

Memo

To:	Kim Smith	Job No:	1018677
From:	Mark Pennington	Date:	29 July 2022
Subject:	Flood hazard provisions		

1 Introduction

This memorandum has been prepared to assist Rotorua Lakes Council (RLC) with flooding elements of Plan Change 11 to the Rotorua District Plan, this being the Housing Plan Change. This memorandum covers two topics, these being:

- Impervious surfaces, in particular how control of these can assist in management of the impact of housing intensification on flooding
- Setting a flood depth threshold above which control (resource consent or other) of development in flood-prone areas is necessary.

In a separate document, prepared by Tonkin + Taylor (T+T), the results of a flood risk assessment covering urban Rotorua are set out.

2 Impervious areas

2.1 Definition

An impervious surface is one through which infiltration of surface wetness to the ground is unable to occur due to the surface covering being impermeable. Examples include roads, roofs and hardstand areas which are typically associated with urban land use. When an otherwise pervious area is developed to include an increase in impervious surfaces, the rainfall-runoff response from that area is changed. These changes can result in adverse flood effects.

2.2 Effect of increased impervious areas on runoff response

The formation of impervious area over previously pervious area generally involves several changes to the way surface runoff is generated in response to rainfall. Often these changes involve removal of vegetation to create slopes of uniform grade (no puddles) from smooth impervious material (asphalt, concrete, etc). With impervious surfaces covering underlying material, rainfall no longer has the ability to infiltrate into the soil and must either pond or flow off the surface. This will generally increase the total amount of rainfall that is able to become runoff (by reducing infiltration) and will often speed up the response of the catchment (i.e. flow from the catchment will rise more quickly if covered in impervious surface when compared to pervious surface). In Figure 1 a schematised response from an example catchment to increases in impervious cover is shown. Generally, the following effects are expected given a higher the percentage of impervious cover for a given catchment:

- Higher peak runoff rate;
- Larger total runoff volume;

- Shorter time from the start of rainfall to the peak runoff.

The above factors are often contributors to surface flooding. In most cases, increasing percentage impervious in a catchment increases the likelihood of downstream flooding.

