

[REDACTED]

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From: Official Information  
Sent: Thursday, 20 April 2017 4:38 p.m.  
To: [REDACTED]  
Subject: LGOIMA 17/118 response - [REDACTED] - infrastructure  
Attachments: LGOIMA 17-118 response climate change.DOCX; Evidence in Chief (Council) - Mr Graham Harrington - Natural Hazards - 2....pdf

Dear [REDACTED]

Thank you for your email, received on 21 March 2017. You requested the following information, under the Local Government Official Information and Meetings Act 1987 (LGOIMA):

- "1. The most recent, up-to-date list of all Christchurch Council infrastructure that could/is expected to be affected by climate change in the future. Please include in a list the location of the infrastructure, what it is and how it could/would be affected.*
- 2. A copy of any reports, including drafts, and/or modelling prepared by officials in the past five years on how climate change will affect council infrastructure."*

#### Refinement of request

On 29 March 2017, you refined the scope of your request to the following:

*"I guess in regards to climate change the most tangible would be rising sea levels and what impact they could have. By infrastructure, I would be largely referring to council owned buildings, but if work had been done on say the impact on water/sewage systems etc then could extend to that as well."*

#### Release of information

Please find attached a response to your LGOIMA request, as well as a document referred to in the attached response: "Evidence to the District Plan Hearings".

You have the right to ask the Ombudsman to investigate and review our decision. Complaints can be sent by email to [info@ombudsman.parliament.nz](mailto:info@ombudsman.parliament.nz), by fax to (04) 471 2254, or by post to The Ombudsman, PO Box 10152, Wellington 6143.

#### Publication of responses to LGOIMA requests

Please note: our LGOIMA responses may be published on the Christchurch City Council website a month after they have been responded to, with requesters' personal details withheld. If you have any concerns about this please contact the Official Information team on [officialinformation@ccc.govt.nz](mailto:officialinformation@ccc.govt.nz).

Yours sincerely,

Anna Sinclair  
Public Information Adviser  
Office of the Chief Executive  
Christchurch City Council  
53 Hereford Street, Christchurch 8011  
PO Box 73016, Christchurch 8154

*With respect, I request the following information under the terms of the LGOIMA Act 1989:*

*1. The most recent, up-to-date list of all Christchurch Council infrastructure that could/is expected to be affected by climate change (refined to sea level rise) in the future. Please include in a list the location of the infrastructure, what it is and how it could/would be affected.*

The Council does not hold a list of all Christchurch Council infrastructure that could/is expected to be affected by climate change in the future. Therefore, we are refusing this part of your request under section 17(e) of the LGOIMA – the information requested does not exist or cannot be found.

*2. A copy of any reports, including drafts, and/or modelling prepared by officials in the past five years on how climate change will affect council infrastructure.*

Climate change information has been, and will be considered, along with the final planning provisions in the Christchurch Replacement District Plan, as the Council plans the maintenance, repair and rebuild of the Council's infrastructure and facilities across the city.

For example, information from the Coastal Hazard Assessment Report (2015) was factored into the planning, design and budget for the Sumner Community Facility and Library.

Council strategies and plans which consider climate change include:

- Infrastructure Strategy 2015-2045  
Report available at <https://ccc.govt.nz/search-results/?gsaQuery=Infrastructure+Strategy>
- The Proposed Christchurch Replacement District Plan  
Report available at <http://proposeddistrictplan1.ccc.govt.nz/>
- Climate Smart Strategy 2010-2025  
Report available at <https://ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/strategies/climate-smart-strategy/>

In the past five years, the Council has commissioned reports to help gain an understanding of the effects of climate change, including sea level rise and the increasing frequency and severity of weather events and their potential effects.

These reports include:

- Coastal Hazard Assessment Report (2015). This report is currently undergoing a second peer review. The revision is expected to be completed in May. Report available at <https://www.ccc.govt.nz/environment/land/coast/coastalhazards/technical-reports/>
- Effects of Sea Level Rise for Christchurch City (Tonkin & Taylor 2013) – available at the above link, under 'previous report'
- Evidence to the District Plan Hearings – Graham Harrington (attached, Refer sections 6.3, 6.4)
- Ōtākaro /Avon River Stormwater Management Plan. Report available at [http://files.ecan.govt.nz/public/consent-projects/ccc-stormwater/02\\_CRC160056\\_Application\\_Avon\\_Stormwater\\_Management\\_Plan.PDF](http://files.ecan.govt.nz/public/consent-projects/ccc-stormwater/02_CRC160056_Application_Avon_Stormwater_Management_Plan.PDF)

- Comprehensive Stormwater Network Discharge consent. Report available at: <https://ecan.govt.nz/do-it-online/resource-consents/notifications-and-submissions/current-consent-projects/christchurch-city-council-comprehensive-stormwater-network-discharge/>
- Estuary Tidal Barrier Pre-Feasibility Study. Report available at: <https://www.ccc.govt.nz/assets/Documents/Environment/Water/Tidal-Barrier/Avon-Heathcote-Estuary-Tidal-Barrier-Pre-Feasibility-Study.pdf>

### The Land Drainage Recovery Programme

In responding to the Canterbury Earthquake Sequence the Council initiated the Land Drainage Recovery Programme in 2012. This programme investigates and undertakes physical works to repair damage to waterways and address increases in flood risk across the city. Within this programme there are a large number of projects. Many of these projects have considered the impacts of climate change on the community and the wider stormwater / land drainage networks (through consideration of sea level rise resilience / adaptation or allowing for increased rainfall intensity in design capacity) in order to make informed decisions on infrastructure. The scale of the programme is significant and the number of reports available that, in part, consider the effects of climate change is extensive.

However, the Council's understanding of climate change impacts is still being enhanced through further investigation with projects currently underway looking at the long term future for flood management. Some of this work was triggered by a report to Council's Infrastructure, Transport and Environment Committee in July 2016:

[http://christchurch.infocouncil.biz/Open/2016/07/ITEC\\_20160712\\_AGN\\_519\\_AT\\_WEB.htm](http://christchurch.infocouncil.biz/Open/2016/07/ITEC_20160712_AGN_519_AT_WEB.htm) (Item 6).

