Report

WAIMAKARIRI DISTRICT
Localised Flood Hazard Assessment 2015

Prepared by the Project Delivery Unit
Waimakariri District Council

July 2015

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1 EXECUTIVE SUMMARY

On behalf of the Manager Utilities & Roading and Manager Planning & Regulation, the Project Delivery Unit has conducted a District Wide Localised Flood Hazard Assessment.

This investigation builds on the work undertaken by the Project Delivery Unit in 2014 A copy of the 2014 assessment con be found in TRIM Reference 101004035773.

The purpose of this investigation was to model the flood effects across the District for the 100, 200 and 500 ARI (Annual Recurrence Interval) rain events. The maximum flood depths and corresponding maximum velocities will be used to generate a map of flood hazards. The flood hazard maps will be used in Council planning documents and form a layer on the Council GIS to be used in producing Council LIMs.

Models have been produced that model the full district north and south of the Ashley River. Only the Lees Valley catchment upstream of Ashley Gorge has not been included due to insufficient ground data being available.

There have been a number of minor changes made to the modelling methodology and new data included from what was used in the 2014 Study. These changes are shown in Table A below

Table A - Differences between 2014 and 2015 models

2014 Study	2015 Study	Effect
LCDB3 dataset used for Roughness	LCDB4 dataset used for Roughness	Better model accuracy using more up to date information
2005 LiDAR used together with 2011 LiDAR in the Kaiapoi area	2014 LiDAR used across the eastern parts of the district where available. 2005 LiDAR used elsewhere.	Better model accuracy using more up to date information
Climate Change factor of 0.5m used for sea level rise	Climate Change factor of 1.0m used for sea level rise	Some increase in flood level in coastal areas where sea level rise has an impact.
No allowance for Buildings	2014 Building outlines used to modify the model DEM and the model roughness.	Better model accuracy using more up to date information.
MIKE 21 2012 Software with Rectangular Grid Used	MIKE 21 2014 Software with Flexible Mesh Used	Significant improvements in model run times but only minor effects on model results.

The overall effect of the changes is relatively minor, notwithstanding some of the effects in the Kaiapoi area.

In the Kaiapoi area there is a general increase in flood depths in the area to the north of the township between Lineside Road and the Northern Motorway. Conversely there is a general decrease in flood depth to the southeast of the township in the 200 year and 500 year events. Although in the 100 year ARI event the flood level has generally increased across most of the surrounding area.

The changes in the flood levels in Kaiapoi are likely due to a number of factors which include Earthquake Effects, Subdivision and Sea Level Rise.

The results show that over approximately 90% of the modelled area, the flood depths have changed by less than 100mm from the 2014 results. This indicates the model results are similar to the previous work undertaken.

Based largely on the fact the new results are using better and more up to date information it is reasonable to conclude the new modelling methodology has produced a better quality set of results.

It is expected that the results from this study will be incorporated into the Council GIS, the District Plan and form part of the information contained within LIMS. However some further work is required around the setting of building floor levels in urban areas and these areas should be excluded from the results displayed on the Council's GIS until more refined modelling has been undertaken in these areas.

The modelling results are shown in the appendices of this report and are also available as high resolution pdf plans. The results will also been stored in ArcMap geodatabases for detailed analysis and display on the Council GIS system.

The main limitations of this modelling work relate to the use of a 10m or 12m grid and the exclusion of the primary infrastructure. Both of these will limit the accuracy of the modelling results. However the results are considered suitable for assessing flood hazard at a district wide level and for planning purposes when considering the suitability of land for development.

It is expected this work can be used as a tool to help set floor levels in the Rural Zone. However it is expected that urban areas and areas subject to plan changes should require specific flood mitigation measures to allow buildings to only meet requirements under the Building Act and/or RPS.

Future modelling of the urban areas is proposed which will allow more detailed assessment to be undertaken of the urban schemes. Therefore it is recommended that the results from this study are not applied to urban areas and new dwellings in urban areas are only required to meet Building Act requirements until such time as the urban modelling work is completed.

Further work could be undertaken to improve the accuracy of the modelling results including:

- Updated LiDAR data for future development areas and the western part of the district
- Updated Land Use data across the district
- More refined assessment of the impervious area
- Inclusion of more primary infrastructure in the models
- More refined modelling of the rivers within the models

Any additional modelling work will be limited by modelling resources within the PDU and technological advancements in both software and available hardware.

While current guidelines for climate change have been incorporated into this assessment, it is observed that climate change predictions are likely to evolve over time. Any future modelling work should therefore take into account future climate change forecasts

It is recommended that a budget of $50,000 is made available every 5 years to undertake a revision of this modelling work to take advantage of new data and information and to ensure the modelling results remain current.

Undertaking a model validation would provide confidence that the model is representing reality, although this requires a major rain event (> ARI of 100 years) to occur to make this worthwhile. In the event of a major rain event occurring, a budget of $15,000 should be made available to undertake this work in the future.

2 RECOMMENDATIONS

Following the conclusion of the 2015 Localised Hazard Flood Assessment, it is recommended that:

1. The Manager Utilities & Roading and Manager Planning & Regulation Receive this Report (TRIM 150410056887).
2. The results from the models are adopted for defining flood depth and flood hazard within the district
3. The results from this study are incorporated in the District Plan
4. The flood depths and flood hazard maps are made available on the Council GIS for inclusion in LIMs where appropriate.
5. The results from this study are used for the setting of Building Floor Levels in the Rural Zone in line with current practice
6. The results from this study are not used to set floor levels in urban areas and new dwellings in urban areas are only required to meet Building Act requirements until such time as the urban modelling work is completed.
7. The Councils considers undertaking a detailed study into mitigation measures for the Kaiapoi township to achieve flood protection in the 200 year ARI storm event.
8. Further work is undertaken to revise the results from this study when new LiDAR or land use data becomes available or if new climate change information becomes available
9. The Council collects finished ground levels for new subdivision areas wherever possible to maintain a current Digital Elevation Model (DEM).
10. The Council collects and maintains an electronic database of new building outlines and finished floor levels as part of the Building Consent Process. This should also include any existing floor level information on existing flood prone buildings.
11. A budget of $50,000 is made available every 5 years to update the modelling results.
12. A budget of $15,000 is made available in the event of a major storm occurring in order to undertake a model validation.
13. The Council considers expanding the existing rain gauge network to include areas that have had flooding issues in recent times and ensure that the existing network is fully operational at all times

3 BACKGROUND

The following summarises the studies that have led to the development of this project.

3.1 ECan Ashley and Waimakariri River Breakouts 2005

Environment Canterbury (ECan) undertook work in 2005 to model the effects from flood breakouts on the both the Ashley and Waimakariri Rivers. This work focussed on known breakout points on both river systems. The rivers were modelled and coupled to a 2D model of the floodplain. The results included maps of both the flood depth and flood hazard for the 100 year, 200 year and 500 year ARI events.

The Council has subsequently used the information from the 200 year ARI results to assist with planning decisions and these have been incorporated into District Plan Change 27 (in draft form).

3.2 Cam River Pilot Study 2009

Following the work undertaken by ECan on the river breakouts the Council had identified a need to undertake an assessment on localised flooding due to rainfall.

In 2009 DHI approached the Council to demonstrate a flood hazard assessment methodology known as ‘Rapid Hazard Flood Modelling’. This methodology uses 2D modelling techniques incorporating a Detailed Elevation Model (DEM) and applying a rain event to the DEM to produce plots of water depth and velocity in response to the rain event.

The Council subsequently commissioned DHI to undertake a pilot study on the Cam River catchment to assess the value of this methodology with a view towards undertaking a larger assessment of flood risk across the district.

3.3 Localised Flood Hazard Assessment 2010

Following the 2009 pilot study a Council resolution in 2009 required the consideration of the 100 year ARI event for localised flooding. The Council subsequently commissioned another study to model the 100 year ARI event across the majority of the district.

The study area included 10 sub-catchments over an area of 849 km^2. The catchments chosen were largely those with existing high levels of development or good potential for development. Figure 1 shows the study area.

Following a tendering process DHI were selected to undertake the study with GHD selected to undertake a peer review of the work. DHI produced 10 models for each of the catchments using the Rapid Hazard Flood methodology together with maps showing the maximum flood depth and velocities for each catchment.

The models were constructed using a combination of 10m and 20m grids derived from 2005 LiDAR data. Rainfall data was based on HIRDS version 3 with a 16% climate change allowance and the rain was applied uniformly across each model with a constant loss factor of 30% to account for infiltration and other losses. In keeping with the Rapid Hazard methodology the models were constructed as 2D models and excluded any primary infrastructure such as pipes and culverts. However a small number of culverts were included in the model to account for major culverts capable of carrying a 100 year ARI storm event.

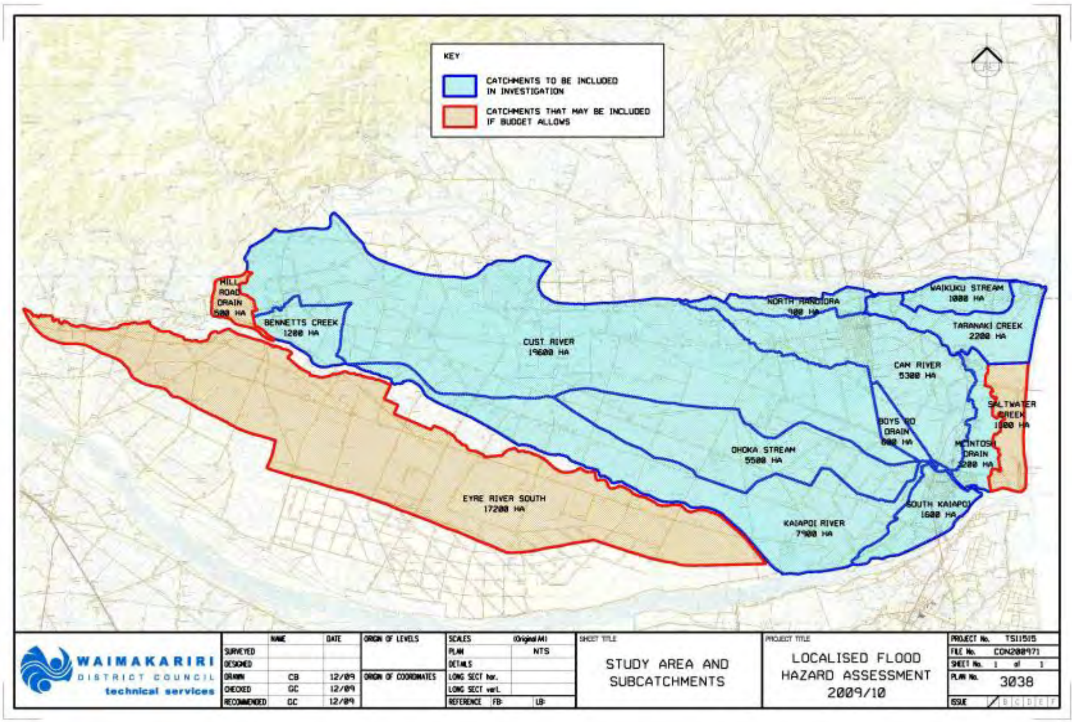

Figure 1 – Localised Flood Hazard Assessment 2010 Study Areas

The results from this work have been used by the Council for strategic planning purposes, identifying overland flow paths and to give an indication of flood levels. The Council has been reluctant to use these models for specifying building floor heights as it was considered inappropriate to do so.

Refer to Report 101004035773 for more information.

3.4 Post Earthquake Flood Assessment 2011

Following the September 2010 and February 2011 Canterbury earthquakes, DHI was commissioned by the Council to undertake a revision of the South Kaiapoi and Saltwater McIntosh models to assess the effects of ground movement on flood depth in these areas.

The models were revised with 2011 LiDAR data collected in the Kaiapoi area and incorporated a number of additional culverts together with a 5m grid to model a 50 year ARI event.

