FLOOD RISK ASSESSMENT FOR A CATCHMENT SPANNING DIFFERENT DISTRICTS – A PILOT STUDY

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ABSTRACT

The Waimapu Stream, which flows into the Tauranga Harbour estuary, has a flood-prone lower catchment area that lies within the Tauranga City area. Most of its catchment, however, lies outside of Tauranga City in the Western Bay of Plenty District. The entire catchment lies within the Bay of Plenty Region.

There has been concern expressed that flooding effects within Tauranga City can be exacerbated by changes in land use that occur within the Western Bay of Plenty District, over which Tauranga City Council has little or no control. Collaboration between the different authorities has been identified as fundamental principle to ensure a sustainable management of the catchment. Bay of Plenty Regional Council has initiated a Flood Risk Project to develop a Regional Flood Risk Management Framework and a Regional Flood Risk Management Strategy, using the Waimapu Stream catchment as one of the pilot studies.

Analyses have been undertaken in this catchment in an attempt to quantify the management constraints as well as opportunities that exist within the overall flood risk framework implementation. Of significance in the lower catchment are predicted flood depths and velocity-depth product (used for safety evaluation), while land use practices in the upper catchment require management to reduce the sediment load to the Tauranga harbour.

In this paper the approach to this pilot study is explained in detail. The study uses a risk-based assessment for identifying ongoing management of the catchment over the next 100 years to ensure that the current flood risk is maintained or mitigated to an acceptable level.

KEYWORDS

Flood risk, catchment management

1 INTRODUCTION

The Waimapu Stream catchment is 11,164 hectares in area and flows from Otanewainuku north to the harbour between Windermere and Greerton. A locality plan is shown in Figure 1.1. The Waimapu catchment spans both the Tauranga and Otanewainuku Ecological Districts, and stretches approximately from Ohauiti Rd to Pyes Pa Rd. The catchment is about 21 km long and 6 km wide. It includes 236 km of stream, or 472 km of riparian margins and 3 km of harbour margin.

The primary waterways in the catchment are the Waimapu and Waiorohi Rivers. There are four named tributary streams (Kirikiri, Mangarewarewa, Pukekonui and Toropeke) and numerous unnamed tributaries. The Waiorohi tributary supplies half of Tauranga City's municipal water so protection of water quality is a priority.

