URBAN WAVES: SECONDARY FLOW CONTROL CHALLENGES AND RESPONSES IN HAMILTON

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ABSTRACT

The predicted increased intensity and frequency of significant storm events, combined with drives for increased intensification of the existing built-up areas, means adequate freeboard and effective secondary flowpaths are going to be critical to avoid unnecessary costs and hardship associated with urban flooding. This paper reviews Hamilton City's progress with the challenges associated with establishing and protecting secondary flowpaths over recent years from the legal, engineering, and consenting perspectives. The results of new flood hazard assessment are discussed as is how Council is incorporating this information into the Proposed District Plan. As the hazard plots cover over half of the City, this has involved some detailed consideration of appropriate responses. A related topic of setting acceptable freeboards for floor levels adjacent to flood areas is also explored considering the Building Code and New Zealand Standard 4404:2010 documents both offer an arbitrary 0.5m freeboard for habitable floors. An alternative approach based on modeling the hazard as represented by the catchment area, depth and speed of flow is presented. The paper will benefit local government representatives and be of interest to a wide spectrum of the industry.

KEYWORDS

freeboard, natural hazards, flood risk, easements, local government, building code, NZS4404:2010

1 INTRODUCTION

Reviewing the on-the ground impact of the subdivisional and building codes in relation to secondary flowpaths and freeboard has lead Hamilton City Council (HCC) to change the developmental code and conditions of resource consent. Inclusion of higher freeboard requirements in development requirements led to some resistance from the local development industry. Consequently after some consultation, calculation and review, a revised, risk based freeboard proposal was developed.

Further related work has been done for the preparation of the Draft District Plan and the revised Development Manual (that will be known as the Infrastructure Technical Specification (ITS)). The paper is a summary of the progress to date and remaining challenges. The content is focused on residential situations due to the discussion of interaction with relevant provisions of the Building Code.

2 HISTORICAL ISSUES AND RESPONSES

2.1 LEGACY FLOW PATHS

The soils around Hamilton are predominately alluvial deposits from the Waikato River, these are supplemented by large areas of peat and volcanic ash. The result is soils with highly variable, but generally sufficient soakage characteristics to handle low density development. Consequently, the city developed with soakage and open drain networks. River flooding was common until the dams where installed. Away from the river, surface flooding increased in proportion with the intensity of development until a major program of works was undertaken in the late 1970's and through the 1980s. This resolved most of the problem sites, particularly in the CBD. From around this time, roads in new developments have been recessed to provide the secondary overland flowpath.

Most of the city is now reticulated to deal with the 2 year Average Recurrence Interval (ARI) storm. However, in the older residential areas of the city, the pipe network was not able to avoid all of the legacy issues and recent LiDAR based modeling has provided clear visual evidence of where overland flow crosses property boundaries away from (but on its way to) the River and established gully networks as shown in Figure 1