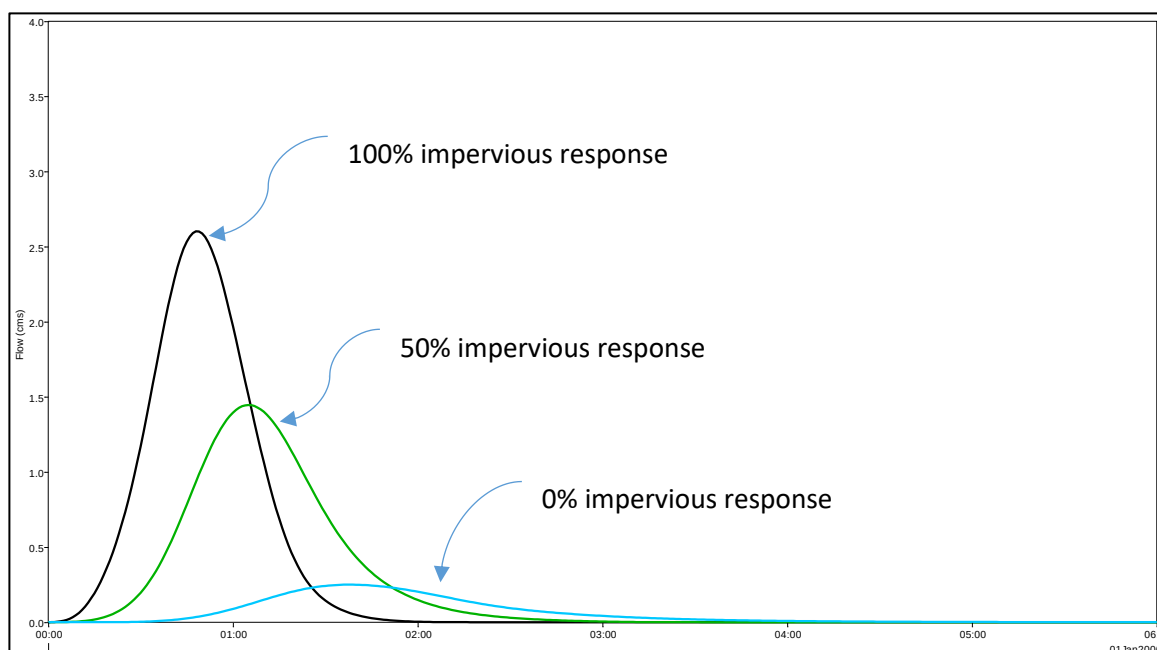


Figure 1: Typical response from a catchment with differing impervious coverage

The effect that changing from pervious to impervious has on catchment response is not uniform across Rotorua. In areas where the undisturbed ground is of high permeability, there would need to be a large rainfall event for surface runoff to occur. Conversely, in areas where surface soils are relatively impermeable, these areas act as impervious surfaces following saturation.

Thus, the surface soil type has an influence on the magnitude of effect caused by an increase in impervious surface coverage. The increase in runoff as a result of an increase in impervious area is based on the difference in rainfall/runoff response between the unmodified and modified surfaces.

2.3 Percentage of impervious cover

In undeveloped areas the percentage of impervious area is usually close to zero, with the only impervious areas being roads and buildings at low density coverage. Once areas have become developed (urbanised), a greater portion of the total area becomes covered in impervious surfaces. For example, CBD areas, comprised largely of roads, car parks and buildings, are comprised of higher percentages of impervious area than residential areas.

Impervious coverage in a catchment is often referenced as a percentage of total area that is covered in impervious surface. By definition this takes account of lot size, as opposed to seeking an impervious area measurement. For example, a 1,000 m² lot with 500 m² of impervious area is shown to be 50% impervious, whereas a 500 m² lot with 500 m² of impervious coverage (i.e. the same impervious area) is shown to be 100% impervious.

Typical percentage impervious in urban areas is around 50-60%. In Figure 2 accurately measured impervious area of 5 different areas are shown alongside aerial photographs of each area. Type 1, shown as 84.2% impervious, is a heavily urbanised area with little “green” surface coverage. Type 3 shows a developing area, with a mix of developed and undeveloped areas and an overall average percentage impervious of 25.7%.