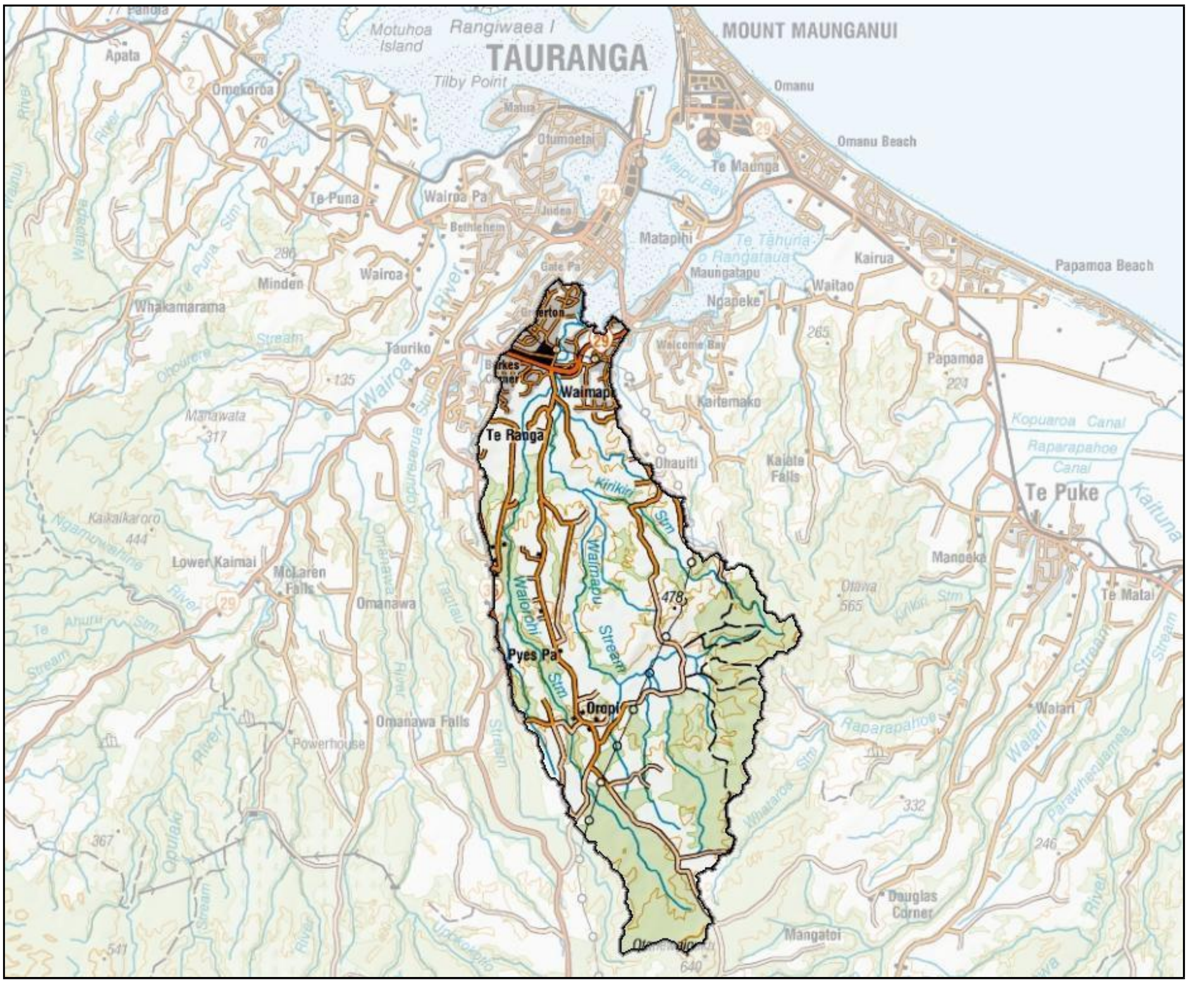


Figure 1.1: Waimapu Stream catchment location

Most of the Waimapu Stream catchment is located in the Western Bay of Plenty District, with a small part being within Tauranga City.

In the lower catchment, much of the flat land adjacent to the river has been developed for industrial use. These areas have been shown to be relatively flood-prone. Tauranga City Council (TCC) has commissioned a hydrological/hydraulic modelling study of the lower catchment area (within the TCC jurisdiction) and this is understood to have confirmed the flood-prone nature in this area. Model results have been used to understand the predicted flood depths in response to different rainfall and tidal events and also to determine the areas within which safety is of potential concern.

Concern has been raised that flood management in the lower part of the catchment (including silt management) within the Tauranga City area is strongly affected by land use decisions made in the upper catchment, yet Tauranga City Council have little or no control over these activities. As a result of this, the Bay of Plenty Regional Council (BoPRC) commissioned a flood risk management project, aimed at addressing these “cross boundary” issues. In parallel with this, the BoPRC has also notified a change (Change 2, Natural Hazards) to the Regional Policy Statement (RPS). This document sets out a risk management framework for natural hazards, and includes a guide to conducting a risk-based assessment which can be applied to any natural hazard.

Given the advanced state of analysis and assessment for the Waimapu catchment, it was decided that this risk-based methodology be applied in an attempt to understand the current risk envelope, and to assist in planning for the future to (1) not result in any increase in flood risk and (2) to contribute to the cross boundary catchment management approaches to be put forward.

2 FLOOD RISK ASSESSMENT

The RPS sets out a risk assessment methodology that includes identification of the “event of maximum risk”. A conceptual curve is presented that shows how a risk may be at a maximum across a range of event likelihoods. This curve is shown in Figure 2.1.

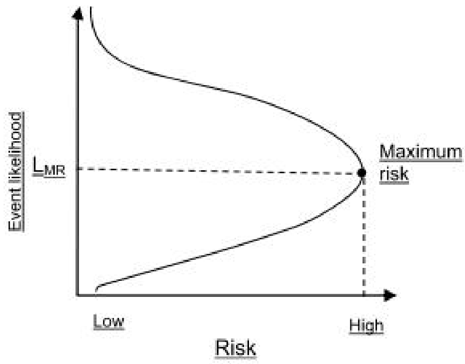


Figure 2.1: Conceptual curve showing risk versus event probability

Definition of “risk” in this context is made up of an assessment of consequence over a range of likelihoods, and is fitted to a “traffic light” risk screening matrix, as shown in Figure 2.2.

