and recorded flows was using a unique calibration for each event, but there is some variability in calibration parameters for the four calibration events. The calibration parameters shown in Table 7 indicate that there were only small differences between the calibration parameters for each storm event.

2.5 HYDROLOGICAL MODEL VALIDATION

Based on the results of the calibration, the parameters shown in Table 8 and Table 9 were chosen as the most representative calibration parameters. These were applied for model validation for the Mangawheu and Tourist Road catchments respectively.

Table 8 Validation parameters for Mangawheu catchment

Rainfall	Hunua Rainfall +10%
Transformation	Delmarva SCS
SCS Curve Number	84
Lag time	180 mins

Table 9 Validation parameters for Tourist Road catchment

<table>
<tr><td colspan="2">Rainfall</td><td>Average Rainfall from all gauges +10%</td></tr>
<tr><td colspan="2">Transformation</td><td>Standard SCS</td></tr>
<tr><td colspan="2">SCS Curve Number</td><td>82</td></tr>
<tr><td colspan="2">Lag time</td><td>450 mins</td></tr>
<tr><td rowspan="4">Hydraulic Routing (travel time/weighed difference)</td><td>Mangawheu flow gauge to Tourist Road</td><td>5.5 hrs</td></tr>
<tr><td>Confluence of Mangawheu Stream and Wairoa River to Tourist Road</td><td>4 hrs</td></tr>
<tr><td>Cosseys dam to confluence with Wairoa River</td><td>0.25 hrs</td></tr>
<tr><td>Wairoa dam to confluence of Wairoa River with Mangawheu Stream</td><td>0.5 hrs</td></tr>
</table>

The storm event of 12 October 2003 with peak flows of approximately 90m^3/s was identified as a suitable event for model validation. It was a suitable event as it represented a large and relatively recent storm event, where flows less than 125m^3/s were recorded at Tourist Road.

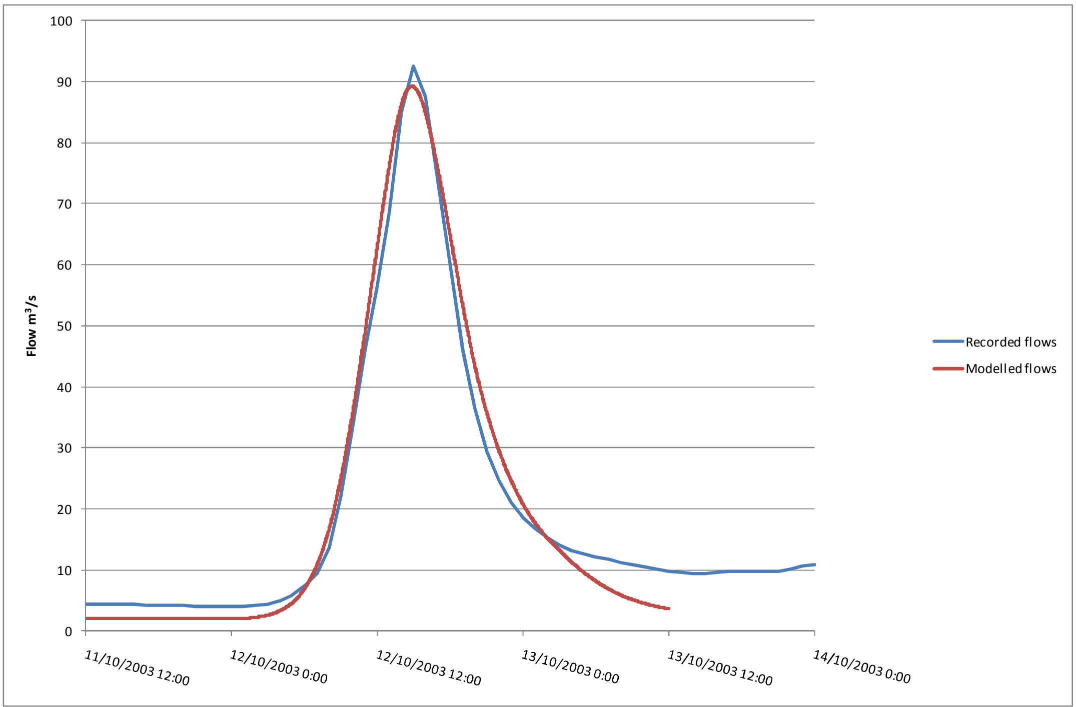
Flows less than 1m^3/s were recorded from the Wairoa dam during this storm event, and no flows were recorded from Cosseys dam. Therefore for the purposes of model validation, flows from the dams were excluded.

2.5.1 HYDROLOGICAL MODEL VALIDATION RESULTS

The result of the model predicted flows and the Tourist Road flow gauge flows for the validation storm event of 12 October 2003, can be seen in Figure 5.