Refer to Report 110621025131 for more information.

3.5 Canterbury Regional Policy Statement 2013

The Canterbury Regional Policy Statement (RPS) directs Council to set out objectives, policies and methods within the District Plan based upon 500 year (high hazard) and 200 year (low hazard) ARI return events.

The Council's District Plan is required to 'give effect' to the RPS.

3.6 Localised Flood Hazard Assessment 2013

Following the RPS in 2013 the Council undertook a study investigating the effects of 100 year, 200 year and 500 year events. This work built on the work undertaken in 2010 and 2011 using the existing models as a basis for applying the rainfall events. This work was undertaken in-house using the Project Delivery Unit and peer reviewed by DHI.

A new rainfall methodology was introduced that featured a spatially varying rainfall grid and incorporated soil specific infiltration parameters.

Although this work was based on using the existing 10 sub-catchment models developed in 2010 and 2011, it also featured the construction of 2 new Full Catchment models of all catchments north and south of the Ashley River. Only the Lees Valley catchments were not modelled as part of this study. Figure 2 shows the catchments modelled as part of this study.

The results from the Full Catchment models were subsequently used to display flood depth and flood hazard information as these represented a more accurate dataset than the sub-catchment models. The results were put onto the Council GIS and have been subsequently included in LIM applications.

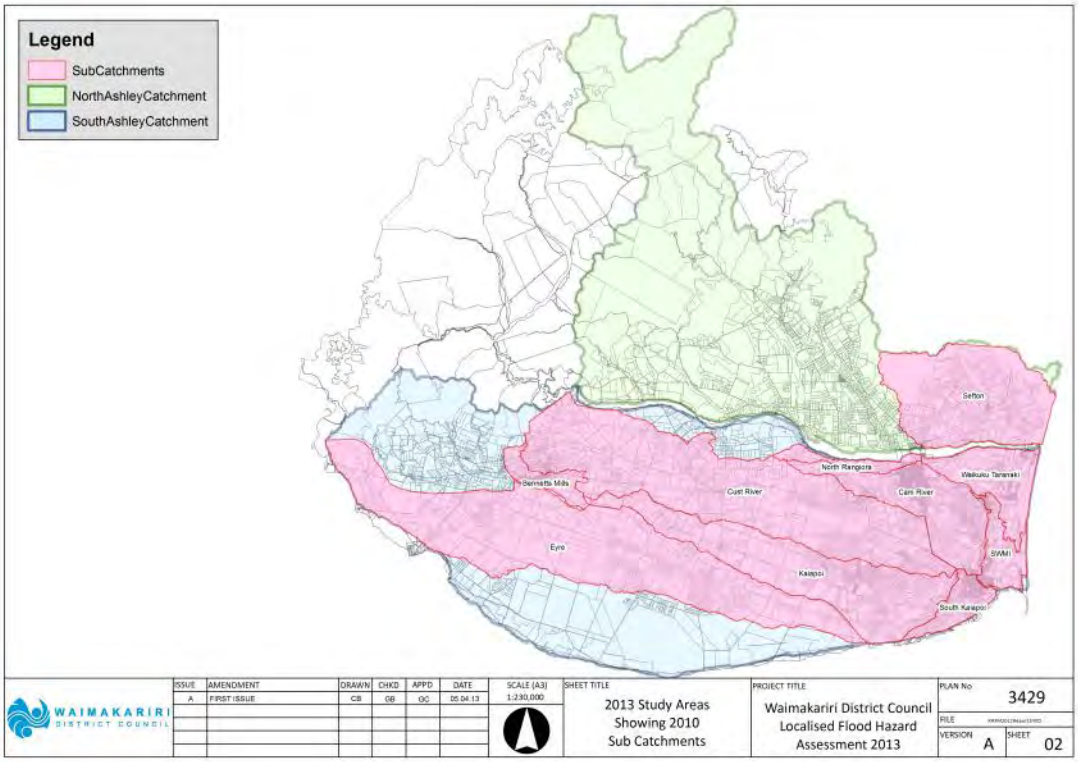

Figure 2 - 2013 Modelled Catchments

Refer to Report 130412026127 for more information.

3.7 DHI Peer Review 2013

The 2013 Localised Flood Hazard Assessment (Trim Ref 130709051996) was peer reviewed by DHI Ltd and produced the following key recommendations:

1. The Coriolis force calculation does not need to be used in the models
2. Important sub-grid features should be built into the 10m grid such as railway embankments
3. The LCDB3 dataset should be used over the LCDB2 dataset for land use
4. A specific roughness category for roads should be introduced
5. The Boundary Conditions for the Ashley and Waimakariri Rivers should be re-considered to allow overtopping at floodbanks
6. Weirs should be introduced at culverts to allow for overtopping where it is likely to occur
7. The flood hazard calculation should be undertaken at every time step

These improvements were subsequently incorporated into the 2014 study.

3.8 Localised Flood Hazard Assessment 2014

Following the 2013 DHI Peer Review the Council undertook additional modelling incorporating the recommendations from the Peer Review. This work was largely based on the 2013 study with a number of improvements as outlined in the following table. Refer TRIM reference 140331032427.

2013 Study	2014 Study	Effect
Coriolis force calculation was applied	Coriolis force calculation not applied	Improvement to Model runtimes
Join errors evident in bathymetry data sets	Join errors identified and removed in revised models	Better accuracy and model stability
No sub-grid features burned into DEM grid	Stopbanks and Railway embankments burned into the DEM grid	Better model accuracy
LCDB2 dataset used for Roughness	LCDB3 dataset used for Roughness	Better model accuracy using more up to date information
No roughness category used for roadways	A roughness category applied for roadways	Better model accuracy
Model boundaries at River Stopbanks	Riverbeds for the Ashley and Waimakariri Rivers included in model with single boundary at river mouth	Better model accuracy, allowing for overtopping of stopbanks and better model stability reducing the number of boundary conditions.
Culverts used in model where culvert size was expected to convey a 100 year storm event	Some additional culverts added due to railway embankments being burned into grid. Checks made of downstream and upstream channel sections	Better model accuracy
No weirs used in models	Weirs added to culverts where overtopping may occur	Better model accuracy. Increase in water levels downstream of some culverts with a corresponding decrease in water level upstream of culvert
Global impervious percentage of 3% used	Different impervious percentages used for Rural, Urban Residential and Commercial land.	Better model accuracy. Increased volume of runoff and water level downstream of urban areas. Reduced volume of runoff and water level in rural areas.
WDC generated DEM used for areas with no LiDAR data	Landcare Research 25m DEM used for areas with no LiDAR data	Little or no change.

2013 Study	2014 Study	Effect
Landcare Soil Classification Map used for soil drainage factors	Landcare Soil Drainage Map used for soil drainage factors	Reduced runoff. Where no soil classification was available a drainage factor of 3 was used previously. The Soil Drainage Map generally has higher drainage factors of 4 and 5 for these areas.
MIKE 21 2011 Software Used	MIKE 2012 Software Used	No significant change.

The key differences between the 2013 and 2014 studies was the inclusion of sub-grid features such as stopbanks being burnt into the DEM and the inclusion of weirs at key culverts where overtopping was expected to occur.

This work was undertaken in-house using the Project Delivery Unit and subsequently peer reviewed again by DHI.

4 OVERVIEW

4.1 Project Scope

The 2015 study is a refinement of the 2014 Flood Hazard Assessment and incorporates a number of changes as a result of new data and new software becoming available. Specifically, the 2015 study incorporates the following refinements:

Table 1 - Differences between 2014 and 2015 models

2014 Study	2015 Study	Effect
LCDB3 dataset used for Roughness	LCDB4 dataset used for Roughness	Better model accuracy using more up to date information
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No allowance for Buildings	2014 Building outlines used to modify the model DEM and the model roughness.	Better model accuracy using more up to date information.
MIKE 21 2012 Software with Rectangular Grid Used	MIKE 21 2014 Software with Flexible Mesh Used	Significant improvements in model run times but only minor effects on model results.

The purpose of this study is to generate flood maps to show the predicted flood depths and flood hazard for the 100 year, 200 year and 500 year ARI rain events. The Canterbury RPS requires the assessment of 200 year and 500 year events.

Required outputs include maps showing the maximum flood depth and flood hazard. These maps will be incorporated in the Council's District Plan documents and Council GIS system for use by Council officers.

4.2 Study Area

The study area included all district catchments discharging into the Waimakariri River and all catchments discharging into the Ashley River downstream of the Ashley Gorge. The only drainage area excluded was the Ashley River catchment upstream of the Ashley Gorge (Lees Valley). For the purpose of modelling the study area was split into two models north and south of the Ashley River.

The flow channels in the Ashley and Waimakariri Rivers were partially included into the models to simplify the outlet conditions. It should be noted however that these channels were only included to reduce the number of outlets in each model and the channels were not modelled accurately. The Council also does not have suitable software to model these river channels.

Table 2 shows a summary of the two Full Catchment models.

Table 2 – Full Catchment Model Summary

Model	Area	Maximum Elevation
North Ashley	731 km^2	1706 m RL
South Ashley	1183 km^2	1330 m RL

Figure 3 shows a map of all the catchment areas modelled.

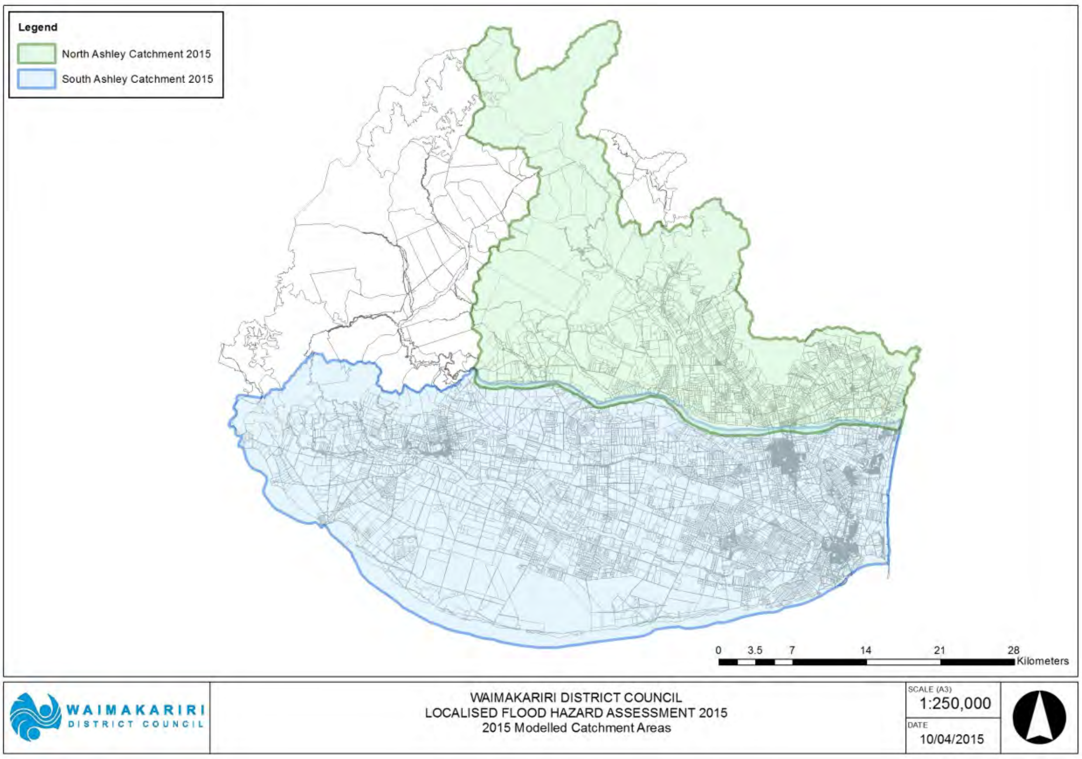

Figure 3 - Map of Modelled Catchments

5 MODEL BUILD AND METHODOLOGY

5.1 Software

The DHI MIKE 21 software (version 2014) has been used for the hydrodynamic simulations. The Flexible Mesh (FM) engine was used to undertake the model simulations. DHI MIKE Zero was used to manipulate the model inputs and undertake analysis of the modelling results. The runoff engine in DHI MIKE URBAN was used to produce the rainfall hyetographs.