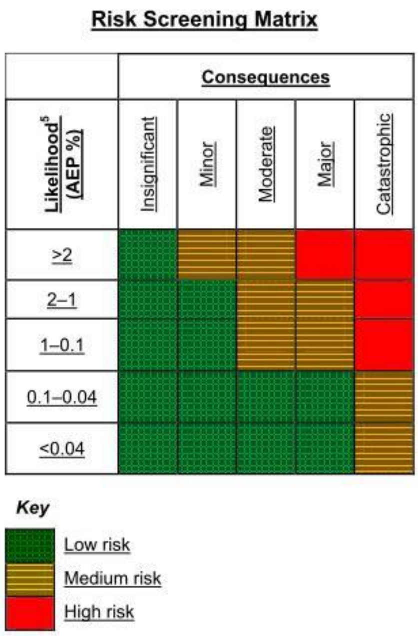


Figure 2.2: Risk screening matrix

Consequence assessment is completed by consideration of the number of buildings located within a Hazard Susceptibility Area (HSA) that would be *functionally compromised* by natural hazard events of different likelihood of occurrence. For example, a consequence is judged as being “catastrophic” if more than 50 percent of buildings within the HSA would be functionally compromised in a natural hazard event. By reference to the table above, this would be considered a *high* risk if such a consequence were attained in an event with likelihood at or above a 0.1% Annual Exceedance Probability.

The consequence table used is replicated in Figure 2.3.

Consequence level	Built			Lifelines utilities	Health & safety
	Social/cultural	Buildings	Critical buildings		
Catastrophic	≥25% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	≥50% of affected buildings within hazard assessment area have functionality compromised.	≥25% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for > 1 month (affecting ≥ 20% of the town/city population) OR out for > 6 months (affecting < 20% of the town/city population).	>101 dead and/or >1001 injured
Major	11–24% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	21–49% of buildings within hazard assessment area have functionality compromised.	11–24% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 week – 1 month (affecting ≥ 20% of the town/city population) OR out for 6 weeks to 6 months (affecting < 20% of the town/city population).	11–100 dead and/or 101–1000 injured
Moderate	6–10% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	11–20% of buildings within hazard assessment area have functionality compromised.	6–10% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 day to 1 week (affecting ≥ 20% of the town/city population) OR out for 1 week to 6 weeks (affecting < 20% of the town/city population).	2–10 dead and/or 11–100 injured
Minor	1–5% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	2–10% of buildings within hazard assessment area have functionality compromised.	1–5% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 2 hours to 1 day (affecting ≥ 20% of the town/city population) OR out for 1 day to 1 week (affecting < 20% of the town/city population).	≤1 dead and/or 1–10 injured
Insignificant	No buildings of social/cultural significance within hazard assessment area have functionality compromised.	<1% of affected buildings within hazard assessment area have functionality compromised.	No damage within hazard assessment area, fully functional.	A lifeline utility service is out for up to 2 hours (affecting ≥ 20% of the town/city population) OR out for up to 1 day (affecting < 20% of the town/city population).	No dead No injured

NB for the purpose of Table 7:

- *the term "town/city population" means the catchment of people within the hazard assessment area that is served by the lifeline utility, except that with respect to a lifeline utility that predominantly or exclusively serves a population outside the hazard assessment area, it means the population in the area served by the lifeline utility.*
- *the applicable consequence level will be the one that corresponds to the row that represents the highest measured or estimated consequence.*

Figure 2.3: Consequence table

3 FLOOD MODELLING

In order to assess flood consequences across a range of event likelihoods, a flood hazard model was created for the Waimapu Catchment. The details of the model build and sensitivity analysis are not covered in this paper, but the model was shown to be able to produce results of acceptable accuracy and was also developed such that run-time was sufficiently short to enable multiple scenarios to be investigated.

4 RISK ASSESSMENT

The risk assessment methodology was applied to the catchment as per Appendix K of Proposed Change 2 to the Bay of Plenty Regional Policy statement. The methodology was augmented slightly by applying it to a wide range of return periods from 10% Annual Exceedance Probability (AEP) to 0.2% AEP to enable an understanding of the 'risk curve' (Figure 2.1) for the catchment and find the event of maximum risk. Two rainfall cases were analysed: the present day case (2015 rainfall) and a future case adjusted for climate change (2115 rainfall).

4.1 DEFINITION OF HAZARD SUSCEPTIBILITY AREA (HSA)

The Hazard Susceptibility Area (HSA) is defined as the maximum spatial extent of a particular hazard. For flooding in the Waimapu catchment this has been taken as the extent of flooding where flood depths exceed 0.1 m in response to a 500 year event with future rainfall (adjusted for 2115 climate change) and existing landcover. The 'noise' in the model results was reduced by deleting any areas of the HSA that did not exceed two grids in size (50 m^2). The extent of the HSA is shown in blue in Figure 4.1.