The model results shown in Figure 5 relate very closely to the recorded flows at Tourist Road. This gives good confidence that the hydrological model reasonably represents the catchment runoff characteristic from upstream of Tourist Road. There remains some uncertainty with the modeling of larger flows, as the largest of the peak flows used for calibration and verification was of 90m^3/s at Tourist Road gauge.

Figure 5 Hydrological model validation result



2.6 ADDITIONAL CATCHMENTS

In addition to the calibrated catchments previously discussed, additional uncalibrated catchments were represented in the model (see Figure 1 for locations):

- Taitaia (divided into 8 sub-catchments)
- Clevedon township
- Holdens Road Catchment
- Clevedon North
- Wairoa Mouth
- Urungahauhau.

In addition, the two catchments at Cosseys Dam and Wairoa Dam were treated differently due to a number of assumptions regarding dam operation that differentiates them from the other catchments.

For the uncalibrated catchments the SCS loss method and transformation method was used to represent the catchment losses. For each sub-catchment, an assessment of lag time and initial abstraction was made. The curve number for all additional catchments was based on the calibrated curve number used in the Tourist Road catchment (excluding Wairoa and Cosseys Dam catchments).

Table 10 Subcatchment characteristics for uncalibrated catchments

Catchment		Area (km^2)	Initial Abstraction (mm)	Curve Number	Lag time (min)
Taitaia	T1	11.66	5	82	50
	T2	5.21	5	82	25
	T3	6.96	5	82	58
	T4	7.14	5	82	56
	T5	8.84	5	82	47
	T6	1.58	5	82	40
	T7	0.45	5	82	10
	Clevedon Taitaia (T8)	1.78	5	82	32
Clevedon Wairoa u/s		5..17	5	82	66
Clevedon Wairoa d/s		0.35	5	82	17
Holdens Road Catchment		11.0	5	82	100
Clevedon North		9.24	5	82	79
Wairoa Mouth		3.67	5	82	18

The catchments upstream from Wairoa and Cosseys dam were independently assessed for SCS curve number and lag time. It was not considered appropriate to use the calibrated SCS curve number for Tourist Road for the two dammed catchments because the vegetation cover and terrain was different to the rest of the catchment.

Table 11 Sub-catchment characteristics for Wairoa and Cosseys dam catchments

Catchment	Area (km^2)	Initial Abstraction (mm)	Curve Number	Lag time (min)
Cosseys Dam	21.3	5	74	30
Wairoa Dam	13.24	5	74	43

In discussion with MCC, we agreed that for flood hazard mapping purposes it was appropriate to use the conservative assumption that the water levels in the dams were at maximum normal operating level at the start of the design storm event.

Flood conveyance through the reservoirs was represented using storage versus elevation curve for the reservoirs, and then flow conveyance across the dam spillways was calculated based on spillway rating curves (T&T, 2005).

2.7 FLOWS FOR HYDRAULIC MODEL

The hydrological model was used to generate the inflow hydrographs for the design rainfall events.

The design rainfall hyetographs were applied to the hydrological model to determine runoff hydrographs from each sub-catchments. A key assumption was the same design rainfall occurred across the catchment at the same time, with exception of the Cosseys and Wairoa dam catchments (where increased rainfall was used, see Section 2.3.1).

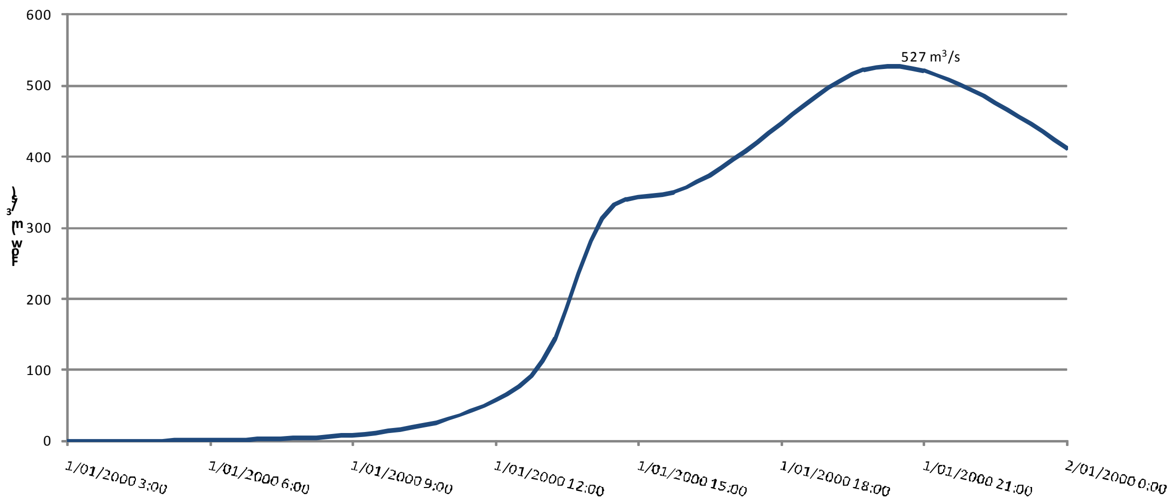
The peak flows from each of the sub-catchments are summarised in Table 12, and a flow hydrograph at Tourist Road can be seen in Figure 6.