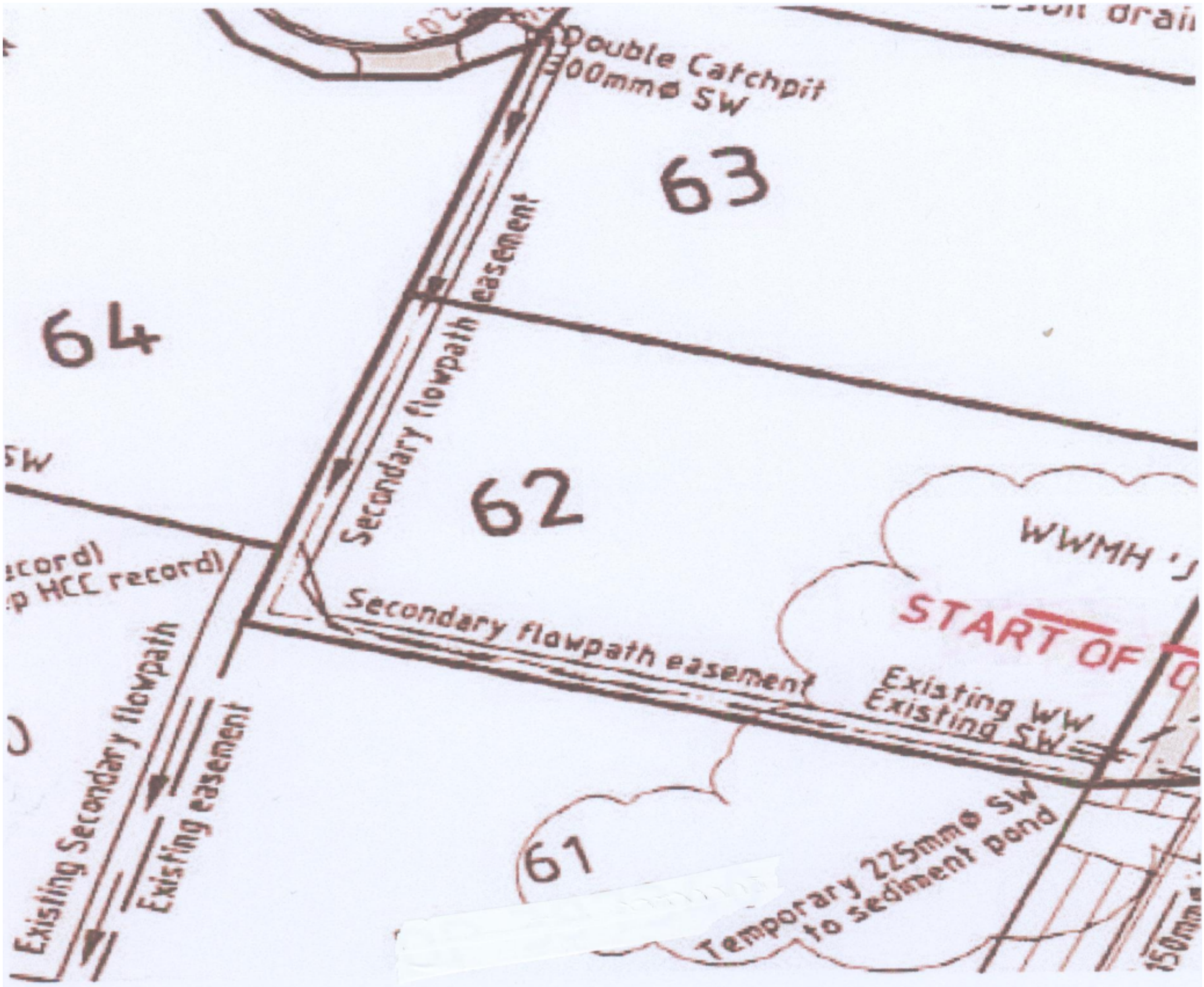
Figure 1: Example of legacy overland flow path

2.2 FAILED EASEMENTS

The requirement to provide for secondary flow has been embedded in standard conditions of resource consent for subdivisions for many years. However, the standard wording, which required the consent holder to establish an easement that "prevented alteration of the flowpath", was not effective. The wording that ended up on the title only locked in the right to discharge and did not forbid interference of the function. The example shown in Photograph 1 shows an ignored easement. In Stage 1 of this subdivision, a flowpath easement was identified and yet, by the time the developer came to do the uphill stage, they realised that the previous provision was not going to work. The owner had installed a retaining wall, leveled their property and undertaken other landscaping that would have the effect of directing water to their back door rather than down the easement to the street frontage. Figure 2 shows the "solution" where the developer created a right-angle easement on Lot 62 to redirect the stormwater around the corner to another street. This is but one of many examples of ineffective easements throughout the city.