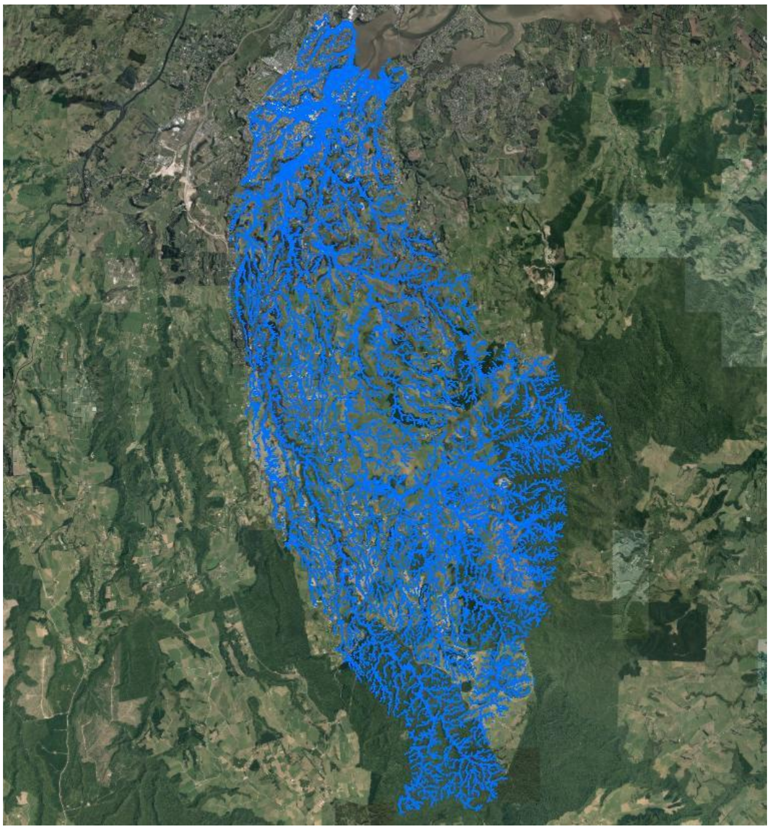


Figure 4.1: Hazard Susceptibility Area for Waimapu Catchment

A check was done for areas where anticipated flow velocity was high but at small depth, with such areas potentially needing to be included in the HSA. Experimental data as reported in Australian Rainfall and Runoff (2010) indicates that little data exist for areas where depth is less than 100mm and that flow velocity would need to exceed 3.5 m/s for the hazard at depth below 200mm to be considered more than minor. No areas were encountered where such conditions exist in the Waimapu catchment, and so the HSA was not modified taking this into account.

Once the extent of the HSA was identified the buildings that were partially or fully within the HSA were identified and categorised as either critical buildings (fire stations, police stations, hospitals, medical centres, civil defence centres etc.), buildings of social or cultural significance (educational facilities, places of worship, museums, marae, libraries etc.) or miscellaneous buildings (residential, commercial, industrial and all other buildings). A sample of the HSA is shown in Figure 4.2 in which the different building types are identified (green for miscellaneous buildings, yellow for social/cultural buildings and red for critical buildings).