**BEFORE THE CHRISTCHURCH REPLACEMENT  
DISTRICT PLAN INDEPENDENT HEARINGS PANEL**

**IN THE MATTER** of the Resource  
Management Act 1991  
and the Canterbury  
Earthquake (Christchurch  
Replacement District  
Plan) Order 2014

**AND**

**IN THE MATTER** of the Natural Hazards  
Proposal

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**STATEMENT OF EVIDENCE OF GRAHAM JAMES HARRINGTON  
ON BEHALF OF CHRISTCHURCH CITY COUNCIL**

**SURFACE WATER PLANNER**

**13 FEBRUARY 2015**

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## 1. INTRODUCTION

- 1.1 My full name is Graham James Harrington. I am the Senior Surface Water Planner in the Christchurch City Council's City Operations Group's Assets and Network Planning section.
- 1.2 My role involves overseeing the city's hydrometric network which involves monitoring of rainfall, surface water levels and groundwater levels. It also involves overseeing many of the river and catchment modelling projects which are mostly performed by consultants engaged by the Council.
- 1.3 I have worked for the Christchurch City Council (**Council**) for the last nine years. Prior to joining the Council I worked for 29 years with the Ministry of Agriculture, initially as a soil and water engineer and subsequently in a number of management positions within the Ministry. I have a Masters of Engineering with distinction from the University of Canterbury.
- 1.4 I have extensive experience in the development of management plans for stormwater and drainage issues in Christchurch. I have been closely involved in providing advice on flood management issues both before and after the Canterbury earthquakes. This has included modelling flood risks and designing regulatory responses to changing flood event conditions and risks.
- 1.5 I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2014 and that I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions that I express, and that this evidence is within my area of expertise, except where I state that I am relying on the evidence of another person.
- 1.6 I attended the facilitated caucusing of flood experts on 19 January 2015 and have signed the joint statement of the experts as a result.

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**1.7** The key documents I have used, or referred to, in forming my view while preparing this brief of evidence are listed below or appear in context in my evidence:

- (a) the Natural Hazards Proposal;
- (b) the section 32 evaluation report; and
- (c) the statements of evidence of Ms Iris Brookland, Mr Greg Whyte and Mr Mark Ivamy.

## **2. SCOPE**

**2.1** My evidence is on the flooding aspects of the Natural Hazards Proposal. I explain the flooding issues that exist in Christchurch, and provide some background to the flooding modelling in Christchurch and how the model results have been subject to a form of quality assurance.

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**2.2** I also respond to a number of submissions in my evidence.

## **3. EXECUTIVE SUMMARY**

**3.1** Christchurch plans to use the pRDP to give effect to Policy 11.3.2 of Canterbury Regional Policy Statement (**RPS**). It requires that development be avoided in areas subject to a 1/200 year return interval flood event however mitigation is permitted if there is no increased risk to life and provided the subdivision, use or development meets the other criteria set out in Policy 11.3.2, which includes a consideration as to whether it is likely that the property would suffer material damage in an inundation event .

**3.2** One commonly used form of mitigation is that the floor levels are set above the 1/200 year level and this has the result that the vulnerable dwelling floors are protected and the neighbourhoods are resilient and self reliant. In addition the pDRP will be used to identify flood ponding areas which should remain and act as natural detention basins which will keep flood peaks to a minimum in flood prone areas. High hazard

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areas will be identified in stage 2 of the pRDP. Developments or intensification of these areas will be restricted or avoided.

- 3.3** This evidence is an overview, however, along with the evidence of Ms Iris Brookland and Mr Greg Whyte, it describes the data and computer modelling methodologies and the interpretation of the model results which are used as the basis for the mapping of the zones subject to a 1/200 year return interval flood event and determining minimum floor levels for such zones. These zones in the pRDP are called the Floor Level and Fill Management Areas (**FLFMA**). The same models are used to determine the flood ponding areas and the high flooding hazard areas.

#### **4. BACKGROUND OF FLOODING IN CHRISTCHURCH**

- 4.1** The flat land which comprises most of Christchurch City is on the Waimakariri flood plain. The Canterbury Regional Council (Environment Canterbury) has built and maintains a flood defence system from the Waimakariri River consisting of primary and secondary stopbanks. That defence system has a high design performance standard of approximately 1/10,000 years. Therefore, the City Council does not plan in the District Plan for flooding from the Waimakariri River because it is regarded as a very remote possibility.
- 4.2** The main rivers in Christchurch – namely the Avon, Heathcote, Halswell and Styx – have a spring-fed base flow which arises from the aquifers underlying the floodplain. These rivers, which have relatively small surface water catchments, also respond to local rainfall in the Christchurch area, which from time to time causes flooding beyond the river and tributary channels.
- 4.3** Flooding in Christchurch is well documented in the History of the Drainage Board in its publication “Swamp to City” in 1989. The Drainage Board was established in 1875 and its functions were transferred to the Christchurch City Council in 1989. The initial focus of the Board was on sanitary sewers because the death rate from



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diseases such as typhoid, diphtheria and dysentery was the highest of any centre in New Zealand.

- 4.4** The publication documents flooding in the 1920s, 1945, 1963, 1968, 1974, 1975, 1976, 1977, 1978, 1979 and 1986. The events of the 1970s and 1986 led to the construction of the Woolston Cut in the Heathcote River and the Dudley Creek diversion. There have been subsequent significant rainfall events notably in 1992 (accompanied by snow) and also in 1994 and 1999. Between 1999 and 2012 was a benign period without significant storm events, however in 2012, 2013 and 2014 there were significant flooding events following the Canterbury Earthquakes.
- 4.5** The Council has done a number of modelling exercises to determine the effect of the earthquakes on the risk of flooding and it is clear that some areas are now at an increased risk and others have a lowered risk. From my analysis, it is also clear that the significant rainfall in early March 2014 would have produced flooding regardless of the earthquake effects.
- 4.6** The event in early March 2014 produced significant flooding in the Avon and Heathcote catchments. There was less flooding in the Styx and Halswell catchments because of the particular rainfall distribution in that event, which tapered off as you move away from the Port Hills.
- 4.7** The increase in flooding as a result of the earthquakes are most evident in areas close to the waterways where there is soft soil which settled and thus became more flood prone. The Ferrymead area was uplifted in the earthquake so it became less flood prone, however this uplift has changed the pattern of upstream flooding in the Ferry Road area.
- 4.8** The flooding in the developed areas of Christchurch is mostly relatively shallow and not particularly fast flowing. It can however, be very disruptive and rise above some existing floor levels, particularly in the older developed areas. Less attention was paid to the possibility of flooding when the older areas were initially developed.