ERSI ArcGIS (Version 10.1) was used to manipulate the LiDAR (Light Detection And Ranging) information to generate the DEMs (Digital Elevation Models), generate the roughness grids and delineate the catchments. ArcGIS was also used to display the results.

5.2 Ground Data

The ground data used in the models came from a combination of sources. Table 3 summarises the ground data used in the models.

Table 3 – Ground Data used in the models

Data Source	Year of Collection	Owner	Notes
District LiDAR	2005	WDC	Includes the whole district excluding hills to the west and north. Flown by AAM Hatch. Accuracy 0.15m.
Rural Aerials DTM	2012	WDC	Done as part of 2012 Rural Aerial Survey. Includes all land within the district excluding Lees Valley and surrounding hills. Flown by Aerial Surveys. Accuracy 2.0m
Eastern District LiDAR	2014	WDC	Includes the eastern part of the district to a point west of Rangiora. Also includes some river channels further to the west. Flown by Aerial Surveys. Accuracy 0.15m.
Topographical Contours	N/A	LINZ	Ground DEM generated from 20m contours derived from topographic maps. Accuracy 10m.

All LiDAR data used was filtered ground data except for the 2012 DTM (Digital Terrain Model) obtained from the aerial photography.

The two South Ashley and North Ashley Models incorporate a combination of all datasets using the most accurate set of data where possible.

Figure 4 shows the extent of each ground dataset used in the model.

In all cases the LiDAR and ground data was converted into the New Zealand Transverse Mercator map projection to be used in the model.

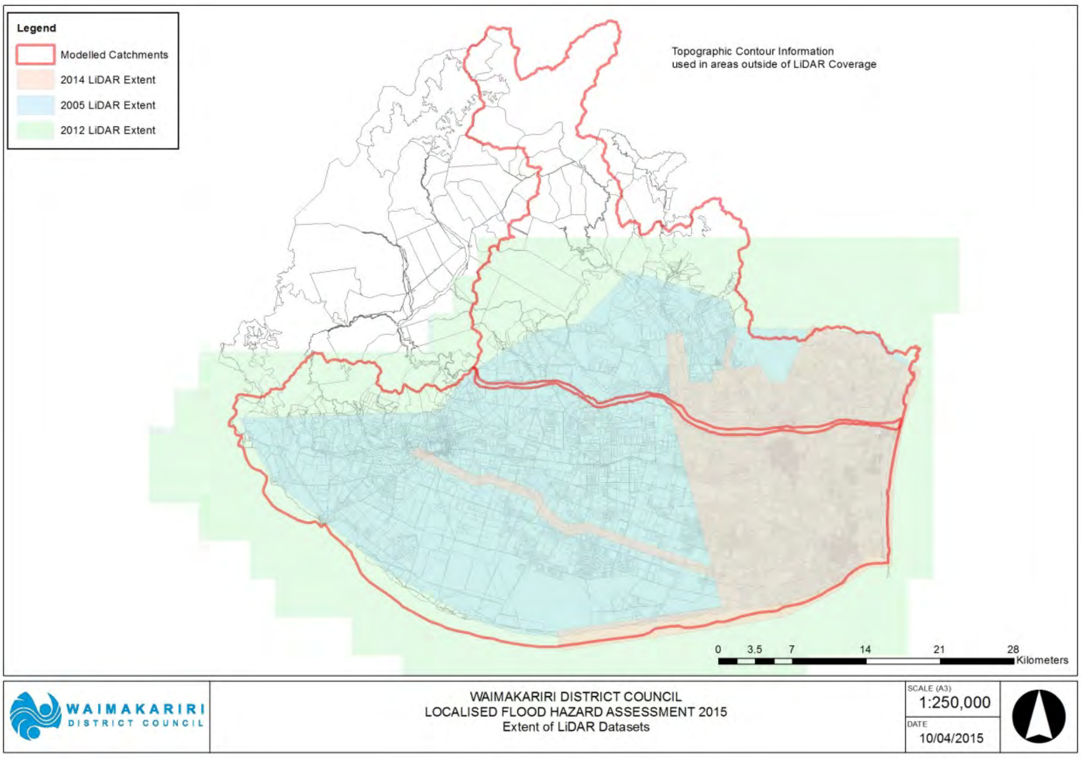

Figure 4 – Extent of Ground Datasets used in the models

5.3 *Catchment Delineation and DEM*

The ground data outlined in Section 5.2 was used to generate a raster for the full district including those areas where catchments extended past the district boundary. The four datasets were mosaicked together to generate one single 2m x 2m raster based on the following hierarchy:

1. 2014 Eastern District LiDAR
2. 2005 District LiDAR
3. 2012 Rural Aerial DTM
4. 20m Topographic Contours

The 2014 Eastern District LiDAR was the most accurate and up to date data available so this was used wherever possible. The topographic contour data was the least accurate and was only used where no other information was available.

A Watershed Analysis was undertaken in ArcGIS to generate the catchment areas for the North Ashley and South Ashley Full Catchment Models. A new raster was generated for each and re-sampled into a 10m or 12m grid and imported into the DHI .dfs2 format. The .dfs2 file was subsequently converted into a rectangular flexible mesh grid for modelling using the Flexible Mesh modelling engine in MIKE 21.

The North Ashley model was modelled using a 10m grid which was the same resolution used in the 2014 study. Due to limitations with the new Flexible Mesh software the South Ashley model was modelled using a 12m grid.

Features such as stopbanks and railway embankments were ‘burned’ into the DEM grid where necessary to better model the effects of these structures on impeding flow across the flood plain. Refer to Figure 5 for a plan of the embankment features burned into the DEM.

In areas where the LiDAR did not represent the bed level of key waterways (such as the Kaiapoi River) the ground level was artificially lowered to better represent these waterways. Refer to Figure 6 for a plan of the waterway areas which were lowered in the DEM. The sections of waterway lowered in the DEM were all tidal in nature.

Where building outlines where available these were used to raise the ground level in the DEM by a nominal 200mm to better simulate the effect of the house foundation impeding flow. The building outlines were not included in the 2014 study.

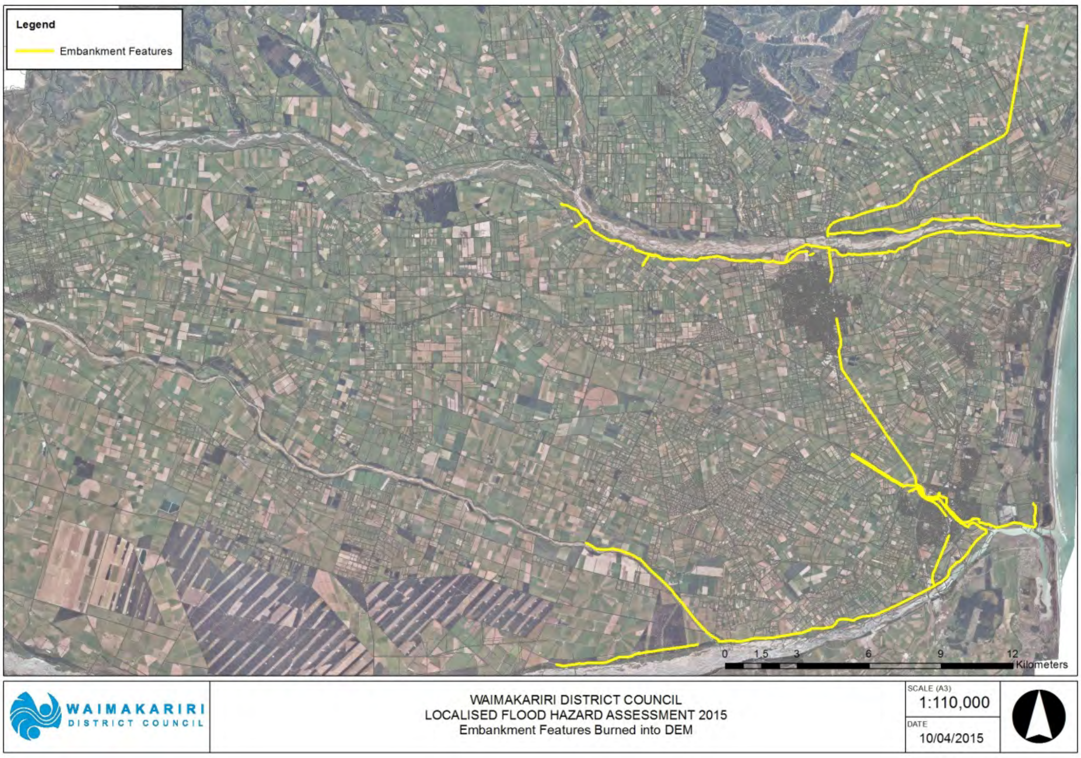

Figure 5 - Embankment Features Burned into DEM

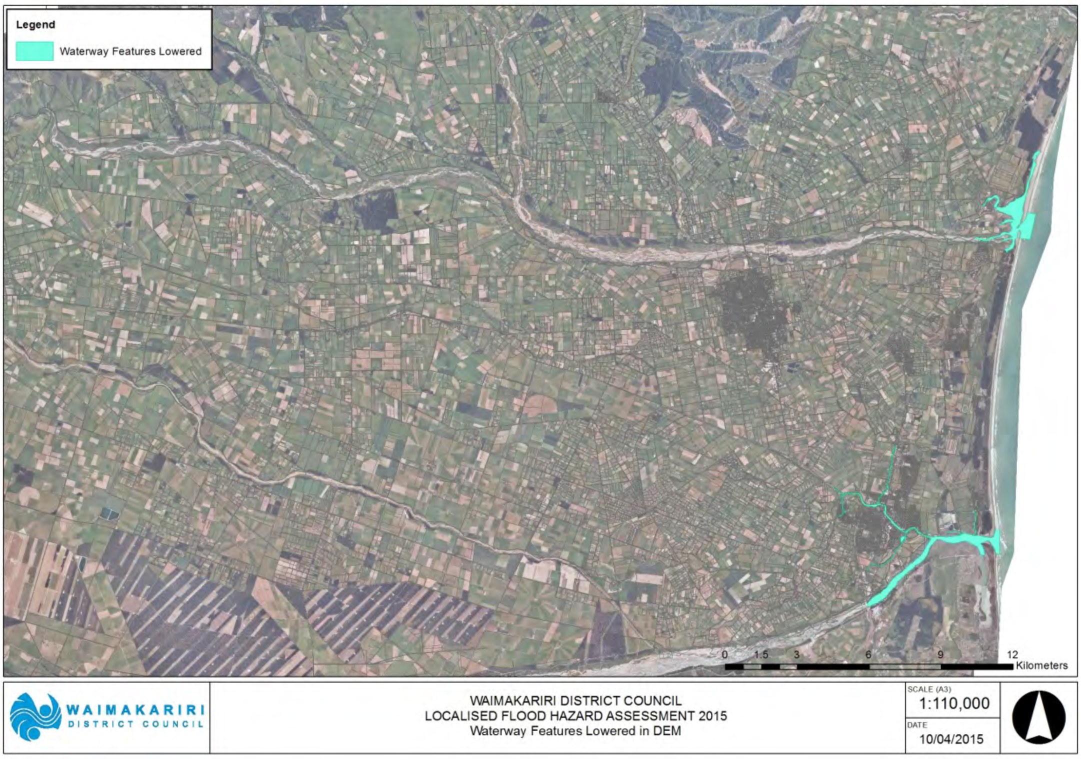

Figure 6 - Waterway Features Lowered in DEM

5.4 Drainage Structures

The two models for North Ashley and South Ashley have incorporated a number of additional structures modelled either as culverts in the MIKE 21 package or simply modelled by changing the DEM to allow flow to pass through an embankment unimpeded. Where it was identified in previous results that flow could pass over the culvert a weir was introduced that those locations with a width of 10m equal to the grid size. The culverts and weirs are all generally the same as those modelled as part of the 2014 study.