Photograph 1: Example of ignored easement

Figure 2: The right angle flowpath easement



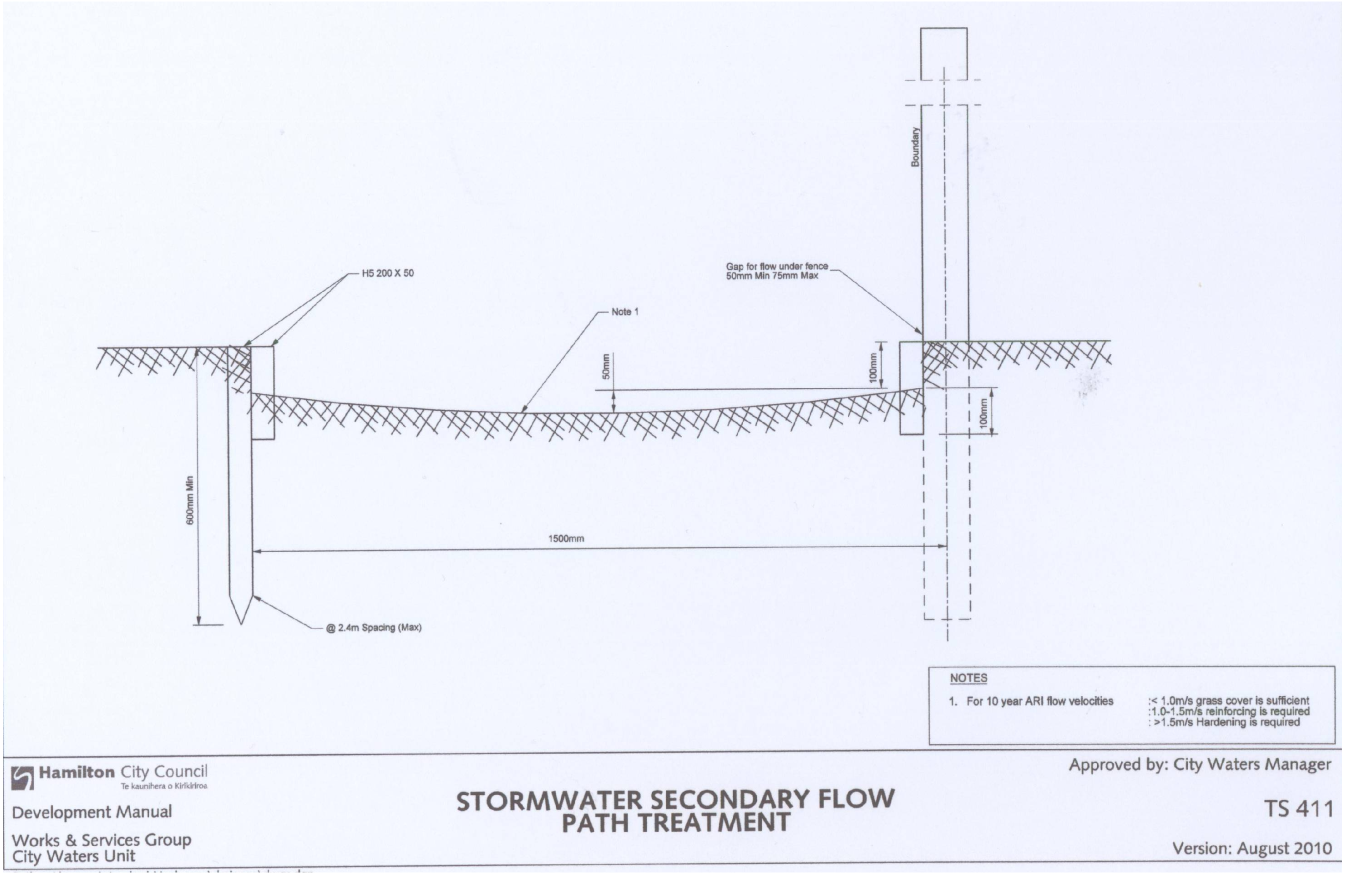
2.3 FLOW PATH RESPONSES

In an attempt to resolve this issue, Council has created a simpler easement condition but added another Resource Management Act s221 Consent Notice requirement to maintain the function of the flowpath. The notice is related to a condition requiring "management of stormwater for the whole development" which is the permanent obligation that justifies the use of a consent notice.

The second key change in response to failed easements was to make the flowpath construction more obvious. This seeks to address the observation that many builders and owners act as if they are unaware of the flowpath easement and function particularly after "someone" has filled the area in with dirt, garden clippings etc.

The Development Manual was changed to include the requirements shown in Figure 3

Figure 3: Example of more obvious overland flowpath



This change was not well received by the development industry and legal threats were made based on loss of sale value. However the effective counter arguments were to point out that Council's role is to seek to protect properties from inundation; in perpetuity, and that the developers where able to decide how the overland flowpaths interacted with their development.

The subsequent positive response is that developers and their agents are now much more concerned with secondary flow management and usually keep it to roads and Local Purpose Reserves – Access; that join cul-de-sacs to other roads.

2.4 EARLY FREEBOARD INITIATIVES

The HCC Development Manual has had a long standing requirement to provide for overland flow for 50 year ARI storm events and consider blockage of key culverts within the development and freeboard, in the context of the 100 year ARI storm.

Whilst this requirement has served well in general, there was uncertainty in application between 50 and 100 year events and the application of the culvert blockage aspect. This was resolved by requiring designs to cater for 1 in 100 year ARI storm secondary flows "whilst maintaining at least 0.5m freeboard to building platforms on upstream property". This change was implemented before the new version of NZS 4404:2010 (4404) provided for the freeboard to building platform or underfloor levels (see Section 3.2 below).

The adoption of the Council requirement combined with the new NZS standard highlighted a range of challenges for the development industry including issues associated with:

- Calculation of appropriate flood levels;
- Impact of finished contours and associate earthworks costs;
- Transferring the requirement to the future owners/builders via Consent Notice or Covenant; and
- Infill developments failing to meet the requirement.

Each of these points is discussed briefly below.

2.4.1 FLOOD LEVEL CALCULATIONS

As HCC has not yet determined comprehensive city wide flood levels, individual site determination is required. Whilst consultants are available to undertake the flood level calculations, the local development industry has not been used to including this work in their proposals for infill redevelopment and hence resisted, citing the time and cost impacts.