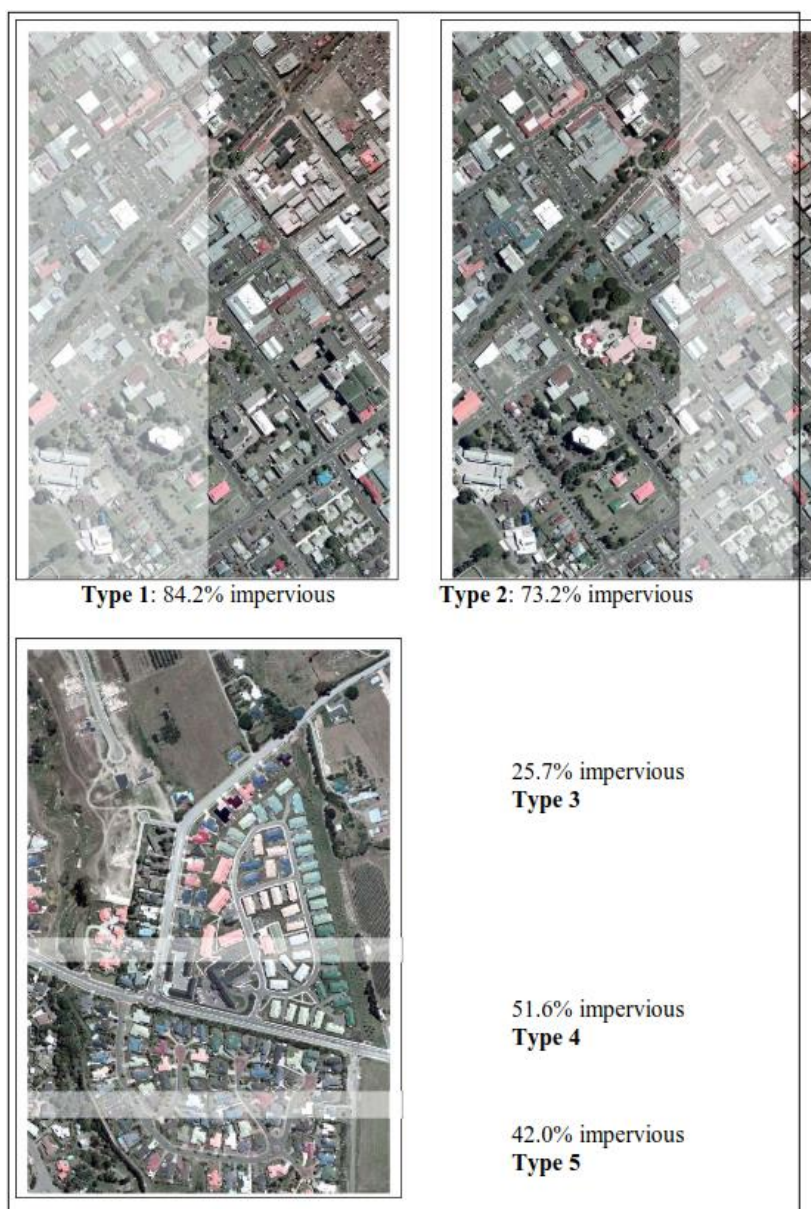


Figure 2: Measured impervious area percentages

2.4 Existing impervious area controls in Rotorua

Under the existing District Plan rules, it is possible to develop Residential 1 zones to a maximum of 80% impervious, and Residential 2 zones to a maximum of 100% impervious. In most cases, the existing development is to lesser degrees than these maxima. The current flood situation in Rotorua has been analysed based on the maximum allowable development.

It is understood that, in facilitation of urban growth initiatives, intensification of urban zones in Rotorua is being considered. On its own, intensification may worsen the existing flood situation. However, if the permitted maxima for impervious surface coverage are able to be reduced from the 80% / 100% allowances described above, then this would somewhat offset the increases that would accompany intensification.

2.5 The need for impervious surface control

Given demands for housing, future increased density of development is required. While flooding areas can be identified under current District Plan zone rules, potential flood impact as a result of development can be reduced if maximum development thresholds are reduced while still allowing for increased development.

In Figure 3 a schematic section of an urban catchment is shown. In this it can be seen that land use outside of existing flooding areas can contribute to flooding within flooding areas. Should additional surface runoff be generated (through increased impervious coverage) and conveyed (downhill) to existing flooding areas, it is possible that increases in flood hazard will be experienced.

Furthermore, conveyance of increased volumes of surface runoff can lead to exacerbated flood safety issues, related to flow rates, velocities and flood depths.