Table 4 lists the culverts incorporated into the models for North Ashley and South Ashley and a note where a weir has also been used. Figure 7 shows the culverts and weirs incorporated into the North Ashley and South Ashley models.

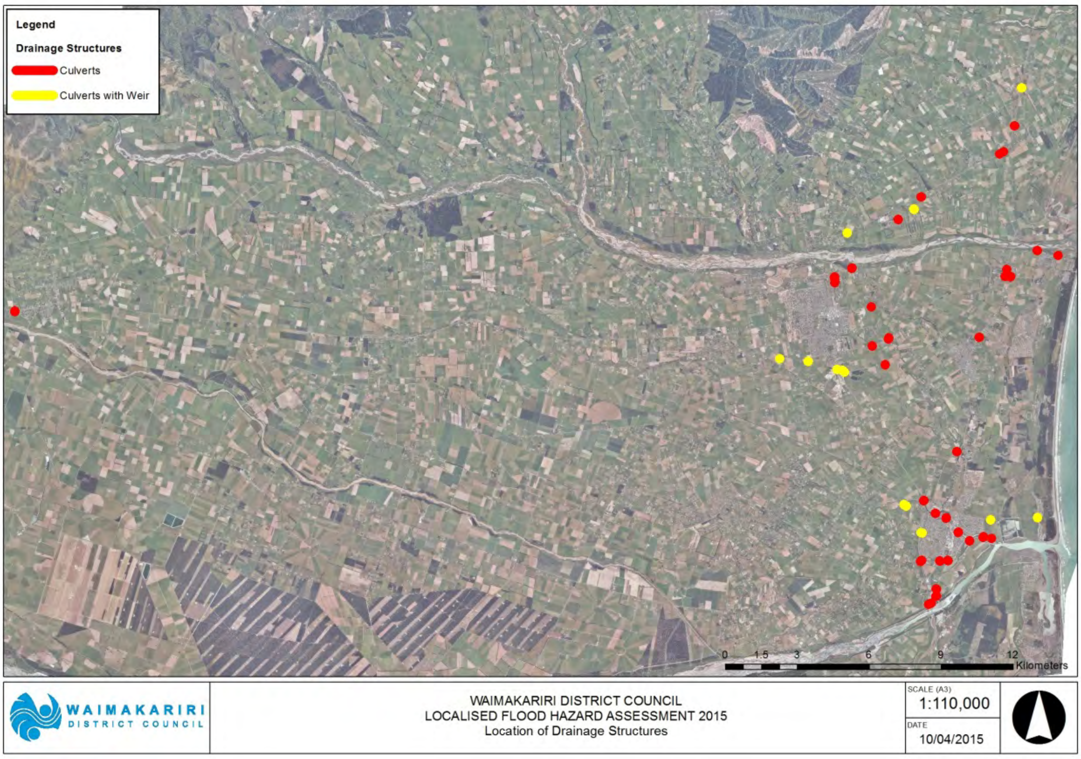

Figure 7 – Location of Drainage Structures used in the Full Catchment Models

Table 4 – Drainage Structures used in the Full Catchment Models

Model	Name	Type	No	Length (m)	Modelled Length (m)	Flap Valve	Invert Level (m RL)	Weir	Weir Height
South Ashley	McIntosh Drain Outlet	2.7m x 1.5m box	1	8.0	10	Yes	-0.785		
South Ashley	McIntosh Drain Beach Road Culvert	2.2m dia pipe	1	18.8	20	No	-0.515	YES	2.2
South Ashley	Feldwick Drain Outlet	0.9m dia pipe	1	23.9	20	Yes	-0.195		
South Ashley	Saltwater Creek Beach Road Culvert	1.05m dia pipe	1	9.8	10	Yes	-0.595	YES	1.52
South Ashley	Courtenay Stream Outlet	1.05m dia pipe	4	10.2	20	Yes	0.005		
South Ashley	Courtenay Stream Doubledays Road Culvert	1.8m x 1.5m box	1	20.5	20	No	1.005		
South Ashley	Courtenay Stream Motorway Culvert	1.05m dia pipe	1	46.9	50	No	1.215		
South Ashley	Greigs Drain Motorway Culvert	1.5m dia pipe	1	116.7	120	No	1.505		
South Ashley	Kaikanui Stream Railway	1m x 1m box	4	13.9	10	No	0.5		

Model	Name	Type	No	Length (m)	Modelled Length (m)	Flap Valve	Invert Level (m RL)	Weir	Weir Height
	Culvert								
South Ashley	Kaikanui Stream Williams Street Culvert	2m dia pipe	2	23.0	20	No	0.95		
South Ashley	Kaikanui Stream Motorway Culvert	1.5m dia pipe	1	68.1	70	No	1.3		
South Ashley	Bowler Street Outlet	0.675m dia pipe	1	26.3	30	Yes	0.07		
South Ashley	Dudley Stream Outlet	1.8m x 1.2m box	1	27.3	30	Yes	0.175		
South Ashley	Adderley Terrace Outlet	1.05m dia pipe	1	19.9	20	Yes	0		
South Ashley	Parnhams Drain Motorway Culvert	1.5m dia pipe	1	74.3	70	No	0.595	YES	2.91
South Ashley	Taranaki Creek SH1 Culvert	5.5m x 1.5m box	1	11.6	10	No	9		
South Ashley	Waikuku Stream SH1 Culvert	3m x 1.5m box	1	24.5	20	No	6		
South Ashley	Waikuku Stream Waikuku Beach Road Culvert	3m x 1.5m box	1	10.0	10	No	5.3		
South Ashley	Waikuku North Creek Culvert	3m x 1.5m box	1	14.1	10	No	5.5		
South Ashley	Mill Stream Island Road Culvert	10m x 2m box	1	10.9	10	No	1.2	YES	5
South Ashley	Boys Road Drain Outlet	4m x 2m box	1	17.1	20	Yes	0.1		
South Ashley	Taranaki Creek Outlet	2.7m x 1.5m box	1	5.6	10	Yes	0		
South Ashley	Waikuku Stream Outlet	1.05m dia pipe	4	14.2	10	Yes	2.5		
South Ashley	Southbrook Marsh Road Culvert	2m x 1m box	1	6.7	10	No	15.9	YES	17.3
South Ashley	Southbrook Station Road Culvert	2.4m dia pipe	2	13.8	10	No	16.24	YES	18.4
South Ashley	Southbrook Southbrook Road Culvert	2.4m dia pipe	2	21.5	20	No	17.63	YES	19.6
South Ashley	Southbrook Townsend Road Culvert	3m x 1.5m box	1	6.8	10	No	23.02	YES	24
South Ashley	Southbrook Lehmans Road Culvert	2.4m x 1.2m box	1	8.0	10	No	30.25	YES	31.6
South Ashley	Northbrook Marsh Road Culvert	7.6m x 1.5m box	1	10.6	10	No	9.43		
South Ashley	Northbrook Boys Road Culvert	2.4m x 1.2m box	2	11.9	10	No	11.8		
South Ashley	Cam River Motorway Culvert	20m x 2m box	1	15.0	20	No	0.7		
South Ashley	Cam River Kippenberger Ave Culvert	5m x 2m box	1	14.4	10	No	21		
South Ashley	Mill Road Culvert	1.9m x 1.9m box	1	35.4	40	No	243.135		
South Ashley	Kaiapoi River Island Road Culvert	10m x 2m box	1	9.3	10	No	1.3	YES	4
South Ashley	Cam River Boys Road Culvert	3m x 1.5m box	1	14.8	10	No	13.2		
South Ashley	Cam River Northbrook Road Culvert	3m x 1.5m box	1	8.9	10	No	13.3		
South Ashley	North Drain Railway Culvert	1.6m dia pipe	1	251.3	250	No	30.185		
South Ashley	North Drain Outlet	0.9m dia pipe	1	24.5	20	Yes	29.345		
North Ashley	Railway Culvert 1	1m dia pipe	2	14.2	10	No	32.1	YES	34.5
North Ashley	Railway Culvert 2	1m dia pipe	2	9.6	10	No	20.05		
North Ashley	Railway Culvert 3	10m x 2m box	1	13.9	10	No	15.5	YES	19.35
North Ashley	Railway Culvert 4	1m dia pipe	2	9.7	10	No	3.9		
North Ashley	Railway Culvert 5	3m x 2m box	1	7.8	10	No	15.3		
North Ashley	Railway Culvert 6	3m x 2m box	1	5.3	10	No	26	YES	27.9
North Ashley	Railway Culvert 3a	1m dia pipe	2	10.8	10	No	18.2		
North Ashley	Railway Culvert 4a	0.75m dia pipe	4	6.1	10	No	4.1		

5.5 Surface Roughness

Surface roughness in the MIKE 21 model is represented by a Manning's M friction coefficient and mapped onto a rectangular grid of the same resolution as the ground surface grid. The spatial variation is derived from the LCDB4 (Land Cover Database Version 4) land use classification from MfE (Ministry for the Environment).

A roughness category was also created for roadways to model the effect of reduced roughness along the roadway corridors and an additional category was created for buildings to model the effect of increased roughness where water flows through a building. The building roughness was not modelled in the 2014 study.

Table 5 details the different land use types and corresponding Manning's roughness and Figure 8 shows a map of the district with the corresponding land use values from the LCDB4 database. Figure 9 shows the Mannings Roughness factors used in the models.

Table 5 – LCDB4 Land Types and Corresponding Mannings Factors

Description (based on LCDB3)	Code	n	M
Built-up Area	1	0.050	20
Urban Parkland / Open Space	2	0.033	30
Surface Mine	3	0.050	20
Dump	4	0.125	8
Transport Infrastructure	5	0.100	10
Coastal Sand and Gravel	10	0.020	50
River and Lakeshore Gravel and Rock	11	0.020	50
Landslide	12	0.020	50
Alpine Gravel and Rock	13	0.020	50
Alpine Grass-/Herbfield	15	0.050	20
Lake and Pond	20	0.020	50
Estuarine Open Water	22	0.020	50
Short-rotation Cropland	30	0.050	20
Vineyard	31	0.125	8
Orchard and Other Perennial Crops	32	0.125	8
High Producing Exotic Grassland	40	0.050	20
Low Producing Grassland	41	0.100	10
Tall Tussock Grassland	43	0.050	20
Herbaceous Freshwater Vegetation	45	0.100	10
Herbaceous Saline Vegetation	46	0.100	10
Flaxland	47	0.050	20
Gorse and Broom	51	0.125	8
Manuka and or Kanuka	52	0.125	8
Sub Alpine Shurbland	55	0.050	20
Mixed Exotic Shrubland	56	0.050	20
Major Shelterbelts	61	0.125	8
Afforestation (not imaged)	62	0.125	8
Afforestation (imaged, post LCDB 1)	63	0.125	8
Forest Harvested	64	0.125	8
Pine Forest – Open Canopy	65	0.125	8
Pine Forest – Closed Canopy	66	0.125	8
Other Exotic Forest	67	0.125	8
Deciduous Hardwoods	68	0.125	8
Indigenous Forest	69	0.125	8
Mangrove	70	0.100	10
Roadway	n/a	0.013	80
Building	n/a	0.333	3

The M value for 'Built Up Area' has been changed from 10 to 20 from the 2014 work as Buildings have now been included separately with a M value of 3. The new value of 20 ensures that on average the Built Up areas retain a value of 10.