Table 12 Summary of peak sub-catchment flows

Catchments	**Sub-catchments**	**Peak flow (m^3/s)**
Wairoa Upstream of Tourist Road	Mangawheu	131
	Cosseys dam	224
	Wairoa dam	46
	Wairoa upstream of Tourist Road (excluding Mangawheu, Cosseys and Wairoa)	309
	Wairoa River at Tourist Road (sub-total)	**527**
Taitaia	T1	158
	T2	94
	T3	87
	T4	91
	T5	124
	T6	23
	T7	11
	Clevedon Taitaia (T8)	29
Clevedon Wairoa u/s	Located upstream of bridge	61
Clevedon Wairoa d/s	Located downstream of bridge	7
Holdens Road Catchment		104
Clevedon North		99
Wairoa Mouth		75

The predicted 100 year ARI flow at Tourist Road from the hydrological models is $527m^3/s$. This represents a 100 year ARI storm event, inclusive of a 16.8% increase in rainfall to account for climate change and a scenario where the dams are full at the start of the storm event.

Figure 6 100 year ARI flow hydrograph at Tourist Road



3 HYDRAULIC MODEL

3.1.1 MODEL

The hydraulic modelling was carried out using the DHI Mike Flood modelling suite. The modelling approach combined a 1D representation (Mike 11) of the river channel with a 2D representation (Mike 21) of the floodplain. This ensures optimal representation of the channel geometry and floodplain topography.

The 2D model was used to determine the flood areas within the area of interest. It extended from the Tourist Road flow gauge to approximately 6.7 km downstream from Clevedon township. The 1D model extended downstream to the coast to ensure that the effects from seawater level on flood levels at Clevedon were considered (see Figure 1). The 1D and 2D models were linked dynamically using Mike Flood.

3.1.2 MODEL BUILD

The channel topography in the Wairoa River and Taitaia Stream was determined from cross section surveys of the watercourses. In addition to the cross section survey of the watercourses, 12 culverts or bridges were surveyed for inclusion in the hydraulic model.

The floodplain topography was created using a 5m by 5m grid based on LiDAR data. The LiDAR was modified in locations represented only by the 2D model where culverts or other submerged structures were not represented in the LiDAR data (e.g. bridges) by creating "opening" in the topography to allow flow through.

Preliminary model runs were carried out to determine approximate floodplain extents. Based on these results, we noted that the land cover and land use within the flood extent was similar across the model. We therefore used one constant roughness value for the watercourses and another constant value for the floodplain. The following Mannings n values were used:

Wairoa River and Taitaia Stream, n = 0.0375
Floodplain, n =0.04.

The flood flows for the 100 year ARI design storm event are largely outside the watercourse channel, so the roughness of the watercourse is unlikely to affect the flood depths significantly.

3.2 MODEL BOUNDARIES

The flow boundary conditions to the hydraulic model were determined from the hydrological model. The downstream end of the hydraulic model is controlled by sea water levels. The downstream boundary in the hydraulic model is located within the Tamaki Strait area of the Hauraki Gulf.

The SDP states that "future development in Clevedon should take a conservative approach based on available information regarding climate change, particularly with respect to floodplains and sea level changes." Therefore, in discussion with MCC, and in accordance with the SDP, an approach that combines the upper limits of sea level at the coast with peak design flows from the catchment was adopted.

Given a range in 100 year ARI water level indicated by a NIWA (2008) report, and with consideration of T&T (2010) 100 year ARI levels, a downstream water level of RL 3.15m was adopted for the 100 year ARI flood hazard mapping.

The approach of using 100 year ARI flood flows combined with upper limits of sea levels at the coast is conservative since the probability of the peaks of all events combining is likely to represent a lower probability event. However, the events are also not entirely independent, with tropical storms typically providing a situation of high rainfall with elevated water levels.

3.3 HYDRAULIC MODEL CALIBRATION

Calibration of the hydraulic model for water level was dependant on availability of observed flood levels. There are no water level gauges in either the Taitaia Stream or Wairoa River downstream of Tourist Road. Therefore flood levels for model calibration were assessed using surveyed levels from historical photographs. The calibration process involved using the hydraulic model to predict water levels, and then the water levels were compared with surveyed water levels from flood photographs.