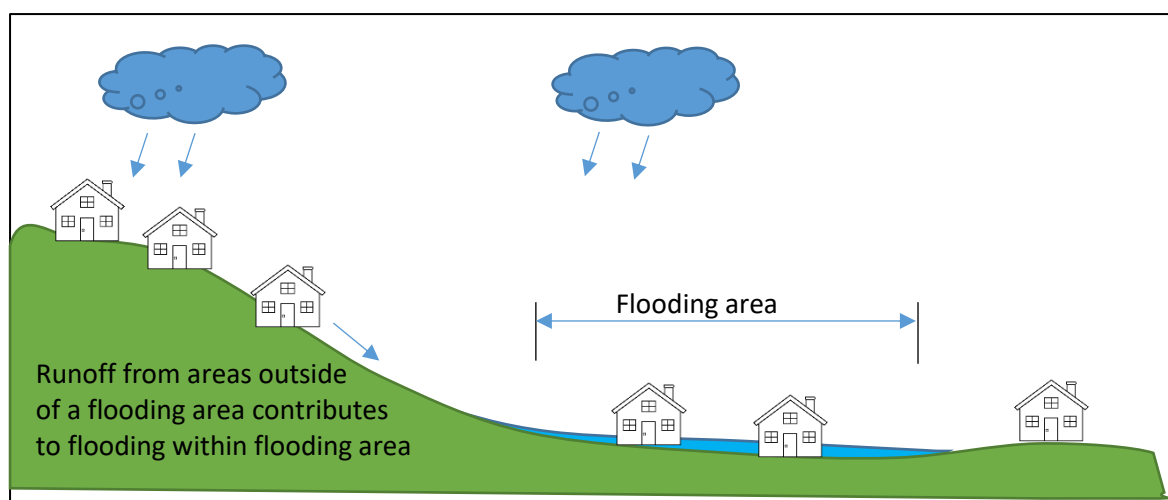
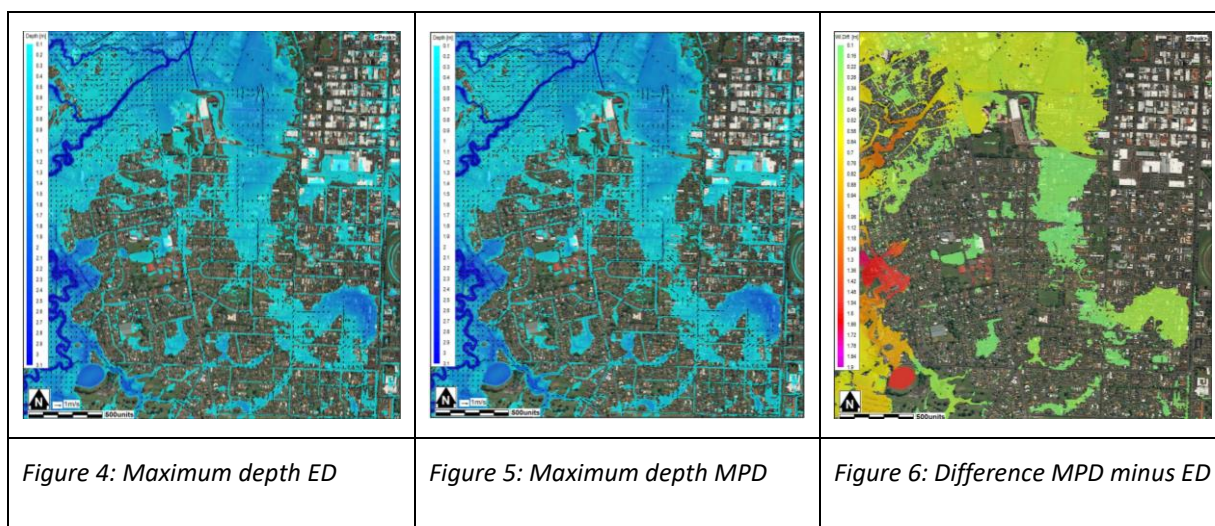


Figure 3: Catchment section – schematic

The effects identified above have been shown to be real through application of city-wide flood modelling and mapping undertaken by RLC. Ways to reduce the potential for exacerbated downstream flooding resulting from development include placing limits on the amount of impervious area that can be developed in the urban areas. This will have the effect of ensuring that there is a limit on total runoff volume likely to be conveyed to downstream flooding areas.

In Figure 4 the maximum modelled flood depths for a specified event (in this case, 100-year ARI 2130 design rainfall event) using an estimate of the existing percentage impervious (ED) have been plotted for a sample area in Rotorua. In Figure 5 the maximum depths resulting from simulation of the same event, but using Maximum Probable Development (MPD) percentages of impervious area consistent with the current rules are shown. The effect of the change in percentage of impervious is shown in Figure 6, which shows the difference in peak flood level between the two scenarios (MPD minus ED).

While the exact ED and MPD spatial variation of flooding is likely to vary spatially, the above demonstrates the type of effect that can be incurred purely from a change (in this case an increase) in impervious area. Figure 6 shows peak flood level increases in a future climate 100-year ARI event as being a possible consequence of unmitigated increases in impervious area.



2.6 Maximum permitted impervious cover

Reducing the maximum impervious cover is one method that the Council can use to reduce the impact of intensification on flood hazard and on flood risk. This can be used alongside other stormwater interventions to reduce the impact on flood levels, as well as methods to reduce the consequences of flooding on developments (restrictions in areas prone to flooding) and will assist to reduce the scale of these other interventions.

Flood modelling for Rotorua should include an allowance for residential site imperviousness to increase to the levels permitted in the District Plan. In this way the future expected flooded areas can be mapped, enabling implementation of associated District Plan rules to manage risk and activities within areas predicted to be prone to flooding.

3 Flood depth thresholds

A key consideration with intensification is the protection of property while allowing development to occur.