ArcGIS was used to re-sample the LCDB4 raster file obtained from MfE into the same resolution as the ground surface grid for the North Ashley and South Ashley Models and the cells re-coded to populate the M values in Table 5. The grid was then imported into the DHI .dfs2 format for modelling.

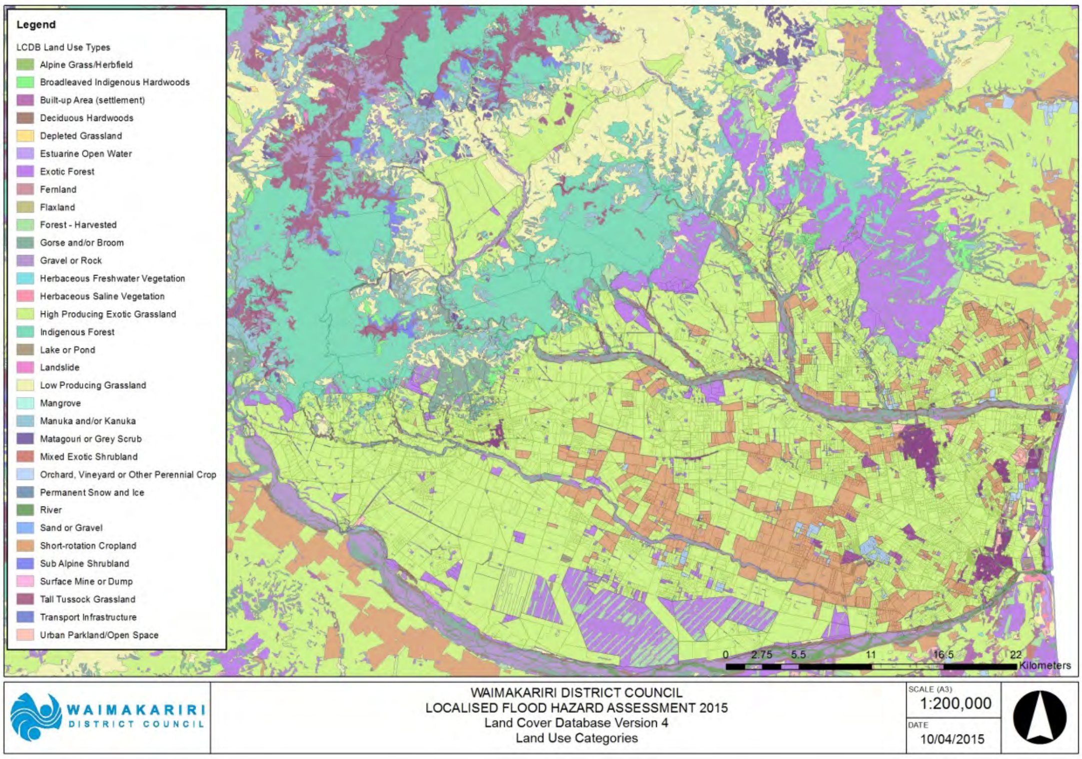

Figure 8 – LCDB4 Land Types

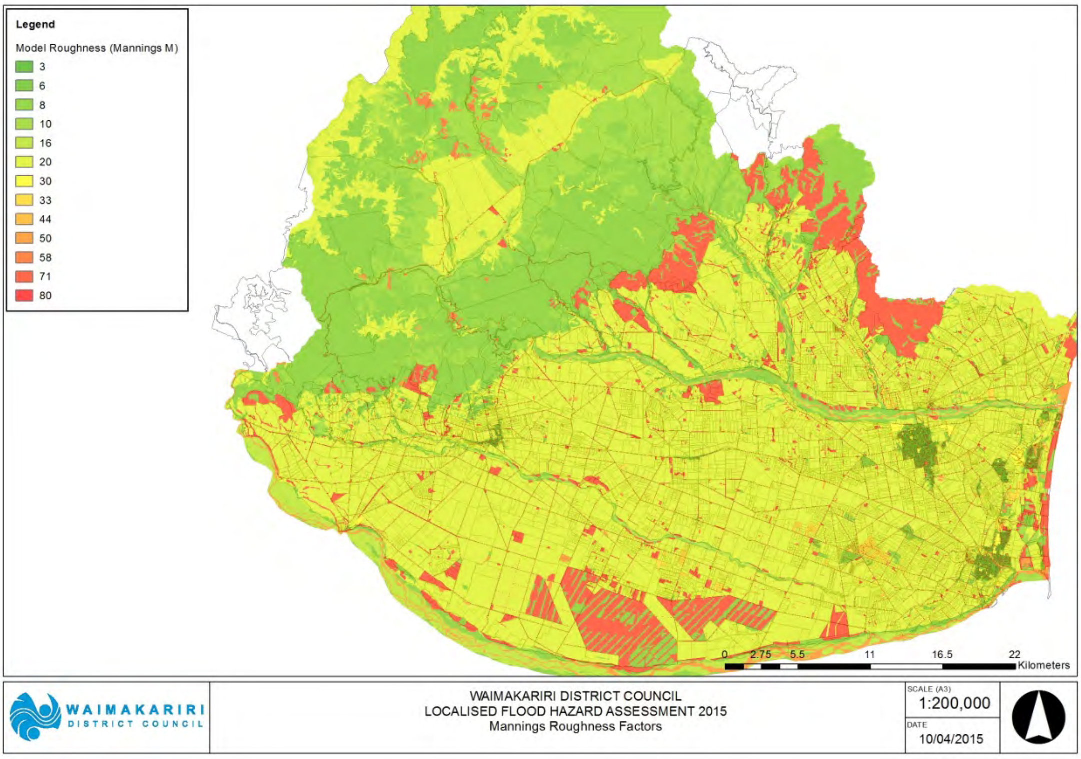

Figure 9 – Mannings Roughness Factors used in the Models

5.6 *Rainfall*

100 year, 200 year and 500 year ARI design rainfall events were used in the model simulations to produce corresponding flood hazard information. The models used a spatially varying rainfall grid based on soil infiltration parameters to accurately estimate the net runoff (less infiltration losses) in different parts of the catchment.

To spatially distribute the rainfall data the district was split up into a grid of thirty six 10 km x 10 km cells. For each cell a rainfall depth was obtained from HIRDS version 3 at the centroid and a 16% climate change factor was applied. The 16% factor is based on recommended figures from the Ministry for the Environment.

Each grid cell was split into 5 different soil drainage categories based on soil shapefiles from the Landcare Research database.

Figure 10 shows the rainfall grid used together with the soil drainage categories applied.

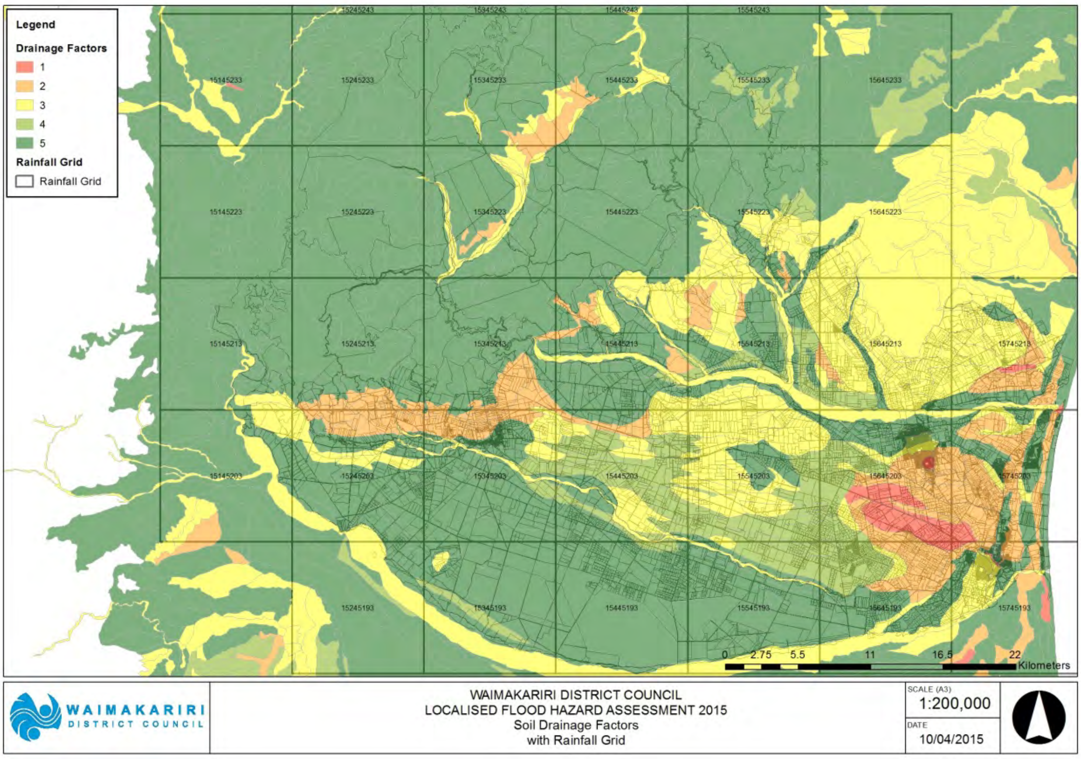

Figure 10 – Rainfall Grid with Soil Drainage Categories

Table 6 summarises the rainfall depths used in the model.

Table 6 – Modelled Rainfall Depths

Rainfall Grid ID	X Coordinate	Y Coordinate	100 year ARI Rain Depth (mm)	200 year ARI Rain Depth (mm)	500 year ARI Rain Depth (mm)
15245243	1524000	5243000	180.33	201.93	234.43
15345243	1534000	5243000	283.64	320.50	376.57
15445243	1544000	5243000	219.29	250.81	299.42
15545243	1554000	5243000	212.84	245.73	297.03
15145233	1514000	5233000	180.45	203.90	239.58
15245233	1524000	5233000	311.08	351.44	412.79
15345233	1534000	5233000	234.70	267.73	318.53
15445233	1544000	5233000	194.55	224.00	269.79
15545233	1554000	5233000	201.55	233.89	284.62
15645233	1564000	5233000	208.34	241.46	293.36
15145223	1514000	5223000	222.57	257.37	311.74
15245223	1524000	5223000	309.79	359.91	438.66
15345223	1534000	5223000	215.87	252.24	309.76
15445223	1544000	5223000	286.87	335.05	411.20
15545223	1554000	5223000	241.00	283.38	350.89
15645223	1564000	5223000	237.18	277.18	340.43
15145213	1514000	5213000	224.97	261.02	317.56
15245213	1524000	5213000	342.74	401.84	495.69
15345213	1534000	5213000	273.96	321.70	397.65
15445213	1544000	5213000	223.50	263.51	327.44
15545213	1554000	5213000	208.05	244.31	301.99
15645213	1564000	5213000	219.76	257.73	318.03
15745213	1574000	5213000	201.19	236.62	293.08
15145203	1514000	5203000	192.82	223.56	271.75
15245203	1524000	5203000	202.65	237.23	292.03
15345203	1534000	5203000	209.03	245.77	304.28
15445203	1544000	5203000	199.38	234.03	289.13
15545203	1554000	5203000	189.13	221.97	274.17
15645203	1564000	5203000	187.07	220.52	273.99
15745203	1574000	5203000	185.49	216.42	265.26
15245193	1524000	5193000	177.91	207.67	254.67
15345193	1534000	5193000	182.47	214.01	264.12
15445193	1544000	5193000	171.86	200.85	246.71
15545193	1554000	5193000	163.67	191.20	234.74
15645193	1564000	5193000	171.30	199.90	245.04
15745193	1574000	5193000	160.67	186.57	227.22

A MIKE URBAN Model B Runoff Simulation was used to generate the rainfall hyetograph to be used in the MIKE 21 model. MIKE URBAN Model B uses the Hortons equation to calculate infiltration. The parameters used in the MIKE URBAN model correspond to verified parameters used by the Council for urban stormwater modelling.

Table 7 lists the MIKE URBAN Model B Runoff parameters.