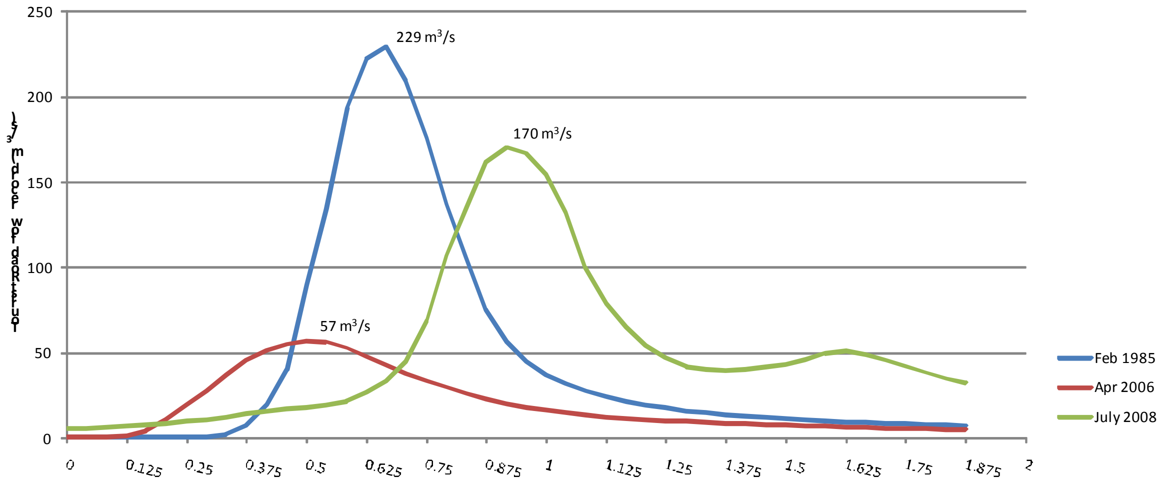
The permanent flow gauge at Tourist Road was used to provide upstream inflows to the Wairoa River branch of the model for model calibration.

There are no flow records in the Taitaia Stream, therefore all inflows to the stream (including those into the Wairoa River downstream from Tourist Road) were determined from the hydrological model using rainfall recorded from the Hunua gauge (see Section 2.6).

The closest permanent tide gauge to the mouth of the Wairoa is located at Port of Auckland, and there were no other water level gauges located along the Wairoa River that could be used for a downstream model boundary. Tide levels increase as distance eastwards from Port of Auckland increases. Therefore a water level increase of 0.1m was applied to the Port of Auckland tide gauge records to make them applicable to the mouth of the Wairoa River. The 0.1m increase was based on results shown in the NIWA (2008) report.

Historical flood levels were surveyed at a number of locations for historical storm events based on photographs. These levels were used to help calibrate the hydraulic model. Photographs of three storm events were assessed for suitability of use for hydraulic model calibration. Flows for the three storm events can be seen in Figure 7.

Figure 7 Tourist Rd flow record for three historical events where water level records are available



Only one water level record was available for the April 2006 storm event, and given that the recorded flows were also comparatively small we did not consider the event further for hydraulic model calibration.

Both the 1985 and 2008 flood events produced flows in excess of 125 m^3/s at the Tourist Road flow gauge (see Section 2.4). Given that the peak flows for the 1985 and 2008 event were 229 m^3/s and 170 m^3/s respectively, we have more confidence in the lower 2008 flows because it exceeds the 125 m^3/s limit by less. In addition, we were able to obtain more water level records for the 2008 event, over a wider area, than for the 1985 records. We were also able to use anecdotal information from local residents to supplement the 2008 data because it was a relatively recent flood event. Therefore the hydraulic model calibration was focused on the storm event of 30 July 2008.

3.3.1 HYDRAULIC MODEL CALIBRATION RESULTS

A comparison of surveyed water levels and modelled water levels can be seen in Table 13.

Table 13 Hydraulic model calibration – storm event of 30 July 2008

Watercourse	Location	Recorded level (m RL)	Model predicted level (m RL)	Difference (m)
Wairoa	Polo Grounds 1	2.63	2.79	+0.16
Wairoa	Fire station	3.53	3.4	-0.13
Wairoa	116 Monument Rd	6.01	6.04	+0.03
	(2 locations adjacent to property)	6.2	6.12	-0.08
Taitaia	Camp Sladdin footbridge	4.63	4.59	-0.04

The results of the hydraulic calibration indicate that the flood levels predicted by the model are similar to the surveyed levels from the flood photographs, to within 0.16m. Three of the locations are located along the Wairoa River and the results indicate that the model predictions slightly exceed the recorded levels in the upper part of the model. There is a suggestion that the model slightly under-predicts water levels in the Wairoa River downstream of the Clevedon – Kawakawa Road bridge.

Given that the hydraulic model calibration could only be carried out for one storm event due to availability of data, we are unable to analyse in detail the cause of the under-prediction downstream of the Clevedon-Kawakawa Road bridge, and whether it would be a general trend for all storm events.