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**4.9** Christchurch is low lying in relation to the sea so there are areas of Christchurch which can flood simply as a result of a high tide. The stopbanks in the lower Avon River were built to prevent tidal flooding in the area. Much of that area has now been red-zoned following the earthquakes.

**4.10** High tides also cause higher water levels further up the channels. These are called "backwater effects" and can lead to tidal related flooding at points higher than the actual tide level in the sea.

**4.11** Sea level rise is a significant issue for Christchurch. It directly adds to the level of the sea that is modelled and generates corresponding backwater effects. The Tonkin and Taylor report on the implications of sea level rise for Christchurch produced in August 2013 recommends that the Council should plan for the possibility of a 1.0m Sea Level Rise by 2115 and this is addressed in Mr Mark Ivamy's evidence for the Council.

**5. BACKGROUND OF FLOODING MODELLING AND MAPPING OF FLOOD MANAGEMENT AREAS IN THE OPERATIVE CITY PLAN**

**5.1** The Council began river computer modelling projects about 25 years ago when the technology became available to undertake such work and these models have grown in extent and sophistication over the years. Initially the models addressed flooding in the close vicinity of the rivers and more recently considerable detail has been added to the tributary areas.

**5.2** Now that the main channels have been modelled, the ongoing development consists of adding detail to the tributary catchment areas. Typically a project will be identified in a sub-catchment because of the need for new infrastructure – or in response to a particular flood event – and a small model of that area will be developed and tested. This small model will then be incorporated into the larger catchment model for future integrated flood investigations.

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- 5.3** The recent earthquakes have prompted an unprecedented use of the models to test the effects of the changes in topography resulting from the earthquakes – and this has also prompted more detail being added to the models so that particular aspects of interest can be further investigated.
- 5.4** The Council uses the DHI model software as its corporate standard but the main models have been managed by separate consultants for commercial and logistical reasons. The DHI model software is described in Greg Whyte's evidence. The Heathcote model has been managed by NIWA; the Avon model and Halswell models by DHI, and the Styx model by GHD. The smaller Sumner model has been managed in house by Ms Iris Brookland who is also giving evidence to this hearing.
- 5.5** The models are in a continuous state of development – with detail being provided in many cases by consultants other than those mentioned above. These additional consultants have developed many of the detailed sub-catchment models for subsequent incorporation into the main models. GHD was commissioned to develop a specification for the modelling to ensure that a consistent standard of model is produced. This is now being applied to all the models that are produced ("Stormwater Modelling Specification for Flood Studies" 2012). This includes directions on such things as: project planning, definition of model extents, review of existing data, model building and model performance assessment.
- 5.6** As the models continue to be developed it is important to understand the state of model development and the parameters used in the model which produced any given set of model results. GHD was also commissioned to produce a model status report format to document the model's form at any point in time. ("Stormwater Modelling Consolidation Model Status Report Summary" 2012). The procedure is to produce these status reports to accompany model results, when any particular important stage in model development is reached. We see this as being useful for tracking the development of the models as well as informing interested technical specialists about the parameters

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which were used so they can form a view on whether the model is suitable for their particular interests.

- 5.7** Variation 48 of the operative district plan introduced the concepts of the Flood Management Areas and the Flood Ponding Areas. These Flood Management Areas delineated in relatively well known flood risk areas and where there was suitable modelling information to map the extents. The models were less sophisticated and the ground surface information was less detailed than what we have today. They included an allowance for 0.5m sea level rise rather than the 1.0m sea level rise used by the modelling for the pRDP.
- 5.8** The Flood Ponding Areas were identified where significant natural ponding occurred which, if they no longer existed, would markedly increase flood peaks in developed areas of the catchment. A prime example of this is Hendersons basin which serves to limit the flood peaks in the Heathcote River

## **6. REVISED MODELLING THROUGH DISTRICT PLAN REVIEW**

- 6.1** The pRDP incorporates remapping of the revised extent of 1 in 200 year flooding. The computer based flood models used by Council engineers and consultants are explained in detail in Mr Greg Whyte's evidence and the delineation of the flood model results into Flood Level and Fill Management Areas (**FLFMA**) is explained in detail in Ms Iris Brookland's evidence.
- 6.2** I refer to their evidence and do not wish to repeat it, but for the necessary background to my evidence, the flood models that are relevant to the FLFMAs that are mapped in the pRDP, are:
- (a) the Avon Catchment Model and the Flockton Basin Model within the Avon Catchment area;
  - (b) the Styx Catchment model;
  - (c) the Heathcote Catchment Model and the Avoca Valley catchment model plus the Bells Creek model in the lower Heathcote;

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- (d) the Halswell catchment model;
  - (e) the Sumner catchment model; and
  - (f) the tide level in the tidal areas.

**6.3** The pRDP has adopted a 1.0m sea level rise for the purposes of setting floor levels for residential properties. Sea level rise needs to be used in calculations to determine the extent of the FLFMA in coastal areas and also to determine permitted minimum floor levels. This corresponds to a reasonable expectation of the 100 year life of modern residential buildings for which we routinely set design minimum floor levels.

**6.4** The modelling also considers the predicted increase in rainfall intensity as a result of climate change. The present rainfall intensities are increased by 16% for the purposes of setting design floor levels in accord with Ministry for the Environment guidelines (Tools for estimating the effects of Climate Change on Flood Flow. A guidance Manual for Local Government in New Zealand, 2010).

**6.5** Policy 11.3.2 of the RPS is set out in full below for ease of referene:

**Policy 11.3.2 – Avoid development in areas subject to inundation**

In areas not subject to Policy 11.3.1 that are subject to inundation by a 0.5% AEP flood event; any new subdivision, use and development (excluding critical infrastructure) shall be avoided unless there is no increased risk to life, and the subdivision, use or development:

- (1) is of a type that is not likely to suffer material damage in an inundation event; or
- (2) is ancillary or incidental to the main development; or
- (3) meets all of the following criteria:

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- (a) new buildings have an appropriate floor level above the 0.5% AEP design flood level; and
  - (b) hazardous substances will not be inundated during a 0.5% AEP flood event, provided that a higher standard of management of inundation hazard events may be adopted where local catchment conditions warrant (as determined by a cost/benefit assessment.)

When determining areas subject to inundation, climate change projections including sea level rise are to be taken into account.