2.4.2 EARTHWORKS IMPACTS

The earthworks impacts of freeboard requirements are potentially compounded by keeping overland flow paths within roads rather than private property. Consequently in a 100year ARI event, most roads will have more than 100mm of flow down the channel. This effectively means all houses adjacent to a road need to have a floor level 500+mm above the kerb. Looking at this in cross-section terms for a typical urban section with 3m set back behind a 4.5m berm there is 7.5m to rise 500mm i.e. by having a raised floor or by grading the surface at 1:15 or 6.7% which is a high grade for most of the city which has relatively flat terrain.

2.4.3 TRANSFERRING RESPONSIBILITY FOR BUILDING FREEBOARD

As 4404 provides for freeboard to be measured to building platform or the underside of the floor structure as applicable, industry feedback has indicated confusion as to what the standard reference point is. Experience has shown that once Council staff clarify the situation, the developers can determine the required floor level. Subsequently they decide whether they are going to raise the building platform to achieve the freeboard or simply pass the requirement on to the future owner/builder. The legal means to transfer the requirement has focussed on consent notices in Hamilton. However; covenants can also be used; each of which have their advantages and neither of which get read by some owners/builders.

2.4.4 INFILL REDEVELOPMENT FREEBOARD

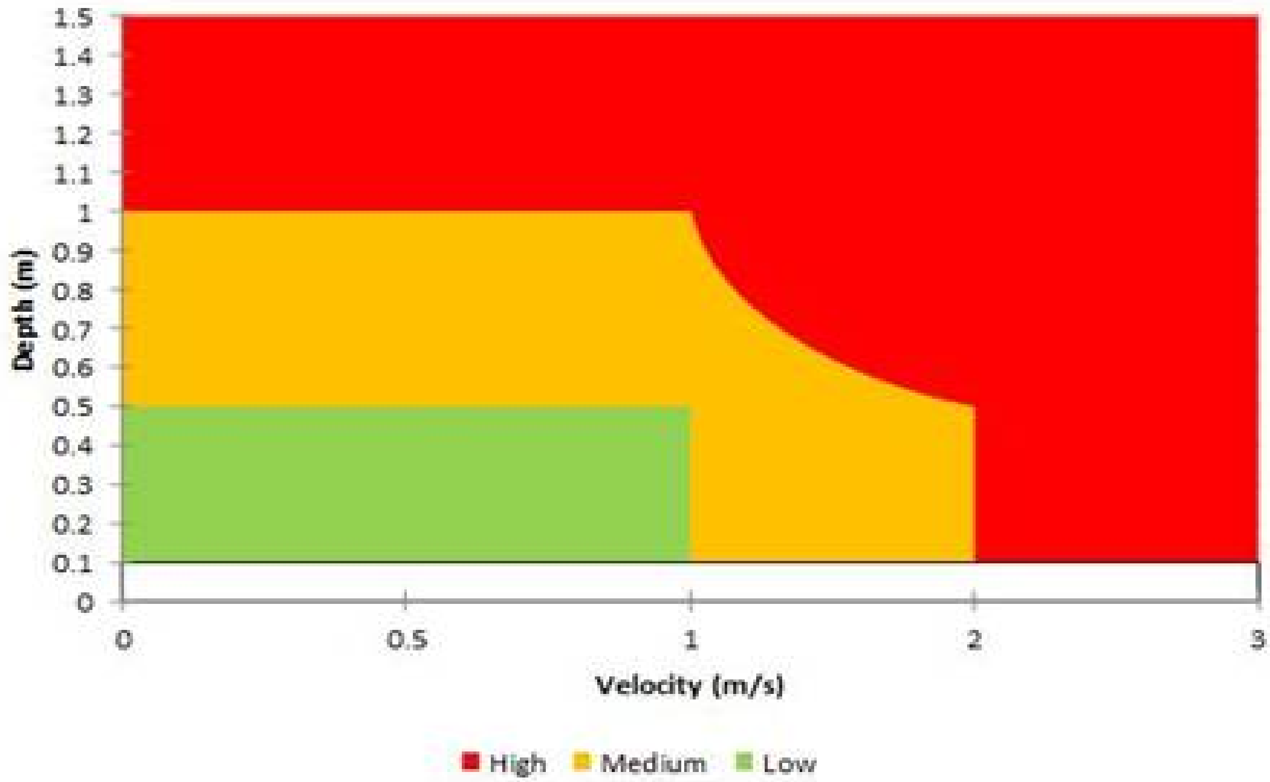
Both the current HCC Development Manual and 4404 require design for the 1% event for secondary flow for infill developments; however, the practical reality is that many cannot reasonably comply with freeboard, site coverage, setback and access requirements. In some cases notices on title under the Building Act S72-74 will be applicable. In many cases a reduced freeboard will be accepted as improved from the previous situation. Refer to http://www.qualityplanning.org.nz/plan-topics/natural-hazards/appendix-10.php for description of the application of these clauses.