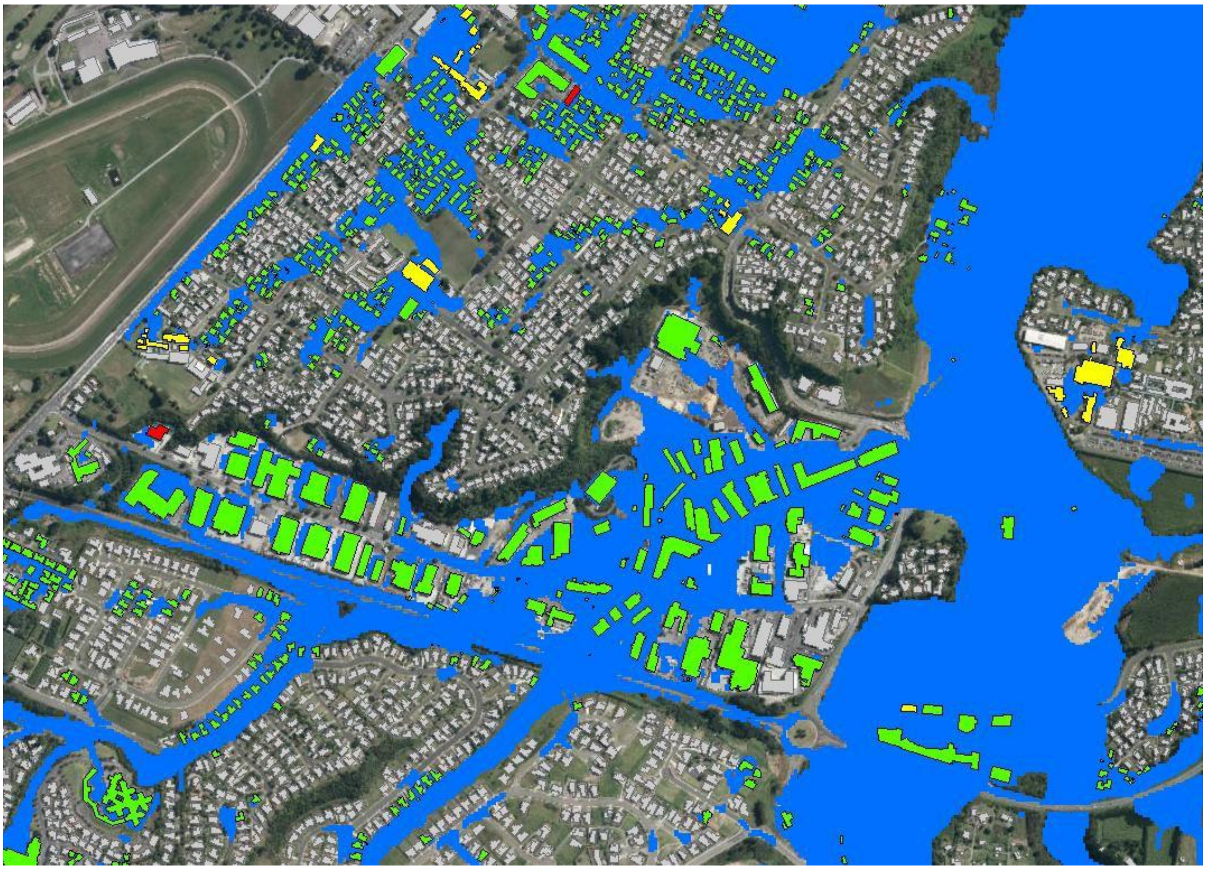


Figure 4.2: Sample Hazard Susceptibility Area with Building Types

4.2 DEFINITION OF "FUNCTIONALLY COMPROMISED"

When the analysis was first undertaken, it was assumed that any predicted flooding, 100 mm or deeper, at the footprint of a building would result in the building being "functionally compromised". The result of the risk assessment using this approach was that for all events considered (from 0.2% to 10% AEP), the catchment consequence level as per the RPS assessment methodology emerged as "*catastrophic*". This was thought to be unreasonable, so further sensitivity analysis was carried out. A similar result was obtained when the threshold depth at a building footprint was raised from 100 to 200 mm. However, a more pragmatic result emerged when the threshold depth was raised to 500 mm, meaning that for this assessment, the definition of "functionally compromised" in reference to a building is that when the predicted depth of flooding at the building footprint equals or exceeds 500 mm. Clearly, having detail of actual floor levels of all buildings would aid greatly with this, but in the Waimapu catchment this information is not readily available.

The definition of "functionally compromised" in a flooding context is difficult to define. Some studies indicate that building damage is incurred when flooding to below floor level occurs (ie underside of bearers), and other studies indicate that damage is initiated when flood level rises to above floor level. Foundation type clearly is a factor in determination of whether or not inundation to floor level occurs. Functionality may also be seen to be compromised when flooding prevents access to a building, without damage necessarily occurring to the building itself. Therefore, in the absence of further detail, this broad assumption of "functionally compromised" being taken to mean "predicted flood depth at a building footprint of 500mm or more" has been adopted.

It is noted that it may be appropriate to have different depth thresholds for different building types before functionality is compromised. For example, it may be inconsequential if access to a single storey detached building (e.g. garage) is lost due to a flooded access road during a flood, but the same would not be true of a civil defence or other critical building.

4.3 QUANTITATIVE ANALYSIS OF CONSEQUENCE

A quantitative analysis of consequence was undertaken for each return period by counting buildings within the flood extent for the three respective categories (miscellaneous, social/cultural and critical). Consequence levels were assigned based on the percentage of buildings within the HSA that were functionally compromised and the guidance in Table 7 of the RPS (reproduced in Figure 2.3). The results from the quantitative analysis building effects for the present day case are summarised in Table 4.1 and Figure 4.3 below.