Table 7 – MIKE URBAN Model B Runoff Parameters

Parameter	DRAINAGE 1	DRAINAGE2	DRAINAGE3	DRAINAGE4	DRAINAGE5
Wetting Impervious Steep (m)	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Wetting Impervious Flat (m)	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Wetting Pervious (m)	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Storage Impervious Flat (m)	1.50E-03	1.50E-03	1.50E-03	1.50E-03	1.50E-03
Storage Pervious (m)	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03
Start Infiltration Pervious (m/s)	4.17E-07	1.39E-06	2.78E-06	6.94E-06	2.08E-05
End Infiltration Pervious (m/s)	1.25E-07	4.17E-07	8.33E-07	2.08E-06	6.25E-06
Exponent Pervious (s^{-1})	1.16E-04	8.17E-05	7.12E-05	6.46E-05	5.79E-05
Inverse Horton's Equation Pervious (s^{-1})	4.63E-06	5.38E-06	6.15E-06	7.89E-06	1.39E-05
Manning Number Impervious Steep	80	80	80	80	80
Manning Number Impervious Flat	65	65	65	65	65
Manning Number Pervious	12	12	12	12	12

For each runoff simulation a nominal catchment area of 100 m^2 was used and an impervious area according to the Land Type in Table 8 was applied to the 'Impervious Steep' parameter r. The remaining pervious area was applied to the 'Pervious Medium' parameter.

Table 8 – MIKE URBAN Model B Runoff Parameters

Land Type	Impervious Steep Percentage	Pervious Medium Percentage
Commercial/Industrial	80	20
Urban Residential	50	50
Rural	1	99

Figure 11 shows where the different land use types were applied.

Each permutation of Rainfall Grid, Soil Drainage Category and Land Type were simulated using a series of MIKE URBAN catchments corresponding to the different permutations.

The rainfall hyetograph used in the MIKE URBAN runoff model corresponded to a 24 hour nested storm using rainfall depths from the 1, 3, 6, 9, 12, 18 and 24 hour events. The MIKE URBAN runoff files were the same used in the 2014 study.

Figure 12 shows an example of the MIKE URBAN hyetograph used.

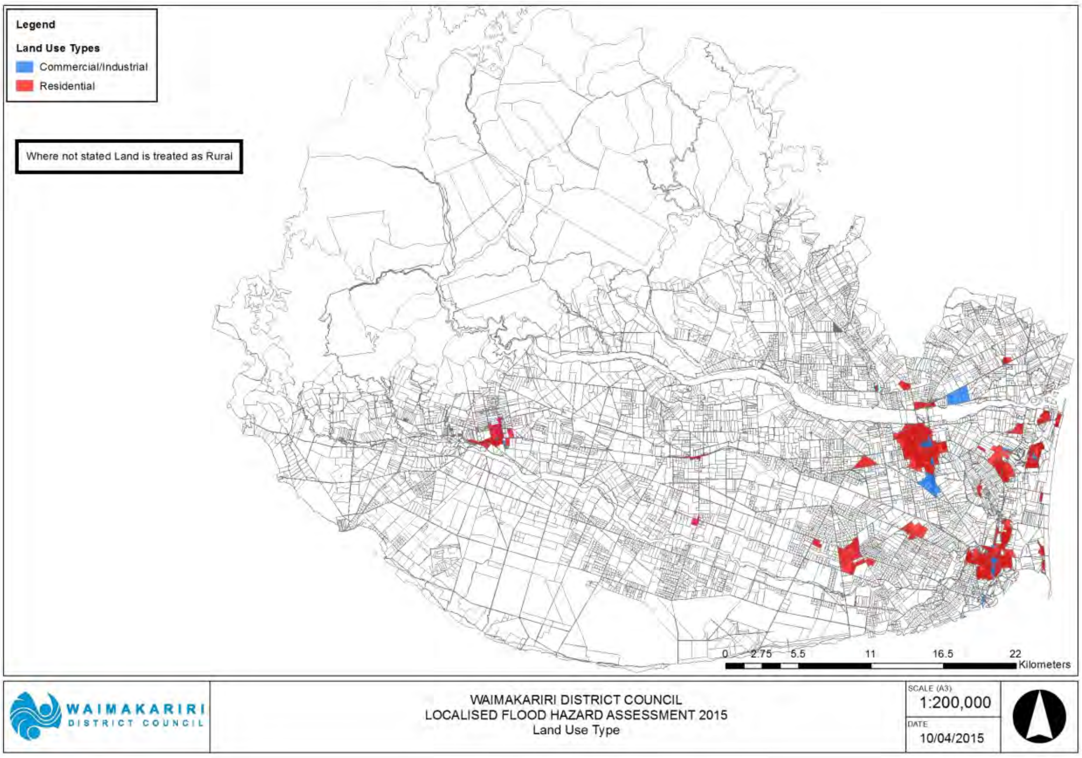

Figure 11 – Plan of Land Types used to determine Impervious Values

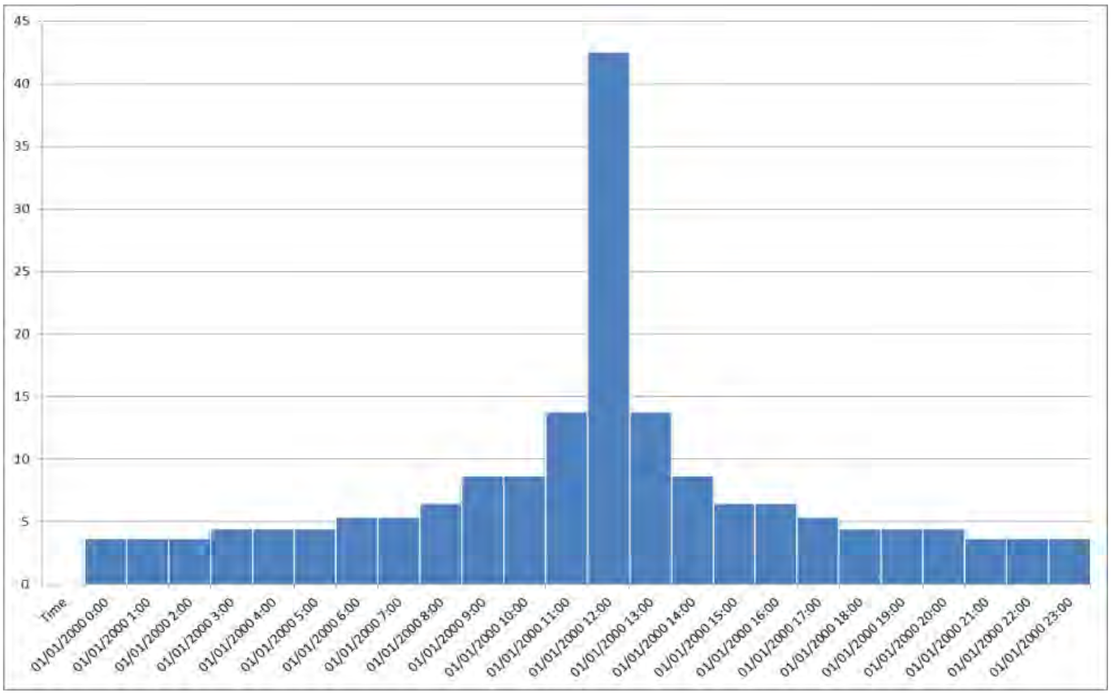

Figure 12 – Example of MIKE URBAN Hyetograph

The resulting runoff outputs from the MIKE URBAN model were combined together into a single .dfs0 file and combined with a .dsf2 file containing information on the rainfall grids, soil drainage categories and land types to produce a spatially varying .dfs2 rainfall file to be used in the MIKE 21 model.

5.7 Downstream Water Level Boundaries

The location of the water level boundaries used in this study were the same as those used in the 2014 study. However the climate change allowance was increased from 0.5m in the 2014 study to 1.0m in the current study. This is based on current advice from the Ministry for the Environment and is consistent with the approach being taken by Christchurch City Council and other New Zealand Local Authorities.

The riverbeds of the Waimakariri and Ashley Rivers were incorporated into the models and a single boundary condition was placed at the mouth of each river.

The open boundary of each model was chosen to represent an outlet of the catchment discharging to the ocean. The ocean water level has been defined as a constant value of 1.0m MSL in terms of the Lyttelton Datum. This is obtained from a constant level of 0m MSL plus 1.0m allowance for climate change.

As the outlets were free draining to the ocean there were no flap valves included.

Table 9 lists the downstream water level boundaries used at each outlet point and the corresponding models.

Table 9 – Modelled Downstream Water Level Boundaries

Model	Outlet	Water Level Boundary (m) RL	Receiving Water Body	Flap Valve
South Ashley	Waimakariri River	1.0	Pacific Ocean	N
South Ashley	Ashley River	1.0	Pacific Ocean	N
North Ashley	Ashley River	1.0	Pacific Ocean	N

5.8 Initial Conditions

The initial conditions for each model simulation used a constant value of 1.0m in line with the downstream water level boundary condition.

5.9 Model Simulations

The DHI MIKE 21 FM modelling software has been used for the hydrodynamic simulations. The model simulations produce results data that are stored as time series data values at a time interval of 40 minutes with a spatial distribution at a resolution equal to that of the rectangular flexible mesh model grid (either 10m x 10m or 12m x 12m).

A 2-dimensional (depth averaged) hydrodynamic simulation has been carried out for each catchment with the rainfall time series and coastal or river water levels as inputs to the model. The rainfall has been applied to each of the grid cells within the catchment. The hydrodynamic simulation solves the 2-dimensional (depth averaged), continuity (mass balance) and momentum (force balance) equations to generate the 2-dimensional time evolution of flood water movement on the catchment surface.

The time step used for each simulation varies between 0.5 and 30 seconds for the models.

6 RESULTS

The DHI MIKE 21 FM modelling software has been used for the hydrodynamic simulations.

The results from the hydrodynamic model have been processed to provide maps of the maximum water depth and maximum flood flow speed elevation at each grid cell for each catchment and each rain event. A plot of flood hazard has also been computed based on the WDC schema (Refer Figure 14).

The Waimakariri and Ashley Riverbeds have been excluded from the results as the results from this study do not accurately reflect the true 100 year, 200 year and 500 year ARI flood levels in these waterways.

Refer to Appendix B for result files of Maximum Flood Depth

Refer to Appendix C for result files of Maximum Velocity

Refer to Appendix D for result files of Flood Hazard.

The results are also available in high resolution pdf plans and are stored in ArcMap geodatabases for detailed analysis and for presentation on the Council GIS.

6.1 Result Files

The model simulations produce .dfsu result files that store time series data values at a time interval of 20 minutes with a spatial distribution equal to the flexible mesh model grid (either 10m x 10m or 12m x 12m). The result files store information on both water depth and speed at each time step.

The .dfsu flexible mesh files were subsequently converted into rectangular grid .dfs2 files to calculate the maximum water depth and maximum velocity for display and manipulation with ArcGIS. ArcGIS was then used to display the results and calculate the flood hazard based on the maximum depth and velocity and according to the WDC schema.

The flood hazard relationship is outlined in Section 6.4.

6.2 Continuity Checks

In order to ensure reliable simulation results continuity checks (volume balance) were carried out on each model simulation. Table 10 details the results for each simulation.

Table 10 – Continuity Checks

Model	Simulation	Initial Volume in Model Area (m^3)	Final Volume in Model Area (m^3)	Total Volume from Precipitation (m^3)	Total Outflow from Boundaries (m^3)	Continuity Balance (m^3)	Continuity Balance (%)
South Ashley	100yr	664,826	42,351,406	61,384,369	19,702,138	4,350	< 0.01%
South Ashley	200yr	664,826	50,007,480	80,643,029	31,337,102	36,726	0.05%
South Ashley	500yr	664,826	62,033,782	119,957,449	58,641,891	53,397	0.04%
North Ashley	100yr	197,143	11,199,730	36,865,581	25,863,089	95	< 0.01%
North Ashley	200yr	197,143	12,782,832	48,365,983	35,780,449	156	< 0.01%
North Ashley	500yr	197,143	16,556,678	71,866,432	55,507,178	281	< 0.01%

The continuity balances are all good with less than 1.0% continuity errors across all the simulations.