- 6.6** The policy clearly requires that development be avoided in areas subject to flooding in a 1/200 year event, but mitigation is permissible where there is no increased risk to life, provided the subdivision, use or development meets the other aspects of Policy 11.3.2. It is unusual, and probably uneconomic, for local communal flood protection schemes to be designed to such a high standard. Therefore, area wide mitigation is not an appropriate solution to manage the flooding risk, and the approach adopted through the Natural Hazards Proposal is to ensure that new floor levels are designed to be above the 1/200 year flood event. Street flooding and flooding onto properties could occur during such an event, but the approach seeks to ensure that floors are protected as these are generally the most vulnerable assets on a floodplain.
- 6.7** The expectation is that flood mitigation schemes, such as proposed in Flockton Basin, will provide a reduction in street flooding in more frequent events but would be overwhelmed - or otherwise fail - in a 1/200 year event. For the same reason, the present stopbanks along the River Avon – or any future tidal protection systems - are assumed to have failed and the main protection is the level of the floors.

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- 6.8** It is not unusual to have higher than normal tide levels during a storm event as a result of low barometric pressure and storm surge effects. The modelling therefore incorporates these effects. The approach to modelling is to take the highest flood levels resulting from modelling a "1/200 year rainfall with a 1/20 year tide" and a "1/20 year rainfall with a 1/200 year tide". The rationale for this is that rainfall events are often accompanied by high tides, however it would be unduly conservative to assume a 1/200 year tide would coincide with a 1/200 year rainfall.

## **7. HYDROMETRIC DATA**

- 7.1** The Council has maintained and added to the hydrometric network which was established by the Christchurch Drainage Board. Data is also shared from the Regional Council (ECan) river level gauges. This network of 21 rain gauges and 25 river level gauges presently provide real time information at 15 minute (or less) intervals.
- 7.2** There is an almost continuous daily rainfall record for the Botanic Gardens dating back as far as 1873 – however it was not until 1962 that records of rainfall began at hourly intervals and this has progressively been reduced to sub-hourly recording. This provides Christchurch with a good basis for its rainfall statistics, which have been compiled by NIWA (Review of the frequency of high intensity rainfalls in Christchurch 2009)
- 7.3** Continuous water level and river flow gauging data began in about 1980 and additional sites were added in 1989. The statistics of the flood levels are therefore less well established than the rainfall statistics.
- 7.4** Tide levels have been analysed and statistics generated by Derek Goring (Mulgor Consulting Ltd – "Sea level Boundary conditions for Bridge St and Ferrymead" 2010 and "Extreme Sea Levels at Sumner Head and Styx River" 2008) based on recordings at the "Styx tidegates", "Sumner Head", "Avon at Bridge St" and "Heathcote at Ferrymead".

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**7.5** River cross-sections which were at locations established by the Christchurch Drainage Board have been re-surveyed following the earthquakes to provide a comparison of earthquake effects and to ensure that the present modelling is correct in the post-earthquake era.

**7.6** The topography in the earlier models was based on a 2003 LiDAR survey. Since the earthquakes began there have been five LiDAR partial or full surveys of the Christchurch area. The most recent of these surveys was a partial survey in February 2012. The models generally use the most recent topographical information available for that area.

## **8. PEER REVIEW**

**8.1** Various submitters have raised the question as to whether the models have been subject to peer review - presumably as a form of quality assurance that the results produced by the models are fit for purpose. I agree that a formal peer review could be helpful in identifying model shortcomings and suggesting improvements, however it is only one of a series of cross checks and balances that have already been applied to the models and the model results. These are listed below.

**8.2** Firstly, most of these models already have a long history of development, mostly in excess of 20 years. In this process, they have been managed by a series of professional modellers who have had the opportunity, and the need, to investigate the model for the purposes of the time, and also calibrate and verify the model against recorded storms. As part of the standard management of the models, they have also performed "sanity" checks at point of particular interest in the model results.

**8.3** Secondly, the data from known flooding events in terms of recorded levels and flooding complaints is taken into account when floor level assessments are done. The significant flooding event in early March 2014 has provided valuable information with which to verify model predictions. This data is overlaid on other maps when assessments are being made. Where modelling information is incomplete or



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unavailable in an area, then manual calculations of flooding depths are made.

**8.4** Thirdly, other modelling information from alternative models is assessed against the City Council models. Christchurch city catchments have also been modelled for post-earthquake increased flooding vulnerability by EQC using alternative software called "Tuflow". The results of this model have been made available to the City Council for comparison purposes with the City Council models. The Tuflow results are for a different scenario than assumed by the District Plan standards, however they can alert experienced staff to different patterns of flooding for further investigation. The Tuflow model results are routinely overlaid on the City Council model in a GIS viewer when doing specific site assessments and discrepancies are resolved prior to determining a suitable minimum floor level for that site. The Council also has access to results from an alternative "Rain on Grid" DHI model which are also used for comparison purposes.

**8.5** It is noteworthy that Tonkin and Taylor independently assessed the models for the purposes of advising EQC on earthquake Increased Flooding Vulnerability (**IFV**) of residential properties and considered them to be suitable for that purpose, but supplemented the DHI models with the Tuflow model estimates for similar reasons to those discussed in the previous paragraph.

**8.6** Fourthly, the proposed design flood levels include an allowance for 1.0m sea level rise. Such an increase in tide levels will cause flooding over a considerable area of land and this effect simply dominates the model flood level assessment. As a consequence, we are therefore not reliant on any model results in these tidal areas for setting design floor levels. More information will be given on this in Ms Brookland's evidence.

**8.7** Fifthly, design floor levels and the FLFMA includes a "freeboard" or safety allowance of 400mm above the assessed flood level. This allowance is to cater for unpredictable events that occur during a storm (such as blockage of channels). It also provides for errors in land level

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assessments, errors in setting out floor levels, errors in modelling, and also waves generated by wind or passing cars.