Anecdotal information from farm-owners on the Taitaia Stream (along Twilight Road) would indicate that the flood extent along the Taitaia Stream for the July 2008 storm event is in good agreement with their recollections. The results also suggest that the model predictions at Camp Sladdin are similar to the peak water level recorded by the photograph of the footbridge.

There remains some uncertainty with the modeling of larger flows, as the flood event used to calibrate/validate the hydraulic model was considerable smaller than the 100 year ARI flood event.

3.4 100 YEAR ARI FLOOD EXTENT

The hydrological model was used to determine flows for input into the hydraulic model for the 100 year ARI design storm. The hydraulic model was then used to determine the flooding extent and level.

3.4.1 SCENARIO

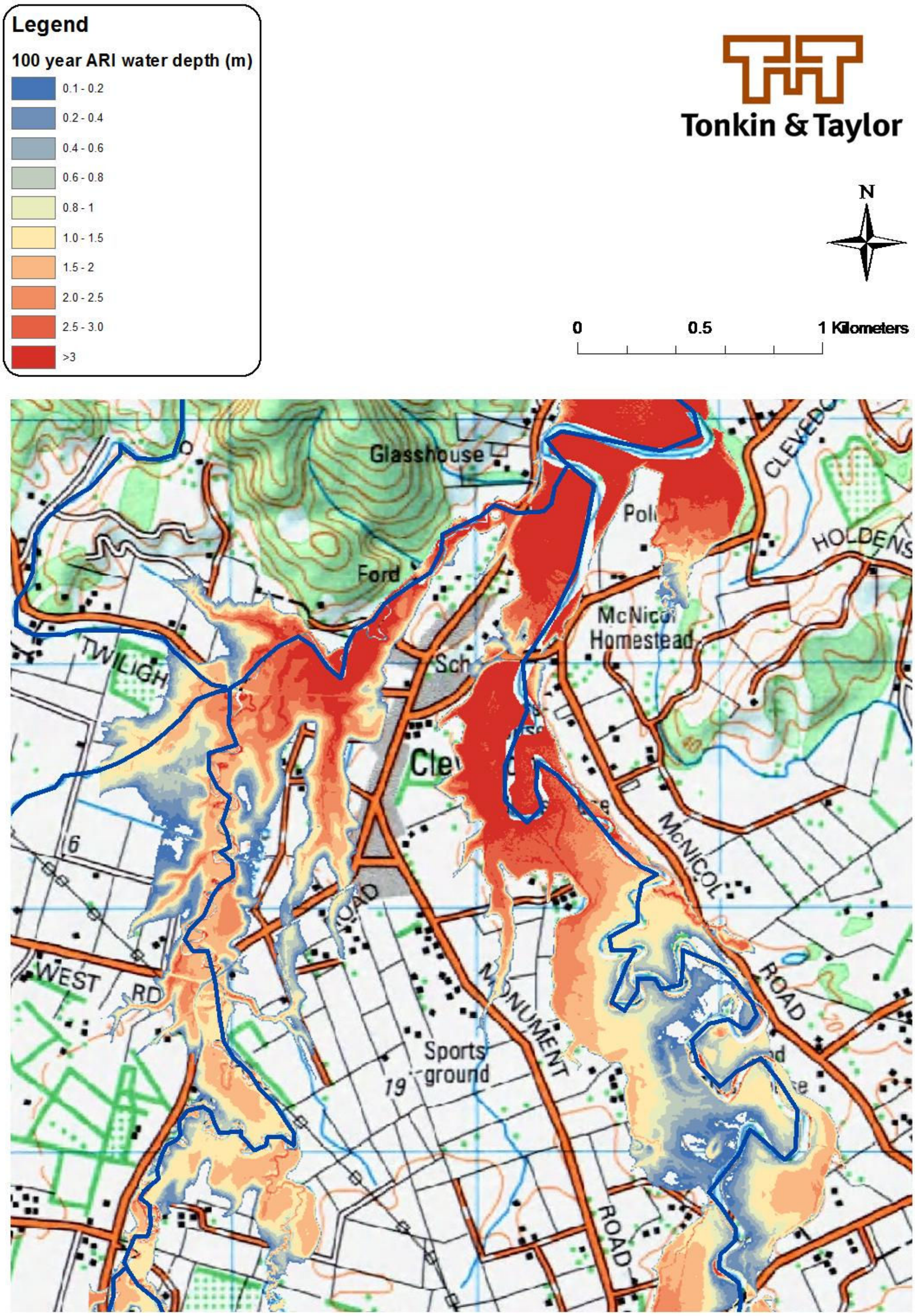
The scenario that has been adopted to represent the 100 year flood extent comprises the following:

- 100 year ARI design rainfall from TP108 (with areal reduction factor of 0.83 applied)
- Climate change in accordance with best practice from MfE
- Cosseys dam and Wairoa dam both being full at the start of the design storm event
- 100 year ARI sea level as a sea water level boundary.