6.3 Comparison with 2014 Results

A comparison was made between the model results from the 2014 study and the current study to determine where changes have occurred as a result of changes to the modelling methodology and new LiDAR information. Figure 13 shows the change in flood depth for the 200 year simulation from the 2014 results to the current results.

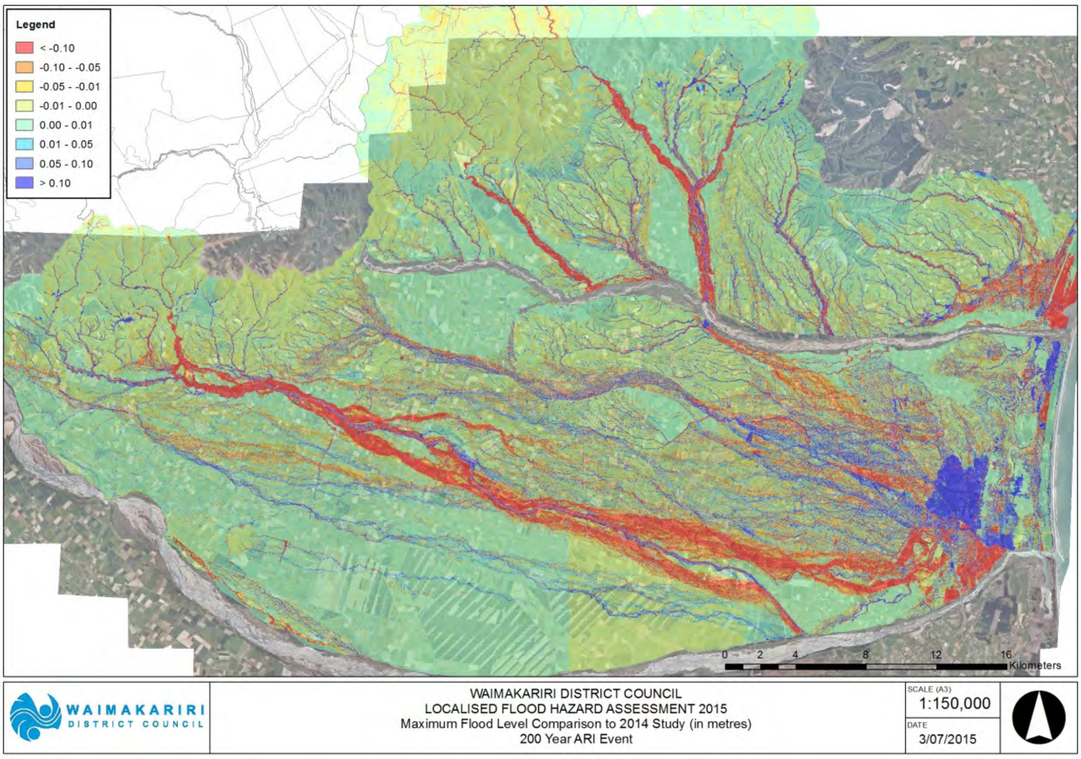

Figure 13 – Flood Depth Comparison between 2014 and 2015 Results

Table 11 shows the percentage of area that has changed by less than 100mm in comparison to the 2014 results.

Table 11 - Depth Comparison Table

Model	Simulation	Total Number of Grid Cells	Cells with Depth Change less than 100mm	Percentage of Model with Depth Change less than 100mm
South Ashley	100yr	335,418	306,662	91.4%
South Ashley	200yr	336,101	291,946	86.9%
South Ashley	500yr	335,542	281,920	84.0%
North Ashley	100yr	165,165	154,766	93.7%
North Ashley	200yr	164,626	151,293	91.9%
North Ashley	500yr	162,932	148,510	91.1%

The results show that in all scenarios the depths have changed by less than 100mm across approximately 90% of the modelled area. This indicates the model results are similar to the previous work undertaken.

Refer to Appendix E for additional plots showing a comparison with the 2014 results.

6.4 Flood Hazard Assessment

The Flood Hazard Assessment was based on the New South Wales schema. The Flood Hazard Category is based on a function of Flood Depth and Velocity (or speed) of the water. The categories were calculated using the maximum flood depth and maximum flood velocities from the model results.

Figure 14 shows the Flood Hazard Categories used in the model results.

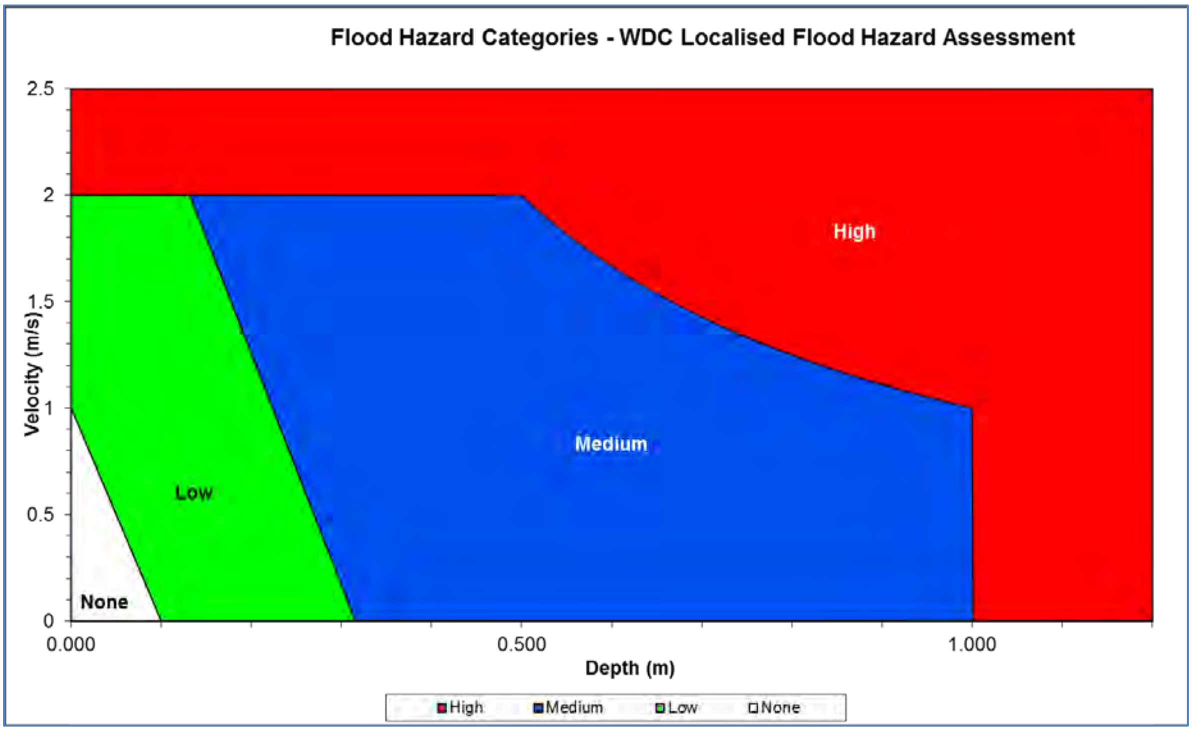

Figure 14 – WDC Flood Hazard Categories

Refer to Appendix D for plots showing the Flood Hazard Map for each simulation.

6.5 Limitations

No quantitative or qualitative validation has been carried out for the flood events. Quantitative validation may prove difficult because of the fact that the simulation results represent an abstract design rainfall event. Some qualitative model validation may prove beneficial and it is recommended that this is carried out in the future as budget and resources allow.

The quantitative accuracy of the results from modelling is dependent on a range of factors including the quality of the input data, the modelling methodology and the resolution of the model grids.

The following points should be noted when utilising the outputs from this report.

- The LiDAR data has an estimated vertical accuracy of 0.15m. Significant deviations in vertical accuracy can occur in areas of dense vegetation. Below water ground levels are not reliably represented in the LiDAR data.
- Hydrological processes are represented in an undistributed way with losses and climate change applied to the rainfall depths.
- The in-channel hydraulic routing for small water courses (typically of width of the order of less than 5 grid cells) is not accurately resolved in the models.
- The resolution of the 10m or 12m model grids may not resolve the sub grid features that have an impact on the evolution of the flooding within the catchment (eg road embankments and narrow open channel drainage networks).
- Stormwater reticulation capacity in the primary network was not considered in these models.

7 DISCUSSION

7.1 Comparison to 2014 Study

There were a number of minor changes made to the 2014 modelling methodology when undertaking this study. These changes have been outlined previously in Table 1.

In rural areas water depths have largely remained unchanged with differences less than 100mm across most of the rural land. The most significant changes in water depth can be seen within the major flow channels and in the Kaiapoi area.

Water depths have generally decreased in many of the major drainage channels and streams, although conversely some of the adjacent overland flow paths show a general increase. It is unclear as to why these differences are being seen but it is likely the new LiDAR data combined with the use of the Flexible Mesh engine may be producing some slightly difference results. Many of the streams and overland flowpaths are not modelled accurately using the 10m and 12m modelled grids so the likelihood of there being differences in the modelled results are greater.

There are some clear differences in areas where major subdivision has occurred since the 2005 LiDAR was flown. These include:

- Pegasus Town
- Silverstream (Kaiapoi)
- Beach Grove (Kaiapoi)
- Sovereign Palms (Kaiapoi)
- Oxford Park (Rangiora)
- Arlington Park (Rangiora)
- East Rangiora
- Southbrook Industrial Area

In subdivisions such as Silverstream in Kaiapoi there has been a noticeable decrease in flood level as the land has been raised significantly. Conversely some of the surrounding land has shown some increases in flood level. In many of the other subdivisions there is a combination of increases and decreases corresponding to cut and fill activities to construct the new roads and building platforms.

In the Kaiapoi area there is a general increase in flood depths in the area to the north of the township between Lineside Road and the Northern Motorway. Conversely there is a general decrease in flood depth to the southeast of the township in the 200 year and 500 year events. Interestingly in the 100 year ARI event the flood level has generally increased across most of the surrounding area.

The changes in the flood levels in Kaiapoi are likely due to a number of factors which include:

1. Earthquake Effects – some parts of Kaiapoi and the surrounding land have experienced ground movement as the result of the 2010 and 2011 Canterbury Earthquakes. It is likely this is having an effect on flood levels in some areas.

2. Subdivision – some of the new developments in the Kaiapoi area have imported fill to raise the land. It is likely this will be having both positive and negative effects for some properties as the imported fill will be displacing

floodwaters into some surrounding areas and potentially blocking off flowpaths into others.

3. Sea Level Rise – the new climate change allowance for sea level rise has been increased from 0.5m to 1.0m in this study. It is likely this will be adversely affecting flood levels in some areas.

Further work would be required to determine the true effects from each of these factors on the Kaiapoi area. It should also be noted that because the modelling is relatively coarse for use in urban areas and does not account for primary infrastructure including pumpstations the results may be over-predicting the level of flooding in Kaiapoi.

The overall effect of the changes is relatively minor, notwithstanding some of the effects in the Kaiapoi area.

Based largely on the fact the new results are using better and more up to date information it is reasonable to conclude the new modelling methodology has produced a better quality set of results.

Refer to Appendix E for plans showing the water depth differences between the 2014 and 2015 studies.

7.2 Climate Change Values

This study has adopted the latest climate change values as recommended by MfE and adopted by the Christchurch City Council.