Table 4.1: Functionally compromised building count for different events: 2015 rainfall scenario

	10yr 2015		20yr 2015		50yr 2015		100yr 2015		500yr 2015	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Misc buildings	135	6.3%	186	8.7%	290	13.5%	377	17.6%	517	24.1%
Social/cultural buildings	2	5.7%	6	17.1%	8	22.9%	9	25.7%	9	25.7%
Critical buildings	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

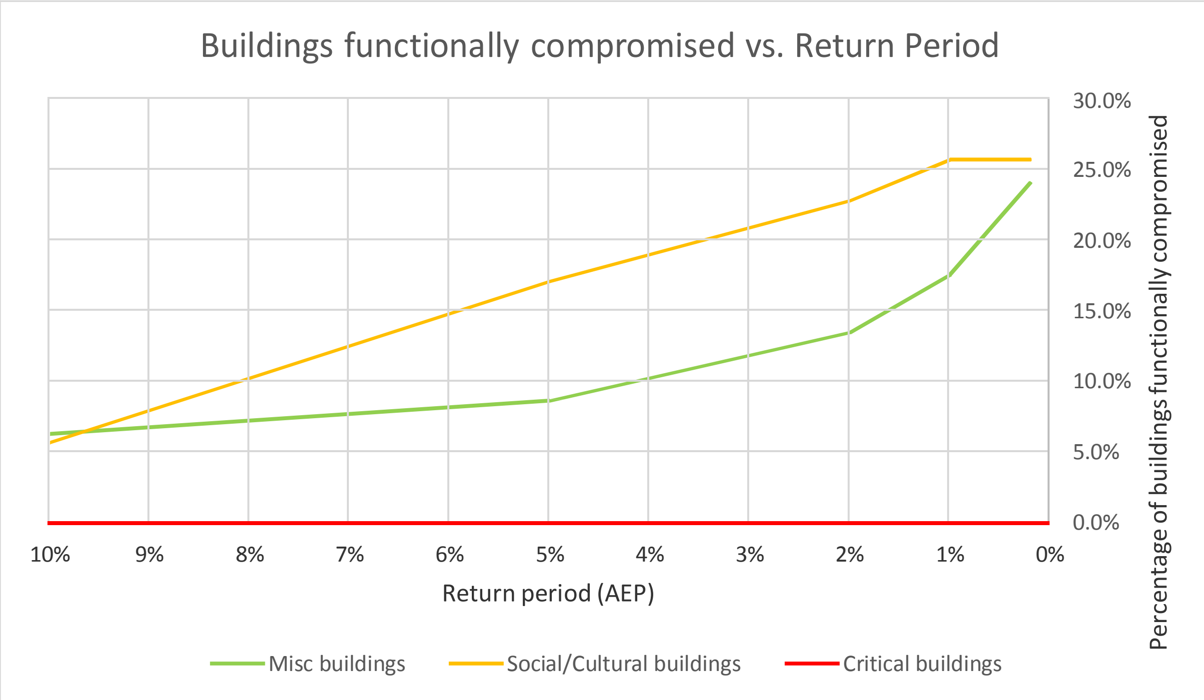
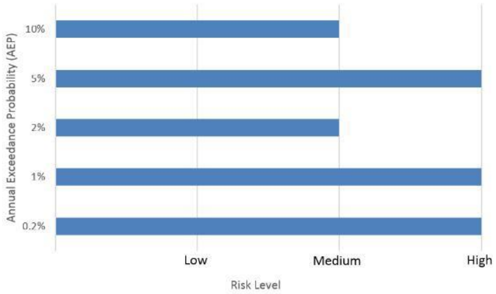


Figure 4.3: Percentage of Buildings with Compromised Functionality for different events (2015 rainfall)

4.4 RESULTS OF RISK ASSESSMENT

Risk levels were assigned for each of the return periods based on the consequence level and risk screening matrix given in Appendix K (reproduced in Figure 2.2) of the Bay of Plenty RPS. The results for the 2015 rainfall are shown in the table below.