3.1 Accuracy and uncertainty

In most cases, urban flood predictions are made using hydrological and hydraulic models. These models generally have computation precision of tens of millimetres in terms of flood level prediction. That is, such models generally cannot be considered accurate to millimetre precision.

A typical input to a hydraulic model is a Digital Elevation Model (DEM), which represents the bare ground surface in a way that can be read by the hydraulic computation engine. In CGD (2014) reference is made to the accuracy of LiDAR datasets, and of the resulting accuracy of Digital Elevation Models (DEM's) that are derived from LiDAR surveys. This report indicates that, for many LiDAR surveys carried out, resulting DEM's have a stated vertical accuracy of about +/- 150mm.

Using the DEM as an input to the hydraulic model, the modelled flood level results carry a similar degree of vertical accuracy. Thus any flooding predicted by a model that is less than 150mm in depth may be a DEM artefact instead of being necessarily "real".

Because of the above, it is generally not possible to predict flooding (in terms of depth and extent) to millimetre precision. Therefore, a depth threshold is required above which flooding is considered to be "real" (it should not be a zero depth threshold).

In many flood hazard guidance documents the concept of “freeboard” is employed, to deal with uncertainty in matching predicted flooding with actual flooding.

3.2 Default Building Offsets

Most buildings are constructed with floor that is raised somewhat above surrounding ground level. This vertical offset is usually no less than 150 mm to meet requirements of the NZBC . That is, in most cases the floor level of a building is at least 150mm above the level of the surrounding ground.

3.3 Impact of floodplain filling

Syme (2011) demonstrated that there are thresholds below which development in the form of filling of the floodplain can have minimal effect. This threshold can be driven by flood level/depth or by some other parameter, such as the depth-velocity product. For example, if an area is filled where there is 1 mm of predicted flooding, the effect is likely to be negligible. The same is unlikely to be true if the areas to be filled would otherwise be prone to 1 m of flooding. The threshold at which the effect changes from insignificant to significant is of relevance.

3.4 Safety considerations

Urban floodplain management frequently involves consideration of overland flow paths. These overland flow paths are often defined by considering safety to people, and for this maximum depth x velocity product of flood model results has relevance. An example is shown below, taken from Australian Rainfall and Runoff. In this it is shown that $DxV < 0.4 \text{ m}^2/\text{s}$ presents low hazard to adults and children.

$DV \cdot (\text{m}^2\text{s}^{-1})$	Infants, small children (H.M. ≤ 25) and frail/older persons	Children (H.M. = 25 to 50)	Adults (H.M. > 50)
0	Safe	Safe	Safe
0 – 0.4	Extreme Hazard; Dangerous to all	Low Hazard ¹	Low Hazard ¹
0.4 – 0.6		Significant Hazard; Dangerous to most	
0.6 – 0.8		Extreme Hazard; Dangerous to all	Moderate Hazard; Dangerous to some ²
0.8 – 1.2			Significant Hazard; Dangerous to most ³
> 1.2			Extreme Hazard; Dangerous to all

Figure 7: Safety criteria (from Australian Rainfall and Runoff)

Instead of the above, safety concerns can also be addressed through consideration of depth or velocity as stand-alone variables. This is shown in Figure 8. For example, from this figure it can be seen that flood depth in excess of 1.2 m is considered high hazard for all people, regardless of velocity. Similarly, velocity in excess of 3 m/s is considered unsafe regardless of depth.