The two key climate change figures used in this report were:

- 16% additional rainfall volume
- 1.0m sea level rise

The sea level rise figure in particular has some effect on the Kaiapoi area as much of the existing land is less than 1.5m above mean sea level and some of the surrounding rural land is less than 1.0m above mean sea level. The modelling has predicted much of the town will be severely affected in a 100+ year ARI event using a sea level rise figure of 1.0m. This would make achieving the RPS 200 year ARI standard difficult without significant flood mitigation measures. It is therefore recommended that a separate study be undertaken to better understand the effects of climate change on the Kaiapoi township and any mitigation measures that could be considered.

As additional work is undertaken on climate change it is expected that these key figures and the recommendations from the MfE will change over time. It is therefore recommended that any future work considers the latest climate change information.

7.3 Design Rain Event

This study used a nested 24 hour storm event based on HIRDS version 3 data with a 16% allowance for climate change. The 24 hour event was chosen as staff considered this to be a sensible duration to model district wide flooding during a 100 year or greater ARI event.

Due to individual catchment characteristics some catchments may experience higher levels of flooding during a longer or shorter duration storm event.

A simple assessment of the time of concentration for the South Ashley catchment indicates it should be in the order of 15 hours. However previous Council modelling work has indicated smaller catchments like the Southbrook Stream have a critical storm duration of approximately 12 hours. This indicates the critical storm for the models should be in the order of 24 hours. Therefore using a 24 hour storm event for this study appears reasonable.

The nested event used in the models includes the 1 hour, 3 hour, 6 hour and 12 hour rain events within the storm profile. This means the modelling should provide a reasonable indication of flood levels for these shorter duration events. It is acknowledged that modelling a series of simulations for each rainfall duration is a more robust method for determining the critical storm event. However time and resource constraints on this project meant it was only practical to model one rainfall simulation for each ARI event.

7.4 Possible Future Work

The modelling work that has been undertaken in this study has used the best information available and has generally maximised the available software and hardware resources available to the WDC. However it would still be possible to undertake some improvements to the models to improve the accuracy of the model simulations subject to new data becoming available. These improvements are discussed below.

It is recommended that a budget of $50,000 is made available every 5 years to undertake a revision of this modelling work to take advantage of new data and information and to ensure the modelling results remain current.

7.4.1 LiDAR Data

One of the limitations of the models is the accuracy of the LiDAR information in some parts of the district, in particular growth areas where the shape of the land is changing.

The 2014 LiDAR used in the eastern part of the district has picked up the majority of new subdivision areas since 2005, however many of these subdivisions are still in a state of development, meaning the latest LiDAR is already out of date in some areas. The 2005 LiDAR used in the remainder of the district is still relatively accurate as the western portions of the district have not experience the same level of development as the east. However there has been some development undertaken in the west since 2005 that has not been picked up in this study, in particular some of the dairy conversions that have been undertaken in the Oxford Rural area. There is evidence that shows these are having an effect on overland flow paths in some areas.

Current residential development around Rangiora, Kaiapoi and Woodend will further reduce the accuracy of the current DEM in these areas and further intensification of farmland and rural residential development in the west will also reduce the accuracy of the DEM in these areas.

It is therefore recommended that the Council collect finished ground levels (where possible) for new subdivision areas and include these in a DEM combined with LiDAR data that is maintained as a current 'best record' of ground shape.

It is also recommended that the Council consider developing a LiDAR acquisition strategy and make budget provision to update the LiDAR records on a semi regular basis. It is suggested this could be in the order of 10 to 15 years.

7.4.2 Land Use Classification Database

The Land Use Classification Database maintained by MfE is reasonably up to date across most of the district. However this information can quickly become out of date when significant residential development occurs, such is the case currently in the Waimakariri District. Updating the roughness data in the models whenever a new version of this database is available would help improve the accuracy of the results.

7.4.3 Runoff Methodology

Although the runoff methodology is considered relatively sound some other improvements could be made in a future model build.

Impervious figures of 80%, 50% and 1% were used in Commercial, Residential and Rural areas respectively. A more detailed assessment of impervious figures with more specific impervious figures would help improve the accuracy of the runoff data.

Running a series of rain events with different durations would ensure the most critical event was used for each catchment, improving the quality of the results. However the approach taken in this study to use a nested storm over a 24 hour period is the most practical solution as the time taken to run a simulation on the North Ashley and South Ashley models is in the order of days. It would not be practical to run a series of different storm durations with the software and hardware currently available.

7.4.4 Primary Infrastructure

The existing flood hazard models fit the description of a Rapid Hazard Flood Model that excludes primary drainage infrastructure such as pipes and open drains. Incorporating the primary infrastructure into the model by constructing a coupled 1D-2D model using MIKE URBAN and/or MIKE 11 would further improve the accuracy of the model.

However to construct such a model for the North Ashley and South Ashley catchments would require a significant amount of time and budget and it is likely that a more powerful computer would also be required to run the simulations in a timely manner.

Work is currently being undertaken in Rangiora and Kaiapoi to construct more robust urban models for these towns that better account for rural catchment flows. It is expected that in the future the output from these models could be used in place of the flood hazard model results to better represent 100, 200 and 500 year flood levels in these areas.

7.4.5 Lees Valley

Lees Valley is the only part of the district not modelled as part of this study. There is currently no good quality LiDAR information available for this area and the area is sparsely populated with little likelihood of development in the foreseeable future. Therefore modelling this area would not be a high priority for the Council.

This catchment could be modelled if a better quality LiDAR dataset was obtained and doing so would provide flood hazarding modelling for the entire district.

7.4.6 Ashley and Waimakariri Rivers

This modelling work has not included any detailed assessment of the Ashley and Waimakariri Rivers which form the part of the extents for the North Ashley and South Ashley models. A more detailed assessment of the water levels in both rivers during one of the simulated rain events would provide a more robust assessment of boundary conditions. It should be noted however the peak levels in both rivers are unlikely to coincide with peak flood levels in the upstream catchments.

Coupling these 2D models with the 1D ECan models for the Waimakariri and Ashley Rivers would be another possibility, however any such work would have to be undertaken by ECan or an external consultant as the Council does not have the software or expertise to run these river models.

7.4.7 Building Information

Following an exercise to map all existing buildings and structures in the urban areas in 2014 these building outlines have been incorporated into this study to better reflect the effect of these on overland flow paths. These building outlines will also be used in future 1D-2D urban coupled stormwater models to improve the accuracy of the modelling in these areas.

Some coarse assumptions have been used to model the floor level of these buildings and having a better and more accurate source of data for building floor levels would improve modelling accuracy. Updating this building outline layer is also seen as important otherwise new buildings will not be captured and the layer will become out of date.

It is therefore recommended that the Council collect information on new buildings including the building outline and finished floor level as part of the Building Consent process. It is also recommended that the Council collect information on the finished floor level of existing buildings where the building is known to be flood prone and this information is stored within the building outline layer in GIS.

7.5 Building Floor Levels

The previous 2014 study was designed to act as a strategic tool to assist with planning decisions around growth areas, not necessary to be used as a means of establishing building floor levels. However it was subsequently acknowledged that this work represents the best source of information available for establishing floor levels in the Waimakariri District and the modelling work represents the best means of doing this. Therefore the results from the 2014 study have been used to help set Building Floor Levels across the district together with suitable levels of freeboard.

The following table outlines the approach that has been adopted:

Flood Hazard Category (200 year ARI event)	Maximum Depth	Recommended Finished Floor Level Height	Notes
None	100mm	400mm	400mm is the adopted minimum level for all buildings in the rural zone
Low	300mm	600mm	Can be reduced following more detailed analysis of the flood depth results
Medium	1000mm	-	Building may be allowed but a detailed flood assessment is required to determine the floor level
High	> 1000mm	n/a	No building is allowed

The current approach is underpinned by a philosophy that any new building floor level should have at least 300mm freeboard in a 1 in 200 year ARI event. In the rural areas this has meant a 400mm minimum requirement has been adopted to reflect the fact that flood levels could be up to 100mm even in areas where no significant flooding has been predicted. The 300mm freeboard is to account for inaccuracies in the modelling results and wave action.

The Council has allowed lower levels in some areas where a more specific assessment has been undertaken or where the applicant only needs to comply with Building Act requirements which require a 1 in 50 year level of protection. It is intended that the results from this study will form part of the Council's District Plan, enabling the Council to make the 1 in 200 year protection a requirement of all new future dwellings.

The existing approach is considered reasonable for rural areas and it is recommended that this is formally adopted within the District Plan.

It is expected that urban areas and areas subject to plan changes should require specific flood mitigation measures to allow buildings to only meet requirements under the Building Act and/or RPS.

Future modelling of the urban areas is proposed which will allow more detailed assessment to be undertaken of the urban schemes. Therefore it is recommended that the results from this study are not applied to urban areas and new dwellings in urban areas are only required to meet Building Act requirements until such time as the urban modelling work is completed.

In all cases any proposed Building Floor Level should take into account site specific features such as low spots or defined overland flow paths.

7.6 ECan Ashley and Waimakariri Breakout Modelling

The results from this study don't allow for a corresponding river breakout from the Ashley and Waimakariri Rivers. ECan have undertaking this modelling work for both rivers using the same software used in the study and adopting the same flood hazard ratings.

In some areas of the district it is likely the ECan modelling work will produce higher flood levels and the results from this work should also be considered in these areas.

7.7 Model Validation

These model results are based on a theoretical design storm event and best knowledge of catchment parameters. It would be beneficial to conduct a validation of the model using an actual storm event to provide confidence that the model is representing reality. The cost of this work would be approximately $15,000 including additional modelling licence costs.

However it should be acknowledged that the model could only be validated using a major storm event as the primary infrastructure is not in the model. In order to undertake a worthwhile validation a storm event in the order of 1 in 100 years would need to be used.

A good network of rainfall gauges would also be necessary to undertake any kind of validation as rainfall does vary spatially across the district. The existing Council network of rainfall gauges provides a reasonable coverage across the district but consideration should be given to expanding the network to include areas such as Mairaki Downs, View Hill and Loburn that have experience flooding issues in recent times but have no nearby rainfall gauge. It is also considered important to ensure the existing network is fully operational at all times. During a recent rain event in June 2014 3 of the 6 Council rain gauges were not operating at the time of the storm.

It is therefore recommended that in the event of a major storm event occurring in the Waimakariri District in the future a budget of $15,000 is made available to undertake a model validation of the South Ashley and North Ashley Models.

It is also recommended that the Council consider expanding the existing rain gauge network to include areas that have had flooding issues in recent times and ensure that the existing network is fully operational at all times.

8 CONCLUSION

The more refined modelling methodology and more up to date data used in the 2015 modelling has resulted in a more accurate result than the work undertaken in 2014.

Further work could be undertaken to improve the accuracy of the modelling results including:

- Updated LiDAR data for future development areas and the western part of the district
- Updated Land Use data across the district
- More refined assessment of the impervious area
- Inclusion of more primary infrastructure in the models
- More refined modelling of the rivers within the models

Further work is also required in urban areas and especially in Kaiapoi to better model and understand the effects of a major 100+ year ARI event.

Undertaking a model validation would provide confidence that the model is representing reality, although this requires a major rain event to occur to make this worthwhile. In the event of a major rain event occurring, a budget of $15,000 should be made available to undertake this work in the future.

It is expected that the results from this study will be incorporated into the Council GIS, the District Plan and form part of the information contained within LIMS. However some further work is required around the setting of building floor levels in urban areas and these areas should be excluded from the results displayed on the Council's GIS until more refined modelling has been undertaken in these areas.

The modelling results are shown in the appendices of this report and are also available as high resolution pdf plans. The results will also been stored in ArcMap geodatabases for detailed analysis and display on the Council GIS system.

Any additional modelling work will be limited by modelling resources within the PDU and technological advancements in both software and available hardware. Any future modelling work should also take into account changes in climate change forecasts.

It is recommended that a budget of $50,000 is made available every 5 years to undertake a revision of this modelling work to take advantage of new data and information and to ensure the modelling results remain current.