Exceedance Probability (AEP)	**Risk level 2015***
10%	Medium
5%	High
2%	Medium
1%	High
0.2%	High

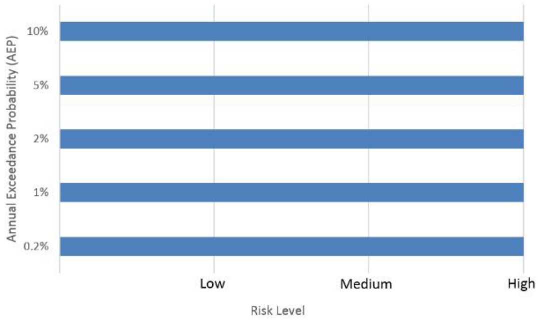


*Assumes that the critical consequence level is derived from the effect on buildings (lifeline utilities and deaths/injuries not assessed)

The results for the 2015 rainfall case do not show a 'curved' pattern, or anything similar to that anticipated in the RPS (Figure 2.1). Inspection of the consequence levels for each return period show that the consequence is *minor* for the 10% AEP event, *major* for the 5% and 2% AEP events and *catastrophic* for the 1% and 0.2% AEP events. The decrease in risk level from the 5% event to the 2% event is due to the consequence remaining the same but the likelihood decreasing. This pattern where no single event stands out as the event of maximum risk according to the Appendix K methodology could easily occur and will depend on the catchment characteristics and the layout of the risk screening matrix.

The sensitivity of these results were assessed by repeating the process with the future climate. The results for 2115 scenario are shown in the table below.

Exceedance Probability (AEP)	Risk level 2115*
10%	High
5%	High
2%	High
1%	High
0.2%	High



These results show the risk level as being the maximum classification of high for all events. Therefore no event of maximum risk is distinguishable. It also shows how, without any future building or development in the catchment, climate change alone could increase the existing risk profile.

5 RESULTS INTERPRETATION

The results of the risk screening undertaken indicate the Waimapu catchment, in its current state, to be exposed to a *high* flood risk. This is the highest category, and it could therefore be argued that, no matter what future catchment development occurs, the risk can never increase (ie it cannot be increased beyond “high”). This result is unhelpful to the purposes set out in the introduction to this paper, where a catchment management approach is sought whereby cross-boundary issues can be agreed and addressed.

A separate investigation was undertaken, where a series of different land use changes were considered, with the effects on resulting floodable area (not a count of functionally compromised buildings) being considered. In order to isolate the cross boundary effects, a series of model runs were undertaken where there is no rainfall considered to occur outside of the Tauranga City boundary. In this way, no upstream catchment management could be held responsible for flooding that was predicted to occur. A sample of these results is shown in Figure 5.1.

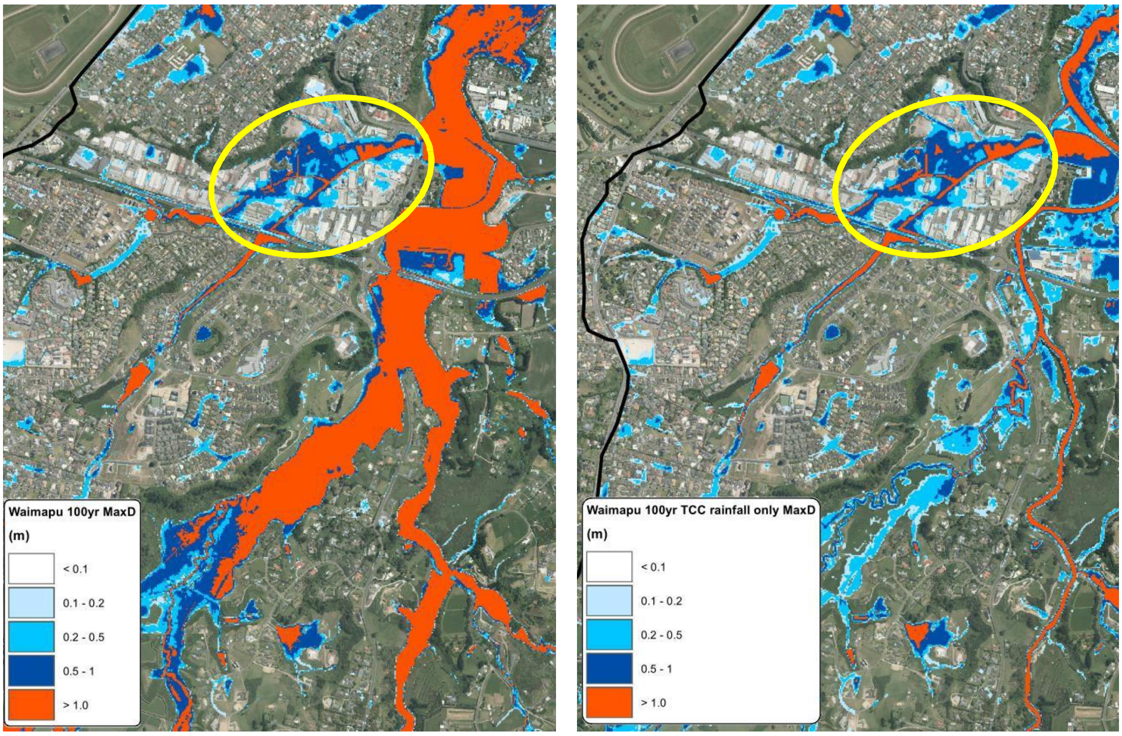


Figure 5.1: Comparison of results for spatially varied rainfall

In the above figure it can be seen that much of the industrial area within the catchment (within yellow circles) is subject to flooding by rainfall only, without any contribution from the upstream catchment within the Western Bay of Plenty District.