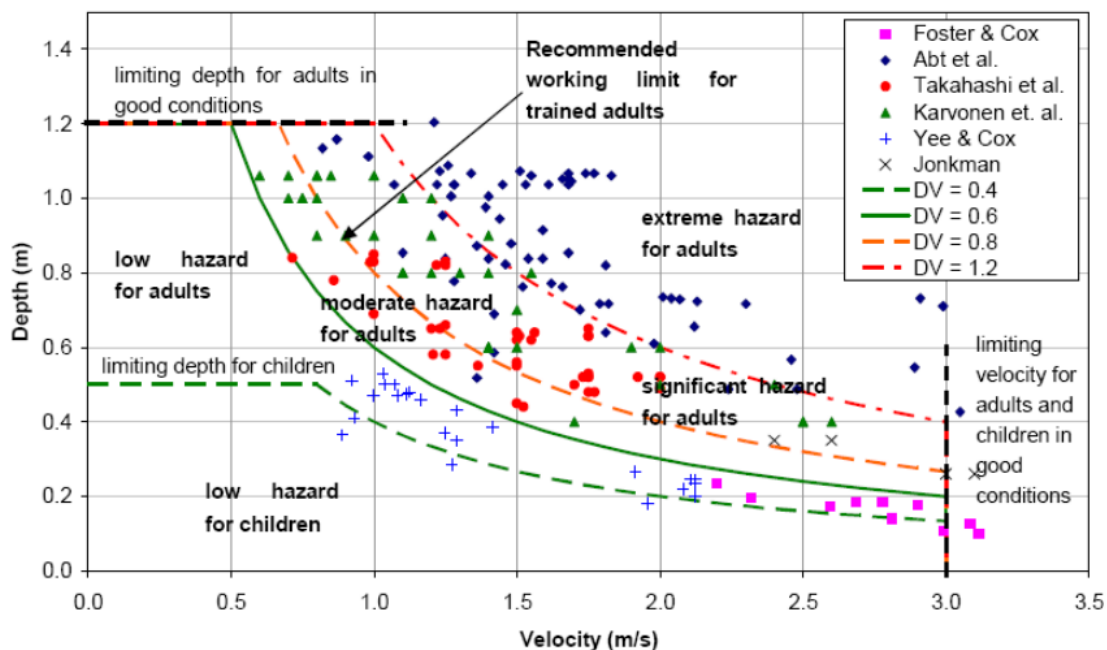


Figure 8: Safety criteria in urban flooding (Australian Rainfall and Runoff)

A flood depth of 300 mm is generally of low hazard, until velocity exceeds about 1.4 m/s based on the guidance given in Australian Rainfall and Runoff.

3.5 Protection of property from flooding effects

As indicated above, it is difficult to predict flood levels to millimetre precision and a pragmatic threshold is required to control this effect. Selection of this threshold is arbitrary. For example, flood extents have been plotted in Figure 9 to two different depth thresholds: 100 mm and 300 mm. In most cases, flood extents from direct rainfall models are not plotted with depth threshold of less than 100 mm (i.e. only areas that are modelled to flood to a depth of at least 100 mm are shown to be subject to the flood hazard). What can be seen in Figure 9 is that areas of major flooding are captured by both the 100mm and 300mm mapping thresholds, while peripheral flooding areas are only represented with the lower 100mm threshold for flood mapping. If this mapping threshold were further reduced, the resulting flood extent would increase.

In Figure 9 the areas coloured orange show flood depth >300 mm, while areas in green show areas where maximum depth is between 100 mm and 300 mm.