- 8.8** The application of the freeboard to the *FLFMA flood extents* (or outer limits) is an automated process directly linked to the model results. The effect is to provide a horizontal buffer area around the predicted flood extents. The process of setting the outer extents of the FLFMA actually uses a freeboard of 250mm but this allows for the normal practice of houses being approximately 150mm above the natural ground and thus the total freeboard to the floor level remains as 400mm, with the result that the outer extent of the FLFMA is thus minimised.
- 8.9** On very flat areas of Christchurch the FLFMA buffer area could unreasonably extend the outer bound of the FLFMA, so this has been limited to no more than 60m in a north-south or east-west direction beyond the predicted flooded area. This is described further in Ms Brookland's evidence.
- 8.10** The application of the freeboard to the *design floor levels* is an automated process in the tidal and other areas of high model certainty, for example along the river main channels. In areas beyond this, the design floor levels are cross-checked such as using information from other models or recorded flooding or flooding complaints or manual calculations before releasing a design floor level.
- 8.11** The models are calibrated and verified using recorded rainfall and channel flow and level data to ensure that they produce results which reasonably mimic the real events.
- 8.12** The process of determining a design floor level or the extent of the FLFMA applies as much science as is available, but it assumes an ideal storm in combination with an ideal tide and fully functional drainage systems. To that extent, the models will produce results for design purposes which will not be the same as any real flooding event. Real events have an irregular rainfall distribution in time and also an uneven distribution across the catchment. The design storms are an

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attempt to provide an envelope to cover a real storm's variability and limit the flooding risk to an acceptable return interval which, for the reasons explained earlier, is specified as 1/200 years return interval (0.5% annual exceedence probability) in the FLFMA.

**8.13** Given the range of cross checks and safety factors involved in the preparation of the design floor levels and FLFMA extents, it is my view that a further model peer review is not necessary in order to be reasonably satisfied that the modelled results are reliable for planning purposes

**8.14** The flooding expert caucusing also addressed this matter. The group agreed that "within the FLFMA, there are sufficient model result, supplemented by additional data, to set minimum floor levels for a 200 year design event". The group also noted that some of the recent additions to the models had been peer reviewed that the models were "the best available information" for the purposes of this work on the district plan. The final recommendation was "that peer reviews should continue to be carried out where possible in the future at key stages of model development".

**8.15** Finally, I note that Mr Greg Whyte has also provided evidence on the integrity of the flood models and routine peer reviews.

## **9. RESPONSE TO SPECIFIC SUBMISSIONS**

**9.1** In these responses, I have used a convention of placing the reference page number after the decimal point so that the reference can be easily found in the submission. I have also copied information from my evidence above to answer submitters questions where it seems to assist and to minimise cross references.

### **Maurice Carter Ltd [377.22]**

**9.2** Maurice Carter Ltd seeks confirmation that the Council modelling has been subject to appropriate technical scrutiny and peer review.

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Maurice Carter also seeks that permitted activity standards for buildings in FLFMA's are specified.

9.3 I have addressed this in the "peer review" section of my evidence above and refer to it in response to this submission point. In summary, the Council's models have not been subject to a formal peer review. Calibration, verification and other cross checks on the model results have been performed as described above and in my view they are satisfactory for the purposes of estimating the extents of the FLFMA and for determining design floor levels. We are aware of deficiencies in the models and in such areas manual specific site assessments are undertaken for floor levels which draw on many sources of information. It is for this reason that permitted floor levels cannot presently be provided in all areas of the city.

#### **Tonkin and Taylor [970.12]**

- **Climate change effects and recurrence interval terminology and freeboard**

9.4 Tonkin and Taylor (T&T) have suggested that it may be appropriate to decouple the effects of climate change and sea level rise.

9.5 Climate change sea level rise and temperature effects are incorporated in the modelling in ways that are consistent with MfE guidelines. It would therefore be inappropriate to de-couple the effects of climate change with sea level rise in this context.

9.6 T&T have suggested that we should adopt a particular method of describing return intervals.

9.7 There are a number of ways of describing return intervals for natural hazards. Another common method is to use 0.5% AEP. In spite of that, the meaning of the method the Council has chosen to describe return intervals is, in my view clear.

9.8 T&T have questioned whether there is an inconsistency in our application of freeboard to the FLFMA and to design floor levels.

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**9.9** The freeboard of 250mm in setting the extents of the FLFMA allows for the normal practice of houses being approximately 150mm above the natural ground and thus, as described earlier, the total freeboard to the floor level is 400mm. Therefore there is no inconsistency with the floor level freeboard.

**Tonkin and Taylor [970.13]**

- **Sumner model not listed**
- **Coastal inundation**
- **Varying sea level rise to "as adopted by CCC".**

**9.10** T&T commented that the Sumner model was not listed and that they were unclear about how the coastal inundation was calculated. There are models for the Halswell and the Sumner areas – as well as the Heathcote, Avon and Styx Catchments as listed in my evidence but which were regrettably not described in detail in the plan review documentation.

**9.11** T&T correctly concluded that coastal inundation is captured by the 12.3m floor level above the CCC datum. This matter was also raised in the CERA [495] submission

**9.12** T&T also suggested that a variable sea level rise could be specified in the plan however that would mean that the plan would have to be re-notified each time the sea level rise was changed.

**Tonkin and Taylor [970.13]**

- **Alternative T&T Tuflow model**
- **Peer review**

**9.13** T& T have suggested that the alternative Tonkin and Taylor "rain on grid" type "Tuflow" model could have been used for calculating floor levels and FLFMA extents.

**9.14** The Tuflow model results used for EQC have been provided to the Council and this has been helpful because it has full coverage of Christchurch and is being used to compare flow patterns with the CCC

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models. It however does not contain the same level of detail as the CCC model. For example, it represents pipes as channels and has a number of other shortcomings for CCC purposes. The CCC does have access to a DHI rain on grid model which has a similar methodology and it has also been used for comparative purposes. At this time, we do not propose to change the modelling package and in my view it would be undesirable to have two modelling systems, one being used internally and the other being used externally for communicating to the public especially if they produced inconsistent results.

- 9.15 T&T and others have questioned whether the Council's models have been peer reviewed and I have addressed this issue in my evidence above.

**Tonkin and Taylor [970.13]**

- **Secondary drainage system**
- **Model Build reports**

- 9.16 The secondary drainage system is a current requirement and exists in recent subdivisions. It does however not exist in all historically developed areas and thus I agree with T&T that recent flooding demonstrated that secondary flow paths are not available in all parts of the city.

- 9.17 T&T suggest that model build reports should be produced. A system of model status reports is in place. This is similar to a model build report and based on recommendations from GHD.

**Tonkin and Taylor [970.14]**

- **Gaps in the model coverage**

- 9.18 T&T have commented that there are gaps in the model coverage. These areas are where the models are not fully developed and are therefore serviced by site-specific assessments for floor levels.