Further analyses were conducted, with changes to land use in the upper catchment being considered. A sample result from these analyses is where forestry land use in the upper catchment was changed to pasture. The resultant effect on peak flood depth in a design event was considered in the area of interest. In Figure 5.2 two plots are presented for the following scenarios:

- All pasture in the catchment converted to forestry: investigate change to peak flood depth
- All forestry in catchment converted to pasture: investigate change to peak flood depth.

A change from forestry to pasture would be expected to have an effect of increased flood discharge due to lower losses and increased flow rate from the surface (lower roughness). These were expected to result in increased peak flood depth in the lower catchment. Conversely, a land use change where all pasture is converted to forestry was expected to have the reverse effect.

The results are shown in Figure 5.2. Evident from these is while the change to all forestry does result in lower peak flood levels, this effect does not extend to within the principal area of concern (yellow circles in Figure 5.1). The change to all pasture does cause a small negative effect in the area of concern in that tailwater level is slightly raised. However, overall the effects of upper catchment land use change are relatively modest in the area of specific interest.

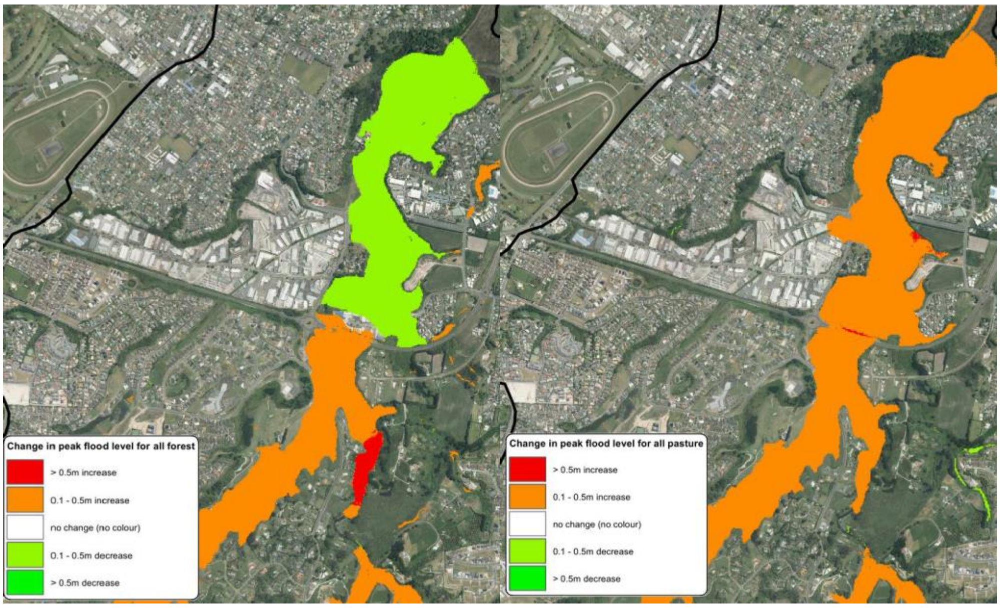


Figure 5.2: Effects of land use change

A wide range of additional analyses were carried out, in investigation of the perceived "cross boundary" effects. In general these resulted in small changes being exhibited to peak flood level, depth and velocity-depth product in the Tauranga City area. A separate investigation has also been carried out to assess the likely silt yield from the catchment, and whether or not a reduction in silt load could be achieved through changes in land use.

6 CONCLUSIONS

The results of this assessment can be summarized as follows:

- Flood risk in the catchment is "high" for the status quo. Sensitivity assessment of the input parameters to this analysis has still resulted in flood risk being regarded as "high". No change to land use was found to be able to reduce the risk.
- Upper catchment land use change cannot improve flood risk in the lower catchment.
- Upper catchment land use change has minimal effect on worsening lower catchment flood risk.
- Most flood issues are locally generated.
- Local scale options (as opposed to catchment-wide options) are most appropriate for addressing flood risk.