3 NEW DISTRICT PLAN PROPOSALS

3.1 FLOOD HAZARD MATRIX

The District Plan Review has yet to be completed (notification expected in October 2012), however the final draft provisions include a response to the proposed Regional Policy Statement (RPS) issued by Waikato Regional Council (WRC) and acknowledge the 4404 lead on freeboard. The flood hazard areas used to identify areas subject to different policies and levels of control is based on the Flood Hazard Matrix shown in Figure 3. This matrix was developed based on local and international guidance. Locally Auckland, Christchurch and Dunedin approaches were reviewed (AECOM, 2012) and, whilst their matrixes are all different, the common themes have influenced the Hamilton matrix. International research from Australia, United States and Europe (in particular HUT, 2000) was also useful in setting the values.

Figure 3: Hamilton City Flood Hazard Matrix



The combination of these influences was worked through with Council staff and consultants to arrive at the final thresholds. Briefly the threshold reasoning can be summarized as:

For the vertical depth access, 0.1metre (m) is less than the building code freeboard for residential buildings and is unlikely to cause anyone to be destabilized. 0.5m is a safety threshold depth for vulnerable persons and beyond all estimates of modeling uncertainty. 1.0 m depth threatens personal stability and is set as the High Risk threshold by WRC.

For the horizontal velocity axis, 1.0metre per second (m/s) is a limit considering vulnerable persons and fragile building elements and 2.0m/s is a warning velocity for all persons and general building elements and is set as the High Risk threshold by WRC.

The scoop on the boundary of the medium and high zones is based on the depth x the velocity being greater or less than $1.0m^2/s$.

3.2 DRAFT DISTRICT PLAN PROVISIONS

The proposal is that if the hazard mapping based on the Low-Medium-High areas of the matrix covers any part of a development site, then the freeboard requirements apply. Where the medium or high flood mapping covers the area of proposed works, then additional planning limitations would apply.

The current Draft District Plan standards relating to freeboard provisions are reproduced below. Note, the freeboard height table at b) and words in section c) are directly adopted from 4404.

“NEW BUILDINGS, REPLACEMENT OR REBUILDING OF EXISTING LAWFULLY ESTABLISHED BUILDINGS, AND ALTERATIONS OR ADDITIONS TO EXISTING BUILDINGS

a) Within any Flood Hazard Area sub-floor structures shall be designed so that they are open and allow the free passage of floodwaters in a 1% annual exceedance probability design storm to pass beneath so that floodwaters are not diverted or displaced onto any other site.

b) Within and Flood Hazard Area or on a site where part of that site is affected by a Flood Hazard Area the following minimum freeboard heights shall be complied with, which are additional to the top water flood level of the 1% annual exceedance probability design storm.

Building use	Minimum freeboard height
i) Residential buildings (including attached garages)	0.5m
ii) Commercial and industrial buildings	0.3m
iii) Non-habitable residential buildings and detached garages	0.2m

c) Minimum freeboard heights shall be measured from the top water level of the 1% annual exceedance probability design storm to whichever is applicable of the following:

i) Building platform level

i) The underside of the floor joists; or

ii) Underside of the floor slab.

d) Freeboard shall comply with the recommendations of any site-specific flood risk assessment report prepared in accordance with Information Requirements in XXX if this is different to that specified above.”

3.3 PROGRESS ON MODELLING COVERAGE

Two levels of modelling have been undertaken being Rapid Flood Assessment (RFA) and Detailed Flood Mapping. The RFA indicated that over half of the city was potentially subject to surface flooding. However, based on expert engineering and legal advice, this data was not deemed reliable enough to use as the basis of District Plan rules. To date, the detailed modelling required to support the District Plan is complete for less than 20% of the city. This coverage will expand as Integrated Catchment Management Plans are prepared for all city catchments.

4 NEW FREEBOARD IDEAS

4.1 BUILDING AND SUBDIVISION CODE FREEBOARD REQUIREMENTS

The New Zealand Building Code (NZBC) requires that the 2% annual probability (50 year) storm shall not enter housing and communal buildings. The Building Code *Compliance Document for the NZBC E1 – Surface Water* (E1) requirement Clause E1.3.2 is that, in the absence of more accurate data from the territorial authority (Clause 1.0.1) a freeboard of 500mm be provided to the “floor level” where the water depth is at least 100mm ***and*** extends between the building and road or common carpark that would allow a vehicle generated wave to reach the building (Clause 4.3.1). If one of these criteria do not apply then 150mm freeboard is all that is required, (the same as for low risk sites under Acceptable Solution E1/AS1).