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**All of Government [495.85]**

- **Support alternative mitigation measures other than raising floor levels where the level of risk can be reduced.**

**9.19** The Government submission suggested that alternative mitigation measures should be employed where the level of risk can be reduced.

**9.20** The proposed district plan is attempting to give effect to Policy 11.3.2 of RPS which requires that development be avoided in areas subject to flooding in a 1/200 year event, but states that mitigation is permitted where there is no increased risk to life, provided the subdivision, use and development complies with the other matters set out in Policy 11.3.2. As stated above, in my view it is unusual, and probably uneconomic, for communal flood protection schemes to have such a high design standard so the approach in the pRDP to giving effect to the RPS requirement is to ensure that new floor levels are designed to be above the 1/200 year flood event and thus afford protection and resilience to the most vulnerable element in the catchment.

**9.21** The expectation is that flood mitigation schemes such as proposed in Flockton Basin will provide a reduction in street flooding in more frequent events but would be overwhelmed or otherwise fail in a 1/200 year event. For the same reason the present stopbanks along the River Avon are assumed to have failed and the main protection is the level of the floors.

**9.22** Raising floor levels is a robust means of limiting flood damage in extreme flooding events, as normal communal schemes which protect for more frequent events would be overwhelmed. Normal communal schemes nonetheless have a place in protecting the whole scheme area for less rare events.

**All of Government [495.85]**

- **Terminology is consistent with engineering practice, and refers to 200-year ARI (Average Recurrence Interval) or 1/200 AEP (Annual Exceedance Probability).**

**9.23** As mentioned in the response to the T&T submission [970.12], there are a number of ways of describing return intervals for natural hazards.

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**All of Government [495.85]**

- **FLFMA extent should be mapped with the same freeboard requirement as would be applied to minimum floor levels to avoid boundary inconsistencies.**

**9.24** As noted in response to T&T submission [970.12] above, the freeboard of 250mm in setting the extents of the FLFMA allows for the normal practice of houses being approximately 150mm above the natural ground and thus the total freeboard to the floor level is 400mm. As a consequence boundary inconsistencies do not arise.

**All of Government [495.85]**

- **Make reference to the hydraulic model to be used for assessment of Sumner.**

**9.25** Regrettably the Sumner model was not listed in the documentation however and this was also noted in the Government submission. For more details, a Status Report for the Sumner Model is available. See also the evidence of Ms Brookland.

**All of Government [495.95]**

- **Wet proofing, dry proofing and corrosion free building materials utilised below the 1 in 200 year flood level.**
- **Openings in fully enclosed areas below the 1 in 200 year flood level for automatic entry and exit of floodwater.**
- **Safe access to areas out of the flood plain and arrangements for access to any building or work during a flood.**

**9.26** The Government submission noted a number of building options as above as an alternative to setting floor levels above the 1/200 year level.

**9.27** A 1/200 year event is rather rare so it is appropriate to protect the most vulnerable areas such as the floor levels to this standard – but a lesser standard could perhaps apply to other areas. The building consent process could address these alternative approaches on a site-by-site basis



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**All of Government [495.101]**

- **Amend the modelling freeboard to vary across the mapped area to reflect areas of higher certainty which require less freeboard**
- **Amend the modelling freeboard to refer to the validity of modelling which includes determination of appropriate freeboard if any**
- **Consider reducing the area in which the rules requiring floor levels to be raised is applied to reflect the accuracy and degree of certainty in the modelling**

**9.28** Modelling uncertainty is only one element in the need for freeboard provision. As I mentioned earlier, the other elements such as blockages, wind and vehicle waves and survey/construction errors are also accommodated in the freeboard allowance. Therefore the notion of varying the freeboard to reflect the level of modelling uncertainty is not justifiable or easily quantifiable and, in my opinion, is likely to lead to suggestions of an inconsistent approach being taken by the Council.

**9.29** The requirement is to set new floor levels above the 1/200 year flood level. If the model prediction is regarded as uncertain then a manual site specific estimate is done to ensure that the 1/200 year requirement is fulfilled. This is clearly labour intensive but it is my opinion that it will need to be done until such time as the locations of modelling uncertainty which exist in the land subject to flood risk are rectified .

**Marks Family Trust [975]**

- **Removal of the property from the FLFMA**

**9.30** The proposed district plan is attempting to give effect to Policy 11.3.2 of Canterbury Regional Policy Statement which requires that development be avoided in areas subject to flooding in a 1/200 year event but mitigation is permitted where there is no increased risk to life, among other matters. It is unusual, and probably uneconomic, for communal flood protection schemes to have such a high design standard so the approach is to ensure that new floor levels are designed to be above the 1/200 year flood event. It would therefore be inappropriate to remove these properties from the FLFMA

**9.31** It should be noted that where a property is partially in the FLFMA and the proposed building is not in the FLFMA then the floor level is not controlled by FLFMA rules

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**All of Government [495.70]**

- **The proposal's treatment of risk is guided by the RPS (Policies 11.2 and 11.3) which provides strong guidance on the level of risk that should be addressed**
- **The Council goes further than required by the RPS in addressing risk, by taking into account high-end sea-level rise estimates, adding 'freeboard' estimates, combining hazards in its estimates, and using regulatory provisions as the main tool for risk mitigation**
- **The Natural Hazards Proposal deals with multiple risks, but the risks that have the greatest effect on the largest area are those covered by the Flood and Fill Management Areas.**

**9.32** The T&T report on the implications of sea level rise for Christchurch produced in August 2013 recommends that the Council should plan for the possibility of a 1.0m Sea Level Rise by 2115. This is a mid-range estimate, rather than a high-end estimate of sea level rise in the next 100 years and is appropriate for the life of the buildings which would need to comply with the floor level requirements.

**9.33** With regard to combining of hazards, the hazards of rainfall and tide levels have been combined in practical ways – because higher-than-normal tides often accompany rain storms as a result of low atmospheric pressures and storm surge effects.

**9.34** The freeboard allowance of 400mm covers all forms of estimation and construction error and drainage system failure as well as waves. It is a pragmatic allowance - as any one of these causes could result in a 400mm error, but there is a very small chance that they will all apply simultaneously to any given situation.

**9.35** It is my opinion that regulation is an appropriate tool for this risk mitigation, and that the regulatory approach is appropriate in this instance, as it targets floor levels which are the most vulnerable risk area to a level of protection which would not be available from most other forms of communal flood protection. It also makes the community self reliant and resilient.