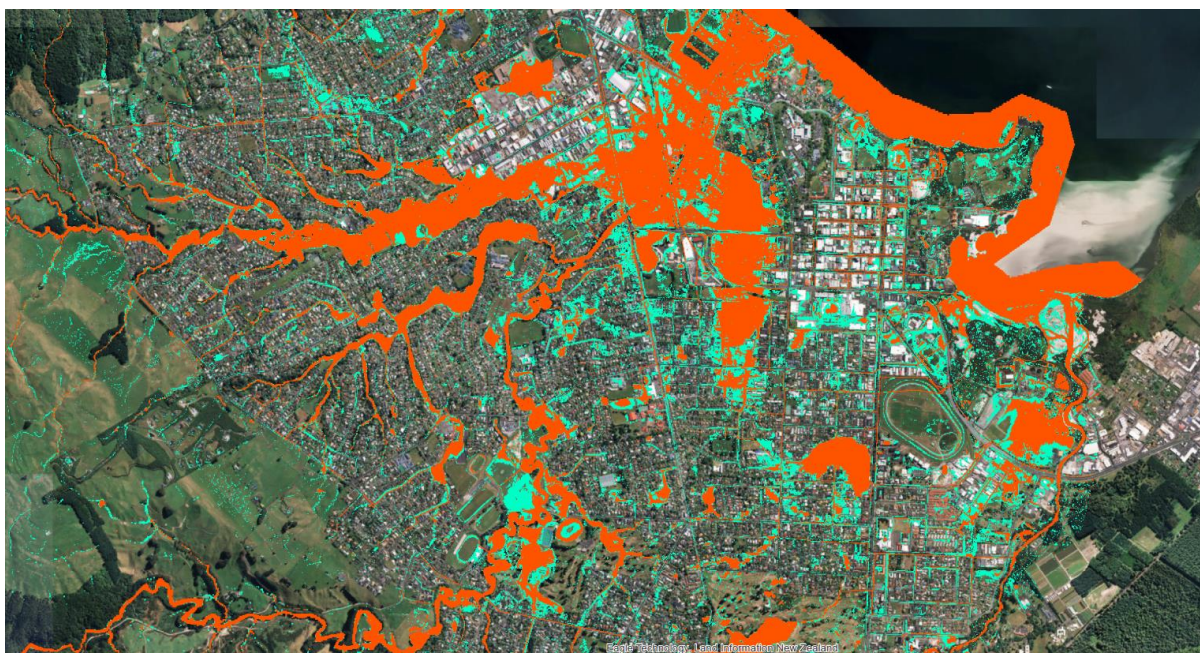


Figure 9: Mapped flood extent >100 mm depth in green, >300 mm depth in orange

3.6 Protection of the conveyance function of the urban drainage network

In Figure 10 the same flood extents as shown in Figure 9 are shown, but overlaid with an overland flow path threshold of $0.4 \text{ m}^2/\text{s}$. What this shows is if the flood hazard is mapped to a 300 mm threshold depth, this includes all overland flow paths (shown as areas where $dxv > 0.4 \text{ m}^2/\text{s}$) in the mapped area.

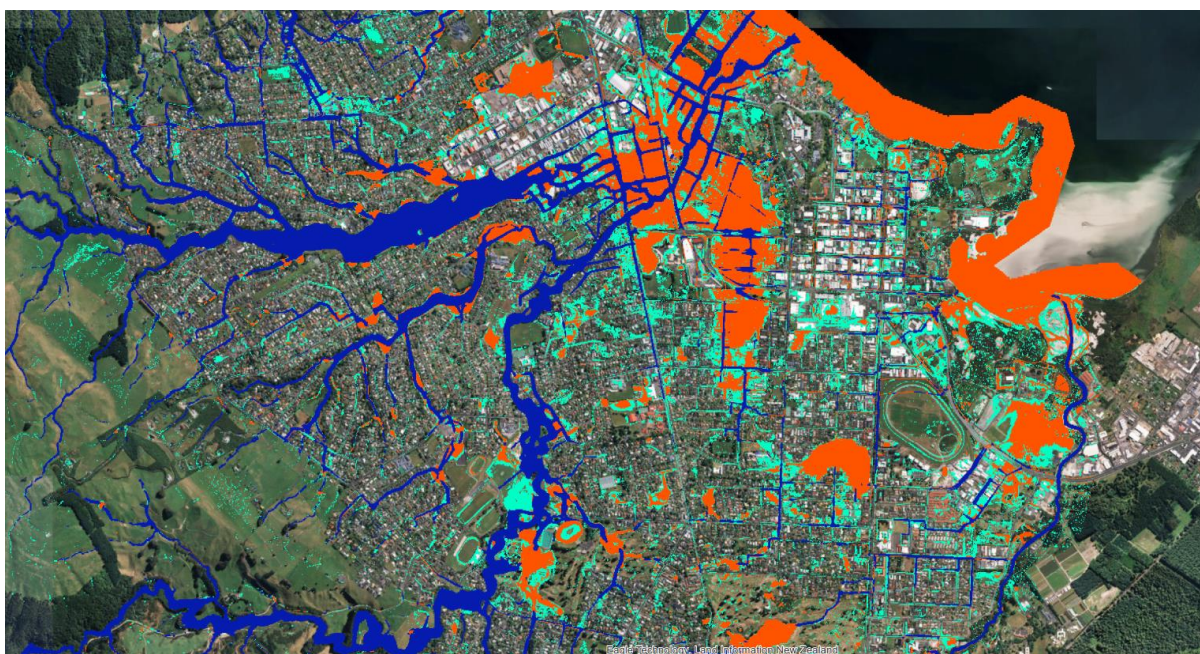


Figure 10: Mapped flood extent >100 mm depth in blue, >300 mm depth in orange and $dxv > 0.4 \text{ m}^2/\text{s}$ in dark blue

3.7 Summary

The arguments presented above have indicated the need for some non-zero flood depth threshold below which a lesser degree of building control is warranted. Control (such as a requirement for resource consent) is needed for areas where flood hazard is deemed significant either to the subject site or to adjacent or hydraulically connected sites. A threshold of 300mm has been suggested (and has been adopted elsewhere in NZ).