NZS 4404:2010 Land Development and Subdivision Infrastructure Section 4.3.5.2 recommends freeboard be provided to the building platform or the underside of the floor structure. The freeboard shall be as specified in the District Plan ***or*** 0.5m above the computed 1% (100 year) Annual Exceedance Probability (AEP) Design Storm for habitable dwellings.

Thus two standards apply as shown in table 1:

Table 1: Freeboard Design Criteria

Design Criteria	**E1 standard**	**4404 standard**
Storm event	2%, 50 year	1%, 100 year
Residential Freeboard	0.5m	0.5m
Freeboard reference	floor level	ground or underfloor

Two issues related to freeboard

- The reference should be "Finished Floor Level" (FFL) as dealing with builders around Hamilton has indicated that this is the language they like to speak. Reasons for this include that FFL is shown on the approved plans, and is easy to check when seeking to have a Certificate of Code Compliance issued.
- The simplified rules presented in the codes fail a reality check based on scale as the same 0.5m freeboard applies for a cul-de-sac catchment of 12 houses that will generate only channel full flow as the Waikato River that will rise 7+metres.

The proposed Waikato Regional Policy Statement Policy 13.2 is seeking to avoid development within the 1% AEP floodplain and denotes high risk flooding criteria without addressing freeboard directly.

The differing standards and the vagueness around the components of freeboard suggested that more research is required in this area. Rouse (2011) reported a similar conclusion when summarising survey answers from "central government managers and regional council river managers" concerning research gaps and this includes: "Uncertainty analysis – combining uncertainties from different forecast models to understand any general rules for estimating freeboard etc"

4.2 CLARIFICATIONS OF FREEBOARD COMPONENTS

4.2.1 EXAMPLES

Whilst the proposed District Plan is conservative in adopting the new national standard values, my experience with developers suggests that this approach is not always cost-effective. Hence, further enquiry and understanding was justified. Whilst most local references to freeboard adopt 0.5m without explaining the components, the following examples are somewhat enlightening.

The 4404 freeboard definition allows for waves but also calculation and construction inaccuracies and localised effects in the flow channel (Clause 1.2.2). This definition highlights that the necessary freeboard can vary according to very localised effects in streams or flowpaths.

Harris (2003) reports that CCC (Christchurch City Council) "considers that the 11.7 m represents protection against a 1 in 50 year flood with the 0.4 m sea level rise, and **includes 0.3 m freeboard for wind and wave set up and a further 0.1 m safety margin**." Emphasis added.

Building Act determination 99/005 Porteous (1999)

"The 500 mm freeboard mentioned in the draft is made up of:
(i) **150 mm for uncertainties in determining flood level**. (Emphasis added)

That is considered a reasonable allowance for the general case of a 100 hectare catchment to which the draft is limited, and it is also considered appropriate for the much bigger [catchment concerned] on the basis that the Catchment Management Plan was no doubt the result of sophisticated modelling and calculation.
(ii) **350 mm for a wave generated by a vehicle. This in turn is made up of 200 mm wave height plus 150 mm run-up when the wave hits the building**. (Emphasis added)
A 200 mm wave will be sustained so long as there is a minimum 100 mm depth of water, and will travel a considerable distance. A reduction in the depth of 100 mm between the source and the building will cause the wave to break."

This determination refers to Building Act determination 98/003 Porteous (1998) which contains additional relevant quotes:

"4.2.2 That condition corresponds to a requirement in the territorial authority's 1991 "Watercourse Guidelines" to the effect that the estimated surface water level in the 1% storm shall be 500 mm below the underside of the floor joists. As the territorial authority said: Council has a regulatory role under the Building Act (Building Consents) and the Resource Management Act (Resource Consents). **In some instances methods of complying with both Acts may not coincide. Customers are unlikely to appreciate having their attention drawn at a later time to an aspect of non-coincident criteria. In this particular case the governing criteria for floor levels is Resource Management Act not Building Act (ie. 500 mm above 1% AEP level).",** (Emphasis added)
The Authority disagreed with this conclusion, the Building Act stands alone with regard to Building Consents and consent must be issued if the building complies. Hence Councils must use other mechanisms to enforce other standards regardless of the apparently contradictory messages that this will send to consent applicants.

"4.2.3 The applicant disputed that 500 mm freeboard, submitting an opinion from a consulting engineer that: In this situation, flow levels are relatively low and the flood is not in a confined valley situation. Consequently, 300 mm can be considered as adequate freeboard."
This argument was rejected by the Authority due to insufficient evidence, but this does emphasises the need for case by case determinations.