3.4.2 RESULTS

The model results for the hydraulic model calibration are shown in Figure 8. The results display the maximum water depth and flood extents for areas inundated by more than 0.1 m water depth.

Figure 8 100 year ARI flood extents



4 SENSITIVITY ASSESSMENT

To account for areas of uncertainty we have used conservative assumptions to estimate the 100 year ARI flood extent. However to help determine confidence levels in the flood extent, a sensitivity assessment was carried out.

The sensitivity assessment was carried out to assess the flood extents for two scenarios:

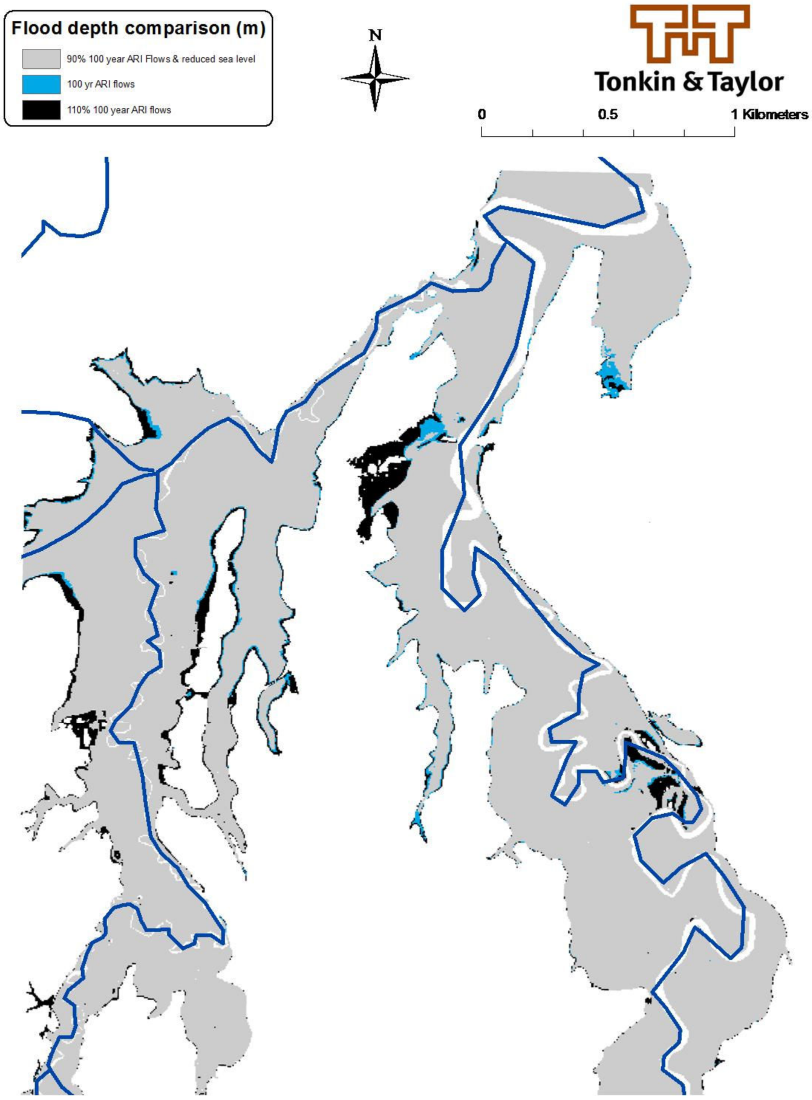
1. An increase in design flows of 10% to determine the effect on flood extent if flows were underestimated
2. A decrease in design flows of 10% and a reduction in the design sea level, to determine the effect on flood extent if predictions of flow were overly conservative.

The increase/decrease in design flows was applied to all sub-catchments in the model. The reduction in sea level considered the effect of reducing the sea level from RL3.15 m to RL1.83 m, which is considered to be the approximate level of MHWS at the mouth of the Wairoa River based on information in NIWA (2008).

4.1 RESULTS

The results of the sensitivity assessment have been compared for five known locations. The results of the sensitivity assessment indicated that there was a range in predicted peak water level of between 0.43 m and 0.63 m at the locations. A comparison of flood extent for the three sensitivity scenarios was carried out to determine whether the changes observed in water levels significantly altered the flood extents. The flood extents can be seen in Figure 9.

Figure 9 Comparison of 100 year ARI flows at Tourist Road from calibrated and uncalibrated hydrological model



The results show that for the scenarios modelled, in general the flood extent is relatively insensitive to changes in flow/water depth. An exception is the area near the fire station where the 10% increase in the 100 year ARI flood causes a noticeable increase in the flood extent up the western bank of the Wairoa River towards Clevedon township. Other areas where an increase in flood extent can be observed occurs where the low gradient of the ground results in increased flood extents. In contrast, the majority of the floodplain of the Wairoa River and Taitaia Stream are well defined with relatively steep slopes along the edge. This indicates that the flood extents are relatively insensitive to small changes in water level.