The discussion above has shown that a 300mm flood depth threshold (in a 1%AEP event with climate change) provides a reasonable trigger for requiring resource consent for buildings.

A schematic section for the proposed rule framework is shown in Figure 11.

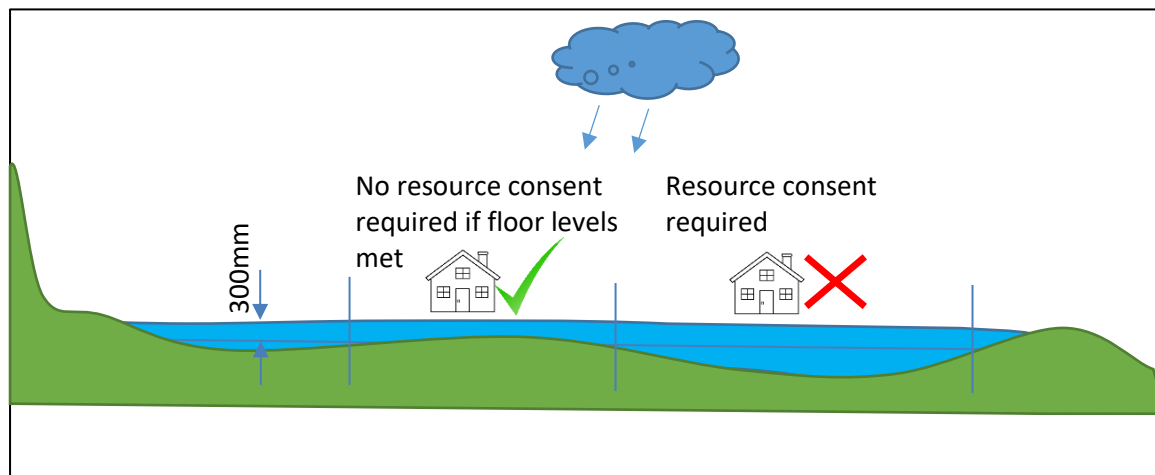


Figure 11: Catchment section – schematic rule framework

Adoption of the 300 mm depth threshold for resource consent effectively relieves the requirement for resource consent in areas where maximum flood depth is less than 300 mm is predicted, provided minimum floor level standards are met. Whereas buildings in areas with flood depths greater than 300mm would be assessed against policies and objectives with respect to:

- Considering whether the location is suitable and whether options available to mitigate the hazard
- Avoiding impacts on other property and infrastructure
- Assessing whether safe evacuation routes or refuge during flood events is provided
- Maintaining the function and storage capacity of overland flowpaths and river corridors.

This rule framework is explained as a first step in the improvement of the provisions for managing flooding, focusing on the protection of buildings with the intensification of an urban area subject to flooding. A further flooding plan change alongside mapping of overland flowpaths and river corridors is expected to further address:

- The protection of overland flowpaths from structures and earthworks
- Potentially, providing additional provisions to address social and cultural buildings in areas that flood.

4 Conclusion

This memorandum has covered two specific topics, these being the percentage of impervious coverage allowed in urban residential catchments in Rotorua and the flood depth threshold for

application of rules in the District Plan. Conclusions resulting are summarised in the bullet points below.

- Reducing maximum impervious standards would assist to manage the impact of intensification on flood risk.
- A flood depth threshold is required for application of the proposed rule framework. The absolute threshold is somewhat arbitrary, and a depth of 300mm in a 1%AEP event with climate change provides a reasonable threshold for requiring resource consent for buildings.

5 References

CGD (2014), Canterbury Geotechnical Database Technical Specification 03, *“Verification of LiDAR acquired before and after the Canterbury Earthquake Sequence”*, April 2014.

Syme (2011), *Mapping of floodways and floodplain development zones using 2D models*, Water New Zealand 7th South Pacific Stormwater Conference, 2011.

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