"The Authority considers that surface water does not enter a residential building until it reaches the floor level of the lowest habitable room in that building. In deciding whether water will enter a building, an appropriate allowance is to be made for:
(a) Any uncertainties in the estimate of the surface water level; and
(b) Possible wave-type effects from water flowing around obstacles, vehicular traffic, wind, and other causes. (emphasis added)
Such an allowance is generally referred to as a "freeboard"."

"The Authority has had occasion to consider the practice of selected territorial authorities in this regard. Their required freeboards vary from territorial authority to territorial authority with a range of 150 to 500 mm. The necessary freeboard might well depend on the particular circumstances of the case concerned, so that ***any particular freeboard used in practice by any particular territorial authority should be subject to appropriate modifications to suit the particular circumstances of the building concerned.*** "(Emphasis added)

4.2.2 KEY FREEBOARD MESSAGES

The suggested key messages extracted from these examples are:

- The combined effect of uncertainty, waves, run up, blockage, or debris can drive the need for significant freeboard to protect buildings from floodwaters entering floors.

- Modelling uncertainty yields a minimum of 150mm of freeboard

- Protection from waves action requires a minimum of 300mm freeboard.

- Case specific assessment of the risk is justified regardless of the generalised freeboard levels derived from modelling.

- The Building Code requirement for 500mm freeboard is mandatory if the adjacent road or carpark criterion is met, unless freeboard data is available from the territorial authority (to a level of robustness acceptable to the Building Industry Authority).

- Generally Council's must use other Acts to require a higher freeboard than the Building Act.

4.3 AN ALTERNATIVE APPROACH TO SETTING FREEBOARD

To help overcome some of the issues associated with freeboard as discussed above, an alternative approach to freeboard is being proposed in the ITS. This would the form guidance for the preparation of a "site-specific flood risk assessment report" as provided for in the Draft District Plan (refer Section 3.2 above).

The central component of the proposed approach is to undertake catchment specific freeboard determination based on risk factors of catchment size, secondary flow/ponding depth and velocity. The required freeboard to Finished Floor Level (FFL) for residential dwellings, communal buildings and attached garages would be the highest value determined from Tables 2-4. Note a value of 175mm has been adopted for floor thickness to simply the application.

For greenfield developments, developers will provide the relevant modelling as part of their engineering plans. For infill developments Council will supply flood velocity and depth information (as it becomes available) to avoid excessive design cost for developers.

4.3.1 TABLE USAGE

The required freeboard to FFL for each Habitable Dwellings and attached garages is the highest value determined from tables 2-4 or at least 500mm where 100mm of flooding extends to the building as detailed in E1.

Commercial and industrial building FFL may be 200mm lower, non-habitable residential buildings and detached garages may be 300mm lower but in no case shall any building FFL be located lower that the calculated flood level plus 175mm.

Tables 3 and 4 include more steps than the hazard matrix in relation to depth and velocity to reflect the growing risks, however, the impact of known localised effects e.g. reduction in flow path cross-section or rapid changes of flow direction should also be considered in the final selection of an appropriate freeboard.

4.3.2 COSTS AND BENEFITS

For greenfield areas, developers in Hamilton are already required to show overland flow paths and flooding depths so the additional work required to use tables 2-4 is generally expected to be compensated by the reduced direct or indirect cost of compliance with the lower freeboard.

For infill developments, where Council has the depth and velocity data available, the process will usually deliver a net cost reduction. In other cases, most infill developers are expected to simply apply the proposed District Plan (i.e. 4404) standard rather than attempt the modeling path.

Table 2 - Upstream Catchment Area

ha	mm
0.5<	175
0.5	185
1	200
2	225
3	250
4	275
5	300
6	325
7	350
8	375
9	400
10	425
11	450
12	475
13	500
14	525
15	550
16	575
17	600
18	625
19	650
20+	675

Table 3 - Water Depth on site

mm	mm
<100	175
100-249	225
250-499	350
500-749	475
750-999	600
1000+	675

Table 4 – Flow Velocity on site

m/s	mm
<0.5	175
0.5-.99	300
1.0-1.49	425
1.5-1.99	550
2+	675

5 REMAINING ISSUES

Whilst improvement has been made or is in progress by HCC in relation to flowpaths and freeboard issues, the following challenges still need to be dealt with:

- long term preservation of flowpath function;
- retrofitting flowpaths and/or easements in established areas; and
- alignment of Building Act and engineering standards.

Each of these points is briefly discussed below.

5.1 PRESERVATION OF FLOWPATH FUNCTION

Whilst the measures to improve the legal and practical preservation of overland flow paths on private property have helped the situation, more work is required to make the solutions permanent. Currently, even the known flow paths on private property are not recorded on the Council GIS, nor is there any comprehensive schedule of where they are. Beyond the private flowpaths, some on Council property e.g. in parks will require regular inspection. Thus, identification is required as a first step and then allocation of the responsibility to inspect and organise reinstatement needs to be undertaken by Council. Additional measures such as inclusion of the role in the Council Level of Service document is also recommended to assist the perpetual vigilance required.