The results of the flood hazard mapping sensitivity assessment indicate that there can be a good level of confidence in the flood extents. It has also identified the small number of locations where a precautionary approach may be best adopted to determining development areas. The sensitivity assessment might be used in the future as a consideration for setting freeboard levels for development.

5 DISCUSSION

The results of the hydrological calibration indicated that a higher SCS curve number was required to represent the Wairoa catchment than we would expect as prior to model calibration a curve numbers of 74 was estimated. Different lag time values were also assessed. Figure 10 demonstrates the change to 100 year ARI design flow that would have occurred if an uncalibrated hydrological model was used.

Figure 10 Comparison of 100 year ARI flows at Tourist Road from calibrated and uncalibrated hydrological model

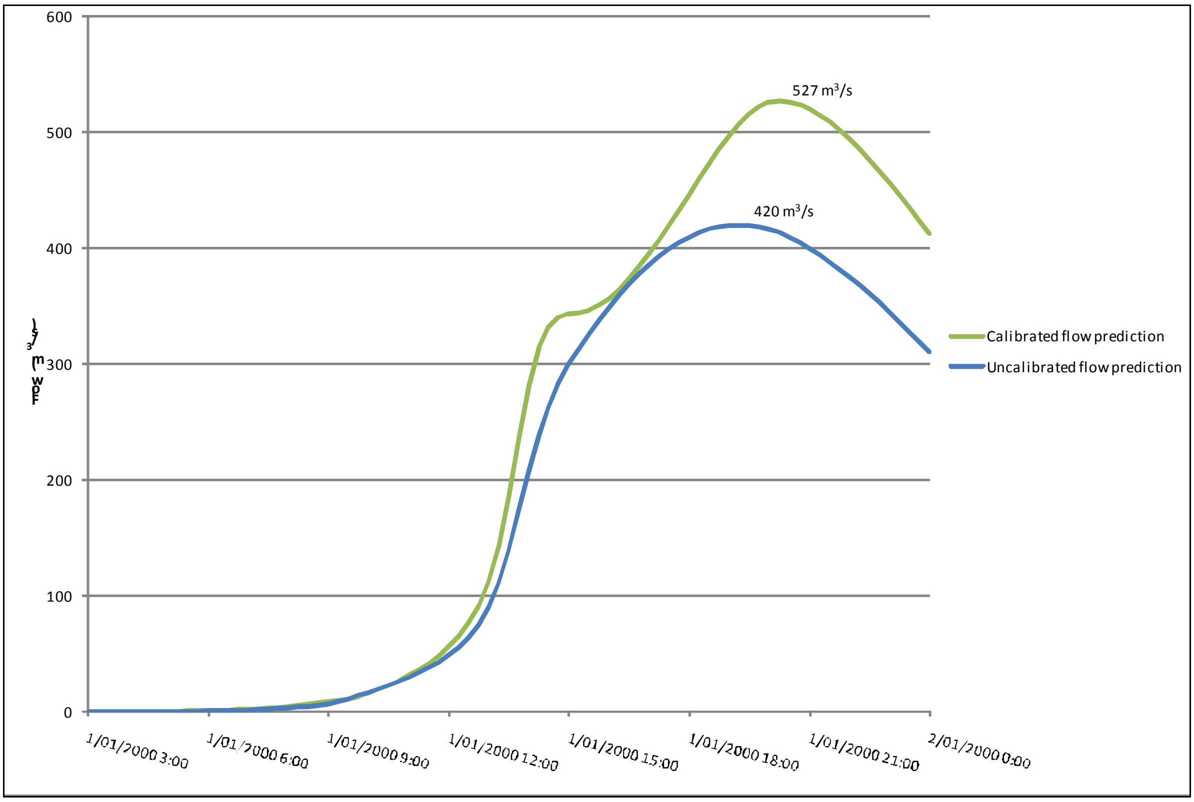
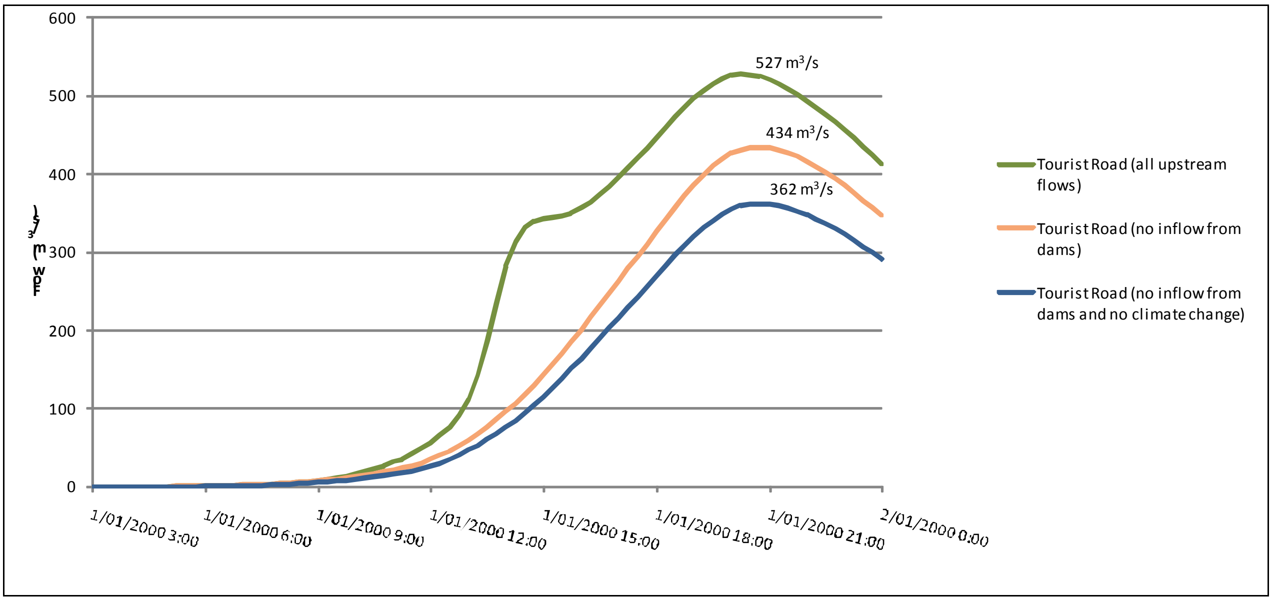