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**Chrys Horn [1153.1]**

- **Please include a provision that landowners and potential purchasers be provided with an estimate of the flooding risk for their land, or the land they are looking to purchase**

9.36 This information is provided on the flooding and floor level maps which are currently on the City Council Website at:

<http://maps.cera.govt.nz/advanced-viewer/?Viewer=Ccc-Floor-Levels>

9.37 It is planned that this data will be continued, extended and updated into the future. It is thus available to anyone unless their site has yet to be finally modelled in which case flooding and floor level information can be requested from the Council

**Peter Haughey [195.1] & Burwood Pegasus Community Board[375.4]**

- **Erect stopbanks along the Avon Heathcote estuary**

9.38 Stopbanks are an additional form of protection that could be contemplated, especially for protection from more frequent street flooding, but they do not provide the same certainty of protection to vulnerable floors because water can pond on either side of a stopbank in extreme local Christchurch rainfall events. This is unlike the stopbanks on the Waimakariri which flood because of distant rainfall or snowmelt and so water is unlikely to arise on both sides of the stopbanks in a major event.

9.39 In my opinion, it is unlikely that stopbanks designed for a 1/200 year event, and associated pumping to clear water accumulated behind the stopbanks, would be regarded as affordable by the community.

**Isaac Conservation and Wildlife Trust [704.10]**

- **Amend section 5.3.2 b. Restrict activities locating where they could undermine the integrity of the Waimakariri River secondary stopbank system, unless effects of the activities on the secondary stopbank can be mitigated.**

9.40 "Mitigation" may not be sufficient in view of the consequences of the Waimakariri stopbank failure. Avoidance of undermining the integrity of the stopbanks is therefore necessary. In my opinion, the wording of

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section “5.3.2 Policy Flood Protection Works b” as it stands does not preclude activities which would not undermine the integrity of the stopbank.

**Case [957.7]**

- **The inclusion of the consideration of alternative storage**

**9.41** The Case submission considered that the wording of rule 5.8.1.2 c which limits the Councils discretion to “Any proposed mitigation measures and their effectiveness and environmental impact, including any benefits associated with flood management” should include the consideration of the creation of alternative storage.

**9.42** The wording of 5.8.1.2 c as it stands does not appear to preclude the consideration of mitigation by the creation of alternative (or compensatory) storage. However other wording may make this matter more clear. A recommendation to this effect was also made by the experts joint statement on flooding.

**Cashmere Park Trust and Cashmere Rural Landowners [328.1]**

- **Remove the 400mm freeboard till further planning is done**

**9.43** In my opinion, for the reasons set out earlier in my evidence, the 400mm freeboard is a necessary allowance which will avoid subsequent retrofitting of flood mitigation measures if any of a number of imperfections arise in the course of development or during a storm event – including waves on the surface of the water. If further planning work is necessary the conservative tendency would be to increase the freeboard tolerance rather than to reduce it and thus I do not accept the proposition to remove the 400mm freeboard till further planning is done.

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#### **CERA – All of Government [495.92]**

- **Reduce the area in which rules requiring floor levels to be raised apply to reflect accuracy and degree of certainty in the modelling**

9.44 We agree with the general idea of this part of CERA's submission. Parts of the Christchurch floodplains have not been included in the FLFMA pending further modelling. Further extensions to the FLFMA will be notified in phase 2 of the pDPR when we have more certainty in the modelling of those areas.

#### **CERA – All of Government [495]**

- **Terminology is consistent with engineering practice, and refers to 200-year ARI (Average Recurrence Interval) or 1/200 AEP Annual Exceedance Probability).**

9.45 This matter was also noted in the T&T submission. There are a number of ways of describing return intervals for natural hazards as discussed above.

#### **CERA – All of Government [495.92]**

- **Delete reference to 1m sea level rise and replace with *"including the current adopted sea level rise prediction as adopted by Christchurch City Council"*.**

9.46 This matter was also noted in the T&T submission. A variable sea level rise specified in the plan would mean that the District Plan would need to be re-notified each time the Council wanted to change the Sea level rise provision.

#### **Dan Van Asch [1062.2]**

- **Where possible, and with reference to detailed catchment information, enhance the flood storage capacity and function of natural floodplains, wetlands and ponding areas.**

9.47 Considerable investigation has been done in relation to the storage potential of various natural basins in the upper Heathcote catchment in support of the South West Integrated Catchment Management Plan and in support of Variation 48 to the present City Plan which established the Flood Ponding Area in Hendersons Basin. Future works are planned for Cashmere/Worsleys valley in conjunction with

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subdivision in that area and there are also possibilities for flood storage in Hoon Hay Valley, but no detailed work has been done in that area.

9.48 The present policy contains the wording "a. Maintain the flood storage capacity and function of natural floodplains, wetlands and ponding areas, including the Hendersons Basin, Cashmere Stream Floodplain, Hoon Hay Valley, Cashmere-Worsleys Ponding Area, Cranford Basin, and Lower Styx Ponding Area"

9.49 In principle I agree with the suggestion that the policy could be more pro-active wording by adding "a. Maintain **and enhance**...." to the present wording. I think it would go without saying that the latest detailed catchment information would be used to progress any such initiative.

#### **Generation Zero [1149.8]**

- **We contend that any development should need to take into account how it might be affected by a reasonable mid-level prediction of sea level rise before it is able to be approved. In Christchurch we have seen the impacts of having to move large areas of housing due to unacceptable risk factors. It would be an insult to allow development into areas where the risk of sea level rise is high.**
- **Planning should be done so that built infrastructure takes into account risks and is resilient to climate change and other natural hazard risks for extended periods of time and growth.**

9.50 The Generation Zero submission as stated above seems to very much support the thrust of the policies and implementation of these in the proposed district plan.

#### **NPT [707.6]**

- **For example in an identified flood hazard area (eg a floor level and fill management area), where a building is proposed to be established, even a small building could conceivably be said to potentially displace flood waters and therefore be transferring risk to other places.**

9.51 NPT have suggested that Policy 5.2.5 be deleted. Among other things this policy deals with the need to avoid worsening, adding or transferring hazard.

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**9.52** NPT's comment above raises a question of materiality and the adequacy of the drainage system in the location. Generally such matters are dealt with on a case-by-case basis – but the principle remains that the risk needs to be mitigated if there is significant displacement and/or diversion of water which would have more than minimal detrimental effects elsewhere. My view therefore is that such a policy is necessary.