5.2 RETROFITTING THE BUILT ENVIRONMENT

As highlighted in section 2.3 it requires ongoing vigilance from Council staff to successfully provide for flood protection in new areas. Not surprisingly, in existing developed areas it can be extremely difficult and expensive to attempt to retrofit or reinstate adequate flood protection. The following extracts from the Waikato Proposed Regional Policy Statement Explanation for Rule 13.2 outline part of the issue. "*The intention is to reduce the risks to the regional community from natural hazards, recognising that different tools and approaches are required and appropriate in different situations – for example, for greenfield sites versus developed sites"* and *"Because existing lawfully established activities have some protection under the Resource Management Act (section 10), there are limitations on how territorial authorities can manage existing development.*"

Whilst minor progress has been made in recent years on a case by case basis in response to resource consent applications for re-development, insignificant progress has been achieved by this approach. Hence, a more targeted response is required and as the detailed mapping is completed across the city, the scope of the problem will be clarified. As cost implications are likely to be significant, a risk based prioritisation process will be required.

In some cases, increasing the size of the reticulated system and/or inlet capacity will be a cost effective way to address the problem and this will be part of the site by site analysis.

5.3 BUILDING ACT AND ENGINEERING STANDARD ALIGNMENT

The current mismatch of terminology, freeboard reference point and design storm between the engineering and building standards is very problematic for all parts of the industry as the following sections briefly discuss.

5.3.1 LEVEL TERMINOLOGY

The difference between the NZBC requirement for water not to enter the building and the engineering standard comparison to under the floor means in practice the levels are around 150mm different even through the same 0.5m freeboard is used. Explaining (or justifying) this different approach to industry stakeholders and residents is a difficult and unnecessary distraction from communicating the main precautionary message.

5.3.2 STORM FREQUENCY/PROBABILITY TERMINOLOGY

This paper deliberately demonstrates the frustrating and often confusing use of the two methods of defining design storms. Whilst AEP and ARI are often regarded as similar and reciprocal, this is not strictly true as they are different concepts. The information at NSCC, 2012 is a useful clarification of the key aspects and appropriate application. A national policy decision choosing one method would be beneficial for all stakeholders.

5.3.3 REFERENCE POINT

The writers of 4404 have attempted to cover the range of application options for existing and new situations (refer 3.2 (e) above). However; based on Hamilton practise, this would imply that the subdivision developer should build up building platforms to solve the freeboard risk. Locally, building platforms are often not tightly defined at subdivision stage, and therefore this could lead to excessive fill, with associated earthmoving and general environmental impacts. There is also the issue of efficient cost allocation where strict adoption of the 4404 guideline in this way does not give industry the option of passing the responsibility and flexibility to meet the freeboard to the future owner/builder.

5.3.4 DESIGN STORM

Council funded detailed mapping of the 2% AEP (50 year ARI) events is less likely to happen in the future as Councils are directed to consider the 100 Year/1% event by 4404 and the Ministry for the Environment guidance documents (MfE, 2010). Undertaking mapping for a specific project when the levels will generally be only slightly less than the 100year levels would seem to be an unnecessary expense.

6 CONCLUSIONS

This paper has briefly updated industry stakeholders on progress in Hamilton City regarding secondary flowpath management and freeboard determination and how these are proposed to be addressed in the new District Plan and Infrastructure Technical Specification.

Summary points are:

- Secondary flowpath management requires attention from Councils to require the provision and maintenance in perpetuity. Checking the effectiveness of consent conditions and on the ground works is recommended to ensure the intent is translated into reality.

- The current simplified approach to freeboard used by the codes reduces the cost of modeling but increases the cost of compliance through additional earthworks or building elevation to meet the level. Whilst this is appropriate for many areas, HCC being a relatively small and mostly urban or future urban jurisdiction can justify the cost of modeling. Hence HCC has invested in initial flood hazard modeling of the existing urban environment and will progressively produce maps for the entire city.

- The proposed alternative freeboard calculation method allows a risk-based assessment approach built upon modeling data to tailor the freeboard response to the specific catchment situation. As HCC will be able to provide developers with depth and velocity information for a progressively increasing number of infill developments, the cost of the new regime will be minimised. Developers still have the option to adopt the default District Plan (i.e. 4404) thresholds and will need to adopt the NZBC E1 freeboard as a minimum where appropriate.

- Alignment of the approaches taken in the 4404, NZBC and related national documents with regard to rainfall-runoff flow calculation and management and setting freeboard levels would be beneficial. Further work in this area is recommended for the benefit of all stakeholders.

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