Figure 10 shows that if an uncalibrated hydrological model was used, the flood extents for Clevedon would have been under-predicted. This would mean that restrictions to development would not adequately protect development along the edge of the floodplain for 100 year ARI flood event.

In order to test the sensitivity of flow to the conservative catchment scenarios adopted for this study, we carried out an assessment of flows at Tourist Road without the runoff from the dams included, and without including climate change. A comparison of the 100 year ARI design hydrographs at Tourist Road for different dam and climate scenarios is shown in Figure 11.

Figure 11 Comparison of flow hydrograph at Tourist Road for different catchment assumptions



The hydrographs shown in Figure 11 show that the assumptions regarding climate change and flows from dams will significantly affect the hydrograph used for flood hazard mapping. The assumption that the dams are full at the start of the storm event means that nearly 100 m^3/s of the peak flows at Tourist Road are from the catchments upstream from the Wairoa and Cossey dams. Climate change assumptions increase peak flows by an approximately a further 70 m^3/s.

For flood conveyance along the Wairoa and Taitaia watercourses, there is a well defined flood extent comprising of a relatively narrow water course, a wide, flat floodplain and steep slopes along the edge of the floodplain. Therefore assumptions for the upstream catchment do not significantly affect flood extent. However, as demonstrated in Figure 11, hydrological assumptions have the ability to significantly affect flood extent at other locations.

6 CONCLUSIONS

A hydrological model was developed to represent inflows to the Wairoa and Taitaia catchment. A number of records from rain gauges and flow gauges within the catchments permitted calibration of the hydrological model for large areas of the Wairoa catchment. However it was not possible to calibrate the hydrological model for catchments downstream of Tourist Road or the Taitaia catchment. Where calibration was possible, a good level of agreement was obtained between model predictions and historical flow records.

For the Wairoa catchment upstream of Tourist Road, we identified that if flow and rainfall records were not available, an uncalibrated model would likely have underestimated peak flows by approximately 100 m^3/s. This would mean that restrictions to development may not adequately protect development along the edge of the floodplain for 100 year ARI flows.

Conservative assumptions regarding flow attenuation at the Wairoa and Cosseys dams were used when determining the 100 year ARI flows in the Wairoa River. The use of conservative assumptions where the attenuation of flow in the dams is likely to have increased the peak flow by approximately 100 m^3/s in comparison with non-conservative assumptions regarding flow attenuation in the dams.

A sensitivity assessment of flood extents at Clevedon was carried out for 100 year ARI flows that were increased and decreased by 10%, along with a reduction in sea level for the 10% reduction scenario. The results of the sensitivity assessment indicated that the flood extent is relatively insensitive to changes in flow/water depth with the exception of a relatively small area immediately downstream of the Clevedon-Kawakawa Road where an increase in flows/water depth caused an increase in flood extent.

The results of the flood hazard mapping sensitivity assessment indicate that there can be a good level of confidence in the flood extents that will be used for the Clevedon Village SDP. It has also identified the small number of locations where a precautionary approach may be best adopted to determining development areas. The sensitivity assessment could be used in the future as a consideration for setting freeboard levels for development.

ACKNOWLEDGEMENTS

This study was funded by the former Manukau City Council, now Auckland Council. Viewpoints expressed in this paper are those of the authors and do not reflect policy or otherwise of the Auckland Council.

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