**Smith [1471]**

- **Reduce the 200 years down to 100 years (double the present 50 years)**

**9.53** The Smith submission is suggesting that the return interval standards proposed are too high.

**9.54** The 1/50 year design standard relates to the requirements of the Building Act

**9.55** The proposed district plan is giving effect to Policy 11.3.2 of Canterbury Regional Policy Statement which requires that development be avoided in areas subject to flooding in a 1/200 year event but mitigation is permitted where there is no increased risk to life.

**9.56** This is the reason for floor levels being set at the 1/200 year level plus freeboard - but it does not require that flooding of land does not occur in such an event. The vulnerable floors in dwellings are thus protected in the fairly rare 1/200 year events which offers the community a high degree of self reliance and resilience.

**Stedman [9]**

- **Clear out and deepen the river channels and remove plants which restrict river flows**

**9.57** The Stedman submission suggests that clearing out the river channels and removing plants is an appropriate response to flooding. The required level of protection which is a 1/200 year flood event is however, well beyond the normal "within bank" capacity of the rivers and tributaries of Christchurch. Flooding onto the floodplains is therefore inevitable in such an extreme event. It is likely that most

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flood protection measures – including channel clearance and those provided for new subdivisions - will have failed or have been overwhelmed in such an event.

**9.58** The Proposed District Plan is aimed at providing protection to the most vulnerable assets - which are those above floor levels – in an extreme 1/200 year event. It assumes that local river stopbanks have been overtopped or otherwise failed and it assumes that no special dredging measures are in place.

**9.59** The maintenance standards for rivers and other surface water management infrastructure is not addressed in the District Plan but rather in the Council's Activity Management Plan's

**Cr Hasson [979]**

- **Add the Halswell River Basin catchment area to the list in section 5.3.3**

**9.60** Submitter Cr Hasson from Selwyn District Council has requested that the flood storage areas in the Halswell River basin be protected to protect infrastructure in the Halswell catchment but outside the Christchurch City Council district.

**9.61** The investigations of the Halswell catchment have not reached the stage of the investigations in other Christchurch catchments. It is clear that there are high hazard flooding areas within the portion of the Halswell catchment within the Christchurch territorial boundaries and that there are also areas which should be identified as FLFMA which include the Flood Management Area in the operative plan and other areas as well. These matters will be progressed in stage 2 of the review.



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### **Halswell Residents Association [306]**

- **Concern about Meadowlands Development and provision of detailed information about flood scenarios and stormwater contamination.**

**9.62** The Halswell Residents association expressed concern that developments such as Meadowlands may lead to flooding in other areas.

**9.63** The Meadowlands and all other new developments will be required to mitigate its adverse stormwater effects and is not solely reliant on the one measure of setting sufficiently high floor levels for flood protection

**9.64** With respect to the provision of detailed flooding risk information, detailed flooding maps are being made available on the Council's website and this includes floor level information as it becomes available. There are no plans to provide the high level of detail of flooding scenarios and descriptions which are being requested in paragraph 2.4 of the submission. That would require extensive investigations on a site-by-site basis which are beyond the scope of the present modelling programme.

### **GM Bennett [391]**

- **Flooding and flood management in the South West of the city – Halswell Hoon Hay Area**

**9.65** GM Bennett has expressed concern about the inadequacy of stormwater management facilities in the South West Area. The examples of dedicated ponding areas in Wigram Skys and on the Southern Motorway which are cited by as good examples of what need to be done by GM Bennett are outcomes of the South West Area stormwater management plan and these approaches are planned for all the greenfield developments in that area.

**9.66** The photograph included in the submission shows Hendersons Basin which has been defined in the city plan as a “flood ponding area” for the purposes of continuing its function as a “natural detention basin” and limit flooding particularly along the Heathcote River downstream of

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the basin. The City Council has purchased a significant proportion of the basin for stormwater management purposes.

**M Leigh [435]**

- **30 Blair Avenue Increases in density will lead to more water in Dudley Creek**

**9.67** M Leigh is concerned that increases in density will necessarily lead to increases in runoff. In response to paragraph 4 of the submission, any increase in site coverage are usually examined for their significance in terms of increases in runoff as a part of a the building consent process and mitigation is specified as necessary.

**N D Bacon [731]**

- **Questions about the flood boundary lines on the property at 376 Sparks Rd**

**9.68** The zig-zag lines which have been questioned by ND Bacon are the representation of the square flood model cells which show the boundary of the zones. Most of the property is in the Hendersons basin flood ponding area and a slightly larger proportion in the FLFMA.

**P & J McAfee [746]**

- **Floor Level and Fill management area Petrie Warden and Averill St**

**9.69** The submitters questioned why some areas of Petrie Street flooded in recent events which are not in the FLFMA and why their property is included in the FLFMA.

**9.70** The FLFMA is determined by modelling a design storm of a 1/200 year return interval and then adding a 250mm freeboard above that predicted level. It also assumes a 16% increase in rainfall intensity as a result of climate change effects. I would expect therefore, that the FLFMA would be a larger area than actually experienced flooding in the March 2014 flood event and other recent flood events. So this would explain why a property which did not flood in recent events is included in the FLFMA. I do not have sufficient information to

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understand why some local properties which did flood recently are not included in the FLFMA.

- 9.71** With regard to FLFMA boundaries crossing properties, the boundaries relate to the contour of the land rather than the property boundaries so the FLFMA will cross property boundaries.
- 9.72** With regard to the question of methods of control, if the building is on the property, but outside the FLFMA boundary then it will not be subject to the floor levels being set according to FLFMA rules. Being within the FLFMA generally will alert anyone that the level of new floors of a house in any building consent application should be determined with reference to predicted 1/200 year flooding in the vicinity and that land filling, which may displace or divert floodwaters, may need to be controlled.

**M Thacker Okains Bay. [963]**

- **Safety issue of flooding on the road**

- 9.73** M Thacker has raised the issue of flooding on the main access road in Okains Bay and proposed that an alternative route be formed.
- 9.74** This is a primarily roading issue beyond the scope of the District plan review. From a flooding perspective, the Okains bay floodplain is very flat and low lying with respect to the sea. It is also surrounded by steep hills which produce sediment which tends to block the formed channels. It is therefore a very difficult area in which to manage flooding



**Graham James Harrington**

**13 February 2015**